DOT/FAA/CT-03/05
HF-STD-001

FAA Technical Center
Atlantic City International Airport, NJ 08405

Human Factors Design Standard

For Acquisition of Commercial-Off-The-Shelf Subsystems, Non-Developmental Items, and Developmental Systems

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May 2003

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US Department
of Transportation
Federal Aviation
Administration

Sponsored by:
Office of the
Chief Scientific
and Technical
Advisor for
Human Factors
AAR-100

Technical Report Documentation Page

1. Report No. DOT/FAA/CT-03/05 HF-STD-001	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle HUMAN FACTORS DESIGN STANDARD (HFDS) For Acquisition of Commercial Off-The-Shelf Subsystems, Non-Developmental Items, and Developmental Systems		**5. Report Date** May 2003 **6. Performing Organization Code** ACB-220
7. Author(s) Vicki Ahlstrom, ACB-220; Kelly Longo, Titan Systems		**8. Performing Organization Report No.** DOT/FAA/CT-03/05 HF-STD-001
9. Performing Organization Name and Address U.S. Department of Transportation Federal Aviation Administration Technical Center Atlantic City International Airport, NJ 08405		**10. Work Unit No** **11. Contract or Grant No.**
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Headquarters Human Factors Division 800 Independence Avenue, SW Washington, DC 20591		**13. Type of Report and Period Covered** **14. Sponsoring Agency Code** AAR-100
15. Supplementary Notes:		

16. Abstract

The Human Factors Design Standard (HFDS) provides reference information to assist in the selection, analysis, design, development, and evaluation of new and modified Federal Aviation Administration (FAA) systems and equipment. This document is based largely on the 1996 Human Factors Design Guide (HFDG) produced by the FAA in 1996. It converts the original guidelines document to a standard and incorporates updated information, including the newly revised chapters on automation and human-computer interface. The updated document includes extensive reorganization of material based on user feedback on how the document has been used in the past. Additional information has been also been added to help the users better understand tradeoffs involved with specific design criteria. This standard covers a broad range of human factors topics that pertain to automation, maintenance, displays and printers, controls and visual indicators, alarms, alerts and voice output, input devices, workplace design, system security, safety, the environment, and anthropometry documentation. This document also includes extensive human-computer interface information.

17. Key Words Human factors, Human-equipment interfaces, Human-computer interfaces, automation, design for maintenance, workplace design, user documentation, system security, personnel safety, environment, input device, monitors, displays, printers, computer-human interface, CHI, alarms, auditory, automation, maintenance, displays and printers, controls and visual indicators, alarms, alerts and voice output, input devices, workplace design, system security, safety, the environment, and anthropometry documentation.	**18. Distribution Statement** This document is available to the public through: the National Technical Information Service, Springfield, VA 22161 through the internet at (http://acb220.tc.faa.gov/hfdg/default.htm), or in CD ROM format by sending a request to: HFDS project lead William J. Hughes Technical Center ACB-220, Human Factors Group, Bldg 28 Atlantic City International Airport, NJ 08405

19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No of pages** 982	**22. Price**

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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Foreword

The *Human Factors Design Standard (HFDS) for Acquisition of Commercial-off-the-Shelf (COTS) Subsystems, Non-Developmental Items (NDI), and Developmental Systems* is a comprehensive reference tool that will help human factors professionals within the Federal Aviation Administration (FAA) and contractor organizations to efficiently carry out FAA human factors policy.

The HFDS was developed by the Human Factors Group at the FAA Technical Center to consolidate and capitalize upon multiple sources of human factors design and evaluation guidelines. It provides FAA system modernization programs access to the most applicable human factors guidance. This document is intended to overcome the limitations associated with using other design standards in an FAA environment.

Application of this design standard is not a substitute for in-depth professional human factors practice. The FAA Acquisition Management System refers to Human factors as a *critical* aspect of aviation safety and effectiveness. It requires that Integrated Product Teams assure that planning, analysis, development, implementation, and in-service activities include human factors engineering. It states that human factors engineering should be integrated with the systems engineering and development effort, throughout the acquisition process. This document can serve as a critical tool for aiding this process by providing input to acquisition and development documentation, processes, and activities. However, human factors acquisition standards and processes are to be professionally applied. The use of the HFDS requires expert professional judgment on its application to systems and equipment.

This document compiles extensive guidance from diverse sources for human factors applications integral to the procurement, acquisition, design, development, and testing of FAA systems, facilities, and equipment. It will aid in identifying functional, product, and NAS specification requirements and in ensuring acceptable human factors practice and products.

This edition of the HFDS is applicable to COTS and NDI procurements as well as new developmental system or equipment acquisitions. The relationship between hardware and software subsystems and the human subsystem's characteristics must be determined and tested in advance of commitments to procure and implement COTS and NDI equipment and systems. These characteristics can include human roles, organizations, interfaces, tasks, training, and human performance effectiveness.

The HFDS draws heavily from human factors information published by the Department of Defense, National Aeronautics and Space Administration, and Department of Energy. The FAA recognizes the excellent quality of information found in many of the technical documents and handbooks written by these agencies.

The HFDS contains 15 chapters, only some of which have been revised. Some of the chapters that have not been revised reference military standards that are no longer current. The military standards referenced in this document and their status (if known) are now listed in an appendix to this document.

Many individuals contributed to the creation of this document. Todd Truitt contributed extensively to Chapter 3 (Automation). Linda Johnson edited and proofread the entire document. Bonnie Kudrick assisted in the completion of the document and getting the document produced. Jean Dunn completed the final technical editing and formatted the Table of Contents.

As described in the introduction (Chapter 1), several of the chapters in this document have been rewritten or revised from the 1996 Human Factors Design Guide. Each of these chapters were reviewed by a group of human factors experts. The insight of these individuals was invaluable in producing this document. The following individuals served as reviewers on one or more of the chapters: Paul Krois, Alan Poston, Glen Hewitt, Dino Piccione, Dan Herschler, Chuck Overbey, and Raja Parasuraman (Chapter 3 only).

The 1996 Human Factors Design Guide was created in Word Perfect, and later converted to Word 6, then revised by us in Word 2000. As we went through each chapter, these conversions provided us with innumerable surprises and challenges. With the help of first Kelly Longo and then Bonnie Kudrick, I hope that we have fixed all of the formatting anomalies. If you as a user discover something that was not fixed, please contact us at the address on the comment sheet.

Request for feedback and comments. This is considered a living document, which means that although every effort has been made to make it usable and comprehensive, we acknowledge that there will always be room for improvement. User feedback in the form of corrections or improvements is encouraged. Comments can be made at any time by using the form at the end of the document.

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1 Introduction

As the National Airspace System (NAS) continues to modernize, new systems and equipment are continually being added to the existing architecture. The integration of human factors into the development and procurement of these new systems is vital to the success of the future NAS. Although the Human Factors Design Guide (HFDG) (Department of Transportation, 1996) has been available for a number of years and provided vital information, it did not have the weight and impact of a design standard. Instead, the Military Standard (MIL-STD) 1472 D (Department of Defense, 1989) was commonly cited in FAA system specifications. To meet the current needs of the FAA, information within the HFDG needed to be updated, broadened to include both Air Traffic (AT) and Airways Facilities (AF), and changed into standards instead of guidelines.

The present document revises and expands upon the previously published material. It broadens the focus to include both AT and AF systems and has been modified into a set of standards instead of a set of guidelines, providing a common source of FAA-specific design requirements. The resulting set of standards can then be tailored to meet the needs of AT and AF systems, as not all requirements are applicable to all systems.

In this revision, many changes have been made to the material from the earlier version of the document in order to meet the needs described above. These changes include major expansion and revisions to the content of key chapters and organizational changes made to enhance usability. It also includes a change of the name from Human Factors Design Guide (HFDG) to Human Factors Design Standard (HFDS). This introductory chapter describes the changes, serves to familiarize readers with the formatting conventions used in this document, and presents a framework for the application of the standards.

1.1 Background

The original document was modeled largely after the MIL-STD-1472. However, the original HFDG was published as a guidelines document. This revised version is released as a standard instead of a guidelines document to better match the original intent of the document as a replacement for the use of MIL-STD-1472 for FAA systems and equipment. As a standard, the HFDS contains design criteria in the form of “should” and “shall” statements. In line with the more stringent requirements of a standard, information that was not based on empirical evidence or best practices was removed.

The HFDS retains the goal of providing a comprehensive reference document. The organization, format, style, and contents have been revised for easy access and understanding. The original documentcontained 14 chapters covering a broad range of topics. The current document contains 15 chapters due to the expansion of information already available in the 1996 version, including completely revised chapters on computer human interface and automation.

This document was developed as a comprehensive reference tool to help FAA and contractor human factors professionals carry out FAA human factors policy. As a guide, it consolidated human factors knowledge, practice, and prior experience for application to new systems and equipment. It was conceived as a "living document" to be revised as new information became available. Aside from revisions to individual chapters, this document represents the first major revision of the HFDG since its release in 1996.

When the original document was written, there was little in the way of comprehensive human factors guidelines. Human factors knowledge consisted of scattered papers, articles, and technical reports. This lack of formal documentation posed a problem for those wishing to apply human factors design criteria to the acquisition of new systems and equipment. In addition to the time and effort necessary to collect and sift through a multitude of different human factors sources, many documents were difficult or costly to obtain. The HFDG provided a more complete reference by collecting disparate information into a single consolidated reference source. This information was organized into 14 major chapters including general design requirements, maintenance automation, designing equipment for maintenance, human-equipment interfaces, computer-human interfaces, workplace design, user documentation, system security, personnel safety, environment, anthropometry, and biomechanics.

Since the release of the original HFDG, there has been an increased interest in guidelines, both within the government and in industrial and commercial organizations, with an associated increase in human factors research to support the guidelines. This increased interest has resulted in many government and commercial organizations developing in-house guidelines material, particularly on the topic of computer-human interface. Other, primarily government or government-sponsored groups, focused on developing ergonomic and accessibility guidelines. This document selectively draws upon these new information sources while covering a broad range of human factors topics to meet the needs of FAA missions and systems. This compilation of design criteria represents the most comprehensive information available within a single reference source; for this reason, this document is the primary human factors authority for the development and procurement of FAA systems and equipment.

The original HFDG focused principally on the Airway Facilities environment. Thus, a strong emphasis existed in the area of maintenance. Since the document was published in 1996, however, it has provided guidance not only for maintenance acquisitions but for acquisitions and development in other areas of the FAA as well. It is widely used to aid human factors professionals in supporting a broad range of acquisitions involving air traffic control, automation, aviation security, communication, navigation, and surveillance technologies.

Therefore, an additional challenge for the revision effort was to broaden the focus beyond maintenance issues.

1.2 Purpose

The purpose of this HFDS is to provide a single easy-to-use source of human factors design criteria oriented to the needs of the FAA mission and systems. An additional goal is to facilitate use of appropriate design criteria by organizing the document so that users can easily locate the needed information.

1.3 Objectives

The objectives developed to create this document reflect the working philosophy used to form the HFDS into a useful human factors reference tool.

Some of the objectives were to

a. place relevant human factors information in a single document rather than multiple diverse human factors documents;

b. provide highly relevant information based on research or accepted practices for use by FAA and contractor human factors professionals in system acquisitions or modifications and in the evaluation and selection of Commercial Off-The-Shelf (COTS) and Non-Developmental Items (NDI) procurements;

c. provide human factors information in the form of clear, concise, usable standards;

d. organize the document so that users could easily locate the needed information;

e. use credible, up-to-date sources;

f. provide a strong and comprehensive computer-human interface section;

g. promote human-interface consistency within and among subsystems; and

h. serve as a basis for general human factors test and evaluation information and checklist procedures.

1.4 Scope

This document presents human factors design standards that are to be applied to new, modified, or updated facilities, systems, and equipment that will be managed, operated, or maintained by the FAA. It covers a broad range of human factors topics that pertain to input devices, automation, maintenance, controls, computer-human interface, workplace design, documentation, system security, safety, the environment, anthropometry, alarms, audio, and voice.

This document is relevant to all phases of the FAA development process, from the mission-need determination phase through production and deployment phases. It is to be considered for any engineering changes or modifications that affect the human interaction with the operational system. This document provides information that can be used in the evaluation and selection of COTS or NDI equipment. Similarly, it may be applied to advanced research programs transitioning to new FAA systems.

This document does not address technical efforts, developmental processes, methodologies, studies, or evaluations that are necessary during an acquisition or developmental process.

1.5 Process

A thorough, step-by-step process was used to achieve the stated objectives for this document. Some of the steps that were taken toward achieving our goals follow.

a. The wording and scope of the guidelines and topics were carefully reviewed and revised to broaden the focus beyond the maintenance environment for the revised chapters.

b. Standards without verifiable references were removed.

c. The newly revised chapters were integrated into the document.

d. Discrepancies and typographical errors in non-revised chapters were corrected.

e. Sources were moved to the end of each standard.

f. New reference lists were created for each chapter.

g. New glossaries were created for each chapter.

h. A cumulative reference list and glossary were created.

i. New indices and tables of contents were created for each chapter.

j. A new cumulative index and table of contents was created.

k. The material in the document was compared against the standard FAA-G-2100, and any discrepancies were resolved.

l. Material was reorganized to make the document more usable, resulting in the deletion of two chapters and the creation of three new chapters.

m. Material was reviewed and revised by technical editors.

1.5.1 Expert review

These steps resulted in a draft document. Once draft material was created, the validity of it was assessed using a review process. A panel of human factors experts served as reviewers for updated chapter material and the document as a whole. The reviewers commented on the technical content of the material, the clarity of the design criteria, the usability of the information, and the organization of the material. The review process resulted in numerous suggested changes.

1.6 Significant changes

The revision resulted in several notable changes.

The revised Automation Chapter 3 includes 126 new source references. The review of these source documents resulted in the addition of over 100 new standards that were incorporated into the revised chapter.

The revised Computer-Human Interface Chapter 8 includes 22 new source references from government agencies and private industry. The review of these source documents resulted in the addition of 512 new standards that were incorporated into the revised chapter.

The reorganization of the revised Chapters 3 and 8 involved a systematic regrouping of information as well as the removal of redundant standards.

All statements that could not be verified by published reports, papers, technical notes, or other standard or guideline documents were removed.

All of the standards in the revised chapters were rewritten to contain only one “should” or “shall” standard per rule or guideline.

New material on wheelchair anthropometrics was added to Chapter 14.

1.6.1 Reorganization

A human factors reference book is only useful if it meets the users' needs. Vincente, Burns, & Pawlak, (1998) have criticized the usefulness of human factors reference documents. They state that these reference documents do not analyze the users' needs and that there is a gap between the research presented by the documents and the needs of system designers that impedes the transfer of information. Although there may always be some sort of gap between research and the needs of designers, the authors of this document have tried to minimize that gap. They evaluated how users make use of design guides by consulting with FAA human factors professionals and analyzing documents from acquisition and design programs.

Vincente et al. (1998) suggest four steps to ensure effective design guidance. The first step is to identify topics relevant to design problems and questions. The second step is to transform the research into usable guidance. The third step is to organize the material in a way that makes it easy for the users to find the information they need. Fourth, they recommend formatting the information so that is easy to use and understand.

These suggestions were considered during the development of the HFDS. The Computer Human Interface and Automation chapters are both very relevant to design problems and questions. The Computer Human Interface chapter is one of the most frequently used chapters by FAA human factors specialists in the design of products and systems. The revision of the Automation chapter reflects a trend toward increasing automation within the FAA. With increasing automation, there is a concomitant increase in the need for automation-specific guidance and design criteria. Both the Computer Human Interface and Automation chapters have been completely revised in the HFDS.

The authors have also taken steps to make the information within the HFDS more usable. They have rewritten the design criteria so that there is only one should or shall statement per paragraph. They added sources at the end of each design statement to help designers if they need to find additional information on the referenced topic and give the users the ability to weight the relevance of the design criteria based on the source. Also, they provided additional examples and discussions to help the users interpret the information that is presented. This additional information enables designers to make informed decisions regarding tradeoffs involved with certain design criteria. For example, if the criterion calls for not more than seven items in a menu and a designer wishes to have eight items, what might the consequences be? The additional information provided in the discussion can provide insight on tradeoffs such as this.

The authors have reorganized the topics and standards within the document to more closely align with the way the document was being used for FAA system acquisition and design, making it easier for users to find the needed information. In our analysis of how the information has been used, we found that it is not often that users need the entire document at the same time. Instead, they tend to use a single topic area at a time. By creating table of contents, glossaries, references, and indexes for each chapter, we make it possible for users to use a single chapter in isolation of the remainder of the document.

After adding all of the new material and revising and updating the existing design criteria, the authors reorganized the topics and standards within the document to facilitate the location of information. They grouped related topics, created new chapters based on the analysis of use, and created new sections from areas that had been expanded due to new information. These changes are summarized in Exhibit 1.

Exhibit 1. Summary of changes resulting in the HFDS

Original chapter number	Original chapter titles	Current location of information
1	Introduction	Completely revised and rewritten.
2	Complementary documents	Integrated with reference section where appropriate.
3	Definitions	Individual definitions moved to the end of appropriate chapters and in entirety as a glossary at the end of document.
4	General design requirements	Revised and moved to Chapter 2 – entitled General design requirements.
5	Maintenance automation	Completely rewritten, reorganized, and updated with new information added; expanded focus beyond maintenance, renamed "automation." moved to Chapter 3.
6	Designing equipment for maintenance	6.12.1 Alarms has been moved to Chapter 7 Alarms, audio, and voice. 6.12.3 Diagnostic aids has been moved to Chapter 3 – Automation.
7	Human-equipment interfaces	7.2 Video displays moved to Chapter 5 – Displays and printers. 7.3 Audio displays moved to Chapter 7 – Alarms, audio, and voice. 7.4 Controls changed to Chapter 6; entire chapter renamed as Controls and visual indicators.
8	Human-computer maintenance	Completely revised chapter, renamed Computer-human interface: 588 new design criteria. 8.2.17 Alarms moved to Chapter 7 – Alarms, audio, and voice. 8.21 Input devices moved to Chapter 9-Input devices.
9	Workplace design	Moved to Chapter 10 Removed some design criteria that could not be verified against the original source material. Revised and updated accessibility material; reorganized chapter to accommodate accessibility material.
10	User documentation	Removed some design criteria that could not be verified with the original source material, moved to Chapter 15. Revised and updated accessibility material.
11	System security	Removed some design criteria that could not be verified with the original source material.
12	Personnel safety	Removed some design criteria that could not be verified with the original source material.
13	Environment	Removed some design criteria that could not be verified with the original source material.
14	Anthropometry and biomechanics	Re-created tables to fix discrepancy discovered with source material. Added material on wheelchair anthropometrics.
	References	Updated format to reflect APA style and added new references as appropriate, moved out of Appendix to References section.
	Sources	Sources were placed at the end of the standards throughout the entire document
	Standard actions-push buttons	Integrated as appropriate into glossary and standards.
	Standard verbs	Integrated as appropriate into glossary and standards.
	Glossary	Contains definitions from all chapters.
	Index	Completely updated.
	HFDG to HFDS Cross reference	Table that allows users to find where specific information from the HFDG is now located in the HFDS

1.7 Using this document

No single human factors professional or designer can be expected to be knowledgeable in all aspects of human factors. By collecting information based on research and best practices, this document makes available the collective knowledge of many human factors professionals.

Contrary to the idea that human factors standards apply only to developmental acquisition programs, COTS items can also benefit from the application of human factors standards. COTS items, software, in particular, have a great deal of variability in quality of interface design. The information within this document can be useful to compare the quality of design for different COTS items, facilitating informed acquisition decisions.

The application of the standards in this document cannot guarantee good design for a variety of reasons. Although this document focuses on achieving good design and consistency within and between systems, the standards within this document can be implemented in different ways. Standards cannot replace good human factors expertise. A designer who is very knowledgeable in human factors might do well without using any standards whereas a novice designer might do poorly even with the help of standards.

The result of using this document in development and acquisitions will be a more usable system. However, even systems that are carefully designed using this document in conjunction with a human factors expert will need to be verified through means such as prototyping and testing with representative users. Testing will allow the designer to confirm the positive design features and identify any negative design features that my have been missed by the standards and the human factors professional.

Although these standards are necessarily general in order to apply to the wide range of systems and equipment within the FAA, they can be made into system specific rules. Not all of the standards proposed here may be applicable to every system. For any particular system, some of the standards will be relevant and some will not. Additionally, the use of this document cannot substitute for knowledge of task (user and system) requirements. It assumes the user has detailed knowledge of user and system needs.

1.7.1 Tailoring

Design standards such as those contained in this document must be generally worded so that they might apply to many different system applications. Before they can be applied to a specific system or piece of equipment however, these generally worded standards often need to be converted into system-specific rules. For example, a standard that states that the options in a menu should be ordered in a way that minimizes user navigation may be rewritten for a specific system to specify the exact ordering of the items used for the system. This process is known as tailoring.

Tailoring is the process of selecting and evaluating individual standards to determine the extent to which they apply to a specific system or piece of equipment. It includes the process of modifying these standards to ensure that there is an optimal balance between operational needs and cost.

Tailoring of the standards may not always be possible. If the specifics of a system are not known in advance, a chapter or section of the HFDS may need to be cited in its entirety, with tailoring occurring later in the process. The HFDS has been reorganized to facilitate these cases. For example, the information on input devices has been given its own chapter, as has audio alarms.

Not every standard contained within this document will be applicable to every system. The application of every standard within this document to a single system would likely result in a system that was cost prohibitive. Tailoring the standards contained within this document to ensure applicability to a specific system avoids unnecessary efforts, overly restrictive design, and exorbitant costs.

Whose responsibility should it be to tailor the standards? Ideally, it should be the joint responsibility of human factors experts, vendors or system developers, users, and program managers. In order to tailor standards, the members of this working coalition must have a thorough understanding of task requirements and user characteristics. Each of these groups has something unique to contribute to the process. Users have knowledge of the task, people from the program office and vendors have knowledge of the costs involved in implementing recommendations, and human factors experts have knowledge of human factors. Together, these representatives can determine which of the items will provide the most benefit overall.

As a first step in standards tailoring, a human factors practitioner must review the sections of this document to identify those standards that are relevant to the acquisition being considered. Chapters of this document have been reorganized to facilitate this process. For example, someone wishing to procure a new keyboard for a system can easily skip to the chapter on input devices and extract the relevant information.

For a complex system or one with many components, the list of relevant standards may be extensive (for example, elements of the chapters on automation, input devices, auditory alarms, and computer-human interfaces). Once all relevant standards have been identified on a general level, the standards should be reviewed to decide which specific ones are most appropriate for the particular system or equipment.

1.8 Format

This section discusses the formatting conventions used in this document, which facilitate the use of the material. The format of this document is intended to help the user easily navigate through, locate, and use information. By using this information on organization and format, the user of the document should be able to skim the material and quickly find information on topics of interest.

Each chapter now contains its own table of contents, glossary, reference list, and index. This allows the chapters to be used relatively independently, if necessary, and for the user to quickly identify the sources if they need additional information.

Each standard is now followed immediately by the source citation. This allows the user to better understand the context that the reference came from and make better-informed decisions about the applicability of the particular standard to a system.

1.8.1 Measurements

Measurements and dimensions used throughout the document are expressed in International System units. As a convenience, the metric units are accompanied by their customary English system equivalents in parentheses. This practice is consistent with other standard and handbook sources.

1.8.2 Topical completeness

Within each chapter, when a standard is applicable to more than one topic, that standard has been included in a general information section. In the original document, guidelines were often repeated in more than one area of a chapter or more than one chapter. To the extent possible, these redundancies were removed, particularly in the revised chapters. Instead, associated information, which may be related, is appropriately cross-referenced, noted as "(see x.x. ...)."

Where directly relevant information is found elsewhere in the document, a cross reference, which states "(see section or paragraph x.x. ...)," is used. To ease the users' tasks, such direct cross-referencing was held to a minimum.

1.8.3 Headers and footers

Headers and footers are provided to simplify navigation through the document. The major section topic number and name appear in the header of each page. The footer contains the page number centered on each page preceded by the chapter number.

1.8.4 Heading and text locations

Introductory text, standards, and explanatory text appear in the right-hand column. Headings appear in the left-hand column and provide a concise title that reflects the contents found in each section.

1.8.5 Features specific to each standard

Each standard has features that provide specific information to the user of this document. Each feature is described in this section.

1.8.5.1 Contents

Each standard provides clear and concise information concerning a single specific topic.

1.8.5.2 Identification and use of "shall" and "should"

Each statement specified in this document is identified as a “shall” or “should” statement. As a standard, this document contains both requirements and recommendations. Requirements are indicated by “shall” statements, whereas, recommendations are indicated by “should” statements. Requirements and recommendations are collectively referred to in this document as standards.

A solid black square (■) adjacent to the statement identifies the "shall" statements. These requirements originate from or are comparable to statements from authoritative sources such as those associated with FAA orders, standards, and military specifications.

Each “should” statement is identified by an open white square (□). These recommendations represent best practices information that is applicable in most cases but may involve trade-offs or be influenced by context-specific factors.

1.8.5.3 Numbering of standards

The standards are numbered consecutively within each section with each having a distinct number that indicates the section/subsection in which the standard is located.

1.8.5.4 Titles

Each standard has a relevant and concise title, which allows the user to quickly evaluate the content of the standard.

1.8.5.5 Sources

Each standard is followed immediately by the source citation. The source citation shows the document author and the date the document was either written or published. This allows the user to better understand the context that the reference came from and make more informed decisions about the applicability of the particular standard to a system. Complete citations for the sources used are listed at the end of each chapter. A master list of all of the references used in the document is located at the end of the document.

1.8.5.6 Additional information

There are times when additional information can help to clarify a standard. When a standard requires additional information to clarify the meaning, the information is provided by adding a discussion, explanation, or an exhibit immediately following the standard.

Some of the standards are followed by a discussion paragraph. These paragraphs generally provide the reasoning behind the paragraph or, sometimes, further definition of terms used in the paragraph.

Examples can help the user to better understand a standard, however, there is a risk that the specific example used to clarify the standard could cause the user to interpret the standard more narrowly than intended. Therefore, we remind the reader that examples are meant to clarify the standard but are not meant to narrow the application of the standard.

Rather than two separate series of tables and figures, the HFDS has a single series of exhibits. An exhibit contains tabular information, illustrative information, or both. Thus, tabular and graphic information, which are to be used together, can be found within the same exhibit. Exhibits follow closely to the text that refers to them.

1.8.6 Glossary

Following the reference list at the end of each chapter is a glossary of words found in that individual chapter. The glossary defines words used in the standards, particularly terms that may be unfamiliar to the user, have multiple possible definitions, or may be used more narrowly in the standards than the general definition of the word. At the end of this document is a cumulative glossary that combines the glossaries from each of the individual chapters.

1.8.7 Index

Following each chapter is a topical index of the material found in that chapter. At the end of the document is a consolidated index that includes all of the chapters. The index is intended to help readers find information on a particular subject, independent of the topical organization of the information within the chapters.

1.8.8 References

At the end of each chapter, following the standards, is a list of references from that chapter. A cumulative reference list containing references from all of the chapters is located at the end of the document.

1.9 Superceded documents

The current document represents the first major revision of the HFDG. However, prior to the release of this document, two key chapters, Chapter 8 on Human Computer Interface, and Chapter 3 on Automation, were revised and released as final reports and/or technical notes. The Human Factors Design Standard supercedes the following documents:

HFDG Version 1.0 (Report Number DOT/FAA/CT-96/01)-January 1996

HFDG Version 1.1-December 1997

Computer-Human Interface Guidelines: A revision to Chapter 8 of the Human Factors Design Guide (DOT/FAA/CT-TN00/30). (Ahlstrom, V., & Longo, K., 2000).

Human Factors Design Guide Update (Report Number DOT/FAA/CT-96/01): A Revision to Chapter 8-Computer Human Interface Guidelines (DOT/FAA/CT01/08). (Ahlstrom, V., & Longo, K., 2001).

Human Factors Design Guide Update (Report Number DOT/FAA/CT-96/01): A Revision to Chapter 5-Automation Guidelines. Atlantic City International Airport, NJ: Federal Aviation Administration William J. Hughes Technical Center (DOT/FAA/CT02/11). (Ahlstrom, V., Longo, K., & Truitt, T., 2002).

1.10 Future of this document

The HFDS is considered to be a living document. It will be updated as needed to keep current with emerging research, technological advances, and user feedback. This will provide the most current human factors knowledge in a usable tool. The authors welcome suggestions for improvement of this document. Comments and suggestions should be addressed to:

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Glossary

Tailoring - The process of selecting and evaluating individual standards to determine the extent to which they apply to a specific system or piece of equipment. It includes the process of modifying these standards to ensure that there is an optimal balance between operational needs and cost.

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2 General design requirements

This section includes general human factors principles for designing or selecting systems and equipment.

2.1 Basic design elements

- ▪ **2.1.1 Make systems durable.** Systems and equipment shall be sufficiently durable to operate and maintain under the conditions for which it was designed or procured. [Source: Department of Defense (MIL-STD-1472F), 1999]

- ▫ **2.1.2 Allocate functions appropriately.** Functions should be allocated to equipment or personnel so as to achieve reliable system performance with the needed sensitivity, precision, time, and safety at minimum cost and with the minimum level skills required to maintain and operate the system. [Source: MIL-STD-1472F, 1999]

  Discussion. The Automation chapter (Chapter 3) of this document provides information on how to determine which functions are better performed by machines and which functions are better performed by people.

- ▪ **2.1.3 Test with users.** Systems and equipment human factors considerations shall employ early and continuous testing with actual users in a realistic environment. [Source: Ameritech, 1998; Galitz, 1993]

- ▫ **2.1.4 Make the system reliable.** The system should be reliable, thereby maximizing the availability to the users. [Source: Galitz, 1993]

  Discussion. A system does not have to experience a complete shut down to be considered unreliable by the user. A system that is functioning, but performing its intended function poorly may cause the user to consider the system unreliable. For instance, the user may perceive the system as unreliable if it misses alert conditions, provides incomplete information about the operational situation, or performs in a degraded state under certain operational conditions. [Source: Galitz, 1993]

2.2 Simplicity

■ **2.2.1 Design for simplicity.** The system or equipment design shall be as simple as possible, consistent with the desired human-machine system functions, and compatible with the expected maintenance and operational concepts. [Source: MIL-STD-1472F, 1999]

Discussion. Equipment designed with simplicity in mind is generally more reliable and easier for personnel to maintain and operate. When different designs are compared from a human factors view, the simplest design usually has less potential for human error.

■ **2.2.2 Minimize training.** Systems and equipment shall be capable of being maintained, operated, and repaired in the planned operational and maintenance environment with minimal training. [Source: MIL-STD-1472F, 1999]

□ **2.2.3 Make functions obvious.** Systems and equipment should be designed so that basic system functions are obvious to the user. [Source: Martin & Dong, 1999]

Discussion. If the basic functions are obvious to the user, the user will be able to understand the core system tasks with a minimum amount of prior training.

2.3 Consistency

□ **2.3.1 Make design consistent.** Systems and equipment should be designed to be consistent, appearing, behaving, and responding the same throughout. [Galitz, 1993]

Definition. Consistent means adhering to the same principles with minimal variation. For systems, this entails maintaining a common design philosophy. Consistent design allows users to take general knowledge and skills learned from one system and apply it to other similar systems without extensive learning or training. [Source: CTA, 1996]

Example. An example of a consistent design philosophy would be to use direct manipulation (point-and-click and drag-and-drop of icons) across systems instead of using direct manipulation on one system and command line interface on another system.

- **2.3.2 Be consistent with user mental model.** To decrease learning or training times, systems should be designed to be consistent with the mental model of the users. [Source: CTA, 1996]

  Discussion. The following are some areas that can be exploited to obtain consistency with user mental models in system design:

  a. Analogy with real life objects

  b. Experience with similar systems

  c. Previous operational experience [Source: CTA, 1996]

- **2.3.3 Minimize inconsistency.** If an occasional departure from consistent design is necessary to support user task performance, designers should minimize the extent of the inconsistency with the rest of the user interface. [Source: CTA, 1996]

2.4 Standardization

- **2.4.1 Standardize hardware and software.** Hardware and software designs shall be standardized to the degree practical and compatible with system functions and purposes. [Source: MIL-STD-1472F, 1999]

  Definition. Standardization refers to common user-interface features across multiple applications.

  Discussion. Standardized hardware would use consistent fasteners, switches, breakers, and connectors within and across equipment. When software is standardized, applications that address common functions employ the same user dialogs, interfaces, and procedures. Standardization simplifies maintenance procedures and reduces the tools required, the potential for human error, training time, skill requirements, inventory of spares, and documentation. [Source: MIL-STD-1472F, 1999; Department of Defense (MIL-HDBK-759C), 1995]

  Example. The length of time that it takes the user to mentally process the contents of a screen nearly doubles when the position of the screen elements is varied. [Source: Teitelbaum & Granda, 1983]

- **2.4.2 Maintain identical interfaces for identical functions.** Equipment with identical functions shall employ identical or similar interfaces. [Source: MIL-STD-1472F, 1999]

- **2.4.3 Make controls, displays, marking, coding, labeling, and arrangement uniform.** Controls, displays, marking, coding, labeling, and arrangement schemes shall be uniform for common functions of all equipment. [Source: MIL-STD-1472F, 1999]

- **2.4.4 Make appearance distinctive.** Units of equipment or modules that have different functions should be distinctive in their appearance and identification. [Source: DOE-HDBK-1140, 2001]

- **2.4.5 Standardize terminology, look, and feel.** Systems and equipment should have standardized terminology, look, and feel. [Source: Avery & Bowser, 1992]

  Discussion. Standardized terminology eliminates differences in names assigned to and descriptions of the same functions and features. A standardized look minimizes differences in the appearance of displays based upon different styles. A standardized feel minimizes differences in the actions a user takes to interact with an application. [Source: Galitz, 1993]

- **2.4.6 Make functionally similar equipment interchangeable.** Equipment that has the same form and function shall be interchangeable throughout a system and related systems. [Source: MIL-STD-1472F, 1999]

- **2.4.7 Make functionally different equipment non-interchangeable.** If equipment is not interchangeable functionally, it shall not be interchangeable physically. [Source: MIL-STD-1472F, 1999]

2.5 Safety

- **2.5.1 Incorporate safety factors.** System and equipment design shall incorporate applicable system and personal safety factors that affect human performance including those that minimize human error under normal, degraded, or emergency conditions and under adverse environments. [Source: MIL-STD-1472F, 1999]

  Discussion. Specific design criteria on workplace design, personnel safety, and environment, can be found in Chapters 10, 12, and 13 of this document.

- **2.5.2 Provide a fail-safe design.** A fail-safe design shall be provided for systems in which failure could cause catastrophic damage, injury to personnel, or inadvertent operation of equipment. [Source: MIL-STD-1472F, 1999]

■ **2.5.3 Make systems error resistant.** Users shall be protected from making errors to the maximum possible extent. [Source: Martin & Dong, 1999]

Discussion. To make a system **error resistant** is to make it difficult for a user to make an error. Simplicity in design and the provision of clear information are tools to improve error resistance. Electronic checklists also have the potential to improve error resistance by providing reminders of items that need to be completed. [Source: Billings, 1991]

□ **2.5.4 Make systems error tolerant.** Systems should be tolerant of human errors. [Source: Galitz, 1993]

Discussion. To make a system **error tolerant** is to mitigate the effects of human errors that are committed. Error tolerance can be improved by adding monitoring capabilities. [Source: Billings, 1991]

□ **2.5.5 Warn of potentially unsafe actions.** Systems and equipment should warn users before they initiate a task that may result in potentially serious consequences. [Source: Apple Computer Incorporated, 1995]

■ **2.5.6 Identify safe and unsafe states and actions.** Systems and equipment shall clearly identify safe and unsafe operating states and actions. [Source: Wallace, Peng, & Ippolito, 1992]

■ **2.5.7 Provide emergency procedures for critical systems**. For critical software, systems, or equipment, there shall be a clear, step-by-step description of procedures to be conducted in the event of failure. [Source: Wallace, Peng, & Ippolito, 1992]

■ **2.5.8 Provide redundancy.** There shall be redundant means to access systems and equipment that provide a critical function. [Source: Wallace, Peng, & Ippolito, 1992]

□ **2.5.9 Design systems to be modular.** Systems and equipment should be modular in design. [Source: Wallace, Peng, & Ippolito, 1992]

Definition. To be **modular** means to be designed with standardized or uniform components. The advantage of a modular design is that if one component fails, it is easier to replace.

■ **2.5.10 Provide warning labels.** Design, location, procedural guidance, and suitable warning labels shall be provided to prevent damage to equipment while it is being handled, installed, operated, or maintained. [Source: MIL-STD-1472F, 1999]

■ **2.5.11 Prevent misalignment and improper mounting.** Equipment shall include physical features that prevent improper mounting or alignment, or at least have labels or codes to identify proper mounting and alignment. [Source: MIL-STD-1472F, 1999]

2.6 User-centered perspective

Definition. A **user-centered perspective** involves focusing on the needs and requirements of the end user throughout the design, acquisition, or development process.

▪ 2.6.1 **Provide timely and informative feedback.** Systems and equipment shall provide timely and informative feedback to user actions to keep the users informed about what is happening. [Apple Computer Incorporated, 1995]

> **Discussion.** For feedback to be informative, it must be understandable to the users. For example, if a user picks up the phone, the presence of a particular tone indicates that the line is available and ready for use. The change in the tone indicates changes in the availability of the system (e.g., dialing, call placed but waiting for answer, busy).

▫ 2.6.2 **Provide predictable results to user actions.** User actions should cause predictable results. [Source: Martin & Dong, 1999]

▫ 2.6.3 **Use familiar terms and images.** Systems and equipment should use terms and images familiar to the user. [Source: Martin & Dong, 1999]

▪ 2.6.4 **Design within user abilities.** The design of systems, equipment, and facilities shall conform to the capabilities and limitations of the users to operate and maintain it in its operational environment and not exceed user capabilities. [Source: MIL-HDBK-759C, 1995]

▫ 2.6.5 **Maximize human performance.** Systems and equipment should be designed to foster effective procedures, work patterns, and personnel safety and health and minimize factors that degrade human performance. [Source: MIL-HDBK-759C, 1995]

▫ 2.6.6 **Minimize training requirements.** Systems and equipment should be designed to minimize personnel and training requirements within the limits of time, cost, and performance trade-offs. [Source: MIL-HDBK-759C, 1995]

▫ 2.6.7 **Design to meet user requirements**. Systems and equipment should be designed to meet specific user requirements, providing the functionality to meet those requirements. [Source: Avery & Bowser, 1992]

▫ 2.6.8 **Minimize user actions.** Systems and equipment should be designed to minimize hand and eye movements, thus maximizing efficiency. [Source: Galitz, 1993]

▫ 2.6.9 **Facilitate transfer of skills.** Systems and equipment should be designed to allow skills acquired in one circumstance to be used in another. (Consistency and standardization help to accomplish this.) [Source: Galitz, 1993]

■ **2.6.10 Design for 5th to 95th percentile.** Systems and equipment shall be, at minimum, designed for personnel from the 5th through the 95th percentile levels of the human physical characteristics that represent the user population. [Source: MIL-STD-1472F, 1999]

□ **2.6.11 Accommodate physical diversity.** Systems and equipment should accommodate the maximum range (so as to address 100%) of the user population. [Source: MIL-STD-1472F, 1999]

Discussion. Systems must be designed to accommodate all of the users. Yet, design guidelines often suggest to accommodate some portion of the demographic database of essential user measurements (such as the 5th through 95th percentile). This approach ostensibly excludes only the extremes of the population.

However, depending upon the source of the demographic database, some significant portion of the user population may be excluded. Also, since body proportions are not linearly correlated, someone who is 5th percentile in height may not be 5th percentile in reach or leg length. Thus, using some portion of the demographic database (5th to 95th percentile) in one dimension may include 90% of the population, but using the 5th to 95th percentile for all body dimensions is likely to exclude much more of the population. Obviously, as the percentile range is extended, significant cost/benefit tradeoffs are incurred.

In some cases, it is not feasible to design for every individual. However, it is necessary to make every reasonable *accommodation* for all users to safely and efficiently perform their tasks. This can be accomplished through a variety of approaches, including conducting appropriate analyses to determine the full range of the user population, innovating designs for adjustability into the system, providing accessories or features that accommodate other users as the need arises, or providing custom modifications.

■ **2.6.12 Design to accommodate people with disabilities.** Systems and equipment shall provide reasonable accommodation for users with disabilities where appropriate. [Source: General Services Administration (Section 508), 2000]

Discussion. Make a reasonable effort to provide people with disabilities access to and use of systems and equipment that all people can access and use.

□ **2.6.13 Provide enough flexibility for different user skill levels.** Systems and equipment should be flexible enough to accommodate the interaction styles of users with differing skill and experience levels. [Source: Ameritech, 1998]

□ **2.6.14 Maximize user subjective satisfaction.** Systems should be designed so that users like the new system or equipment. [Source: Ameritech, 1998]

Discussion. Users like a system that is well designed because it helps them accomplish their task and is easy to use without causing unnecessary workload.

2.7 Support

□ **2.7.1 Provide help.** Help should be available in the event that the user has difficulty operating or maintaining software, systems or equipment. [Source: CTA, 1996]

Discussion. Help can come in many forms such as a customer support number that can be called for technical assistance, on-line help, and even user manuals.

2.8 Maintenance

□ **2.8.1 Design for common tools.** Systems and equipment should be designed to require only common hand tools for maintenance unless specialized tools provide a significant advantage over common hand tools or where required by security considerations. [Source: MIL-HDBK-759C, 1995; MIL-STD-1472F, 1999]

■ **2.8.2 Make systems easy to maintain.** Systems and equipment shall be designed so that they can be maintained in the least amount of time, at the lowest cost, and with a minimum expenditure of support resources. [Source: Department of Energy (DOE HFAC1), 1992]

Glossary

Consistent - Consistent means adhering to the same principles with minimal variation.

Modular - To be modular means to be designed with standardized or uniform components.

Standardization - Standardization refers to common user-interface features across multiple applications.

User-centered perspective - A user-centered perspective involves focusing on the needs and requirements of the end user throughout the design, acquisition, or development process.

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3 Automation

Definition. Automation is the independent accomplishment of a function by a device or system that was formerly carried out by a human. [Source: National Research Council (NRC), 1998; Parasuraman & Riley, 1997]

3.1 General

□ **3.1.1 Minimum automation human factors requirements.** An automated system should

a. provide sufficient information to keep the user informed of its operating mode, intent, function, and output;

b. inform the user of automation failure or degradation;

c. inform the user if potentially unsafe modes are manually selected;

d. not interfere with manual task performance; and

e. allow for manual override. [Source: Veridian (AHCI), 1998; Billings, 1997]

■ **3.1.2 Place user in command.** Automated systems shall prevent the removal of the user from the command role. [Source: Billings, 1997]

Discussion. The reasoning behind this rule is twofold. First, it is ultimately the user who is responsible for the task. Second, automation is subject to failure. Therefore, it is the user, not the automation who must be in control of the system with the automation playing a subservient role. [Source: Billings, 1997]

■ **3.1.3 Automate only to improve performance.** Functions shall be automated only if they improve system performance without reducing human involvement, situation awareness, or human performance in carrying out the intended task. [Source: Billings, 1991]

Discussion. The introduction of automation is often intended to reduce workload and augment performance; however, this is not always the result. Automation can lead to distraction from the primary task, increased workload, boredom, or complacency. Automation can also have psychosocial impacts, influencing job satisfaction or self worth. [Source: Bowers, Deaton, Oser, Prince & Kolb, 1995; Danaher, 1980; Edwards, 1976; Parasuraman, Molloy, Mouloua, & Hilburn, 1996; Wiener, 1989; Wiener & Curry, 1980]

- □ **3.1.4 Automate with good reason.** Automation should be used to support the user(s) where appropriate (human-centered automation), not implemented simply because the technology is available (technology-centered automation). [Source: Billings, 1997]

- ■ **3.1.5 Enable users to carry out tasks.** Automation shall help or enable the users to carry out their responsibilities and tasks safely, efficiently, and effectively. [Source: Billings, 1991]

  Definitions. Carrying out a task **effectively** means producing the desired result. Carrying out a task **efficiently** means that the desired result is produced with a minimum of waste (usually in relation to time).

- ■ **3.1.6 Provide a clear relationship with user tasks.** The relationships between display, control, decision aid, and information structure and user tasks and functions shall be clear to the user. [Source: Nuclear Regulatory Commission (NUREG-0700), 1996; Nuclear Regulatory Commission (NUREG/CR-6105), 1994]

  Discussion. The user needs to be able to see clearly how the display or decision aid, and so on, facilitates the completion of the necessary task.

- ■ **3.1.7 Ensure active user involvement in operation.** Users shall be given an active role through relevant and meaningful tasks in the operation of a system regardless of the level of automation being employed. [Source: AHCI, 1998; Billings, 1991]

  Discussion. User awareness of system state cannot be sustained passively. Active involvement is essential for operators to exercise their responsibilities and be able to respond to emergencies. Reducing active involvement may be detrimental to the user's understanding of important information, may lead to longer response times in case of emergencies, or, in the long term, may lead to loss of relevant knowledge or skills. [Source: Galster, Duley, Masalonis, & Parasuraman, 2001; Garland & Hopkin, 1994; Hopkin, 1988; Sarter & Woods, 1992 (as found in Scerbo, 1996); Wickens, 1992 (as found in Scerbo, 1996)]

- □ **3.1.8 Make procedures suitable to user expertise.** Procedures employed in automation should be appropriate to the user's level of expertise with the system. [Source: Defense Information Systems Agency (DISA), 1996]

  Example. Shortcuts such as function keys can be provided for the more experienced users, whereas novice users can still use standard procedures.

- ▫ **3.1.9 Implement based on goals for system.** How automation is implemented should be determined by the explicit goals of the system, not by comparison between automated and manual systems. [Source: Wiener & Curry, 1980]

  Discussion. When automation is implemented, explicit goals of the system need to be kept in mind, thus, an automated system does not need to perform a task the same way as it was performed manually to be effective.

- ▫ **3.1.10 Avoid increasing demands for cognitive resources.** Automation should not increase the demands for cognitive resources (thinking or conscious mental processes). [Source: Bainbridge, 1983; Parasuraman & Riley, 1997; Wiener & Curry, 1980; Woods, 1996]

  Discussion. Automation that increases the demand for cognitive resources is poorly designed. Expert users in complex, dynamic systems have been observed to cope with poorly designed automation by using only a subset of the available functionality, especially during periods of high workload. [Source: Woods, 1996]

- ▫ **3.1.11 Avoid extreme workload levels.** Extreme levels of workload (low or high) due to automation use should be avoided. [Source: Hilburn, Jorna, Byrne, & Parasuraman, 1996; NRC, 1993; Warm, Dember, & Hancock, 1996; Wiener, 1988]

  Discussion. Extreme levels of workload can be caused by poorly designed automation. Poorly designed automation can cause extreme workload levels by increasing workloads when they are already high (for example, for pilots, during the high workload flight phases of take-off and landing) and decreasing workloads that are already low (for example, providing a pilot with the ability to engage autopilot during the low workload “cruise” phase of a flight). Automation is often introduced to reduce workload. However, reduction of workload may not always be advantageous, for example, if workload is already low. [Source: Hilburn et al., 1996; Parasuraman & Mouloua, 1996]

- ▪ **3.1.12 Prevent distraction from operations.** User interaction with automation shall not require the user to take significant amounts of attention away from the primary task. [Source: Danaher, 1980]

  Discussion. When automation requires the user or one member of the user team to devote a significant amount of attention to adjusting or monitoring the automation, this removes the user away from minute-to-minute operations, thereby taking the user out of the loop. This can be especially dangerous if an abnormal situation occurs that needs to be remedied quickly. [Source: Danaher, 1980]

□ **3.1.13 Avoid interruption at inappropriate times.** Automation should not interrupt at inappropriate times such as during periods of high workload or during critical moments in a process. [Source: Woods, 1996]

> **Discussion.** An interruption during high workload or at a critical moment can cause a delay in the user's ability to respond to a malfunction, leading to a potential failure. If the user is attending to a malfunction in an automated task and is interrupted, the interruption depletes the user's mental resources causing him to be less capable of averting the potential failure. For example, in the cockpit, certain automation functions might be stopped from interrupting during the takeoff and landing portions of flight.

□ **3.1.14 Make tasks easier to perform.** An automated task should be less difficult to perform than the manual task it replaces. [Source: AHCI, 1998]

□ **3.1.15 Guide the use of automation.** Standard operating procedures and company policies should guide users in the appropriate use of automation, although the user should be ultimately responsible to make the decision to use or not use the automation. [Source: Billings, 1997; Parasuraman & Riley, 1997]

■ **3.1.16 Provide easy data access.** Data that are needed by the user shall be easily accessible. [Source: NUREG/CR-6105, 1994; NUREG-0700, 1996]

> **Discussion.** User requirements can serve as a guide of whether the data are available at all times, accessible at the users' discretion, or not at all if the user does not need information.

□ **3.1.17 Prompt for data entry format.** The automated system should prompt users as to the correct data entry format. [Source: Billings, 1996]

> **Example.** If the automated system requires that the data be entered in all capital letters, it should specifically tell the user to enter the data in capital letters.

□ **3.1.18 Make it error resistant and error tolerant.** Automation should be error resistant and error tolerant. [Source: Billings, 1991]

> **Discussion.** To make a system **error resistant** is to make it difficult for a user to make an error. Simplicity in design and the provision of clear information are tools to improve error resistance. **Error tolerance** is the ability to mitigate the effects of human errors that are committed. Error tolerance can be improved by adding monitoring capabilities to the automation. Electronic checklists also have the potential to improve error resistance by providing reminders of items that need to be completed. [Source: Billings, 1991]

■ 3.1.19 **Make system behavior predictable.** Automated systems shall behave predictably so that the user knows the purpose of the automation and how the operation will be affected by that automation. [Source: Billings, 1991, 1996]

Discussion. The predictability of an automated system allows the user to know what to expect when the automation is functioning correctly. This makes it easier for the user to recognize when the system is not functioning. [Source: Billings, 1996]

■ 3.1.20 **Ensure safe operations are within human capacity.** Systems shall not be so reliant on automation or on human skills degraded by automation use that human users can no longer safely recover from emergencies or operate the system manually if the automation fails. [Source: Billings, 1996; NRC, 1998]

Discussion. A balance is needed between the efficiency created by automation, the need for the operator to be able to recover from emergencies, and control the system manually in case the automation fails.

□ 3.1.21 **Provide means of user override.** The automation should not be able to veto user actions leaving the user without means to override or violate the rules that govern the automation unless there is not enough time for the user to make a decision. [Source: Garland & Hopkin, 1994; Inagaki, 1999]

Discussion. Problems with automation can occur when the automated options do not apply to a situation and the user is restricted to the options provided by the automation.

■ 3.1.22 **Provide interaction consistency.** The way that automation systems interact with their users shall reflect a high degree of consistency within and between systems. [Source: NUREG-0700, 1996]

Discussion. There are many possible types of interaction, such as menu selection, direct manipulation, and form-filling. (See Chapter 8 on computer-human interfaces for more information on interaction). An example of inconsistent interaction would be having one system require filling in forms as the interaction method, whereas another system requires menu-driven interaction.

□ 3.1.23 **Make systems easy to understand and use.** Automated systems and associated integrated information displays should be intuitive, easy to understand, and easy to use. [Source: Billings, 1991; Sarter & Woods, 1994; Woods, 1996]

Discussion. System operations that are easily interpretable or understandable by the user can facilitate the detection of improper operation and the diagnosis of malfunctions. [Source: Wiener & Curry, 1980]

□ 3.1.24 **Make systems simple to learn.** Automation should be simple for the users to learn. [Source: Billings, 1991; Wiener & Curry, 1980]

▫ **3.1.25 Provide means to check input and setup data.** Automated systems should provide a way to check automation setup and to check information used as input for the automated system. [Source: Wiener & Curry, 1980; Wickens, 2000]

Discussion. Automation failures are often due to setup error. Although the automated system itself could check some of the setup, independent error-checking equipment or procedures may be needed. The user needs to be able to distinguish whether a failure occurred due to the automation setup or due to an inaccuracy in the input information. An automation failure could have been caused by a malfunction of an algorithm or by the input of inaccurate data. For example, if the automated system relies on primary radar and secondary radar as inputs and uses an algorithm to predict conflicts, a failure could arise from faulty data from either the primary or secondary radar or from the algorithm that combines this information. [Source: Wiener & Curry, 1980; Wickens, 2000]

3.2 Design and evaluation

▫ **3.2.1 Involve users in design.** Users should be involved in the design of an automated tool. [Source: Amalberti, 1999; Billings, 1997; Parasuraman, Sheridan, & Wickens, 2000]

Discussion. Input from the user is essential in defining information requirements.

▫ **3.2.2 Design based on human-centered goals and functions.** Design of automation should begin by choosing the human-centered criteria (goals) of the system and then defining the functions that the system will perform. [Source: Wiener & Curry, 1980]

Discussion. Defining the goals and functions of an automated system may require the use of task analysis.

▪ **3.2.3 Consider effect on coordination.** When new automation is introduced, the designers shall consider the possibility of negative effects on team coordination. [Source: Wiener, 1989]

Discussion. Automation may deplete team interaction and cooperation unless all parties are provided with information that allows them to be actively involved in the task. Automation can cause physical difficulty in seeing what the other team member is doing, reduce the ability to cross monitor, change traditional roles and responsibilities, and change the manner in which team members attempt to help one another. [Source: Danaher, 1980; Rudisill, 1994]

- ■ 3.2.4 **Assess overall impact.** The overall impact of automation shall be thoroughly examined before implementation to ensure that changes do not result in additional complexities, loss of situational awareness, or possibilities for error. [Source: Woods, 1996]

  Discussion. Automation of some user tasks may result in the user processing less information or processing information at less depth. A diminished understanding and appreciation for the overall situation may result. [Source: Garland & Hopkin, 1994]

- ▫ 3.2.5 **Validate system design.** Contextually valid human-in-the-loop experiments and simulations should be conducted to validate and refine automated system design. [Source: NRC, 1998]

- ■ 3.2.6 **Evaluate interactions with other functions.** Possible interactions with other tools, system functions, and user tasks shall be evaluated when new automation is designed. [Source: NRC, 1998]

- ■ 3.2.7 **Test as a whole.** New automation components shall be tested with the complete system, including other automated components of the system, to ensure they function together as an effective whole. [Source: NRC, 1998]

- ■ 3.2.8 **Test normal and failure modes.** Automated systems shall be tested under normal modes of operation and under failure modes of the automation. [Source: NRC, 1998; Wickens, 2000]

- ■ 3.2.9 **Test before implementation.** Automated systems shall be tested in a realistic operational environment with representative users before implementation to ensure that operator performance is not compromised and workload is not increased. [Source: Drury, 1998]

3.3 System response and feedback

- ▫ 3.3.1 **Visualize consequences of decisions.** The user should be able to visualize the consequences of a decision, whether made by the user or the automated system. [Source: Billings, 1996]

- ▫ 3.3.2 **Provide brief and unambiguous command response.** Automated system responses to user commands should be brief and unambiguous. [Source: Billings, 1997]

- ▫ 3.3.3 **Keep users aware of function.** The automated system should keep the user aware on a continuing basis of the function (or malfunction) of each automated system and the results of that function (or malfunction). [Source: Billings, 1996]

- ▫ 3.3.4 **Provide effective feedback.** Automation should provide the user with effective feedback on its actions and the purpose of these actions. [Source: Woods, 1996]

  Discussion. When feedback is poor, automation is considered silent. Silent automation may result in coordination and system failures. Users may be surprised by the behavior of silent automation. [Source: Woods, 1996]

3.4 Interface

- ▫ 3.4.1 **Keep it simple.** The automation interfaces should represent the simplest design consistent with functions and tasks of the users. [Source: NUREG-0700, 1996]

  Discussion. Simplicity for the user is achieved by attaining compatibility between the design and human perceptual, physical, cognitive, and dynamic motor responsiveness capabilities. (See Chapter 8 on computer-human interfaces for more information on interface design.) [Source: NUREG-0700, 1996]

- ■ 3.4.2 **Provide interface consistency.** Human interfaces in automation programs and systems shall have a high degree of consistency. [Source: NUREG-0700, 1996]

  Discussion. Consistency can be obtained by presenting information in predictable locations and keeping elements of screens such as headers, fields, and labels consistent in appearance and relative location throughout a system or application. (See Chapter 8 on computer-human interfaces for more information on interface design.) [Source: Shneiderman, 1998]

- ▫ 3.4.3 **Be consistent with user expectations.** Automated systems and interfaces should be consistent with the expectations and understandings of users. [Source: Billings, 1991, 1996]

- ■ 3.4.4 **Make interface structure logical.** Automation interfaces shall reflect an obvious logic based on user task needs and capabilities. [Source: NUREG/CR-6105, 1994; NUREG-0700, 1996]

- ■ 3.4.5 **Make location status obvious.** Interfaces and navigation aids shall make it easy for users to know where they are in the data space. [Source: NUREG/CR-6105, 1994; NUREG-0700, 1996]

- ▫ 3.4.6 **Use spatial representations where possible.** Where possible, spatial representations of information should be used instead of verbal or textual displays in high workload situations. [Source: Barnes, 1981]

  Discussion. Although humans are often better able to attend to spatial representations, it is not always easy or even possible to create spatial representations of information. [Source: Barnes, 1981]

▫ **3.4.7 Present dynamic information in real time.** Dynamic information (information that changes over time) should be presented in real time and on demand to ensure accurate and timely decision-making. [Source: Morris, Rouse, & Ward, 1985]

3.5 User acceptance and trust

▫ **3.5.1 Increasing user trust in automation.** To increase user trust in automation, automation performance should be

a. reliable and predictable with minimal errors,

b. robust (able to perform under a variety of circumstances),

c. familiar (use terms and procedures familiar to the user), and

d. useful. [Source: Lee & Moray, 1992; Lerch & Prietula, 1989; Masalonis & Parasuraman, 1999; Muir, 1987 (as found in Riley, 1996); NRC, 1998]

Discussion. Trust in automation tends to be relatively stable. However, changes in trust may occur over time. User trust in automation can increase with reliable and predictable performance. Decreases in trust may occur as a result of some critical error or automation failure. It is more difficult for users to regain trust in automation after a failure than to develop an initial trust. Higher trust in automation is not always better because automation errors may be overlooked due to complacency. Decreases in trust typically occur suddenly, but increases happen slowly and steadily. The consequences of an automation failure (for example, the magnitude of an error) impact the decline in trust. [Source: Lee & Moray, 1992; Lerch & Prietula, 1989; Masalonis & Parasuraman, 1999; Riley, 1996; NRC 1998]

▫ **3.5.2 Provide training for users to develop trust in automation reliability.** Training should be provided to enable the user to calibrate their trust in the automated system. [Source: Cohen, Parasuraman, & Freeman, 1998]

Discussion. Training will allow the user to develop an adequate model of how reliable or unreliable the automation is under specific conditions.

▫ **3.5.3 Ensure automation availability.** The automated system should be available to the user as needed. [Source: Morris, Rouse, & Ward, 1985]

▪ **3.5.4 Prevent interference with user tasks.** The automated system shall not interfere with task performance. [Source: Andes, 1987]

Discussion. A user will be less likely to accept an automated system that interferes with their ability to perform tasks. [Source: Andes, 1987]

■ **3.5.5 Provide accurate and reliable information.** Automation shall provide accurate and reliable information. [Source: Andes, 1987]

Discussion. When users believe automation to be highly reliable, they place greater trust in it. However, there is a trade-off involved with a constant high level of automation reliability and predictability. Constant high levels of automation reliability and predictability may be more likely to promote complacency and may cause users to monitor automation with less vigilance. [Source: Dzindolet, Pierce, Beck, & Dawe, 1999; Parasuraman, Molloy, & Singh, 1993, (as found in Masalonis & Parasuraman, 1999); Wiener, 1981]

□ **3.5.6 Minimize changes due to automation.** Changes in cognitive processing, ways of thinking, and methods and skills used for new automation should be minimized. [Source: Garland & Hopkin, 1994]

Discussion. Automation that requires different kinds of cognitive processing, ways of thinking, and discarding of traditional methods and skills may cause the system to be both less efficient and less acceptable to the users. This could include automatic conversion of data into a usable format. [Source: Garland & Hopkin, 1994]

□ **3.5.7 Promote understanding of automation function.** To promote user acceptance of automation, users should be taught how an automated system functions. [Source: Cohen, Parasuraman, & Freeman, 1998; Dzindolet et al., 1999; Lehner, Mullin, & Cohen, 1989]

Discussion. The better the user understands the automation, the more likely the user is to trust the automation appropriately. Designers need to alter the false belief that automation is perfect and ensure that the users understand when the automation is likely to become unreliable. [Source: Dzindolet et al., 1999]

3.6 Modes

□ **3.6.1 Clearly identify modes and functions.** When control, display, or automation functions change in different modes of operation, mode and function identification and status should be clear. [Source: Billings, 1991; Sarter & Woods, 1995]

Discussion. Lack of effective feedback on the state of automation (including which mode is active) can lead to mode errors. [Source: Sarter & Woods, 1995]

- **3.6.2 Identify alternatives in rarely used modes.** Seldom-used modes and functions should be clearly identified. [Source: Billings, 1991]

  Example. As automated systems become more complex with many modes and functions, the cognitive burden caused by the need for mode awareness increases. Seldom-used modes and functions will pose the largest burden on the user because of a lack of familiarity. Enabling the user to immediately recognize the purpose of modes and functions, such as labeling the engine failure function "ENG OUT," can lessen this burden. [Source: Billings, 1997]

- **3.6.3 Make frequently used modes easy to get to.** Frequently used modes should be more accessible than infrequently used modes. [Source: AHCI, 1998]

- **3.6.4 Number of modes.** The number of different modes for a given system should be minimized. [Source: AHCI, 1998]

  Discussion. Multiple modes will provide a means of flexibility but will introduce more opportunities for error. Furthermore, automation that has multiple modes of operation can be difficult to learn and can produce increases in workload. Users must understand and remember how and when to use each mode, and they must remember which mode is currently active. [Source: Scerbo, 1996; Woods, 1996]

- **3.6.5 Allow switching between modes.** The user should be able to easily switch between modes. [Source: AHCI, 1998]

- **3.6.6 Provide consistent features and functions.** Features and functions that are common between display modes should be consistent. [Source: AHCI, 1998]

  Discussion. In the original Standard Terminal Automation Replacement System (STARS), the Full Service Level (FSL) and the Emergency Service Level (ESL) had independent and inconsistent interfaces requiring users to learn two different interfaces: mouse interaction styles and status-coding schemes. This can lead to additional training requirements and workload. The human factors team recommended that the two subsystems have identical coding strategies, identical access and execution of system commands, consistent data display formatting, and consistent monitoring and reporting of resources. [Source: Standard Terminal Automation Replacement System Human Factors Team, 1997, 1998]

- **3.6.7 Alert user to potentially hazardous interactions.** The automated system should alert the user to the implications of interactions between modes, especially when they are potentially hazardous. [Source: Billings, 1996]

□ **3.6.8 Alert users of unsafe modes.** The automated system should either prevent the use of potentially unsafe modes or alert the user that a particular mode may be hazardous. [Source: Billings, 1996]

3.7 Monitoring

■ **3.7.1 Allow users to monitor automated systems.** The system shall be designed so that users are able to monitor the automated systems and the functionality of its hardware and software, including the display of status and trend information, as needed. [Source: Billings, 1991]

Discussion. One way that this can be accomplished is by providing the user with access to raw data that the automation processes.

■ **3.7.2 Display changing data as graphic.** Changing data that must be monitored by the users should be displayed in a graphic format. [Source: Smith & Mosier, 1986]

□ **3.7.3 Make users active in control and monitoring.** Automation should be designed so that users are involved in active control and monitoring rather than just passive monitors. [Source: Hilburn, Jorna, & Parasuraman, 1995; Wickens & Kessel, 1979]

Discussion. Automation failures may be easier to detect when users are involved in both active control and monitoring, than when they are just passive monitors. [Source: Hilburn, et al., 1995; Wickens & Kessel, 1979]

□ **3.7.4 Allocate cognitive resources for monitoring.** System designers should allow adequate cognitive resources for monitoring by ensuring that task load does not become excessive. [Source: Wiener & Curry, 1980]

Discussion. Users of automated systems may experience higher levels of mental workload than manual controllers due to monitoring, diagnosis, and planning, with significant cognitive demand resulting from relatively "simple" vigilance tasks. [Source: Deaton & Parasuraman, 1993; Sheridan, 1970; Warm et al., 1996]

□ **3.7.5 Limit monitoring time.** Users should not be required to perform purely monitoring tasks for longer than 20 minutes at a time. [Source: Parasuraman et al., 1993; Warm et al., 1996]

Discussion. Users may become complacent in monitoring automated systems if they have other tasks to complete simultaneously. Such decrements in user monitoring of automated systems have been observed to occur in the laboratory in as little as 20 minutes. [Source: Parasuraman et al., 1993; Warm et al., 1996]

- **3.7.6 Integrate displays.** When users must monitor multiple displays, important events should occur in the same display in order to promote effective monitoring performance. [Source: Warm et al., 1996]

- **3.7.7 Minimize spatial uncertainty.** Important events should occur in the same location on a display in order to promote effective monitoring performance. [Source: Warm et al., 1996]

  Discussion. Users will be able to detect a particular event more easily if they know where that event will occur (i.e., spatial certainty). Spatial uncertainty has been shown to increase perceived workload and decrease performance efficiency. If users do not know where on a display an event will occur then they must engage in visual scanning to look for the event. [Source: Adams & Boulter, 1964; Warm et al., 1996)]

- **3.7.8 Provide indication of monitoring.** Automated systems that are without incident for long periods of time should provide some type of indication that the automation is still monitoring the system. [Source: AHCI, 1998]

- **3.7.9 Warn of potential user errors.** Automated systems should be able to monitor user interactions and to warn of user errors. [Source: Billings, 1991]

  Discussion. To monitor user interactions and to warn of user errors, automated systems may need to be able to receive input information on user intentions.

- **3.7.10 Monitor critical functions.** Critical automation functions should be independently monitored by the user. [Source: Billings, 1996]

  Definition. A **critical function** is a function that can cause system failure when a malfunction is not attended to immediately.

  Discussion. When a function is critical, combining the monitoring of that critical function with other, possibly less critical functions may lead to delays in response. When a critical function is independently monitored, a user can respond to a malfunction very quickly (within one second). If a user is attending to another task when there is a malfunction, there will be a delay in the user's response (several seconds). In this period of delayed response, the malfunction can cause the system to fail. For this reason, critical functions require constant attention. Critical automation functions do assist in the completion of critical tasks, however they do not assist in freeing the user to attend to other tasks. [Source: Parasuraman et al., 1996]

- **3.7.11 Ensure adequate understanding.** Users should be given an adequate understanding (mental model) of how the automated system works in order to monitor effectively. [Source: Carroll & Olsen, 1988 (as found in Scerbo, 1996); Wickens, 1992 (as found in Scerbo, 1996); Wickens & Flach, 1988; Woods, 1994 (as found in Scerbo, 1996); Woods, 1996]

  Discussion. Users must possess accurate mental models of automated systems in order to monitor effectively, comprehend current situations, plan their actions, predict future system states, remember past instructions, and diagnose system failures. One way to establish adequate mental models is through training. [Source: Scerbo, 1996; Wickens, 1992 (as found in Scerbo, 1996); Wickens & Flach, 1988; Woods, 1994 (as found in Scerbo, 1996); Woods, 1996]

- **3.7.12 Provide intermittent manual control.** Intermittent periods of manual control should be used during extended periods of task automation to improve monitoring of the automation. (See adaptive automation-Section 3.13.) [Source: Morrison, Cohen, & Gluckman, 1993; Parasuraman et al., 1993]

  Discussion. Complacency is a major concern with automation. Intermittent periods of manual control have been advocated as a means of minimizing complacency. Automation may also result in the decrement of cognitive abilities such as instrument scan and navigation/positional [situation] awareness and the loss of manual skills, making transitions from automated to conventional systems difficult. Because automation can decrease basic manual skills, these skills should be used and maintained. Intermittent periods of manual control during which automation is suspended periodically can promote optimal user performance, and allow better recovery from failure, regardless of the type of task that is automated. [Source: Endsley & Kiris, 1995; Morrison et al., 1993; Rudisill, 1994; Wickens, 1992 (as found in Scerbo, 1996)]

- **3.7.13 Minimize noise.** Environmental noise should be minimized to ensure optimal vigilance. [Source: Warm et al., 1996]

  Discussion. Vigilance will be reduced when high levels of intermittent noise are present in the environment, especially if the information processing task demands are high. Noise is defined as sounds that are loud, disagreeable or unwanted. Music, however, may act as a stimulant and offset decrements in arousal due to fatigue and prolonged performance. [Source: Davies, Lang & Shackleton, 1973; Hancock, 1984 (as found in Warm et al., 1996); Matthews, Davies, Westerman, & Stammers, 2000]

- **3.7.14 Consider circadian rhythm effects on performance.** System designers should consider the effects of circadian rhythms on user vigilance and monitoring performance. [Source: Colquhoun, 1977 (as found in Warm et al., 1996)]

  Discussion. It will be most difficult for users to maintain monitoring performance during the early morning (8:00 a.m.) when body temperature is low. Performance will peak late in the day (between 5:00 p.m. and 9:00 p.m.) as body temperature rises. Monitoring performance will then decline again as body temperature drops. Maintaining monitoring performance can also be difficult for users working irregular work schedules. Working consecutive night shifts, prolonged work shifts, or starting hours that are too early can cause users to experience a desynchronization of their circadian rhythm caused by the accumulation of sleep deficit and fatigue. [Source: Costa, 1999; Warm et al., 1996]

- **3.7.15 Consider potential vigilance decrements.** The effects on vigilance due to the use of automation should be considered before introducing new automation. [Source: Warm et al., 1996]

  Discussion. A **vigilance decrement**, that is, a continuously decreasing ability to maintain attention over time while monitoring, may occur with the use of automation.

  Vigilance decrements do not occur because monitoring tasks are under stimulating. Rather, they require a large amount of cognitive resources and are often frustrating. Vigilance decrements have been observed to occur for both expert and novice users in high fidelity simulations and real-world operations. [Source: Baker, 1962; Colquhoun, 1967, 1977; Mackworth, 1948, 1961; Schmidke, 1976 (as found in Warm et al., 1996); Warm et al., 1996]

  How hard the user must work in order to maintain vigilance can be determined by at least two factors. First, workload is affected by the ease with which relevant signals can be detected. Signals that have low salience are more difficult to detect than signals high in salience. Visual fatigue will also require more effort to be expended in order to detect a signal. Second, musculo-skeletal fatigue associated with maintaining a fixed posture will increase the workload needed to perform optimal monitoring. [Source: Dember, Warm, Nelson, Simons, Hancock, & Gluckman, 1993; Warm et al., 1996]

3.8 Fault management

Fault management relates to how the user notices and recovers from system failures. Such failures may or may not be detected by automation. Fault management has been defined to include the four distinct tasks of detection, diagnosis, prognosis, and compensation. [Source: Rogers, Schutte, & Latorella, 1996]

- ▪ **3.8.1 Ensure safety should automation fail.** Automated systems shall allow for manual control and preservation of safe operations should the automation of one or more components of the system, on which the automation depends, fail. [Source: NRC, 1998]

  Discussion. The resumption of manual control needs to be within the capacity of the user, without relying on manual skills that may be degraded by the use of automation. [Source: NRC, 1998]

- ▪ **3.8.2 Make failures apparent.** Automation failures shall be made unambiguously obvious to the user. [Source: AHCI, 1998; Billings, 1991]

  Discussion. Stress, preoccupation, and distraction may reduce the user's ability to detect faults. [Source: Rogers et al., 1996]

- ▫ **3.8.3 Provide adequate early warning notification.** Early warning notification of pending automation failure or performance decrements should use estimates of the time needed for the user to adjust to task load changes due to automation failure. [Source: Morrison, Gluckman, & Deaton, 1990]

  Discussion. In situations where automation failure would require user intervention, it is useful for the user to be warned that he or she will need to take manual control before the automated system fails. Ideally, this warning needs to come in adequate time to allow the user to adjust to the new task load. There may, however, be cases where it is not possible to provide advance notification of pending failure or where the estimate of time needed for the user to take control is unknown. [Source: Morrison et al., 1990]

- ▪ **3.8.4 Inform user of potential failure.** The user shall be informed of automation performance decrements, potential failures, and malfunctions. [Source: Billings, 1996]

  Discussion. It can increase workload for the user to continually monitor the automation for failure. Advance knowledge about potential failures can also help the user prepare to take manual control.

- ▪ **3.8.5 Automate diagnostic aids.** Fault isolation, inspection, and checkout tasks shall be automated to the extent practical. [Source: National Aeronautics and Space Administration (NASA-STD-3000A), 1989]

- **3.8.6 Incorporate automatic self-checking components.** All essential electronic computer and peripheral components that are part of a system shall incorporate an automatic self-check diagnostic test of software and hardware, both at power up and at the request of the operator, to ensure they are functioning properly. [Source: Department of Defense (MIL-STD-1472F), 1999]

- **3.8.7 Provide capability for on-demand system check.** On-demand system checkout shall be available. [Source: NASA-STD-3000A, 1989]

- **3.8.8 Make sensor status verifiable.** The status of sensors on replacement units shall be verifiable with respect to accuracy and proper operation. [Source: NASA-STD-3000A, 1989]

- **3.8.9 Permit status verification without disassembly.** When feasible, equipment shall permit verification of operational status prior to installation without the need for disassembly. [Source: NASA-STD-3000A, 1989]

- **3.8.10 Permit fault detection without disassembly.** Equipment shall permit fault detection and isolation without removing components, through the use of built-in test, integrated diagnostics, or standard test equipment. [Source: Department of Defense (MIL-STD-1800A), 1990; NASA-STD-3000A, 1989]

- **3.8.11 Facilitate rapid fault detection.** Equipment design shall facilitate rapid fault detection and isolation of defective items to permit their prompt removal and replacement. [Source: MIL-STD-1472F, 1999; NASA-STD-3000A, 1989]

- **3.8.12 Identify failures without ambiguity.** Fault detection and isolation shall identify without ambiguity which component has failed. [Source: MIL-STD-1800A, 1990; NASA-STD-3000A, 1989]

- **3.8.13 Provide portable diagnostic tools.** When built-in test equipment is not available, diagnostic tools or portable equipment shall be provided to aid in fault isolation. [Source: NASA-STD-3000A, 1989]

- **3.8.14 Identify first alarm event.** Automated warning systems should provide a means for identifying the first event in a series of alarm events. [Source: NUREG-0700, 1996]

  Discussion. When a series of interrelated alarms occur, information identifying which component first exceeded the set threshold can be valuable in determining the initiating cause of a problem. [Source: NUREG-0700, 1996]

- **3.8.15 Provide sufficient diagnostic information.** The user should be provided with sufficient information and controls to diagnose automated warning system operation. [Source: Wiener & Curry, 1980]

  Discussion. In order for the user to diagnose the automated system, diagnostics information needs to be self-explanatory and in plain English. The diagnostic information must provide the user with the information they need without requiring the user to seek additional references, or a help function, to understand the problem and the recommended solution.

3.9 False alarms

- **3.9.1 False alarm rates.** False alarm rates should not be so frequent as to cause the user to mistrust the automated system. [Source: NUREG/CR-6105, 1994; Parasuraman, Hancock, & Olofinboba, 1997; Wiener & Curry, 1980]

  Discussion. The trade-off between alerting the user to off-normal conditions and the creation of nuisance alarms needs to be considered when determining appropriate alarm set points. A system that is designed to minimize misses, at all costs, is likely to have frequent false alarms. However, automated systems that have frequent false alarms are unlikely to be trusted or even tolerated. When there is low probability that the alarm is a true alarm (the "cry-wolf" phenomenon), users tend to ignore, mistrust or turn off alarms. Setting the false alarm threshold requires careful evaluation of the trade offs between missed signals and false alarms including not only the decision thresholds at which the system is set, but also the probabilities of the condition to be detected. [Source: NRC, 1997]

- **3.9.2 Inform users of the probability of a true alarm.** Users should be informed of the inevitable occurrence of automation false alarms particularly when base rates are low. [Source: NRC, 1998]

  Discussion. When the probability of an event is low, the odds of a true alarm can be quite low for even a very sensitive warning system, causing inevitable false alarms. [Source: NRC, 1998; Parasuraman et al., 1997]

3.10 Training

- **3.10.1 Introducing new automation.** New automation should be introduced with advanced briefing and subsequent training procedures. [Source: Billings, 1997; NRC, 1998; Parasuraman & Riley, 1997]

  Discussion. The introduction of new automation may introduce changes in traditional roles and responsibilities, a redistribution of authority for tasks or changes to the nature of the cognitive demands imposed on the human operator. [Source: Bowers et al., 1995; Wiener, 1989]

- **3.10.2 Prepare users for changes.** Before automation is introduced, users should be informed of associated changes and increases in the work effort, as well as the benefits associated with the automation. [Source: DISA, 1996; Scerbo, 1996]

  Discussion. The roles and responsibilities of the users, cognitive demands, and operational procedures may change as a result of introducing automation. [Source: Bowers, Deaton, Oser, Prince, & Kolb, 1995]

- **3.10.3 Train users to understand automated functions.** Initial training in the use of automation should be sufficient for the users to fully understand how the automation functions within the particular system, as well as how to use the automation. [Source: Billings, 1997]

  Discussion. Lack of knowledge and understanding of how automation works can make it difficult for users to assess potential problems and may result in improper use of automation. [Source: Rudisill, 1995]

- **3.10.4 Train users to backup automation.** Users should be provided with backup training in performing any tasks replaced by automation or in operating any backup systems replaced by automation. [Source: DISA, 1996]

- **3.10.5 Train to recognize inappropriate use of automation.** Users should be trained to recognize inappropriate uses of an automated tool including automation bias (the use of automation in a heuristic manner as opposed to actively seeking and processing information). [Source: DISA, 1996; Dzindolet, Pierce, Beck, & Dawe, 1999; Mosier & Skitka, 1999]

  Discussion. There are different categories of inappropriate automation use, including automation bias, ignoring or turning off the automation, and improper implementation of automation.

  Users may rely on automated decision aids in a heuristic manner (referred to as **automation bias**). Using heuristics is to apply simple decision-making rules to make inferences or to draw conclusions simply and quickly. Heuristics are useful principles having wide application, but may not be strictly accurate. Usually a heuristic strategy is optimal, however, under certain conditions heuristics will be inappropriate and errors or misuse may occur. Automation bias leads to errors of omission (failure to notice system anomalies when automation fails) and errors of commission (acceptance of automated decisions without cross-checking or in presence of contradictory information). Training will help prevent automation bias and help the user learn to examine multiple sources of information before making a decision. Early training on automation bias may reduce commission errors for users new to automation, but may be less likely to reduce omission errors or errors made by expert users.

  Inappropriate use of automation may be influenced by various individual factors such as self-confidence in completing the task, trust in the automation, differential effects of fatigue, and how all of these factors combined weigh into the decision making process. Inappropriate use of automation can be due to misuse (automation bias, complacency), disuse (ignoring or turning off automation) or abuse (improper implementation of automation). [Source: Dzindolet et al., 1999; Lee & Moray, 1992; Mosier & Skitka, 1996; Mosier, Skitka, Dunbar, Burdick, McDonnell, & Rosenblatt, 1998; Muir, 1987 (as found in Scerbo, 1996); Parasuraman & Riley, 1997; Riley, 1996]

- **3.10.6 Train users when to question automation.** Users should be trained to recognize and understand the conditions under which automation may be unreliable, and to learn the conditions where it performs well (when or when not to question the automation). [Source: Cohen et al., 1998; Dzindolet et al., 1999]

  Discussion. Users must learn not to categorically accept the recommendation of a decision aid. Understanding the automation's weaknesses allows users to better judge how much they should trust the automation without becoming overconfident in its performance. This recognition process may impose an additional workload on the user. [Source: Dzindolet et al., 1999]

▫ **3.10.7 Avoid over-reliance on automation.** Users should be trained not to become overly reliant on automation. [Source: Mosier, Skitka, Heers, & Burdick, 1997; Parasuraman & Riley, 1997]

Discussion. When users rely on automation too much they become susceptible to automation-induced complacency. Monitoring failures are likely to occur when users become overly reliant on automation. [Source: Mosier, Skitka, & Korte, 1994; Parasuraman et al., 1993]

▫ **3.10.8 Train for risk assessment and reduction.** Users should be trained on risk assessment and actions needed for risk reduction. [Source: Mosier & Skitka, 1999]

▪ **3.10.9 Train for failure recovery transitions.** Users shall be trained on transitioning from automated to conventional systems. [Source: Rudisill, 1994]

Discussion. If automation were to fail, users need to be skilled at both recognizing the failure and taking manual control.

▫ **3.10.10 Stress interaction skills.** Training programs should stress user-automation interaction skills and cognitive/problem solving skills rather than psychomotor skills. [Source: Sarter & Woods, 1994]

Discussion. Problems in automation may not be inherent in the technology itself. Problems can arise due to limitations in the integration of the user and automation. The user and automation should be integrated by developing a joint, distributed cognitive system by means of training and design. [Source: Sarter & Woods, 1994]

▫ **3.10.11 Train for changes due to automation.** When automation requires different kinds of cognitive processing, ways of thinking, and discarding of traditional methods and skills, then training should be designed to address problems related to these changes. [Source: Garland & Hopkin, 1994]

▫ **3.10.12 Train to identify normal output.** Users should be trained on what constitutes the normal automation output so that the user can easily determine whether the system is functioning properly. [Source: Morris, et al., 1985]

3.11 Function allocation/levels of automation

There are many possible levels of automation (see Exhibit 3.11) including: automation that automatically executes tasks, automation that performs tasks when pre-specified conditions are met, and automation that suggest a course of action or facilitates a decision. [Source: Billings, 1997; NRC, 1998; Parasuraman et al., 2000]

Exhibit 3.11 Levels of automation, from high to low. [Source: NRC, 1998; Sheridan, 1996]

The system acts autonomously without human intervention
The system informs the user after executing the action only if the system decides it is necessary
The system informs the user after executing the action only upon user request
The system executes an action and then informs the user
The system allows the user a limited time to veto before executing an action
The system executes an action upon user approval
The system suggests one alternative
The system narrows the selection down to a few
The system offers a complete set of action alternatives
The system offers no assistance

- 3.11.1 **Evaluate function allocation alternatives.** Alternative function allocations including fully manual, partially automated, fully automated, and adaptive allocation should be evaluated for feasibility and effectiveness. [Source: Wiener & Curry, 1980]

- 3.11.2 **Evaluate through simulation.** Alternative schemes for the allocation of functions should be examined in the context of the whole system through the use of high fidelity simulations. [Source: Wiener & Curry, 1980]

  Discussion. Because there may be multiple potential schemes in the allocation of functions, simulating these schemes in the context of the whole system will allow them to be evaluated properly. A scheme that seems to be the most appropriate in regards to accomplishing a specific task may not be the best choice in relation to the functioning of the entire automated system.

- 3.11.3 **Only automate functions performed well by machines.** Only functions that are performed well by machines should be automated, not functions that are performed better by humans. [Source: Drury, 1998]

- 3.11.4 **Automate full behavioral modules.** Behavioral modules in their entirety should either be automated or preserved as manual subtasks, not fractionally (partially) automated. [Source: Vortac, Barile, Albright, Truitt, Manning, & Bain, 1996]

  Discussion. A behavioral module is a unitized set of actions that can be performed in an over-learned, automatic fashion with very little effort. When a set of cognitive or behavioral actions is frequently performed together they will eventually form a module. Automation that replaces only a portion of a module will produce no advantage in performance and may inhibit performance. [Source: Vortac et al., 1996]

- **3.11.5 Give tasks requiring flexibility to user.** Tasks that are performed in an unpredictable environment requiring flexibility and adaptability should be allocated to the user. [Source: AHCI, 1998]

- **3.11.6 Make roles and responsibilities clear.** The automated system should make it clear whether the user or computer is supposed to perform a particular task at a specific time. [Source: Parasuraman & Riley, 1997]

- **3.11.7 Provide means for changing roles and responsibilities.** The automated system should provide a means for changing the allocation of roles and responsibilities. [Source: Parasuraman & Riley, 1997]

- **3.11.8 Automation of high-risk actions or decisions.** For system tasks associated with greater uncertainty and risk, automation should not proceed beyond the level of suggesting a preferred decision/action alternative. [Source: NRC, 1998]

  Discussion. High levels of automation can be used for tasks involving relatively little uncertainty and risk. [Source: NRC, 1998]

3.12 Information automation

Definition. Information automation includes information acquisition and integration. This type of automation would include filtering, distributing or transforming data, providing confidence estimates and integrity checks, and enabling user requests.

- **3.12.1 Indicate if data are incomplete, missing, uncertain, or invalid.** The automated system should provide a means to indicate to the user that data are incomplete, missing, unreliable, or invalid or that the system is relying on backup data. [Source: AHCI, 1998]

- **3.12.2 Provide automatic update.** When the displayed data are changed as a result of external events, the user should be provided with the option of having an automatic update of changed information. [Source: AHCI, 1998]

- **3.12.3 Provide multiple output formats.** System designers should provide information in multiple formats (for example, text, graphics, voice, and video) to allow better communication and reduction of workload. [Source: Scerbo, 1996]

  Discussion. Communication will be improved by allowing information to be presented in the most understandable format. Eliminating the need to translate information into a specific format will reduce workload. [Source: Scerbo, 1996]

▫ **3.12.4 Show accurate status.** Information presented to the user should accurately reflect system and environment status in a manner so that the user rapidly recognizes, easily understands, and easily projects system outcomes in relation to system and user goals. [Source: Endsley & Kiris, 1995; NUREG-0700, 1996]

▫ **3.12.5 Minimize errors.** Error-prone conditions should be minimized by maintaining user awareness, providing adequate training, developing standard operating procedures, and fostering crew coordination. [Source: Sheehan, 1995]

Discussion. Errors due to automation may arise from data entry errors, monitoring failures, system workarounds, and mode misapplication. Error-prone conditions in automated systems may result from lack of mode awareness, lack of situation awareness, lack of systems awareness, increased heads down time, over-dependence on automation, and interrupted crew coordination. Automation-related errors usually occur in conjunction with other factors such as haste, inattention, fatigue, or distraction. [Source: Sheehan, 1995]

▪ **3.12.6 Information displays.** Information displays shall support and reinforce status and situation awareness at all times. [Source: Billings, 1991, 1996]

Discussion. A primary objective of information automation is to maintain and enhance situation awareness. However, too much information presented simultaneously may become cluttered and make visual search difficult, interfering with status, decision-making, or control. It is important for the user to be able to easily locate needed information. [Source: Billings, 1991]

The user's ability to detect a signal while monitoring varies inversely with the rate at which neutral background events are repeated. [Source: Lanzetta, Dember, Warm, & Berch, 1987; Parasuraman, 1979 (as found in Warm et al., 1996)]

▫ **3.12.7 Situation displays.** Event data should be combined with a map background when the geographic location of changing events needs to be shown. [Source: Smith & Mosier, 1986]

▪ **3.12.8 Present information consistent with task priorities.** Both the content of the information made available through automation and the ways in which it is presented shall be consistent with the task priorities. [Source: Billings, 1996]

▫ **3.12.9 Cueing important information.** When information must be updated quickly, the most important information should be cued to ensure it will be the first to be processed by the user. [Source: Wickens, 2000]

Discussion. It is important that the cues be correct, as there may be significant costs of invalid cueing. [Source: Wickens, 2000]

- **3.12.10 Queue messages automatically.** Incoming messages should be queued automatically by the system so they do not disrupt current information handling tasks. [Source: Smith & Mosier, 1986]

- **3.12.11 Highlight changed data.** Data changes that occur following automatic display update should be temporarily highlighted. [Source: Smith & Mosier, 1986]

- **3.12.12 Store and prioritize lists of information.** Long lists of information, tasks, and so on, should be stored and prioritized by the automated aid to minimize the number of decision alternatives and reduce the visual processing load of human operators. [Source: Barnes, 1981]

- **3.12.13 Integrate display elements only if performance is enhanced.** Display elements should only be integrated if it will enhance status interpretation, decision-making, situation awareness, or other aspects of task performance. [Source: Billings, 1991]

- **3.12.14 Integrated displays.** Integrated displays should combine various information automated system elements into a single representation. [Source: Billings, 1996; Parasuraman et al., 2000]

  Discussion. Feedback information that is widely distributed among various indicators can result in insufficient monitoring of automation and/or mode confusion. In such cases, monitoring adequacy is limited by inefficient scanning patterns and information that is difficult to integrate. [Source: Mosier & Skitka, 1999]

- **3.12.15 Automatically arrange information depending on status.** System information should be automatically reorganized into integrated or non-integrated arrangements depending on the current system status. [Source: Forester, 1987; Parasuraman, et al., 1996]

  Discussion. Integrated information arrangement allows the user to assess the overall status of the system. Integrating display components into aggregated arrangements may reduce the attention demands of fault detection. Non-integrated arrangement of components draws user attention to system errors or other relevant information. Presenting the information in a format relevant to the state of the system can facilitate the ability of the user to quickly and easily assess the system status. [Source: Forester, 1987; Parasuraman et al., 1996]

- **3.12.16 Make cues equally prominent.** Automated and non-automated cues should be made equally prominent to enable users to collect confirming/disconfirming evidence before deciding on appropriate action. [Source: Mosier & Skitka, 1999]

  Discussion. Automation bias, the tendency to use automation in a heuristic manner, may be suppressed if other, non-automated sources of information are presented with salience equal to that of the automated information. [Source: Mosier & Skitka, 1999]

3.13 Adaptive automation

Definition. Adaptive automation is the real time allocation of tasks to the user or automated system in a flexible manner, changing the automation to meet current situational demands. Adaptive automation may benefit user performance by allowing the user to remain in active control of the system instead of becoming a passive observer. Active control may prevent performance decrements associated with long-term monitoring, loss of situation awareness and manual skill degradation. [Source: Morrison et al., 1990; NRC, 1998; Scerbo, 1996; Scerbo & Mouloua, 1999]

Discussion. Laboratory experiments have shown that short periods of automation use (for example, 10-minute cycles of manual and automated control) do not result in performance decrements. This suggests that intermittent periods of manual control may help to maintain performance in the presence of automation. [Source: Gluckman, Carmody, Morrison, Hitchcock, & Warm, 1993 (as found in Scerbo, 1996); Parasuraman, Hilburn, Molloy, & Singh, 1991]

□ 3.13.1 **Help during high workload.** Automation should be designed to adapt by providing the most help during times of highest user workload, and somewhat less help during times of lowest workload. [Source: Billings, 1996; Parasuraman, Mouloua & Hilburn, 1998]

Discussion. Research has shown that adaptive automation may reduce mental workload most effectively during periods of high taskload. [Source: Hilburn et al., 1996]

□ 3.13.2 **When not to implement adaptive automation.** Adaptive automation should not be implemented unexpectedly or at a time when the user may not desire the aiding. [Source: Scerbo, 1996]

Discussion. The timing of adaptation may have critical impact on user acceptance of automation. Studies show that users prefer to be in control of the system. However, there are times that automation may need to be initiated by the system, particularly when changes in workload occur rapidly or are unexpected by the user. [Source: Harris, Goernert, Hancock, & Arthur, 1994 (as found in Scerbo, 1996)]

- **3.13.3 When to implement adaptive automation.** Adaptive automation should be implemented at the point at which the user ignores a critical amount of information. [Source: Sen, 1984]

  Discussion. Fatigue (or other factors) may prevent users from recognizing the best time to utilize automation and performance decrements may consequently occur. One indication that the user is being overloaded is an increase in the amount of information he must ignore in order to make a timely decision. Thus, the designer can use a threshold critical amount of ignored information as an indicator that the user is overloaded and implement adaptive automation at that point (to help reduce workload). What constitutes a critical amount of information can vary depending on the particular task and may best be determined on a system-by-system basis. [Source: Harris, Hancock, & Arthur, 1993 (as found in Scerbo, 1996); Sen, 1984]

- **3.13.4 Adapt to skill of the user.** Adaptive automation should be used to increase the performance of users with different skill levels. [Source: Norico & Stanley, 1989]

  Discussion. By adapting to the skill of the user, adaptive automation can increase the proficiency of the novice user and prevent frustration that might otherwise occur with complex systems.

- **3.13.5 Make adaptive automation at least as skilled as user.** Adaptive automation should be at least as skilled as the user, if not greater, to promote optimal user performance. [Source: Woods, 1996]

- **3.13.6 Modeling of human behavior.** Modeling of human behavior for aid-initiated intervention should at least include: task execution goal states, environment representation (graphical), situation assessment information and planning, and commitment logic. [Source: Andes & Hunt, 1989]

  Discussion. When modeling user behavior, it ought to be noted that users vary greatly in the way they employ automation. [Source: Lee, 1992; Lee & Moray, 1992 (as found in Riley, 1996)]

- **3.13.7 Interface adaptation.** When dynamic adaptation of the interface is used, it should be attained by utilizing information provided to the system through user interactions within a specific context. [Source: Norico & Stanley, 1989]

  Discussion. Dynamic adaptation of the interface may promote operator acceptance of automation.

- **3.13.8 Menu adaptation.** When dynamic adaptation of menus is used, the resultant menus should offer only the options that are relevant to the current environment. [Source: Barnes, 1985]

  Discussion. Dynamic adaptation of the menus occurs when menus are altered to reflect the needs of the current environment. This approach may reduce user workload. [Source: Barnes, 1985]

- **3.13.9 Use direct manipulation interfaces.** Direct manipulation interfaces should be used to minimize the impact of a transition to manual control. [Source: Morrison et al., 1993]

  Discussion. An example of **direct manipulation** is a graphical user interface (GUI). In direct manipulation, the user controls the interaction with the computer by acting directly on objects on the display screen. An object may be an icon, menu option, symbol, button, or dialog box. (See Chapter 8 on computer-human interfaces for more information on direct manipulation.) [Source: Shneiderman, 1998]

3.14 Decision aids

Definition. Decision aids (sometimes referred to as decision support systems) are automated systems that provide support to human decision-making processes either unsolicited or by user request. Decision aids can narrow the decision alternatives to a few or suggest a preferred decision based on available data. [Source: Wiener, 1988]

- **3.14.1 When to use.** Decision aids should be used

  a. for managing system complexity;

  b. for assisting users in coping with information overload;

  c. for focusing the user's attention;

  d. for assisting the user in accomplishing time-consuming activities more quickly;

  e. when limited data results in uncertainty;

  f. for overcoming human limitations that are associated with uncertainty, the emotional components of decision-making, finite-memory capacity, and systematic and cognitive biases; and

  g. for assisting the user in retrieving, retaining, representing or manipulating large amounts of information, combining multiple cues or criteria, allocating resources, managing detailed information, performing computations, and selecting and deciding among alternatives. [Source: AHCI, 1998; DISA, 1996]

▫ **3.14.2 When to avoid.** Decision aids should not be used

a. when solutions are obvious;

b. when one alternative clearly dominates all other options;

c. when there is insufficient time to act upon a decision;

d. when the user is not authorized to make decisions; or

e. for cognitive tasks in which humans excel, including generalization and adapting to novel situations. [Source: AHCI, 1998]

▫ **3.14.3 Let users determine decision aid use.** Users should be able to determine when and how the decision aid should be used. [Source: Parasuraman & Riley, 1997]

▫ **3.14.4 Use terms and criteria appropriate to users.** Decision aids should use terminology and criteria appropriate to the target user group. [Source: DISA, 1996]

▫ **3.14.5 Reduce number of response options.** Decision aids should reduce the number of response options. [Source: Barnes, 1985]

Discussion. The number of options that the user must consider is expected to decrease when a decision aid is used. Reducing the response options focuses the user's attention onto the most viable options.

▫ **3.14.6 Assist user decisions.** Decision aids should assist, rather than replace, human decision makers by providing data for making judgments rather than commands that the user must execute. [Source: AHCI, 1998; DISA, 1996; Parasuraman & Riley, 1997]

▫ **3.14.7 Make support consistent with mental models.** The support provided by decision aids should be consistent with user cognitive strategies and expectations (mental models). [Source: NUREG-0700, 1996]

Definition. A **mental model** is an individual's understanding of the processes underlying system operation. [Source: NRC, 1998; Parasuraman et al., 1996]

▫ **3.14.8 Do not cancel ongoing user tasks.** Use of decision aids should not require ongoing user tasks to be cancelled. [Source: NUREG-0700, 1996]

▫ **3.14.9 Minimize query of user.** Decision aids should minimize query of the users for information. [Source: NUREG-0700, 1996]

▫ **3.14.10 Minimize data entry.** Decision aids should minimize user data entry requirements. [Source: DISA, 1996]

- **3.14.11 Provide ability for planning strategy or guiding process.** Decision aids should be capable of planning a strategy to address a problem or guide a complex process. [Source: NUREG-0700, 1996]

- **3.14.12 Accept user direction.** Decision aids should accept direction from the users on which problem solving strategy to employ when alternative strategies are available. [Source: NUREG-0700, 1996]

- **3.14.13 Prioritize alternatives.** When more than one alternative is available, the decision aid should provide the alternatives in a recommended prioritization scheme based on mission and task analysis. [Source: AHCI, 1998]

- **3.14.14 Alert user when unable to process.** Decision aids should alert the user when a problem or situation is beyond its capability. [Source: NUREG-0700, 1996]

- **3.14.15 Be flexible in type and sequence of input accepted.** Decision aids should be flexible in the types and sequencing of user inputs accepted. [Source: NUREG-0700, 1996]

- **3.14.16 Estimate uncertainty and rationale.** Decision aids should estimate and indicate the certainty of analysis and provide the rationale for the estimate. [Source: NUREG-0700, 1996]

- **3.14.17 Make derived or processed data accessible.** When information used by a decision aid is derived or processed, the data from which it is derived should be either visible or accessible for verification. [Source: Billings, 1996]

  Discussion. Data that are not critical for operation can be made available only upon request.

- **3.14.18 Provide hard copy of decision aid use.** The user should be able to obtain hard copy print outs of data including screen displays, rules and facts, data employed, hypotheses tested, and summary information. [Source: NUREG-0700, 1996]

- **3.14.19 Allow access to procedural information.** Decision aids should give the user access to procedural information used by the aid. [Source: Morris, Rouse & Ward, 1985; NUREG-0700, 1996]

  Discussion. Procedural information is information about the rules or algorithms used by the decision aid. Knowledge of procedural information fosters user acceptance of the aid because the user is able to understand how the aid functions. As the user becomes more familiar with a given situation, he or she requires less procedural information. [Source: Morris, Rouse & Ward, 1985]

- **3.14.20 Provide user controlled level of explanation detail.** When the system provides explanations to the user, it should supply a short explanation initially, with the ability to make available more detail at the user's request, including access to process information or an explanation for the rules, knowledge-basis, and solutions used by the decision aid. [Source: DISA, 1996; NUREG-0700, 1996]

  Discussion. Process information is the information about how the aid accomplishes a task. This information is required by users to decide whether to use the aid in unfamiliar situations and for identifying the nature and extent of malfunctions. [Source: Morris et al., 1985]

- **3.14.21 Provide clear explanations to user.** When the system provides explanations to the user, the explanation should use terms familiar to the user and maintain consistency with the immediate task. [Source: DISA, 1996]

- **3.14.22 Present information with appropriate detail.** Decision aids should present information at the level of detail that is appropriate to the immediate task, with no more information than is essential. [Source: AHCI, 1998]

- **3.14.23 Avoid repeated information.** Decision aids should avoid repeating information that is already available. [Source: AHCI, 1998]

- **3.14.24 Integrate decision aids.** Decision aids should be fully integrated and consistent with the rest of the computer-human interface. [Source: NUREG-0700, 1996]

- **3.14.25 Alert to newly available information.** Decision aids should alert the user to changes in the status of important system information such as when critical information becomes available during decision aid utilization. [Source: NUREG-0700, 1996]

  Discussion. Critical information in this standard refers to information that may have a significant impact on task completion.

- **3.14.26 Alert to meaningful events or patterns.** Decision aids should automatically notify the user of meaningful patterns or events such as when it predicts a future problem. [Source: AHCI, 1998]

- **3.14.27 Predict based on historical data.** Decision aids should be able to predict future data based on historical data and current conditions. [Source: AHCI, 1998]

- **3.14.28 Provide ability to represent relationships graphically.** Decision aids should be able to graphically represent system relationships, its rules network, and reasoning process. [Source: NUREG-0700, 1996]

- **3.14.29 Identify simulation mode.** When decision aids have a simulation mode, entering the simulation mode should require an explicit command and result in a distinguishable change in output. [Source: NUREG-0700, 1996]

- **3.14.30 Provide knowledge of intent.** Each element in an intelligent human-machine system shall have knowledge of the intent of the other elements. [Source: Billings, 1996; NRC, 1998; Parasuraman et al., 2000]

  Discussion. Monitoring of the system by the user and the user by the system can only be effective if each knows what the other one is trying to accomplish. [Source: Billings, 1996]

- **3.14.31 Adapt with situational demands.** When adaptive decision aiding is used, the level of decision aiding should change with the situational demands in order to optimize performance (See Section 3.13 on adaptive automation). [Source: Rouse, 1988]

  Discussion. The criticality of a given task can change dramatically depending on the current situation. [Source: Derrick, 1988]

- **3.14.32 Adaptive decision aiding implementation.** Adaptive decision aiding should be applied when resource loading, performance, error frequency, and deviations from intent exceed threshold levels (See Section 3.13 on adaptive automation). [Source: Andes, 1987]

  Discussion. Resource loading, performance, errors, and deviations from intent can be used as indicators to determine when the user might need the help of the automated decision aid. The threshold levels of these indicators, specifying the optimal time to implement decision aiding may need to be determined on a system-by-system basis, possibly through simulation.

- **3.14.33 Provide planning assistance.** Adaptive decision aiding interfaces should allow the user to receive direct assistance in planning how to carry out the intended task. [Source: Tyler & Treu, 1989]

- **3.14.34 Allow user to initiate automation implementation.** The user should be able to initiate automated aids even if system-initiated automation is the norm. [Source: Billings, 1997; Harris, Hancock, Arthur, & Caird, 1995]

  Discussion. User acceptance of automation centers on whether the user feels in control of the system. [Source: Rouse, 1988]

3.15 Control automation

Definition. Control automation is when the system executes actions or control tasks with some level of autonomy.

▫ **3.15.1 Make automated tasks easily understood.** When automated control actions are performed, the automated tasks should be easily understood by users and similar to user control actions. [Source: Billings, 1991]

▫ **3.15.2 Limit control automation authority.** Control automation should not be able to jeopardize safety or make a difficult situation worse. [Source: AHCI, 1998]

▫ **3.15.3 Provide appropriate range of control options.** Automated systems should provide the user with an appropriate range of control options that are flexible enough to accommodate the full range of operating conditions for which it was certified. [Source: AHCI, 1998; Parasuraman & Riley, 1997; Sarter & Woods, 1995]

> **Discussion.** Highly flexible automated systems can be useful when the user knows how to implement the various options across a wide spectrum of operational situations. However, the multiple options that are associated with highly flexible systems also require additional cognitive resources in order for the user to remember which mode is active. [Source: Woods, 1996]

▪ **3.15.4 Provide immediate feedback.** To promote successful situation awareness of the automated system, the user shall be given immediate feedback to command and control orders. [Source: Morris & Zee, 1988]

▫ **3.15.5 Allow for different user styles.** Control automation should be flexible enough to allow for different user styles and responses without imposing new tasks on users or affecting automation performance. [Source: Wiener & Curry, 1980; Woods, 1996]

▪ **3.15.6 Make available override and backup alternatives.** Override and backup control alternatives shall be available for automation controls that are critical to the integrity of the system or when lives depend on the system. [Source: Billings, 1991]

▪ **3.15.7 Make backup information easy to get.** Information for backup or override capability shall be readily accessible. [Source: Billings, 1991]

▫ **3.15.8 Allow overriding out-of-tolerance conditions.** When a user might need to operate in out-of-tolerance conditions, then a deliberate overriding action should be possible. [Source: Billings, 1991]

> **Discussion.** There may be cases, particularly in an emergency situation, when the user needs to operate in out-of-tolerance conditions. [Source: Billings, 1996]

Glossary

Adaptive automation - The real time allocation of tasks to the user or automated system in a flexible manner, changing the automation to meet current situational demands. Adaptive automation may benefit user performance by allowing the user to remain in active control of the system instead of becoming a passive observer.

Automation - A device or system that independently carries out a task that was formerly carried out by a human.

Automation bias - When users rely on automated decision aids in a heuristic manner.

Control automation - Control automation is when an automated system executes actions or control tasks with some level of autonomy.

Critical function - A critical function is a function that can cause system failure when a malfunction is not attended to immediately.

Decision aids - Decision aids (sometimes referred to as decision support systems) are automated systems that provide support to human decision-making processes either unsolicited or by user request. Decision aids can narrow the decision alternatives to a few or suggest a preferred decision based on available data.

Direct manipulation - Direct manipulation is when the user controls the interaction with the computer by acting directly on objects on the display screen. An object may be an icon, menu option, symbol, button, or dialog box. An example of direct manipulation is a GUI.

Effectively - Carrying out a task effectively means producing the desired result.

Efficiently - Carrying out a task efficiently means that the desired result is produced with a minimum of waste (usually in relation to time).

Information automation - Includes information acquisition and integration. This type of automation would include filtering, distributing or transforming data, providing confidence estimates and integrity checks, and enabling user requests

Mental model - A mental model is an individual's understanding of the processes underlying system operation.

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4 Designing equipment for maintenance

This section contains human factors rules intended to make equipment maintenance easy, fast, and safe. Equipment maintenance does not, of course, occur in isolation. The overall system of which the equipment is a part affects the design of the equipment; for example, if the system must run continuously, the equipment might be designed to allow maintenance while it is in operation, or some sort of redundancy might be provided. The system maintenance concept also affects equipment design; for example, is a particular unit of equipment intended to be repaired on site? Is it intended to be removed and repaired at another location? Or is it intended to be discarded and replaced with another unit? A third factor affecting equipment design is the physical environment in which it will be located; will it be exposed to weather or to temperature extremes? Will the user be wearing gloves or other protective clothing? Finally, equipment must accommodate characteristics of the users themselves, their sizes and shapes, their skills, and their training.

4.1 General

This section contains rules for: (a) designing equipment in general, (b) emphasizing maintenance during the design of equipment, modules, and components, (c) maximizing the use of existing equipment and tools, (d) minimizing the skill and training requirements for users, and (e) minimizing the need for maintenance.

4.1.1 General design guidance

One of the most important aspects of designing equipment for maintenance is the breaking up of a unit of equipment into modules that are independent, interchangeable, and easily replaced. If warranted, these modules can also be disposable. Other important aspects are: ease of access to test and service points, ease of access to internal parts and components, and, if warranted, built-in testing, diagnostic and fault localization capability.

Definitions. A **unit of equipment** is an assemblage of items that may include modules, components, and parts that are packaged together into a single hardware package. For example, a computer, its keyboard, and its visual display are all units of equipment, as are radio transmitters and receivers. A **module** is an assemblage of two or more interconnected parts or components that comprise a single, physical and functional entity. It is this singular functionality that defines a module. A **component** is a subdivision of a unit of equipment that can be treated as an object by the user, but which can be further broken down into parts. A mounting board together with its mounted parts is an example of a component. A **part** is an object that cannot normally be broken down further without destroying its designated use. Fuses, resistors, and capacitors are examples of parts.

□ **4.1.1.1 General design guidance.** The following features should be incorporated into the design of all equipment, modules, and components, as appropriate:

a. simplification of maintenance functions,

b. modularization of equipment and components,

c. minimization of the number and complexity of maintenance tasks,

d. use of built-in testing, diagnostic, and fault localization capabilities,

e. use of disposable modules, components, and parts, where cost effective and appropriate,

f. simplification of design,

g. quick and easy access to all units of equipment, modules, components and parts that require maintenance, inspection, removal, or replacement,

h. compliance with lifting, carrying, and force criteria,

i. minimization of the numbers and types of tools and test equipment required for maintenance,

j. design alternatives dependent on the skills and training needed by maintainers and operators,

k. maximization of the safety and protection of users and equipment,

l. ease of assembly, disassembly, installation, and removal,

m. elimination of precise torque requirements,

n. ability to perform maintenance from above and outside rather than from underneath and inside,

o. use of self lubrication, and

p. use of sealed and lubricated modules. [Source: Department of Defense (MIL-HDBK-759B), 1992]

- **4.1.1.2 Use of existing items.** If an existing unit of equipment, module, component, or part meets the relevant requirements and the applicable human engineering criteria in this document, designers shall use that existing item rather than design a new one. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999]

  Discussion. Relevant requirements include performance, maintainability, and reliability criteria designated by the acquisition program office. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999]

  Definition. Item is a nonspecific term used to denote any product, available or in design or development, including parts, components, modules, and units of equipment. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999]

4.1.2 Emphasizing maintenance during design

- **4.1.2.1 Non-interruption of continuous operation.** Equipment that is part of a system that must operate continuously shall be capable of undergoing maintenance without interrupting the operation. [Source: NASA-STD-3000A, 1989]

- **4.1.2.2 Redundancy to prevent interruption.** If continuous operation is required and required maintenance on a unit of equipment would interrupt the operation, redundant equipment shall be provided. [Source: NASA-STD-3000A, 1989]

- **4.1.2.3 Degraded operation.** When warranted by its importance in a system, a unit of equipment that has a partial failure shall be designed to operate in a degraded mode while awaiting maintenance. This degraded operation shall not cause damage to other equipment or components, nor shall it aggravate the original fault. Degraded operation and faults shall be sensed and appropriate information identified, displayed, or transmitted to users and, if appropriate, to operators. [Source: NASA-STD-3000A, 1989]

- **4.1.2.4 Automation of fault detection and isolation.** When warranted, equipment shall have automatic fault detection and isolation capability. [Source: NASA-STD-3000A, 1989]

- **4.1.2.5 Equipment independence for maintenance.** Units of equipment shall be as independent (functionally, mechanically, electrically, and electronically) as is practical (see Paragraph 4.3.1.1). [Source: NASA-STD-3000A, 1989]

- ■ **4.1.2.6 Designing for safety of users.** Equipment shall not present hazardous conditions to users as they perform maintenance procedures. A positive means (for example, disconnects or lockouts) shall be designed into equipment and used to control hazardous conditions and facilitate safety as outlined in OSHA 29 CFR 1910.147. [Source: 29 CFR 1910.147; NASA-STD-3000A, 1989]

  Definitions. A **hazardous condition** is the presence of energy or a substance which is likely to cause death or injury by reason of physical force, shock, radiation, explosion, flames, poison, corrosion, oxidation, irritation or other debilitation. Biological and chemical hazards can have debilitating effects through disease or interference with physiological functions. A **hazardous location** is a space within a facility, room, or open environment where a hazardous condition exists or is accessible or exposed within the system or equipment located within the space. [Source: NASA-STD-3000A, 1989]

- □ **4.1.2.7 Dividing equipment into modules.** Heavy, large, or complex equipment should be divided into modules. [Source: AFSC DH 1-3, 1980]

  Discussion. Modularization of equipment can make it easier to: (a) locate and isolate malfunctions, (b) properly allocate maintenance functions and responsibilities, (c) reach, remove, and maintain components, and (d) handle the equipment for installation and repair. [Source: AFSC DH 1-3, 1980]

- ■ **4.1.2.8 Replacement of failed components.** Equipment shall be designed so that components that fail frequently (such as lamps and fuses) can be easily replaced. [Source: NASA-STD-3000A, 1989]

4.1.3 Optimize skills and training

- □ **4.1.3.1 Optimize balance between use, maintenance, and special skills.** As practical, the balance between ease of use, maintenance, and the need for special skills on the part of the users should be optimized. [Source: NASA-STD-3000A, 1989]

- ■ **4.1.3.2 Optimize balance between ease of use and training.** As practical, optimize the balance between ease of use and training on the part of the users. Special training shall only be required when equipment or automation is implemented or has undergone major modification. [Source: NASA-STD-3000A, 1989]

4.1.4 Minimizing need for maintenance

- **4.1.4.1 Ease of servicing.** Equipment shall be designed so that it can be serviced in its installed position. [Source: AFSC DH 1-3, 1980]

- **4.1.4.2 Minimize maintenance time.** Equipment shall be designed to minimize the time required for maintenance. [Source: NASA-STD-3000A, 1989]

4.2 Designing equipment for handling

The purpose in designing equipment for handling is to increase the efficiency of the user and to reduce the likelihood of injury to the user or damage to the equipment. The topics covered in this section include (a) the weight, size, and shape of the equipment, (b) the provision of handles and grasp areas, (c) the provision of stands, rests, and alignment aids, (d) designing for remote handling, and (e) designing for the use of hoists, jacks, and cranes.

4.2.1 General

- **4.2.1.1 Prevention of damage.** Units of equipment shall be designed, located, and protected so that they will not be damaged when they are stored, shipped, handled, installed, operated, or maintained. Susceptibility to damage shall be clearly identified. Procedural guidance and suitable warning labels shall be provided to help prevent such damage. [Source: MIL-STD-1800A, 1990]

- **4.2.1.2 Minimal number of maintainers.** Units of equipment shall be designed, placed, and mounted so that they can be installed and removed by a minimum number of people wearing clothing appropriate to the environment. [Source: MIL-STD-1472F, 1999]

4.2.2 Weight

The weight limits provided in this section assume that they will be lifted by able-bodied people.

- 4.2.2.1 **Maximum weight of units of equipment to be lifted by one person.** If a unit of equipment is designed to be lifted by a single person, its weight shall not exceed the value in Exhibit 4.2.2.1 that is appropriate for the height to which it is to be lifted and the size of the unit as it affects the distance between the body and the grip. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999]

Exhibit 4.2.2.1 Maximum weight limits for objects lifted by one person using both hands

Height to which lifted	460 mm (18 in)	610 mm (24 in)	150 mm (6 in)	300 mm (12 in)
.9 m (3 ft)	20.2 kg (44 lb)	13.3 kg (29.3 lb)	10.1 kg (22 lb)	6.6 kg (14.7 lb)
1.5 m (5 ft)	16.8 kg (37 lb)	11.2 kg (24.7 lb)	8.4 kg (18.5 lb)	5.6 kg (12.3 lb)

- 4.2.2.2 **Lifting in the presence of obstacles.** The values given in Exhibit 4.2.2.1 assume that there are no obstacles between the person lifting and the surface onto which the object is to be placed. If there is an obstacle, such as a lower shelf, the weight limit shall be reduced by 33% for an obstacle protruding 300 mm (12 in), 50% for an obstacle protruding 460 mm (18 in), and 66% for an obstacle protruding 610 mm (24 in). No lift shall be performed at a reach distance greater than 635 mm (25 in). If the allowable weight must be reduced by both size (distance between body and grip) and obstacle considerations, only the more restrictive single value shall apply, that is, two reductions shall not be applied. [Source: MIL-STD-1472F, 1999]

- 4.2.2.3 **Maximum weight of units of equipment to be lifted by two people.** If a unit of equipment is designed to be lifted by two people, the weight lifted by either one of them shall not exceed the appropriate value given in Exhibit 4.2.2.1; thus, if the weight of the unit is distributed uniformly, the maximum weight is twice that for a single person. [Source: MIL-STD-1472F, 1999]

- **4.2.2.4 Maximum weight of units of equipment to be lifted by three or more people.** If a unit of equipment is designed to be lifted by three or more people, the weight lifted by any one of them shall not exceed the appropriate value given in Exhibit 4.2.2.1. The maximum weight of the unit may be increased by three-fourths of the single person value for each person in addition to the first. Thus, the maximum weight shall not exceed

  $$X + 0.75(N-1)\,X$$

  where X is the appropriate value from Exhibit 4.2.2.1, and N is the number of people lifting. This increase assumes that the unit is large enough that the people lifting do not interfere with each other. [Source: MIL-STD-1472F, 1999]

- **4.2.2.5 Maximum weight of units of equipment to be carried by one person.** The weight of a unit of equipment designed to be carried by one person shall not exceed 16 kg (35 lb). This limit applies to carrying distances up to 10 m (33 ft). [Source: MIL-STD-1472F, 1999]

- **4.2.2.6 Maximum weight of units of equipment to be carried by more than one person.** If a unit of equipment is designed to be carried by two people, the weight carried by either one of them shall not exceed 19 kg (42 lb); thus, if the weight of the unit is distributed uniformly, the maximum weight of the unit is 38 kg (84 lb). This limit applies to carrying distances up to 10 m (33 ft). [Source: MIL-STD-1472F, 1999]

- **4.2.2.7 Maximum weight of units of equipment to be carried by more than two people.** If a unit of equipment is designed to be carried by more than two people, the total weight shall not exceed 19 kg (42 lb) plus 14.3 kg (31.5 lb) for each person carrying in addition to the first. This increase in weight assumes that the unit is large enough that the people carrying do not interfere with each other. This limit applies to carrying distances up to 10 m (33 ft). [Source: MIL-STD-1472F, 1999]

- **4.2.2.8 Lifting eyes or jacking points.** Units of equipment weighing more than 68 kg (150 lb) shall have lifting eyes or jacking points (see Paragraph 4.2.10 Designing for use of hoists, jacks, and cranes). [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; MIL-STD-1800A, 1990]

- ▫ **4.2.2.9 Reducing weight by removing parts.** Heavy pieces of equipment should be made more manageable by designing them with removable parts. [Source: AFSC DH 1-3, 1980]

- **4.2.2.10 Labeling heavy units.** Any unit of equipment heavier than 13.6 kg (30 lbs) or designed to be lifted or carried by more than one person shall be labeled according to Paragraph 4.3.5.1.3. [Source: MIL-STD-1800A, 1990]

4.2.3 Size

The size of a unit of equipment affects its weight limits; a large unit intended to be handled by one person cannot weigh as much as a smaller one, as can be seen in Exhibit 4.2.2.1. Similarly, a unit intended to be handled by two or more people that is so small that the people interfere with each other cannot weigh as much as a unit that is large enough to avoid such interference.

- ▫ **4.2.3.1 Desirable size.** Each unit of equipment should be small enough for one person to lift or carry. [Source: AFSC DH 1-3, 1980]

- ▫ **4.2.3.2 Reducing size by removing parts.** Units of equipment that are too large to be handled by one person should be designed with removable parts to reduce their size. [Source: AFSC DH 1-3, 1980]

4.2.4 Shape

- ▪ **4.2.4.1 Avoiding protuberances.** Equipment shall be designed with a minimum number of bulges or extensions that might interfere with handling. [Source: MIL-STD-1472F, 1999]

- ▪ **4.2.4.2 Removing protuberances.** If a unit of equipment includes irregular bulges or extensions that make handling difficult, the bulges or extensions shall be easily removable by hand or with common hand tools. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

4.2.5 Handles

A handle is a permanent part of a unit of equipment that is designed to be grasped by the hand. Handles may extend out from the unit so that the fingers wrap around them, or they may be recessed areas so that the fingers fit inside an opening. Extended handles may be rigid or folding.

The size, number, and location of handles depend upon: (a) the weight and center of gravity of the unit, (b) the number of people lifting or carrying the unit, (c) the type of clothing worn and whether or not gloves are worn, (d) the position of the unit before handling and its final position, (e) the frequency with which the unit is handled, and (f) any additional uses the handles may serve. [Source: UCRL-15673, 1985]

4.2.5.1 When handles are needed

- ▪ **4.2.5.1.1 Units of equipment designed for carrying.** Units of equipment intended to be carried shall have handles or grasp areas. [Source: MIL-HDBK-759B, 1992; MIL-STD-1800A, 1990]

- **4.2.5.1.2 Units of equipment weighing less than 4.5 kg (10 lb).** Units of equipment weighing less than 4.5 kg (10 lb) shall have handles if they would otherwise be difficult to grasp, remove, or carry. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992]

- **4.2.5.1.3 Units of equipment weighing between 4.5 and 18 kg (10 to 40 lb).** Units of equipment weighing between 4.5 kg (10 lb) and 18 kg (40 lb) shall have one or more handles that permit easy handling of the unit by one person. If the unit is bulky or if its weight is unevenly distributed, the handles shall permit easy handling by two people. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

- **4.2.5.1.4 Units of equipment weighing between 18 and 68 kg (40 to 150 lb).** Units of equipment weighing between 18 kg (40 lb) and 68 kg (150 lb) shall have handles that provide easy handling of the unit by two or more people. If the unit is very large, it shall have lifting eyes (see Paragraph 4.2.10.1). [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

- **4.2.5.1.5 Force limits.** The force exerted pulling or pushing a handle or grasp area shall not exceed the values given in Exhibit 4.2.5.1.5 for the appropriate elbow angle. The values provided in the Exhibit shall be reduced by 30% if the work is performed in excess of 30 minutes. The values given are projected to a mixed male and female population by taking two-thirds of the values for a male population. For a more detailed coverage of pulling and pushing limits, see Snook & Ciriello (1991). [Source: MIL-STD-1472F, 1999]

Exhibit 4.2.5.1.5 Maximum force limits for pulling and pushing units of equipment using handles or grasp areas.

Degree of elbow flexion	Pulling		Pushing	
	Left arm N (lbf)	Right arm N (lbf)	Left arm N (lbf)	Right arm N (lbf)
180	148 (33)	154 (35)	125 (28)	148 (33)
150	125 (28)	166 (37)	89 (20)	125 (28)
120	101 (23)	125 (28)	77 (17)	107 (24)
90	95 (21)	110 (25)	65 (15)	107 (24)
60	77 (17)	71 (16)	65 (15)	101 (23)

4.2.5.2 Handle characteristics

- **4.2.5.2.1 Handle comfort.** Handles shall be comfortable and easy to grasp; they shall not cut into the hand or cause undue pressure on the fingers. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- **4.2.5.2.2 Handle surface.** The surface of handles shall be sufficiently hard that grit and grime do not become embedded during normal use. [Source: MIL-STD-1472F, 1999]

- **4.2.5.2.3 Handle conductivity.** The handle material that comes into contact with a user's hand shall not conduct heat or electricity. [Source: MIL-STD-1472F, 1999]

- **4.2.5.2.4 Handle attachment.** Handles shall be permanently attached to the unit of equipment. [Source: MIL-HDBK-759B, 1992]

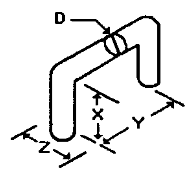
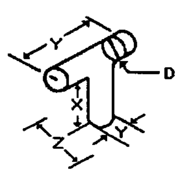
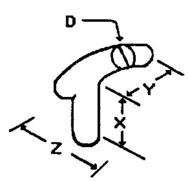
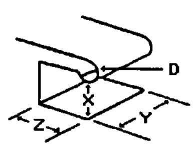
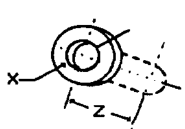
- **4.2.5.2.5 Stops for hinged or folding handles.** Hinged or folding handles shall have a stop that holds them perpendicular to the surface on which they are mounted when they are moved into carrying position. It shall require only one hand to move them into this position. [Source: AFSC DH 1-3, 1980; MIL-STD-1800A, 1990; MIL-STD-1472F, 1999]

4.2.5.3 Dimensions

The dimensions of handles depend primarily upon the type of handle, the weight of the unit of equipment, and the type of hand covering the user wears (none, gloves, or mittens). Other factors affecting handle dimensions include the normal operating position of the unit, the frequency and distance it is lifted or carried, and whether or not the handle has an additional purpose, such as protecting the front of the equipment or serving as a stand when the equipment is in its maintenance position. [Source: MIL-HDBK-759B, 1992]

- **4.2.5.3.1 Minimum handle dimensions by type of handle and hand covering.** Handles shall equal or exceed the dimensions in Exhibit 4.2.5.3.1 for the appropriate type of handle and the user's hand covering. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; UCRL-15673, 1985]

Exhibit 4.2.5.3.1 Minimum handle dimensions

	Type of handle		Bare hand X	Bare hand Y	Bare hand Z	Gloved hand X	Gloved hand Y	Gloved hand Z	Mittened hand X	Mittened hand Y	Mittened hand Z
	Two-finger bar	mm	32	65	75	38	75	75		N/A	
		(in)	(1.25)	(2.50)	(3.0)	(1.5)	(3.0)	(3.0)		N/A	
	One-hand bar	mm	48	111	75	50	125	100	75	135	150
		(in)	(1.88)	(4.37)	(3.0)	(2.0)	(5.0)	(4.0)	(3.0)	(5.25)	(6.0)
	Two-hand bar	mm	48	215	75	50	270	100	75	280	150
		(in)	(1.88)	(8.5)	(3.0)	(2.0)	(10.5)	(4.0)	(3.0)	(11.0)	(6.0)
	T-bar	mm	38	100	75	50	115	100		N/A	
		(in)	(1.5)	(4.0)	(3.0)	(2.0)	(4.5)	(4.0)		N/A	
	J-bar	mm	50	100	75	50	115	100	75	125	150
		(in)	(2.0)	(4.0)	(3.0)	(2.0)	(4.5)	(4.0)	(3.0)	(5.0)	(6.0)
	Two-finger recess	mm	32	65	50	38	75	50		N/A	
		(in)	(1.25)	(2.5)	(2.0)	(1.5)	(3.0)	(2.0)		N/A	
	One-hand recess	mm	50	110	90	90	135	100	90	135	125
		(in)	(2.0)	(4.25)	(3.5)	(3.5)	(5.25)	(4.0)	(3.5)	(5.25)	(5.0)
	Finger-tip recess	mm	19	-	13	25	-	19		N/A	
		(in)	(0.75)	-	(0.5)	(1.0)	-	(0.75)		N/A	
	One-finger recess	mm	32	-	50	38	-	50		N/A	
		(in)	(1.25)	-	(2.0)	(1.5)	-	(2.0)		N/A	

- **4.2.5.3.2 Minimum handle diameter by weight of unit of equipment.** Heavier units require handles of greater diameter. The diameter of the handle shall equal or exceed the value given in Exhibit 4.2.5.3.2 for the appropriate weight range. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999]

Exhibit 4.2.5.3.2 Minimum handle diameter required by weight of unit of equipment

Weight	Diameter
Up to 6.8 kg: (15 lb)	6 mm: (¼ in)
6.8 to 9.1 kg: (15 to 20 lb)	13 mm: (½ in)
9.1 to 18.1 kg: (20 to 40 lb)	19 mm: (¾ in)
Over 18.1 kg: (40 lb)	25 mm: (1 in)

- **4.2.5.3.3 Finger curl.** The size and shape of a handle shall allow the user's fingers to curl around the handle at least 120°. [Source: MIL-STD-1472F, 1999]

4.2.5.4 Location

The location of handles with respect to the center of gravity of a unit of equipment determines the tendency of the unit to tip or sway when it is lifted or carried. Placing the handles above the center of gravity and placing pairs of handles on opposite sides of the unit on a line passing through the center of gravity horizontally ensure the stability of the unit. However, other considerations may outweigh these "balance" considerations. For example, if a unit is intended to be pulled out of a rack, its handles will probably be located on the front of the unit.

- **4.2.5.4.1 Single handles.** A single handle should be located directly above the center of gravity of a unit of equipment. [Source: MIL-STD-1472F, 1999; UCRL-15673, 1985]

- **4.2.5.4.2 Pairs of handles.** The two handles of a pair of handles should be located on opposite sides of the unit of equipment on or above a line passing horizontally through the unit's center of gravity. [Source: MIL-STD-1472F, 1999; UCRL-15673, 1985]

- **4.2.5.4.3 Exposure to hazards.** Handles shall be located so that their use does not expose a user to thermal or electrical hazards. [Source: MIL-STD-1800A, 1990]

■ **4.2.5.4.4 Structural clearance.** Handles shall be located to provide a clearance of at least 50 mm (2 in) between the handle and any obstruction when the equipment is in its installed or maintenance position. [Source: MIL-STD-1472F, 1999]

4.2.6 Grasp areas

□ **4.2.6.1 Location of grasp area.** Grasp areas should be located above the center of gravity of a unit of equipment so that the unit does not tend to tip or sway when it is lifted or carried. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

■ **4.2.6.2 Grasp area finish.** Grasp areas shall have a nonslip finish. If the bottom of a unit of equipment is designed to serve as a grasp area, the bottom surface shall have a nonslip finish. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

■ **4.2.6.3 Grasp area material.** The material used for the grasp area shall be sufficiently hard that grit and grime do not become embedded in it during normal use. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

■ **4.2.6.4 Grasp area conductivity.** Grasp area material shall not conduct heat or electricity. [Source: MIL-STD-1472F, 1999]

4.2.7 Stands and rests

If a unit of equipment contains components that could be damaged easily during maintenance, stands or rests might be provided to protect the susceptible parts. If the unit has handles, the handles can be designed to serve as the stands or rests.

■ **4.2.7.1 Prevention of damage.** If appropriate and practical, units of equipment that contain components that are susceptible to damage shall have stands or rests that protect the susceptible components when the unit is in its maintenance position. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

■ **4.2.7.2 Integral to chassis.** When provided, stands or rests shall be part of the basic chassis of the unit of equipment. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

□ **4.2.7.3 Handles as stands or rests.** If a unit of equipment requiring stands or rests has handles, the handles should be designed to serve as the stands or rests. [Source: AFSC DH 1-3, 1980]

4.2.8 Alignment aids

Ideally, it would be impossible to install equipment incorrectly. Alignment aids can help to achieve correct installation. The emphasis in this section is on physical devices, such as guides and pins, but labels can also serve as alignment aids.

- ■ **4.2.8.1 Guides, tracks, and stops.** Guides, tracks, and stops shall be provided wherever appropriate to facilitate handling and to prevent damage to equipment and injury to users. [Source: MIL-STD-1472F, 1999]

- ■ **4.2.8.2 Prevention of improper mounting.** Units of equipment shall include physical features (such as supports, guides, or alignment pins) that prevent improper mounting. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; NASA-STD-3000A, 1989]

- □ **4.2.8.3 Alignment of light-weight units of equipment.** Units of equipment weighing less than 9 kg (20 lb) should have bottom-mounted alignment pins. [Source: MIL-HDBK-759B, 1992]

- □ **4.2.8.4 Alignment of heavy units of equipment.** Units of equipment weighing more than 9 kg (20 lb) should have side-aligning guides so that the unit can be slid into place. [Source: MIL-HDBK-759B, 1992]

- ■ **4.2.8.5 Labeling units of equipment.** Units of equipment shall have labels that identify their proper alignment, unless the alignment is immediately obvious. [Source: MIL-STD-1472F, 1999]

- ■ **4.2.8.6 Labeling insertion holes.** If a unit of equipment has holes through which connectors or other objects that require proper alignment are inserted, the holes shall have labels showing proper alignment of the object to be inserted. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

4.2.9 Designing for remote handling

- ■ **4.2.9.1 Alignment aids.** All units of equipment designed for remote handling shall have alignment aids. [Source: MIL-STD-1800A, 1990]

- ■ **4.2.9.2 Quick-action connectors.** All connectors on units of equipment designed for remote handling shall be of the quick-action type. [Source: MIL-STD-1800A, 1990]

- ■ **4.2.9.3 Fasteners.** All fasteners on units of equipment designed for remote handling shall be of the captive type and shall be operable by remote handling techniques. [Source: MIL-STD-1800A, 1990]

- **4.2.9.4 Latches.** All latches on units of equipment designed for remote handling shall: (a) be operable from a single point, (b) have positive catches, and (c) provide a clear visual indication of the latch position. [Source: MIL-STD-1800A, 1990]

4.2.10 Designing for use of hoists, jacks, and cranes

- **4.2.10.1 Location of assistance points.** The lifting eyes or jacking points shall be located so that the unit of equipment does not tilt or swing uncontrollably while it is being lifted. [Source: MIL-STD-1472F, 1999]

- **4.2.10.2 Labeling.** Lifting eyes and jacking points shall be labeled conspicuously. [Source: MIL-HDBK-759B, 1992; MIL-STD-1800A, 1990]

4.3 Packaging, arrangement, and mounting of equipment

Equipment can be packaged, arranged, and mounted in a variety of ways. This section gives rules to narrow the choices. Several goals and principles underlie the requirements and rules of this section. They include:

a. avoiding irregular, fragile, or awkward extensions to equipment, or, if they cannot be avoided, ensuring that such extensions are easy to remove,

b. packaging equipment so that it can be handled by one person or as few people as possible,

c. arranging different units of equipment so that maintenance by one specialist does not require moving or handling equipment maintained by another specialist,

d. mounting equipment so that it is easily installed or removed and readily accessible for maintenance,

e. mounting equipment in a way that minimizes the need for the user to bend, stretch, crawl, assume awkward positions, or move from place to place in performing maintenance tasks, and

f. minimizing the need for tools, particularly specialized tools.

4.3.1 Unitization of equipment

Unitization is the packaging of equipment in physically and functionally distinct units that can be easily removed and replaced. This sort of separation can have a number of advantages, such as providing easy access to malfunctioning equipment, allowing a high degree of standardization, simplifying and speeding equipment design by using previously developed standardized designs, and reducing the skill and training requirements for users.

Definitions. A **unit of equipment** is an assemblage of items that may include modules, components, and parts that are packaged together into a single hardware package. For example, a computer, its keyboard, and its visual display are all units of equipment, as are radio transmitters and receivers. A **module** is an assemblage of two or more interconnected parts or components that comprise a single, physical and functional entity. It is this singular functionality that defines a module. A **component** is a subdivision of a unit of equipment that can be treated as an object by the user, but which can be further broken down into parts. A mounting board together with its mounted parts is an example of a component. A **part** is an object that cannot normally be broken down further without destroying its designated use. Fuses, resistors, and capacitors are examples of parts. The **packaging** of a unit of equipment is the assembling, mounting, and enclosing of the items it includes.

■ **4.3.1.1 Functional independence.** Units of equipment shall correspond to the functional design of the equipment and shall maximize the functional independence of each unit while minimizing the interaction between units (see Paragraph 4.1.2.5). [Source: UCRL-15673, 1985]

■ **4.3.1.2 Packaging equipment.** Whenever possible, units of equipment shall be independent, interchangeable, and easy to replace. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; UCRL-15673, 1985]

■ **4.3.1.3 Ease of installation.** All equipment shall be easy to mount and easy to connect to other equipment. [Source: MIL-HDBK-759B, 1992]

■ **4.3.1.4 Independent adjustment.** Units of equipment shall be capable of being checked and adjusted separately; when interconnected with other units, they shall require little or no additional adjustment. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

□ **4.3.1.5 Handling by one person.** Units of equipment should be installable and removable by one person (see Paragraph 4.2.2 on weight limits). [Source: UCRL-15673, 1985]

- **4.3.1.6 Interconnectivity.** The number of inputs and outputs associated with a unit of equipment shall be minimized. [Source: AFSC DH 1-3, 1980]

- **4.3.1.7 Protrusions.** Any irregular protrusions on a unit of equipment, such as cables, waveguides, or hoses shall be easily removable to prevent damage during installation and maintenance. [Source: AFSC DH 1-3, 1980]

- **4.3.1.8 Prevention of incorrect mounting.** Units of equipment should be designed so that they cannot be mounted incorrectly. [Source: MIL-HDBK-759B, 1992]

4.3.2 Interchangeability, non-interchangeability

Units of equipment may be interchangeable physically, functionally, or both. This section contains rules that might be summarized in the general statements that if two units of equipment are interchangeable functionally, they will also be interchangeable physically; if they are not interchangeable functionally, they will not be interchangeable physically.

- **4.3.2.1 Interchangeability of equivalent units of equipment.** Units of equipment having the same form and function shall be interchangeable throughout a system and related systems. [Source: UCRL-15673, 1985]

- **4.3.2.2 Identifiable interchangeable units of equipment.** Interchangeable units of equipment shall be clearly identifiable and easily distinguishable from units that are similar, but not interchangeable. Identification methods might be physical (such as size, shape, and mounting provisions), visual (such as color-coding), or verbal (such as labeling). [Source: MIL-STD-1472F, 1999]

- **4.3.2.3 Non-interchangeability of nonequivalent units of equipment.** Units of equipment that are not functionally interchangeable shall not be physically interchangeable. [Source: MIL-STD-1472F, 1999; UCRL-15673, 1985]

- **4.3.2.4 Identifiable non-interchangeable units of equipment.** Non-interchangeable units of equipment shall be clearly identifiable and readily distinguishable from units that are interchangeable. Identification methods might be physical (such as size, shape, and mounting provisions), visual (such as color-coding), or verbal (such as labeling). [Source: UCRL-15673, 1985]

4.3.3 Mounting in drawers, on racks, and on hinges

4.3.3.1 General

- ▪ **4.3.3.1.1 Mounting frequently-moved units of equipment.** Units of equipment that must be moved frequently from their installed positions for maintenance shall be mounted in drawers, on sliding racks, or on hinges. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999]

- ▪ **4.3.3.1.2 Mounting of heavy units of equipment.** Heavy, relatively inaccessible units of equipment that must be inspected or maintained shall be mounted in drawers, on sliding racks, or equipment covers on hinges. [Source: MIL-HDBK-759B, 1992]

- ▪ **4.3.3.1.3 Access to rear or bottom of units of equipment.** If the maintainer must have access to the rear or bottom of units of equipment mounted in drawers, on sliding racks, or equipment covers on hinges, the units shall open or rotate fully and remain in that position (held by braces, for example) without being supported by the maintainer. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; MIL-STD-1800A, 1990]

- ▪ **4.3.3.1.4 Avoidance of instability.** If opening or extending a unit of equipment that is mounted in a drawer, on a sliding rack, or on hinges would shift the center of gravity of the mounting structure so that it becomes unstable, the structure shall be securely fastened. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

- ▫ **4.3.3.1.5 Attachment of equipment.** Units of equipment mounted in drawers, on sliding racks, or on hinges should be attached only to the drawer, rack, or hinge and to interconnecting lines and cables. [Source: UCRL-15673, 1985]

- ▪ **4.3.3.1.6 Ease of moving mounted units of equipment.** When units of equipment are mounted in drawers, on sliding racks, or on hinges, the drawers, racks, or hinges shall be easy (require few operations) to open or extend. [Source: UCRL-15673, 1985]

- ▪ **4.3.3.1.7 Maximum force to move mounted units of equipment**. The force needed to open or rotate a drawer, slide, or hinged mount shall not exceed the values given in Paragraph 4.2.5.1.5. [Source: UCRL-15673, 1985]

- ▫ **4.3.3.1.8 Guards and shields.** If needed to protect fragile or sensitive components, drawers and racks should include guards or shields. [Source: UCRL-15673, 1985]

4.3.3.2 Restraints and supports

Equipment mounted in drawers, on sliding racks, or on hinges must be protected with stops or supports that prevent it from falling or tipping over and that hold it in position both for operation and for maintenance. These stops and supports must be easily overridden so that the equipment can be easily removed and replaced.

- 4.3.3.2.1 **Limit stops.** Limit stops shall be provided on all drawer, slide, or hinge mounted equipment that must be moved from its operating position to a maintenance position. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; NASA-STD-3000A, 1989]

  Definition. Limit stops are mechanisms that restrict a moving object or part by stopping it at predetermined (limit) positions. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; NASA-STD-3000A, 1989]

- 4.3.3.2.2 **Automatic locks.** Drawers and slides shall lock automatically in both the operating and maintenance positions. [Source: MIL-STD-1472F, 1999; UCRL-15673, 1985]

- 4.3.3.2.3 **Lock release.** The locks holding drawers and slides in the operating and maintenance positions shall be easy to release, preferably requiring only one hand to operate. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; NASA-STD-3000A, 1989]

- 4.3.3.2.4 **Supports for hinge-mounted equipment.** Hinge-mounted equipment shall have a means of support to hold it in both the operating and maintenance positions. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

4.3.3.3 External connectors and interlocks

- 4.3.3.3.1 **Preservation of external connections.** If external connections are required for maintenance as well as for normal operation, mounting shall be designed so that these connections are not broken when the unit of equipment is slid or rotated into its maintenance position. [Source: UCRL-15673, 1985]

- 4.3.3.3.2 **Breaking of external connections.** If it is required that external connections be broken for maintenance, interlocks shall be provided that break the connections when the equipment is slid or rotated into its maintenance position. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

- 4.3.3.3.3 **External connectors as part of supporting structure.** If equipment mounted in a drawer or on a sliding rack is intended to be removed and replaced by users, and if external connections are not required during maintenance, the drawer or rack shall be provided with connectors on the rear of the equipment that mate with connectors mounted on the structure. [Source: MIL-STD-1472F, 1999]

4.3.4 Positioning equipment

Some general considerations affecting the positioning of equipment are:

a. Avoid locations where the equipment or the user would be exposed to damage or injury.

b. Avoid locations where the equipment or the user would be exposed to oil, dirt, or other contaminants.

c. Choose the most accessible locations for the most frequently serviced equipment.

d. Choose the most accessible locations for the heaviest or bulkiest equipment.

e. Choose the most protected locations for the most fragile or sensitive equipment.

4.3.4.1 Physical accessibility

- 4.3.4.1.1 **Complete visual and physical access.** Equipment shall be positioned so that the maintainer has complete visual and physical access to all parts of the equipment on which maintenance is performed; this includes access openings, adjustment points, test points, cables, connectors, labels, and mounting fasteners. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; NASA-STD-3000A, 1989]

- 4.3.4.1.2 **Freedom from structural obstruction.** Units of equipment shall be positioned so that neither visual nor physical access is obstructed by structural members or permanently installed equipment. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; UCRL-15673, 1985]

- 4.3.4.1.3 **Working space.** Units of equipment shall be positioned so that there is sufficient space around them for the use of any tools and test equipment required for their maintenance [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; NASA-STD-3000A, 1989]

- 4.3.4.1.4 **Room to open covers.** Units of equipment shall be positioned with sufficient clearance from other equipment and structures to permit unhindered opening of any covers that are opened during maintenance tasks. [Source: AFSC DH 1-3, 1980]

- 4.3.4.1.5 **Stacking or blocking equipment.** Units of equipment shall not be stacked or placed in front of or behind other units; each unit shall be positioned so that it is both visually and physically accessible without the removal of another unit. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; MIL-STD-1800A, 1990; NASA-STD-3000A, 1989; UCRL-15673, 1985]

- **4.3.4.1.6 Full extension or rotation.** Units of equipment mounted in drawers, on sliding racks, or on hinges shall be positioned so that the drawer, rack, or hinge can be opened or extended without hindrance. [Source: MIL-STD-1472F, 1999; NASA-STD-3000A, 1989]

- **4.3.4.1.7 Working level.** Units of equipment should be positioned so that they are at the most favorable working level; this is usually between the maintainer's hip and shoulder height, from approximately 1 to 1.5 m (3 to 5 ft). [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- **4.3.4.1.8 Visual access.** Units of equipment that require frequent visual inspection shall be positioned so that the components to be inspected (such as displays, test points, and labels) can be seen easily without the removal of any other equipment. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992]

- **4.3.4.1.9 Removal path.** Units of equipment intended to be replaceable by maintainers shall be positioned so that they can be removed along a straight or moderately curved path, not along a sharply bent path. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999]

4.3.4.2 Relative accessibility

In addition to considerations of physical accessibility, the positioning of equipment is affected by its indispensability, the frequency with which it is serviced or maintained, the relationship of one unit of equipment to other units, and the difficulty with which it is serviced or maintained.

- **4.3.4.2.1 Criticality of equipment.** The most critical units of equipment shall be the most accessible. Accessibility may be compromised for highly reliable critical equipment. [Source: MIL-STD-1472F, 1999; NASA-STD-3000A, 1989]

- **4.3.4.2.2 Frequency of access.** If criticality is not a factor, equipment requiring the most frequent servicing or maintenance shall be the most accessible. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; NASA-STD-3000A, 1989; UCRL-15673, 1985]

- **4.3.4.2.3 Grouping to minimize movement.** Units of equipment maintained by the same person shall be positioned near each other (provided the operational grouping of equipment remains in close proximity) to minimize the amount of movement required of the maintainer. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999]

- **4.3.4.2.4 Non-interaction with equipment maintained by others.** Access to units of equipment maintained by one type of maintenance specialist shall not require moving equipment maintained by another type of specialist. When conflicts with Paragraphs 4.3.4.2.1 through 4.3.4.2.3 occur, the previous paragraphs shall have priority. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

- 4.3.4.2.5 **Difficulty of moving.** Units of equipment that are difficult to move shall not prevent convenient access to other units. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

- 4.3.4.2.6 **Non-interaction with equipment not in need of maintenance.** It shall not be necessary to remove or disable an operable unit of equipment to obtain access to a unit requiring maintenance. [Source: NASA-STD-3000A, 1989]

4.3.5 Labeling and marking

Labels on equipment can be used to (a) identify the equipment, (b) state warnings or cautions, (c) supply useful information, such as instructions, the weight of the equipment, or calibration information, and (d) record and supply historical data, such as periodic readings or the date of servicing or replacement.

Definitions. A **label** is alphanumeric information that identifies or describes an object. Labels can be printed directly on or adjacent to the object, or they can be printed on a card or plate that is attached to the object or adjacent to the object. **Marking** is nonverbal information, such as colors or symbols, which identifies or describes an object. Marking can appear directly on or adjacent to the object, or it can be printed on a card or plate that is attached to the object or adjacent to the object.

4.3.5.1 Types of labels

- 4.3.5.1.1 **Equipment identification.** All units of equipment shall have identifying labels. These labels shall be securely attached, permanent, nonfading, oil-, gasoline-, and corrosion-resistant, and shall include all of the following that are applicable: (a) contract order or task number, (b) equipment name, (c) specification number, (d) manufacturer's part number, (e) serial number, (f) manufacturer's name and address, and (g) if necessary, stock number. [Source: UCRL-15673, 1985]

Discussion. Note that OSHA 29 CFR 1910.303 (e) requires that electrical equipment itself must have a manufacturers name or trademark or other descriptive material which identifies product responsibility and includes markings giving voltage, current, wattage or other ratings. [Source: 29 CFR 1910.303; UCRL-15673, 1985]

- 4.3.5.1.2 **Hazard labels.** If any hazard exists in servicing or maintaining a unit of equipment, the equipment shall have a warning label attached that describes the hazard. [Source: MIL-HDBK-759B, 1992]

Discussion. Electrical equipment that is to be used in hazardous locations must be marked to show the hazardous location class and group (from National Fire Protection Association 70) and operating temperatures. [Source: MIL-HDBK-759B, 1992]

- **4.3.5.1.3 Weight labels.** Weight and center of gravity caution placards shall be placed on any unit of equipment to be moved for maintenance if its weight exceeds 13.6 kg (30 lbs). If it is designed to be lifted or carried by more than one person, the label shall include the number of people recommended to lift or carry it (see Paragraph 4.2.2.10). [Source: MIL-HDBK-759B, 1992; MIL-STD-1800A, 1990]

- **4.3.5.1.4 Instruction labels.** If there are critical instructions for the servicing or maintenance of a unit of equipment, and if these instructions are not likely to be available through other means, they shall be provided in a label on the equipment. [Source: UCRL-15673, 1985]

- **4.3.5.1.5 Data labels.** If there are critical data that must be available to or recorded by the maintainer of a unit of equipment, and if there is no other provision for them, a label shall be provided for these data. [Source: UCRL-15673, 1985]

4.3.5.2 Location and orientation

- **4.3.5.2.1 Readability.** Equipment labels shall be located so that they are visible and readable with the equipment in its installed position. [Source: UCRL-15673, 1985]

- **4.3.5.2.2 Preserving readability.** Equipment labels shall be located so that they will not become obscured by dirt, moisture, or other foreign materials. If these materials are likely to accumulate, the labels shall be mounted on a vertical surface. [Source: UCRL-15673, 1985]

- □ **4.3.5.2.3 Consistent location.** Labels on similar units of equipment should be placed in approximately the same location on each. [Source: UCRL-15673, 1985]

- **4.3.5.2.4 Horizontal orientation.** Labels shall be oriented so that alphanumeric characters are read horizontally, not vertically. [Source: UCRL-15673, 1985]

4.3.5.3 Typographic matters

- 4.3.5.3.1 **Character height for viewing distance.** Unless circumstances require otherwise, labels shall be clearly legible at a viewing distance of 710 mm (28 in). The recommended height for letters and numerals at this distance is approximately 5 mm (.18 in). Exhibit 4.3.5.3.1 gives minimum character heights for other viewing distances. [Source: UCRL-15673, 1985]

  Exhibit 4.3.5.3.1 Minimum character height for various viewing distances

Viewing distance	Minimum height
Less than 0.5 m (20 in)	2.3 mm (0.1 in)
0.5 - 1.0 m (20 - 40 in)	4.7 mm (0.2 in)
1.0 - 2.0 m (40 - 80 in)	9.4 mm (0.4 in)
2.0 - 4.0 m (80 - 160 in)	18 mm (0.75 in)

- 4.3.5.3.2 **Stroke width in normal illumination.** If labels are expected to be read under normal illumination, characters shall be black on a white or light background, and stroke width shall be 1/6 to 1/7 of the height. [Source: UCRL-15673, 1985]

- 4.3.5.3.3 **Stroke width in dim illumination.** If labels are expected to be read under dim illumination, characters shall be white on a black or dark background, and stroke width shall be from 1/7 to 1/8 of the height. [Source: UCRL-15673, 1985]

- 4.3.5.3.4 **Width to height ratios.** The width to height ratio of letters and numerals shall be 3:5 with the exceptions of "M" and "W," which shall be 4:5, "4," which shall be one stroke width wider, and "I" and "1," which shall be one stroke wide. [Source: UCRL-15673, 1985]

- 4.3.5.3.5 **Character spacing.** The spacing between characters shall be at least one stroke width. [Source: UCRL-15673, 1985]

- 4.3.5.3.6 **Word spacing.** The spacing between words shall be approximately the width of one normal-width character. [Source: UCRL-15673, 1985]

- 4.3.5.3.7 **Line spacing.** The spacing between lines shall be at least one-half the character height. [Source: UCRL-15673, 1985]

- 4.3.5.3.8 **Case of letters.** If the text on a label is exclusively single words, such as names, the words shall appear as all capital letters; if the text is phrases or sentences, the text shall appear as mixed case letters. [Source: UCRL-15673, 1985]

- **4.3.5.3.9 Text and background combinations.** Text and background combinations shall provide sufficient contrast to ensure legibility. Black characters may appear on white, yellow, light gray, matte-finished brass or aluminum, or any bright plated backgrounds; white characters may appear on dark backgrounds; other acceptable combinations are blue on white, green on white, green on red, and red on yellow. [Source: UCRL-15673, 1985]

4.3.5.4 Wording

- **4.3.5.4.1 Consistency.** Designations and terms used on labels shall be consistent with designations and terms in user documentation and parts catalogs. [Source: UCRL-15673, 1985]

- **4.3.5.4.2 Wording.** The wording of labels should be brief but explanatory, using words that are familiar to maintainers. Abbreviations and abstract terms should be used only if it can be reasonably expected that they will be known to all maintainers. [Source: UCRL-15673, 1985]

- **4.3.5.4.3 Instructions.** Labels containing a series of steps to be carried out should list the steps, not present them in paragraph form. [Source: UCRL-15673, 1985]

4.3.5.5 Markings

- **4.3.5.5.1 Number of color codes.** If color-coding is used, the number of different colors shall not exceed nine. [Source: UCRL-15673, 1985]

- **4.3.5.5.2 Recommended colors.** If color-coding is used, the colors shall be distinguishable by both color-normal and color-deficient persons. Colors meeting this criterion are given in Exhibit 4.3.5.5.2. [Source: UCRL-15673, 1985]

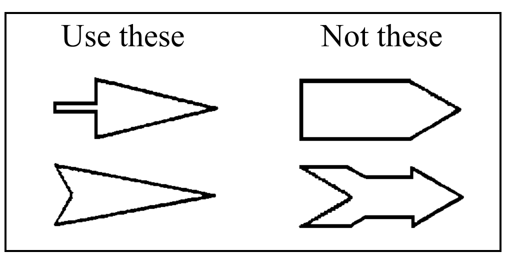
Exhibit 4.3.5.5.2 Recommended colors

Color	Spec No*
Red	1110
Orange	1210
Yellow	1310
Blue	10B 7/6
Purple	2715
Gray	1625
Buff	1745
White	1755
Black	1770

* From Fed. Spec. II-C-595 except for blue, which is from Munsell (1942)

- **4.3.5.5.3 Arrows.** Arrows used in labels or markings should be clearly recognizable and easily identifiable from a distance. Sharp angles and a tapered overall shape are preferable to wide angles and a relatively uniform overall shape (see Exhibit 4.3.5.5.3). [Source: UCRL-15673, 1985]

Exhibit 4.3.5.5.3 Good and bad arrows



4.4 Access openings

This section contains rules for access openings, that is, openings in a case, cover, panel, or door through which a maintainer requires visual or physical access or both, to perform maintenance tasks. Rules are given for properties of the openings, how to ensure both visual and physical access, the size, shape, and location of the openings, and their labeling. Rules regarding covers for access openings are given in Section 4.5.

4.4.1 General

■ 4.4.1.1 **When an access opening is required.** An access opening shall be provided whenever a maintenance task would otherwise require removing a case or covering, opening a fitting, or dismantling a unit. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; UCRL-15673, 1985]

□ 4.4.1.2 **Number of openings.** One large opening should be provided rather than several small ones. [Source: NASA-STD-3000A, 1989; UCRL-15673, 1985]

■ 4.4.1.3 **Prevention of injury or damage.** The edges of access openings shall be either (a) sufficiently rounded and smoothly finished or (b) covered or coated sufficiently to prevent injury to the maintainer's person, clothing, and equipment. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; NASA-STD-3000A, 1989]

□ 4.4.1.4 **Uncovered openings.** When environmental, operational, and safety conditions permit, openings should be left uncovered. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; UCRL-15673, 1985]

■ 4.4.1.5 **Unacceptability of rivets.** Riveted panels or doors shall not be used to cover access openings. Quick-action fasteners shall be used except in cases when the panel or door is subjected to stress or pressure, in which case screws shall be used. [Source: MIL-HDBK-759B, 1992]

4.4.2 Access

■ 4.4.2.1 **Visual and physical access.** If a maintainer must see what he or she is doing inside the opening, then either the opening shall be large enough and positioned so that the maintainer has the necessary view, or separate openings shall be provided for visual and physical access. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; NASA-STD-3000A, 1989; UCRL-15673, 1985]

- ▫ **4.4.2.2 Visual access only.** If a maintenance task requires only visual access, the access opening should be designed and positioned so that the maintainer can see whatever is needed without removing panels or other components. Such openings should not compromise personnel safety. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

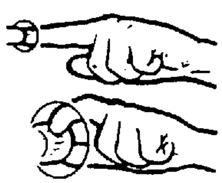
- ▪ **4.4.2.3 Physical access only.** Physical access without visual access, that is, access in which the maintainer cannot see what he or she is doing inside an access opening, shall not be provided without approval of the acquisition program office. [Source: MIL-STD-1472F, 1999]

4.4.3 Size

- ▪ **4.4.3.1 Accommodation.** An access opening shall be large enough to accommodate whatever combination of components, tools, body parts, clothing, and movements is required to perform the task. [Source: MIL-STD-1472F, 1999]

- ▪ **4.4.3.2 Dimensions for one- or two-finger access.** Dimensions of openings intended to allow access by one or two fingers shall equal or exceed those given in Exhibit 4.4.3.2. [Source: MIL-STD-1472F, 1999]

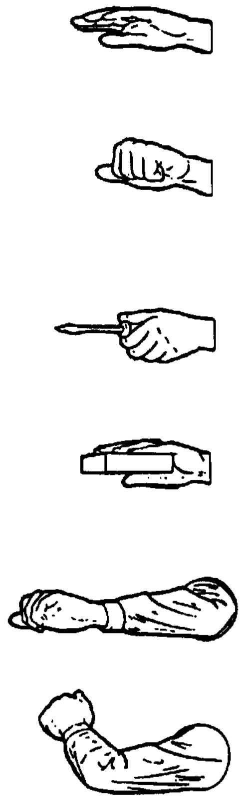
Exhibit 4.4.3.2 Minimum dimensions of openings designed for access by one or two fingers without visual access [Source: MIL-STD-1472F, 1999; AFSC DH 1-3, 1980]



Action	Bare hand mm (in)	Gloved hand mm (in)
Push button	32 (1.25)	38 (1.5)
Turn knob having diameter X	X + 50 (2.0)	X + 65 (2.5)

- 4.4.3.3 **Dimensions for one hand or arm access.** Dimensions for openings intended to allow access by one hand or one arm shall equal or exceed those given in Exhibit 4.4.3.3. [Source: MIL-STD-1472F, 1999; AFSC DH 1-3, 1980]

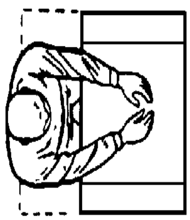
Exhibit 4.4.3.3 Minimum dimensions of openings designed for access by one hand or arm without visual access.



	Height mm (in)	Width mm (in)	Diameter mm (in)
Empty hand, to wrist			
Bare hand, flat	55 (2.25)	100 (4.0)	100 (4.0)
Bare hand, rolled	95 (3.75)	95 (3.75)	95 (3.75)
Glove or mitten	100 (4.0)	150 (6.0)	150 (6.0)
Arctic mitten	125 (5.0)	165 (6.5)	165 (6.5)
Clenched hand, to wrist			
Bare hand	5 (3.75)	125 (5.0)	125 (5.0)
Glove or mitten	115 (4.5)	150 (6.0)	150 (6.0)
Arctic mitten	180 (7.0)	215 (8.5)	215 (8.5)
Hand plus 25 mm object, to wrist			
Bare hand	95 (3.75)	95 (3.75)	95 (3.75)
Glove or mitten	150 (6.0)	150 (6.0)	150 (6.0)
Arctic mitten	180 (7.0)	180 (7.0)	180 (7.0)
Hand plus X mm object, to wrist			
Bare hand	X + 45 (1.75) clearance around object		
Glove or mitten	X + 65 (2.5) clearance around object		
Arctic mitten	X + 90 (3.5) clearance around object		
Arm to elbow			
Light clothing	100 (4.0)	115 (4.5)	115 (4.5)
Arctic clothing	180 (7.0)	180 (7.0)	180 (7.0)
With object	Same clearances as hand plus object		
Arm to shoulder			
Light clothing	125 (5.0)	125 (5.0)	125 (5.0)
Arctic clothing	215 (8.5)	215 (8.5)	215 (8.5)
With object	Same clearances as hand plus object		

- **4.4.3.4 Dimensions for two-hand access.** Dimensions of openings intended to allow access by two hands shall equal or exceed those given in Exhibit 4.4.3.4. [Source: MIL-STD-1472F, 1999; AFSC DH 1-3, 1980]

Exhibit 4.4.3.4 Minimum dimensions of openings designed for access by two hands without visual access



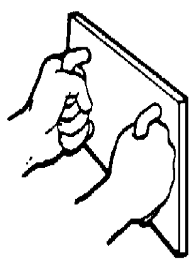
Reaching with both hands to depth of 150 to 500 mm (6 to 20 in):

Light clothing:

Width: 200 mm (8 in) or depth of reach*
Height: 125 mm (5 in)

Arctic clothing:

Width: 150 mm (6 in) plus ¾ the depth of reach
Height: 180 mm (7 in)

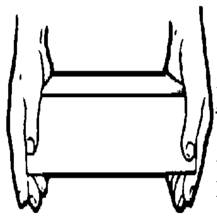


Reaching full arm's length (to shoulders) with both arms:

Width: 500 mm (20 in)
Height: 125 mm (5 in)

Inserting box grasped by handles on front:

13 mm (½ in) clearance around box,
assuming adequate clearance around handles



Inserting box with hands on the sides:

Light clothing:

Width: Box plus 115 mm (4½ in)
Height: 125 mm (5 in) or 13 mm (½ in) around box*

Arctic clothing:

Width: Box plus 180 mm (7 in)

4.4.4 Shape

As with size, the shape of an access opening is influenced by (a) the body appendages and equipment that will pass through the opening, (b) the movements the maintainer will perform inside the opening, and (c) the maintainer's need for visual access through the opening. The shape need not be a conventional shape such as a circle or rectangle.

- 4.4.4.1 **Shape appropriate to task.** The shape of an access opening shall allow the maintainer to perform those tasks requiring access through the opening. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; NASA-STD-3000A, 1989; UCRL-15673, 1985]

4.4.5 Location

- 4.4.5.1 **On accessible surfaces.** Access openings shall be located on equipment surfaces that are accessible when the equipment is in its normal operating position. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- 4.4.5.2 **Near related displays, controls, and connectors.** Access openings shall be located within easy view and reach of any test points, displays, controls, or connectors that require access in performing a particular maintenance task. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- 4.4.5.3 **Away from hazards.** Access openings shall be located at a safe distance or shielded from any hazards such as high voltages or dangerous moving parts to which the maintainer might be exposed. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- 4.4.5.4 **Comfortable for maintainer.** Access openings shall be located so that they do not require undue bending, stretching or other awkward body postures of the maintainer while he or she performs required tasks. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; UCRL-15673, 1985]

- ▫ 4.4.5.5 **Easy removal of components.** Access openings should be located so that heavy or bulky components can be pulled out rather than lifted out. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- 4.4.5.6 **Conformance with related items.** If work stands or carts are used in the maintenance tasks, access openings shall conform to the height of the stands or carts. [Source: UCRL-15673, 1985]

- 4.4.5.7 **Free of obstructions.** Access openings shall be located so that it is not necessary to remove any components or wires to reach them. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

■ **4.4.5.8 Impervious to environmental conditions.** Access openings shall be located so that environmental conditions such as rain, snow, and ice neither interfere with access nor damage components when the access is open. [Source: MIL-HDBK-759B, 1992]

4.4.6 Labeling and marking

The rules in this section apply only to labeling and marking access openings; if the opening has a cover, the relevant rules are given in Paragraphs 4.5.4 and 4.5.5.

■ **4.4.6.1 Identification of opening.** Each access opening shall be labeled with a name, number, letter or other symbol and referred to by that identification in maintenance instructions. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

□ **4.4.6.2 Identification of accessible components and maintenance tasks.** Each access opening should be labeled with identifiers for the maintainable components accessible through the opening. This labeling may also include information about equipment to be used in the maintenance tasks and procedural information about the tasks themselves. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; UCRL-15673, 1985]

■ **4.4.6.3 Warning labels.** If any hazardous condition exists inside an access opening (such as high voltages or dangerous moving parts), the opening shall have a conspicuous warning label advising the maintainer of the hazard and stating any necessary precautions. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; UCRL-15673, 1985]

4.5 Cases, covers, guards, and shields

This section contains rules governing the size, mounts, shape, location, fasteners, interlocks, and labels of cases, covers, guards, and shields.

> **Definitions.** A **case** is the part of a unit of equipment that encloses and protects the equipment from its surroundings. It may also serve to protect the surroundings - including users - from the equipment. A **cover** is a part of a unit of equipment that closes an access opening. A **guard** is an enclosure or barrier intended to prevent inadvertent or unauthorized operation of a control. A **shield** is an enclosure or barrier intended to protect components that are susceptible to damage or to protect maintainers from possible injury.

Covers, guards, and shields may take a variety of forms, including (a) hinged doors or caps, (b) sliding doors or caps, (c) removable doors or caps, (d) removable panels, and (e) physical barriers.

Hinged doors and caps allow the fastest and easiest access; they require few fasteners and, depending upon their orientation, may not need support in the open position. They do require "swinging" space, and they may intrude on the user's workspace.

Sliding doors or caps are particularly useful where "swinging" space is limited. They do not generally provide a tight seal.

Removable doors or caps require little space for opening and, once removed, do not interfere with working space. Handling them does take time and effort.

Removable panels can give access to large portions of a unit of equipment. They do not require "swinging" space, but they may be awkward to handle or susceptible to damage.

4.5.1 General

▫ **4.5.1.1 Fasteners.** Cases and covers should be fastened in accordance with Section 4.6 Fasteners.

- **4.5.1.2 Preferred type of cover.** The cover of an access opening shall be appropriate to the type of access required and the prevailing environmental conditions as outlined in Exhibit 4.5.1.2. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; NASA-STD-3000A, 1989; UCRL-15673, 1985]

Exhibit 4.5.1.2 Type of covering for type of access and environmental conditions

Condition	Physical access	Visual access
No adverse condition	No cover	No cover
Debris, moisture, other foreign material present	Hand-operated, latched, sliding or hinged cap or door, or, less desirable, a removable panel with captive, quick-action fasteners	Transparent plastic window
Subject to wear or contact with solvents		Break-resistant glass window
Stress or pressure requirements	Removeable panel with the smallest number of the largest screws that meet the requirements	Opaque cover plate with the smallest number of the largest screws that meet the requirements

- **4.5.1.3 Accessibility.** Cases shall be designed so that they can be opened, removed, and replaced without dismantling the equipment or associated equipment and items. [Source: MIL-HDBK-759B, 1992]

- **4.5.1.4 How to open.** It shall be clear to the user how to open a case or cover, either through a property of the case or cover itself, such as its shape, or by the provision of instructions on or near the case or cover. [Source: AFSC DH 1-3, 1980]

- **4.5.1.5 Lift case, not equipment.** The case for a unit of equipment shall be designed so that the case is lifted off the equipment, not so that the equipment is lifted out of the case. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999]

- **4.5.1.6 Ease of removal and replacement.** Cases shall be easy to open, remove, and replace. [Source: AFSC DH 1-3, 1980]

- **4.5.1.7 Accessibility upon opening or removal.** Cases and units of equipment shall be designed so that when a case is opened or removed, all portions of the equipment that are relevant to the user task are accessible. The opened case shall not obscure or interfere with any controls, displays, test points, service points, or connections relevant to the user task. [Source: MIL-HDBK-759B, 1992]

□ **4.5.1.8 Minimizing need for removal.** Cases and equipment should be designed to minimize the need to remove the case. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

> **Example.** Adjustment controls, test points, and service points might be made accessible without requiring opening or removing the case. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

□ **4.5.1.9 Ease of opening.** Cases, covers, and fasteners should be selected or designed so that their combination makes the easiest to remove, open, and close while meeting the closure and structural requirements of the equipment. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

> **Example.** A case or cover that is opened relatively frequently but that does not need to be sealed tightly might be a hinged door with a quick-release latch. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

■ **4.5.1.10 Fastened-unfastened indication.** Cases and covers shall be designed or mounted so that it is clear whether or not they are fastened when they are in place. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; UCRL-15673, 1985]

> **Example.** Cases and covers might be spring loaded so that they stay open when they are not fastened. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; UCRL-15673, 1985]

■ **4.5.1.11 Handles or grasp areas.** If a case or cover is heavy or difficult to open, remove, or replace, it shall have one or more handles, grasp areas, lifting eyes, or a combination of these. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; UCRL-15673, 1985]

■ **4.5.1.12 Accommodate gloves.** If present, handles and grasp areas shall accommodate any gloves or other special clothing the user might be expected to wear. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; UCRL-15673, 1985]

■ **4.5.1.13 Shift in balance of equipment.** Hinged or sliding doors shall not unbalance equipment when they are opened. [Source: MIL-HDBK-759B, 1992]

> **Discussion.** If an imbalance would otherwise result, the case or cover or the equipment might have some sort of prop or support to prevent the unbalance. [Source: MIL-HDBK-759B, 1992]

■ **4.5.1.14 Stops and retaining devices.** Attached cases and covers shall have stops or retaining devices that hold them in both the open and closed positions. These stops and retainers shall be appropriate to the ambient environment. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

> **Example.** An access door on equipment out of doors and subject to wind would need a more secure restraint than one on equipment located indoors. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- **4.5.1.15 Ventilation holes.** If a case, cover, or shield requires ventilation holes, the holes shall be small enough to prevent inadvertent insertion of objects that might touch high voltage sources or moving parts. [Source: AFSC DH 1-3, 1980]

- **4.5.1.16 Rounded edges.** The corners and edges of cases and covers shall be smooth or rounded so that they do not injure the user or damage his or her clothing. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; UCRL-15673, 1985]

- **4.5.1.17 Small removable covers.** Small removable caps or covers that might be susceptible to dropping or loss, perhaps with resulting damage to components inside the opening, shall be attached to the equipment or structure. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; UCRL-15673, 1985]

- **4.5.1.18 Alignment aids.** If a case is heavy or awkward to handle, or if it encloses delicate, sensitive components, the case or the equipment shall have guide pins, tracks, or some other alignment device to help guide the case while it is being opened, removed, or replaced. [Source: MIL-HDBK-759B, 1992]

- **4.5.1.19 Sealing material.** If the equipment design includes sealing material between the case and the base to which it is attached, the sealing material and its mounting method shall be selected so that the material is not damaged while the case is being opened, removed, or replaced. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992]

- **4.5.1.20 Accessible with equipment in installed position.** When maintenance tasks require that a cover be opened with the equipment in its installed position, both the cover and its fasteners shall be located so that they are visually and physically accessible with the equipment in that position. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

4.5.2 Size

- **4.5.2.1 Size of covers.** Cases and covers shall be as small and light in weight as possible while meeting the closure, structural, and ease of maintenance requirements of the equipment. [Source: UCRL-15673, 1985]

  Discussion. It is most desirable that covers be openable, removable, and transportable with one hand; next most desirable that they require handling by only one person; least desirable, that they require handling by two or more people. [Source: UCRL-15673, 1985]

- **4.5.2.2 Precise movements not required.** Cases shall be sufficiently larger than the items they cover so that they can be opened, removed, and replaced without requiring precise movements on the part of the user. [Source: MIL-STD-1472F, 1999]

■ **4.5.2.3 Clearance between case and components.** Cases shall be large enough that they do not damage internal wiring or components when they are opened, removed, or replaced. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999]

4.5.3 Shape

■ **4.5.3.1 Appropriate to opening.** The shape of a case or cover shall be appropriate to the opening or item it covers and shall provide the degree of closure required. [Source: MIL-HDBK-759B, 1992]

■ **4.5.3.2 Proper orientation.** If a removable access cover requires a particular orientation, the cover shall be designed to prevent attachment in any other orientation. [Source: UCRL-15673, 1985]

Example. This might be accomplished by: (a) giving the cover an asymmetric or irregular shape, (b) including alignment guides or pins, or (c) arranging the holes for fasteners asymmetrically. [Source: UCRL-15673, 1985]

4.5.4 Hinged covers

■ **4.5.4.1 Safe operation.** Hinged cases and covers shall be designed so that opening and closing them will not interfere with, damage, or have the potential for harmful contact with wires or other components. [Source: UCRL-15673, 1985]

■ **4.5.4.2 Self-supporting.** Hinged cases and covers shall have stops or retainers that hold them in the open position. These stops shall also prevent the case or cover from swinging into or falling on fragile equipment, from swinging into the users themselves, and from springing the hinges. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; NASA-STD-3000A, 1989; UCRL-15673, 1985]

□ **4.5.4.3 Operable with one hand.** The user should be able to open and close a hinged case or cover using only one hand. [Source: MIL-STD-1472F, 1999]

■ **4.5.4.4 Noninterference of open cover with accessibility.** Hinged and sliding covers shall be located so that when they are open, they do not interfere with access to the openings themselves, or to related controls, displays, test points, and the like. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; UCRL-15673, 1985]

4.5.5 Sliding doors and caps

■ **4.5.5.1 Safe operation.** Sliding doors and caps shall be designed so that opening and closing them will not interfere with, damage, or have the potential for harmful contact with wires or other components. [Source: UCRL-15673, 1985]

- 4.5.5.2 **Positive locking.** Sliding doors and caps should lock in the closed position, giving the user feedback, perhaps with a "snap" action or an audible click, when they are closed. They should also lock and give feedback in the open position unless they are removed when opened. [Source: UCRL-15673, 1985]

- 4.5.5.3 **Non-jamming.** Sliding doors and caps should not bind or jam while being opened or closed. [Source: UCRL-15673, 1985]

- 4.5.5.4 **Easy hand operation.** Sliding doors and caps should be easy to open and close without the use of tools. [Source: UCRL-15673, 1985]

4.5.6 Interlocks

Interlocks are distinguished from lockouts and tagouts.

Definitions. Interlocks are devices (for example, switches) connected with a cover, shield, or case that disable the associated internal hazard (usually electrical) when the cover, shield, or case is opened. OSHA regulations discuss lockout and tagout procedures to be used in the workplace during maintenance or operations to protect from electrical hazards. A **lockout** uses a mechanical means to disable a control or switch in its safe position (for example, electricity disconnected) and to prevent its activation without the use of undue force or tools. **Tagouts** are tags that are attached to a control or place of hazard to identify the required control condition and hazard associated with an ongoing mode of operation or maintenance.

- 4.5.6.1 **Protection from hazards.** If a hazardous condition (such as a high voltage or moving parts) exists inside a case or behind a cover or shield, that cover or shield shall have an interlock that disables the hazard (including both ac and dc power sources) when the case, cover, or shield is removed or opened. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; UCRL-15673, 1985]

Discussion. Human protection from hazardous conditions with unexpected energization or release of stored energy is treated in OSHA 29 CFR 1910.301 -308, 331 -335, and 399. The OSHA 29 CFR 1910.333 requires the simultaneous use of both tagout and lockout in the workplace; OSHA 29 CFR 1910.333 states that interlocks shall not be the sole means of de-energizing circuits of equipment and are not substitutes for lockout and tagout procedures and practice. [Source: AFSC DH 1-3, 1980; 29 CFR 1910.301 -308, 331 -335, and 399; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; UCRL-15673, 1985]

- **4.5.6.2 Interlock override switch.** If a task requires that a user work on hazardous equipment that is equipped with a disabling interlock, the equipment shall have an interlock override switch that permits manual bypassing or overriding of the interlock when the cover is open. This override switch shall automatically reset to the non-by-pass position, which is the safe operating position when the case or cover is replaced. OSHA 29 CFR 1910.333 requires that only qualified personnel be allowed to disable an interlock. [Source: AFSC DH 1-3, 1980; 29 CFR 1910.333; UCRL-15673, 1985]

- **4.5.6.3 Labeling covers with interlocks.** If a case, cover, or shield has an interlock, a label stating the presence of both the hazard and the interlock shall be placed on the equipment or the case or cover so that it is visible both when the case or cover is in place and when it is open or removed. [Source: MIL-STD-1472F, 1999]

  Discussion. It is important that the label contain sufficient information, particularly if there is more than one hazard present. For example, if there is the possibility of an electrical hazard from either ac or dc current, such as when a system has battery backup, the label must inform of both hazards.

4.5.7 Labeling and marking

- **4.5.7.1 Method of opening.** If the method for opening a case or cover is not obvious, a label with opening instructions shall be attached to the outside of the cover itself or to the equipment adjacent to the cover. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; UCRL-15673, 1985]

- **4.5.7.2 Hazard labels.** If a hazardous condition exists inside a case or behind a cover, a label fully describing the hazard shall be attached to the case or cover itself or adjacent to the case or cover. Opening or removing the case or cover shall neither remove nor visually obstruct the label. [Source: MIL-STD-1472F, 1999]

- **4.5.7.3 Instructional labels.** If instructions are provided regarding maintenance tasks, components, test points or service points inside a case or opening, they shall be oriented horizontally with respect to the user and attached to the case or cover itself or adjacent to the equipment so that the instructions remain visible when the case or cover is opened. [Source: MIL-STD-1472F, 1999]

4.6 Fasteners

This section contains general rules for fasteners and specific rules for nuts and bolts, screws, the heads of bolts and screws, latches and catches, and other fastening devices. Additional rules are provided for quick fastening and releasing devices, captive fasteners, and the labeling and marking of fasteners.

Definition. Fasteners are devices that join, attach, and mount parts, components, cases, covers, and units of equipment. They include quick fastening and releasing devices, screws, bolts, latches, catches, rivets, retainer rings, and retainer chains. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

Fasteners are available in a wide variety of types and sizes, and new types appear frequently. Designers are advised to review the varieties available before selecting fasteners for a particular application. Factors influencing the choice of a fastener for a particular application include (a) the stress and environmental factors the fastener must withstand, (b) the tools and clearance required to fasten and release the fastener, (c) the frequency with which the fastener will be fastened and released, (d) the speed with which the fastener must be fastened and released, (e) the types and varieties of other fasteners used in that and related applications, and (f) the clothing, especially gloves or mittens, the maintainer may be expected to wear. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

4.6.1 General

- **4.6.1.1 Fastener security.** Fasteners shall hold securely in their operating environment, for example, withstanding the effects of vibration, wind gusts, and pressure. [Source: MIL-STD-1472F, 1999]

- **4.6.1.2 Number and ease of opening.** The fasteners for a given application shall be the fewest in number and the simplest to operate that meet the closure, structural, and ease of maintenance requirements for the application. [Source: MIL-STD-1472F, 1999]

- **4.6.1.3 Common fasteners.** To the extent possible, fasteners shall be interchangeable throughout a given application. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- **4.6.1.4 Self-alignment.** Fasteners shall be selected or designed so that they are easily aligned with their retaining catches, nuts, blocks, or inserts. This alignment shall occur without binding and without damage to fastener threads or receptacles. [Source: UCRL-15673, 1985]

- **4.6.1.5 Operable by hand or common hand tools.** Fasteners shall be operable by hand if possible; otherwise, by common hand tools. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

□ **4.6.1.6 Open-closed indication.** Fasteners should give a clear indication that they are open (unfastened) or closed (fastened). [Source: MIL-STD-1472F, 1999]

■ **4.6.1.7 Hole size.** The holes through which fasteners pass shall be large enough to permit inserting or "starting" the fasteners even when parts are not perfectly aligned. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; MIL-STD-1800A, 1990]

■ **4.6.1.8 Fastener variety.** The variety of fasteners used in a particular application (that is, the number of different types and sizes) shall be the minimum that meets the requirements for closure, structure, and ease of maintenance. These requirements include such aspects as stress, bonding, pressure, temperature, and shielding. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; UCRL-15673, 1985]

Discussion. Minimizing the variety of fasteners simplifies the stocking of spare parts and reduces the danger that maintainers will damage fasteners or equipment by using the wrong tool or the wrong fastener. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; UCRL-15673, 1985]

■ **4.6.1.9 When different fasteners are required.** If removal or insertion of a wrong fastener could result in damage to equipment or a change in calibration settings, distinguishably different fasteners shall be used. [Source: MIL-STD-1472F, 1999]

■ **4.6.1.10 Different fasteners must be distinguishable.** If more than one type of fastener is required for a unit of equipment:

a. The different types shall be easily distinguishable from each other, for example, screws with different threads might also be different in physical size. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992]

b. The fastener-receptacle interface shall permit the maintainer to distinguish the intended location of each fastener easily. [Source: MIL-STD-1472F, 1999]

■ **4.6.1.11 Location of fasteners.** Fasteners shall be located so that they

a. are easily accessible to the maintainer without requiring the removal of other parts or units,

b. can be operated with little or no interference from other structures,

c. do not interfere with each other or with other components,

d. are not hazardous to maintainers or potentially damaging to wires or hoses, and

e. have adequate clearance to permit easy hand or tool operation. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; UCRL-15673, 1985]

■ **4.6.1.12 Strength of hand-operated fasteners.** Fasteners that are normally operated by hand shall be strong enough to withstand being operated with a tool. [Source: MIL-HDBK-759B, 1992]

■ **4.6.1.13 Painted or coated fasteners.** If fasteners are painted or coated, the paint or coating shall not adversely affect their removal or installation. [Source: NASA-STD-3000A, 1989]

□ **4.6.1.14 Precise torque requirements.** Equipment should be designed so that precise torque on fasteners is not required. If it is required, fasteners that incorporate torque indications should be used. [Source: AFSC DH 1-3, 1980]

Examples. Some examples of fasteners that incorporate torque indications are (a) nuts that break away, (b) crushable washers that give a visual indication that correct torque has been reached, and (c) tools that crimp the nut and achieve the correct torque. [Source: AFSC DH 1-3, 1980]

■ **4.6.1.15 Torqued fasteners.** If a precise torque is required, the fastener shall be located so that the torquing tool can be applied directly, without the use of irregular extensions. [Source: MIL-STD-1472F, 1999]

□ **4.6.1.16 Quick-action fasteners.** Fasteners for cases and covers should be of the quick-action type, requiring only part of a turn or a snap action to fasten and unfasten. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992]

■ **4.6.1.17 Covers as structural members.** When covers serve as stress-bearing structural members, their fasteners shall be large and strong enough to withstand the stress. [Source: UCRL-15673, 1985]

4.6.2 Number

- ■ **4.6.2.1 Minimum that meets requirements.** The number of fasteners used in a particular application shall be the minimum number that meets the closure, structural, and ease of maintenance requirements. A few large fasteners are preferable to many small fasteners as long as they meet the requirements. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; UCRL-15673, 1985]

- □ **4.6.2.2 Mounting.** No more than four fasteners should be used to mount a unit of equipment. [Source: UCRL-15673, 1985]

- □ **4.6.2.3 Minimize by using hinges, catches, latches, and quick fastening and releasing devices.** Hinges, catches, latches, and quick fastening and releasing devices should be used to reduce the number of fasteners whenever they meet the other relevant requirements. [Source: MIL-STD-1472F, 1999; UCRL-15673, 1985]

- □ **4.6.2.4 Minimize by using tongue-and-slot design.** Tongue-and-slot design should be used whenever possible in covers and cases to minimize the number of fasteners. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999]

4.6.3 Types

This section lists rules for different types of fasteners. For ease of maintenance, the order of preference by type is: (a) quick fastening and releasing devices, (b) latches and catches, (c) captive fasteners, (d) screws, and (e) nuts and bolts. [Source: MIL-HDBK-759B, 1992]

4.6.3.1 Nuts and bolts

Nuts and bolts are relatively time consuming to install and remove. The maintainer usually has to have access to both ends of the bolt, to use both hands, and to make fairly precise movements in starting the nut. Often the maintainer has to use two tools, one for the bolt and one for the nut. The inclusion of washers increases the number of parts to handle and possibly lose.

- ■ **4.6.3.1.1 Bolt length.** Bolts shall be no longer than necessary for their given application. If a nut is used, at least two threads of the bolt shall extend beyond the nut when the nut is tightened. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- □ **4.6.3.1.2 Bolt threads.** The bolt threads should be no finer than strength requirements dictate. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- □ **4.6.3.1.3 Turns to tighten.** The number of turns to tighten a bolt should be less than 10. [Source: UCRL-15673, 1985]

- ■ **4.6.3.1.4 Hexagonal nuts.** Hexagonal nuts shall be used in high-torque applications. [Source: UCRL-15673, 1985]

▫ **4.6.3.1.5 Wing and knurled nuts.** Wing nuts or knurled nuts should be used in low-torque applications. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

▪ **4.6.3.1.6 Left-hand threads.** Left-hand threaded nuts and bolts shall be used only when conditions require them, for example to prevent loosening due to rotation. When used, they shall be coded by marking, shape, or color so that they are easily distinguishable from right-hand threaded nuts and bolts. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

▪ **4.6.3.1.7 Lock washers.** Lock washers or other restraining measures shall be used to prevent nuts and bolts from loosening under vibration. [Source: MIL-HDBK-759B, 1992]

▫ **4.6.3.1.8 Removal and replacement with one hand or tool.** Nuts and bolts that are removed and replaced frequently or that are relatively inaccessible should be mounted so that they can be removed and replaced with one hand or one tool. A recess should be provided to hold either the bolt or the nut. [Source: MIL-HDBK-759B, 1992]

▫ **4.6.3.1.9 Bolt mounting.** Bolts should be mounted with their heads up so that they remain in position if the nut falls off. [Source: UCRL-15673, 1985]

4.6.3.2 Screws

Screws are relatively time consuming to insert and remove, and their threads and slots are susceptible to damage. However, screwdrivers usually require less operating space than wrenches, and they usually require the use of only one hand. In addition, screws are usually used alone, as opposed to bolts, which are usually used in combination with washers and nuts. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

▫ **4.6.3.2.1 Number of turns.** The number of turns to tighten or loosen a screw should be less than ten. [Source: UCRL-15673, 1985]

▫ **4.6.3.2.2 Slot depth.** Screw heads should have deep slots that will resist damage. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

▪ **4.6.3.2.3 "Straight-in" screwdriver orientation.** Screws shall be used only when screwdrivers can be used in a "straight-in" orientation; the use of offset screwdrivers shall not be required. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

▪ **4.6.3.2.4 Blind operation.** If a screw must be operated in a position in which the maintainer cannot see its head, a guide shall be provided to help position the screwdriver. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

Example. The screw might be located at the bottom of a cylindrical hole so that the hole guides the screwdriver to the screw head. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

▫ **4.6.3.2.5 Screws for pressurized enclosures.** Fine-thread screws should be used for pressurized units. [Source: UCRL-15673, 1985]

- ▫ **4.6.3.2.6 Countersunk screws.** Screws should be countersunk when a smooth surface is required. [Source: UCRL-15673, 1985]

- ▫ **4.6.3.2.7 Screws for thin panels.** Flat-head screws should not be used on panels less than 2.4 mm (3/32 in) thick. [Source: UCRL-15673, 1985]

- ▪ **4.6.3.2.8 Self-tapping screws.** If a unit of equipment requires more than one size of self-tapping screw, the different sizes shall be kept to a minimum, and they shall all have the same type of head. [Source: UCRL-15673, 1985]

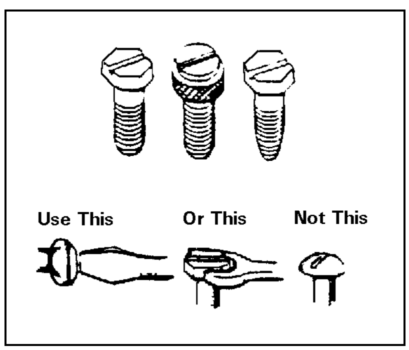
4.6.3.3 Screw and bolt heads

Combination-head bolts and screws are preferable to other bolts and screws because they allow operation with both wrenches and screwdrivers. Slotted hexagonal heads are preferable to slotted knurled heads. Combination-head bolts and screws reduce the likelihood of damaged slots and stuck fasteners. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- ▪ **4.6.3.3.1 Same heads for screws and bolts.** To the extent possible, all bolts and screws on a given unit of equipment shall have the same size and type of head so that maintainers can operate all of them with a single tool. [Source: MIL-STD-1472F, 1999]

- ▫ **4.6.3.3.2 Combination-head bolts and screws.** Combination-head bolts and screws should be used, preferably those having slotted, hexagonal heads. Exhibit 4.6.3.3.2 shows examples of combination-head bolts and screws; the combinations illustrated are slotted-hexagonal and slotted-knurled. [Source: MIL-STD-1472F, 1999]

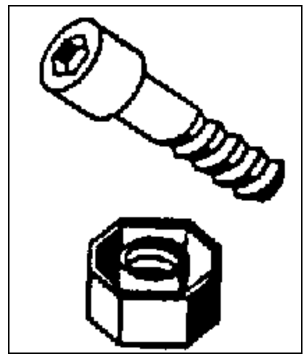
Exhibit 4.6.3.3.2 Examples of combination-head bolts and screws



- ▪ **4.6.3.3.3 Straight-slot and cross-recess type internal fasteners.** Non-combination straight-slot or cross-recess type internal fasteners shall not be used except to fasten wood. [Source: MIL-STD-1472F, 1999]

- **4.6.3.3.4 Internal-wrenching fasteners -- where to use.** Internal-wrenching fasteners shall not be used except where a flat, smooth surface is required and where the fasteners are protected from the accumulation of foreign material such as dirt, ice, or snow. Exhibit 4.6.3.3.4 shows an example of an internal-wrenching bolt and an internal-wrenching nut. [Source: MIL-STD-1472F, 1999; UCRL-15673, 1985]

Exhibit 4.6.3.3.4 Example of an internal-wrenching bolt and nut



- **4.6.3.3.5 High-torque fasteners.** If a torque of more than 14 Nùm (10 ft-lb) is required, fasteners shall have external hexagonal or double-hexagonal heads. If external-wrenching heads cannot meet functional or personnel safety requirements, or in situations in which the fastener is protected from accumulation of foreign material, internal-wrenching fasteners may be used. [Source: MIL-STD-1472F, 1999]

- **4.6.3.3.6 Low-torque fasteners.** If a torque of less than 14 Nùm (10 ft-lb) is required, fastener heads should be one of the following types: (a) combination-head, (b) hexagonal, external-grip head, (c) hexagonal internal-grip heads, or (d) Torq-set. [Source: MIL-STD-1472F, 1999]

4.6.3.4 Latches and catches

Latches and catches can be operated quickly and easily. They do not require the use of tools, and they have good holding power, but they cannot be used where smooth surfaces are required. [Source: UCRL-15673, 1985]

- **4.6.3.4.1 Positive catch.** Latches and catches shall have a positive catch. [Source: UCRL-15673, 1985]

- **4.6.3.4.2 Visual indication.** Latches and catches shall give a clear visual indication that the latch or catch is engaged. [Source: UCRL-15673, 1985]

- **4.6.3.4.3 Spring-loading of catches.** Catches should be spring-loaded so that they lock on contact rather than requiring some other action by the maintainer. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- **4.6.3.4.4 Nonhazardous.** The spring action or snap-down force in a catch or latch shall not be so strong that it could injure the maintainer. [Source: MIL-HDBK-759B, 1992]

- **4.6.3.4.5 Associated handles**. If a latch or catch is associated with a handle, the release mechanism for the latch or catch shall be located on or near the handle so that release and opening can be accomplished with one hand. [Source: MIL-HDBK-759B, 1992]

- **4.6.3.4.6 Preventing inadvertent operation.** Latches and catches shall be located and positioned so that it is not likely that they will be operated inadvertently under normal operating conditions. [Source: UCRL-15673, 1985]

4.6.3.5 Other fastening devices

This section gives rules for a variety of additional fastening devices, including cotter pins and keys, retainer rings, safety wire, rivets, retainer chains, and washers.

- **4.6.3.5.1 Integral fasteners not allowed.** Fasteners shall not be an integral part of the equipment's housing; studs are an example of disallowed integral fasteners. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- ▫ **4.6.3.5.2 Cotter pins and keys.** Criteria for cotter pins and keys are:

  a. Pins and keys should fit snugly, but not so tightly that they cannot be slid in and out by hand.

  b. The heads of cotter keys should be large enough so that they do not slip through the hole and so that they are easy to remove. [Source: UCRL-15673, 1985]

- **4.6.3.5.3 Retainer rings.** Criteria for retainer rings are:

  a. Retainer rings shall be easy to remove and replace when worn.

  b. When possible, retainer rings shall lock into position with a positive snap.

  c. Twist-to-lock retainer rings shall have spring tension to prevent their loosening. [Source: UCRL-15673, 1985]

- ▫ **4.6.3.5.4 Pin-and-hook fasteners.** If a cover must have the ability to survive nuclear, biological and chemical hazards, it should be attached with pins and hooks rather than hinges. [Source: MIL-STD-1472F, 1999]

▪ **4.6.3.5.5 Safety wire.** Criteria for safety wire are:

a. Safety wire shall be used only when self-locking fasteners or fasteners with cotter pins are not adequate to withstand the expected vibration or stress.

b. When safety wire is used, it shall be easy to remove and replace.

c. If a visible means of detecting that a fastener has become loosened or has changed position is required, safety wire shall be used. [Source: UCRL-15673, 1985]

▪ **4.6.3.5.6 Rivets.** Rivets are permanent fasteners that are difficult and time consuming to remove and replace; they are not ordinarily used on parts that might require removal. Criteria for rivets are:

a. Rivets shall not be used to attach hinges, latches, catches, or other quick fastening and releasing devices.

b. Rivets shall be of softer material than the pieces they fasten.

c. The holes for shear rivets shall be drilled to close tolerances. Maintenance instructions shall specify these tolerances and the sizes of plug gauges and reamers to be used. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

▫ **4.6.3.5.7 Retainer chains.** Retainer chains or locking bars are used to (a) keep hatches or doors from opening too far or from springing their hinges, (b) convert doors or covers into shelves for the maintainer, (c) prevent small covers or caps from being misplaced, (d) secure small, special tools at the location where they will be used, (e) secure objects that might otherwise fall and get lost, and (f) secure objects that might otherwise fall and injure the maintainer or damage the equipment. Criteria for retainer chains are:

a. Only link, sash, or woven-mesh type chains should be used. Bead-link chain should not be used; it is more breakable than other types.

b. Retainer chains should be attached with screws or bolts so that they can be disconnected easily if necessary.

c. Each end of a retainer chain should have an eyelet.

d. Retainer chains for filler caps should be attached externally, not internally.

e. Chains should not be used where they might interfere with moving parts.

f. If chain covers are required, they should be flexible and durable. [Source: UCRL-15673, 1985]

□ **4.6.3.5.8 Washers.** Criteria for washers are:

a. Washers should fit tightly against the underside of the fastener head.

b. Washers should fit the shaft snugly, but should be easy to remove.

c. Split-ring washers should be used with static loads in excess of 55 g (2 oz).

d. Lock washers should be used with lock nuts for maximum locking action. [Source: UCRL-15673, 1985]

4.6.3.6 Quick fastening and releasing devices

Quick fastening and releasing devices are quick (by definition) and easy to use. They require no tools; they can be operated with only one hand; and they are good for securing plug-in components, small components, and covers. However, they have relatively low holding power, and they cannot be used where a smooth surface is required. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

■ **4.6.3.6.1 Frequent access.** Quick fastening and releasing devices shall be used for components that must be dismantled or removed frequently. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; UCRL-15673, 1985]

■ **4.6.3.6.2 Tools not required.** Quick fastening and releasing devices shall fasten and release easily without the use of tools. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

■ **4.6.3.6.3 Single motion.** Quick fastening and releasing devices shall operate with a single motion of the hand, for example, requiring no more than one complete revolution. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

■ **4.6.3.6.4 Visual indication of state.** Quick fastening and releasing devices shall give a clear visual indication that they are fastened or released. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

■ **4.6.3.6.5 Minimum turns.** Wherever bolts or screws are used, they shall be selected so that fastening them requires only the minimum number of turns necessary to meet the closure and structural requirements of the application. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999]

Discussion. Bolts and screws requiring more than the minimum number of turns may be excepted from this rule if they are used to reduce the variety of fasteners in a unit of equipment. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999]

4.6.3.7 Captive versus removable

Captive fasteners can be time consuming and difficult to operate. They usually require the use of a tool, but the tool can usually be operated with one hand. The fasteners stay in place, thus saving handling time and avoiding the possible loss of parts. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

■ 4.6.3.7.1 **When to use.** Captive fasteners shall be used whenever dropping a fastener or a related part, such as a washer or bolt, might cause damage or excessive loss of time. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999]

■ 4.6.3.7.2 **Operation and replacement.** Captive fasteners shall be operable by hand or with common hand tools, and they shall be easily replaceable if damaged. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

■ 4.6.3.7.3 **"Quarter-turn" fasteners.** If "quarter-turn" type fasteners are used, they shall be self-locking and spring-loaded. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

□ 4.6.3.7.4 **Access covers.** Access covers that are removed frequently should have captive fasteners. [Source: MIL-STD-1472F, 1999]

□ 4.6.3.7.5 **Small removable pins, caps, and covers.** Small removable pins, caps, and covers should be attached, probably with a retainer chain, so that they are not lost or dropped into the equipment. [Source: MIL-HDBK-759B, 1992]

□ 4.6.3.7.6 **Mounting bolts.** Mounting bolts should be semi-permanently captive, perhaps by means of "snap-on" collars. [Source: AFSC DH 1-3, 1980]

4.6.4 Labeling, marking, and coding

□ 4.6.4.1 **Mounting bolts.** Bolts that mount units of equipment should be color coded or perhaps embossed with the letter "M" to distinguish them from other visible fasteners. [Source: AFSC DH 1-3, 1980]

□ 4.6.4.2 **Fasteners requiring torquing.** Fasteners that require a precise torque should have labels on or near the fasteners stating the required torque value and the torquing sequence. [Source: MIL-STD-1472F, 1999]

■ 4.6.4.3 **Durability of marking.** If fasteners are marked or coded, the marks or codes shall withstand exposure to any chemicals, fuels, weather, or other adverse conditions in their ambient environment. [Source: UCRL-15673, 1985]

■ 4.6.4.4 **Consistent coding.** If a coding system for fasteners is used, it shall be consistent throughout a unit of equipment and for similar or related units of equipment. [Source: UCRL-15673, 1985]

4.7 Connectors

This section contains rules for various types of connectors (plug-in, threaded, and quick-action), for the location and accessibility of connectors, and for alignment aids. It also contains rules specific to electrical connectors and to fluid and gas connectors, including rules for their labeling and marking.

> **Definition.** A **connector** is a piece of hardware that joins or attaches lines or cables to other lines or cables or to units of equipment. The term is used rather loosely to refer to either of the two parts that mate with each other and to the plug that mates with a receptacle.

4.7.1 General

▫ **4.7.1.1 Fluid and gas line connectors.** Connectors utilized for fluid and gas lines should comply with Paragraph 4.8.2 Fluid and gas lines.

▫ **4.7.1.2 Connector gaskets and seals.** Gaskets and seals used in connectors should comply with Paragraph 4.8.2.4 Gaskets and seals.

▪ **4.7.1.3 Fast, easy operation.** Connectors shall be selected or designed to permit fast, easy maintenance operations, including such tasks as testing, servicing, removing, and replacing units of equipment and components. [Source: MIL-HDBK-759B, 1992]

▪ **4.7.1.4 Safety.** Connectors shall be selected or designed to ensure the safety of maintainers and equipment from pressures, contents, or voltages during the release of connectors. [Source: MIL-HDBK-759B, 1992]

▪ **4.7.1.5 Hand or common tool operation.** Connectors shall be selected or designed to permit operation by hand or by common hand tools. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

▪ **4.7.1.6 Compatibility.** Connectors shall be selected or designed to be compatible with their associated lines and cables, fasteners, mounting, environmental extremes, and maintenance routines. [Source: MIL-HDBK-759B, 1992]

▪ **4.7.1.7 Protection of connectors.** If a connector is susceptible to damage, it shall be protected by one or more of the following measures: (a) recessing the receptacle, (b) recessing delicate parts such as pins and keys within the connector, and (c) providing a protective cap, insert, cover, case, or shield. [Source: MIL-HDBK-759B, 1992]

▪ **4.7.1.8 Captive covers.** If a connector has a protective cover, the cover shall be of the captive type. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

4.7.2 Types

4.7.2.1 Distinctive

■ **4.7.2.1.1 Distinctive types.** Connectors for lines serving different functions, for example, fuel lines and water lines, or electrical power lines and radio-frequency signal lines, shall be distinctively different and physically incompatible. [Source: UCRL-15673, 1985]

■ **4.7.2.1.2 Preventing mismatching.** Connectors serving the same or similar functions shall be selected or designed to minimize the likelihood of mismatching. [Source: MIL-HDBK-759B, 1992]

Discussion. Preferably this will be accomplished by making the connectors physically incompatible, for example, by using connectors of different sizes or by using alignment pins or keys. If that is not feasible, coding by color may be acceptable.

4.7.2.2 Plug-in

Plug-in connectors are the easiest and least time consuming to use, but they have low holding power. They are particularly convenient where frequent connection and disconnection is required. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

□ **4.7.2.2.1 When to use.** If a line or cable is likely to be connected and disconnected frequently, and if the line or cable is not likely to be pulled accidentally, plug-in connectors should be used. [Source: MIL-HDBK-759B, 1992]

■ **4.7.2.2.2 Preventing damage.** Plug-in connectors and their receptacles shall be selected or designed so that the plug cannot be inserted into a receptacle that it does not match. An attempt to insert a plug into a non-matching receptacle shall damage neither the plug nor the receptacle. [Source: MIL-STD-1800A, 1990]

4.7.2.3 Threaded

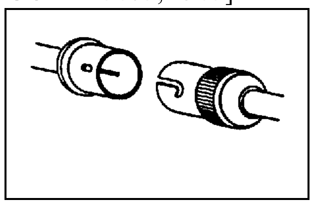
Threaded connectors provide very secure connections, particularly when locked in place with set screws, retainers, or safety wires. They are more time consuming to connect and disconnect than plug-in connectors.

■ **4.7.2.3.1 Ease of operation.** Threaded connectors shall be selected or designed so that they meet the holding requirements for the connection with a minimum number of turns. [Source: MIL-HDBK-759B, 1992]

4.7.2.4 Quick-action

Quick-action connectors are, as their name implies, quick and easy to use. They include connectors that operate in one of the following ways: (a) by a snap action, (b) by rotating the connector up to one complete turn, (c) by triggering a latch or spring device, and (d) by removal of an external pin. Exhibit 4.7.2.4 illustrates a common type of quick-action connector, one that operates with a quarter-turn rotation. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

Exhibit 4.7.2.4 Example of a quick-action connector
[Source: UCRL-15673, 1985]



- 4.7.2.4.1 **When to use.** Quick-action connectors shall be used when units of equipment or components must be connected or disconnected frequently or when connection and disconnection must be completed quickly, provided that they meet all other requirements for the connection, such as holding or sealing. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; UCRL-15673, 1985]

- 4.7.2.4.2 **Self-locking.** Quick-action connectors shall have self-locking catches that prevent loosening and ensure a secure connection. [Source: UCRL-15673, 1985]

4.7.3 Location and accessibility

- 4.7.3.1 **Visual and physical access.** Connectors shall be located so that maintainers can see, reach, connect, and disconnect them easily and safely. [Source: MIL-HDBK-759B, 1992; NASA-STD-3000A, 1989]

- 4.7.3.2 **Unobstructed access.** Connectors shall be located so that they can be seen and reached without the disassembly or removal of other equipment or components. [Source: MIL-HDBK-759B, 1992]

- 4.7.3.3 **Relative accessibility.** The connectors that are connected and disconnected most frequently shall be the most accessible. [Source: MIL-HDBK-759B, 1992]

- 4.7.3.4 **Full access.** The rear of plug connectors shall be accessible for testing and servicing. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; NASA-STD-3000A, 1989]

- 4.7.3.5 **Protected from dislodging and damage.** Connectors shall be located so that they are not dislodged or damaged by the movement of people or objects in their vicinity. [Source: MIL-HDBK-759B, 1992]

- **4.7.3.6 Minimum spacing.** The space between a connector and any other connector or obstruction shall be sufficient to permit the connector to be grasped as firmly as necessary for connecting and disconnecting it. This spacing shall be at least:

  a. 25 mm (1 in) if the connector is operated with bare fingers,

  b. 32 mm (1.25 in) if the connector is operated with gloved fingers,

  c. 64 mm (2.5 in) if the connector must be "gripped firmly," and

  d. 75mm (3 in) if the connector is operated with mittened hands. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999]

- **4.7.3.7 Measuring clearance.** Clearance shall be measured from the outermost portion of the connector, that is, from the backshell, strain relief clamp, dust cover, or electromagnetic interference shield or radio frequency interference shield, if they exist, and it shall permit a rotation of at least 270°. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999]

- **4.7.3.8 Space for wrench.** If the connector requires high torque, there shall be enough space around it to permit use of a wrench. [Source: MIL-STD-1472F, 1999]

4.7.4 Alignment aids

- **4.7.4.1 Preventing misalignment.** Wherever a particular orientation of a connector is required, the connector and its receptacle shall be provided with an aligning device, such as a pin or key way, that prevents the connector from being inserted in any but the correct orientation. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

  Discussion. Even when an alignment device is provided, care must be taken to ensure that the connector is not symmetric, which would permit connection 180° from the correct orientation.

- **4.7.4.2 Alignment before contact.** Alignment devices shall ensure that correct alignment is achieved before electrical contact is made. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; UCRL-15673, 1985; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

- **4.7.4.3 Aligning the alignment devices.** If a unit of equipment has more than one connector having the same sort of alignment device, all of those connectors shall be oriented so that the alignment device is in the same relative position. For example, all alignment keys might be at the top. [Source: MIL-STD-1472F, 1999]

▪ **4.7.4.4 Alignment coding.** If a connector has an alignment device, the connector shall be durably marked or coded to show the position of the alignment device. Methods for marking or coding include painted stripes and arrows. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; MIL-HDBK-759B, 1992; AFSC DH 1-3, 1980]

▪ **4.7.4.5 Alignment of drawer connectors.** If a module or unit of equipment is mounted in a drawer with a connector at the back that mates with a connector in the rack, guide pins or other alignment devices shall be provided to ensure proper mating. [Source: MIL-STD-1472F, 1999]

4.7.5 Electrical connections

4.7.5.1 Plugs and receptacles

▫ **4.7.5.1.1 Fast, easy connection.** Unless precluded by other requirements, electrical connectors should be of the plug-in or quick-action types. [Source: UCRL-15673, 1985]

▪ **4.7.5.1.2 Prevention of insertion errors.** Electrical plugs shall be selected or designed so that it is physically impossible to insert a plug in the wrong receptacle or to insert it into a receptacle the wrong way. Some ways in which this can be accomplished are:

a. Use plugs with polarized prongs or prongs of different sizes,

b. Use plugs having different numbers of pins or different configurations of pins, and

c. Use plugs of different sizes. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

▫ **4.7.5.1.3 Alignment.** Alignment of electrical connections should comply with Paragraph 4.7.4 Alignment aids.

▪ **4.7.5.1.4 Few plugs, many contacts.** Where applicable, electrical connections shall be accomplished by using few connectors with many contacts rather than many connectors with few contacts. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; UCRL-15673, 1985]

▪ **4.7.5.1.5 "Hot" leads.** Wiring shall be routed through plugs and receptacles so that "hot" leads are not exposed in either the plug or the receptacle when they are disconnected. [Source: MIL-HDBK-759B, 1992]

▪ **4.7.5.1.6 "Cold" plugs.** Wiring shall be routed so that receptacles are "hot," and plugs are "cold" when they are disconnected. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; UCRL-15673, 1985]

▪ **4.7.5.1.7 Electrical charges.** Disconnected plugs and leads shall not expose maintainers to stored electrical charges. [Source: UCRL-15673, 1985]

- ▫ **4.7.5.1.8 Self-locking or latching.** Electrical connectors should be self-locking or should have safety catches; they should not require safety wire. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- ▫ **4.7.5.1.9 Insertion force.** Electrical connectors should require low insertion forces to minimize the possibility of damaging the connector or injuring the maintainer. [Source: MIL-HDBK-759B, 1992]

- ▪ **4.7.5.1.10 Durability.** Plugs and pins shall be selected or designed to withstand rough use. [Source: UCRL-15673, 1985]

- ▪ **4.7.5.1.11 Non-shorting contacts.** Connectors shall be selected or designed so that electrical contacts cannot be shorted by external objects. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

- ▪ **4.7.5.1.12 Pin identification.** Each pin on each plug shall be clearly identified or coded, using labels or color or shape coding. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

- ▫ **4.7.5.1.13 Test points.** If test points are required to measure inputs or outputs that cannot be easily checked otherwise, they should be provided: (a) on the plug itself, or (b) on an adapter that can be inserted between the plug and the receptacle. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

- ▫ **4.7.5.1.14 Disassembly by hand or using common hand tools.** The disassembly of connectors to change pin connections should not require the use of special tools; it should be possible by hand or with the use of common hand tools. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

- ▪ **4.7.5.1.15 Drawer module connectors.** Units of equipment that are mounted in drawers and that do not require that connections be maintained when the drawer is extended, shall be provided with plugs mounted on the back of the drawer. These plugs shall have alignment guides that allow the unit to be slid back into place and mate with receptacles in the cabinet to accomplish whatever electrical interconnections among the drawer, other equipment in the cabinet, and external connections are required. [Source: MIL-STD-1800A, 1990]

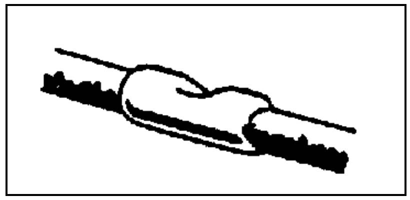
4.7.5.2 Wire connections

This section contains rules governing the arrangement and attachment of individual wires. Lugs and crimp-on devices are preferable to wire-wrap, pig tailing, and soldering for connecting or splicing individual wires. Soldering provides the most secure connection, but it is also the most time-consuming.

- ▪ **4.7.5.2.1 Spacing of leads.** It shall be easy for maintainers to perform any necessary operations on leads, in particular connecting and disconnecting them. This may be accomplished by adequate spacing of the terminals to which they are attached, or by ensuring that the leads are long enough that the maintainer can separate them. [Source: MIL-HDBK-759B, 1992]

▫ **4.7.5.2.2 Extra wire length.** If wires terminate in lugs or crimp-on devices, the wires shall be long enough to permit at least six replacements of the devices. Exhibit 4.7.5.2.2 illustrates an example of a crimp-on splice. [Source: UCRL-15673, 1985]

Exhibit 4.7.5.2.2 Example of a crimp-on splice.
[Source: UCRL-15673, 1985]

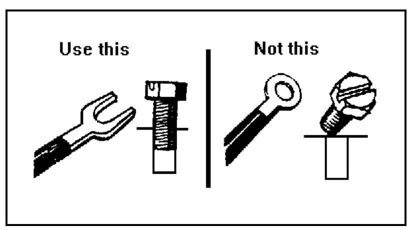


■ **4.7.5.2.3 Clamping insulation.** Lugs and crimp-on devices shall clamp the insulation as well as the conductor. [Source: UCRL-15673, 1985]

■ **4.7.5.2.4 Compatibility of lugs with terminals.** Lugs shall be compatible with terminal post requirements. [Source: UCRL-15673, 1985]

▫ **4.7.5.2.5 U-lugs.** U-lugs should be used rather than O-lugs (or eye lugs). Exhibit 4.7.5.2.5 illustrates a U-lug and an O-lug. [Source: UCRL-15673, 1985; AFSC DH 1-3, 1980]

Exhibit 4.7.5.2.5 Examples of a U-lug and an O-lug [Source: UCRL-15673, 1985]



■ **4.7.5.2.6 Soldered connections.** Soldered connections shall be compatible with terminal post requirements. [Source: UCRL-15673, 1985]

■ **4.7.5.2.7 Spacing of terminals.** Terminals to which wires are to be soldered shall be far enough apart that work on one terminal does not damage neighboring terminals or nearby parts. [Source: UCRL-15673, 1985; AFSC DH 1-3, 1980]

■ **4.7.5.2.8 Length of terminals.** Terminals or other connections to which wires are soldered shall be long enough that soldering does not damage anything nearby. [Source: UCRL-15673, 1985; AFSC DH 1-3, 1980]

■ **4.7.5.2.9 Soldered wires.** The end of a wire soldered to a terminal shall extend beyond the solder so that the wire will be easy to remove. [Source: UCRL-15673, 1985]

- **4.7.5.2.10 Wire wrapping or pig tailing.** Wire wrapping and pig tailing shall not be used unless authorized by the acquisition program office. [Source: UCRL-15673, 1985]

4.7.6 Labeling, marking, and coding

Coding and identifying connectors and associated parts can expedite maintenance and troubleshooting procedures by keying the connectors to references in job instructions and by identifying replaceable parts for ordering. Labeling, marking and coding can also provide appropriate warnings and cautions.

- **4.7.6.1 Matching connectors or plugs and receptacles.** Each connector or plug and its corresponding connector or receptacle shall be labeled or coded so that the two parts are easily matched. [Source: MIL-HDBK-759B, 1992]

- **4.7.6.2 Non-interchangeable connectors.** Non-interchangeable connectors shall be labeled or coded so that they are clearly distinguishable. Coding methods include shape, size, and color. [Source: MIL-HDBK-759B, 1992]

- **4.7.6.3 Matching wires to terminals or pins.** Each wire in a connector or receptacle shall be clearly identified with its terminal post or pin. [Source: MIL-HDBK-759B, 1992]

- **4.7.6.4 Identification of terminals on terminal strips or blocks.** Terminals on terminal strips or blocks shall be identified on the terminal strip or block itself or on the chassis, adjacent to the terminals (same as paragraphs 4.8.1.8.3 and 4.9.5.8). [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

- **4.7.6.5 Location of labels and codes -- connectors.** Labels and codes on connectors shall be located, in order of preference, (a) directly on the connector, (b) on plates permanently attached to the connector, or (c) on tabs or tapes attached to the connector. [Source: MIL-HDBK-759B, 1992]

- **4.7.6.6 Location of labels and codes -- receptacles.** Labels and codes for receptacles shall be located, in order of preference, (a) directly on the receptacle, (b) on the surface or panel immediately adjacent to the receptacle or, if it is recessed, adjacent to its access opening. [Source: MIL-HDBK-759B, 1992]

- **4.7.6.7 Consistency of labels and codes.** Labels and codes on connectors shall be consistent with labels and codes on associated items, such as pins, terminals, and receptacles. [Source: MIL-HDBK-759B, 1992]

- **4.7.6.8 Warnings and cautions.** If any hazard to maintainers or equipment exists in the connection or disconnection of a connector, the connector shall be labeled or coded with an appropriate warning or caution. [Source: MIL-HDBK-759B, 1992]

▪ **4.7.6.9 Marking electrical connections.** Marking adjacent to plugs, jacks and other electrical connectors shall identify the connected circuits to preclude cross connections. [Source: MIL-HDBK-454]

4.8 Lines and cables

General rules for lines and cables are given in this section. The routing and mounting of electrical cables (including extension and mock-up cables) and fluid and gas lines are covered, as well as their labeling and marking.

> **Definitions.** A **cable** is a number of lines bound together within a single, permanent sheath. A **line** is any single length of pipe, wire, or tubing.

Lines and cables most often end in connectors, and some rules regarding connectors are also given in this section. See Section 4.7 for detailed information pertaining to connectors. [Source: UCRL-15673, 1985]

4.8.1 Electrical

4.8.1.1 General

▪ **4.8.1.1.1 Selection.** Lines and cables shall be selected, designed, bound, mounted, and routed to:

a. preclude wear out, breakage, or damage,

b. facilitate logical and efficient divisions of maintenance responsibilities, and

c. allow maintainers to quickly and easily: (a) troubleshoot, test, check, and isolate malfunctions, (b) remove, repair, and replace other units of equipment and components, and (c) connect and disconnect lines and cables. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

▫ **4.8.1.1.2 Insulation.** Clear plastic insulation should be used where possible to allow rapid detection of internal breaks. [Source: UCRL-15673, 1985]

▫ **4.8.1.1.3 Minimization.** Lines and cables should be designed to minimize the number of:

a. types and varieties of lines and cables,

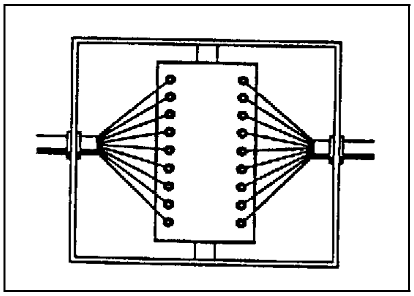
b. different lengths of otherwise identical lines or cables, and

c. related connectors, fittings, and fixtures. [Source: UCRL-15673, 1985]

■ **4.8.1.1.4 Quick-action connections.** When maintenance requires that cables be connected or disconnected easily or frequently, cables shall terminate in quick-action connectors. [Source: UCRL-15673, 1985]

■ **4.8.1.1.5 Cable "fan out".** The wires in cables shall "fan out as seen in Exhibit 4.8.1.1.5 so that the individual wires can be attached to junction boxes, terminal blocks, or other mounts. Each attachment point shall be easily identifiable and easy to reach with test probes. [Source: MIL-HDBK-759B, 1992]

Exhibit 4.8.1.1.5 Fanning out cables [Source: UCRL-15673, 1985]



□ **4.8.1.1.6 Preformed cables.** Preformed cables should be used wherever possible to minimize wiring errors and allow for the use of more flexible and efficient assembly methods. Spare lines should be included to allow for growth and to speed wiring time as agreed upon by the acquisition agency. [Source: UCRL-15673, 1985]

■ **4.8.1.1.7 Harnesses.** When harnesses are used, they shall

a. be designed, fabricated, and installed as units,

b. be held securely with lacing twine or other means acceptable to the user, and

c. keep the individual conductors essentially parallel, so they do not intertwine, though twisted pairs may be used when required. [Source: UCRL-15673, 1985; AFSC DH 1-3, 1980]

■ **4.8.1.1.8 Protection.** Shields or other protection shall be provided for easily damaged conductors such as waveguides, high-frequency cables, and insulated high-voltage cables. [Source: MIL-HDBK-759B, 1992]

■ **4.8.1.1.9 Exposed cables.** Exposed cables shall be protected from mechanical damage. For example, armored cables might be used where damage is likely. [Source: MIL-HDBK-759B, 1992]

■ **4.8.1.1.10 Special purpose cables.** Cables intended for use in the presence of nuclear, biological, or chemical hazards shall be sealed. [Source: MIL-STD-1800A, 1990]

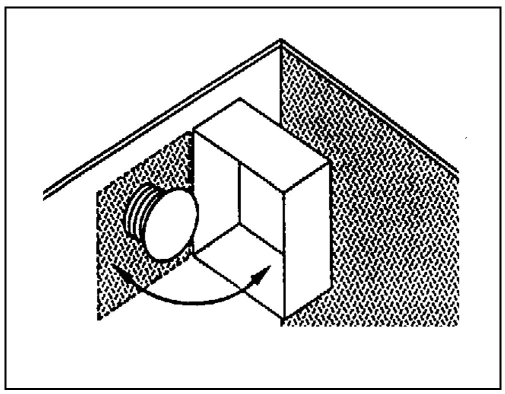
- **4.8.1.1.11 Insect protection.** If damage from termites is likely, line and cable insulation shall be protected by coating it with compounds of creosote, antimony, or other acceptable mixtures. [Source: UCRL-15673, 1985]

- **4.8.1.1.12 Fluid protection.** All electrical lines and cables shall be protected from oil, grease, fuel, hydraulic fluid, water or cleaning solvents. These may damage insulation and may result in injury to personnel. [Source: MIL-HDBK-759B, 1992]

- **4.8.1.1.13 Storage space.** If long electrical cables are required for auxiliary power or test equipment, storage space shall be provided. [Source: MIL-HDBK-759B, 1992]

  Example. Often, a storage compartment is present, but no easy means is provided for coiling the wire into a shape and size that will permit storage. A simple means of accomplishing this is a cable winder, a device around which the cable can be wrapped (see Exhibit 4.8.1.1.13).

Exhibit 4.8.1.1.13 Cable winder



- **4.8.1.1.14 Use of grommets.** When cables must pass over sharp edges, insulation shall be protected from fraying or other damage by grommets or equivalent means. [Source: MIL-STD-1472F, 1999; MIL-HDBK-759B, 1992]

4.8.1.2 Length of cables and leads

- **4.8.1.2.1 Length of cables.** If a circuit might be affected by differences in the length of a cable, the length of cables should be the same for each installation of a given type of electronic equipment. [Source: MIL-HDBK-759B, 1992; AFSC DH 1-3, 1980]

  Discussion. Even if a unit can be adjusted to compensate for differences in the length of the cable, using different lengths of cable means that an adjustment made on the bench might be out of tolerance when the unit is installed. [Source: MIL-HDBK-759B, 1992; AFSC DH 1-3, 1980]

- **4.8.1.2.2 Extra cable.** Cables shall be long enough so that a unit of equipment can be moved to a convenient place for maintenance activities; extension cables shall be provided if necessary. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

- **4.8.1.2.3 Accessibility.** Cables shall be long enough so that units of equipment mounted in drawers and on slide-out racks can be worked on without breaking electrical connections. [Source: AFSC DH 1-3, 1980; MIL-STD-1800A, 1990]

- **4.8.1.2.4 Cable length and connectors.** Cables shall be long enough so that connectors can be easily connected and disconnected. [Source: AFSC DH 1-3, 1980; NASA-STD-3000A, 1989]

- **4.8.1.2.5 Length of leads.** Lead lengths shall be as short as possible but long enough to allow all of the following that apply (see Paragraph 4.7.5.2.1):

  a. easy connection and disconnection, with enough slack to back the wire away from the point of attachment to facilitate removal of the unit,

  b. sufficient slack for at least two (preferably six) replacements of terminal fittings, electrical considerations permitting,

  c. movements of parts to which they may be attached (doors, covers, and the like) without undue stress or bending,

  d. connection, disconnection, or movement without requiring a bending radius of less than six times the diameter of the lead, and

  e. movement of the units that are difficult to handle in their mounted position to a more convenient position for connection or disconnection. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

- **4.8.1.2.6 Slack.** Leads or cables to moving parts, doors, and covers shall have adequate slack and protection so that they

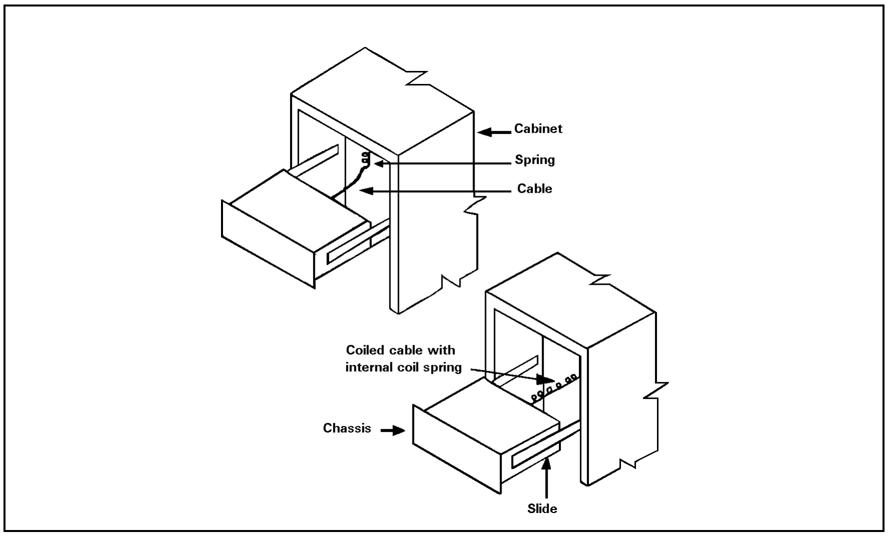
  a. permit movement, such as pulling out a drawer for maintenance, without breaking the electrical connection,

  b. fold out of the way when the part is moved,

  c. are not pinched or otherwise damaged when the part is returned to its original position (see Exhibit 4.8.1.2.6 for the use of springs and cable mechanisms to prevent pinching),

  d. do not chafe or break under the repeated flexing required. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

Exhibit 4.8.1.2.6 Recoiling slack cable
[Source: MIL-HDBK-759B, 1992]



4.8.1.3 Routing and mounting

- **4.8.1.3.1 Routing considerations.** Lines and cables shall be routed so they will not be

  a. pinched or stressed by loose objects, doors, lids, covers, sliding drawers, or roll-out racks,

  b. walked on or rolled over by heavy traffic,

  c. used for hand- or foot-holds (a protective guard should be placed over the cables where the possibility of such use exists), or

  d. bent or sharply twisted. [Source: AFSC DH 1-3, 1980]

- **4.8.1.3.2 Combining lines.** The layout and routing of lines shall be determined during design and made as simple and functionally logical as possible by combining lines into cables (preferable) or combining lines into harnesses if cables are not used. [Source: UCRL-15673, 1985]

- **4.8.1.3.3 Segregate conductors.** Conductors shall be segregated into cables or harnesses according to their functions and relationships to replaceable equipment. [Source: UCRL-15673, 1985]

- **4.8.1.3.4 Routing over pipes.** Electrical wires and cables shall be mounted above, rather than under, pipes or fluid containers. [Source: MIL-HDBK-759B, 1992]

- **4.8.1.3.5 Lightly insulated wires.** Lines and cables that are lightly insulated shall be at least 19 mm (0.75 in) from a potential ground. [Source: UCRL-15673, 1985]

- **4.8.1.3.6 Protection.** Raceways, stuffing tubes, conduit, junction boxes, and insulation shall be provided as necessary to obtain the required degree of protection, security of mounting, and ease of maintenance. [Source: UCRL-15673, 1985]

- **4.8.1.3.7 Visual and physical access.** Lines, cables, and wire harnesses shall be routed so that they are readily accessible for inspection and repair, especially at points of connection, splicing, and testing. [Source: NASA-STD-3000A, 1989; MIL-STD-1800A, 1990; MIL-STD-1472F, 1999; MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- **4.8.1.3.8 Unobstructed access.** Lines and cables shall be accessible without requiring disassembly or removal of other equipment or components. [Source: MIL-HDBK-759B, 1992]

- **4.8.1.3.9 Replacement.** Lines and cables shall be accessible throughout their route for removal and replacement if they are damaged. [Source: MIL-HDBK-759B, 1992]

- **4.8.1.3.10 Areas to avoid.** High voltage lines and cables shall be routed away from sensitive equipment, high temperature sources, work areas, controls, and the like. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

- **4.8.1.3.11 Ease of maintenance.** Line and cable routing shall facilitate maintenance by ensuring that each unit of equipment can be moved to a convenient place for maintenance activities; extension cables shall be provided if necessary. [Source: MIL-HDBK-759B, 1992]

- **4.8.1.3.12 Non-obstruction.** Line and cable routing shall not obstruct visual or physical access to equipment for operation or maintenance. [Source: MIL-STD-1472F, 1999]

- **4.8.1.3.13 Remote switches.** Lines and cables shall not be routed through remote switches that may be turned on and off inadvertently while maintenance is being performed. [Source: UCRL-15673, 1985]

- **4.8.1.3.14 Cables within racks.** Cables shall not be terminated or mounted on the front of cabinets, control panels, display panels, or on the face of equipment racks. Test cables are an exception to this criterion (see Paragraph 4.8.1.6.4). [Source: NASA-STD-3000A, 1989; UCRL-15673, 1985]

- **4.8.1.3.15 Shortest route.** Lines and cables shall be routed over the shortest runs allowable by lead, mounting, and other requirements. [Source: UCRL-15673, 1985]

4.8.1.4 Leads

- **4.8.1.4.1 No weight-bearing.** Leads shall be mounted so that they do not bear the weight of cables, harnesses, or other components. [Source: UCRL-15673, 1985]

- **4.8.1.4.2 Support.** Leads shall be mounted so that they are supported at splices and points of connection. [Source: UCRL-15673, 1985]

- **4.8.1.4.3 Orientation.** Where possible, leads shall be mounted so that they are oriented in a way that prevents erroneous connection or "crossing". [Source: UCRL-15673, 1985]

- **4.8.1.4.4 No flexing.** Leads shall be mounted so that they do not allow flexing at weak areas, for example, at splices, solder points, points where the conductor is bare or crimped, or points where strands are tinned together. [Source: UCRL-15673, 1985]

- **4.8.1.4.5 Signal checks.** Signal flow checks shall be made possible by the appropriate arrangement, location, and mounting of leads. [Source: UCRL-15673, 1985]

4.8.1.5 Clamps and mounting plates

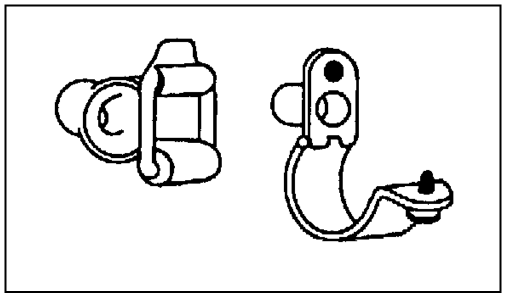
- **4.8.1.5.1 Snug fit.** Clamps and mounting plates shall fit snugly without deforming or crimping the line or cable. [Source: UCRL-15673, 1985]

- **4.8.1.5.2 Spacing.** Clamps and mounting plates shall be operable by hand or with common hand tools. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- **4.8.1.5.3 Special clamps.** Quick-release clamps (hinged or spring) shall be used if cables are removed frequently. Hinged clamps are preferable for non-overhead mounting, because they support the weight of the line during maintenance, freeing the maintainer's hands for other tasks. Exhibit 4.8.1.5.3 shows these two types of clamps. [Source: MIL-HDBK-759B, 1992]

  Discussion. For overhead mounting, a spring clamp with a hinged, locking latch over the clamp's open side is preferable because it would help prevent accidents. [Source: MIL-HDBK-759B, 1992]

Exhibit 4.8.1.5.3 Quick-release clamps, hinged and spring



- **4.8.1.5.4 Placement.** Clamps and mounting plates shall be located at both ends of bends where the bending radius is 75 mm (3 in) or less. [Source: UCRL-15673, 1985]

- **4.8.1.5.5 Unsupported cable.** Lengths of cable or wire longer than 300 mm (12 in) shall be attached to the equipment chassis by means of clamps, unless contained in wiring ducts or cable retractors. [Source: MIL-STD-1800A, 1990; MIL-HDBK-759B, 1992]

- **4.8.1.5.6 Visibility of clamps.** All clamps shall be visible when equipment is installed. [Source: MIL-STD-1800A, 1990]

- **4.8.1.5.7 Mechanically-mounted clamps.** If a wire or cable is not routed through a wiring duct or conduit, it shall be attached with mechanically-mounted (not adhesive) cable clamps. [Source: MIL-STD-1472F, 1999]

  Discussion. Mechanically-mounted clamps can ensure the correct routing of electrical cables within and between units of equipment. They can also (a) ensure that cables do not hinder or obstruct equipment maintenance, (b) prevent chafing due to contact with an adjacent surface, and (c) facilitate the mating of cables with their associated equipment. [Source: MIL-STD-1472F, 1999]

- **4.8.1.5.8 Non-conductive.** Clamps and mounting plates that secure a conductor shall be nonconductive or properly insulated. [Source: UCRL-15673, 1985]

4.8.1.6 Test and extension cables

Test and extension cables need to be planned, designed, and provided to increase the efficiency and ease of maintenance.

- ■ **4.8.1.6.1 Easy access.** Test and extension cables shall allow equipment and components to be moved to a convenient location for the performance of maintenance activities. [Source: UCRL-15673, 1985]

- □ **4.8.1.6.2 Multiple related functions.** Test and extension cables should serve as many related functions as possible, but should avoid the possibility of misuse or misconnection. [Source: UCRL-15673, 1985]

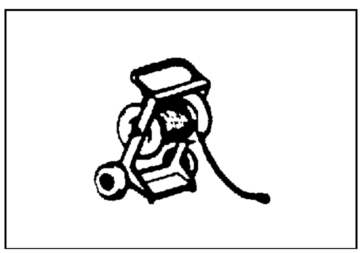
- ■ **4.8.1.6.3 Support equipment.** Test and extension cables shall permit support equipment to be placed in a convenient location. [Source: UCRL-15673, 1985]

- ■ **4.8.1.6.4 Noninterference.** If it is essential that test cables terminate on control and display panels, the panel test receptacles shall be located so that the test cables will not visually or physically interfere with operational controls and displays. [Source: NASA-STD-3000A, 1989; MIL-STD-1800A, 1990]

- ■ **4.8.1.6.5 Storage provisions.** Adequate storage shall be provided for test and extension cables. For example, racks, hooks, or cable winders might be provided within the storage place. [Source: UCRL-15673, 1985]

- ■ **4.8.1.6.6 Handling devices for cable.** Reels or reel carts shall be provided for handling large, heavy, or long lines of cable (see Exhibit 4.8.1.6.6). [Source: UCRL-15673, 1985]

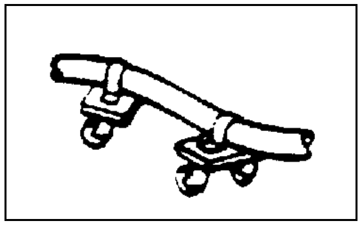
Exhibit 4.8.1.6.6 An example of a line and cable reel cart. [Source: UCRL-15673, 1985]



- □ **4.8.1.6.7 Automatic rewind.** If reels or reel carts are provided, they should rewind the cable automatically, when possible. [Source: UCRL-15673, 1985]

- **4.8.1.6.8 Mobile support.** If especially large lines or cables must be moved frequently, wheels or other mobile supports shall be provided. Exhibit 4.8.1.6.8 shows an example of a line and cable mobile support. [Source: UCRL-15673, 1985]

Exhibit 4.8.1.6.8 Line and cable mobile support
[Source: UCRL-15673, 1985]



4.8.1.7 Bench mockup cables

- **4.8.1.7.1 Extension cables.** Bench mockups shall have extension cables for all units so that the units can be removed from the bench mockup for the performance of maintenance activities. [Source: AFSC DH 1-3, 1980]

- **4.8.1.7.2 Connectors on mockup cables.** Bench mockup cables shall have connectors that require only a strong push or pull to connect or disconnect them. Bench mockup cables are not subject to strong vibration or shock, but they are connected and disconnected frequently. [Source: AFSC DH 1-3, 1980]

- **4.8.1.7.3 Coverings.** Mockup cables shall have an extra-heavy covering (for example, vinyl tubing) to protect them from wear resulting from frequent connection and disconnection. [Source: AFSC DH 1-3, 1980]

- **4.8.1.7.4 Checking signal flow.** Bench mockup cables, including extension cables for units of equipment, shall have test points to check the signal flow through each wire. [Source: AFSC DH 1-3, 1980]

  Examples. One method for accomplishing this is to provide test points at the connector; another is to provide test points on the junction boxes or terminal strips. [Source: AFSC DH 1-3, 1980]

4.8.1.8 Labeling, marking, and coding

- **4.8.1.8.1 Coding wire.** Insulated wire, cables, and electrical connectors shall be color- or number-coded in accordance with standards (for example, MIL-STD-195 and MIL-STD-681) acceptable to the acquisition agency. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

  Discussion. Number-coded wire, cables, and electrical connectors are preferred so that maintainers who have problems discriminating various colors may be able to identify these items. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

- **4.8.1.8.2 Identification.** Cables shall be labeled to indicate the equipment with which they are associated and the connectors with which they mate. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

- **4.8.1.8.3 Identification of terminals on terminal strips or blocks.** Terminals on terminal strips or blocks shall be identified on the terminal strip or block itself or on the chassis, adjacent to the terminals (same as Paragraphs 4.7.6.4 and 4.9.5.8). [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

- **4.8.1.8.4 Methods of color-coding.** Conductors shall be color-coded using, in order of preference, (a) solid-color insulation, (b) solid-color insulation with a colored-stripe tracer, or (c) color braid insulation with a woven tracer. [Source: MIL-HDBK-759B, 1992]

  Explanation. Exhibit 4.8.1.8.4 shows 12 different pattern variations based on different insulation and tracer colors. For more than 12 wires, see MIL-STD-686C. If a wire's color-coding is susceptible to becoming obscured, wires may be coded with numbered metal tags. [Source: MIL-HDBK-759B, 1992]

Exhibit 4.8.1.8.4 Electrical cable coding

Number of Conductor	Basic Color	Tracer
1	Black	None
2	White	None
3	Red	None
4	Green	None
5	Orange	None
6	Blue	None
7	White	Black
8	Red	Black
9	Green	Black
10	Orange	Black
11	Blue	Black
12	Black	White

- **4.8.1.8.5 Cables within a sheath.** Cables containing individually insulated conductors with a common sheath shall be coded. The coding shall be repeated every 300 mm (12 in) along their entire length. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

- **4.8.1.8.6 Coding for orientation.** Coding by such means as color or labels shall identify the correct item and its proper orientation or replacement. [Source: MIL-STD-1472F, 1999]

4.8.2 Fluid and gas lines

4.8.2.1 General

- ▫ **4.8.2.1.1 Connectors.** Fluid and gas line connectors should comply with Section 4.7 Connectors.

- ▫ **4.8.2.1.2 Use of flexible tubing.** Flexible tubing should be used instead of rigid lines because it allows more flexibility in handling, can be backed-off easily, and is easier to thread through equipment when replacement is required. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- ▫ **4.8.2.1.3 Use of flexible hose.** Flexible hose should be used rather than pipes or tubing where minimum space is available for removing, handling, or replacing lines. [Source: UCRL-15673, 1985]

- ▪ **4.8.2.1.4 Quick-action connectors.** Quick-action connectors shall be used on lines that require frequent disconnection. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- ▫ **4.8.2.1.5 Preventing leakage.** When quick-action connectors are used, self-sealing features should be provided to prevent leakage of fluid when the line is disconnected. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- ▪ **4.8.2.1.6 Leakage tests.** Fluid and gas line connectors shall be located and installed so that leakage tests can be performed easily and without danger to the maintainer or the equipment. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- ▪ **4.8.2.1.7 Control of leakage and spillage.** Fluid and gas line connectors shall be selected or designed so that leakage and accidental spillage during connection and disconnection are prevented or controlled so that they do not injure maintainers or damage equipment. [Source: MIL-HDBK-759B, 1992; NASA-STD-3000A, 1989]

- ▪ **4.8.2.1.8 Standardized fittings.** To avoid the possibility of mismating connectors during service or maintenance, fittings shall be standardized so that lines that differ in the substances they carry cannot be interchanged. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- ▪ **4.8.2.1.9 Avoiding spraying fluids.** Lines shall be kept from spraying or draining fluid on personnel or equipment during disconnection by locating connections away from work areas and sensitive components, shielding sensitive components where required, and providing drains and bleed fittings so lines can be drained or depressurized before they are disconnected. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- **4.8.2.1.10 High-pressure lines.** Systems that contain liquids or high pressure gases (pressures exceeding 125 psi) shall be provided with isolation or disconnect valves to permit isolation for servicing and to aid in leak detection. [Source: NASA-STD-3000A, 1989]

- **4.8.2.1.11 Cutoff valves.** Cutoff valves shall be provided at appropriate locations in the system to permit isolation or drainage of the system for maintenance and during emergencies. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- **4.8.2.1.12 Draining and filling.** Fluid and gas line connectors shall be located and installed so that draining, filling, and other maintenance involving the connectors or lines can be accomplished without jacking up the equipment. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

- **4.8.2.1.13 Avoiding drainage problems.** Drainage problems shall be avoided by

  a. designing lines so they can be emptied completely if necessary,

  b. making bends horizontal, rather than vertical, to avoid fluid traps,

  c. avoiding low points or dips in lines that make them difficult to drain, and

  d. providing special drains where low points do occur. [Source: MIL-HDBK-759B, 1992]

- **4.8.2.1.14 Exposure to noise and vibration.** Fluid and gas line connectors shall be located and installed so that maintenance activities involving them do not require that the maintainer be exposed to extreme noise, vibration, or other danger. [Source: MIL-HDBK-759B, 1992]

4.8.2.2 Routing and mounting

- **4.8.2.2.1 Accessibility.** Fluid and gas lines mounted in cable trays shall be located for ready access. [Source: NASA-STD-3000A, 1989]

- **4.8.2.2.2 Connectors for rigid lines.** Connectors for rigid fluid and gas lines shall be located and installed so that it is not necessary to back the lines off or remove other equipment or components to connect or disconnect the connectors. [Source: UCRL-15673, 1985]

  Discussion. Protruding gaskets or seals might be susceptible to damage, and that damage might spread internally, destroying the seal. Tapered nylon or Teflon washers of appropriate size can be employed to prevent extrusion. [Source: UCRL-15673, 1985]

- **4.8.2.2.3 Areas to avoid.** High-pressure lines and cables shall be routed away from sensitive equipment, high temperature sources, work areas, controls, and the like. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- **4.8.2.2.4 Fuel lines.** Fuel lines shall be routed below electrical cables and hot pipes. [Source: MIL-HDBK-759B, 1992]

- **4.8.2.2.5 Heat resistant liners.** If fluid and gas lines are likely to become extremely hot, clamps and mounting plates shall be lined with heat resistant material so the maintainer will not be burned. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

- **4.8.2.2.6 Avoiding line kinking.** Fluid and gas lines should be installed and mounted with sufficient clearance from surrounding equipment and structures to allow the maintainer to disconnect and remove the lines without bending or kinking them. [Source: UCRL-15673, 1985]

4.8.2.3 Clamps and supports

- **4.8.2.3.1 External service supports.** Unmounted lines attached to equipment (for example, lines from external service or test equipment or lines attached for other purposes) shall have supports capable of withstanding

  a. the initial surges of pressure through the line,

  b. the weight of external extensions, and

  c. the wear and tear of handling and repeated connection and disconnection. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

- **4.8.2.3.2 Spring clamps.** Spring clamps shall be used to mount tubing and fluid pipes that may require frequent removal and replacement. [Source: MIL-HDBK-759B, 1992]

  Discussion. For overhead mounting, a spring clamp shall be used with a hinged-locking latch over the clamp's open side to prevent accidents (see Paragraph 4.8.1.5.3). [Source: MIL-HDBK-759B, 1992]

4.8.2.4 Gaskets and seals

- **4.8.2.4.1 Replaceable, renewable gaskets and seals.** Gaskets and seals used in connectors for fluid and gas lines shall be selected and installed to be replaceable or to have renewable wearing surfaces; it shall not be necessary to discard the connector when the seal is damaged or worn. [Source: UCRL-15673, 1985]

- **4.8.2.4.2 Repair and replacement of gaskets and seals.** Gaskets and seals used in connectors for fluid and gas lines shall be easily inserted and removed, without requiring the removal of other connector parts or the disassembly of other equipment. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- **4.8.2.4.3 Ability to identify gaskets and seals.** Part numbers for gaskets and seals used in connectors for fluid and gas lines shall be easily identifiable. This may be accomplished through labeling, coding, marking, or user documentation. [Source: UCRL-15673, 1985]

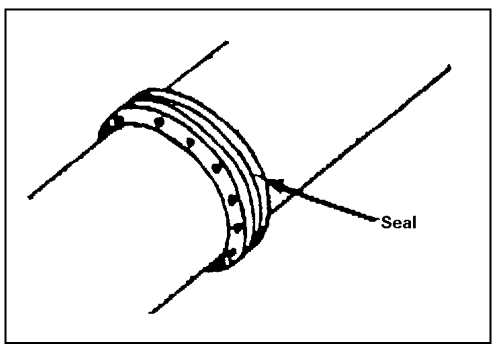
- **4.8.2.4.4 Life expectancy of gaskets and seals.** Job instructions shall state the life expectancy of gaskets and seals and recommend when they should be changed. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

- **4.8.2.4.5 Prevent entrance of air.** If the entrance of air into a disconnected fluid or gas line would create a maintenance problem, as for example, in a hydraulic line, gaskets and seals used in connectors shall prevent the entrance of air when the line is disconnected. [Source: UCRL-15673, 1985]

- **4.8.2.4.6 Tightening to offset shrinkage.** If a gasket or seal used in a fluid or gas line connector is subject to shrinkage, the connector shall permit tightening to offset the shrinkage. [Source: UCRL-15673, 1985]

- **4.8.2.4.7 Visibility.** Gaskets and seals used in fluid and gas line connectors shall be visible after they are installed so that maintainers can see that the gasket or seal is present as illustrated in Exhibit 4.8.2.4.7. [Source: MIL-HDBK-759B, 1992]

Exhibit 4.8.2.4.7 Externally visible seals
[Source: MIL-HDBK-759B, 1992]



- **4.8.2.4.8 Non-protrusion.** Gaskets and seals used in fluid and gas connectors shall not protrude beyond the coupling. [Source: UCRL-15673, 1985]

  Discussion. Protruding gaskets and seals might be susceptible to damage, and that damage might spread internally, destroying the seal. Tapered nylon or Teflon washers of appropriate size can be employed to prevent extrusion. [Source: UCRL-15673, 1985]

4.8.2.5 Labeling, marking, and coding

- **4.8.2.5.1 Fluid conductor coding.** Fluid conductors shall be either color coded (see Exhibit 4.8.2.5.1), or coded by metal tags. Metal tags shall be used where adverse conditions (such as grease or mud) could obscure colors; otherwise, color-coding shall be used. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

Exhibit 4.8.2.5.1 Color-coding of fluid conductors

Contents	Valve handwheels and operating levers	Fed. Std 595 color number and chip
Steam	White	17886
Potable water	Dark blue	15044
Nitrogen	Light gray	16376
High pressure air	Dark gray	16081
Low pressure air	Tan	10324
Oxygen	Light green	14449
Salt water	Dark green	14062
Fuel oil	Yellow	13538
Lube oil	Yellow	13538
Fire protection	Red	11105
Foam discharge	Striped red/ green	11105 14062
Gasoline	Yellow	13538
Feedwater	Light blue	15200
Hydraulic	Orange	12246
Freon	Dark purple	17100
Hydrogen	Chartreuse	23814
Sewage	Gold	17043

▪ **4.8.2.5.2 Valve color-coding.** Valves shall be color-coded in accordance with the substances they control or the function they perform. Exhibit 4.8.2.5.2 lists recommended color codes for valves by substance. [Source: UCRL-15673, 1985]

Exhibit 4.8.2.5.2 Valve color-coding scheme

Contents	Color
Fuel	Red
Water injection	Red -gray-red
Lubrication	Yellow
Hydraulic	Blue & yellow
Pneumatic	Orange & blue
Instrument air	Orange & gray
Coolant	Blue
Breathing oxygen	Green
Air conditioning	Brown & gray
Fire protection	Brown
De-icing	Gray
Compressed gases	Orange
Electrical conduit	Brown & orange

- 4.8.2.5.3 **Hydraulic and pneumatic line coding.** Hydraulic and pneumatic lines shall be coded based on arrangement, size, shape, and color as necessary. Exhibit 4.8.2.5.3 lists color-codes for lines by function. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

Exhibit 4.8.2.5.3 Hydraulic and pneumatic line color-coding scheme

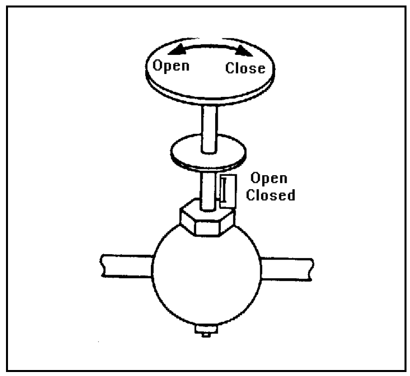
Function	Color	Definition of function
Intensified pressure	Black	Pressure in excess of supply pressure induced by booster or intensifier.
Supply pressure	Red	Pressure of the power-actuating fluid.
Charging pressure	Intermittent red	Pump-inlet pressure, higher than atmospheric pressure.
Reduced pressure	Intermittent red	Auxiliary pressure lower than supply pressure.
Metered flow	Yellow	Fluid at a controlled flow rate (other than pump delivery).
Exhaust	Blue	Return of the power-actuating fluid to reservoir.
Intake side	Green	Subatmospheric pressure, usually on the intake of the pump.
Drain	Green	Return of leakage of control-actuating fluid to reservoir.
Inactive	Blank	Fluid within the circuit but not serving a functional purpose during the phase being represented.

- **4.8.2.5.4 Label contents.** Codes and labels shall be provided on, or adjacent to, the line as necessary to indicate the direction of flow. [Source: MIL-HDBK-759B, 1992]

- **4.8.2.5.5 Valve position labeling.** Labels or other marking devices shall be provided to clearly designate the position of a valve control. Exhibit 4.8.2.5.5 illustrates labeling of a valve control. [Source: UCRL-15673, 1985]

  Example. A rider, as illustrated in Exhibit 4.8.2.5.5, may be attached to the shaft to indicate the fully opened and fully closed positions. [Source: UCRL-15673, 1985]

Exhibit 4.8.2.5.5 Value position labeling
[Source: UCRL-15673, 1985]



4.9 Packaging, layout, and mounting of internal components

Criteria and rules for the packaging, layout, mounting, labeling, and marking of internal modules, components, and parts are given in this section. All of these can affect the ease or difficulty of maintenance activities.

Definitions. A **module** is an assemblage of two or more interconnected parts or components that comprise a single physical and functional entity (for example, a printed circuit board). It is this singular functionality that defines a module. A **component** is a subdivision of a unit of equipment that can be treated as an object by the maintainer, but which can be further broken down into parts. A mounting board together with its mounted parts is an example of a component. A **part** is an object that cannot normally be broken down further without destroying its designated use. Fuses, resistors, and capacitors are examples of parts. **Packaging** is the grouping of functions, components, and parts into units or modules; **layout** is the physical arrangement of the parts and components that make up a module or a unit of equipment; **mounting** is the positioning and attachment of parts, components, and modules.

4.9.1 General

▪ **4.9.1.1 Accessibility.** Parts and modules on which maintenance is performed shall be positioned so that the maintainer has complete visual and physical access. [Source: MIL-HDBK-759B, 1992]

▪ **4.9.1.2 Minimize tool requirements.** Parts and modules shall be packaged, laid out, and mounted so that maintenance activities require a minimum number and variety of tools, preferably only common hand tools. [Source: MIL-HDBK-759B, 1992]

▫ **4.9.1.3 Minimize maintainer movement.** Parts and modules should be packaged, laid out, and mounted so that a minimum of movement is required of the maintainer in carrying out maintenance activities. [Source: UCRL-15673, 1985]

▫ **4.9.1.4 Organized by maintenance specialty.** Parts and modules should be packaged, laid out, and mounted so that maintenance activities by one maintenance specialist do not require removal or handling of equipment or components maintained by another specialist. [Source: UCRL-15673, 1985]

4.9.2 Packaging

Dividing a unit of equipment into a number of separate modules has several advantages: it can permit specialization by maintainers; it can speed up corrective maintenance; and it can make working on malfunctioning units easier.

Definition. Modularization is the separation of equipment into physically and functionally distinct units that can be easily removed and replaced.

4.9.2.1 Modularization

▫ **4.9.2.1.1 Modularization.** Units of equipment should be divided into as many modules as are electrically and mechanically practical and feasible for maintenance (see also Paragraph 4.1.2.7). [Source: AFSC DH 1-3, 1980; MIL-STD-1800A, 1990; UCRL-15673, 1985]

▪ **4.9.2.1.2 Single function.** A module shall contain only parts that contribute to a single function; it shall not provide multiple, divergent functions. [Source: UCRL-15673, 1985]

▪ **4.9.2.1.3 Physical and functional interchangeability.** If modules are physically interchangeable, they shall also be functionally interchangeable; if they are not functionally interchangeable, they shall not be physically interchangeable. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; NASA-STD-3000A, 1989]

▪ **4.9.2.1.4 Ability to distinguish non-interchangeable modules.** Non-interchangeable modules shall be distinguishably different in appearance, and this difference shall be apparent when the module is in its installed position. [Source: NASA-STD-3000A, 1989]

▫ **4.9.2.1.5 Unreliable components.** If a module contains some parts that are significantly less reliable than the remaining parts, the unreliable parts should be accessible without removal of the module. [Source: UCRL-15673, 1985]

▪ **4.9.2.1.6 Maintenance in installed location.** Modules shall be designed so that required maintenance can be performed with the module in its installed position, without requiring disconnection, disassembly, or removal of other modules. [Source: MIL-HDBK-759B, 1992]

▪ **4.9.2.1.7 Testing.** Modules shall be designed to permit testing when they are removed from their installed position, and they shall require little or no calibration immediately after installation. [Source: UCRL-15673, 1985]

4.9.2.2 Modularization methods

The breaking up of a unit of equipment into modules is done in accordance with one or more of the following methods: (a) logical flow packaging, (b) circuit packaging, or (c) component packaging.

In logical flow packaging, circuits, parts, and components are packaged and arranged in correspondence with their functional relationships.

In circuit packaging, all parts of a single circuit or logically related group of parts, and only that circuit or group, are placed in a separate module.

In component packaging, similar parts or components are located together; for example, all the fuses or all the relays might be grouped together.

□ 4.9.2.2.1 **Modularization method.** The modularization of equipment should be done using one or more of the following methods, in this order of preference: (a) logical flow packaging, (b) circuit packaging, (c) component packaging. [Source: UCRL-15673, 1985]

■ 4.9.2.2.2 **Logical flow packaging.** If logical flow packaging is used:

a. Circuits and parts shall be packaged and located in an arrangement that parallels their functional relationships.

b. A module shall be designed so that only single input and output checks are necessary to isolate a fault in the module.

c. The unidirectional signal flow within a module shall be clearly indicated. [Source: UCRL-15673, 1985]

■ 4.9.2.2.3 **Circuit packaging.** If circuit packaging is used:

a. All parts of a given circuit or group of logically related parts shall be located in a single module.

b. A module shall contain only one circuit or group of related parts.

c. The circuit shall be packaged as a single terminal board or plug-in module when possible.

d. Circuits shall be grouped to minimize crisscrossing of signals among modules. [Source: UCRL-15673, 1985]

□ **4.9.2.2.4 Component packaging.** If component packaging is used:

a. Similar components should be grouped in one location, for example, all fuses or all relays.

b. Inexpensive components should be placed on separate plug-in boards that can be discarded upon failure.

c. Similar parts that are likely to require replacement at approximately the same time should be grouped together.

d. Components requiring the same maintenance activity should be grouped together; for example test points or components requiring a particular cleaning method. [Source: UCRL-15673, 1985]

■ **4.9.2.2.5 Printed circuit boards.** If printed circuit boards are used:

a. Printed circuit boards shall be designed and mounted for ease of removal and foolproof replacement.

b. Plug-in printed circuit boards shall be structurally rigid and easy to remove and replace, providing finger access and gripping aids if necessary.

c. Feedback shall be provided to the maintainer when plug-in printed circuit boards are securely connected.

d. Printed circuit boards shall be identified in accordance with MIL-STD-130, and references for parts mounted on the board shall be provided in accordance with MIL-HDBK-454, Requirement 67. [Source: MIL-STD-1472F, 1999]

4.9.3 Layout

Rules governing the layout of the parts that make up a module fall into three general categories: (a) accessibility of the parts, (b) logical or functional grouping of parts, and (c) protection of maintainers and equipment from hazards.

4.9.3.1 Accessibility

■ **4.9.3.1.1 No interference from other parts.** Modules shall be laid out so that all parts can be removed and replaced without interference from and without removal of other parts. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992]

■ **4.9.3.1.2 No stacking of parts.** The parts that make up a module shall be mounted in an orderly, flat, two-dimensional array; they shall not be stacked one on top of another. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999]

- ▫ **4.9.3.1.3 Consistent orientation.** If a module has more than one part of the same type that must be inserted in a particular orientation (connectors, for example), all those parts should be oriented in the same direction. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992]

- ▪ **4.9.3.1.4 Spacing of parts.** The parts that make up a module shall be positioned so that any required tools (such as test probes or soldering irons) can be used without difficulty. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992]

- ▪ **4.9.3.1.5 Separation of parts and wiring on printed circuit boards.** On printed circuit boards, all parts shall be mounted on one side of the board, and all wiring (including printed circuits) shall be placed on the other side. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

- ▪ **4.9.3.1.6 Frequently inspected component parts.** Parts that require frequent visual inspection (fuses, for example) shall be located where they can be seen easily without the removal of panels, covers, or other modules. [Source: AFSC DH 1-3, 1980]

- ▪ **4.9.3.1.7 High failure-rate parts.** Parts that have a high failure rate, such as fuses, shall be located where they can be seen and replaced without the removal of other parts. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999]

- ▫ **4.9.3.1.8 Indicator lights.** If a module contains indicator lights, it should be possible to change the lights from the front panel, that is, without opening or removing the module. [Source: UCRL-15673, 1985]

- ▪ **4.9.3.1.9 Shutoff switches.** If the module contains emergency shutoff switches, they shall be positioned within easy reach of the maintainer, and they shall be located or guarded to prevent inadvertent operation. [Source: MIL-STD-1800A, 1990]

- ▪ **4.9.3.1.10 Visual and physical accessibility.** Test points, adjustment points, and cable and line connectors shall be located where the maintainer can see them easily and perform any required operations on them without interference. [Source: UCRL-15673, 1985]

4.9.3.2 Grouping of parts

- ▪ **4.9.3.2.1 Grouping maintenance displays.** All maintenance displays relevant to a particular task shall be grouped together and located where they are easily visible to the maintainer. [Source: UCRL-15673, 1985]

- ▫ **4.9.3.2.2 Separating maintenance and operational displays.** If a module contains both maintenance and operational displays, the maintenance displays should be separated from the operational displays. [Source: UCRL-15673, 1985]

4.9.3.3 Hazard protection

- **4.9.3.3.1 Avoidance of damage to parts and wiring.** The parts and wiring of a module shall be located and arranged so that they are not damaged when the module or the unit of equipment of which they are part is opened and closed. [Source: AFSC DH 1-3, 1980]

- **4.9.3.3.2 Avoidance of damage from handling.** Parts that are susceptible to damage during maintenance activities shall be located or shielded so that they will not be damaged during these activities. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; UCRL-15673, 1985]

- **4.9.3.3.3 Avoidance of damage from the environment.** Parts shall be positioned so that they are not likely to be damaged by oil, other fluids, dirt, or static electricity. [Source: UCRL-15673, 1985]

- **4.9.3.3.4 Protecting maintainers from heat and electrical shock.** If a module contains parts that retain heat or electrical potential after power is turned off, those parts shall be located where maintainers will not touch them during maintenance activities, or they shall be shielded to protect the maintainers. In addition, heat-producing parts shall be shielded to protect maintainers from injury. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- **4.9.3.3.5 Bleeder networks.** Parts that retain electrical potential after power is turned off shall be equipped with bleeder networks. [Source: MIL-HDBK-759B, 1992]

- **4.9.3.3.6 Separating internal controls from hazardous voltages.** Internal controls such as switches and adjustment controls shall not be located where maintainers might come into contact with hazardous voltages while operating the controls. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; UCRL-15673, 1985]

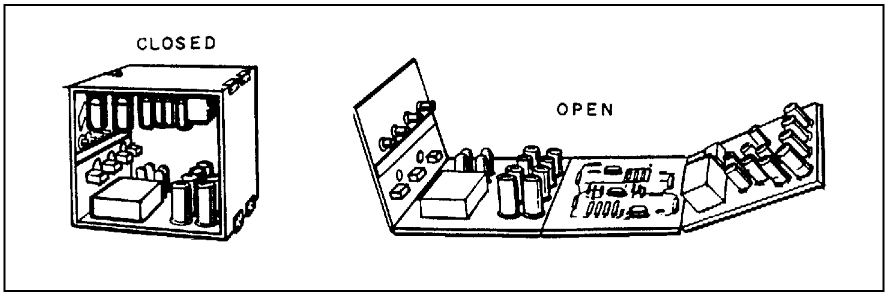
- **4.9.3.3.7 High current switching devices.** High current switching devices shall be shielded to prevent maintainers from coming into contact with them. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

4.9.4 Mounting

This section describes several methods for mounting modules and gives criteria and rules pertaining to these methods; it then lists more general criteria and rules. In mounting a particular module, it may be appropriate to use more than one of these methods simultaneously. [Source: UCRL-15673, 1985]

▫ 4.9.4.1 **Foldout mounting.** Foldout mounting should be used whenever feasible. Exhibit 4.9.4.1 gives an example of foldout mounting. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

Exhibit 4.9.4.1 Example of foldout mounting construction
[Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992, 5.6.18.11; UCRL-15673, 1985]



▪ 4.9.4.2 **Prevention of damage with foldout mounting.** If foldout mounting is used, parts and wiring shall be positioned so that they are not damaged during opening and closing. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

▪ 4.9.4.3 **Support for hinged mounting.** If a module is mounted on hinges, some sort of brace or support shall be provided to hold the module in the "out" or "open" position. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

▪ 4.9.4.4 **Rests and stands.** If a module contains parts that might be damaged when it is moved into position for maintenance activities, the module shall include rests or stands that protect those parts. These rests and stands shall be integral parts of the construction of the module. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

▫ 4.9.4.5 **Characteristics of straps and brackets.** Straps and brackets should:

a. be thick and rounded enough so that there are no sharp edges, and

b. be shorter than the part or module they hold so that they provide a clamping action. [Source: UCRL-15673, 1985]

□ **4.9.4.6 Shock mounts.** Shock mounts should be used as appropriate to

a. eliminate vibration that would make displays and markings difficult to read,

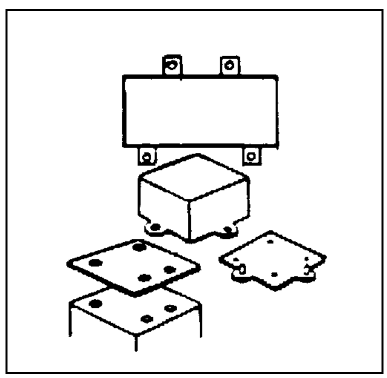
b. reduce noise levels that might be hazardous to maintainers, and

c. reduce levels of vibration that might be hazardous to maintainers or equipment. [Source: UCRL-15673, 1985]

■ **4.9.4.7 Preventing mounting errors by physical design.** Modules shall be designed so that it is physically impossible to mount them incorrectly. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; NASA-STD-3000A, 1989; UCRL-15673, 1985]

Discussion. Incorrect mounting includes reversal, mismating, and misaligning. Measures to prevent incorrect mounting include (a) the incorporation of keys or other aligning devices, (b) the provision of asymmetrical mounting brackets, and (c) the provision of asymmetrical mounting holes. Exhibit 4.9.4.7 illustrates all three of these measures. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; NASA-STD-3000A, 1989; UCRL-15673, 1985]

Exhibit 4.9.4.7 Error-free mounting provisions
[Source: UCRL-15673, 1985]



■ **4.9.4.8 Mounting and orientation of similar items.** Parts and modules that are similar shall use the same mounting method and be mounted with the same orientation. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

■ **4.9.4.9 Accessibility.** Parts and modules that are intended to be removed and replaced by maintainers shall be mounted so that they can be removed without the removal of other parts or modules and without interference from other parts or modules. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992; MIL-STD-1800A, 1990]

- ■ **4.9.4.10 Controls.** Modules shall be mounted so that it is not necessary to disconnect controls that may be needed for maintenance. [Source: AFSC DH 1-3, 1980]

- ■ **4.9.4.11 Common hand tools.** Modules shall be designed so that they are replaceable by hand or with common hand tools. [Source: AFSC DH 1-3, 1980]

- □ **4.9.4.12 Front access.** Modules designed to be replaceable should be accessible through the front surface of the equipment rather than the back. [Source: AFSC DH 1-3, 1980; NASA-STD-3000A, 1989]

- ■ **4.9.4.13 Orientation of modules within cases.** If a module has a case, the proper orientation of the module within its case shall be obvious, preferably through the physical design of the case, rather than through labeling. [Source: MIL-STD-1472F, 1999]

- ■ **4.9.4.14 "Plug-in" connectors.** Electrical connections between modules shall be made using plug-in connectors unless special requirements, such as holding power or sealing, dictate another type. [Source: AFSC DH 1-3, 1980; MIL-STD-1472F, 1999; NASA-STD-3000A, 1989]

4.9.5 Labeling and marking

- ■ **4.9.5.1 When to use labels and markings.** Labels or markings shall be used to

  a. outline and identify functional groups of parts,

  b. identify each part by name or symbol,

  c. indicate direction of current or signal flow to aid troubleshooting, and

  d. if applicable, identify the value and tolerance level of parts. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

- ■ **4.9.5.2 Location of labels and markings -- consistency.** Labels and markings shall be placed consistently in relation to the parts to which they refer. This placement may be on or immediately adjacent to the part. [Source: UCRL-15673, 1985]

- □ **4.9.5.3 Location of labels and markings -- eye level.** If the part being labeled or marked will be below eye level in its installed position, the label or mark should be above the item; if the item will be above eye level, the label or mark should be below the item. [Source: UCRL-15673, 1985]

- ■ **4.9.5.4 Visibility.** Labels and markings shall be placed so that the maintainer can see them without having to move or remove anything. [Source: UCRL-15673, 1985]

- **4.9.5.5 Orientation.** Labels shall be horizontally oriented so that the maintainer can read them while the module is in its installed position. [Source: UCRL-15673, 1985]

- **4.9.5.6 Electrical parts.** Small electrical parts that are attached to mounting boards (resistors and capacitors, for example) shall be labeled or marked on the mounting boards. [Source: UCRL-15673, 1985]

- **4.9.5.7 Parts requiring identification.** The following parts shall be identified with labels or markings on the parts themselves or on the chassis or board adjacent to the part:

  a. all parts identified by designations in drawings, schematics, and parts descriptions of the module,

  b. all wires, sockets, plugs, receptacles, and similar parts having designations in wiring diagrams of the module,

  c. all replaceable mechanical parts,

  d. all semi-fixed electrical items, such as fuses and ferrule-clipped resistors, and

  e. items having critical polarity or impedance ratings. [Source: UCRL-15673, 1985]

- **4.9.5.8 Identification of terminals on terminal strips or blocks.** Terminals on terminal strips or blocks shall be identified on the terminal strip or block itself or on the chassis, adjacent to the terminals (same as Paragraphs 4.7.6.4 and 4.8.1.8.3). [Source: UCRL-15673, 1985]

- **4.9.5.9 Identification of terminals on parts.** Each terminal of a part having terminals (transformers, relays, and capacitors, for example) shall be identified adjacent to the terminal. [Source: UCRL-15673, 1985]

- **4.9.5.10 Identification of parts accessible from both sides.** Receptacles for plugs and other parts that are accessible from both sides of a board or panel shall be identified on both sides. [Source: UCRL-15673, 1985]

- **4.9.5.11 Adequacy of markings.** Markings shall be sufficient to identify a part or component. [Source: UCRL-15673, 1985]

- **4.9.5.12 Durability of markings.** Markings shall be durable enough to last the life of the equipment. [Source: UCRL-15673, 1985]

- **4.9.5.13 Marking stacked parts.** If parts or modules are stacked, marking shall permit identification of the individual parts or modules. [Source: UCRL-15673, 1985]

- **4.9.5.14 Marking enclosed parts.** If a part or module is enclosed or shielded, the marking shall be placed outside the enclosure or shield. [Source: UCRL-15673, 1985]

- **4.9.5.15 Designation of parts.** The alphanumeric designation of a part shall be in accordance with MIL-STD-16 or comparable industry standards. [Source: UCRL-15673, 1985]

- **4.9.5.16 Hazard warnings.** If any hazard exists in connection with a part or module, a warning or caution label shall be provided on the part or module, on the case or cover, or both. [Source: UCRL-15673, 1985]

- **4.9.5.17 Labeling symmetric parts.** Parts that are symmetric in shape shall be labeled or marked to indicate the proper orientation for mounting. [Source: MIL-HDBK-759B, 1992]

- **4.9.5.18 Auxiliary information for parts.** Parts to which auxiliary information applies (for example, values and tolerances of resistors and capacitors) shall be labeled with that information. Preferably this information will be in alphanumeric, not coded, form. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

4.10 Adjustment controls

Rules for accessing, adjusting, sequencing, and reading adjustment controls are given in this section.

- **4.10.1 Controls and feedback.** Each adjustment control shall provide feedback. This feedback might be visual, audible, or tactile. [Source: MIL-STD-1800A, 1990]

- **4.10.2 Simultaneous access to controls and displays.** Maintainers shall have simultaneous access to an adjustment control and its associated display or other source of feedback; that is, they shall be able to observe the effects of adjustments as they are made. [Source: UCRL-15673, 1985]

- □ **4.10.3 Location of adjustment controls.** All the adjustment controls for a module or unit of equipment should be located on a single surface, preferably the front panel or face of the equipment. [Source: MIL-HDBK-759B, 1992]

- □ **4.10.4 Differentiating maintenance controls from operational controls.** When maintenance and operation of a unit of equipment are performed by different sets of people, the maintenance and operational controls should not appear on the same panel. If maintenance and operational controls do appear on the same panel, the maintenance controls should be grouped and separated from the operational controls. If appropriate, the maintenance controls might also be guarded with removable covers so as not to interfere with the operator's performance. [Source: UCRL-15673, 1985; NASA-STD-3000A, 1989]

- **4.10.5 Independence of adjustment controls.** Where possible and practical, the adjustment of one control shall be independent of the adjustments of other controls. [Source: MIL-HDBK-759B, 1992]

- ■ **4.10.6 Sequential adjustments.** If the adjustment of one control affects the adjustment of another, the controls shall be arranged in sequential order, and labeled or marked to indicate the order of adjustment. [Source: MIL-HDBK-759B, 1992]

- □ **4.10.7 Functionally related adjustments.** If a maintenance task consists of adjusting several functionally related variables, a single control with a switch for selecting the particular function should be provided so that the maintainer can select the functions in sequence and make adjustments with the same control. [Source: UCRL-15673, 1985]

- ■ **4.10.8 Direct readings.** If a maintenance task requires adjusting a control to achieve a certain value or range of values, the display shall permit direct reading of the value or range; the maintainer shall not have to convert or transform the reading. [Source: MIL-HDBK-759B, 1992]

- □ **4.10.9 Knob adjustments preferred to screwdriver adjustments.** Knob adjustments should be used rather than screwdriver adjustments, especially if the adjustment is made more than once a month. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

- ■ **4.10.10 Screwdriver adjustments -- preventing slipping.** When screwdriver adjustment controls are used, a positive means, such as guides or slots, shall be provided to prevent the screwdriver tip from slipping. [Source: MIL-STD-1800A, 1990]

- ■ **4.10.11 Screwdriver guides.** If a screwdriver adjustment must be made without the maintainer being able to see the control, or if the control is located near a high voltage, screwdriver guides shall be provided (see Paragraph 4.6.3.2.4). [Source: MIL-STD-1472F, 1999; UCRL-15673, 1985]

- ■ **4.10.12 Use of mirrors or flashlights.** Maintainers shall not have to use mirrors or flashlights in making adjustments. [Source: MIL-STD-1472F, 1999]

- □ **4.10.13 Remote adjustments.** If it is not practical to provide access to an internally located control, a remote control should be provided. [Source: UCRL-15673, 1985]

- ■ **4.10.14 Degree of adjustment.** Controls shall accommodate the degree of adjustment required, that is, gross adjustment, fine adjustment, or both. [Source: MIL-STD-1800A, 1990]

- ■ **4.10.15 Mechanical stops.** Adjustment controls intended to have a limited range of motion shall have mechanical stops; these stops shall be capable of withstanding a force or torque 100 times greater than the resistance to movement within the range of adjustment. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

- ■ **4.10.16 Preventing inadvertent adjustment.** Adjustment controls shall be located and mounted so that they cannot be adjusted inadvertently by the maintainer. [Source: MIL-HDBK-759B, 1992]

- **4.10.17 Critical or sensitive adjustments.** Critical or sensitive adjustments shall incorporate features, such as locking devices, to prevent inadvertent or accidental adjustment. If a locking device is used, operation of the locking device shall not change the adjustment setting. [Source: MIL-STD-1472F, 1999]

- **4.10.18 Hand or arm support.** If an adjustment control or the maintainer will be subjected to disturbing vibration during adjustment, a suitable hand or arm support shall be provided. [Source: MIL-STD-1472F, 1999]

- **4.10.19 Avoidance of hazards.** Adjustment controls shall not be located close to dangerous voltages, moving machinery, or other hazards. If a hazardous location cannot be avoided, the controls shall be appropriately labeled, shielded, and guarded. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

4.11 Fuses and circuit breakers

This section contains rules for systems that use fuses and circuit breakers. General rules address the selection and use of fuses and circuit breakers, the design characteristics of fuses, push-pull circuit breakers, toggle bat and legend switch circuit breakers, and the labeling of fuses and circuit breakers.

4.11.1 General

- **4.11.1.1 Selection of fuses and circuit breakers.** Fuses and circuit breakers should be selected so that they are appropriate to the particular function they will perform. Exhibit 4.11.1.1 lists the appropriate type of fuse or circuit breaker for a variety of functions. [Source: MIL-HDBK-759B, 1992]

  Discussion. When selecting fuses or circuit breakers, consider the suitability of each to perform a particular function. There are two types of circuit breakers, thermal air and magnetic air. Thermal air circuit breakers are used primarily for overcurrent circuit protection. They are best adapted to dc circuits up to 250 volts, and to ac circuits up to 600 volts in capacities up to 600 amperes. Magnetic air circuit breakers may be used to provide protection in event of overcurrent, undercurrent, reverse current, low voltage, and reverse phase. [Source: MIL-HDBK-759B, 1992]

Exhibit 4.11.1.1 General comparison of fuses and circuit breakers

Function	Fuse	Thermal air	Magnetic air
Instantaneous action	X		X
Time delay features	X	X	X
Resetting		X	X
Adjustable tripping range for other than maximum			X
Automatic resetting			X
Remote control resetting and tripping			X
Overcurrent protection	X	X	X
Low current, reverse current, and low voltage protection			X

- ■ 4.11.1.2 **Location of fuses and circuit breakers.** Fuses and circuit breakers shall be grouped in a minimum number of centralized, readily accessible locations for removal, replacement, and resetting. [Source: NASA-STD-3000A, 1989; MIL-STD-1472F, 1999; MIL-HDBK-759B, 1992]

- ■ 4.11.1.3 **Verification of an open circuit.** An indication shall be provided when a fuse or circuit breaker has opened a circuit. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990; NASA-STD-3000A, 1989]

- □ 4.11.1.4 **Individual fused units.** Fuses or circuit breakers should be provided so that each unit of a system is separately fused and adequately protected from harmful variations in voltages. [Source: MIL-HDBK-759B, 1992]

4.11.2 Fuses

- ■ 4.11.2.1 **Using fuses.** Fuses shall conform to MIL-F-15160. [Source: MIL-HDBK-759B, 1992]

- ■ 4.11.2.2 **Worker safety.** Fuse installations shall be designed so that only the "cold" terminal of the fuse can be touched by maintenance personnel. [Source: MIL-HDBK-759B, 1992]

- ■ 4.11.2.3 **Safeguarding the circuit.** Fuses shall be provided that safeguard the circuit if the wrong switch or jack position is used. [Source: MIL-HDBK-759B, 1992]

- ▫ 4.11.2.4 **Quick-disconnect fuse holders.** Fuse holder cups or caps should be of the quick-disconnect type rather than the screw-in type; they should be knurled and large enough to be removed easily by hand. [Source: MIL-HDBK-759B, 1992]

- ■ 4.11.2.5 **No special tools for fuse replacement.** Fuse replacement shall not require special tools, unless they are needed for safety. [Source MIL-STD-1800A, 1990; MIL-STD-1472F, 1999; AFSC DH 1-3, 1980]

- ■ 4.11.2.6 **No other components to be removed.** Fuses shall be located so they can be replaced without removing any other components. [Source: MIL-HDBK-759B, 1992; MIL-STD-1800A, 1990; AFSC DH 1-3, 1980; MIL-STD-1472F, 1999]

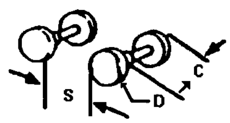
- ■ 4.11.2.7 **Spare fuse provisions.** Spare fuses and holders for them shall be provided and located near fuse holders. Labels adjacent to these spare fuse holders shall contain the word "SPARE" and shall state the fuse values and functions. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

- ▫ 4.11.2.8 **Anticorrosion precautions.** A silicon electrical lubricating compound should be applied to the fuse and the interior of the fuse holder. The exterior of the fuse holder (except contact surfaces) should be coated with fungicidal varnish. Sealed fuses should be used. [Source: MIL-HDBK-759B, 1992]

4.11.3 Push-pull circuit breakers

- ■ 4.11.3.1 **Push-pull circuit breaker specifications.** Push-pull actuated circuit breaker dimensions, displacement, and separation shall conform to Exhibit 4.11.3.1. [Source: MIL-STD-1472F, 1999]

Exhibit 4.11.3.1 Push-pull circuit breaker specifications
[Source: MIL-STD-1472F; MIL-HDBK-759B, 1992; MIL-STD-1800A]

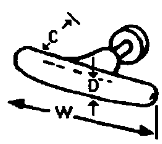


Push-pull control, low resistance, for two-position, mechanical and electrical systems. Alternate three position plus rotary function acceptable for application such as vehicle headlight plus parking lights, panel and dome lights. Provide serrated rim.

D. Minimum diameter 19 mm (0.75 in)	C. Minimum clearance 25 mm (1.0 in) add 13 mm (0.5 in for gloved hand	12-38 mm (0.5-1.5 in) Minimum between pull positions: 13 mm (0.5 in)	S. Minimum space between: 38 mm (1.5 in) add 13 mm (0.5 in) for gloved hand

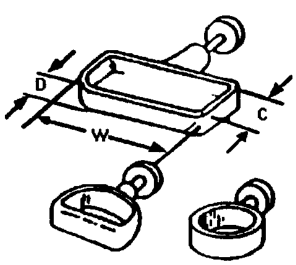
Alternate handle; miniature electrical panel switch only. Avoid glove use application.

D. Minimum N/A diameter: 6.5 mm (0.25 in)	L. Minimum length 19 mm (0.75 in)	Minimum: 13 mm (0.5 in)	S. Minimum space between: 25 mm (1 in)



High-force push-pull, for two-position mechanical system only.

W. Minimum width: 100 mm (4 in)	D. Depth: 16-38 mm (0.6-1.5 in)	C. Minimum clearance: 38 mm (1.5 in) add 6 mm (0.24 in) for gloved hand	Minimum 25 mm (1 in) Preferred: 50 mm (2 in)



Same as above. Preferred where possible garment or cable-snag possibility exists.

W. Minimum width: 100 mm (4 in)	D. Depth: 16-38 mm (0.6-1.5 in)	C. Minimum clearance 38 mm (1.5 in)	Minimum: 25 mm (1 in) Preferred: 50 mm (2 in)	S. Minimum space between: 13 mm (0.5 in)

Note. 1 and 2 finger pulls also acceptable for less than 18 N (4.0 lb) application

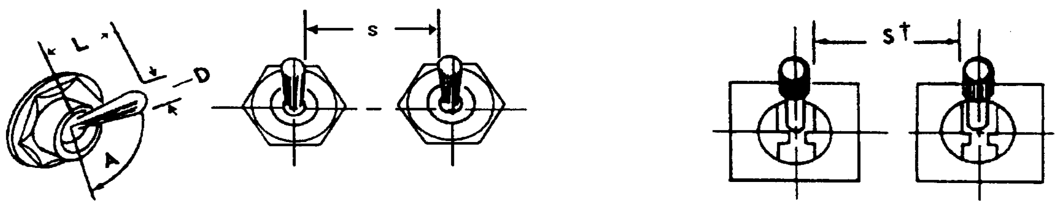
- 4.11.3.2 **Power switches.** Push-pull type circuit breakers shall not be used as power switches. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

4.11.4 Toggle bat and legend switch circuit breakers

Toggle bat and legend switch actuated circuit breakers may be used to control electrical power. [Source: MIL-STD-1472F, 1999]

- **4.11.4.1 Toggle bat specifications.** Dimensions, resistance, displacement, and separation for toggle bat actuated breakers shall comply with Exhibit 4.11.4.1. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

Exhibit 4.11.4.1 Toggle bat specifications



	Dimensions			Resistance	
	L Arm length *	L Arm length **	D Control tip	Small switch	Large switch
Minimum	13 mm (0.5 in)	38 mm (1.5 in)	3 mm (0.13 in)	2.8 N (10 oz)	2.8 N (10 oz)
Maximum	50 mm (2 in)	50 mm (2 in)	25 mm (1 in)	4.5 N (16 oz)	11 N (40 oz)

Displacement between positions

	A 2 position	A 3 position
Minimum	30°	17°
Maximum	80°	40°
Preferred	-	25°

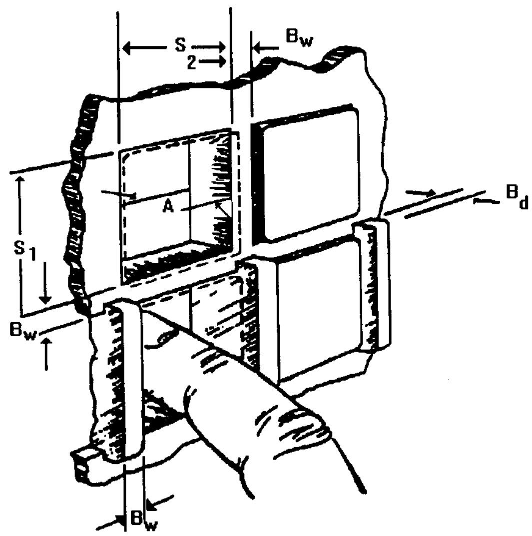
Separation

	S Single finger operation	S Single finger operation †	S Single finger sequential operation	S Simultaneous operation by different fingers
Minimum	19 mm (0.75 in)	25 mm (1 in)	13 mm (0.5in)	16 mm (0.63 in)
Optimum	50 mm (2 in)	50 mm (2 in)	25 mm (1 in)	19 mm (0.75 in)

* Use by bare hand
** Use with heavy handwear
† Using a lever lock toggle switch

- **4.11.4.2 Legend switch specifications.** Legend switch actuated breakers shall comply with the dimension, displacement, separation, and resistance criteria shown in Exhibit 4.11.4.2. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

Exhibit 4.11.4.2 Legend switch specifications. [Source: MIL-STD-1472F; MIL-STD-1800A]



	S_1, S_2 Size	A Displacement	Barriers B_w	Barriers B_d	Resistance
Minimum	19 mm* (0.75 in)	3 mm** (0.13 in)	3 mm (0.13 in)	5 mm (0.38 in)	2.8 N*** (10 oz)
Maximum	38 mm (1.5 in)	6 mm (0.25 in)	6 mm (0.25 in)	6 mm (0.25 in)	16.7 N (60 oz)

* 15 mm (0.63 in) where the switch is not depressed below the panel.
** 5 mm (0.38 in) for positive position switches.
*** 5.6 N (20 oz) for use in moving vehicles.

Note: B_w also refers to switch separation

4.11.5 Labeling and marking

- ■ **4.11.5.1 Fuses and circuit breakers.** Fuses and circuit breakers shall be permanently labeled or marked. The labeling or marking shall be legible in the anticipated ambient illumination range for the maintainer's location. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

- ■ **4.11.5.2 Fuse ratings.** A fuse's rating shall be indicated adjacent to the fuse. The rating shall be in whole numbers, common fractions, such as 1/2, or whole numbers and common fractions, such as 2 1/2. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472F, 1999]

- ■ **4.11.5.3 Circuits.** The area of equipment served by a fuse or circuit breaker shall be identified. [Source: MIL-STD-1800A, 1990; MIL-STD-1472F, 1999]

4.12 Test points and service points

Strategically placed test points make signals available to maintenance personnel for checking, adjusting, and troubleshooting. Test points are recommended for units of equipment that are not completely self-checking. [Source: UCRL-15673, 1985]

> **Definition. Test points** are a means for conveniently and safely determining the operational status of equipment and for isolating malfunctions. **Service points** are a means for lubricating, filling, draining, charging, and performing other service functions. They permit the routine performance of these services on all equipment and components requiring them. [Source: UCRL-15673, 1985]

4.12.1 Adjustment controls

- ■ **4.12.1.1 Location.** An adjustment control associated with a test point shall be located near the test point and shall provide a signal at the test point that indicates clearly when the correct adjustment has been achieved. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992]

- □ **4.12.1.2 Individual adjustment controls.** A test point should not have more than one associated adjustment control. [Source: AFSC DH 1-3, 1980]

4.12.2 Location and arrangement

□ **4.12.2.1 Test points for units of equipment.** A test point should be provided for each input to and output from a unit of equipment. [Source: AFSC DH 1-3, 1980]

■ **4.12.2.2 Arranging test points.** When testing complexity warrants, test points shall be arranged on a single control panel or on a series of functionally autonomous panels. [Source: UCRL-15673, 1985; AFSC DH 1-3, 1980]

□ **4.12.2.3 Tracing signals.** Test points should be provided to permit the systematic tracing of signals and voltages through a unit of equipment. These test points allow a maintainer to determine the point at which signals or voltages in a malfunctioning unit are out of tolerance. [Source: AFSC DH 1-3, 1980]

■ **4.12.2.4 Test and service point accessibility.** All test and service points shall be physically and visually accessible to the maintainer. [Source: MIL-HDBK-759B, 1992]

■ **4.12.2.5 Proximity to associated controls and displays.** Test and service points shall be located in physical and visual proximity to the controls and displays used to make the adjustments associated with the points. [Source: NASA-STD-3000A, 1989; MIL-STD-1472F, 1999; UCRL-15673, 1985]

□ **4.12.2.6 Test and service point location.** Test and service points should be provided, designed, and located in accordance with their frequency of use and any applicable time limits on maintenance activities. [Source: MIL-HDBK-759B, 1992]

□ **4.12.2.7 Minimizing testing and servicing.** Requirements for periodic or repetitive testing and servicing of components should be avoided if possible by using sealed bearings, oil impregnated bushings, highly reliable components, and the like. [Source: UCRL-15673, 1985]

■ **4.12.2.8 Minimizing test and service points.** To reduce the number of test and service points required, built-in indicators, center reading meters, pressure gauges, direct reading fluid level gauges, and the like shall be used for quick checks, thus avoiding the need for auxiliary equipment. [Source: UCRL-15673, 1985]

□ **4.12.2.9 Avoid isolated test or service points.** Isolated test or service points should be avoided; such points are likely to be overlooked or neglected. [Source: MIL-HDBK-759B, 1992]

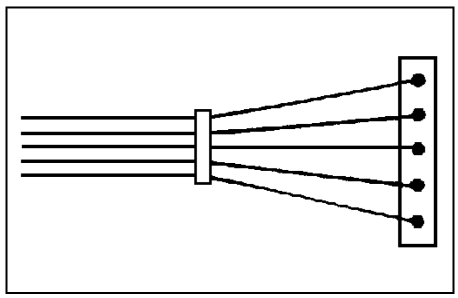
■ **4.12.2.10 Compatibility of test and service points.** Test and service points shall be designed for compatibility with checking, troubleshooting, and servicing procedures and with test and service equipment. [Source: UCRL-15673, 1985]

□ **4.12.2.11 Distinctive connections.** Distinctively different connectors or fittings should be provided for each type of test or service equipment (for example, grease and oil fittings should be distinctively different from each other) to minimize the likelihood of error. [Source: MIL-HDBK-759B, 1992]

□ **4.12.2.12 Avoid separate accessories.** Separate funnels, strainers, adapters, and other accessories should be avoided. Where practical, these accessories should be built into the equipment or the service equipment, so that they need not be handled separately. [Source: MIL-HDBK-759B, 1992]

□ **4.12.2.13 Terminal strips.** If special test points are not provided on electrical equipment, cables should be fanned out on terminal strips as illustrated in Exhibit 4.12.2.13. [Source: UCRL-15673, 1985]

Exhibit 4.12.2.13 Terminal strips



4.12.3 Drain points

■ **4.12.3.1 Drain provisions.** Drains shall be provided on all fluid tanks and systems, fluid filled cases, filter systems, float chambers, and other items that are likely to contain fluid that would otherwise be difficult to remove. [Source: UCRL-15673, 1985]

□ **4.12.3.2 Minimization.** The number of types and sizes of drain fittings should be minimized and standardized throughout the system. [Source: UCRL-15673, 1985]

□ **4.12.3.3 Valves and petcocks versus drain plugs.** Whenever practical, valves or petcocks should be used rather than drain plugs. [Source: UCRL-15673, 1985]

■ **4.12.3.4 Drain plugs**. Drain plugs shall require only common hand tools for operation, and their placement shall ensure adequate tool and work clearance for operation. [Source: UCRL-15673, 1985]

■ **4.12.3.5 Labels.** Drain cocks or valves shall be clearly labeled to indicate open and closed positions, and the direction of movement required for opening. [Source: UCRL-15673, 1985]

■ **4.12.3.6 Drain cock motions.** Drain cocks shall always close with clockwise motion and open with counterclockwise motion. [Source: UCRL-15673, 1985]

- ■ 4.12.3.7 **Instruction labels.** Instruction labels shall be provided, as necessary, to ensure that the fluid system is properly prepared prior to draining. [Source: UCRL-15673, 1985]

- ■ 4.12.3.8 **Accessibility.** As applicable, drain points shall be designed, located, and installed

  a. where they are reachable and operable by the maintainer,

  b. so that fluid will not drain or spill on equipment or personnel,

  c. at the lowest point in the system if complete draining is required,

  d. to permit selective draining or bleeding to facilitate maintenance procedures,

  e. to permit drainage directly into a waste container without use of separate adapters or piping, and

  f. so that fuel or other combustible fluids cannot run down to or collect in hazardous areas. [Source: UCRL-15673, 1985]

4.12.4 Accessibility

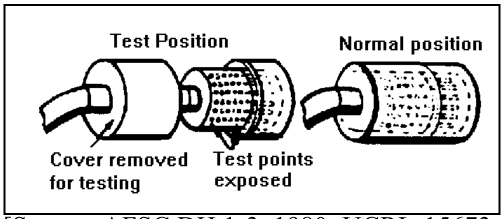
- ■ 4.12.4.1 **Test and service point accessibility.** Test and service points shall be easily accessible for checking and troubleshooting. Recommended minimum clearances are 19 mm (0.75 in) when only finger control is required, and 75 mm (3 in) when the gloved hand is used. [Source: UCRL-15673, 1985; AFSC DH 1-3, 1980]

- □ 4.12.4.2 **Test probe guides.** Suitable guides for test probes should be provided when test points are located internally. [Source: UCRL-15673, 1985]

- □ 4.12.4.3 **Test accesses.** Test accesses should be provided for mechanical components likely to wear. For example, brake assemblies should be provided with an inspection opening to permit insertion of a gauge for determining the clearance between the brake lining and drum. [Source: UCRL-15673, 1985; AFSC DH 1-3, 1980]

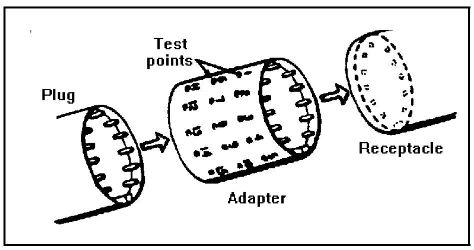
▪ **4.12.4.4 Test points in plugs.** If appropriate, plugs with integral test points for each input and output shall be used. If dust or moisture is a factor, an integral sliding cover for the test points shall be provided on the plug, as shown in Exhibit 4.12.4.4 (a). An acceptable alternative is the provision of a test-point adapter for insertion between a plug and its receptacle, as shown in Exhibit 4.12.4.4 (b). [Source: AFSC DH 1-3, 1980]

Exhibit 4.12.4.4 (a) Test plug with sliding cover



[Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

Exhibit 4.12.4.4 (b) Test point adapter



[Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

4.12.5 Safety

▪ **4.12.5.1 Test point shielding.** All test points shall be located or shielded to protect the maintainer against contact with high voltages. [Source: AFSC DH 1-3, 1980]

▪ **4.12.5.2 Minimum clearance.** Test and service points shall be separated by more than a hand's width, 114 mm (4.5 in), from the nearest hazard. [Source: UCRL-15673, 1985]

▫ **4.12.5.3 Recessed test and service points.** Test and service points should be recessed to protect them from damage by personnel, dust, moisture, and the like. [Source: UCRL-15673, 1985]

▫ **4.12.5.4 High pressure test indicators.** High pressure test indicators should be used wherever possible to avoid some of the hazards associated with making temporary high pressure connections. [Source: UCRL-15673, 1985]

- ■ **4.12.5.5 Ground points.** If a good grounding point is not available, a special "ground" point shall be provided. Connection to this special ground point shall be made during tests of a given unit. [Source: UCRL-15673, 1985]

  Discussion. Maintainers may have difficulty if only painted surfaces are available for ground connections. [Source: UCRL-15673, 1985]

- ▫ **4.12.5.6 Shields around lubrication points.** Shields should be provided around lubrication points that may be serviced while equipment is operating. [Source: UCRL-15673, 1985]

4.12.6 Labeling, marking, and coding

- ■ **4.12.6.1 Label location.** Labels for test and service points shall be in full view of the maintainer making connections or adjustments. [Source: UCRL-15673, 1985]

- ■ **4.12.6.2 Distinguishable marking.** Test and service points shall be designed and marked so that they are easily distinguishable, for example, by coding them with distinctive colors. [Source: UCRL-15673, 1985; AFSC DH 1-3, 1980]

- ■ **4.12.6.3 Distinguishing test and service points.** If color-coding is used, the color of test points shall be clearly different from the color of service points. [Source: UCRL-15673, 1985]

- ■ **4.12.6.4 Hazardous points.** Hazardous test and service points shall be labeled to warn maintainers about any possible injury to themselves or damage to internal circuits. [Source: NASA-STD-3000A, 1989; UCRL-15673, 1985]

- ■ **4.12.6.5 Identification of test points.** Each test point shall be clearly labeled with a number, letter, symbol, or description of its function or, at a minimum, with a code number keyed to the user documentation. [Source: NASA-STD-3000A, 1989; AFSC DH 1-3, 1980]

- ▫ **4.12.6.6 Luminescent markings.** If test points must be read under very low ambient illumination, they should be marked in phosphorescent colors. [Source: AFSC DH 1-3, 1980]

- ▫ **4.12.6.7 Tolerance limits.** Each test point should be labeled with the tolerance limits of the signal to be measured there. [Source: AFSC DH 1-3, 1980]

- ■ **4.12.6.8 Internal test and service points.** When a test or service point is located internally, its location shall be indicated on the cover or adjacent to its access opening on the surface of the equipment. [Source: UCRL-15673, 1985]

4.13 Test equipment

This section contains general rules for test equipment and specific rules for four types of test equipment: (a) built-in, (b) go, no-go, (c) automatic, and (d) collating. Bench mockups and storage for test equipment are also addressed.

Definitions. Built-in test equipment is an integral part of a unit of equipment and can range from a simple voltmeter to a complex automatic checker. **Go, no-go test equipment** provides one of two alternative answers to any question. For example, it tells whether a given signal is in or out of tolerance. **Automatic test equipment** checks two or more signals in sequence without the intervention of a maintainer. The test usually stops when the first out-of-tolerance signal is detected. **Collating test equipment** presents the results of two or more checks as a single display; for example, a light might come on only if a number of different signals are in tolerance. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

4.13.1 General

Test equipment is intended to (a) simplify the job of the maintainer, (b) reduce the preparation or turn-around time for installing, maintaining, and repairing systems, and (c) reduce total maintenance costs. It needs to be fast, easy, and safe to use.

The type of test equipment is decided upon in the early stages of equipment design. Selection of test equipment depends on (a) the mission and operational characteristics of the equipment, (b) the anticipated reliability of the equipment, (c) the maintenance concept, (d) the available personnel, (e) the operational environment, (f) the logistics support requirements, and (g) the development time and cost. [Source: UCRL-15673, 1985]

4.13.1.1 General characteristics

The following general rules are aimed at simplifying the maintainers' job.

- **4.13.1.1.1 Test equipment treatment.** Test equipment and bench mockups shall be treated like any other equipment with respect to design requirements for units, covers, cases, cables, connectors, test points, displays, and controls. [Source: UCRL-15673, 1985, 1.8.2]

- **4.13.1.1.2 Accuracy of test equipment.** The accuracy of all test equipment shall exceed that of the equipment being tested. [Source: NASA-STD-3000A, 1989]

- **4.13.1.1.3 Conversion tables.** Conversion tables shall not be used in deciding if equipment is within tolerances. [Source: UCRL-15673, 1985]

- ▫ **4.13.1.1.4 Selector switches.** Selector switches should be used rather than multiple plug-in connections as long as the effects of switching do not degrade the desired information. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

  Discussion. Selector switches can be used more quickly than plug-in connections, and they reduce the likelihood of faulty connections. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

- ▪ **4.13.1.1.5 Maintenance instructions.** Clear operating and maintenance instructions shall be prepared and available to the maintainer. [Source: AFSC DH 1-3, 1980]

- ▪ **4.13.1.1.6 Storing instructions.** Full instructions shall be stored inside the test equipment's cover or case, if any, or attached to a metal plate containing a checklist for operating the equipment. [Source: AFSC DH 1-3, 1980]

- ▫ **4.13.1.1.7 Labeling.** The outer case and all removable parts should be clearly labeled with the equipment identification, including its purpose and any precautions that should be observed in using it. [Source: AFSC DH 1-3, 1980]

- ▪ **4.13.1.1.8 Label contents.** The label shall contain all items the maintainer must be able to recognize, read, or use. [Source: AFSC DH 1-3, 1980]

4.13.1.2 Safety

- ▪ **4.13.1.2.1 Shielding hazardous parts.** Test equipment shall be designed so that all exposed moving and cutting parts are shielded to prevent maintainer injuries during maintenance tasks. [Source: UCRL-15673, 1985]

- ▫ **4.13.1.2.2 Minimizing hazards.** When possible, fail-safe features should be incorporated in test equipment to minimize any danger to maintainers or equipment. [Source: UCRL-15673, 1985]

- ▪ **4.13.1.2.3 Internal controls.** Internal controls shall be located away from dangerous voltages. [Source: UCRL-15673, 1985]

- ▪ **4.13.1.2.4 Safeguarding high voltages.** High voltage areas shall be insulated or shielded. [Source: UCRL-15673, 1985]

- ▪ **4.13.1.2.5 Warning labels.** Adequate warnings shall be provided wherever potential hazards exist. [Source: UCRL-15673, 1985]

4.13.1.3 Ease of use

- ▪ **4.13.1.3.1 Accessibility.** Adjustment points, test points, cables, connectors, and labels for all required maintenance tasks shall be visually and physically accessible. Access openings necessary to connect test equipment using required tools shall accommodate maintainers and equipment as specified in Paragraph 4.4.3 and Paragraph 4.12.4.1. [Source: MIL-STD-1800A, 1990]

- **4.13.1.3.2 Minimizing test equipment.** The number and types of test equipment and accessories, such as connectors and test cables, should be minimized. [Source: UCRL-15673, 1985]

- **4.13.1.3.3 Ease of use.** Equipment should be simple to operate, have self-checking and calibrating features, and have a minimum number of controls and displays. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

- **4.13.1.3.4 Reducing the number and complexity of steps.** The number and complexity of steps should be reduced by grouping controls (such as by sequence or criticality) or by making certain operations automatic. [Source: AFSC DH 1-3, 1980]

- **4.13.1.3.5 Individual operation.** Test equipment should be designed for operation by one person. [Source: UCRL-15673, 1985]

4.13.1.4 Controls and displays

- **4.13.1.4.1 Calibration check.** Test equipment should be easily calibrated or equipped with a simple check (for example, a go, no-go indicator) to indicate whether or not the test equipment is out of calibration or is malfunctioning. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

- **4.13.1.4.2 Warm-up indicators.** A warm-up indicator should be provided, if applicable, to show when the test equipment is warmed up and ready to use. If such a signal cannot be provided, a label near the warm-up switch should state clearly how much warm-up time is required. [Source: UCRL-15673, 1985; AFSC DH 1-3, 1980]

- **4.13.1.4.3 Automatic shutoff switches.** If feasible, test equipment should have an automatic shutoff. If it is not feasible, test equipment should have both warning lights and written warnings to remind the maintainer to turn the equipment off when finished. [Source: UCRL-15673, 1985]

- **4.13.1.4.4 Misalignment.** Controls and displays should be designed to prevent misalignment that might be caused by vibration, service use, or accidental contact. [Source: UCRL-15673, 1985]

4.13.2 Built-in test equipment (and partially built-in, portable, and test panels)

The advantages of built-in test equipment include (a) being less likely than portable test equipment to be lost or damaged, (b) being available when needed, and (c) requiring no special storage facilities.

The disadvantages of built-in test equipment include (a) adding to the weight and space requirements of the equipment being tested, (b) requiring more built-in test equipment because a separate item is usually required for each unit of equipment, (c) transporting built-in test equipment to a point for convenient calibration may be more difficult than transporting portable test equipment, and (d) installing test equipment permanently may increase the complexity of wiring for the system and may even increase the amount of maintenance activity.

Definition. Built-in test equipment is an integral part of a unit of equipment and can range from a simple voltmeter to a complex automatic checker.

4.13.2.1 Completely built-in test equipment

- 4.13.2.1.1 **Combining test points.** If a unit of equipment has built-in test capabilities, all maintenance tests should be performed with the built-in test unit. [Source: AFSC DH 1-3, 1980]

- 4.13.2.1.2 **Efficiency.** If possible, built-in test units should be integrated into the equipment for efficient maintenance and troubleshooting. [Source: UCRL-15673, 1985]

  Discussion. If voltages and wave shapes must be checked, for example, the test unit might consist of a meter, an oscilloscope, and a rotary switch for selecting circuits. [Source: UCRL-15673, 1985]

- 4.13.2.1.3 **Easy to use.** Meters and oscilloscopes should have fixed, preset circuits so that the meter always reads center scale and the oscilloscope requires no adjustment. [Source: UCRL-15673, 1985]

- 4.13.2.1.4 **In-tolerance.** Either an in-tolerance meter reading or an in-tolerance waveshape on the oscilloscope should be coded for each position of the rotary switch. If more test points are needed than can be handled by a single switch, multiple switches can be used. [Source: UCRL-15673, 1985]

4.13.2.2 Partially built-in test equipment

- 4.13.2.2.1 **Combining test points.** If possible, all test points should be incorporated into one built-in unit of test equipment. [Source: AFSC DH 1-3, 1980]

□ **4.13.2.2.2 Test capabilities.** To the extent feasible, all the test capabilities described in Paragraph 4.13.2.1 should be built-in. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

Example. A center-reading meter might be mounted on each major component that can be checked by a meter, and a set of test jacks might be provided as an outlet for signals requiring an oscilloscope. [Source: AFSC DH 1-3, 1980; UCRL-15673, 1985]

4.13.2.3 Portable test equipment

■ **4.13.2.3.1 When to use.** If it is not practical to incorporate all test points into one unit of built-in test equipment or to provide a center-reading meter and test jacks for an external oscilloscope, a portable test unit shall be provided. [Source: AFSC DH 1-3, 1980]

■ **4.13.2.3.2 Single connection.** Portable test equipment shall connect to its associated unit of equipment or partially built-in test equipment through a single, multi-prong connector. [Source: NASA-STD-3000A, 1989; AFSC DH 1-3, 1980; UCRL-15673, 1985]

■ **4.13.2.3.3 Internal storage.** Portable test equipment shall have enough storage space in its handling case or lid to contain leads, probes, spares, and any special tools required for operation. [Source: MIL-STD-1800A, 1990; MIL-STD-1472F, 1999]

■ **4.13.2.3.4 Operating instructions.** Instructions for operating portable test equipment shall be provided on the face of the test equipment, on its case or cover, if any, or in a special storage compartment in the test. These instructions shall be easily readable by the maintainer while the test equipment is being operated. If applicable, the instructions shall include a reminder to calibrate the equipment and instructions for calibration. [Source: MIL-STD-1800A, 1990]

■ **4.13.2.3.5 Calibration records.** If applicable, a placard shall be attached to the equipment for recording calibration information, including tolerance check values. [Source: MIL-STD-1472F, 1999]

4.13.2.4 Built-in test panel

□ **4.13.2.4.1 When to use.** If built-in, partially built-in, or portable test units are not practical, a test panel should be provided on the equipment. [Source: UCRL-15673, 1985]

■ **4.13.2.4.2 Test point connections.** Test points shall permit the connection of appropriate test equipment, such as voltage meters or oscilloscopes. [Source: UCRL-15673, 1985]

□ **4.13.2.4.3 Block diagram.** The test points on a test panel should be arranged within a miniature block diagram of the system, with each block representing components or units of equipment. [Source: UCRL-15673, 1985]

- **4.13.2.4.4 Overlays.** Overlays for the test panel should be provided to direct the maintainer to test points that should be checked and the order in which they should be checked. Instructions should be provided in the user documentation. [Source: UCRL-15673, 1985]

- **4.13.2.4.5 Tolerance limits for signals.** Tolerance limits for signals should be shown on overlays, and test points should be coded on the test panel. Full instructions should be provided in user documentation so that they are still available in the event an overlay is lost. [Source: UCRL-15673, 1985]

4.13.3 Test equipment

There are three classifications of test equipment: **go/no-go test equipment**, **automatic test equipment**, and **collating test equipment.**

> **Definition. Go, no-go test equipment** provides one of two alternative answers to any question. For example, it tells whether a given signal is in or out of tolerance.
>
> **Definition. Automatic test equipment** checks two or more signals in sequence without the intervention of a maintainer. Testing usually stops when the first out-of-tolerance signal is detected.
>
> **Definition. Collating test equipment** presents the results of two or more checks as a single display; for example, a "test passed" light would come on only if all of the relevant signals are in tolerance.

The advantages of go, no-go test equipment include (a) presenting information in a clear, unambiguous manner and (b) simplifying difficult tasks, such as balancing circuits and checking complex waveshapes.

The disadvantages include (a) requiring unique circuitry for each signal value to be tested (sometimes, however, ordinary displays can be converted to go, no-go displays by appropriate use of reference scales such as a colored section on a meter dial), (b) increasing the number and complexity of circuits required, which will probably add to initial cost and development time and increase the rate of test equipment breakdown, (c) providing relatively little help to the maintainer in checking common voltages or simple waveshapes, and (d) requiring a special model for many or most units of equipment. [Source: UCRL-15673, 1985]

An advantage of automatic test equipment is that it can make a rapid sequence of checks with little or no chance of omitting steps.

Disadvantages of automatic test equipment include: (a) it can be relatively expensive, large, and heavy, and it may require maintenance of itself, (b) it can be relatively specialized, with little versatility, (c) it can require self-checking features to detect test equipment malfunctioning, which adds to cost and to problems of maintaining the test equipment, and (d) it will probably require a special model for each unit of equipment. [Source: UCRL-15673, 1985; AFSC DH 1-3, 1980]

An advantage of collating test equipment is that it reduces the number of displays the maintainer must read, thereby reducing testing time and, probably, errors.

The disadvantages are similar to those for go, no-go and automatic test equipment. [Source: UCRL-15673, 1985; AFSC DH 1-3, 1980]

□ **4.13.3.1 Identification of out-of-tolerance signals.** If equipment fails a test performed by collating test equipment, the test equipment should indicate which signal(s) are out of tolerance, not just that the equipment failed the test. [Source: UCRL-15673, 1985]

4.13.4 Bench mockups

□ **4.13.4.1 Accessibility.** Bench mockup cables should comply with 4.8.1.7, Bench mockup cables.

■ **4.13.4.2 Accessibility.** Adequate space shall be provided in the layout of a mockup to allow the maintainer to perform any required maintenance activities on the units. [Source: AFSC DH 1-3, 1980]

■ **4.13.4.3 Support for test equipment.** Pullout shelves or some other method of supporting the test equipment shall be provided while the test equipment is being used. [Source: AFSC DH 1-3, 1980]

□ **4.13.4.4 Test leads.** Test leads should require no more than a fraction of a turn for attachment to the equipment being maintained. [Source: AFSC DH 1-3, 1980]

■ **4.13.4.5 Signal values.** The operating instructions for bench mockups shall include correct signal values and tolerances for each test point. [Source: AFSC DH 1-3, 1980]

□ **4.13.4.6 Covers.** Transparent, plastic covers should be used on mockup units that contain parts whose operation may be checked visually, unless a metal cover is needed for electrical shielding. [Source: AFSC DH 1-3, 1980]

■ **4.13.4.7 Easy access.** All mockup units shall be installed so that every unit is accessible without removing any other unit. [Source: AFSC DH 1-3, 1980]

4.13.5 Storage space

- **4.13.5.1 Available storage.** Storage space shall be provided for removable items, for example, test leads. [Source: AFSC DH 1-3, 1980]

- **4.13.5.2 Securing accessories.** Fasteners and holders shall be provided to hold accessories securely and safely in the storage compartment. [Source: AFSC DH 1-3, 1980]

- **4.13.5.3 Labeling.** A label shall show the intended contents of the storage compartment and how they should be stored. [Source: AFSC DH 1-3, 1980]

- **4.13.5.4 Handles.** If test equipment has hinged handles on the cover or case, the handles shall be recessed for convenient storage. [Source: AFSC DH 1-3, 1980]

4.14 Tools

Rules for common hand tools and special tools are given in this section. The tools required by maintainers depend upon the nature of the maintenance tasks and the characteristics of the equipment. It is highly desirable that the need for special tools, that is, tools other than the most common types and sizes of hand tools, be eliminated or at least minimized. This goal can best be accomplished early in the equipment design process, but it deserves attention throughout design and development. [Source: MIL-HDBK-759B, 1992]

4.14.1 General

- **4.14.1.1 Minimize maintenance tools.** Units of equipment shall be designed to minimize the numbers and types of auxiliary tools required to accomplish maintenance tasks. [Source: NASA-STD-3000A, 1989]

- **4.14.1.2 Use common tools.** Whenever possible, units of equipment shall be designed to use common tools for maintenance. [Source: AFSC DH 1-3, 1980; MIL-HDBK-759B, 1992]

- **4.14.1.3 Minimize variety and sizes of tools required.** The variety and number of different sizes of tools required shall be minimized; ideally, the tools required shall be limited to those normally found in a maintainer's tool kit. [Source: MIL-HDBK-759B, 1992]

- **4.14.1.4 Special tools.** Uncommon or specially-designed tools shall be used only when common hand tools do not satisfy the requirements or when the special tools provide a significant advantage over common hand tools. Special tools shall not be required or used without the approval of the acquisition program office. [Source: MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

4.14.2 Common hand tools

- ■ **4.14.2.1 Use common test equipment and tools.** Systems and units of equipment shall be designed so that maintenance can be accomplished with common test equipment and tools. [Source: AFSC DH 1-3, 1980]

- ■ **4.14.2.2 Gripping surfaces.** Tool handles shall have adequate gripping surfaces. [Source: MIL-HDBK-759B, 1992]

- □ **4.14.2.3 Providing thongs.** If a tool will be used where dropping it could cause injury, damage, or significant loss of time, the tool should be provided with a thong or other means of attachment to the maintainer or the equipment. [Source: MIL-HDBK-759B, 1992]

- ■ **4.14.2.4 Insulation of handles.** If a tool will be used in the vicinity of voltages in excess of 30 volts, the tool handle and any other part of the tool the maintainer is likely to touch shall be electrically insulated. [Source: MIL-HDBK-759B, 1992]

4.14.3 Special tools

- ■ **4.14.3.1 Reasons for requiring special tools.** Special tools shall be required only when common tools cannot be used or when they are necessary to facilitate maintenance tasks, reduce time, or improve accuracy. [Source: MIL-HDBK-759B, 1992]

- ■ **4.14.3.2 Availability of special tools.** If a special tool is required for the maintenance of a unit of equipment, the tool shall be made available at the same time as the equipment. [Source: MIL-HDBK-759B, 1992]

- □ **4.14.3.3 Attach to equipment.** If a unit of equipment requires a special tool for maintenance, the tool should be mounted on or attached to the equipment in a readily accessible location. [Source: MIL-STD-1472F, 1999]

Glossary

Automatic test equipment - Checks two or more signals in sequence without the intervention of a maintainer. The test usually stops when the first out-of-tolerance signal is detected.

Built-in test equipment - An integral part of a unit of equipment and can range from a simple voltmeter to a complex automatic checker.

Cable - A number of lines bound together within a single, permanent sheath.

Case - The part of a unit of equipment that encloses and protects the equipment from its surroundings. It may also serve to protect the surroundings - including maintainers - from the equipment.

Collating test equipment - Presents the results of two or more checks as a single display; for example, a light might come on only if a number of different signals are in tolerance.

Component - A subdivision of a unit of equipment that can be treated as an object by the maintainer, but which can be further broken down into parts. A mounting board together with its mounted parts is an example of a component.

Connector - A piece of hardware that joins or attaches lines or cables to other lines or cables or to units of equipment. The term is used rather loosely to refer to either of the two parts that mate with each other and to the plug that mates with a receptacle.

Cover - A part of a unit of equipment that closes an access opening.

Fasteners - Devices that join, attach, and mount parts, components, cases, covers, and units of equipment. They include quick fastening and releasing devices, screws, bolts, latches, catches, rivets, retainer rings, and retainer chains.

Go, no-go test equipment - Provides one of two alternative answers to any question. For example, it tells whether a given signal is in or out of tolerance.

Guard - An enclosure or barrier intended to prevent inadvertent or unauthorized operation of a control.

Hazardous condition - The presence of energy or a substance which is likely to cause death or injury by reason of physical force, shock, radiation, explosion, flames, poison, corrosion, oxidation, irritation or other debilitation. Biological and chemical hazards can have debilitating effects through disease or interference with physiological functions.

Hazardous location - A space within a facility, room, or open environment where a hazardous condition exists or is accessible or exposed within the system or equipment located within the space.

Interlocks - Devices (for example, switches) connected with a cover, shield, or case that disable the associated internal hazard (usually electrical) when the cover, shield, or case is opened. OSHA regulations discuss lockout and tagout procedures to be used in the workplace during maintenance or operations to protect from electrical hazards.

Item - A nonspecific term used to denote any product, available or in design or development, including parts, components, modules, and units of equipment.

Label - Alphanumeric information that identifies or describes an object. Labels can be printed directly on or adjacent to the object, or they can be printed on a card or plate that is attached to the object or adjacent to the object.

Layout - The physical arrangement of the parts and components that make up a module or a unit of equipment.

Limit stops - Mechanisms that restrict a moving object or part by stopping it at predetermined (limit) positions.

Line - Any single length of pipe, wire, or tubing.

Lockout - Uses a mechanical means to disable a control or switch in its safe position (for example, electricity disconnected) and to prevent its activation without the use of undue force or tools.

Marking - Nonverbal information, such as colors or symbols, that identifies or describes an object. Marking can appear directly on or adjacent to the object, or it can be printed on a card or plate that is attached to the object or adjacent to the object.

Modularization - The separation of equipment into physically and functionally distinct units that can be easily removed and replaced.

Module - An assemblage of two or more interconnected parts or components that comprise a single, physical and functional entity. It is this singular functionality that defines a module.

Mounting - The positioning and attachment of parts, components, and modules.

Packaging - (of a unit of equipment) - The assembling, mounting, and enclosing of the items it includes.

Part - An object that cannot normally be broken down further without destroying its designated use. Fuses, resistors, and capacitors are examples of parts.

Service points - A means for lubricating, filling, draining, charging, and performing other service functions. They permit the routine performance of these services on all equipment and components requiring them.

Shield - An enclosure or barrier intended to protect components that are susceptible to damage or to protect maintainers from possible injury.

Tagouts - Tags that are attached to a control or place of hazard to identify the required control condition and hazard associated with an ongoing mode of operation or maintenance.

Test points - A means for conveniently and safely determining the operational status of equipment and for isolating malfunctions.

Unit of equipment - An assemblage of items that may include modules, components, and parts that are packaged together into a single hardware package. For example, a computer, its keyboard, and its visual display are all units of equipment, as are radio transmitters and receivers.

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5 Displays and printers

This section presents information on different means of presenting output information to the user visually. In particular, this chapter covers different types of monitors (also known as Video Display Terminals (VDTs), Video Display Units (VDUs), or Cathode Ray Tubes (CRTs)), projection displays, stereoscopic displays, printers and plotters.

5.1 Displays

This section covers visual displays used for information output. It does not address touch screen displays or visual indicators such as LED displays and lights accompanying switches and controls. Touch screen displays are in the input devices chapter (Chapter 9) and visual indicators are addressed in the chapter on controls and visual indicators (Chapter 6).

5.1.1 General

□ **5.1.1.1 Make displays function under operational conditions.** Visual displays should function under any circumstance corresponding with the operational and use philosophies of the system. [Source: Department of Defense (MIL-STD-1472F), 1999]

■ **5.1.1.2 Make displays legible under all conditions.** Visual displays shall be legible under all anticipated viewing conditions. [Source: MIL-STD-1472F, 1999]

Discussion. Factors affecting the **legibility** of a display include the nature and characteristics of the display itself, ambient lighting, and viewing distance.

□ **5.1.1.3 Avoid unnecessary markings.** Trademarks, company names, and other markings not needed to identify a display or aid in performing tasks should not be displayed on a panel face. [Source: MIL-STD-1472F, 1999]

■ **5.1.1.4 Ensure adequate refresh rate.** Displays that require refreshing of information such as CRTs, heads up displays, and collimated displays, shall be refreshed at a rate that insures that the displayed information is sufficiently current for the users to perform their tasks. [Source: MIL-STD-1472F, 1999]

Definition. Refresh rate is the rate in cycles per second (Hz) at which the displayed contents of a computer screen are periodically regenerated.

- **5.1.1.5 Provide adjustable contrast and brightness.** Visual displays should provide users with the capability of adjusting contrast and/or brightness. [Source: Vanderheiden & Vanderheiden, 1991]

- **5.1.1.6 Controls should conform to Chapter 6.** Controls for displays should conform to the design criteria contained in Chapter 6, Controls and visual indicators.

5.1.2 Location and arrangement

- **5.1.2.1 Locate displays to be readable without assuming uncomfortable positions.** Displays shall be located so that a user can read them to the degree of accuracy required without having to assume an uncomfortable, awkward, or unsafe position. [Source: MIL-STD-1472F, 1999]

  Discussion. Locating visual displays so that the users can see the information can include positioning the displays so they are readable to users in wheelchairs. [Source: Vanderheiden & Vanderheiden, 1991]

- **5.1.2.2 Make readable without special equipment.** A user should be able to read a visual display without the use of a ladder, a flashlight, or other special equipment. [Source: MIL-STD-1472F, 1999]

- **5.1.2.3 Locate directly in front of user** A screen should be directly in front of the user when the user is in his or her normal working position. [Source: Department of Energy (DOE-HFAC 1), 1992]

  Discussion. Locating the screen off-center can cause the user to adopt uncomfortable or awkward positions, leading to pain. Exceptions to this rule are when the users look at the monitor infrequently.

- **5.1.2.4 Place the top of the screen below eye level.** The top of the screen should not be above the viewer's eye level. [Source: DOE-HFAC 1, 1992]

  Discussion. By placing the top of the screen below eye level, the user can view the information on the screen using a downward gaze. When people view the displays at eye level, they tend to blink less and eyes can get dry and irritated. A downward gaze exposes less of the eye to the atmosphere, preventing dry eyes. [Source: Tsubota & Nakamori, 1993].

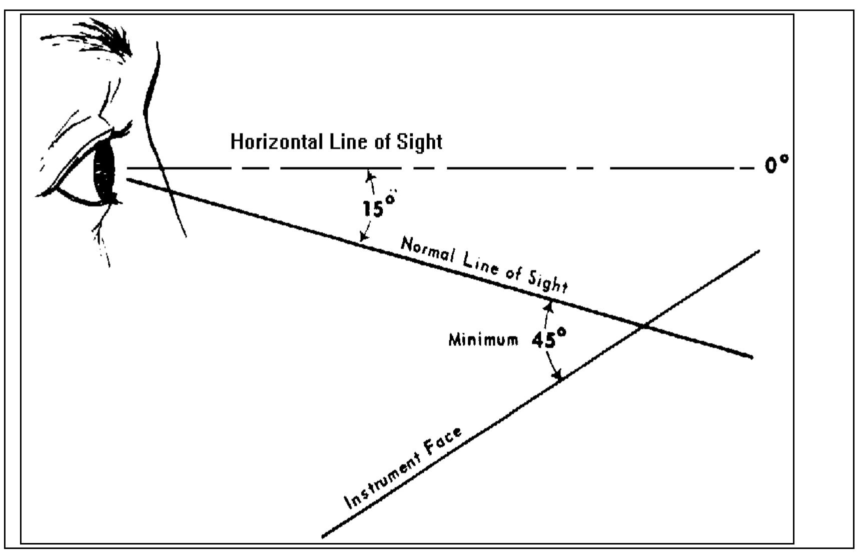
□ **5.1.2.5 Make line of sight below horizontal.** The line of sight from the viewer's eyes to the center of the screen should be between 10° and 60° below horizontal, preferably allowing the user to set the angle most comfortable for him or her within this range. [Source: DOE-HFAC 1, 1992; Balci & Aghazadeh, 1998; MIL-STD 1472F, 1999, American National Standard Institute (ANSI), 1988]

Discussion. The resting position of the eyes, considered to be the most comfortable position, is 15° below the horizontal. However, a lower monitor position improves the ability to accommodate and facilitates convergence (the turning in of eyes to focus on a nearby object), particularly for persons over 40 years old. Additionally, a monitor location 40° below horizontal can reduce discomfort in the neck, shoulders, forearms, and wrists for users wearing bifocals. [Source: Balci & Aghazadeh, 1998; Krimsky, 1948; Morgan, Cook, Chapanis & Lund, 1963; Ripple, 1952; Tyrrell & Leibowitz, 1990;]

□ **5.1.2.6 Orient perpendicular to line of sight.** Display screens should be positioned so that the face is perpendicular to the user's line of sight whenever feasible. [Source: DOE-HFAC 1, 1992]

Discussion. Tilting the monitor downward can lead to increased discomfort both physically and visually, particularly in the neck area, versus a monitor tilted back a little. [Source: Ankrum, Hansen, & Nemeth, 1995; Ankrum & Nemeth, 1995]

Exhibit 5.1.2.7 Display face not tilted more than 45° to user's line of sight [Source: MIL-STD-1472F, 1999]



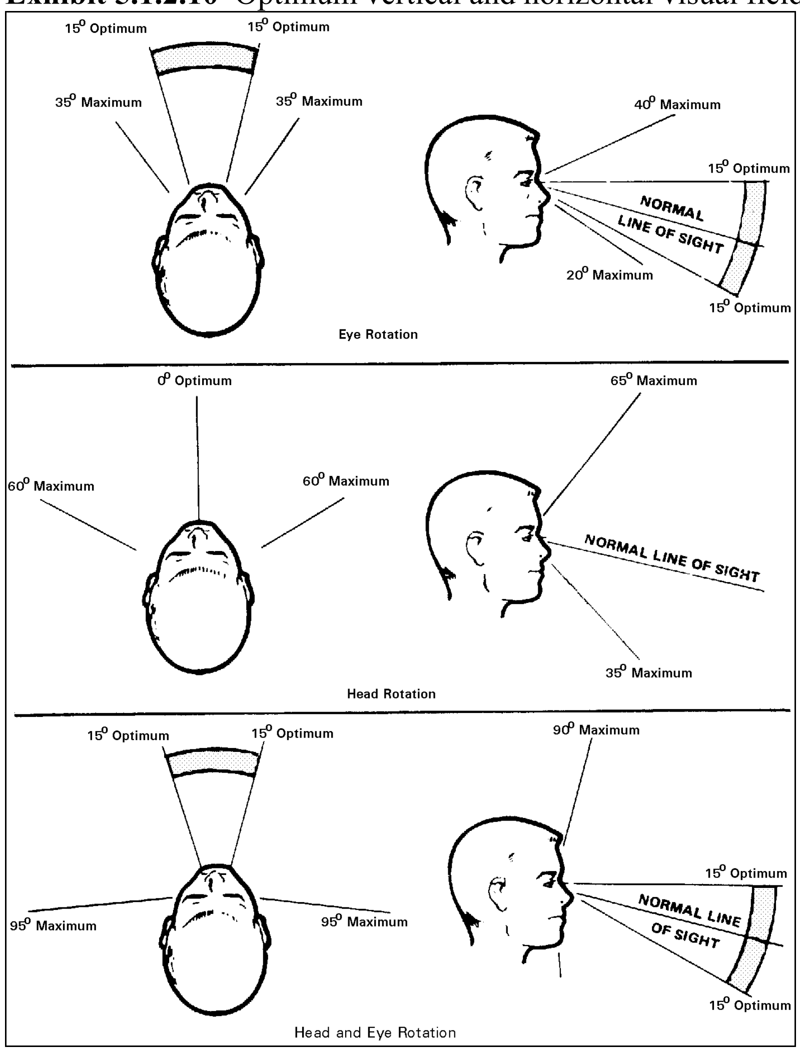
- **5.1.2.7 Avoid excessive tilt.** The display face shall not be tilted more than 45° from the normal line of sight as illustrated in Exhibit 5.1.2.7. [Source: MIL-STD-1472F, 1999]

- **5.1.2.8 Group task-related displays together.** All displays necessary to support a user's activities or sequence of activities should be grouped together. [Source: MIL-STD-1472F, 1999]

- **5.1.2.9 Arrange according to function and sequence.** Displays shall be arranged in relation to one another according to their sequence of use or the functional relations of the components they represent. [Source: MIL-STD-1472F, 1999]

Discussion. In general, it is beneficial if displays are arranged sequentially within a functional group so that they provide a left-to-right or top-to-bottom information flow within the group because this is how people read.

Exhibit 5.1.2.10 Optimum vertical and horizontal visual fields



- **5.1.2.10 Locate critical displays in central visual field.** Critical or frequently used displays shall be located in the **central visual field**, as illustrated in Exhibit 5.1.2.10, and occupy a privileged position in that field (e.g., the top or left-most position). [Source: MIL-STD-1472F, 1999]

  Discussion. Focal vision is the central 30° of the visual field, pictured as the shaded area in the top panel of the Exhibit 5.1.2.10, (along with the range of eye movements with the head stationary). This is the area that people use to look at objects in the world, moving their eyes as needed to bring images of the object on to the **fovea**, which is the area of highest acuity. When an object is outside of the focal area, a person will usually turn the head rather than simply move the eyes. The range of head rotation is illustrated in the second panel of Exhibit 5.1.2.10. The combined range of combined head and eye movement is illustrated in the third panel of Exhibit 5.1.2.10. By locating frequently used displays in the central 30° of visual field, the user is not required to move his or her head to bring the information into the focal area, presumably minimizing neck strain.

- **5.1.2.11 Arrange displays consistently.** The arrangement of displays within a system shall be consistent from application to application. [Source: MIL-STD-1472F, 1999]

- **5.1.2.12 Distance for monitors with controls.** If there is a control associated with a display, the viewing distance from the eye reference point of a seated user to the associated display and control shall not exceed 635 mm (25 in). [Source: MIL-STD-1472F, 1999]

  Discussion. The reach distance for a 5^{th} percentile female is 26 inches, so setting the distance at 25 inches insures that the 5^{th} percentile female can reach the controls. The 5^{th} percentile female measurements and reach ranges represent the customary minimal design criteria. Designing to accommodate the minimal reach range will increase the likelihood that the entire user population can reach the controls.

■ **5.1.2.13 Maintain at least a minimum viewing distance.** The viewing distance from the eye to a display shall not be less than 330 mm (13 in), unless the periods of viewing will be short or if dim signals must be detected, in which case the minimum can be 250 mm (10 in). [Source: MIL-STD-1472F, 1999]

> **Discussion.** In general, a further viewing distance is preferred. Earlier recommendations were to locate the monitor at the same viewing distance as the distance for reading hard copy 307 mm- 410 mm (12-16 inches). However, new research has found that eyestrain is not increased when the document and monitor were viewed at different distances. Less eyestrain is reported for 980 mm (38 in) viewing distances than 660 mm (26 in). Users judged 50 cm (20 in) as too close for computer work and performance suffered at this distance over a 100 cm (40 in) distance. Users with presbyopia (common in people over 40) may require corrective lenses to view displays further than 16 in from the eye. [Source: ANSI, 1988; Owens & Wolf-Kelly, 1987; Jaschinski-Kruza, 1990]

□ **5.1.2.14 Determine maximum viewing distance by legibility.** Maximum viewing distance for displays should be determined by the legibility of the displayed information. [Source: MIL-STD-1472F, 1999]

> **Discussion.** The further the screen is from the viewer, the more difficult it is for the eyes to resolve fine detail. This can often be fixed by displaying screen items at larger resolution.

□ **5.1.2.15 Modify displayed information when viewing distance exceeds 20 inches.** Information on displays that are located at viewing distances greater than 20 in should be appropriately modified in aspects such as display size, symbol size, brightness ranges, and resolution to ensure legibility of displayed information. [Source: MIL-STD-1472F, 1999]

> **Discussion.** A general rule of thumb is that items viewed at twice the distance will appear half as large. As the preferred character size for readability is 20-22 arc minutes, the size of the characters on the display will need to be larger to maintain the preferred character size at greater distances. [Source: ANSI, 1988]

- **5.1.2.16 Allow users to set viewing distance where possible.** Although there may be a set normal viewing distance, workplace design should not restrict observers from viewing a CRT from other distances. [Source: MIL-STD-1472F, 1999]

  Example. The set distance between the viewer's eye and the CRT screen may be 20 in, but the viewer may occasionally want to lean forward to take a closer look at the information displayed on the screen.

  Discussion. Users have individual differences in their preferred viewing distances. Particularly for workstations with a single user, it is preferable for users to adjust the viewing distance to their preferred distance. Users report more visual strain when they are forced to work at a distance shorter than their preferred distance. [Source: Jaschinski, Heuer, & Kylian, 1998]

- **5.1.2.17 Do not allow vibration to interfere with tasks.** Vibration of visual displays shall not hinder users in the performance of their tasks. [Source: MIL-STD-1472F, 1999]

5.2 Cathode ray tube displays

A **Cathode Ray Tube** or CRT is the tube of a television or computer monitor in which rays of electrons are beamed onto a phosphorescent screen to produce images. CRT is often used as a generic term for a computer monitor. Three key specifications for a CRT are the maximum resolution it will display (determined by dot pitch and resolution), the refresh rate, and whether it is interlaced or non-interlaced. An **interlaced** display produces a video image by displaying alternate scan lines. A **non-interlaced** display produces a video image by displaying all lines in a frame in one pass from top to bottom before the next frame appears. Non-interlaced displays are preferred to reduce the perception of flicker. (**Flicker** is the appearance of flashing or wavering light that occurs in a computer display.) Negative aspects of CRTs are that they use a lot of electricity and take up a lot of space.

5.2.1 General

- **5.2.1.1 Refresh rate.** CRT displays shall be refreshed at a rate of at least 65 Hz, preferably more than 100 Hz to avoid the perception of flicker on monitors for photosensitive users. [Source: ANSI, 1988; Bauer & Cavonius, 1980; Cardosi & Murphy 1995, DOE-HFAC 1, 1992; Vanderheiden & Vanderheiden, 1991]

  Discussion. A refresh rate of 100 Hz on a non interlaced monitor is considered sufficient to ensure that flicker is well beyond the threshold of perception even in the peripheral vision where sensitivity is higher. (A 100 Hz refresh rate on an interlaced monitor refreshes a given line only 50 times a second, causing noticeable flicker.) Individual differences exist in flicker sensitivity. The perception of flicker increases in the peripheral vision, so the bigger the monitor is, the higher the refresh rate will need to be to ensure flicker is not a problem. [Source: Bauer & Cavonius, 1980]

- **5.2.1.2 Avoid display induced seizures.** Displays shall be designed to maximize the number of people who can view them without experiencing a seizure. [Source: Vanderheiden & Vanderheiden, 1991]

  Discussion. Seizures may be induced by flashing screen cursors or by flickering displays, particularly when the flash rates are between 10 and 25 Hz, with peak levels occurring between 15-20 Hz. Flicker sensitivity becomes greater with increases in light intensity and the proportion of the visual field that is flickering. Some users experience seizure responses when exposed to flicker rates of 15-20 Hz even when their eyes are closed. [Source: Vanderheiden & Vanderheiden, 1991]

■ **5.2.1.3 Flicker.** CRT displays shall have no apparent flicker to at least 90 % of a sample of the user population when viewed under the expected conditions of use. [Source: ANSI, 1988; DOE-HFAC 1, 1992; Cardosi & Murphy, 1995]

Discussion. The refresh rate is one of several factors that can cause the user to perceive flicker. The perception of flicker increases in the peripheral vision, so the bigger the monitor is, the higher the refresh rate will need to be to ensure flicker is not a problem.

Ambient illumination, display contrast, colors used, and the **phosphor** persistence of the monitor also contribute to the perception of monitor flicker. One of the traditional ways of minimizing flicker is by keeping the screen as dark as possible.

A longer decay rate on the phosphor (high persistence phosphor) decreases the flicker perception but can produce trails or after images behind moving elements. There are also individual differences and age differences in the ability to perceive flicker, with younger people generally being more sensitive.

□ **5.2.1.4 Use medium persistence phosphors.** General purpose CRTs should use medium-persistence phosphors. [Source: DOE-HFAC 1, 1992]

Discussion. High-persistence phosphors tend to produce trails or after images behind moving elements, and low-persistence phosphors are more likely to result in a perceptible flicker. [Source: DOE-HFAC 1, 1992]

■ **5.2.1.5 Ensure color fringes do not affect performance.** Color fringes on images on CRT displays, if perceptible, shall not have an adverse effect on a user's perception or performance. [Source: MIL-STD-1472F, 1999]

Definition. Color fringes are the pixels along the border of an object that contain a combination of the selection and background colors.

■ **5.2.1.6 Avoid jitter.** Deviations in the location of a displayed element shall be equal to or less than .0002 mm per mm of viewing distance over the period of a second. [Source: ANSI, 1988]

Definition. Jitter is a departure from geometric stability. It occurs when pixels in displayed objects move instead of remaining in a fixed position.

- **5.2.1.7 Maintain uniform element size.** The size of a display element (for example, an alphanumeric character or symbol) should not vary by more than 10 % regardless of its location within the display. [Source: ANSI, 1988]

  Discussion. If you type the capital letter E such that it fills the screen, all of the Es, from the ones in the center to those on the outer edge, should appear to be the same size.

- **5.2.1.8 Minimize element displacement.** The displacement of a single display element's position shall vary by less than 5 % of the display element box height relative to those above and below, or right and left of it. [Source: ANSI, 1988]

- **5.2.1.9 Maintain column and row linearity.** Rows and columns shall be parallel and orthogonal to each other with the linearity of any column or row not varying by more than 2 % of the length of the column or row. [Source: ANSI, 1988]

5.2.2 Luminance and contrast

- **5.2.2.1 Minimize luminance variation across the display.** Luminance shall not vary by more than 50 % from the center to the edge of the display. [Source: ANSI, 1988]

  Definition. Luminance is the physical measure of the amount of light emitted by or reflected in a given direction from the display. Luminance is expressed in candela per meter squared or foot lamberts. **Foot lamberts** is a measure that has been corrected for the visual system's differential sensitivity to different wavelengths, giving an approximation to perceived brightness. [Source: Murch, 1987]

- **5.2.2.2 Luminance.** Either characters or their background, whichever has higher luminance, shall have a luminance of at least 35 cd/m^2 (10 fL). [Source: MIL-STD-1472F, 1999]

  Discussion. Increasing luminance reduces pupil diameter, reducing distortions and improving speed of accommodation and depth of field, especially for users over 40 who tend to lose some of their ability to accommodate. However, higher luminance increases sensitivity to flicker. [Source: Bauer & Cavonius, 1980]

- **5.2.2.3 Screen luminance.** The ambient screen illumination shall not contribute more than 25 % of screen brightness through diffuse reflection and phosphor excitation. [Source: MIL-STD-1472F, 1999]

- **5.2.2.4 Provide a control for adjusting luminance.** A control shall be provided to vary the CRT luminance from 10 % of minimum ambient luminance to full CRT luminance. [Source: MIL-STD-1472F, 1999]

- **5.2.2.5 Provide a control for adjusting contrast ratio.** A control shall be provided to vary the foreground-background contrast ratio. [Source: MIL-STD-1472F, 1999]

  Definition. Contrast ratio is the luminance of the foreground divided by the luminance of the background. It indicates how much brighter a pure white output would be than a pure black output. The greater the contrast, the sharper the image will be. Also called luminance ratio, contrast ratios for CRTs are generally better than those for active matrix LCDs, which are better than those for passive matrix LCDs.

- **5.2.2.6 Facilitate detection of faint signals.** When the detection of faint signals is required, and when the ambient illumination may be above 2.7 lux (0.25 ft-c), CRTs shall be hooded, shielded, or recessed. [Source: MIL-STD-1472F, 1999]

- **5.2.2.7 Ensure CRT luminance exceeds adjacent surfaces.** With the exception of emergency indicators, no light source in the immediate surrounding area shall be of greater luminance than the CRT signal. [Source: MIL-STD-1472F, 1999]

- **5.2.2.8 Provide adequate ambient illumination.** The ambient lighting levels in areas of the CRT shall be appropriate for other visual functions such as setting controls, reading instruments, and maintenance, but shall not degrade the visibility of signals on the CRT display. [Source: MIL-STD-1472F, 1999]

  Discussion. Automatic adjustment of CRT brightness may be used if the adjustment is a function of ambient illumination and the range of adjustment is adequate for the full range of ambient illumination. [Source: MIL-STD-1472F, 1999]

- **5.2.2.9 Provide controls to modulate ambient lighting.** If ambient illumination in an area where a CRT display is used is variable, controls shall be provided to dim all light sources, including illuminated panels, indicators, and switches in the immediate vicinity of the CRT. [Source: MIL-STD-1472F, 1999]

5.2.3 Glare control

Glare may be of two types, diffuse or specular. **Diffuse glare** is caused by the general environmental illuminance, which effectively reduces the display contrast. **Specular glare** is the appearance of unwanted images (reflections) on the display surface. The most effective method of glare control is to design the workplace so that neither type is produced. Other methods include screen meshes placed over the display surface, etched faceplates, anti-reflective coatings, and bonded quarterwave filters. All of these degrade both contrast and resolution to some degree.

▪ **5.2.3.1 Minimize or eliminate glare.** Glare shall be eliminated or minimized.

Discussion. Some of the methods that can be used to eliminate or minimize glare are

a. proper placement of the CRT relative to light sources,

b. use of an anti-glare treatment, such as a diffusing surface or an optical coating, or

c. filter control of the light sources. [Source: ANSI, 1988; MIL-STD-1472F, 1999]

Hoods are often unacceptable for this purpose because they tend to restrict the viewing angle of screens. Do not allow the use of anti-glare treatments to violate the requirements for luminance, contrast, and resolution contained in this section. [Source: ANSI, 1988; MIL-STD-1472F, 1999]

▪ **5.2.3.2 Make adjacent surfaces matte.** Surfaces adjacent to the CRT shall have a dull, matte finish. [Source: MIL-STD-1472F, 1999]

▪ **5.2.3.3 Minimize reflections.** Displays shall be constructed, arranged, and mounted to prevent interference from reflections of illumination sources, windows, and other visual displays. [Source: MIL-STD-1472F, 1999]

Discussion. If necessary, shields, filters, or other techniques may be used to ensure that system performance is not degraded. [Source: MIL-STD-1472F, 1999]

5.2.4 Resolution

■ **5.2.4.1 Allow discrimination of similar characters.** When presenting alphanumeric characters, displays shall allow discrimination of similar characters. [Source: MIL-STD-1472F, 1999]

Example. The letter "l" and the number "1", or the letter "Z" and the number "2" are easily confused.

■ **5.2.4.2 Resolution for CRTs.** CRTs for displaying simple alphanumeric text shall have a resolution of at least 0.8 resolution elements per mm (20 per in). [Source: DOE-HFAC 1, 1992]

□ **5.2.4.3 Minimum resolution for alphanumeric characters.** Alphanumeric characters should have at least 10 resolution elements per character height. [Source: DOE-HFAC 1, 1992]

■ **5.2.4.4 Resolution for high reading speed.** When high reading speed is required, high resolution monitors with at least 35 pixels per mm (90 dpi) shall be used. [Source: DOE-HFAC 1, 1992]

Discussion. Higher resolution displays (greater than 90dpi) are associated with increases in visual performance and decreases in visual fatigue in visual search tasks. [Source: Ziefle, 1998]

□ **5.2.4.5 Resolution for complex symbols.** CRTs for displaying complex symbols and graphic detail should have at least 100 resolution elements per inch. [Source: DOE-HFAC 1, 1992]

5.3 Flat-panel displays

In flat-panel displays, images are formed from discrete, nonoverlapping, rectangular pixels. These images can differ from images on CRTs in character-to-character spacing, interline spacing, character and symbol design, the effect of ambient illumination, image polarity, and failure mode. [Source: Avery & Bowser (DOE HFDG ATCCS V2.0), 1992]

□ **5.3.1 Character formation -- vertical orientation.** Characters in a vertical orientation should be formed from a matrix of at least 9 by 13 pixels. [Source: DOE HFDG ATCCS V2.0, 1992]

□ **5.3.2 Minimum character formation for nonvertical orientation.** Characters in a nonvertical orientation should be formed from a matrix of at least 8 by 11 pixels, preferably 15 by 21 pixels. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **5.3.3 Character stroke width.** Character stroke width should not exceed the minimum and maximum values given in Exhibit 5.3.3. [Source: DOE HFDG ATCCS V2.0, 1992]

Definition: Stroke width is the thickness of the lines used to make up the number or letter.

Exhibit 5.3.3 Stroke width for pixel-generated characters. All numbers are in pixels.

Upper case character height	Minimum stroke width	Maximum stroke width
7 to 8	1	1
9 to 12	1	2
13 to 14	2	2
15 to 20	2	3
21 to 23	2	4

▫ **5.3.4 Minimum and preferred character height-width relationship.** The width of characters of a given height should not exceed the minimum and maximum values given in Exhibit 5.3.4. The exhibit also includes the preferred values. [Source: DOE HFDG ATCCS V2.0, 1992]

Exhibit 5.3.4 Height-width relationship for upper case pixel-generated characters. All numbers are in pixels.

Character height	Minimum width	Preferred width	Maximum width
7	4	5	5
8	4	6	7
9	5	6	8
10	5	7	9
11	6	8	10
12	6	9	11
13	6	9	12
14	7	10	13
15 or 16	8	11	14

▫ **5.3.5 Image formation time when motion artifacts are unimportant.** If motion artifacts are not important, image formation time should not exceed 55 msec. [Source: DOE HFDG ATCCS V2.0, 1992]

Definition. Motion artifacts are the after images (made up of the previously drawn object that have not yet decayed enough to disappear) that one sees that appear to follow a moving display object. They often look like the tail of a comet following the object in motion.

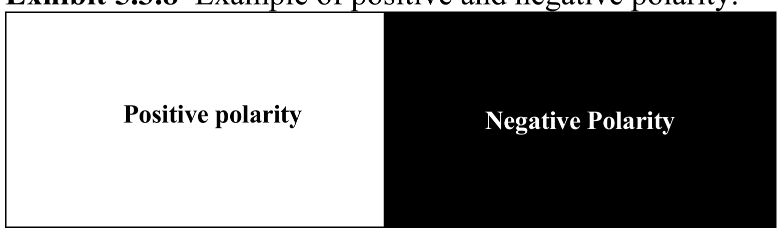
- **5.3.6 Image formation time when motion artifacts are important.** If motion artifacts are important, image formation time should not exceed 10 msec. [Source: DOE HFDG ATCCS V2.0, 1992]

- **5.3.7 Minimize pixel failure rate.** Displays should be selected and maintained so that the pixel failure rate does not exceed 1%. [Source: DOE HFDG ATCCS V2.0, 1992]

- **5.3.8 Use positive polarity when all else is equal.** If character stroke width, modulation, and luminance values are approximately equal for both polarities, the positive polarity (dark characters on a light background) should be used. (see Exhibit 5.3.8). [Source: DOE HFDG ATCCS V2.0, 1992]

  Discussion. Reflections are less visible on a bright background than on a dark background.

Exhibit 5.3.8 Example of positive and negative polarity.



- **5.3.9 Treat displays to minimize reflections.** All flat panel displays should incorporate a first-surface treatment to diminish specular reflections. [Source: DOE HFDG ATCCS V2.0, 1992]

5.4 Liquid crystal displays

Liquid crystal displays (LCDs) are a type of flat-panel display that works by suspending liquid crystals between two transparent sheets of polarizing material. An electric current passes through the liquid causing the crystals to act like a shutter, either permitting light to pass through or blocking the light so that it cannot pass through. Most LCDs are backlit to make them easier to read in bright environments. LCDs are especially suited for information display in environments where ambient illumination is high. Their advantages include excellent contrast, long life, rugged design, low voltage, and low power consumption (except when backlit). Their disadvantages include slow speed, limited color capability, limited temperature range, and manufacturing problems for larger panels with higher resolution. [Source: DOE HFDG ATCCS V2.0, 1992]

- **5.4.1 Use only with adequate illumination.** LCDs should be used only with adequate levels of ambient illumination. [Source: DOE HFDG ATCCS V2.0, 1992]

  Discussion. LCD reading performance improves as ambient illumination increases over the range 20 to 1500 lx. [Source: DOE HFDG ATCCS V2.0, 1992]

- **5.4.2 Polarity.** For reflective LCDs, the image should be light characters on a dark background; for backlighted (transmissive) LCDs, the image should be dark characters on a light background. [Source: DOE HFDG ATCCS V2.0, 1992]

- **5.4.3 Minimize backlighting.** The amount of backlighting used should be minimized. [Source: DOE HFDG ATCCS V2.0, 1992]

  Discussion. LCD reading errors increase as backlighting increases over the range of 0 to 122 cd/m^2. [Source: DOE HFDG ATCCS V2.0, 1992]

- **5.4.4 LCDs used in low ambient illumination.** If LCDs are used in the presence of low ambient illumination, users should be able to adjust the viewing angle and the amount of backlight. [Source: DOE HFDG ATCCS V2.0, 1992]

- **5.4.5 Minimize off-axis viewing of backlit LCDs.** If used, backlit LCDs should be located so that off-axis viewing is minimized. [Source: DOE HFDG ATCCS V2.0, 1992]

  Discussion. The readability of many LCD screens drops off considerably as does the brightness particularly with a 45 degree off axis viewing angle. This may not be as much of a problem with newer LCD technology that claims a higher off axis viewing angle.

- **5.4.6 Incident illumination.** The incident illumination on the surface of LCD displays should be at least 35∏/R lux, with R equaling reflectivity of the display at its most reflective state. [Source: ANSI, 1988]

5.5 Gas plasma displays

A **gas plasma display** is a type of flat-panel display that works by placing neon gas between one plate coated with vertical conductive print and another plate coated with horizontal conductive print to form a grid. A point of light (pixel) is created at the intersection of a horizontal and vertical line that has been charged with an electric current. A major advantage of gas plasma displays is the availability of very bright, high-resolution displays, some of which can be viewed in direct sunlight. Other advantages are uniformity, high resolution, large size, long life, ruggedness, excellent viewing angle, and the absence of flicker. Some disadvantages are high voltage and power requirements, complex drive circuits, low luminous efficiency, relatively large pixel size, and limited color capability.

5.6 Electroluminescent displays

Electroluminescent displays (ELD) may be used where display visibility from multiple viewer positions, high display uniformity, high MTBF, high resolution, low display volume, low heat dissipation, and low power consumption are more important than display of multicolored objects, high brightness images, or sunlight readability. They are also lightweight, and provide display flexibility, therefore, they may be used instead of mechanical instruments. They may also be used where sudden lamp failure could result in catastrophic consequences. [Source: MIL-STD-1472F, 1999]

■ 5.6.1 **Alphanumeric character and symbol size.** The height of alphanumeric characters and geometric or pictorial symbols shall subtend a visual angle of at least 15 min. [Source: MIL-STD-1472F, 1999]

> **Definition. Visual angle** is the angle subtended by objects measured in minutes of arc. It represents an apparent size of an object based on the relationship between an object's distance from the viewer and its size (perpendicular to the viewer's line of sight). For example, if an object that is size ***h*** is at a distance ***d*** from the retina, the visual angle subtended (***x***) is equal to arctan (***h***/***d***).

□ 5.6.2 **Evaluate through prototyping.** The use of ELDs should be evaluated through prototyping before being incorporated in a new system. [Source: DOE HFDG ATCCS V2.0, 1992]

□ 5.6.3 **Verify acceptability by users.** The acceptability of ELDs should be verified by the expected users. [Source: DOE HFDG ATCCS V2.0, 1992]

5.7 Large-screen displays

The selection or design of a large-screen display, especially a projection display, may be more complex than that of other workstation displays. The effects of ambient illumination, observer location, type of data to be displayed, visual acuity for symbol size and contrast, screen size, screen format, symbol luminance, and screen gain are all important factors.

5.7.1 General

▫ 5.7.1.1 **When to use.** Large-screen displays should be used when

a. more than one user needs to refer to the same displayed information, but space or other constraints make the use of a single, common display preferable to many, individual displays.

b. one or more members of a team of users need to be able to move about, yet still need access to displayed information. [Source: MIL-STD-1472F, 1999]

▪ 5.7.1.2 **When not to use.** Large-screen displays shall not be used if the spatial and environmental conditions do not allow all users to have appropriate visual access in terms of viewing distance, angle, and lack of interference from intervening objects, personnel, and ambient lighting. (If the display is optically projected, see Paragraph 5.9.2). [Source: MIL-STD-1472F, 1999]

▪ 5.7.1.3 **Viewing distance.** The display shall be near enough that the most distant viewers can resolve the critical details presented, but not closer to any viewer than 1/2 the display width or height, whichever is greater. [Source: MIL-STD-1472F, 1999]

▪ 5.7.1.4 **Locate so that view is not obscured.** A large-screen display shall be located so that its critical users do not have their view of it obscured by persons moving about in their normal traffic patterns. [Source: MIL-STD-1472F, 1999]

▪ 5.7.1.5 **Ensure critical information cannot be deleted.** Control of large-screen group display systems shall ensure that critical information cannot be modified or deleted inadvertently or arbitrarily. [Source: MIL-STD-1472F, 1999]

- **5.7.1.6 Place display changes in control of users.** Changes in the group display shall be under the control of designated users who operate according to pre-established procedures, on command of a person in charge, or both. [Source: MIL-STD-1472F, 1999]

- **5.7.1.7 Separate display.** When a user must make changes that are of interest only to him or her, a separate, remote display shall be provided. [Source: MIL-STD-1472F, 1999]

5.7.2 Large-screen optical projection displays

- **5.7.2.1 When to use.** When ambient light can be properly controlled, optical projection displays shall be used for applications requiring group presentation, pictorial and spatial information, past history versus real-time presentation, synthetically generated pictures, simulation of the external world, or superimposition of data from more than one source. [Source: MIL-STD-1472F, 1999]

- **5.7.2.2 When to use rear projection.** Rear projection shall be used where physical obstructions to front projection result in poor visibility, or where work areas require high ambient illumination for other activities. [Source: MIL-STD-1472F, 1999]

- **5.7.2.3 Viewing distance and screen size.** The ratio of viewing distance to screen size (measured diagonally) shall be not more than 8:1 and not less than 2:1. The optimum ratio is 4:1; the preferred range is not less than 3:1 or more than 6:1. [Source: MIL-STD-1472F, 1999]

- **5.7.2.4 Viewing angle for groups.** The angle off center-line for viewing a large-screen display shall not be greater than 30° for groups. The optimum viewing angle is 0°; and the preferred limit is 20°. [Source: MIL-STD-1472F, 1999]

- **5.7.2.5 Viewing angle for individuals.** The angle off center-line for viewing a large-screen display shall not be greater than 10° for individuals. [Source: MIL-STD-1472F, 1999]

- **5.7.2.6 Image luminance with no film in the projector.** The image luminance with no film in the operating projector shall be not less than 17 cd/m^2 (5 fL), and not more than 70 cd/m^2 (20 fL). [Source: MIL-STD-1472F, 1999]

- **5.7.2.7 Luminance ratio across the screen.** The ratio of maximum to minimum luminance across the screen shall be not greater than 3:1. The optimum ratio of maximum to minimum luminance across the screen is 1:1, and the preferred limit is 1.5:1. [Source: MIL-STD-1472F, 1999]

- **5.7.2.8 Luminance ratio as a function of viewing location.** The ratio of maximum to minimum luminance as a function of viewing location shall be not greater than 4:1. The optimum ratio of maximum to minimum luminance as a function of viewing location is 1:1, and the preferred limit is 2:1. [Source: MIL-STD-1472F, 1999]

- **5.7.2.9 Luminance ratio of ambient light to brightest image.** The ratio of ambient light to the brightest part of an image shall not be greater than 1:10 for black and white images and 2:10 for images with gray scale or color, while maintaining optimum image luminance. The optimum ratio of ambient light to the brightest part of the image is 0:1, and the preferred range is 1:100 to 1:500. [Source: MIL-STD-1472F, 1999]

  Discussion. The optimum image luminance is 35 cd/m2 (10 fL), and the preferred range is from 27 to 48 cd/m2 (8 to 14 fL).

- **5.7.2.10 Luminance of screen center at the maximum viewing angle.** The luminance of the screen center at the maximum viewing angle shall be at least half its maximum luminance. [Source: MIL-STD-1472F, 1999]

- □ **5.7.2.11 Luminance ratio.** Under optimal ambient lighting conditions, the luminance ratio for optically projected displays should be 500:1. [Source: MIL-STD-1472F, 1999]

  Definition. Luminance ratio is the ratio of the luminance of an object to that of its surrounding field or background. [Source: MIL-STD-1472F, 1999]

- **5.7.2.12 Minimum luminance ratio for viewing charts and text.** The minimum luminance ratio for viewing charts, printed text, and other line work shall be 5:1. [Source: MIL-STD-1472F, 1999]

- **5.7.2.13 Minimum luminance ratio for images with limited range of detail.** The minimum luminance ratio for images that contain limited shadows and detail with a limited luminance range, such as animation or photographs, shall be 25:1. [Source: MIL-STD-1472F, 1999]

- **5.7.2.14 Minimum luminance ratio for images with a full range.** The minimum luminance ratio for images that contain a full range of colors, or grays in black-and-white photographs, shall be 100:1. [Source: MIL-STD-1472F, 1999]

- **5.7.2.15 Minimize distortion.** Distortion of the projected image shall be minimized by ensuring that the screen is as nearly as possible perpendicular to the light beam from the projector. [Source: MIL-STD-1472F, 1999]

5.8 Stereoscopic displays

Stereoscopic displays generate the sensation of three dimensions, height, width and depth within the human visual system. Three-dimensional display technology may be "stereoscopic," which requires that users wear special glasses that provide different images to the two eyes, or "auto stereoscopic," which does not require any special viewing aids. There are situations in which three-dimensional images can enhance user performance or increase the "naturalness" of the presentation of complex spatial data. Emerging technology in this area is likely to have the disadvantages of limiting the field of view, the number of viewers, and the nature of data that can be displayed. [Source: DOE HFDG ATCCS V2.0, 1992]

■ 5.8.1 **Use only if third dimension is meaningful.** Three-dimensional displays shall be used only if the third dimension conveys a real benefit to the user. [Source: DOE HFDG ATCCS V2.0, 1992]

□ 5.8.2 **Do not slow system performance.** The three-dimensional presentation of information should not slow information display, degrade image quality, or degrade other aspects of system performance. [Source: DOE HFDG ATCCS V2.0, 1992]

□ 5.8.3 **Avoid interocular crosstalk.** There should be no interocular crosstalk, that is, the left eye should not see the images intended for the right eye, and vice versa. [Source: DOE HFDG ATCCS V2.0, 1992]

□ 5.8.4 **Avoid saturated primary colors.** Secondary colors should be used in coding stereoscopic images; saturated primary colors should be avoided. [Source: DOE HFDG ATCCS V2.0, 1992]

Discussion. Saturated primary colors can produce depth perceptions by themselves, which might interfere with the stereoscopically produced depth perceptions. **Primary colors** for light emitting displays such as CRTs are Red, Green, and Blue (RGB) and **secondary colors** are Cyan, Magenta, and Yellow (CMY). This is different than the primary colors for subtractive color mixture (like mixing paints), which are Yellow, Red, and Blue. [Source: DOE HFDG ATCCS V2.0, 1992]

□ **5.8.5 Temporal modulation for dynamic displays.** If dynamic three-dimensional displays are used, the temporal modulation of stereopsis should be approximately 1 Hz to ensure the most accurate perception of stereo motion. [Source: DOE HFDG ATCCS V2.0, 1992]

Definition. Stereopsis (also called stereoscopic vision) is three dimensional depth perception based on retinal disparity. As the eyes are slightly separated, each eye sees a slightly different image, when these images are fused in the brain. The result is a perception of depth or stereoscopic vision.

□ **5.8.6 Separate depth-coded objects.** Depth-coded objects should be separated spatially to eliminate disparity averaging, crowding, and repulsion. [Source: DOE HFDG ATCCS V2.0, 1992]

Definition. Disparity is the computation of depth values based on the lateral distance between corresponding picture elements in both image planes of stereo vision.

□ **5.8.7 Scale images according to disparity.** Image size should be scaled according to the disparity of the image. [Source: DOE HFDG ATCCS V2.0, 1992]

□ **5.8.8 Provide individual size scaling if critical to task performance.** If accurate size perception is critical to task performance, size scaling should be done for each observer. [Source: DOE HFDG ATCCS V2.0, 1992]

□ **5.8.9 Co-modulate luminance and stereopsis.** Luminance should be co-modulated with stereopsis. [Source: DOE HFDG ATCCS V2.0, 1992]

Discussion. Brightness is also a depth cue, with brighter objects being perceived as nearer. [Source: DOE HFDG ATCCS V2.0, 1992]

5.9 Printers

□ **5.9.1 When to use.** Printers should be used if a visual record of data is necessary or desirable. [Source: MIL-STD-1472F, 1999]

■ **5.9.2 Minimum contrast.** A minimum luminance contrast of 3.0 shall be provided between the printed material and the background on which it is printed. [Source: MIL-STD-1472F, 1999]

■ **5.9.3 Provide illumination where needed.** If the printed matter would not be legible in the planned operational ambient illumination, the printer shall be provided with internal illumination. [Source: MIL-STD-1472F, 1999]

■ **5.9.4 Provide a take up device.** A take-up device shall be provided for printed material. [Source: MIL-STD-1472F, 1999]

□ **5.9.5 Allow for annotation.** If applicable, printers should be mounted so that the user can write or mark on printed matter easily while it is still in the printer. [Source: MIL-STD-1472F, 1999]

■ **5.9.6 Ensure legibility.** The print shall be free from character line misregistration, character tilt, and smear. [Source: MIL-STD-1472F, 1999]

■ **5.9.7 Ensure readability of printed tapes.** If information is printed on tapes, the information on tapes shall be printed in such a manner that it can be read as it is received from the machine without requiring the cutting and pasting of tape sections. [Source: MIL-STD-1472F, 1999]

■ **5.9.8 Controls, feedback, and normal operations.** Printers shall conform to the rules in this standard with respect to

a. the controls and displays used to start, stop, and adjust the machine and its critical operating elements,

b. giving a positive indication of the remaining supply of materials such as paper and ink,

c. operations performed by the user, such as inserting, adjusting, removing, replenishing, and replacing supplies and materials without requiring disassembly or special tools, and

d. operations performed on site by a technician, such as adjustments and replacements not ordinarily performed by the user. [Source: MIL-STD-1472F, 1999]

□ **5.9.9 Locate printed outputs within reach.** Printed output should be located within easy reach of those who need it. [Source: Vanderheiden & Vanderheiden, 1991]

Discussion. Improperly located printouts may not be reachable to users in a wheelchair because of the location of the printer. [Source: Vanderheiden & Vanderheiden, 1991

5.10 Plotters and recorders

□ **5.10.1 When to use.** Plotters or recorders should be used if a visual record of continuous graphic data is necessary or desirable. [Source: MIL-STD-1472F, 1999]

- 5.10.2 **Do not obscure critical graphics while plotting or recording.** Critical graphics (those points, curves, or grids that must be observed while a recording is being made) shall not be obscured by the pen assembly, arm, or other hardware elements. [Source: MIL-STD-1472F, 1999]

- 5.10.3 **Provide adequate contrast.** Luminance contrast between a plotted function and the background on which it is drawn shall be at least 1.0. [Source: MIL-STD-1472F, 1999]

- 5.10.4 **Provide a take up device.** If necessary or desirable, a take-up device shall be provided for plotted material. [Source: MIL-STD-1472F, 1999]

- 5.10.5 **Provide an overlay if needed.** If it is critical to the proper interpretation of graphic data as they are being generated, a graphic overlay shall be provided. [Source: MIL-STD-1472F, 1999]

- 5.10.6 **Do not obscure data.** Graphic overlays shall not obscure or distort the data. [Source: MIL-STD-1472F, 1999]

- 5.10.7 **Resist smudge and smear.** Output from plotters shall be resistant to smudging and smearing under operational use. [Source: MIL-STD-1472F, 1999]

- 5.10.8 **Allow annotation.** If applicable, plotters and recorders shall be designed or mounted so that the user can write on or mark the paper while it is still in the plotter or recorder. [Source: MIL-STD-1472F, 1999]

- 5.10.9 **Controls, feedback, and normal operations.** Plotters and recorders shall conform to the rules in this standard with respect to

  a. the controls and displays used to start, stop, and adjust the machine and its critical operating elements,

  b. giving a positive indication of the remaining supply of materials such as paper and ink,

  c. operations performed by the user, such as inserting, adjusting, removing, replenishing, and replacing supplies and materials without requiring disassembly or special tools, and

  d. operations performed on site by a technician, such as adjustments and replacements not ordinarily performed by the user. [Source: MIL-STD-1472F, 1999]

5.11 Accommodating people with disabilities

Accessibility in design extends general design principles to cover those individuals who are faced with either temporary or permanent limitations in some dimension of human ability (sight, hearing, physical mobility, etc.). Although these rules are meant to make systems more accessible and thus make systems available to an increased number of users, it is not possible to design everything for use by everyone. However, there are often adaptations that can significantly increase system accessibility and usefulness. The goal of this section is to make systems more accessible and thus maximize the number of potential users.

□ 5.11.1 **Maximize the number of people who can see output.** Visual displays intended to be accessible should be designed to maximize the number of people who can clearly see the presented output. [Source: Vanderheiden & Vanderheiden, 1991]

Discussion. For instance, users with decreased visual abilities may have difficulty seeing small output or complex fonts and graphics. Other users may have difficulty seeing objects if there is insufficient contrast between the object and the background or may be especially sensitive to glare. [Source: Vanderheiden & Vanderheiden, 1991]

□ 5.11.2 **Ensure that visual outputs are not missed.** Equipment intended to be accessible should be designed to minimize the number of people who will miss important information if they cannot see. [Source: Vanderheiden & Vanderheiden, 1991]

Discussion. Visual output, for example, information presented on screens, paper printouts, warning lights, and dials, may not be seen at all by some users. [Source: Vanderheiden & Vanderheiden, 1991]

□ 5.11.3 **Provide connection points for alternative output devices.** Computers and computer systems should provide a point to which an alternative output device can be connected. [Source: Scadden & Vanderheiden, 1988]

Discussion. The connection point might be a standard serial or parallel port. Alternative output devices include speech synthesizers and Braille display devices. [Source: Scadden & Vanderheiden, 1988]

□ 5.11.4 **Provide speech output compatibility.** Computers and computer systems should provide a built-in speech output capability or provide a point to which a speech synthesizer can be connected. [Source: Scadden & Vanderheiden, 1988]

- **5.11.5 Facilitate the manipulation of printouts.** The manipulation of printouts should be facilitated by providing reaching and grasping devices such as reachers, artificial hands or hooks, and mouthsticks with clasps attached if the printouts are not within easy reach of the user. [Source: Vanderheiden & Vanderheiden, 1991]

- **5.11.6 Provide redundant auditory output.** Redundant auditory output should be provided in addition to a visual display if the visual display cannot be made physically accessible to a person in a wheelchair. [Source: Vanderheiden & Vanderheiden, 1991]

- **5.11.7 Attach larger displays or accommodating assistive devices.** If a visual display is not sufficient for users with difficulty seeing small output, a means should be provided of either attaching larger-image displays or utilizing other special assistive devices, such as an electronic magnifier, a voice synthesizer or a braille printer. [Source: Vanderheiden & Vanderheiden, 1991]

- **5.11.8 Provide redundant visual information.** A system should provide warnings, cues, and all other critical visual information redundantly in audible or tactile form if it is intended for use by a visually impaired person or a user who may have their attention focused elsewhere. [Source: Vanderheiden & Vanderheiden, 1991]

Glossary

Cathode Ray Tube (CRT) - A vacuum tube of a television or computer monitor in which the inner surface is coated with phosphors which glow and produce light when hit by an electron beam. CRT is often used as a generic term for a computer monitor.

Central visual field - Central visual field (sometimes referred to as the focal area) is the central 30° of the visual field. This is the area that people use to look at objects in the world, moving their eyes as needed to bring images of the object on to the fovea, which is the area of highest acuity. When an object is outside of the focal area, a person will usually turn their head rather than simply move their eyes.

Color fringes - Are the pixels along the border of an object that contain a combination of the selection and background colors.

Contrast - The range between the lightest tones and the darkest tones. The lower the number value, the more closely the shades will resemble each other. The higher the number, the more the shades will stand out from each other.

Contrast ratio - The luminance of the foreground divided by the luminance of the background. It indicates how much brighter a pure white output would be than a pure black output. The greater the contrast, the sharper the image will be. Also called luminance ratio.

CRT - See Cathode Ray Tube

Diffuse glare - A type of glare caused by the general ambient luminance, which effectively reduces the display contrast without producing significant specular reflection.

Disparity - The computation of depth values based on the lateral distance between corresponding picture elements in both image planes of stereovision.

ELD - See electroluminescent displays.

Electroluminescent displays (ELD) - A flat-panel display, the type typically used for laptop computers, that works by placing a thin phosphorescent film between one plate coated with vertical wires and another plate with horizontal wires, to form a grid. When an electrical current passes through a horizontal and a vertical wire, the phosphorescent film at this intersection glows, creating a point of light (pixel).

Flicker - The appearance of flashing that occurs in a computer display when the display is not refreshed frequently enough causing the phosphor to begin to decay prior to being refreshed.

Focal vision - The central 30° of the visual field. It is the area that people use to look at objects in the world, moving their eyes as needed to bring images of the object on to the fovea, which is the area of highest acuity.

Foot lamberts - Is a measure that has been corrected for the visual system's differential sensitivity to different wavelengths, giving an approximation to perceived brightness.

Fovea - The small central region of the retina that exhibits the greatest sensitivity to detail and color.

Gas plasma displays - Is a type of flat-panel display that works by placing neon gas between one plate coated with vertical conductive print and another plate coated with horizontal conductive print to form a grid. A point of light (pixel) is created at the intersection of a horizontal and vertical line that has been charged with an electric current.

Interlaced - A display that produces a video image by displaying alternate scan lines.

Interocular crosstalk - When the left eye can see the images intended for the right eye, and vice versa.

Jitter - A departure from geometric stability, which occurs when pixels in displayed objects move instead of remaining in a fixed position.

LCD - See liquid crystal display.

Legibility - The extent to which the user can decipher or read alphanumeric characters or text.

Liquid crystal display (LCD) - Is a flat-panel display that works by suspending liquid crystals between two transparent sheets of polarizing material. An electric current passes through the liquid causing the crystals to act like a shutter, either permitting light to pass through or blocking the light so that it cannot pass through.

Luminance - Is the physical measure of the amount of light emitted by or reflected in a given direction from the display. Luminance is expressed in candela per meter squared or foot lamberts.

Luminance ratio - The luminance of the foreground divided by the luminance of the background. It indicates how much brighter a pure white output would be than a pure black output. The greater the contrast, the sharper the image will be. It is also called contrast ratio.

Motion artifacts - The after images made up of the previously drawn object that have not yet decayed enough to disappear that one sees that appear to follow a moving display object. They often look like the tail of a comet following the object in motion.

Non interlaced - A display that produces a video image by displaying all lines in a frame in one pass from top to bottom before the next frame appears.

Phosphor - A luminescent substance, used to coat the inside of a CRT, which emits visible light when illuminated by electrons within an evacuated glass tube.

Polarity - The relationship between the brightness of the background and an image. A bright image on a dark background is negative polarity and a dark image on a bright background is positive polarity.

Primary colors – Primary colors for displays are Red, Green, and Blue (RGB) for light emitting displays such as CRTs. This is different than the primary colors for subtractive color mixture (like mixing paints), which are Yellow, Red and Blue.

Refresh rate - The rate (in cycles per second or Hz) at which the displayed contents of a computer screen are regenerated.

Resolution - The number of pixel elements per square inch.

Secondary colors – Secondary colors are Cyan, Magenta, and Yellow (CMY) for light emitting displays such as CRTs.

Specular glare - The appearance of unwanted images (reflections) on the display surface.

Stereopsis - (also called stereoscopic vision) Three dimensional depth perception based on retinal disparity. As the eyes are slightly separated, each eye sees a slightly different image, when these images are fused in the brain. The result is a perception of depth or stereoscopic vision.

Stereoscopic display - A method used to generate the sensation of three dimensions within the human visual system. Three-dimensional display technology may be "stereoscopic," which requires that users wear special glasses that provide different images to the two eyes, or "auto stereoscopic," which does not require any special viewing aids.

Stereoscopic vision - See Stereopsis.

Stroke width - The thickness of the lines used to make up the number or letter.

Viewing angle - The angle off the center line from which a displayed will be viewed

Visual angle - The angle subtended by objects measured in minutes of arc. It represents an apparent size of an object based on the relationship between an object's distance from the viewer and its size (perpendicular to the viewer's line of sight). For example, if an object that is size $\boldsymbol{h}$ is at a distance $\boldsymbol{d}$ from the retina the visual angle subtended, $\boldsymbol{x}$, is: $\boldsymbol{x}$ = arctan ($\boldsymbol{h}/\boldsymbol{d}$).

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6 Controls and visual indicators

This section contains human factors engineering rules for the design and selection of visual indicators and controls that are part of the human-equipment interfaces in FAA systems. Both general and specific design rules are provided for indicator-control integration and various types of controls.

6.1 Controls

This section contains rules for controls in general as well as for a wide variety of specific hand- and foot-operated controls. At times, the line between what is considered a control and what is considered an input device can be blurred, such as the use of pushbuttons in conjunction with trackballs in some systems and the use of knobs to adjust parameters (such as range) in other systems. Information on keyboards, trackballs, stylus pens, joysticks and mice contained in the section on input devices (Chapter 9).

6.1.1 General control information

6.1.1.1 Selection of controls

- **6.1.1.1.1 Distribution of workload.** Controls shall be selected and arranged so that none of a user's limbs is overburdened. [Source: Department of Defense (MIL-STD-1472F), 1999]

- **6.1.1.1.2 Multirotation controls.** Multirotation controls shall be used when precision is required over a wide range of adjustment. [Source: MIL-STD-1472F, 1999]

- **6.1.1.1.3 Detent stops.** Detent controls shall be selected whenever the operational mode requires control operation in discrete steps. [Source: MIL-STD-1472F, 1999]

- **6.1.1.1.4 Limit stops.** Stops shall be provided at the beginning and end of the range of control positions if the control is not to be operated beyond the indicated end positions or specified limits. [Source: MIL-STD-1472F, 1999]

□ **6.1.1.1.5 Characteristics of common controls.** The characteristics of different potential controls should be considered in the selection of a control for a given use. Characteristics of common controls for discrete adjustments are given in Exhibit 6.1.1.1.5 (a); characteristics of common controls for continuous adjustments are give in Exhibit 6.1.1.1.5 (b). [Source: Department of Energy (DOE-HFAC1), 1992]

Exhibit 6.1.1.1.5 (a) Characteristics of common controls for discrete adjustments

Discrete adjustment

Characteristics	Rotary selector switch	Thumb-wheel	Hand push button	Foot push-button	Toggle switch
Large forces can be developed	-	-	-	-	-
Time required to make control setting	Medium to quick	-	Very quick	Quick	Very quick
Recommended number of control positions (settings)	3 to 24	3 to 24	2	2	2 to 3
Space requirements for location and operation of control	Medium	Small	Small	Large	Small
Likelyhood of accidental activation	Low	Low	Medium	High	Medium
Desireable limits to control movement	270°	-	3mm x 30mm .13" x 1.5"	13 mm x 100mm .5" x4"	120°
Effectiveness of coding	Good	Poor	Fair to Good	Poor	Fair
Effectiveness of visually identifying control position	Fair to good	Good	Poor †	Poor	Fair to good
Effectiveness of nonvisually identifying control position	Fair to good	Poor	Fair	Poor	Good
Effectiveness of check-reading to determine control position when part of a group of like controls	Good	Good	Poor †	Poor	Good
Effectiveness of operating control simultaneously with like controls in an array	Poor	Good	Good	Poor	Good
Effectiveness as part of a combine control	Fair	Fair	Good	Poor	Good

† Exception: when control is back-lighted and light comes on when control is activated.

Exhibit 6.1.1.1.5 (b) Characteristics of common controls for continuous adjustments

	Continuous adjustment					
Characterisitcs	**Knob**	**Thumb-wheel**	**Hand wheel**	**Crank**	**Pedal**	**Lever**
Large forces can be developed	No	No	Yes	Yes	Yes	Yes
Time required to make control setting	-	-	-	-	-	-
Recommended number of control positions (settings)	-	-	-	-	-	-
Space requirements for location and operation of control	Small to medium	Small	Large	Medium to large	Large	Medium to large
Likelyhood of accidental activation	Medium	High	High	Medium	Medium	High
Desireable limits to control movement	Un-limited	180°	±60°	Un-limited	Small *	±45°
Effectiveness of coding	Good	Poor	Fair	Fair	Poor	Good
Effectiveness of visually identifying control position	Fair‡ to good	Poor	Poor to fair	Poor §	Poor	Fair to good
Effectiveness of nonvisually identifying control position	Poor to good	Poor	Poor to fair	Poor §	Poor to fair	Poor to fair
Effectiveness of check-reading to determine control position when part of a group of like controls	Good ‡	Poor	Poor	Poor §	Poor	Good
Effectiveness of operating control simultaneously with like controls in an array	Poor	Good	Poor	Poor	Poor	Good
Effectiveness as part of a combine control	Good ¶	Good	Good	Poor	Poor	Good

* Except for rotary which have unlimited range.
§ Assumes control makes more than one rotation.
‡ Applicable only when control makes less than one rotation. Round knobs must also have a pointer attached.
¶ Effective primarily when mounted concentrically on one axis with other knobs.

6.1.1.2 Direction of movement

- **6.1.1.2.1 Consistency of movement.** Movement of a control forward, clockwise, to the right, up, or pressing a control, shall turn the equipment or component on, cause the quantity to increase, or cause the equipment or component to move forward, clockwise, to the right, or up. [Source: MIL-STD-1472F, 1999]

  Discussion. Valve controls are exempt from this rule; their operation is specified in Paragraphs 6.1.1.2.2 and 6.1.1.2.3. [Source: MIL-STD-1472F, 1999]

- **6.1.1.2.2 Valve controls.** Rotary valve controls should open the valve with a counterclockwise motion. [Source: MIL-STD-1472F, 1999]

- **6.1.1.2.3 Labeling and marking valve controls.** Valve controls shall be provided with double-ended arrows showing the direction of operations and labeled at each end to indicate the functional result (e.g., open and close). [Source: MIL-STD-1472F, 1999]

6.1.1.3 Arrangement and grouping

- **6.1.1.3.1 Grouping controls.** Controls that are operated in a task-driven sequence or which are operated together shall be grouped together along with their associated displays. [Source: MIL-STD-1472F, 1999]

- **6.1.1.3.2 Arrangement by order of occurrence.** When several steps of a sequence are selected by one control, the steps shall be arranged by order of occurrence to minimize control movements and prevent cycling through unnecessary steps. Cycling through the control's ON/OFF position shall be avoided. [Source: MIL-STD-1472F, 1999]

- **6.1.1.3.3 Sequential operation.** Where sequential operations follow a fixed pattern, controls shall be arranged to facilitate operation (e.g., a left-to-right/top-to-bottom pattern, as on a printed page). [Source: MIL-STD-1472F, 1999]

- **6.1.1.3.4 Location of primary controls.** The most important and the most frequently used controls shall have the most favorable positions with respect to ease of seeing, reaching, and grasping (particularly rotary controls and those requiring fine settings). [Source: MIL-STD-1472F, 1999]

- **6.1.1.3.5 Consistency.** The arrangement of functionally similar, or identical, primary controls shall be consistent from panel to panel throughout a system or unit of equipment. [Source: MIL-STD-1472F, 1999]

- **6.1.1.3.6 Remote controls.** Controls, operated at a position remote from the display, equipment, or controlled vehicle, shall be arranged to facilitate direction-of-movement consistency. [Source: MIL-STD-1472F, 1999]

- **6.1.1.3.7 Controls for maintenance and adjustment.** In general, controls used solely for maintenance and adjustment shall be covered during normal equipment operation, but shall be readily accessible and visible to a user when required. [Source: MIL-STD-1472F, 1999]

- **6.1.1.3.8 Spacing.** Spacing between two controls of different types or between a single control and an obstruction shall be at least that specified in Exhibit 6.1.1.3.8. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.1.3.8 Minimum spacing between controls

	Toggle switches	* Push buttons	Continuous rotary controls	Rotary selector switches	Discrete thumbwheel controls
Toggle switches	See Exhibit 7.4.4.10.1	13 mm (0.5 in)	19 mm (0.75 in)	19 mm (0.75 in)	13 mm (0.5 in)
* Push buttons	13 mm (0.5 in)	See Exhibit 7.4.4.8.1	13 mm (0.5 in)	13 mm (0.5 in)	13 mm (0.5 in)
Continuous rotary controls	19 mm (0.75 in)	13 mm (0.5 in)	See exhibit 7.4.4.4.1	25 mm (1.0 in)	19 mm (0.75 in)
Rotary selector switches	19 mm (0.75 in)	13 mm (0.5 in)	25 mm (1.0 in)	See exhibit 7.4.4.1.1	19 mm (0.75 in)
Discrete thumbwheel	13 mm (0.5 in)	13 mm (0.5 in)	19 mm (0.75 in)	19 mm (0.75 in)	See exhibit 7.4.4.3.8

* For push buttons not separated by barriers.

Note. All values are for one hand operation. Distances are measured from edge of each control.

- **6.1.1.3.9 Spacing to accommodate hand wear.** Spacing shall be increased as appropriate to accommodate the wearing of gloves, mittens, or other protective hand wear. [Source: MIL-STD-1472F, 1999]

6.1.1.4 Coding

- **6.1.1.4.1 Methods and requirements.** The coding of controls for a particular application, for example, by size or color, shall be governed by the relative advantages and disadvantages of each type of coding as shown in Exhibit 6.1.1.4.1. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.1.4.1 Advantages and disadvantages of different types of coding

Advantages	**Location**	**Shape**	**Size**	**Mode of operation**	**Labeling**	**Color**
Improves visual identification	X	X	X		X	X
Improves nonvisual indentification (tactual and kinesthetic)	X	X	X	X		
Helps standardization	X	X	X	X	X	X
Aids identification under low levels of illumination and colored lighting	X	X	X	X	A	A
May aid in identifying control position (settings)		X		X	X	
Requires little (if any) training; is not subject to forgiving					X	
Disadvantages						
May require extra space	X	X	X	X	X	
Affects manipulation of the control (ease of use)	X	X	X	X		
Limited number of available coding categories	X	X	X	X		X
May be less effective if operator wears gloves		X	X	X		
Controls must be viewed (for example, must be within visual areas and with adequate illumination present)					X	X

Note:
A - When transilluminated

- **6.1.1.4.2 Coding to differentiate.** Where coding is used to differentiate among controls, application of the code shall be uniform throughout the system. [Source: MIL-STD-1472F, 1999]

- **6.1.1.4.3 Location coding.** Controls associated with similar functions should be in the same relative location from work station to work station and from panel to panel. [Source: MIL-STD-1472F, 1999]

- **6.1.1.4.4 Size coding.** No more than three different sizes shall be used to code controls for discrimination by absolute size. [Source: MIL-STD-1472F, 1999]

- **6.1.1.4.5 Consistent size coding.** Controls used for performing the same function on different items of equipment shall be the same size. [Source: MIL-STD-1472F, 1999]

- **6.1.1.4.6 Knob diameter as the coding parameter.** When knob diameter is used as the coding parameter, the differences between diameters shall be not less than 13 mm (0.5 in). [Source: MIL-STD-1472F, 1999]

- **6.1.1.4.7 Knob thickness as the coding parameter.** When knob thickness is the coding parameter, the differences between thickness shall be not less than 10 mm (0.4 in). [Source: MIL-STD-1472F, 1999]

- **6.1.1.4.8 Shape-coding.** When shape-coding is used

  a. the coded feature shall not interfere with ease of control manipulation.

  b. shapes shall be identifiable by hand and by eye regardless of the position and orientation of the control knob or handle.

  c. shapes shall be tactually identifiable when gloves must be worn.

  d. the number of shapes to be identified by each operator based on absolute discrimination shall be not more than 10.

  e. shape-coded knobs and handles shall be positively and non-reversibly attached to their shafts to preclude incorrect attachment when replacement is required.

  f. shapes shall be associated with or resemble the control function, and not alternate functions. [Source: MIL-STD-1472F, 1999]

  Discussion. Shape-coding may be used to ensure identification of control knobs or handles by “feel” where visual identification is not possible, diversion of operator visual attention to identify the proper control would detract from mission accomplishment, or where the consequences of incorrect control selection would be severe.

- ▫ **6.1.1.4.9 Control colors.** Controls should be black (17038, 27038, or 37038) or gray (26231 or 36231). [Source: MIL-STD-1472F, 1999]

- ▫ **6.1.1.4.10 Color-coding of controls.** When color-coding is required, only the following colors identified in FED-STD-595 should be selected for control coding:

  a. Red, 11105, 21105, 31105

  b. Green, 14187

  c. Orange-Yellow, 13538, 23538, 33538

  d. White, 17875, 27875, 37875

  e. Blue, 15123 should be used if an additional color is absolutely necessary. [Source: MIL-STD-1472F, 1999]

- ▪ **6.1.1.4.11 Association of control with visual indicator.** When color-coding must be used to relate a control to its corresponding display, the same color shall be used for both the control and the display. [Source: MIL-STD-1472F, 1999]

- ▪ **6.1.1.4.12 Control panel contrast.** Sufficient color/brightness contrast between the control and its background shall be provided to ensure prompt and accurate identification by the operator. [Source: MIL-STD-1472F, 1999]

- ▪ **6.1.1.4.13 Ambient lighting and limitations on color-coding.** Color-coding shall be compatible with anticipated ambient light during the mission. [Source: MIL-STD-1472F, 1999]

- ▪ **6.1.1.4.14 Alternative primary coding.** Color-coding shall not be used as the primary identification medium if the spectral characteristics of such ambient light or the operator's adaptation to that light varies as the result of such factors as solar glare, filtration of light, and variation from natural to artificial light. [Source: MIL-STD-1472F, 1999]

- ▪ **6.1.1.4.15 Alternatives to red lighting.** If red lighting is to be used during a portion of the mission, controls that would otherwise be coded red shall be coded by orange-yellow and black striping. [Source: MIL-STD-1472F, 1999]

6.1.1.5 Compatibility with hand wear and blind operation

- ▪ **6.1.1.5.1 Compatibility with hand wear.** Controls shall be compatible with hand wear to be utilized in the anticipated environment. [Source: MIL-STD-1472F, 1999]

  Discussion. Unless otherwise specified, all dimensions cited herein are for bare hands and need to be adjusted where necessary for use with gloves or mittens. [Source: MIL-STD-1472F, 1999]

- **6.1.1.5.2 Use of prototypes.** . When the use of hand wear is anticipated, the compatibility of a control with the hand wear should be evaluated through the use of prototypes. [Source: DOE-HFAC1, 1992]

- **6.1.1.5.3 "Blind" operation.** Where "blind" operation is necessary, hand controls shall be shape-coded, or separated from adjacent controls by at least 125 mm (5 in). [Source: MIL-STD-1472F, 1999]

6.1.1.6 Prevention of accidental actuation

- **6.1.1.6.1 Location and design.** Controls shall be designed and located so that they are not susceptible to being moved accidentally or inadvertently, particularly critical controls where such operation might cause equipment damage, personnel injury, or system performance degradation. [Source: MIL-STD-1472F, 1999]

- **6.1.1.6.2 Internal controls**. Internal or hidden controls should be protected from inadvertent actuation or movement, because it is usually not obvious that such controls have been disturbed and it may be difficult and time consuming to locate and readjust them. [Source: MIL-STD-1472F, 1999]

- **6.1.1.6.3 Rapid operation.** Any method of protecting a control from inadvertent operation shall not preclude operation within the time required. [Source: MIL-STD-1472F, 1999]

- **6.1.1.6.4 Methods.** If a control must be protected from accidental actuation, one or more of the following methods shall be used:

  a. Locate and orient the control so that a user is not likely to strike or move it accidentally in the normal sequence of control movements.

  b. Recess, shield, or otherwise surround the control with a physical barrier. The control shall be entirely contained within the recess or barrier envelope.

  c. Cover or guard the control, but without using safety or lock wire.

  d. Interlock the control so that extra movement (e.g., a side movement out of a detent position or a pull-to-engage clutch) or the prior operation of a related or locking control is required.

  e. Provide the control with resistance, such as viscous or coulomb friction, spring loading, or inertia, so that definite or sustained effort is required for actuation.

  f. Lock the control to prevent its quickly passing through a position when strict sequential activation is necessary (i.e., the control is moved only to the next position, then delayed).

  g. Design the control for operation by rotary action. [Source: MIL-STD-1472F, 1999]

- **6.1.1.6.5 "Dead man" controls.** "Dead man" controls, which will result in system shut-down to a non-critical operating state when force or input is removed, shall be utilized wherever operator incapacity can produce a critical system condition. [Source: MIL-STD-1472F, 1999]

6.1.2 Labeling and marking controls

Design rules for labels, markings, and colors for controls are given in this section. In this section, the term "label" is intended to include legends, placards, signs, and markings.

6.1.2.1 General

Label characteristics need to be consistent with requirements for accuracy of identification, time available for recognition or other responses, distance at which the labels must be read, illumination level and color, criticality of the function labeled, and label design within and among controls and systems. [Source: MIL-STD-1472F, 1999]

- **6.1.2.1.1 Use.** Labels shall be provided whenever it is necessary for users: (1) to locate and identify controls (2) to interpret and follow procedures, or (3) to avoid hazards. [Source: MIL-STD-1472F, 1999]

- **6.1.2.1.2 Size graduation.** To reduce confusion and operator search time, labels shall be graduated in size. [Source: MIL-STD-1472F, 1999]

- **6.1.2.1.3 Character size on group labels.** The characters in group labels shall be larger than those used to identify individual controls and displays. [Source: MIL-STD-1472F, 1999]

- **6.1.2.1.4 Character size for controls and displays.** The characters identifying controls and displays shall be larger than the characters identifying control positions. [Source: MIL-STD-1472F, 1999]

- **6.1.2.1.5 Determination of smallest character size.** With the smallest characters determined by viewing conditions, the dimensions of each character shall be at least approximately 25 % larger than those of the next smaller label. [Source: MIL-STD-1472F, 1999]

- **6.1.2.1.6 Demarcation with size graduation.** To best apply size graduation, the components should be functionally grouped and demarcated or spaced to reveal system and subsystem groupings. [Source: Electric Power Research Institute (EPRI NP 6209), 1988]

- **6.1.2.1.7 General requirements.** Controls and displays shall be appropriately and clearly labeled with the basic information needed for proper identification, utilization, actuation, or manipulation of the element. [Source: MIL-STD-1472F, 1999]

- **6.1.2.1.8 Principles of labeling.** Labels shall

  a. give the user relevant information needed to perform his or her task (for example, make or model of equipment)

  b. be supplemented where appropriate with other coding such as color and shape (as in warning or danger signs,

  c. use only boldface type to emphasize words or phrases, and

  d. if appropriate, be etched or embossed into the surface for durability, rather than stamped, stenciled, or printed. [Source: Department of Defense (MIL-HDBK-759B), 1992]

- **6.1.2.1.9 Avoid similar labels.** Similar names for different controls shall be avoided. [Source: MIL-STD-1472F, 1999]

- **6.1.2.1.10 Meaningful labels.** Controls shall be labeled in terms of what is being measured or controlled, taking into account the user as well as the purpose of the control or visual indicator. [Source: MIL-STD-1472F, 1999]

- **6.1.2.1.11 Function labels.** The labels for controls shall indicate the functional result of control movement such as increase, ON, and OFF and include calibration data where applicable and be visible during normal operation of the control. [Source: MIL-STD-1472F, 1999]

- **6.1.2.1.12 Functional relationship.** When controls and displays must be used together to make adjustments, appropriate labels shall indicate their functional relationship. [Source: MIL-STD-1472F, 1999]

- **6.1.2.1.13 Functional relationship.** Terminology used on control labels shall be consistent. [Source: MIL-STD-1472F, 1999]

- **6.1.2.1.14 Label mounting.** Labels that are not part of the equipment or component shall be securely attached to prevent their loss, damage, slippage, or accidental removal and attached to a structural member that is not removed during equipment servicing or routine maintenance. [Source: MIL-STD-1472F, 1999]

- **6.1.2.1.15 Label removal.** Users should be able to remove a label without damaging the surface to which it was attached. [Source: EPRI NP 6209]

- **6.1.2.1.16 Curved labels.** Curved labels (for example, a label that is wrapped around a pipe or cable) shall be avoided. [Source: MIL-STD-1472F, 1999]

- **6.1.2.1.17 Label reflectance.** Labels shall be constructed of non-reflective materials to avoid illegibility due to a light source being reflected back to the viewer. [Source: EPRI NP 6209]

- **6.1.2.1.18 Tag mounting.** When tags are used, they should be attached securely to equipment components by means of durable stranded stainless steel cable, clamps, or chains. [Source: EPRI NP 6209]

- **6.1.2.1.19 Non-interference of tag.** The length of the cable, clamp, or chain should be minimal so that the tag will not interfere with the operation or maintenance of the equipment. [Source: EPRI NP 6209]

6.1.2.2 Location and orientation

- **6.1.2.2.1 Readability.** Control labels shall be located so that they are visible and readable with the control in its installed position. [Source: MIL-STD-1472F, 1999]

- **6.1.2.2.2 No obstruction.** Labels shall not be located where they obscure other information needed by the user or where a control or user's normal hand or arm position will obscure the label. [Source: MIL-STD-1472F, 1999]

▪ **6.1.2.2.3 Position near control or visual indicator.** Labels shall be placed very near the control that they identify. [Source: MIL-STD-1472F, 1999]

▫ **6.1.2.2.4 Above control or visual indicator.** Labels should normally be placed above the control they describe, or when located above eye level, may be located below the control if label visibility will be enhanced. [Source: MIL-STD-1472F, 1999]

▫ **6.1.2.2.5 Separate labels.** Adjacent labels should be separated by sufficient space so they are not read as one continuous label. [Source: MIL-STD-1472F, 1999]

▪ **6.1.2.2.6 Functional grouping.** Labels shall be used to identify functionally grouped controls. [Source: MIL-STD-1472F, 1999]

▪ **6.1.2.2.7 Line enclosing a grouping.** When a line is used to enclose a functional group and define its boundaries, the label shall be centered at the top of the group either in a break in the line or just below the line. [Source: MIL-STD-1472F, 1999]

▪ **6.1.2.2.8 Colored areas.** When colored areas are used and sufficient space is available, the label shall be centered at the top within the area. [Source: MIL-STD-1472F, 1999]

▪ **6.1.2.2.9 Functional grouping.** When there is insufficient room for the label to be centered in the enclosed or colored area, it shall be located in the best available space provided the grouping is demarcated. [Source: MIL-STD-1472F, 1999]

▫ **6.1.2.2.10 Label highlighted.** The summary label should be bordered or otherwise highlighted to make it stand out. [Source: MIL-STD-1472F, 1999]

▫ **6.1.2.2.11 Consistent location.** Labels should be located consistently throughout the system. [Source: MIL-STD-1472F, 1999]

▫ **6.1.2.2.12 Hierarchical labeling.** A hierarchical labeling scheme should be used on panels to reduce confusion and search time based on the following:

a. Use major labels to identify major systems or user workstations.

b. Use subordinate or group labels to identify subsystem or functional groups.

c. Use component labels to identify each panel or console element.

d. Do not repeat information contained in higher-level labels in lower level labels. [Source: MIL-STD-1472F, 1999]

- **6.1.2.2.13 Horizontal orientation.** Labels shall be oriented so that alphanumeric characters are read horizontally from left to right. [Source: MIL-STD-1472F, 1999]

- **6.1.2.2.14 Vertical orientation.** Vertical orientation should be used only when labels are not critical for personnel safety or performance and where space is limited. When used, vertical labels should read from top to bottom. [Source: MIL-STD-1472F, 1999]

- **6.1.2.2.15 Preserving readability.** Labels shall be mounted so as to minimize wear or obscuration by grease, grime, or dirt, and shall remain legible for the overhaul interval of the labeled equipment. [Source: MIL-STD-1472F, 1999]

6.1.2.3 Design of label characters

- **6.1.2.3.1 Character height for viewing distance.** Unless circumstances require otherwise, labels shall be clearly legible at a viewing distance of 710 mm (28 in). The recommended height for letters and numerals at this distance is approximately 5 mm (0.18 in). Exhibit 6.1.2.3.1 gives minimum character heights for other viewing distances. [Source: Department of Energy (UCRL-15673), 1985]

Exhibit 6.1.2.3.1 Minimum character height for various viewing distances under normal luminance levels

Viewing distance	Minimum height
Less than 0.5 m (20 in)	2.3 mm (0.1 in)
0.5 - 1.0 m (20 - 40 in)	4.7 mm (0.2 in)
1.0 - 2.0 m (40 - 80 in)	9.4 mm (0.4 in)
2.0 - 4.0 m (80 - 160 in)	18 mm (0.75 in)
4.0 - 9.0 m (13 - 30 ft)	38 mm (1.5 in)

- **6.1.2.3.2 Stroke width in normal illumination.** If labels are expected to be read under normal illumination, characters shall be black on a white or light background, and stroke width shall be 1/6 to 1/7 of the height [Source: MIL-STD-1472F, 1999]

- **6.1.2.3.3 Stroke width in dim illumination.** Where dark adaptation is required or legibility at night is a critical factor, and white characters are specified on a dark background, the stroke width of the characters shall be from 1/7 to 1/8 of the height. [Source: MIL-STD-1472F, 1999]

- **6.1.2.3.4 Consistent stroke width.** The stroke width shall be the same for all letters and numerals of equal height. [Source: MIL-STD-1472F, 1999]

- **6.1.2.3.5 Stroke width for transilluminated characters.** For transilluminated characters, the stroke width shall be 1/10 of the height. [Source: MIL-STD-1472F, 1999]

- **6.1.2.3.6 Width to height ratios.** The width-to-height ratio of letters and numerals shall be 4:5 for "M" and "W," one stroke width wider for "4," one stroke wide for "I" and "1," and 3:5 all other letters and numerals. [Source: MIL-STD-1472F, 1999]

- **6.1.2.3.7 Character spacing.** The minimum space between characters shall be one stroke width. [Source: MIL-STD-1472F, 1999]

- **6.1.2.3.8 Word spacing.** The spacing between words shall be approximately the width of one normal-width character. [Source: MIL-STD-1472F, 1999]

- **6.1.2.3.9 Line spacing.** The minimum space between lines shall be approximately one-half the character height. [Source: MIL-STD-1472F, 1999]

- **6.1.2.3.10 Case of letters for single word labels.** When the text on a label is exclusively single words, such as names, the words shall appear as all capital letters. [Source: MIL-STD-1472F, 1999]

- **6.1.2.3.11 Case of letters for multiple words labels.** When the text on a label are phrases or sentences, the text shall appear as mixed case letters. [Source: MIL-STD-1472F, 1999]

- **6.1.2.3.12 Contrast.** When the ambient illumination will be above 10 lux (0.9 ft-c), dark characters on a light background shall be used. [Source: MIL-STD-1472F, 1999]

  Discussion. Black letters on a white background offer the best contrast. Good contrast is also provided by black on yellow, dark blue on white, dark green on white, and dark red on white. [Source: MIL-STD-1472F, 1999]

- **6.1.2.3.13 Non-interfering dark adaptation.** When dark adaptation is required, the visually indicated alphanumeric characters shall be visible without interfering with night vision requirements. [Source: MIL-STD-1472F, 1999]

- □ **6.1.2.3.14 Marking characteristics for dark adaptation.** When dark adaptation is required, markings should be white on a dark background. [Source: MIL-STD-1472F, 1999]

- □ **6.1.2.3.15 Style or font.** A simple font without serifs should be selected. [Source: Nuclear Regulatory Commission (NUREG-0700), 1981; EPRI NP 6209]

□ **6.1.2.3.16 Confusion between characters.** When a label contains pairs of characters that might be confused, the following applies.

a. The lower case letter "l" should have a short extension at the bottom extending to the right.

b. The numeral "1" should have a short extension at the top extending to the left.

c. The numeral "0" should appear narrower than the letter "O" of a given font. [Source: MIL-HDBK-759B, 1992]

□ **6.1.2.3.17 Borders.** Space should be provided between characters and words to prevent the label from appearing crowded or difficult to read with a minimum clearance around a character or word of 1/2 character height or more. [Source: MIL-HDBK-759B, 1992]

Discussion. However, clearance around a character, a word, or a set of words should not make the label appear "lost" within a large expanse of background. [Source: MIL-HDBK-759B, 1992]

6.1.2.4 Wording and information

□ **6.1.2.4.1 Wording.** Labels should be unambiguous and as concise as possible without distorting the intended meaning or information. [Source: MIL-STD-1472F, 1999]

□ **6.1.2.4.2 Minimize redundancy.** Redundancy should be minimized. [Source: MIL-STD-1472F, 1999]

□ **6.1.2.4.3 Identify specific function.** Where a general function is obvious, only the specific function should be identified (e.g., “rpm” rather than “engine rpm”). [Source: MIL-STD-1472F, 1999]

■ **6.1.2.4.4 Simplicity.** Control labels shall convey verbal meaning in the most direct manner by using simple words and phrases. [Source: DOE-HFAC1, 1992, MIL-STD-1472F, 1999]

□ **6.1.2.4.5 Abbreviations.** Abbreviations should be used in labels only if they are familiar to the users and users, for example, psi and km. [Source: DOE-HFAC1, 1992, MIL-STD-1472F, 1999]

■ **6.1.2.4.6 Consistency.** Designations and terms used on labels shall be consistent with designations and terms in user documentation and parts catalogs. [Source: UCRL-15673, 1985]

■ **6.1.2.4.7 Irrelevant information.** Trade names and other irrelevant information shall not appear on labels. [Source: MIL-STD-1472F, 1999]

- **6.1.2.4.8 Relevant information.** Labels shall be provided whenever personnel must identify, interpret, or follow procedures or avoid hazards. [Source: MIL-STD-1472F, 1999]

- **6.1.2.4.9 Pictorial symbols.** When pictorial symbols are used in place of or in addition to word labels, they shall be completely unambiguous in the expected visual operating environment, and not be used on a control that may rotate and thus position the symbol so that it may be confusing. [Source: MIL-HDBK-759B, 1992]

6.1.3 Foot-operated controls

- **6.1.3.1 When to use.** Foot-operated controls should be used under the following conditions:

  a. A control operation requires either greater force than the upper body can produce or a force close to the upper body fatigue threshold.

  b. The user's hands are expected to be occupied with other manual control tasks at the time an additional control action is needed.

  c. A specific foot-operated control has been so well established that a user would expect it, for example, aircraft rudder and brake pedals and automotive clutch, brake, and accelerator pedals.

  d. A safety "shutdown" control is needed during an operation in which the user's hands cannot be freed to reach a safety switch. [Source: MIL-STD-1472F, 1999]

- **6.1.3.2 When not to use.** Foot-operated controls should not be used under the following conditions:

  a. A standing user is confronted with a sensitive balancing requirement, such as a moving platform, that would make it difficult to balance on one foot while operating the control with the other.

  b. A precise control action is required.

  c. Selection from many controls is required. [Source: MIL-STD-1472F, 1999]

- **6.1.3.3 Location of foot controls.** Foot controls shall be located and designed so that they can be operated in as natural a way as practicable. [Source: MIL-STD-1472F, 1999]

- **6.1.3.4 What to avoid.** The following shall be avoided in the design of foot operated controls:

  a. frequent, maximum reaching,

  b. requiring that the leg or foot be held in an awkward position for extended periods of time,

  c. requiring that a user operate a control frequently or for an extended period of time while sitting in an awkward or uncomfortable position,

  d. requiring frequent or prolonged application of maximum force,

  e. requiring that a user search for a particular foot control in order to select the proper one, and

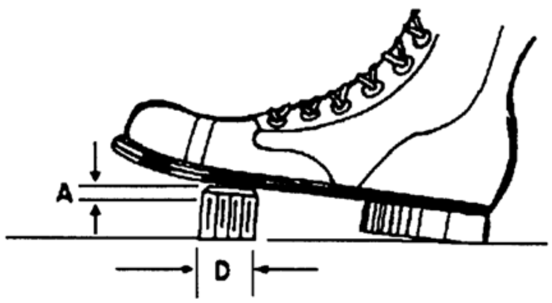
  f. placing a foot control where it might be stepped on and actuated inadvertently or where typical movement from one foot control to another creates conditions in which the foot or clothing might be entrapped by an intervening control as a user moves the foot from one control to another. [Source: MIL-STD-1472F, 1999]

- **6.1.3.5 Configuration and placement.** Configuration and placement of foot-operated controls shall accommodate the anthropometry of the operator's foot wearing operational shoes or boots with each foot-operated control located so that (a) actuating it by one foot does not interfere with actuating a control by the other foot and (b) foot and leg movements are natural and easily accomplished within the work station where the foot controls are located. [Source: MIL-STD-1472F, 1999]

6.1.4 Foot-operated switches

- **6.1.4.1 Foot-operated switch dimensions.** The dimensions, resistance, and displacement of foot-operated switches shall not exceed the maximum and minimum values given in Exhibit 6.1.4.1. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.4.1 Foot-operated switch specifications



	Diameter D	Resistance		Displacement A			
		Foot will not rest on control	Foot will rest on control	Normal operation	Heavy boot operation	Ankle flexion only	Total leg movement
Minimum	13 mm (0.5 in)	18 N (4 lb)	45 N (10 lb)	13 mm (0.5 in)	25 mm (1 in)	25 mm (1 in)	25 mm (1 in)
Maximum	-	90 N (20 lb)	90 N (20 lb)	65 mm (2.5 in)	65 mm (2.5 in)	65 mm (2.5 in)	100 mm (4 in)

- **6.1.4.2 Multiple foot-operated switch separation.** Although only one switch per foot is recommended, when it is necessary that more than one switch be operated by the same foot, those switches shall be separated by at least 75 mm (3.0 in) horizontally and 200 mm (8.0 in) vertically. [Source: MIL-STD-1472F, 1999]

- **6.1.4.3 When to use.** Foot-operated switches should be used only where the operator is likely to have both hands occupied when switch actuation may be required, or when load sharing among limbs is desirable. [Source: MIL-STD-1472F, 1999]

  Discussion. Because foot-operated switches are susceptible to accidental actuation, limit their use to non-critical or infrequent operations such as press-to-talk communication or vehicle headlight dimming. [Source: MIL-STD-1472F, 1999]

- **6.1.4.4 Operation.** Foot switches shall be positioned for operation by the toe and ball of the foot rather than by the heel. [Source: MIL-STD-1472F, 1999]

- **6.1.4.5 Obstruction free placement.** They shall not be located near an obstruction that would prevent a user from centering the ball of the foot on the switch button. [Source: MIL-STD-1472F, 1999]

  Discussion. A pedal may be used over the button to aid in locating and operating the switch. [Source: MIL-STD-1472F, 1999]

- **6.1.4.6 Operation in wet or slippery conditions** When the switch may become wet and slippery, the switch cap surface should provide a high degree of frictional resistance. [Source: MIL-STD-1472F, 1999]

- **6.1.4.7 Feedback.** A positive indication of control actuation shall be provided (e.g., snap feel, audible click, or associated visual or audio display). [Source: MIL-STD-1472F, 1999]

6.1.5 Hand-operated controls

6.1.5.1 Rotary selector switches

- **6.1.5.1.1 Rotary selector switch specifications.** The dimensions, resistance, displacement, and separation between adjacent edges of areas swept by rotary selector switches should not exceed the maximum and minimum values given in Exhibit 6.1.5.1.5. [Source: MIL-STD-1472F, 1999]

- **6.1.5.1.2 When to use.** When a switch must have three or more detented positions, a rotary selector switch should be used. [Source: MIL-STD-1472F, 1999]

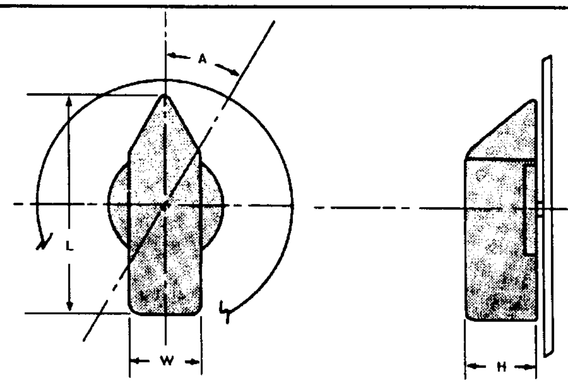
- **6.1.5.1.3 Two detented positions.** When only two detented positions are needed, a rotary switch should not be used unless prompt visual identification of the switch position is of prime importance, and speed of control operation is not critical. [Source: MIL-STD-1472F, 1999]

- **6.1.5.1.4 Moving pointer, fixed scale.** Rotary selector switches should have moving pointers and fixed scales. [Source: MIL-STD-1472F, 1999]

■ **6.1.5.1.5 Shape.** Moving pointer knobs shall be bar-shaped, with parallel sides and with the indicating end tapered to a point, as illustrated in Exhibit 6.1.5.1.5. [Source: MIL-STD-1472F, 1999]

Exception. Exceptions may be justified if pointer knobs are shape coded or if space is restricted and torque is light. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.5.1.5 Rotary selector switch



Dimensions

	Length L	Width W	Height H	Resistance
Minimum	25 mm (1 in)	--	16 mm (0.6 in)	115 mN*m (1 in*lb)
Maximum	100 mm (4 in)	25 mm (1 in)	75 mm (3 in)	680 mN*m (6 in*lb)

	Displacement A †	Displacement A ‡	Separation One-hand random	Separation Two-hand operation
Minimum	15°	30°	25 mm (1 in)	75 mm (3 in)
Maximum	40°	90°	--	--
Preferred	--	--	50 mm (2 in)	125 mm (5 in)

† For facility performance

‡ When special engineering requirements demand large separation or when tactually ("blind") positioned controls are required.

- **6.1.5.1.6 Shape coding.** Shape coding shall be used if a number of rotary controls located on the same panel and used for different functions might otherwise be confused. [Source: MIL-STD-1472F, 1999]

- **6.1.5.1.7 Reference line.** A rotary switch control shall have an associated reference line. This line shall have a luminance contrast of at least 3.0 with the color of the switch control under all lighting conditions. [Source: MIL-STD-1472F, 1999]

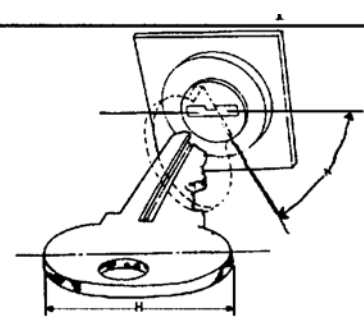
- **6.1.5.1.8 Parallax.** The knob pointer shall be mounted sufficiently close to its scale to minimize parallax between the pointer and scale markings. When viewed from the user's normal working position, parallax errors shall not exceed 25 % of the distance between scale markings. [Source: MIL-STD-1472F, 1999]

6.1.5.2 Key-operated switches

Key-operated switches are used to prevent unauthorized operation. Ordinarily, they provide ON and OFF system operation.

- **6.1.5.2.1 Key-operated switch specifications.** The dimensions, displacement, and resistance shall not exceed the maximum and minimum values given in Exhibit 6.1.5.2.1. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.5.2.1 Key-operated switch specifications



	Displacement (A)	Height (H)	Resistance
Minimum	30°	13 mm (0.5 in)	115 mN*m (1 in*lb)
Maximum	90°	75 mm (3 in)	680 mN*m (6 in*lb)

- **6.1.5.2.2 Color, shape, and size coding.** Use color, shape, or size coding or a combination according to the following:

  a. Color shall be used to aid in identifying various keys by function or use.

  b. Red shall be reserved for emergency functions.

  c. Color-coding shall be used only if ambient illumination is adequate to differentiate the colors.

  d. Shape-coding may be used when it is desirable to identify a given key by feel.

  e. When shape coding is used, sharp corners shall be avoided.

  f. Size-coding shall also be used if no more than two sizes are employed and the sizes range from a minimum height of 13mm (0.5 in) to a maximum height of 75mm (3 in.) [Source: MIL-STD-1472F, 1999].

- **6.1.5.2.3 Marking and labeling.** Key-operated switches shall be appropriately marked and labeled. [Source: MIL-STD-1472F, 1999]

- **6.1.5.2.4 Teeth on both edges.** Keys for key-operated switches shall have teeth on both edges and shall fit the lock with either side up or forward. [Source: MIL-STD-1472F, 1999]

- **6.1.5.2.5 Teeth on a single edge.** When Paragraph 6.1.5.2.4 has been waived and keys with a single row of teeth are used, the lock shall be positioned so that the teeth point up or forward. [Source: MIL-STD-1472F, 1999]

- **6.1.5.2.6 ON-OFF switches.** Key-operated ON-OFF switches shall be positioned so that the key is vertical when the switch is OFF. [Source: MIL-STD-1472F, 1999]

- ▫ **6.1.5.2.7 Direction of rotation.** The key should turn clockwise from the vertical OFF position to the ON position. [Source: MIL-STD-1472F, 1999]

- ▫ **6.1.5.2.8 Key removal.** Users should normally be able to remove the key from the switch only when the switch is in the OFF position. [Source: MIL-STD-1472F, 1999]

6.1.5.3 Discrete thumbwheel controls

- ▫ **6.1.5.3.1 When to use.** Thumbwheel controls should be used only when the function requires a compact digital input device, for example, to enter a series of numbers, and a readout is needed for verification. [Source: MIL-STD-1472F, 1999]

- **6.1.5.3.2 Shape.** Each position around the circumference of a discrete thumbwheel shall have a concave surface or be separated by a high-friction area that is raised from the periphery of the thumbwheel. [Source: MIL-STD-1472F, 1999]

- **6.1.5.3.3 Viewing of thumbwheel digits.** The thumbwheel shall not preclude viewing the digits within a 30° viewing angle to the left and right of a perpendicular to the thumbwheel digits. [Source: MIL-STD-1472F, 1999]

- **6.1.5.3.4 Coding.** Thumbwheel controls should be coded by location, labeling, and color (e.g., reversing the colors of the least significant digit wheel as on typical odometers). [Source: MIL-STD-1472F, 1999]

- **6.1.5.3.5 Coding of thumbwheel switches.** Where used as input devices, thumbwheel switch Off or Normal positions should be color coded to permit a visual check that the digits have been reset to their Off or Normal positions. [Source: MIL-STD-1472F, 1999]

- **6.1.5.3.6 Direction of movement.** Moving the thumbwheel edge forward, upward, or to the right shall increase the setting. [Source: MIL-STD-1472F, 1999]

- **6.1.5.3.7 Internal illuminance and appearance of characters.** When ambient illumination will provide visual indicator illuminance less than 3.5 cd/m^2 (1 fL), the thumbwheel shall be illuminated internally with the digits appearing as illuminated characters on a black background, with approximate dimensions as follows:

  a. height: at least 4.8 mm (0.19 in),

  b. height-to-width ratio: 3:2, and

  c. height-to-stroke width ratio: 10:1. [Source: MIL-STD-1472F, 1999]

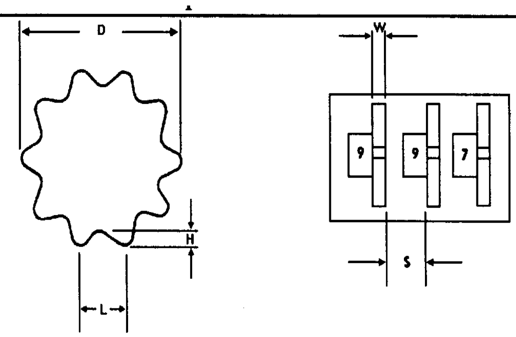
- **6.1.5.3.8 External illuminance and appearance of characters.** When external illumination is used, digits should be bold, black numerals engraved on a light or white background with the dimensions approximately as those in Paragraph 6.1.5.3.7, with a height-to-stroke width ratio approximately 5:1. [Source: MIL-STD-1472F, 1999]

  Discussion. When ambient illumination will provide visual indicator illuminance equal to or greater than 3.5 cd/m2 (1 fL), internal illumination is not required.

- **6.1.5.3.9 Visibility.** Thumbwheel design shall permit viewing of inline digital read-out from all operator positions. [Source: MIL-STD-1472F, 1999]

- **6.1.5.3.10 Dimensions.** Thumbwheel dimensions shall not exceed the maximum and minimum dimensions given in Exhibit 6.1.5.3.10. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.5.3.10 Discrete thumbwheel dimensions



	D Trough Diameter	L distance	W Width	H Depth	S Separation	Resistance
Minimum	30 mm (1.1 in)	11 mm (0.4 in)	3 mm (0.1 in)	3 mm (0.1 in)	10 mm (0.4 in)	1.7 N (6 oz)
Maximum	75 mm (3 in)	1,9 mm (0.75 in)	--	13 mm (0.5 in)	--	5.6 N (20 oz)

- **6.1.5.3.11 Provide detents.** Detents shall be provided for discrete position thumbwheels. [Source: MIL-STD-1472F, 1999]

- **6.1.5.3.12 Increase resistance between detents** Resistance shall increase between detents (within the limits given in Exhibit 6.1.5.3.10) so that the thumbwheel will not rest between detents, but rather will snap into position at a detent. [Source: MIL-STD-1472F, 1999]

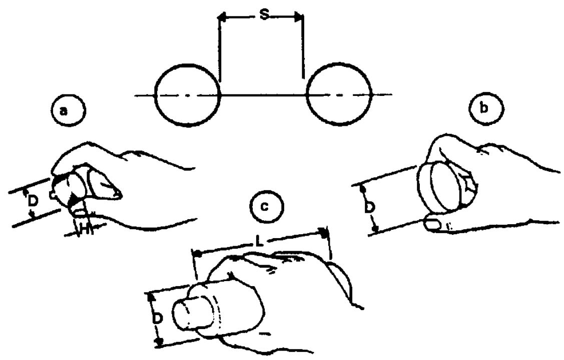
- **6.1.5.3.13 Separation.** Adjacent edges of thumbwheel controls shall be separated by at least 10 mm (0.4 in to preclude accidental activation of adjacent controls during use. [Source: MIL-STD-1472F, 1999]

6.1.5.4 Knobs

- **6.1.5.4.1 Knob specifications.** The dimensions of knobs shall not exceed the maximum and minimum values specified in Exhibit 6.1.5.4.1 with torque (turning resistance) and separation between adjacent edges of knobs conforming to the values given in the exhibit. [Source: MIL-STD-1472F, 1999]

  Discussion. Within the limits stated, and provided that resistance is low and that the knob can be easily grasped, knob size is relatively unimportant. If panel space is limited, knobs may approximate the minimum values, with their resistance as low as possible, but not so low that they might be turned by vibration or by a mere touch. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.5.4.1 Knob Specifications



	a Fingertip grasp		b Thumb and finger encircled	c Palm grasp	
	H Height	D Diameter	D Diameter	D Diameter	L Length
Minimum	13 mm (0.5 in)	10 mm (0.4 in)	25 mm (1.0 in)	38 mm (1.5 in)	75 mm (3.0 in)
Maximum	25 mm (1.0 in)	100 mm (4.0 in)	75 mm (3.0 in)	75 mm (3.0 in)	

	Torque		Separation	
	†	‡	S One hand individually	S Two hands simultaneously
Minimum	--	--	25 mm (1 in)	50 mm (2 in)
Optimum	--	--	50 mm (2 in)	125 mm (5 in)
Maximum	32 mN*m (4.5 in*oz)	42 mN*m (6.0 in*oz)	--	--

† To and including 25 mm (1 in) diameter knobs
‡ Greater than 25 mm (1 in) diameter knobs

- **6.1.5.4.2 When to use.** A knob should be used if low force or precise adjustment of a continuous variable is required. [Source: MIL-STD-1472F, 1999]

- **6.1.5.4.3 Moving knob vs fixed scale knob.** A moving knob with a fixed scale should be used rather than a moving scale with a fixed index for most tasks. [Source: MIL-STD-1472F, 1999]

- **6.1.5.4.4 Single-revolution knob.** When the position of a single-revolution knob must be distinguishable, the knob should have a pointer or marker. [Source: MIL-STD-1472F, 1999]

- **6.1.5.4.5 Knob style.** Rotating knob controls for different types of control actions should be distinguishable both visually and tactually and not be easily confused with one another. [Source: NUREG-0700, 1981]

- **6.1.5.4.6 Knob position indication.** When knowledge of the position of a knob or its setting is important, the knob should be shape coded or include a pointer or other means to make its position apparent. [Source: NUREG-0700, 1981]

6.1.5.5 Ganged control knobs

- **6.1.5.5.1 Ganged control knob specifications.** The dimensions for two and three knob assemblies shall not exceed the maximum or minimum values given in Exhibit 6.1.5.5.1 with torque (turning resistance) not exceeding the values given in the exhibit and separation at least at the minimum given in the exhibit for the appropriate type of operation. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.5.5.1 Ganged control knob specifications

	Two knob assembly				Three knob assembly					
	H_1	H_2	D_1	D_2	H_1	H_2	H_3	D_1	D_2	D_3
Minimum	16 mm (.6 in)	13 mm (.5 in)	13 mm (.5 in)	22 mm (.9 in)	19 mm (.75 in)	19 mm (.75 in)	6 mm (.25 in)	13 mm (.5 in)	44 mm (1.75 in)	75 mm (3 in)
Maximum	-	-	-	100 mm (4 in)	-	-	-	-	-	100 mm (4 in)

	Torque		Separation			
			One hand individually		Two hand simultaneously	
	†	‡	Bare	Gloved	Bare	Gloved
Minimum	--	--	25 mm (1.0 in)	63 mm (2.5 in)	50 mm (2.0 in)	90 mm (3.5 in)
Optimum	--	--	50 mm (2.0 in)	90 mm (3.5 in)	75 mm (3.0 in)	100 mm (4.0 in)
Maximum	32 mN*m (4.5 in*oz)	42 mN*m (6.0 in*oz)	--	--	--	--

† To and including 25 mm (1.0 in) diameter knobs
‡ Greater than 25 mm (1.0 in) diameter knobs

□ **6.1.5.5.2 When to use.** Ganged knob assemblies should be used only if panel space is limited and when used, the number ganged should be minimized. [Source: MIL-STD-1472F, 1999]

□ **6.1.5.5.3 Three-knob assemblies.** Three-knob assemblies should be avoided. [Source: MIL-STD-1472F, 1999]

□ **6.1.5.5.4 When to avoid.** Ganged knobs should not be used under the following conditions:

a. Extremely accurate or rapid operations are required.

b. Frequent changes are necessary.

c. The user is likely to be wearing gloves.

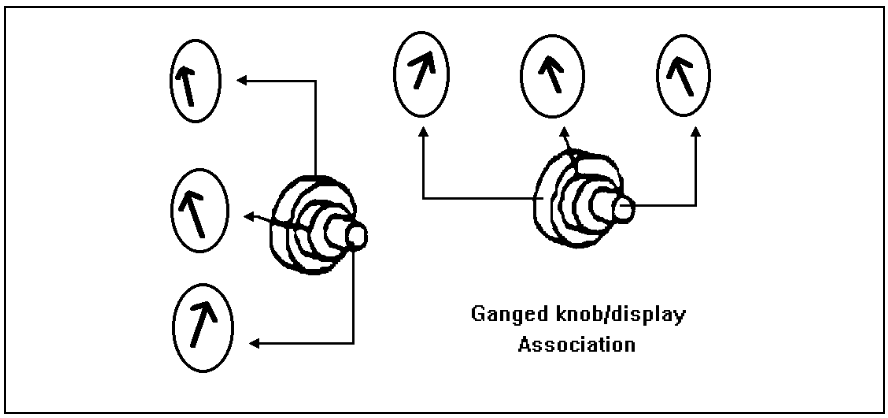
d. The equipment is likely to be exposed to weather or field conditions. [Source: MIL-STD-1472F, 1999]

□ **6.1.5.5.5 Serrations.** Knobs should be serrated with knobs for precise adjustments having fine serrations and knobs for gross adjustments having coarse serrations. [Source: MIL-STD-1472F, 1999]

- **6.1.5.5.6 Marking.** An indexing mark or pointer shall be provided for each knob and differ sufficiently from one knob in an assembly to another so that it is apparent which indexing mark is associated with which knob. [Source: MIL-STD-1472F, 1999]

- **6.1.5.5.7 Knob and visual indicator relationship.** When the knobs of a ganged assembly are associated with an array of visual indicators, the knob closest to the panel shall be associated with the left-most visual indicator in a horizontal array or to the uppermost visual indicator in a vertical array, as illustrated in Exhibit 6.1.5.5.7. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.5.5.7 Relationship between ganged knobs and their associated visual indicators
[Source: DOE-HFAC1, 1992]



- **6.1.5.5.8 Inadvertent movement, critical.** When it is critical that one knob not be moved inadvertently while another knob is being moved, a secondary knob control movement shall be required. [Source: MIL-STD-1472F, 1999]

  Example. It might be necessary to press the top knob in or down to engage its control shaft. [Source: MIL-STD-1472F, 1999]

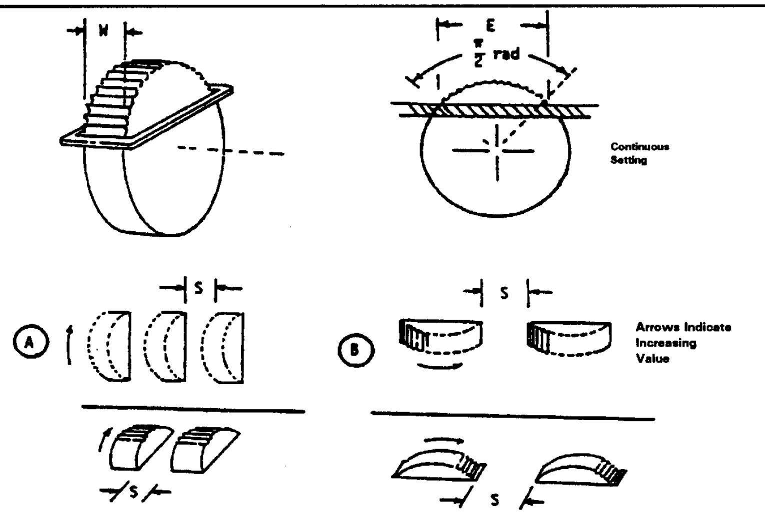
- **6.1.5.5.9 Inadvertent movement, non-critical.** When inadvertent movement of one knob while another is being adjusted is undesirable but not critical, the "optimum" separation dimensions in Exhibit 6.1.5.5.1 should be used. [Source: MIL-STD-1472F, 1999]

  Discussion. Using different colors for the individual knobs can help in their identification. [Source: MIL-STD-1472F, 1999]

6.1.5.6 Continuous adjustment thumbwheels

- **6.1.5.6.1 Continuous thumbwheel specifications.** The dimensions, separation, and resistance of thumbwheels shall not exceed the maximum and minimum values given in Exhibit 6.1.5.6.1. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.5.6.1 Continuous thumbwheel specifications



	E Rim exposure	W Width	S A	S B	Resistance
Minimum	25 mm † (1.0 in)	3 mm (0.1 in)	25 mm (1.0 in) Add 13 mm (0.5 in) for gloves	50 mm (2.0 in) Add 25 mm (1.0 in) for gloves	To minimize effects of inadvertent input if operator subject to motion
Maximum	100 mm (4.0 in)	23 mm (0.9 in)	N/A	N/A	3.3 N (12 oz)

† Preferred. Some miniature applications may require less.

- **6.1.5.6.2 When to use.** When an application will benefit from the compactness of a thumbwheel, a continuously adjustable thumbwheel should be used rather than a rotary knob. [Source: MIL-STD-1472F, 1999]

- **6.1.5.6.3 Orientation and movement.** Thumbwheels shall be oriented and move in the directions specified in Exhibit 6.1.5.6.1. [Source: MIL-STD-1472F, 1999]

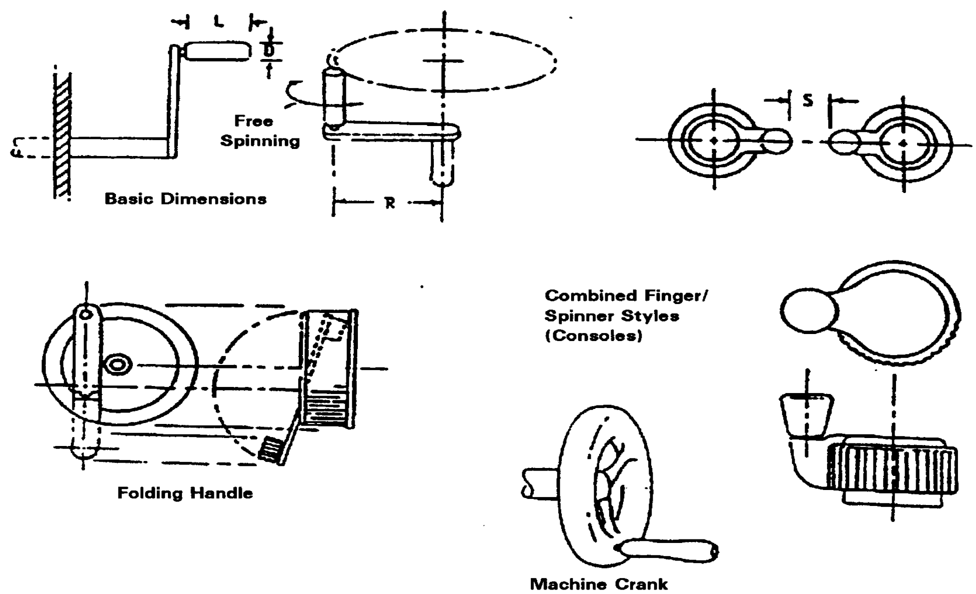
- **6.1.5.6.4 Turning aids.** The rim of a thumbwheel shall be serrated or provided with a high friction surface to make it easy to turn. [Source: MIL-STD-1472F, 1999]

- **6.1.5.6.5 OFF position.** A continuous adjustment thumbwheel that has an OFF position shall have a detent at that position. [Source: MIL-STD-1472F, 1999]

6.1.5.7 Cranks

- **6.1.5.7.1 Crank specifications.** The dimensions, resistance, and separation of adjacent circular swept areas of cranks shall not exceed the maximum and minimum values given in Exhibit 6.1.5.7.1. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.5.7.1 Crank specifications



		Handle		R, Turning radius	
Load	**Specification**	**L, length**	**D, diameter**	**Rate below 100 RPM**	**Rate above 100 RPM**
Light loads:	Minimum	25 mm(1.0 in)	10 mm(0.4 in)	38 mm(1.5 in)	13 mm(0.5 in)
Less than	Preferred	38 mm(1.5 in)	13 mm(0.5 in)	75 mm(3.0 in)	65 mm(2.5 in)
22N (5.0 lb) (Wrist and finger movement)	Maximum	75 mm(3.0 in)	16 mm(0.6 in)	125 mm(5.0 in	115 mm(4.5 in)
Heavy loads:	Minimum	75 mm(3.0 in)	25 mm(1.0 in)	190 mm(7.5 in)	125 mm(5.0 in)
22 N (5.0 lb)	Preferred	95 mm(3.75 in)	25 mm(1.0 in)	-- --	-- --
or more. arm movement)	Maximum	-- --	38 mm(1.5 in)	510 mm(20.0 in)	230 mm(9.0 in)

- **6.1.5.7.2 When to use.** Cranks should be used for any task that requires many rotations of a control, particularly if high rates or large forces are involved. [Source: MIL-STD-1472F, 1999]

  Discussion. For tasks that involve large slewing movements as well as small, fine adjustments, a crank handle may be mounted on a knob or hand wheel. The crank would then be used for slewing and the knob or hand wheel for the fine adjustment.

- **6.1.5.7.3 Numerical selection.** When a crank is used for tuning or another process involving numerical selection, each rotation of the crank should correspond to a multiple of 1, 10, 100, or other appropriate value. [Source: MIL-STD-1472F, 1999]

- **6.1.5.7.4 Extreme precision in numerical selection.** When extreme precision is required in an X-Y control, for example, in setting crosshairs or reticles in reading a map, a simultaneously operated pair of hand cranks should be used in preference to other two-axis controllers. [Source: MIL-STD-1472F, 1999]

  Discussion. Be certain that the gear ratios and dynamic characteristics of such cranks permit precise placement of the followers without over- or undershooting and successive corrective movements. [Source: MIL-STD-1472F, 1999]

- **6.1.5.7.5 Grip handle.** The handle of a hand crank shall turn freely around its shaft. [Source: MIL-STD-1472F, 1999]

- **6.1.5.7.6 Folding handles.** When a crank handle might be a hazard to persons passing by, or if it is critical that the handle not be moved inadvertently, a folding handle should be used that is stable in both the extended and folded positions. [Source: MIL-STD-1472F, 1999]

- **6.1.5.7.7 Crank balance.** In applications in which resistance is low, the crank shall be balanced so that the weight of the handle does not move the crank from its last setting. [Source: MIL-STD-1472F, 1999]

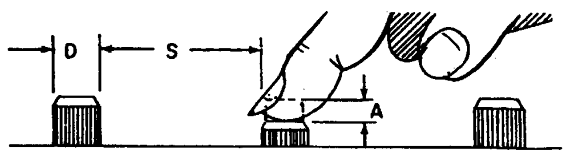
6.1.5.8 Push buttons

- **6.1.5.8.1 Push button specifications.** The dimensions, resistance, displacement, and separation of push buttons shall not exceed the maximum and minimum values given in Exhibit 6.1.5.8.1. [Source: MIL-STD-1472F, 1999]

  Exception. Push buttons used in keyboards are exempt from this requirement. [Source: MIL-STD-1472F, 1999]

  Note. Mechanical interlocks or barriers may be used instead of the separation specified in Exhibit 6.1.5.8.1. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.5.8.1 Push button specifications



	Dimensions Diameter D		Resistance		
	Fingertip	Thumb or palm	Single finger	Different fingers	Thumb or palm
Minimum	9.5 mm (0.375 in)	19 mm (0.75 in)	2.8 N (10 oz)	1.4 N (5 oz)	2.8 N (10 oz)
Maximum	25 mm (1 in)		11 N (40 oz)	5.6 N (20 oz)	23 N (80 Oz)

Displacement A

	Fingertip	Thumb or palm
Minimum	2 mm (0.08 in)	3 mm (0.125 in)
Maximum	6 mm (0.25 in)	38 mm (1.5 in)

Separation S

	Single finger	Single finger sequential	Different fingers	Thumb or palm
Minimum	13 mm (0.5 in)	6 mm (0.25 in)	6 mm (0.25 in)	25 mm (1 in)
Preferred	50 mm (2 in)	13 mm (0.5 in)	13 mm (0.5 in)	150 mm (6 in)

Note: These data are for barehand operation. For gloved hand operation, the minimum values should be suitably adjusted

- ▫ **6.1.5.8.2 When to use.** Push buttons should be used if a control is needed for momentary contact or to activate a locking circuit, particularly if the control will be used frequently. [Source: MIL-STD-1472F, 1999]

- ▪ **6.1.5.8.3 When not to use.** Push buttons shall not be used if the status of a function must be indicated by the position of its control. [Source: MIL-STD-1472F, 1999]

- ▫ **6.1.5.8.4 Shape.** The surface of a push button should be concave to accommodate a fingertip. If it is not concave, it should have a nonslip surface. [Source: MIL-STD-1472F, 1999]

- ▪ **6.1.5.8.5 Positive feedback.** A push button shall provide positive feedback of operation, for example, a "snap" action, an audible click, or an integral light. [Source: MIL-STD-1472F, 1999]

- ▪ **6.1.5.8.6 Prevention of inadvertent operation.** A channel or cover guard shall be provided when accidental actuation of the control must be prevented. [Source: MIL-STD-1472F, 1999]

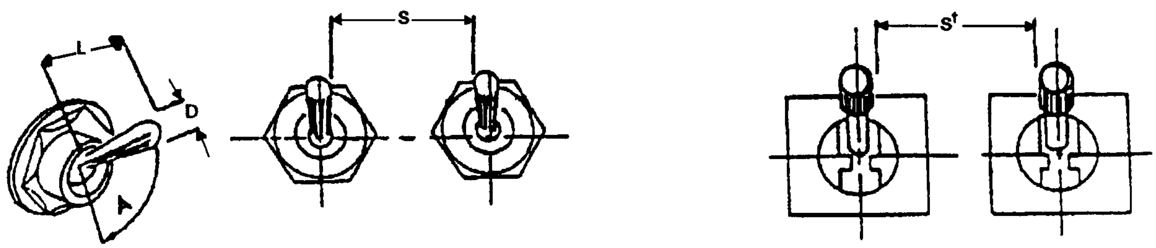
- ▪ **6.1.5.8.7 Non-interference by cover guard.** When a cover guard is in the open position, it shall not interfere with operation of the protected device or adjacent controls. [Source: MIL-STD-1472F, 1999]

6.1.5.9 Toggle switches

- ▪ **6.1.5.9.1 Toggle switch specifications.** The dimensions, resistance, displacement, and separation of toggle switches shall not exceed the maximum and minimum values given in Exhibit 6.1.5.9.1. [Source: MIL-STD-1472F, 1999]

  Definition. A **toggle switch** is a switch with discrete positions operated by a lever. Controls having the same size and shape, but that allow continuous adjustments are **levers**. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.5.9.1 Toggle switch specifications



	Dimensions			Resistance	
	L Arm length *	L Arm length **	D Control tip	Small switch	Large switch
Minimum	13 mm (0.5 in)	38 mm (1.5 in)	3 mm (0.13 in)	2.8 N (10 oz)	2.8 N (10 oz)
Maximum	50 mm (2 in)	50 mm (2 in)	25 mm (1 in)	4.5 N (16 oz)	11 N (40 oz)

Displacement between positions

	A 2 position	A 3 position
Minimum	30°	17°
Maximum	80°	40°
Preferred	-	25°

Separation

	S Single finger operation †	S Single finger sequential operation	S Simultaneous operation by different fingers	
Minimum	19 mm (0.75 in)	25 mm (1 in)	13 mm (0.5 in)	16 mm (0.63 in)
Optimum	50 mm (2 in)	50 mm (2 in)	25 mm (1 in)	19 mm (0.75 in)

* Use by bare hand
** Use with heavy handwear
† Using a lever lock toggle switch

- **6.1.5.9.2 Toggle switch resistance.** The resistance of a toggle switch shall increase as the switch is moved toward its midpoint, then decrease as the switch "snaps" into its alternate position. (See Exhibit 6.1.5.9.1). [Source: MIL-STD-1472F, 1999]

- **6.1.5.9.3 Toggle switch position.** The switch shall not be capable of remaining between positions without being held. (See Exhibit 6.1.5.9.1). [Source: MIL-STD-1472F, 1999]

- **6.1.5.9.4 When to use.** Toggle switches should be used for functions that require two discrete positions or where space limitations are severe. [Source: MIL-STD-1472F, 1999]

- **6.1.5.9.5 Three-position toggle switches.** A toggle switch having three positions shall be used only if (1) the use of some other type of control such as a rotary switch or a legend switch is not feasible, or (2) the toggle switch is a spring-loaded switch with the center position being the OFF position. [Source: MIL-STD-1472F, 1999]

- **6.1.5.9.6 Spring-loaded toggle switches.** A toggle switch that latches in one position and is spring-loaded to return to center from the other shall not be used if release from the spring-loaded position would allow the switch lever to travel past the center position. [Source: MIL-STD-1472F, 1999]

- **6.1.5.9.7 Preventing accidental actuation.** When it is imperative that a toggle switch not be operated inadvertently, for example, if actuation might result in a critical or hazardous condition, the switch shall be protected by means of a barrier or a cover, however, not by safety or lock wire. [Source: MIL-STD-1472F, 1999]

- **6.1.5.9.8 Cover lifting resistance.** The resistance to lifting a cover shall not exceed 13 N (3 lb). [Source: MIL-STD-1472F, 1999]

- **6.1.5.9.9 Non-interference of cover.** When a cover is used, it shall not interfere with the operation of the switch or of adjacent controls. [Source: MIL-STD-1472F, 1999]

- **6.1.5.9.10 Positive feedback.** A toggle switch shall provide positive feedback, for example, a "snap" action, an audible click, or an integral or associated light. [Source: MIL-STD-1472F, 1999]

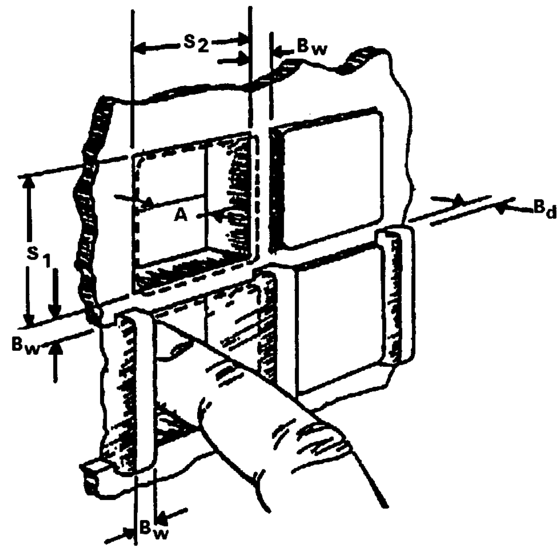
- **6.1.5.9.11 Vertical orientation.** Toggle switches should be oriented vertically, and, if applicable, make OFF be in the down position. [Source: MIL-STD-1472F, 1999]

- **6.1.5.9.12 Horizontal orientation.** A horizontal orientation should be used only to make the switch compatible with its controlled function or equipment location. [Source: MIL-STD-1472F, 1999]

6.1.5.10 Legend switches

- **6.1.5.10.1 Legend switch specifications.** The dimensions, resistance, and displacement of legend switches and the separation of adjacent legend switches shall not exceed the maximum and minimum values given in Exhibit 6.1.5.10.1. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.5.10.1 Legend switch specifications



	S_1, S_2 Size	A Displacement	Barriers B_w	Barriers B_d	Resistance
Minimum	19 mm* (0.75 in)	3 mm** (0.13 in)	3 mm (0.13 in)	5 mm (0.38 in)	2.8 N*** (10 oz)
Maximum	38 mm (1.5 in)	6 mm (0.25 in)	6 mm (0.25 in)	6 mm (0.25 in)	16.7 N (60 oz)

* 15 mm (0.63 in) where the switch is not depressed below the panel.
** 5 mm (0.38 in) for positive position switches.
*** 5.6 N (20 oz) for use in moving vehicles.

- **6.1.5.10.2 Avoiding inadvertent activation.** Critical switches and switches likely to be activated inadvertently shall have barriers unless specified otherwise. [Source: MIL-STD-1472F, 1999]

- **6.1.5.10.3 Avoiding inadvertent activation.** The height of barriers (measured from the surface of the panel) shall not exceed the maximum and minimum values given in Exhibit 6.1.5.10.1. [Source: MIL-STD-1472F, 1999]

- **6.1.5.10.4 Positive feedback.** A legend switch shall provide positive feedback of operation, for example, a "snap" action, an audible click, or an integral or associated light. [Source: MIL-STD-1472F, 1999]

- **6.1.5.10.5 Legibility of legend.** The legend on a legend switch shall be legible with and without internal illumination. [Source: MIL-STD-1472F, 1999]

- **6.1.5.10.6 Lamp replacement.** The lamp within a legend switch shall be replaceable from the front of the panel by hand. [Source: MIL-STD-1472F, 1999]

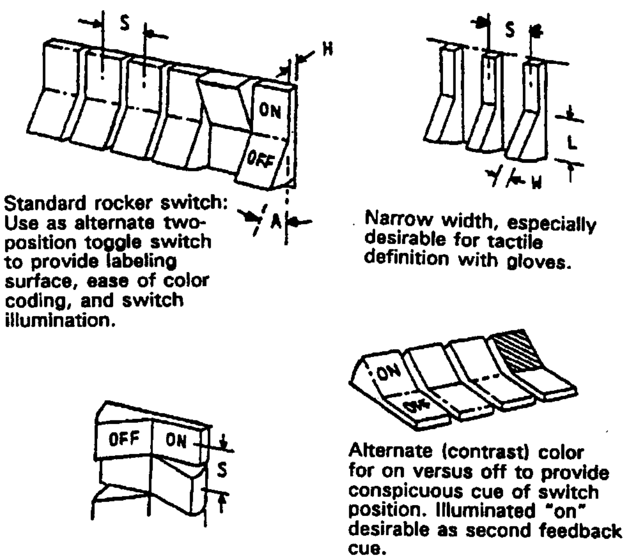
- **6.1.5.10.7 Cover replacement.** The covers of legend switches should be marked or coded to ensure that each cover can be replaced on its associated switch if it has been removed. [Source: MIL-STD-1472F, 1999]

- **6.1.5.10.8 Legends.** The legend on a legend switch shall not exceed three lines of characters. [Source: MIL-STD-1472F, 1999]

6.1.5.11 Rocker switches

- **6.1.5.11.1 Rocker switch specifications.** The dimensions, resistance, displacement, and separation of rocker switches shall not exceed the maximum and minimum values given in Exhibit 6.1.5.11.1. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.5.11.1 Rocker switch specifications



	Dimensions		Resistance
	W. width	L. length	
Minimum	6 mm (0.25 in)	13 mm (0.5 in)	2.8 N (10 oz)
Maximum			11 N (40 oz)

	Displacement		Separation (center-to-center)	
	H, height depressed	A, angle	S (Bare hand)	S (Gloved hand)
Minimum	3 mm (0.1 in)	30°	19 mm (0.75 in)	32 mm (1.25 in)

- ■ **6.1.5.11.2 Rocker switch resistance.** The resistance of a rocker switch shall increase as the upper portion is pressed down or in, then decrease so that the switch "snaps" into position. [Source: MIL-STD-1472F, 1999]

  Discussion. It may be desirable to color code the two portions of a rocker switch as an aid in identifying the switch's position, for example, the portion indicating ON might be one color, and the portion indicating OFF might be another. [Source: MIL-STD-1472F, 1999]

- ■ **6.1.5.11.3 Rocker switch position.** A rocker switch shall not be capable of stopping between positions. [Source: MIL-STD-1472F, 1999]

- □ **6.1.5.11.4 When to use.** Rocker switches should be used rather than toggle switches if (1) a toggle switch handle might interfere with or be interfered with surrounding activity, or (2) panel space is too limited for the labeling of toggle switch positions. [Source: MIL-STD-1472F, 1999]

- ■ **6.1.5.11.5 Three-position rocker switches.** Rocker switches with three positions shall be used only if (1) the switch is spring-loaded, with the center position being OFF, or (2) the use of another type of control such as a rotary switch or a legend switch is not feasible. [Source: MIL-STD-1472F, 1999]

- ■ **6.1.5.11.6 Preventing accidental actuation.** If it is imperative that a rocker switch not be operated inadvertently, for example, if actuation might result in a critical or hazardous condition, the switch shall be protected, for example, with a channel guard, barrier, cover, or an equivalent protective measure. [Source: MIL-STD-1472F, 1999]

- ■ **6.1.5.11.7 Positive feedback.** A rocker switch shall provide positive feedback of operation, for example, a "snap" action, an audible click, or an integral or associated light. [Source: MIL-STD-1472F, 1999]

- ■ **6.1.5.11.8 Orientation.** When practicable, rocker switches shall be oriented vertically. Actuation of the upper portion, that is, depressing it, shall turn the equipment or component ON, cause a quantity to increase, or cause movement of a unit equipment or a component clockwise, forward, up, or to the right. Rocker switches shall be oriented horizontally only to make the switch compatible with the controlled function or equipment location. [Source: MIL-STD-1472F, 1999]

- □ **6.1.5.11.9 Illumination.** When a rocker switch will be used where the ambient illumination will provide visual indicator illuminance of less than 3.5 cd/m^2 (1 fL), the switch should be illuminated internally. [Source: MIL-STD-1472F, 1999]

- ■ **6.1.5.11.10 Labels.** When a rocker switch is illuminated, any alphanumeric characters shall appear as illuminated characters on an opaque background. [Source: MIL-STD-1472F, 1999]

- **6.1.5.11.11 Character size on illuminated rocker switches.** When a rocker switch is illuminated, any alphanumeric characters shall:

  a. be at least 4.8 mm (0.19 in) in height,

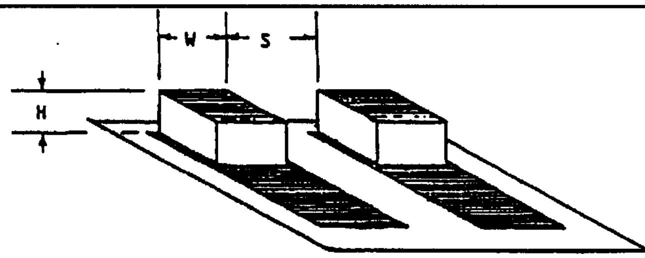
  b. have a height-to-width ratio of 3:2, and

  c. have a height-to-stroke-width ratio of 10:1. [Source: MIL-STD-1472F, 1999]

6.1.5.12 Slide switches

- **6.1.5.12.1 Slide switch specifications.** The dimensions, resistance, and separation of slide switches shall not exceed the maximum and minimum values given in Exhibit 6.1.5.12.1. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.5.12.1 Slide switch specifications



	Dimensions			Resistance	
	H Actuator height †	H Actuator height ‡	W Actuator width	Small switch	Large switch
Minimum	6 mm (0.25 in)	13 mm (0.5 in)	6 mm (0.1 in)	2.8 N (10 oz)	2.8 N (10 oz)
Maximum	-	-	25 mm (1.0 in)	4.5 N (16 oz)	11 N (40 oz)

	S, separation		
	Single finger operation	Single finger sequential operation	Simultaneous operation by different fingers
Minimum	19 mm (0.75 in)	13 mm (0.5 in)	16 mm (0.6 in)
Optimum	50 mm (2.0 in)	25 mm (1.0 in)	19 mm (0.75 in)

† Use with bare

‡ Use with heavy handwear

- **6.1.5.12.2 Detents.** Each position of a slide switch shall have a detent. [Source: MIL-STD-1472F, 1999]

- **6.1.5.12.3 Slide switch resistance.** Resistance between positions shall increase and then decrease so that the switch "snaps" into position. [Source: MIL-STD-1472F, 1999]

- **6.1.5.12.4 Slide switch location.** A slide switch shall not be capable of stopping between positions. [Source: MIL-STD-1472F, 1999]

- **6.1.5.12.5 Preventing accidental actuation.** When it is imperative that a slide switch not be operated inadvertently, for example, when operation might result in a critical or hazardous condition, the switch shall be protected. [Source: MIL-STD-1472F, 1999]

  Discussion. Protection might be by means of a channel guard, barrier, cover, or an equivalent protective measure. [Source: MIL-STD-1472F, 1999]

- **6.1.5.12.6 Vertical orientation.** Slide switches shall be oriented vertically, with movement of the slide up or away from the user turning the equipment or component ON, causing a quantity to increase, or causing the equipment or component to move clockwise, forward, up, or to the right. [Source: MIL-STD-1472F, 1999]

- **6.1.5.12.7 Horizontal orientation.** Horizontal orientation shall be used only to make the switch compatible with its controlled function or equipment location. [Source: MIL-STD-1472F, 1999]

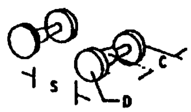
- **6.1.5.12.8 Positive feedback.** A slide switch that has more than two positions shall provide an indication of its setting, for example, by means of a pointer located on the side of the slide handle. [Source: MIL-STD-1472F, 1999]

6.1.5.13 Discrete push-pull controls

- **6.1.5.13.1 Push-pull control specifications.** The dimensions, displacement, and separation of push-pull controls shall not exceed the maximum and minimum values given in Exhibit 6.1.5.13.1. [Source: MIL-STD-1472F, 1999]

  Discussion. Push-pull controls may be used to select one of two discrete functions or, if panel space is limited, to combine two related, but distinct functions, such as a combination ON-OFF switch and volume control into a single control. A three-position push-pull control may be acceptable in isolated instances in which the criticality of inadvertent selection of the wrong position has no serious consequences; for example, the OFF-parking lights-headlights switch on some automobiles. [Source: MIL-STD-1472F, 1999]

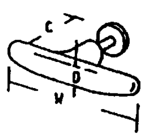
Exhibit 6.1.5.13.1 Push-pull control specifications



Push-pull control, low resistance, for two-position, mechanical and electrical systems. Alternate three position plus rotary function acceptable for application such as vehicle headlight plus parking lights, panel and dome lights. Provide serrated rim.

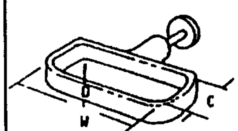
Minimium diamter (D)	Minimum clearance (C)	Displacement	Minimum space (S) between controls:
19 mm (0.75 in)	25 mm (1.0 in) add13 mm (0.5 in) for gloved hand	12-38 mm (0.5-1.5 in) Minimum between pull positons: 13 mm (0.5 in)	38 mm (1.5 in) add13 mm (0.5 in) for gloved hand

Alternate handle; miniature electrical panel switch only. Avoid glove use application.

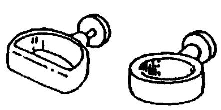


Minimum diameter (D)	Minimum clearance (C)	Minimum length	Minimum displacement	Minimum space between (S)
6.5 mm (0.25 in)	N/A	19 mm (0.75 in)	13 mm (0.5 in)	25 mm (1 in)

High force push-pull, for two-position mechanical system only.



Minimum width (W)	Depth (D)	Minimum clearance (C)	Minimum displacement
100 mm (4 in)	16-38 mm (0.6-1.5 in)	38 mm (1.5 in) add 6 mm (0.24 in) for gloved hand	25 mm (1 in) Preferred: 50 mm (2 in)



Same as above. The following values are preferred where possible garment or cable-snag possibility exists.

Minimum width (W)	Depth (D)	Minimum clearance (C)	Minimum displacement	Minimum space between (S)
100 mm (4 in)	16-38 mm (0.6 in - 1.5 in)	38 mm (1.5 in)	25 mm (1 in) Preferred: 50 mm (2 in)	13 mm (0.5 in)

Note. 1 and 2 finger pulls are also acceptable for less than 18 N (4.0 lb) application

▫ **6.1.5.13.2 When to use.** Push-pull controls should be used sparingly and primarily in applications in which they have been used traditionally, for example, vehicle headlight switches. [Source: MIL-STD-1472F, 1999]

▪ **6.1.5.13.3 Rotation.** Push-pull controls shall normally be keyed to a nonrotating shaft. Exceptions are (1) combination push-pull and rotate controls, and (2) special applications, for example, one in which a handle is rotated to disengage something. Combination push-pull and rotate knobs shall have a serrated rim to suggest both visually and tactually that the knob can be rotated and to help prevent fingers from slipping when they turn the knob. [Source: MIL-STD-1472F, 1999]

▪ **6.1.5.13.4 Detents.** Push-pull controls shall have detents to provide tactile indication of positions. [Source: MIL-STD-1472F, 1999]

▪ **6.1.5.13.5 Snagging and inadvertent operation.** Push-pull controls shall be designed and located to prevent

a. the snagging of clothing, wires, and cables,

b. their being bumped by passers by, and

c. their being bumped by someone reaching for or operating another nearby control. [Source: MIL-STD-1472F, 1999]

▪ **6.1.5.13.6 Direction of movement.** The direction of movement of a push-pull control shall conform to the following:

a. Pulling the control toward the user shall turn ON or actuate the associated equipment or function; pushing the control away from the user shall turn OFF or deactuate the equipment or function.

b. Turning a combination push-pull and rotary control clockwise shall actuate or increase the function. [Source: MIL-STD-1472F, 1999]

▫ **6.1.5.13.7 Resistance for a panel control.** The force required to push or pull a panel control with the fingers should not exceed 18 N (4 lb). [Source: MIL-STD-1472F, 1999]

▫ **6.1.5.13.8 Resistance for a T-bar.** The force required to push or pull a T-bar with four fingers should not exceed 45 N (10 lb). [Source: MIL-STD-1472F, 1999]

6.1.5.14 Printed circuit switches

Printed circuit (PC) switches may be used if manual programming functions are needed in systems that employ printed circuit boards. [Source: MIL-STD-1472F, 1999]

- **6.1.5.14.1 Dimensions.** PC switches shall be large enough to permit error-free manipulation by a person using a pencil or pen. PC switch actuators shall not require the use of a special tool for their operation. [Source: MIL-STD-1472F, 1999]

- **6.1.5.14.2 Resistance.** The resistance of a PC switch shall be high enough to avoid inadvertent actuation under the expected conditions of use, increase to a maximum halfway between positions, then decrease again so that the switch actuator "snaps" into position, and not be capable of stopping between positions. [Source: MIL-STD-1472F, 1999]

- **6.1.5.14.3 Displacement.** Sliding PC switch actuators shall have enough displacement to permit easy identification of the switch position with displacement at least twice the width or thickness of the actuator. [Source: MIL-STD-1472F, 1999]

- **6.1.5.14.4 Rocker switches.** When rocker switches are used, the actuated portion of the switch shall be flush with the panel surface. [Source: MIL-STD-1472F, 1999]

- **6.1.5.14.5 Separation.** When two or more PC switches are grouped together, their actuators shall be far enough apart to permit error-free operation of the individual switches. [Source: MIL-STD-1472F, 1999]

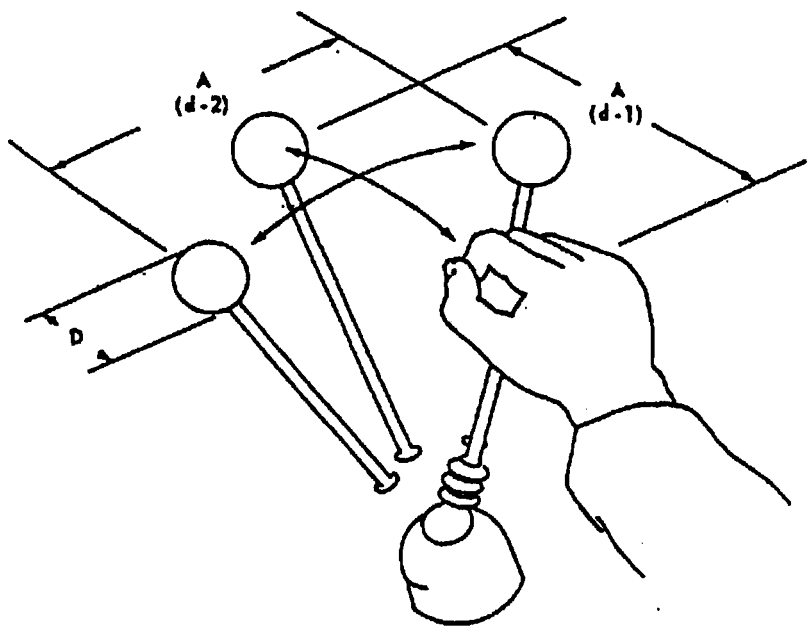
- **6.1.5.14.6 Shape.** The surface of the actuator shall be indented to accept the point of a pen or pencil with the indentation deep enough that the point does not slip as the actuator is manipulated. [Source: MIL-STD-1472F, 1999]

6.1.5.15 Levers

- **6.1.5.15.1 Lever specifications.** The dimensions, resistance, displacement, and separation of levers shall not exceed the maximum and minimum values given in Exhibit 6.1.5.15.1. [Source: MIL-STD-1472F, 1999]

    Note. The dominant hand can supply slightly more force than the nondominant hand, but the difference is not significant. The same amount of push-pull force can be applied when the control is along the median plane of the body as when it is directly in front of the arm, 180 mm (7 in) from the median plane. If the control is placed in front of the opposite (unused) arm, only 75 % as much force can be applied. If the control is 250 to 480 mm (10 to 19 in) forward of the seat reference point, twice as much push-pull force can be applied with two hands as with one-hand operation. Outside this range, two-hand operation becomes less effective. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.5.15.1 Lever specifications



	Diameter D		Resistance (d - 1)		Resistance (d - 2)	
	Finger grasp	Hand grasp	One hand	Two hands	One hand	Two hands
Minimum	13 mm (0.5 in)	38 mm (1.5 in)	9 N (2.0 lb)	9 N (2.0 lb)	9 N (2.0 lb)	9 N (2.0 lb)
Maximum	38 mm (1.5 in)	75 mm (3.0 in)	135 N (30 lb)	220 N (50 lb)	90 N (20 lb)	135 N (30 lb)

	Displacement A		Separation	
	Forward (d - 1)	Lateral (d - 2)	One hand random	Two hands simultaneously
Minimum	--	-- (2.0 in)	50 mm (3.0 in)	75 mm
Preferred	--	-- (4.0 in)	100 mm (5.0 in)	125 mm
Maximum	360 mm (14 in)	970 mm (38 in)	--	--

- ▫ **6.1.5.15.2 When to use.** Levers should be used when a large amount of force is needed, or if multidimensional movement of the control is needed. [Source: MIL-STD-1472F, 1999]

- ▪ **6.1.5.15.3 Coding.** When several levers are located near one another, the lever handles shall be coded. [Source: MIL-STD-1472F, 1999]

- ▪ **6.1.5.15.4 Labeling.** When practicable, all levers shall be labeled with their function and direction of motion. [Source: MIL-STD-1472F, 1999]

- ▪ **6.1.5.15.5 Limb support.** When a lever will be used to make fine or continuous adjustments, a support for the appropriate limb shall be provided as follows:

  a. For large hand movements, a support for the elbow.

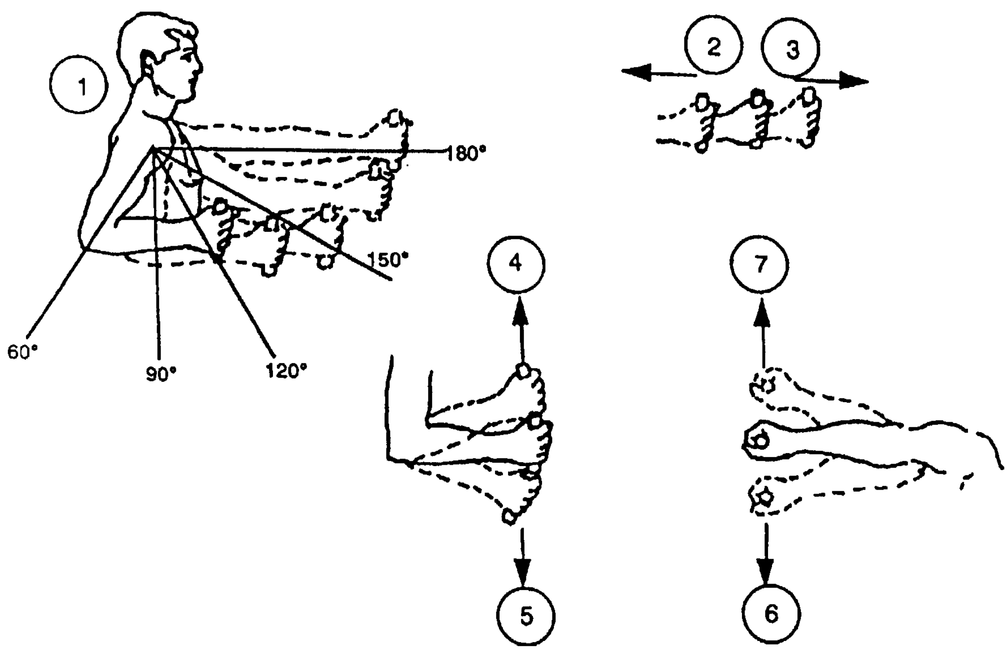
  b. For small hand movements, a support for the forearm.

  c. For finger movements, a support for the wrist. [Source: MIL-STD-1472F, 1999]

6.1.5.16 Hand controls requiring high force

- **6.1.5.16.1 Specifications for males.** Arm, hand, and thumb-finger controls that require high control force shall not exceed the limits given in Exhibit 6.1.5.16.1. The values in the exhibit are for males. [Source: MIL-STD-1472F, 1999]

Exhibit 6.1.5.16.1 Hand-force hand control specifications



Arm strength N (lb)

1	2		3		4		5		6		7	
Degree of elbow flexion	Pull		Push		Up		Down		In		Out	
	L	R	L	R	L	R	L	R	L	R	L	R
180°	222 (50)	231 (52)	187 (42)	222 (50)	40 (9)	62 (14)	58 (13)	76 (17)	58 (13)	89 (20)	36 (8)	62 (14)
150°	187 (42)	249 (56)	133 (30)	187 (42)	67 (15)	80 (18)	80 (18)	89 (20)	67 (15)	89 (20)	36 (8)	67 (15)
120°	151 (34)	187 (42)	116 (26)	160 (36)	76 (17)	107 (24)	93 (21)	116 (26)	89 (20)	98 (22)	45 (10)	67 (15)
90°	142 (32)	165 (37)	98 (22)	160 (36)	76 (17)	89 (20)	93 (21)	116 (26)	71 (16)	80 (18)	45 (10)	71 (16)
60°	116 (26)	107 (24)	98 (22)	151 (34)	67 (15)	89 (20)	80 (18)	89 (20)	76 (17)	89 (20)	53 (12)	76 (17)

Note. L = Left
R = Right

- **6.1.5.16.2 Specifications for females.** When the control will be used by females, the limits shall be reduced by one-third. [Source: MIL-STD-1472F, 1999]

- **6.1.5.16.3 When not to use.** In general, controls requiring forces greater than the strength limits of the weakest segment of the expected user population, high force controls, and sustained application of high force (that is, durations longer than 3 sec) shall not be used. [Source: MIL-STD-1472F, 1999]

  Exception. High force controls can be used when the user's normal working position provides proper body support, limb support, or both.

6.1.5.17 Miniature controls

- **6.1.5.17.1 Dimensions and separation.** The dimensions and separation of miniature controls shall be the maximum permitted by the available space up to the maximum values specified in this standard for standard-sized controls of the same type. [Source: MIL-STD-1472F, 1999]

- **6.1.5.17.2 Resistance and displacement.** The resistance and displacement of miniature controls should be the same as the resistance and displacement of standard-sized controls of the same type. [Source: MIL-STD-1472F, 1999]

- **6.1.5.17.3 When to use.** Miniature controls shall be used only if severe space limitations exist. [Source: MIL-STD-1472F, 1999]

- **6.1.5.17.4 When not to use.** Miniature controls shall not be used if space is adequate for standard-size controls, and when users are likely to wear gloves or mittens. [Source: MIL-STD-1472F, 1999]

- **6.1.5.17.5 Other requirements.** Other design considerations, such as labeling and orientation, shall conform to those in this standard for standard-size controls of the same type. [Source: MIL-STD-1472F, 1999]

6.2 Visual indicators

6.2.1 General visual indicator information

6.2.1.1 Coding of visual indicators

This section contains general rules for visual coding. Additional specific rules are given in sections pertaining to specific types of visual indicators.

▪ **6.2.1.1.1 Objectives.** Coding shall be used to facilitate (1) discrimination between individual displays, (2) identification of functionally-related displays, (3) recognition of the relationship between displays, (4) identification of critical information within a display, and to preserve conventional practices and arrangements for warning and alerting systems. [Source: MIL-STD-1472F, 1999]

▪ **6.2.1.1.2 Visual coding methods.** Visual indicators shall be coded by color, size, location, shape, or flash coding as applicable. [Source: MIL-STD-1472F, 1999]

▪ **6.2.1.1.3 Consistency.** Visual coding shall be consistent within a system or unit of equipment and between similar units of equipment. [Source: MIL-STD-1472F, 1999]

▫ **6.2.1.1.4 Visual coding of priority levels.** Visual signals should be coded to indicate the priority level of the signal. [Source: MIL-STD-1472F, 1999]

> **Discussion.** Acceptable coding methods include color, position, shape, flashing, and symbol. [Source: MIL-STD-1472F, 1999]

▪ **6.2.1.1.5 Emergency conditions.** Flashing red shall be used to denote emergency conditions that require immediate user action to avert impending injury, equipment damage, or both with an approximately equal on and off time flashing rate from three to five flashes per second. [Source: MIL-STD-1472F, 1999]

▪ **6.2.1.1.6 Flasher failure.** When an emergency condition exists and the flasher fails, the light shall illuminate and burn steadily. [Source: MIL-STD-1472F, 1999]

▪ **6.2.1.1.7 Visual tiles.** If visual tiles are used, their legends shall

a. be concise, specific, and unambiguous;

b. use abbreviations or acronyms consistent throughout the equipment or system, and

c. be legible in worst-case conditions, for example, from the far end of the room, or from a spot that maximizes glare. [Source: DOE-HFAC1, 1992]

▪ **6.2.1.1.8 Singular in purpose.** A visual alarm, with the exception of master caution, warning, and advisory indicators, shall be singular in purpose yet comprehensive in meaning without referring the user to other alarm indicators for other warning information. [Source: DOE-HFAC1, 1992]

6.2.1.2 Analog and digital coding

▫ **6.2.1.2.1 Analog and digital coding.** Information should be coded in either digital or analog form. [Source: DOE-HFAC1, 1992]

Discussion. Displays such as meters, plotters, and bar charts on CRTs are examples of analog displays; digital counters and numbers presented on CRTs are examples of digital displays. [Source: DOE-HFAC1, 1992]

▫ **6.2.1.2.2 When to use digital displays.** Digital displays should be used if there is a need for quick, precise readings of quantitative values and trend information is not needed. [Source: DOE-HFAC1, 1992]

▪ **6.2.1.2.3 When not to use digital displays.** Digital displays shall not be used if (1) they are the only information displays and perception of a pattern of variation is important or (2) values change so slowly or rapidly that reading them is difficult. [Source: MIL-STD-1472F, 1999]

▫ **6.2.1.2.4 When to use analog displays.** Analog displays should be used if (1) values need to be considered in relation to ranges or zones or (2) trend information is required. [Source: DOE-HFAC1, 1992]

6.2.2 Transilluminated displays

This section contains rules for transilluminated displays.

Definition. A **transilluminated display** is a display in which light passes through the element being viewed. These displays include panels and indicators that use back- or edge-lighting and that use clear, translucent, fluorescent, or sandwich material. There are three general types of transilluminated displays that are widely used: (1) legend lights that present information in the form of meaningful words, numbers, symbols, and abbreviations, (2) simple indicator lights, and (3) panel assemblies that present qualitative status or system readiness information. [Source: MIL-STD-1472F, 1999]

6.2.2.1 General

□ **6.2.2.1.1 When to use.** Transilluminated displays should be used to provide qualitative information that requires immediate attention or an immediate response or to draw attention to important information. [Source: MIL-STD-1472F, 1999]

Discussion. Transilluminated displays may also be used occasionally for maintenance and adjustment information. [Source: MIL-STD-1472F, 1999]

■ **6.2.2.1.2 Limited use of lights and illuminated displays.** Lights and illuminated indicators shall be used sparingly, reserved for displaying only that information necessary for effective system operation. [Source: MIL-STD-1472F, 1999]

■ **6.2.2.1.3 Meaning of illumination.** Lights, including those used in illuminated push buttons, shall indicate equipment response and not simply control position. [Source: MIL-STD-1472F, 1999]

■ **6.2.2.1.4 Positive feedback.** Changes in display status shall signify changes in functional status, rather than simply a response to control activation. [Source: MIL-STD-1472F, 1999]

■ **6.2.2.1.5 Meaning of no illumination.** The absence or removal of illumination of a transilluminated display shall not be used to indicate (1) a malfunction, "no-go," or out-of-tolerance condition, (2) a "ready" or in-tolerance condition unless the bulb can be easily tested by the operator or (3) a "power off" condition on a maintenance display. [Source: MIL-STD-1472F, 1999]

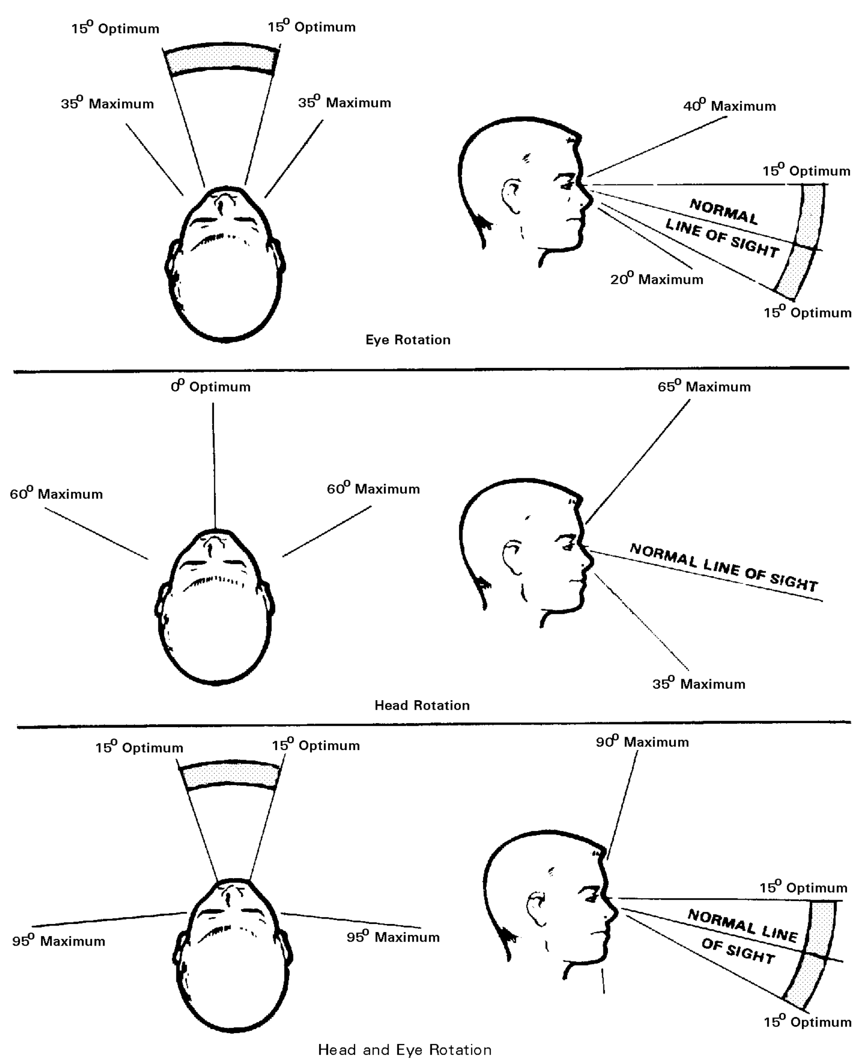
Discussion. The absence of illumination of a "power on" indicator is acceptable for an operational display. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.6 Grouping of indicator lights.** Master caution lights, master warning lights, master advisory lights, and summation lights used to indicate the condition of an entire subsystem shall be set apart from lights that show the status of subsystem components, except as required in Paragraph 6.2.2.1.8. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.7 Location of transilluminated indicators.** When a transilluminated indicator is associated with a control, it shall be located so that the association of the indicator with the control is unambiguous and so that the light is visible as a user is operating the control. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.8 Location of indicators for critical functions.** Indicators for critical functions shall be located within 15° of the user's normal line of sight, as illustrated in Exhibit 6.2.2.1.8. [Source: MIL-STD-1472F, 1999]

Exhibit 6.2.2.1.8 Optimum vertical and horizontal visual fields.



- **6.2.2.1.9 Location of control device.** The lever, switch, or other control device by which the user takes an action in response to the indicator shall be an integral part of or located as close as possible to the indicator. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.10 Maintenance displays.** Indicator lights used solely for maintenance and adjustment shall be covered or not visible during normal operation of the equipment, but shall be readily accessible when needed. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.11 Luminance.** The luminance of a transilluminated display shall be compatible with the expected ambient illuminance level, and shall be at least 10 %greater than the surrounding luminance. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.12 Glare reduction.** When glare must be reduced, the luminance of the transilluminated display shall not exceed 300 % of the surrounding luminance. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.13 Variable luminance.** When a display will be used in varied ambient illuminance, a dimming control shall be provided with a range of control that permits the display to be legible under the expected range of ambient illuminance. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.14 Dimming in non-critical operations.** Dimming to full OFF may be provided in noncritical operations, but shall not be used if inadvertent failure to turn an indicator ON could lead to a critical maintenance failure, such as the failure to detect or perform a critical step in a maintenance procedure. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.15 False or obscured indication.** Direct or reflected light shall not make indicators appear illuminated when they are not, or appear extinguished when they are illuminated. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.16 Self reflection.** Self-reflection shall be minimized by proper orientation of the display with respect to the observer. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.17 Contrast within an indicator.** The luminance contrast within an indicator shall be at least 2.0. [Source: MIL-STD-1472F, 1999]

  Exception. Special displays specifically designed for legibility in sunlight are exempt from this criterion. [Source: MIL-STD-1472F, 1999]

  Definition. Luminance contrast is the contrast between a figure and its background. Luminance contrast (C) is equal to the difference between the higher luminance value (L_1) and the lower (L_2) divided by the lower value (L_2): $C = (L_1 - L_2)/L_2$.

- **6.2.2.1.18 Low ambient illumination.** When low ambient illumination is expected, the luminance contrast shall be at least 9.0 with the background luminance less than the figure luminance. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.19 Lamp redundancy.** Incandescent lamps used in displays shall be redundant, either through dual filaments or dual lamps. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.20 Indication of lamp replacement.** When one filament or lamp fails, the intensity of the display shall decrease sufficiently to indicate the need for lamp replacement, but not so much that the performance of a user is degraded. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.21 Lamp testing.** When a control panel includes indicator lights using incandescent lamps, it shall also include a means to test the lamps (see Paragraph 6.2.3.5, for exception). When maintenance procedures require dark adaptation, a means for reducing the total brightness of the indicators during testing shall be provided. [Source: MIL-STD-1472F, 1999]

  Discussion. When the panel contains three or fewer lamps, it is preferable that each lamp have its own "press-to-test" control. Otherwise, it is preferable that there be a single control that tests all lamps at the same time. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.22 Maintenance procedures.** When maintenance procedures require dark adaptation, a means for reducing the total brightness of the indicators during testing shall be provided. [Source: MIL-STD-1472F, 1999]

- ▫ **6.2.2.1.23 Indicator circuit testing.** A means should be provided for testing the operation of indicator circuits. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.24 Removal and replacement of lamps.** Where possible, lamps shall be removable and replaceable through the front of the display panel. Removal and replacement of lamps shall not require the use of tools and shall be accomplished easily and rapidly. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.25 Nonhazardous lamp replacement.** The removal and replacement of lamps while power is applied to the equipment shall not pose a hazard to the user and shall not damage indicator circuit components. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.26 Proper installation of indicator covers.** When the design of indicator covers does not prevent their inadvertent interchange, a means shall be provided for checking the covers after installation to ensure that they are properly installed. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.27 Color-coding.** Color-coding of transilluminated displays shall be in accordance with Exhibit 6.2.2.1.27. [Source: MIL-STD-1472F, 1999]

Exhibit 6.2.2.1.27 Color-coding of transilluminated displays

Color	Use	Examples
flashing red	to indicate an emergency condition that requires immediate action to avert impending injury, equipment damage, or both	
red	to indicate that (1) the system or a portion of the system is inoperative, or (2) successful task completion is not possible until appropriate corrective or override action is taken	"no-go" "error" "failure" "malfunction"
yellow	to indicate (1) a marginal condition, (2) an unexpected delay, (3) that caution is necessary, or (4) that rechecking is necessary	
green	to indicate that (1) equipment is "in tolerance," (2) conditions are satisfactory, or (3) it is all right to proceed	"go ahead" "in tolerance" "ready" "function activated"
white	to indicate system conditions that do not have "right" or "wrong" implications	(1) indicating which of several functions has been selected, (2) indicating a transitory condition such as an action or test in progress, provided such indications have no implications of success or failure
blue	to advise only	

- **6.2.2.1.28 Flashing lights.** The use of flashing lights shall be minimized and used only to call a user's attention to a condition requiring immediate action. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.29 Flash rate.** The flash rate shall be not less than three and not more than five flashes per second, with the on and off times being approximately equal. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.30 Multiple flashing indicators.** When more than one flashing indicator is located within a user's field of view, their flashes shall be synchronized. [Source: MIL-STD-1472F, 1999]

- **6.2.2.1.31 Failed flashing device.** When the indicator is activated but the flashing device has failed, the light shall remain ON. [Source: MIL-STD-1472F, 1999]

6.2.2.2 Legend lights

- **6.2.2.2.1 When to use.** Legend lights shall be used in preference to simple indicator lights except where design considerations demand that simple indicators be used. [Source: MIL-STD-1472F, 1999]

- **6.2.2.2.2 Color-coding.** The color-coding of legend lights shall conform to Exhibit 6.2.2.1.27. [Source: MIL-STD-1472F, 1999]

- **6.2.2.2.3 Size of legend lights.** Legend lights indicating existing or impending hazards (flashing red, red, and yellow) and master summation "go" (green) and "no-go" (red) shall be discriminably larger than other legend lights. [Source: MIL-STD-1472F, 1999]

- **6.2.2.2.4 Illuminated label with opaque background.** An illuminated label and an opaque background shall be used (1) if dark adaptation of the user's eyes is required, (2) if the level of ambient illumination is high, or (3) if needed under other illumination conditions to distinguish control switches from display indicators with similar or identical labels. [Source: MIL-STD-1472F, 1999]

- **6.2.2.2.5 Opaque label with illuminated background.** An opaque label on an illuminated background shall be used: (1) if the indicator is a critical alerting indicator, such as a master warning light, or (2) if dark adaptation is not required. [Source: MIL-STD-1472F, 1999]

- **6.2.2.2.6 Lettering of legends.** The size and other characteristics of the lettering of legends on legend switches shall conform to Section 6.1.2.4. [Source: MIL-STD-1472F, 1999]

- **6.2.2.2.7 Visibility and legibility of legend.** In general, the lettering on single-legend indicators shall be visible and legible whether or not the indicator is illuminated. [Source: MIL-STD-1472F, 1999]

- **6.2.2.2.8 Multi-legend indicators.** Indicators that are capable of presenting more than one legend shall present only one legend at a time, that is, allowing only the legend in use to be visible. [Source: MIL-STD-1472F, 1999]

- **6.2.2.2.9 Stacked legends.** When the indicator "stacks" the different legends, it shall be designed so that it meets the following criteria.

  a. Legends higher in the stack do not obscure legends lower in the stack.

  b. Parallax is minimized.

  c. The brightness and contrast between the legend and background is approximately equal from one legend to another. [Source: MIL-STD-1472F, 1999]

6.2.2.3 Simple indicator lights

- **6.2.2.3.1 When to use.** When design considerations preclude the use of legend lights, simple indicator lights should be used. [Source: MIL-STD-1472F, 1999]

- **6.2.2.3.2 Spacing.** The spacing between adjacent edges of simple round indicator light fixtures shall permit unambiguous labeling, signal interpretation, and convenient lamp removal and replacement. [Source: MIL-STD-1472F, 1999]

- **6.2.2.3.3 Coding.** The coding of simple indicator lights by size and color shall conform to Exhibit 6.2.2.3.3. [Source: MIL-STD-1472F, 1999]

  Discussion. The different sizes shown in Exhibit 6.2.2.3.3 are intended to vary the attention-demanding property of the lights. It is assumed that larger lights are at least equal in luminance to smaller ones. [Source: MIL-STD-1472F, 1999]

Exhibit 6.2.2.3.3 Coding of simple indicator lights

Size/type	Red	Color Yellow	Green	White
13 mm (0.5 in) diameter or smaller/ steady	Malfunction, action stopped, failure, stop	Delay, check, recheck, acceptable, action	Go ahead, in tolerance, ready	Functional or physical position, action in progress
25 mm (1 in) diameter or larger/steady	Master summation (system or subsystem)	Extreme caution (impending danger)	Master summation (system or subsystem)	
25 mm (1 in) diameter or larger/flashing (3 to 5 per sec)	Emergency condition (impending personnel or equipment disaster)			

6.2.2.4 Transilluminated panel assemblies

- **6.2.2.4.1 When to use.** Transilluminated panel assemblies should be used to

  a. Provide illuminated labels for control panels,

  b. serve as a light source for transilluminated control knobs;

  c. provide illuminated association markings on a control panel, for example, connecting lines between controls, or outlines around a functionally-related group of controls, displays, or both; and

  d. provide a pictorial representation of a system process, communication network, or other information/component organization. [Source: MIL-STD-1472F, 1999]

- **6.2.2.4.2 Large, single, pictorial graphic panels.** Large, single, pictorial graphic panels used to display system processing, communications networks, or other similar applications shall comply with the requirements for visibility, legibility, color, and illumination as specified in this standard. [Source: MIL-STD-1472F, 1999]

- **6.2.2.4.3 Replacing lamps.** When replaceable incandescent lamps are used as the source of illumination for integral lighting of panel assemblies, the lamps shall be readily accessible without disconnecting the panel. [Source: MIL-STD-1472F, 1999]

- **6.2.2.4.4 Sufficient number of lamps.** A sufficient number of lamps shall be provided so that failure of one lamp will not cause any part of the display to be unreadable. [Source: MIL-STD-1472F, 1999]

- **6.2.2.4.5 Brightness.** The brightness of illuminated markings and transilluminated controls shall be compatible with the ambient environment and operating conditions, for example, dark adaptation requirements. [Source: MIL-STD-1472F, 1999]

  Discussion. Provide brightness controls (dimming) as necessary to maintain appropriate visibility and dark adaptation levels.

6.2.3 Dot matrix and segmented displays

- **6.2.3.1 Seven-segment displays.** Seven-segment displays shall only be used to present numeric information. [Source: MIL-STD-1472F, 1999]

  Discussion. Dot matrix, 14-segment, and 16-segment displays may be used for applications involving interactive computer systems, instruments, avionics, navigation, and communication equipment, wherever the presentation of alphanumeric, vector-graphic, symbolic, or real-time information is required. [Source: MIL-STD-1472F, 1999]

- **6.2.3.2 Minimum matrix size.** The smallest matrix for defining a symbol shall be 5 by 7 dots for stationary symbols and 8 by 11 dots for rotating symbols. [Source: MIL-STD-1472F, 1999]

- **6.2.3.3 Preferred matrix size.** The preferred minimum size for a dot matrix shall be 7 by 9 for stationary symbols and 15 by 21 for rotating symbols. [Source: MIL-STD-1472F, 1999]

- **6.2.3.4 Visual angle.** Alphanumeric characters and symbols formed from dot matrixes shall subtend a visual angle of at least 20 min. [Source: MIL-STD-1472F, 1999]

- □ **6.2.3.5 Viewing angle.** Dot matrix and segmented displays should not be designed for viewing at an angle exceeding 35° from perpendicular to the display. [Source: MIL-STD-1472F, 1999]

- **6.2.3.6 Emitter color.** Monochromatic displays shall use one of these colors in the following order of preference: green (555 nm), yellow (575 nm), orange (585 nm), and red (660 nm) with blue emitters not being used. [Source: MIL-STD-1472F, 1999]

- **6.2.3.7 Intensity control.** Dimming controls shall be provided when applicable to maintain appropriate legibility and a user's dark adaptation level. [Source: MIL-STD-1472F, 1999]

6.2.4 Light emitting diodes

- **6.2.4.1 General.** Light emitting diodes (LEDs) shall conform to the same rules as transilluminated displays. [Source: MIL-STD-1472F, 1999]

- **6.2.4.2 When to use.** LEDs should be used for transilluminated displays, including legend and simple indicator lights, and for matrix (alphanumeric) displays, only if the display is bright enough to be readable in the environment of intended use. [Source: MIL-STD-1472F, 1999]

  Note: The display may be "washed out" at high levels of illumination. [Source: MIL-STD-1472F, 1999]

- **6.2.4.3 Intensity control.** The dimming of LEDs should be proportionate with the dimming of incandescent lamps in the work place. [Source: MIL-STD-1472F, 1999]

- **6.2.4.4 Color-coding for non-red displays.** The color-coding of LEDs other than red alphanumeric displays shall conform to the uses listed in Exhibit 6.2.2.1.27. Red alphanumeric displays shall not be used near red lights that are used in the ways stated in the exhibit. [Source: MIL-STD-1472F, 1999]

- **6.2.4.5 Red alphanumeric displays.** Red alphanumeric displays shall not be used near red lights that are used in the ways stated in the exhibit. [Source: MIL-STD-1472F, 1999]

- **6.2.4.6 Testing.** LED indicator lights having a rating of 100,000 hours mean time between failures shall not require the lamp test capability specified in Paragraph 6.2.2.1.27. [Source: MIL-STD-1472F, 1999]

- **6.2.4.7 Location of red alphanumeric LEDs and segmented displays.** Red LED and segmented displays shall not be grouped with or located adjacent to red warning lights. [Source: MIL-STD-1472F, 1999]

6.2.5 Counters, printers, and flags displays

This section contains rules for direct-reading counters, printers, and flags. Exhibit 6.2.5 lists characteristics and ratings of the goodness of each of these types of display for a variety of uses.

Exhibit 6.2.5 Characteristics and ratings for direct-reading counters, printers, and flags

Use	Counters	Printers	Flags
Quantitative information	**(Good)** Minimum time and error for exact numerical value; however, cannot be read when changing rapidly.	**(Good)** Minimum time and error for exact numerical value. Provides reference records.	Not applicable
Qualitative information	**(Poor)** Numbers must be read. Position changes not easily detected.	**(Poor)** Numbers must be read. Position changes not easily detected.	**(Good)** Easily detected. Economical of space.
Setting	**(Good)** Most accurate monitoring of numerical setting. Relation to motion of setting knob less direct than for moving pointer. Not readable during rapid setting.	Not applicable	Not applicable
Tracking	**(Poor)** No gross position changes to aid monitoring.	Not applicable	Not applicable
General	Most economical of space and illumination. Scale length limited only by number of counter drums.	Limited application.	Limited application.

6.2.5.1 Counters

The rules in this section apply primarily to mechanical counters.

- ▫ **6.2.5.1.1 When to use.** Counters should be used to present quantitative data if a quick, precise indication is required and if a continuous trend indication is not required. [Source: MIL-STD-1472F, 1999]

- ▪ **6.2.5.1.2 Mounting.** Counters shall be mounted as close as possible to the panel surface to minimize parallax and shadows and to maximize the viewing angle. [Source: MIL-STD-1472F, 1999]

- ▪ **6.2.5.1.3 Movement.** The counters shall move in the following ways.

  a. Numbers shall change by snap action rather than by continuous movement.

  b. If an observer is expected to read the numbers consecutively, the numbers shall not change faster than 2 times a second.

  c. Clockwise rotation of the counter reset knob shall increase the counter indication or reset the counter.

  d. Counters that indicate sequencing operations shall reset automatically upon completion of the sequence. Provision shall also be made for manual resetting. If push buttons are used for manual resetting, the force required to operate them shall not exceed 16.7 N (60 oz). [Source: MIL-STD-1472F, 1999]

- ▪ **6.2.5.1.4 Illumination.** Counters used in areas in which ambient illumination provides display luminance below 3.5 cd/m^2 (1 fL) shall be self-illuminating. [Source: MIL-STD-1472F, 1999]

- ▪ **6.2.5.1.5 Spacing between numerals.** The horizontal separation between numerals shall be between 1/4 and 1/5 the numeral width. Commas shall not be used. [Source: MIL-STD-1472F, 1999]

- ▪ **6.2.5.1.6 Finish.** The surface of the counter drums and surrounding areas shall have a dull, matte finish to minimize glare. [Source: MIL-STD-1472F, 1999]

- ▪ **6.2.5.1.7 Contrast.** The numerals shall have a high contrast with their background. For example, black on white or white on black. [Source: MIL-STD-1472F, 1999]

6.2.5.2 Flags

- **6.2.5.2.1 When to use.** Flags should be used to display qualitative, nonemergency conditions. See Exhibit 6.2.5 for the characteristics and appropriate uses of flags. [Source: MIL-STD-1472F, 1999]

- **6.2.5.2.2 Mounting.** Flags shall be mounted as close to the surface of the panel as possible without restricting their movement and without obscuring necessary information. [Source: MIL-STD-1472F, 1999]

- **6.2.5.2.3 Snap action.** Flags shall operate with a snap action. [Source: MIL-STD-1472F, 1999]

- **6.2.5.2.4 Contrast.** Luminance contrast between a flag and its background shall be at least 3.0 under all expected lighting conditions. [Source: MIL-STD-1472F, 1999]

- **6.2.5.2.5 Malfunction indication.** When a flag is used to indicate the malfunction of a visual display, the malfunction position of the flag shall obscure part of the user's view of the malfunctioning display and be readily apparent to the user under all expected lighting conditions. [Source: MIL-STD-1472F, 1999]

- **6.2.5.2.6 Legend.** When a legend is provided on a flag, the lettering shall appear upright when the flag assumes the active position. [Source: MIL-STD-1472F, 1999]

- **6.2.5.2.7 Test provision.** A convenient means shall be provided for testing the operation of flags. [Source: MIL-STD-1472F, 1999]

6.2.6 Scale indicators

6.2.6.1 General

There are two general types of scale indicators, those in which the scale is fixed and the pointer moves, and those in which the pointer is fixed and the scale moves. In either case, the scales can be circular, curved (that is, an arc), straight and oriented vertically, or straight and oriented horizontally. Characteristics and ratings of the goodness of each type for a variety of uses are given in Exhibit 6.2.6.1 [Source: MIL-STD-1472F, 1999]

Exhibit 6.2.6.1 Characteristics and ratings of fixed and moveable pointer scales for various uses

	Scales	
Use	**Moving pointer**	**Fixed pointer**
Quantitative information	**(Fair)** May be difficult to read while pointer is in motion.	**(Fair)** May be difficult to read while pointer is in motion.
Qualitative information	**(Good)** Location of pointer easy. Numbers and scale need not be read. Position change easily detected	**(Poor)** Difficult to judge direction and magnitude of deviation without reading numbers and scale
Setting	**(Good)** Simple and direct relation of motion of pointer to motion of setting knob. Position change aids monitoring	**(Fair)** Relation to motion of setting knob may be ambiguous. No pointer position change to aid monitoring. Not readable during rapid setting.
Tracking	**(Good)** Pointer position readily controlled and monitored. Simplest relation to manual control motion.	**(Fair)** No position changes to aid monitoring. Relation to control motion somewhat ambiguous.
General	Requires largest exposed and illuminated area on panel. Scale length limited unless multiple pointers are used.	Saves panel space. Only small section of scale need be exposed and illuminated.

- ▪ **6.2.6.1.1 When to use.** Moving-pointer, fixed-scale indicators shall be used rather than fixed-pointer, moving-scale indicators. [Source: MIL-STD-1472F, 1999]

- ▫ **6.2.6.1.2 Type of information.** Scale indicators should be used (1) to display quantitative information in combination with qualitative information, for example, trend or direction-of-motion, and (2) if quantitative information is to be displayed and there is no need (such as speed or accuracy) for the use of printers or counters. [Source: MIL-STD-1472F, 1999]

- ▪ **6.2.6.1.3 Linear scales.** Linear scales shall be used in preference to nonlinear scales unless system requirements clearly dictate non-linearity to satisfy user information requirements. [Source: MIL-STD-1472F, 1999]

- ▪ **6.2.6.1.4 Scale graduations.** Scale graduations shall progress by 1, 2, or 5 units or decimal multiples thereof. [Source: MIL-STD-1472F, 1999]

- ▪ **6.2.6.1.5 Intermediate marks.** The number of minor or intermediate marks between numbered scale marks shall not exceed nine. [Source: MIL-STD-1472F, 1999]

- ▪ **6.2.6.1.6 Numerals.** Whole numbers shall be used for major graduation marks unless the measurement is normally expressed in decimals. [Source: MIL-STD-1472F, 1999]

- ▪ **6.2.6.1.7 Scale starting point.** Display scales shall start at zero unless this is inappropriate for the information displayed. [Source: MIL-STD-1472F, 1999]

- ▫ **6.2.6.1.8 Pointer length.** Control and display pointers should extend to, but not overlap, the shortest scale graduation marks. [Source: MIL-STD-1472F, 1999]

- ▫ **6.2.6.1.9 Pointer tip.** Each side of the pointer tip should be tapered at a 20° angle (for a total included angle of 40°), terminating in a flat tip equal in width to the width of the minor scale graduations. [Source: MIL-STD-1472F, 1999]

- ▪ **6.2.6.1.10 Pointer mounting.** The pointer shall be mounted as close as possible to the face of the dial to minimize parallax. [Source: MIL-STD-1472F, 1999]

- ▪ **6.2.6.1.11 Pointer color.** Pointer color from the tip to the center of the dial shall be the same as the color of the marks with the tail of the pointer being the same color as the dial face, unless the tail is used as an indicator itself or unless the pointer is used for horizontal alignment. [Source: MIL-STD-1472F, 1999]

- ▪ **6.2.6.1.12 Luminance contrast.** The luminance contrast between the scale face and the markings and between the scale face and the pointer shall be at least 3.0. [Source: MIL-STD-1472F, 1999]

- ▪ **6.2.6.1.13 Calibration information.** Provisions shall be made for placing calibration information on instruments without degrading dial legibility. [Source: MIL-STD-1472F, 1999]

- ▫ **6.2.6.1.14 Coding.** Coding, for example, by pattern or color, should be used on the face of scale indicators to convey such information as (1) desirable, undesirable, and inefficient operating ranges; (2) dangerous operating levels; and (3) warnings and cautions. [Source: MIL-STD-1472F, 1999]

- ▪ **6.2.6.1.15 Pattern or color-coding.** When a given range on a scale indicates a desired operating or other condition, that range shall be made readily identifiable by means of pattern- or color-coding on the face of the indicator. [Source: MIL-STD-1472F, 1999]

- ▪ **6.2.6.1.16 Use of colors.** Red, yellow, and green shall be used in accordance with the meanings specified in Exhibit 6.2.2.1.27 and be distinguishable under all expected lighting conditions. [Source: MIL-STD-1472F, 1999]

- **6.2.6.1.17 Pattern coding.** When a scale having ranges will be viewed under low or colored illumination, the ranges should be coded by patterns rather than by color. [Source: MIL-STD-1472F, 1999]

6.2.6.2 Moving-pointer, fixed-scale indicators

- **6.2.6.2.1 Numerical progression.** Numerical values shall increase on fixed scales in the clockwise direction, from left to right and from bottom to top for curved, horizontal, and vertical scales, respectively. [Source: MIL-STD-1472F, 1999]

- **6.2.6.2.2 Orientation.** Numbers on fixed scales shall be oriented in the upright position. [Source: MIL-STD-1472F, 1999]

- **6.2.6.2.3 Scale reading and pointer movement.** The magnitude of a scale reading shall increase as the pointer moves clockwise, up, or to the right. [Source: MIL-STD-1472F, 1999]

- **6.2.6.2.4 Zero position and direction of movement.** When positive and negative values are displayed in opposite directions from a zero or a null position, the magnitude of a positive scale reading shall increase as the pointer moves clockwise, up, or to the right, and the magnitude of a negative reading shall increase as the pointer moves counterclockwise, down, or to the left with the zero or null point located at either the 12 or 9 o'clock position. [Source: MIL-STD-1472F, 1999]

- **6.2.6.2.5 Pointer alignment, circular scales.** When stable values exist for normal operating conditions in a group of circular-scale indicators, the indicators shall be arranged either in rows so that all pointers line up horizontally on the 9 o'clock position under normal operating conditions or in columns so that all pointers line up vertically on the 12 o'clock position under normal operating conditions. [Source: MIL-STD-1472F, 1999]

- **6.2.6.2.6 Indicators arranged in a matrix.** When the indicators are arranged in a matrix, the pointers shall be aligned on the 9 o'clock position rather than the 12 o'clock position. [Source: MIL-STD-1472F, 1999]

- **6.2.6.2.7 Scale break.** Curved scales that do not indicate complete revolutions shall have a break between the two ends of the scale of at least 10°. [Source: MIL-STD-1472F, 1999]

- **6.2.6.2.8 Number of pointers.** When precise readings are required, no more than two coaxial pointers shall be mounted on one indicator face. [Source: MIL-STD-1472F, 1999]

- **6.2.6.2.9 Pointer alignment, noncircular scales.** When stable values exist for normal operating conditions in a group of indicators, vertical scales shall be arranged in rows so that the pointers are aligned horizontally, and horizontal scales arranged in columns so that the pointers are aligned vertically. [Source: MIL-STD-1472F, 1999]

- **6.2.6.2.10 Relative position of scale marks and numbers.** When reading time and accuracy are critical, circular scale markings and location of associated numbers shall be arranged to prevent pointers from covering any portion of the scale marks or numerals. [Source: MIL-STD-1472F, 1999]

  Discussion. If readout accuracy is not critical, that is, if the gross relationship between the pointer and a number is all that is required, the numbers may be placed inside the scale markings, where they are obscured by the pointer when it moves over them. [Source: MIL-STD-1472F, 1999]

- **6.2.6.2.11 Minimize parallax.** Scale marks shall be on or close to the plane of the pointer tip to minimize parallax. [Source: MIL-STD-1472F, 1999]

- **6.2.6.2.12 Placement of pointers.** Pointers shall be located to the right of vertical scales and at the bottom of horizontal scales. [Source: MIL-STD-1472F, 1999]

- **6.2.6.2.13 Placement of numbers.** Numbers shall be placed on the side of graduation marks away from the pointer so that the pointer does not obscure the numbers. [Source: MIL-STD-1472F, 1999]

  Discussion. When the space for circular or curved scales is so limited that the graduations would be difficult to read with this placement, the numbers may be placed inside the graduation marks. [Source: MIL-STD-1472F, 1999]

6.2.6.3 Fixed-pointer moving-scale indicators

- **6.2.6.3.1 When to use.** A fixed-pointer, moving-scale indicator shall be used only when an operation requires it and when it has been approved by the acquisition program office. [Source: MIL-STD-1472F, 1999]

- **6.2.6.3.2 Numerical progression.** On fixed-pointer, moving-scale indicators, numbers shall increase in magnitude in the clockwise direction around the face of a circular or curved dial so that a counter-clockwise movement of the dial results in a higher reading. On vertical or horizontal straight moving scales, numbers shall increase from bottom to top or from left to right. respectively. [Source: MIL-STD-1472F, 1999]

- **6.2.6.3.3 Vertical or horizontal straight moving scales.** On vertical or horizontal straight moving scales, numbers shall increase from bottom to top or from left to right. respectively. [Source: MIL-STD-1472F, 1999]

- **6.2.6.3.4 Orientation.** Numbers on moving scales shall be upright when in the reading position, that is, as they move past the pointer. [Source: MIL-STD-1472F, 1999]

- **6.2.6.3.5 Alignment of pointer or fixed reference line.** For circular scales, the pointer or fixed reference line shall be aligned at the 12 o'clock position for right-left directional information and at the 9 o'clock position for up-down information. [Source: MIL-STD-1472F, 1999]

  Discussion. For purely quantitative information, either position may be used. [Source: MIL-STD-1472F, 1999]

- **6.2.6.3.6 Setting.** When a display will be used for setting a value, for example, tuning a receiver to a specific frequency, the unused portion of the dial face shall be covered, and the open window shall be large enough to permit at least one numbered graduation to appear at each side of any setting. [Source: MIL-STD-1472F, 1999]

- **6.2.6.3.7 Tracking.** When a display will be used for tracking, as in the case of a directional indicator, the whole face of the dial shall be exposed. [Source: MIL-STD-1472F, 1999]

- **6.2.6.3.8 Moving tape displays.** When the length of a scale exceeds the limits of the display and if compression of the scale markings would make the display illegible or subject to errors in reading, a moving tape scale should be used. [Source: MIL-STD-1472F, 1999]

- **6.2.6.3.9 Composite scalar and pictorial displays.** Functionally related information from scales, pointers, and pictorialized symbols is sometimes combined to produce a single display, for example, an artificial horizon or a display that shows both true and relative bearings. The design of these composite displays shall conform to the rules of this section for direction-of-motion, scale-pointer relationships, and legibility. [Source: MIL-STD-1472F, 1999]

6.3 Visual indicator-control integration

This section contains design rules addressing the relationships, groupings, and movement of visual indicators associated with controls.

6.3.1 Basic visual indicator-control relationships

- **6.3.1.1 Relationship.** The relationship of a control to its associated visual indicator and a visual indicator to its associated control shall be immediately apparent and unambiguous to the user. [Source: MIL-STD-1472F, 1999]

  Discussion. Indicator-control relationships can be made apparent through the use of one or more of the following: proximity, grouping, coding, demarcation, labeling, spacing, color-coding, insert panels, and panel relief. [Source: MIL-STD-1472F, 1999]

- **6.3.1.2 No obstruction.** The control itself and the user's hand should not obscure the visual indicator. [Source: MIL-STD-1472F, 1999]

  Discussion. Frequently, controls are located below visual indicators so that both right- and left-handed people are accommodated. [Source: MIL-STD-1472F, 1999]

- **6.3.1.3 Complexity and precision to allow discrimination.** The complexity and precision of visual indicators shall not exceed the ability of the user to discriminate detail. [Source: MIL-STD-1472F, 1999]

- **6.3.1.4 Complexity and precision to allow manipulation.** The complexity and precision of controls shall not exceed the user's manipulative capability, including manual dexterity, coordination, and reaction time, under the dynamic conditions and environment in which his or her performance is expected to occur. [Source: MIL-STD-1472F, 1999]

- **6.3.1.5 Feedback.** A visual indicator associated with a control shall provide rapid feedback that the user perceives it to be instantaneous for any operation of the control. [Source: MIL-STD-1472F, 1999]

- **6.3.1.6 Time lag.** When there is a time lag between control activation and ultimate system state, the system should provide immediate feedback to the user of the process and direction of parameter change. [Source: MIL-STD-1472F, 1999]

- **6.3.1.7 Illumination.** Adjustable illumination shall be provided for all visual indicators and for any labels or markings for visual indicators , controls, and panels that must be read at night or under darkened conditions. [Source: MIL-STD-1472F, 1999]

- **6.3.1.8 Simultaneous access.** When more than one user requires simultaneous access to the same controls and visual indicators, each user shall have the physical and visual access to the controls and visual indicators necessary to perform his or her tasks. [Source: MIL-STD-1472F, 1999]

- **6.3.1.9 Emergency controls and visual indicators.** Emergency controls and visual indicators shall be located where they can be seen and reached quickly and easily. [Source: MIL-STD-1472F, 1999]

6.3.2 Grouping of visual indicator and controls

- **6.3.2.1 Functional grouping.** When functional grouping is used, related controls and visual indicators shall be located near one another and arranged in functional groups, for example, power, status, and test. [Source: MIL-STD-1472F, 1999]

- **6.3.2.2 Sequence.** The controls and visual indicators within a functional group shall be located to provide for left-to-right or top-to-bottom order of use, or both. [Source: MIL-STD-1472F, 1999]

- ▫ **6.3.2.3 Arrangement by frequency of use.** Provided that the integrity of grouping by function and sequence is not compromised, the more frequently used and the most important groups should be located in areas of easiest access. [Source: MIL-STD-1472F, 1999]

- ▫ **6.3.2.4 Marking functional groups.** A functional group of controls and visual indicators should be indicated by a technique such as enclosing the group with a line marked on the panel or color-coding the group. [Source: MIL-STD-1472F, 1999]

- **6.3.2.5 Consistency.** The location of recurring functional groups and individual items on different panels shall be consistent from panel to panel. [Source: MIL-STD-1472F, 1999]

- **6.3.2.6 Mirror image arrangements.** Mirror image arrangements shall not be used. [Source: MIL-STD-1472F, 1999]

- ▪ **6.3.2.7 Location and arrangement.** When large numbers of controls and visual indicators are used, they shall be located and arranged to aid in identifying the controls used with each visual indicator, the equipment component affected by each control, and the equipment component described by each visual indicator. [Source: MIL-STD-1472F, 1999]

- ▪ **6.3.2.8 Arrangement within groups.** Controls and visual indicators within functional groups shall be located according to operational sequence, function, or both. [Source: MIL-STD-1472F, 1999]

- ▫ **6.3.2.9 Logical flow arrangement.** When there is no unique operational sequence, the controls and visual indicators within a functional group should be arranged in a manner consistent with their logical flow. [Source: MIL-STD-1472F, 1999]

- ▫ **6.3.2.10 Arrangement by importance or frequency of use.** When the controls and visual indicators within a functional group are not used in any specific sequence, they should be arranged either in accordance with their importance or their frequency of use. [Source: MIL-STD-1472F, 1999]

- ▪ **6.3.2.11 Different arrangement of controls and visual indicators.** When controls are arranged in fewer rows than visual indicators, controls affecting the top row of visual indicators shall be positioned at the far left; controls affecting the second row of visual indicators shall be placed immediately to the right of these, and so on. [Source: MIL-STD-1472F, 1999]

- ▪ **6.3.2.12 Vertical and horizontal arrays.** When a horizontal row of visual indicators is associated with a vertical column of controls or vice versa, the farthest left item in the horizontal array shall correspond to the top item in the vertical array. [Source: MIL-STD-1472F, 1999]

  Discussion. Avoid this type of arrangement whenever possible. [Source: MIL-STD-1472F, 1999]

- ▪ **6.3.2.13 Simultaneous use.** A visual indicator that is monitored concurrently with manipulation of a related control shall be located so that the user does not have to observe the visual indicator from an extreme visual angle, thus avoiding the possible introduction of errors due to parallax. [Source: MIL-STD-1472F, 1999]

- ▪ **6.3.2.14 Multiple visual indicators.** When manipulating one control requires reading several visual indicators, the control shall be placed as near as possible to the related visual indicator and preferably beneath the middle of the visual indicators but not so as to obscure visual indicators when manipulating the control. [Source: MIL-STD-1472F, 1999]

- ▪ **6.3.2.15 Combined control.** When more than one visual indicator is affected by a combined control, the visual indicators shall be arranged from left to right with the combined control below the center of the visual indicators, but not so as to obscure the visual indicators when manipulating the control. [Source: MIL-STD-1472F, 1999]

- ▫ **6.3.2.16 Visual indicators selected by switches.** When one of a group of visual indicators is selected for viewing with a rotary selector switch, the visual indicators should be arranged so that their sequence corresponds to the switch positions. [Source: NUREG-0700, 1981]

  Example. The top or left-most visual indicator might correspond to switch position one; the next visual indicator down or to the right, to switch position two, and so on. [Source: NUREG-0700, 1981]

- ▫ **6.3.2.17 Position of OFF switch.** When the switch includes an OFF position, the OFF position should be to the left of the first active position (that is, it should be the most counter- clockwise position). [Source: NUREG-0700, 1981]

- ▫ **6.3.2.18 Non-selected indicators.** Visual indicators that are not selected should read off-scale, not zero. [Source: NUREG-0700, 1981]

- ▫ **6.3.2.19 Separated controls and visual indicators.** When controls are located on panels separate from their associated visual indicators , the control and visual indicator panels should be adjacent to each other. [Source: MIL-STD-1472F, 1999]

  Discussion. The preferred arrangement is to place the visual indicator panel above the control panel. [Source: MIL-STD-1472F, 1999]

- ▪ **6.3.2.20 Arrangement of separated controls and visual indicators.** When controls and visual indicators are located on separate panels, the arrangement of the controls shall correspond to the arrangement of the associated visual indicators. [Source: MIL-STD-1472F, 1999]

- ▪ **6.3.2.21 Correspondence of controls and visual indicators with equipment.** When a group of equipment components have the same function, the arrangement of controls and visual indicators shall correspond to the physical arrangement of their associated equipment components. [Source: MIL-STD-1472F, 1999]

- ▫ **6.3.2.22 Alternative techniques.** When none of the preceding rules for arranging controls and visual indicators applies, some other technique, such as color-coding, should be used to indicate the association of controls and visual indicators. [Source: NUREG-0700, 1981]

6.3.3 Movement relationships

- **6.3.3.1 Visual indicator response to control.** The response of a visual indicator to control movements shall be consistent, predictable, and compatible with the user's expectations. [Source: MIL-STD-1472F, 1999]

- **6.3.3.2 Visual indicator response time.** The time lag between system response to a control input and visual indicator presentation of that response shall be minimized, consistent with safe and effective system operation. [Source: MIL-STD-1472F, 1999]

- **6.3.3.3 Moving pointer, circular scale.** Clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall produce a clockwise movement of circular scale pointers and an increase in the magnitude of the setting. [Source: MIL-STD-1472F, 1999]

- **6.3.3.4 Moving pointer, linear scale.** Clockwise movement of a rotary control or forward, upward, or rightward movement of a linear control shall produce a movement up or to the right for horizontal and vertical scale pointers and an increase in the magnitude of the reading. [Source: MIL-STD-1472F, 1999]

- **6.3.3.5 Digital visual indicators and arrays of indicator lights.** Clockwise movement of a rotary control or movement of a linear control forward, up, or to the right should produce increasing values in digital visual indicators and a bottom-to-top or left-to-right movement in an array of indicator lights. [Source: MIL-STD-1472F, 1999; NUREG-0700, 1981]

- **6.3.3.6 Fixed pointer, moving scale.** Visual indicators with moving scales and fixed pointers or cursors should be avoided. [Source: MIL-STD-1472F, 1999]

- **6.3.3.7 Fixed pointer, moving circular scale.** Clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall produce a counterclockwise movement of the scale and an increase in the magnitude of the reading. [Source: MIL-STD-1472F, 1999]

- **6.3.3.8 Fixed pointer, moving linear scale.** When use of a vertical or horizontal fixed pointer moving scale indicators is necessary, clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall produce a movement of the scale down or to the left and an increase in the magnitude of the reading. [Source: MIL-STD-1472F, 1999]

- **6.3.3.9 Direct linkage through an arc greater than 180 degrees.** When a control and visual indicator are directly linked, a rotary control shall be used if the indicator moves through an arc of more than 180 degrees. [Source: MIL-STD-1472F, 1999]

- **6.3.3.10 Direct linkage through an arc less than 180 degrees.** If the indicator moves through an arc of less than 180 degrees, a linear control should be used, provided the path of control movement parallels the average path of the indicator movement and the indicator and control move in the same relative direction. [Source: MIL-STD-1472F, 1999]

- **6.3.3.11 Common plane.** Direction of control movements shall be consistent with related movements of associated visual indicators or equipment components. [Source: MIL-STD-1472F, 1999

- **6.3.3.12 Movement direction.** When a rotary control and a linear display are in the same plane, the part of the control adjacent to the visual indicator shall move in the same direction as the moving part of the visual indicator. [Source: MIL-STD-1472F, 1999]

- **6.3.3.13 Labeling.** When the control-visual indicator relationships specified in this section cannot be followed, controls shall be clearly labeled to indicate the direction of control movement required. [Source: MIL-STD-1472F, 1999]

6.3.4 Visual indicator to control movement ratio

- **6.3.4.1 Minimization of time.** Control/visual indicator ratios for continuous adjustment controls shall minimize the time required to make desired control movements (slewing and fine adjusting), consistent with visual indicator size, tolerance requirements, viewing distance, and time delays. [Source: MIL-STD-1472F, 1999]

- **6.3.4.2 Wide range of visual indicator movement.** When a wide range of visual indicator element movement is required, a small movement of the control shall yield a large movement of the visual indicator element. When a small range of visual indicator movement is required, a large movement of the control shall result in a small movement of the visual indicator, consistent with the final accuracy required. [Source: MIL-STD-1472F, 1999]

- **6.3.4.3 Small range of visual indicator movement.** When a small range of visual indicator movement is required, a large movement of the control shall result in a small movement of the visual indicator, consistent with the final accuracy required. [Source: MIL-STD-1472F, 1999]

- **6.3.4.4 Knob, coarse setting.** When a knob is provided for making coarse display element settings on linear scales— 0.4 to 2.5 mm (0.016 to 0.100 in) tolerance—approximately 150 mm (6 in) visual indicator element movement shall be provided for one complete turn of the knob. [Source: MIL-STD-1472F, 1999]

- **6.3.4.5 Knob, fine setting.** For fine setting on linear scales—0.2 to 0.4 mm (0.008 to 0.016 in) tolerance—25 to 50 mm (1 to 2 in) of visual indicator element movement shall be provided for one complete turn of the knob. [Source: MIL-STD-1472F, 1999]

- **6.3.4.6 Bracketing.** When bracketing is used to locate a maximum or minimum rather than a specific value, the control knob shall swing through an arc of not less than 10° nor more than 30° on either side of the target value in order to make the peak or dip associated with that value clearly noticeable. [Source: MIL-STD-1472F, 1999]

- **6.3.4.7 Lever, coarse setting.** When a lever is provided for coarse settings (0.4 to 2.5 mm (0.016 to 0.100 in) tolerance), one unit of visual indicator element movement shall be induced by three units of lever movement. [Source: MIL-STD-1472F, 1999]

- **6.3.4.8 Counters.** When a counter is provided, one complete revolution of the control shall result in approximately 50 counts, for example, five revolutions of a 10-count drum. [Source: MIL-STD-1472F, 1999]

6.3.5 Failure indicators

- **6.3.5.1. Overload indicators.** When appropriate, an overload indicator shall be provided for each major unit of equipment, component, or circuit, even if it may sometimes be desirable to keep the overloaded item in operation. [Source: National Aeronautics and Space Administration(NASA-STD-3000A), 1989; Department of Defense(MIL-STD-1472D), 1989; Department of Defense(MIL-STD-1800A), 1990]

- **6.3.5.2 Out of range indicators.** When equipment has failed or is not operating within tolerance limits, an indication shall be provided. [Source: NASA-STD-3000A, 1989; MIL-STD-1472D, 1989; MIL-STD-1800A, 1990]

- **6.3.5.3 Power failure indicators.** When a power failure occurs, an indication shall be provided. [Source: MIL-STD-1472D, 1989; NASA-STD-3000A, 1989]

- **6.3.5.4 Open circuit indicators.** When a fuse or circuit breaker has failed, an indication shall be provided. [Source: MIL-STD-1472D, 1989; MIL-STD-1800A, 1990; NASA-STD-3000A, 1989]

- **6.3.5.5 Power-on indicator.** A power-on indicator that extinguishes with loss of power shall be provided. [Source: MIL-STD-1800A, 1990]

6.4 Accommodating people with disabilities

Accessibility in design extends general design principles to cover those individuals who are faced with either temporary or permanent limitations in some dimension of human ability (e.g., sight, hearing, physical mobility, etc.). Although these rules are meant to make systems more accessible and thus make systems available to an increased number of users, it is not possible to design everything for use by everyone. However, there are often adaptations that can significantly increase system accessibility and usefulness. The goal of this section is to make systems more accessible and thus maximize the number of potential users.

Definitions. A **disability** is a physical or mental impairment that substantially limits one or more of a person's major life activities. A **reasonable accommodation** is any modification or adjustment to a job or the work environment that will enable a qualified person with a disability to participate in the application process and to perform essential job functions.

6.4.1 Control accessibility

- **6.4.1.1 Manipulating controls.** Equipment intended to be accessible should be designed to maximize the number of people who can physically operate controls and other input mechanisms. [Source: Vanderheiden & Vanderheiden, 1991]

  Discussion. People who may be unable to operate controls or who can operate them only with difficulty include people with severe weakness, people with missing limbs or digits, people with poor coordination or impaired muscular control, and people with limited movement control. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.2 Minimal force to operate.** Controls intended to be accessible should be designed to minimize the amount of force required to operate a control or provide a means for adjusting the required force. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.3 Ample space between controls.** Controls intended to be accessible should provide ample space between controls for adaptations such as larger knobs or levers. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.4 Alternatives to continuous action.** Equipment meant to be accessible should minimize or provide alternatives to requiring the user to perform continuous action, such as holding a button down. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.5 Alternatives to simultaneous actions.** Equipment meant to be accessible should provide alternatives to requiring simultaneous actions, such as holding down a control key while pressing another key. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.6 Operation with either hand.** Controls should be able to be operated with either the right or the left hand. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.7 Non slip buttons.** Controls should use concave and/or nonslip tops on buttons or provide a ridge around flat keypad buttons. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.8 Alternatives to quick response buttons.** To provide accessibility to more users, controls that normally require a quick response should provide an alternate input method that is not time dependant or the capability of adjusting the required input time interval. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.9 Alternatives to fine motor control.** To provide accessibility to more users, an alternate mechanism that does not require fine motor control should be provided for controls that normally require fine motor control. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.10 Avoid controls that require complex motions.** Controls that require complex motions such as simultaneous twisting and pushing should be avoided. [Source: Vanderheiden & Vanderheiden, 1991; Kanis, 1993]

- **6.4.1.11 Minimize force requirements.** To make controls accessible for users with impaired hand strength, the amount of force necessary to operate controls should be as small as possible. [Source: Kanis, 1993]

- **6.4.1.12 Unobstructed access.** There should be no obstructions that would interfere with a user's ability to manipulate a control. [Source: Kanis, 1993]

- **6.4.1.13 Momentary, not continuous, operation.** A control should not require the user to continuously hold it down in order to activate it unless safety requirements dictate otherwise. [Source: Kanis, 1993]

- **6.4.1.14 Unconstrained manipulation.** To allow accessibility for users with impaired hand strength, a control should be designed to permit users great flexibility in how the control is manipulated, whether by using the fingers, the full hand, or both hands. [Source: Kanis, 1993]

- **6.4.1.15 Reaching controls.** Controls and input devices on equipment intended to be accessible should be located within easy reach of intended users, including short people and people who have limited reach, such as those in wheelchairs. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.16 Arrange by frequency of use.** Controls that must be used frequently should be placed in positions that are the most easily reached with the minimum change of body position and where wrist or arm support is available. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.17 Alternative activation for unreachable controls.** To make controls that are unreachable to some users accessible, alternative mans of operations such as a redundant speech input option or remote control should be provided. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.18 Identifying controls without sight.** Equipment intended to be accessible to the visually impaired should be designed to maximize the number of people who can find and identify individual controls even if they cannot see them. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.19 Nonvisual means for identifying controls.** Equipment intended to be accessible to the visually impaired should provide a nonvisual means for differentiating controls such as by correlating size, shape, or texture with importance or function. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.20 Sufficient space for labeling.** Equipment intended to be accessible to the visually impaired should provide adequate space for tactile localization and identification and labeling with large print or Braille. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.21 Controls near controlled objects**. Controls should be located close to the objects they control. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.22 Logical layout of controls**. Controls should be arranged in a manner that is logical and easy to understand. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.23 Provide ridges on flat control buttons**. Flat panel buttons should provide a ridge or raised lip around the buttons. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.24 Alternative input options**. Controls that are not accessible to the visually impaired should provide an alternative means of manipulation such as a redundant speech recognition input option for the visually impaired user. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.25 Reading control labels.** Equipment intended to be accessible should be designed to maximize the number of people who can read the labels on controls. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.26 Large lettering on labels.** The lettering of labels on equipment intended to be accessible should be as large as practical. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.27 Labels readable from wheelchair.** Important labels on equipment intended to be accessible should be placed where they can be read by short people or people in wheelchairs. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.28 Alternative labeling for visually impaired.** Stick on tactile labels or large print labels should be made available as options for equipment intended to be accessible to the visually impaired. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.29 Avoid the use of blue, green and violet coding.** Systems that will be used by aging users should avoid the use of blue, green and violet coding. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.30 Group controls.** Controls should be arranged in groups that facilitate tactile identification. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.31 Determining control status.** Equipment intended to be accessible to the visually impaired should be designed to maximize the number of people who can determine the status or setting of controls through nonvisual means. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.32 Multi-sensory indication of status.** Controls meant to be accessible to visually impaired users should provide multi-sensory indications of control status (positions or levels). [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.33 Use knobs with pointers.** Knobs intended for use by the visually impaired should have highly visible raised pointers with a tactile orientation cue. [Source: Vanderheiden & Vanderheiden, 1991]

- **6.4.1.34 Moving pointers and stationary scales.** Controls intended to be accessible should use moving pointers and stationary scales rather than moving scales and stationary pointers. [Source: Vanderheiden & Vanderheiden, 1991]

Glossary

Disability - A disability is a physical or mental impairment that substantially limits one or more of a person's major life activities.

Levers - Levers are controls having the same size and shape, but that allow continuous adjustment.

Luminance contrast - Luminance contrast is the contrast between a figure and its background.

Reasonable accommodation - Reasonable accommodation is any modification or adjustment to a job or the work environment that will enable a qualified person with a disability to participate in the application process and to perform essential job functions.

Toggle switch - A toggle switch is a switch with discrete positions operated by a lever.

Transilluminated display - A transilluminated display is a display in which light passes through the element being viewed.

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7 Alarms, audio, and voice communications

This section presents general criteria and rules for audio alarms and displays, voice signals and alarms, controls for audio warning devices, and voice communication systems.

7.1 Alarms and alerts

7.1.1 General

▪ **7.1.1.1 When to use.** If equipment is not regularly monitored, an audio alarm shall be provided to indicate malfunctions or conditions that would cause personnel injury or equipment damage. [Source: Department of Defense (MIL-STD-1472F), 1999]

▪ **7.1.1.2 Be clear and unambiguous.** Alerting and warning systems shall be unambiguous, with a clear indication of the cause for the alert. [Source: Billings, 1996]

▫ **7.1.1.3 Alarm system characteristics.** Alarms systems should

a. alert the user to the fact that a problem exists,

b. inform the user of the priority and nature of the problem,

c. guide the user's initial responses, and

d. confirm in a timely manner whether the user's response corrected the problem. [Source: Nuclear Regulatory Commission (NUREG-0700), 1981]

▫ **7.1.1.4 Indicate degree of problem.** Alarms/alerts should indicate the degree of malfunction or emergency. [Source: Wiener & Curry, 1980]

▫ **7.1.1.5 Alarm in appropriate mode**. When a parameter value represents a fault in some modes and not in others, it should only be alarmed in the appropriate modes. [Source: Nuclear Regulatory Commission (NUREG/CR-6105), 1994]

▪ **7.1.1.6 Signal loss of redundancy.** When part of a redundant system, unit of equipment, module, or component becomes inoperable, an alarm signaling the loss of redundancy shall be provided to the user immediately. [Source: National Aeronautics and Space Administration (NASA STD 3000A), 1989]

▫ **7.1.1.7 Allow access to current alarm settings.** When alarm signals are based on user defined logic, the system should allow the users to access current alarm settings that are specified in terms of dimensions (variables) covered and which values (categories) are established as critical. [Source: Smith and Mosier, 1986]

- ▪ **7.1.1.8 Provide greater probability of detection.** An alerting and warning system or signal shall provide the user with a greater probability of detecting the triggering condition than his or her normal observation would provide in the absence of the alerting or warning system or signal. [Source: MIL-STD-1472F, 1999]

- ▪ **7.1.1.9 Provide help.** When necessary, users shall be able to request help and related information for the operation and processing of critical and non-critical alarms, messages, and signals. [Source: Department of Defense (MIL-STD-1801), 1987]

- ▪ **7.1.1.10 Areas with high ambient illumination.** Auditory as well as visual alarms shall be provided when the users work in an area with a high degree of ambient illumination. [Source: Department of Energy (UCRL-15673), 1985]

- ▪ **7.1.1.11 Provide redundant visual warning.** All nonverbal audio signals shall be accompanied by a visual signal that defines the condition. [Source: MIL-STD-1472F, 1999]

- ▪ **7.1.1.12 Supplement visual displays.** When used in conjunction with a visual display, an audio signal shall be supplementary or supportive, alerting and directing the user's attention to the appropriate visual display. [Source: MIL-STD-1472F, 1999]

7.1.2 Alarm implementation

- ▫ **7.1.2.1 Prioritize presentation.** Alarms should be automatically organized and presented to the users in prioritized form, with the most significant alarms receiving the highest priority. [Source: NUREG-0700, 1981]

  Discussion. Prioritization of alarms can be based on the immediacy of required action and impact on overall safety. [Source: NUREG/CR-6105, 1994]

- ▫ **7.1.2.2 Display by significance.** The display of alarms with higher current operational significance should automatically override the display of alarms with lower current operational significance. [Source: NUREG-0700, 1981]

- ▪ **7.1.2.3 Simultaneous alarms.** When two or more incidents or malfunctions occur simultaneously, the one generating a message of higher priority shall be presented first. After presentation of the highest priority message, remaining messages shall be presented in descending order of priority. [Source: MIL-STD-1472F, 1999]

- ▫ **7.1.2.4 Limit number of priority levels.** The number of priority levels for alarm messages should be limited to four. [Source: Department of Energy (DOE STD HFAC), 1992]

- ▪ **7.1.2.5 Establish priority system.** A message priority system shall be established so that a more critical message shall override the presentation of any message having a lower priority. [Source: MIL-STD-1472F, 1999]

Definition. Caution - A signal that indicates the existence of a condition requiring attention but not immediate action. [Source: Department of Defense (MIL-STD-411), 1991]

Warning - A signal that indicates the existence of a hazardous condition requiring immediate action to prevent loss of life, equipment damage, or a service interruption. [Source: MIL-STD-411, 1991]

Advisory - A signal that indicates a safe or normal configuration, condition of performance, or operation of essential equipment or attracts attention and imparts information for routine action purposes. [Source: MIL-STD-411, 1991]

▪ **7.1.2.6 Using warning signals.** Warning signals shall be used to indicate the existence of a hazardous condition requiring immediate action to prevent loss of life, equipment damage, or a service interruption. [Source: MIL-STD-411, 1991]

▪ **7.1.2.7 Using caution signals.** Caution signals shall be used to indicate conditions requiring awareness but not necessarily immediate action. [Source: MIL-STD-1472F, 1999]

▪ **7.1.2.8 Distinguish caution signals.** Caution signals shall be readily distinguishable from warning signals. [Source: MIL-STD-1472F, 1999]

▪ **7.1.2.9 Make alarms distinctive and consistent.** Alarm signals and messages shall be distinctive and consistent for each class of event. [Source: Avery, L.W., & Bowser, S.E. (DOE HFDG ATCCS V2.0), 1992; Department of Defense (MIL-HDBK-761A), 1989; MIL-STD-1801, 1987]

Example. A signal alerting a user to an incoming message would be different from a signal alerting a user to a hazardous condition. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

▫ **7.1.2.10 Make information simple and understandable.** Processed alarm information should be simple enough that users can easily evaluate the meaning or validity of the resulting alarm messages. [Source: NUREG-0700, 1981]

Discussion. Complex processing can impact the user's ability to understand the constraints and limitations of alarm processing and the validity of resulting alarms. Users rely on the system's information. Thus, it is essential that the users understand the validity of the data, how they are processed, and the limitations of the system. [Source: NUREG-0700, 1981]

- ▫ **7.1.2.11 Status indication.** System status indication generally should be presented on a separate display from the alarm indicators. [Source: NUREG-0700, 1981]

  Discussion. Status indication is not intended to alert the user to the need for action. When status indication is presented together with alarm information, it can increase the demands on the user. [Source: NUREG-0700, 1981]

- ▫ **7.1.2.12 Alarm filtering.** Filtering should only be used for alarms that have no current operational significance. [Source: NUREG-0700, 1981]

  Discussion. Alarm **filtering** is a technique by which unnecessary alarms are eliminated. This differs from alarm **suppression** in which alarm messages are not displayed but are available to the user upon request. [Source: NUREG-0700, 1981]

- ▫ **7.1.2.13 Use of suppressed alarms.** When a single alarmed event invariably leads to subsequent alarmed events, the primary alarmed event should be shown with the subsequent events suppressed, as long as it does not interfere with the user's tasks. [Source: NUREG-0700, 1981]

- ▫ **7.1.2.14 Access to suppressed alarms.** When an alarm is suppressed, users should be able to access the alarm information that is not shown. [Source: NUREG-0700, 1981]

- ▫ **7.1.2.15 Ease of accessing suppressed alarms.** The method for accessing information on suppressed alarms should not be excessively complex. [Source: NUREG/CR-6105, 1994]

- ▫ **7.1.2.16 Training for alerts.** Training techniques should be devised to ensure that users are exposed to all forms of alerts and possible combinations of alerts and that they understand how to deal with them. [Source: Wiener & Curry, 1980]

7.1.3 Reliability

- ▪ **7.1.3.1 System failure.** In the event of a complete system failure, the system shall integrate messages and report the system failure rather than the failure of components. [Source: MIL-STD-1472F, 1999]

- ▪ **7.1.3.2 False alarms.** The design of audio display devices and circuits shall preclude false alarms. [Source: MIL-STD-1472F, 1999]

- ▪ **7.1.3.3 Failure.** The audio display device and circuit shall be designed to preclude warning signal failure in the event of system or equipment failure and vice versa. [Source: MIL-STD-1472F, 1999]

- ▪ **7.1.3.4 Circuit test.** All audio displays shall be equipped with circuit test devices or other means of testing their operation. [Source: MIL-STD-1472F, 1999]

- **7.1.3.5 Alarm input validation.** Alarm system inputs (such as sensors) should be validated to ensure that spurious alarms are not presented to the user. [Source: NUREG-0700, 1981]

- **7.1.3.6 Noise filtering.** Alarm systems should have the capability to filter out noise signals to eliminate unnecessary alarms. [Source: NUREG-0700, 1981]

  Discussion. Spurious alarms can be generated through signals momentarily exceeding the threshold. Time filtering and/or time delay processing can be used to prevent these signals from generating alarms. [Source: NUREG-0700, 1981]

7.2 Audio signals and audio alarms

7.2.1 General

- **7.2.1.1 General.** Audio signals should be provided, as necessary, to warn personnel of impending danger, alert a user to a critical change in system or equipment status, and to remind a user of critical actions that must be taken. [Source: MIL-STD-1472F, 1999]

- **7.2.1.2 Use of auditory signals.** Auditory signals shall only be used when such signals contribute to understanding of and appropriate responses to the operational and task environment. [Source: Ameritech Services, Inc., 1996]

- **7.2.1.3 Avoid negative consequences.** Auditory signals shall not result in user or operator confusion, errors, or inefficiencies in response. [Source: Ameritech Services, Inc., 1996]

- **7.2.1.4 Advantages to audio signals.** An audio signal should be provided when any of the following conditions apply.

  a. The information to be processed is short, simple, transitory, and requires immediate or time-based response.

  b. The use of a visual display might be inappropriate because of overburdening of the visual modality, ambient light variability or limitation, user mobility, degradation of vision by vibration, other environmental considerations, or anticipated user inattention.

  c. The criticality of a response to a visual signal makes supplementary or redundant alerting desirable.

  d. It is desirable to warn, alert, or cue the user for subsequent or additional responses.

  e. Custom or usage has created anticipation of an audio display.

  f. Voice communication is necessary or desirable. [Source: MIL-STD-1472F, 1999]

■ **7.2.1.5 Compatible with environment.** The intensity, duration, and source location of audio alarms and signals shall be compatible with the acoustical environment of the intended receiver. [Source: MIL-STD-1472F, 1999]

□ **7.2.1.6 Alarms for normal conditions.** Auditory alarms should not be used to indicate normal conditions. [Source: Wiener, 1988]

□ **7.2.1.7 Signal type.** When an audio signal is used, the particular type of signal (tone, complex sound, or speech) should be the best for the intended use as indicated in Exhibit 7.2.1.7. [Source: MIL-STD-1472F, 1999]

Exhibit 7.2.1.7 Characteristics and ratings of audio signals for various uses.

Use	Tones (periodic)	Complex Sounds (non periodic)	Speech
Quantitative Indication	**(Poor)** Maximum of 5 to 6 tones absolutely recognizable.	**(Poor)** Interpolation between signals inaccurate.	**(Good)** Minimum time and error in obtaining exact value in terms compatible with response
Qualitative Indication	**(Poor to fair)** Difficult to judge approximate value and direction of deviation from null setting unless presented in close temporal sequence.	**(Poor)** Difficult to judge approximate deviation from desired value.	**(Good)** Information concerning displacement direction, and rate presented in form compatible with required response.
Status Indication	**(Good)** Start and stop timing; continuous information if rate of change of input is low.	**(Good)** Especially suitable for irregularly occurring signals, such as alarms.	**(Poor)** Inefficient; more easily masked; problem of repeatability.
Tracking	**(Fair)** Null position easily monitored; problem of signal-response compatibility	**(Poor)** Required qualitative indications difficult to provide.	**(Good)** Meaning intrinsic in signal.
General	Good for automatic communication of limited information; must be learned; easily generated.	Some sounds available with common meaning, (e.g., a fire bell); easily generated.	Most effective for rapid, but not automatic, communication or complex, multidimensional information; meaning intrinsic in signal and context, if standardized, minimum learning required

▪ **7.2.1.8 User evaluation of alarms.** Auditory signals shall be tested and evaluated for usability, operational suitability, and user acceptance using representative users in as near to a realistic operational environment as possible before the signals are incorporated into a system. [Source: Ameritech Services Inc., 1996]

Discussion. All auditory signals, including verbal signals, act as symbols that users must learn and interpret in the light of their operational and task environment. When designers overuse sound, the auditory signals often are ignored and can cause annoyance, interference, or confusion for the system users.

▫ **7.2.1.9 User setting of alarm parameters.** When appropriate to the task, a system or application should allow a user to set the parameter or condition that results in a software-generated alarm, alert, or status message. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

Example and discussion. Some examples of parameters or conditions are priorities, percentages, and absolute values or ranges of values. When multiple users are involved with a system, it may be the supervisors who determine the alarm parameters, not the individual users.

▫ **7.2.1.10 When users should not set alarm parameters.** User setting of parameters should not be allowed when (1) the settings by one user might affect the reception of alarms by another user; (2) the settings might affect the safety of systems, equipment, or personnel; or (3) alarm parameters are determined by functional, procedural, or legal requirements. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

▫ **7.2.1.11 Alerting capabilities.** Signals with high alerting capacities should be provided when the system or equipment imposes a requirement on the user for concentration of attention. [Source: MIL-STD-1472F, 1999]

▫ **7.2.1.12 Avoid startle.** Signals should not be so startling that they preclude appropriate responses or interfere with other functions by diverting attention away from other critical signals. [Source: MIL-STD-1472F, 1999]

▫ **7.2.1.13 Auditory feedback.** The most common auditory feedback, the system beep, should be used with other forms of notification such as flashing or message dialogs. [Source: Microsoft Corp., 1992]

7.2.2 Number of signals

□ **7.2.2.1 Number of audio signals for absolute identification.** When absolute identification is required, the number of signals to be identified should not exceed four. [Source: MIL-STD-1472F, 1999]

> **Discussion.** Research shows that between 4 to 7 alarms can be acquired reasonably quickly, performance decreases dramatically for additional alarms. The meanings associated with up to nine alarms can be retained if the alarms are presented regularly. [Source: Patterson, 1982; Stanton & Edworthy, 1994]

□ **7.2.2.2 Number of audio signals for relative identification.** When relative discrimination is required, the number of alarm signals should not exceed 12. [Source: Stanton & Edworthy, 1994]

□ **7.2.2.3 Single audio signal.** A single audio signal should be used in conjunction with multiple visual displays only if immediate identification of the appropriate visual display is not critical to personnel safety or system performance. [Source: MIL-STD-1472F, 1999]

7.2.3 Differentiating signals

□ **7.2.3.1 Differentiating signals.** Auditory signals that require different user responses should be easily distinguishable from one another. [Source: MIL-STD-1472F, 1999]

> **Example.** Varying frequency, modulation, or both can differentiate signals. One purpose of differentiating the signals is to minimize the user's search of visual displays. [Source: MIL-STD-1472F, 1999]

■ **7.2.3.2 Differentiation from routine signals.** Audio alarms intended to attract the user's attention to a malfunction or failure shall be different from routine signals such as bells, buzzers, random noises generated by air conditioning and other equipment and normal operation noises. [Source: MIL-STD-1472F, 1999]

■ **7.2.3.3 Multiple audio signals.** When several different audio signals will be used to alert a user to different conditions, the signals shall be distinctive in intensity, pitch, or use of beats and harmonics. [Source: MIL-STD-1472F, 1999]

□ **7.2.3.4 Unsuitable auditory signals.** Auditory signals should not be used if they resemble sounds that can occur in the actual operational setting. [Source: National Air Traffic Services, 1999]

> **Example.** Sounds that are similar to navigational signals or radio transmissions and hisses or humming sounds similar to electrical interference would not be good candidates for audio signals.

- **7.2.3.5 Noninterference.** Audio warning signals shall not interfere with any other critical functions or warning signals or mask any other critical audio signals. [Source: MIL-STD-1472F, 1999]

7.2.4 Signal meaning

- **7.2.4.1 Consistent signals.** The meaning of audio warning signals selected for a particular function in a system should be consistent with warning signal meanings already established for that function. [Source: MIL-STD-1472F, 1999]

- **7.2.4.2 New meanings for standard signals.** Standard signals shall not be used to convey new meanings. [Source: MIL-STD-1472F, 1999]

- **7.2.4.3 Established signals.** Established signals should be used provided they are compatible with the acoustic environment and voice communication systems. [Source: MIL-STD-1472F, 1999]

- **7.2.4.4 Consistent meanings.** The meaning of audio warning signals selected for a particular function in a system should be consistent with warning signal meanings already established for that function. [Source: MIL-STD-1472F, 1999]

7.2.5 Periodicity

- **7.2.5.1 Intermittence.** Auditory signals should be intermittent rather than continuous. [Source: MIL-HDBK-761A, 1989]

  Discussion. Continuous tones are the most easily confused signals, even if they vary considerably in pitch. Furthermore, the human auditory system quickly adapts to continuous auditory stimulation. [Source: Merideth & Edworthy, 1994]

- **7.2.5.2 Nature of signals.** Audio warning signals should consist of two elements, an alerting signal and an identifying or action signal. [Source: MIL-STD-1472F, 1999]

- **7.2.5.3 Modulated signals.** Modulated warning signals should either be modulated from 1-8 beeps per second or warbling with a pitch rise and fall of 1-3 cycles per second. [Source: Sanders & McCormick, 1993]

7.2.6 Duration

- **7.2.6.1 Two-element signals.** When reaction time is critical and a two-element signal is used, an alerting signal of 0.5 seconds duration shall be provided followed by an identifying or action signal with all essential information being transmitted in the first 2 seconds of the identifying or action signal. [Source: MIL-STD-1472F, 1999]

- **7.2.6.2 Reaction time critical.** When reaction time is critical, signals shall be of short duration. [Source: MIL-STD-1472F, 1999]

- **7.2.6.3 Single-element signal.** When a single-element signal is used, all essential information shall be transmitted in the first 0.5 seconds. [Source: MIL-STD-1472F, 1999]

- **7.2.6.4 Duration.** Audio warning signal duration shall be at least 0.5 seconds and may continue until the appropriate response is made. [Source: MIL-STD-1472F, 1999]

- **7.2.6.5 Duration limitations.** Signals that persist or increase progressively in loudness shall not be used if manual shutoff may interfere with the corrective action required. [Source: MIL-STD-1472F, 1999]

- **7.2.6.6 Signal termination.** Completion of a corrective action by the user or by other means shall automatically terminate the signal. [Source: MIL-STD-1472F, 1999]

7.2.7 Frequency

- **7.2.7.1 Audibility.** An alarm/warning signal shall provide an audio level in at least one octave band between 200 and 5,000 Hertz such that the signal is at least 10 dBA SPL (sound pressure level) above the ambient noise level, or 20 dBA SPL above the amplitude of the masked threshold, or at such a level that assures personnel are adequately alerted to the danger or status so as to take the appropriate response, when measured within 1 foot of the responder's ear, or at more than 2 feet from the alarm. [Source: MIL STD 1472F, 1999; NASA-STD-3000, 1995]

- **7.2.7.2 Frequency range.** The frequency range of a warning signal shall be between 200 and 5,000 Hz, preferably between 500 and 3,000 Hz. [Source: MIL-STD-1472F, 1999]

- **7.2.7.3 Frequency for long distances.** When a signal must be audible at a distance of 300 m (985 ft) or more, the frequency shall be below 1,000 Hz. [Source: MIL-STD-1472F, 1999]

- **7.2.7.4 Signals around obstacles.** When the signal must be heard around obstacles or through partitions, the frequency shall be below 500 Hz. [Source: MIL-STD-1472F, 1999]

- **7.2.7.5 Frequencies differing from background.** The selected frequency band shall differ from the most intense background frequencies. [Source: MIL-STD-1472F, 1999]

- **7.2.7.6 Spurious signals.** The frequency of a warning tone shall be different from that of the electric power employed in the system to preclude the possibility that a minor equipment failure might generate a spurious signal. [Source: MIL-STD-1472F, 1999]

- ▫ **7.2.7.7 Frequencies difficult to localize.** Mid-frequencies (1500-3000 Hz) should not be used for auditory alarms that require localization. [Source: Sanders & McCormick, 1993]

7.2.8 Intensity (loudness)

□ **7.2.8.1 Environmental compatibility.** The intensity, duration, and source location of an auditory signal should be compatible with the acoustic environment of the intended receiver as well as with the requirements of other personnel within acoustic range of the signal. [Source: MIL-HDBK-761A, 1989]

Discussion. Avoid the use of loud sounds unless the task requires it (e.g., the environment is loud and it is critical that the user hear the sounds).

■ **7.2.8.2 Compatibility with clothing and equipment.** When the audio alarms and signals must be heard and understood through equipment or garments (e.g., parka hoods and hearing protective devices covering the ears of a listener), audio signals shall be loud enough to compensate for the attenuation characteristics of the garments without exceeding 115 dB(A) for emergency signals and 90 dB(A) for other signals. [Source: MIL-STD-1472F, 1999]

■ **7.2.8.3 Exceeding ambient noise.** Auditory signals shall exceed the prevailing ambient noise level by at least 10 dB(A) or any maximum sound level with a duration of 30 seconds by at least 5 dB(A), whichever is louder, without exceeding 115 dB(A)for emergency signals or 90 dB(A) for other signals. [Source: MIL-STD-1472F, 1999; NUREG-0700, 1981]

■ **7.2.8.4 Maximum intensity.** The intensity of evacuation and emergency signals shall not exceed 115 dB(A). The intensity of other signals shall not exceed 90 dB(A). [Source: MIL-STD-1472F, 1999; NUREG-0700, 1981]

■ **7.2.8.5 Control of volume.** The user, the sensing mechanism, or both shall control the volume (loudness) of an audio warning signal depending upon the operational situation and personnel safety. [Source: MIL-STD-1472F, 1999]

■ **7.2.8.6 Volume limits.** Volume control movement shall be restricted to prevent reducing the volume to an inaudible level or increasing it to an unacceptably high level. [Source: MIL-STD-1472F, 1999]

□ **7.2.8.7 Appropriate use.** Auditory coding should be used

a. to alert users to critical conditions or operations;

b. to supplement visual signals;

c. to present information in situations in which visual presentation is not feasible; and

d. to provide feedback for control actuation, data entry, or the completion of timing cycles and sequences. [Source: MIL-HDBK-761A, 1989]

▫ **7.2.8.8 Inappropriate use.** Auditory coding should not be used when ambient noise prevents effective listening. [Source: National Air Traffic Services, 1999]

7.2.9 Acknowledging signals

▪ **7.2.9.1 Special acknowledgement of critical alarms.** When a user must acknowledge a special or critical alarm in a unique way (e.g., with a special combination of key strokes), this special acknowledgement shall not inhibit or slow the response to the condition initiating the alarm. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

▪ **7.2.9.2 Alarm reset.** A system or application shall provide users with a simple means for turning off non-critical auditory alarms without erasing any displayed message that accompanies the auditory signal. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

▪ **7.2.9.3 Acknowledging and terminating alarms.** A system or application shall provide users with a means of acknowledging alarms and of turning off alarm signals once the alarms have been acknowledged or the condition generating the alarm has been corrected. [Source: MIL-STD-1801, 1987]

▪ **7.2.9.4 Procedures for acknowledging alarms.** Procedures for acknowledgment and termination shall not decrease the speed and accuracy of operator reaction to the alerting situation. [Source: MIL-STD-1801, 1987]

▪ **7.2.9.5 Consistent means of acknowledging.** A simple, consistent means of acknowledging auditory signals shall be provided. [Source: MIL-HDBK-761A, 1989]

▪ **7.2.9.6 Acknowledging non-critical signals.** When the signal is non-critical, the acknowledgement action shall also turn the signal off. [Source: MIL-HDBK-761A, 1989]

▪ **7.2.9.7 Acknowledging alarms indicating loss of redundancy.** Users shall be able to acknowledge an alarm signaling the loss of redundancy, with the lack of available redundancy continuously displayed until the redundant system, equipment, module, or component becomes operable again. [Source: NASA STD 3000A, 1989]

▪ **7.2.9.8 Automatic and manual shutoff.** If an audio signal is designed to persist as long as it contributes useful information, a shutoff switch controllable by the user, the sensing mechanism, or both, shall be provided consistent with the operational situation and personnel safety. [Source: MIL-STD-1472F, 1999]

▪ **7.2.9.9 Automatic reset.** An automatic reset function for audio signals shall be provided, whether the signals are designed to terminate automatically, manually, or both. The automatic reset function shall be controlled by a sensing mechanism that recycles the signal system to a specified condition as a function of time or the state of the signaling system so that the warning device can sound again if the condition reappears. [Source: MIL-STD-1472F, 1999]

- ▪ **7.2.9.10 Ganging to mode switches.** Volume controls may be ganged to mode switches to provide maximum output during operational phases in which intense noise can occur and to provide reduced volume at other times. This ganging shall not be done if there is a possibility that intense noise could occur in an emergency situation during a phase in which the volume would be decreased below an audible level. [Source: MIL-STD-1472F, 1999]

- ▪ **7.2.9.11 Caution signal controls.** Audio caution signals shall be provided with manual reset and volume controls. [Source: MIL-STD-1472F, 1999]

7.2.10 Presentation over headsets

- ▪ **7.2.10.1 Headset.** When the user will wear earphones covering both ears during normal equipment operation, the audio warning signal shall be directed to the user's headset as well as to the work area. [Source: MIL-STD-1472F, 1999]

- ▫ **7.2.10.2 When not to use headsets.** Binaural headsets should not be used in any operational environment with ambient noise below 85 dB(A) if that environment contains sounds that provide the user with useful information and that information cannot be directed to the user's headset. [Source: MIL-STD-1472F, 1999]

  Discussion. Such sounds may include voices, machine noise that indicates wear or malfunctions, and other auditory indications of system performance or mission status. [Source: MIL-STD-1472F, 1999]

- ▫ **7.2.10.3 Separate channels.** When feasible, a warning signal delivered to a headset that might mask another essential audio signal should be delivered to one ear and the other signal to the other ear. [Source: MIL-STD-1472F, 1999]

- ▫ **7.2.10.4 Dichotic presentation.** When earphones will be worn in an operational environment, a dichotic presentation should be used whenever feasible, with the signal alternating from one ear to the other by means of a dual-channel headset. [Source: MIL-STD-1472F, 1999]

7.3 Voice signals and voice alarms

7.3.1 General

□ **7.3.1.1 When to use.** Voice signals should be used

a. to supplement visual displays when communication flexibility is necessary,

b. when coded signal meanings are numerous or may be forgotten,

c. for presentation of complex directions or instructions,

d. when ambient noise may mask simple tonal signals,

e. in conjunction with tonal signals, and

f. for presentation of continuous information when the rate of change is low. [Source: MIL-HDBK-761A, 1989]

■ **7.3.1.2 Nature of signals.** Voice signals shall consist of a brief, standardized speech signal (e.g., a verbal message) to identify the specific condition and suggest an appropriate action. [Source: MIL-STD-1472F, 1999]

□ **7.3.1.3 Presentation of voice signals.** Verbal signals should be preceded by an initial non-speech alerting signal to attract the users attention if the verbal warning signals are used for other types of information as well as warnings. [Source: Sanders & McCormick, 1993]

□ **7.3.1.4 Acknowledging warning signals.** The system should require that users acknowledge spoken warning signals. [Source: MIL-HDBK-761A, 1989]

7.3.2 Intensity

■ **7.3.2.1 Intensity.** Verbal signals for critical functions shall be at least 20 dB above the speech interference level at the operating position of the intended receiver but shall not exceed 90 dB(A). [Source: NUREG-0700, 1981; MIL-STD-1472F, 1999]

Definition. Speech interference level is a measure of the effectiveness of noise in masking speech. It is the arithmetic mean of the same pressure levels of interfering noise (in dB) in the four octave bands centered on the frequencies 500, 1000, 2000, and 4000 Hz, respectively. The unit of speech interference is the decibel (dB). [Source: NUREG-0700, 1981; MIL-STD-1472F, 1999]

□ **7.3.2.2 Speech intensity.** Speech intensity should be appropriate to the expected ambient noise environment, with a signal to noise ratio of at least 5:1. [Source: MIL-HDBK-761A, 1989]

7.3.3 Word selection

■ **7.3.3.1 Word choice.** The words used in verbal signals shall be concise, intelligible, and appropriate to the task and the information presented. [Source: MIL-HDBK-761A, 1989]

□ **7.3.3.2 Word characteristic prioritization.** Word selection priority should all be intelligibility, descriptiveness, and conciseness, in that order. [Source: MIL-STD-1472F, 1999]

Discussion. Given the prioritization criteria above, if two word choices are being considered and both are concise, intelligible, and appropriate, but one is more intelligible, the one that is the most intelligible of the two should be used even if the other word choice is more concise.

□ **7.3.3.3 Words to avoid.** To the extent possible, words that rhyme with other words or that sound similar in other ways should be avoided if these other words might be used in the same context and, therefore, possibly be confused with the original words. [Source: MIL-HDBK-761A, 1989]

□ **7.3.3.4 Formal words.** Formal or correct words should be used; slang, jargon, and colloquial words should be avoided. [Source: MIL-HDBK-761A, 1989]

□ **7.3.3.5 Alphabetic information.** Alphabetic information should be presented using a phonetic alphabet that uses words like alpha, bravo, and Charlie rather than the letters A, B, and C. [Source: MIL-HDBK-761A, 1989]

7.3.4 Presentation

□ **7.3.4.1 Average talker.** Spoken messages should sound like an average talker from the user country without a regional dialect. [Source: MIL-HDBK-761A, 1989]

□ **7.3.4.2 Distinctive voices.** When different categories of voice signals are used, a different, distinctive voice should be used for each category of data. [Source: MIL-HDBK-761A, 1989]

Example. One voice might be used for instructional messages and another for warnings. [Source: MIL-HDBK-761A, 1989]

□ **7.3.4.3 Content.** Spoken messages should be brief, informative, and to the point. [Source: MIL-HDBK-761A, 1989]

▫ **7.3.4.4 Type of voice.** The voice used in recording verbal warning signals should be mature and distinct enough not to be confused with voice communications including radio and intercom communications. [Source: MIL-STD-1472F, 1999]

▪ **7.3.4.5 Delivery style.** Voice signals shall be presented in a formal, impersonal manner. [Source: MIL-STD-1472F, 1999]

▪ **7.3.4.6 Repetition.** Critical warning signals shall be repeated with not more than a 3 sec pause between messages until the condition is corrected or overridden by an operator or user. [Source: MIL-STD-1472F, 1999]

▪ **7.3.4.7 Speech processing.** Verbal warning signals shall be processed only if necessary to increase or preserve intelligibility, for example, by increasing the strength of consonant sounds relative to vowel strength. [Source: MIL-STD-1472F, 1999]

Discussion. When a signal must be relatively intense because of high ambient noise, peak clipping may be used to protect the listener against auditory overload. [Source: MIL-STD-1472F, 1999]

7.4 Voice communication systems

7.4.1 Speech intelligibility

▫ **7.4.1.1 Evaluation method.** If information about the speech intelligibility of a system is needed, the most appropriate of the following methods should be selected.

a. The phonetically balanced (PB) word test should be used when the highest accuracy and sensitivity are required. It is difficult to administer accurately and requires a long training time (typically 20-40 hours) before the responses of the listeners have peaked and are stable.

b. The modified rhyme test (MRT) described in ANSI 3.2 should be used to measure the communication performance of most military communication systems. It is easy to administer and requires only a short training time of 1-2 hours.

c. The articulation index (AI) and/or the speech transmission index (STI) are predictive estimators of intelligibility. They should be used to estimate system performance during the concept and design phase but not as a substitute for intelligibility test when system hardware is available. [Source: MIL-STD-1472F, 1999]

- **7.4.1.2 Intelligibility criteria.** Speech intelligibility shall meet the criterion in Exhibit 7.4.1.2 for the appropriate communication requirement and evaluation method. [Source: MIL-STD-1472F, 1999]

Exhibit 7.4.1.2 Speech intelligibility criteria for voice communication systems

COMMUNICATION REQUIREMENT	SCORE		
	PB	MRT	AI[1]
Exceptionally high intelligibility; separate syllables understood	90%	97%	0.7
Normal acceptable intelligibility; about 98% of sentences correctly heard; single digits understood	75%	91%	0.5
Minimally acceptable intelligibility; limited standardized phrases understood; about 90% sentences correctly heard (not acceptable for operational equipment)	43%	75%	0.3

[1] The Articulation Index (AI) should not be used to measure intelligibility of synthetic speech because some key acoustic features are not present in non-human "speech." Instead, intelligibility of synthetic speech should be measured using representative panels of talkers and listeners.

7.4.2 Speech transmission equipment

- **7.4.2.1 Frequency range.** Microphones and associated system-input devices shall respond optimally to that part of the speech spectrum most essential to intelligibility (i.e., 200 to 6,100 Hz). Where system engineering necessitates speech-transmission bandwidths narrower than 200 to 6,100 Hz, the minimum acceptable frequency range shall be 250 to 4,000 Hz. [Source: MIL-STD-1472F, 1999]

- **7.4.2.2 Dynamic range.** The dynamic range of a microphone used with a selected amplifier shall be great enough to admit variations in signal input of at least 50 dB. [Source: MIL-STD-1472F, 1999]

- **7.4.2.3 Noise canceling microphones.** In very loud, low frequency noise environments (100 dB overall), noise canceling microphones shall be used and shall be capable of effecting an improvement of at least 10 dB peak-speech to root-mean-square noise ratio as compared with microphones that are not noise canceling, but that have equivalent transmission characteristics. [Source: MIL-STD-1472F, 1999]

▪ 7.4.2.4 **Pre-emphasis.** If necessary, speech system input devices shall employ frequency pre-emphasis with a positive slope frequency characteristic no greater than 18 dB per octave from 140 to 1,500 Hz, and no greater than 9 dB per octave over the frequency range of 1,500 to 4,800 Hz when no clipping is used. [Source: MIL-STD-1472F, 1999]

Discussion. If speech signals are to be transmitted over channels that have less than 15 dB peak-speech to root-mean-square noise ratios, peak-clipping of 12 to 20 dB may be employed at system input and can be preceded by frequency pre-emphasis. [Source: MIL-STD-1472F, 1999]

▫ 7.4.2.5 **Noise shields.** If the talker is in an intense noise field, the microphone should be put in a noise shield. Noise shields should be designed to meet the following requirements:

a. a volume of at least 250 cu cm (15.25 cu in) to permit a pressure gradient microphone to function normally,

b. a good seal against the face achieved by pressure of the hand or by tension straps,

c. a hole or combination of holes covering a total area of 65 sq mm (0.1 sq in) in the shield to prevent pressure buildup,

d. prevention of a standing wave pattern by shape or by use of sound absorbing material, and

e. no impediment to voice effort, mouth or jaw movement, or breathing. [Source: MIL-STD-1472F, 1999]

7.4.3 Speech reception equipment

▪ 7.4.3.1 **Frequency range.** Headphones and loudspeakers shall be subject to the same frequency response restrictions as microphones and transmission equipment except that loudspeakers for use in multi-speaker installations and multiple channels fed into headphones (e.g., where several speech channels are to be monitored simultaneously) shall respond uniformly (±5 dB) from 100 to 4,800 Hz. [Source: MIL-STD-1472F, 1999]

■ **7.4.3.2 Use of de-emphasis.** If transmission equipment employs pre-emphasis and peak clipping is not used, reception equipment shall employ frequency de-emphasis of characteristics complementary to those of pre-emphasis only if it improves intelligibility, that is, de-emphasis shall be a negative-slope frequency response not greater than 9 dB per octave over the frequency range of 140 to 4,800 Hz. [Source: MIL-STD-1472F, 1999]

■ **7.4.3.3 Monitoring of speakers.** If several channels are to be monitored simultaneously by means of loudspeakers, the speakers shall be mounted at least 10° apart in the horizontal plane frontal quadrant, from 45° left to 45° right of the user's normal forward-facing position. [Source: MIL-STD-1472F, 1999]

■ **7.4.3.4 Filtering of speaker signals.** If additional channel differentiation is required, apparent lateral separation shall be enhanced by applying low-pass filtering (frequency cutoff, Fc=1,800 Hz) to signals fed to loudspeakers on one side of the central user position. If there are three channels involved, one channel shall be left unfiltered; a high-pass filter with a 1,000 Hz cutoff shall be provided in the second channel; and a low-pass filter with a 2,500 Hz cutoff shall be provided in the third channel. A visual signal shall be provided to show which channel is in use. [Source: MIL-STD-1472F, 1999]

■ **7.4.3.5 Speaker and side tone.** The speaker's verbal input shall be in phase with its reproduction as heard on the headset. This side tone shall not be filtered or modified before it is received in the headset. [Source: MIL-STD-1472F, 1999]

■ **7.4.3.6 Use of binaural headsets.** If listeners will be working in high ambient noise (85 dB(A) or above), binaural rather than monaural headsets shall be provided. Unless operational requirements dictate otherwise, binaural headsets shall be wired so that the sound reaches the two ears in opposing phases. [Source: MIL-STD-1472F, 1999]

□ **7.4.3.7 Binaural headsets.** Binaural headsets should be capable of reducing the perceived ambient noise level to less than 85 dB(A). Provisions should be incorporated to furnish the same protection to those who wear glasses. [Source: MIL-STD-1472F, 1999]

■ **7.4.3.8 Speaker and side tone.** The speaker's verbal input shall be in phase with its reproduction as heard on the headset. This side tone shall not be filtered or modified before it is received in the headset. [Source: MIL-STD-1472F, 1999]

7.4.4 Design for user comfort and convenience

- **7.4.4.1 Comfort.** Communication equipment to be worn by a user, such as headphones and telephone headsets, shall be designed to preclude user discomfort. Metal parts of a headset shall not come into contact with a user's skin. [Source: MIL-STD-1472F, 1999]

- **7.4.4.2 Hands-free operation.** User microphones, headphones, and telephone headsets shall be designed to permit hands-free operation under normal working conditions. Specialized emergency equipment may be exempt from this criterion. [Source: MIL-STD-1472F, 1999]

- **7.4.4.3 Accessibility of handsets.** When communication requirements necessitate the use of several telephone handsets, the accessibility of their locations when not in use shall be determined by operational priority, that is, the most frequently or most urgently needed handset shall be the most accessible. The handsets may be color coded if the users will be able to perceive the coding under normal working conditions. [Source: MIL-STD-1472F, 1999]

7.4.5 Operating controls for voice communication equipment

- **7.4.5.1 Volume controls.** Accessible volume or gain controls shall be provided for each communication receiving channel, such as loudspeakers or headphones, with sufficient electrical power to drive the sound pressure level to at least 100 dB overall, when using two earphones. The minimum setting of the volume control shall be limited to an audible level, that is, it shall be impossible to inadvertently disable the system using the volume control. [Source: MIL-STD-1472F, 1999]

- ◻ **7.4.5.2 Separate controls for power and volume.** Separate controls should be provided for power (ON-OFF) and for volume control. [Source: MIL-STD-1472F, 1999]

- **7.4.5.3 Combined power and volume controls.** If power and volume controls are combined because of space limitations, an easily noticeable detent position shall be provided between the OFF position and the lower end of the continuous range of volume adjustment, and the OFF position shall be labeled. [Source: MIL-STD-1472F, 1999]

- **7.4.5.4 Squelch control.** If communication channels are to be continuously monitored, each channel shall be provided with a signal-activated switching device (squelch control) to suppress channel noise during no-signal periods. A manually operated ON-OFF switch shall be provided to deactivate squelching during the reception of weak signals. [Source: MIL-STD-1472F, 1999]

- **7.4.5.5 Foot-operated controls.** When normal working conditions will permit the operator to remain seated at the working position and require access to "talk-listen" or "send-receive" control switches, or if console operation requires the use of both hands, foot-operated controls shall be provided. [Source: MIL-STD-1472F, 1999]

- **7.4.5.6 Duplicate emergency controls.** Hand-operated controls for the same functions as foot operated controls shall be provided for emergency use and for use when the operator may need to move from one position to another. [Source: MIL-STD-1472F, 1999]

7.4.6 Conventional telephone systems

- **7.4.6.1 General.** In special environments such as control rooms, selection and placement of conventional telephone systems may be more critical than in a normal office environment. Within such specialized environments, systems selected for use shall provide a good frequency response in that portion of the spectrum essential for speech intelligibility. The standard telephone band pass of 200 to 3,300 Hz is acceptable. Handsets shall be compatible with users' hand sizes and mouth-to-ear distances. Again, the standard telephone dimensions are acceptable. Handsets shall provide firm ear contact. [Source: NUREG-0700, 1981]

- **7.4.6.2 Cords.** Cords shall be non-kinking or self-retracting and of sufficient length to permit reasonable user mobility. Cords shall be positioned to avoid entangling critical controls or becoming entangled with passing people or objects. [Source: NUREG-0700, 1981]

- **7.4.6.3 Handset cradles.** Vertically mounted handset cradles shall be designed and located to prevent the handset from being knocked out of the cradle by passing people or objects. [Source: NUREG-0700, 1981]

- **7.4.6.4 Multiple telephones.** If several telephones are located close to each other, they shall be coded to indicate circuit or function. [Source: NUREG-0700, 1981]

- **7.4.6.5 Press-to-talk button.** If a press-to-talk button is used, the button shall be convenient to both left- and right-handed people. [Source: NUREG-0700, 1981]

▫ **7.4.6.6 Switching.** Switching should be designed and programmed to minimize delay in making desired connections under both normal and emergency conditions. [Source: NUREG-0700, 1981]

▪ **7.4.6.7 Priority.** Switching shall be programmed to give the control room and critical functions automatic priority of access to the switching system. [Source: NUREG-0700, 1981]

▫ **7.4.6.8 Noisy environments.** In noisy environments, volume controls should be provided for loudness of ringing and speaker output. [Source: NUREG-0700, 1981]

Glossary

Advisory - A signal that indicates a safe or normal configuration, condition of performance, or operation of essential equipment, or attracts attention and imparts information for routine action purposes.

Alarm filtering - A technique by which unnecessary alarms are eliminated.

Alarm suppression - Alarm messages are not displayed but are available to the user upon request.

Caution - A signal that indicates the existence of a condition requiring attention but not immediate action.

Speech interference level - A measure of the effectiveness of noise in masking speech. It is the arithmetic mean of the same pressure levels of interfering noise in the four octave bands centered on the frequencies 500, 1000, 2000, and 4000 Hz, respectively. The unit of speech interference is the decibel (dB).

Warning - A signal that indicates the existence of a hazardous condition requiring immediate action to prevent loss of life, equipment damage, or a service interruption.

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8 Computer-human interface

8.1 Screen design

Screen design refers to the way information is arranged and presented on a display screen. Different systems and applications can perform many tasks. Some systems rely heavily on databases and do not require immediate user response to information displayed on their screens. Other systems, such as control systems, require that the users make immediate decisions and issue commands based on information displayed to them. The designer needs to understand the primary function of the system being developed to provide an effective screen design.

8.1.1 General principles

▫ **8.1.1.1 Simplicity.** Information should be presented simply and in a well-organized manner. Ways to achieve simplicity include the following:

a. The screen should appear to be orderly and clutter-free.

b. Information should be presented in consistent, predictable locations.

c. The language used should be plain and simple.

d. The means for moving around the screen and to related screens should be simple.

e. Interrelationships should be indicated clearly. [Source: Avery & Bowser (DOE HFDG ATCCS V2.0), 1992; Avery & Bowser (DOD HCISG V2.0), 1992]

▫ **8.1.1.2 Minimal information density.** The information density (the amount of information per unit area) of a screen should be minimized by presenting only information that is essential to a user at any given time. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▫ **8.1.1.3 Screen density.** For text displays, screen density (the ratio of characters to blank spaces) should not exceed 60 %; that is, not more than 60 % of the available character spaces should be filled. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▪ **8.1.1.4 Directly usable form.** Information shall be presented to a user in a directly usable form; a user shall not have to decode or interpret data. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

□ **8.1.1.5 Whole data sets.** Whenever possible, users should be able to see the whole data set of interest, such as an entire page, map, or graphic. [Source: Department of Defense (MIL-HDBK-761A), 1989]

□ **8.1.1.6 Minimizing the user's short-term memory load.** A window should contain all relevant information and should allow a user to complete the task without having to refer to additional information. [Source: Department of the Navy (DON UISNCCS, 1992), 1992]

Example. The application might provide a calendar if specific day and date information is needed.

■ **8.1.1.7 Vocabulary.** The words used in all non-editable text shall be task-oriented and familiar to users. [Source: DON UISNCCS, 1992]

□ **8.1.1.8 Date and time information.** When task performance requires or implies the need to assess the timeliness of information, the display should include time and date information associated with the data. [Source: MIL-HDBK-761A, 1989]

8.1.2 Context

□ **8.1.2.1 Context.** Context should be provided for displayed data. [Source: MIL-HDBK-761A, 1989]

Example. When a user is changing parameters for a facility, relevant information concerning that facility should be displayed. [Source: MIL-HDBK-761A, 1989]

□ **8.1.2.2 Maintaining context.** An application should provide a means for ensuring that a user maintains an understanding of the context in which a task is being performed. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

Example. The application might display the results of those previous transactions that affect the current one, or it might display currently available options. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

■ **8.1.2.3 Highlighting.** When a user is performing an operation on a selected object in a display, that object shall be highlighted. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

Discussion. In many applications, at least two different methods of selection highlighting can be provided. The first of these highlighting methods occurs when the **pointer** comes to rest for a predetermined time on a selected object. This is sometimes referred to as dwell emphasis, and it tells the user which object the computer perceives the user is about to select. This highlighting is normally dim white. The second type of highlighting occurs when an actual selection has been made and is normally a bright white. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- ▪ **8.1.2.4 Display of context information.** Information intended to provide a context for the current user-computer interaction shall be displayed consistently for all transactions within an application and among related applications. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- ▪ **8.1.2.5 Distinctive position and format.** Displayed options, context information, command entry areas, prompts, advisory messages, and other displayed items (for example, titles and time signals) relevant to transaction control shall be distinctive in location and format. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.1.2.6 Operational mode.** When an application provides different operational modes, the current mode shall be continuously indicated to a user. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- ▫ **8.1.2.7 Current context indication.** When the consequences of a control entry will differ depending upon the context established by a prior action, a continuous indication of current context should be displayed. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- ▪ **8.1.2.8 No repetitive entry of data.** A user shall not have to reenter data already entered in the current application session or control session. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.1.2.9 Action history.** An application should maintain a summary of the transactions that produced the current context and display it at a user's request with an **UNDO** feature linked to each step in the action history. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- ▪ **8.1.2.10 Control parameters display.** A user shall be able to review all active control parameters upon request. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

  Discussion. Control parameters can include current and default settings and settings applicable to a particular mode of operation. These parameters apply to the application software and to parameters of an external system being remotely monitored and controlled. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

8.1.3 Format

- ▪ **8.1.3.1 Title.** Every screen shall have a title or header at the top that is separate and distinguishable from the body of the screen and describes briefly the contents or purpose of the screen. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- ▪ **8.1.3.2 Reserved areas.** Any interactive elements used in a screen (for example, prompts, menu bars, command lines, and message areas) shall appear consistently in the same screen location throughout the system or application. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- **8.1.3.3 Minimal visual competition.** Information on a display screen should be organized so that visual competition among distinct items of information is minimized. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- **8.1.3.4 Arrangement of screen elements.** Screens should be arranged so that there is a clear differentiation between instructions and data. [Source: DOE HFDG ATCCS V2.0, 1992;DOD HCISG V2.0, 1992]

- **8.1.3.5 Location of displayed instructions.** When instructions to users are included in a display, instructions on how to do something on the screen should precede (be located above or to the left of) the relevant object; instructions about the disposition of the completed screen should be at the bottom of the screen. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- **8.1.3.6 Matching layout to task.** Application designers should design the screen layout so that users can move quickly and easily among items and can manipulate objects in ways that support task performance. [Source: DON UISNCCS, 1992]

  Example. When an application generates information that will be presented a page at a time, provide users with controls for performing paging operations. [Source: DON UISNCCS, 1992]

- **8.1.3.7 Minimal user effort.** Screens should be designed to minimize both eye and pointer movement and the number of keystrokes required to complete a task. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- **8.1.3.8 Matching layout to users' natural patterns.** Screen layout should conform to users' natural scanning order and probable selection sequences. Usually, the order will be from left to right and top to bottom. [Source: DON UISNCCS, 1992]

  Example. In button sets and menus, the most frequent choice should appear in the leftmost or top position. [Source: DON UISNCCS, 1992]

- **8.1.3.9 Priority of displayed information.** Information should be prioritized so that the most important or critical information is displayed all the time and less important or critical information can be displayed upon a user's request. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- **8.1.3.10 User control.** Users should be able to control the amount, format, and complexity of displayed data as necessary to meet task requirements. [Source: MIL-HDBK-761A, 1989]

- **8.1.3.11 Grouped information.** Groups of data items should be separated by a blank space, lines, color-coding, or other visually distinctive means. [Source: MIL-HDBK-761A, 1989]

▫ **8.1.3.12 Task-critical information.** When a window contains task-critical information, that information should be displayed in a way that users can identify easily, (for example, separating it from other information by a blank space). [Source: DON UISNCCS, 1992]

▪ **8.1.3.13 Primary viewing area.** Information that is particularly important or that requires immediate user response shall be displayed in the user's primary viewing area. [Source: DOD HCISG V2.0, 1992]

▫ **8.1.3.14 Location by importance.** The most important information and controls associated with a task should be located in the upper left part of its window and the least important at the bottom. [Source: DON UISNCCS, 1992]

▪ **8.1.3.15 Ordering of information.** When displayed information is to be used in some spatial or chronological order, its arrangement on the screen shall preserve that order. [Source: DOD HCISG V2.0, 1992]

▪ **8.1.3.16 Ordering method.** When ordering displayed information by sequence, function, frequency, or importance is not appropriate, some other method such as alphabetical or chronological shall be followed. [Source: DOD HCISG V2.0, 1992]

▫ **8.1.3.17 Integrated information.** When a user needs a variety of data to complete a task, those data should be provided in an integrated window or display, not partitioned in separate windows or displays. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; Smith & Mosier, 1986]

8.1.4 Consistency

▪ **8.1.4.1 Consistent screen structure.** Screens throughout a system or application shall have a consistent structure that is evident to users. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▪ **8.1.4.2 Consistent screen elements.** Elements of screens such as headers, fields, and labels shall have consistent appearance and relative location throughout a system or application. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▪ **8.1.4.3 Input prompts.** When applicable, an input prompt shall have a consistent location on all displays throughout a system or application. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▪ **8.1.4.4 Instructions and error messages.** Instructions and error messages shall appear in a consistent location on the screen. [Source: National Air Traffic Services, 1999]

▪ **8.1.4.5 Display formats.** The different elements of display formats shall be distinctive within a display. [Source: MIL-HDBK-761A, 1989]

- **8.1.4.6 Consistent with user expectations.** Data shall be displayed consistently, using standards and conventions familiar to users. [Source: MIL-HDBK-761A, 1989]

- **8.1.4.7 Consistency within applications.** Data display shall be consistent in word choice, format, and basic style throughout an application and related applications. [Source: MIL-HDBK-761A, 1989]

8.1.5 Initial display

- **8.1.5.1 Initial display.** The initial display a user sees shall provide access to the highest level functions, resources, and applications available to the user, including access to the log on screen, user preference settings, utilities (for example, a calculator, clock, and calendar), and system-level Help. [Source: DOD HCISG V2.0, 1992]

- **8.1.5.2 Starting point.** In any display, it shall be obvious where the user is intended to start. Ordinarily, this will be at the upper left part of the screen. [Source: DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992]

  Discussion. This might be accomplished by placing the pointer or cursor, if there is one, at that point or by highlighting the first part of the screen. [Source: DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992]

8.2 Text entry and display

8.2.1 General

- **8.2.1.1 Complex formats.** Complex formats and embellishments that do not convey useful information shall be avoided. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.2.1.2 Appropriateness of format.** The format shall be appropriate to the user's level of training and experience. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.2.1.3 User selection of style.** When appropriate, users should be able to select alternative styles of presentation (for example, graphical or text). [Source: DOE HFDG ATCCS V2.0, 1992]

8.2.2 Luminance

▪ **8.2.2.1 Luminance contrast.** Text-background luminance contrast ratios for a variety of tasks and conditions shall not be less than those given in Exhibit 8.2.2.1. [Source: DOD HCISG V2.0, 1992]

Exhibit 8.2.2.1 Luminance contrast ratios for various conditions.

Condition	Ratio of foreground to background
Bright ambient illumination	> 7:1
Dark ambient illumination	3:1 to 5:1
To attract attention	>7:1
To sharpen edges	>7:1
Continuous reading	3:1 to 5:1
Camouflage images or smooth edges	< 3:1

▫ **8.2.2.2 Dynamic text.** The luminance of dynamic data should be eight times that of the background. [Source: National Air Traffic Services, 1999]

8.2.3 Data entry and editing

▫ **8.2.3.1 Case conversion.** When an application requires that all text be in one case, for example upper case, the application should accept typed uppercase and lowercase letters as equivalent and automatically convert the improper case to the proper one. [Source: DON UISNCCS, 1992]

▫ **8.2.3.2 Wild card search characters.** When an application provides a character string-search capability, it should include the following wild card characters:

a. @ should represent any single upper- or lower-case alphabetic character. For example, abc@d would retrieve abcad, abcEd, and abczd; it would not retrieve abc7d or abcd.

b. # should represent any single numeric character. For example, 123#4 would retrieve 12334, 12394, and 12304; it would not retrieve 123554 or 123A4.

c. ? should represent any single alphanumeric character (for example, any upper- or lower-case alphabetic character, any number, or any punctuation mark). For example, abc?d would retrieve abcAd, abc5d, and abc,d; it would not retrieve abcxxd.

d. * should represent zero or more alphanumeric characters. For example, abc*d would retrieve abcd, abcad, and abcjf75/kld. [Source: DON UISNCCS, 1992]

- **8.2.3.3 Unfilled spaces.** Users shall not have to move a space at a time over unfilled spaces in variable length fields. [Source: MIL-HDBK-761A, 1989]

- **8.2.3.4 Leading and trailing zeros.** For fixed length fields, a user shall not have to enter leading or trailing zeros to fill a field. [Source: DOE HFDG ATCCS V2.0, 1992]

  Example. In a fixed length field that requires four digits, if a three-digit number such as 813 is entered into that field, do not require the user to precede the number with a leading zero (for example, 0813). Likewise, in a fixed length field involving decimal values, do not require the user to enter a value such as 10 with trailing zeros (for example, 10.00).

- **8.2.3.5 Justification of entries.** When a user makes an entry that does not fill a variable length field, the entry shall be automatically justified when the cursor leaves the field. Unless otherwise required by processing or display requirements, justification shall be as follows:

  a. Alphanumeric input shall be left justified.

  b. Integer numerical data shall be right justified.

  c. Decimal numerical data shall be decimal-point justified. [Source: MIL-HDBK-761A, 1989]

- **8.2.3.6 User pacing.** The user, not the system, shall set the pace. [Source: Department of Defense (MIL-STD-1472F), 1999]

- **8.2.3.7 Interrupt capabilities.** Users shall have the ability to use **Backup**, **Cancel**, and **Restart** actions to edit a form at any time prior to the final completion action. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.2.3.8 Editing entries.** Users shall be able to move the cursor to any unprotected field and change any entry prior to taking a final completion action. [Source: MIL-HDBK-761A, 1989]

- **8.2.3.9 Explicit completion action.** A form shall not be removed from display until the user takes an explicit completion action such as pressing the **Enter** key. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

8.2.4 Text entry

8.2.4.1 General

- **8.2.4.1.1 Document operations.** As appropriate, users should be able to **Save, Retrieve, Edit, Delete, Print** (all or specified portions such as a selection, single page, or range of pages), and **Rename** documents. [Source: DON UISNCCS, 1992]

- ▫ **8.2.4.1.2 Text manipulation.** When appropriate, users should be able to specify the format of a document (for example, set margins and tab stops) and to select the font type, size, and style for text. [Source: DON UISNCCS, 1992]

- ▪ **8.2.4.1.3 Undo.** Users shall be able to reverse a previous action or actions with an **Undo** command. [Source: Apple Computer Inc., 1992]

- ▫ **8.2.4.1.4 Line breaks and page breaks.** Automatic line breaks and page breaks should be provided. [Source: DON UISNCCS, 1992]

- ▫ **8.2.4.1.5 Page numbering.** Users should be able to assign page numbers as well as have them supplied automatically. [Source: DON UISNCCS, 1992]

- ▫ **8.2.4.1.6 Search and replace capabilities.** Users should have both search and search-and-replace capabilities in text windows. [Source: DON UISNCCS, 1992]

- ▫ **8.2.4.1.7 Insert mode.** Insert should be the default text entry mode. [Source: DON UISNCCS, 1992]

- ▫ **8.2.4.1.8 Backspace key.** The **Backspace** key should delete the character to the left of the text cursor. [Source: DON UISNCCS, 1992]

- ▫ **8.2.4.1.9 Delete key.** The **Delete** key should delete the character to the right of the cursor. [Source: DON UISNCCS, 1992]

- ▫ **8.2.4.1.10 Manipulating text.** Users should be able to highlight blocks of text and perform such operations as moving, copying, and deleting on the blocks. [Source: DON UISNCCS, 1992]

- ▪ **8.2.4.1.11 Text entry.** Text entry shall be possible only when the text cursor is visible in a location that can accept text entry. [Source: DON UISNCCS, 1992]

- ▪ **8.2.4.1.12 Current position in document.** The current position in the document (for example, the current page or line number) shall be displayed in a consistent location, such as in the window's message area. [Source: DON UISNCCS, 1992]

- ▪ **8.2.4.1.13 Text input area.** The system shall provide a sufficient screen-working area that permits users to enter and edit text. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.2.4.1.14 Multiple input devices.** When the system provides more than one input device, for example, both a **pointing device** and a keyboard, a user should not have to alternate between devices. [Source: MIL-HDBK-761A, 1989]

  Discussion. One solution is to provide both devices with the ability to perform all operations. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.2.4.1.15 Frequently used text blocks.** When applicable, a system should provide users a means for storing and retrieving frequently used blocks of text (for example, distribution lists). [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- **8.2.4.1.16 Status of requests.** The user should be informed of the status of requests for printouts (for example, when a printout has been completed). [Source: CTA, 1996]

8.2.4.2 Text frames

- **8.2.4.2.1 Text frame.** The user should be able to move unselected text frames by clicking inside the frame and dragging inside it, and selected frames by dragging the outside border of the frame. [Source: Microsoft Corp., 1992]

  Definition. A **text frame** is a sizable field into which the user can type text. This is a dynamic form of an edit field not to be confused with the text box. Although text frames are generally rectangular, other shapes may also be used. [Source: Microsoft Corp., 1992]

- **8.2.4.2.2 Resizing a text frame.** When a text frame is resized, the text should be rewrapped to fit within the new borders of the frame. [Source: Microsoft Corp., 1992]

- **8.2.4.2.3 Text frame pointer.** When the pointer is over an unselected text frame, it should appear as an arrow. When the frame is selected, the pointer should change to an I-beam over the text, to an arrow over the border, and to a resize pointer over a resize handle. [Source: Microsoft Corp., 1992]

- **8.2.4.2.4 Resizing text frames.** When a text frame is selected, it should have resize handles. [Source: Microsoft Corp., 1992]

8.2.4.3 Formatting

- **8.2.4.3.1 Text format.** The system should provide a default format for standard text input. [Source: MIL-HDBK-761A, 1989]

- **8.2.4.3.2 Custom text format.** When a system provides users with the ability to define their own formats, it should include a means for them to store those formats for future use. [Source: MIL-HDBK-761A, 1989]

- **8.2.4.3.3 Page formatting.** The system should provide users with an easy means for specifying page formats, including margins and tabs. [Source: MIL-HDBK-761A, 1989]

- **8.2.4.3.4 Automatic line breaks.** The system should provide automatic line breaks and automatic word-wrap when text reaches the right margin. [Source: MIL-HDBK-761A, 1989]

- **8.2.4.3.5 User specified line breaks.** The system should provide for user-specified line breaks. [Source: MIL-HDBK-761A, 1989]

- **8.2.4.3.6 Default justification of text.** Unless otherwise specified by a user, text should be left justified with consistent spacing between words as it is entered. [Source: MIL-HDBK-761A, 1989]

- **8.2.4.3.7 User defined text justification.** Left, right, center, and full justification should be provided as user options. [Source: MIL-HDBK-761A, 1989]

- **8.2.4.3.8 Automatic hyphenation.** The system should provide automatic hyphenation of words at a user's request. [Source: MIL-HDBK-761A, 1989]

- **8.2.4.3.9 Default hyphenation.** The default mode should be no hyphenation. [Source: MIL-HDBK-761A, 1989]

- **8.2.4.3.10 Page breaks.** The system should provide automatic page breaks and user-specified page breaks. [Source: MIL-HDBK-761A, 1989]

- **8.2.4.3.11 Widow-orphan protection.** Users should be able to specify a minimum number of lines of a paragraph that will appear at the bottom or top of a page (widow-orphan protection). [Source: MIL-HDBK-761A, 1989]

- **8.2.4.3.12 Page numbering.** Automatically incremented page numbering should be provided. [Source: MIL-HDBK-761A, 1989]

- **8.2.4.3.13 Default numbering and override.** Page numbering should begin with one by default, but allow users to override the default by specifying a beginning page number. [Source: MIL-HDBK-761A, 1989]

8.2.5 Text display

This section contains criteria and rules for displaying text.

8.2.5.1 General

- **8.2.5.1.1 Consistent wording and structure.** The wording and grammatical structure of displayed data and labels shall be consistent throughout an application and related applications. [Source: MIL-HDBK-761A, 1989]

- **8.2.5.1.2 Sentence structure.** In continuous text, sentences should be simple, affirmative, and active, as opposed to complex or compound, negative, and passive. [Source: DON UISNCCS, 1992]

- **8.2.5.1.3 Sentences begin with main topic.** The main topic sentence should be located near the beginning of the paragraph. [Source: Ameritech Services Inc., 1998]

- **8.2.5.1.4 Clarity of wording.** Text displays should use clear and simple wording. [Source: Ameritech Services Inc., 1998]

- **8.2.5.1.5 Concise wording.** The text should be worded concisely to aid in comprehension. [Source: Ameritech Services Inc., 1998]

- **8.2.5.1.6 Punctuation.** Punctuation should only be used consistently and only when needed within complete sentences to add clarity, or to partition long data items. [Source: National Air Traffic Services, 1999]

- ▫ **8.2.5.1.7 Syntax.** Syntax should be consistent throughout an operating system. [Source: National Air Traffic Services, 1999]

  Example. Always use commas, spaces, and the like in the same way and in the same position within command sentences. [Source: National Air Traffic Services, 1999]

- ▫ **8.2.5.1.8 Breaking up words.** When displaying text, words should remain intact with minimal breaking or hyphenation between the lines of text. [Source: National Air Traffic Services, 1999]

  Discussion. Placing a word entirely on a single line increases readability. [Source: National Air Traffic Services, 1999]

- ▫ **8.2.5.1.9 Breaking up large blocks of text.** Large blocks of text should be broken into smaller, meaningful portions to minimize the amount of information requiring the user's attention at any given time. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

  Discussion. Continuous text can be broken up by the use of blank lines or by using lines drawn between or around portions of text. The readability of large amounts of text may be improved by presenting the text in two columns. The use of different intensity levels is another possibility but may be undesirable depending upon the levels available and the ambient lighting conditions.

- ▫ **8.2.5.1.10 Minimum number of displayed lines.** When a user must read continuous text on-line, a minimum of four lines of text should be displayed at one time. [Source: Nuclear Regulatory Commission, 1996]

- ▫ **8.2.5.1.11 Contrast.** Text should be displayed as black characters on a white or light background. [Source: DON UISNCCS, 1992]

- ▪ **8.2.5.1.12 Stationary text.** Text information shall be stationary on the screen, not scrolled continuously except with user action. [Source: DOD HCISG V2.0, 1992]

- ▪ **8.2.5.1.13 Distinctive appearance.** Text entered by a user shall be clearly distinguishable from system-supplied text that also appears on the screen. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.2.5.1.14 Display text.** The user shall be allowed to display text as it will be printed, including underlining, boldface, subscript, superscript, special characters, special symbols, and different styles and sizes of type. [Source: CTA, 1996]

8.2.5.2 Text in windows

- ▫ **8.2.5.2.1 Arabic vs. Roman numerals.** When information elements in a window will be numbered, Arabic numerals should be used, not Roman numerals. [Source: DON UISNCCS, 1992]

- ▫ **8.2.5.2.2 Consistent structure for non-editable text.** Each type of non-editable text (for example, titles, labels, and instructions) displayed in windows should have a consistent grammatical structure. For example, all instructions might be complete, imperative sentences. [Source: DON UISNCCS, 1992]

- ▫ **8.2.5.2.3 Punctuation.** Normal punctuation rules should be followed. Contractions and hyphenation should be avoided. [Source: DON UISNCCS, 1992]

- ▪ **8.2.5.2.4 Sequences.** Sequences of events or steps shall be presented in the proper order. [Source: DON UISNCCS, 1992]

- ▪ **8.2.5.2.5 Referents.** The referents for pronouns such as "it" and "they" shall be easily identifiable. [Source: DON UISNCCS, 1992]

8.2.5.3 Text alignment

- ▫ **8.2.5.3.1 Orderly format.** Designers should attend to the alignment and labeling to improve user-interface consistency.

  a. Align decimal points when listing numbers with decimal values.

  b. When decimal values are not used, numbers are flushed right.

  c. Alphabetic listings are flushed left.

  d. Labels describe the contents of the lists and are flushed left or centered. [Source: CTA, 1996]

- ▫ **8.2.5.3.2 Alignment grid.** The system should provide the capability of aligning objects on an invisible rule or grid structure at a user's request. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.2.5.3.3 Grid intervals.** Users should be able to specify grid intervals. [Source: MIL-HDBK-761A, 1989]

8.2.5.4 Abbreviations

- ▪ **8.2.5.4.1 Abbreviations.** When a system or application uses abbreviations in its user-computer interface, the abbreviations shall be unique, distinct, and unambiguous so as not confuse users. [Source: MIL-HDBK-761A, 1989; Department of Defense (MIL-STD-12D), 1981]

  Definition. An **abbreviation** is any shortened form or abridgment of a word, expression, or phrase used to conserve space or time. Thus, the term abbreviation includes initializations, contractions, and acronyms.

- ▪ **8.2.5.4.2 System operation time.** The use of abbreviations shall not add to system operation time. [Source: MIL-HDBK-761A, 1989; MIL-STD-12D, 1981]

- ▪ **8.2.5.4.3 Use of abbreviations.** When the abbreviation of a word is not clear or may be misinterpreted, the entire word shall be used. [Source: Department of Defense, 1984]

- ▪ **8.2.5.4.4 Minimal use.** The use of abbreviations shall be minimized. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- ▫ **8.2.5.4.5 Acronyms.** Acronyms should be used only if they will be seen more than once, are significantly shorter than the term they represent, and the users will commonly understand them. [Source: DON UISNCCS, 1992]

- ▫ **8.2.5.4.6 Acronym format.** Acronyms should be displayed in all upper-case letters. [Source: DON UISNCCS, 1992]

- ▪ **8.2.5.4.7 Consistent abbreviation use.** When abbreviations are used, they shall be used consistently throughout an application or set of related applications. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- ▫ **8.2.5.4.8 Familiar abbreviations.** Abbreviations and acronyms should conform to familiar usage and user expectations. [Source: Smith & Mosier, 1986]

  Discussion. Assigning new meanings to familiar acronyms from a previous system could cause confusion for the users. Conversely, using a familiar acronym and maintaining the previous meaning can facilitate learning. Source: Smith & Mosier, 1986]

- ▫ **8.2.5.4.9 Selecting abbreviations.** When a word needs to be abbreviated, the abbreviation should be selected from FAA Order 7340.1, taken from commonly used abbreviations, or constructed according to the rules of the U.S. Government Printing Office *Style Manual*. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.2.5.4.10 Definitions of abbreviations.** When a system or application uses abbreviations in its user-computer interactions, it shall provide an easy on-line, context-sensitive means for a user to learn the definition of an abbreviation, such as an on-line dictionary or Help screen. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; DON UISNCCS, 1992]

- ▫ **8.2.5.4.11 Punctuation.** All punctuation marks should be omitted from acronyms and abbreviations unless confusion or misinterpretation would occur as a result of their omission. [Source: Department of Defense, 1984]

- ▫ **8.2.5.4.12 Alphabetic similarity.** Abbreviations should retain an alphabetic similarity to the longer word or phrase. [Source: FAA, 2000]

- ▫ **8.2.5.4.13 Words not to abbreviate.** Words of five letters or less should not be abbreviated unless common usage has rendered the word and its abbreviation completely synonymous in recognition and intelligibility. [Source: FAA, 2000; Department of Defense, 1984]

- ▫ **8.2.5.4.14 Prepositions, conjunctions and articles.** Prepositions, conjunctions, and articles should be omitted when forming acronyms. [Source: FAA, 2000]

- ▫ **8.2.5.4.15 Pronounceable acronyms**. A pronounceable word should be attained, if possible, when creating an acronym. [Source: FAA, 2000]

8.2.5.5 Labeling

- ▫ **8.2.5.5.1 Distinct, unique, descriptive labels.** Each data group, message, or display should contain a distinct, unique, descriptive, and consistently worded title or label. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.2.5.5.2 Alphanumeric labels.** The labels of screens should be alphanumeric. When they are not complete words, labels should be abbreviations that are short enough (three to seven characters) or meaningful enough to be learned and remembered easily. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.2.5.5.3 Consistency.** Label locations and formats should be consistent. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.2.5.5.4 Spacing.** At least one blank line should separate a title from the body of a display. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.2.5.5.5 Display identification.** When a system allows users to select and manipulate displays, each display shall have an identifying label and other identifying information to support display control and data access. [Source: MIL-HDBK-761A, 1989]

8.2.5.6 Characters and spacing

- ▫ **8.2.5.6.1 Spacing between characters.** Spacing between characters should be at least 10% of character height. [Source: DOD HCISG V2.0, 1992]

- ▪ **8.2.5.6.2 Spacing between words.** Spacing between words shall be at least one character width for equally spaced characters or the width of capital N for proportionally spaced characters. [Source: MIL-STD-1472F, 1999]

- ▪ **8.2.5.6.3 Spacing between lines.** Spacing between lines shall be at least two stroke widths or 15% of character height, whichever is greater. This space is in addition to any space required for accent marks on upper case characters and descenders on lower case letters. [Source: DOD HCISG V2.0, 1992]

  Discussion. The interline spacing recommended for text displayed on terminals is greater than that recommended for printed material. *Descenders* are the part of lowercase letters that extend below the base line on which the letter is positioned.

- ▪ **8.2.5.6.4 Spacing between paragraphs.** Paragraphs shall be separated by a blank line. [Source: DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992]

□ **8.2.5.6.5 Preferred character height.** The character height for maximum legibility and readability should be 20 to 22 minutes of arc. [Source: American National Standards Institute(ANSI), 1988]

> **Discussion.** To account for both the size of symbols and characters and the viewing distance, visual angle should be used as the unit of measurement. Visual angles are specified in terms of minutes of arc or degrees (1 degree = 60 minutes of arc).

■ **8.2.5.6.6 Minimum character height.** The minimum character height for tasks in which legibility is important shall be 16 minutes of arc. [Source: ANSI, 1988]

□ **8.2.5.6.7 Time insensitive character recognition.** Character height for reading tasks in which identification of individual characters is not time-critical should be at least 10 minutes of arc. [Source: ANSI, 1988]

□ **8.2.5.6.8 Maximum character height.** The maximum character height for non-contextual groups of characters should not exceed 45 minutes of arc. [Source: ANSI, 1988]

■ **8.2.5.6.9 Maximum character height for reading.** The maximum character height for readability shall be 24 minutes of arc. [Source: ANSI, 1988]

■ **8.2.5.6.10 Character width.** The ratio of character height to width shall be

a. 1:0.7 to 1:0.9 for equally-spaced characters and lines of 80 or fewer characters,

b. at least 1:0.5 if it is necessary to have more than 80 characters per line, or

c. as much as 1:1 for characters such as M and W for proportionally spaced characters. [Source: DOD HCISG V2.0, 1992]

□ **8.2.5.6.11 Character luminance.** In a monochromatic display, the variation of a peak luminance of character elements (dots or strokes) should not exceed a ratio of 1.5:1 within a character. [Source: National Air Traffic Services, 1999]

□ **8.2.5.6.12 Character contrast.** For optimum legibility, character contrast should be between 6:1 and 10:1. [Source: National Air Traffic Services, 1999]

> **Discussion.** Legibility may diminish with contrasts below 3:1, whereas contrasts above 15:1 may cause visual discomfort. [Source: National Air Traffic Services, 1999]

□ **8.2.5.6.13 Adjustable contrast.** Contrast should be adjustable to compensate for ambient lighting conditions. [Source: National Air Traffic Services, 1999]

- ◽ **8.2.5.6.14 Stroke width.** Stroke width should be 10 to 12.5 % of character height. [Source: DOD HCISG V2.0, 1992]

- ◽ **8.2.5.6.15 Minimum dot matrix.** When characters are formed using a dot matrix, the matrix should be at least 7 dots wide and 9 dots high. [Source: DOD HCISG V2.0, 1992; DON UISNCCS, 1992]

  Discussion. Alphanumeric characters are generally created using either the dot matrix method (using matrices of round or square dots) or the grid method (using strokes). The dot matrix method is the more legible of the two. [Source: National Air Traffic Services, 1999]

- ◽ **8.2.5.6.16 Dot matrix shape.** The dots used to form dot matrix characters should be round or square. [Source: National Air Traffic Services, 1999]

8.2.5.7 Text font

- ◽ **8.2.5.7.1 User-selectable font size.** When an application cannot satisfy the range of viewing requirements with a single text font, the application should provide text font size as a user-selectable option. [Source: DON UISNCCS, 1992]

  Discussion. Consider that differences exist between typefaces. For example, 10 pt letters in one typeface may have the same character size as 12 pt letters in another. A *font* refers to a particular typeface and size (for example, 12 point Times New Roman).

- ◽ **8.2.5.7.2 Fonts to differentiate information.** Multiple fonts should be used to indicate categories of information or for moderate emphasis. [Source: National Air Traffic Services, 1999]

- ◾ **8.2.5.7.3 Number of different fonts.** There shall be a limit of two different fonts displayed on any one screen. [Source: National Air Traffic Services, 1999]

- ◽ **8.2.5.7.4 Text size and style.** Variations in the size and style within a font should be used to categorize the information into different levels. [Source National Air Traffic Services, 1999]

- ◽ **8.2.5.7.5 Serif typeface.** For maximum readability, serif fonts should be used for continuous body text, as long as the typeface is large or the resolution is high enough not to distort the serifs. [Source: Neilson, 2000]

  Definition. A **serif** is the small cross stroke at the end of the main stroke of the letter.

- ◽ **8.2.5.7.6 Sans serif typeface.** Sans serif typeface should be used for small text and low resolution displays. [Source: Neilson, 2000]

8.2.5.8 Capitalization

- **8.2.5.8.1 Capitalization.** Text should be presented in a combination of uppercase and lowercase letters, following standard capitalization rules (for example, the U. S. Government Printing Office *Style Manual*). [Source: DON UISNCCS, 1992]

- **8.2.5.8.2 Capitalization of phrases for emphasis.** In general, capitalization shall not be used to emphasize phrases or sentences. [Source: Department of Defense (MIL-STD-490A), 1984]

  Discussion. Continuous text is easiest to read and comprehend when it is presented in mixed case letters. Single words are recognized better when printed in all upper case letters. Thus, if used sparingly and wisely, capitalization can be used to indicate to readers that a word has special significance.

- **8.2.5.8.3 Use of capitals.** Capitalization should *only* be used for: headlines, key phrases or acronyms, short items to draw the user's attention to important text (for example, field labels or a window title), the first letter in a sentence, or a single character in each word in a title or label. [Source: National Air Traffic Services, 1999]

- **8.2.5.8.4 Mixed case.** Mixed case should be used for continuous text, messages, menu descriptions, button descriptions, or screen identification. [Source: National Air Traffic Services, 1999]

8.2.6 Text coding

8.2.6.1 Alphanumeric coding

- **8.2.6.1.1 Supplemental use only.** Alphanumeric coding should not be used as the sole means to call attention to important or critical information. [Source: MIL-HDBK-761A, 1989]

- **8.2.6.1.2 Case of letters.** Alphanumeric codes should use either upper case letters or lower case letters consistently and not use mixed case letters. [Source: MIL-HDBK-761A, 1989]

  Discussion. Mixed case words are often seen in tables and sometimes in labels. The added capital letters can interfere with quick reading and differ from the expected convention of only capitalizing proper names and titles, thus contributing to difficulty in comprehension. Attend to the size of letters for legibility of the smallest letters in all cases.

- **8.2.6.1.3 Mixed letter and number codes.** When codes contain both letters and numbers, the letters should be grouped and the numbers should be grouped, rather than interspersing letters with numbers. [Source: MIL-HDBK-761A, 1989]

  Example. The code HW5 might be used rather than the code H5W. [Source: MIL-HDBK-761A, 1989]

- **8.2.6.1.4 Length of codes.** Arbitrary alphanumeric codes that are to be recalled by users should have no more than five characters and should be the same length. [Source: MIL-HDBK-761A, 1989]

- **8.2.6.1.5 Punctuation in codes.** In alphanumeric codes, punctuation should be used only when the code may be confused with a word. [Source: CTA, 1996]

- **8.2.6.1.6 Short abbreviations or arbitrary codes.** When arbitrary codes must be remembered by the user, characters should be grouped in blocks of three to five characters, separated by a minimum of one blank space or other separating character such as a hyphen or slash. [Source: Nuclear Regulatory Commission, 1996]

- **8.2.6.1.7 Avoid O and I in arbitrary codes.** The use of the letters O and I in a non-meaningful code should be avoided because they are easily confused with the numbers 0 (zero) and 1 (one), respectively. [Source: Nuclear Regulatory Commission, 1996]

8.2.6.2 Underlining coding

- **8.2.6.2.1 Use of underlining.** Underlining should only be used for mildly emphasizing information, indicating key words or phrases, or distinguishing fields from text. [Source: National Air Traffic Services, 1999]

- **8.2.6.2.2 Underlining text.** Underlining should not be used for large amounts of consecutive text. [Source: National Air Traffic Services, 1999]

  Discussion. Underlining can reduce the legibility of text, making reading difficult. [Source: National Air Traffic Services, 1999]

8.2.6.3 Bold coding

- **8.2.6.3.1 Suitability/appropriateness of bold coding.** Bold coding should be used for strong emphasis. [Source: National Air Traffic Services, 1999]

- **8.2.6.3.2 Number of levels of bold coding.** No more than three levels of bold coding should be used. [Source: National Air Traffic Services, 1999]

8.2.6.4 Numeric coding

- **8.2.6.4.1 Digital form.** Data should not be presented in digital form unless the user needs specific numeric values. [Source: National Air Traffic Services, 1999]

- **8.2.6.4.2 Number of characters.** Numeric codes should be limited to fewer than seven characters. [Source: National Air Traffic Services, 1999]

8.2.7 Numeric and date/time format

- **8.2.7.1 Number system.** Numeric data should be displayed in the decimal rather than binary, octal, hexadecimal, or other number system. [Source: Nuclear Regulatory Commission, 1996]

- **8.2.7.2 Leading zeros.** Leading zeros in numeric entries for whole numbers should be suppressed. [Source: Nuclear Regulatory Commission, 1996]

- **8.2.7.3 Justification.** Integers should be right justified. [Source: National Air Traffic Services, 1999]

- **8.2.7.4 Decimals**. The system should not require the entry of the decimal point at the end of an integer. [Source: CTA, 1996]

- **8.2.7.5 Maintaining significant digits.** A displayed value should contain the number of significant digits required for users to perform their tasks. [Source: Nuclear Regulatory Commission, 1996]

- **8.2.7.6 Display range.** Numeric displays should accommodate the full range of the variable. [Source: Nuclear Regulatory Commission, 1996]

- **8.2.7.7 Orientation of numbers.** All numbers should be oriented upright. [Source: Nuclear Regulatory Commission, 1996]

8.2.8 Paging

- **8.2.8.1 Multi-page displays.** When a data set contains too much data for presentation in a single display, the data should be partitioned into separately displayable pages. [Source: MIL-HDBK-761A, 1989]

- **8.2.8.2 Partitioning data among pages.** Related data should appear on the same page in an integrated display rather than being partitioned into separate pages. [Source: MIL-HDBK-761A, 1989]

- **8.2.8.3 Labeling pages.** Each page in a multi-page data set should be labeled to show its relation to the others. For example, the first page of a three-page set might be labeled **Page 1 of 3**. [Source: MIL-HDBK-761A, 1989]

- **8.2.8.4 Consistent orientation.** A consistent orientation for display framing should be used. [Source: Nuclear Regulatory Commission, 1996]

□ **8.2.8.5 Moving through data.** A consistent and easy means should be provided for moving through a data set, for example, scrolling, paging, or panning. [Source: MIL-HDBK-761A, 1989; MIL-HDBK-761A, 1989]

Definitions. Scrolling is a method used to move through the contents of a window or list in a dialogue box using the scroll-bar or scroll arrows. **Paging** is the process of scrolling through data one page at a time. **Panning** is an orientation of display framing in which a user conceives of the display frame as moving over a fixed array of data. [Source: MIL-HDBK-761A, 1989; MIL-HDBK-761A, 1989]

□ **8.2.8.6 Moving through continuous text.** Scrolling, not panning, should be provided for moving through continuous text. [Source: MIL-HDBK-761A, 1989]

■ **8.2.8.7 User search of grouped information.** Paging, instead of panning or scrolling, shall be used for a user search of logically grouped information such as data forms. [Source: CTA, 1996]

Discussion. Although experienced computer users perform equally well with paging or scrolling for logically grouped information, inexperienced computer users tend to perform better with using a paging method. Thus, when both experienced and inexperienced users will be using the application, use of paging is the better method.

8.2.9 Lists

□ **8.2.9.1 Lists.** A series or list of text elements should be presented vertically, not horizontally. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

□ **8.2.9.2 Display of lists.** A series of related items should be displayed as a list to support quick, accurate scanning. [Source: CTA, 1996]

□ **8.2.9.3 Number of columns.** A single column should be used for a list, with each item in the list starting in a new row. [Source: CTA, 1996]

□ **8.2.9.4 Multiple columns.** For a more compact display of a long list, designers should use multiple columns with items ordered vertically within each column. [Source: CTA, 1996]

□ **8.2.9.5 Order of items.** Designers should base the order of items on natural rationale such as frequency of use, related functionality, or the normal sequence of user actions. [Source: CTA, 1996]

□ **8.2.9.6 Consistent rationale.** Designers should maintain the same rationale for the order of items for each instance of a particular list. [Source: CTA, 1996]

- ▫ **8.2.9.7 Alphabetical order.** When there is no apparent logical basis for ordering items, then the items should be listed alphabetically. [Source: CTA, 1996]

- ▫ **8.2.9.8 Vertical list extension beyond one page.** Where lists extend over more than one page, the last line of one page should be the first line on the succeeding page. [Source: Nuclear Regulatory Commission, 1996]

- ▫ **8.2.9.9 Hierarchic structure for long lists.** For a long list extending more than one displayed page, a hierarchic structure should be used to permit its logical partitioning into related shorter lists. [Source: Nuclear Regulatory Commission, 1996]

- ▪ **8.2.9.10 Numbering items on multi-display lists.** When the items in a numbered list do not all fit on one display, the entire set of items shall be numbered continuously and not start anew with each display. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.2.9.11 Numbering items on a list.** Arabic numerals (not Roman) shall be used when numbering items on a list. [Source: National Air Traffic Services, 1999]

8.2.10 Tables

- ▫ **8.2.10.1 When to use.** When sets of data must be entered sequentially or when data are keyed row by row, a tabular format should be used. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.2.10.2 Structure.** Ordering of columns in tables should proceed with an index (if used) on the leftmost edge of the display followed by the most important column, and so on. [Source: Ameritech Services Inc., 1998]

  Example. When the table is organized alphabetically (by last name), place the last name in the column on the far left, with the rest of the columns (for example, first name and address) from left to right according to their significance to the task. [Source: Ameritech Services Inc., 1998]

- ▪ **8.2.10.3 Large tables.** When a table is too large to fit in the available display area, as much of the top left portion as will fit shall be initially displayed, and appropriate scroll-bars or similar mechanisms be provided to give the user the capability to determine the data that show up in the table. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.2.10.4 Scroll-bars on large tables.** Scroll-bars should be provided on the right or left side and on the bottom or top of large tables that require scrolling. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.2.10.5 Arrangement in scrolling tables**. Rows and columns shall be arranged according to some logic, for example, chronologically or alphabetically. [Source: CTA, 1996]

- **8.2.10.6 Compared columns**. Columns that will be compared often by the users should be located near one another. [Source: Ameritech Services Inc., 1998]

- **8.2.10.7 Scanning cues.** Adequate separation shall be provided between columns and between groups of rows. [Source: CTA, 1996]

  Example. To increase readability, insert at least three spaces between columns and a blank line after every fifth row.

- **8.2.10.8 Unique labels.** Each row and column shall be uniquely and informatively labeled, and the labels shall be distinct from the data cells. [Source: MIL-HDBK-761A, 1989]

- **8.2.10.9 Row and column headings.** Row and column labels or headings shall reflect information the user had before consulting the table (the user's perspective, information, and language). [Source: CTA, 1996]

- **8.2.10.10 Labels in scrolling tables.** When a user scrolls a large table, the row or column labels that remain relevant shall not scroll but shall remain in place. [Source: MIL-HDBK-761A, 1989]

  Example. When the rows scroll up or down, the column labels shall remain in place. [Source: MIL-HDBK-761A, 1989]

- **8.2.10.11 Leading and trailing zeros.** Users shall not have to type leading zeros (before numbers to the left of the decimal point) or trailing zeros (following numbers to the right of the decimal point) when entering numeric data into a table. [Source: MIL-HDBK-761A, 1989]

- **8.2.10.12 Automatic justification.** Data typed into a cell of a table shall be justified automatically when the user moves the cursor to the next cell with justification as follows:

  a. Alphanumeric input left justified.

  b. Integer numerical data right justified.

  c. Decimal numerical data decimal point justified. [Source: MIL-HDBK-761A, 1989]

- **8.2.10.13 Navigation with the Tab key.** The **Tab** key shall move the cursor to the first position of the next cell to the right of its current position, or, if the current position is in the last cell in a row, to the first position of the first cell in the next row. [Source: MIL-HDBK-761A, 1989]

- **8.2.10.14 Navigation using Shift and Tab keys.** Pressing **Shift** and **Tab** simultaneously shall move the cursor to the first position in the next cell to the left of the current position, or, if the current position is in the first cell in a row, to the first position in the last cell in the preceding row. [Source: MIL-HDBK-761A, 1989]

- **8.2.10.15 Navigation.** The user shall be allowed to move through a table using the arrow keys. [Source: Ameritech Services Inc., 1998]

8.2.11 Forms

Form filling as a means of data entry is especially appropriate if some flexibility is needed (for example, the inclusion of optional as well as required items), if users will have moderate training, or if computer response might be slow.

8.2.11.1 General

- 8.2.11.1.1 **Title.** Each form shall have a title located at the top of the form. [Source: DOE HFDG ATCCS V2.0, 1992]

- 8.2.11.1.2 **Consistency.** Forms, labels, fields, messages, and instructions that appear on different displays shall be as consistent as possible within an application and among related applications. [Source: DOE HFDG ATCCS V2.0, 1992]

- 8.2.11.1.3 **Field Help.** Help shall be provided for fields. [Source: DOE HFDG ATCCS V2.0, 1992]

  Discussion. Some Help might be provided automatically when the cursor arrives in a field, such as an explanatory message or a menu of acceptable entries. Context sensitive help might be provided in other ways, including an operation that offers Help on the field that contains the cursor and one that provides Help on the field when a user moves the pointer onto the field label and clicks the appropriate button. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ 8.2.11.1.4 **Grouping and sequencing**. Groups and sequences in a form should reflect the way the user performs the task. [Source: Ameritech Services Inc., 1998]

8.2.11.2 Fields

- 8.2.11.2.1 **Appearance.** Fields shall have a distinctive appearance and distinct limits. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

  Example. A series of underscores or a rectangle perhaps in inverse video can be used to clearly distinguish fields from each other and from other objects and information on the screen. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- ▫ 8.2.11.2.2 **Field length.** Data entry fields should be of fixed length, even if the entries may be of variable length. If useful to the user, a field should give a cue as to its length, for example, by using separated underscores (_ _ _ _ _). [Source: DOE HFDG ATCCS V2.0, 1992]

- 8.2.11.2.3 **Entry does not overwrite field delineators.** Characters that are overwritten as a user enters data shall not designate fields. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- 8.2.11.2.4 **Unfilled portion of field.** When a field accepts variable length entries, users shall not have to remove or fill any unneeded portion. [Source: MIL-HDBK-761A, 1989]

- **8.2.11.2.5 Multiple required fields.** When a form has one or more required field, the user shall have to make an entry in each required field to be able to complete the form as intended. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.2.11.2.6 Disabled Save option.** When a form has one or more required field, the **Save** option shall be displayed as unavailable until all of the required fields have been filled. [Source: DOE HFDG ATCCS V2.0, 1992]

  Examples. A user might be given an error message if he or she tries to leave a required field without making an entry, or a user might be given an error message if he or she tries to **Save** a form without making an entry in all required fields. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.2.11.2.7 Optional fields distinct from required fields.** When a form has both optional and required fields, the two types of fields shall be easily distinguishable. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; Smith & Mosier, 1986]

  Examples. One way to do this would be to use different label terminators for the two types of fields. For example, the labels of optional fields might be followed by a colon (:), and the labels of required fields might be followed by a slash (/). Another way would be to use different appearances for the fields themselves. For example, a required field might appear as underscores (____) and an optional field as a row of dots (......). [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; ESD-TR-86-278, 1986]

- **8.2.11.2.8 Intra-field separators.** When possible, fields provided for data that include separators or some sort of formatting (for example, slashes separating the month, day, and year in dates or a decimal point separating dollars and cents) shall include the separators or formatting as part of the field. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; ESD-TR-86-278, 1986]

  Examples. A field for a date might appear:
  DATE: __/__/__.

  A field for a telephone number might appear:
  TELEPHONE NUMBER: (___) ___-____.

8.2.11.3 Text fields

- **8.2.11.3.1 When to use.** When a user must be able to type input from the keyboard, a text field shall be provided. [Source: DON UISNCCS, 1992]

- **8.2.11.3.2 Scrolling fields.** When a text field will accept more text than can be displayed in the field, a scroll-bar shall be provided to enable users to see the entire text. [Source: DON UISNCCS, 1992]

- ▪ **8.2.11.3.3 Multiple lines of text.** When the anticipated text is expected to exceed a single line, the text field shall be large enough to view multiple lines simultaneously. [Source: DON UISNCCS, 1992]

8.2.11.4 Field labels

- ▪ **8.2.11.4.1 Field labels.** Every data field shall have a label that uniquely identifies the field. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

  Discussion. A single label is sufficient for a series of fields of the same type arrayed in a row or column. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- ▪ **8.2.11.4.2 Labels distinct from other information.** Labels shall be distinct from data entries and from other information on the screen including text boxes, control options, and messages. [Source: MIL-HDBK-761A, 1989]

  Example. Do not place boxes around labels, which can make them appear to be text boxes. Instead, labels can be differentiated by font or size.

- ▪ **8.2.11.4.3 Labels not editable.** Field labels shall not be editable by users, at least not while they are in form-filling mode. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.2.11.4.4 Case options.** For legibility, labels should be displayed consistently in either all capitals or in mixed cases, with the first letter of the word capitalized. [Source: CTA, 1996]

- ▪ **8.2.11.4.5 Consistent content.** Throughout form filling and database entry, label content shall consistently be relevant to the group of users. [Source: Ameritech Services Inc., 1996]

- ▫ **8.2.11.4.6 Standard characters.** Labels should be constructed using only standard alphabetic characters, avoiding contractions, hyphenations, and abbreviations. [Source: Ameritech Services Inc., 1996]

  Exception. Abbreviations can be used when they are in common usage and easily understood by all users of the application.

- ▫ **8.2.11.4.7 Descriptive labels.** A label should specify or suggest the entry that goes into the field. Numbers and other arbitrary codes should not be used as field labels. [Source: MIL-HDBK-761A, 1989]

  Discussion. Complete words are preferred as labels, but predefined terms, codes, and abbreviations may be acceptable. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.2.11.4.8 Terms used in labels.** Labels for data fields should be composed of terms that are familiar to the user, relevant to the topic of the form, and easily understood by a typical user. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.2.11.4.9 Label terminator.** Field labels shall terminate with a special symbol that designates the end of the label and the beginning of the field (a colon ":" is frequently used for this purpose), or a blank space that follows the terminator and separates it from the beginning of the field when the label is to the left of the field. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- **8.2.11.4.10 Consistent location.** Labels shall be located consistently with respect to their fields. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

  Discussion. The preferred location for a label is to the left of or above its field. When a form contains both single label-field pairs and arrays (rows or columns) of fields with a single label, the location of labels for the single label-field pairs may be different from the labels for the arrays of fields. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- **8.2.11.4.11 Unit of measurement.** When a field entry involves a unit of measurement, the unit shall be included as part of the label or field. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; ESD-TR-86-278, 1986]

  Examples.

  COST: $_____.__

  LENGTH (ft): __________

- **8.2.11.4.12 Alternative units.** When measurements might be in different units, for example, inches or millimeters, users shall not have to transform them at the time of data entry. [Source: MIL-HDBK-761A, 1989]

  Discussion. Providing a field for each unit of measurement, where the user selects the correct field, might solve this problem. Another solution might be to have one field for the quantity and another field for the unit of measurement. [Source: MIL-HDBK-761A, 1989]

- **8.2.11.4.13 Displaying labels.** Labels shall be displayed in a left-to-right (horizontal) orientation, as opposed to vertically or in any other off-horizontal orientation. [Source: CTA, 1996]

- **8.2.11.4.14 Field label spacing.** Labels shall be separated from one another by at least two standard character spaces. [Source: CTA, 1996]

8.2.11.5 Layout

- **8.2.11.5.1 Correspondence between screen and document.** When users will transfer data from hard copy documents, the screen layout shall correspond to the hard copy in the order and grouping of data items. For this case, it is desirable that the displayed form look as much like the source document as possible. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- **8.2.11.5.2 Layout with no source document.** When input is not from source documents or hard copy forms, data fields shall be ordered and grouped logically, using sequence, frequency of use, importance, and functional associations as organizing principles. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- **8.2.11.5.3 Multi-page forms.** When a form is too large to fit in the available screen area, it should be broken into pages, and each page should be labeled with its number and the total number (for example, **Page 1 of 3**). [Source: DOE HFDG ATCCS V2.0, 1992]

8.2.11.6 Navigation

- **8.2.11.6.1 Initial cursor position.** When a form first appears, the cursor shall be placed automatically in the first position of the first field. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- **8.2.11.6.2 Easy cursor movement.** The system shall provide one or more easy ways to move the cursor among fields. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.2.11.6.3 Movement with keyboard.** When the primary means of entering data in fields is the keyboard, the cursor movement methods shall include keyboard keys such as the **Tab** key(s) and the arrow keys. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.2.11.6.4 Movement with pointing device.** When a pointing device is available, a user shall be able to move the cursor to any field by moving the pointer into the field and clicking the appropriate button. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.2.11.6.5 Multiple devices.** When both a keyboard and pointing device is available, cursor movement shall be allowed using either device. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.2.11.6.6 No automatic movement.** The cursor should not be moved automatically among fields. Cursor movement should occur only upon explicit user action, such as pressing the **Tab** key. [Source: DOE HFDG ATCCS V2.0, 1992]

  Exception. There may be cases in which automatic movement is desirable. For example, if skilled users enter numerous entries of fixed length, it may be preferable to move the cursor automatically to the next field when the current field is filled. The danger is that a missed or extra character may result in erroneous entries in many fields before the user notices. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.2.11.6.7 Navigation only to fields.** A user shall be able to move the cursor only into fields and onto control objects on the screen, not onto labels or other non data-entry areas. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.2.11.6.8 Protected fields.** When a form has protected fields, a user shall not be able to move the cursor into a protected field. [Source: MIL-HDBK-761A, 1989]

  Explanation. A field might be protected from some users and not from others. Other fields might be reserved for the display of computed values. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.2.11.6.9 Moving to next and previous fields.** When the fields in a form will be traversed sequentially, a user should be able to move the cursor to the next field by pressing the **Tab** key, and to the previous field by pressing the **Shift** and **Tab** keys simultaneously. [Source: MIL-HDBK-761A, 1989]

  Discussion. This sort of movement requires a predefined path through a form that specifies which field is next and which is previous. Presumably, such a path will traverse each field once and only once in a systematic way, for example, from left to right and top to bottom. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.2.11.6.10 Navigation with a pointer.** When fields may not necessarily be traversed in a set order, a pointing device in addition to keyboard should also be available for selecting fields. [Source: MIL-HDBK-761A, 1989]

8.2.11.7 Defaults

- ▫ **8.2.11.7.1 When to use.** When a form is expected to have the same entry in a particular field most of the time; that entry should appear in that field as a default entry when the form first appears. [Source: Smith & Mosier, 1986]

- ▪ **8.2.11.7.2 Displaying default values.** A field that has a default value shall have that value appear in the field automatically when the form appears. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.2.11.7.3 Replacing default values in fields.** When an entry is normally made in a field by typing, a user shall be able to replace that value by moving the cursor into that field and typing, causing the default value to disappear immediately after the first keystroke. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.2.11.7.4 Retaining default value.** When a default value is replaced, the default value itself shall not be affected so that the next time the form appears, the same default value will appear in the field. [Source: DOE HFDG ATCCS V2.0, 1992]

  Exception. An exception to this rule is when an application permits a user to select whether he or she wants the application to retain the last entry or a previous default value as the current default setting. [Source: DOE HFDG ATCCS V2.0, 1992]

8.2.11.8 Error management

- **8.2.11.8.1 Easy error correction.** Users shall be able to correct errors easily on a character-by-character and field-by-field basis. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.2.11.8.2 Unacceptable entries.** When a field has a set or range of acceptable values and a user enters an unacceptable value, the system shall either

  a. provide an error message when the user tries to leave the field and not move the cursor from the field; or

  b. allow the user to continue moving through the form and, when the user tries to perform the completion action, provide an error message and move the cursor to the field in error. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.2.11.8.3 Omitted fields.** When a user fails to make an entry in a required field, the system shall either

  a. provide an error message when the user tries to leave the field and not move the cursor from the field; or

  b. allow the user to continue moving through the form and, when the user tries to perform the completion action, provide an error message and move the cursor to the field in error. [Source: MIL-HDBK-761A, 1989]

- **8.2.11.8.4 Deliberate omissions.** When applicable, a system or application should provide a special symbol that a user can enter in a required field. This symbol will allow the user to defer the required entry and continue with the remainder of the form. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.2.11.8.5 Deferred entry.** When a user has deferred data entry in a field, the system should prompt the user for the deferred data if it is required for processing. [Source: Smith & Mosier, 1986]

- ▫ **8.2.11.8.6 Distinctive fields.** Data fields should be visually distinguishable from other displayed information. [Source: MIL-HDBK-761A, 1989]

8.3 Graphical information

8.3.1 General

- ▫ **8.3.1.1 Value display.** When appropriate, users should be able to select a data point on a graph and obtain a display of the associated value or values. [Source: DOE HFDG ATCCS V2.0, 1992]

  Discussion. Users might also be given the option of choosing between tabular and graphical displays. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.3.1.2 Consistency.** Graphics shall be consistent in design, format, and labeling throughout an application and related applications. [Source: DOE HFDG ATCCS V2.0, 1992]

  Example. When graphic data are labeled, the text would appear in a consistent location in relation to the graphic elements. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.3.1.3 Labels.** Displayed graphics shall be clearly labeled. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.1.4 Robustness.** Graphics should be designed to remain useful when reproduced or reduced in size. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.3.1.5 Reference values.** When users are required to make comparative evaluations against reference values, the reference values shall be displayed. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.1.6 Displaying data values with graphics.** When precise readings of values are required, the actual data values should be displayed in addition to the plotted data. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.1.7 Supplementary text.** The use of supplementary text should be minimized and used only within the framework of the graph to emphasize features of data requiring user attention or to enhance user understanding. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.1.8 Changing or dynamic data.** Graphic display format should be used when the users must monitor changing or dynamic data. [Source: Smith & Mosier, 1986]

  Discussion. Although it is often preferable to have the computer monitor the data and alert the user of abnormalities, when the user must monitor the data, displaying the data in graphic format can make it easier for the user to detect changes and deviations from the norm. [Source: Smith & Mosier, 1986]

8.3.2 Maps and tactical displays

8.3.2.1 Characteristics

- ▫ **8.3.2.1.1 Map visibility.** When important for task performance and to the extent possible, other displays, such as dialog boxes and windows, should not obscure a map display. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.2.1.2 Map cursor.** The cursor in a map display should be a cross-hair design that has a high contrast with the background and subtend a visual angle of at least 20 minutes of arc. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.2.1.3 Intensity.** The intensity of the map should be controllable to allow the map to be dimmed without losing all the map features. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.2.1.4 Map as background.** When an application uses one map intensively, it is recommended that the map be used as the background or base screen, which should be the maximum display size possible to promote readability. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.3.2.1.5 Map size.** Map displays shall be large enough to permit the simultaneous presentation and visual integration required by users. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.3.2.1.6 Map coverage.** Maps shall cover the areas and display all the essential features and details users need to perform their tasks. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.2.1.7 Context for displayed map.** When a displayed map is not the entire map, an inset should be provided that shows the entire map with the displayed portion highlighted. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.2.1.8 Curvature.** When large geographic areas are displayed, the curvature of the earth should be treated consistently in all displays. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.2.1.9 Automatic registration.** The system should provide automatic registration of graphic data with background map information at all display scales. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.2.1.10 Situation displays as overlays.** Situation displays should be provided as overlays to their related maps. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.2.1.11 Consistent orientation.** When more than one map will be displayed, all maps should have the same orientation, usually with north at the top. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.2.1.12 Coding areas of special interest.** Map areas of special interest should be coded by color or shading. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.2.1.13 Coding for compared areas.** When users must make relative comparisons among areas, shades of a single color, rather than different colors, should be used with the gradation from light to dark corresponding to the variation represented by the shades. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.2.1.14 Reading a map.** Users should be provided with a means for easily determining distance and bearing between any two points on a map. [Source: DON UISNCCS, 1992]

- ▫ **8.3.2.1.15 Automated tools.** When users must perform complex analyses of maps, the system should provide the specific automated tools they need. [Source: DOE HFDG ATCCS V2.0, 1992]

  Example. The system might provide an automated program that prioritizes all alarms displayed on a map. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.2.1.16 Labeling features.** To the extent possible without cluttering the display, all significant features should be labeled. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.2.1.17 Consistent label position.** Map labels should be positioned consistently with respect to the feature they identify, for example, to the left of or below the feature, but without obscuring important information. [Source: DON UISNCCS, 1992]

- ▪ **8.3.2.1.18 Label legibility.** Labels shall remain legible at all display resolutions. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.2.1.19 Labeling symbols.** Critical symbols should be labeled automatically. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.2.1.20 Displaying information about symbols.** Users should have a means for displaying identifying information about unlabeled symbols. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.2.1.21 Association of symbols with map features.** A symbol should be placed accurately with respect to the map feature with which it is associated, or connected to the feature with an arrow, line, or other pointing device so that the association between feature and symbol is clear. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.3.2.1.22 Color-coding symbols.** Color-coding of symbols shall conform to the criteria and rules for color and color-coding. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.3.2.1.23 Color in overlays.** When color is used in overlays, it shall conform to the color criteria and rules. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.1.24 Color-coding key**. When a color overlay is available for a map, a color-coding key that explains each color should be displayed whenever the overlay is displayed. [Source: DON UISNCCS, 1992]

- **8.3.2.1.25 Text integrated with overlays.** Text on maps should be integrated with overlays so that the overlay does not obscure the text. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.1.26 Connecting text to features.** When the text is offset from the feature to which it refers, it should be connected to the feature with a line or arrow. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.1.27 No overlapping of symbols.** Map symbols should not overlap, particularly if overlapping would obscure their identity. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.1.28 Revealing obscured symbols.** When overlap is unavoidable, users should have a means of revealing obscured symbols. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.1.29 Selecting a symbol on a dense map.** When symbols on a map are densely packed or overlapped, users should have a way to select the desired symbol easily and accurately (for example, by selecting it from a pop-up menu). [Source: DON UISNCCS, 1992]

- **8.3.2.1.30 Distinguishing among symbols.** Users should be able to distinguish among symbols that represent coincident points and to obtain information that will allow them to resolve ambiguities among symbols. [Source: DON UISNCCS, 1992]

- **8.3.2.1.31 User editing of labels and overlays.** When authorized, users should be able to **Add**, **Edit**, **Reposition**, and **Delete** labels and overlays on a map. [Source: DON UISNCCS, 1992]

- **8.3.2.1.32 Reducing clutter.** Users should be provided with a means for reducing clutter without losing essential information, such as the use of filters. [Source: DOE HFDG ATCCS V2.0, 1992]

  Example. Users can use a filter to reduce the clutter of a map display by filtering out such things as overlays, roads, cities, vegetation, and topography. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.1.33 Filters.** The labels and titles of filters should communicate their function clearly to users. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.1.34 Coordinate readings.** When location information will be needed frequently, users should have the option of constant coordinates in units of their choosing. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.1.35 Overlay coordinates.** Users should be able to specify cursor coordinates for the placement of an overlay. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.1.36 Determining coordinates.** Users should be able to obtain the exact map coordinates of any symbol or map feature. [Source: DOE HFDG ATCCS V2.0, 1992]

8.3.2.2 Graphic display manipulation

- **8.3.2.2.1 User control of map appearance.** Users should be able to customize a map to conform to the task being performed. Methods include

  a. pan and zoom,

  b. return to initial appearance,

  c. define a home position and return to this position easily,

  d. move a map window,

  e. define the map appearance (for example, assign colors to areas), and

  f. select the objects that appear on the map and change the appearance of critical information. [Source: DON UISNCCS, 1992]

- **8.3.2.2.2 Map manipulation tools.** The system should provide users with all appropriate tools for moving easily around a map, including zooming and panning as well as insets, registration, and keys for scale. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.2.3 Panning.** When it is required by their tasks, users should be able to move (pan) the viewpoint or window over the entire map in any direction. As long as it meets users' needs, panning may be either continuous or discrete. [Source: DOE HFDG ATCCS V2.0, 1992]

  Definition. Panning is an orientation of display framing in which a user conceives of the display frame as moving over a fixed array of data.

- **8.3.2.2.4 Location information.** Users should be provided feedback on the relative location of the displayed portion during panning and zooming operations. [Source: DOE HFDG ATCCS V2.0, 1992]

  Example. The currently displayed portion might be highlighted on an inset display of the entire map. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.2.5 Return to start.** When panning is provided, users should have the ability to return to the starting configuration quickly and easily. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.2.6 Zooming.** Users should be able to zoom a display in and out, that is, increase and decrease the portion of the entire map displayed on the screen. [Source: DOE HFDG ATCCS V2.0, 1992]

▪ **8.3.2.2.7 Zooming and legibility.** Zooming in and out shall not interfere with the ability of users to read symbols, labels, and other map features. [Source: DOE HFDG ATCCS V2.0, 1992]

> **Discussion.** It may be appropriate to vary the amount of detail displayed in accordance with the degree of zooming used. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.2.2.8 Discrete vs. continuous zooming.** The method of zooming provided, discrete or continuous, should be acceptable to the users. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.2.2.9 Return to default.** When zooming is provided, an easy means to return to the default display should also be provided. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.2.2.10 Indication of changing scale.** Displays that change scale during zooming should include an indicator that shows the current scale. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.2.2.11 Selecting information for updating.** When appropriate, users should be able to select categories of information that will be updated automatically on a map display. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.2.2.12 Stable reference elements.** When a map is updated automatically, it should contain some elements that remain stable that users can use as reference points. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.2.2.13 Identification of updates.** Users should have a means for easily identifying updates and changes to a displayed map. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.2.2.14 Critical changes.** Critical changes to a displayed map should be easily distinguishable from other changes. [Source: DOE HFDG ATCCS V2.0, 1992]

> **Example.** Critical changes might be highlighted and remain highlighted until acknowledged by a user. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.2.2.15 Control of frequency of updating.** When appropriate to the task, users should be able to control the frequency with which a display is updated. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.2.2.16 Rate of updating.** When the users must track the changes as they occur, the rate at which a display is updated should not exceed the perceptual abilities of its users. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.2.2.17 Freezing a dynamic display.** Where appropriate, users should be able to freeze a dynamic display, preventing further updates until the display is unfrozen. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.2.18 Frozen displays.** Frozen displays should include an indication of their frozen state. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.2.19 Resuming from frozen displays.** Users should be able to choose to resume updating from the current time or from the time the display was frozen. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.2.20 Resuming from time the display was frozen.** When users choose to resume updating from the time the display was frozen, the user should be alerted to the fact that these data are not current. [Source: DON UISNCCS, 1992]

  Discussion. When the display is resumed from the time that it was frozen, the information is out-of-date by the amount of time that the display was frozen.

- **8.3.2.2.21 Control of rate of sequencing.** When appropriate, users should be able to control the rate of display sequencing. [Source: DOE HFDG ATCCS V2.0, 1992]

  Definition. Display sequencing is a means of reducing clutter by displaying a series of partial displays (for example, a map and a series of overlays) or of displaying data sequentially. It can also be used as a form of animation. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.2.22 Direction of sequencing.** When appropriate, users should be able to view sequential displays backwards as well as forwards. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.2.23 Viewing selected displays.** Users should be able to return quickly to a selected display in a sequence of displays. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.2.24 Grid overlay.** Users should be able to display and remove a grid overlay on a map. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.2.25 Integrated grid.** When present, a grid should be integrated with the coordinate system of the map. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.2.26 Map legend.** Map displays should have associated legends. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.2.27 Dynamic map legend.** When a map is dynamic, the legend should change as the map does so that the information (including such data as the map scale, cursor location, and status) is continuously relevant to the current display. [Source: DOE HFDG ATCCS V2.0, 1992]

8.3.2.3 Creating and editing map graphics

- **8.3.2.3.1 Standard symbol library.** Users should have available a library of standard symbols and a means of transferring and manipulating them. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.3.2 Labeling symbols.** Users should have an easy means for labeling symbols. [Source: DOE HFDG ATCCS V2.0, 1992]

  Discussion. It might be desirable to provide an automated feature that would aid the user in labeling symbols and enforcing labeling conventions. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.3.3 Tools for constructing symbols and overlays.** When appropriate, users should be provided with tools that would aid them in constructing new symbols and graphic overlays. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.3.4 Editing displays.** When appropriate, users should be able to add to and delete symbols, labels, and other features from displays without destroying background information. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.3.5 Expanding displays.** Users should be able to expand an area of a display when necessary for the accurate placement of critical data. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.3.6 Editing display elements.** Users should be able to perform the following editing operations on elements in map displays:

  a. **Select** elements on the display, causing selected elements to be highlighted.

  b. **Move** selected elements on the display.

  c. **Remove** and **Restore** selected elements on the display.

  d. **Name, Store,** and **Retrieve** graphic displays and elements. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.3.7 Identifying attributes.** When appropriate, users should be able to identify the currently selected attributes easily. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.3.8 Changing display attributes.** Users should be able to change the attributes of selected display elements. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.3.9 Changing display attributes by selection.** Users should be able to change display attributes such as color, symbols, and line types by selecting the attributes from displays, rather than by naming the options. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.2.3.10 Print preview.** Users should be able to preview symbols and overlays before printing them. [Source: DOE HFDG ATCCS V2.0, 1992]

8.3.3 Graphs

8.3.3.1 Scales, labels, and coding

▪ **8.3.3.1.1 Standard conventions.** Scales shall conform to the following conventions:

a. Values shall increase with distance from an origin.

b. Independent variables shall be plotted along the horizontal axis.

c. Dependent variables shall be plotted along the vertical axis. [Source: DOE HFDG ATCCS V2.0, 1992]

▪ **8.3.3.1.2 Consistent use of symbols.** Symbols, when used, shall be assigned unique meanings and used consistently throughout an application and related applications. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.3.1.3 Color and pattern coding.** When colors or patterns are used to fill enclosed areas, the following rules apply:

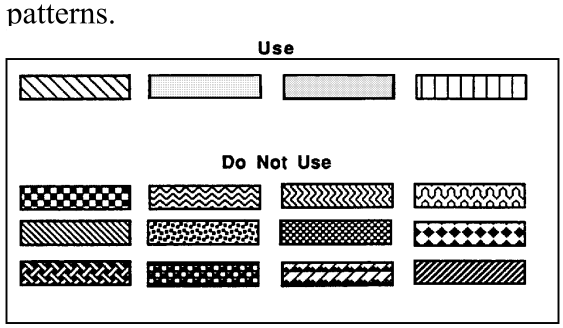
a. Color-coding should be redundant with another form of coding.

b. When the graphic is not likely to be printed, color should be used rather than patterning.

c. When the graphic is likely to be printed, patterning should be used rather than color. [Source: DOE HFDG ATCCS V2.0, 1992]

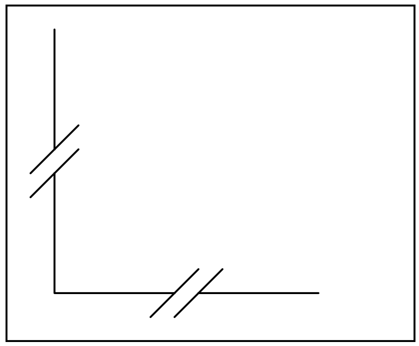
▫ **8.3.3.1.4 Patterns**. When patterns are used, they should be simple hatching and shading, not complex patterns that produce visual illusions of vibration or motion. Exhibit 8.3.3.1.4 illustrates acceptable and unacceptable patterns. [Source: DOE HFDG ATCCS V2.0, 1992]

Exhibit 8.3.3.1.4 Examples of acceptable and unacceptable patterns.



- **8.3.3.1.5 Breaks in axes.** When data are concentrated in a way that makes it desirable to show only a portion of an axis of a graph, the axis shall include the origin and be drawn with a break in it as illustrated in Exhibit 8.3.3.1.5. [Source: DOE HFDG ATCCS V2.0, 1992]

Exhibit 8.3.3.1.5 Example of axes with breaks.



- **8.3.3.1.6 One scale per axis.** Graphs should use only one scale on each axis, as opposed to separate scales for separate curves of the graph. [Source: National Air Traffic Services, 1999]

- **8.3.3.1.7 Multiple scales on graphs.** When graphs with multiple scales must be used, an interactive display should be provided so that when a user selects a curve, the corresponding scale is highlighted. [Source: National Air Traffic Services, 1999]

- **8.3.3.1.8 Duplicate axes.** When necessary to make a graph more readable, one or both of the horizontal and vertical axes should be repeated at the top or right of the graph, as appropriate. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.3.1.9 Consistent formats.** When separate graphs are to be compared or when different sets of data are to be plotted on the same graph, the formats and scales shall be identical. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.3.1.10 Labeling multiple curves.** When a single graph includes multiple curves, each curve should be clearly identified. [Source: National Air Traffic Services, 1999]

  Discussion. Curves can be identified by an adjacent label or by using color or line coding. [Source: National Air Traffic Services, 1999]

- **8.3.3.1.11 Linear scales.** In general, linear scales should be used rather than other types, such as logarithmic. [Source: DOE HFDG ATCCS V2.0, 1992]

  Discussion. Logarithmic scales may be appropriate for comparing rates of change. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.3.1.12 Circular scales.** For one-revolution circular scales, zero should be at 7 o'clock, and the maximum value should be at 5 o'clock, with a 60-degree break in the arc. [Source: Nuclear Regulatory Commission, 1996]

▫ **8.3.3.1.13 Single scale per axis.** An axis should represent only a single scale. [Source: DOE HFDG ATCCS V2.0, 1992]

▪ **8.3.3.1.14 Labeling axes.** Each axis shall have a label that describes the axis and its units of measurement. [Source: DOE HFDG ATCCS V2.0, 1992]

▪ **8.3.3.1.15 Tick marks.** Each axis shall have numbered or labeled tick marks corresponding to major scale divisions. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.3.1.16 Scale divisions.** Scales should not have more than 12 major scale divisions, and each major division should not be subdivided into more than 10 parts. [Source: DOE HFDG ATCCS V2.0, 1992]

▪ **8.3.3.1.17 Numeric scales.** Numeric scales shall begin with zero, cover the entire range of the data, and, when applicable, the major divisions labeled with decimal multiples of whole numbers. [Source: DOE HFDG ATCCS V2.0, 1992]

> **Discussion.** This rule prevents the distortion or misinterpretation of data that can result when the origin is omitted or if the scale does not continuously span the data range. It also helps make valid comparisons of different graphs possible. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.3.1.18 Labeling data elements.** Labels, rather than legends or keys, should be used to identify plotted data elements. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.3.1.19 Label format.** Labels should use upper and lowercase sans serif fonts. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.3.1.20 Label location.** Labels should be located adjacent to the elements they identify, and be oriented to permit normal left-to-right reading. [Source: DOE HFDG ATCCS V2.0, 1992]

> **Discussion.** When it is awkward to place the labels adjacent to the elements, they may be connected to the elements by arrows, lines, or other pointing conventions. [Source: DOE HFDG ATCCS V2.0, 1992]

▪ **8.3.3.1.21 Location of legends and keys.** When a graph requires a legend or key, the legend or key shall be located inside the rectangular bounds of the graph unless such a location would interfere with interpretation of the displayed data. [Source: DOE HFDG ATCCS V2.0, 1992]

8.3.3.2 Grid lines

The addition of grid lines to graphs can be helpful to users.

Definition. Grid lines are horizontal lines, vertical lines, or both, extending from the scale divisions of one or both axes of a graph and intended to aid users in locating and reading data points.

- ▫ **8.3.3.2.1 When to use.** Grid lines should be used only when they are necessary to help users achieve a desired level of precision. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.3.2.2 Grid lines vs. data.** Grid lines should be easily distinguishable from data without obscuring data. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.3.2.3 User choice.** When grid lines are provided, they should be provided in a way that gives users the option of displaying them or not. [Source: DOE HFDG ATCCS V2.0, 1992]

8.3.3.3 Lines and curves

- ▫ **8.3.3.3.1 Use of lines and curves.** Straight lines between data points or smoothed curves through the points should be used to show relationships between two variables. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.3.3.2 Labeling multiple lines and curves.** When a graph contains more than one line or curve, each one should have an identifying label. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.3.3.3 Order of legend.** When a legend is used to identify the lines in a graph, then, to the extent possible, the lines should appear in the legend in the same order they appear in the graph. [Source: DOE HFDG ATCCS V2.0, 1992]

  Discussion. The preferred location for labeling a line or curve is adjacent to it, but if the spacing of the lines or curves makes this difficult, it is acceptable to use a legend. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.3.3.4 Highlighting critical lines and curves.** When one curve or line in a graph is critical, that one should be highlighted. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.3.3.3.5 Coding lines and curves.** When lines and curves are coded to distinguish among multiple curves on the same graph, the coding shall be used consistently throughout an application and related applications for the same types of data. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.3.3.6 Display of projected values.** Curves representing values projected beyond the actual data set should be coded distinctly from curves representing actual data. [Source: DOE HFDG ATCCS V2.0, 1992; Nuclear Regulatory Commission, 1996]

- **8.3.3.3.7 Cyclic data.** When cyclic data are displayed, at least one full cycle should be presented. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.3.3.8 Trending time intervals.** Trend displays should be capable of showing data collected during time intervals of different lengths. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.3.9 Multiple trend lines.** When the user must compare data represented by separate curves, the curves should be displayed in one combined graph. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.3.10 Stability of trend data.** Trend rates should not vary as a result of minor fluctuations in data or oscillatory behavior that may be superimposed on a well-defined trend. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.3.11 Indication of non-representative trend data.** It should be indicated to the user when the rate value, in a simple quantitative rate of change value, does not accurately represent the trend because of minor fluctuations or oscillations. [Source: Nuclear Regulatory Commission, 1996]

8.3.3.4 Areas

- **8.3.3.4.1 Area between curves.** When emphasis is on the area between two curves, that area should be filled with color or a pattern. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.3.4.2 Stacked curves.** When cumulative data are represented by stacked curves, the curves should be ordered with the least variable at the bottom and the most variable at the top. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.3.4.3 Labeling areas.** Areas in graphs should be labeled within the areas, to the extent possible. [Source: DOE HFDG ATCCS V2.0, 1992]

8.3.3.5 Scatter plots

- **8.3.3.5.1 When to use.** Scatter plots should be used to show the spatial distribution of points within a coordination system. [Source: DOE HFDG ATCCS V2.0, 1992]

  Discussion. Scatter plots are sometimes used to show dispersal intended to indicate non-correlation of variables. However, users will often perceive patterns in scattered data points where none actually exist. Curves can be superimposed on scatter plots (data plotted as points in a two-dimensional graph) to indicate computed data trends, correlations, or other derived statistical measures, thus combining two types of graphic display. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.5.2 Highlighting points.** When a scatter plot contains points of particular importance, those points should be highlighted. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.3.5.3 Grouping scatter plots to show multiple relations.** When scatter plots are being examined to determine relationships among several variables, the scatter plots should be displayed as an ordered group (matrix), with each indicating the relation between just two variables. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.5.4 Interactive analysis of grouped scatter plots.** When scatter plots are grouped in a single display to show relations among several variables, an interactive aid should be provided for analysis so that if a user selects a set of data in one plot, then the corresponding data points in other plots will be highlighted. [Source: Nuclear Regulatory Commission, 1996]

8.3.3.6 Bar charts and histograms

- **8.3.3.6.1 Labeling paired bars.** When bars are displayed in pairs, they should be labeled as a unit, with individual distinguishing labels for each bar. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.6.2 Bar spacing.** When data must be compared, bars should be adjacent to one another and spaced so that a direct visual comparison can be made without eye movement. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.6.3 Consistent orientation of bars**. In a related series of bar charts, a consistent orientation of the bars (vertical or horizontal) should be adopted. [Source: Nuclear Regulatory Commission,]

- **8.3.3.6.4 Highlighting.** When one bar represents data of a particular significance, then that bar should be highlighted. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.6.5 Zero reference on deviation bar charts.** The zero reference should be the center of the deviation bar chart. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.6.6 Normal range on deviation bar charts.** On a deviation bar chart, the range of normal conditions for positive or negative deviations should represent no more than 10% of the total range. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.6.7 Indication of magnitude on deviation bar charts.** The magnitude of each variable should be displayed when a deviation bar display is used as a primary display format for safety condition parameters. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.6.8 Coding segmented bar charts**. Segmented bars in which differently coded segments are shown cumulatively within a bar should be used when both the total measures and the portions represented by the segments are of interest. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.6.9 Ordering data in segmented bars.** The data categories should be ordered within each bar in the same sequence, with the least variable categories displayed at the bottom and the most variable at the top. [Source: Nuclear Regulatory Commission, 1996]

8.3.3.7 Pie charts

- **8.3.3.7.1 When to use.** Pie charts should be used to show the proportional distribution of categories with respect to the sum of the categories. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.3.7.2 When not to use.** When accurate judgments of magnitudes are required, bar charts should be used rather than pie charts. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.3.7.3 Labeling pie chart segments.** Pie chart segments should be labeled inside the segments, if possible. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.3.7.4 Label orientation.** Segment labels should be oriented for normal left-to-right reading. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.3.7.5 Label content.** Segment labels should include a number stating either the percentage of the whole number represented by the segment, the absolute number the segment represents, or both. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.3.7.6 Highlighting segments.** Segments requiring emphasis should be highlighted or displaced slightly from the rest of the pie chart. [Source: DOE HFDG ATCCS V2.0, 1992]

8.3.3.8 Linear profile charts

- **8.3.3.8.1 Linear profile pattern recognition.** The graph should form recognizable geometric patterns for specific abnormal conditions. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.8.2 Coding linear profile charts.** The area below the profile line should be shaded to provide a more distinguishable profile. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.8.3 Labeling linear profile charts.** Labels should be provided along the bottom of linear profile charts to identify each parameter. [Source: Nuclear Regulatory Commission, 1996]

8.3.3.9 Circular profile chart

- **8.3.3.9.1 Circular profile chart recognition.** The circular profile chart should form a recognizable geometric pattern for specific abnormal conditions. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.9.2 Labeling circular profile displays.** Labels should be provided to identify each radial line. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.9.3 Coding circular profile displays.** The profile should be shaded to enhance the operator's perception of system status. [Source: Nuclear Regulatory Commission, 1996]

8.3.3.10 Segmented curve graphs

- ▫ **8.3.3.10.1 Depicting bands in segmented curve graphs.** All segments in a segmented curve graph should be related to the total value. [Source: Nuclear Regulatory Commission, 1996]

- ▫ **8.3.3.10.2 Ordering data in segmented curve graphs**. The data categories in a segmented curve graph should be ordered so that the least variable curves are displayed at the bottom and the most variable at the top. [Source: Nuclear Regulatory Commission, 1996]

- ▫ **8.3.3.10.3 Coding segmented curve graphs**. The different bands of segmented curve graphs should be labeled directly within the textured or shaded bands. [Source: Nuclear Regulatory Commission, 1996]

- ▫ **8.3.3.10.4 Labeling segmented curve graphs**. Where space permits, the different bands of segmented curve graphs should be labeled directly within the textured or shaded bands. [Source: Nuclear Regulatory Commission, 1996]

8.3.3.11 Flowcharts

Flowcharts. Flowcharts are appropriate for showing schematic representations of sequential processes and as aids to solving problems if solutions can be reached by answering a series of questions. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.3.11.1 Flowchart design.** Flowchart design should follow either

  a. logical or sequential order, or

  b. minimum path length. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.3.11.2 Flowchart symbol set.** There should be a standard set of flowchart symbols. [Source: Nuclear Regulatory Commission, 1996]

- ▪ **8.3.3.11.3 Consistency.** Words and phrases used for the same purpose shall be consistent throughout a flowchart, an application, and related applications. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.3.11.4 Highlighting.** Paths or portions of a flowchart that deserve particular attention should be highlighted. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.3.11.5 Flowcharts as decision aids.** Flowcharts used as decision aids should require only one decision at each step. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.3.3.11.6 Logically ordered options.** Flowcharts used as decision aids should provide a logically ordered list of available options. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.3.11.7 Flowchart orientation.** When possible, flowcharts should be oriented so that paths conform

a. left-to-right,

b. top-to-bottom, or

c. clockwise. [Source: DOE HFDG ATCCS V2.0, 1992]

8.3.3.12 Diagrams

Diagrams are appropriate if users require information about spatial relationships among objects but not the level of detail provided by pictures.

▫ **8.3.3.12.1 Large diagrams.** When a diagram is too large to view all at once, it should

a. be presented in separate sections, with an overview that indicates the separate sections,

b. have consistent notation throughout the diagram, and

c. provide an easy means for users to move among the sections. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.3.3.12.2 Level of detail.** Mimics and diagrams should contain the minimum amount of detail required to yield a meaningful pictorial representation. [Source: Nuclear Regulatory Commission, 1996]

▫ **8.3.3.12.3 Component identification.** System components represented on mimic lines should be identified. [Source: Nuclear Regulatory Commission, 1996]

▫ **8.3.3.12.4 Line points of origin.** All flow path origin points should be labeled or end at labeled components. [Source: Nuclear Regulatory Commission, 1996]

▫ **8.3.3.12.5 Line termination points.** All flow path line destination or terminal points should be labeled or end at labeled components. [Source: Nuclear Regulatory Commission, 1996]

▫ **8.3.3.12.6 Directional arrowheads.** Flow directions should be clearly indicated by distinctive arrowheads. [Source: Nuclear Regulatory Commission, 1996]

▫ **8.3.3.12.7 Line coding.** Flow lines should be coded (for example, by color and/or width) to indicate important information. [Source: Nuclear Regulatory Commission, 1996]

▫ **8.3.3.12.8 Overlapping lines.** Overlapping of flow path lines should be avoided. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.12.9 Symbol-data integration.** Where symbols are used to represent equipment components and process flow or signal paths, numerical data should be presented reflecting inputs and outputs associated with equipment. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.3.12.10 Highlighting portions of diagrams.** When portions of a diagram require special attention, those portions should be highlighted. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.3.12.11 Rotation of diagrams.** When users may need to view a diagram from different perspectives, the application should provide the capability of rotating the diagram. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.3.12.12 Rotated diagram labels.** The labels of a rotated diagram should be displayed "right-side up" and be legible from the user's perspective. [Source: DOE HFDG ATCCS V2.0, 1992]

8.3.4 Graphics entry and manipulation

8.3.4.1 Graphics entry and editing

- **8.3.4.1.1 Drawing lines.** The system should draw lines between user specified points. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.1.2 Drawing figures.** The system should support the drawing of rectangles, circles, arcs, ovals, and other figures. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.1.3 Constraining lines.** Users should be able to constrain lines to be exactly vertical or horizontal. They should also be able to specify that a line is perpendicular or parallel to another line. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.1.4 Alignment grid.** The system should provide the capability of aligning objects on an invisible rule or grid structure at a user's request and at user specified grid intervals. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.1.5 Alternate drawing methods.** When required by the task, alternate methods should be provided for drawing objects. For example, a circle might be drawn by specifying a center and a radius or diameter, or by specifying the size and location of an enclosing square. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.1.6 Automatic figure completion.** Users should be able to select automatic figure completion, that is, automatic closure of polygons. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.1.7 Required line connection.** When separately drawn lines must connect at terminal points, the system should automatically make the connections. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.1.8 Displaying attributes.** When desired by the user, object attributes should be displayed as selected and not be represented as appended codes or by some other means. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.1.9 Colors and patterns.** Users should be able to fill enclosed areas with colors or patterns. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.1.10 Selectable elements and attributes.** Users should be able to select and edit display elements (for example, lines) and their attributes (for example, thickness) by pointing to and selecting from displayed examples. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.1.11 Manipulating objects.** Users should be able to copy, rotate, and reverse (produce mirror images) objects both horizontally and vertically. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.1.12 Editing objects.** User-selectable objects should be easily repositioned, duplicated, and deleted. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.1.13 Scaling objects.** Users should be able to enlarge and reduce the size of objects. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.1.14 Zoom capability.** A zoom capability should be provided to enlarge critical display areas. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.1.15 Overlapping objects.** When two objects overlap, if the user desires it, the system should obscure the overlapped portion of the less important object. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.1.16 Grouping objects.** The system should provide a means to group separate objects into a single grouped object that can then be treated as a single object. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.1.17 Suitability/appropriateness of drop shadows.** Drop shadows should be used to make important elements appear closer to the user. [Source: CTA, 1996]

- **8.3.4.1.18 Placement of shadows.** Shadows should be placed at the lower right of icons and buttons, as if light were coming from the upper left and along the bottom and right side of a pull-down menu, dialog box, or window to attract the user's attention. [Source: CTA, 1996]

- **8.3.4.1.19 Beveled edges.** Beveled edges should be considered to bring important screen elements into the foreground. Beveled edges may be used on icons, buttons, menus, dialog boxes, and windows. [Source: CTA, 1996]

- **8.3.4.1.20 Enhancing three-dimensional effects.** Shading should be used at the bottom and right beveled edges to enhance the three-dimensional effect. [Source: CTA, 1996]

8.3.4.2 User aids

- **8.3.4.2.1 Entering data for plotting.** When complex graphic data must be entered quickly, computer aids should be provided. [Source: MIL-HDBK-761A, 1989]

  Example. When plotting data within Cartesian coordinates, the system automatically draws lines between the specified points of a function. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.2.2 Plotting stored data.** The system should support automatic plotting of stored data. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.2.3 Scaling graphic data.** The system should provide for automatic scaling of graphic data, and be able to modify system-generated scales. [Source: MIL-HDBK-761A, 1989]

8.3.4.3 Creating and editing

Computer aids such as those listed in this section need to be provided for the entry and organization of complex graphic data. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.4.3.1 Validation.** The application software should validate data entered. [Source: DOE HFDG ATCCS V2.0, 1992]

  Discussion. Validation might include comparison of a range or set of values with other entries. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.4.3.2 Plotting aids.** When plotting formats are known, templates or other data entry aids should be provided. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.4.3.3 Plotting stored data.** The application should provide automated or aided plotting and editing of stored data. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.4.3.4 Minimize clutter.** Old data points should be removed after some fixed period of time. [Source: Nuclear Regulatory Commission, 1996]

- **8.3.4.3.5 Automated production of scales.** The application should automatically adjust the range of scales or provide the user with automated aids for scaling graphic data. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.4.3.6 Line drawing.** The application should provide users with automated aids for drawing straight and curvilinear lines. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.4.3.7 Automatic completion of polygons.** The application should provide automatic completion to users drawing polygons, providing a line that connects the current cursor position to its starting point and giving the user the option to make the provided line a permanent part of the figure. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.4.3.8 Joining lines.** The application should provide automated assistance in joining lines. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.4.3.9 Designating line segments.** Users should be able to identify and select line segments for moving and editing. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.4.3.10 Grid references.** The application should provide optional, adjustable grid references to aid users in aligning horizontal and vertical lines. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.4.3.11 User-specified rules.** Users should be able to specify rules for attributes, relationships, and design and have the computer apply those rules automatically during the design process. For example, a user might specify that hand-drawn lines be straightened or that the angles between intersecting lines be adjusted. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.4.3.12 Computer aids.** The application should provide prompts and computer-aided methods for drawing figures. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.4.3.13 Scale changes.** The application should allow users to edit or create drawings in a large scale and then reduce them to the desired scale. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.4.3.14 Basic operations.** The application should allow users to resize, copy, move, rotate, and produce mirror images of objects. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.4.3.15 Grouping elements.** The application should allow users to select and group elements that can then be treated as a single object. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.4.3.16 Area fill capability.** The application should allow users to fill enclosed areas with selected attributes such as color or patterns. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.3.4.3.17 Automated aids.** When users must perform detailed analyses of images, the application should provide automated aids (for example, the capability to zoom in on a portion of the picture). [Source: DOE HFDG ATCCS V2.0, 1992]

8.3.4.4 Panning and zooming

- **8.3.4.4.1 When to provide scrolling, paging, and panning.** When information to be displayed exceeds the available display area, the system should provide a scrolling, paging, or panning capability. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.4.2 When to provide zooming.** When a user will need to view objects such as pictures, diagrams, or maps in detail, the system should provide a zooming capability. [Source: MIL-HDBK-761A, 1989]

  Discussion. When zooming has expanded a portion of a display, it is also desirable to display the portion in its original size and as much of its surrounding context as will fit. Alternatively, the original display might be reduced and displayed with the enlarged portion highlighted. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.4.3 Scale indication.** When zooming has expanded a portion of a display, the system should provide a scale indicating the amount of expansion. [Source: MIL-HDBK-761A, 1989]

- **8.3.4.4.4 Scale integration.** Panning and zooming functions should be integrated with and include scales and other overlaid data, such as scale marks and range vectors. [Source: MIL-HDBK-761A, 1989]

8.4 Concealed information

8.4.1 Information suppression

- **8.4.1.1 Suppression indication.** When the display of information is temporarily suppressed, an indication of this suppression shall be provided on the display. [Source: MIL-HDBK-761A, 1989]

- **8.4.1.2 Indication of changes in suppressed information.** The user should be notified of any significant changes in suppressed information, restoring suppressed data quickly to the originally displayed form. [Source: MIL-HDBK-761A, 1989]

- **8.4.1.3 Restoration of suppressed information.** The system shall provide a quick and easy means for restoring suppressed information. [Source: MIL-HDBK-761A, 1989]

- **8.4.1.4 Suppression.** The user should be permitted to suppress displayed data not required for the task at hand. [Source CTA, 1996]

8.5 Dynamic information update

8.5.1 General

- **8.5.1.1 Rate of change or gross values.** When users must identify the rate of change or read only gross values, the rate of update should be from two to five times a second. [Source: DON UISNCCS, 1992]

- ■ **8.5.1.2 Update rate.** When a task requires that a user read changing data, individual data items shall be displayed long enough for the user to read them reliably and accurately. [Source: MIL-HDBK-761A, 1989]

  Example. An Air Traffic Control Specialist may be required to read the speed or bearing of an aircraft as it changes. [Source: MIL-HDBK-761A, 1989]

- ■ **8.5.1.3 Alphanumeric data.** Alphanumeric data that users are required to read reliably and accurately shall not be updated more often than once a second. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.5.1.4 User control of automatic updating.** Users should be able to select the categories of information that will be updated automatically and to specify the frequency and rate at which the information will be updated (within the range capable of being met by the information source and the processing equipment). [Source: DON UISNCCS, 1992]

- ▫ **8.5.1.5 User stop of update.** When appropriate, the application should provide users the ability to temporarily stop and then resume updating automatically changing information. [Source: DON UISNCCS, 1992]

- ▫ **8.5.1.6 Initial erasure to replace changed data.** When the computer generates a display to update changed data, the old items should be erased before adding new data items to the display. [Source: Nuclear Regulatory Commission, 1996]

- ▫ **8.5.1.7 Dynamic information in frozen, inactive, and minimized windows.** Applications should notify users of critical information that becomes available in frozen, inactive, and minimized windows, such as data changes that result from automatic updating of a display. [Source: CTA, 1996; DON UISNCCS, 1992]

- ▫ **8.5.1.8 Predictions and trends based on changing data.** Integrated trend displays and predictive displays should be provided if the user must determine trends over time or make predictions based on changing data. [Source: CTA, 1996]

8.6 Coding

This section contains rules on coding not covered in other sections. Information on text coding, color-coding, auditory coding, and coding in menus is contained in Section 8.2.5 on text displays, Section 8.6.2 on color displays, Chapter 7 on auditory displays, and Section 8.7.5 on menus.

8.6.1 General

□ **8.6.1.1 When to use.** When coding is used, it should differentiate items of information, call a user's attention to important information; unusual situations, or potential problems that require user action; or indicate changes in the state of a system. [Source: MIL-HDBK-761A, 1989]

□ **8.6.1.2 Visual coding of critical information.** A user's attention should be drawn to critical or abnormal information by highlighting, inverse video, color-coding, or other means. [Source: DON UISNCCS, 1992; Smith & Mosier, 1986]

□ **8.6.1.3 Coding data categories.** Categories of data should be coded if a user must distinguish the data included in the categories rapidly and if the data items are distributed in an irregular way on the display. [Source: MIL-HDBK-761A, 1989]

■ **8.6.1.4 Misuse of coding.** Visual coding shall be used for functional, not decorative, purposes. [Source: National Air Traffic Services, 1999]

□ **8.6.1.5 Meaningful codes.** When codes are used, they should be meaningful rather than arbitrary. [Source: MIL-HDBK-761A, 1989]

> **Example.** Male and female might be coded **M** and **F** rather than 1 and 2. [Source: MIL-HDBK-761A, 1989]

■ **8.6.1.6 Consistent coding.** Coding shall be consistent throughout an application and related applications. [Source: MIL-HDBK-761A, 1989]

□ **8.6.1.7 Special codes.** Codes that are assigned a special meaning in a display should be defined at the bottom of the display. [Source: MIL-HDBK-761A, 1989]

□ **8.6.1.8 Attention-getting techniques.** Coding techniques that have strong attention-getting qualities (for example, color and flashing) should be used sparingly and judiciously. [Source: National Air Traffic Services, 1999]

8.6.2 Color

Color can be helpful in differentiating classes of information in complex, dense, and critical displays. Users often express a preference for color, even when it does not improve their performance. Although it may improve motivation and memory, performance advantages associated with the use of color tend to be highly task dependent. For example, color is helpful in class-coding tasks. Its high conspicuity value means that less time is wasted in checking targets that are not in the required class.

8.6.2.1 General

▫ 8.6.2.1.1 **When to use color.** Color should be used

a. to augment a user's understanding of the information being presented,

b. to attach specific meaning to a portion of text or a symbol,

c. to direct a user's attention to something (highlighting critical elements),

d. to reduce clutter,

e. to identify and classify information,

f. to indicate changes in status,

g. as a formatting aid, and

h. to enhance legibility. [Source: DOD HCISG V2.0, 1992; National Air Traffic Services, 1999]

▪ 8.6.2.1.2 **Conservative use.** Color shall be used conservatively as an information discriminator, especially when the color deficiency in the user population is unknown. [Source: DOD HCISG V2.0, 1992, MIL-HDBK-761A, 1989]

▪ 8.6.2.1.3 **Consistency.** Colors shall be used consistently within a screen, within an application, and across a set of applications. [Source: DON UISNCCS, 1992]

▪ 8.6.2.1.4 **Data categories.** When color is used to identify data categories, its use shall not conflict with other color-coding conventions. [Source: MIL-HDBK-761A, 1989]

▫ 8.6.2.1.5 **Redundant use.** Color-coding should not be used as the only means of conveying information, indicating an action, prompting a response, or distinguishing a visual element; it should be redundant to some other means of coding. [Source: MIL-HDBK-761A, 1989; General Services Administration, 2000]

▪ 8.6.2.1.6 **Use of color.** Colors shall be easy to discriminate from one another, with each color representing only one category of displayed data. [Source: DOD HCISG V2.0, 1992]

- □ **8.6.2.1.7 Readability.** The use of color should not reduce screen readability. [Source: DOD HCISG V2.0, 1992]

- □ **8.6.2.1.8 Adding color.** Color should only be added after the effectiveness of a screen has been maximized in an achromatic format. [Source: DOD HCISG V2.0, 1992]

- ■ **8.6.2.1.9 Small areas.** Users shall not have to discriminate among colors in small areas. [Source: DOD HCISG V2.0, 1992]

- ■ **8.6.2.1.10 Coding small areas.** When small areas of the display must be coded, they shall be coded achromatically. [Source: DOD HCISG V2.0, 1992]

- □ **8.6.2.1.11 Color legends**. Color should not be used to substitute for written legends. [Source: National Air Traffic Services, 1999]

- □ **8.6.2.1.12 Unknown target.** Color should not be used if multiple other items in the display are or might be the same color as the target. [Source: National Air Traffic Services, 1999]

  Discussion. Color can improve performance in visual search tasks when the color of the target is known. However, if the color of the target is not known, color can act as a distracter and degrade performance. This effect is more pronounced with increasing display density. [Source: National Air Traffic Services, 1999]

8.6.2.2 Color selection

- □ **8.6.2.2.1 Drawing attention.** Brighter or more saturated colors should be used to draw a user's attention to critical data. [Source: MIL-HDBK-761A, 1989]

  Discussion: Highly saturated colors may lead to unwanted effects such as afterimages; particularly undesirable effects (for example, binocular rivalry) can arise from highly saturated reds located near highly saturated blues.

- □ **8.6.2.2.2 Color brightness.** When color is used to emphasize information, the brightest color should be used for the most important information. [Source: DOD HCISG V2.0, 1992]

- □ **8.6.2.2.3 Tonal coding.** Tonal coding should be used to show relative values of a single variable. [Source: DOD HCISG V2.0, 1992]

  Definition. Tonal coding is coding based on different shades of the same hue or different patterns or textures.

- □ **8.6.2.2.4 Ordered coding.** When tonal coding is used to display relative values of a variable, the lightest shade should correspond to the smallest value, and the darkest shade to the highest value. [Source: DOD HCISG V2.0, 1992]

- □ **8.6.2.2.5 Use of hues.** When similar hues are used, they should be used only with logically related information. [Source: DOD HCISG V2.0, 1992]

- **8.6.2.2.6 Colors for infrequently used information.** Shorter wavelength colors (for example, blue and green) should be used to display information that is used infrequently, such as status or background information. [Source: DOD HCISG V2.0, 1992]

- **8.6.2.2.7 Blue.** Blue should not be used as the foreground color if resolution of fine details is required. [Source: DOD HCISG V2.0, 1992]

    Discussion. Blue can be used to code large symbols if symbol identification is not a problem. Blue is also acceptable as a background color. [Source: Department of Energy (DOE-HFAC 1), 1992]

- **8.6.2.2.8 Colors for specific illumination conditions.** Red should be used only if high ambient illumination is expected, and green and yellow if a broad range of illumination is expected. [Source: DOD HCISG V2.0, 1992]

- **8.6.2.2.9 Compatibility with realistic conditions.** Colors used for coding should be easily differentiable under realistic operating conditions, including ambient lighting and display type. [Source: Smith & Mosier, 1986]

- **8.6.2.2.10 Green, yellow, and red.** When green, yellow, and red are used, they shall be used in combination with other cues, such as brightness and saturation, to enhance their distinctiveness. [Source: DOD HCISG V2.0, 1992]

- **8.6.2.2.11 Preferred colors for extensive viewing.** When light images on a dark background will be viewed extensively, the images should be amber or green rather than white. [Source: DOE-HFAC 1, 1992]

■ **8.6.2.2.12 Limitations of color usage.** The following restrictions on the use of specific colors shall be incorporated into display design.

a. If orange is used, it shall be readily differentiated from red, yellow, and white.

b. Magenta shall be used sparingly.

c. Pure blue shall not be used on a dark background for text, thin lines, or high resolution information.

d. Simultaneous presentation of both pure red and pure blue (and to a lesser extent, red and green or blue and green) on a dark background shall be avoided since they may result in a three dimensional effect, unless this effect is intentional or acceptable.

e. Dominant wavelengths above 650 nm shall be avoided because people with protanopic vision are noticeably less sensitive to these wavelengths.

f. Once a color is assigned a specific use or meaning, no other color shall be used for the same purpose. [Source: DOE-HFAC 1, 1992]

8.6.2.3 Location

□ **8.6.2.3.1 Peripheral vision.** The use of color-coding should be reserved for portions of visual displays that will normally be in the user's direct line of sight, and white should be used to code peripheral signals. [Source: National Air Traffic Services, 1999; DOE-HFAC 1, 1992]

Discussion. Peripheral vision is very poor at discriminating colors; therefore, only large colored objects will be distinguished in the peripheral visual field. [Source: National Air Traffic Services, 1999]

□ **8.6.2.3.2 Colors in the periphery.** When colors are used for items in peripheral vision (for example, at the periphery of large screen displays), blue, yellow, black, or white should be used instead of red and green (which should not be used for items located in peripheral vision). [Source: DOD HCISG V2.0, 1992]

8.6.2.4 Meaning

□ **8.6.2.4.1 One meaning per color.** Each color should represent only one category of displayed data. [Source: DOD HCISG V2.0, 1992]

- **8.6.2.4.2 Retain meaning of colors.** When the user community has previously established meanings for various colors, the designer shall retain those meanings. Thus, a color should not signify a different condition than it signified in the previous system. [Source: CTA, 1996]

  Discussion. Many FAA domains have set conventions regarding color use that need to be considered before applying color-coding.

- **8.6.2.4.3 Reserved meanings.** Color-coding shall conform to the following reserved meanings consistent with conventional associations for particular colors:

  a. Red shall indicate conditions such as no-go, error, failure, or malfunction.

  b. Flashing red shall be used only to indicate emergency conditions requiring immediate user action to avert personnel injury or equipment damage.

  c. Yellow shall indicate marginal conditions, alert users to situations where caution or rechecking is necessary, or notify users of an unexpected delay.

  d. Green shall indicate that a monitored process or unit of equipment is within tolerance, that a condition is satisfactory, or that it is all right to proceed with an operation or transaction.

  e. White shall indicate alternative functions or system conditions that do not have operability or safety implications.

  f. Blue shall be used only as an advisory color. [Source: MIL-HDBK-761A, 1989]

  Discussion. The use of colors to indicate conventional meanings is also dependent on the color appearing against an appropriately contrasting background. For instance, white or light gray is appropriate for black text. [Source: MIL-HDBK-761A, 1989]

- **8.6.2.4.4 Colors for action and status.** Longer wavelength colors (for example, red and orange) should be used to suggest action or a demand for a response. [Source: DOD HCISG V2.0, 1992]

8.6.2.5 Color relative to adjacent colors

- **8.6.2.5.1 Relative color.** The color of other figures and the background relative to a particular item should be considered in order to provide the appropriate color contrast and emphasis to the color-coding of a particular item. [Source: MIL-HDBK-761A, 1989]

- **8.6.2.5.2 Color pairs to avoid.** Designers should avoid the color combinations listed in Exhibit 8.6.2.5.2.

Exhibit 8.6.2.5.2 Color combinations to avoid. [Source: CTA, 1996]

Saturated Red and Blue	Saturated Red and Green
Saturated Blue and Green	Saturated Yellow and Green
Yellow on Purple	Green on White
Yellow on Green	Blue on Black
Magenta on Green	Red on Black
Magenta on Black	Yellow on White

- **8.6.2.5.3 Test colors.** Selected colors should be tested with users to verify that the colors can be easily discriminated from each other. [Source: CTA, 1996]

- **8.6.2.5.4 Colors for comparison.** Green, yellow, and red should be avoided as comparison colors for application information requiring important or frequent discriminations. [Source: DOD HCISG V2.0, 1992]

- **8.6.2.5.5 Adjacent colors.** Highly saturated colors with significantly different wavelengths (those toward opposite ends of the spectrum) should not be used next to each other. [Source: DOD HCISG V2.0, 1992]

  Definition. Saturation is the relative amount of whiteness in a chromatic color. [Source: DOD HCISG V2.0, 1992]

- **8.6.2.5.6 Color saturation.** When possible, highly saturated colors should be used to maximize differences among colors. [Source: DOE-HFAC 1, 1992]

  Discussion. If hue saturation combinations are used to provide different values for a color code, caution needs to be taken to ensure that changes in saturation do not produce unwanted effects or colors difficult to see under some viewing conditions, such as high levels of ambient illumination. [Source: DOE-HFAC 1, 1992]

- **8.6.2.5.7 Conveying similarity.** Similar colors should be used to convey similarity among items; examples are orange/yellow and blue/violet. [Source: DOD HCISG V2.0, 1992]

- **8.6.2.5.8 Discrimination of colors.** The colors selected for coding on a screen shall be easily discriminated from one another in all expected operating conditions. [Source: DOD HCISG V2.0, 1992]

- ■ **8.6.2.5.9 Varying lightness.** Color combinations that are similar in lightness shall be avoided (for example, navy blue on black, yellow on white). [Source: CTA, 1996]

  Discussion. Consider the effects of varying levels of saturation (color intensity) and the effects of varying levels of lightness (amount of white mixed with color) on the ability to discriminate colors and on color interactions. [Source: CTA, 1996]

- □ **8.6.2.5.10 Number of levels on colored displays**. Due to the relationship between brightness and color, a maximum of two luminance levels should be used for coding on colored displays. [Source: National Air Traffic Services, 1999]

8.6.2.6 Foreground/background

- □ **8.6.2.6.1 Foreground and background contrast.** The foreground color should contrast highly with the background color. [Source: DOD HCISG V2.0, 1992]

  Definition. Contrast is the difference in luminance of two areas. Contrast is often represented in terms of a **contrast ratio,** expressed as the ratio of foreground to background luminance (for example, 7:1). [Source: DOD HCISG V2.0, 1992]

- ■ **8.6.2.6.2 Text-background contrast.** The contrast between text and its background shall be sufficiently high to ensure readability of the text. [Source: DOD HCISG V2.0, 1992]

- ■ **8.6.2.6.3 Color foreground/background difference.** In general, the color foreground shall differ from its background by a minimum of 100 $_\Delta$E (CIE Yu' v') distances. [Source: DOD HCISG V2.0, 1992]

- □ **8.6.2.6.4 Contrast.** An adequate contrast of at least 7:1 should be maintained between foreground and background colors to enhance color perception and perceived image resolution. [Source: CTA, 1996]

  Discussion. To maximize color contrast, consider using complementary colors (yellow on dark blue) if appropriate for the user's task environment. [Source: CTA, 1996]

- □ **8.6.2.6.5 Contrast in dim lighting.** The contrast should be increased if the screen will be viewed under dim lighting conditions. [Source: CTA, 1996]

- □ **8.6.2.6.6 Achromatic background.** A medium achromatic background (for example, dark or medium gray) should be used to maximize the visibility of foreground colors. [Source: CTA, 1996]

8.6.2.7 Number of colors

- ▫ **8.6.2.7.1 Number of colors to use.** Color should be introduced into screens conservatively, using relatively few colors to designate critical categories of displayed data and only if it will facilitate user understanding or performance**.** [Source: DOD HCISG V2.0, 1992]

- ▪ **8.6.2.7.2 Task requirements.** Task performance requirements shall be used as the basis for determining the number of colors presented together on the same screen. [Source: CTA, 1996]

- ▫ **8.6.2.7.3 Maximum number of colors.** The total number of colors used should not exceed four for a single alphanumeric screen and seven for a set of related screens. [Source: DOD HCISG V2.0, 1992]

- ▫ **8.6.2.7.4 Additional colors.** Additional colors (more than four) should be reserved for special use (for example, in map displays). [Source: DOD HCISG V2.0, 1992]

  Discussion. Only eight or nine highly saturated colors can be easily discriminated. [Source: DOD HCISG V2.0, 1992]

- ▫ **8.6.2.7.5 Recommended number of colors.** Designers should limit the number of colors to be used.

  a. No more than six distinct colors or shades of gray should be used if the user must recall the meanings of colors or shades.

  b. No more than six distinct colors should be used if the user must perform rapid visual searching based on color discrimination. [Source: CTA, 1996]

8.6.2.8 Keys/legends

- ▫ **8.6.2.8.1 Color key.** When the use of color is extensive or unusual (for example, if functional requirements dictate the use of more than the recommended number of colors or shades of gray) or when a display may be used infrequently, the display should include a color key or legend that explains the color/shade meanings. [Source: DOD HCISG V2.0, 1992]

- ▫ **8.6.2.8.2 Key accessibility.** When used, a color key should be readily accessible and visible without the user having to scroll or expand the display. [Source: DOD HCISG V2.0, 1992]

- ▫ **8.6.2.8.3 Colors in key.** A color key should include the actual colors being defined. [Source: DOD HCISG V2.0, 1992]

8.6.2.9 User preferred color sets

- ▫ **8.6.2.9.1 User preferences.** When appropriate to the functionality of an application, users should have the option of selecting from a variety of color sets as a user preference setting for aspects of an application that do not involve coding or status. [Source: DON UISNCCS, 1992]

- **8.6.2.9.2 Easy return to default color scheme.** When users are allowed to change color settings of aspects of an application that do not involve coding, the application shall provide an easy way to restore the default color scheme. [Source: DOD HCISG V2.0, 1992]

- **8.6.2.9.3 Portable applications.** When an application is likely to be used on different hardware configurations, it shall be able to accommodate the possible differences in color representations in the different configurations. [Source: DOD HCISG V2.0, 1992]

- **8.6.2.9.4 Status colors.** Status colors shall be assigned during installation, and users shall not be allowed to change them. [Source: DOD HCISG V2.0, 1992]

- **8.6.2.9.4 Coding and status colors.** When different users will share a computer monitor, individual users shall not be able to change colors for coding and status of facilities, services, or equipment such as alarms or alerts. [Source: DON UISNCCS, 1992]

- **8.6.2.9.5 Range of color contrast.** When users are allowed to adjust the color and contrast settings, a variety of color selections capable of producing a range of contrast levels shall be provided. [Source: General Services Administration, 2000]

8.6.2.10 Color-coded symbols

- **8.6.2.10.1 Code symbol, not text.** When color is used to indicate status changes, a box or other shape adjacent to the text shall change color, instead of the text itself. [Source: DOD HCISG V2.0, 1992]

8.6.3 Brightness/intensity coding

- **8.6.3.1 Consistent meaning.** Brightness coding shall have a single meaning throughout an application and related applications. [Source: MIL-HDBK-761A, 1989]

- **8.6.3.2 Number of levels.** The number of brightness intensity levels used as codes shall not exceed three. [Source: MIL-HDBK-761A, 1989]

  Discussion. Two levels of brightness intensity may be optimal because of possible difficulty in discriminating brightness levels. Three levels of brightness is the **maximum** when tasks need such discriminations. [Source: Ameritech Services Inc., 1996; MIL-HDBK-761A, 1989]

- **8.6.3.3 Brightness ratios.** Each level of brightness shall be separated from an adjacent level by a 2:1 ratio. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.6.3.4 High brightness.** High brightness should be used to call attention to errors in data-entry fields and to highlight answer fields on question and answer screens. [Source: CTA, 1996]

□ **8.6.3.5 More than one brightness level.** When two brightness levels are used to code information, the higher brightness should apply to the more critical information, and the lower brightness to the less critical information. [Source: National Air Traffic Services, 1999]

▪ **8.6.3.6 Highlighting during operations.** When a user is performing an operation on a selected object in a display, that object shall be highlighted. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

Discussion. In many applications, at least two different methods of selection highlighting can be provided. The first of these highlighting methods occurs when the pointer comes to rest for a predetermined time on a selected object. This is sometimes referred to as **dwell emphasis**, and it tells the user which object the computer perceives the user is about to select. This highlighting is normally dim white. The second type of highlighting occurs when an actual selection has been made, and is normally a bright white. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

▪ **8.6.3.7 Highlighting on dark backgrounds.** When the background is dark, white highlighting shall be used with dark letters to draw attention to particular data or portions of the screen. [Source: DOD HCISG V2.0, 1992]

▪ **8.6.3.8 Highlighting on light backgrounds.** When the background is light, dark highlighting shall be used with white letters to draw attention to particular data or portions of the screen. [Source: DOD HCISG V2.0, 1992]

▪ **8.6.3.9 Size and number of areas highlighted.** The size and number of areas highlighted shall be minimized. [Source: DOD HCISG V2.0, 1992]

□ **8.6.3.10 Reverse video.** Reverse video (for example, brightness inversion) should be used to highlight critical items requiring user attention, and return to a normal brightness when the user has responded. [Source: CTA, 1996]

Discussion. Although it does have good attention-getting capability, reverse video should be used in moderation because it can reduce legibility. [Source: Ameritech Services Inc., 1998]

8.6.4 Line coding

Lines can be used to aid in focusing the user's attention on related information or to separate unrelated groupings of information. Line borders delineate the boundaries of menu bars, display-control options, and entire windows. Lines can be coded by such attributes as width or thickness, color, and pattern (for example, solid, dashed, and dotted).

- ▫ **8.6.4.1 Consistency.** Line codes should be used consistently to symbolize corresponding data. [Source: Smith & Mosier, 1986]

- ▫ **8.6.4.2 Length.** Line-length coding should be used for spatial categorizations in a single dimension, such as velocity or distance. [Source: CTA, 1996; MIL-HDBK-761A, 1989]

  Discussion. The designer should be aware that long lines might add clutter to a display. [Source: CTA, 1996]

- ▫ **8.6.4.3 Direction.** Spatial categorization in two dimensions, for example, an aircraft altitude or bearing, should be coded by line direction. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.6.4.4 Graphic lines.** Graphic lines should contain a minimum of 50 resolution elements per inch, which will give the user a sense of continuity. [Source: National Air Traffic Services, 1999]

- ▫ **8.6.4.5 Line orientation.** When the orientation of a line is used to code direction or value, contextual information should also be provided. [Source: National Air Traffic Services, 1999]

- ▫ **8.6.4.6 Line angle.** The maximum number of codes for line-angle coding should be 11. [Source: National Air Traffic Services, 1999]

- ▫ **8.6.4.7 Line width.** The maximum number of widths for line-width coding should be three. [Source: National Air Traffic Services, 1999]

- ▫ **8.6.4.8 Line type.** Line coding by type (for example, solid, dashed, dotted), by width, or by other attributes should be used to indicate association between elements. [Source: CTA, 1996]

- ▫ **8.6.4.9 Use.** Line coding should be used sparingly. [Source: CTA, 1996]

8.6.5 Symbol coding

- ▪ **8.6.5.1 Special symbols.** When special symbols such as asterisks or arrows are used, they shall be used consistently and with unique meanings throughout an application and related applications. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.6.5.2 Special symbols and alphanumeric displays.** When used to draw attention to a selected item in alphanumeric displays, the symbol should be separated from the beginning of the word by a space. [Source: Nuclear Regulatory Commission, 1996]

8.6.6 Shape coding

- **8.6.6.1 Use.** The designer should use shape categories (for example, circles, triangles, and squares) to code related objects and to support the user's ability to discriminate between various categories of displayed data. [Source: CTA, 1996]

- **8.6.6.2 Number of shape codes.** Where geometric shape coding is used and each shape is required to be identified without reference to any other, the number of shapes in the set should ideally be 5 and not normally exceed 15. [Source: MIL-HDBK-761A, 1989]

  Discussion. The number of shapes used is dependant upon how often they are seen.

- **8.6.6.3 Resolution.** The designer should ensure that screen resolution is adequate for shape coding. [Source: National Air Traffic Services, 1999]

  Discussion. Good resolution is essential in guaranteeing that shapes are not mistaken for other shapes, such as confusing a hexagon for a circle. [Source: National Air Traffic Services, 1999]

- **8.6.6.4 Shapes to use.** Shapes used for shape coding should be based on established standards. [Source: National Air Traffic Services, 1999]

8.6.7 Size coding

- **8.6.7.1 Use.** Size coding should only be used when there is a low density of items on the display. [Source: National Air Traffic Services, 1999]

- ▪ **8.6.7.2 Number of sizes.** The number of different sizes used as codes shall not exceed three. [Source: MIL-HDBK-761A, 1989]

  Discussion. Limiting size coding to only two to three sizes is preferable. Search time is longer for items coded by size than items coded by shape or color. [Source: National Air Traffic Services, 1999]

- **8.6.7.3 Size coding vs. font style coding.** Within a text file or table, the use of a different font style should be preferred over the use of a different size for highlighting information. [Source: Nuclear Regulatory Commission, 1996]

- **8.6.7.4 Larger sized object.** A larger sized object used for coding should be 1.5 times the height of the next smaller object (for example, characters, symbols, and shapes) if it needs to be identified based on size. [Source: CTA, 1996]

8.6.8 Texture coding

- **8.6.8.1 Use.** Texture coding should be used redundantly with another form of coding (for example, color). [Source: National Air Traffic Services, 1999]

- **8.6.8.2 Hatching.** Simple hatching should be used instead of elaborate patterns. [Source: National Air Traffic Services, 1999]

- **8.6.8.3 Distracting effects.** Texture coding should be tested by users to avoid potentially distracting visual effects. [Source: National Air Traffic Services, 1999]

8.6.9 Spatial coding

- **8.6.9.1 Use.** Spatial coding should be used to give meaning to an item of information, such as to identify it as a menu item, or to indicate title pages, information fields, alarms, and active and static display areas. [Source: Nuclear Regulatory Commission, 1996]

- **8.6.9.2 Consistency.** Spatial coding should be used consistently throughout the system. [Source: Nuclear Regulatory Commission, 1996]

- **8.6.9.3 Importance.** Spatial coding should be used to indicate alarm importance. [Source: Nuclear Regulatory Commission, 1996]

- **8.6.9.4 Grouping.** White space should be used with group-related items. [Source: National Air Traffic Services, 1999]

- **8.6.9.5 Unrelated items.** When there is no need to show a relationship between items, spatial coding should not be used. [Source: National Air Traffic Services, 1999]

8.6.10 Multidimensional coding

- **8.6.10.1 Three-dimensional effects.** Three-dimensional effects should be used in moderation on any single display, as overuse may be self-defeating. [Source: National Air Traffic Services, 1999]

8.6.11 Flash or blink coding

- **8.6.11.1 When to use.** Flash or blink coding should only be used to indicate an urgent need for the user's attention and response, or to indicate the active location for data entry. [Source: CTA, 1996; MIL-HDBK-761A, 1989]

  Discussion. Placing a blinking cursor at the point where user input will be accepted is a common use of flash coding. Overuse of flash or blink coding has a high potential to distract the user, can reduce character legibility, and may cause visual fatigue. [Source: CTA, 1996; MIL-HDBK-761A, 1989; Smith & Mosier, 1986]

- ▫ **8.6.11.2 Small area.** Only a small area of the screen should flash or blink at any time. [Source: Nuclear Regulatory Commission, 1996]

- ▪ **8.6.11.3 Flashing rate.** The rate of flashing shall be in the range of two to five Hertz (flashes per second) with a minimum ON interval of 50 percent. [Source: MIL-HDBK-761A, 1989; Smith & Mosier, 1986]

  Discussion. Although equal ON and OFF intervals are often suggested, coding can be effective even with a shorter OFF interval. [Source: Smith & Mosier, 1986]

- ▫ **8.6.11.4 Distinguishing multiple flash rates**. When two flash rates are used, the higher rate should apply to the more critical information, and the lower rate should be less than two flashes per second. [Source: MIL-HDBK-761A, 1989; Nuclear Regulatory Commission, 1996]

- ▫ **8.6.11.5 Flash acknowledgement.** When flash coding is used, users should have a means of acknowledging the flashing, which, when appropriate, automatically stops the flashing. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.6.11.6 When not to use.** Data or text that the user must read should never blink or flash because a blinking object is, by definition, not displayed continuously and can be read only when it is displayed. [Source: CTA, 1996]

- ▫ **8.6.11.7 Displayed objects.** When a displayed object is to be flash coded, a flashing symbol adjacent to the object should be used rather than flashing of the object itself. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.6.11.8 Flash coding for text.** When a user must read a displayed item that is flash coded, an extra symbol should be used to mark the item, such as an asterisk or arrow that flashes rather than having the item itself flash. [Source: Nuclear Regulatory Commission, 1996]

- ▫ **8.6.11.9 Flashing text.** When flash coding must be used on text, the flash rate should be 1/3 Hz to 1 Hz with an on/off cycle of 70%. [Source: National Air Traffic Services, 1999]

8.7 Interaction

8.7.1 Interaction method

- **8.7.1.1 Selection of interaction type.** There are several interaction types listed below. The type of interaction selected shall be appropriate to the task requirements, the characteristics of the system, and the abilities of the users.

a. The **question and answer** interaction type is appropriate when the task is routine data entry; the characteristics of the data are known and the question and answer sequence can be constrained; users are expected to have little or no training; and computer response is expected to be moderately fast.

b. The **form filling** interaction type is appropriate when flexibility in data entry is needed, users are expected to be moderately trained, computer response may be slow, and an aid in composing complex control entries would be helpful.

c. The **menu selection** interaction type is appropriate when tasks involve choices from constrained sets of alternatives; entry of arbitrary data is seldom required; users are expected to have little training; a command set is too large, too infrequent, or too inconsequential for users to remember; and computer response is relatively fast.

d. The **function key** interaction type is appropriate for use in conjunction with other types of interaction method when tasks require only a limited number of control entries, or when an immediate means for accomplishing frequent control entries or transactions is desirable.

e. **The command language interaction type** is appropriate when tasks involve a wide range of control entries, users are expected to be highly trained or will use the system frequently, and control entries may be mixed with data entries in arbitrary sequence.

f. The **query language** interaction type is appropriate when tasks emphasize unpredictable information retrieval and users are highly trained.

g. The **constrained natural language** interaction type is appropriate when task requirements are wide-ranging or poorly defined and users are expected to have moderate training.

h. The **direct manipulation** interaction type is appropriate when tasks mimic physical manipulation of concrete objects such as positioning graphical objects, moving blocks of text, and resizing objects. It is also appropriate for casual system users and users expected to have little or no training. [Source: MIL-HDBK-761A, 1989; ESD-TR-86-278, 1986]

- **8.7.1.2 Distinctive display of control information.** Displays shall be designed so that features relevant to the interactive method, such as prompts and messages, are distinctive in position and format. [Source: DOE HFDG ATCCS V2.0, 1992]

8.7.2 Hierarchical levels

- **8.7.2.1 Hierarchical levels.** When hierarchical levels are used to control a process or sequence, the number of levels shall be minimized. [Source: MIL-HDBK-761A, 1989]

- **8.7.2.2 Hierarchical levels format.** When hierarchical levels are used, display and input formats shall be similar within levels. [Source: MIL-HDBK-761A, 1989]

- **8.7.2.3 Hierarchical levels current position.** When hierarchical levels are used, the system shall indicate the current position within a sequence. [Source: MIL-HDBK-761A, 1989]

8.7.3 Question-answer

- **8.7.3.1 Consistency.** The format and question-answer procedures shall be consistent throughout an application and related applications. [Source: Nuclear Regulatory Commission, 1996]

- **8.7.3.2 Singular presentation of questions.** Users shall only be presented with and required to answer one question at a time. [Source: MIL-HDBK-761A, 1989; Department of Defense (MIL-STD-1801), 1987]

- **8.7.3.3 List appropriate responses.** To the extent possible, users shall be provided a default or a list of the most appropriate responses from which they may select the desired response. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- □ **8.7.3.4 Display of interrelated answers.** When a system poses a series of questions to the user, and the answer to the current question is dependent upon how a previous question was answered, answers to all questions within the series should be displayed until all questions have been answered. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- **8.7.3.5 Sequence compatibility with source document.** When questions require entry of data from a source document, the question sequence shall match the data sequence within the source document. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- □ **8.7.3.6 Clarity.** Questions should be in clear, simple language. [Source: CTA, 1996]

- □ **8.7.3.7 Positive format.** Questions should be phrased in a positive manner. Avoid negative questions. [Source: CTA, 1996]

8.7.4 Form-filling

- **8.7.4.1 Consistency.** The structures and formats of form-filling interactions shall be consistent and logical throughout an application and related applications. [Source: MIL-HDBK-761A, 1989]

- **8.7.4.2 Default entries.** Wherever possible, default entries shall appear in their fields when a form is displayed in form-filling interactions. [Source: MIL-HDBK-761A, 1989]

- **8.7.4.3 Default listing.** A default listing or screen shall be provided in which authorized users may view and change default settings of fields. [Source: Smith & Mosier, 1986]

8.7.5 Menus

The use of menus as an interaction method is widespread, often in conjunction with other methods such as direct manipulation. Menus are usable with little or no training on the part of the user. If the meanings of the options are clear, the user can be guided step-by-step through an application. Menus do have some disadvantages, however; they can slow down an experienced user; they can occupy a considerable amount of display space; and, in complex sequences, users may become lost in the menu structure. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

Definitions. A **menu** is a list of options from which a user makes a selection or selections. An **option** is one of the selectable items in a menu. **Selection** is the action a user makes in choosing a menu option. Selection may be accomplished by pointing, by typing, or by pressing a function key. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

8.7.5.1 General

- **8.7.5.1.1 Use.** Menus should be used for selecting values and choosing from a set of related options. [Source: DON UISNCCS, 1992]

- **8.7.5.1.2 Selecting a mutually exclusive option.** When users need to choose one option from a number of mutually exclusive options,

  a. **radio buttons** should be used for up to 6 options,

  b. a **menu** should be used for up to 10 options, and

  c. a **scrolling menu** should be used for more than 10 options. [Source: DON UISNCCS, 1992]

- **8.7.5.1.3 Menus distinct from other displayed information.** Menus shall be distinct from the other objects or information on the screen. [Source: MIL-HDBK-761A, 1989; DOE HFDG ATCCS V2.0, 1992; MIL-STD-1801, 1987; DOD HCISG V2.0, 1992]

- **8.7.5.1.4 Consistent style.** Menus throughout an application shall conform to a single style of interface (for example, Microsoft Windows or Macintosh). [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.7.5.1.5 Consistent menus and options.** When the same menu or option appears in different displays within an application, it shall be consistent in wording and organization. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- **8.7.5.1.6 Instructions.** Instructions pertaining to menus shall appear in a Help window in a consistent location on the screen. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- **8.7.5.1.7 Menu width.** The menu should be wide enough for the longest menu item and its accelerator, ellipsis, or cascade indicator. [Source: Ameritech Services Inc., 1996]

  Definition. Accelerators are keyboard commands that can be used instead of pointing and clicking on menu options. They are indicated by underlining the proper character and placing the keyboard alternative in parenthesis after the option (for example, <u>B</u>old (Ctrl+B). [Source: National Air Traffic Services, 1999]

  Definition. Ellipses are visual indicators, such as three dots (...), used to distinguish menu options that branch to other sub-menus from menu options that will immediately perform an operation. [Source: National Air Traffic Services, 1999]

- **8.7.5.1.8 Menu length.** The design of menus should take into account the response time and display rate of the system so that when the computer response time to a user action is long, menus have relatively more options (be broad and shallow); and when display rate is slow (if it takes a long time to complete the drawing of a display), menus have relatively fewer items (be narrow and deep). [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

8.7.5.2 Menu titles

- **8.7.5.2.1 Menu titles.** Menu titles and menu options shall be easily distinguishable. [Source: Ameritech Services Inc., 1996]

- **8.7.5.2.2 Titles for groups of options.** When the options in a menu are grouped and titled, the titles should be easy to understand and unique. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-STD-1801, 1987]

- **8.7.5.2.3 Appearance of group titles.** The titles of groups of options shall appear in a format that is clearly distinguishable from that of the options themselves. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- **8.7.5.2.4 Distinguishing menu titles**. Menu titles shall be easily distinguished from the options. [Source: Ameritech Services Inc., 1996]

- **8.7.5.2.5 Numbering menu titles.** Menu titles shall not be numbered. [Source: MIL-HDBK-761A, 1989; Defense Information Systems Agency, 1995]

- **8.7.5.2.6 Capitalization in menu titles.** The first letter shall be capitalized, as well as other significant words, except for prepositions and articles. [Source: MIL-HDBK-761A, 1989; Defense Information Systems Agency, 1995]

- **8.7.5.2.7 Acronyms in titles.** When the title contains an acronym, it shall be capitalized. [Source: Defense Information Systems Agency, 1995]

- **8.7.5.2.8 Menu titles as options.** The menu title shall not appear as an option in the menu. [Source: MIL-HDBK-761A, 1989]

- **8.7.5.2.9 Ellipses and right arrows.** The menu title shall not contain ellipses or a right-pointing arrow. [Source: Defense Information Systems Agency, 1995]

8.7.5.3 Menu options

- **8.7.5.3.1 Highlighting menu options.** A menu option should be highlighted when the pointer is on the menu option. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- **8.7.5.3.2 Option capitalization.** Options should be displayed in mixed case letters, with only the first letter of the first word and acronyms capitalized. [Source: DON UISNCCS, 1992, V1.1]

- **8.7.5.3.3 Number of selections per menu.** A user should be allowed to select only one option from a menu or menu group. [Source: MIL-HDBK-761A, 1989]

- **8.7.5.3.4 Number of options.** The number of options in a menu should not be more than 10 or less than 3. [Source: MIL-HDBK-761A, 1989]

- **8.7.5.3.5 Display of all options.** A menu should display explicitly and completely all options available to a user at the current step in a transaction sequence. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- **8.7.5.3.6 Distinguishing unavailable options.** When a menu contains options that are temporarily unavailable, the unavailable options shall be displayed but clearly distinguishable from available options. [Source: MIL-HDBK-761A, 1989]

  Example. Unavailable options might be displayed at reduced intensity (grayed out). [Source: MIL-HDBK-761A, 1989]

- **8.7.5.3.7 Menus with no available options.** When all the options on a menu are unavailable, then the menu title and all the options shall be disabled (grayed out). [Source: Ameritech Services Inc., 1996]

- **8.7.5.3.8 Disabled menu.** The user shall be able to pull down the menu to view its items even if the menu is disabled. [Source: Ameritech Services Inc., 1996]

- **8.7.5.3.9 Feedback for menu selection.** When a user selects a menu option, and no computer response is immediately observable, the software shall provide some other acknowledgment of the selection. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

    Example. The software might display a watch, hourglass, or a message stating the delay remaining or the elapsed time. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

8.7.5.4 Types of options

- **8.7.5.4.1 Distinguishing types of options.** When a menu contains options of different types, the types shall be distinguishable. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

    Example. Options that lead to other menus might be followed by a triangle that points to where the subsequent menu will appear (□ or ∇). A menu option that requires additional information from the user might be followed by an ellipsis (...). [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- **8.7.5.4.2 Types of menu options**. There shall be no more than two types of options in a menu: attributes and commands. [Source: Apple Computer Inc., 1992]

    Definition. Attributes are instructions that change the characteristics of a selected item. An example of an attribute is changing text from standard to bold type. **Commands** are instructions that cause a device to perform some action. [Source: Apple Computer Inc., 1992]

- **8.7.5.4.3 Attribute options.** The titles of attributes shall be adjectives or adjective phrases because these describe the specific feature of that attribute. [Source: Apple Computer Inc., 1992]

    Example. Choosing the option **Italic** changes the features of the selected text from normal to italic. [Source: Apple Computer Inc., 1992]

- **8.7.5.4.4 Command options.** The titles of commands shall be verbs or verb phrases because they declare action. [Source: Apple Computer Inc., 1992]

    Example. The command **Save** causes the computer to save the data.

8.7.5.5 Wording of options

▫ **8.7.5.5.1 Worded as commands.** Options should be worded as commands to the computer, not questions to the user. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

> **Example.** The command **Copy** instructs the computer to copy selected data. [Source: Apple Computer Inc., 1992]

▪ **8.7.5.5.2 Terminology.** The wording of options shall use terminology familiar to the user but shall distinguish each option from every other option in the menu. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▪ **8.7.5.5.3 Consistent with command language.** When menu selection is used in conjunction with command language interaction, the wording of menu options shall be consistent with the command language. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

> **Definition.** A **command language** is a limited programming language used strictly for executing a series of commands (for example, Linux, any DOS shells). [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▫ **8.7.5.5.4 Terse wording.** Options should be tersely worded, preferably a single word. [Source: Apple Computer Inc., 1992]

▫ **8.7.5.5.5 Indicate changes.** The attribute option label should be worded to describe the changes that will occur to the selected text or object. [Source: Apple Computer Inc., 1992]

8.7.5.6 Option organization

▫ **8.7.5.6.1 Alignment of options.** With the exception of a menu bar, the options in a menu should be presented in a single vertical column, aligned and left justified. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

▫ **8.7.5.6.2 Separator lines.** A solid horizontal line the same color as the option labels should be placed between long, logically related groups of options. [Source: CTA, 1996]

▪ **8.7.5.6.3 Ordering a small number of options.** When a group of options or a menu contains a small number of options, the options shall be ordered by logical sequence or frequency of use. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▪ **8.7.5.6.4 Ordering a large number of options.** When a group of options or a menu contains a very large number of options, the options shall be ordered alphabetically. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▪ **8.7.5.6.5 Logical grouping of options.** When options are grouped in a menu, they shall be presented in logical groups. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- ■ **8.7.5.6.6 Ordering of groups.** Groups of options in a menu shall be ordered logically, and, when there is no apparent logical ordering, ordered by their importance or expected frequency of use. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- ■ **8.7.5.6.7 Default option.** The most likely selection in a menu list shall be made the default option. [Source: CTA, 1996]

- ■ **8.7.5.6.8 Placing destructive command options.** When menu organization is based on such principles as frequency of use, the designer shall place destructive commands (**Delete, Exit**) at the bottom of the menu. [Source: CTA, 1996]

- ■ **8.7.5.6.9 Placement of opposing action options.** The designer shall not place options for opposing actions adjacent to each other. [Source: CTA, 1996]

  Example. Do not place the **Delete** option next to the **Save** option. [Source: CTA, 1996]

- □ **8.7.5.6.10 Numbering menu options.** Menu options should not be numbered except when the task sequencing is important in an application window. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

8.7.5.7 Menu bars

- □ **8.7.5.7.1 When to use.** A menu bar should only be used if the display screen size and resolution permit fast and accurate movement of the cursor onto the options. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

  Definition. A **menu bar** is a narrow panel, usually at the top of a computer screen in menu-based computer systems that continually displays the highest-level menu options for selection by the user. The options on a menu bar are usually the names of other menus. [Source: Ameritech Services Inc., 1996, National Air Traffic Services, 1999]

- □ **8.7.5.7.2 Menu bars for primary windows.** Primary windows should have menu bars that extend the full width of the primary window. [Source: Ameritech Services Inc., 1996]

  Definition. A **primary window** is a top or high-level window in an application. It is the main location of user interaction and functions independently of other primary windows in the application.

- □ **8.7.5.7.3 Visibility of menu bar options.** Menu bar options should remain visible at all times or until the user makes a selection. [Source: CTA, 1996]

- □ **8.7.5.7.4 Number of options.** Menu bars should contain no more than 10 options plus **Help**. [Source: DON UISNCCS, 1992]

- ▫ **8.7.5.7.5 Placement of options.** The options should begin at the left margin and extend to the right with **Help** located consistently, with enough space between them so that they can be read easily and accommodate the longest options in the pull-down menus. [Source: DON UISNCCS, 1992]

- ▫ **8.7.5.7.6 Duplicate options.** Options in window menu bars should not duplicate options in the system menu bar. [Source: DON UISNCCS, 1992]

- ▫ **8.7.5.7.7 Names of menu bar options.** Each menu that appears as an option in a menu bar should have a title that is unique in the application. [Source: DON UISNCCS, 1992]

- ▫ **8.7.5.7.8 Same menu bar in different windows.** When the same menu occurs in different windows, it should have the same title in each. [Source: DON UISNCCS, 1992]

- ▫ **8.7.5.7.9 Mnemonic.** Each title in a menu bar should have a mnemonic to permit selection from the keyboard. [Source: DON UISNCCS, 1992]

8.7.5.8 The system menu

- ▫ **8.7.5.8.1 System menu.** Each system should provide a system menu that includes options to end a session, print selections, review system status, define user preferences, manage alerts, change a password, access peripherals, and perform file management. [Source: DON UISNCCS, 1992]

- ▫ **8.7.5.8.2 Accessing system menu options.** System menu options should be available through a System option in the system menu bar. [Source: DON UISNCCS, 1992]

- ▪ **8.7.5.8.3 Organization of a system-level menu.** The options of a system-level menu shall be grouped, labeled, and ordered in terms of their logical function, frequency of use, and criticality. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- ▪ **8.7.5.8.4 Availability of system-level menu options.** Appropriate system-level menu options shall always be available. [Source: DON UISNCCS, 1992]

- ▫ **8.7.5.8.5 Utilities menu.** A Utilities option should be included in the system menu bar to support the functionality provided by the system. [Source: DON UISNCCS, 1992]

  Example. Examples include such resources as word processing, spreadsheets, and electronic mail. [Source: DON UISNCCS, 1992]

8.7.5.9 The system menu bar

- ▫ **8.7.5.9.1 System window menu bar.** The set of options that appears in the system menu bar should describe the overall functionality of the system. [Source: DON UISNCCS, 1992]

- ▪ **8.7.5.9.2 System menu bar content.** The system menu bar shall list the titles of menus that are available at the system level which provide access to the application level programs available to the user. [Source: DON UISNCCS, 1992]

- ▫ **8.7.5.9.3 Consistent options and order across systems.** To the extent possible, menu bar options and their order in the system menu should be the same across systems. [Source: DON UISNCCS, 1992, V1.1]

- ▫ **8.7.5.9.4 Consistent name across systems.** When the same application appears in different systems, it should have the same name in each system and be available in the same system-level menu. [Source: DON UISNCCS, 1992, V1.1]

- ▫ **8.7.5.9.5 Access to Help.** When users are working in an application, they should be able to select **Help** from the system menu bar at any time. [Source: DON UISNCCS, 1992]

- ▫ **8.7.5.9.6 Navigation aid.** Each system should include a navigation aid accessible through **Help** that provides an overview of the system and allows users to navigate quickly to a particular part of the system. [Source: DON UISNCCS, 1992]

  Example. The system might provide a graphical representation of the system that would allow a user to select one part and have the appropriate window displayed on the screen. [Source: DON UISNCCS, 1992]

8.7.5.10 Pull-down menus

- ▫ **8.7.5.10.1 When to use.** Pull-down menus should be used rather than pop-up menus if the position of the cursor on the screen is not important for information or option retrieval. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

  Definition. A **pull-down menu** is a menu associated with an option on a menu bar that appears when a menu bar option is selected.

  Discussion. Pull-down menus have limited applicability in data entry but may be useful for such activities as retrieving files. The advantage of pull-down menus over pop-up menus is that pull-down menus always have a visual cue in the form of a menu. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- ▪ **8.7.5.10.2 Consistent location.** Pull-down menus shall always appear immediately below the option whose selection leads to their appearance. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.7.5.10.3 Menu width.** The menu should be wide enough to accommodate the longest option and its keyboard accelerator, if present. [Source: DON UISNCCS, 1992]

- ▪ **8.7.5.10.4 Titles.** The title of a pull-down menu shall be the option on the menu bar with which the pull-down menu is associated. [Source: DON UISNCCS, 1992]

- ▪ **8.7.5.10.5 Unique title.** The title of a pull-down menu shall be unique in the menu bar and, to the extent possible, describe or identify the options in the pull-down menu. [Source: DON UISNCCS, 1992]

- ▫ **8.7.5.10.6 Outlining.** Pull-down menus should be outlined with a border or drop shadow. [Source: CTA, 1996]

- ▫ **8.7.5.10.7 Instructions.** Instructions should not be placed in pull-down menus. [Source: CTA, 1996]

- ▫ **8.7.5.10.8 Cascading pull-down.** When a pull-down option leads to a second-level cascading pull-down, the option label should be followed with a right-pointing arrow. [Source: CTA, 1996]

- ▪ **8.7.5.10.9 Separators to divide groups of options.** Separators shall offset choice groups. [Source: Ameritech Services Inc., 1996]

  Definition. A **group** on a pull-down menu is any set of menu items between two separators or the whole list if there are no separators on the pull-down menu. [Source: Ameritech Services Inc., 1996]

- ▫ **8.7.5.10.10 Number of options.** The number of options in a pull-down menu should not be more than 10 or less than 3. [Source: DON UISNCCS, 1992]

- ▫ **8.7.5.10.11 Presentation of options.** The options in a pull-down menu should be displayed one option per line. [Source: DON UISNCCS, 1992]

- ▫ **8.7.5.10.12 Minimize scrolling.** To the extent possible, all options should be present to minimize scrolling. [Source: CTA, 1996]

- ▪ **8.7.5.10.13 Types of pull-down menu options.** The options in a pull-down menu shall be one of five types: commands, names of windows or forms that will be displayed, names of other menus, sets of exclusive options, or sets of nonexclusive options. [Source: DON UISNCCS, 1992]

- ▫ **8.7.5.10.14 Execution of commands.** Command options should be executed as soon as the user selects them. [Source: DON UISNCCS, 1992]

- ▪ **8.7.5.10.15 Names of windows or forms that will be displayed.** When names of windows or forms that will be displayed are used as options in pull down menus, they shall be identified by a special symbol, for example, an ellipsis (...). [Source: DON UISNCCS, 1992]

- ▪ **8.7.5.10.16 Names of other menus.** When names of other menus are used as options in a pull-down menu, they shall be identified by a special symbol, for example, an arrow (→) or triangle (>) that points to the location where the menu will appear. [Source: DON UISNCCS, 1992]

- ▪ **8.7.5.10.17 Sets of exclusive options.** Sets of exclusive options shall be identified by special symbol, for example, a filled circle (●) for the selected option and an open circle (○) for the unselected options. [Source: DON UISNCCS, 1992]

- ▪ **8.7.5.10.18 Sets of nonexclusive options.** Sets of nonexclusive options shall be identified by special symbols, for example, a marked square (☒) for the selected option(s), if any, and an open square (☐) for the unselected option(s), if any. [Source: DON UISNCCS, 1992]

- ▪ **8.7.5.10.19 Distinguishing unavailable options.** When a pull-down menu contains options that are temporarily unavailable, the unavailable options shall be displayed but clearly distinguishable from available options. [Source: DON UISNCCS, 1992; MIL-HDBK-761A, 1989]

  Example. Unavailable options might be displayed at reduced intensity (grayed out). [Source: DON UISNCCS, 1992; MIL-HDBK-761A, 1989]

- ▫ **8.7.5.10.20 Option selection.** A user should be able to select an option on a pull-down menu by moving the pointer onto the desired item and selecting it. [Source: Ameritech Services Inc., 1996]

- ▫ **8.7.5.10.21 Exclusive option selection.** When only one option in a menu can be selected, a selection indicator should move to the chosen item and remain until another item is selected, with the indicated menu item remaining in effect until another item is chosen. [Source: Ameritech Services Inc., 1996]

- ▪ **8.7.5.10.22 Options requiring more user information.** When menu items on a pull-down menu require additional user information before the transaction can be completed, the designer shall follow each such item with ellipses (…). [Source: Ameritech Services Inc., 1996]

  Discussion. The ellipse indicates that a dialog box will result from selecting that item. [Source: Ameritech Services Inc., 1996]

8.7.5.11 Hierarchical menus

- ▫ **8.7.5.11.1 When to use.** Hierarchical menus should be used when there are more than 10 options and the options can be organized in a branching structure. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

  Definition. A **hierarchical menu** is a large series of options or menus that is organized as a multi-level, branching structure in which an option in a higher-level menu is the name of another menu at the next lower level. The options in the lowest level menus are not the names of other menus. They are commands, or selectable values such as color squares on a palette, or specific Auto Text choices (Dear Sir, To Whom It May Concern, etc.). [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

▫ **8.7.5.11.2 Menu titles as options.** Designers should use a subset of menu titles in the pull-down menu as the option items in the hierarchical menu. [Source: Ameritech Services Inc., 1996]

▫ **8.7.5.11.3 Organizing and labeling hierarchical menus.** Hierarchical menus should be organized and labeled to guide the user within the hierarchical structure. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

> **Example.** When a user selects an option from a hierarchical menu, the menu and the selected option remain on display with the selected option highlighted. The lower-level menu that results from the selection is displayed adjacent to the selected option. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▪ **8.7.5.11.4 Consistent design and use.** The design and use of hierarchical menus shall be consistent across tasks and transactions within an application. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989]

▫ **8.7.5.11.5 Minimum number of levels.** The number of selections required to reach the desired option in hierarchical menus should be no more than 4. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; Shneiderman, 1998]

> **Discussion.** Broad, shallow structures are preferred over narrow, deep ones.

▫ **8.7.5.11.6 Easy selection of important options.** Hierarchical menus should permit immediate user access to critical or frequently selected options. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989]

▪ **8.7.5.11.7 Indicating current position in menu structure.** An indication of the user's current position in a hierarchical menu structure shall be provided. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989]

▫ **8.7.5.11.8 Hierarchical menus in graphical user interfaces (GUI).** Hierarchical menus designed in a GUI should be as simple as possible, avoiding complex graphical structures. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▪ **8.7.5.11.9 Control entries.** The top-level menu in a hierarchical menu structure shall serve as a consistent starting point for control entries. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989;MIL-STD-1801, 1987]

> **Definition. Control entries** are user input for sequence control, such as function key activation, menu selection, and command entry. [Source: Carlow International Inc., 1992]

▪ **8.7.5.11.10 Top-level menu.** A user shall be able to return easily to the top-level menu in a hierarchical menu structure at any time. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- ▪ **8.7.5.11.11 Return to system-level menu.** A user shall be able to return to a system-level menu from anywhere in a hierarchical menu structure with one simple control action. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989]

- ▪ **8.7.5.11.12 Return to next higher level.** A user shall be able to return to the next higher-level menu from anywhere in a hierarchical menu structure with one simple control action. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989]

- ▫ **8.7.5.11.13 Lower-level menus.** The options contained in a menu below the top level should be logically related to each other. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.7.5.11.14 Bypassing menu selections.** The system or application should allow a user to bypass a series of menu selections by making an equivalent command entry. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

  Definition. Command entries are a type of control entry that enables the user to initiate a message to the system that will specify desired functions. [Source: Carlow International Inc., 1992]

- ▫ **8.7.5.11.15 Software navigation aids.** Software navigation aids should be provided to assist the users in quickly selecting the desired menu (for example, a tree diagram or organization chart) by permitting a user to select a menu directly without going through intermediate steps. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- ▫ **8.7.5.11.16 Marking preferred menu locations.** The capability should be provided for the user to mark points in the menu structure where they might want to return and return to such a point by issuing a command. [Source: CTA, 1996]

8.7.5.12 Cascading menus

- ▫ **8.7.5.12.1 When to use.** Cascaded menus should be considered when the menu bar is crowded and the grouping of options is obvious to the user. [Source: Ameritech Services Inc., 1996]

- ▫ **8.7.5.12.2 Cascading menus.** Cascading menus should follow the same rules as hierarchical menus. [Source: Microsoft Corp., 1992]

  Definition. A **cascading menu** is a type of hierarchical menu in which a submenu is attached to the right side of a menu item. Cascading menus can be added to drop-down menus, pop-up menus, or even other cascading menus. [Source: Microsoft Corp., 1992]

- **8.7.5.12.3 Cascade indicator.** Every cascaded menu item that leads to cascading menus shall be marked with a cascade indicator after the menu item name. [Source: Ameritech Services Inc., 1996]

  Discussion. The indicator is commonly a right pointing arrow (>) that is placed on the right side of the menu option items. This tells the user that a sub-menu exists for that item and that, when it is selected, the submenu will appear next to the item.

- **8.7.5.12.4 Number of levels.** Because cascaded menus require the user to remember where options are located or buried (the original menu may be partially hidden by the new cascaded menu), the number of levels should be limited to one. [Source: Ameritech Services Inc., 1996]

8.7.5.13 Scrolling menus

- **8.7.5.13.1 When to use.** Scrolling capability shall be provided for menus used in data entry that are too long to display in their entirety (for example, lists of retrievable files or acceptable entries for a filed). [Source: Apple Computer Inc., 1992]

  Definition. A **scrolling menu** is a menu usually containing many options that does not display all of the options at once. It includes a scroll-bar that permits the sequential display of all options. Scrolling menus are also called list boxes and scrolling lists.

- **8.7.5.13.2 Scroll-bar.** The scroll-bar shall be placed at the right of the displayed options. [Source: DON UISNCCS, 1992]

- **8.7.5.13.3 Menu title.** When the menu has a title, it shall appear above the displayed options and be easily distinguishable from the options. [Source: DON UISNCCS, 1992]

- **8.7.5.13.4 Option display.** The displayed options in a scrolling menu shall be arranged vertically with one option per line. [Source: DON UISNCCS, 1992]

- **8.7.5.13.5 Order of options.** The options in a scrolling menu should be ordered in a way that minimizes user navigation. [Source: DON UISNCCS, 1992]

  Example. They might be ordered by expected frequency of use or in chronological or other sequential order. [Source: DON UISNCCS, 1992]

- **8.7.5.13.6 Alphabetical arrangement.** When ordering by expected frequency of use or in chronological or other sequential order is not appropriate, options should be ordered alphabetically. [Source: DON UISNCCS, 1992]

- **8.7.5.13.7 Display of all options in a scrolling menu.** All the options in a scrolling menu shall be available for explicit and complete display through scrolling. [Source: Apple Computer Inc., 1992]

- ■ **8.7.5.13.8 Indication of additional options.** It shall be obvious to users that there are more options than are visible. [Source: Apple Computer Inc., 1992]

  Discussion. The presence of a scroll-bar may be sufficient to indicate the existence of additional options.

- □ **8.7.5.13.9 Search capability.** When a scrolling menu is large, for example, 50 options or more, the application should provide a search capability that would allow users to type a few characters of the option and search for those characters. [Source: DON UISNCCS, 1992]

- □ **8.7.5.13.10 Spin box.** A spin box should be used only for highly predictable discrete sets of options. [Source: Ameritech Services Inc., 1996]

  Definition. A **spin box** (also known as a **spin button**) is a variation of the scrolling menu or list. A spin box is made up of a text box and two arrows and displays a sequence of mutually exclusive choices. [Source: Ameritech Services Inc., 1996]

8.7.5.14 Pop-up menus

Pop-up menus can be very useful in data entry. They can present to a user the permissible entries for a field, thus eliminating the need for the user to remember the entries, preventing invalid entries, and eliminating potential typing errors. A pop-up menu resembles a pull-down menu, but it is not associated with the top-level menus listed in the menu bar. [Source: CTA, 1996]

- □ **8.7.5.14.1 Pop-up menus.** Pop-up menus should follow the rules for standard pull-down menus, except they do not have a title. [Source: Microsoft Corp., 1992]

  Definition. Pop-up menus are menus that only appear on user demand. They are often associated with a particular object on a display, (for example, a pop-up menu listing acceptable command options close to the immediate work area). Because they are not displayed all of the time, they do not take up valuable screen space. They provide an efficient way to access commands because they eliminate the need for the user to navigate to a menu bar or control bar. A pop-up menu typically contains 5 to 10 options presented in a vertical listing. [Source: Microsoft Corp., 1992]

- □ **8.7.5.14.2 Attribute lists.** Pop-up menus should not be used for accumulating attribute lists such as text style choices. [Source: Apple Computer Inc., 1992]

- □ **8.7.5.14.3 Actions**. Pop-up menus should not be used as a means of providing more commands; therefore, they should not contain actions (verbs). [Source: Apple Computer Inc., 1992]

▫ **8.7.5.14.4 Distinguishing the pop-up menu.** The pop-up menu should be made distinct from the screen background by giving it a contrasting yet complementary background or by giving it a solid-line border. [Source: CTA, 1996]

▪ **8.7.5.14.5 Title.** A title shall be displayed for each pop-up menu. [Source: CTA, 1996]

▪ **8.7.5.14.6 Pop-up menu location.** A pop-up menu shall be placed directly below the pointer used to select it and near the object or higher-level menu that is being manipulated. [Source: CTA, 1996]

▪ **8.7.5.14.7 Indication of pop-up menu.** An indication or cue shall be provided to the existence of a pop-up menu. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

> **Example.** Highlight the portion of the display that can be selected to access the hidden menu, provide a textual message indicating that a hidden menu is available, or change the shape of the cursor when it is located in a selectable area.

▪ **8.7.5.14.8 Selecting an option using a pointing device.** A user shall be able to select an option on a pop-up menu by moving the pointer onto the desired option and clicking the appropriate button. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

> **Explanation.** This method is preferred to holding the button down while moving the cursor and releasing it to make a selection. The deliberate click method is less prone to error. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▫ **8.7.5.14.9 Selection highlighting.** When an option in a pop-up menu remains on display after it has been selected, it should remain highlighted. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▫ **8.7.5.14.10 Pop-up menus leading to cascading menus.** When an option in a pop-up menu leads to a cascading menu, a right-pointing triangle (►) should be placed after the option label. [Source: CTA, 1996]

▫ **8.7.5.14.11 Options leading to cascading menus.** Selected options that lead to a cascading menu should remain highlighted and serve as the title for the cascading menu. [Source: CTA, 1996]

▫ **8.7.5.14.12 Type-in pop-up menus.** When a list of likely choices is displayed in a pop-up menu, the user should be able to type in a choice that was not anticipated. [Source: Apple Computer Inc., 1992]

> **Discussion.** In this situation, making all preset choices visible allows the user to make a selection from the list provided. For example, when choosing screen magnification size, the user should be able to pick from a list of suggested sizes or type in a specific value. [Source: Apple Computer Inc., 1992]

8.7.5.15 Tear-off menus

- **8.7.5.15.1 When to use.** A graphic tear-off menu should be used instead of a fixed palette when it can save display space and provide greater flexibility. [Source: CTA, 1996]

  Definition. A **tear-off menu** is a menu that can be removed from the menu bar and moved to another location on the screen where it can remain on display. Tear-off menus are also called “tacked” or “pushpin” menus. [Source: CTA, 1996]

- **8.7.5.15.2 Location.** Tear-off menus should be placed so that the user can make multiple selections before dismissing it. [Source: CTA, 1996]

- **8.7.5.15.3 Moving and re-sizing.** The user should have the capability to move and re-size the tear-off menu. [Source: CTA, 1996]

8.7.5.16 Toggled menus

- **8.7.5.16.1 Toggled menu options.** Toggled menu options shall be used for two and only two opposite commands that are accessed frequently. [Source: Ameritech Services Inc., 1996]

  Definition. Toggled menu options are used to issue commands as a binary selection of one of two opposite commands. [Source: Ameritech Services Inc., 1996]

- **8.7.5.16.2 Naming toggled menu options.** Toggled menu options shall begin with verbs that clearly state the outcome of selecting that menu item. [Source: Ameritech Services Inc., 1996]

8.7.5.17 Graphic menus

Definition. Graphic menus (palettes) are a set of unlabeled symbols, typically presented within small rectangles. Symbols may be icons, patterns, characters, or drawings that represent an operation. Palettes are used widely in drawing and painting packages but are commonly found in word-processing applications as well. [Source: CTA, 1996]

- **8.7.5.17.1 Symbols**. Symbols within graphic palettes should be labeled unless they are self-explanatory. [Source: CTA, 1996]

- **8.7.5.17.2 Mode indicator.** Upon selection of a symbol or tool, a reminder should be displayed to indicate the mode that has been activated. [Source: CTA, 1996]

- **8.7.5.17.3 Moving and re-sizing.** The user should have the capability to move and re-size the palette. [Source: CTA, 1996]

8.7.6 Menu Interaction

8.7.6.1 Selecting options

- ▪ **8.7.6.1.1 Equivalence of input devices.** The system or application shall provide a user with the ability to use any of the input devices available to select a menu option. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

  Example. When a user has both a pointing device and a keyboard available, he or she can use either to select an option. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- ▪ **8.7.6.1.2 Initial cursor position for keyboards.** When a user must select among displayed options using a keyboard, the cursor shall be placed on the default option in the control entry area (with that control entry area having implicit input focus) when the display appears. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- ▫ **8.7.6.1.3 Selection by pointing.** When menu selection is the primary interactive method, and especially when selections are made from extensive lists of options, selection by pointing device should be provided. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- ▫ **8.7.6.1.4 Method of selecting by pointing.** The method for selecting an option by pointing should be that of moving the cursor onto the desired option and clicking the select button on the pointing device. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- ▪ **8.7.6.1.5 Initial cursor position for pointing devices.** When a user must select among displayed options using a pointing device, the cursor shall be placed on the default option when the display appears. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989]

- ▫ **8.7.6.1.6 Size of selectable area.** The effective pointing area for menu options should be as large as is consistently possible. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

  Explanation. The pointing area for a menu option is the area in which the user can place the cursor with a pointing device to select that particular option.

- ▪ **8.7.6.1.7 Minimum pointing area size.** The effective pointing area for menu options shall be at least the displayed option label plus a half-character distance around that label. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- ▪ **8.7.6.1.8 Two-action activation.** When menu selection is accomplished with a pointing device, activation shall consist of two actions: (1) designation, in which a user positions the cursor on the desired option, and (2) activation, in which a user makes a separate, explicit control entry (clicking the appropriate mouse button). [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- ▫ **8.7.6.1.9 Shortcuts.** Shortcut methods should be provided for experienced users to bypass the menu structure for frequently accessed options. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- ▫ **8.7.6.1.10 Abbreviated entries.** When menu selection is by code entry, the application should accept both the complete and minimum distinguishing abbreviated forms of the code. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

  Example. An application might accept **Q, QU,** and **QUIT** as equivalent. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- ▪ **8.7.6.1.11 Stacking menu selections.** When the selection of options from menus is accomplished by entering codes, and when a series of selections can be anticipated before the menus themselves are displayed, the user shall be able to combine selections into a single, stacked entry that is equivalent to the series of selections but without having the menus displayed. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

  Definition. Stacking is the stringing together of commands so that they can all be executed with a single command. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

8.7.6.2 Mnemonic coding and keyboard accelerators in menus

- ▫ **8.7.6.2.1 When to use.** Each menu title and each option in a menu should have a mnemonic. [Source: DON UISNCCS, 1992]

  Definition and discussion. A **mnemonic** is a single letter that a user can type to select an option in a menu. Mnemonic letters are the easiest codes to remember because numbers are more difficult. Non-mnemonic letters are the most difficult. Letters as codes also have a numerical advantage over numbers (there are 26 letters as opposed to only 10 numbers). Numbers have the advantages of making sequencing clear, being easier to locate on a keyboard by non-typists, and allowing a user to know immediately how many options are available.

▪ **8.7.6.2.2 Appointing a mnemonic.** The mnemonic for an option shall be different from any other mnemonic in the menu. [Source: DON UISNCCS, 1992]

Discussion. The preferred letter is the first letter. However, when that letter is used as another mnemonic in the menu or associated menus, another letter, preferably the second character letter, may be used. [Source: DON UISNCCS, 1992]

▫ **8.7.6.2.3 Mnemonic and keyboard accelerator.** The mnemonic for an option should use the same letter in the keyboard accelerator if there is one that includes a letter. [Source: Ameritech Services Inc., 1996]

Definition. A **keyboard accelerator** is a key or simultaneous combination of keys that a user can type to select an option in a menu without having to display the menu. Both mnemonics and accelerators are shortcuts that a user can type from the keyboard. [Source: DON UISNCCS, 1992]

Example. **S** might be the mnemonic for a **Save** option, and the simultaneous pressing of **Ctrl** and the letter **S** might be its keyboard accelerator. [Source: Ameritech Services Inc., 1996]

▪ **8.7.6.2.4 Underlining mnemonic.** The mnemonic for an option shall be underlined. [Source: DON UISNCCS, 1992]

▪ **8.7.6.2.5 Displaying mnemonics and accelerators.** Mnemonics and accelerators shall be displayed as part of the menu option. Exhibit 8.7.6.2.5 shows one way of indicating mnemonics (the underscored letters) and accelerators (the key combinations at the right). [Source: DON UISNCCS, 1992]

Exhibit 8.7.6.2.5 Mnemonics and accelerators

Mnemonics	Accelerators
Undo	Ctrl + Z
Cut	Ctrl + X
Copy	Ctrl + C
Paste	Ctrl + V
Clear	Del

- **8.7.6.2.6 Using a number as an accelerator.** When menu items are numbered, the number should be underlined and used as the mnemonic. [Source: Ameritech Services Inc., 1996]

  Discussion. The difference between a mnemonic and an accelerator is that choosing an option with a mnemonic requires the user to type the single letter mnemonic while the menu is displayed. When using an accelerator to choose an option, the user must type a key or simultaneous combination of keys. However, the menu does not have to be displayed.

- **8.7.6.2.7 Letter vs. numeric codes.** Letter and numeric codes should not be used in the same menu. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- **8.7.6.2.8 Numbering menu options.** When menu options are numbered, numbering shall start with 1, not with 0. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- **8.7.6.2.9 Numeric coding.** When using numeric codes, six or fewer characters shall be used. [Source: CTA, 1996]

- **8.7.6.2.10 Displaying option codes.** When menu options are coded, the codes shall be displayed with their options in a consistent, distinctive manner. [Source: DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989]

  Examples. When numeric coding is used, the numerals might appear immediately to the left of the options. When mnemonic coding is used, the mnemonic letter or letters might be boldfaced (**U**ndo) or underlined (<u>U</u>ndo). [Source: DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989]

- **8.7.6.2.11 Keyboard accelerators.** Applications should provide keyboard accelerators (or hot keys) for frequently selected menu options. [Source: DON UISNCCS, 1992]

- **8.7.6.2.12 Keyboard accelerators in the menu.** Keyboard accelerators should appear right justified on the same line as the option in the menu, separated by enough space to appear visually distinct, as seen in Exhibit 8.7.6.2.5. [Source: DON UISNCCS, 1992]

- **8.7.6.2.13 Selecting an option in a menu using its accelerator.** When a menu has accelerators, a user shall be able to select an option in the menu by typing its accelerator. [Source: DON UISNCCS, 1992]

- **8.7.6.2.14 Case sensitivity of mnemonics and keyboard accelerators**. Mnemonics and keyboard accelerators shall not be case sensitive, with upper and lower case letters being equivalent. [Source: DON UISNCCS, 1992]

8.7.7 Function keys

- ▫ **8.7.7.1 When to use.** Function keys should be used for tasks requiring only a limited number of control entries or for use in conjunction with other dialogue types as a ready means of accomplishing critical entries that must be made quickly without syntax error. [Source: Smith & Mosier, 1986]

  Definition. Function keys are labeled keys that serve as keyboard short cuts (for example, F1, F2, F3, or with the function name, such as Delete or Insert) by combining in one key the actions of a sequence of individual keys. [Source: National Air Traffic Services, 1999]

- ▫ **8.7.7.2 Single function.** When feasible, a function key should be assigned only one function. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.7.7.3 Consistency within an application.** When the same function is used in different operational modes within an application, it shall be assigned the same key for all modes. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- ▪ **8.7.7.4 Consistency across applications.** When the same function is used in related applications, it shall be assigned to the same key in all applications. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.7.7.5 Feedback.** Feedback, such as a text message or audible signal, shall be provided to the user for function key activation. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- ▫ **8.7.7.6 Soft function keys.** When soft function keys are used, representations of the function keys with the same spatial configuration as the hard function keys should be presented on the screen as near as possible to the hard keys. [Source: DOE HFDG ATCCS V2.0, 1992]

  Definition. A **soft function key** is an area on the screen that represents a function key. If a function key is assigned more than one function in an application, an associated soft key can be labeled with the function that is currently assigned to the key. A **hard function key** is the physical function key on the keyboard.

- ▫ **8.7.7.7 Soft function key activation.** When activating a soft function key with a pointing device, the user should be able to initiate the function both by pressing the corresponding hard function key on the keyboard and by selecting the soft key on the screen with the pointing device. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.7.7.8 Disabling of unused function keys.** Function keys that are unassigned or that are assigned a function that is not applicable at the moment shall be disabled. [Source: MIL-HDBK-761A, 1989; DOE HFDG ATCCS V2.0, 1992; MIL-STD-1801, 1987]

▪ **8.7.7.9 Indicating active function keys.** When some function keys are active and some are not, the active keys shall be indicated. [Source: MIL-HDBK-761A, 1989; DOE HFDG ATCCS V2.0, 1992; MIL-STD-1801, 1987]

Discussion. This might be done by displaying only the active keys as soft keys on the screen or by displaying active soft keys differently from inactive ones. [Source: MIL-HDBK-761A, 1989; DOE HFDG ATCCS V2.0, 1992; MIL-STD-1801, 1987

▪ **8.7.7.10 Easy return to base-level functions.** When the functions assigned to a set of keys change as a result of user selection, it shall be easy for the user to return them to the initial, base level functions. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

Discussion. One way this might be done is to include the equivalent of a "Main Menu" key in all sets other than the base set of function keys. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

▫ **8.7.7.11 User-defined functions (macros).** When desirable, users should be able to define their own functions and assign them to function keys, either temporarily or permanently. [Source: MIL-HDBK-761A, 1989]

Discussion. The capability to define functions should not be provided if macros defined by one user might be used inadvertently by another user. [Source: MIL-HDBK-761A, 1989]

▪ **8.7.7.12 Single-key operation for continuously available functions.** When a function is available continuously, pressing its assigned function key or selecting a corresponding soft key shall initiate it. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

▪ **8.7.7.13 Frequently used functions.** When a function will be used frequently, when its use is critical, or when its timely use is critical, it shall be initiated with a single key operation. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

▪ **8.7.7.14 Importance and frequency of use.** Functions shall be assigned to keys in accordance with their importance and frequency of use. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

Example. An emergency function might be given the most prominent position, or the most frequently used function might be given the most convenient location. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

▪ **8.7.7.15 Single key press.** A function key shall perform its labeled function with a single press of the function key. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- ▪ **8.7.7.16 Repeated key presses.** Function keys shall not change function with repeated key presses unless there is a change in mode, and then only after indication of the new function. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- ▫ **8.7.7.17 Relationship of functions assigned to the same key.** When two or more sets of functions are assigned to function keys and they are accessed by simultaneously pressing a function key and another key, such as **Shift, Ctrl,** or **Alt,** the logical relationship should be consistent from one set of functions to another. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

  Example. In a text processing application, one set of functions might apply to lines, another to paragraphs, and another to pages. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- ▪ **8.7.7.18 Labeling single-function keys.** A function key assigned a single function shall have a label on the keycap that clearly identifies the function and clearly distinguishes that function from others. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- ▪ **8.7.7.19 Labeling multifunction keys.** When a key is used for more than one function, the user shall be informed which function is currently available. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

  Discussion. One way to accomplish this is to display a label on a soft key on an adjacent portion of the screen. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- ▪ **8.7.7.20 Easy re-labeling.** Provisions shall be made for easy re-labeling of variable function keys. [Source: Department of Defense, 1996]

- ▫ **8.7.7.21 Labels of keys with changing functions.** Labels for variable function keys located along the perimeter of a display should be generated on the display face as a soft key when users or system administrators will change the functions often. [Source: Department of Defense, 1996]

- ▫ **8.7.7.22 Shifted characters.** Shift keys should not be used to operate variable function keys. [Source: Department of Defense, 1996]

- ▪ **8.7.6.2.23 Indicating status.** When applicable, the active or inactive status of a function key shall be indicated. [Source: MIL-HDBK-761A, 1989]

  Example. One way to accomplish this is to change the appearance of displayed labels on the screen. An example would be dimming inactive keys or displaying one state in dark text on a light background and the reverse for the other state. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.7.6.2.24 Labeling of menu items selectable with function keys.** When items from a menu are to be selected using function keys, the items should be labeled with function key numbers (for example, **F1** and **F2**), and appear as soft key labels above the function keys when screen real estate is not at a premium. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.7.6.2.25 Safeguarding.** Function keys that have potentially disruptive consequences shall be safeguarded. Safeguarding may take the form of physical protection, software disabling, interlocks, or multiple key combinations. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

8.8 General interactive techniques

8.8.1 Direct manipulation

- ▫ **8.8.1.1 When to use.** Direct manipulation should be used for casual system users as a means of enhancing a user's understanding of control actions and offered as a simple alternative to learning a command language when computer response time is fast. [Source: Nuclear Regulatory Commission, 1996]

  Definition. In a graphical user interface (GUI), a major type of interactive dialog is **direct manipulation**. In a direct manipulation dialog, the user controls the interface with the computer by acting directly on objects on the display screen. An object may be an icon, menu option, symbol, button, or dialog box. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.8.1.2 Direct manipulation interface.** The direct manipulation interface should include windows for containing the data file and menus for additional objects and actions that are not easily represented by pictographic icons. [Source: Nuclear Regulatory Commission, 1996]

- ▫ **8.8.1.3 Drag transfer.** When a system provides direct manipulation, a user should be able to move and copy data and objects by first marking the data or object, if necessary, then placing the pointer on it, holding down the appropriate button on the pointing device, and dragging it to the desired location. [Source: DON UISNCCS, 1992]

8.8.2 Command language

□ **8.8.2.1 When to use.** Command language should be used

a. for tasks involving a wide range of control entries,

b. where users may be highly trained and will use the system frequently, and

c. for tasks where control entries may be mixed with data entries in arbitrary sequence. [Source: Smith & Mosier, 1986]

Definition. A **command language** is a limited programming language used strictly for executing a series of commands (for example, Linux, DOS prompt). [Source: MIL-STD-1801, 1987]

■ **8.8.2.2 Command entry.** A command language shall be designed so that users can enter commands in terms of functions desired without concern for internal computer processing, storage, and retrieval mechanisms. [Source: MIL-STD-1801, 1987]

■ **8.8.2.3 Consistent syntax.** Command language syntax shall be consistent within an application and across related applications. [Source: MIL-HDBK-761A, 1989]

Definition. The **syntax** of a command language is the set of rules governing the language. Examples would be rules about the order in which parts of a command occur or rules about punctuation in commands (for example, options in DOS are preceded by a backslash). [Source: MIL-HDBK-761A, 1989]

□ **8.8.2.4 Complexity of command language.** The complexity of a command language should be minimized, especially for untrained or infrequent users. [Source: MIL-HDBK-761A, 1989]

■ **8.8.2.5 Organization of command language features.** The command language shall be designed so that its features (functions) are organized in groups for ease of learning and use. [Source: MIL-HDBK-761A, 1989: MIL-STD-1801, 1987]

Example. Enable the user to display the next of a set of received messages with some simple command, such as READ NEXT, instead of entering the complete command to retrieve a message that might include specification of message, message list, format, and output device.

▫ **8.8.2.6 Command stacking.** Users should be able to make control entries in accordance with task requirements, entering more than one command before entering an execute command, if that best meets the task requirements. [Source: DOE HFDG ATCCS V2.0, 1992]

> **Definition. Stacking** is the stringing together of commands so that they can all be executed with a single command. **Control entries** are a specific set of commands defined by the command language.

▪ **8.8.2.7 Command entry area.** Each display shall provide a command entry area that is located consistently across displays, for example, at the bottom of the screen. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

▪ **8.8.2.8 Distinctive wording of commands.** Words in a command language shall be distinctive from one another, emphasizing significant differences in function. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

▪ **8.8.2.9 Consistent wording of commands.** All words and their abbreviations in the command language shall be consistent in meaning and spelling from one transaction to another and from one task to another. [Source: MIL-STD-1801, 1987]

▪ **8.8.2.10 Familiar wording.** Words for use in command language dialog shall be chosen to reflect the user's point of view and shall correspond to the user's operational language. [Source: MIL-STD-1801, 1987]

▫ **8.8.2.11 Abbreviation of commands.** When a command language is necessary for the system and if the operators may be experienced users, then commands should also have abbreviated forms having five or less characters. [Source: MIL-HDBK-761A, 1989]

▫ **8.8.2.12 Selection of commands.** Commands should be designed to aid memory. [Source: MIL-HDBK-761A, 1989]

▫ **8.8.2.13 Alternate wording.** When a system will have many novice or infrequent users, it should recognize a variety of synonyms or alternative syntax for each word defined in the command language. [Source: MIL-HDBK-761A, 1989]

▪ **8.8.2.14 Spelling errors.** Commands shall be selected so that likely spelling errors do not result in valid commands. [Source: MIL-HDBK-761A, 1989]

> **Example.** Using **DEL** for Delete and **SEL** for Select might result in a spelling-induced error because the D and S keys are adjacent on QWERTY keyboards. [Source: MIL-HDBK-761A, 1989]

▫ **8.8.2.15 Word length.** The length of an individual input word, such as a command or a key word, should not exceed seven characters. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.8.2.16 Number of characters** Commands shall have at least one alphabetic or numeric character. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.8.2.17 Non-alphanumeric characters in commands.** Commands consisting of only non-alphanumeric characters (for example, $ or @) shall not be used. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.8.2.18 Case equivalence.** Upper and lower case letters should be treated as equivalent for control entries. [Source: Smith & Mosier, 1986]

- ▪ **8.8.2.19 Punctuation.** The use of punctuation in commands shall be minimized. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.8.2.20 Use of delimiter.** When a delimiter is needed, one delimiter, such as the slash (/), shall be used throughout an application and related applications. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.8.2.21 Blank spaces.** Blank spaces should not be used or interpreted by an application. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.8.2.22 Editing commands.** Users shall be able to edit textual commands, after they are typed but before they are executed, using standard editing techniques. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.8.2.23 Execution.** Once a textual command has been composed, an explicit enter or execute action by the user shall be required. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.8.2.24 Feedback.** When the execution of a command might result in a delay, the system should provide feedback to the users to let them know that the command is being processed properly and, if possible, provide an estimate of how long it will take to complete. [Source: MIL-HDBK-761A, 1989; Smith & Mosier, 1986]

- ▪ **8.8.2.25 Command confirmation.** When the execution of a command might result in the deletion or modification of data or other potentially adverse consequences, the system or application shall inform the user of the nature of the consequence and request that the user confirm the command unless an **UNDO** command is available. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.8.2.26 Unrecognized commands.** When the system or application does not recognize a command a user has entered, the system or application shall inform the user and request the user to revise or replace the command. [Source: MIL-HDBK-761A, 1989]

8.8.3 Queries

8.8.3.1 General

- ▫ **8.8.3.1.1 When to use.** Query language should be used for tasks emphasizing unpredictable information retrieval and with moderately trained users. [Source: MIL-HDBK-761A, 1989]

  Definitions. A **database** is a set of interrelated data stored in a computer. A **query** is the process of specifying, locating, and retrieving data matching specified characteristics from a database.

- ▫ **8.8.3.1.2 Ease of use.** A query language should be easy to learn and use. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.8.3.1.3 Interactive.** A query language should permit on-line, interactive use as opposed to batch or off-line use. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.8.3.1.4 Organization of data.** A query language shall be designed so that it considers the structure or organization of the data as perceived by the user group. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- ▪ **8.8.3.1.5 Task-oriented queries.** A user shall be able to specify which data are requested without having to tell the system how to find the data. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- ▫ **8.8.3.1.6 User assistance.** A query language should assist users in the construction of complex queries and in narrowing down overly broad queries. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.8.3.1.7 Large-scale retrieval confirmation.** When a query will result in a large or time-consuming data retrieval, the user shall be notified of the amount of data or time and asked to confirm the transaction or take further action to narrow the query before proceeding. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- ▪ **8.8.3.1.8 Retrieval interrupt.** The user shall be able to interrupt the retrieval process. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- ▫ **8.8.3.1.9 Logical combination queries.** A query language should permit the use of logical combinations in the formation of a query. [Source: MIL-HDBK-761A, 1989]

  Example. Combinations that might be permitted include "and," "or," and "not." [Source: MIL-HDBK-761A, 1989]

▫ **8.8.3.1.10 Subsequent queries.** A query language should permit the linking of sequential queries so that subsequent queries can be based on the results of prior queries. [Source: MIL-HDBK-761A, 1989]

> **Example.** An example might be: "Of those records retrieved, how many...?" [Source: MIL-HDBK-761A, 1989]

▪ **8.8.3.1.11 Flexible queries.** When natural language query is permitted, the system or application shall allow users to employ alternative forms when initiating queries. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

> **Example.** A system might accept all of the following as equivalent:
>
> Update network display within 3 miles.
> Update network display in a 3-mile radius.
> Update network display out to 3 miles.

▫ **8.8.3.1.12 Error detection and correction.** A query language should detect and notify users of syntax errors in queries and assist them in correcting the errors. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.8.3.1.13 Spelling and word variants.** A query language should recognize spelling variations (for example, gray and grey), acronyms, inverted word order (for example, television monitor and monitor, television), and truncations. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.8.3.1.14 Formats matched to user needs.** Query and display formats should be matched to the nature of the searches users will make. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.8.3.1.15 Number of formats.** When appropriate, more than one format should be provided for queries and displays. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.8.3.1.16 User preferences.** To the extent practicable, users should be able to choose the type of format (pictorial, verbal, or tabular) they prefer for queries and displays. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.8.3.1.17 Importance of search terms.** A query language should permit users to rank order the search terms in importance and use this ranking in displaying the retrieved information. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.8.3.1.18 Redisplay.** A query language should retain the results of the previous search so that they can be redisplayed without repeating the search. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.8.3.1.19 Punctuation.** A query language should automatically remove or ignore punctuation in search terms. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.8.3.1.20 Word roots.** A query language should include a means for reducing words to their root forms, for example, by removing suffixes and searching for the roots. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.8.3.1.21 Exceptions.** A query language should provide for a list of exceptional words that are accepted literally, that is, that are not reduced to their roots. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.8.3.1.22 Appearance of output.** The appearance, print format, and organization of the output should be natural and acceptable to the users. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.8.3.1.23 User-specified output.** Users should be able to specify report formats. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.8.3.1.24 Command clarity.** Commands should be clear, unambiguous, and distinctive. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.8.3.1.25 Minimal user effort.** The number of keystrokes required of users should be minimized. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.8.3.1.26 Reuse of queries.** A query language should permit reuse of frequent queries. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.8.3.1.27 User definition of macros**. A query language should allow the user to define macros. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.8.3.1.28 Keyboard accelerators**. A query language should incorporate keyboard accelerators. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.8.3.1.29 Automatic periodic backup.** A query language should automatically back up data periodically when specified by the user. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.8.3.1.30 Restore.** A query language should have a **Restore** utility to recover backup data. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.8.3.1.31 Pause and Resume.** A query language should have a **Pause** and **Resume** capability that would allow a user to stop working with the query language and resume at a later time. [Source: DOE HFDG ATCCS V2.0, 1992]

8.8.3.2 Query screen design

▫ **8.8.3.2.1 Relevant information only.** Query screens should include only information that is relevant to the task, that is, information necessary to perform actions, make decisions, or answer questions. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.8.3.2.2 Frequently used information.** The most frequently used information should be located in the upper left portion of a screen and, if multiple screens are involved, on the first screen or screens. [Source: DOE HFDG ATCCS V2.0, 1992]

8.8.3.3 Searching

▫ **8.8.3.3.1 Searching operations.** A query language should provide the following searching operations to users.

These include

a. a **Select** operation that enables users to select the desired data-base;

b. **Create** and **Erase** operations that enable users to create and erase data sets;

c. a **Combine** operation that enables users to combine data sets;

d. a **Report** operation that enables users to format, name, specify, display, print, and save a query;

e. a **Restrict** operation that enables users to restrict the output of a retrieval set;

f. a **Save** operation that enables users to save the results of a search; and

g. a **Search history** operation that enables users to view a list of previous search commands upon request. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.8.3.3.2 Control operations.** A query language should provide control operations to users. These include

a. a **Mark** operation that stores the current field value for future reference (for example, marking a field or record for deletion),

b. a **Describe** operation that enables users to receive a detailed explanation or description of the current field value,

c. a **Drop** operation that drops the current field from the structure, and

d. a **Status** operation that enables users to request status information. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.8.3.3.3 Query formulation operations.** A query language should provide query formulation operations. These include

a. a **Select** operation that identifies the fields from tables and functions that will appear in the query results,

b. a **Compile** operation that generates and validates an executable operation,

c. a **Run** or **Do query** operation that causes execution of the query,

d. a **Show** operation that allows various presentations of a tabular result and that could be used to present a preview of the results of a query or report,

e. a **Modify** operation that allows users to make changes in the definition of an existing query or report, and

f. a **Save** operation that allows storage and repeated use or modification of a query. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.8.3.3.4 Recognizing abbreviations.** A query language should recognize both the abbreviated and the unabbreviated term. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.8.3.3.5 Search time feedback.** A query language should inform users if a search will take more than a short time to complete. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.8.3.3.6 Prompting the user.** When a search will take more than a short time to complete or will overload the computer, a query language should prompt the user to confirm, modify, or terminate the search. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.8.3.3.7 Additional operations.** A query language should provide additional operations. These include

a. a **Browse** operation that enables users to navigate through a data-base;

b. a **Report format** operation that enables users to format the results of queries as reports;

c. a **Search index** operation that enables users to view the list of words and phrases available for searching, including a link to a data-base thesaurus to suggest additional search terms;

d. a **Proximity searching** operation that enables users to search for words or terms in a positional relationship with word index fields (for example, titles or abstracts);

e. a logical search operation using the logical operators and, or, and not;

f. an iterative operation that enables users to define a search, view the results, and re-refine the search as many times as necessary;

g. an operation to specify a range of values for searching;

h. an operation to specify fields for searching;

i. an operation to specify field values for searching;

j. an operation to order field values (for example, numerically or alphabetically); and

k. an operation to search across files that enables users to obtain the number of references including the search term in all potential databases. [Source: DOE HFDG ATCCS V2.0, 1992]

8.8.3.4 Multiple levels

▫ **8.8.3.4.1 Accommodating users differing in experience.** A query language should accommodate users with different levels of experience. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.8.3.4.2 Changing levels.** Users should be able to change the level at which they interact with the language at any time during a session. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.8.3.4.3 Context-sensitive help.** Context-sensitive help should be available upon user request at all levels. [Source: DOE HFDG ATCCS V2.0, 1992]

8.8.3.5 Novice and expert users

- **8.8.3.5.1 Novice level.** At the novice level, a query language should enable a user to begin work with little or no training. [Source: DOE HFDG ATCCS V2.0, 1992]

  Discussion. A novice interface may contain only a subset of the search capabilities and fewer searchable fields, with the result that it may not attain the same specificity or variety of search techniques. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.8.3.5.2 Prompting novices.** At the novice level, a query language should prompt users to select options from lists and should provide explanations of the options. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.8.3.5.3 Commands for novices.** The command set for novices should be fewer and simpler than the command set for experts. [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.8.3.5.4 Experienced users.** When the normal user guidance techniques provided might slow experienced users, alternative modes should also be provided that allow the bypassing of these normal techniques. [Source: MIL-HDBK-761A, 1989]

- **8.8.3.5.5 Commands for experts.** A query language for experts should allow the expert users to enter more than one command at a time. [Source: DOE HFDG ATCCS V2.0, 1992]

8.9 User-initiated interrupts

8.9.1 General

- **8.9.1.1 User interruption of transactions.** A system or application shall permit a user to interrupt or terminate the current transaction. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- **8.9.1.2 Distinct interrupts.** Each type of interrupt shall have a separate control option and a distinct name. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

  Example. The following types of interrupts may be provided: **Cancel, Escape, Back, Restart, Abort, Stop, Pause-Continue,** and **Suspend.** [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- **8.9.1.3 Stored or entered data.** User interruptions shall not change or remove stored or entered data, with the exception of the **Cancel** interrupt. [Source: MIL-HDBK-761A, 1989]

- **8.9.1.4 Back (or Go-back).** A nondestructive **Back** or **Go-back** option shall be provided to return the display to the last previous transaction. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- **8.9.1.5 Cancel (or Undo).** When appropriate, a system or application shall provide a **Cancel** or **Undo** option that will erase changes just made by a user and restore the current display to its previous state. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- **8.9.1.6 Undo.** The **Undo** command shall be used to reverse the effect of the user's previous operation. [Source: Apple Computer Inc., 1992]

- **8.9.1.7 Reversing Undo.** The user shall be able to reverse the effect of the last **Undo** command either by selecting the **Undo** command a second time or selecting a **Redo** command. [Source: Apple Computer Inc., 1992]

- **8.9.1.8 End, Exit, or Stop.** When appropriate, a system or application shall provide an **End, Exit,** or **Stop** option to conclude a repetitive transaction sequence. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- **8.9.1.9 Pause and Continue.** When appropriate, a system or application shall provide **Pause** and **Continue** options that will interrupt and later resume, respectively, a transaction sequence without any change to data entries or control logic for the interrupted transaction. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- **8.9.1.10 Indicating pause status.** When a **Pause** option is provided and selected, the system or application shall provide an indication that the transaction sequence has been halted. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- **8.9.1.11 Resuming paused interactions.** The system or application shall prompt the user to select **Continue** to resume the interrupted sequence. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- **8.9.1.12 Restart (or Revert).** When appropriate, a system or application shall provide a **Restart** (or **Revert**) option that will cancel entries made in a defined transaction sequence and will return the user to the beginning of the sequence. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989;MIL-STD-1801, 1987]

- **8.9.1.13 Confirming Restart interactions.** When a **Restart** will result in the loss of data or changes, the system shall require a confirming action by the user. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- **8.9.1.14 Review.** When appropriate, a system or application shall provide a nondestructive **Review** option that will return to the first display in a defined transaction sequence, permitting the user to review a sequence of entries and make necessary changes. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- **8.9.1.15 Suspend.** When appropriate, a system or application shall provide a **Suspend** option that permits a user to preserve the current state of a transaction while leaving the system and to resume the transaction at a later time. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- **8.9.1.16 Indicating suspended status.** When a system or application provides a **Suspend** option, it shall display an indication that a transaction has been suspended whenever the option has been selected. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- **8.9.1.17 Resuming suspended transactions.** The system shall prompt the user with information on how to resume the suspended transaction at his or her next log on. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

  Example. The user might see: "Type **Exit** to return to application." [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

8.9.2 Freeze frame

- □ **8.9.2.1. Freezing changing data.** Applications in which displayed data are changed automatically should allow users to freeze the display temporarily. [Source: MIL-HDBK-761A, 1989]

- ■ **8.9.2.2 Labeling a frozen display.** When a display is frozen, its frozen status shall be clearly indicated. [Source: MIL-HDBK-761A, 1989]

- □ **8.9.2.3 Notification of changes while display is frozen.** Users should be notified of any significant changes that occur while a display is frozen. [Source: MIL-HDBK-761A, 1989]

- ■ **8.9.2.4 Unfreezing a display.** Unless specified otherwise by the user, when a frozen display is released from its frozen state, it shall indicate conditions at the time of release, not the time it was frozen. [Source: MIL-HDBK-761A, 1989]

8.10 File management functions

8.10.1 General

- ■ **8.10.1.1 Saving and retrieving graphic data.** An easy means shall be provided for saving and retrieving data. [Source: MIL-HDBK-761A, 1989]

- ■ **8.10.1.2 Stored files.** Users shall be able to specify names for storing text or graphic data files and be able to view lists of these stored files. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.10.1.3 Saving to a data file.** The user should be able to save the information entered into a file by a single action that will permit the user to continue interacting with the file. [Source: Nuclear Regulatory Commission (NUREG-0700), 1996]

- ▪ **8.10.1.4 Protection against exiting a file without saving.** The user shall be prompted to save the file contents when exiting a file. [Source: NUREG-0700, 1996]

- ▫ **8.10.1.5 Recovery of file.** Information from a file that has been modified and stored with the "save" action should be retrievable with a single action. [Source: NUREG-0700, 1996]

- ▫ **8.10.1.6 Automatic saving of a file.** The system should provide the capability to automatically save a file at frequent intervals during the editing process. [Source: NUREG-0700, 1996]

- ▫ **8.10.1.7 Automatic backup.** Users should have the option of invoking an automatic backup function that retains previous versions of files. [Source: NUREG-0700, 1996]

8.10.2 Clipboard

- ▫ **8.10.2.1 Automatic placement of cut data in buffer.** When selected data are cut or copied from a text file, tabular file, and/or graphics file and placed in a temporary editing buffer, the data should be placed in the buffer automatically, with the only specific action required by the user being the cut or copy action. [Source: NUREG-0700, 1996]

- ▫ **8.10.2.2 Contents of temporary buffer.** The contents of the temporary buffer should remain intact after the application from which the contents were taken is closed. [Source: NUREG-0700, 1996]

- ▫ **8.10.2.3 Default condition of buffer.** The default condition should be that additions to the temporary editing buffer are not cumulative. [Source: NUREG-0700, 1996]

- ▫ **8.10.2.4 Access to contents of temporary buffer.** The user should be able to access the contents of the temporary editing buffer in a window with a single action. [Source: NUREG-07001996]

- ▪ **8.10.2.5 Clipboard.** The clipboard shall be used to transfer data among compatible applications and desk accessories. [Source: Apple Computer Inc., 1992]

- ▪ **8.10.2.6 Showing clipboard contents.** The application shall show the contents of the clipboard in a window. [Source: Apple Computer Inc., 1992]

- ▪ **8.10.2.7 Viewable contents.** The contents of the clipboard shall be viewable but not editable while they are on the clipboard. [Source: Apple Computer Inc., 1992]

8.10.3 File management commands

- **8.10.3.1 New.** A **NEW** command should be provided to allow the user to open a new file. [Source: Apple Computer Inc., 1992]

- **8.10.3.2 Open.** An **OPEN** command should be provided to open an existing file. [Source: Apple Computer Inc., 1992]

- **8.10.3.3 Print.** The user should be able to initiate a process for printing the contents of a file. [Source: Apple Computer Inc., 1992]

- **8.10.3.4 Revert.** A **REVERT** command should be provided allowing the user to replace the current file with the version that was most recently saved. [Source: Apple Computer Inc., 1992]

- **8.10.3.5 Save.** A **SAVE** command should be provided allowing the user to save a file to a storage device under the same file name and prompt the user to provide a name if the file does not have one. [Source: Apple Computer Inc., 1992]

- **8.10.3.6 Save as.** A **SAVE AS** command should be provided allowing the user to save a copy of a file under a new name and prompt the user for the new name. [Source: Apple Computer Inc., 1992]

- **8.10.3.7 Copy.** The user should have the ability to create a copy of a file. [Source: Apple Computer Inc., 1992]

- **8.10.3.8 Delete.** The user should be able to delete a file from a storage device. [Source: Microsoft Corp., 1992]

- **8.10.3.9 Confirmation of delete request.** The application should request confirmation prior to deletion of the file. [Source: Apple Computer Inc., 1992]

- **8.10.3.10 Archive.** The user should be given the ability to create a backup copy of a file. [Source: Apple Computer Inc., 1992]

- **8.10.3.11 Close.** The user should be able to close a file. [Source: Apple Computer Inc., 1992]

- **8.10.3.12 Confirmation of close request.** The application should request confirmation and allow the user to save the changes when there are unsaved changes that have been made to the file that is being closed. [Source: Apple Computer Inc., 1992]

8.11 Selection methods

8.11.1 Selection options

- **8.11.1.1 Selecting data.** Applications should provide a means for the user to select data. [Source: Microsoft Corp., 1992]

- **8.11.1.2 Selecting single or multiple items.** Users should be able to select single or multiple items. [Source: Microsoft Corp., 1992]

8.11.2 Highlighting

- ▫ **8.11.2.1 Highlighting to indicate selections.** When text is selected, it should appear highlighted. [Source: Microsoft Corp., 1992]

  Discussion. The appearance of highlighted text will vary according to system specifications and the type of display used. [Source: Microsoft Corp., 1992]

- ▫ **8.11.2.2 Highlighting on monochrome displays.** Reverse video should be used to indicate selected data on monochrome displays. [Source: Microsoft Corp., 1992]

- ▫ **8.11.2.3 Highlighting on gray-scale displays.** The selection should be marked with a shade of gray on gray-scale displays. [Source: Microsoft Corp., 1992]

- ▫ **8.11.2.4 Highlighting on color displays.** A highlight color should be used on color displays. [Source: Microsoft Corp., 1992]

- ▫ **8.11.2.5 Highlighting graphics.** Graphics should be highlighted in the same way as text by the addition of rectangles with resizing handles or by a combination thereof. [Source: Microsoft Corp., 1992]

- ▫ **8.11.2.6 Highlighting text in dialog boxes.** The same methods used in data windows should be used to highlight text in dialog boxes. [Source: Microsoft Corp., 1992]

- ▫ **8.11.2.7 Highlighting toolboxes and 3D buttons.** For 3D buttons such as toolboxes, the depressed button graphic should be used to indicate selection. [Source: Microsoft Corp., 1992]

- ▫ **8.11.2.8 Highlighting value set controls.** An outline frame in the highlight color should surround the chosen value for value set controls that do not contain 3D buttons. [Source: Microsoft Corp., 1992]

- ▪ **8.11.2.9 Highlighting critical information.** Critical information in user guidance shall be highlighted using the same methods used to highlight critical information in other types of data display. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.11.2.10 Leaving selections highlighted.** A selection should remain highlighted in an inactive window only when it is useful to the user. [Source: Microsoft Corp., 1992]

- ▪ **8.11.2.11 Active end of selection.** The active end of the selection shall be the end opposite the anchor point. [Source: Microsoft Corp., 1992]

- ▪ **8.11.2.12 Extending a selection.** The user shall extend the selection by moving the active end away from the anchor point. [Source: Microsoft Corp., 1992]

- ▪ **8.11.2.13 Shortening selections.** The user shall shorten the selection by moving the active end toward the anchor point. [Source: Microsoft Corp., 1992]

- ▪ **8.11.2.14 Insertion point.** The selection shall serve as an insertion point when the active end reaches the anchor point. [Source: Microsoft Corp., 1992]

- ▪ **8.11.2.15 Direction of extending selections.** The user shall be able to extend a selection in either direction from the insertion point but not in both directions simultaneously. [Source: Microsoft Corp., 1992]

- ▫ **8.11.2.16 De-selection method.** Currently selected items should be deselected if the user clicks on new data. [Source: Microsoft Corp., 1992]

- ▪ **8.11.2.17 De-selection and data.** Deselecting shall not delete the data. [Source: Microsoft Corp., 1992]

- ▫ **8.11.2.18 Deselecting groups of data**. Items in multiple (contiguous or disjoint) selections should be able to be deselected by the user singularly or as a group. [Source: Microsoft Corp., 1992]

- ▫ **8.11.2.19 Margin selection in text arrays.** In text arrays displayed in windows, users should be able to select lines, paragraphs, or entire documents by clicking in the left margin area between the left window frame and the left edge of the text. [Source: Microsoft Corp., 1992]

  Discussion. Margin selection is a convenient way to select large sections of data with a single click. In text, margin selection should be used to select lines, paragraphs, or entire documents. In data arrays, it should be used to select rows and columns. [Source: Microsoft Corp., 1992]

- ▫ **8.11.2.20 Margin selection in data arrays.** Users should be able to select columns and rows in data arrays by clicking on the row and column labels. [Source: Microsoft Corp., 1992]

- ▫ **8.11.2.21 Using outline selection for graphical objects.** The user should be able to use **outline selection** to drag an outline around an object, a set of objects, or a portion of an object while holding down a mouse button. [Source: Microsoft Corp., 1992]

- ▪ **8.11.2.22 Items selected with outline selection.** When the mouse button is released, all objects falling completely within the outline shall be selected and preexisting selections removed. [Source: Microsoft Corp., 1992]

  Definition. Outline selection is an extended form of drag selection that is particularly useful for graphical objects when normal drag selection conflicts with moving objects with the mouse. [Source: Microsoft Corp., 1992]

- ▪ **8.11.2.23 Outline selection of bitmaps.** When outline selection is used for bitmaps, only the parts of the bitmap falling within the outline shall be selected. [Source: Microsoft Corp., 1992]

- ▫ **8.11.2.24 Keyboard selection.** Keyboard selection should indicate the data that will be affected by any action the user initiates. [Source: Microsoft Corp., 1992]

- ▫ **8.11.2.25 Keyboard techniques for continuous selection.** In text-based applications, the user should be able to select a single insertion point with the keyboard by navigating to the desired location, which then becomes the new anchor point. [Source: Microsoft Corp., 1992]

- ▫ **8.11.2.26 Selecting a range of characters in a text display.** A user should be able to select a range of characters in a text display using the **SHIFT** key in conjunction with navigation keys. [Source: Microsoft Corp., 1992]

  Definition/discussion. Several keys, such as **Home, End, Page Up, Page Down**, and the arrow keys, are dedicated to keyboard navigation and thereby are called the **navigation keys**. By holding down the **SHIFT** key while pressing any navigation key (for example, **Home, End, Page Up, Page Down**, or an arrow key), the cursor moves to the location implied by the navigation key, and all characters between the anchor point and the destination are selected. The anchor point does not move. Unlike mouse navigation, keyboard navigation changes the selection unless **Scroll Lock** mode is in effect. [Source: Microsoft Corp., 1992]

- ▫ **8.11.2.27 Selection methods.** There are various selection techniques that should be used.

  a. **Selection by clicking –** To select by clicking, the user positions the pointer over the desired item and clicks the mouse button. A click refers to pressing and releasing a particular button on the mouse input device. Depending on the software and platform being used, selection may require a single or a double click.

  b. **Selection by dragging –** To select by dragging, the user drags the cursor over a range of items while holding down the mouse button.

  c. **Changing a selection with command-click -** To make discontinuous selection in a text or array application, the user selects the first item in the usual manner and holds down the command key while selecting the remaining items.

  Discussion. Each item is selected in the same manner as if it were the whole selection, but because the command key is held down, the new items are added to the existing selection instead of replacing it. If one of the pieces selected with command-click is already within an existing part of the selection, the item is removed from the selection. [Source: Apple Computer Inc., 1992]

8.12 Transaction options

8.12.1 General

▪ **8.12.1.1 User-specified transaction timing.** When appropriate to task requirements, users shall be able to specify transaction timing. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989;MIL-STD-1801, 1987]

> **Example.** Users might be able to specify when a transaction starts, when it is completed, and the periodic scheduling of repeated transactions. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989;MIL-STD-1801, 1987]

▪ **8.12.1.2 User-memory load.** The number of mnemonics, codes, special or long sequences, and special instructions that users may need to learn shall be minimized. [Source: MIL-HDBK-761A, 1989]

▪ **8.12.1.3 Number of characters for codes.** When the user must recall alphanumeric codes, the codes shall be limited to five characters. [Source: CTA, 1996]

▫ **8.12.1.4 Control entries distinguishable from text.** Control entries that are displayed in text (for example, paragraph indentation symbols and printer commands such as begin and end underline) should be distinguishable from the main text. [Source: MIL-HDBK-761A, 1989]

▪ **8.12.1.5 Prompting control entries.** The system or application shall provide the user whatever information is required to guide control entries. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

> **Examples.** Prompts may be incorporated into a display at any point in a transaction sequence that will be helpful, or prompts may appear in response to a request for help. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

▪ **8.12.1.6 Consistent control prompting.** When prompts are used to guide the user in making control entries, the selected prompts shall be used consistently. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

▪ **8.12.1.7 List of basic control options.** A list of basic control options that are always available to a user shall be easily displayable. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

> **Discussion.** This list can serve as a "home base" or starting point for control entries. An example is the system-level menu. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

▫ **8.12.1.8 Appropriate specific options.** A list of the control options that are specifically appropriate for a particular transaction should be displayed in the working display or by user command. [Source: MIL-HDBK-761A, 1989]

▫ **8.12.1.9 Option wording.** The wording of control options should be task oriented, reflecting a user's view of the current transaction. [Source: MIL-HDBK-761A, 1989]

> **Example.** When users use the term "assign," the control option should also be **Assign**. [Source: MIL-HDBK-761A, 1989]

▫ **8.12.1.10 Option presentation.** The items presented in a list of basic options should be grouped, labeled, and ordered according to logical function, sequence, frequency, or criticality of use. [Source: MIL-HDBK-761A, 1989]

▪ **8.12.1.11 Option code display.** When users must select options by entering codes, the code associated with each option shall be displayed in a consistent manner and shall be distinct from other codes. [Source: DOE HFDG ATCCS V2.0, 1992]

▪ **8.12.1.12 Displaying control defaults.** When control is accomplished by keyed command or option code entries and a default entry is defined, the default shall be displayed to the user. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

▪ **8.12.1.13 Initial cursor position for pointing devices.** When a user must select among displayed options using a pointing device, the cursor shall be placed on the default option when the display appears. [Source: DOE HFDG ATCCS V2.0, 1992]

> **Definition.** A **cursor** is a marker on the display screen that indicates the position where the computer expects the next input or will display the next output. The cursor may be positioned by the computer or by the user. [Source: DOE HFDG ATCCS V2.0, 1992]

▪ **8.12.1.14 Initial cursor position for keyboards.** When a user must select among displayed options using a keyboard, the cursor shall be placed on the default option in the control entry area (with that control entry area having implicit input focus) when the display appears. [Source: DOE HFDG ATCCS V2.0, 1992]

▪ **8.12.1.15 Consistent continue option.** At any step in a defined sequence of transactions, if there is only a single appropriate next step, the system or application shall provide a consistent control option. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

▪ **8.12.1.16 Control option for signaling data entry.** When data entry is involved, an explicit **Enter** or **Tab** control option signaling entry shall be used rather than a **Continue** or **Next** action. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

▫ **8.12.1.17 Dead-end transactions.** A transaction should never leave a user without further available options. [Source: MIL-HDBK-761A, 1989]

▫ **8.12.1.18 Options at completion of a transaction.** A transaction should provide next steps or alternatives (for example, **Continue, Abort,** or **Go to main directory**) at the end of a transaction. [Source: MIL-HDBK-761A, 1989]

8.12.2 Stacked commands

▫ **8.12.2.1 Command stacking.** A system or application should permit but not require a user to enter a sequence (or stack) of command names, abbreviations, and option codes as a single stacked command. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

> **Example.** A stack of commands might execute a complete task. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

▪ **8.12.2.2 Entering stacked commands.** Stacked commands shall be entered in the same order that would be used if they were entered singly. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

▫ **8.12.2.3 Highlighting errors.** When there is an error in a stack, the system or application should highlight the point of error and prompt the user for a correct entry. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

▪ **8.12.2.4 Punctuation of stacked commands.** Required punctuation of stacked commands shall be minimized. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

▪ **8.12.2.5 Delimiters for stacked commands.** A delimiter to separate commands shall be adopted and used consistently. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

> **Example.** The slash (/) might be adopted as the delimiter, and a stacked command might be: **Sort/Save/Transmit.** [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

▫ **8.12.2.6 Intuitive delimiters.** The delimiter should be made as intuitive as possible by using an ampersand (&), a plus sign (+), or a comma (,). [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

▫ **8.12.2.7 User-defined stacks (macros).** A system or application should allow a user to define a series of graphical- or character-based control entries, assign the series a name (macro), and subsequently enter the series by simply entering the name of the macro. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- ▫ **8.12.2.8 Index of macros.** Users should have access to their macros and programmable function keys with their respective composition of commands. [Source: Nuclear Regulatory Commission, 1996]

- ▫ **8.12.2.9 Modification of defined macros.** A user should be restricted from modifying a macro or programmable function key defined or created by a different user. [Source: Nuclear Regulatory Commission, 1996]

- ▫ **8.12.2.10 No duplication of macro names.** Users should not be able to duplicate macro names. [Source: Nuclear Regulatory Commission, 1996]

8.13 Controls

8.13.1 General

- ▪ **8.13.1.1 Consistent and distinctive.** Each type of control in an application shall be consistent and visually distinct from other types of controls. [Source: DON UISNCCS, 1992]

  Example. Push buttons are consistent and distinct from radio buttons (exclusive button sets). [Source: DON UISNCCS, 1992]

- ▪ **8.13.1.2 Distinct from other objects.** Controls shall differ in appearance from other text and graphics in an application window. [Source: DON UISNCCS, 1992]

8.13.2 Display of control options

- ▪ **8.13.2.1 Control locations and options.** Screen control locations and control options shall be clearly and appropriately indicated. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.13.2.2 Default values.** When the system prompts a user for a parameter that has a default value assigned, the default value shall be displayed. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.13.2.3 Control information.** When a control for manipulating the display becomes available, information the user needs for its use shall also be displayed. [Source: MIL-HDBK-761A, 1989]

8.13.3 Icons

Visual symbols are pictorial representations that stand for or suggest something else. Visual symbols displayed on computer screens for the purpose of interacting with the system are often referred to as icons. Icons may be used to represent operations, processes, and data structures graphically, and they may be used as a means of exercising control over system functions, components, and data structures.

▫ **8.13.3.1 Design of symbols.** To the extent possible, a symbol should be an analog of the object it represents in general use and well known to the users or based on established standards or conventional meanings. [Source: MIL-HDBK-761A, 1989]

▪ **8.13.3.2 Resolution.** Iconic representation shall not be used if display resolution is low. [Source: MIL-HDBK-761A, 1989]

▪ **8.13.3.3 Description.** An icon shall consist of a graphic image and, where space permits, an identifying label. [Source: DON UISNCCS, 1992]

▪ **8.13.3.4 Icon label.** Each icon shall have a text label corresponding to the object or action, which appears adjacent to the icon shortly after the pointer focus is placed on the icon. [Source: CTA, 1996]

▪ **8.13.3.5 Obscuring label.** The icon designer shall not let the label obscure the icon. [Source: CTA, 1996]

▪ **8.13.3.6 Consistency.** When images are used to identify controls, status indicators, or other programmatic elements, the meaning assigned to those images shall be consistent throughout an application and across related applications. [Source: MIL-HDBK-761A, 1989, General Services Administration, 2000]

▫ **8.13.3.7 Icon design.** To the extent possible, icons should be simple line drawings that suggest the physical object or operation they represent. [Source: MIL-HDBK-761A, 1989]

▫ **8.13.3.8 Avoid humorous representations.** Humorous representations should be avoided in icons. [Source: MIL-HDBK-761A, 1989]

▫ **8.13.3.9 Selecting icons.** In selecting a new icon, the user should consult standard symbol sets available from the American National Standards Institute (ANSI) and other sources to find established icons that may meet the need. [Source: CTA, 1996]

- ▫ **8.13.3.10 Creating icons.** When existing icons are not satisfactory, the user should create drawings that are meaningful representations to users, easily recognizable, and visually distinct from each other. [Source: CTA, 1996]

  Examples. Icons may be designed to represent a process or operation literally (for example, a drawing of an aircraft), functionally (for example, a figure representing a network), or operationally (for example, a drawing of a pen in hand on paper). [Source: MIL-HDBK-761A, 1989]

- ▫ **8.13.3.11 Avoid abstract icons.** Abstract icons are likely to be very difficult to learn and remember and should be avoided. [Source: CTA, 1996]

- ▪ **8.13.3.12 Selectable area of an icon.** Designers shall make the selectable area of an icon large enough to reduce the risk of error and increase the user's ease in selecting the icon. [Source: Ameritech Services Inc., 1996]

- ▪ **8.13.3.13 Minimum selectable area.** The selectable area or hotspot outside of the area of the icon shall be at least 4 millimeters. [Source: Ameritech Services Inc., 1996]

  Definition. The selectable area in which a user can place the pointer and successfully select an icon is often called the **hot spot**. [Source: Ameritech Services Inc., 1996]

- ▪ **8.13.3.14 Icon spacing.** Icons shall be positioned at least 10 millimeters apart from each other, as measured from perimeter to perimeter. [Source: Ameritech Services Inc., 1996]

- ▫ **8.13.3.15 Manipulation of icons.** When direct manipulation interaction is used, the system or application should use a pointing device as the primary means of manipulation. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.13.3.16 Upright orientation.** Icons and symbols should always be oriented "upright." [Source: Nuclear Regulatory Commission, 1996]

- ▫ **8.13.3.17 User preferences.** Users should have the option of changing the default location of icons. [Source: DON UISNCCS, 1992]

- ▫ **8.13.3.18 Retaining user preferences.** User-selected locations for icons should be retained across sessions. [Source: DON UISNCCS, 1992]

- ▫ **8.13.3.19 Moving icons.** Users should be able to move icons using similar methods available for moving windows. [Source: DON UISNCCS, 1992]

- ▫ **8.13.3.20 Number of icons.** Designers should display fewer than 20 icons simultaneously on the same screen. [Source: CTA, 1996]

- ▫ **8.13.3.21 Grouping icons.** Icons should be grouped according to similar shapes and colors that depict a common relationship. [Source: CTA, 1996]

- ▫ **8.13.3.22 Icon highlighting.** Icons selected by the user should be highlighted. [Source: CTA, 1996]

- ▪ **8.13.3.23 Icon documentation.** A glossary shall be provided in on-line help containing a list of standard icons and their associated objects and actions. [Source: CTA, 1996]

- ▫ **8.13.3.24 Testing icons.** Prior to implementation, icons should be tested for effectiveness and acceptability with a representative user group. [Source: CTA, 1996]

- ▫ **8.13.3.25 Action icons.** When a window includes action icons, they should be arranged along the left margin of the window. [Source: DON UISNCCS, 1992]

- ▫ **8.13.3.26 Number of action icons.** The number of action icons in a window should not exceed 20. [Source: DON UISNCCS, 1992]

- ▪ **8.13.3.27 Action icons bound to window.** When a window includes action icons, a user shall not be able to move the icons outside the window. [Source: DON UISNCCS, 1992]

8.13.4 Palettes

Lists and palettes are both effective ways of allowing users to access options. Palettes can be used in selection operations involving icons, patterns, colors, characters, or drawings. They allow the user to select an action or attribute from a group of icons fixed in a window. Palettes can be fixed or floating. [Source: Ameritech Services Inc., 1996]

- ▫ **8.13.4.1 Use of floating palettes.** Floating palettes should be used when the attributes on the palette are utilized frequently at specific times and infrequently at others. [Source: Ameritech Services Inc., 1996]

- ▫ **8.13.4.2 Floating palettes.** Floating palettes should be available through the application menus. [Source: Ameritech Services Inc., 1996]

- ▫ **8.13.4.3 Moving floating palettes.** The user should be able to move selected floating palettes to other areas on the screen. [Source: Ameritech Services Inc., 1996]

- ▫ **8.13.4.4 Visual feedback.** Visual feedback for the current palette selection should be provided. [Source: Apple Computer Inc., 1992]

- ▫ **8.13.4.5 Tool palette.** In a palette that contains tools, the selected tool should be highlighted. [Source: Apple Computer Inc., 1992]

- ▫ **8.13.4.6 Pattern or color palettes.** In a palette that contains patterns or colors, the currently selected item should be outlined and include a preview area that shows the effect of the current selection. [Source: Apple Computer Inc., 1992]

- **8.13.4.7 Selection indicator.** When the user clicks on a new palette item, the selection indicator should change to show the new item. [Source: Apple Computer Inc., 1992]

- **8.13.4.8 Tracking feedback.** As a user drags the cursor over the items in a palette, each item should be highlighted or outlined. [Source: Apple Computer Inc., 1992]

- **8.13.4.9 Active items.** Only one item in a palette should be active at a time. [Source: Apple Computer Inc., 1992]

- **8.13.4.10 Fixed palettes.** Fixed palettes should be permanently placed in an application environment when the attributes on the palette will be accessed frequently. [Source: Ameritech Services Inc., 1996]

- **8.13.4.11 Fixed palette location.** Fixed palettes should be placed on the left side of the application window or along the top of the window under the title bar. [Source: Apple Computer Inc., 1992]

  Discussion. These positions keep the palette from interfering with standard window controls. [Source: Apple Computer Inc., 1992]

8.13.5 Push buttons

This section presents rules on push buttons (also referred to as command buttons) for general use. For specific information on the use of push buttons in windows, see the Windows section (Section 8.14).

- **8.13.5.1 Consistent appearance.** All push buttons in a window should have the same size and shape. [Source: DON UISNCCS, 1992]

- **8.13.5.2 Minimum push button size.** The size should accommodate the largest label. [Source: DON UISNCCS, 1992]

- **8.13.5.3 Labels.** A push button shall have either a text or graphic label. [Source: DON UISNCCS, 1992]

- **8.13.5.4 Consistent labels.** Push button labels shall be consistent throughout an application and related applications. [Source: DON UISNCCS, 1992]

- **8.13.5.5 Text label length.** Push button labels should be short and unambiguous. [Source: DON UISNCCS, 1992]

- **8.13.5.6 Push button label.** The push button label should describe the results of pressing the button and reflect the action that will be taken by the application rather than the user. [Source: DON UISNCCS, 1992]

- **8.13.5.7 Activating a push button.** A user shall be able to activate a push button by moving the pointer onto the button and pressing the appropriate pointer button. [Source: DON UISNCCS, 1992]

- ▪ **8.13.5.8 Activated push buttons.** The push button shall be highlighted while the pointer button is depressed. [Source: DON UISNCCS, 1992]

- ▪ **8.13.5.9 Activating controls using push buttons.** The control shall be activated when the pointer button is released, and the push button is reverted to its normal appearance. [Source: DON UISNCCS, 1992]

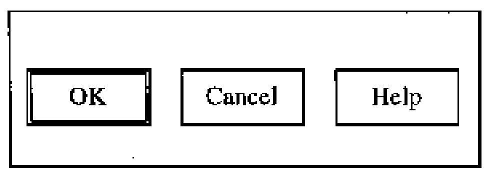
- ▪ **8.13.5.10 Activating buttons using the keyboard.** A user shall be able to activate a push button using the keyboard. [Source: DON UISNCCS, 1992]

- □ **8.13.5.11 Information prior to push button action.** When the user must supply additional information before the system can carry out a push button action, the designer should provide ellipses (…) after the push button caption to indicate that a dialog box (or control window) will be presented. [Source: CTA, 1996]

- ▪ **8.13.5.12 Default push buttons.** Default push buttons shall be clearly distinguishable from the other push buttons. [Source: DON UISNCCS, 1992]

  Example. They may have an extra border as illustrated in Exhibit 8.13.5.12, be highlighted, or appear three-dimensional. [Source: DON UISNCCS, 1992]

Exhibit 8.13.5.12 Example of a default push button.



8.13.6 Radio buttons

Definition. Radio buttons (also known as **exclusive buttons** or **option buttons**) are single, two-state choices, which are mutually exclusive from each other. [Source: Ameritech Services Inc., 1996]

- ▪ **8.13.6.1 When to use.** Radio buttons shall be used if it is required that one and only one of a set of mutually exclusive options be selected. [Source: DON UISNCCS, 1992]

- ▪ **8.13.6.2 Number of radio buttons.** An individual radio button shall always be part of a mutually exclusive group of two or more radio buttons. [Source: Microsoft Corp., 1992]

- ▪ **8.13.6.3 Selecting a radio button inactivates other radio buttons.** A radio button that is active shall cause all of the other radio buttons in its group to be inactive. [Source: Ameritech Services Inc., 1996]

- ■ **8.13.6.4 Selecting a radio button using a pointing device.** A user shall be able to select a radio button using a pointing device by moving the pointer onto the radio button and clicking the appropriate device button. [Source: DON UISNCCS, 1992]

- ■ **8.13.6.5 Selecting a radio button using the keyboard.** A user shall be able to select a radio button using the keyboard by moving a location cursor to the desired button (for example, using the arrow keys) and pressing the **Enter** key. [Source: DON UISNCCS, 1992]

- ■ **8.13.6.6 Exclusive selection.** Selecting one radio button item shall deselect any other radio button in its group previously selected. [Source: Ameritech Services Inc., 1996]

- □ **8.13.6.7 Identifying a set of radio buttons.** A box should be drawn around a group of radio buttons to visually separate the group from other interface features. [Source: Ameritech Services Inc., 1996]

- ■ **8.13.6.8 Selected button highlighted.** Selecting a button that is already highlighted shall not change its state. [Source: DON UISNCCS, 1992]

- ■ **8.13.6.9 Radio button labels.** Labels shall be provided for each set of radio buttons. [Source: CTA, 1996]

- ■ **8.13.6.10 Labeling individual radio buttons.** Radio buttons and labels shall be left justified in the columnar format. [Source: CTA, 1996]

- ■ **8.13.6.11 Labeling single panels of radio buttons.** When a screen or window contains only one panel of radio buttons, the screen or window title shall serve as the panel label. [Source: CTA, 1996]

- ■ **8.13.6.12 Selection area.** The selection target area for radio buttons shall include the radio button and its label. [Source: CTA, 1996]

- ■ **8.13.6.13 Moving a cursor to an option.** Moving the cursor to an option shall highlight the label by reverse video, reverse color, or a dashed box around the label. [Source: CTA, 1996]

- ■ **8.13.6.14 Sets of radio buttons.** Radio button sets shall contain from two to seven items, but the user shall always have at least two radio buttons in each set. [Source: Apple Computer Inc., 1992]

  Discussion. When 9 or more options must be presented, consider using a scrollable list or a drop-down list instead of radio buttons. [Source: CTA, 1996]

- □ **8.13.6.15 Unavailable options.** When a particular option is not available, it should be displayed as subdued or grayed-out in relation to the brightness of the available options. [Source: CTA, 1996]

8.13.7 Check boxes

Check boxes (also known as nonexclusive buttons) are single, two-state choices. For example, a check box can be on, (checked) or off (not checked). A check box group is a collection of two-state choices, all of which apply to the same selected object. Check boxes can be grouped. [Source: Microsoft Corp., 1992]

▪ **8.13.7.1 When to use.** Check boxes shall be provided if a user must be able to select any number, including none, of a set of options. [Source: DON UISNCCS, 1992]

> **Example.** In specifying the appearance of text, a user might want to select both **Bold** and **Italic**. [Source: DON UISNCCS, 1992]

▪ **8.13.7.2 Effect of activating a check box.** A check box that is activated shall not change the status of any other choice in the group. [Source: DON UISNCCS, 1992]

▪ **8.13.7.3 Selecting check boxes.** Users shall be able to toggle selected and unselected states on a check box using either a pointing device or the keyboard. [Source: DON UISNCCS, 1992]

▪ **8.13.7.4 Check box states.** Check boxes shall have two states, selected and unselected. [Source: DON UISNCCS, 1992]

▪ **8.13.7.5 Labeling check boxes.** Labels shall be provided for each set of check boxes. [Source: CTA, 1996]

▫ **8.13.7.6 Consistent labeling.** Label style and orientation for check boxes should remain consistent for groups of check boxes within an application and across related applications. [Source: CTA, 1996]

▪ **8.13.7.7 Arrangement of check boxes.** Check boxes shall be arranged in logical order so that the most frequently used boxes are at the top or at the left, depending on how the boxes are oriented. [Source: CTA, 1996]

▫ **8.13.7.8 Alignment of check boxes.** Check boxes should have a columnar orientation with the boxes aligned to the left. [Source: CTA, 1996]

▪ **8.13.7.9 Alignment of check boxes when space is limited.** When there is limited space, a horizontal orientation shall be used with adequate separation (three spaces) between each box. [Source: CTA, 1996]

▪ **8.13.7.10 Check box height and width.** When grouping check boxes, the boxes shall be equal in height and width. [Source: CTA, 1996]

8.13.8 List boxes

8.13.8.1 General

A **list box** presents lists of choices in a dialog box.

- **8.13.8.1.1 When to use.** List boxes should be used when choices are displayed for the user. [Source: Microsoft Corp., 1992]

- **8.13.8.1.2 Long lists in list boxes.** Long lists in list boxes should be accompanied by scrolling capability. [Source: Microsoft Corp., 1992]

- **8.13.8.1.3 Inactive list boxes.** The label and list items for an inactive list box should be dimmed. [Source: Microsoft Corp., 1992]

- **8.13.8.1.4 Standard single-selection list boxes.** Standard list boxes should always remain the same size. [Source: Microsoft Corp., 1992]

- **8.13.8.1.5 List box height.** The list box should be high enough to accommodate three to eight list items if possible within the height of a dialog box. [Source: Microsoft Corp., 1992]

- **8.13.8.1.6 List box width.** A list box should be a few spaces wider than the average width of the items in the list. [Source: Microsoft Corp., 1992]

- **8.13.8.1.7 Items too wide for list box.** When an item is too wide for the list in a list box, a horizontal scroll-bar should be placed at the bottom of the list. [Source: Microsoft Corp., 1992]

8.13.8.2 Drop-down list boxes

- **8.13.8.2.1 Drop-down list box.** A drop-down list box should have a fixed width. [Source: Microsoft Corp., 1992]

- **8.13.8.2.2 Drop-down list height when closed.** A drop-down list should be only tall enough to show one item when closed. [Source: Microsoft Corp., 1992]

- **8.13.8.2.3 Drop-down list when open.** The height of an opened drop-down list should be enough to accommodate three to eight items. [Source: Microsoft Corp., 1992]

- **8.13.8.2.4 Drop-down list with more than eight items.** Drop-down lists containing nine or more items should have a vertical scroll-bar. [Source: Microsoft Corp., 1992]

- **8.13.8.2.5 Extended-selection list boxes.** Extended-selection lists should be used when the user might select more than one list entry at a time from a list in which related items are contiguous. [Source: Microsoft Corp., 1992]

▫ **8.13.8.2.6 Multiple-selection list boxes.** Multiple-selection lists should be used when users might select several entries at a time from a list in which related items are not contiguous. [Source: Microsoft Corp., 1992]

> **Discussion.** Multiple-selection lists are optimized for disjoint selection, whereas extended-selection lists provide easy range selection. [Source: Microsoft Corp., 1992]

▫ **8.13.8.2.7 Text boxes.** The user should be able to accept, edit, delete, or replace the current text in a text box. [Source: Microsoft Corp., 1992]

> **Definition. Text boxes** are edit controls into which the user types information. Most text boxes are one line tall, but applications can also use multi-line text boxes. [Source: Microsoft Corp., 1992]

▫ **8.13.8.2.8 Entering characters in the text box.** The system should allow the user to enter characters in a text box by pressing character keys. [Source: Microsoft Corp., 1992]
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▫ **8.13.8.2.9 Multi-line text boxes.** Data in a multi-line text box that are too wide to fit on a single line should wrap to the following line. [Source: Microsoft Corp., 1992]

▫ **8.13.8.2.10 Combo boxes.** Combo boxes should be used when the user needs to be able to either select one of the displayed responses or enter a new response. [Source: Microsoft Corp., 1992]

> **Definition.** A **combo box** is a special type of text box with an attached list of options. Combo boxes allow the user to either select from the given list or type in an alternative response. There are two types of combo boxes, standard and drop-down. [Source: Microsoft Corp., 1992]

▫ **8.13.8.2.11 Typing options into combo boxes.** A combo box should allow the user to enter a response if the desired option is not displayed in the list. [Source: Microsoft Corp., 1992]

> **Definition. Standard combo boxes** include a text box and a standard list. [Source: Microsoft Corp., 1992]

▪ **8.13.8.2.12 Scroll-bar on combo box list.** The scroll-bar shall only be used on a combo box list if the list is expected to display more entries than can be shown at one time. [Source: Microsoft Corp., 1992]

▫ **8.13.8.2.13 Ordering items in combo boxes.** List entries should be organized in alphabetical order unless an application requires a different organization. [Source: Microsoft Corp., 1992]

▫ **8.13.8.2.14 Moving the selection in the list.** A user should be able to move up and down the list of a combo box with input focus by using the up and down arrow keys. [Source: Microsoft Corp., 1992]

- **8.13.8.2.15 Moving left and right in an edit field.** The user should be able to move the cursor left or right in the edit field of the combo box by using the left or right arrow keys. [Source: Microsoft Corp., 1992]

- **8.13.8.2.16 Drop-down combo boxes.** Drop-down combo boxes should be used instead of standard combo boxes when the space is limited. [Source: Microsoft Corp., 1992]

  Definition. A **drop-down combo box** consists of a text box, a down arrow button, and a drop-down list. [Source: Microsoft Corp., 1992]

- **8.13.8.2.17 Width of drop-down combo box.** The list segment of an open drop-down combo box should extend to the right border of the down arrow button. [Source: Microsoft Corp., 1992]

- **8.13.8.2.18 Spin box options.** A spin box should be used for a limited set of discrete, ordered options and to display values that consist of several subcomponents. [Source: Microsoft Corp., 1992]

  Definition. A **spin box** (also known as a **spin button**) is a variation of the scrolling menu or list. Spin boxes are specialized text boxes that accept only a limited set of discrete, ordered input values. A spin box includes a text box with a pair of arrows attached to the right side of the text box that allow a user to display a sequence of mutually exclusive choices, for example, months of the year. [Source: Ameritech Services Inc., 1996]

- **8.13.8.2.19 Entering values into spin boxes.** The spin box should allow the user to enter a new value into the text box that is not available presently as one of the options. [Source: Microsoft Corp., 1992]

- **8.13.8.2.20 Increasing and decreasing spin box values.** The user should be able to increase the value in a spin box by clicking the **UP ARROW** key or decrease the value by clicking the **DOWN ARROW** key. [Source: Microsoft Corp., 1992]

- **8.13.8.2.21 Arrows on a spin box.** Spin box arrows should operate like scroll-bar arrows for a concealed descending list. [Source: Microsoft Corp., 1992]

8.13.9 Special graphical controls

A graphic control allows for a simple interpretation of what the control represents and how it works. Specially designed graphics maintain this idea with each graphic being unique in appearance and function. A specialized graphic clearly represents an actual physical object and is only used when it is less complicated than other options offered by the application. Examples of graphical controls include sliders, volume knobs, color wheels, and color sliders. [Source: Ameritech Services Inc., 1996]

□ **8.13.9.1 When to use sliders.** Sliders are appropriate and should be used when users must set a value within a fixed range and the precise value is less important than relative position. [Source: Open Look (GUIASG), 1990]

Definition. A **slider** is a control used to set a value and give a visual indication of the setting. [Source: GUIASG, 1990]

Example. Sliders can be used when setting the volume level of a tone signal. [Source: GUIASG, 1990]

■ **8.13.9.2 Components of a slider.** A slider shall have a movable marker that indicates the current setting and a line or rectangular area along which it moves. [Source: DON UISNCCS, 1992]

Discussion. Tick marks and numeric values may be added to the line or rectangular area of the slider. [Source: DON UISNCCS, 1992]

□ **8.13.9.3 Readout.** When appropriate, the slider should provide a numerical readout of the current setting. [Source: DON UISNCCS, 1992]

■ **8.13.9.4 Slider operation.** Users shall be able to change the setting of a slider by moving the pointer onto the marker and dragging it. [Source: DON UISNCCS, 1992]

■ **8.13.9.5 Labeling sliders.** A slider shall have a label or title that indicates the purpose of the slider. [Source: DON UISNCCS, 1992]

8.13.10 Cursors

8.13.10.1 General

■ **8.13.10.1.1 Multiple cursors.** Multiple cursors shall be avoided unless needed for user tasks. [Source: MIL-HDBK-761A, 1989]

■ **8.13.10.1.2 Distinguishing cursors.** When more than one cursor is provided, each shall be easily distinguishable from the other(s), with the status of each (active or inactive) being easily distinguishable. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.13.10.1.3 Cursor movement.** When entering and editing text, users shall be able to move the cursor freely within a displayed page to specify items for change and to make changes directly in the text. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.13.10.1.4 Enhanced cursor movement.** As applicable, users should be able to move the cursor by units of character, line, and page. [Source: MIL-HDBK-761A, 1989]

8.13.10.2 Text cursor

- ▪ **8.13.10.2.1 Text cursor.** The text cursor shall be an I-beam in insert mode and a box over a character in replace mode. [Source: DON UISNCCS, 1992]

- ▪ **8.13.10.2.2 Text cursor height.** The height of an I-beam text cursor shall be the same as that of the adjacent text character. [Source: Nuclear Regulatory Commission, 1996]

- ▪ **8.13.10.2.3 Text cursor flash rate.** The text cursor shall flash at a rate between 2 and 5 Hz. [Source: DON UISNCCS, 1992]

  Discussion. A blink rate of 2 to 3 Hz with a 50% duty cycle is preferred. With a 50% duty cycle, the cursor would be ON half the time and OFF half the time. In some systems, users are allowed to set the blink rate for a location cursor through window management functions.

- ▪ **8.13.10.2.4 Avoiding flashing-induced seizures.** Flash or display refresh rate shall not be within the 15-20 Hz range. [Source: Vanderheiden & Vanderheiden, 1991]

  Discussion. People who are sensitive to seizures may have seizures induced by flashing screen cursors or by flickering displays, particularly near the 15-20 Hz range. Therefore, flicker or refresh rates should be as far above or below this range as possible or practical. [Source: Vanderheiden & Vanderheiden, 1991]

- ▪ **8.13.10.2.5 Lost input focus.** When the text object containing the text cursor loses input focus, the cursor shall stop flashing. [Source: DON UISNCCS, 1992; Ameritech Services Inc., 1996]

- ▪ **8.13.10.2.6 Regained text object input focus.** When the text object regains input focus, the cursor shall return to normal brightness and resume flashing. [Source: Ameritech Services Inc., 1996; DON UISNCCS, 1992]

  Discussion. Input focus means that the indicated location, window, or object in the text field is currently active. Unless the user changes this active state, that will be the object or location that will be acted upon by the next text editing or entry transaction. [Source: DON UISNCCS, 1992; Ameritech Services Inc., 1996]

- ▪ **8.13.10.2.7 Text cursor location.** When a window first receives input focus, the text cursor shall be placed in the text area where typing is most likely to occur. [Source: DON UISNCCS, 1992]

- ▪ **8.13.10.2.8 Regaining window input focus.** When the cursor disappears from view when its window loses focus, the cursor shall reappear at the same location when the window regains focus. [Source: DON UISNCCS, 1992]

- ▪ **8.13.10.2.9 Input device for moving the text cursor.** Users shall be able to move the text cursor within and among text entry areas using both the pointing device and the keyboard. [Source: DON UISNCCS, 1992]

- ▫ **8.13.10.2.10 Cursor home position for common work area.** The home position for the cursor should be consistent across similar types of displays in a common work area. [Source: Department of Defense, 1996]

- ▪ **8.13.10.2.11 Text cursor display.** The pointer shall change to an I-beam (text cursor) only when the pointer moves into an area in which text entry is possible. [Source: DON UISNCCS, 1992]

- ▪ **8.13.10.2.12 Moving text cursor out of text entry area.** Users shall not be able to move the text cursor into areas in which text entry is not possible. [Source: DON UISNCCS, 1992]

8.13.10.3 Graphics cursor

- ▫ **8.13.10.3.1 Graphics cursor.** The cursor for creating graphics displays should be distinctive, easy to position, and have a point that can be used to select and manipulate small graphic objects. [Source: MIL-HDBK-761A, 1989]

8.13.10.4 Cursor as a status indicator

Changing the shape of the cursor is one way that an application might indicate the current status when an operation in progress takes more than 2 or 3 seconds to complete and the user cannot continue working in that application until the operation finishes. [Source Microsoft Corp., 1992]

- ▫ **8.13.10.4.1 Distinctiveness of cursor as status indicator.** A cursor used as a status indicator should be distinct from the normal cursor. [Source Microsoft Corp., 1992]

- ▫ **8.13.10.4.2 Reverting to normal cursor in accessible windows.** When the user moves the pointer to a second, accessible window, the normal pointer for that window should appear. [Source Microsoft Corp., 1992]

- ▫ **8.13.10.4.3 Graphics cursor operation.** A graphics cursor operation should have a movement (pointing) component that positions the cursor and an activation component that activates the position to manipulate a display element (for example, selecting an object to move or drawing a line). [Source: MIL-HDBK-761A, 1989; DOE HFDG ATCCS V2.0, 1992]

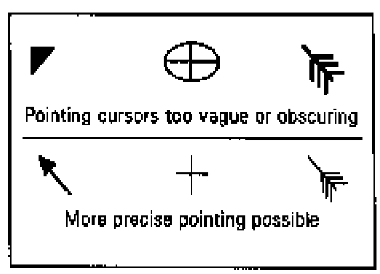
- ▪ **8.13.10.4.4 Input focus indication.** A well-defined on-screen indication of the current focus shall be provided that moves among interactive interface elements as the input focus changes. [Source: General Services Administration, 2000]

8.13.10.5 Position or pointing cursors

Position or pointing cursors are used to point to controls on a display. They may at times obscure other screen objects. The pointer cursor is often the left pointing arrow. The pointer is used to make selections and to click in menus and control buttons; to resize windows; to click, hold, and drag objects; and to click on a location to move the location cursor in text and field editing. [Source: Ameritech Services Inc., 1996]

- ▪ **8.13.10.5.1 Size.** Position or pointing cursors shall maintain their size across all screen locations during movement. [Source: Ameritech Services Inc., 1996]
- ▪ **8.13.10.5.2 Blink.** Position or pointing cursors shall not blink. [Source: Ameritech Services Inc., 1996]
- ▪ **8.13.10.5.3 Rate of movement.** Position or pointing cursors shall move rapidly in response to the pointing device (less than 100 msec). [Source: Ameritech Services Inc., 1996]
- ▫ **8.13.10.5.4 Pointer visibility.** The pointer should disappear when a user begins typing and reappear when the user stops typing or when he or she moves the pointing device. [Source: DON UISNCCS, 1992]
- ▪ **8.13.10.5.5 Movement.** Position or pointing cursors shall not move without input of the user. [Source: Ameritech Services Inc., 1996]
- ▪ **8.13.10.5.6 Hotspot.** A pointer shall have a hotspot, that is, an active point (although this active point may not be readily apparent to the user) to indicate the precise location where an operation will occur. These points are specified for a variety of pointer shapes in Exhibit 8.13.10.5.6 [Source: DOE HFDG ATCCS V2.0, 1992]

Exhibit 8.13.10.5.6 Examples of better and worse pointing cursors.



Definition. A **hotspot** for a pointer is the precise part of a screen pointer that marks the screen position where an operation on a pointing device will have an effect. [Source: DOE HFDG ATCCS V2.0, 1992]

8.13.10.6 Pointer shapes

- **8.13.10.6.1 General-purpose pointer shape.** An arrow pointing up and to the left (↖) shall be the general-purpose pointer. [Source: DOE HFDG ATCCS V2.0, 1992]

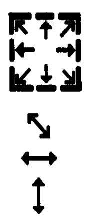
- **8.13.10.6.2 Redefining pointer shape.** An application shall redefine the shape of a pointer only when the pointer is inside an application window (including the border). [Source: DOE HFDG ATCCS V2.0, 1992]

- **8.13.10.6.3 Limit pointer shapes.** The designer shall use only those pointer shapes necessary for user understanding of the functionality. [Source: Ameritech Services Inc., 1996]

- **8.13.10.6.4 Hotspot and pointer shape.** The screen location of a hotspot shall not change if the pointer changes from one shape to another. [Source: DOE HFDG ATCCS V2.0, 1992]

- ◽ **8.13.10.6.5 When to create new pointer shapes.** When no adequate pointer shape exists, such as those depicted in Exhibit 8.13.10.6.5, a new pointer should be created. [Source: DOE HFDG ATCCS V2.0, 1992]

Exhibit 8.13.10.6.5 Pointer shapes associated with functions.

Shape	Name	Function	Hotspot
	Arrow	**Pointing.** Used in most window areas for object selection.	The point of the arrow.
	I-beam	**Pointing.** Used in text areas to position the text cursor and perform actions on text. The I-beam pointer is hidden during the time between any keyboard action and pointer movement (that is, when text entry is occurring at the location of the text cursor).	On the vertical bar of the I-beam about one-third from the top.
	Watch (or hourglass)	**Working.** Indicates that an operation is being performed in a window area. When the working pointer is displayed, all pointing device and keyboard actions are ignored in the area.	Not applicable
	Caution sign	**Caution.** Indicates that action is expected in another window area before input can be made in the current area and that the pointer has no effect in the area. When the caution pointer is displayed, all pointing device and keyboard actions are ignored in the area.	Not applicable
	Resize pointer	**Resize.** Indicates positions for area resize, with the direction of the arrow in the pointer indicating the direction of increasing size. The horizontal and vertical resize pointers indicate resize in either the horizontal or vertical direction. The diagonal resize pointers indicate resize in both the horizontal and vertical directions simultaneously. The resize pointer appears when the pointer is on the frame border.	On the corner or line at the position pointed to by the arrow.
	Move arrows	**Moving.** Indicates a move operation in progress or a resize operation before the resize direction has been determined. During a resize operation, the four-directional arrow pointer indicates a direction for resizing and changes to the appropriate resize arrow when the pointer is on the frame border.	The intersection of the arrows.
	Sight or cross	**Sighting.** Used to make fine position selections (for example, to select a location on a map display).	The intersection of the lines.

▫ **8.13.10.6.6 How to create new pointer shapes.** The new shape should be easy to see, obscure as little information as possible on the screen, have a hotspot that is obvious and easy to locate, provide a hint of its purpose, and not be easily confused with other objects on the screen. [Source: DOE HFDG ATCCS V2.0, 1992]

8.13.10.7 Location cursors

Location cursors serve to show the location of an operation on a display. The location pointer is usually an I-beam cursor in text processing or data entry.

▪ **8.13.10.7.1 Distinctive against background.** Location cursors shall be distinctive against their backgrounds. [Source: Ameritech Services Inc., 1996]

▪ **8.13.10.7.2 Obscuring characters.** Location cursors shall not obscure characters. [Source: Ameritech Services Inc., 1996]

▫ **8.13.10.7.3 Blink rate.** The blink rate for location cursors should be somewhere between 2 to 3 Hz. [Source: Ameritech Services Inc., 1996]

▫ **8.13.10.7.4 Duty cycle.** Location cursors should have a 50% (half on half off) duty cycle. [Source: Ameritech Services Inc., 1996]

8.14 Windows

This section contains rules on windows with the exception of help windows, which is presented in Section 8.16, Help.

8.14.1 General

Definitions. Windows can be either modal or modeless. A **modal** window is a window with which a user must interact before being able to interact with any other windows. That is, a user cannot interact with other windows as long as the modal window is displayed. When a window is **modeless**, a user can interact with other windows.

▪ **8.14.1.1 Hardware limitations on the use of windowing.** Windowing shall be avoided when the hardware has limitations. These limitations include

a. small screen size resulting in frequent manipulation of the screen by the user;

b. slow processing speed resulting in slow operation by the computer; or

c. low screen resolution resulting in less effective visual coding, especially for map graphics, symbols, and icons. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.14.1.2 User-specified windows.** When there is a need to view several different types of data simultaneously, the user shall be able to display and select separate windows on a single CRT screen. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.14.1.3 Number of allowable open windows.** The number of allowable open windows shall not compromise system response time. [Source: DOE HFDG ATCCS V2.0, 1992]

  Discussion. Each open window requires system resources in terms of memory and processing speed. A limit on the maximum number of windows that can be effectively opened for each system needs to be predetermined. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.14.1.4 Window size.** Windows should be large enough to: present all relevant information for the task, not obscure important information, not cause crowding or visual confusion, and minimize the need for scrolling. [Source: National Air Traffic Services, 1999]

- ▫ **8.14.1.5 Window default size.** The default size of the window should be less than the full size of the entire screen. [Source: National Air Traffic Services, 1999]

- ▪ **8.14.1.6 Window default location.** Each window shall have a default location at which the window appears when it is first opened. [Source: DON UISNCCS, 1992]

- ▫ **8.14.1.7 Minimum window size for text.** Windows used to present text should be at least 12 lines tall. [Source: National Air Traffic Services, 1999]

- ▫ **8.14.1.8 Minimum window size for alphanumeric information.** Windows used to present alphanumeric information should be at least 7 lines tall. [Source: National Air Traffic Services, 1999]

- ▫ **8.14.1.9 Minimum window size.** The minimum window size should permit the display of the title and menu bar, if any. [Source: DON UISNCCS, 1992]

- ▪ **8.14.1.10 Consistency in window organization.** The windows in an application and related applications shall have a consistent organizational scheme for the key elements of the windows. [Source: DON UISNCCS, 1992]

- ▪ **8.14.1.11 Elements to include in windows.** Individual windows shall contain only those elements appropriate to the particular task, but the elements shall be consistent from window to window throughout the application. [Source: DON UISNCCS, 1992]

- ▫ **8.14.1.12 Initial window contents and organization.** The initial contents and organization of a window should permit a user to accomplish the window purpose easily and efficiently. [Source: DON UISNCCS, 1992]

▫ **8.14.1.13 Initial size.** When possible, the initial size of a window should permit the display of all its contents. [Source: DON UISNCCS, 1992]

▫ **8.14.1.14 Initial placement.** The initial placement of a window should be based on

a. the importance of the information (critical information should be placed in the center of the user's field of view),

b. information already displayed that should not be obscured,

c. the distance from the current pointer location (pointer movement should be minimized), and

d. when applicable, information already displayed that is relevant to the window. [Source: DON UISNCCS, 1992]

8.14.2 Window components

This section contains general rules on particular window components. Look to the specific window types (Section 8.14.3) to find type-specific information on each of these components.

8.14.2.1 Title bar and title

▪ **8.14.2.1.1 Use.** A title bar shall appear as a rectangular area at the top of a window inside the window border and with the title of the window in the center. [Source: DON UISNCCS, 1992]

▫ **8.14.2.1.2 Title bar controls.** Window title bars should contain a control at the left end that, when activated, produces a menu of window management options and **Minimize**, **Maximize/Restore,** and **Close** controls at the right end. [Source: DON UISNCCS, 1992]

Discussion. Rules for the operation of these controls are presented in Section 8.14.6 dealing with window operations. [Source: DON UISNCCS, 1992]

▪ **8.14.2.1.3 Titles for primary windows.** The title shall be the application name followed by the opened file name, separated by a single dash (-). [Source: Ameritech Services Inc., 1996]

▫ **8.14.2.1.4 Multiple instances of opening the same file or object.** When the user has multiple instances of the same object or file open simultaneously, then each instance should be titled with a colon and an instance number appended to the title in the order that it was opened. [Source: Ameritech Services Inc., 1996]

Example. When the file is named myreport.doc, the second instance of opening that same document file since the computer and software was booted would be myreport:2 in the title bar. The first instance title bar would change to myreport:1 in its title bar when both are open simultaneously. [Source: Ameritech Services Inc., 1996]

▪ **8.14.2.1.5 Titles for secondary windows.** Titles shall begin with the object under focus and be followed by the action underway. [Source: Ameritech Services Inc., 1996]

> **Example.** Printer - Set Up is the title with the printer being the object under focus and the action underway being a set-up action. [Source: Ameritech Services Inc., 1996]

▪ **8.14.2.1.6 Capitalization in window titles.** Significant words in the title (except user-defined words) shall be capitalized. [Source: Ameritech Services Inc., 1996]

8.14.2.2 Border

▫ **8.14.2.2.1 Border.** A window should have a distinct border that encloses all of the window components. [Source: DON UISNCCS, 1992]

8.14.2.3 Working or client area

▪ **8.14.2.3.1 Working or client area of windows.** Every window shall have a working or client area. [Source: Ameritech Services Inc., 1996]

> **Definition. Working area (or client area)** is the main area of the window that users employ to do their operational or application tasks. It is the area where users make their inputs and receive their outputs. [Source: Ameritech Services Inc., 1996]

8.14.2.4 Scroll-bars

▪ **8.14.2.4.1 When to use.** Scroll-bars shall be provided whenever the size of a textual or graphic entity exceeds the space available to display it. [Source: DON UISNCCS, 1992]

▪ **8.14.2.4.2 When not to use.** When the entire document fits in a display area, scroll-bars are unnecessary and shall be deactivated. [Source: Ameritech Services Inc., 1996]

▫ **8.14.2.4.3 Directional preference for scrolling.** When there is a choice, vertical (top-to-bottom) scrolling should be used instead of horizontal (left to right) scrolling. [Source: Galitz, 1993]

▪ **8.14.2.4.4 Scroll-bars on active windows.** Scroll-bars shall be displayed in full contrast for the active window only (the window that displays the user's current input). [Source: CTA, 1996; DON UISNCCS, 1992]

▫ **8.14.2.4.5 Vertical scroll-bar size.** A vertical scroll-bar should be the height of the scrollable portion of the window. [Source: National Air Traffic Services, 1999]

▫ **8.14.2.4.6 Horizontal scroll-bar size.** A horizontal scroll-bar should be at least one-half the width of the scrollable portion of the window. [Source: National Air Traffic Services, 1999]

▪ **8.14.2.4.7 Changing scroll-bar components.** Scroll-bar components shall change when the window size or information position changes, reflecting the present status. [Source: National Air Traffic Services, 1999]

▫ **8.14.2.4.8 Arrows to indicate direction of scrolling.** Directional arrows should be provided in small boxes distinct from the scroll area to indicate the direction that scrolling may be performed. [Source: National Air Traffic Services, 1999]

> **Discussion.** Up/down arrows would indicate vertical scrolling direction, and left/right arrows would indicate horizontal scrolling direction. [Source: National Air Traffic Services, 1999]

▪ **8.14.2.4.9 Subdued directional arrows.** The appropriate directional arrow shall be subdued or grayed out if no information is currently available through scrolling in a particular direction. [Source: National Air Traffic Services, 1999]

▫ **8.14.2.4.10 Scroll area or container.** The scroll-bar should be a filled-in bar, which contrasts with the window and the screen body background. [Source: National Air Traffic Services, 1999]

▪ **8.14.2.4.11 Scroll-bar entire-entity indicator.** A scroll-bar shall contain a vertical or horizontal line or area along which the scroll box can move, the length of which represents the entire entity. [Source: DON UISNCCS, 1992]

▪ **8.14.2.4.12 Scroll box.** A scroll-bar shall contain a movable symbol such as a box or rectangle that contrasts with the scroll area. [Source: National Air Traffic Services, 1999]

> **Discussion.** The scroll box is also known as the slider box or scroll handle. [Source: National Air Traffic Services, 1999]

▫ **8.14.2.4.13 Scroll box position.** The scroll box should indicate by its spatial position the relative location in the file of the information being viewed. [Source: National Air Traffic Services, 1999]

▪ **8.14.2.4.14 Scroll box size.** The size of the scroll box shall indicate proportionately the amount of the document displayed in the window relative to the percentage of available information in the file being viewed. [Source: National Air Traffic Services, 1999]

> **Discussion.** If the document is short, the displayed amount of the document is large and thus so is the scroll box. If the document is long, then the displayed amount and scroll box are small. For long documents, a minimal or default size scroll box is used. [Source: Ameritech Services Inc., 1996]

▫ **8.14.2.4.15 Indicating page number of viewed page.** When selected with the pointing device, the scroll box should display within it or near it the page number of material to be viewed. [Source: National Air Traffic Services, 1999]

- ▫ **8.14.2.4.16 Indicating selected scroll box.** When the scroll box has been selected, it should be indicated to the user in some visually distinctive way. [Source: National Air Traffic Services, 1999]

- ▪ **8.14.2.4.17 Scroll box operations.** Users shall be able to drag the scroll box continuously along its line or area using a pointing device. [Source: National Air Traffic Services, 1999]

- ▪ **8.14.2.4.18 Stepping through units using a scroll-bar.** A scroll-bar shall contain two symbols that allow a user to step forward or backward through the entire entity a unit at a time (for example, one page at a time). [Source: DON UISNCCS, 1992]

8.14.2.5 Message bar

The information area in primary windows is called the message bar or message area.

- ▫ **8.14.2.5.1 Location of message bar.** The message bar should be placed near the bottom of an active window. [Source: Microsoft Corp., 1992]

- ▫ **8.14.2.5.2 Use of message bar.** The message bar should display status information about a selection, a command, or a process; display help information; and explain highlighted menu items. [Source: Microsoft Corp., 1992]

- ▫ **8.14.2.5.3 Messages longer than the message bar.** Messages too long to be presented in the message bar should be displayed in message dialog boxes. [Source: Microsoft Corp., 1992]

- ▫ **8.14.2.5.4 Display of message bar.** The user should be able to turn the message bar on or off by a menu selection. [Source: Microsoft Corp., 1992]

- ▫ **8.14.2.5.5 Automatic removal of messages.** The message bar should automatically remove messages that are no longer relevant. [Source: Ameritech Services Inc., 1996]

- ▪ **8.14.2.5.6 Message types.** The message bar shall be a read-only, non-scrolling display for messages. [Source: Ameritech Services Inc., 1996]

- **8.14.2.5.7 Text placed in information area.** Text placed in the information area should be helpful but non-critical application messages to users. [Source: Ameritech Services Inc., 1996]

  Examples. The information can be about settings in use by the application or about objects being manipulated. The information area can be used to present information concerning a command, menu item, or button under cursor focus (it may even be information about the results of selecting the item). It could be used to suggest the default action, the most appropriate action, or how to perform actions under cursor focus. Other uses are to tell (instruct) how many items in a focused list box can be selected, (for example, select one or select as many as apply) or to inform the user that an action has been successfully completed. [Source: Ameritech Services Inc., 1996]

- **8.14.2.5.8 Location for routine messages.** The left side of a message bar should be used for routine, simple help and status messages. [Source: DON UISNCCS, 1992]

- **8.14.2.5.9 Location for window information.** The right side of a message bar should be used to present information about the window, such as the name of an object or the page number. [Source: DON UISNCCS, 1992]

8.14.2.6 Status bar

- **8.14.2.6.1 Status bar.** The status bar should present information about the current state of the application including brief messages, current cursor location, and mode. [Source: Microsoft Corp., 1992]

  Definition. The **status bar** is a special type of the message bar used to present information about the current status of the application. [Source: Microsoft Corp., 1992]

- **8.14.2.6.2 Indication of normal modes.** The status bar should indicate normal or default modes by the absence of the indicator for the non-normal modes. [Source: Microsoft Corp., 1992]

- **8.14.2.6.3 Display of status bar.** Users should be provided with a means to control whether or not to display the status bar. [Source: Microsoft Corp., 1992]

8.14.2.7 Control bar

Control bars can be rulers, such as in word processing programs, or toolboxes and color/pattern palettes, such as in graphics programs. [Source: Microsoft Corp., 1992]

- **8.14.2.7.1 Use.** Control bars should be used for frequently used features and commands. [Source: Microsoft Corp., 1992]

- ▫ **8.14.2.7.2 Position.** Fixed control bars should be located at a fixed position within the application window, and movable control bars should be placed in a supplemental window or a dialog box, able to be moved to a position selected by the user. [Source: Microsoft Corp., 1992]

- ▫ **8.14.2.7.3 Commands for fixed-position control bars.** Commands for fixed-position control bars in the main application window should be displayed as options under the **View** menu. [Source: Microsoft Corp., 1992]

- ▫ **8.14.2.7.4 Display of control bars.** Users should be allowed to specify which control bars, if any, they wish to display. [Source: Microsoft Corp., 1992]

- ▪ **8.14.2.7.5 Location relative to window.** A window shall never conceal the movable control bar with which it is associated. [Source: Microsoft Corp., 1992]

- ▫ **8.14.2.7.6 Movable control bar components.** A small title bar and control menu box should be provided for each movable control bar. [Source: Microsoft Corp., 1992]

  Discussion. It is not necessary for the title bar of a movable control bar to contain a title; its main function is to allow the user to drag the control bar to a new position. [Source: Microsoft Corp., 1992]

8.14.2.8 Push buttons

This section presents rules for push buttons specific to their use in windows. Additional, more general information on push buttons is presented in Section 8.13.5, Push buttons.

- ▫ **8.14.2.8.1 Push button location.** The top, bottom, or sides of the working area should be reserved for push buttons that provide actions that can be taken in the window. [Source: DON UISNCCS, 1992]

- ▫ **8.14.2.8.2 Display of push buttons.** The push buttons should be displayed in a horizontal row or vertical column centered with the window. [Source: DON UISNCCS, 1992]

- ▫ **8.14.2.8.3 Same buttons in different windows.** When the same buttons are used for different windows, they should be placed consistently in the same location. [Source: DON UISNCCS, 1992]

- ▫ **8.14.2.8.4 Consistent order.** Push button order should be consistent throughout an application. [Source: DON UISNCCS, 1992]

- ▫ **8.14.2.8.5 Help button.** When **Help** may be needed by the user and does not appear in a window menu bar, the window should have a **Help** button located at the bottom right corner of the working area of the window. [Source: DON UISNCCS, 1992]

- ▫ **8.14.2.8.6 Button order.** Buttons should be ordered from left to right (or top to bottom for vertical rows) according to frequency of use, sequence of use, or with positive actions at the left or top and negative or canceling actions at the right or bottom. [Source: DON UISNCCS, 1992]

- ▫ **8.14.2.8.7 Number of default buttons.** Designers should use no more than one default button in a control window. [Source: Ameritech Services Inc., 1996]

- ▫ **8.14.2.8.8 Location of default button.** When a default button is used in a control window, it should be the leftmost or topmost button. [Source: Ameritech Services Inc., 1996]

- ▪ **8.14.2.8.9 Push buttons not to use as default.** A push button assigned an action that is potentially destructive shall not be designated as the default button. [Source: DON UISNCCS, 1992]

- ▫ **8.14.2.8.10 Grouping related buttons.** Related push buttons should be placed together. [Source: CTA, 1996]

- ▫ **8.14.2.8.11 Visibility of buttons.** When push buttons are required for system interaction, they should always be visible on a primary display. [Source: Ameritech Services Inc., 1996]

8.14.3 Window types

8.14.3.1 Primary and secondary windows

Definitions. A **primary window** is a top or high-level window in an application. A **secondary window** is a window that is displayed from within a primary window or another secondary window. Secondary windows are sometimes called child windows.

- ▪ **8.14.3.1.1 Primary windows.** A primary window shall contain a title bar, a border, window controls, and a working area or client area. [Source: DON UISNCCS, 1992]

  Discussion. The primary window may also contain a menu bar, controls, objects, and icons. [Source: DON UISNCCS, 1992]

- ▫ **8.14.3.1.2 Message area in primary windows.** Primary windows should have message areas. [Source: DON UISNCCS, 1992]

  Discussion. The message area may be a dedicated area, or it may be an area that is used temporarily when a message is presented but is available for other uses otherwise. [Source: DON UISNCCS, 1992]

□ **8.14.3.1.3 Application primary window.** Every application should initially display a primary window. [Source: Ameritech Services Inc., 1996]

Discussion. Displaying a primary window provides an initial application context for the user. [Source: Ameritech Services Inc., 1996]

8.14.3.1.4 When to display a primary window. Applications should display a primary window as soon as the application starts, without leaving the screen blank. [Source: Ameritech Services Inc., 1996]

□ **8.14.3.1.5 Multiple primary window capability.** As necessary for performance of the intended user tasks, an application should be capable of having multiple primary windows open at the same time. [Source: Ameritech Services Inc., 1996]

□ **8.14.3.1.6 Independence of primary windows.** Primary windows should be independent of one another in the application. [Source: Ameritech Services Inc., 1996]

Example. Multiple spreadsheets may be open at the same time.

■ **8.14.3.1.7 Secondary windows.** A secondary window shall contain a title bar, a working area, and any of the other window components appropriate to the application. [Source: DON UISNCCS, 1992]

□ **8.14.3.1.8 When to use.** A secondary window should be used to temporarily add data (for example, help screens, menus, or other features) to a display as a means to control or display divergent information or to segregate and control separate operations. [Source: CTA, 1996]

□ **8.14.3.1.9 Secondary window constraints.** A secondary window should be associated with a particular primary or other secondary window. [Source: OSF/Motif Style Guide, 1993]

□ **8.14.3.1.10 Calling up other secondary windows.** A secondary window should be able to call up additional secondary windows to further the interaction. [Source: Ameritech Services Inc., 1996]

□ **8.14.3.1.11 Placement of secondary windows.** When present, a secondary window should appear within the borders of and on top of (superimposed on) a portion of its "parent" window. [Source: OSF/Motif Style Guide, 1993]

□ **8.14.3.1.12 Closing a secondary window.** Closing a secondary window should not affect the parent window. [Source: OSF/Motif Style Guide, 1993]

□ **8.14.3.1.13 Removing secondary windows.** A secondary window should be removed when its parent window is removed. [Source: OSF/Motif Style Guide, 1993]

- **8.14.3.1.14 Number of secondary windows.** The number of secondary windows should be limited to avoid creating navigation problems for the user. [Source: CTA, 1996]

- **8.14.3.1.15 Secondary windows covering primary window.** Secondary windows should not cover any part of the primary window that a user needs to see or use to do his or her task. [Source: Ameritech Services Inc., 1996]

- **8.14.3.1.16 Modeless secondary windows.** Modeless secondary windows should provide dialogs that do not require immediate attention and commands that do not need to be done before moving on. [Source: Ameritech Services Inc., 1996]

- **8.14.3.1.17 Moving modeless secondary windows.** Modeless secondary windows should themselves be moveable. [Source: Ameritech Services Inc., 1996]

- **8.14.3.1.18 Modal secondary windows.** Designers should only use modal secondary windows for serious problems for which an explicit response is required of the user before continuing. [Source: Ameritech Services Inc., 1996]

- **8.14.3.1.19 Moving modal secondary windows.** Modal secondary windows should not be movable. [Source: Ameritech Services Inc., 1996]

8.14.3.2 Application windows

- **8.14.3.2.1 Components of application windows.** All application windows should have a border or frame, a title bar, window controls, and a working area. [Source: DON UISNCCS, 1992]

  Discussion. Depending on the needs of the user, application windows may also contain a window menu bar, a command entry area, and a message area. [Source: DON UISNCCS, 1992]

- **8.14.3.2.2 Location of title bar.** The title bar shall extend across the top of the window. [Source: DON UISNCCS, 1992]

- **8.14.3.2.3 Location of title in window title bar.** The window title shall appear centered in the window title bar. [Source: DON UISNCCS, 1992]

- **8.14.3.2.4 Capitalization of title.** The window title shall be in mixed-case letters. [Source: Ameritech Services Inc., 1996]

- **8.14.3.2.5 Title content.** The title shall be as informative as possible, describing the purpose of the window and may also include the name of the application. [Source: DON UISNCCS, 1992]

- **8.14.3.2.6 Title of window based on option selection.** When a window is displayed as a result of the selection of an option in a menu, the title of the window shall be the same as the wording of the option. [Source: DON UISNCCS, 1992]

- **8.14.3.2.7 Location of window controls.** Window controls shall be located on the title bar with **Minimize, Restore/ Maximize,** and **Close** options at the right end and a control producing a menu of window management options on the left end. [Source: DON UISNCCS, 1992]

- **8.14.3.2.8 Location of menu bar.** When used, the menu bar shall extend across the window just below the title bar. [Source: DON UISNCCS, 1992]

- **8.14.3.2.9 Location of working area.** The working area shall occupy all the space inside the border that is not occupied by another component. [Source: DON UISNCCS, 1992]

- **8.14.3.2.10 Location of command entry area.** When used, the command entry area shall extend across the bottom of the window just above the message area. [Source: DON UISNCCS, 1992]

- **8.14.3.2.11 Location of message area.** When used, the message area shall extend across the bottom of the window. [Source: DON UISNCCS, 1992]

- **8.14.3.2.12 Application window behavior.** The user should be able to move and resize application windows. [Source: Microsoft Corp., 1992]

- **8.14.3.2.13 Operations in an application window.** Most application operations should take place within the application window. These three exceptions may appear outside of the application window

  a. dialogs or drop-down menus in resized windows,

  b. movable dialog boxes, and

  c. the **Help** window. [Source: Microsoft Corp., 1992]

- **8.14.3.2.14 Switching windows.** The user should be able to use either the mouse or the keyboard to switch from one application window to another and from one secondary window to another within the same application. [Source: Microsoft Corp., 1992]

8.14.3.3 The system window

- **8.14.3.3.1 Appearance.** The system window shall appear when system startup is complete. [Source: DON UISNCCS, 1992]

- **8.14.3.3.2 System-window size.** The system window shall occupy the entire screen. [Source: DON UISNCCS, 1992]

- **8.14.3.3.3 System-window components.** All system windows shall have a border or frame, a title bar, window controls, and a working area. [Source: DON UISNCCS, 1992]

▪ **8.14.3.3.4 Location of title bar.** The system window shall contain a system title bar that extends across the top of the screen. [Source: DON UISNCCS, 1992]

▪ **8.14.3.3.5 Location of title.** The system-title bar shall contain a centered title that identifies the system. [Source: DON UISNCCS, 1992]

Discussion. The system-title bar may also include optional components such as status indicators and a date and time display. [Source: DON UISNCCS, 1992]

▪ **8.14.3.3.6 Location of menu bar.** The system window shall contain a system-menu bar that extends across the screen located just below the system-title bar. [Source: DON UISNCCS, 1992]

▪ **8.14.3.3.7 Display area.** The system window shall contain an area available for the display of application windows that occupies the remainder of the screen. [Source: DON UISNCCS, 1992]

Discussion. The application area of the system window may contain icons that represent application windows or action icons common to all applications. [Source: DON UISNCCS, 1992]

▫ **8.14.3.3.8 System window behavior.** Users should not be able to move or resize the system window, nor shall they be able to obscure the system-title bar or system menu bar. [Source: DON UISNCCS, 1992]

8.14.3.4 Data-entry windows

This section covers information on the windows used for data entry. For specific information on data entry, see Section 8.2.3, Data Entry and Editing.

▫ **8.14.3.4.1 Data-entry window elements.** A data-entry window should contain a title that describes the purpose or contents of the window, a set of labeled fields, vertical or horizontal scroll-bars or both if the contents do not fit in the window's working area, and controls appropriate to the task. [Source: DON UISNCCS, 1992]

Definition. A **data-entry window** is a window that contains a set of labeled fields for entering, changing, and deleting data. It may also contain labeled data display fields, which a user cannot change. [Source: DON UISNCCS, 1992]

▫ **8.14.3.4.2 Data window organization.** The organization of a data-entry window should be consistent with the task it represents. [Source: DON UISNCCS, 1992]

Example. Data fields are arranged by sequence of use, frequency of use, or importance with related fields grouped together and separated from unrelated fields. [Source: DON UISNCCS, 1992]

▫ **8.14.3.4.3 Multi-page data entry windows.** Every effort should be made to minimize the number of pages in data entry windows, particularly if the user is expected to change pages frequently while entering data. When the contents of a set of data-entry fields do not fit the window working area,

a. the window should provide users the ability to page, scroll, or both, through the entire set; and

b. if the fields are arranged in rows, columns, or both, the labels of the rows or columns should remain in place when the rows or columns scroll or page. [Source: DON UISNCCS, 1992]

▫ **8.14.3.4.4 Push buttons in data-entry windows.** When a data entry window contains push buttons, the buttons should be placed in a row at the bottom of the working area, visually separated from the data fields. [Source: DON UISNCCS, 1992]

▫ **8.14.3.4.5 Controls for data-entry windows.** A data entry window should contain the controls appropriate to the task. [Source: DON UISNCCS, 1992]

Examples. When the contents require more than one page, the window would contain controls for paging. It might also be appropriate to include controls for clearing entries and restarting data entry. [Source: DON UISNCCS, 1992]

▪ **8.14.3.4.6 Saving entered data.** When a user has finished making entries in a data-entry window, he or she shall be able to save the entries by taking an explicit action such as selecting a **Save** menu option or activating an **Apply** or **OK** push button. [Source: DON UISNCCS, 1992]

8.14.3.5 Text windows

▫ **8.14.3.5.1 Width of a text window.** A window intended for the display of textual information should be wide enough to display an entire line of anticipated text without horizontal scrolling. [Source: DON UISNCCS, 1992]

▪ **8.14.3.5.2 Text window too small for entire document.** When an entire text document does not fit in the current window, the window shall have a vertical scroll-bar or a similar mechanism (positioned either on the right or left side of a window) so that users can view the entire document. [Source: DON UISNCCS, 1992]

8.14.3.6 Map windows

▫ **8.14.3.6.1 Map window elements.** A map window should include (1) a title; (2) identifying information such as coordinates, area, and scale; (3) the map itself; (4) a continuous coordinate indicator that states the pointer location; and (5) appropriate controls. [Source: DON UISNCCS, 1992]

8.14.3.7 Utility windows

- **8.14.3.7.1 Utility windows.** Utility windows should float on top of document windows. [Source: Apple Computer Inc., 1992]

  Definition. A **utility window** is a supplementary window that provides the users with additional tools or controls such as a tool palette or a set of text attributes.

8.14.4 Message windows

This section contains criteria and rules for several special purpose message windows (also called message boxes). These include dialog boxes, request windows, error-message windows, information-message windows, confirmation-message windows, warning-message windows, and working-message windows.

Definition/discussion. A **message window** (sometimes called a **message box**) is a secondary window that provides users with non-critical information, progress information about lengthy processes, alerts to unusual events, and/or warnings of potential dangers. Message windows may be modal or modeless.

8.14.4.1 General

- **8.14.4.1.1 Disallowed operations.** Users should not be able to **Minimize** or **Resize** message windows. [Source: DON UISNCCS, 1992]

- **8.14.4.1.2 Message windows.** Message windows should contain a title, a symbol that indicates the type of message, the message itself, and one or more push buttons. [Source: DON UISNCCS, 1992]

  Discussion. Some examples of possible symbols for different types of messages are: **i** for information messages; **?** for request and confirmation messages; **!** for warning messages; and a watch, clock, or hourglass for working messages. [Source: DON UISNCCS, 1992]

- **8.14.4.1.3 Message windows.** When covering underlying information is a problem, movable message windows should be used. [Source: Ameritech Services Inc., 1996]

- **8.14.4.1.4 Message wording.** The messages in message windows should use language that is meaningful to users and should require no further documentation or translation. [Source: DON UISNCCS, 1992]

- **8.14.4.1.5 Message content.** Messages should focus on what needs to be done, not on what was done wrong. [Source: DON UISNCCS, 1992]

- **8.14.4.1.6 Message window size.** Message windows should be just large enough to display the information required. [Source: DON UISNCCS, 1992]

- ▫ **8.14.4.1.7 Message window location.** Message windows should be distinctive in appearance and be located in a standard location on the screen. [Source: DON UISNCCS, 1992]

8.14.4.2 Request message window

- ▫ **8.14.4.2.1 Request message window use.** A request message window should be used when it is necessary to request information from a user before processing can proceed. [Source: DON UISNCCS, 1992]

- ▫ **8.14.4.2.2 Request message window components.** A request message window should contain a title, a question symbol (**?**), a message indicating the information required, and all of the following push buttons that apply in the order in which they are listed: **OK, Apply, Reset, Cancel,** and **Help**. [Source: DON UISNCCS, 1992]

  Discussion. A message window may also contain a text field.

8.14.4.3 Information message window

- ▫ **8.14.4.3.1 Information message window use.** An information message window should be used to convey non-critical information that requires acknowledgement. [Source: DON UISNCCS, 1992]

- ▪ **8.14.4.3.2 Information message windows.** Information message windows shall be modal and require acknowledgement. [Source: DON UISNCCS, 1992]

- ▫ **8.14.4.3.3 Information message window components.** An information message window should contain an information symbol (**i**), a message, and the following push buttons below the message in the order listed: **OK** and **Help**. [Source: DON UISNCCS, 1992]

  Discussion. The message area described in paragraph 8.14.4.1.3 is different than this information message window; the message area is for messages that do not require acknowledgement. [Source: DON UISNCCS, 1992]

- ▪ **8.14.4.3.4 Information message window behavior.** Information message windows shall not appear to the user to interrupt processing by the application. [Source: DON UISNCCS, 1992]

  Discussion. If the application interrupts processing, make sure that it is transparent to the user. [Source: DON UISNCCS, 1992]

8.14.4.4 Confirmation message window

- ▫ **8.14.4.4.1 Confirmation message window use.** Confirmation message windows should be used to request clarification of a previous user action. [Source: DON UISNCCS, 1992]

- ▫ **8.14.4.4.2 Requiring user response.** The application should suspend processing until the user responds to a confirmation message window. [Source: DON UISNCCS, 1992]

- ▫ **8.14.4.4.3 Confirmation message window components.** Confirmation message windows should contain a question symbol (**?**), a message, and one of the following sets of push buttons below the message in the order listed: {**Yes, No,** and **Help**} or {**Yes, No, Cancel**, and **Help**}. [Source: DON UISNCCS, 1992]

8.14.4.5 Warning message window

- ▫ **8.14.4.5.1 Warning message window use.** Critical messages warning users of destructive consequences of actions should be displayed in warning message windows. [Source: DON UISNCCS, 1992]

- ▫ **8.14.4.5.2 Suspending processing.** When a warning message window appears, processing should be suspended until a user responds to the message. [Source: DON UISNCCS, 1992]

- ▫ **8.14.4.5.3 Warning message window contents.** Warning message windows should contain a warning symbol **(!)**, a message, and one of the following sets of push buttons below the message in the order listed: {**Yes, No,** and **Help}** or {**OK, Cancel,** and **Help}**. [Source: Ameritech Services Inc., 1996; DON UISNCCS, 1992]

- ▫ **8.14.4.5.4 Accompanying audible warning signals.** Warning messages should be accompanied by an audible signal. [Source: DON UISNCCS, 1992]

  Discussion. An auditory beep indicating the nature of the error may be considered based upon the criticality of the error and the logic of the integrated alarm system, if present.

8.14.4.6 Working message window

- ▪ **8.14.4.6.1 Working message window use.** When the processing time resulting from a user action will exceed 2 seconds, the system shall display a working message window. [Source: DON UISNCCS, 1992]

- ▪ **8.14.4.6.2 Working message windows.** The display of a working message window shall not interrupt processing. [Source: DON UISNCCS, 1992]

- ▪ **8.14.4.6.3 Working message window display.** The working message window shall remain on display until processing is completed or until the user minimizes the window or cancels the process. [Source: DON UISNCCS, 1992]

- ▪ **8.14.4.6.4 Working message window removal.** The window shall be removed automatically when processing is completed. [Source: DON UISNCCS, 1992]

▪ **8.14.4.6.5 Working message window contents.** Working message windows shall contain a working symbol, a message, and one of the following sets of push buttons below the message, in the order listed: {**OK** and **Help**}, {**OK, Cancel,** and **Help**}, {**OK, Stop,** and **Help**}, or {**OK, Pause, Resume, Stop,** and **Help**}. [Source: DON UISNCCS, 1992]

▫ **8.14.4.6.6 Progressive working windows.** When processing time will be lengthy, the window should be updated to indicate the status of processing (for example, percent complete or time remaining) or should include a scale showing the proportion of processing completed. [Source: DON UISNCCS, 1992]

8.14.4.7 Dialog boxes

Dialog boxes may be movable or fixed, of a single size or two alternate sizes, modal (requiring a response before continuing), semi-modal, or modeless, and may present limited response options or more complex options. [Source: Microsoft Corp., 1992]

▫ **8.14.4.7.1 Modeless dialog boxes.** Modeless dialog boxes should be used for getting user input and for making changes to a document. [Source: Apple Computer Inc., 1992]

▫ **8.14.4.7.2 Modal dialog boxes.** Modal dialog boxes should be used to make the user give necessary information before carrying out the current operation. [Source: Apple Computer Inc., 1992]

▫ **8.14.4.7.3 Movable modal dialog boxes.** Movable modal dialog boxes should be used when input is needed from the user and for making changes to a document while allowing the user to switch to another application. [Source: Apple Computer Inc., 1992]

▫ **8.14.4.7.4 Dialog boxes (control windows).** Sets of controls that perform similar or related functions should be grouped and presented together in a dialog box (also called a control window). [Source: DON UISNCCS, 1992]

▫ **8.14.4.7.5 Format.** A dialog box should have a border and a title that clearly indicates the function of the set of controls. [Source: DON UISNCCS, 1992]

▫ **8.14.4.7.6 Unavailable controls.** When a control is temporarily unavailable, it should be displayed at reduced intensity. [Source: DON UISNCCS, 1992]

▫ **8.14.4.7.7 Push buttons for control functions.** Each function of a dialog box should have a push button. [Source: CTA, 1996]

▫ **8.14.4.7.8 Size of control windows.** Control windows should be smaller than application windows. [Source: CTA, 1996]

▫ **8.14.4.7.9 Visibility of control windows.** Control windows (dialog boxes), when activated, should be visible on a primary display. [Source: Ameritech Services Inc., 1996]

- **8.14.4.7.10 Dialogs covering underlying information.** When covering underlying information is a problem, the application should use movable dialog boxes. [Source: Ameritech Services Inc., 1996]

- **8.14.4.7.11 Movable dialog box format.** A movable dialog box should contain a title bar consisting of a control menu and a title. [Source: Microsoft Corp., 1992]

- **8.14.4.7.12 Fixed dialog box format.** A dialog box that is immovable should not contain a title bar. [Source: Microsoft Corp., 1992]

- **8.14.4.7.13 Use of fixed vs. movable dialog boxes.** An application should primarily use movable dialog boxes; the user can reposition these to view obscured data. [Source: Microsoft Corp., 1992]

- **8.14.4.7.14 Alert box use.** Alert boxes (a type of modal dialog box) should be used for communicating error conditions or preventing any other activity until the user responds to the error condition. [Source: Apple Computer Inc., 1992]

  Discussion. **Alert boxes** are applied to display messages to users to inform them of situations that may require their attention or are possibly dangerous. [Source: Apple Computer Inc., 1992]

- **8.14.4.7.15 Indication of alert severity.** An icon should be provided within the alert box that indicates the degree of severity of the alert message. [Source: Apple Computer Inc., 1992]

8.14.4.8 Error dialog box

- **8.14.4.8.1 Error dialog box components.** An error message window should contain an error symbol, a message, and the following push buttons below the message in the order listed: **OK, Cancel,** and **Help**. [Source: DON UISNCCS, 1992]

- ■ **8.14.4.8.2 Error dialog box modality.** Error windows shall be modal, requiring user acknowledgement in order to continue. [Source: Ameritech Services Inc., 1996]

  Discussion. An accompanying auditory alert indicating the nature of the error may be considered if warranted by the criticality of the error and the logic of the system. [Source: Ameritech Services Inc., 1996]

- **8.14.4.8.3 Use of an error dialog box.** When an error is detected in a system that uses windows, a dialog box should appear that specifies the error. [Source: Ameritech Services Inc., 1996]

- **8.14.4.8.4 Placement of error dialog box.** An error dialog box should not be placed in front of the error. [Source: Ameritech Services Inc., 1996]

- ▫ **8.14.4.8.5 Error acknowledgement.** After the user acknowledges the error, the dialog box should disappear, and the actual field that contains the error should be highlighted. [Source: Ameritech Services Inc., 1996]

8.14.5 Window states

8.14.5.1 Open windows

- ▪ **8.14.5.1.1 Input from system.** An open window shall be capable of receiving input from the system. [Source: DON UISNCCS, 1992]

- ▪ **8.14.5.1.2 Input from user.** A window that is open and active shall be capable of receiving input from a user. [Source: DON UISNCCS, 1992]

- ▪ **8.14.5.1.3 Visibility.** An open window shall be completely visible on the screen at the time it is opened and when it is active. [Source: DON UISNCCS, 1992]

  Discussion. More than one window can be opened on a screen at the same time. An open window may be partially or totally obscured by another open window; that is, an open window may or may not be visible. [Source: DON UISNCCS, 1992]

8.14.5.2 Closed windows

- ▪ **8.14.5.2.1 Closed window.** A closed window shall have no appearance on the screen, either as a window or as an icon. [Source: DON UISNCCS, 1992]

- ▪ **8.14.5.2.2 Closing a primary window.** When a primary window is closed, it and any of its secondary windows shall be removed from the screen. [Source: DON UISNCCS, 1992]

- ▪ **8.14.5.2.3 Reassigning input focus from closed window.** When a window that was closed had input focus, the user shall explicitly select another window to have focus, instead of having the application arbitrarily assign focus to another window on the screen unless emergency action is required. [Source: DON UISNCCS, 1992]

- ▫ **8.14.5.2.4 Closing a secondary window.** When a secondary window is closed, it and any of its secondary windows should be removed from the screen without affecting the parent window except for the disappearance of the secondary window. [Source: DON UISNCCS, 1992]

8.14.5.3 Active window

- ▪ **8.14.5.3.1 Making a window active.** A window shall be made active by clicking anywhere inside the window frame or picking it from the window menu. [Source: Ameritech Services Inc., 1996]

  Discussion. The active window is the one with which the user is working at any time; it has input focus. [Source: DON UISNCCS, 1992]

- ▪ **8.14.5.3.2 Active windows.** Only one window at a time shall be active. [Source: DON UISNCCS, 1992]

- ▪ **8.14.5.3.3 Visibility of active window.** The active window shall not be obscured by any other window or icon. [Source: DON UISNCCS, 1992]

- ▫ **8.14.5.3.4 Active window.** When more than one window is selected and opened, the last window activated should be designated as the active window. [Source: National Air Traffic Services, 1999]

- ▫ **8.14.5.3.5 Overlapping windows.** When windows are allowed to overlap, the active window should be in front of and not overlapped by other windows. [Source: National Air Traffic Services, 1999]

- ▫ **8.14.5.3.6 Location upon activation.** When a window is activated, it should appear in front of any other window that is currently open. [Source: National Air Traffic Services, 1999]

- ▪ **8.14.5.3.7 Distinguishing active windows.** An active window shall be distinguishable from inactive windows. [Source: DON UISNCCS, 1992]

  Exception. Complex situations may occur where one window has input focus for keyboard and mouse inputs and another window has input for voice entries. [Source: DON UISNCCS, 1992]

- ▪ **8.14.5.3.8 Making a window active.** When a window is made active, all other windows shall be made inactive, although there may still be operations (for example, background processing) occurring in the inactive windows. [Source: Ameritech Services Inc., 1996]

  Discussion. An inactive window continues to be displayed on the screen but may be obscured by other windows. [Source: DON UISNCCS, 1992]

- ▪ **8.14.5.3.9 When a window becomes inactive.** When a window becomes inactive, it shall cause selections to be deselected, the title bar to become inoperative, and the other window elements to disappear or change appearance (for example, supplemental windows or floating palettes). [Source: Ameritech Services Inc., 1996]

- **8.14.5.3.10 Effect of reactivating window on selections.** When a window is reactivated, it should not have an affect on any pre-existing selection. [Source: Microsoft Corp., 1992]

- **8.14.5.3.11 State of reactivated window.** Upon reactivation, a window should be restored to the state that it was in when it was last activated. [Source: Microsoft Corp., 1992]

  Example. When a window is activated, the title bar will become operative, the window and its contents visible, and all window elements will appear. Anything deselected when the window was made inactive will be selected again.

8.14.5.4 Input focus

- **8.14.5.4.1 One input focus.** Regardless of the number of windows open in an application, only one window at a time (the active window) shall be able to receive input from a pointing device or the keyboard. [Source: DON UISNCCS, 1992]

  Definition. Input focus is the notion that only one window and usually only one object in a window at a time is capable of accepting input from a pointing device or the keyboard. Input focus can be explicit (the user must move the pointer into the window and click the appropriate mouse button) or implicit (the user must only move the pointer into the window). [Source: Ameritech Services Inc., 1996]

- **8.14.5.4.2 User assignable input focus.** Users shall be able to assign input focus to any open window of the current application either with a pointing device or from the keyboard. [Source: DON UISNCCS, 1992]

- **8.14.5.4.3 Assigning input focus with a pointing device.** Users shall be able to assign input focus to any window that is wholly or partially visible by moving the pointer onto any visible portion (and clicking the appropriate button where explicit input focus is necessary). [Source: DON UISNCCS, 1992]

- **8.14.5.4.4 Window with input focus.** When any portion of a window was obscured by another window, upon activation, the window with input focus shall be made wholly visible. [Source: DON UISNCCS, 1992]

- **8.14.5.4.5 Moving input focus using the keyboard.** Users shall be able to press a single key or specific key combinations to move the input focus forward or backward through the open windows one window at a time in the order in which they were opened. [Source: DON UISNCCS, 1992]

- **8.14.5.4.6 Single object focus.** Only one object in the window having input focus shall be able to receive input from a pointing device or the keyboard. [Source: DON UISNCCS, 1992]

- **8.14.5.4.7 Indicating the object having input focus.** When an object has input focus, that object shall be indicated with a location cursor or highlighting. [Source: DON UISNCCS, 1992]

- **8.14.5.4.8 Location of input focus in a window.** When a window first appears, the location cursor or highlighting shall be placed on the object that users are most likely to select, for example, a text field or a default push button. [Source: DON UISNCCS, 1992]

- **8.14.5.4.9 Windows regaining input focus.** When a window has lost and then regained input focus, the location cursor or highlighting shall be placed on the object that last had input focus in the window. [Source: DON UISNCCS, 1992]

- **8.14.5.4.10 Moving input focus.** A user shall be able to move the input focus among objects in the window using either the pointing device or the keyboard. [Source: DON UISNCCS, 1992]

- **8.14.5.4.11 Assigning input focus to an object.** Users shall be able to assign input focus to an object within a window using either the pointing device or the keyboard. [Source: DON UISNCCS, 1992]

- **8.14.5.4.12 Moving input focus to an object with a pointing device.** Users shall be able to move input focus among objects within a window by moving the pointer onto an object (and clicking the appropriate button where explicit input focus is necessary). [Source: DON UISNCCS, 1992]

8.14.6 Window operations

For each system or application, the window operations that are performed need to be identified and their manner of execution made consistent throughout the system.

8.14.6.1 Splitting windows

- **8.14.6.1.1 Where to split a window.** Window split capabilities shall be provided that allow the user to divide the window into panes at any location along the scroll-bar. [Source: Ameritech Services Inc., 1996]

  Example. A window can be split allowing a user to see two parts of a spreadsheet or document at the same time. [Source: Microsoft Corp., 1992]

- **8.14.6.1.2 Different views.** A split window should allow the user to display different views of the same information such as print view and outline view. [Source: Microsoft Corp., 1992]

- **8.14.6.1.3 Splitting a window.** The user should be able to split the application window into two or more separate viewing areas called panes. [Source: Microsoft Corp., 1992]

  Definition. The separate viewing areas in a split window are called **panes**. [Source: Microsoft Corp., 1992]

- **8.14.6.1.4 Number of panes.** The user should be allowed to split the window into as many panes as is useful and practical. [Source: Microsoft Corp., 1992]

- ▫ **8.14.6.1.5 Windows with panes.** All panes in a window should be kept within the window. [Source: Microsoft Corp., 1992]

- ▪ **8.14.6.1.6 Manipulating windowpanes.** Each pane of a split window shall be independent in its manipulation. [Source: Ameritech Services Inc., 1996]

- ▫ **8.14.6.1.7 Split box.** For all windows that are capable of being split, applications should provide a split box. [Source: Microsoft Corp., 1992]

  Definition. A **split bar** is the divider placed across the middle of the window that separates the panes. A **split box** is a rectangular indicator located inside the scroll-bar of a split window or immediately above the scroll-bar of a split-able window. Note however, that in some rules, the split box is called the split bar. [Source: Microsoft Corp., 1992]

- ▫ **8.14.6.1.8 Using a split box to split a window.** The user should be able to drag the split box to a location in the scroll-bar where the new pane is to begin. [Source: Apple Computer Inc., 1992]

- ▫ **8.14.6.1.9 Moving a split bar.** A user should be able to move a split bar up or down by pressing the arrow keys or dragging it with the mouse. [Source: Microsoft Corp., 1992]

- ▫ **8.14.6.1.10 Scroll-bars for split windows.** When a window is split, scroll-bars should be displayed on the panes perpendicular to the direction of the split. [Source: Microsoft Corp., 1992]

- ▪ **8.14.6.1.11 Separate scroll-bars.** After a window is split, separate scroll-bars shall appear on either side of the split bar or split box. [Source: Ameritech Services Inc., 1996]

8.14.6.2 Minimizing windows

- ▪ **8.14.6.2.1 Minimize window.** When a user minimizes an open window, the window and any open secondary windows shall be replaced by the window's icon. [Source: DON UISNCCS, 1992]

- ▫ **8.14.6.2.2 Uniqueness of icons representing minimized windows.** Any window that can be **minimized** should have a unique icon or label that serves as an identifier of the window it represents. [Source: Ameritech Services Inc., 1996; GUIASG, 1990]

  Definition. A **minimize** operation reduces a window’s presence into a standby icon button on the information line at the bottom of the screen. **Iconize** or **Iconify** are older and potentially confusing terms for the minimize operation because icons are widely used beyond representing a minimized active window. [Source: Ameritech Services Inc., 1996; GUIASG, 1990]

- ▫ **8.14.6.2.3 Processes occurring in minimized windows.** Any processing occurring in a window should continue after the window is minimized. [Source: DON UISNCCS, 1992]

- **8.14.6.2.4 Minimize operation.** Where applicable, the application shall provide a minimize operation that changes a window into an icon button at the bottom of the screen. [Source: DON UISNCCS, 1992]

- **8.14.6.2.5 Minimizing a window using a pointing device.** When a window can be minimized, a user shall be able to minimize the window by moving the pointer onto the **Minimize** control in the title bar and clicking the appropriate button or by selecting **Minimize** from the window menu or control menu. [Source: DON UISNCCS, 1992]

- **8.14.6.2.6 Minimizing a window using the keyboard.** When a window can be minimized, a user shall be able to minimize the window using the keyboard by selecting **Minimize** from the window menu. [Source: Ameritech Services Inc., 1996]

- **8.14.6.2.7 Minimized window menu.** A minimized window shall have a menu that contains the same options as its window system menu with the exceptions of the **Resize** and **Minimize** options. (When a window menu includes **Resize** and **Minimize** options, these options shall appear on the menu as unavailable.) [Source: DON UISNCCS, 1992]

- **8.14.6.2.8 Selecting options from a minimized window menu.** A user shall select a minimized window menu item using standard option selection methods. [Source: DON UISNCCS, 1992]

- **8.14.6.2.9 Removing minimized window menu.** A user shall be able to remove a minimized window menu by moving the pointer off the menu and clicking the appropriate button. [Source: DON UISNCCS, 1992]

- **8.14.6.2.10 Location of minimized windows.** Unless specified otherwise by the application, the icons representing minimized windows shall be placed in the lower left corner of the screen, arrayed in a row from left to right in the order in which they are created. [Source: DON UISNCCS, 1992]

8.14.6.3 Maximizing windows

- **8.14.6.3.1 Maximizing a window.** When the user clicks on the **Maximize** button, the application shall enlarge the window to its largest size or to encompass the entire display screen, which ever is smaller. [Source: Ameritech Services Inc., 1996]

- **8.14.6.3.2 Maximize button on maximized windows.** When a window is maximized, the **Maximize** button shall assume a **Restore** function, and the button shall take on the **Restore** icon and function. [Source: Ameritech Services Inc., 1996]

- **8.14.6.3.3 Maximize.** When the window can be resized, the application shall provide a **Maximize** operation that enlarges a window to its maximum size. [Source: DON UISNCCS, 1992]

8.14.6.4 Restoring windows

- **8.14.6.4.1 The restore function.** A click on the **Restore** button shall change the window and any associated secondary windows to the size and location where they had been prior to last being maximized or minimized. [Source: DON UISNCCS, 1992]

- **8.14.6.4.2 Status of restored window.** A restored window shall have active status. [Source: Ameritech Services Inc., 1996; DON UISNCCS, 1992]

- **8.14.6.4.3 Restoring the window.** A user shall be able to restore a window and any secondary windows that were displayed when the window was minimized. This is done by moving the pointer and clicking on the icon representing the minimized window or displaying the menu of the minimized window and selecting **Restore**. [Source: DON UISNCCS, 1992]

- **8.14.6.4.4 Equivalence of input device.** It shall be possible to restore a minimized window by either using the pointing device or by using the keyboard. [Source: DON UISNCCS, 1992]

- **8.14.6.4.5 Restoring window to default size.** Where applicable, the application shall provide a **Restore** operation that enables a user to restore a minimized or maximized window to its default size. [Source: DON UISNCCS, 1992]

- **8.14.6.4.6 Restore option on full sized windows.** The **Restore** option shall be unavailable when the window is its default size. [Source: DON UISNCCS, 1992]

8.14.6.5 Closing windows

- **8.14.6.5.1 Closing the window.** A user shall be able to close a window and any secondary windows associated with the window by moving the pointer and clicking on the **Close** control or displaying the menu of the minimized window and selecting **Close**. [Source: DON UISNCCS, 1992]

- **8.14.6.5.2 Close.** When the window can be closed, the application shall provide a **Close** operation that enables a user to close a window, that is, to remove it from the screen and stop processing operations associated with the window. [Source: DON UISNCCS, 1992]

- **8.14.6.5.3 Confirming Close.** When processing is occurring or when unsaved data have been generated in the window, users shall be required to confirm the **Close** action before the window is removed from the screen and processing stops. [Source: DON UISNCCS, 1992]

8.14.6.6 Moving windows

- **8.14.6.6.1 Move capability.** Where applicable, the application shall provide a **Move** operation that enables a user to move a window on the screen. [Source: DON UISNCCS, 1992]

- ▫ **8.14.6.6.2 Movement without activation.** The application should permit the user to move a window without making the window active. [Source: National Air Traffic Services, 1999]

  Discussion. In some applications, users are not able to move all windows. For example, some windows are only advisory in nature, such as the amount of processing time remaining. These types of windows cannot be moved, closed, minimized to icon size, or resized by the user.

- ▪ **8.14.6.6.3 Moving a window with a pointing device.** When a window is movable and a pointing device is available, a user shall be able to move the window by moving the pointer into the window title bar, pressing the appropriate button on the pointing device, and dragging the window to its new location. [Source: DON UISNCCS, 1992]

  Discussion. As the user moves the pointing device, the window or an outline of the window will move on the screen, resulting in the display of the window in the new location when the button is released.

- ▪ **8.14.6.6.4 Window movement limits**. The user shall never be able to move a window off the display so that it cannot be seen, although it may be completely hidden by one or more other windows. [Source: Ameritech Services Inc., 1996]

8.14.6.7 Resizing windows

- ▪ **8.14.6.7.1 Resize.** Where applicable, the application shall provide a **Resize** operation that enables a user to change the size of a window. [Source: DON UISNCCS, 1992]

- ▪ **8.14.6.7.2 Moved or resized windows.** When a window has been moved or resized or both and is then closed and reopened during an application session, it shall reappear in the size and location it had when it was closed. [Source: DON UISNCCS, 1992]

- ▪ **8.14.6.7.3 Default location for moved or resized windows.** When a window has been moved or resized in the current session, it shall appear in its default location at the next application session. [Source: DON UISNCCS, 1992]

- ▪ **8.14.6.7.4 Obscuring critical information.** Critical information shall not be obscured during window resizing. [Source: CTA, 1996]

- ▪ **8.14.6.7.5 Resizing a window using a pointing device.** When a pointing device is available, a user shall be able to resize a resizable window by (1) moving the pointer onto the window's border, (2) pressing and holding the appropriate button on the pointing device, (3) dragging the border to the desired position, and (4) releasing the button resulting in the window being displayed in its new size. [Source: DON UISNCCS, 1992]

- ▪ **8.14.6.7.6 Changing window using a pointer.** When dragging the border of a window, the window itself or an outline of the window shall move with the pointer, indicating the changing size of the window, while leaving the window displayed in its original position. [Source: National Air Traffic Services, 1999]

- ▪ **8.14.6.7.7 Resizing in one direction.** Resizing a window by placing the pointer onto an edge of the window (top, bottom, or sides) shall permit changing its size in one direction only. [Source: DON UISNCCS, 1992]

- ▪ **8.14.6.7.8 Resizing in two directions.** Resizing a window by placing the pointer onto a corner shall permit changing the size of a window in two directions at once. [Source: DON UISNCCS, 1992]

- ▫ **8.14.6.7.9 Standard sizing buttons.** Standard buttons should be provided by which the user may control the size of the window (from minimum through variable to maximum). [Source: CTA, 1996]

- ▫ **8.14.6.7.10 Reformatting of text, graphics and icons.** Upon resizing of a window, text, graphics, or icon layouts should reformat so that they remain visible. [Source: CTA, 1996]

- ▫ **8.14.6.7.11 Only borders affected.** When a user resizes a window, only the border(s) affected should move, not the objects within the borders. [Source: DON UISNCCS, 1992]

- ▫ **8.14.6.7.12 Proportional image size change.** When the size of a window changes but the content remains the same, the image size should change proportionately as the window size changes. [Source: National Air Traffic Services, 1999]

- ▫ **8.14.6.7.13 Scroll bars.** When a window becomes too small to display its objects, vertical or horizontal scroll-bars or both should be added. [Source: DON UISNCCS, 1992]

  Discussion. When appropriate, the size to which a window can be reduced may be restricted so that its objects cannot be obscured. [Source: DON UISNCCS, 1992]

8.14.6.8 Operations in windows

- ▫ **8.14.6.8.1 Moving and copying objects.** Users should be able to perform the following operations on objects in a window. These operations are

  a. to move an object to another location in the same window,

  b. to move an object to a different window,

  c. to copy an object and place the copy at a different location in the same window,

  d. to copy an object and place the copy in a different window. [Source: DON UISNCCS, 1992]

8.14.7 Window navigation

8.14.7.1 General

- ▫ **8.14.7.1.1 Software navigation aids.** The user should be able to switch between software modules in a quick, easy manner using an interface such as a tree or organization chart. This function should include the ability to select a menu or submenu directly, without going through intermediate steps. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.14.7.1.2 Open window map.** When using an overlapping window structure, applications should provide a user-requested iconic or text map indication of all open windows to allow the user to easily identify all open (especially hidden) windows. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.14.7.1.3 Suitability/appropriateness of overlapping windows.** An overlapping window format should be used in cases where

  a. the task requires variable or unconstrained types, sizes, numbers, contents, and/or arrangement of windows;

  b. the visual display is small or such low resolution that users cannot view meaningful amounts of information in individual tiled windows;

  c. user activities cut across independent tasks;

  d. tasks require frequent window manipulation; and

  e. users are expert or use the application frequently. [Source: National Air Traffic Services, 1999]

- ▫ **8.14.7.1.4 Overlapping windows.** Overlapping windows should not cover needed underlying screen information; the underlying screen title; or navigation controls that may be needed. [Source: National Air Traffic Services, 1999]

- ▪ **8.14.7.1.5 Destructive overlays.** Window overlays shall be nondestructive. [Source: National Air Traffic Services, 1999]

- ▪ **8.14.7.1.6 Overlaid data.** Overlaid data shall not be permanently erased. [Source: National Air Traffic Services, 1999]

- ▫ **8.14.7.1.7 Background patterns.** When windows overlap, neutral background patterns should be used instead of complex background patterns because the complex patterns may create unwanted visual effects. [Source: National Air Traffic Services, 1999]

- ▫ **8.14.7.1.8 Active designation from open window map.** Users should be given the capability to designate the active window through the iconic or text open window map by highlighting the window representation. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.14.7.1.9 Expanded window explanation of open window map.** When possible, the user should be able to query an open window map for expanded information (for example, the date it was created, its size, or a description of the subject or application) on the file or application operating in the window. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.14.7.1.10 Window forward function with window map.** When an iconic or text map is provided for determining the numbers and names of open windows in an overlapping system, the user should be able to bring a window forward from the map without having to resize or move other windows. [Source: DOE HFDG ATCCS V2.0, 1992]

8.15 System Operations

8.15.1 General

▫ **8.15.1.1 System support functions.** Each system should provide a screen saver, the ability to suspend a session without completely logging off (the system would continue all active processes but not allow interaction until a user logs on again), and easy identification of and navigation among all open windows. [Source: DON UISNCCS, 1992]

▫ **8.15.1.2 Resetting parameters.** At the end of a session, any parameters with settings that apply only to the current session should be reset to their default values. [Source: DON UISNCCS, 1992]

▪ **8.15.1.3 System interrupts.** A system or application shall interrupt a user only when necessary to prompt the user for a response, to provide essential feedback, or to inform the user of errors. [Source: DOE HFDG ATCCS V2.0, 1992]

▪ **8.15.1.4 Indication of activation.** No system function shall be activated without an indication to the user. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

▪ **8.15.1.5 Entry acknowledgement.** Every user action shall result in a response from the system. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

▫ **8.15.1.6 User-specified settings.** Users should be able to review user specified interface parameters and reset them at any time during a session. [Source: DON UISNCCS, 1992]

Discussion. Design the system with a default for each setting, and decide which interface parameters users will be given access to and allowed to set. Decide which of these settings will remain in effect for the current session only and which will be in effect whenever that user logs on. [Source: DON UISNCCS, 1992]

8.15.2 Screen saver

- ▫ **8.15.2.1 Screen saver.** Computer system software should, when necessary to preserve the monitor, provide a screen saver that blanks computer screens or displays a message or graphic display that changes periodically when the computer has been idle for a period of time. [Source: DOD HCISG V2.0, 1992]

  Exception. A screen-saver mode is not appropriate for displays containing screens such as a constant monitor screen or a display in which users must track an activity over a period of time.

- ▫ **8.15.2.2 Screen-saver activation.** The time activation of the screen saver should be user selectable with a suggested activation time of 5 minutes. [Source: DOD HCISG V2.0, 1992]

- ▫ **8.15.2.3 Screen-saver deactivation.** The screen saver should be deactivated when any new activity is detected, including pressing any key on the keyboard or moving a pointing device. [Source: DOD HCISG V2.0, 1992]

8.15.3 System access, log on and log off

- ▪ **8.15.3.1 System access through log on process.** When necessary, each system shall implement a log on procedure that users must complete before they can access any system functions. [Source: DON UISNCCS, 1992]

  Discussion. Systems may restrict the applications available to a user based on the user's log on identification. Alternatively, systems may require users to log on to individual applications or groups of applications. [Source: DON UISNCCS, 1992]

- ▪ **8.15.3.2 Multiple user access.** Where multiple users have simultaneous access to computer control or output, the operation by one person shall not interfere with the operations of another unless mission survival necessitates pre-emption. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.15.3.3 User access pre-emption.** Where applicable, provisions for pre-emption and pre-notification shall be provided. [Source: Department of Defense, 1996]

- ▪ **8.15.3.4 Resuming pre-empted operations.** Provisions shall be made for the pre-empted user to be able to resume operations without information loss. [Source: Department of Defense, 1996]

- ▫ **8.15.3.5 Log on screen.** When a system uses a log on procedure, a log on screen should be displayed automatically as soon as a user completes any required start-up or power-up procedures. [Source: DOD HCISG V2.0, 1992]

- ▫ **8.15.3.6 Log on status.** When the system is unavailable for log on, it should display a message stating the system status and when it will be available. [Source: DON UISNCCS, 1992]

- ■ **8.15.3.7 Log on prompts.** When a system log on procedure includes both an identification component (for example, a user's name) and an authentication component (for example, a user's password), the system shall provide a self-explanatory prompt for each component with each prompt on a separate line. [Source: DOD HCISG V2.0, 1992]

- ■ **8.15.3.8 User name and password.** When a log on procedure includes the entry of a user's name and a password, the system shall show the user's name but shall not display the password on the screen. [Source: DOD HCISG V2.0, 1992]

- ■ **8.15.3.9 Error messages.** When a user makes an error during the log on procedure, the system shall display an error message in the system message area or in a standard pop-up error window that provides guidance on how to correct the error but not information that could assist someone trying to break into the system. [Source: DOD HCISG V2.0, 1992]

- □ **8.15.3.10 Completion of log on.** Upon completion of a log on, the system should display a main menu or an application window. [Source: DOD HCISG V2.0, 1992]

- ■ **8.15.3.11 System log off.** Once a user is logged on a system, the user shall be able to log off a system at any time by selecting the **Log off** option from a system-level menu. [Source: DOD HCISG V2.0, 1992]

- □ **8.15.3.12 Applications running during log off.** The system should notify the user of any applications that are still running before confirming a system log off. [Source: DON UISNCCS, 1992]

- ■ **8.15.3.13 Confirming a log off.** The system shall prompt the user to confirm a log off request. [Source: DOD HCISG V2.0, 1992]

- ■ **8.15.3.14 Completion of log off.** After completing a system log off, the system shall display the initial system log on screen. [Source: DOD HCISG V2.0, 1992; DON UISNCCS, 1992]

- □ **8.15.3.15 Automatic log off time.** When a system includes an automatic log off due to user inactivity, a standard elapsed time modifiable by the user should be designated. [Source: DON UISNCCS, 1992]

- □ **8.15.3.16 Automatic log off warning.** During periods of inactivity, the system should display a message accompanied by an auditory warning signal stating the action necessary to avoid automatic log off (for example, a keystroke or movement of the pointing device). [Source: DON UISNCCS, 1992]

- ▫ **8.15.3.17 Auto-saving data after automatic log off.** When automatic log off occurs, the system should auto-save any unsaved data, display a message indicating that automatic log off has occurred, and provide the name of the file in which data have been saved. [Source: DON UISNCCS, 1992]

8.15.4 Application - log on and log off

An application available in a system may require its own log on and log off procedures separate from the system log on.

- ■ **8.15.4.1 Log on.** When an application log on is required in addition to the system log on, it shall conform to the same rules as system log on. [Source: DON UISNCCS, 1992]

- ■ **8.15.4.2 Log off.** Logging off an application shall be accomplished with an exit function that is available to users at all times while they are logged on to the application. [Source: DOD HCISG V2.0, 1992]

- ■ **8.15.4.3 Confirming an exit.** The system shall prompt the user to confirm an application-exit request. [Source: DOD HCISG V2.0, 1992]

- ■ **8.15.4.4 Preserving unfinished work.** When the application contains unsaved inputs when the log off request is made, the application shall prompt the user to save the work, confirm the log off, or cancel the request. [Source: DOD HCISG V2.0, 1992]

- ■ **8.15.4.5 Logging off an application.** Logging off an application shall result in the removal of all screens associated with that application. [Source: DOD HCISG V2.0, 1992]

- ■ **8.15.4.6 Single application.** When there is only one application running, logging off of that application shall result in the system main menu being displayed. [Source: DOD HCISG V2.0, 1992]

- ■ **8.15.4.7 Multiple applications.** When there are multiple applications running, logging off an application shall result in the next most current application being displayed. [Source: DOD HCISG V2.0, 1992]

8.15.5 Data back up

- ▫ **8.15.5.1 Paper copy.** Users should be able to obtain a paper copy of the exact contents of an alphanumeric or graphic display in systems in which mass storage is limited, mass stored data can be lost by power interruption, or record keeping is required. [Source: MIL-HDBK-761A, 1989]

- **8.15.5.2 Computer failure.** When partial computer hardware or software failure occurs, the program should allow for orderly shutdown and establish a checkpoint so restoration can be accomplished without loss of computing performed to date. [Source: Department of Defense, 1996]

  Discussion. Critical FAA facilities and services often have redundant computer systems that switch to backup or degraded operations modes during failures. This rule is a reminder to conserve appropriate data and facilitate restoration where prior work needs to be preserved.

8.15.6 System response time

In designing any application, response time is critical. The response of an application is dependent on hardware and other processes requiring central processor unit (CPU) use (for example, a multitasking system may be slowed by other concurrent applications) and therefore, is hard to quantify. Thus, the rules in this section need to take into account such factors.

8.15.6.1 General

- **8.15.6.1.1 Appropriate system response time.** The response time of a system to a user action shall be appropriate to the type of transaction, the time constraints of the task, and any specific data processing requirements. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- **8.15.6.1.2 Maximum system response times.** System response times shall not exceed the values given in Exhibit 8.17.6.1.2 for the system tasks listed. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

Exhibit 8.15.6.1.2 Maximum system response times for routine system tasks.

System interpretation	Response time definition	Maximum response time (sec)
Key response	From key depression until positive response, for example, "click" or display echo	0.1
Key print (echo)	From key depression until appearance of character	0.2
Page turn	From end of request until first few lines are visible	1.0
Page scan	From end of request until text begins to scroll	0.5
Data field entry	From selection of field until visual verification	0.2
Function selection	From selection of command until response	2.0
Pointing	From input of point to display of point or pointing device	0.2
Drawing, sketching	From input of point to display of point, line, arc, etc.	0.2
Local update	Change to image or display using local data base, for example, new menu list display	0.5
Host update	Change where data are at host in a readily accessible form, for example, a display scale change	2.0
File update	Image or display update requiring access to a host file	10.0
Simple inquiry	From command until display of a common message	2.0
Complex inquiry	Response message that requires seldom used calculations in graphic form	10.0
Error feedback	From entry of input until error message appears	2.0

- **8.15.6.1.3 System response-time variability.** The variability of system response times for processing various types of control actions shall be minimized. [Source: MIL-HDBK-761A, 1989]

- **8.15.6.1.4 Maximum system-response time variability.** System-response time variability shall not exceed 5% when processing in the range of 0 to 2 sec; 10% when processing in the range 2 to 5 sec; and 15% when processing longer than 5 sec. [Source: MIL-HDBK-761A, 1989]

- **8.15.6.1.5 Acknowledgement of delayed processing.** When the processing of a control entry must be delayed, the current control entry shall be acknowledged. [Source: MIL-HDBK-761A, 1989]

- **8.15.6.1.6 Notification of processing completion.** When the processing is time consuming or not otherwise obvious, the system shall notify the user when the processing is complete. [Source: MIL-HDBK-761A, 1989]

8.15.6.2 Keyboard lockout

▫ **8.15.6.2.1 Response-time-induced keyboard lockout.** When application processing prohibits acceptance of keyboard input and no keyboard buffer is available, the application should lock out the keyboard until the application can accept input. [Source: DOE HFDG ATCCS V2.0, 1992]

Definition. Keyboard lockout is a state determined by an application in which the application does not accept input from the keyboard. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.15.6.2.2 Notification of keyboard lockout.** When keyboard lockout occurs, as alert should be displayed to indicate the user that lockout has occurred. [Source: DOE HFDG ATCCS V2.0, 1992; Nuclear Regulatory Commission, 1996]

▪ **8.15.6.2.3 Lockout duration.** Temporary lockout of a keyboard or other device due to processing of a transaction control entry shall be minimized. [Source: MIL-HDBK-761A, 1989]

▪ **8.15.6.2.4 Lockout indication.** When an application incorporates keyboard lockout, it shall provide a clear indication to users when the keyboard is locked out and when it is not. [Source: DOE HFDG ATCCS V2.0, 1992]

Example. One way this might be done is to change the shape of the cursor or pointer to a watch or hourglass. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.15.6.2.5 Lockout override.** An application that incorporates keyboard lockout should also provide a means for overriding the lockout, such as by assigning a function key to have this effect. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.15.6.2.6 Preserving processing prior to lockout override.** When lockout override is provided and it is invoked, the system should not reset and lose any processing that was completed before the override was invoked. [Source: DOE HFDG ATCCS V2.0, 1992]

8.15.7 Prompting

▪ **8.15.7.1 Prompting.** A system or application shall prompt users for all required input parameters, request additional or corrected information as needed, provide orientation (as to the computer processes to users) during transactions, and indicate any errors that are detected. [Source: MIL-HDBK-761A, 1989]

▪ **8.15.7.2 Prompt contents.** When the computer is waiting for input from a user, it shall indicate clearly where on the screen the input is expected and, to the extent possible, what information is expected. [Source: MIL-HDBK-761A, 1989]

▪ **8.15.7.3 Location of prompts.** Prompting messages shall appear in a consistent location on the screen. [Source: MIL-HDBK-761A, 1989]

Example. Prompting could occur at the beginning of the next line to be typed, in the data field where an entry is to be made, at a command input line, or within a menu window from which a selection is to be made. [Source: MIL-HDBK-761A, 1989]

▫ **8.15.7.4 Duration of prompts.** When a computer requests information from a user, any instructions about how to supply the information should remain visible until the user complies or takes some other action. [Source: DOE HFDG ATCCS V2.0, 1992]

▫ **8.15.7.5 User-selected level of prompting detail.** A system or application should permit users to select the level of detail they want in prompts. [Source: MIL-HDBK-761A, 1989]

Exception. Do not provide this capability if the system or application is shared in a way that would allow one user selection to affect another user. [Source: MIL-HDBK-761A, 1989]

▫ **8.15.7.6 User requested prompts.** The system should allow a user to request the display of prompts for the entry of data and command parameters. [Source: MIL-STD-1801, 1987]

8.15.8 Feedback

▫ **8.15.8.1 System not available.** When the system is not immediately available after system startup, the system should provide feedback to the user, indicating average system response time or known periods of unavailability, and disable the keyboard and pointing device until startup is complete.

Example. This feedback could take many forms such as displaying a message stating its unavailability, showing a status bar, or changing the pointer shape to a watch or hourglass.

▫ **8.15.8.2 System available.** When startup is complete and the system becomes available, the system should remove any messages indicating that it is unavailable, return the pointer to its normal shape, and enable the keyboard and pointing device. [Source: DON UISNCCS, 1992]

▪ **8.15.8.3 Feedback.** Designers shall present feedback by way of status, confirmation, and verification information throughout the interaction. [Source: Department of Defense, 1996]

- ▫ **8.15.8.4 Periodic feedback messages.** Successive periodic feedback messages should differ in wording from presentation to presentation or be otherwise indicated. [Source: MIL-HDBK-761A, 1989]

  Example. Three successive messages might be (1) "Processing search -- please wait." (2) "Search continuing -- please wait." (3) "Processing search -- wait please." [Source: MIL-HDBK-761A, 1989]

- ▪ **8.15.8.5 "Working" indication.** When a system or application takes more than 2 seconds to complete an operation initiated by a user action and during this time it is incapable of accepting further input from the user, it shall inform the user that action is continuing. [Source: DOE HFDG ATCCS V2.0, 1992]

  Discussion. A dynamic aspect to the working message is highly desirable. For example, the message might display the percent of processing that has been completed or that remains, with the percentage updated regularly. When this is not possible, a display that changes with time is still desirable (for example, a row of dots with a new dot added periodically). [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.15.8.6 Standby.** When the user must stand by due to system functioning, a “working,” “busy,” or “wait” message or appropriate icon should be displayed until user interaction is again possible. [Source: Department of Defense, 1996]

- ▪ **8.15.8.7 Periodic feedback.** When the system takes more than 2 seconds to respond, it shall provide periodic feedback to the user indicating that normal operation is occurring. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- ▫ **8.15.8.8 Delays greater than 15 seconds.** The user should be informed if the delay is likely to exceed 15 seconds. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.15.8.9 Delays exceeding 60 seconds.** For delays exceeding 60 seconds, a countdown display should show delay time remaining. [Source: Department of Defense, 1996]

- ▪ **8.15.8.10 Delayed computer response.** When the computer response to a user request is greater than 15 seconds, the computer shall give a clear and positive indication (for example, an auditory signal) when processing is complete. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.15.8.11 Feedback message content.** Feedback messages shall be self-explanatory. (Users shall not be required to translate feedback messages by use of reference system or code sheets.) [Source: Department of Defense, 1996]

- ▫ **8.15.8.12 Abbreviations in feedback.** Abbreviations should be avoided in feedback messages. [Source: Department of Defense, 1996]

- **8.15.8.13 Feedback for delayed response to function key activation.** When the function key activation does not result in an immediately observable response from the computer, the user shall be given some other form of acknowledgment or feedback. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- **8.15.8.14 Time consuming process.** The system shall give the user warning information before a command is invoked that it will be time consuming to process. [Source: Department of Defense, 1996]

- **8.15.8.15 Process outcome.** When a control process or sequence is completed or aborted by the system, positive indication shall be presented to the user concerning the outcome of the process and the requirements for subsequent user action. [Source: Department of Defense, 1996]

- **8.15.8.16 Current mode indication.** When multiple modes of operation exist, a means should be provided to remind the user of the current mode. [Source: Department of Defense, 1996]

- **8.15.8.17 Highlighted option acknowledgement.** Any displayed message or datum selected as an option or input to the system shall be highlighted to indicate acknowledgement by the system. [Source: Department of Defense, 1996]

- **8.15.8.18 Rejected input feedback.** When the system rejects user input, self-explanatory feedback shall be provided to indicate the reason for rejection and the required corrective action. [Source: Department of Defense, 1996]

8.15.9 Status information

- **8.15.9.1 Availability of status information.** Information about the current status of the system should be available to users at all times and, as appropriate to the system, provided automatically or upon user request. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

  Discussion. System status information might include information about data processing status, system availability, operational mode, system load, other users, and external systems. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- **8.15.9.2 Status of alarm settings.** Users should be able to obtain status information concerning current alarm settings (for example, the dimensions or variables covered and the values or categories established as critical). [Source: MIL-HDBK-761A, 1989]

- **8.15.9.3 Status of other systems or users.** When interaction with other systems or users is required, status information about the other systems or users should be available. [Source: MIL-HDBK-761A, 1989]

8.15.10 Routine messages

- ▪ **8.15.10.1 Routine feedback.** The system shall provide users with consistent, routine feedback regarding such activities as control entries, computer processing, and print requests. [Source: MIL-STD-1801, 1987]

- ▫ **8.15.10.2 User control.** When appropriate, users should be able to specify the level or type of system message they want to receive. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- ▫ **8.15.10.3 Clarity of purpose.** The wording of routine messages should make clear to the user that they provide status or feedback information, not that they indicate errors or requests for a user action. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

8.15.11 Error management

8.15.11.1 General

- ▫ **8.15.11.1.1 User-detected errors.** A user should be able to stop a control process at any point in a sequence to correct an error. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.15.11.1.2 Appropriate response to all entries.** A system or application shall provide an appropriate response to all possible control entries, correct and incorrect. [Source: MIL-HDBK-761A, 1989; DOE HFDG ATCCS V2.0, 1992]

  Example. The selection of an incorrect function key might result in a message listing the appropriate selections. [Source: MIL-HDBK-761A, 1989; DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.15.11.1.3 System detection of error type.** A system or application should be able to distinguish among program errors, equipment failures, and operator errors, and, if a failure results in a shutdown, allow for minimum loss of work performed. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.15.11.1.4 Fast error detection.** User errors should be detected and reported by the system as soon as possible so that they can be corrected in a timely manner. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.15.11.1.5 Immediate data correction.** When a user has completed a data entry transaction and an error is detected, the user shall be able to make corrections directly and immediately. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.15.11.1.6 Prompting command correction.** When a system or application does not recognize an element of a command entry, the system should prompt the user to correct that element rather than require reentry of the entire command. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.15.11.1.7 Display duration.** Notices, alerts, and informational displays should remain visible to a user until he or she responds with an appropriate action. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.15.11.1.8 Enter action for corrections.** A system or application shall require an explicit user action to reenter corrected material after a user has completed correcting an error. [Source: MIL-HDBK-761A, 1989; DOE HFDG ATCCS V2.0, 1992; MIL-STD-1801, 1987]

- ▪ **8.15.11.1.9 User action for reentry.** The enter action for reentry of corrected items shall be the same as the enter action for the original entry. [Source: MIL-HDBK-761A, 1989; DOE HFDG ATCCS V2.0, 1992; MIL-STD-1801, 1987]

- ▪ **8.15.11.1.10 Return to main interaction.** A system or application shall provide an easy means to return to the previous page after error correction. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.15.11.1.11 User confirmation of destructive actions.** When a control entry (including log off) will result in a change in stored data, procedures, or system operation (particularly if it is not easily reversible), the system or application shall explicitly notify the user of the potential loss of data, and require a confirmation before implementing the action. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-STD-1801, 1987]

- ▪ **8.15.11.1.12 Confirmation key for destructive actions.** The **Enter** key shall not be used for confirmation of destructive actions. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-STD-1801, 1987]

- ▪ **8.15.11.1.13 Flexible "go back" for error correction.** A system or application shall allow a user to go back easily to previous steps in a transaction sequence in order to correct an error or make any other desired change. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.15.11.1.14 Undo control action.** A system or application should provide an **Undo** operation that immediately reverses the last previous control action. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-STD-1801, 1987; CTA, 1996]

- ▫ **8.15.11.1.15 Reversing undo.** A second **Undo** action that reverses an original **Undo** action should be provided to reinstate whatever was just undone. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-STD-1801, 1987; CTA, 1996]

- ▪ **8.15.11.1.16 Error recovery.** All conditions and information relevant for user recovery from an error shall be displayed to the user. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-STD-1801, 1987]

- ▪ **8.15.11.1.17 Timeliness of error feedback.** Error messages and error feedback about the data or control entry shall be given within 2 to 4 seconds after the user completes the entry in which the error is detected. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-STD-1801, 1987]

8.15.11.2 Error messages

- ▫ **8.15.11.2.1 System-detected need for help.** To the extent practicable, a system or application should detect inappropriate user entries and actions, automatically interrupt the task, and either suggest an appropriate entry or action or ask the users to confirm or clarify their intentions. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

  Examples. The system might provide a message when it detects an error, an out-of-range response, a missing parameter, a duplicated entry, or an unusually long pause on the part of the user. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- ▪ **8.15.11.2.2 Confirmation messages.** When a user entry might cause the loss or destruction of data or a disruption of a system, the system shall display a cautionary message and require that the user confirm the entry. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-STD-1801, 1987]

- ▪ **8.15.11.2.3 Multilevel messages.** When appropriate, the system shall provide more than one level of error messages with successive levels providing increasingly detailed levels of explanation. [Source: MIL-STD-1801, 1987]

- ▫ **8.15.11.2.4 Multiple errors.** When a system detects multiple errors, it should describe the first error and inform the user of the total number of additional errors, move the cursor to the location of the first error, and, when appropriate, provide a means for the user to request sequential display of the additional error messages. [Source: MIL-STD-1801, 1987]

- ▫ **8.15.11.2.5 Non-disruptive error messages.** The display of error messages should not disrupt ongoing user activity. [Source: MIL-STD-1801, 1987]

  Example. An error message should not be displayed until a user has completed an entry. [Source: MIL-STD-1801, 1987]

- ▪ **8.15.11.2.6 Coding of error messages.** Messages that require special user attention shall be coded appropriately and distinctively. [Source: MIL-STD-1801, 1987]

- ▫ **8.15.11.2.7 Content of error messages.** When applicable, error messages should state the error detected, the input field containing the error, and the corrective action. [Source: Ameritech Services Inc., 1996]

  Example. When the user enters a date in the incorrect format, the messages would read, “Format is MM/DD/YY.” [Source: Ameritech Services Inc., 1996]

□ **8.15.11.2.8 Additional information.** The user should be permitted to request a more detailed explanation of the error and additional information about the ongoing operation. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; CTA, 1996]

Example. An error message could have a **Show more** push button.

■ **8.15.11.2.9 Wording of error messages**. Error messages shall be brief, specific, and task-oriented. [Source: MIL-STD-1801, 1987]

■ **8.15.11.2.10 Specificity of error messages.** Error messages shall provide information that pertains specifically to the operation of the task instead of offering general information. [Source: Ameritech Services Inc., 1996]

Discussion. Make the user aware of the consequences of an action before suggesting that action. For example, say "To delete text, press Enter," instead of "Press Enter to delete text." [Source: Ameritech Services Inc., 1996]

□ **8.15.11.2.11 Tone of error messages.** In general, error messages should be worded as advice or suggestions. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

□ **8.15.11.2.12 Correcting errors.** When possible, after detecting an error, users should not have to reenter the entire entry, only the portion of the entry or command that is in error. [Source: MIL-STD-1801, 1987]

■ **8.15.11.2.13 Cursor placement.** After an error message is displayed, the cursor shall be placed at the location of the error. [Source: MIL-STD-1801, 1987]

■ **8.15.11.2.14 Instructions and error messages.** Instructions and error messages shall appear in a consistent location on the screen. [Source: DOD HCISG V2.0, 1992]

8.15.11.3 Command interaction errors

■ **8.15.11.3.1 Command editing.** A system or application shall permit a user to edit an extended command during its composition before taking an explicit **Enter** action. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

■ **8.15.11.3.2 Command correction prompting.** A system or application shall prompt a user to correct an element of a command entry that is not recognized or that is logically inappropriate. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

■ **8.15.11.3.3 Faulty commands.** Whenever possible, a faulty command shall be retained in the command entry area of the display, with the cursor automatically positioned at the incorrect item and an advisory message displayed that describes the problem. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- ▫ **8.15.11.3.4 Unrecognized commands.** When a menu selection, function key, or command entry is invalid or inoperative at the time of selection, no action should result except the display of an advisory message telling the user what is wrong and which functions, options, or commands are appropriate. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.15.11.3.5 Errors in stacked commands.** When an error is detected in a series of stacked command entries, the system shall operate consistently in one of the following modes: (1) execute commands up to the point of error, or (2) require the user to correct any errors before executing any of the commands. [Source: MIL-HDBK-761A, 1989; DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.15.11.3.6 Partial execution of stacked commands.** When only a portion of a stack of commands can be executed, the system or application shall notify the user and provide appropriate guidance to permit correction, completion, or cancellation of the command. [Source: DOE HFDG ATCCS V2.0, 1992]

- ▪ **8.15.11.3.7 Stacked command execution.** When the system detects an error in a stack of commands it is processing, it shall notify the user and promptly (within 4 sec) provide guidance to permit correction, completion, or cancellation of the stacked commands. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- ▫ **8.15.11.3.8 Repeated errors.** When an error is repeated, causing the same error message to be repeated in succession, the message should be reworded for the third repetition and all following error messages that apply to that error. [Source: Ameritech Services Inc., 1996]

8.15.12 Data validation

- ▫ **8.15.12.1 Validation on input.** To the extent possible, the system should validate graphic information as it is created by providing a message when a given value is outside the standard range. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.15.12.2 Format and content.** When possible, the system should automatically check data for format and content. [Source: MIL-HDBK-761A, 1989]

  Example. A date entered as February 31 will result in a content error message. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.15.12.3 Valid data.** Valid data entries should be accepted and processed without any further user action. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.15.12.4 Invalid data.** Data and command entries that do not meet validation testing should result in a message asking for correction or confirmation. [Source: MIL-HDBK-761A, 1989]

▫ **8.15.12.5 Probable errors.** When validation testing detects a probable error, an error message should be displayed at the completion of the data entry without interrupting an ongoing transaction. [Source: MIL-HDBK-761A, 1989]

8.16 Help

8.16.1 On-line help

On-line Help can provide procedural aids, the ability to recover from errors, and advice without requiring a user to exit from the application. Ideally, on-line Help is always available and sensitive to the context within which it is requested. [Source: DOD HCISG V2.0, 1992]

Definition. On-line Help is primarily an interactive, context-sensitive source of information that can tell a user what entry to make at the current location in an application, what keystrokes are required, or what steps are required to complete a task. Secondarily, on-line Help is a form of on-line documentation and reference information. [Source: DOD HCISG V2.0, 1992]

An on-line Help facility may provide any or all of three types of Help: advice, active Help, and passive Help.

Advice is an interactive, context-sensitive source of information that indicates what entry to make at the current location in the application, the required keystroke(s), or which steps to take to complete the task. [Source: DOD HCISG V2.0, 1992]

Active Help senses an inappropriate entry and interrupts the task to ask users what they are attempting and if they are sure they want to complete the operation they have just initiated. Depending upon the user response to the question, active Help then suggests the correct action. [Source: DOD HCISG V2.0, 1992]

Passive Help simply responds to user requests for information. The information may be in the form of on-line system documentation, such as a user's guide or a list of functions performed by combinations of key presses. [Source: DOE HFDG ATCCS V2.0, 1992]

8.16.2 General

▫ **8.16.2.1 Availability of on-line Help.** Specific user guidance information should be available on-line for display at any point in a transaction sequence. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; DOD HCISG V2.0, 1992; MIL-STD-1801, 1987]

- □ **8.16.2.2 Automatic Help.** The Help function should be activated automatically (offering Help) when the user is making repeated errors. [Source: CTA, 1996]

- □ **8.16.2.3 On-line guidance.** The system should provide users with appropriate on-line data, command indexes, and dictionaries to guide them in the selection and composition of data and command entries. [Source: MIL-STD-1801, 1987]

- □ **8.16.2.4 Content of on-line guidance.** On-line guidance material should include all applicable definitions, lists of allowable entries, ranges of acceptable values, and reference material describing system capabilities and procedures. [Source: MIL-STD-1801, 1987]

- □ **8.16.2.5 User-centered Help.** On-line Help should be user-centered, that is, based on the task the user is trying to complete and not on the characteristics of the application. [Source: DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992]

- □ **8.16.2.6 User-requested Help on errors.** When an error occurs and the user requests Help, the Help should provide a useful description of the error and suggest at least one recovery technique. [Source: CTA, 1996]

- ■ **8.16.2.7 Consistent and distinguishable formats.** User guidance shall be displayed consistently in a format that is distinguishable from that of other displayed data. [Source: DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989]

- □ **8.16.2.8 Location of displayed Help.** To the extent possible, the display of Help should not obscure the object about which Help was requested. [Source: DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992]

- ■ **8.16.2.9 Duration of on-line Help.** On-line Help shall remain visible until the user chooses to remove it. [Source: Ameritech Services Inc., 1996]

- □ **8.16.2.10 Printing Help information.** Users should be able to print displayed Help information. [Source: DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992; MIL-STD-1801, 1987]

- ■ **8.16.2.11 Searching on-line Help.** Users shall be able to search through on-line Help displays. [Source: MIL-STD-1801, 1987]

- □ **8.16.2.12 User annotations.** Users should be able to annotate existing Help messages. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- □ **8.16.2.13 Synonyms for standard terminology.** When a user requests Help on a topic, the computer should accept synonyms and abbreviations. [Source: NUREG-0700, 1996]

- □ **8.16.2.14 Clarifying Help requests.** When a request for Help is ambiguous in content, the computer should initiate a dialogue to specify what data, message, or command requires explanation. [Source: NUREG 0700, 1996]

- **8.16.2.15 User requests.** Users should be able to request Help on selected topics. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- **8.16.2.16 Help availability.** Both system-level and application-level Help should be available to users and provided in the following ways:

  a. As a menu title in the system menu bar. This level of Help should describe system capabilities and provide information on how to use Help. It may include an on-line tutorial for users and a system navigation aid.

  b. As a menu title in an application menu bar. This level of Help should include general information on application functionality. It may include an on-line, cross-referenced index so that users can obtain information about particular windows, actions, and commands. When the application uses action icons, it may provide Help through an action icon.

  c. As a push button or check box in a window. This level of Help should provide information about the actions that can be taken in the window.

  d. As a message in the message area of a window. This level of Help should explain how to complete the initiation of an action.

  e. As a function available from the keyboard. This level of Help should provide information about the object in a window that has input focus. The information may be displayed in a message window or in the message area of the window in which the object appears. [Source: DON UISNCCS, 1992]

8.16.3 Access and return

- **8.16.3.1 Access from and return to application.** Users should be able to access Help from within an application, (that is, without leaving the application), and return to where they were before requesting Help. [Source: DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992]

- **8.16.3.2 Help icon and function key.** The system or application should place a Help icon on the screen and designate a function key as the Help key. [Source: CTA, 1996]

- **8.16.3.3 Use of Help icon and function keys.** Systems and applications should use the Help icon and the Help key consistently throughout the application. [Source: CTA, 1996]

- ▫ **8.16.3.4 Reminder of accessibility.** Users should be provided with a constant reminder of **Help** availability. [Source: DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992]

  Example. This might be accomplished by the display of the word **Help** in a menu bar or by displaying a push button labeled **Help**. [Source: DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.16.3.5 Notification of unavailability of Help.** When **Help** is not always available, users should be informed when it is not available. [Source: DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992]

  Example. Dimming a Help label might do this. [Source: DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.16.3.6 Standard action.** Users should be able to obtain on-line Help by using a standard action that is always available. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.16.3.7 Consistent access.** The procedures for accessing on-line Help should be consistent throughout an application and related applications. [Source: DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992]

- ▫ **8.16.3.8 Easy access.** Users should not be required to memorize lengthy sequences or refer to secondary written procedures to access on-line Help. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.16.3.9 Help command.** The system shall provide a **Help** command that allows users to obtain on-line guidance information. [Source: MIL-STD-1801, 1987]

- ▫ **8.16.3.10 Easy alternation between Help display and original display.** Users should be able to alternate easily between a Help display and the display from which Help was requested. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.16.3.11 Easy return.** After requesting and receiving Help, a user should be provided with an easy means to return to the display from which Help was requested. [Source: DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

- ▫ **8.16.3.12 Control options.** Any Help or guidance display should include any relevant control options. [Source: MIL-HDBK-761A, 1989]

  Example. A Help window might include an **OK** push button for removing the window. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.16.3.13 Single action.** Users shall be able to access and exit **Help** with a single action, for example, a single keystroke or a single click of a pointing device. [Source: DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992]

- **8.16.3.14 Marking topics for retrieval.** When the number of topics in an on-line Help facility is large and if it would be useful to users to be able to customize the facility by marking individual topics for retrieval, the facility should provide this capability. That is, allow users to be able to mark individual topics and then retrieve only the marked topics. [Source: DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992]

- **8.16.3.15 Synonyms.** Synonyms for standard terminology should be recognized by Help routines, requiring only that the user enter a term for which they are interested in obtaining Help. [Source: Ameritech Services Inc., 1996; MIL-HDBK-761A, 1989]

- **8.16.3.16 Misspelled words.** When a user enters a term for which they are interested in obtaining Help, the application should accept close spelling matches. [Source: Ameritech Services Inc., 1996; MIL-HDBK-761A, 1989]

8.16.4 Context sensitivity

- **8.16.4.1 Task-oriented Help.** The information provided in response to a **Help** request shall be relevant to the task and the current transaction within the task. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- **8.16.4.2 Ambiguous context.** When the context in which a request for Help is made is ambiguous, the system should initiate a dialog in which the user can specify what data, message, or command requires explanation. [Source: MIL-HDBK-761A, 1989]

- **8.16.4.3 Context information in Help display.** When a user's request for Help depends upon the context established by previous entries, an indication of that context should be included in the Help display. [Source: MIL-HDBK-761A, 1989]

- **8.16.4.4 List valid entries.** When a user makes an invalid entry, the system should provide a list of valid entries. [Source: Ameritech Services Inc., 1996; DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992]

  Example. If the user types PITTABURGH, offer a list of suggested choices that would allow the user to make a correction without having to re-key the entry. [Source: Ameritech Services Inc., 1996; DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992]

- **8.16.4.5 Historical context.** When appropriate, users should be able to request a displayed record of past transactions. [Source: MIL-HDBK-761A, 1989]

8.16.5 Wording and style

□ **8.16.5.1 Wording.** The following practices should be applied in wording Help information.

a. The most important information should be placed at the beginning of each on-line Help message.

b. Messages should be stated in short, simple, consistently structured in the active instead of passive voice.

c. Messages should be positively worded. Negative statements should only be used for stating exceptions to rules.

d. Common words with apparent meanings should be used. Abbreviations or contractions should not be used. [Source: Ameritech Services Inc., 1996]

■ **8.16.5.2 Appropriate to user.** Help information shall be appropriate to the experience and training of the system users. [Source: DOD HCISG V2.0, 1992]

Discussion. When appropriate, Help messages may incorporate special terms and technical jargon that is well understood and employed in the user's task environment.

□ **8.16.5.3 Visual style.** The visual style of on-line Help should maintain a great deal of white space with no more than 40% of the pixels used for words and figures. [Source: Ameritech Services Inc., 1996]

8.16.6 Content

□ **8.16.6.1 Scope.** On-line Help should include: (1) memory aids, (2) basic information likely to be of use only to novices, (3) material selected from written documentation, (4) explanations that go beyond written documentation, (5) information that might seem obvious but may not be to all users, and (6) step-by-step instructions on how to perform the most common tasks. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

□ **8.16.6.2 Only relevant information.** Help displays should contain only information relevant to the current requirements of the user. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

□ **8.16.6.3 Multilevel Help.** The system should provide multiple levels of Help with successive levels providing increasingly detailed levels of explanation. [Source: MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

▫ **8.16.6.4 Help on Help.** On-line Help should include Help on how to use the on-line Help which includes

a. a description of all Help displays;

b. instructions on how to access Help from anywhere in the system, including alternative routes, if any;

c. instructions on navigating through Help, including scrolling, paging, and moving to related topics, and

d. a description of the current window, including its function and any tasks the user can perform. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▪ **8.16.6.5 Titles.** Each **Help** display shall have a title that identifies its contents and reflects the location from which it originated. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▫ **8.16.6.6 System information.** On-line Help should include a description of system capabilities and procedures. [Source: MIL-HDBK-761A, 1989]

▫ **8.16.6.7 Application information.** On-line Help should include a description of the application, including its capabilities, components, options, and structure. [Source: DOD HCISG V2.0, 1992]

▫ **8.16.6.8 Available commands.** When an application uses commands, an on-line index and description of all commands should be available. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989]

▫ **8.16.6.9 Command examples.** When appropriate, Help displays should include examples of correct input or valid commands, which include realistic commands and parameters, not just formal syntax. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▫ **8.16.6.10 Command format.** When appropriate, Help displays should include a description of the format of a specified command and a list of allowable commands. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▫ **8.16.6.11 Function keys.** On-line Help should provide multilevel descriptions of the actions assigned to function keys. [Source: DOD HCISG V2.0, 1992]

▫ **8.16.6.12 Prompts, requests, and definitions.** On-line Help should provide multilevel Help on any displayed prompts or requests and definitions of all-important terms. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

▫ **8.16.6.13 Error messages.** On-line Help should provide multilevel Help on error messages. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- **8.16.6.14 Shortcuts.** On-line Help should point out shortcuts and infrequently used features to users. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

- **8.16.6.15 Help index.** An on-line index of Help topics should be available to users. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992; MIL-HDBK-761A, 1989]

- **8.16.6.16 Finding Help topics.** The on-line Help facility should allow users to press any alphabetic key and obtain a list of the Help topics beginning with that letter, and then allow the users to select a topic from the list and obtain the Help information for that topic. [Source: DOE HFDG ATCCS V2.0, 1992; DOD HCISG V2.0, 1992]

8.16.7 Help windows

- **8.16.7.1 Help window elements.** A **Help** window should include a title that identifies the contents, a working area that displays the **Help** information, and an **OK** push button to remove the window. [Source: DON UISNCCS, 1992]

- **8.16.7.2 Printing the Help window.** Users should be able to print part or all of the contents of a **Help** window. [Source: DON UISNCCS, 1992]

- **8.16.7.3 Size. Help** windows should be wide enough to display complete lines of text and long enough to display all the lines, if practical. [Source: DON UISNCCS, 1992]

- **8.16.7.4 Placement.** The **Help** window should be placed so that it does not obscure the object it describes. [Source: DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992]

- **8.16.7.5 Help window.** When the **Help** display is in a window, the window should be movable and resizable. [Source: DOD HCISG V2.0, 1992; DOE HFDG ATCCS V2.0, 1992]

- **8.16.7.6 Help information.** A **Help** window should describe the object or explain the steps required to initiate the action about which **Help** was requested. [Source: DON UISNCCS, 1992]

- **8.16.7.7 Removal of Help windows. Help** windows should be removed from the screen either at the user's request or when the object or window about which **Help** was requested is removed, minimized, or closed. [Source: DON UISNCCS, 1992]

- **8.16.7.8 Keeping a Help window open.** Users should be able to keep a **Help** window displayed while continuing to work with the application. [Source: DON UISNCCS, 1992]

8.17 Data communication

Although the computer-human interface rules in the previous sections apply to data communication software as well, there are some rules that are specific to data application programs. The rules presented in this section are those specific to data communication applications and should be considered in addition to the rules of the previous section.

8.17.1 General

- ▪ **8.17.1.1 Consistent procedures.** Procedures for preparing, sending, and receiving messages shall be consistent within and across data communication applications. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.17.1.2 Message handling windows.** Windows intended for sending and receiving electronic messages shall conform to the general criteria and rules for data entry windows. [Source: DON UISNCCS, 1992]

- ▫ **8.17.1.3 Message display.** When a message is displayed, it should appear in a text window with all the capabilities of these windows such as scrolling and printing. [Source: DON UISNCCS, 1992]

- ▪ **8.17.1.4 Explicit user actions.** Both sending and receiving of messages shall be accomplished by explicit user action. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.17.1.5 Interruptible by user.** Users should be able to interrupt message preparation or review. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.17.1.6 Resuming activity.** The user should be able to resume message preparation or review from the point of interruption. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.17.1.7 Printing messages.** Users should be able to print copies of transmitted messages. [Source: MIL-HDBK-761A, 1989]

8.17.2 Preparing messages

- ▫ **8.17.2.1 User-designed format.** Unless a need exists for a specific message format, users should be able to compose and transmit messages as unformatted text or with a format of their own design. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.17.2.2 Application-supplied format.** When messages must conform to a defined format, a preformatted message form shall be available to users. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.17.2.3 Incorporating existing data.** Users should be able to incorporate existing file data (including other messages received or transmitted) into messages. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.17.2.4 Saving prepared messages.** Users should be able to save draft messages during preparation and after completion. [Source: MIL-HDBK-761A, 1989]

8.17.3 Sending messages

- ▫ **8.17.3.1 User initiation of data transmission.** Data transmission should be initiated by an explicit user action (for example, a **Send** command). [Source: MIL-HDBK-761A, 1989]

- ▫ **8.17.3.2 What users can transmit.** Users should be able to transmit both information that is displayed on their screens and information stored in files. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.17.3.3 Appended information.** When a message is sent, the sender's address and the date and time of message creation and transmission should be appended automatically. [Source: National Air Traffic Services, 1999]

- ▫ **8.17.3.4 Transmitted message log.** A record of transmitted messages should automatically be maintained. [Source: MIL-HDBK-761A, 1989]

- ▫ **8.17.3.5 Canceling unsent messages.** Users should be able to cancel or abort any message that has not yet been transmitted. [Source: DON UISNCCS, 1992]

- ▫ **8.17.3.6 Automatic message queuing.** Outgoing messages should be automatically queued pending transmission. [Source: National Air Traffic Services, 1999]

- ▫ **8.17.3.7 Specifying message priority.** Users should be able to assign a priority to a message. [Source: National Air Traffic Services, 1999]

- ▫ **8.17.3.8 Automatic assignment of priority.** When the user does not specify a priority preference, the system should assign priority automatically. [Source: National Air Traffic Services, 1999]

- ▫ **8.17.3.9 Notification of delivery.** Users should be able to request notification that a message has been opened by the addressee. [Source: MIL-HDBK-761A, 1989]

- ▪ **8.17.3.10 Notification of unsuccessful transmission.** Users shall be notified if a message could not be transmitted. [Source: DON UISNCCS, 1992]

- ▫ **8.17.3.11 Notification of transmission failure.** When possible, notification of failure to transmit a message should include an explanation of the failure. [Source: MIL-HDBK-761A, 1989]

- **8.17.3.12 Storage of undelivered message.** When message transmission fails, automatic storage of undelivered messages should be provided. [Source: MIL-HDBK-761A, 1989]

- **8.17.3.13 Automatic re-send.** When transmission is unsuccessful due to line unavailability, the system should automatically make repeated attempts to send the message. [Source: DON UISNCCS, 1992]

8.17.4 Addressing messages

- **8.17.4.1 User-specified destinations.** Users should be able to specify destinations to which data will be transmitted. [Source: National Air Traffic Services, 1999]

  Discussion. Destinations may include individuals, groups of individuals, workstations, terminals, and remote printers.

- **8.17.4.2 Editing address fields.** Users should be able to edit the address fields in the header of a message being prepared for transmission. [Source: MIL-HDBK-761A, 1989]

- **8.17.4.3 Message window fields and headers.** Message handling windows should include a basic set of labeled fields, including **Date, From,** and **Time** and an addressee field, a copy to field, a subject field, and a message field which are interpretable by all systems to which messages can be sent. [Source: DON UISNCCS, 1992; MIL-HDBK-761A, 1989]

- **8.17.4.4 Field support.** The application should provide information to help a user make a proper entry in a field. [Source: DON UISNCCS, 1992]

  Example. Prompting can be provided to guide the user in specifying the address for a message. [Source: MIL-HDBK-761A, 1989]

- **8.17.4.5 Address directory.** Users should be able to select addresses from a directory for automatic entry in address fields. [Source: MIL-HDBK-761A, 1989]

- **8.17.4.6 Directory search.** Users should be able to search for addresses in a directory by specifying a complete or partial name or other address information. [Source: MIL-HDBK-761A, 1989]

- **8.17.4.7 Substitute addresses.** Users should be able to define substitute addresses for commonly used addresses and use these substitutes to address messages. [Source: MIL-HDBK-761A, 1989]

  Example. A user might define Jane as the address "jdoe@tc.faa.gov." [Source: MIL-HDBK-761A, 1989]

- **8.17.4.8 Automatic addressing of replies.** When a user replies to a message, the messaging system should provide the appropriate address(es) automatically. [Source: MIL-HDBK-761A, 1989]

□ **8.17.4.9 Distribution lists.** Users should be able to create, store, retrieve, edit, and use distribution lists of commonly used addressees or groups of addressees. [Source: DON UISNCCS, 1992]

□ **8.17.4.10 Valid address.** The system should ensure that an address is valid. [Source: MIL-HDBK-761A, 1989]

Examples. When an address is internal to a system, the system might search an on-line directory to validate the address. When an address is external, the system might ensure that the address contains a valid gateway or that the address format is valid. [Source: MIL-HDBK-761A, 1989]

□ **8.17.4.11 Error correction.** The system should prompt users to correct any errors it detects before initiating message transmission. [Source: MIL-HDBK-761A, 1989]

8.17.5 Receiving messages

□ **8.17.5.1 User control of incoming messages.** Users should be able to specify "filters" based on message source, priority, type, or content that will control the notification of incoming messages. [Source: National Air Traffic Services, 1999]

Discussion. The use of filters allows the user to specify the order in which received messages can be read and what notification is provided for incoming messages. For example, a user might decide that the arrivals of all messages from a particular sender produce a special notification of some kind.

□ **8.17.5.2 User control of incoming messages.** Users should be able to choose the device (files, display, printer) that will receive messages. [Source: MIL-HDBK-761A, 1989]

□ **8.17.5.3 Notification at log on.** Users should be notified at log on of any data transmissions received since their last use of the system. [Source: MIL-HDBK-761A, 1989]

□ **8.17.5.4 Notification during use.** While using the system, users should be notified when they receive a new message. [Source: MIL-HDBK-761A, 1989; DON UISNCCS, 1992]

□ **8.17.5.5 Non-interference of notification.** Notification of the arrival of an electronic message should not interfere with ongoing system use. [Source: MIL-HDBK-761A, 1989]

□ **8.17.5.6 Messages with differing priority.** When incoming messages differ in priority, message notification should reflect that priority. [Source: DON UISNCCS, 1992]

□ **8.17.5.7 Incoming message log.** A log should be maintained of all incoming messages. [Source: MIL-HDBK-761A, 1989]

□ **8.17.5.8 Queuing incoming messages.** Incoming electronic messages should be automatically queued by time of receipt and message priority. [Source: DON UISNCCS, 1992]

- **8.17.5.9 User review of message summary information.** Users should be able to review message summary information (for example, the source, type, and priority) about queued incoming messages. [Source: MIL-HDBK-761A, 1989]

- **8.17.5.10 Nondestructive review.** Unless precluded by security or other considerations, users should be able to review messages in their inbox without having to save, delete, or respond to them. [Source: MIL-HDBK-761A, 1989]

- **8.17.5.11 Incoming message operations.** Users should be able to **Display, Save,** and **Delete** individual messages. [Source: DON UISNCCS, 1992]

- **8.17.5.12 User specification of summary order.** Users should be able to specify the order in which message summaries are listed. [Source: MIL-HDBK-761A, 1989]

- **8.17.5.13 Size indication in message summary.** The message summary should include an indication of the size of the message. [Source: MIL-HDBK-761A, 1989]

- **8.17.5.14 Adding comments to incoming messages.** Users should be able to comment on reviewed messages. [Source: MIL-HDBK-761A, 1989]

- **8.17.5.15 Display of comments.** Comments should be displayed and should be distinct from the message itself. [Source: MIL-HDBK-761A, 1989]

- **8.17.5.16 Naming and describing incoming messages.** Users should be able to assign their own names and other descriptors to received messages. [Source: MIL-HDBK-761A, 1989]

- **8.17.5.17 Disposing of incoming messages.** Users should be able to discard unwanted messages without saving them. [Source: MIL-HDBK-761A, 1989]

- **8.17.5.18 Data preservation.** The arrival of a message in a format incompatible with that of the system shall not result in the loss of the message or of any ongoing transaction. [Source: MIL-HDBK-761A, 1989]

- **8.17.5.19 Notification of incompatible format.** When the format of a data transmission is incompatible with the system receiving it (for example, incompatible with system decoding or with the available devices), the intended recipient should be notified. [Source: MIL-HDBK-761A, 1989]

8.18 Accommodating people with disabilities

The "Americans with Disabilities Act of 1990" (Public Law 101-336) prohibits employment discrimination against qualified individuals with disabilities. If a person's disability creates a barrier to employment, the Act requires that the employer consider whether reasonable accommodations could remove the barrier. The intent of the Act is to permit people with disabilities to compete with people without disabilities on the basis of the same performance standards and requirements once such accommodations have been made.

Definitions. A **disability** is a physical or mental **impairment** that substantially limits one or more of a person's major life activities. A **reasonable accommodation** is any modification or adjustment to a job or the work environment that will enable a qualified person with a disability to participate in the application process and to perform essential job functions.

8.18.1 General

- **8.18.1.1 Executable from a keyboard.** When software is designed to run on a system that has a keyboard, product functions shall be executable from a keyboard itself where the function itself or the result of performing a function can be discerned textually. [Source: General Services Administration, 2000]

- **8.18.1.2 Non-disruption of accessible features.** Applications shall not disrupt or disable activated features of other products or the operating system that are identified as accessibility features, where those features are developed and documented according to industry standards. [Source: General Services Administration, 2000]

- **8.18.1.3 Programmatic distinction of input focus.** The input focus shall be programmatically exposed so that assistive technology can track focus and focus changes. [Source: General Services Administration, 2000]

- **8.18.1.4 Information available to assistive technology.** Sufficient information about a user interface element including the identity, operation, and state of an element shall be available to assistive technology. [Source: General Services Administration, 2000]

- **8.18.1.5 Redundant image and text information.** Where an image represents a program element, the information conveyed by the image shall also be available in text format. [Source: General Services Administration, 2000]

- **8.18.1.6 Textual information.** Textual information shall be provided through operating system functions for displaying text with, at minimum, text content, text input caret location, and text attributes information available. [Source: General Services Administration, 2000]

- **8.18.1.7 Animation.** When animation is displayed, the information shall be displayable in at least one non-animated presentation mode at the option of the user. [Source: General Services Administration, 2000]

- **8.18.1.8 Electronic forms.** When electronic forms are used, the form shall allow people using assistive technology to access the information, field elements, and functionality required for completion and submission of the form including all directions and cues. [Source: General Services Administration, 2000]

8.18.2 Accommodating people with moderate physical disabilities

- **8.18.2.1 Multiple, simultaneous activations.** When a system requires multiple, simultaneous activations, such as the simultaneous depression of two or more keys on a keyboard, the system should provide an optional, alternative mode of operation. [Source: Scadden & Vanderheiden, 1988]

  Example. One possible alternative mode of operation would accept sequential rather than simultaneous activations. [Source: Scadden & Vanderheiden, 1988]

- **8.18.2.2 Timed responses.** When a system requires a response in less than 5 sec or the release of a key in less than 1.5 sec, the system should provide either a means by which a user can adjust the time interval or an alternate mode that does not have the time requirements. [Source: Scadden & Vanderheiden, 1988]

- **8.18.2.3 Minimal number of "small" targets.** The number of small targets should be minimized, especially if they are likely to be the objects of drag operations. [Source: Casali, 1992]

  Discussion. The difficulty of moving a pointer onto an object and moving an object increases as the size of the object decreases. This difficulty is greater for people with disabilities than for people without disabilities. [Source: Casali, 1992]

- **8.18.2.4 Zooming capability.** When a small target cannot be avoided, a zooming capability should be provided. [Source: Casali, 1992]

8.18.3 Accommodating people with visual disabilities

Most of the difficulty people with visual disabilities have with computer systems arises in connection with output displays. Some difficulty also arises from input devices that require eye-hand coordination.

□ **8.18.3.1 Enlarging a display.** People with moderate visual disabilities should be provided a means for enlarging a display [Source: Scadden & Vanderheiden, 1988]

Discussion. This might be accomplished either by providing a means for attaching a larger display or by providing a means for enlarging all or part of the displayed image. People who are blind usually have most of their difficulty with output displays. Some input devices also cause difficulty, for example, touch screens. [Source: Scadden & Vanderheiden, 1988]

□ **8.18.3.2 Alternate display of information.** Visually displayed information, both text and graphics, should be available at the alternative output display for people with severe visual disabilities. [Source: Scadden & Vanderheiden, 1988]

□ **8.18.3.3 Auditory representation granularity.** When a graphical interface is given an auditory representation, the auditory representation should be based on interface objects, not pixels. [Source: Mynatt & Edwards, 1992]

□ **8.18.3.4 Navigation in an auditory representation.** Navigation in an auditory representation should move the user's position among different auditory interface objects. [Source: Mynatt & Edwards, 1992]

Discussion. Standard mouse movement is in terms of pixels, which have little or no meaning in an auditory representation. [Source: Mynatt & Edwards, 1992]

■ **8.18.3.5 Auditory and operational consistency.** Each type of object, such as a push button, shall have consistent auditory representation and operate in a consistent way throughout an auditory interface. [Source: Mynatt & Edwards, 1992]

□ **8.18.3.6 Dual representation.** All interactions that a person without visual disabilities would see between the mouse cursor and objects on the screen should have auditory counterparts. [Source: Edwards, 1988]

Discussion. These sounds may be simple or complex tones or patterns of tones, or speech. [Source: Edwards, 1988]

▫ **8.18.3.7 Objects represented.** An interface with both visual and auditory representation should incorporate into the auditory portion certain objects when they appear in the corresponding visual interface. These objects are:

a. menus,

b. windows,

c. dialogs,

d. buttons, and

e. scroll bars. [Source: Edwards, 1988]

▫ **8.18.3.8 Eliciting an object's name.** A user should be able to elicit the name of the object currently being selected. [Source: Edwards, 1988]

Example. Pressing one of the buttons of a mouse might result in a synthesized speech announcement of the name of the object. [Source: Edwards, 1988]

8.18.4 Accommodating people with hearing disabilities

People who have hearing disabilities and people who are deaf usually have little difficulty using computers. Providing redundant visual outputs to tones and other auditory outputs can eliminate most of the problems they do have.

▫ **8.18.4.1 Redundant visual output.** All information required for system operation and error detection that is presented in auditory form should also be provided or available redundantly in an appropriate visual form. [Source: Scadden & Vanderheiden, 1988]

- **8.18.4.2 Hearing auditory outputs.** Computers and computer systems intended to be accessible to people with hearing disabilities should be designed to maximize the number of users who can hear the auditory outputs. [Source: Vanderheiden & Vanderheiden, 1991]

  Discussion. Auditory information (for example, synthesized speech, beeps, buzzers, tones, and machine noises) may not be heard well enough to elicit the intended response. Possible solutions include

  a. providing a volume adjustment,

  b. making auditory output as loud as practical,

  c. using sounds that have strong middle- and low-frequency components (500 - 3000 Hz),

  d. providing a headphone jack so that people with hearing disabilities can listen at high volume,

  e. providing a separate volume control for headphone jacks,

  f. placing a sound source on the front of a device and away from sources of loud noise,

  g. facilitating the direct use of the telecoil in hearing aids by including in the equipment a built-in inductive coil,

  h. reducing the amount of non-meaningful sound produced by the equipment, and

  i. presenting auditory information continuously or repetitively until the user responds to it. [Source: Vanderheiden & Vanderheiden, 1991]

- **8.18.4.3 Non-overlapping objects.** Objects in an interface that have both visual and auditory representation should not completely obscure other objects (for example, a window that completely overlaps another window). [Source: Edwards, 1988]

- **8.18.4.4 Size and location of objects.** Users should not be able to change the size or move objects that serve as visual symbols of auditory representations. [Source: Edwards, 1988]

Glossary

Abbreviation - Any shortened form or abridgment of a word, expression, or phrase used to conserve space or time, including initializations, contractions, and acronyms.

Accelerators - Keyboard commands that can be used instead of pointing and clicking on menu options. They are indicated by underlining the proper character and placing the keyboard alternative in parenthesis after the option (for example, Bold (Ctrl+B)).

Active Help - A form of Help that senses an inappropriate entry and interrupts the task to ask users what they are attempting and if they are sure they want to complete the operation they have just initiated. Depending upon the user response to the question, active Help then suggests the correct action.

Advice - An interactive, context-sensitive "Help" source that indicates what entry to make at the current location in the application, the required keystroke(s), or which steps to take to complete the task.

Advisory - A signal that indicates a safe or normal configuration, condition of performance, or operation of essential equipment or attracts attention and imparts information for routine action purposes.

Alert - A signal that indicates a condition relating to the effective performance of duties. The condition or message requires the operator or maintainer to take immediate action or indicates that a significant update in information necessary for the effective performance of duties is available.

Alert boxes - Applied to display messages to users to inform them of situations that may require their attention or are possibly dangerous.

Attributes - Instructions that change the characteristics of a selected item. An example of an attribute is changing text from standard to bold type.

Cascading menu - A type of hierarchical menu in which a submenu is attached to the right side of a menu item. Cascading menus can be added to drop-down menus, pop-up menus, or even other cascading menus.

Caution - A signal that indicates the existence of a condition requiring immediate attention but not immediate action.

Client area (or working area) - The main area of the window that users employ to do their operational or application tasks. It is the area where users make their inputs and receive their outputs.

Combo box - A special type of text box with an attached list of options. Combo boxes allow the user to either select from the given list or type in an alternative response. There are two types of combo boxes, standard and drop-down.

Command entries - A type of control entry that enables the user to initiate a message to the system that will specify desired functions.

Command language - A limited programming language used strictly for executing a series of commands (for example, Linux, any DOS shells).

Commands - Instructions that cause a device to perform some action.

Contrast - The difference in luminance of two areas often expressed in terms of a contrast ratio.

Contrast ratio - The luminance level of the foreground divided by the luminance level of the background.

Control entries - User input for sequence control, such as function key activation, menu selection, and command entry.

Copy – Instructs the computer to copy selected data.

Cursor - A marker on the display screen that indicates the position where the computer expects the next input or will display the next output. The cursor may be positioned by the computer or by the user.

Database - A set of interrelated data stored in a computer.

Data-entry window - A window that contains a set of labeled fields for entering, changing, and deleting data. It may also contain labeled data display fields, which a user cannot change.

Direct manipulation - When the user controls the interface with the computer by acting directly on objects on the display screen. An object may be an icon, menu option, symbol, button, or dialog box.

Disability - A physical or mental impairment that substantially limits one or more of a person's major life activities.

Display sequencing - A means of reducing clutter by displaying a series of partial displays (for example, a map and a series of overlays) or of displaying data sequentially. It can also be used as a form of animation.

Drop-down combo box - A combo box that has a down arrow button, and a drop-down list.

Dwell emphasis - When the pointer comes to rest for a predetermined time on a selected object, the computer tells the user which object it perceives the user is about to select.

Ellipses - Visual indicators, such as three dots (...), used to make menu options that branch to other sub-menus distinguishable from menu options that will immediately perform an operation.

Exclusive buttons (option buttons or radio buttons) - Single, two-state choices, which are mutually exclusive from each other.

Function keys - Labeled keys that serve as keyboard short cuts (for example, F1, F2, F3, or with the function name such as Delete or Insert) by combining in one key the actions of a sequence of individual keys.

Graphic menus (palettes) - A set of unlabeled symbols, typically presented within small rectangles. Symbols may be icons, patterns, characters, or drawings that represent an operation. Palettes are used widely in drawing and painting packages but are commonly found in word-processing applications as well.

Grid lines - Horizontal lines, vertical lines, or both, extending from the scale divisions of one or both axes of a graph and intended to aid users in locating and reading data points.

Group - On a pull-down menu is any set of menu items between two separators or the whole list if there are no separators on the pull-down menu.

Hard function key - The physical function key on the keyboard.

Hierarchical menu - A large series of options or menus that is organized as a multi-level, branching structure in which an option in a higher-level menu is the name of another menu at the next lower level. The options in the lowest level menus are not the names of other menus. They are commands or selectable values, such as color squares on a palette or specific Auto Text choices (for example, Dear Sir, or To Whom It May Concern).

Hot spot - The selectable area in which a user can place the pointer and successfully select an icon.

Impairment - A loss or abnormality of physiological or anatomical structure or function.

Input focus - The notion that only one window and usually only one object in a window at a time is capable of accepting input from a pointing device or the keyboard.

Keyboard accelerator - A key or simultaneous combination of keys that a user can type to select an option in a menu without having to display the menu.

Keyboard lockout - A state determined by an application in which the application does not accept input from the keyboard.

Menu - A list of options from which a user makes a selection or selections.

Menu bar - A narrow panel, usually at the top of a computer screen in menu-based computer systems, that continually displays the highest-level menu options for selection by the user. The options on a menu bar are usually the names of other menus.

Message window (**message box**) - A secondary window that provides users with non-critical information, progress information about lengthy processes, alerts to unusual events, and/or warnings of potential dangers. Message windows may be modal or modeless.

Minimize - The operation that reduces a window's presence into a standby icon button on the information line at the bottom of the screen.

Mnemonic - A single letter that a user can type to select an option in a menu.

Modal window - A window with which a user must interact before being able to interact with any other windows. A user cannot interact with other windows as long as the modal window is displayed.

Modeless window - A window that allows a user to interact with other windows.

Navigation keys - Several keys such as **Home, End, Page Up, Page Down**, and the arrow keys, which are dedicated to keyboard navigation.

On-line Help - Primarily an interactive, context-sensitive source of information that can prompt a user what entry to make at the current location in an application, what keystrokes are required, or what steps are required to complete a task. Secondarily, on-line Help is a form of on-line documentation and reference information.

Option - One of the selectable items in a menu.

Option buttons (exclusive buttons or radio buttons) - Single, two-state choices, which are mutually exclusive from each other.

Outline selection - An extended form of drag selection that is particularly useful for graphical objects when normal drag selection conflicts with moving objects with the mouse.

Paging - The process of scrolling through data one page at a time.

Palettes (graphic menus) - A set of unlabeled symbols, typically presented within small rectangles. Symbols may be icons, patterns, characters, or drawings that represent an operation. Palettes are used widely in drawing and painting packages but are commonly found in word-processing applications as well.

Panes - The separate viewing areas in a split window.

Panning - An orientation of display framing in which a user conceives of the display frame as moving over a fixed array of data.

Passive Help - A form of Help that simply responds to user requests for information. The information may be in the form of on-line system documentation, such as a user's guide or a list of functions performed by combinations of key presses.

Pointer - A symbol displayed on the screen that is controlled by a pointing device. Its shape may change depending on the function that is invoked at a particular moment or its location on the screen.

Pointing device - A non-keyboard device that allows a user to navigate rapidly around the screen and to specify and select objects for manipulation and action.

Pop-up menus - Menus that only appear on user demand. They are often associated with a particular object on a display (for example, a pop-up menu listing acceptable command options close to the immediate work area). Because pop-up menus are not displayed all of the time, they do not take up valuable screen space. They provide an efficient way to access commands because they eliminate the need for the user to navigate to a menu bar or control bar. A pop-up menu typically contains 5 to 10 options presented in a vertical listing.

Primary window - A top or high-level window in an application. It is the main location of user interaction and functions independent of other primary windows in the application.

Pull-down menu – A menu associated with an option on a menu bar that appears when a menu bar option is selected.

Query - The process of specifying, locating, and retrieving data matching specified characteristics from a database.

Radio buttons (exclusive buttons or option buttons) - Single, two-state choices, which are mutually exclusive from each other.

Reasonable accommodation - Any modification or adjustment to a job or the work environment that will enable a qualified person with a disability to participate in the application process and to perform essential job functions.

Saturation - The relative amount of whiteness in a chromatic color.

Save - Causes the computer to save the data.

Scrolling - A method used to move through the contents of a window or list in a dialogue box using the scroll-bar or scroll arrows.

Scrolling menu - A menu usually containing many options that does not display all of the options at once. It includes a scroll-bar that permits the sequential display of all options. Scrolling menus are also called list boxes and scrolling lists.

Secondary window - A window that is displayed from within a primary window or another secondary window. Secondary windows are sometimes called child windows.

Selection - The action a user makes in choosing a menu option. Selection may be accomplished by pointing, by typing, or by pressing a function key.

Serif - The small cross stroke at the end of the main stroke of the letter.

Slider - A control used to set a value and give a visual indication of the setting.

Soft function key - An area on the screen that represents a function key.

Spin button (also known as a **spin box**) – A variation of the scrolling menu or list. A spin button is made up of a text box and two arrows and displays a sequence of mutually exclusive choices.

Spin box (also known as a **spin button**) - A variation of the scrolling menu or list. A spin box is made up of a text box and two arrows and displays a sequence of mutually exclusive choices.

Split bar - The divider placed across the middle of the window that separates the panes.

Split box - A rectangular indicator located inside the scroll-bar of a split window or immediately above the scroll-bar of a split-able window. Note, however, that in some rules, the split box is called the split bar.

Stacking - The stringing together of commands so that they can all be executed with a single command.

Standard combo boxes - A special type of text box that includes a standard list of options with all options visible to the user.

Status bar - A special type of message bar used to present information about the current status of the application.

Syntax - The set of rules governing the language of a command language. Examples would be rules about the order in which parts of a command occur or rules about punctuation in commands.

Tear-off menu - A menu that can be removed from the menu bar and moved to another location on the screen where it can remain on display. Tear-off menus are also called “tacked” or “pushpin” menus.

Text boxes - Edit controls into which the user types information. Most text boxes are one line tall, but applications can also use multi-line text boxes.

Text frame - A sizable field into which the user can type text. This is a dynamic form of an edit field and should not be confused with the text box. Although text frames are generally rectangular, other shapes may also be used.

Toggled menu options - Options that are used to issue commands as a binary selection of one of two opposite commands.

Tonal coding - Coding based on different shades of the same hue or different patterns or textures.

Utility window - A supplementary window that provides the users with additional tools or controls such as a tool palette or a set of text attributes.

Warning - A signal that indicates the existence of a hazardous condition requiring immediate action to prevent loss of life, equipment damage, or a service interruption.

Working area (or client area) - The main area of the window that users employ to do their operational or application tasks. It is the area where users make their inputs and receive their outputs.

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9 Input devices

This section provides rules for keyboards, function keys, pointing devices, and some alternative input devices. The advantages and disadvantages of non-keyboard input devices are shown in Exhibit 9.0. The characteristics of these devices need to be considered in the selection of the appropriate controls for a given task.

At times, the line between what is considered a control and what is considered an input device can be blurred, such as the use of pushbuttons in conjunction with trackballs in some systems and the use of knobs to adjust parameters (such as range) in other systems. Information on pushbuttons, knobs, dials, and switches is contained in Chapter 6, Controls and Visual Indicators.

Exhibit 9.0 Advantages and disadvantages of non-keyboard input devices

Type of device	Advantages	Disadvantages
Mouse	Relatively fast	Requires additional flat work surface
	Has low error rates for large targets	Difficult to use for free-hand graphic input
	Allows user to concentrate attention on VDT screen	High error rates with small targets
		Lost time when mouse held backwards or sideways
		Some training needed
		Wheel (ball) slipping sometimes a problem
Directional controllers (joystick and trackball)	Can be used comfortably with minimum fatigue	Slower than the light pen and other “point-to-devices” for simple input and option selections
	Does not cover parts of the screen in use	Must be attached, but not to the display
	Expansion or concentration	Unless there is a large joystick, an inadequate control to display ratio will result for positional control
	Ball control is an efficient use of space	The displacement of the stick controls both the direction and the speed of cursor movement
		Trackball and joystick controllers are difficult to use for accurate free-hand graphic input
		Difficult to integrate the activate switch with the trackball

Exhibit 9.0 (cont.) Advantages and disadvantages of non-keyboard input devices

Light pen	Fast for simple input	May not feel natural to user, like a real pen or pencil does
	Good for tracking moving objects	Requires some fine motor control
	Minimal perceptual motor skills needed	May lack precision because of the aperture distance from the CRT screen surface, and parallax
	Efficient for successful multiple selection	Contact with the computer may be lost unintentionally
	User does not have to scan to find a cursor somewhere on the screen	Frequently requires simultaneous button depression may cause slippage and inaccuracy
	May be adaptable to bar coding	Must be attached to terminal, which may be inconvenient
		Glare problem if pen tilted to reduce arm fatigue
		Fatiguing if pen is held perpendicular to work surface
		If pointing to dark area, may require user to flash the screen to find pen
		One-to-one input only (zero order control)
		May be cumbersome to use with alternate, incompatible entry methods, like the keyboard
		Tends to be used for purposes other than originally intended, such as for key depression
		Tends to be fragile
		Hand may obstruct a portion of screen when in use
		Care must be taken to provide adequate “activate” area around choice point
		Cannot be used on gas plasma panel

Exhibit 9.0 (cont.) Advantages and disadvantages of non-keyboard input devices

Stylus and grid	Good for graphic entry	Extra space required on work surface
	Can be designed to be used on horizontal surface	Displacement of visual feedback from motor activity may cause coordination problems
	Multipurpose input device	Entering hand printed characters to be recognized by the system is very slow (fewer than 40 characters/min) compared with typewriter entry (averaging 200 recognition characters/min)
	Minimal difficulty going from graphic input if character is built into the system, and the tablet is used for the input Spatial correspondence between displays and control movement	Entering hand printed characters to be recognized by the system is very slow (fewer than 40 characters/min) compared with typewriter entry (averaging 200 recognition characters/min)
Touch screen	No separate input device	Low resolution
	Fast	Finger can block view
		Fingerprints on screen
		Tires arm
Voice activation	Does not require hands	Entry can be slow
	Does not require user to shift gaze	Must use specified vocabulary
	Useful for low light conditions	Some systems must be individualized to specific user
	Allows simultaneous activation of more than one control mode	If individual’s voice changes (for example, become stressed) system may not respond
	Could be used in lieu of a translator, allowing natural, conversational version of different languages to control complicated systems	May require headset
		Speaker-dependent systems require template loading time

9.1 Keyboards

Keyboards vary greatly in the number and arrangement of keys. Most keyboards include the following:

a. **Alphanumeric keys -** The letters of the alphabet, numerals, and punctuation symbols (numeric keypads may be separate on portable computers).

b. **Dedicated formatting keys** - Keys for text formatting operations such as a **Space** bar, a **Tab** key, and a **Return** or **Enter** key.

c. **Modifier keys** - Keys that modify or qualify the effects of other keys for as long as they are held down, for example, **Shift, Ctrl,** and **Alt.**

d. **Navigation keys** - Keys that move a cursor, for example, **Arrow** keys, **Home, End, Page Up,** and **Page Down.**

e. **Fixed-function key** - Keys provided for extra or general functions, typically labeled **F1, F2,** and so on.

f. **Special purpose keys** - Keys that have a special function, such as **Help, Delete,** and **Backspace.**

▪ **9.1.1 When to use.** If applicable, keyboards shall be provided for the entry of alphabetic, numeric, and other special characters into the system. [Source: Department of Defense, (MIL-STD-1472D), 1989]

▪ **9.1.2 Include a numeric keypad for entering numeric data.** If an application requires substantial and repetitive input of numeric data, the keyboard shall include a numeric keypad. [Source: MIL-STD-1472D, 1989; Department of Defense (MIL-STD-1801), 1987]

▪ **9.1.3 Numeric keyboards.** Keyboards intended solely for the entry of numbers shall have the numerals "1" through "9" arranged in a three by three array, with "0" centered below the bottom row. [Source: Department of Energy (DOE-HFAC1), 1992]

▪ **9.1.4 Numeric keyboards for communication.** If the keyboard will be used primarily for communications, it shall use the "telephone" arrangement, that is, with the numerals 1, 2, and 3 in the top row. [Source: DOE-HFAC1, 1992]

▪ **9.1.5 Numeric keyboards for number manipulation.** If the keyboard will be used primarily for manipulating numbers, it shall use the "calculator" arrangement, that is, with the numerals 1, 2, and 3 in the bottom row. [Source: DOE-HFAC1, 1992]

▪ **9.1.6 Alphanumeric keyboards.** Keyboards intended for the entry of both alphabetic and numeric information shall conform to the standard "QWERTY" arrangement. [Source: DOE-HFAC1, 1992]

- ◻ 9.1.7 **Key size.** The minimum horizontal surface width for a key on a typing keyboard should be 12 mm. [Source: American National Standard Institute (ANSI), 1988]

- ◻ 9.1.8 **Horizontal spacing of keys.** Horizontal centerline distances should be between 18-19 mm. [Source: ANSI, 1988]

- ◻ 9.1.9 **Vertical spacing of keys.** Vertical centerline distances should be between 18-21 mm. [Source: ANSI, 1988]

- ■ 9.1.10 **Force to depress keys.** The maximum force needed to depress keys shall measure between 0.25N and 1.5N with a preferred range between 0.5N and 0.6N. [Source: ANSI, 1988]

- ◻ 9.1.11 **Keyboard slope.** The slope of the keyboard for typing should be between 0 and 25 degrees, preferably less than 15 degrees. [Source: ANSI, 1988]

- ◻ 9.1.12 **Standard keyboards.** If feasible, standard keyboards should be used. Nonstandard keyboards should contain only those keys that are used by the keyboard user. [Source: Nuclear Regulatory Commission (NUREG-0700), 1996; DOE-HFAC1, 1992]

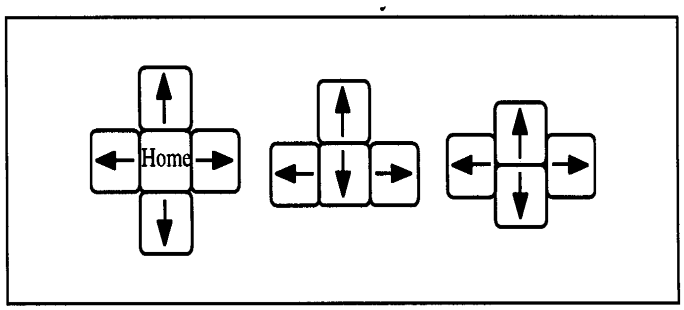
  Discussion. The presence of non-relevant keys, such as those that might be used by programmers, adds to keyboard complexity and may induce errors. [Source: NUREG-0700, 1996; DOE-HFAC1, 1992]

- ■ 9.1.13 **Two-dimensional cursor control.** If a keyboard will be used for text processing, it shall provide for movement of the cursor in two dimensions, for example by including a set of cursor control keys. [Source: DOE-HFAC1, 1992]

- ◻ 9.1.14 **Cursor control key layout.** If cursor control keys are included, they should be arranged in a two-dimensional array. [Source: DOE-HFAC1, 1992]

- ■ 9.1.15 **Cursor movement keys.** Cursor movement keys shall be arranged in a spatial configuration reflecting the direction of actual cursor movement. Exhibit 9.1.15 shows the arrangement of cursor movement keys. [Source: National Aeronautics and Space Administration (NASA-STD-3000A), 1989; DOE-HFAC1, 1992]

Exhibit 9.1.15 Cursor movement keys



- **9.1.16 Positive feedback.** Where applicable, feedback shall be provided to inform the operator that the intended key was pressed and that the next operation may be initiated. [Source: MIL-STD-1472F, 1999]

- **9.1.17 Changing data.** Users shall be provided a means to change previous entries by delete, backspace, and insert actions. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

- **9.1.18 Keyboard equivalents to function keys.** If an application assigns operations to function keys, the operations that can be performed with a function key should also be performable with alphanumeric keys. [Source: Keane (DISA HCISG V1.0), 1992]

- **9.1.19 Keyboard equivalents to pointing device operations.** If an application provides both a keyboard and a pointing device, the operations that can be performed with the pointing device should also be performable with the keyboard. [Source: DISA HCISG V1.0, 1992]

- **9.1.20 Consistent keyboards.** If a system contains more than one keyboard, the configuration of alphanumeric, numeric, and special function keys shall be consistent throughout the system. [Source: MIL-STD-1472F, 1999]

9.2 Fixed-function keys

- **9.2.1 Standardization.** Fixed-function keys should be standardized throughout the system. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

- **9.2.2 Availability.** Fixed-function keys should be selected to control functions that are continuously available; that is, the lock out of fixed-function keys should be minimized. Mechanical overlays should not be used to lock out function keys. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

- **9.2.3 Non-active keys.** When a keyboard is dedicated for use with only a specific application, blank keys on the keyboard should replace non-active fixed-function keys. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

- **9.2.4 Grouping.** Fixed-function keys shall be grouped logically and shall be placed in distinctive locations. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

9.3 Pointing devices

This section contains rules for pointing devices in general, the shape of the pointer itself, and buttons on pointing devices.

Definitions. A **pointing device** is a non-keyboard device that allows a user to navigate rapidly around the screen and to specify and select objects for manipulation and action. Examples include a mouse, trackball, stylus and grid, and light pen. A **pointer** is a symbol displayed on the screen that is controlled by a pointing device. Its shape may change depending on the function that is invoked at a particular moment or its location on the screen.

9.3.1 General

- **9.3.1.1 Functionality.** When present, a pointing device shall be capable of (1) moving a pointer on the screen, (2) selecting objects on which the pointer is placed, and (3) drop and drag operations. [Source: Department of the Navy (DON UISNCCS), 1992]

- **9.3.1.2 Single pointer.** A pointing device shall be associated with a single pointer on the screen. [Source: DON UISNCCS, 1992]

- **9.3.1.3 Moving the pointer.** A user shall be able to move the pointer on the screen by moving all or part of the pointing device. The pointer shall move in the same direction that the pointing device moves. A user shall be able to move the pointer anywhere on the screen. [Source: DON UISNCCS, 1992]

- **9.3.1.4 Non-disappearance of pointer.** A pointer shall not move beyond the outer boundaries of the screen nor shall it disappear from sight. [Source: DON UISNCCS, 1992]

  Exception. When there is another screen adjacent to the first, the pointer may move from one screen to the other. This rule does not apply when a cursor is moved quickly and the screen refresh rate is too slow to show the full path of the cursor. [Source: DON UISNCCS, 1992]

▫ **9.3.1.5 Control of the pointer.** A pointer should not move on the screen unless a user moves the pointing device. That is, an application should not move a pointer arbitrarily. [Source: DON UISNCCS, 1992]

Exceptions. One exception to this rule is if an application automatically moves the pointer in conjunction with the scroll bar. For example, when the user clicks on the down arrow to scroll through a document, the application may automatically move the pointer so that the pointer will remain on the scroll arrow.

Another case may be when the pointer "jumps" or "snaps-to" a default button because the user has selected that default option. [Source: DON UISNCCS, 1992]

▪ **9.3.1.6 Pointer stability.** The stability of the pointer shall be within 1.3 mm (0.05 in) in any direction; the preferred stability is within 0.25 mm (0.01 in). [Source: DON UISNCCS, 1992]

▫ **9.3.1.7 Movement ratio.** The ratio of movement of the pointing device to the movement of the pointer should default to approximately 1:1 and be adjustable by the user. [Source: DON UISNCCS, 1992]

▫ **9.3.1.8 Type of device.** The pointing device selected for an application should be the one thatmost appropriately meets the application requirements and is most cost-effective. The appropriateness of some specific types of pointing devices for tasks is as follows:

a. A **mouse** is a general purpose-pointing device suitable for a wide range of applications.

b. A **joystick** is appropriate for tasks requiring precise adjustments and continuous control.

c. A **trackball** is appropriate for generating precise X and Y output values and cumulative travel in any direction.

d. A **light pen** is appropriate for non-critical, imprecise functions, especially if the primary task is item selection.

e. A **stylus and grid** is appropriate for graphic entry. [Source: MIL-STD-1472D, 1989; MIL-STD-1801, 1987]

Discussion. Another factor that may contribute to the appropriateness of a given input device is the expectations, experiences, or preferences of the intended user population. If a given user population has a wealth of experience, familiarity, or acquired skill with a particular type of device, careful consideration needs to be given to replicate the features, functionality, performance, and "feel" to which they are accustomed. [Source: MIL-STD-1472D, 1989; MIL-STD-1801, 1987]

9.3.2 Mouse

- **9.3.2.1 Use.** A mouse should be used for zero order control only (for example, the generation of X and Y outputs by the controller results in proportional displacement of the pointer). [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

  Discussion. This type of pointing device may be used on any flat surface to generate X and Y coordinate values that control the position of the pointer on the associated display. It may be used for data pick off or for entry of coordinate values. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

- **9.3.2.2 Dynamic characteristics.** The design of the mouse and the placement of the maneuvering surface shall allow the user to consistently orient the mouse within 10° of the correct orientation without visual reference to the mouse. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

  Discussion. If the user grasps the mouse in what seems to be the correct orientation and moves it rectilinearly along what is assumed to be straight up the Y-axis, then the direction of movement of the cursor on the CRT is to be between 350° and 10°. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

- **9.3.2.3 Easily moved.** The mouse shall be easy to move in any direction without a change of hand grasp. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

- **9.3.2.4 Lateral range.** A complete lateral movement of the mouse from side to side within the maneuvering area (such as a mouse pad) shall move the pointer from side to side on the display regardless of the scale setting or offset unless expanded movement is selected for an automatic sequencing mode of operation. Users shall be able to specify or modify the lateral movement ratio. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

- **9.3.2.5 Dimensions and shape.** The mouse shall have no sharp edges but shall be shaped roughly as a rectangular solid, with limiting dimensions as shown in Exhibit 9.3.2.5. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

Exhibit 9.3.2.5 Dimensions of a mouse

Dimension	**Minimum mm (in)**	**Maximum mm (in)**
Width (spanned by thumb to finger grasp)	40 (1.6)	70 (2.8)
Length	70 (2.8)	120 (4.7)
Thickness	25 (1.0)	40 (1.6)

9.3.3 Joystick and trackball

Joysticks and trackballs are appropriate to use if precise input functions are required. They are most useful when used to control direct pointing, rather than discrete controls such as cursor control keys.

9.3.3.1 General

- **9.3.3.1.1 Activation and deactivation.** A discrete mechanism shall be provided to allow the user to activate and deactivate the joystick or trackball. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

Definitions. A **displacement joystick** is a joystick that moves in the direction it is pushed. Displacement joysticks are usually spring-loaded so that they return to their center position. An **isometric joystick** responds to the amount and direction of pressure applied to it, but it does not move. Displacement joysticks usually require less force than isometric joysticks and are thus less fatiguing over long operating periods.

9.3.3.2 Hand-operated displacement joysticks

- **9.3.3.2.1 Specifications.** The handgrip length of a hand-operated displacement joystick shall be in the range 110 to 180 mm (4.3 to 7.1 in); the grip diameter shall not exceed 50 mm (2 in); clearance shall be at least 100 mm (4 in) to the side and 50 mm (2 in) to the rear. If the joystick is contained in a separate module, the module shall be mounted to allow operation of the joystick without the base slipping, moving, or tilting. [Source: MIL-STD-1472F, 1999]

- **9.3.3.2.2 Movement characteristics.** Movement shall not exceed 45° from the center position. Movement shall be smooth in all directions, and positioning of a follower shall be attainable without noticeable backlash, cross-coupling, or need for multiple corrective movements. If the joystick is to be used for generating free-drawn graphics, the CRT shall have a refresh rate sufficiently high to give the appearance of a continuous track when the follower is moved. Delay between control movement and the confirming visual indicator response shall be minimized and shall not exceed 0.1 sec. [Source: MIL-STD-1472F, 1999]

▫ **9.3.3.2.3 When to use.** If accuracy is more important than speed, a displacement joystick should be used rather than an isometric joystick. If a displacement joystick is used for rate control, the joystick should be spring-loaded so that it returns to center. If a joystick will have a secondary control, a displacement joystick should be used rather than an isometric joystick. [Source: MIL-STD-1472F, 1999]

Discussion. Uses of displacement joysticks include (1) picking data from a CRT, (2) generating free-drawn graphics, (3) controlling a vehicle, (4) aiming sensors, and (5) serving as a mounting platform for a secondary control such as thumb- or finger-operated switches. [Source: MIL-STD-1472F, 1999]

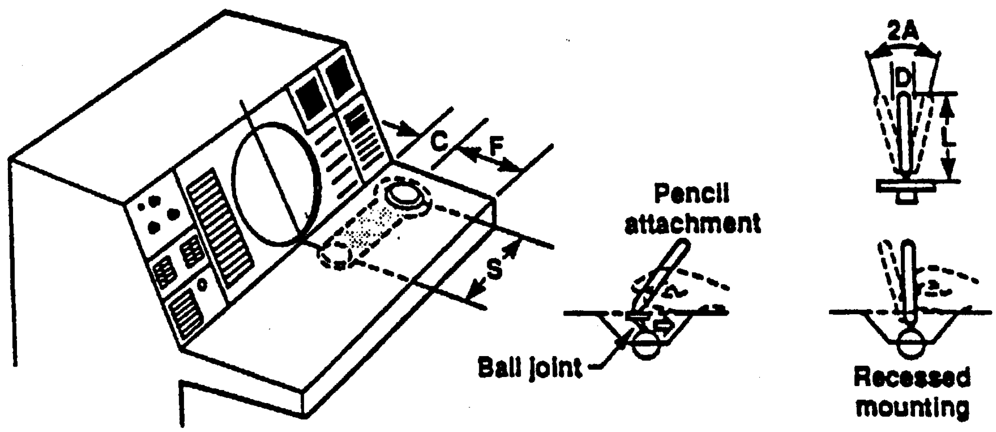
▪ **9.3.3.2.4 When not to use.** Displacement joysticks shall not be used with automatic sequencing of a CRT cursor or tracking symbol if they have a dead band near the center or hysteresis. An exception may be made if they are instrumented for null return or zero-set to the instantaneous position of the joystick at the time of sequencing. Upon termination of the automatic sequencing routine, the joystick center shall again be registered to the scope center. [Source: MIL-STD-1472F, 1999]

9.3.3.3 Finger-operated displacement joysticks

Finger-operated displacement joysticks are useful for free-drawn graphics. In this application, they are not usually spring-loaded to return to center. It is desirable that they have sufficient friction to remain in their last position when the hand is removed.

▪ **9.3.3.3.1 Finger-operated displacement joystick specifications.** The dimensions, resistance, and clearance of finger-operated displacement joysticks shall not exceed the maximum or minimum values given in Exhibit 9.3.3.3.1. [Source: MIL-STD-1472F, 1999]

Exhibit 9.3.3.3.1 Finger-operated displacement joystick specifications



	D diameter	L length	Resistance	A Displacement	S display clearance to stick clearance	C around stick	F stick clearance to shelf front
Minimum	6.5 mm (0.25 in)	75 mm (3.0 in)	3.3 N (12.0 oz)	--	0	†	120 mm (4.75 in)
Maximum	16 mm (0.6 in)	150 mm (6.0 in)	8.9 N (32 oz)	45°	400 mm (15.75 in)	--	250 mm (9.9 in)

† Maximum stick excursion plus 100 mm (4.0 in).

- 9.3.3.3.2 **Mounting.** The joystick shall be mounted in a way that provides forearm or wrist support. If the joystick is a separate modular device, the module shall be mounted so that the joystick can be manipulated without slippage, movement, or tilting of its base. [Source: MIL-STD-1472F, 1999]

- **9.3.3.3.3 Movement characteristics.** Movement shall not exceed 45° from the center position. Movement shall be smooth in all directions, and positioning of a follower shall be attainable without noticeable backlash, cross-coupling, or need for multiple corrective movements. Control ratios, friction, and inertia shall meet the dual requirements of rapid gross positioning and precise fine positioning. Recessed mounting or pencil attachments may be used as indicated in Exhibit 9.3.3.3.1 to provide greater precision of control. If the joystick is to be used for generating free-drawn graphics, the CRT shall have a refresh rate sufficiently high to give the appearance of a continuous track when the follower is moved. Delay between control movement and the confirming visual indicator response shall be minimized and shall not exceed 0.1 sec. [Source: MIL-STD-1472F, 1999]

9.3.3.4 Thumb tip and fingertip-operated displacement joysticks

- **9.3.3.4.1 Usage.** Thumb tip and fingertip-operated displacement joysticks may be mounted on a handgrip, which can serve as a steady rest to damp vibration or increase precision. If they are so mounted, the handgrip shall not itself also function as a joystick. [Source: MIL-STD-1472F, 1999]

- **9.3.3.4.2 Mounting.** Thumb tip and fingertip-operated displacement joysticks shall be mounted in a way that provides wrist or hand support. Console-mounted joysticks shall be mounted as shown in Exhibit 9.3.3.3.1. [Source: MIL-STD-1472F, 1999]

- **9.3.3.4.3 Movement characteristics.** Movement shall not exceed 45° from the center position. If the joystick is a separate modular device, the module shall be mounted so that the joystick can be manipulated without slippage, movement, or tilting of its base. [Source: MIL-STD-1472F, 1999]

9.3.3.5 Hand-operated isometric joysticks

Isometric joysticks are also known as "stiff" sticks, "force" sticks, and "pressure" sticks. These joysticks have no perceptible movement, but they can respond to the amount and direction of pressure applied. They are appropriate for tasks requiring precise or continuous control movement in two or more related dimensions. They are particularly appropriate for applications in which (1) there is a need for return to a precise center after each use, (2) feedback to the user is primarily visual rather than tactual from the control itself, and (3) there is minimal delay and tight coupling between the control and system reaction. They may also be used as mounting platforms for secondary controls, such as thumb- and finger-operated switches, although operation of secondary controls is more likely to induce error on an isometric handgrip than on a displacement handgrip. [Source: MIL-STD-1472F, 1999]

- **9.3.3.5.1 Specifications.** The handgrip length of a hand-operated isometric joystick shall be in the range of 110 to 180 mm (4.3 to 7.1 in). The grip diameter shall not exceed 50 mm (2 in). Clearances of 100 mm (4 in) to the side and 50 mm (2 in) to the rear shall be provided to allow for hand movement. The maximum force for full output shall not exceed 118 N (26.7 lb). [Source: MIL-STD-1472F, 1999]

- **9.3.3.5.2 Mounting.** Hand-operated isometric joysticks shall be mounted in a way that provides forearm support. If the joystick is a separate modular device, the module shall be mounted so that the joystick can be manipulated without slippage, movement, or tilting of its base. [Source: MIL-STD-1472F, 1999]

9.3.3.6 Thumb tip and fingertip-operated isometric joysticks

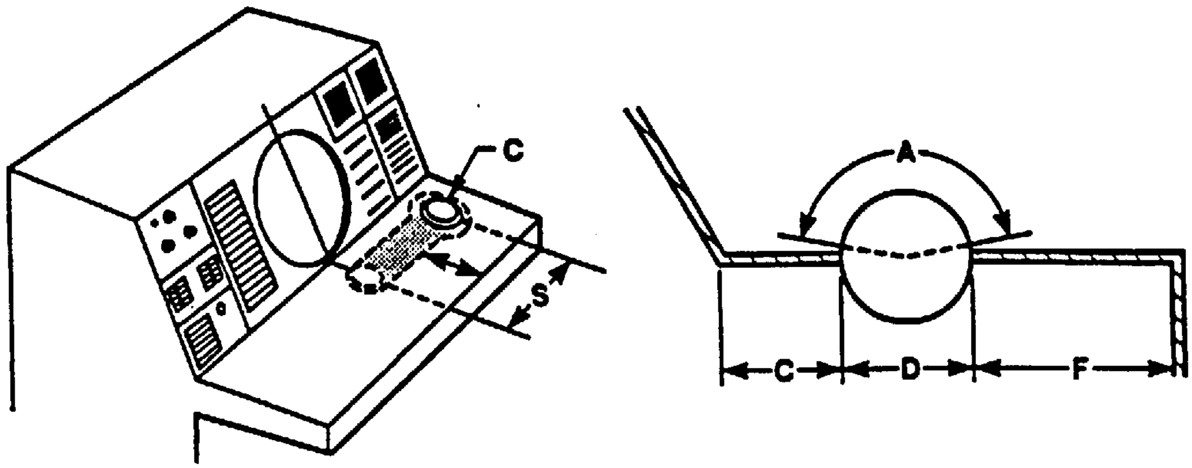
- **9.3.3.6.1 Mounting.** Thumb tip- and fingertip-operated isometric joysticks shall be mounted in a way that provides wrist or hand support. They may be mounted on a handgrip that serves as a steady rest to damp vibrations or to increase precision. If they are so mounted, the handgrip itself shall not function simultaneously as a joystick controller. Console-mounted joysticks shall be mounted as shown in Exhibit 9.3.3.3.1. If the joystick is a separate modular device, the module shall be mounted so that the joystick can be manipulated without slippage, movement, or tilting of its base. [Source: MIL-STD-1472F, 1999]

9.3.3.7 Ball controls

Other names for ball controls are "track ball," "ball tracker," "joy ball," and "rolling ball."

- **9.3.3.7.1 Specifications.** The dimensions, exposure, resistance, and clearance of ball controls shall not exceed the maximum and minimum values given in Exhibit 9.3.3.7.1. [Source: MIL-STD-1472F, 1999]

Exhibit 9.3.3.7.1 Ball control specifications
[Source: MIL-STD-1472F, 1999]



	Dimensions		Resistance		Clearance		
	D Diameter	**A Surface exposure**	**Precision required**	**Vibration or acceleration conditions**	**S Display clearance to ball clearance**	**C Around ball**	**F Ball to shelf front**
Minimum	50 mm (2.0 in)	100	--	--	0	50 mm (2.0 in)	120 mm (4.75 in)
Maximum	150 mm (6.0 in)	140	1.0 N (3.6 oz)	1.7 N (6.0 oz)	320 mm (12.6 in)	--	250 mm (9.75 in)
Preferred	100 mm (4.0 in)	120	0.3 N (1.1 oz)	--	--	--	--

- 9.3.3.7.2 **Limb support.** If a ball control will be used to make precise or continuous adjustments, a wrist or arm support or both shall be provided. [Source: MIL-STD-1472F, 1999]

- 9.3.3.7.3 **Movement characteristics.** A ball control shall be capable of rotation in any direction so as to generate any combination of X and Y output values. When moved in either the X or Y direction alone, the control shall exhibit no apparent cross-coupling (that is, movement of the follower in the orthogonal direction). There shall be no backlash apparent to the user. Control ratios and dynamic features shall meet the dual requirements of rapid gross positioning and smooth, precise fine positioning. [Source: MIL-STD-1472F, 1999]

- **9.3.3.7.4 When to use.** Ball controls rotate freely in all directions; therefore, they are suitable for applications such as data pickoff and accumulative travel; however, they do not provide for automatic return to a point of origin. Ball controls should be used only as position controls, that is, applications in which a movement of the ball produces a proportional movement of a follower on a visual indicator. [Source: MIL-STD-1472F, 1999]

- **9.3.3.7.5 Movement of a follower off a visual indicator.** If the application allows a ball control to move its follower off the edge of a visual indicator, the application shall advise the user how to bring the follower back onto the visual indicator. [Source: MIL-STD-1472F, 1999]

9.3.4 Light pen

A light pen is appropriate to use if item selection is the primary type of data entry. For example, a light pen may be used when non-critical, imprecise input functions are required. It may also be used as a track-oriented readout device. It can be positioned on the display screen to detect the presence of a computer-generated track by sensing its refresh pattern. The display system will then present a cursor on the designated track. With suitable additional circuitry, a cursor can be made to track the movement of the light pen across the surface, thus allowing it to function as a two-axis controller capable of serving the same purposes as stylus and grid devices.

- **9.3.4.1 Dimensions and mounting.** A light pen shall be between 120 and 180 mm (4.7 and 7.1 in) long with a diameter between 7 and 20 mm (0.3 and 0.8 in). A clip shall be provided to hold the light pen when it is not in use. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

- **9.3.4.2 Activation.** A light pen shall be equipped with a discrete activating and deactivating mechanism. A push-tip switch, requiring between 0.5 to 1.4 N (2 to 4 oz) of force to activate, is preferred. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

- **9.3.4.3 Feedback.** Two forms of feedback shall be provided to the user when using a light pen:

  a. feedback concerning the position of the light pen, preferably in the form of a displayed cursor or highlighting, that informs the user that the system is recognizing the presence of the light pen. The feedback shall be large enough to be seen under the point of the light pen.

  b. feedback that the light pen has been activated (for example, the push-tip switch has been triggered) and the input have been received by the system. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

9.3.5 Stylus and grid

A stylus and grid is appropriate to use as a multipurpose input device when combined with a program for character recognition. The stylus and grid are also very good for graphic entry although they are much slower than keyboard entry for alphanumeric data.

Grid and stylus devices may be transparent media placed directly on a visual indicator, or they may be located elsewhere, in a location that makes stylus manipulation convenient.

▪ 9.3.5.1 **Specifications.** A transparent grid used as an overlay on a visual indicator shall conform to the size of the visual indicator. A grid that is displaced from the visual indicator shall conform as closely as possible to the size and orientation of its related visual indicator. The visual indicator shall contain a follower that appears at the position on the visual indicator that corresponds (that is, has the same coordinate values) to the location of the stylus on the grid. [Source: MIL-STD-1472F, 1999]

▪ 9.3.5.2 **Dynamic characteristics.** Movement of the stylus in any direction on the grid surface shall result in smooth movement of the follower in the same direction. Discrete placement of the stylus at any point on the grid shall cause the follower to appear at the corresponding coordinates and to remain steady in position as long as the stylus is not moved. The refresh rate of the follower shall be sufficiently high to ensure the appearance of a continuous track whenever the stylus is used for the generation of free-drawn graphics. [Source: MIL-STD-1472F, 1999]

▫ 9.3.5.3 **When to use.** Grid and stylus devices may be used for data pickoff from a CRT, the entry of points onto a visual indicator, the generation of free-drawn graphics, and similar control applications. These devices should be used only for zero order control functions, that is, applications in which displacement of the stylus from a reference position causes a proportional displacement of the follower. [Source: MIL-STD-1472F, 1999]

▪ 9.3.5.4 **Refresh rate.** The refresh rate for the cursor shall be sufficiently high to ensure the appearance of a continuous track whenever the stylus is used to generate free-drawn graphics. [Source: NASA-STD-3000A, 1989; DOE-HFAC1, 1992]

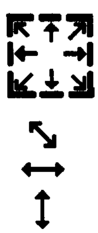
▪ 9.3.5.5 **Remote grid size.** A remote grid shall approximate the size of the display. [Source: NASA-STD-3000A, 1989; DOE-HFAC1, 1992]

▪ 9.3.5.6 **Remote grid placement.** A remote grid shall have an orientation that is consistent with the directional relationships between them and the display without violating any anthropometrics rules. [Source: NASA-STD-3000A, 1989; DOE-HFAC1, 1992]

9.3.6 Pointer shapes

- **9.3.6.1 General-purpose pointer shape.** An arrow pointing up and to the left shall be the general-purpose pointer (↖). This and other examples of pointer shapes associated with specific functions are illustrated in Exhibit 9.3.6.1. If an application provides any of these functions, it shall change the pointer to the associated shape whenever that function is invoked. An application shall redefine the shape of a pointer only when the pointer is inside an application window (including the border). [Source: DON UISNCCS, 1992]

Exhibit 9.3.6.1 Pointer shapes associated with functions

Shape	Name	Function	Hotspot
	Arrow	**Pointing.** Used in most window areas for object selection.	The point of the arrow.
	I-beam	**Pointing.** Used in text areas to position the text cursor and perform actions on text. The I-beam pointer is hidden during the time between any keyboard action and pointer movement (that is, when text entry is occurring at the location of the text cursor).	On the vertical bar of the I-beam about one-third from the top.
	Watch (or hourglass)	**Working.** Indicates that an operation is being performed in a window area. When the working pointer is displayed, all pointing device and keyboard actions are ignored in the area.	Not applicable
	Caution sign	**Caution.** Indicates that action is expected in another window area before input can be made in the current area and that the pointer has no effect in the area. When the caution pointer is displayed, all pointing device and keyboard actions are ignored in the area.	Not applicable
	Resize pointer	**Resize.** Indicates positions for area resize, with the direction of the arrow in the pointer indicating the direction of increasing size. The horizontal and vertical resize pointers indicate resize in either the horizontal or vertical direction. The diagonal resize pointers indicate resize in both the horizontal and vertical directions simultaneously. The resize pointer appears when the pointer is on the frame border.	On the corner or line at the position pointed to by the arrow.
	Move arrows	**Moving.** Indicates a move operation in progress or a resize operation before the resize direction has been determined. During a resize operation, the four-directional arrow pointer indicates a direction for resizing and changes to the appropriate resize arrow when the pointer is on the frame border.	The intersection of the arrows.
	Sight or cross	**Sighting.** Used to make fine position selections (for example, to select a location on a map display).	The intersection of the lines.

▪ **9.3.6.2 "Hotspot."** A pointer shall have a "hotspot," that is an active point (although this active point may not be readily apparent to the user). The hotspot shall indicate the precise location where an operation will occur. These points are specified for a variety of pointer shapes in Exhibit 9.3.6.1. [Source: DON UISNCCS, 1992]

Definition. A **hotspot** is the precise part of a screen pointer that marks the screen position where an operation on a pointing device will have an effect. [Source: DON UISNCCS, 1992]

▪ **9.3.6.3 Hotspot and pointer shape.** The screen location of a hotspot shall not change if the pointer changes from one shape to another. [Source: DON UISNCCS, 1992]

▫ **9.3.6.4 Additional pointer shapes.** If an application provides a function for which a pointer shape does not exist in Exhibit 9.3.6.1, the application may provide a new pointer shape. If this is done, the new shape should (1) be easy to see, (2) obscure as little information as possible on the screen, (3) have a hotspot that is obvious and easy to locate, (4) provide a hint of its purpose, and (5) not be easily confused with other objects on the screen. [Source: DON UISNCCS, 1992]

9.3.7 Pointing device buttons

One or more buttons are provided on pointing devices to allow the manipulation of objects on the screen.

▪ **9.3.7.1 Button operations.** A user shall be able to perform the following actions with any button on a pointing device:

a. Press. Depress a button and hold it down.

b. Release. Release a button that has been depressed.

c. Click. Press and release a button without moving the pointing device.

d. Double click. Press and release a button twice in rapid succession without moving the pointing device.

e. Drag. Depress a button and move the device while holding the button down.

f. Move. Move the pointing device without pressing any buttons. [Source: DON UISNCCS, 1992]

- **9.3.7.2 Button functions.** Each button on a pointing device shall have a specific function (within the context of the application) that is executed whenever a user presses the button. If the device has only one button, that button shall provide the "select" function; if it has two buttons, the left one shall provide the "select" function and the right button shall provide a "menu" function. [Source: DON UISNCCS, 1992]

  Definitions. The **select function** selects or activates objects on the screen or sets the location of the cursor. The **menu function** causes the appearance of a menu appropriate to the location of the pointer. [Source: DON UISNCCS, 1992]

  Discussion. If applicable, a system may require that a middle button be used for a particular function (for example, as another means to execute a default action). An application can map a function to the middle button if the function does not contradict or interfere with the function assigned to this button by the system or by another application. [Source: DON UISNCCS, 1992]

- **9.3.7.3 Left-right reversal.** A system shall provide users the ability to reverse the left-right operation of the buttons. [Source: DON UISNCCS, 1992]

9.4 Alternative input devices (non-keyboard, non-pointing devices)

Application developers are encouraged to use input devices in unique ways to support efficient user performance within an application. In addition, developers might determine that devices such as voice input or touch panels are appropriate alternatives for user input.

9.4.1 General

- **9.4.1.1 Consistent interaction.** If an alternate input device is used in an application, the manner in which users interact with the device (e.g., for navigation or selection) should be consistent with their interactions with other input devices. [Source: DON UISNCCS, 1992]

- **9.4.1.2 Type of device.** The alternate input device selected for an application shall be the one that most appropriately meets the application requirements and is most cost-effective. The appropriateness of some specific types of input devices for tasks is as follows:

  a. A **touch screen or touch panel** is appropriate for data entry and item selection if typing skills are not required.

  b. An **optical character recognition device** is appropriate for the entry of formatted, printed data.

  c. A **voice input** device is appropriate if the user's visual and manual performances are constrained. [Source: MIL-STD-1801, 1987]

9.4.2 Touch interactive devices/Touch panels

A touch-interactive device (TID) is an input device that permits users to interact with the system by pointing to objects on the display. TIDs may degrade image quality through reduced display luminance or through reduced display resolution. These degradations can result from the overlaid device itself and from dirt on the surface resulting from touching. TIDs can also introduce parallax because of the separation between the touch surface and the image, and they can introduce glare problems. [Source: Avery & Bowser (DOE HFDG ATCCS V2.0), 1992]

There are six basic types of TID.

a. **Fixed-wire** TIDs place wires, either in parallel or in a grid, in front of the display. Finger contact with the wire(s) generates the X-Y coordinates of the user's touch. This technology is associated with minimal parallax, 70 to 80% transmissivity, and a medium to high degree of TID glare.

b. **Capacitive** TIDs consist of a transparent conductive film on a glass overlay. Touching the surface changes a small electrical signal passing through the film, and this signal is converted into a corresponding X-Y coordinate. This technology is associated with minimal parallax, 85% transmissivity, and a medium amount of TID glare.

c. **Resistive membrane** TIDs are "sandwich" devices in which a touch results in the contact of two conductive layers. Specific current and voltage levels are associated with individual X-Y coordinates. This technology is associated with minimal parallax, 50 to 60% transmissivity, and a high amount of TID glare.

d. **Infrared or light-emitting diode** TIDs use infrared transmitters along two perpendicular sides of the display frame and photocell receptors along the opposite sides of the frame. A user's touch breaks the matrix of light beams, generating appropriate X-Y coordinates. This technology is associated with noticeable parallax between the plane of the light beams and the screen surface, 100% transmissivity, and no TID-related glare.

e. **Surface acoustic wave** TIDs are similar to infrared TIDs except that they use ultrasonic beams rather than light beams. X-Y coordinates are determined by differential timings in reception of the acoustic waves. This technology is associated with minimal parallax, 92% transmissivity, and a medium amount of TID glare.

f. **Pressure-sensitive** devices use strain gauges mounted between the display screen and an overlay. Output voltages of these strain gauges are encoded into the appropriate X-Y coordinates. This technology is associated with minimal parallax and no TID glare. Transmissivity is not affected because the overlay is built into the display screen.

□ **9.4.2.1 Use.** A touch panel or screen should be used to provide an overlaying control function to a display device (e.g., a CRT, an electro luminescent display, or a programmable indicator) if direct visual reference access and optimum direct control access are desired. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

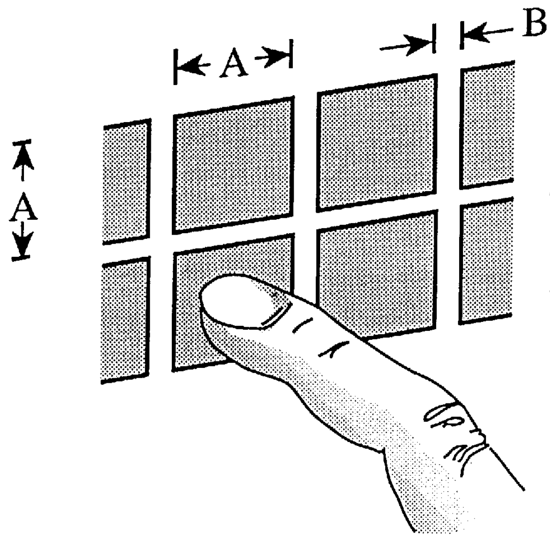
■ **9.4.2.2 Luminance transmission.** Touch panels shall have sufficient luminance transmission to allow the display to be clearly readable in the intended environment. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

■ **9.4.2.3 Positive indication.** A positive indication of touch-panel activation shall be provided to acknowledge the system response to the control action. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

■ **9.4.2.4 Dimensions and separation.** The dimensions and separation of responsive areas of the touch panel shall not exceed the maximum and minimum values given in Exhibit 9.4.2.4. [Source: MIL-STD-1472D, 1989; DOE-HFAC1, 1992]

Note. The maximum values listed in the Exhibit apply to logically grouped touch panel responsive areas. An adverse environment may warrant larger sizes and separations.

Exhibit 9.4.2.4 Touch panel responsive area dimensions



	A Size	B Separation
Minimum	19 mm (0.75 in)	3 mm (0.13 in)
Maximum	38 mm (1.5 in)	6 mm (0.25 in)

- ■ **9.4.2.5 Display feedback.** Display of user command or action feedback for touch panels shall not exceed 0.25 seconds. [Source: MIL-STD-1472D, 1989]

- ▫ **9.4.2.6 Minimal parallax.** Touch-interactive devices should be selected and mounted to minimize parallax problems. [Source: Avery & Bowser (DOE HFDG ATCCS V2.0), 1992]

- ▫ **9.4.2.7 Minimal specular glare.** Touch-interactive devices should be selected and mounted to minimize specular glare. [Source: DOE HFDG ATCCS V2.0, 1992]

9.4.3 Voice control

□ **9.4.3.1 Phonetically distinct vocabulary.** Spoken entries used for transactions should be phonetically distinct from one another to eliminate misinterpretation. Testing should be performed to determine which sounds and words or phrases could be distinguished reliably. [Source: MIL-STD-1472F, 1999]

> **Discussion.** Spoken command entries are not to be chosen arbitrarily. Tradeoffs between phonetic distinctiveness and familiarity of terminology need to be evaluated.

■ **9.4.3.2 Easy error correction.** Feedback and simple error correction procedures shall be provided for speech input so that if the computer has not correctly recognized a spoken entry, the user can easily cancel the entry and try again. [Source: MIL-STD-1472F, 1999]

■ **9.4.3.3 Alternative devices.** Alternative input devices shall be available so that if the system cannot recognize a voice entry after repeated attempts, or the device fails, another type of input entry can be substituted. [Source: MIL-STD-1472F, 1999]

9.5 Interchangeability among input devices

The interchangeability among input devices by the user can be useful during specific operations. Users may want to perform some actions using a keyboard and others actions using a pointing device. The ability to choose which input device must be optional to the user and not a requirement by the system.

□ **9.5.1 Redundant control.** If more than one input device is present, a user should be able to control computer interaction with all of them. For example, a keyboard should be capable of executing navigation and selection operations when used in conjunction with a mouse, light pen, or other input devices. [Source: DON UISNCCS, 1992]

> **Discussion.** Full interchangeability is not required. It is assumed that a user will select the input device that is most appropriate for the task being performed. For example, a user may rely on direct manipulation, using a pointing device such as a mouse or trackball, as the primary means of interaction for object selection and manipulation. Similarly, a user may use a keyboard primarily for text entry and for object selection being performed in conjunction with or interspersed with text entry. [Source: DON UISNCCS, 1992]

9.6 Accommodating people with disabilities

Most of the difficulty experienced by people with physical disabilities in using computer systems stem from using input devices, such as a keyboard or a mouse, and from handling storage media, such as computer diskettes. [Source: Scadden & Vanderheiden, 1988]

- **9.6.1 Redundant pointing functions.** A system that uses a pointing device, such as a mouse, should provide a means for carrying out all of the pointing functions from the keyboard. [Source: Scadden & Vanderheiden, 1988]

- **9.6.2 Toggle select key.** A toggle type of select key should be available as a standard feature or as an option. [Source: Casali, 1992]

  Discussion. People with disabilities may have difficulty simultaneously holding a select button down and moving the device, for example, in "dragging" an object in a graphical display. [Source: Casali, 1992]

- **9.6.3 Avoiding inadvertent operation.** A computer or computer system intended to be operable by people with moderate motor disabilities should provide either a means for delaying the acceptance of a keystroke for a preset, adjustable amount of time or a keyguard or means for mounting a keyguard. [Source: Scadden & Vanderheiden, 1988]

  Definition. A **keyguard** is a keyboard cover with holes over keys. [Source: Scadden & Vanderheiden, 1988]

- **9.6.4 Keyguards.** Keyboards should be designed so that keyguards can be mounted easily. [Source: Scadden & Vanderheiden, 1988]

- **9.6.5 Connection point for alternative input device.** A computer or computer system should provide a point at which an alternative input device can be connected if modifications cannot be made to make a standard input device accessible. [Source: Scadden & Vanderheiden, 1988]

- **9.6.6 Input from alternative device.** The computer should treat input from an alternative device the same as input from standard input devices. [Source: Scadden & Vanderheiden, 1988]

- **9.6.7 Readability of lettering on keys and controls.** The lettering on keys and controls required for the operation of a computer or computer system should be large enough to be read easily and have a distinct contrast with its background. [Source: Scadden & Vanderheiden, 1988]

  Discussion. This might be accomplished by providing keycaps that can be removed easily and replaced with special keycaps for the visually impaired. [Source: Scadden & Vanderheiden, 1988]

- **9.6.8 Alternatives to input devices.** When an input device necessary for computer operation requires continuous visual feedback for operation, an alternate method should be provided for accomplishing as many of the functions as possible. [Source: Scadden & Vanderheiden, 1988]

  Discussion. It may not be possible to provide a reasonable alternative for some functions. For example, inputs such as free hand sketching cannot be done easily without a device that requires eye-hand coordination. [Source: Scadden & Vanderheiden, 1988]

- **9.6.9 Non-visual indication of state of toggle keys.** A computer or computer system should provide blind users with a non-visual indication of the state of toggle keys that is available automatically or upon the user's request. [Source: Scadden & Vanderheiden, 1988]

- **9.6.10 Key demarcation.** All keys should have edges that can be discerned by touch. [Source: Scadden & Vanderheiden, 1988]

  Discussion. In particular, flat membrane keys without ridges outlining the keys are particularly difficult. [Source: Scadden & Vanderheiden, 1988]

- **9.6.11 Identification of "home" keys.** The "home" keys of keyboards and keypads should have a distinct marking that can be discerned by touch. [Source: Scadden & Vanderheiden, 1988]

- **9.6.12 Key labels.** Alternatives to visual key labeling should be made available for visually impaired users. [Source: Scadden & Vanderheiden, 1988]

- **9.6.13 Special display window.** A windowing environment should provide the capability of opening and maintaining a special window that can remain fully visible and available continuously for use by special input routines. [Source: Scadden & Vanderheiden, 1988]

- **9.6.14 Connection point for switches.** Computers and computing systems should provide a point at which at least two momentary contact input switches could be connected. [Source: Scadden & Vanderheiden, 1988]

- **9.6.15 Distinguishing macro input from typed input.** Computers and computing systems should be able to distinguish between typed, auto-repeat, and macro-generated "keystrokes". [Source: Scadden & Vanderheiden, 1988]

  Discussion. "Keystrokes" generated by assistive devices or assistive software may be sent faster than the application software can recognize them, in which case, they may be ignored, thus preventing use of the assistive device or software. [Source: Scadden & Vanderheiden, 1988]

Glossary

Alphanumeric keys - The letters of the alphabet, numerals, and punctuation symbols (numeric keypads may be separate on portable computers).

Dedicated formatting keys - Keys for text formatting operations such as a **Space** bar, a **Tab** key, and a **Return** or **Enter** key.

Displacement joystick - A displacement joystick is a joystick that moves in the direction it is pushed. Displacement joysticks are usually spring-loaded so that they return to their center position.

Fixed-function key - Keys provided for extra or general functions, typically labeled **F1, F2,** and so on.

Hotspot - The precise part of a screen pointer that marks the screen position where an operation on a pointing device will have an effect.

Isometric joystick - An isometric joystick responds to the amount and direction of pressure applied to it, but it does not move. Displacement joysticks usually require less force than isometric joysticks and are thus less fatiguing over long operating periods.

Keyguard - A keyboard cover with holes over keys.

Menu function - Causes the appearance of a menu appropriate to the location of the pointer.

Modifier keys - Keys that modify or qualify the effects of other keys for as long as they are held down, for example, **Shift, Ctrl,** and **Alt.**

Navigation keys - Keys that move a cursor, for example, **Arrow** keys, **Home, End, Page Up,** and **Page Down.**

Pointer - A symbol displayed on the screen that is controlled by a pointing device. Its shape may change depending on the function that is invoked at a particular moment or its location on the screen.

Pointing device - A non-keyboard device that allows a user to navigate rapidly around the screen and to specify and select objects for manipulation and action. Examples include a mouse, trackball, stylus and grid, and light pen.

Select function - Selects or activates objects on the screen or sets the location of the cursor.

Special purpose keys - Keys that have a special function, such as **Help, Delete,** and **Backspace.**

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10 Workstation and Workplace design

This chapter deals with the design criteria associated with workstations and workplaces. A **workstation** is a place designed for a specific task or activity from where work is conducted or operations are directed. Desks, offices, repair benches, tools, equipment, and computer terminals are examples of these special accommodations and equipment. Workstations are designed as areas for one or more workers to use in accomplishing purposeful tasks or jobs. A **workplace** is defined as an area room or establishment where work is done. The chapter is organized so as to start from the design of a single workstation then broaden to multiple workstations and workplaces.

The following design criteria affect systems, equipment, and facility design. Compliance will help enhance the performance of FAA personnel. Some of the rules address the interaction of maintenance and operational activities.

10.1 General

- 10.1.1 **Design for human activities.** Workplace and associated equipment designs shall systematically incorporate the effects of tasks, performance capabilities, physical dimensions, and viewing dimensions for maintainers and for operators. [Source: National Aeronautics and Space Administration (NASA-STD-3000A), 1989]

- 10.1.2 **Physical accommodation.** The physical dimensions of workplaces and equipment shall conform to the anthropometric and biomechanical characteristics of the specific population of users for whom the system is being designed and to the characteristics of the tasks to be performed. Anthropometric and biomechanical data are found in Chapter 14. [Source: NASA-STD-3000A, 1989]

  Examples. Those areas that deal with clearance dimensions that a large portion of the user population could be expected to use frequently or in a life threatening situation require as a minimum the 99th percentile value for clearance. Heavy traffic passageways and normal doorway clearances are examples. Similarly, the 1st percentile values for reach and strength are used as limiting dimensions. These values ensure that the smallest personnel can reach and open escape mechanisms. In most other cases, the convention of designing for the 5th through 95 percentile is used for practical design related reasons. Male and female personnel are included in the anthropometric data. The higher percentile values are often dominated by male data and the lower values by female data (see Chapter 14 and its references for treatments of anthropometric practice).

- 10.1.3 **Work space to permit access.** Space for maintenance access shall be designed into systems and equipment. [Source: Department of the Air Force (AFSC DH 1-3), 1980]

- ▫ **10.1.4 Maintenance independence.** Workplaces, controls, and displays that are associated with maintenance activities should be separate from operator workplaces, controls, and displays. [Source: NASA-STD-3000A, 1989]

- ▫ **10.1.5 Maintenance and operations interference.** Maintenance activities should not interfere with ongoing operator tasks. [Source: NASA-STD-3000A, 1989]

- ▫ **10.1.6 Redundant information.** Where maintenance activities would interfere and where simultaneous activities are necessary, redundant information should be provided to the operators for their ongoing diagnostic and emergency maintenance responsibilities. [Source: NASA-STD-3000A, 1989]

- ▫ **10.1.7 Visibility of displays and controls.** Controls and displays that are solely for maintenance should be readily accessible when needed by maintenance personnel without being visible to the operators. [Source: NASA-STD-3000A, 1989]

- ▪ **10.1.8 Task and general illumination of work space.** Illumination for maintenance shall include general area illumination and task illumination. Refer to Chapter 13 for detailed illumination design criteria. [Source: NASA-STD-3000A, 1989]

- ▪ **10.1.9 Illumination for normal operations and maintenance.** Where simultaneous operations and maintenance activities are necessary, workplace illumination for maintenance activities shall be compatible with illumination requirements for operators' visual tasks. [Source: NASA-STD-3000A, 1989]

- ▪ **10.1.10 Illumination for critical operations and maintenance.** Where it is critical, the design shall ensure that adequate maintenance illumination shall not interfere with operator visual tasks. [Source: NASA-STD-3000A, 1989]

- ▪ **10.1.11 Special information and communications interfaces.** Workspace and interfaces for accessing maintenance information systems and maintenance communications systems shall be provided where these special maintenance linkages are appropriate in the design of the system. [Source: NASA-STD-3000A, 1989]

  Example. Remote maintenance subsystems that include computers, terminals, modems, and networks provide special links to maintenance information and communications systems.

10.2 Workstations and consoles

Standard console designs are addressed in this section. Recommended configurations for sit, sit-stand, and stand consoles are given, and horizontal wrap-around and vertically stacked segment alternatives are provided. Additional consoles for teams that monitor ongoing processes are addressed in this section.

10.2.1 Sit, sit-stand, and stand consoles

The rules that follow are to be used to gain the benefits and potential cost savings inherent in standard consoles, units, and racks. In some cases, planned usage may necessitate unique design solutions.

Discussion. The task performance of a user working with consoles is influenced by 1) the contours and slopes of the console panels, 2) the parallax in viewing displays, 3) the location of displays and controls, and 4) the adequacy of the space to support the console operator.

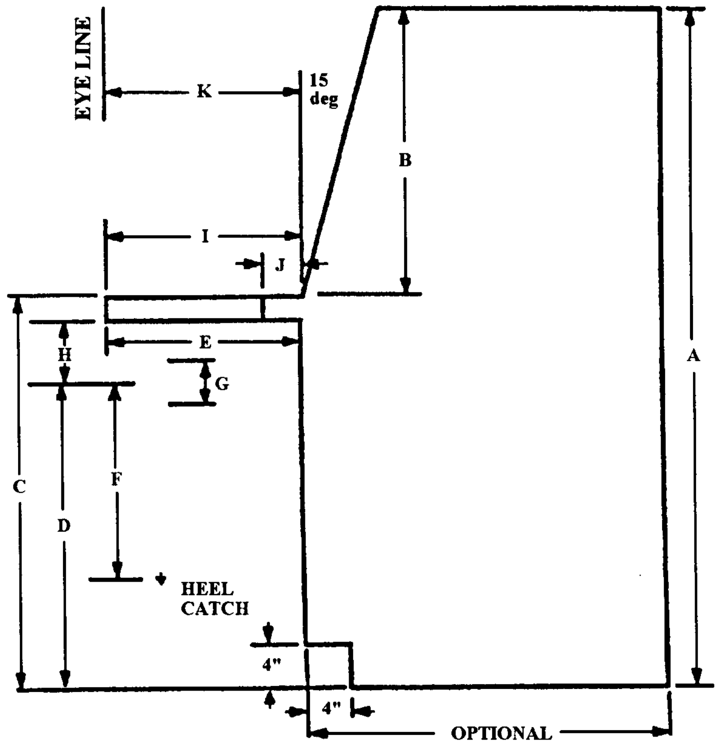
□ **10.2.1.1 Dimensions for console configurations.** Exhibit 10.2.1.1(a) lists five types of consoles for individuals and gives dimensions for alternative standard configurations. Selected configurations should conform to the dimensions listed and illustrated in Exhibit 10.2.1.1(b). [Source: Department of Defense (MIL-HDBK-759B), 1992]

Exhibit 10.2.1.1 (a) Standard console dimensions

Type of console	Maximum total console height from standing surface mm (in)	Suggested vertical dimension of panel (with sills) mm (in)	Writing surface shelf height from standing surface mm (in)	Seat height from standing surface at midpoint of G mm (in)	Maximum console width (not shown) mm (in)
	A	B	C	D	-
1. Sit (with vision over the top)*	1170 (46.0) 1335 (52.5) 1435 (56.5)	520 (20.5) 520 (20.5) 520 (20.5)	650 (25.5) 810 (32.0) 910 (36.0)	435 (17.0) 595 (23.5) 695 (27.5)	1120 (44.0) 1120 (44.0) 1120 (44.0)
2. Sit (without vision over top)	1310 (51.5) 1470 (58.0) 1570 (62.0)	660 (26.0) 660 (26.0) 660 (26.0)	650 (25.5) 810 (32.0) 910 (36.0)	435 (17.0) 595 (23.5) 695 (27.5)	910 (36.0) 910 (36.0) 910 (36.0)
3. Sit-stand (with standing vision over top)	1535 (60.5)	620 (24.5)	910 (36.0)	695 (27.5)	910 (36.0)
4. Stand (with vision over top)	1535 (60.5)	620 (24.5)	910 (36.0)	NA NA	1120 (44.0)
5. Stand (without vision over top)	1830 (72.0)	910 (36.0)	910 (36.0)	NA NA	910 (36.0)

* The range in "A" is provided to allow latitude in the volume of the lower part of the console; note relationship to "C" and "D."

Exhibit 10.2.1.1 (b) Standard console illustration and dimension key



Key	Dimensions	mm	in
A.	Maximum total console height from standing surface	-	-
B.	Suggested vertical dimension of panel, including sills	-	-
C.	Writing surface: shelf height from standing surface	-	-
D.	Seat height from standing surface at midpoint of "G"	-	-
E.*	Minimum knee clearance	460	18.0
F.*	Foot support to sitting surface**	460	18.0
G.*	Seat adjustability	150	6.0
H.*	Mimimum thigh clearance at midpoint of "G"	190	7.5
I.	Writing surface depth including shelf	400	16.0
J.	Mimimum shelf depth	100	4.0
K.	Eye line-to-console front distance	400	16.0

* Not applicable to console types 4 and 5
** Since this dimension must not be exceeded, a heel catch must be added to the chair if "D" exceeds 460 mm (18.0 in).

Note: A shelf thickness of 25 mm (1 in) is assumed. For other shelf thicknesses, suitable adjustments should be made.

▫ **10.2.1.2 Selection of a standard console.** Each console configuration should be selected to accommodate the following task-related variables:

a. visibility over the top of console,

b. user mobility (e.g., sit, sit-stand, or stand requirements),

c. control and display demand for panel space (for example, display legibility, control accessibility),

d. volume of space necessary for leg room and essential equipment beneath the writing surface, and

e. communications demands of the tasks. [Source: Department of Defense (MIL-STD-1472D), 1989]

10.2.2 Seated workstations

In this section, a discussion to help exploit the advantages of the seated position is followed by general rules for ensuring seating compatibility with tasks. The section includes rules for office seating design and for seat cushion, armrest, and footrest design. Temporary swing away seats are also treated. Vehicles and moving platform seats are not addressed in this document.

Designers can exploit the following advantages of seated positions:

a. Seated positions reduce workload by helping maintain the body position and carry body weight.

b. Seats provide comfortable positions that promote long-term focused attention on activities and information in the nearby workspace.

c. Seating can help establish stability to accommodate fine eye-hand coordination tasks.

d. Seating can be designed to accommodate powerful exertions on pedals.

e. Seated workers have more accessibility to equipment and are able to move about to reduce fatigue and boredom,

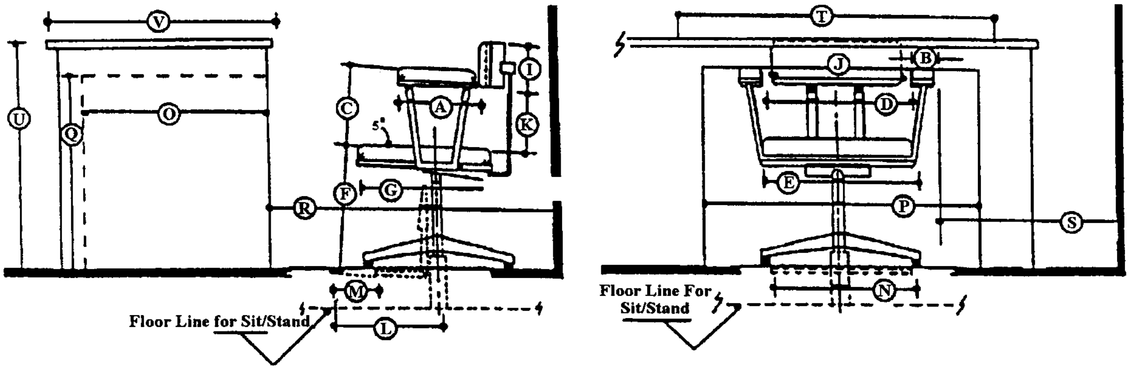
f. Seating can be designed to swivel and move on rollers to extend visual, reach, and communications access. [Source: MIL-HDBK-759B, 1992]

The main disadvantages of seated work positions are that seated workers can apply less arm force and smaller arm movements than standing workers. In addition, seating limits reach with both arms and hands.

- **10.2.2.1 Swivels and rollers.** For most jobs and tasks that do not require heavy work and where seated positions are appropriate, swivel capability and caster rollers should be provided for seat ingress and egress and task performance throughout the workplace. [Source: MIL-HDBK-759B, 1992]

- **10.2.2.2 Seating dimensions.** General seated workplace dimensions are given and illustrated in Exhibit 10.2.2.2. Seat designs and selections should meet or exceed minimum values, provide adjustment ranges and fixed and preferred values when these are compatible with the population and tasks to be performed. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472D, 1989]

Exhibit 10.2.2.2 Seated workspace dimensions and illustrations



Chair	Fixed (mm)	Fixed (in)	Adjustment * (mm)	Adjustment * (in)
Fixed armrests				
	200-255	(8-10)	-	-
B. Width	50	(2)	-	-
C. Height	215	(8)	-	-
D. Separation	460	(18)	-	-
Adjustable armrest from compressed seat				
E. Width	405	(16)	-	
F. Height	460	(18)	± 50	(2)
G. Depth	405	(16)	-	-
Backrest				
H. Space	150	(6)	± 50	(2)
I. Height	380	(15)	-	-
J. Width	405	(16)	-	-
Footrests				
L. From center	180	(7)	-	-
M. Width	150	(6)	-	-
N. Length	255	(10)	-	-

Workspace	Minimum (mm)	Minimum (in)	Preferred (mm)	Preferred (in)
O. Kneehole depth without footrests	460	(18)	-	-
P. Kneehole width	510	(20)	-	-
Q. Kneehole height (standard office)	635	(25)	640	(25)
R. Desk to wall	810	(32)	-	-
S. Armrest to wall	610	(24)	-	-
T. Lateral work clearance				
(1) Shoulders	585	(23)	-	-
(2) Elbows	635	(25)	-	-
(3) Best overall	1000	(39)	-	-
U. Height of work surface	735	(29)	760	(30)
V. Width of work surface				
(1) Elbow rest alone	100	(4)	200	(8)
(2) Writing surface	305	(12)	405	(16)
(3) Desk work area	-	-	910	(36)

* Adjustment range. Adjustability is preferred for these dimensions.

- **10.2.2.3 Knee space height.** The preferred knee space, as shown in Exhibit 10.2.2.2, should be 640 mm (25 in) in height. [Source: MIL-HDBK-759B, 1992]

  Discussion. A footrest will increase the needed knee space.

- **10.2.2.4 Attaining knee space.** Where equipment packaging permits, knee space and associated leg space should be attained by sloping the console surface under the working or writing surface. [Source: MIL-HDBK-759B, 1992]

- **10.2.2.5 Seat cushioning.** Seats should be cushioned whenever workers must remain seated for more than an hour at a time, or for more than 20% of their working time. [Source: MIL-HDBK-759B, 1992]

- **10.2.2.6 Seat cushioning features.** Good seat cushioning should

  a. have flat, firm shape with enough softness to deform,

  b. have resilient material under the cushion to absorb shocks,

  c. support body weight, primarily around the two bony points of the pelvis,

  d. tilt backward 5-7 degrees so the seat (rather than the user's muscles) supports the back,

  e. be shaped to follow the inward curve of the lower back and provide adequate support for it to relieve strain of the back muscles,

  f. avoid applying pressure under the thighs,

  g. incorporate perforated or ventilated materials to prevent hotness or sweating, and

  h. allow the sitter to shift positions. [Source: MIL-HDBK-759B, 1992]

  Discussion. Larger cushioned backrests are best because a larger support area provides the user more opportunities to change position.

- **10.2.2.7 The use of armrests.** Workplace seating should provide armrests so that the elbows can support some upper body weight, unless the rests would be incompatible with the tasks. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472D, 1989]

- **10.2.2.8 Undercut armrests.** Armrests should be undercut to allow space for the hips and thighs. Exhibit 10.2.2.2 provides fixed armrest dimensions. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472D, 1989]

- **10.2.2.9 Removable or adjustable armrests.** Removable or adjustable armrests should be considered when removal is necessary for some primary tasks. The preferred adjustable range is from 190 to 280 mm (7.5 to 11 in) above the compressed seat surface and at least 200 mm (8 in) in length. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472D, 1989]

- **10.2.2.10 Support arm for tracking control.** When seated tasks include the use of a tracking control for frequent or continuous control, the armrest should support the worker's arm in the same plane as the control. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472D, 1989]

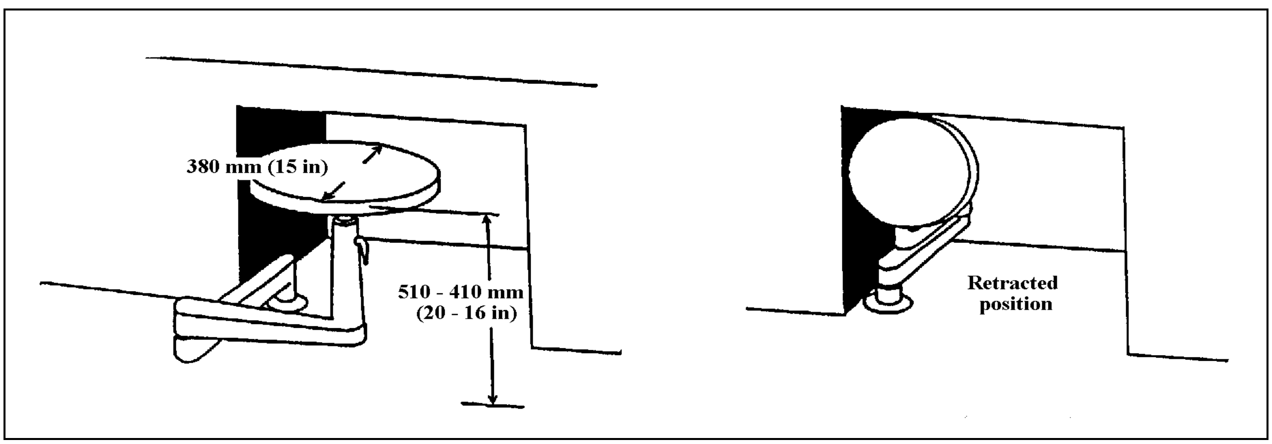
- **10.2.2.11 Footrests.** Whenever workers must sit for extended periods in seats higher than 460 mm (18 in) or work with work surfaces higher than 760 mm (30 in), they should have a footrest. [Source: MIL-HDBK-759B, 1992]

  Explanation. Footrests can provide support and add to comfort for seated jobs. They may be attached to the chair or separate items positioned on the floor.

- **10.2.2.12 Separate footrests.** When footrests are separate items, they should not be allowed to interfere with traffic. [Source: MIL-HDBK-759B, 1992]

- **10.2.2.13 Temporary seats.** Where space limitations and task frequency warrant, a temporary swing away seat should be provided with preferred dimensions of 380 mm (15 in) diameter, 460 mm (18 in) floor to seat top dimension with an adjustability of plus or minus 50 mm (2 in). Exhibit 10.2.2.13 illustrates a swing away seat. [Source: MIL-HDBK-759B, 1992]

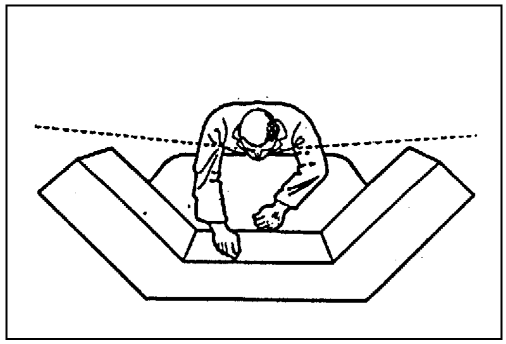
Exhibit 10.2.2.13 Swing-away seat for short-term use



10.2.3 Horizontal wrap-around console alternatives

Whenever the panel space required for a seated console user exceeds that recommended in Exhibit 10.2.1.1 (a) providing standard console dimensions, the special purpose horizontal wrap-around console presented in this section may be used. The concept for this alternative is illustrated in Exhibit 10.2.3.

Exhibit 10.2.3 Example of horizontal wrap-around console



▫ **10.2.3.1. Panel width.** When requirements for preferred panel space for the user exceed a panel width of 1.12 m (44 in), a flat-surface, segmented, wrap-around console should be provided. [Source: MIL-STD-1472D, 1989]

> **Discussion.** This panel facilitates placing controls within the reach of the 5th percentile users.

▫ **10.2.3.2 Panel angles.** The left and right segments should be placed at an angle, measured from the frontal plane of the central segment, so that these segments can be reached by the 5th percentile stationary operator. [Source: MIL-STD-1472D, 1989]

▪ **10.2.3.3 Central segment dimensions with vision over the top.** Where vision over the top is required (thereby limiting vertical panel space), the width of the central segment shall not exceed 1.12 m (44 in). [Source: MIL-STD-1472D, 1989]

▫ **10.2.3.4 Left and right segment dimensions with vision over the top.** Where vision over the top is required (thereby limiting vertical panel space), the left and right segments should not exceed 610 mm (24 in). [Source: MIL-STD-1472D, 1989]

▪ **10.2.3.5 Width dimensions without vision over the top.** Where vision over the top is not required (that is, where the total console height exceeds the seat height by more than 690 mm [27 in]), the width of the central segment shall not exceed 860 mm (34 in). [Source: MIL-STD-1472D, 1989]

▫ **10.2.3.6 Left and right segment dimensions without vision over the top.** Where vision over the top is not required (that is, where the total console height exceeds the seat height by more than 690 mm [27 in]), and that of the left and right segments should not exceed 610 mm (24 in). [Source: MIL-STD-1472D, 1989]

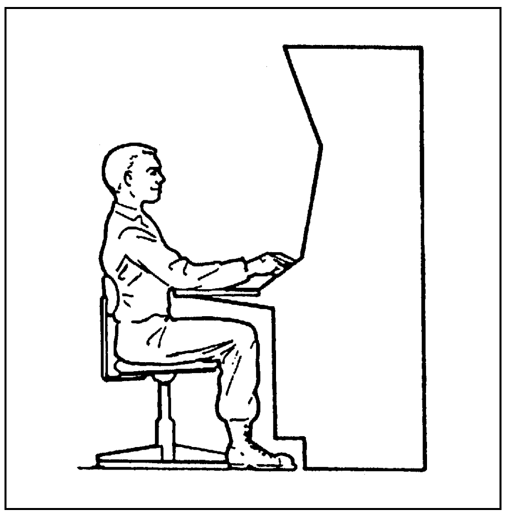
▪ **10.2.3.7 Viewing angle.** The total required left-to-right viewing angle shall not exceed 190 degrees. [Source: MIL-STD-1472D, 1989]

▫ **10.2.3.8 Reduction of viewing angle.** The required left-to-right viewing angle should be reduced whenever possible through appropriate control-display layout. [Source: MIL-STD-1472D, 1989]

10.2.4 Vertical stacked segments for consoles

Another alternative special-purpose console applies to the case where seeing over the top is not required and lateral space is limited. The concept for this individual seated user console is shown in Exhibit 10.2.4.

Exhibit 10.2.4 Examples of vertical stacked segments



▪ **10.2.4.1 Panel division.** Where direct forward vision over the top of the console is not required by a seated person and where lateral space is limited, the panel shall be divided into three vertical stacked segments whose surfaces are perpendicular to the operator's line of sight when the head is moved up or down slightly. [Source: MIL-STD-1472D, 1989]

Discussion. Locating screens above resting eye level can cause the user to adopt uncomfortable or awkward positions, leading to pain. To avoid this, only infrequently used information ought to be located in the upper tiers segments of the consoles. For additional information on display location, see Chapter 5, Displays and printers.

□ **10.2.4.2 Height.** The center of the central segment should be 800 mm (31.5 in) above the seat reference point and not exceed 530 mm (21 in). [Source: MIL-STD-1472D, 1989]

10.2.5 Design and arrangement of multi-person consoles

When a team must monitor, diagnose, or control a large ongoing process or operation, many arrangements of consoles are possible. Exhibit 10.2.5.1 shows several basic console arrangements, variations on the basic arrangements, and an example of a multi-unit control room which incorporates supervisory visual access. This section offers rules for selecting among alternative console arrangements and console designs.

■ **10.2.5.1 Selecting arrangements for team consoles.** Several primary and support factors shall be used in selecting among alternative team console arrangements (see Exhibit 10.2.5.1). The factors to be used are listed in (a) through (q).

Discussion. Primary factors for team console arrangements, (a) through (l), are those that directly involve and impact the ongoing process and mission of the system. Secondary or support factors, (m) through (q), are off-line to the direct process monitoring or control but may influence the layout and design of team consoles.

a. functions and resultant tasks for personnel, hardware, and software components that are necessary for process monitoring and controlling (these functions and tasks must cover normal, degraded, and emergency modes of system operations),

b. necessary team communication interactions and team links with external command and control components of the system,

c. numbers of personnel necessary to handle the expected high workload levels,

d. common viewing requirements and individual visual access requirements,

e. maintenance access for control or processing subsystems,

f. supervisory viewing requirements, ongoing supervisory process control responsibilities, supervisory space and access requirements, and supervisory information and communications requirements,

g. management, maintenance, and operating concepts and policies,

h. architectural and facility engineering constraints,

i. requirements and space constraints associated with primary equipment, controls and displays, computer, printout or readout devices, and closed-circuit monitoring devices,

j. illumination, acoustic, and environmental requirements associated with primary tasks,

k. primary work surface areas for writing and reading,

l. primary storage areas and surfaces for documents, procedures, tools, spares, and supplies,

m. secondary supervisor office privacy requirements,

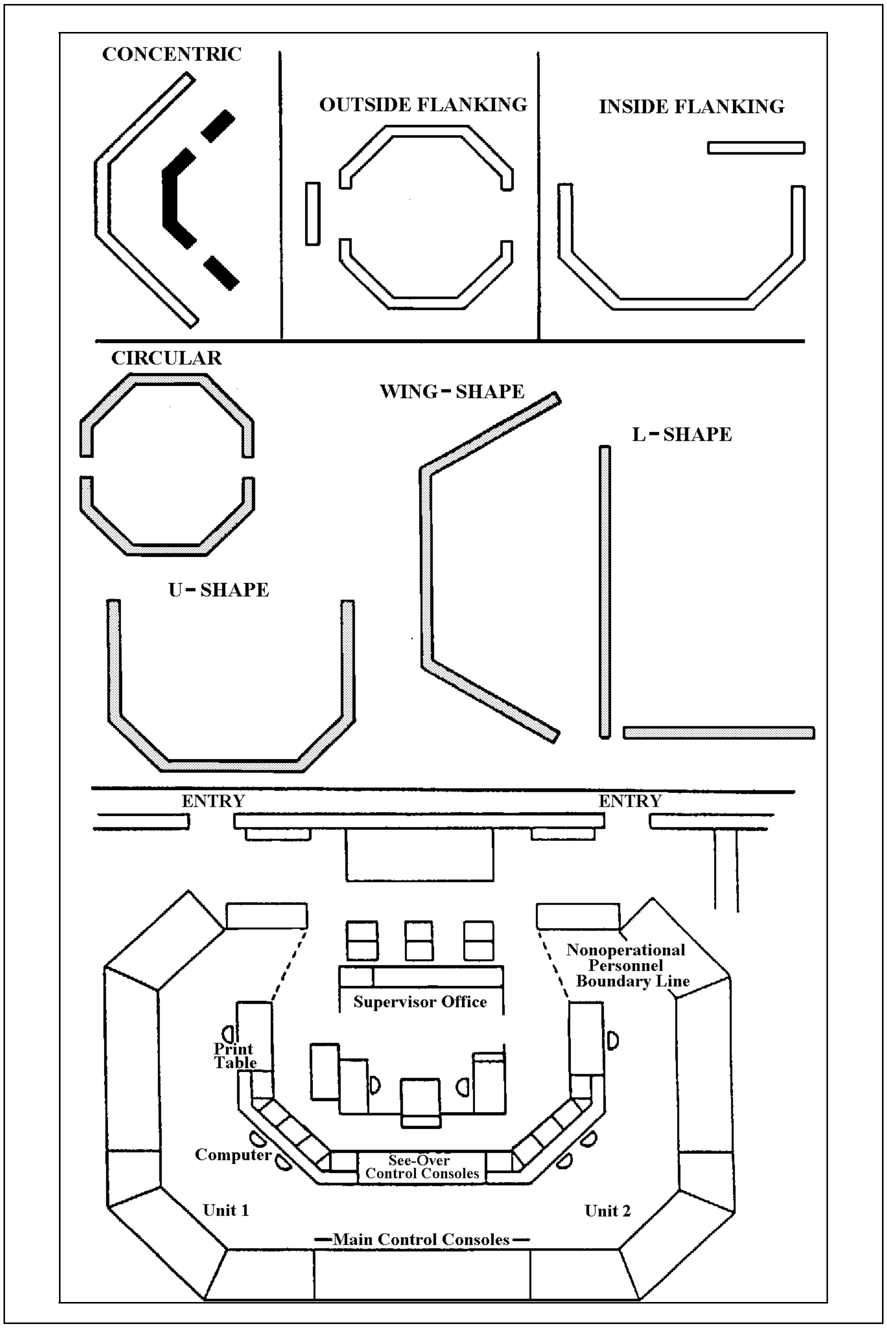
n. security requirements,

o. visitor provisions and traffic areas,

p. personnel conveniences such as restrooms, kitchen, snack, drinking water, and personal belonging storage, and

q. support storage for additional documentation and other housekeeping needs. [Source: Electric Power Research Institute (EPRI NP-36591), 1984]

Exhibit 10.2.5.1 Basic and variations of multi-person console arrangements with an example control room arrangement



▫ **10.2.5.2 Selecting team console types and designs.** Selection and design of individual team position consoles should be made among standard sit, sit-stand, and stand consoles (see Section 10.2.1), free standing consoles, built-in vertical wall consoles, and specially configured consoles based upon the factors that follow:

a. functions and tasks allocated to the types of personnel and position(s) associated with the console,

b. visual access required for common control display areas that may determine the required see-over characteristics,

c. position communication requirements,

d. personnel mobility requirements,

e. reach and visual access areas for consoles (Exhibit 10.2.5.2 shows reach and visual legibility arcs for console design),

f. work surface area requirements,

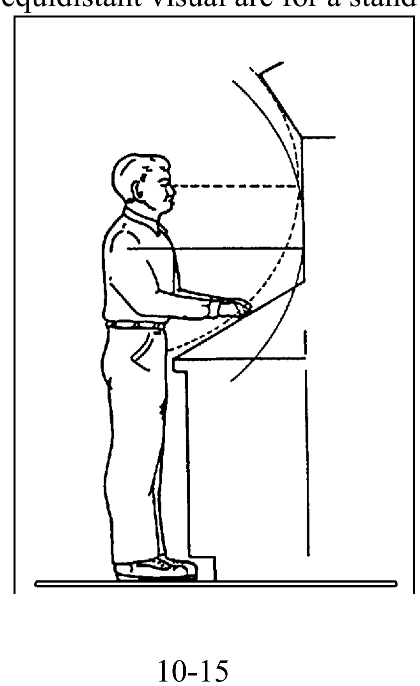
g. requirements to share information, displays, controls, or work surfaces with adjacent positions,

h. the postures required for monitoring and controlling, as well as the durations that such postures must be maintained, and

i. the need for consoles and information standardization across system functions and locations to reduce training and to facilitate interoperability. [Source: EPRI NP-36591, 1984]]

Discussion. In accomplishing the design layout, the designer needs to consider the criticality, durations, and frequency of control and display interactions, as well as the legibility and accuracies required.

Exhibit 10.2.5.2 Concepts of functional reach arc and equidistant visual arc for a stand console



10.2.6 Standing workstations

Standing workstations are used for routine, frequent, or short term jobs or tasks for which the worker needs to be able to face different directions or to move from one position to another. The designer can exploit the following advantages of a standing position when they are compatible with the tasks to be performed:

a. When standing, workers can apply more muscular arm force and make larger arm movements than when seated. These forces may be applied to levers or valves.

b. Standing workers can move to see and use components in areas that would be inaccessible to seated users.

c. Standing workers can move about to reduce fatigue and boredom.

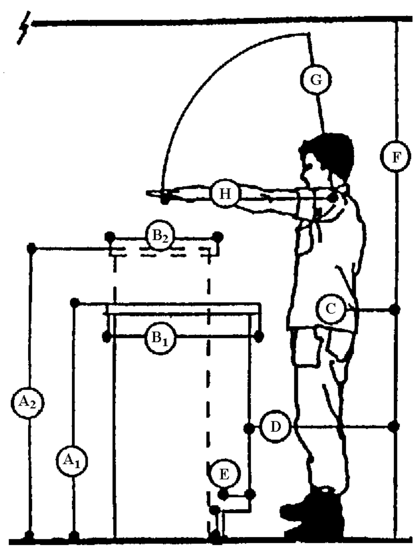
d. Standing workers can use flat working surfaces without knee room, thus saving space.

e. A standing workstation is not as dimensionally constrained as that of the seated operator. Equipment that standing operators view or adjust may be placed anywhere around them as long as it is at the proper height.

Discussion. If the worker is not free to move about, or if the task and attention demands are concentrated so that the worker remains in one position, the workstation should be designed so the worker can sit or take a sit-stand position. The main disadvantage of the standing position is that the worker's physical workload is increased because one constantly has to carry one's own weight and stabilize and balance one's body.

□ **10.2.6.1 Standing workstation and workbench dimensions.** The dimensions of standing workstations and workbenches should meet the minimum and not exceed the maximum preferred values in Exhibit 10.2.6.1 and, when required, provide for adjustments to accommodate the 5th through the 95th percentile of the worker population. [Source: MIL-HDBK-759B, 1992]

Exhibit 10.2.6.1 Standing workstation illustration and dimensions



Work benches

Standard type

A1. Height	91 cm (36 in) above floor
B1. Width	99 cm (39 in) above floor

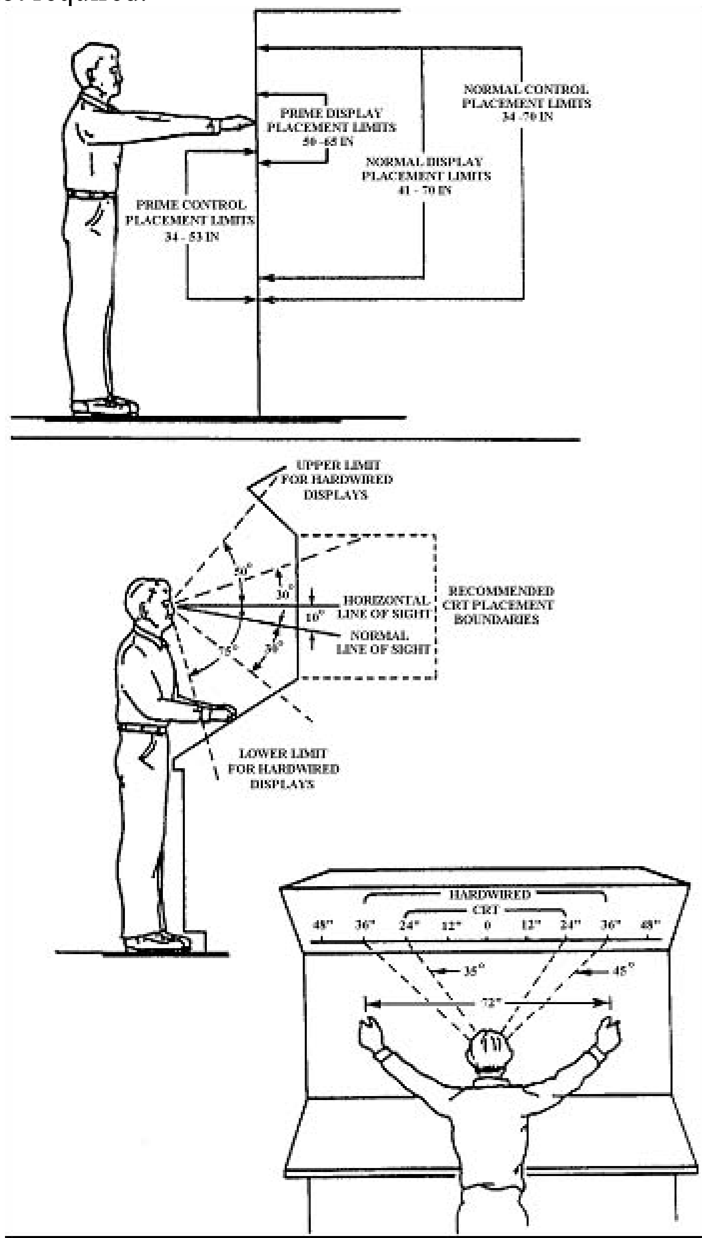
Podium type

A2. Height	104 cm (41 in) above floor
B2. Width	91 cm (36 in) above floor

Work clearances		**Minimum**	**Preferred**	**Arctic**
C. Passing body depth	(mm)	330	380	380
	(in)	13	15	15
D. Standing space	(mm)	760	910	-
	(in)	30	36	-
E. Foot space	(mm)	100X100	-	-
	(in)	4X4	-	-
F. Overhead clearance	(mm)	1855	2030	1930
	(in)	73	80	76
G. Maximum overhead reach	(mm)	-	685	635
	(in)	-	27	25
H. Maximum depth of reach	(mm)	-	585	585
	(in)	-	23	23

▫ **10.2.6.2 Control and display placement on stand consoles.** Prime controls and displays on stand consoles (including CRT displays) should be located in the prime areas and within the boundaries noted in Exhibit 10.2.6.2, which illustrates control and display placement limits for those vertical and stand consoles where see-over capabilities are not required. [Source: EPRI NP-36591, 1984]

Exhibit 10.2.6.2 Control and display placement limits for vertical and stand consoles where see over capabilities are not required.



- ▫ **10.2.6.3 Hardwired display placement.** Hardwired displays, including annunciator displays, should be located horizontally within 45 degrees of the operator's eye reference point with CRT displays restricted to within 35 degrees. [Source: EPRI NP-36591, 1984]

- ▫ **10.2.6.4 Control and display placement on stand consoles.** On consoles where a discrete task sequence of display and control actions is appropriate for a single user's actuation, the sequenced displays and controls should not exceed 1.8 m (72 in) in width so reach and visual access can be accommodated. [Source: EPRI NP-36591, 1984]

  Explanation. The actual display limits on the console will depend upon the distance from which the worker views the console displays. The illustration at the bottom of Exhibit 10.2.6.2 shows a 1.8 m (72 in) dimension as the maximum lateral spread for a discrete task at normal viewing distance.

- ▫ **10.2.6.5 Special team sit-stand console minimum vertical height.** When a sit-stand console requires a see-over capability, the vertical height of the console should be no higher than 1.40 m (55 in). [Source: EPRI NP-36591, 1984]

  Explanation. Where a sit-stand desk surface of at least 410 mm (16 in) deep and 610 mm (24 in) wide is provided, 760 mm (30 in) is preferred.

- ▫ **10.2.6.6 Special team sit-stand console minimum vertical height.** Desk height should be 910 to 960 mm (36 to 38 in) high so that the seated eye height can be about the same as the standing eye height. [Source: EPRI NP-36591, 1984]

- ▫ **10.2.6.7 Special team sit-stand console seat dimensions.** The seat should be adjustable up to 760 mm (30 in) in seat cushion height and have a 460 mm (18 in) diameter footrest located at a constant 460 mm (18 in) below the seat cushion. [Source: EPRI NP-36591, 1984]

- ▪ **10.2.6.8 Kickspace.** All cabinets, consoles, and work surfaces that require an operator or maintainer to stand or sit close to their front surfaces shall contain a kick space at the base of the front surfaces of at least 100 mm (4 in) deep and 100 mm (4 in) high. [Source: MIL-STD-1472D, 1989]

10.2.7 Work surfaces

- ▪ **10.2.7.1 Work surfaces for standing positions.** Work surfaces shall be consistent with the needs of jobs and tasks. Surfaces for standing work shall be 915 mm plus or minus 15 mm (36 in plus or minus .6 in) from the floor. Where machine parts or equipment are manipulated, the surface shall be at least 760 mm (30 in) wide. In all cases, the work surface shall be at least 407 mm (16 in) deep. This lateral depth may be increased based upon the demands of the job. [Source: MIL-STD-1800A, 1990]

- **10.2.7.2 Work surfaces for seated positions.** Surfaces for seated operations shall be 740 - 790 mm (29 - 31 inches) above the floor. Width and depth shall be the same as in Paragraph 10.2.2.3.1. [Source: MIL-STD-1800A, 1990]

  Discussion. For light precision work, work surface height can be increased within the above limits. For work requiring increased force, the work surface height can be lower.

- **10.2.7.3 Writing surfaces.** Writing surfaces shall be at least 610 mm (24 in) wide and 407 mm (16 in) deep. [Source: MIL-STD-1800A, 1990]

- **10.2.7.4 Task sizing of work surfaces.** When a work surface is used for more than one task, the surface dimensions for tasks requiring the most space shall be used. [Source: MIL-STD-1800A, 1990]

10.2.8 Storage

- **10.2.8.1 Storage space.** Adequate space for storage of manuals, worksheets, test equipment, tools, and other materials that are required for use by operational or maintenance personnel shall be provided on consoles and, where appropriate, on equipment. [Source: MIL-STD-1472D, 1989]

10.2.9 Workstations for maintenance repair

- **10.2.9.1 Sizing.** Maintenance repair workstations shall be large enough to handle the largest equipment or component that will require repair. [Source: NASA-STD-3000A, 1989]

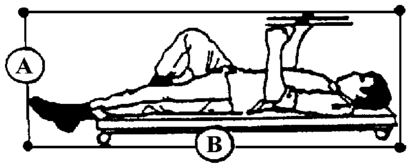
- **10.2.9.2 Special equipment.** Maintenance repair workstations shall be designed to accommodate general purpose, specific purpose, and automated diagnostic and test equipment appropriate to the expected maintenance tasks. [Source: NASA-STD-3000A, 1989]

10.2.10 Workspace for positions other than seated or standing

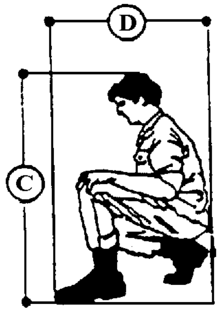
Maintenance work requiring unusual working positions is to be avoided through design. Dimensions for workspace other than seated or standing are illustrated in this section.

- **10.2.10.1 Workspace clearance dimensions.** When personnel must work in or pass through limited spaces, the clearances shall meet or exceed the minimum values given and illustrated in Exhibit 10.2.10.1. [Source: MIL-HDBK-759B, 1992]

Exhibit 10.2.10.1 Dimensions and illustrations for workspaces other than seated or standing

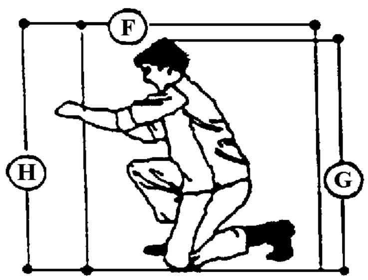


	Supine workspace	**Minimum**	**Preferred**	**Artic clothed**
A	Height	510mm (20in)	610mm (24in)	660mm (26in)
B	Length	1860mm (73in)	1910mm (75in)	1980mm (78in)

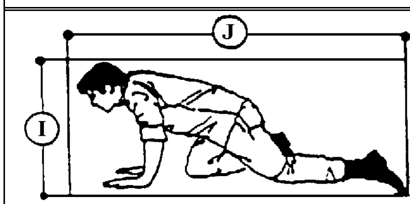


	Squatting workspace	**Minimum**	**Preferred**	**Artic clothed**
C	Height	1220mm (48in)	--	1290mm (51in)
D	Width	685mm (27in)	910mm (36in)	--
	Optimum display area	685mm (27in)	1090mm (43in)	--
	Optimum control area	485mm (19 in)	865mm (34in)	

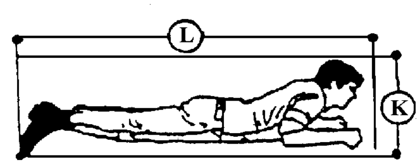
	Stooping workspace	**Minimum**	**Preferred**	**Artic clothed**
E	Width	660mm (26in)	1020mm (40in)	1120mm (44in)
	Optimum display area	810mm (32in)	1220mm (48in)	
	Optimum control area	601mm (24in)	990 mm (39in)	



	Kneeling workspace	**Minimum**	**Preferred**	**Artic clothed**
F	Width	1060mm (42in)	1220mm (48in)	1270mm (50in)
G	Height	1420mm (56in)	--	1500mm (59in)
H	Optimum work point	--	685mm (27in)	--
	Optimum display area	510mm (20in)	890mm (35in)	--
	Optimum control area	510mm (20in)	890mm (35in)	--



	Kneeling crawl space	**Minimum**	**Preferred**	**Artic clothed**
I	Height	785mm (31in)	910mm (36in)	965mm (38in)
J	Length	1500mm (59in)	--	1760mm (69in)



	Prone work or crawl space	**Minimum**	**Preferred**	**Artic clothed**
K	Height	430mm (17in)	510mm (20in)	610mm (24in)
L	Length	2860mm (113in)	--	--

10.3 Workplace layout

10.3.1 Equipment and workstation layout

□ **10.3.1.1 Traffic areas.** Traffic area and traffic flow design should be based upon

a. a consideration of task-based activities in and around workstations,

b. location of workstations and traffic areas so that they interfere minimally with each other,

c. a consideration of the necessary movements of equipment in the work and traffic areas,

d. a consideration of normal traffic conditions, worst cases, and emergency conditions, and

e. a consideration of means by which to avoid collisions and to maximize traffic efficiency. [Source: NASA-STD-3000A, 1989]

■ **10.3.1.2 Layout to minimize traffic and congestion.** Equipment and workstations shall be located so as to minimize congestion in workflow or worker movement and to minimize interference with and from personnel traffic areas. [Source: NASA-STD-3000A, 1989]

□ **10.3.1.3 Equipment grouping by maintenance needs.** Equipment and components maintained by the same technician should be grouped together so the technician will not have to move around in checking or working on the equipment. [Source: MIL-STD-1472D, 1989; MIL-HDBK-759B, 1992; AFSC DH 1-3, 1980]

□ **10.3.1.4 Equipment grouping.** Equipment should be grouped so that no other type of technician has to remove equipment or components before the proper technician can obtain access to make replacements or repairs. [Source: MIL-STD-1472D, 1989; MIL-HDBK-759B, 1992; AFSC DH 1-3, 1980]

Example. Components that require frequent visual inspection of check points, adjustment points, cable-end connection, and labels should be located in positions that can be seen easily.

■ **10.3.1.5 Equipment arrangements for groups of workers.** When groups of two or more people need to be located within a work space, the groups and their equipment shall be arranged so that equipment can be shared, communications requirements can be minimized, necessary face-to-face communications and coordination are facilitated, mutual interference is minimized, and supervision is simplified. [Source: MIL-STD-1472D, 1989]

□ **10.3.1.6 Layout for safety.** All equipment and components should be located to minimize the possibility of equipment damage, personnel injury, or inadvertent actuation. [Source: MIL-HDBK-759B, 1992; AFSC DH 1-3, 1980]

■ **10.3.1.7 Criticality.** The most critical units (based on mission, functions, and tasks) shall be located so as to be most accessible. [Source: MIL-STD-1472D, 1989; NASA-STD-3000A, 1989]

■ **10.3.1.8 Frequency.** Where criticality is not a factor, units expected to require more total use (either more frequent and longer durations of use) shall be more accessible. [Source: MIL-STD-1472D, 1989; NASA-STD-3000A, 1989]

■ **10.3.1.9 Floor space for work and passage.** Floor space shall be planned and designed to ensure the following: (a-f are required by 29 CFR 1910.22)

a. floor space for work areas and for aisle space do not occupy the same space and, thus, the work and passage do not interfere,

b. material and equipment handling tasks are to be used in sizing work and aisle spaces; necessary turning space for materials and equipment is included,

c. the work and aisle space can be kept clean,

d. storage space for material and equipment does not interfere with work or passage,

e. floor work and aisle space are free of protruding nails, splinters, holes, loose boards, or other loose materials,

f. permanent aisles and passageways are appropriately marked,

g. floor loading limits are conspicuously displayed to prevent structural overloading,

h. floor space around electrical utilization equipments is provided in accordance with Paragraph 12.4.1.18, (Design and location of electrical installations and electrical utilization equipment), and

i. free floor space of at least 1.2m (4 ft) is to be provided in front of each equipment rack. [Source: MIL-STD-1472D, 1989; MIL-STD-1800A, 1990]

■ **10.3.1.10 Spacing in front of racks and cabinets.** Clearance from the front of a rack to the nearest facing surface or obstacle shall be at least 1.07 m (42 in). [Source: MIL-STD-1472D, 1989]

■ **10.3.1.11 Spacing between racks and cabinets.** The minimum space between rows of cabinets containing drawers shall be 200 mm (8 in) greater than the depth of the deepest drawer. [Source: MIL-STD-1472D, 1989]

■ **10.3.1.12 Lateral work space.** The minimum lateral work space for racks having drawers or removable equipment shall be as follows (measured from the drawers or equipment in the extended position):

a. For racks having drawers of removable items weighing less than 20 kg (44 lb), allow 460 mm (18 in) on one side and 100 mm (4 in) on the other, and

b. For racks having drawers or removable items weighing over 20 kg (44 lb), allow for two person access (one on each side): 460 mm (18 in) on each side. [Source: MIL-STD-1472D, 1989; MIL-STD-1800A, 1990]

■ **10.3.1.13 Rear access space.** When a maintainer is to have access to the back of an entire rack or panel-mounted unit, the unit shall be installed with sufficient clearance to permit the maintainer to perform all required maintenance tasks, including the removal of the rear panel(s). [Source: AFSC DH 1-3, 1980]

□ **10.3.1.14 Maintenance independence.** Workplaces, controls, and displays that are associated with maintenance activities should be separate from operator workplaces, controls, and displays. [Source: NASA-STD-3000A, 1989; MIL-STD-1472D, 1989]

Discussion. Controls and displays that are solely for maintenance should not be visible to operators but should be readily accessible when needed by maintenance personnel.

10.3.2 Work space features designed into equipment

■ **10.3.2.1 Work space to permit access.** Space for maintenance access shall be designed into the systems and equipment. [Source: AFSC DH 1-3, 1980]

Discussion. Accessibility is influenced by system maintenance concepts, procedures, and tasks. [Source: AFSC DH 1-3, 1980

■ **10.3.2.2 Access space for effective maintenance.** Equipment shall be designed to allow effective maintenance by providing sufficient space for maintenance personnel to access the equipment and components permitting maintainers with 95th percentile values on task related dimensions to have sufficient access and space to perform the maintenance tasks and to use the tools necessary for the tasks. [Source: AFSC DH 1-3, 1980]

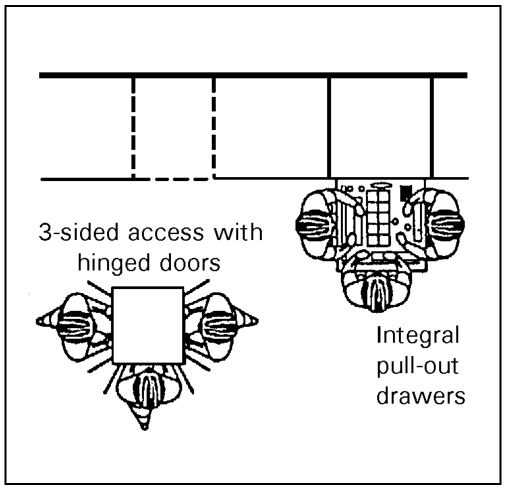
Example. Where maintenance is to be performed at the equipment location, equipment design can include techniques that use the chassis as an integral part of the structure of the equipment, for example, pull out drawers or shelves. These techniques ensure that all components can be reached with a minimum of access space. (See also Chapter 4, Designing equipment for maintenance.

- ■ **10.3.2.3 Reach limits.** Reach limits shall permit the 5th percentile maintainer access to perform the tasks with the appropriate tools. [Source: AFSC DH 1-3, 1980]

- ▫ **10.3.2.4 Access openings.** Access openings should be provided on at least three sides of equipment as illustrated in Exhibit 10.3.2.4, which illustrates the space required for three-sided access with hinged doors versus that required for integral pullout drawers. [Source: AFSC DH 1-3, 1980]

  Discussion. Equipment with panels or hinged access doors may need to be removed before the equipment can be maintained or serviced. Less room is generally required to work on equipment with pull out shelves or drawers than on equipment with access doors or panels. Built in pullout shelves and drawers are preferred to hinged doors or removable panels.

Exhibit 10.3.2.4 Access space through integral design.
[Source: AFSC DH 1-3, 1980]



- ▫ **10.3.2.5 Component locations for access.** Components to be serviced, replaced, or repaired on the equipment should be placed in a plane parallel to and within 150 mm (6 in) of the access openings when hinged doors or removable panels are used. [Source: AFSC DH 1-3, 1980]

- ■ **10.3.2.6 Ease of replacement.** Each unit of equipment and its components shall be designed and installed to ensure ease of replacement. [Source: AFSC DH 1-3, 1980]

- ▫ **10.3.2.7 Access interference.** Each unit should be located so that no other units or equipment need to be removed to reach it. [Source: AFSC DH 1-3, 1980]

- ■ **10.3.2.8 Equipment location to reduce access interference.** Units of equipment shall not be located in recesses, behind, or under structural members or other equipment components where access or removal is difficult. [Source: AFSC DH 1-3, 1980]

- **10.3.2.9 Access to equipment covers.** Technicians shall be able to open unit covers without interference from bulkheads, brackets, or other equipment. [Source: AFSC DH 1-3, 1980]

- **10.3.2.10 Visual access.** Units shall be located so that check points, adjustment points, connectors, and labels face the technician and are not hidden by other units. [Source: AFSC DH 1-3, 1980]

- **10.3.2.11 Clear visual inspection.** Units and components that require frequent visual inspection shall be located so that items being inspected (for example, desiccators or fuses) can be seen easily without removal of panels, covers, or other units. [Source: AFSC DH 1-3, 1980]

- **10.3.2.12 Front removal.** Units of equipment should be designed for removal of components and, if applicable, subordinate units, through the front rather than the back of the equipment. [Source: AFSC DH 1-3, 1980]

10.4 Design of passageways

In complex systems and facilities, passageways are necessary for personnel to be able to get to equipment areas and works stations. These personnel may be required to carry tools and to move equipment through passageways including over steps and through entrances. This subsection covers traffic area walkways; special spaces such as catwalks (to be avoided when possible); platforms and elevators; entrances and exits; and ramps, stairs, and ladders.

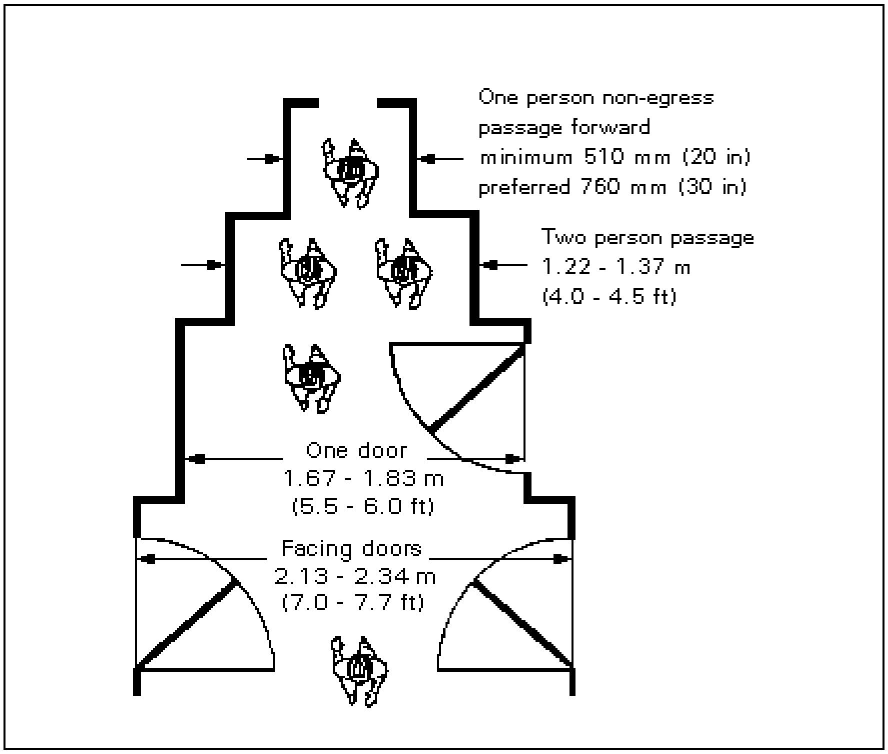
> **Definitions. Passageways** for the purpose of this document are areas across which people must pass for work purposes. **Walkways** are areas designated for walking; **corridors** are walkways that are physically restricted by walls or the like.

10.4.1 Walkways and traffic areas

- **10.4.1.1 Corridor width.** Corridor widths shall be designed for the peak traffic load expected, for traffic directions, and for the number of entrances and exits in the area. [Source: MIL-HDBK-759B, 1992]

▪ **10.4.1.2 Corridors.** To allow personnel to move with tolerable restrictions, the widths of corridors shall equal or exceed those given in Exhibit 10.4.1.2 (see Paragraph 10.4.7.4.1 for OSHA implications when a corridor is designated as part of an emergency egress). [Source: MIL-HDBK-759B, 1992]

Exhibit 10.4.1.2 Walkway and passageway



▫ **10.4.1.3 Added clearance.** Adequate clearance should be allowed for personnel wearing bulky clothing and carrying equipment. [Source: MIL-HDBK-759B, 1992]

> **Example.** A person can move through a corridor 510 mm (20 in) wide with some difficulty; however, a one-person corridor for bulky clothes and comfortable travel should be at least 760 mm (30 in) wide (see Exhibit 10.4.1.2). The dimensions of equipment to be carried or transported may add width to these minimum and preferred values.

▪ **10.4.1.4 Floors.** Passageway floors shall be stable, firm and slip resistant. [Source: Uniform Federal Accessibility Standard (UFAS), 1988]

10.4.2 Wheelchair accessible routes

▪ **10.4.2.1 Minimum accessible routes.** At least one accessible route within the boundary of the site shall be provided from public transportation stops, accessible parking, accessible passenger loading zones, and public streets or sidewalks to the accessible building entrance they serve. [Source: UFAS, 1988]

- **10.4.2.2 Protruding objects.** Protruding objects shall not reduce the clear width of an accessible route or maneuvering space. [Source: UFAS, 1988]

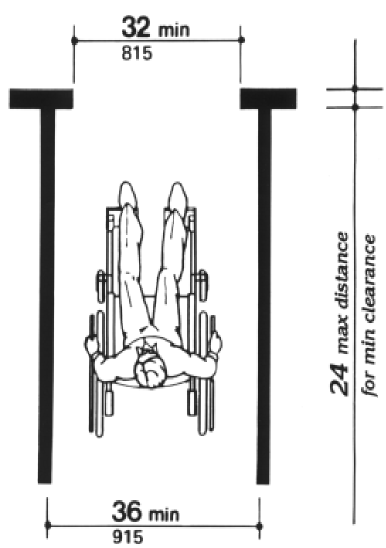
- **10.4.2.3 Connecting routes to other areas.** At least one accessible route shall connect accessible buildings, facilities, elements, and spaces that are on the same site. [Source: UFAS, 1988]

- **10.4.2.4 Connecting entrances to other areas.** At least one accessible route shall connect accessible building or facility entrances with all accessible spaces and elements and with all accessible units within the building or facility. [Source: UFAS, 1988]

- **10.4.2.5 Width.** The minimum clear width of an accessible route for a single wheelchair shall be 32 in (815mm) at a point and 36 in (915 mm) continuously. [Source: UFAS, 1988]

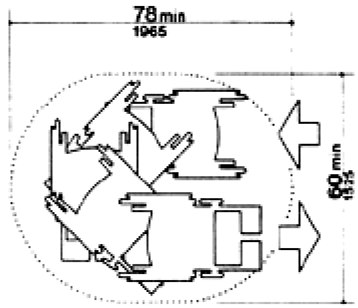
- **10.4.2.6 Making a 90 degree turn around an obstruction.** When a person in a wheelchair must make a 90 degree turn around an obstruction, the minimum clear width of the accessible route shall be a 36 in (915 mm) wide passage into another 36 inch (915 mm) passage if the depth of each leg is a minimum of 48 inches (1220 mm) on the inside dimensions of the turn, as shown in Exhibit 10.4.2.6. [Source: UFAS,1988]

  Exhibit 10.4.2.6 Minimum clearance point for a single wheelchair. [Source: UFAS, 1988]



- □ **10.4.2.7 Making a U-turn in a wheelchair.** When a person in a wheelchair must make a U-turn, the space provided should at minimum be 1965 mm (78 in) by 1525 mm (60 in) as shown in Exhibit 10.4.2.7. [Source: ADAAG, 1998]

Exhibit 10.4.2.7 Dimensions for making a U-turn in a wheelchair.
[Source: UFAS, 1988]



- **10.4.2.8 Passing Space.** When an accessible route has less than 60 in (1525 mm) clear width, then passing spaces at least 60 in by 60 in (1525 mm by 1525 mm) shall be located at reasonable intervals not to exceed 200 ft (61 m). [Source: UFAS, 1988]

  Discussion. A T-intersection of two corridors or walks is an acceptable passing place. [Source: UFAS, 1988]

- **10.4.2.9 Slope.** An accessible route with a running slope greater than 1:20 is a ramp and shall comply with Section 10.4.8 (Ramps, ladders, and stairs). [Source: UFAS, 1988]

- **10.4.2.10 Maximum slope.** Nowhere shall the cross slope of an accessible route exceed 1:50. [Source: UFAS, 1988]

- **10.4.2.11 Exclusion of stairs, steps, and escalators.** An accessible route shall not include stairs, steps, or escalators. [Source UFAS, 1988]

- **10.4.2.12 Egress.** Accessible routes serving any accessible space or element shall also serve as a means of egress for emergencies or connect to an accessible area of rescue assistance. [Source: UFAS, 1988]

10.4.3 Ground and floor surfaces

- **10.4.3.1 Floors.** Passageway floors shall be provided with nonskid or other high friction surfaces. [Source: MIL-HDBK-759B, 1992]

10.4.4 Landings

- 10.4.4.1 **Level landings.** Ramps shall have level landings at bottom and top of each ramp and each ramp run. [Source: MIL-HDBK-759B, 1992]

- 10.4.4.2 **Width.** The landing shall be at least as wide as the ramp run leading to it. [Source: MIL-HDBK-759B, 1992; UFAS, 1988]

- 10.4.4.3 **Length.** The landing length shall be a minimum of 60 in (1525 mm) clear. [Source: MIL-HDBK-759B, 1992; UFAS, 1988]

- 10.4.4.4 **Ramp changes directions.** If ramps change direction at landings, the minimum landing size shall be 60 in by 60 in (1525 mm by 1525 mm). [Source: MIL-HDBK-759B, 1992; UFAS, 1988]

10.4.5 Catwalks, tunnels, and crawl spaces

Catwalks, tunnels, and crawl spaces are specialized facility features used to accommodate unique space or environmental limitations that preclude normal corridors or walkways.

- 10.4.5.1 **Minimum catwalk width.** The minimum catwalk floor width shall be 460 mm (18 inches) to accommodate walking one foot in front of the other and carrying tools or equipment. [Source: VanCott & Kinkade, 1972]

- 10.4.5.2 **Enclosed space ventilation.** Enclosed catwalks, tunnels, and crawl spaces shall have adequate air ventilation to sustain their maximum permissible personnel numbers for an indefinite period. [Source: NASA-STD-3000A, 1989]

  Discussion. Consider both temperature and air quality when determining adequate air ventilation. [Source: NASA-STD-3000A, 1989]

- 10.4.5.3 **Movement or work without mechanical aid.** When special passageways require bending, stooping, or crawling, personnel with 99th percentile dimensions shall be able to accomplish the movement and, where applicable, work without the assistance of other people or of mechanical aids. [Source: NASA-STD-3000A, 1989]

10.4.6 Platforms, elevators, inclinators

10.4.6.1 Platforms

- 10.4.6.1.1 **Hands free work area.** Platform design shall permit both of the users hands to be free for work. [Source: MIL-HDBK-759B, 1992]

- 10.4.6.1.2 **Guardrails.** Guardrails shall be provided in accordance with Section 10.4.6.3 (Platform guardrails, toeholds, screens, and handholds). [Source: MIL-HDBK-759B, 1992]

- **10.4.6.1.3 Permissible gaps with equipment.** Platform design shall provide a continuous closure between the equipment and the platform with average conformation within 50 mm (2 in); avoiding gaps greater than 150 mm (6 in). [Source: MIL-HDBK-759B, 1992]

- **10.4.6.1.4 Protect equipment surface.** Contact plates, cushions, bumpers, or pads shall be used, as necessary, to protect the equipment surfaces. [Source: MIL-HDBK-759B, 1992]

- **10.4.6.1.5 Platform strength.** The platform shall have sufficient strength to hold the worker(s) in addition to the heaviest tools and equipment expected plus a safety factor consistent with design practice for the structural materials. [Source: MIL-HDBK-759B, 1992]

  Discussion. Assume 113.4 kg (250 lb) for each person. [Source: MIL-HDBK-759B, 1992]

- **10.4.6.1.6 Test equipment support.** When test equipment will be used, the design shall provide support for test equipment at the appropriate height for its use. [Source: MIL-HDBK-759B, 1992]

- **10.4.6.1.7 Open metal grating for exterior platforms and work area surfaces.** Exterior platforms and similar work areas shall be constructed of open metal grating. [Source: MIL-STD-1472D, 1989; MIL-STD-1800A, 1990; MIL-W-5044, 1998; MIL-W-5050, 1998]

- **10.4.6.1.8 Alternate surfaces for platforms and work area surfaces.** Where grating is impractical and for alternatively constructed interior platforms and work passageways, floor surfaces shall be treated with non-skid material that conforms to MIL-W-5044 and that is applied in accordance with MIL-W-5050. [Source: MIL-STD-1472D, 1989; MIL-STD-1800A, 1990; MIL-W-5044, 1998; MIL-W-5050, 1998]

10.4.6.2 Portable platforms

- ▫ **10.4.6.2.1 Portable platforms.** Portable platforms should be lightweight in their material and fully collapsible. [Source: MIL-HDBK-759B, 1992]

- **10.4.6.2.2 Platform wheels and brakes.** Any platform on wheels shall have brakes and wheel locks. [Source: MIL-HDBK-759B, 1992]

10.4.6.3 Platform guardrails, toeholds, screens, and handholds

- **10.4.6.3.1 Open sides of personnel platforms.** All open sides of personnel platforms shall be equipped with guardrails, which have at least two rails (an intermediate rail and top rail). [Source: MIL-STD-1472D, 1989]

- **10.4.6.3.2 Guardrails.** The open area of personnel platforms where work is to be done shall be guarded without interfering with work tasks. [Source: MIL-STD-1472D, 1989]

- **10.4.6.3.3 Guardrail dimensions.** Guardrail dimensions shall be as follows:

  a. top rail height at least 1.1 m (42 in)

  b. distance between the platform edge and the centerline of the railing not to exceed 65 mm (2.5 inches)

  c. rail diameter between 37 mm (1.5 in) and 75 mm (3 in). [Source: 29 CFR 1910.23, 1985; MIL-STD-1472D, 1989]

  Discussion. In accordance with OSHA 29 CFR 1910.23 (e), this railing height and diameter range describe the OSHA standard guard railing for platforms, ramps, floor openings, hatches, and wall openings (that a person could fall into). [Source: 29 CFR 1910.23, 1985; MIL-STD-1472D, 1989]

- **10.4.6.3.4 Toe board or guard screen.** A toe board of 10 cm (4 in) to 15 cm (6 in) or a guard screen that extends from the floor base to the intermediate rail shall be used to guard floor openings. [Source: MIL-STD-1472D, 1989; MIL-HDBK-759B, 1992]

  Note. OSHA 29 CFR 1910.23 (e) permits a 102 mm (4 in) toe board as a minimum.

  Discussion. The guard screen is used to prevent a person who falls on the platform from falling from the platform. It can also prevent most tools, parts, and equipment from falling from the platform. Toe boards are intended to prevent tools, parts, and equipment from falling as well as to prevent the worker's foot from slipping off the edge of the platform.

- **10.4.6.3.5 Handholds.** Handholds shall be furnished where needed to assist in climbing onto a platform or as aids in performing the intended maintenance tasks from the platform. [Source: MIL-STD-1472D, 1989]

- **10.4.6.3.6 Handholds, guardrails for adverse conditions or motion.** Handholds and guardrails shall be provided where personnel must stabilize themselves because of high winds, ice, fog or other hazards and when working in moving vehicles. [Source: MIL-HDBK-759B, 1992]

10.4.6.4 Elevators, and hydraulically operated platforms

- **10.4.6.4.1 Elevators, inclinators, and hydraulic work platforms.** Where these passage or work aids are needed, the following operating safety features shall be included:

  a. Maximum load signs located where they can be easily seen.

  b. Guards used to prevent accidental operations of the lift.

  c. An easily reachable capability for manually lowering the platform or elevator provided when feasible.

  d. Floor surface treatment in accordance with the treatment of open platforms in Paragraph 10.4.6.1.8 (Alternate surfaces for platforms and work area surfaces). [Source: MIL-STD-1472D, 1989; MIL-STD-1800A, 1990]

- **10.4.6.4.2 Designed-in safety features.** The following designed-in features shall be provided:

  a. limit stops to prevent injury to personnel and damage to equipment, and

  Definition. Limit stops are mechanical mechanisms designed to restrict a moving object or part by stopping it at predetermined (limit) positions.

  b. an automatic fail-safe brake or other self-locking device in case of lift mechanism failure. [Source: MIL-STD-1472D, 1989]

10.4.7 Entrances and exits

This section covers general rules for entrances and exits. Doorways and normal hinged doors for individual and multi-person entry, alternatives to normal hinged doors, emergency doors, hatches, and emergency escape hatches are treated.

10.4.7.1 General

- **10.4.7.1.1 Entrances for enclosed work areas.** Enclosed work areas should have conventional entrances and exits for routine access and to permit unrestricted flow for all anticipated traffic and movements of equipment. [Source: MIL-HDBK-759B, 1992]

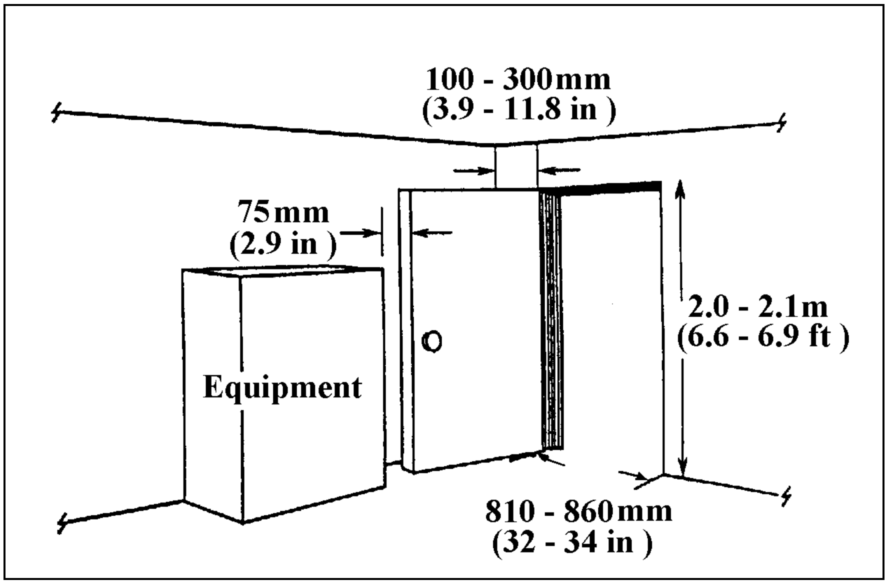
- **10.4.7.1.2 Routine.** Conventional entrances and exits for enclosed work areas should be located so that personnel who are entering or leaving will not inadvertently operate or block access to controls or displays or otherwise interfere with ongoing work in the area. [Source: MIL-HDBK-759B, 1992]

10.4.7.2 Doorways and hinged doors

- 10.4.7.2.1 **Door dimensions.** Hinged doors that allow the passage of one person shall have at least the dimensions shown in Exhibit 10.4.7.2.1. [Source: MIL-STD-1800A, 1990]

  Note. If the depicted area is a means of exit, OSHA 29 CFR 1910.37 (h)(2)(i) requires that the floor to ceiling dimension be at least 2.29 m (7.5 ft) and any protrusions from the ceiling be no less than 2.04 m (6.7 ft).

Exhibit 10.4.7.2.1 Door dimensions. [Source: MIL-HDBK-759B, 1992]



- 10.4.7.2.2 **Perpendicular wall door clearances.** When a door opens inward next to a perpendicular wall, a clearance of at least 100 mm (4 in) between the door at the hinge and the plane of the wall shall be provided (see Exhibit 10.4.7.2.1). [Source: MIL-STD-1800A, 1990]

- 10.4.7.2.3 **Equipment or furniture door clearances.** Equipment or furniture shall not be positioned within 2.9 inches of the swing path of a door that opens inward (see Exhibit 10.4.7.2.1). [Source: MIL-STD-1800A, 1990]

- 10.4.7.2.4 **Door opening direction for normal density traffic.** When the normal traffic density and the exiting personnel traffic in emergency conditions are expected to be low, then hinged doors shall open inward rather than outward into a corridor. [Source: MIL-STD-1800A, 1990]

  Discussion. Opening inward will prevent injury to personnel using the corridor. [Source: MIL-STD-1800A, 1990]

- 10.4.7.2.5 **Door opening direction for high density traffic.** When exiting traffic volume is expected to be high, the door shall have a see-through window and open outward to ensure the feasibility of exiting in an emergency. [Source: MIL-STD-1800A, 1990]

10.4.7.3 Alternative door rules

- **10.4.7.3.1 Sliding and folding doors.** When horizontal or vertical sliding or folding doors are used to allow large pieces of equipment or vehicles to pass through, alternative personnel exits should be available. [Source: MIL-STD-1800A, 1990; MIL-HDBK-759B, 1992]

  Discussion. Because large doors may jam, provide a hinged door for personnel entrance and exit. If horizontal or vertical sliding or folding doors are the only exits available for personnel to egress the building, provide a hinged door built into the sliding or folding door. [Source: MIL-STD-1800A, 1990; MIL-HDBK-759B, 1992]

- **10.4.7.3.2 Swinging doors.** Swinging doors should be used in pairs, one for each direction of traffic, with the hinges attached to a center post that separates the doors. [Source: MIL-STD-1800A, 1990; MIL-HDBK-759B, 1992]

- **10.4.7.3.3 Visual access on swinging doors.** Swinging doors should have openings or windows for visual access to oncoming traffic. [Source: MIL-STD-1800A, 1990; MIL-HDBK-759B, 1992]

- **10.4.7.3.4 Spring mechanisms on swinging doors.** A spring mechanism should only be used when the door size or weight prevents manual opening and closing. [Source: MIL-STD-1800A, 1990; MIL-HDBK-759B, 1992]

  Discussion. Avoid spring closure mechanisms with a light door as this closing arrangement can be hazardous. [Source: MIL-STD-1800A, 1990; MIL-HDBK-759B, 1992]

- **10.4.7.3.5 Revolving doors.** Revolving doors are hazardous and should not be used. [Source: MIL-STD-1800A, 1990; MIL-HDBK-759B, 1992]

- **10.4.7.3.6 Floor to ceiling glass doors or windows.** Where floor to ceiling doors or windows are used, the glass area should be patterned or labeled so that users will not mistake it for an unobstructed passageway. [Source: MIL-STD-1800A, 1990; MIL-HDBK-759B, 1992]

10.4.7.4 Emergency doors

- 10.4.7.4.1 **Space for exit.** Emergency exits shall allow enough space for rapid exit of all occupants, including any who must carry essential equipment or wear bulky clothing without danger of personnel injury or damage to the equipment being carried. [Source: 29 CFR 1910.36-37, 1985; MIL-HDBK-759B, 1992]

  Discussion. OSHA 1910.36-37 and National Fire Protection Association codes specify the design requirements for "ways of exit" from buildings and facilities. A designated means of emergency egress requires a minimum of 18 inches of unobstructed "way of exit" travel from any point in a structure to an exterior safe public way. Design requirements for any unobstructed "way of exit" are functions of the nature of the building construction and contents, the maximum occupancy capacities of its components, and the arrangement of designated "ways of exit."

- 10.4.7.4.2 **Emergency door and exit design and construction.** Emergency doors and exits shall be designed and constructed so that they

  a. are simple to operate,

  b. are readily accessible,

  c. are clearly designated,

  d. are unobstructed,

  e. are simple to locate and operate in the dark,

  f. are capable of being opened in 3 sec or less,

  g. require 44 and 133 N (10 to 30 lbs) of operating force to open,

  h. permit exit by one person in 5 sec or less, and

  i. do not in themselves, or in their operation, constitute a safety hazard. [Source: MIL-STD-1472D, 1989]

  Discussion. A door that is not blocked in the direction of exiting travel is not considered an obstruction. An inside door under low occupancy conditions cannot be less than 71 cm (28 in) in width. For occupancy capacities of 60 to 100 people, the unobstructed minimum widths would range between 76 to 112 cm (30 to 44 in), respectively. When other conditions are considered these minimal dimensions could be larger. If the depicted corridors in Exhibit 10.4.1.2 are designated parts of an emergency "way of exit", the minimal width of the unobstructed way would exclude the swing areas where doors open into the "way of exit."

- **10.4.7.4.3 Ceiling areas along a means of egress.** According to OSHA 29 CFR 1910.37 (h)(2)(i), ceiling areas along a means of egress (including exterior escape paths) shall be at least 2.29 m (7.5 ft) above the floor and protrusions not be lower than 2.04 m (6.7 ft). [Source: 29 CFR 1910.37, 1985]

10.4.7.5 Hatches

- **10.4.7.5.1 Flush with surfaces.** Where structural considerations permit, hatches shall be flush with the floor or wall surfaces. [Source: MIL-STD-1800A, 1990]

- **10.4.7.5.2 Hatch opening motion.** Hatches shall open with a single motion of the hand or foot. [Source: MIL-STD-1800A, 1990]

- **10.4.7.5.3 Hatch opening and closing forces.** When a handle is used, the unlocking force shall not exceed 90 N (20 pounds). [Source: MIL-STD-1800A, 1990]

- **10.4.7.5.4 Hatch opening and closing forces.** Overhead hatches shall require no more than 220 N (50 pounds) for opening and closing or not exceed the fifth percentile arm and hand strength of the user population, whichever is less. [Source: MIL-STD-1800A, 1990; MIL-STD-1472D, 1989]

- **10.4.7.5.5 Clearance dimensions for hatches.** Clearance dimensions for size and passage shall be based upon the 99th percentile values for the expected population and accommodate suitably clothed and equipped maintainers together with any equipment they are expected to carry. [Source: MIL-STD-1472D, 1989]

- **10.4.7.5.6 Limiting dimensions for hatches.** Limiting dimensions for location and operability shall be based upon the 1st percentile values for females in the expected user population. [Source: MIL-STD-1800A, 1990]

  Discussion. Clearance dimensions influence the size for access, accommodation, and entrance by the larger people in the user population. Limiting dimensions permit the smaller people in the user population to reach or view controls and displays and to manipulate latches, handles or accesses.

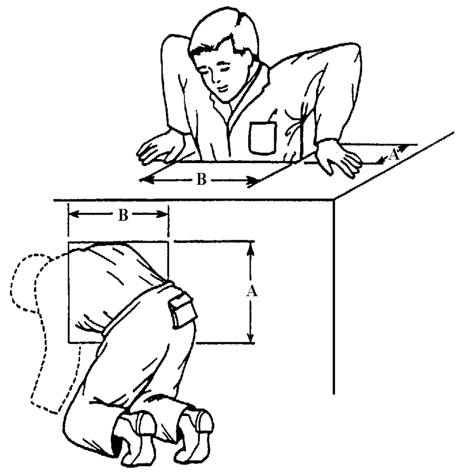
- **10.4.7.5.7 Rescue requirements.** Where rescue of personnel may be required, openings shall be large enough to accommodate two suitably clothed rescuers. [Source: MIL-STD-1800A, 1990]

- **10.4.7.5.8 Rectangular hatch minimums.** When rectangular hatches are used, they shall meet or exceed the minimal whole body dimensions of Exhibit 10.4.7.6.1. [Source: MIL-STD-1800A, 1990]

10.4.7.6 Whole body access

- **10.4.7.6.1 Whole body access.** Dimensions for whole body access shall meet or exceed those shown in Exhibit 10.4.7.6.1. [Source: MIL-STD-1472D, 1989; MIL-STD-1800A, 1990]

Exhibit 10.4.7.6.1 Whole body access dimensions. [Source: MIL-STD-1472D, 1989; MIL-STD-1800A, 1990]



Clothing	Light		Bulky	
Dimensions	**A**	**B**	**A**	**B**
Top and bottom access	330 mm (13 in)	580 mm (23 in)	410 mm (16 in)	690 mm (27 in)
Side access	660 mm	760 mm	740 mm	860 mm

- **10.4.7.6.2 Whole body access with a step down.** Where there is a need to step down through an access and the step distance exceeds 690 mm (27 in), foot rests or steps shall be provided. [Source: MIL-STD-1472D, 1989; MIL-STD-1800A, 1990]

- **10.4.7.6.3 Emergency escape hatches.** Emergency escape hatches shall accommodate the equipment and clothing that escaping personnel will be carrying and wearing, be clear of all external obstructions, and located to avoid external hazards. [Source: MIL-HDBK-759B, 1992]

- **10.4.7.6.4 Emergency escape hatch dimensions.** The minimum and preferred dimensions for special emergency escape hatches shall be (1) rectangular minimum: 405 mm by 610 mm (16 in by 24 in), preferred 510 mm by 710 mm (20 in by 30 in); (2) square minimum: 460 mm (18 in), preferred 560 mm (22 in); (3) circular minimum 560 mm (22 in), preferred 710 mm (30 in). [Source: MIL-HDBK-759B, 1992]

10.4.8 Ramps, ladders, and stairs

10.4.8.1 General

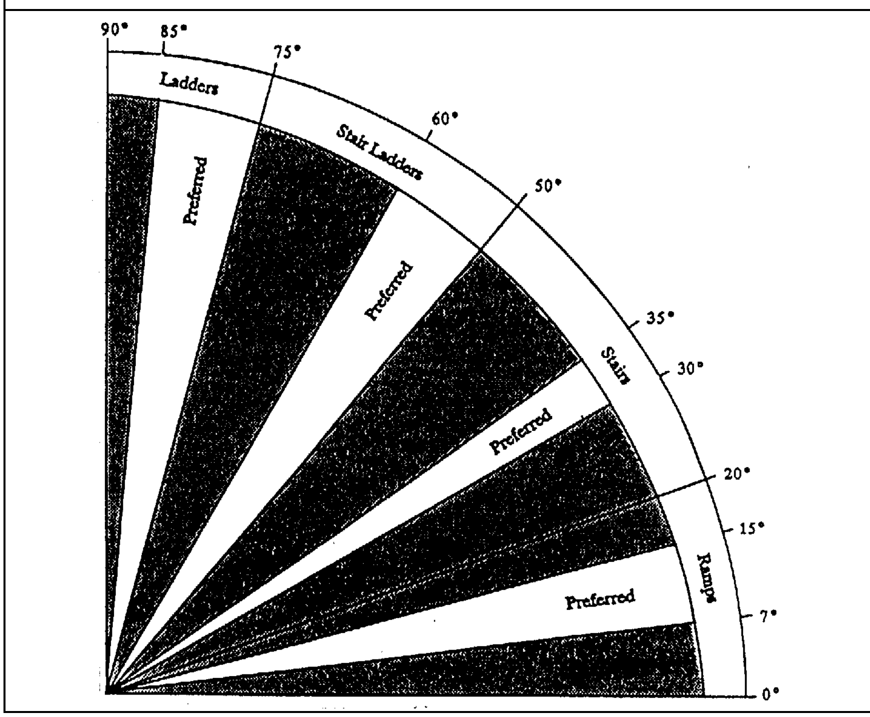
Rules are provided below for selecting and using structures for making changes in elevation of ramps, stairs, and ladders. Common design criteria for these structures are provided as are detailed rules for ramps, stairs, stair ladders, fixed ladders and portable ladders. Stair ladders have steps rather than rungs.

- **10.4.8.1.1 Selection of safest.** The structure that gives the safest and most efficient passage shall be selected. [Source: MIL-STD-1800A, 1990; MIL-STD-1472D, 1989; MIL-HDBK-759B, 1992; Department of Energy (UCRL-15673), 1985]

  Note. The rules for ramps specified in this section apply to "working" ramps (for example, ramps for forklifts from a dock down to the ground) or those used for purposes other than for wheelchair accesses.

- **10.4.8.1.2 Selection based on angle.** The selection of ramps, stairs, stair-ladders, or fixed ladders for specific applications shall be based on the angle of ascent required and the critical criteria levels in Exhibit 10.4.8.1.2. [Source: MIL-STD-1800A, 1990; MIL-STD-1472D, 1989; MIL-HDBK-759B, 1992; UCRL-15673, 1985]

Exhibit 10.4.8.1.2 Type of structure in relation to angle of ascent.



□ **10.4.8.1.3 For heavy carrying.** The following guidance should be followed when selecting structures over which equipment or tools must be carried:

a. Provide ramps, elevators, or equivalent means when maintainers must carry or transport heavy or bulky equipment.

b. Do not use stairs and steps where the user or maintainer must carry bulky loads or loads in excess of 13 kg (29 lbs).

c. Do not use ladders when users or maintainers carry equipment because both hands should be free to grasp and climb ladders.

Exceptions. Vehicular-boarding ladders are not considered to be stair ladders or fixed ladders. Thus, the rules in Section 10.4.8 do not apply. [Source: MIL-HDBK-759B, 1992]

■ **10.4.8.1.4 Material characteristics.** Ramps, stairs, and ladders shall be constructed of materials that are lightweight, nonconductive, splinter-proof, waterproof, weatherproof, humidity-resistant, and resistant to chemical action. [Source: UCRL-15673, 1985]

Discussion. Take into account the environmental conditions during the design phase, including inclement weather (for example, snow, ice, mud, sand, and wind), if applicable. If de-icing is applicable, design them to be tolerant of hot water or steam de-icing. [Source: UCRL-15673, 1985]

■ **10.4.8.1.5 Carrying strength of the structures.** Ramps, stairs, and ladders shall be designed to withstand the total weight of the largest combination of personnel and carried equipment likely to be on them at one time. [Source: UCRL-15673, 1985]

Note. Multiply these estimates by a safety factor appropriate to the materials used. Use 113.4 Kg (250 lb) per person to estimate personnel weight. [Source: UCRL-15673, 1985]

■ **10.4.8.1.6 Nonskid floor surfaces.** Ramps, stairs, and ladders shall be provided with nonskid surfaces on all areas where personnel are expected to walk or stand to work. [Source: UCRL-15673, 1985]

■ **10.4.8.1.7 Warning labels.** Ramps, stairs, and ladders shall have symbols or placards that warn against any hazards associated with their use, (for example, low overhead obstructions, possible shock, and load limits). [Source: UCRL-15673, 1985]

■ **10.4.8.1.8 Handrails.** Ramps, stairs, and ladders shall be equipped with a handrail on each side. [Source: MIL-STD-1472D, 1989]

■ **10.4.8.1.9 Guardrails.** Where personnel could fall into an open area under a ramp, stair, or ladder handrail, an intermediate level guardrail shall be provided. [Source: MIL-STD-1472D, 1989]

■ **10.4.8.1.10 Proper illumination.** Ramps, stairs, and ladders shall be provided with appropriate illumination (see Chapter 13 (Environment) for illumination criteria). [Source: UCRL-15673, 1985]

■ **10.4.8.1.11 Ramp landings.** Ramps shall have level landings at the top and bottom of each ramp and each ramp run that have the following features:

a. the landing at least as wide as the ramp run leading to it,

b. the landing with a minimum length of 1.53 m (60 in) clear,

c. when ramps change direction at landings, a minimum landing size of 1.53 m by 1.53 m (60 in by 60 in), and

d. make the area in front of a doorway located at a landing comply with Section 10.4.7.2. [Source: MIL-HDBK-759B, 1992]

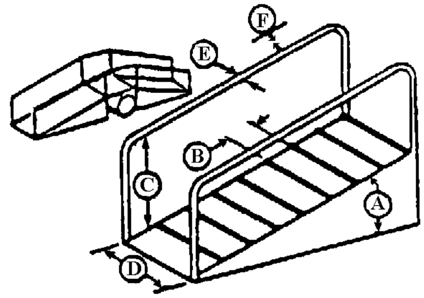
Note. The rules for ramps specified in this section, apply to "working" ramps (for example, ramps for forklifts from a dock down to the ground) or those used for purposes other than for wheelchair accesses.

□ **10.4.8.1.12 Optimum dimensions for ramps.** Dimensions for ramps should conform to the recommended best values for ramps given in Exhibit 10.4.8.1.12. [Source: UCRL-15673, 1985]

■ **10.4.8.1.13 Minimal and maximum dimensions for ramps.** In all cases, dimensions for ramps shall be within the specific minimum and maximum limits shown for ramps given in Exhibit 10.4.8.1.12. [Source: UCRL-15673, 1985]

Note. In Exhibit 10.4.8.1.12, the minimal and best handrail height, diameter, and hand clearance comply with OSHA 29 CFR 1910.23 (e).

Exhibit 10.4.8.1.12 Critical dimensions for ramps.
[Source: UCRL-15673, 1985]

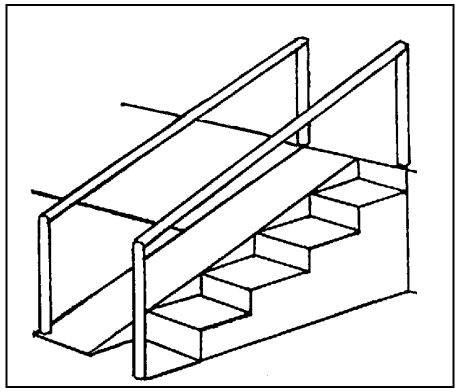


	Min.	Max.	Best
A Angle of rise	-	20°	7-15°
B Distance between cleats	23 cm (9 in)	41 cm (16 in)	36 cm (14 in)
C Height of handrails	95 cm (36 in)	107 cm (42 in)	107 cm (42 in)
D Width	95 cm (36 in)	-	-
E Diameter of handrail	4 cm (1.5 in)	8 cm (3 in)	4 cm (1.5 in)
F Clearance around handrail	8 cm (3 in)	- -	8 cm (3 in)

▪ **10.4.8.1.14 Ramps for pushing or pulling equipment on carts.** When ramps are used to push or pull carts, the designer shall stay within human strength capabilities in establishing the angle of inclination. [Source: MIL-HDBK-759B, 1992]

▫ **10.4.8.1.15 Combined vehicular or cart and personnel traffic.** Stairs should be provided for personnel when vehicles and pedestrians share a ramp and the angle of ramp inclination exceeds 7 degrees. Exhibit 10.4.8.1.15 illustrates a ramp and stairs combination with a pedestrian area on the right side. [Source: MIL-HDBK-759B, 1992]

Exhibit 10.4.8.1.15 Combined ramp and stairs.
[Source: MIL-HDBK-759B, 1992]



- **10.4.8.1.16 Personnel traffic area placement.** Personnel traffic areas should be off to the side or on both sides of the vehicle areas. [Source: MIL-HDBK-759B, 1992]

- **10.4.8.1.17 Separation of vehicular and personnel traffic areas.** Vehicular traffic and walking traffic should be clearly separated by markings and handrails. [Source: MIL-HDBK-759B, 1992]

10.4.8.2 Pedestrian ramps

The rules for ramps specified in this section apply to pedestrian ramps. These ramps are intended for pedestrian traffic including those individuals requiring wheelchair access.

- **10.4.8.2.1 Handrails for ramps.** Ramps for pedestrian traffic should have handrails. [Source: MIL-STD-1472D, 1989]

- **10.4.8.2.2 Nonskid materials for ramps.** Nonskid materials should be used on the floor area of ramps wherever pedestrian traffic is expected. [Source: MIL-STD-1472D, 1989; MIL-HDBK-759B, 1992]

- **10.4.8.2.3 Cleating of ramps.** Where special environmental conditions require cleating of ramps, cleats should be spaced 360 mm (14 in) apart and run from handrail to handrail at right angles to traffic. [Source: MIL-STD-1472D, 1989; MIL-HDBK-759B, 1992]

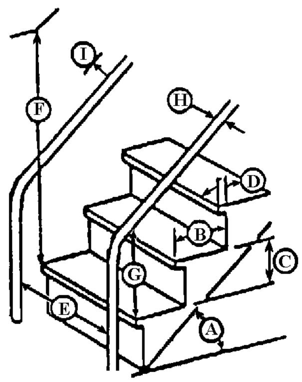
  Discussion. Cleating of ramps facilitates footing for walking and rolling equipment on inclines.

10.4.8.3 Stairs

- **10.4.8.3.1 Dimensions for stairs.** Stair dimensions shall be within the minimum and maximum values shown in the Exhibit 10.4.8.3.1. [Source: UCRL-15673, 1985]

  Discussion. It is recommended that stair dimensions conform to the recommended best values provided in Exhibit 10.4.8.3.1.

Exhibit 10.4.8.3.1 Design requirements for stair dimensions. [Source: UCRL-15673, 1985; MIL-STD-1472D, 1989; MIL-HDBK-759B, 1992; MIL-STD-1800A, 1990]



		Minimum	**Maximum**	**Best**
A	Angle of rise	30°	50°	--
B	Tread depth	24 cm (9.5 in)	30 cm (12 in)	28-30 cm (11-12 in)
C	Riser height	13 cm (5 in)	20 cm (8 in)	17-18 cm (6.5-7 in)
D	Depth of nosing	2 cm (.75 in)	4 cm (1.5 in)	3 cm (1 in)
E	Width (handrail to handrail)			
	One-way stairs	56 cm (22 in)	--	56 cm (22 in)
	Two-way stairs	122 cm (48 in)	--	130 cm (51 in)
F	Minimum overhead clearance	2.1 m (7 ft)	--	2.1 m (7 ft)
G	Height of handrail	76 cm (30 in)	86 cm (34 in)	84 cm (33 in)
H	Diameter of handrail	4 cm (1.5 in)	8 cm (3 in)	4 cm (1.5 in)
I	Hand clearance	8 cm (3 in)	--	8 cm (3 in)

- **10.4.8.3.2 Landings.** There should at least be a landing for each floor level and other landings are recommended for each ten to twelve treads. [Source: MIL-HDBK-759B, 1992]

- **10.4.8.3.3 Riser uniformity.** Riser heights and the height to landings should be uniform. [Source: MIL-HDBK-759B, 1992]

- **10.4.8.3.4 Stair lengths.** Long flights of stairs should be avoided. [Source: MIL-HDBK-759B, 1992]

- **10.4.8.3.5 Open tread and protection beneath.** Where practical, treads should be open with metal screens or kick plates fastened to the underside to avoid injuries from dropped articles. [Source: UCRL-15673, 1985]

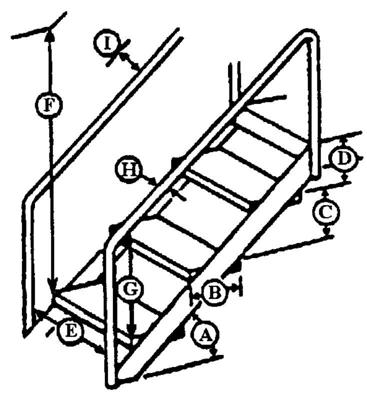
▫ **10.4.8.3.6 Stair design for load carrying.** When people are going to carry loads of more than 9 kg (20 lb) or where stairs are more than two stories high, deep treads, 300 mm (12 in), and low risers 125 mm (5 in) should be used. [Source: UCRL-15673, 1985]

Note. The following criteria are suggested by Building Officials and Code Administrators (BOCA): minimum tread depth, 280 mm (11 in); minimum riser height, 100 mm (4 in); and maximum riser height, 180 mm (7 in). OSHA 29 CFR 1910.23 (e)(6) requires a minimum hand clearance of 75 mm (3 in). Stair railings (hand railings) are a minimum of 76 cm (30 in) and a maximum of 86 cm (34 in) above the leading edge of step treads. OSHA 29 CFR 1910.24 (d) requires that a fixed stairs be a minimum stair rail (handrail) to stair rail distance of 56 cm (22 in) and have a minimum overhead clearance of 2.1 m (7 ft).

10.4.8.4 Stair ladders

- 10.4.8.4.1 **Dimensions for stair ladders.** Stair ladder dimensions shall be within the minimum and maximum best values recommended in Exhibit 10.4.8.4.1. [Source: UCRL-15673, 1985]

Exhibit 10.4.8.4.1 Design requirements for stair ladders.



	Min.	Max.	Best
A Angle of rise	50°	75°	-
B Tread depth for 127 cm (50 in) rise	15 cm (6 in)	25 cm (10 in)	22 cm (8.5 in)
for 191 cm (75 in) rise	8 cm (3 in)	14 cm (5.5 in)	10 cm (4 in)
C Riser height	18 cm (7 in)	30 cm (12 in)	20-23 cm (8-9 in)
D Height, step to landing	15 cm (6 in)	riser riser	riser riser
E Width (handrail to handrail)	56 cm (22 in)	61 cm (24 in)	56 cm (22 in)
F Minimum overhead clearance	173 cm (68 in)	- -	193 cm (76 in)
G Height of handrail	86 cm (34 in)	86 cm (34 in)	86 cm (34 in)
H Diameter of handrail	4 cm (1.5 in)	8 cm (3 in)	4 cm (1.5 in)
I Minimum hand clearance	8 cm (3 in)	- -	8 cm (3 in)

Note. OSHA 29 CFR 1910.28 requires a standard stair railing and not a handrail if the fall distance is greater than 1.2 m (48 in). Also, Exhibit 10.4.8.4.1 shows a drawing of open stairs where OSHA requires stairs to be closed.

- **10.4.8.4.2 Two way traffic with stair ladders.** When simultaneous two way traffic is desired, separate up and down ladders should be provided, located side by side with double center handrails and a minimum separation of 150 mm (6 in) (200 mm (8 in preferred separation)) between these rails. [Source: UCRL-15673, 1985]

  Note. Stair ladders are intended for one person at a time either coming up or down.

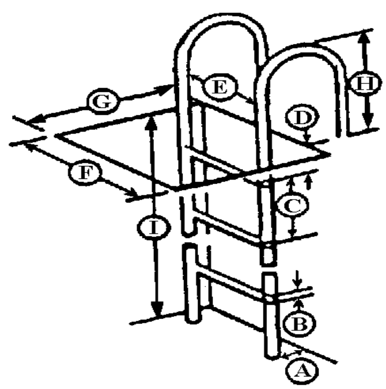
- **10.4.8.4.3 Open treads and protection.** Treads should be open (without risers boards) and have screens or kick plates fastened to the underside to prevent injury to personnel or damage to equipment if objects are dropped. [Source: UCRL-15673, 1985]

10.4.8.5 Fixed ladders

- **10.4.8.5.1 Dimensions for fixed ladders.** Fixed ladder dimensions shall be within the minimum and maximum values in the Exhibit 10.4.8.5.1, preferably conforming to the recommended best values [Source: UCRL-15673, 1985]

  Note. OSHA 29 CFR 1910.27 recommends a maximum rung spacing of 305 cm (12 in) and recommends a minimum clearance of back of the ladder of 18 cm (7 in). OSHA 29 CFR 1910.27 covers many more varieties and dimensions for fixed ladders.

Exhibit 10.4.8.5.1 Design requirements for fixed ladders.

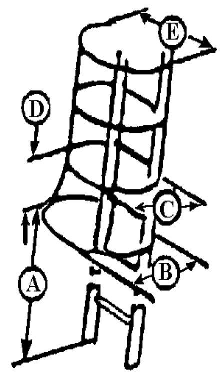


		Minimum	Maximum	Best
A	Angle of rise	60°	90°	75-90°
B	Rung or cleat diameter			
	wood	3 cm (1.18 in)	4 cm (1.5 in)	4 cm (1.5 in)
	protected metal	2 cm (.75 in)	4 cm (1.5 in)	4 cm (1.5 in)
	metal that may rust	3 cm (1.18 in)	4 cm (1.5 in)	4 cm (1.5 in)
C	Rung spacing	23 cm (9 in)	30 cm (12 in)	28-30 cm (11-12 in)
D	Height, rung to landing	15 cm (6 in)	30 cm (12 in)	28-30 cm (11-12 in)
E	Width between stringers	30 cm (12 in)	--	46-53 cm (18-21 in)
F	Climbing clearance width	76 cm (30 in)	--	--
G	Minimum clearance depth			
	in back of ladder	18 cm (7 in)	--	20 cm (8 in)
	on climbing side	91 cm for 76° (36 in for 76°)		
		76 cm for 90° (30 in for 90°)		
H	Height of string above landing	--	--	91cm (36in)
I	Maximum height of climb	--	3m (10ft)	2.4m (8ft)

- **10.4.8.5.2 Guarded landings, entrances.** When fixed ladders are used between several floors, the landings and entrances should be guarded, especially if the ladder well is open. [Source: 29 CFR 1910.27, 1985; UCRL-15673, 1985; MIL-STD-1800A, 1990]

□ **10.4.8.5.3 Cages and safety devices.** Cages or ladder safety devices complying with Exhibit 10.4.8.5.3 should be provided for fixed ladders over 6.1 m (20 ft) long. [Source: 29 CFR 1910.27, 1985; UCRL-15673, 1985; MIL-STD-1800A, 1990]

Exhibit 10.4.8.5.3 Design requirements for fixed ladder cage dimensions.



		Min	Max
A	Height of cage from base of ladder	213 cm (84 in)	244 cm (96 in)
B	Flare at bottom of the cage		"C" + 10.1 cm ("C" + 4 in)
C	Depth of cage from center of ladder	69 cm (27 in)	71 cm (28 in)
D	Distance between cage ribs	- -	46 cm (18 in)
E	Width of cage	69 cm (27 in)	71 (28 in)

■ **10.4.8.5.4 Obstruction free cages.** The inside of fixed ladder cages shall be free of all obstructions. [Source: 29 CFR 1910.27, 1985; UCRL-15673, 1985; MIL-STD-1800A, 1990]

□ **10.4.8.5.5 Rungs versus level steps.** Rungs provide better hand holds than steps, but when handrails are provided on both sides of the ladder, level steps 75 to 100 mm (3 - 4 in) wide should be used. [Source: UCRL-15673, 1985]

□ **10.4.8.5.6 Nonskid surfaces on rungs.** All rungs should have nonskid surfaces. [Source: UCRL-15673, 1985]

□ **10.4.8.5.7 Tread and tread rise.** Tread rise should be open in the rear. [Source: MIL-STD-1472D, 1989]

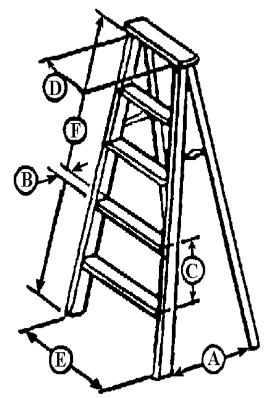
▫ **10.4.8.5.8 Exterior stair ladders.** The surface of treads on exterior stair ladders should be constructed of open grating material or be treated with nonskid material. [Source: MIL-STD-1472D, 1989]

10.4.8.6 Portable ladders

▪ **10.4.8.6.1 Dimensions for portable ladders.** Portable ladder dimensions shall be within the minimum and maximum values (preferably conform to the recommended best values) in Exhibits 10.4.8.6.1 (a) for stepladders and Exhibit 10.4.8.6.1 (b) for portable rung ladders. [Source: 29 CFR 1910.25-26, 1985; UCRL-15673, 1985; MIL-HDBK-759B, 1992]

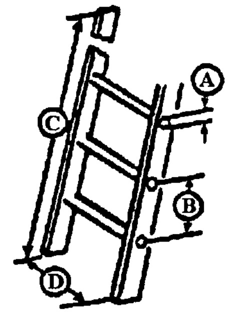
> **Note.** OSHA 29 CFR 1910.25-26 provides guidance for the design and use of ladders. [Source: 29 CFR 1910.25-26, 1985; UCRL-15673, 1985; MIL-HDBK-759B, 1992]

Exhibit 10.4.8.6.1 (a) Design requirements for portable step ladders.



A Spread	9 cm (3.5 in) per 30 cm (12 in) length of front section plus 5 cm (2 in) per 30 cm (12 in) length of back section
B Tread width	minimum: 8 cm (3 in) best: 8-10 cm (3-4 in)
C Step spacing wood:	minimum: 23 cm (9 in) maximum: 30 cm (12 in)
	metal: actual: 30 cm (12 in)
D Width between side rails at top step	wood ladders: 29 cm (11.5 in)* metal ladders: 30 cm (12 in)**
E Width at bottom	add 3 cm (1 in) per foot of length
F Length of ladder	maximum: 6.1 m (20 ft)

Exhibit 10.4.8.6.1 (b) Design requirements for portable rung ladders.



		Min	Max	Best
A	Rung diameter wood	3 cm (1.13 in)	4 cm (1.5 in)	4 cm (1.4 in)
	protected metal	2 cm (0.75 in)	4 cm (1.5 in)	4 cm (1.4 in)
	metal that may rust	3 cm (1.0 in)	4 cm (1.5 in)	4 cm (1.4 in)
B	Rung spacing	30 cm (12 in)	30 cm (12 in)	30 cm (12 in)
C	Maximum ladder length			
	single section ladder		9.1 m (30 ft)	
	two-section metal ladder		14.6 m (48 ft)	
	over two-section wood ladder		18.3 m (60 ft)	
D	Minimum width between side rails			
	metal ladders	30 cm (12 in)		
	wood ladders up to 3.0 m (10 ft)	29 cm (11.5 in)		
	add .64 cm (.25 in) for each added 61 cm (24 in) of length			

■ **10.4.8.6.2 Lifting ladders.** Where one person is to lift ladders and store them by hand, ladder weights shall not exceed 9.0 kg (20 lb) for a lift distance of 1.83 m (6 ft) or 11.3 kg (25 lb) for a lift distance of 1.52 m (5 ft.). [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

□ **10.4.8.6.3 Ladder hinges and locks.** Permanent hinges and locks should be used in preference to bolts and nuts for assembly of two-section extension ladders. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

- **10.4.8.6.4 Weather implications for portable ladders.** Ladders should be provided with rubber-cleated, pivoted feet for use in nonfreezing weather, and steel cleats for use in ice and snow. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

  Note. OSHA 29 CFR 1910.26-29 treats additional details for design and use of a variety of ladders and scaffolding.

Glossary

Corridors - Walkways that are physically restricted by walls or the like.

Limit stops - mechanical mechanisms designed to restrict a moving object or part by stopping it at predetermined (limit) positions.

N - A metric term for the force measure called a Newton**.**

Newton - A one pound force in the English measurement system is equal to 4.4482 Newton (1 lbf = 4.4482 N).

Passageways - Areas across which people must pass for work purposes.

Public entrances - any entrances that are not loading or service entrances.

Walkways - Areas designated for walking.

Workplaces - An area room or establishment where work is done.

Workstations - A place designed for a specific task or activity from where work is conducted or operations are directed. Desks, offices, repair benches, tools, equipment, and computer terminals are examples of these special accommodations and equipment. Workstations are designed as areas for one or more workers to use in accomplishing purposeful tasks or jobs.

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11 System security

Note: In 2000, the FAA came out with FAA Order 1370.82. This order cancelled FAA Order 1600.54B, Automated Information Systems Security Handbook. FAA Order 1600.54B is cited frequently throughout this chapter. The information in this chapter will be revised at a future time to reflect the cancellation of FAA Order 1600.54B.

This chapter pertains to the human factors aspects of security safeguard features for new (or modified) facilities, systems, and equipment that are to be acquired and maintained by the FAA. Human factors considerations can enhance the security effectiveness and suitability of new or upgraded systems.

> **Definition. Security safeguards** are the protective measures and controls that are prescribed to meet the security requirements specified for a system. Those safeguards may include but are not necessarily limited to: operational procedures, physical security, or hardware and software features.

The FAA Order 1600.54, FAA Automated Information Systems Security Handbook, and associated directives explain security safeguards associated with communication security, necessary provisions for classified information, and security safeguards such as Tempest requirements.

> **Discussion.** From a system analysis viewpoint, "security safeguards" need to be thought of as a subsystem of any new operational system. The human component of any operational system or subsystem, as well as the security component need to be considered and technically integrated from the concept phase throughout the procurement and implementation phase.

The FAA modernization program increasingly relies on automated processing systems. New computer technologies make it possible for remote users to access large databases through communication networks. Telecommunications systems and Automated Information Systems (AIS) boundaries are becoming vague and are highly susceptible to interception, unauthorized access, exploitation, and hostile threats.

11.1 General design practice

This section defines the **security architecture** of the NAS and provides human factors rules for risk analysis, interface considerations, certification and accreditation activities, and security test and evaluation. Other general rules for system security are also addressed.

▪ **11.1.1 Accreditation and certification.** The accreditation and certification of FAA AIS shall conform to FAA Order 1600.54. Human factors rules of this section are to be complied with before accreditation and certification are given. [Source: Department of Transportation (FAA Order 1600.54B), 1989]

Definitions. Accreditation is the authorization and approval granted to an AIS or network to process sensitive data in an operational environment. **Certification** is the technical evaluation that supports the accreditation process and establishes the extent to which a particular computer system or network design and implementation meets a pre-specified set of security requirements. [Source: FAA Order 1600.54B, 1989]

▪ **11.1.2 Security test and evaluation.** Test and evaluation activities shall be conducted by the contractor to verify that equipment, software, and facility designs meet the security and associated human factors requirements. [Source: Department of Defense (MIL-STD-46855B), 1979]

11.2 Physical security and access control

Physical security addresses the application of physical barriers and control procedures as preventive measures or countermeasures against threats to resources (for example, automated assets, facilities, telephone lines, or information). Good physical access control takes into account threats to a protected area due to vandalism, theft, modification, or destruction. This section gives rules for regulating the physical access to FAA AIS, the facilities that house those systems, and other FAA assets.

The physical security provided to a facility and AIS is based upon the alternative protection measures derived from security risk and requirements analyses. Provisions for protection are to be built into systems, subsystems, facilities, and equipment work areas in accordance with the selected protection features and the security policies applicable to the NAS environment.

Physical security and access control requirements can be found in FAA Orders 1600.54B and 1600.6C.

- □ **11.2.1 Automatic access control.** When appropriate, automated safeguards should be used to control and monitor access to facilities and automated systems. These safeguards may include access control systems such as smart cards or other authentication technologies described in Section 11.3. [Source: National Research Council (NRC), 1990]

- ■ **11.2.2 Access control log.** Automatic control systems shall be capable of providing, in hard copy and machine-readable format (for later analysis), the date, time, location, and user identity of each valid and invalid entry attempt, and the reason for denial of access for each invalid entry attempt. [Source: NRC, 1990]

11.3 Identification and authentication

The *FAA Automated Information Systems Security Handbook,* FAA Order 1600.54, requires that all FAA automated systems have and use a software user identification and authentication capability.

> **Definitions. Identification** is the process that enables the security safeguards to recognize a user name (usually through a machine-readable name) as an identical match to a name previously listed in an authorized user file. **Authentication** is the act of identifying and confirming the eligibility of a station, originator, or user to access specific categories of information. Authentication is a measure designed to provide protection against fraudulent entry or transmissions by establishing the validity of a transmission, message, station, or originator. **Authorization** is granting, to a user or user group, the right of access to a program, a process, or information.

11.3.1 General

- ■ **11.3.1.1 Task simplicity.** System designers and integrators shall ensure that the identification and authentication tasks for authorized users are straightforward, simple, and consistent with the protection levels of the information to be processed in the system. [Source: Smith & Mosier (ESD-TR-86-278), 1986]

- ■ **11.3.1.2 Log on process.** The log on process associated with the security subsystem shall be completed before a user is able to select any operational options. [Source: ESD-TR-86-278, 1986]

- ■ **11.3.1.3 Log on prompts.** A log on process shall provide prompts for all user entries, passwords, and other data required to confirm user identity. A log on prompt shall be provided automatically upon terminal or system initialization without other user actions. [Source: ESD-TR-86-278, 1986]

▫ **11.3.1.4 Log on delay.** If a user tries to log on to a system and the log on attempt is denied because of system unavailability, an advisory message should be displayed to tell the user what the system status is and when the system will become available.
[Source: ESD-TR-86-278, 1986]

▫ **11.3.1.5 Unsuccessful log on attempts.** The security safeguards should not allow more than three log on attempts. This implementation provides a margin for user error while continuing to protect the system from persistent attempts at illegitimate access. Unsuccessful attempts beyond the third should initiate an alarm for the system administrator or at the terminal or both.
[Source: ESD-TR-86-278, 1986]

▪ **11.3.1.6 Access protection.** The following security measures shall be taken to ensure that security and safety will not be compromised by unauthorized access to an unattended workstation or console.
[Source: ESD-TR-86-278, 1986]

a. An individual's single log-on password shall permit all access and data entry capabilities, from any workstation, that the individual has been authorized. The authorized individual is then responsible to protect his or her password and workstation in accordance with appropriate system and work area security policy.

b. If an individual has authorization for access to sensitive information or for entry of critical data, then that individual's use of his or her password on any authorized workstation shall enable appropriate access.

> **Discussion.** As an option, a pre-programmed protection of the sensitive information (such as a screen saver or "read only" mode) could automatically engage after an appropriate period of workstation disuse. The period would be established by policy and administered by the system and network administrators. After the established period, the system shall default to the pre-programmed protection that excludes all sensitive information and disables data entry capabilities until an authorized individual re-enters his or her password to again validate his or her authentication. The re-entry of a password will be prompted. Upon password authentication the system would continue the previous operation.

The attempted user shall be notified that the terminal is in a locked-out mode for security reasons, if the authentication is not successful (see Paragraph 11.3.1.7).

Discussion. If the system security policy permits an authorized user to continue after the delay, then a correct identification and authentication would be permissible upon prompting. If the new authentication is successful, the system would then prompt the new user with an option to continue at the previous operation or to select another applicable operational mode.

c. The user shall be able to engage this protected "read only" or screen save mode by an input command without waiting for the delay period. Thus, the authorized individual user is always responsible to ensure that his or her workstation is in a protected mode at any time, however brief, when he or she vacates a workstation where sensitive or critical information is accessible.

d. These same security measures and processes shall apply to any remote or network capabilities that can allow access to sensitive or critical information.

e. If the protection required by a., b., c., and d. is not provided for a workstation where critical or sensitive information is processed, then that workstation area shall be physically secured or guarded so that sensitive or critical information cannot be accessed by unauthorized personnel. Information classification levels and their respective physical requirements are detailed in FAA Order 1600.2 and 1600.54, Chapter 5). [Source: ESD-TR-86-278, 1986]

▪ **11.3.1.7 Continuous recognition of user identity.** If a user has been identified and authenticated, data access and change privileges that are authorized for that user shall continue throughout a work session. [Source: ESD-TR-86-278, 1986]

11.3.2 Passwords

The composition, length, source, storage, and ownership of passwords used in FAA AIS are governed by FIPS PUB 112, *Standard for Password Usage*. Password protection mechanisms and management responsibility are to conform to FAA Order 1600.54. [Source: FAA Order 1600.54B, 1989; Department of Defense (CSC-STD-002-85), 1985]

Discussion. Security safeguard designers need to realize that random alphanumeric strings are equivalent to nonsense syllables which are very difficult for humans to memorize or retain, especially if they have five or more characters. Though mnemonic techniques can assist learning, computer-generated passwords will contribute to human memory and input errors. [Source: FAA Order 1600.54B, 1989; CSC-STD-002-85, 1985]

- **11.3.2.1 Changing passwords.** Users should be permitted to change their passwords consistent with the sensitivity or security level of the information being accessed. [Source: ESD-TR-86-278, 1986; CSC-STD-002-85, 1985]

  Discussion. This capability allows users to adapt unique passwords that will minimize erroneous entries. Such a self-chosen capability allows users to make a change when compromise is suspected. [Source: ESD-TR-86-278, 1986; CSC-STD-002-85, 1985]

- **11.3.2.2 Password protection.** Training should be given to users to ensure that common passwords (such as "me", "password", and "ABC") or commonly known user data (such as addresses, names spelled backwards ("ydnA"), and user birth dates) are not used. Self-chosen passwords should be protected by security safeguards. [Source: Department of Defense (MIL-HDBK-761A), 1989]

- **11.3.2.3 Recording of date and time of log on.** After a user logs on, the system shall automatically record the date and time of the log on. [Source: CSC-STD-002-85, 1985]

11.4 Auditing

- **11.4.1 Auditing users or security levels.** Security safeguards shall enable the system administrator to selectively audit the actions of any specific user or users based on individual identity or security level. [Source: Department of Defense (DOD 5200.28-STD), 1983]

11.5 Information and data protection

11.5.1 General

This section gives rules for the protection of classified data, automated transaction logs, and the transmission of messages.

- **11.5.1.1 Automated security measures.** Automated security safeguards shall be provided to protect data security and system integrity to the extent possible. [Source: ESD-TR-86-278, 1986]

  Discussion. The goal of data protection is to minimize data loss resulting from potentially destructive failures, user errors, and unauthorized access. Even careful, conscientious users will sometimes make mistakes, and the user interface needs to mitigate the consequences of those mistakes. [Source: ESD-TR-86-278, 1986]

- **11.5.1.2 Integrity of data.** Security safeguards shall minimize the risk of unauthorized modifications of data files or system control data. [Source: System Specification for Communication System Segment, 1986]

- **11.5.1.3 Warning of threats to security.** Messages or alarm signals shall be provided to warn users and system administrators of potential threats to data security. The number of false alarms shall not negate the effectiveness of the alarms. [Source: ESD-TR-86-278, 1986]

- **11.5.1.4 "Read-only" status.** A "read-only" status indication shall be provided to users not authorized to change displayed data. Authorization for "read-only" data may require logging onto the system when the information warrants such protection (such as classified data). [Source: MIL-HDBK-761A, 1989;ESD-TR-86-278, 1986]

- **11.5.1.5 Degraded system warning.** The system shall generate an alarm when performance of components has degraded beyond established thresholds. [Source: System Specification for Communication System Segment, 1986]

11.5.2 Classified data protection

Classified data must to be processed only in approved, secure areas as defined in FAA Order 1600.54. A computer room that has approval to process classified information is to be designed as a "closed area," in accordance with FAA Order 1600.2C.[Source: FAA Order 1600.54B, 1989]

- **11.5.2.1 Encrypting messages.** If it is necessary to transmit classified or sensitive data over insecure communication channels, automatic encryption shall be provided. This encryption shall be transparent to the user. All requirements for communication security (COMSEC) and the use of cryptographic systems with the FAA are defined in FAA Order 1600.8C. [Source: ESD-TR-86-278, 1986; MIL-HDBK-761A, 1989]

11.5.3 Automated transaction logs

- **11.5.3.1 Automatic recording of data access.** If logs of data access are needed, security safeguards should keep those records automatically. Users should not be responsible for critical record keeping actions. [Source: ESD-TR-86-278, 1986; MIL-HDBK-761A, 1989]

- **11.5.3.2 Informing users of automated record keeping.** Users should be informed concerning the nature and purpose of automated recording of individual actions. [Source: MIL-HDBK-761A, 1989]

  Discussion. This may be accomplished by various methods such as a security briefing or a message at the time of log on. [Source: MIL-HDBK-761A, 1989]

11.5.4 Transmission of messages

- **11.5.4.1 Automatic protection of transmitted data.** Automated measures shall be provided to protect data during transmission (for example, encryption) until the data have been received. [Source: ESD-TR-86-278, 1986]

- **11.5.4.2 Reviewing messages.** Users shall be provided a means of reviewing outgoing messages and their security provisions (for example, its security classification) before transmission. [Source: MIL-HDBK-761A, 1989]

- **11.5.4.3 Confirmation codes.** If a user must confirm the identity of a message source, computer aids such as computer-generated confirmation codes should be provided. [Source: MIL-HDBK-761A, 1989]

11.6 Documentation of security safeguards

This section gives rules for documentation of the security safeguards, their interactions with other systems, the AIS facilities, and the protection of these documents.

- **11.6.1 User documentation.** The user documentation shall provide rules for security safeguard use, a description of how security safeguards interact with each other, and a description of the protective mechanisms they employ in order to facilitate maintenance of the security system. [Source: FAA Order 1600.54B, 1989]

- **11.6.2 Design documentation.** Documentation providing a description of the manufacturer's human-security safeguards interface shall be available for non-developmental items and commercial-off-the-shelf equipment. If the security safeguards are composed of distinct modules, the interfaces between these modules shall also be described. [Source: FAA Order 1600.54B, 1989]

Glossary

Accreditation - The authorization and approval granted to an AIS or network to process sensitive data in an operational environment.

Authentication - The act of identifying and confirming the eligibility of a station, originator, or user to access specific categories of information. Authentication is a measure designed to provide protection against fraudulent entry or transmissions by establishing the validity of a transmission, message, station, or originator.

Authorization - Granting to a user or user group, the right of access to a program, a process, or information.

Certification - The technical evaluation that supports the accreditation process and establishes the extent to which a particular computer system or network design and implementation meets a pre-specified set of security requirements.

Identification - The process that enables the security safeguards to recognize a user name (usually through a machine-readable name) as an identical match to a name previously listed in an authorized user file.

Security architecture - A subset of the overall system architecture that protects the automated system, telecommunication, physical, and informational assets through denial of service and unauthorized (accidental or intentional) disclosure, modification, or destruction.

Security safeguards - The protective measures and controls that are prescribed to meet the security requirements specified for a system. Those safeguards may include but are not necessarily limited to: operational procedures, physical security, or hardware and software features.

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List of exhibits

12 Personnel safety

Human factors design rules that enhance the safety of FAA maintenance personnel are discussed in this section. Chapter 4, Designing equipment for maintenance; Chapter 10, Workplace design; and Chapter 13, Environment, also contain safety rules specific to their respective domains.

12.1 General

This general section discusses safety factors that are derived from human engineering and from application of military safety considerations and from FAA and OSHA health and safety considerations. The latter have precedence.

- **12.1.1 Safety factors.** As part of facility and equipment design, safety factors shall be given major consideration, including, as a minimum, the representative safety rules herein, together with the effective application of the human engineering rules in other sections of this document. Safety factors are also determined from the application of MIL-STD-822B to the acquisition program and from FAA Order 3900.19(B), OSHA 29 CFR 1910 and 1926 as they apply to the program. In the area of safety and health OSHA and FAA documents have precedence. [Source: 29 CFR 1910 and 1926; Department of Defense (MIL-STD-1472F), 1999]

12.2 Work space safety

Rules addressing general work space safety including the safety of maintainers using platforms, ramps, stairs, ladders, and handholds are given in this section.

12.2.1 General

- **12.2.1.1 Hazard alerting or alarm devices.** A hazard alerting or alarm device shall be provided to warn personnel of impending danger or existing hazards such as fire, radio frequency or X radiation, or the presence of combustible or asphyxiating gas. OSHA 29 CFR 1910.165 shall govern employee alarms for fire or other hazards that require escape (see also OSHA 29 CFR 1910.165 Appendixes A, B, and C for rules). [Source: 29 CFR 1910.165; MIL-STD-1472F, 1999; Department of Energy (DOE-HFAC1), 1992]

- **12.2.1.2 Location.** Hazard alerting or alarm devices shall be located where the people who must take corrective action can easily distinguish them. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

- **12.2.1.3 Redundant hazard alerting or alarm devices.** Redundant hazard-alerting devices of different types, for example, a light and a bell, shall be required if ambient noise could mask the audible alarm, or if the warning light could not be seen in the ambient illumination. Tactile devices may be used to alert employees who would not otherwise be able to recognize audible or visual alarms. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

- **12.2.1.4 Physical barriers.** Physical barriers (for example, safety chains, guards, shields, or walls) shall be provided in addition to safety labels, placards, and signs, to prevent contact with hazards, such as moving parts of machinery. Fixed and portable power tools shall be guarded in accordance with OSHA 29 CFR 1910.212 -247. Live electrical parts operating at 50 or more volts shall be guarded in accordance with OSHA 29 CFR 1910.303 (b)(2). Floor and wall openings shall be guarded in accordance with 29 CFR 1910.23. Power transmission apparatus shall be guarded in accordance with OSHA 29 CFR 1910.219. [Source: CFR 1910.212 –247, 29 CFR 1910.303; Department of Defense (MIL-HDBK-759B), 1992]

- **12.2.1.5 Obstruction-free.** Work spaces shall be free of obstructions that could cause injury to personnel either through accidental contact with the obstruction or because the obstruction forces the maintainer to adopt an awkward position. In accordance with OSHA 29 CFR 1910.22, all workplaces shall be kept clean and dry and shall not have obstructions where they would cause a hazard. [Source: 29 CFR 1910.22, MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

- **12.2.1.6 Emergency door and exit design and construction.** Emergency doors and exits shall be designed and constructed so that they:

  a. are simple to operate,

  b. are readily accessible,

  c. are clearly designated,

  d. are unobstructed,

  e. are simple to locate and operate in the dark,

  f. are capable of being opened in 3 sec or less,

  g. require 44 to 133 N (10 to 30 lb) of operating force to open,

  h. permit exit by one person in 5 sec or less, and

  i. do not in themselves, or in their operation, constitute a safety hazard. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

  Note. Means of egress and exit shall comply with OSHA 29 CFR 1910.35 -40.

- **12.2.1.7 Nonskid surfaces.** Stairs, ramps, platforms, and catwalks shall have skid-proof flooring, stair, and step treads. Where applicable, surfaces shall be treated with nonskid material that conforms to MIL-W-5044 and that is applied in accordance with MIL-W-5050. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

- **12.2.1.8 Illumination.** Adequate illumination shall be provided for all work spaces. Recommended and minimum levels are given in Exhibit 12.2.1.8. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

Exhibit 12.2.1.8 Specific task illumination requirements

	Illumination levels Lux* (ft-C)			
Work area or type of task	**Recommended**		**Minimum**	
Corridors	215	(20)	110	(10)
Emergency lighting	NA**		30	(3)
Hallways	215	(20)	110	(10)
Passageways	215	(20)	110	(10)
Repair work:				
general	540	(50)	325	(30)
instrument	2155	(200)	1075	(100)
Service areas, general	215	(20)	110	(10)
Stairways	215	(20)	110	(10)

* As measured at the task object or 760 mm (30 in) above the floor.

** Recommended illumination is the level appropriate to the task.

12.2.2 Platforms, ramps, stairs, ladders, and handholds

- **12.2.2.1 Self-locking devices.** Self-locking or other fail-safe devices shall be incorporated on elevating stands, work platforms, and "draw bridges" to prevent accidental or inadvertent collapsing or falling. Safety requirements of OSHA 29 CFR 1910.21 -30 shall also apply to platforms and scaffolding. [Source: 29 CFR 1910.21 –30; MIL-STD-1472F, 1999; MIL-HDBK-759B, 1992]

- **12.2.2.2 High centers of gravity.** Platforms that have a high center of gravity shall have anchors or outriggers for stability. [Source: MIL-HDBK-759B, 1992]

- ■ **12.2.2.3 Safety measures.** Guardrails, safety bars, or chains shall be installed around platforms and across stair or step openings of ledges, catwalks, and the like. These guards shall be 1.1 m (42 in) above the standing surface. An additional guardrail shall also be provided between the platform and the top guardrail, safety bar, or chain. These top guardrails shall be no more than 1.1 m (42 in.) and no less than 91 cm (36 in.) from the platform. Safety chains shall only be used where it is not feasible to install guardrail or safety bars. [Source: MIL-STD-1472F, 1999]

- ■ **12.2.2.4 Toe board or guard screen.** A toe board of 10 cm (4 in) to 15 cm (4 in) shall be used to guard floor openings or a guard screen shall extend from the floor base to the intermediate rail. [Source: MIL-STD-1472F, 1999]

  Note. OSHA 29 CFR 1910.23 (e) permits a 102 mm (4 in) toe board as a minimum.

  Discussion. The guard screen is used to prevent a person who falls on the platform from falling from the platform. It can also prevent most tools, parts, and equipment from falling from the platform. Toe boards are intended to prevent tools, parts, and equipment from falling as well as to prevent the worker's foot from slipping off the edge of the platform.

- ■ **12.2.2.5 Safety mesh.** Screen or safety mesh shall be installed on the underside of open gratings, platforms, or flooring surfaces where there is a possibility that small tools, parts, or debris may fall through the grating onto maintainers or equipment beneath the platform. [Source: MIL-STD-1472F, 1999]

- ■ **12.2.2.6 Telescoping ladders.** Adequate finger clearance shall be provided between the moving parts of telescoping ladders. [Source: MIL-STD-1472F, 1999]

- □ **12.2.2.7 De-icing ladders and steps.** Ladders and steps should be designed so they can be de-iced with hot water or steam. [Source: MIL-HDBK-759B, 1992]

- ■ **12.2.2.8 Handholds.** Handholds shall be furnished where needed to assist maintainers in climbing onto a platform or in performing the intended maintenance tasks from the platform. [Source: MIL-STD-1472F, 1999]

- ■ **12.2.2.9 Nonfixed handholds.** When a flat surface is desired, handholds shall fold or telescope so they are concealed or flush with the surface except when they are being used. Folding hand grips shall remain securely folded when not in use and maintainers shall not need tools to open them. [Source: MIL-HDBK-759B, 1992]

- □ **12.2.2.10 Fixed handholds.** Handholds should be fixed except when a flat surface is desired. [Source: MIL-HDBK-759B, 1992]

12.3 Equipment-related safety

Safety factors need to be a major part of equipment design. This section gives rules to protect from possible injury when using or working with hazardous equipment.

- ■ **12.3.1 Hazardous operations.** The operation of switches or controls that initiate hazardous operations (for example, equipment-moving devices) shall require the prior operation of a related or locking control. When practical, the critical position of such a control shall activate a visual and auditory warning device in the affected work area. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

- ■ **12.3.2 Accessibility.** Units of equipment shall be located and mounted so that they are accessible to the maintainer with minimal danger from electrical charge, heat, moving parts, radiation, or other hazards (see also Paragraph 12.4.1.1). [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

- ■ **12.3.3 Test equipment stability.** Equipment, particularly portable equipment such as maintenance stands, tables, benches, platforms, and ladders, shall be designed for maximum stability and shall meet OSHA requirements. [Source: MIL-HDBK-759B, 1992]

- ■ **12.3.4 Equipment with wheels.** Equipment with wheels shall be designed to maximize stability and safety when it is moved on ramps or inclines. [Source: MIL-HDBK-759B, 1992]

  Discussion. Ramps and inclines change the equipment's center of gravity. The lower wheels bear a majority of the weight. With heavier equipment, this may mean that weight is concentrated enough to exceed allowable ramp loads. Shifting the center of gravity also increases the risk that equipment will overturn.

- ■ **12.3.5 Mechanically stored energy devices.** Personnel shall be protected from mechanical devices capable of storing energy, such as springs, levers, and torsion bars. A means shall be provided to release the stored energy. [Source: National Aeronautics and Space Administration (NASA-STD-3000A), 1989]

  Discussion. Protection can be achieved by shielding the stored energy devices. The release of stored energy can be achieved by a device that automatically releases the energy or by a device or procedure that permits the personnel to safely release the energy.

- ■ **12.3.6 Safety features.** Where stored energy devices are necessary, safety features such as removal tabs, lockouts, and warning placards shall be provided (see also Section 12.16). [Source: NASA-STD-3000A, 1989]

- □ **12.3.7 Equipment coloring.** Equipment designed for safety, protective, or emergency functions should be colored in accordance with MIL-STD-1473. [Source: MIL-HDBK-759B, 1992]

12.4 Electrical hazards

The principal electrical hazard is shock. The effects of electric shock depend on the body's resistance, the current path through the body, the duration of the shock, the amount of current and voltage, the frequency of the alternating current, and the individual's physical condition. The most critical determinant of injuries is the amount of current conducted through the body. Besides the obvious risk of burns and injuries to the nervous system, electric shock can produce involuntary muscular reactions that injure people. Exhibit 12.4 gives the typical effects of various current intensities. All electrical systems of 30 volts or more are potential shock hazards. Research reveals that most shock deaths result from contacts with electrical systems ranging from 70 to 500 volts. Under extraordinary circumstances, even voltages below 30 volts can cause injury. [Source: MIL-HDBK-759B, 1992;NASA-STD-3000A, 1989]

Exhibit 12.4 Shock current intensities and their effects

Current (mA)	Effects
Less than 1	Usually not felt (no sensation)
1-2	There is a sensation of shock.
3-15	Painful shock occurs, but the individual can still let go.
16-20	Painful shock occurs and the individual may not be able to let go because control of the immediately adjacent muscles is affected.
21-50	Very painful shock occurs plus severe muscular contractions. Breathing typically becomes difficult.
51-100	Ventricular fibrillation (a heart condition that may result in death).
101-200	Same as above except that the results are certain.
201 and up	Severe burns occur as well as muscle contractions so severe that the other muscles stop the heart during the duration of the shock.

12.4.1 General

The two basic types of safety switches for preventing electric shock are interlocks and main-power switches. [Source: MIL-HDBK-759B, 1992]

Definitions. Interlocks are devices (for example, switches) connected with a cover, shield, or case that disable the associated internal hazard (usually electrical) when the cover, shield, or case is opened. OSHA regulations discuss lockout and tagout procedures to be used in the workplace during maintenance or operations to protect from electrical hazards. A **lockout** uses a mechanical mean to disable a control or switch in its safe position (for example, electricity disconnected) and to prevent its activation without the use of undue force or tools. **Tagouts** are tags that are attached to a control or place of hazard associated with an ongoing mode of operation or maintenance.

- **12.4.1.1 Protection from electric shock.** Personnel shall be protected from accidental contact with voltages in excess of 30 volts AC or DC by interlocks, grounding, and other protective devices. [Source: MIL-HDBK-759B, 1992; Department of Defense (MIL-STD-454M), 1989]

Discussion. Human protection from hazardous conditions with unexpected energy or release of stored energy is treated in OSHA 29 CFR 1910.301 -308, 331 -335, and 399. OSHA 29 CFR 1910.333 (b)(2)(iii)(A) requires the simultaneous use of both tagout and lockout in the workplace; OSHA 29 CFR 1910.333 (b)(2)(ii)(B) states that interlocks shall not be the sole mean of de-energizing circuits of equipment and are not substitutes for lockout and tagout procedures and practice. [Source: 29 CFR 1910.301 -308, 331 -335, and 399]

- **12.4.1.2 Rubber insulating equipment.** To help ensure the safety of personnel, insulated rubber gloves and live line tools shall be provided for personnel working on or near energized power circuits and equipment rated over 600 volts. [Source: Department of Transportation (FAA Order 3900.19A), 1982]

- **12.4.1.3 Selection of rubber insulating equipment.** Rubber protective equipment shall be selected in accordance with the voltages and equipment maintained. Exhibit 12.4.1.3 provides proof test for various classes of protective gloves. OSHA 29 CFR 1910.137 specifies that the rubber protective equipment for electrical workers conform to ANSI standards. (See 29 CFR 1910.137 for testing of applicable ANSI standards). FAA Order 3900.19B 145B specifies that new rubber gloves shall be tested before used and at a minimum each 12 months. Reissued rubber glove shall be retested within 9 months of issue. [Source: 29 CFR 1910.137; FAA Order 3900.19A, 1982]

Exhibit 12.4.1.3 Proof test values for protective gloves

		Maximum proof test current (mA)			
Class of glove	**3 min. proof test voltage RMS (Volts)**	**10.5" glove**	**14" glove**	**16" glove**	**18" glove**
Class 0	5,000	8	12	14	16
Class I	10,000	-	14	16	18
Class II	20,000	-	16	18	20
Class III	30,000	-	18	20	22
Class IV	40,000	-	-	22	24

- **12.4.1.4 Static charge buildup.** Equipment design shall prevent static charge buildup or provide a method to discharge it. [Source: NASA-STD-3000A, 1989]

  Discussion. The effects of electrostatic buildup can range from minor discomfort (the shock from walking across a new carpet and touching a metal object) to physical injury.

- **12.4.1.5 Fail-safe.** The design and development of all electronic equipment shall provide fail-safe features for safety of personnel during installation, operation, maintenance, and repair or interchanging of a complete equipment assembly or component parts. [Source: 29 CFR 1910.7; MIL-STD-454M, 1989]

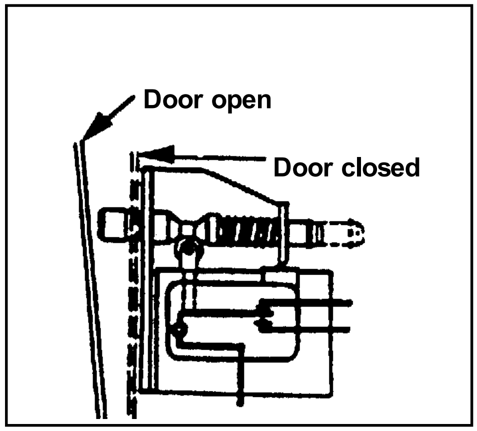
- **12.4.1.6 Electrical conductors.** Electrical conductors with which personnel might come into contact during maintenance activities shall be insulated. [Source: NASA-STD-3000A, 1989]

- **12.4.1.7 Power.** Personnel shall be provided a means for removing power while they are installing, replacing, or repairing components or equipment. [Source: MIL-STD-454M, 1989]

- **12.4.1.8 Covers.** Grounded or nonconductive protective covers shall be provided for all electrical equipment. [Source: NASA-STD-3000A, 1989]

- **12.4.1.9 Bypassable interlocks.** Doors, covers, or lids that provide access to voltage in the range of 70 to 500 volts shall have a bypassable interlock. Equipment that has been bypassed shall conform to OSHA 29 CFR 1910.333 (c)(10). Exhibit 12.4.1.9 shows an example of such an interlock. [Source: 29 CFR 1910.333; MIL-HDBK-759B, 1992; NASA-STD-3000A, 1989; MIL-STD-454M, 1989]

Exhibit 12.4.1.9 An interlock switch



- **12.4.1.10 Non-bypassable interlocks.** Doors, covers or lids that provide access to voltages in excess of 500 volts or allow exposure to microwave and radio frequency radiation in excess of 300 KHz shall have non-bypassable interlocks. [Source: MIL-STD-454M, 1989]

- **12.4.1.11 Interlock override.** If a task requires that a maintainer work on hazardous equipment that is equipped with a disabling interlock, the equipment shall have an interlock override that permits manual bypassing or overriding of the interlock when the case or cover is open. This override shall automatically reset to the safety-protection position when the cover or case is replaced. OSHA 29 CFR 1910.333 requires that only qualified personnel shall be allowed to disable an interlock. [Source: 29 CFR 1910.333; Department of the Air Force (AFSC DH 1-3), 1980; Department of Energy (UCRL-15673), 1985; MIL-HDBK-759B, 1992]

- **12.4.1.12 Medium voltage guarding.** If contacts, terminals, or other similar devices having voltages between 70 and 500 volts ac or dc with respect to ground are exposed, they shall be guarded from accidental contact by maintainers (see Paragraph 12.16.6 concerning wording for medium voltage labels and placards). [Source: MIL-STD-454M, 1989]

- **12.4.1.13 High voltage guarding.** Systems or equipment operating in excess of 500 volts ac or dc shall be completely enclosed (see Paragraph 12.16.7 concerning wording for high voltage labels and placards). [Source: MIL-STD-454M, 1989]

- 12.4.1.14 **Guarding radio frequency (rf) voltages.** Transmitter output terminals, antennas, and other devices that carry sufficient rf voltage to burn or injure personnel shall be guarded from accidental contact. [Source: MIL-STD-454M, 1989]

- 12.4.1.15 **Explosion-proof equipment.** All electrical equipment that will be used near flammable gases or vapors shall be explosion-proof. This equipment shall also be certified or listed by a nationally recognized testing laboratory recognized by OSHA (for example, Underwriters Laboratory). [Source: MIL-HDBK-759B, 1992]

- 12.4.1.16 **Plugs and receptacles.** Plugs and receptacles shall be designed so that a plug of one voltage rating cannot be inserted into a receptacle of another rating. [Source: MIL-STD-1472F, 1999; NASA-STD-3000A, 1989]

- 12.4.1.17 **"Hot" leads.** Wiring shall be routed through plugs and receptacles so that "hot" leads are not exposed in either the plug or the receptacle when they are disconnected. [Source: MIL-STD-1472F, 1999; MIL-HDBK-759B, 1992]

- 12.4.1.18 **Design and location of electrical installations and electrical utilization equipment.** The design and location of electrical installations and electrical utilization equipment shall conform with OSHA 29 CFR 1910.302 through 308 which includes rules for workspace clearances around such equipment dependent upon its nominal voltage to ground and nominal voltage between phases for elevated energized parts. These rules apply to the protection of qualified electrical or electronic repair people, unqualified electrical or electronic repair people, and other unqualified personnel who could be exposed to electrical hazards or to electrical equipment in classified hazardous electrical locations. OSHA 29 CFR 1910.331 -335 address safety related work practices. [Source: 29 CFR 1910.302]

12.4.2 Switches

- 12.4.2.1 **Main-power switches.** A unit of equipment shall have a clearly labeled main-power switch that turns off all power by opening leads from the main-power service connection. [Source: MIL-HDBK-759B, 1992]

- 12.4.2.2 **Main-power switch location.** Main-power switches shall be located so that accidental contact by maintainers will not place the equipment in operation. A lockout shall be provided as specified in OSHA 29 CFR 1910.335 (b)(2). [Source: 29 CFR1910.333(b)(2); MIL-STD-454M, 1989]

- 12.4.2.3 **Physical protection at main-power switches.** The "hot" side of the main-power switch and the incoming power line connections shall be physically protected against accidental contact by maintainers. [Source: MIL-STD-454M, 1989]

- 12.4.2.4 **Arc prevention.** Main-power switches shall be safeguarded to prevent heavy arcing. [Source: MIL-HDBK-759B, 1992]

■ **12.4.2.5 Safety switches.** Safety switches that will deactivate associated mechanical drive components shall be provided for the purpose of disconnecting these components without disconnecting other parts of the equipment. [Source: MIL-STD-454M, 1989]

□ **12.4.2.6 Switch box safety.** The switch box should be designed so the box cannot be opened when the switch is turned on. [Source: MIL-HDBK-759B, 1992]

12.4.3 Discharging devices

Circuits that contain capacitors can store lethal charges for relatively long periods of time therefore all medium- and high-voltage power supplies need devices that discharge the capacitors when they are turned off.

■ **12.4.3.1 Bleeders.** Bleeders shall be incorporated in all power supplies unless they can discharge 30 volts or less within 2 sec after power removal. When a resistive bleeder network is used to discharge capacitors, the bleeder network shall consist of at least two equal valued resistors in parallel. [Source: MIL-HDBK-759B, 1992; MIL-STD-454M, 1989]

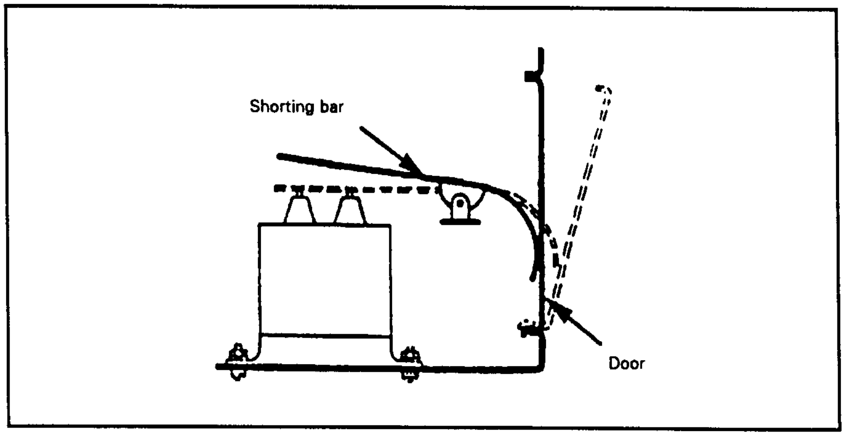
> **Discussion.** It is better to discharge capacitors gradually, rather than shorting them. High-power resistors are often used in place of a grounding rod with several thousand ohms of resistance being a typical value. DC power supplies may be discharged when switched off by having a permanently connected bleeder resistor across the output terminals. The bleeder resistor needs to be of low enough resistance so that it is able to discharge the capacitors quickly after the power is turned off but not so low that it overloads the circuit.

■ **12.4.3.2 Shorting rods.** Shorting rods shall be provided (in addition to bleeder resistors) with all equipment having voltages in excess of 70 volts ac or dc. [Source: MIL-STD-454M, 1989]

> **Discussion.** Some circuits with large, high-voltage capacitors (such as high-voltage radar equipment) cannot use bleeder resistors; other methods need to be used to discharge the capacitors before doing maintenance. Often capacitors are discharged with a shorting or grounding rod that has a well-insulated handle.

- **12.4.3.3 Removing power.** Interlocks shall remove power by mechanical releases or electrical solenoids, before automatic shorting bars (see Exhibit 12.4.3.3) discharge the power supply. These bars shall operate automatically whenever the enclosure is opened and function quickly, with high reliability. [Source: MIL-HDBK-759B, 1992]

Exhibit 12.4.3.3 Automatic shorting bar



- **12.4.3.4 Shorting rod storage.** Where size permits, shorting rods shall be stored within the transmitting equipment, permanently attached, and readily accessible to maintainers. The permanently attached rod shall be connected through a flexible stranded copper wire (covered with a transparent sleeve) to the stud provided at the transmitter main frame. Where size does not permit internal storage of a shorting rod, a grounding stud shall be provided to permit attachment of a portable shorting rod. The connection to the stud shall be such that accidental loosening or high resistance to the ground is prevented. [Source: MIL-STD-454M, 1989]

12.4.4 Grounding

Various grounding techniques are used to protect maintainers from dangerous voltages in equipment. A terminal that is spot-welded to the chassis provides a reliable ground connection. Rules for other methods are also given in this section. [Source: MIL-HDBK-759B, 1992]

- **12.4.4.1 Same common ground.** All enclosures, exposed parts, and the chassis shall be kept at ground potential by a common ground. [Source: MIL-STD-454M, 1989; MIL-HDBK-759B, 1992; NASA-STD-3000A, 1989]

■ **12.4.4.2 Path to ground.** The path from the ground connection to ground shall:

a. be continuous and permanent,

b. have ample carrying capacity to conduct safely any currents that may be imposed on it,

c. have impedance sufficiently low to limit the voltage above ground and to facilitate the operation of the over-current devices in the circuits, and

d. have sufficient strength to minimize the possibility of ground disconnection. [Source: MIL-STD-454M, 1989]

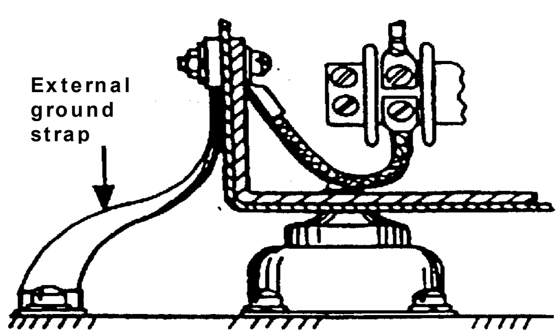
■ **12.4.4.3 Grounding techniques.** If welding is not feasible, for example with aluminum chassis, the ground connection of equipment shall be attached with a machine bolt, lock washer, and nut. [Source: MIL-HDBK-759B, 1992]

■ **12.4.4.4 Nonconductive finishes.** Any nonconductive finish on a unit of equipment shall be removed before attaching the ground connection. [Source: MIL-HDBK-759B, 1992]

■ **12.4.4.5 Rivet connections.** Ground connections shall not be attached with rivets because rivets do not give reliable electrical connections. [Source: MIL-HDBK-759B, 1992]

□ **12.4.4.6 Equipment grounding.** The common ground of equipment should connect to a bolt that goes through the enclosure and that is clearly marked "ENCLOSURE GROUND". An external safety ground strap should, in turn, be connected to this bolt. The external safety ground strap should be a plated flexible copper strap with a current-carrying capacity at least twice as large as the equipment requires (see Exhibit 12.4.4.6). [Source: MIL-HDBK-759B, 1992]

Exhibit 12.4.4.6 Equipment grounding



- **12.4.4.7 Ground connections.** Ground connections to shields, hinges, slides, or other mechanical components shall not be used to complete electrical circuits. [Source: MIL-STD-454M, 1989]

- **12.4.4.8 Hinges and slides.** Hinges and slides shall not be used for grounding paths. [Source: MIL-STD-454M, 1989]

- **12.4.4.9 Panels and doors.** Panels and doors that contain meters, switches, and test points shall be attached or hinged so that they are at the same voltage as the equipment in which they are mounted, whether opened or closed. [Source: MIL-STD-454M, 1989]

  Discussion. A ground is considered satisfactory if the electrical connection between the door or panel and the ground connection exhibits a resistance of 0.1 ohm or less. A satisfactory ground also has sufficient current-carrying capacity to ensure the reliable and immediate tripping of equipment over-current protection devices.

- **12.4.4.10 Ground wire in the cable.** Any external or interconnecting cable in which a ground is part of the circuit shall include a ground wire in the cable. This ground wire shall be terminated at both ends in the same way as the other conductors. [Source: MIL-STD-454M, 1989]

- **12.4.4.11 Cable shields as grounds.** Cable shields shall not be used as current-carrying ground connections except with coaxial cables. [Source: MIL-STD-454M, 1989]

- **12.4.4.12 Test equipment.** Test equipment (signal generators, amplifiers, and oscilloscopes) that is connected by a plug shall have an integral ground prong. [Source: MIL-HDBK-759B, 1992]

12.4.5 Electrical tools and self-powered equipment

- **12.4.5.1 Insulation of tools.** Tools used near high voltages shall be insulated. [Source: MIL-STD-1472F, 1999; NASA-STD-3000A, 1989]

- **12.4.5.2 Electrical cords.** Electrical hand-held power tools shall be designed with three-wire power cords with one wire grounded. Portable tools protected by an approved system of double insulation or its equivalent may be used without a ground wire when approved by the acquisition program office. [Source: MIL-STD-1472F, 1999; NASA-STD-3000A, 1989]

- **12.4.5.3 Exposed surfaces of tools.** Electrical hand-held power tools shall have exposed surfaces that are either nonconducting or are electrically connected to the ground wire. [Source: MIL-STD-1472F, 1999]

  Discussion. Exposed surfaces include cases, grips, handles, switches, triggers, chucks, and other surfaces with which maintainers might come into contact with during operation.

- **12.4.5.4 Same voltage.** All external surfaces of self-powered equipment shall be at the same voltage. [Source: MIL-STD-454M, 1989]

12.5 Physical hazards

General safety rules for physical hazards are given in this section. This section focuses on making equipment free of potential physical hazards to maintainers. Guards, caps, and shields are addressed specifically.

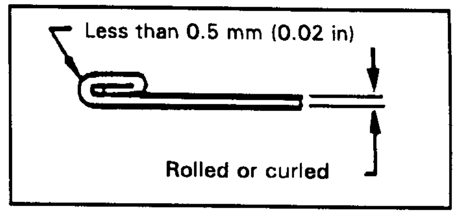
12.5.1 General

- **12.5.1.1 Protective devices.** Protective covers, cases, or padding shall be used on protrusions or other objects that cannot be made completely hazard free. [Source: NASA-STD-3000A, 1989]
- **12.5.1.2 Carried units.** Components and equipment shall be designed so maintainers can carry them without risk of cutting their hands on sharp edges. [Source: MIL-HDBK-759B, 1992]
- **12.5.1.3 Countersunk screws.** Screws shall be countersunk if a smooth surface is required. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

▪ **12.5.1.4 Exposed edges.** Exposed edges shall be either protected by rubber, fiber, or plastic or rounded as follows:

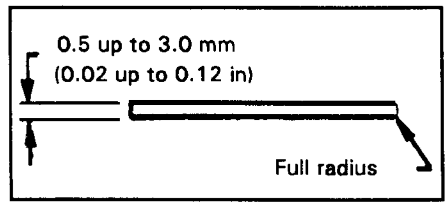
a. The edges of thin sheets less than 0.5 mm (0.02 in) thick shall be rolled or curled as shown in Exhibit 12.5.1.4 (a).

Exhibit 12.5.1.4 (a) Rolling edges of sheets less than 0.5 mm (0.02 in) thick.



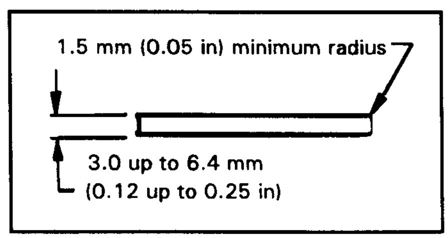
b. Exposed edges 0.5 to 3.0 mm (0.02 up to 0.12 in) thick shall be rounded to a full radius as shown in Exhibit 12.5.1.4 (b).

Exhibit 12.5.1.4 (b) Rounding exposed edges 0.5 up to 3.0 mm (0.02 up to 0.12 in) thick.



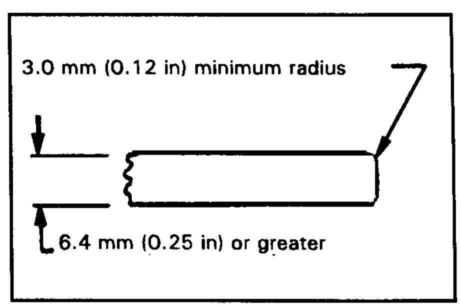
c. Exposed edges 3.0 up to 6.4 mm (0.12 up to 0.25 in) thick shall be rounded to a minimum radius of 1.5 mm (0.05 in) as shown in Exhibit 12.5.1.4 (c).

Exhibit 12.5.1.4 (c) Rounding exposed edges 3.0 to 6.4 mm (0.12 up to 0.25 in) thick.



d. Exposed edges 6.4 mm (0.25 in) thick or greater shall be rounded to a minimum radius of 3.0 mm (0.12 in) as shown in Exhibit 12.5.1.4 (d). [Source: NASA-STD-3000A, 1989]

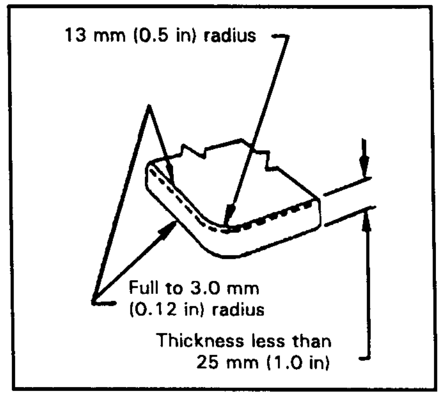
Exhibit 12.5.1.4 (d) Rounding of exposed edges 6.4 mm (0.25 in) thick or greater



■ **12.5.1.5 Exposed corners.** Exposed corners shall be rounded as follows:

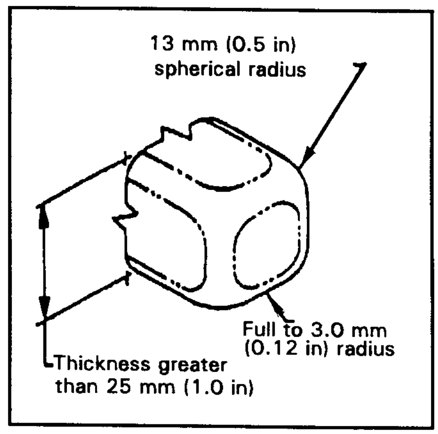
a. Exposed corners less than 25 mm (1.0 in) thick shall be rounded to a minimum radius of 13 mm (0.5 in) as shown in Exhibit 12.5.1.5 (a).

Exhibit 12.5.1.5 (a) Requirements for rounding of corners less than 25 mm (1.0 in) thick.



b. Exposed corners 25 mm (1.0 in) thick or greater shall be rounded to 13 mm (0.5 in) spherical radius, as shown in Exhibit 12.5.1.5 (b). [Source: NASA-STD-3000A, 1989]

Exhibit 12.5.1.5 (b) Requirements for rounding of corners greater than 25 mm (1.0 in) thick.



□ **12.5.1.6 Projecting components.** In areas where maintainers must make rapid movements, small projecting components should be avoided or covered. [Source: MIL-HDBK-759B, 1992]

Discussion. If small projecting parts (such as toggle switches or small knobs) must be mounted on a front panel, recessed mountings of these projecting parts are desirable.

■ **12.5.1.7 Latches.** Latches or similar devices that can pinch fingers shall not be used. [Source: NASA-STD-3000A, 1989]

- ■ **12.5.1.8 Levers, cranks, hooks, and controls.** Levers, cranks, hooks, and controls shall not be located where they can pinch, snag, or cut the maintainer or his or her clothing. [Source: NASA-STD-3000A, 1989]

- ■ **12.5.1.9 Burr free.** Exposed surfaces that can be grasped by the bare hand shall be free of burrs. [Source: NASA-STD-3000A, 1989]

- ■ **12.5.1.10 Capped bolt threads.** Bolts with more than two exposed threads shall be capped to protect the maintainer from the sharp threads. [Source: NASA-STD-3000A, 1989]

- □ **12.5.1.11 Air-exhaust openings.** Air-exhaust openings used to cool equipment should be located so that maintainers are not exposed to moving parts or direct drafts. [Source: MIL-HDBK-759B, 1992]

12.5.2 Guards, caps, and shields

- ■ **12.5.2.1 Avoiding accidental contact.** Equipment shall have shields and guards to prevent maintainers from accidentally touching rotating or oscillating parts such as gears, couplings, levers, cams, and large solenoids. [Source: MIL-HDBK-759B, 1992]

- ■ **12.5.2.2 Enclosure of hazardous components.** Any component that rotates, oscillates, or carries high voltage shall be enclosed so that maintainers cannot accidentally come in contact with the component. [Source: MIL-HDBK-759B, 1992]

- ■ **12.5.2.3 Ventilation holes.** If a cover or shield requires ventilation holes, the holes shall be small enough to prevent inadvertent insertion of objects that might touch high voltage sources or moving parts. [Source: AFSC DH 1-3, 1980]

- ■ **12.5.2.4 High-temperature units of equipment.** High-temperature units of equipment shall be located, guarded, or shielded so that maintainers will not accidentally touch them. [Source: MIL-HDBK-759B, 1992]

- □ **12.5.2.5 Guard design.** Guards should be designed and mounted so that maintainers do not have to remove them in order to inspect components. Guard design and applications should comply, as applicable with provisions of OSHA 29 CFR 1910.211 -222 which addresses guarding for various industries. [Source: 29 CFR 1910.211 – 222; MIL-HDBK-759B, 1992]

12.6 Liquid and gas hazards

This section gives rules for maintaining safety near liquid and gas lines. OSHA 29 CFR 1910.101 -111 address handling of hazardous gases and liquids including those that are flammable and combustible. Electrical requirements associated with such hazards are treated.

- **12.6.1 Releasing gases.** Equipment shall not release gases that combine with the atmosphere to form an acid or corrosive alkali that would be detrimental to the health of the maintainer. [Source: Department of Transportation (FAA-G-2100F), 1993; MIL-STD-454M, 1989]

- **12.6.2 Distinctive types.** Connectors for lines serving different functions, for example, fuel lines and water lines, or electrical power lines and radio-frequency signal lines, shall be distinctively different and physically incompatible. [Source: UCRL-15673, 1985]

- **12.6.3 Automatic shutoffs.** Automatic shutoff devices shall be provided on fluid and fuel service equipment to prevent overflow and spillage. [Source: MIL-STD-1472F, 1999]

- **12.6.4 Avoid spraying fluids.** Lines shall be kept from spraying or draining fluid on personnel or equipment during disconnection by: (1) locating connections away from work areas and sensitive components, (2) shielding sensitive components where required, and (3) providing drains and bleed fittings so lines can be drained or depressurized before they are disconnected. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- **12.6.5 Mercury.** Components and equipment containing mercury shall not be used unless use of mercury is specifically required or approved by the acquisition program office. [Source: FAA-G-2100F, 1993; MIL-STD-454M, 1989]

- **12.6.6 OSHA safety criteria for hazardous gases and liquids.** Design and handling for hazardous liquids and gases shall be governed by OSHA 29 CFR 1910.101 -111. [Source: 29 CFR 1910.101 -111]

12.7 Toxic hazards

All reasonable precautions need to be taken to eliminate hazards from toxic fumes, for example, those from the exhausts of internal combustion engines. From the standpoint of health hazards, the most widespread toxic hazards are carbon monoxide from gasoline engines, and aldehydes and nitrogen oxides from diesel engines. This section gives rules for keeping toxic hazards within safe limits in the maintainer's environment. OSHA 29 CFR 1910 addresses toxic chemical hazards and their control. OSHA 29 CFR 1910.1450 addresses controls and exposures in laboratories. Exposures to cleaning materials is addressed in OSHA 29 CFR 1910.107 and 252. Specific chemical agents, air contaminants and fibers, and processing operations are covered in OSHA 29 CFR 1910.

- **12.7.1 Exposure.** Maintainers shall not be exposed to concentrations of toxic substances in excess of the limits specified in either OSHA 29 CFR 1910 or the American Conference of Governmental Industrial Hygienists Threshold Limit Values. If a discrepancy exists between these documents, OSHA 29 CFR 1910 shall take precedence. [Source: 29 CFR 1910; MIL-STD-1472F, 1999; Department of Defense (MIL-STD-1800A), 1990; MIL-HDBK-759B, 1992]

- **12.7.2 Carbon monoxide.** Maintainers shall not be exposed to concentrations of carbon monoxide (CO) in excess of 50 parts per million (ppm) or 55 mg/m^3. [Source: 29CFR 1910.100; MIL-STD-1472F, 1999; MIL-HDBK-759B, 1992]

  Discussion. Carbon monoxide is particularly dangerous in that it is odorless, colorless, and tasteless. Its effects are cumulative; doses that may be tolerable by individuals over brief periods may prove to be dangerous to them when repeated or prolonged over several hours.

  Carbon monoxide combines with the blood to form carboxyhemoglobin (COHb). CO accumulates rapidly in the blood, however, the body is extremely slow in reducing the COHb level which may account for its toxic action. Maximum COHb levels have been set at 5% for all system design objectives and aviation system performance limits and at 10% for all other system performance.

- **12.7.3 Cadmium oxide fumes.** Maintainers shall not be exposed to more than 0.1 milligrams of cadmium oxide per cubic meter of air. If possible, adequate ventilation shall be provided whenever any silver solder is used. If adequate ventilation cannot be supplied, maintainers shall be provided with respirators to prevent serious exposure to the cadmium oxide fumes. [Source: Department of Transportation (FAA Order 6000.15), 1991]

  Discussion. When a cadmium alloy containing a silver brazing is heated appreciably above its melting point, acutely poisonous brown or yellow cadmium oxide fumes are released. Inhalation of cadmium oxide fumes can result in serious and sometimes fatal damage to maintainers.

- **12.7.4 Fumes from batteries.** Adequate ventilation shall be provided in all battery service facilities. Fumes from batteries can be harmful to maintainers both because of the hazards of breathing the fumes themselves and because the fumes may displace oxygen. [Source: FAA Order 6000.15B, 1991]

- **12.7.5 Safety for toxic chemicals and materials.** Safety design and operation for toxic materials shall be governed by OSHA 29 CFR 1910.1200 and its appendix A. [Source: 29 CFR 1910.1200]

- **12.7.6 Asbestos.** Components and equipment containing asbestos shall not be used. [Source: FAA-G-2100F, 1993]

12.8 Radiation hazards

Radiation emitting systems and equipment require special consideration to minimize hazards to maintainers. Potential hazards arising from nuclear and electromagnetic radiation need to be evaluated by specialized personnel trained in investigating and controlling such hazards. OSHA 29 CFR 1910.96 and .97 address the effects of ionizing and non-ionizing radiation respectively. This section includes the rules for radiation hazards. [Source: 29 CFR 1910.96 and .97; MIL-HDBK-759B, 1992]

- 12.8.1 **Radioactive materials.** Use of radioactive materials shall conform to Nuclear Regulatory Commission regulations and shall require approval of the acquisition program office. [Source: FAA-G-2100F, 1993; MIL-STD-454M, 1989]

- 12.8.2 **Radium.** Radium shall not be used for luminosity (for example, making components visible in the dark). [Source: FAA-G-2100F, 1993; MIL-STD-454M, 1989]

- 12.8.3 **Ionizing radiation exposure.** The radiation measured at any external surface of a unit of equipment producing ionizing radiation shall not exceed 0.5 milliroentgens per hour (rem) at a distance of 50 mm (2 in). Cumulative whole body exposure to maintainers shall not exceed 3 rem for any calendar quarter and 5 rem for any calendar year. The cumulative occupational exposure to an employee shall not exceed 5(n-18) rems where n equals the individual's age at the last birthday. Employees under 18 years of age shall not be exposed to over 10 percent of the allowable calendar quarter dose. OSHA 29 CFR 1910.96 and 97 shall govern protection from and exposure to ionizing and non-ionizing radiation respectively. [Source: 29 CFR 1910.96 and 97; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

- 12.8.4 **Microwave and radio frequency radiation.** Electronic equipment or electrical equipment capable of emitting microwave or radio frequency radiation between 300 KHz and 100 GHz shall be designed, fabricated, shielded, and operated to avoid overexposure of maintainers. According to OSHA 29 CFR 1910.97, partial or whole body electromagnetic radiation between 10 MHZ and 100GHz shall be restricted a maximum of 10mW/cm2 over any 0.1-hour period. Equipment design and installation in any unrestricted area accessible to maintainers shall meet the requirements of IEEE C95.1. [Source: 29 CFR 1910.97]

12.9 Protection from special chemicals

Protection from special chemicals (such as battery electrolyte) cleaning solvents, Polychlorinated Byphenyls, and carcinogens is addressed in this section.

- 12.9.1 **Protection against battery acid.** Maintainers shall be provided acid resistant gloves, aprons and face shields that offer side as well as frontal protection for protection against the splattering of battery acid when they measure storage battery specific gravity or when they handle electrolyte. [Source: 29 CFR 1926.441; Department of Transportation (FAA Order 3900.19A), 1982]

- 12.9.2 **Battery handling area.** Quick drenching facilities shall be provided within 25 feet of a battery handling area. [Source: 29 CFR 1926.441; FAA Order 3900.19A, 1982]

- 12.9.3 **Large-sized service facilities.** If large quantities of electrolyte are handled or a large number of batteries are maintained, facilities shall be provided for quick drenching or flushing of the eyes and body. [Source: FAA Order 3900.19A, 1982]

  Exception. If the storage batteries are of the enclosed type and the facility is equipped with explosion proof or resistant vents, sealed water rinse or neutralizing packs may be used.

- 12.9.4 **Small-sized service facilities.** If small quantities of electrolyte are handled and a small number of batteries are maintained, water rinse for flushing of the eyes and body shall be provided in place of drenching or flushing facilities. [Source: FAA Order 3900.19A, 1982]

- 12.9.5 **Cleaning solvents.** Adequate ventilation shall be provided whenever any solvents or cleaners are used. Solvents that produce fumes (such as carbon tetrachloride) shall not be used and all permissible cleaning solvents shall be stored in safety cans. [Source: FAA Order 6000.15B, 1991]

  Discussion. Inhaled fumes from carbon tetrachloride are extremely hazardous to the respiratory system and some may have a caustic effect on the skin.

- 12.9.6 **Polychlorinated Biphenyls (PCBs).** Maintainers shall be provided protective clothing when handling PCBs. All PCB items (such as transformers, capacitors, hydraulic machinery, and circuit breakers) with PCB concentrations of 500 parts per million shall be marked, inspected, and disposed of according to FAA Order 1050.14. PCBs shall not be used when suitable substitutes are available. [Source: FAA Order 6000.15B, 1991; Department of Transportation (FAA Order 1050.14), 1991]

- 12.9.7 **Carcinogens.** The use of chemicals that have been identified by the Occupational Safety and Health Act (OSHA) as cancer producing substances (carcinogens) shall be evaluated and conform to OSHA 29 CFR 1910. [Source: 29 CFR 1910; MIL-STD-454M, 1989]

12.10 Temperature hazards

Tissue burns can occur when skin temperature reaches 45°C (113°F). Objects at temperatures in excess of this can be touched safely, depending on the: (1) duration of touch, (2) finish and diffusivity of the surfaced touched, (3) force of contact, and (4) size of contact area. Rules for equipment related temperature are given in this section.

- 12.10.1 **"Touch temperature" contact.** Equipment that in normal operation exposes maintainers to surface temperatures outside the range of temperatures shown in Exhibit 12.10.1, shall be shielded. Cryogenic systems shall also be shielded. [Source: DOE-HFAC1, 1992; MIL-STD-1472F, 1999; MIL-STD-454M, 1989]

Exhibit 12.10.1 Upper and lower temperature limit range

	Temperature limits °C (°F)		
Exposure	**Metal**	**Glass**	**Plastic or wood**
Momentary contact	0-60 (32-140)	0-68 (32-154)	0-85 (32-185)
Prolonged contact or handling	0-49 (32-120)	0-59 (32-138)	0-69 (32-156)

- 12.10.2 **Perforation size.** Cases, covers, and shields that are perforated to permit ventilation shall be no larger than 13 mm (.050 in) in diameter to prevent inadvertent insertion of objects that might touch high voltage sources or moving parts. Many smaller perforations are preferable to a few large ones. [Source: MIL-HDBK-759B, 1992]

12.11 Fire Protection

The avoidance and minimization of fire hazards begins with good housekeeping, which needs to be a personal goal of all maintainers. This section gives rules for reducing fire hazards. Fire protection provisions which affect design of facilities and equipment as well as operations and maintenance are governed by OSHA 29 CFR 1910 Subpart Fire Protection L (155 -167) Subpart H Hazardous materials (101 -119) and Associated national consensus standard sponsored by the National Fire Protection Association and the American National Standard Institute. OSHA 29 CFR 1910.307 and 308 address electrical installations in hazardous locations and environments.

- ■ **12.11.1 Nonflammable enclosures.** If capacitors, inductors, and motors are potential fire hazards, they shall have nonflammable enclosures with a minimum number of openings. [Source: MIL-HDBK-759B, 1992]

- □ **12.11.2 Flammable materials.** If possible, designers should avoid specifying the use of flammable materials in equipment. [Source: MIL-HDBK-759B, 1992]

- ■ **12.11.3 Flammable gases.** If possible, equipment shall be designed so that it will not emit flammable gases during storage or operation. If this is not possible, automatic cutoffs and suitable warnings shall be provided. OSHA 29 CFR 1910.101 -119 governs handling of hazardous materials including those that are flammable, combustible, and explosive. [Source: 29 CFR 1910.101 – 119; MIL-HDBK-759B, 1992]

- ■ **12.11.4 Fire extinguishers.** Where fire hazards exist, portable, hand-operated fire extinguishers shall be located where fires will not block their access. [Source: MIL-HDBK-759B, 1992]

- ■ **12.11.5 Selection of fire extinguishers.** Fire extinguishers shall be selected for suitability by the class of fires most likely to occur in an area. OSHA 29 CFR 1910.157 governs the selection and use of fire extinguishers. [Source: 29 CFR 1910.157; MIL-HDBK-759B, 1992]

  Discussion. Class A fires involve ordinary flammable materials such as wood, paper, and rags that can be extinguished with water or aqueous solutions. Class B fires involve flammable liquids such as gasoline, solvents, and greases that can be extinguished by dilution, elimination of air, or blanketing. Class C fires involve electrical equipment such as motors, transformers, and switches that need to be extinguished by a substance that does not conduct electricity.

- **12.11.6 Fire protection criteria.** OSHA 29 CFR 1910 Subpart L Fire protection (155 -165); Subpart H Hazardous materials (101 - 119) and associated national consensus standards sponsored by the National Fire Protection Association and the American National Standards Institute shall govern the fire protection aspects for maintenance of facilities and equipment. OSHA 29 CFR 1910.307 -308 governs electrical installations in hazardous locations and environments. [Source: 29 CFR 1910.307 -308]

12.12 Noise hazards

Noise can be hazardous to maintainers in two general ways: it can cause hearing loss, both temporary and permanent, and it can prevent maintainers from hearing audible warning signals. Rules are given in this section to protect maintainers from these hazards. Rules concerning administrative and engineering controls to reduce noise and a hearing conservation program are given in Chapter 13.5.

- **12.12.1 General noise levels.** Workplace noise shall be maintained at levels that will not (1) interfere with necessary voice, telephone, and radio communication, (2) cause fatigue or injury, or (3) degrade overall system effectiveness. [Source: MIL-STD-1800A, 1990]

- **12.12.2 Noise criteria.** Noise criteria are defined by either the A-weighted sound level, dB(A), or the speech interference level (SIL). The A-weighted sound level is the desired requirement. Where it is not possible to meet the specified A-weighted sound level, the corresponding SIL requirement shall be met. [Source: MIL-STD-1800A, 1990]

  Definitions. Preferred speech interference level (PSIL-4) is a measure of the effectiveness of noise in masking speech. **Speech interference level (SIL or SIL-4)** is the arithmetic mean, in dB (or 20μPa), of sound pressure levels in the four octave bands with center frequencies of 500, 1000, 2000, and 4000 Hz. **A-weighted sound level (dB(A))** is a sound pressure level (in decibels) measured using a sound level meter with an A-weighting network. The A-weighted response is maximum at 2500 Hz, drops rapidly as frequency decreases below 1000 Hz, and gradually decreases above 4000 Hz, thereby approximating the frequency dependent human response to moderate sound levels. ANSI S1.4 gives the definition of A-weighting filter characteristics.

- **12.12.3 Extreme quiet areas.** Ambient noise in areas requiring extreme quiet shall not exceed 35 dB(A) or 27 dB PSIL-4. [Source: MIL-HDBK-759B, 1992]

- **12.12.4 Small office spaces and special areas.** Ambient noise in areas requiring no difficulty with speech communication (for example, libraries and classrooms) shall not exceed 45 dB(A) or 37 dB PSIL-4; conference rooms and offices shall not exceed 38 dB PSIL-4. [Source: FAA-G-2100F, 1993; MIL-HDBK-759B, 1992]

- **12.12.5 Operational areas.** Ambient noise in areas requiring frequent phone use or requiring occasional speech communication (for example, operations centers, control rooms, tower cabs, and dynamic simulation rooms) at distances up to 4.6 m (15 ft) shall not exceed 55 dB(A) or 47 dB PSIL-4; shop offices and laboratories shall not exceed 48 dB PSIL-4. [Source: FAA-G-2100F, 1993; MIL-HDBK-759B, 1992]

- **12.12.6 Equipment areas.** Ambient noise in areas requiring frequent telephone use or frequent speech communication (for example, computer rooms, engineering areas, equipment rooms, and telephone switching centers) at distances up to 1.5 m (5 ft) shall not exceed 65 dB(A) or 57 dB PSIL-4. [Source: FAA-G-2100F, 1993; MIL-HDBK-759B, 1992]

- **12.12.7 High noise, remote areas.** High noise, remote areas that are normally unmanned shall not exceed 85 dB(A). [Source: FAA-G-2100F, 1993]

- **12.12.8 Occupational noise exposure and control.** Administrative or engineering controls shall be used to reduce the sound levels to within permissible noise exposure levels listed in Exhibit 12.12.8. OSHA 29 CFR 1910.95 shall be used in determining equivalent A-weighted sound levels for daily exposure. A hearing conservation program shall be administered any time an employee's noise exposure equals or exceeds an 8-hour time weighted average of 85 db measure on the A scale (slow response) or equivalent without regard to attenuation that may be provided by personal protective equipment. OSHA 29 CFR 1910.95 shall govern the hearing protection program. [Source: 29 CFR 1910.95]

Exhibit 12.12.8 Permissible noise exposure

Maximum hours per day	Sound level dBA (slow response) equivalent A-weighted sound level
8.0	90
6.0	92
4.0	95
3.0	97
2.0	100
1.5	102
1.0	105
0.5	110
0.25	115
Maximum impulse noise	140 (peak sound pressure level)

If daily exposure involves two or more periods at differing levels, the combined effect is used. C_j/T_j is the total time of exposure at a specified level over the time of permissible exposure for that typical level, j. When the sum, $\sum(C_j/T_j)$ of the fractions, $C_1/T_1 + C_2/T_2 + ... + C_j/T_j + ... + C_n/T_n$ is greater than one, the combined exposure exceeds the permissible noise limit value.

12.13 Explosion and implosion hazards

Maintainers are sometimes exposed to risks of explosion (for example, the presence of explosive gases), or of implosion (for example, a scratched cathode ray tube (CRT). Rules are given in this section to protect the maintainer from such hazards.

- 12.13.1 **CRT conformance.** CRTs shall conform to the requirements of UL 1418. [Source: MIL-HDBK-759B, 1992; MIL-STD-454M, 1989]
- 12.13.2 **Terminal end of CRT.** Whenever possible, the terminal end of CRTs shall be located within the equipment housing. If the terminal end extends outside the equipment housing, it shall have a cover strong enough to protect the tube. This cover shall be anchored to the main housing structure firmly enough to withstand shipping and rough handling so that external pressures will not be transmitted to the tube and its wiring. There shall also be a warning inside the equipment informing maintainers that the neck of the tube is fragile and must be handled with caution. [Source: MIL-HDBK-759B, 1992]
- 12.13.3 **Explosion.** Equipment that may be operated, maintained, or stored in an explosive atmosphere shall be designed to eliminate the possibility of an explosion. [Source: MIL-HDBK-759B, 1992]
- 12.13.4 **Minimizing risk of explosion.** Risk of explosion shall be minimized by isolating hazardous substances from heat sources and by using spark arrestors, vents, drains, or other safety techniques. [Source: MIL-HDBK-759B, 1992]
- 12.13.5 **Explosion causing gases.** Materials shall not liberate gases that will produce an explosive atmosphere. [Source: MIL-STD-454M, 1989]

12.14 Radiant energy hazards

This section gives rules for radiant energy (200 nm to 1 m) hazards. This range covers ultraviolet through microwave radiant energy.

12.14.1 Ultraviolet radiant energy (200-315 nm)

- 12.14.1.1 **Exposure limit.** The maximum daily radiant energy exposure to ultraviolet light (200-315 nm) shall not exceed an effective value of 0.003 J/cm^2. [Source: Farrell & Booth, 1975]

Discussion. The equations and tables shown in Exhibit 12.14.1.1 can be used to convert irradiance measured in each part of the spectrum to total effective irradiance.

Definition. Irradiance is the radiant flux density on a given surface.

Exhibit 12.14.1.1 Exposure limit for ultraviolet radiant energy (200 to 315 mm)

$E_{eff} = \sum E_\lambda S_\lambda \Delta_\lambda$, where:

E_{eff} = Effective irradiance in the 200 nm to 315 nm
E_λ = Measured spectral irradiance in mW/cm^2 nm
S_λ = Relative spectral effectiveness (dimensionless) (see below)
Δ_λ = Bandwidth in nanometers (nm)

Wavelength (nm)	Relative spectral effectiveness (S_λ)	Daily exposure limit (mJ/cm^2)
200	0.03	100
210	0.0075	40
220	0.12	25
230	0.19	16
240	0.3	10
250	0.43	7
254	0.5	6
260	0.65	4.6
270	1.0	3.0
280	0.88	3.4
290	0.64	4.7
300	0.30	10.0
305	0.06	50.0
310	0.015	200
315	0.003	1000

Effective irradiance E_{eff} (mW/cm^2)	Maximum exposure per day*
0.0001	8 hr
0.0002	4 hr
0.0004	2 hr
0.0008	1 hr
0.0017	30 min
0.0033	15 min
0.005	10 min
0.01	5 min
0.05	1 min
0.10	30 sec
0.30	10 sec
3.00	1 sec
6.00	0.5 sec
30.00	0.1 sec

* These values assume that no other occupational exposure occurs

12.14.2 Near-ultraviolet radiant energy (315-400 nm)

- **12.14.2.1 Exposure duration greater than 1000 seconds.** The maximum radiant energy exposure to near ultraviolet light (315-400 nm) shall not exceed 0.001 W/cm^2 for exposure durations longer than 1000 sec. [Source: Farrell & Booth, 1975]

- **12.14.2.2 Exposure duration less than 1000 seconds.** The maximum radiant energy exposure limit to near ultraviolet light (315-400 nm) shall not exceed 1 J/cm^2 in any 1000-second period. [Source: Farrell & Booth, 1975]

12.14.3 Visible and near-infrared radiant energy (400-1400 nm)

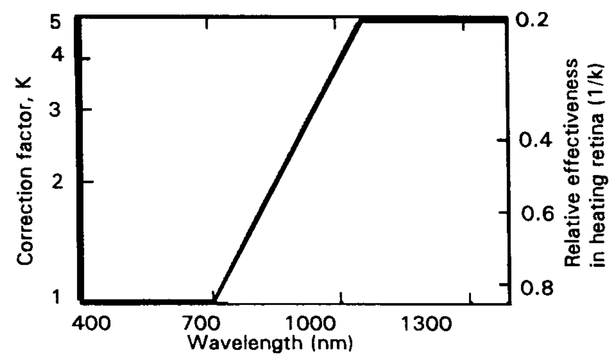
Visible and near-infrared radiant energy, with a wavelength of 400 to approximately 1400 nm, is largely transmitted by the ocular media of the eye and absorbed at the retina. Unlike corneal injury from ultraviolet energy, injury to the retina is generally permanent. As a result, special care must be taken to avoid retinal damage. [Source: Farrell & Booth, 1975]

If appropriate image spectral radiance data are not immediately available, it may be helpful to estimate whether a particular image luminance exceeds permissible exposure limits. The relationship between luminance and radiance has been published for typical lamps, but these values cannot be used directly because radiant energy with a wavelength greater than 700 nm is less effective in heating the retina.

If the spectral distribution of radiant energy in the displayed image is known, the luminosity function for the eye (see Exhibit 12.14.3) can be used to calculate the ratio between luminance and effective radiance, and hence, the permissible luminance. This process is illustrated here for three hypothetical equal-energy-per-wavelength sources that differ in wavelength range.

Exhibit 12.14.3 Relative contribution of different wavelengths to luminance –the luminosity function

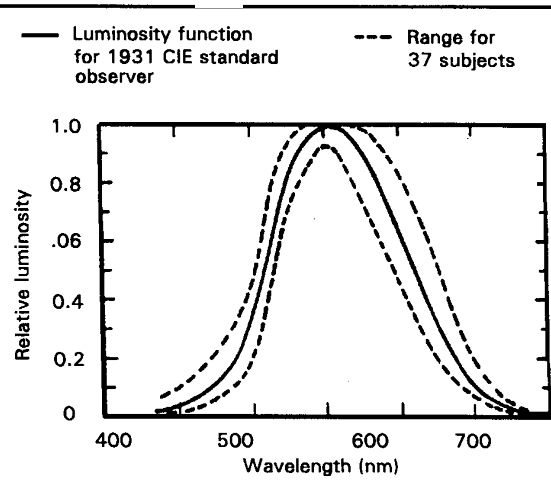
Exposure time (t) seconds	Maximum permissible radiance	
	Energy ($J/cm^2 sr$)	Power ($W/cm^2 sr$)
< 10	$10\,t^{1/3}$ K	$10t^{-2/3}$ K
10 to 10^4	20K	$20Kt^{-1}$
> 10	--	0.002K



- **12.14.3.1 Exposure of the eye.** The maximum radiant energy exposure to visible and near-infrared light (400-1400 nm) shall not exceed the limits given in Exhibit 12.14.3.1. These limits apply to any source larger than 1°. [Source: Farrell & Booth, 1975]

  Note. For wavelengths longer than 700 nm, a correction factor, K, is required to compensate for the increase in absorption in the ocular media and the decrease in absorption by the retina.

Exhibit 12.14.3.1 Maximum safe exposure to 400-1400 nm radiant energy.



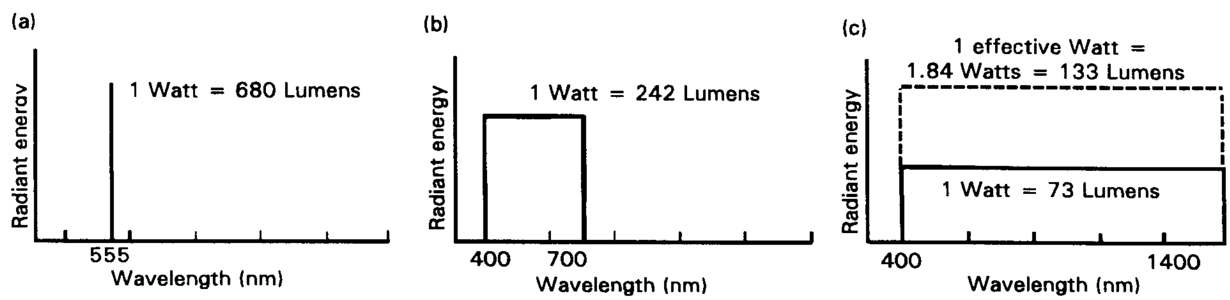
- **12.14.3.2 Exposure of skin.** The maximum radiant energy exposure of a maintainer's skin to visible and near-infrared light (400-1400 nm) shall not exceed 0.2 W/cm^2. [Source: Farrell & Booth, 1975]

- **12.14.3.3 Removing infrared.** If infrared radiant energy exceeds the allowable limit, filters shall be provided to protect the maintainer's eyes from unnecessary heat. [Source: Farrell & Booth, 1975]

- ▫ **12.14.3.4 Maximum display.** High-luminance displays should not exceed 242 lumens per effective watt of the 400 to 700 nm source (see Exhibit 12.14.3.4). [Source: Farrell & Booth, 1975]

  Definition. An **effective watt** is equal to 1.84 watts.

Exhibit 12.14.3.4 Estimation of permissible image luminance



Wavelength range (nm)	Lumens per Watt of radiant energy	Lumens per effective Watt of radiant energy	Image luminance at maximum permissible image radiance cd/m^2 (fl)		
			1 second	100 seconds	10,000 seconds
(a) 555	680	680	68,000,000 (20,000,000)	1,400,000 (410,000)	14,000 (4,100)
(b) 400 to 700	242	242	24,200,000 (7,000,000)	480,000 (140,000)	4,800 (1,400)
(c) 400 to 1400	73	133	13,300,000 (3,900,000)	270,000 (78,000)	2,700 (780)

12.14.4 Far-infrared radiant energy (1400-10^6 nm)

- **12.14.4.1 Short term exposure.** The maximum radiant energy exposure to far-infrared light (1400-10^6 nm) for 60-120 seconds shall not exceed 0.1 W/cm^2. A measurement aperture of 1 mm (0.04 in) shall be used for wavelengths shorter than 10^5 nm, and an aperture of 11 mm (0.43 in) shall be used for longer wavelengths. [Source: Farrell & Booth, 1975]

- **12.14.4.2 Chronic exposure.** The maximum chronic radiant energy exposure to far-infrared light (1400-10^6 nm) shall not exceed 0.01 W/cm^2. A measurement aperture of 1 mm (0.04 in) shall be used for wavelengths shorter than 10^5 nm, and an aperture of 11 mm (0.43 in) shall be used for longer wavelengths. [Source: Farrell & Booth, 1975]

12.14.5 Microwave radiant energy (10^7-10^{11} Hz)

- **12.14.5.1 Exposure limit.** The maximum radiant energy exposure to microwave radiation (10^7-10^{11} Hz, which corresponds to wavelengths of 1 mm (0.04 in) to 1 m (39.37 in)) shall be no more than 0.01 W/cm^2 averaged over a 0.1-hour period. [Source: Farrell & Booth, 1975]

12.15 Laser hazards

This section gives rules for protecting the maintainer from laser hazards.

- **12.15.1 Laser radiation.** Laser equipment and system design, installation, and operational and maintenance procedures shall conform to OSHA 21 CFR 1040. [Source: 21 CFR 1040; Farrell & Booth, 1975]

- **12.15.2 Laser exposure limits.** In accordance with OSHA 29 CFR 1926.54 (j), employees shall not be exposed to laser light intensities above:

  a. Direct staring: 1 microwatt per square centimeter.

  b. Incidental observing: 1 milliwatt per square centimeter.

  c. Diffuse reflected light: 2 1/2 watts per square centimeter.

  Discussion. For safety reasons, laser units need to be set up to operate above head level of employees, when possible. [Source: 29 CFR 1926.54 (j)]

- **12.15.3 Eye protection from laser light.** OSHA 29 CFR 1926.54 shall govern potential exposure areas to direct or reflected laser light. Employees shall be provided with antilaser eye protection devices if any such exposure to laser light greater than 5 milliwatts exists. OSHA 29 CFR 1926.102 (b)(2) shall govern optical density of the eye protection based upon the maximum power density and specific wavelength of the laser. [Source: 29 CFR 1926.54]

- **12.15.4 Labeling of laser protective goggles.** OSHA 29 CFR 1926.102 (b)(2)(ii) shall govern the labeling laser optical protection devices. Labels shall include the following:

  a. Laser wavelengths for intended use.

  b. Optical density of those wavelengths.

  c. The visible light transmission. [Source: 29 CFR 1926.102 (b)(2)(ii)]

- **12.15.5 Laser alignment.** In accordance with OSHA 29 CFR 1926.54 (f) only mechanical or electronic means shall be used as a detector for guiding the internal alignment of a laser. [Source: 29 CFR 1926.54]

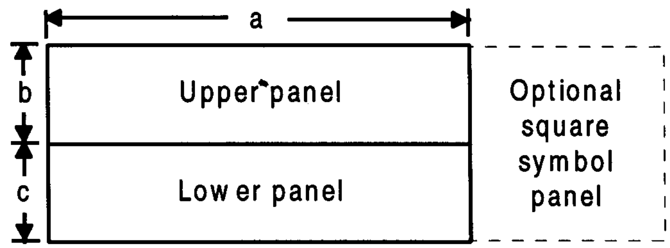
12.16 Safety labels and placards

This section contains rules for the labeling and placing of placards on hazardous components, equipment, and systems. Use of these rules will help to ensure the safety of maintainers and equipment.

- **12.16.1 Warning labels and placards.** Labels or placards shall be placed on or adjacent to any equipment that presents a hazard (for example, high voltage, heat, toxic vapors, explosion, and radiation) to maintainers. These labels or placards shall describe the hazard and state precautions the maintainer can take. [Source: MIL-STD-1472F, 1999; MIL-HDBK-759B, 1992; DOE-HFAC1, 1992; NASA-STD-3000A, 1989; MIL-STD-454M, 1989]

- **12.16.2 Label and placard design.** Labels and placards shall consist of three panels as shown in Exhibit 12.16.2. The ratio of width to height of the upper panel (a:b) shall fall within the range of 2:1 to 5:1 inclusive. The lower panel width shall be equal to the upper panel width (both equal to a). The lower panel height shall be equal to or greater than the upper panel height, but less than twice the width of the sign (b ó c < 2a). The optional symbol panel shall be square with its edge equal to the sum of the upper and lower panel (b + c) and placed to the right of the upper and lower panels. The upper panel shall contain the signal or key work. the lower panel shall contain additional direction or explanation. Wording of this panel shall be brief, provide positive direction (if possible), and be limited to a single hazard. [Source: MIL-STD-1472F, 1999]

Exhibit 12.16.2 Label and placard layout –two panel sign with optional symbol panel



12.16.3 Label and placard design classifications and specifics. Signs shall have one of four classifications:

a. Class I (Danger). Danger labels and placards indicate immediate and grave danger or peril, a hazard capable of producing irreversible damage or injury, and prohibitions against harmful activities. These signs shall have the word "DANGER" in white within a red oval outline with a white on black rectangle in the upper panel. The lower panel, for additional wording, shall be in black or red on a white background.

b. Class II (Caution). Caution labels and placards are used to call attention to potential danger or hazard, or a hazard capable of, or resulting in severe but not irreversible injury or damage. These signs shall have the signal word "CAUTION" in yellow on a black rectangle in the upper panel. The lower panel, for additional wording, shall be in black on a yellow background.

c. Class III (General safety). General safety labels and placards include notice of general practice and rules relating to health, first aid, housekeeping, and general safety other than the two cases above. These signs shall have the appropriate key word in white on a green rectangle in the upper panel. The lower panel, for additional wording, shall be in black or green on a white background.

d. Class IV (Fire and emergency). Fire and emergency labels and placards shall be used only to label or point the way to fire extinguishing equipment, shutoffs, emergency switches, and emergency procedures. These signs shall have the key word in white on a red rectangle in the upper panel. The lower panel, for additional wording, shall be in red on a white background. [Source: MIL-STD-454M, 1989]

- **12.16.4 Label and placard placement.** Labels and placards shall be placed so as to alert and inform in sufficient time to avoid the hazard or to take appropriate action. They shall be: (1) readable from a distance, (2) create no additional distractions, or (3) be hazardous themselves. [Source: MIL-HDBK-759B, 1992; MIL-STD-454M, 1989]

- **12.16.5 Illumination for warning labels and placards.** Warning labels and placards shall be visible under the conditions in which the maintainer needs to see them. Special illumination may be needed to meet this criterion. [Source: MIL-STD-454M, 1989]

- **12.16.6 Wording for medium voltage labels and placards.** If a voltage between 70 and 500 volts is present, a caution label or placard shall be provided that includes the following statement or its equivalent: "CAUTION (insert maximum voltage) VOLTS." The label or placard shall be in accordance with ANSI Z535.2. [Source: MIL-STD-454M, 1989]

- **12.16.7 Wording for high voltage labels and placards.** If a voltage in excess of 500 volts is present, a warning label or placard shall be provided that includes the following statement or its equivalent: "DANGER -- HIGH VOLTAGE (insert maximum voltage) VOLTS." The label or placard shall be in accordance with ANSI Z535.2. [Source: MIL-STD-454M, 1989]

- **12.16.8 Microwave or rf radiation warning labels and placards.** Each unit of equipment that can emit microwave or rf radiation levels between 300 KHz and 100 GHz shall have a warning label or placard. This warning label or placard shall be in accordance with ANSI Z535.2 and ANSI C95.2. Labels shall be provided on all radiation shields and covers to warn maintainers of the radiation hazards involved upon removal. [Source: MIL-STD-454M, 1989]

- **12.16.9 X radiation shield labels or placards.** Shields that protect maintainers from X radiation shall have labels or placards in accordance with OSHA 10 CFR 20. [Source: 10 CFR 20; DOE-HFAC1, 1992; MIL-STD-1472F, 1999]

- **12.16.10 Ionizing radiation symbols.** Ionizing radiation hazard symbols shall be in accordance with ANSI N2.1. [Source: DOE-HFAC1, 1992; MIL-STD-1472F, 1999]

- **12.16.11 Laser warning labels and placards.** Laser warning labels and placards shall be in accordance with OSHA 21 CFR 1040 unless a unit of equipment has been certified as exempt. In accordance with OSHA 29 CFR 1926.54 (d) all areas on which lasers are used shall be posted with standard laser warning placards. [Source: 21 CFR 1040; MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

  Discussion. If a piece of equipment is exempt, the unit of equipment shall have a label or placard that states: CAUTION--This electronic product has been exempted from FDA radiation safety performance standards, as prescribed in the Code of Federal Regulations, Title 21, Chapter I, Subchapter J, pursuant to Exemption No. 76 EL-01 DOD issued on 26 July 1976. This product shall not be used without adequate protective devices or procedures.

- **12.16.12 Line identification.** Liquid and gas lines shall be clearly and unambiguously labeled or coded as to contents, pressure, heat, cold, or other hazardous properties in accordance with MIL-STD-1247. [Source: MIL-HDBK-759B, 1992; MIL-STD-1800A, 1990]

- **12.16.13 Electrical labels and placards.** If appropriate, all receptacles shall be marked with their voltage, phase, and frequency characteristics. [Source: MIL-STD-1472F, 1999; MIL-HDBK-759B, 1992; DOE-HFAC1, 1992]

- **12.16.14 Center of gravity.** If the unit has a high center of gravity or if the weight of a unit of equipment is not evenly distributed, the center of gravity shall be clearly marked. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

- **12.16.15 Weight labels.** Weight and center of gravity caution placards shall be placed on any unit of equipment to be moved for maintenance if its weight exceeds 13.6 kg (30 lbs.). If it is designed to be lifted or carried by more than one person, the label shall include the number of people recommended to lift or carry it. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

- **12.16.16 Weight lifting capacity.** Weight lifting capacity shall be indicated on stands, hoists, lifts, jacks, and similar weight-bearing equipment, to prevent possible overloading. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

Glossary

Effective watt - Equal to 1.84 watts.

Interlocks - Devices (for example, switches) connected with a cover, shield, or case that disable the associated internal hazard (usually electrical) when the cover, shield, or case is opened. OSHA regulations discuss lockout and tagout procedures to be used in the workplace during maintenance or operations to protect from electrical hazards.

Irradiance - The radiant flux density on a given surface.

Lockout - Uses a mechanical mean to disable a control or switch in its safe position (for example, electricity disconnected) and to prevent its activation without the use of undue force or tools.

N - Is a metric term for the force measure called a Newton. One pound force in the English measurement system is equal to 4.4482 Newton (1 lbf = 4.4482 N).

Preferred speech interference level (PSIL-4) - A measure of the effectiveness of noise in masking speech.

Speech interference level (SIL or SIL-4) - The arithmetic mean, in dB (or 20µPa), of sound pressure levels in the four octave bands with center frequencies of 500, 1000, 2000, and 4000 Hz.

Tagouts - Tags that are attached to a control or place of hazard associated with an ongoing mode of operation or maintenance.

Weighted sound level (dB(A)) - A sound pressure level (in decibels) measured using a sound level meter with an A-weighting network. The A-weighted response is maximum at 2500 Hz, drops rapidly as frequency decreases below 1000 Hz, and gradually decreases above 4000 Hz, thereby approximating the frequency dependent human response to moderate sound levels. ANSI S1.4 gives the definition of a-weighting filter characteristics.

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13 Environment

This section contains human factors design rules pertaining to the workplace environment. The topics covered in this section include: (1) general criteria and rules, (2) ventilation, (3) temperature and humidity, (4) illumination, and (5) noise.

13.1 General

There are three major categories of environmental factors that affect systems and equipment design:

a. environmental factors that design can control such as illumination, ventilation rate, and temperature,

b. environmental factors that are a function of design such as noxious substances, vibration, and noise, and

c. environmental factors that design cannot control such as solar radiation, dust, mud, and rain.

▪ 13.1.1 **General environmental extremes.** To maximize the effectiveness of the FAA systems and equipment that are maintained by FAA personnel, the designer shall accommodate the environmental extremes to which the system will be subjected and their effects on human-system performance. FAA systems and equipment shall be capable of sustained operations within the climatic extremes specified in the material requirements documents pertaining to each system or specification. Workplaces shall conform to the rules specified in this document. [Source: Department of Defense (MIL-HDBK-759B), 1992]

□ **13.1.2 Deviations from tolerable conditions.** When deviations from the tolerable conditions stated in this section are necessary, the designer should take into account adverse effects such as:

a. protective clothing or devices which affect the mobility, reach, workplace, access size, maintainability, time to restore, efficient and effective use,

b. reduced human performance,

c. conditions that have little or no direct effect on equipment, but may seriously impair the ability of the user to perform effectively, and

d. conditions that contribute to longer use time or to increased use errors, oversights, or erroneous decisions, and that are detrimental to system availability and performance. [Source: MIL-HDBK-759B, 1992]

Discussion. The above adverse effects can sometimes be minimized through the use of alternatives such as: (1) remote system monitoring, (2) increased workplace area, (3) individual protective measures or supplemental equipment, (4) decreased workloads, (5) acclimation of operating personnel, (6) personnel rotation from one workstation to another, and (7) personnel selection and training.

13.2 Ventilation

General ventilation of the workplace contributes to the comfort and efficiency of the workers. Good ventilation also makes a positive contribution to health. Adequate general and, if needed, specialized ventilation can ensure that concentrations of toxic substances do not reach levels that are hazardous to health.

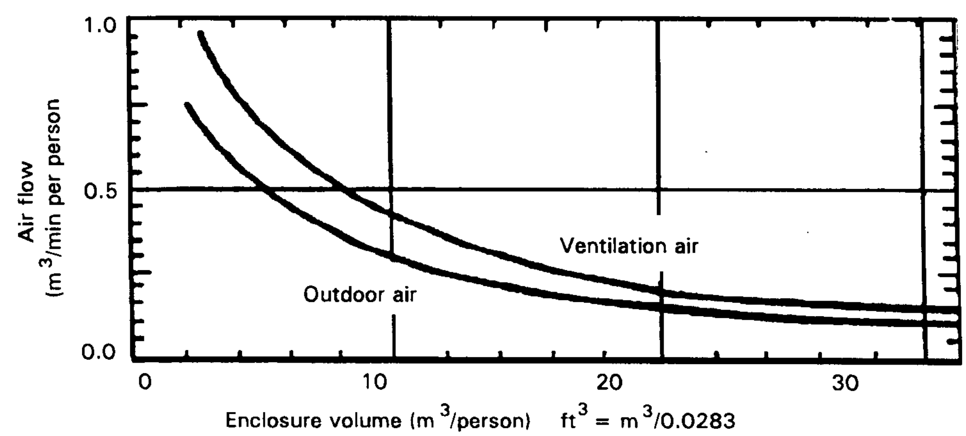
Definition. Ventilation is the process of supplying air to or removing air from any space by natural or mechanical means. From the standpoint of comfort and health, ventilation issues involve both quantity and quality.

■ **13.2.1 General ventilating systems and temperature differentials.** General ventilating systems shall not produce air velocities exceeding 100 ft/min. Temperature differentials between any two points within the workplace shall be maintained below 5.6°C (10°F). [Source: Department of Defense (MIL-STD-1800A), 1990]

■ **13.2.2 Small enclosure ventilation.** If the enclosure volume is 4.25 m^3 (150 ft^3) or less per person, a minimum of 0.85 m^3 (30ft^3) of ventilation air per minute shall be introduced into the enclosure; approximately two-thirds shall be outdoor air. [Source: Department of Defense (MIL-STD-1472D), 1989; MIL-HDBK-759B, 1992]

▪ 13.2.3 **Large enclosure ventilation.** For large enclosures greater than 4.25 m3 (150 ft3), the air supply per person shall be in accordance with the curves in Exhibit 13.2.3. Air shall be moved past personnel at a velocity of not more than 60 m (200 ft) per minute. If personnel use manuals or loose papers, airspeed past these items shall not be more than 30 m (100 ft) per minute. If possible, the preferred air velocity of 20 m (65 ft) per minute shall be used to preclude manual pages from being turned or papers from being blown off work surfaces. [Source: MIL-STD-1472D, 1989; MIL-HDBK-759B, 1992]

Exhibit 13.2.3 Large enclosure ventilation



▪ 13.2.4 **Verification of ventilation.** Performance of the ventilation system shall be verified by analysis, test, and verification. [Source: MIL-STD-1800A, 1990]

Discussion. The analysis will ensure that enough fresh air is supplied to maintain occupant comfort and that toxic substances are properly ventilated. Tests will measure air velocity at all workplaces and ensure that no "dead air" spaces exist. A demonstration will verify that occupants do not experience discomfort due to inadequate ventilation.

▪ 13.2.5 **Protective measures.** Ventilation or other protective measures shall be provided to maintain the levels of gases, vapors, dust, and fumes within the permissible exposure limits specified by OSHA 29 CFR 1910 and the limits specified in the American Conference of Governmental Industrial Hygienists Threshold Limit Values. If a discrepancy exists between these documents, OSHA 29 CFR 1910 shall take precedence. [Source: 29 CFR 1910; MIL-STD-1472D, 1989; MIL-HDBK-759B, 1992]

▪ 13.2.6 **Intakes.** Intakes for ventilation systems shall be located to minimize the introduction of contaminated air from s such as exhaust pipes. [Source: MIL-STD-1472D, 1989; MIL-HDBK-759B, 1992]

- **13.2.7 Control of toxic substances.** If exhaust systems or special ventilating systems are needed to control the concentration of toxic substances, a detailed analysis shall be conducted to identify the substances to be controlled, the health hazard of the substances, and the optimal location and orientation of the ventilating system. For instance, OSHA 29 CFR 1910 addressed ventilation requirements for special operations such as those involving grinding, polishing, buffing, spraying (OSHA 29 CFR 1910.94) and welding (OSHA 29 CFR 1910.252-257). Small confined spaces (inside tanks) present special ventilation problems that may require respirator support. [Source: 29 CFR 1910; 29 CFR 1910.94; 29 CFR 1910.252-257; MIL-STD-1800A, 1990]

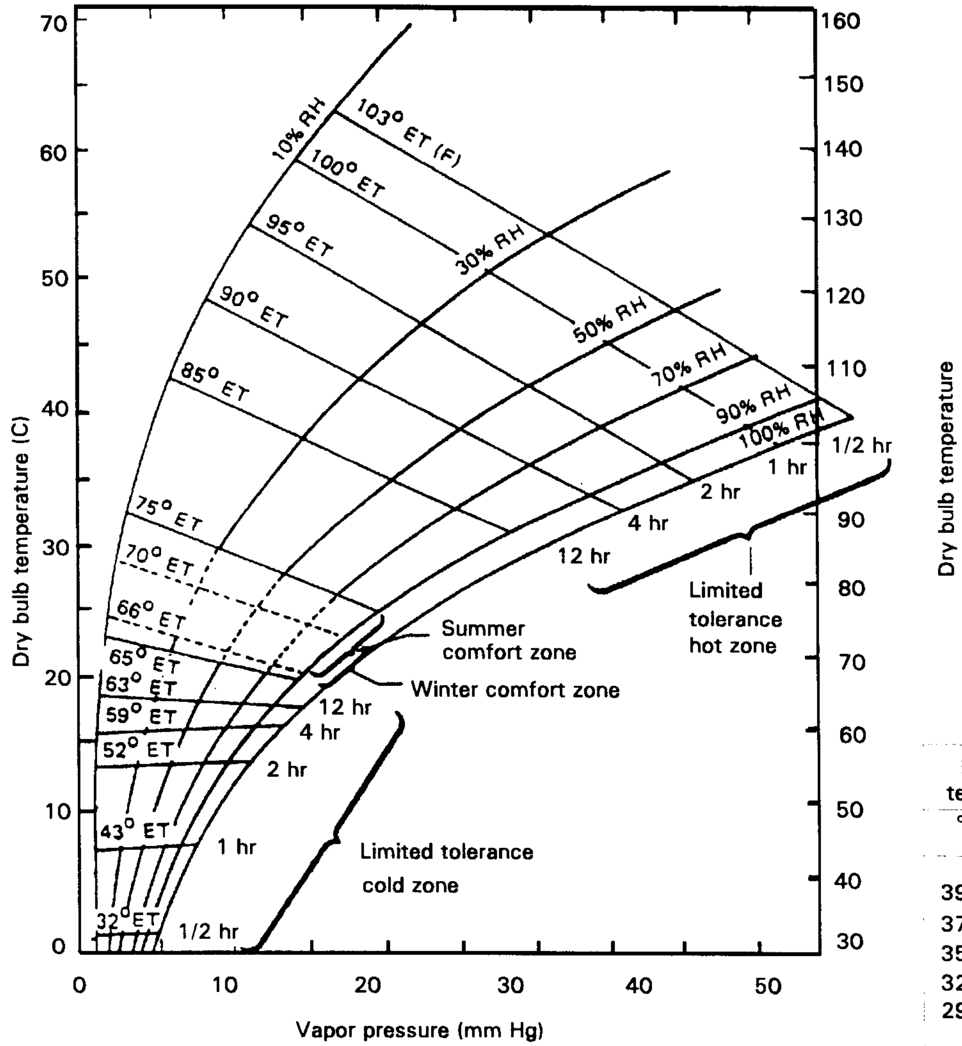
13.3 Temperature and humidity

Maintaining the workplace thermal environment within the range of human tolerance ensures the health, safety and efficiency of the worker.

Heat transfer relationships can become extremely complicated in terms of calculating individual heat balances in the workplace. A tool for determining workplace temperature requirements is the comfort zone chart shown in Exhibit 13.3. The comfort zone varies, depending on clothing and workloads, as shown in the graph. A method of ensuring comfort, in cases where the proper temperature is unknown, is to allow the personnel to set the conditioning controls. In this way, the problem simply becomes one of engineering a heating or cooling system to cope with internal and external hot and cold sources.

Further information for the building environment, including offices, is contained in the latest edition of ANSI/ASHRAE Standard 55. [Source: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1992]

Exhibit 13.3 Comfort zone chart



Conversion of fahrenheit to centigrade: (Celsius) $T_C = 5/9\ (T_F - 32)$

ET = Effective temperature
RH = Relative humidity
hr = Hour

Effective temperature °C	Effective temperature °F
39.4	103
37.8	100
35.0	95
32.2	90
29.4	85
23.9	75
21.1	70
18.9	66
18.3	65
17.2	63
15.0	59
11.1	52
6.1	43
0.0	32

□ **13.3.1 Thermal tolerance and comfort zones.** Temperature and humidity exposure should not exceed the effective temperature limits given in Exhibit 13.3 when corrected for air velocity (see Exhibit 13.3.1). [Source: MIL-STD-1472D, 1989]

Definitions. The **comfort zone** is defined as that range of environmental conditions in which humans can achieve thermal comfort. It is affected by work rate, clothing, and state of acclimatization. **Thermal comfort** can be defined as a mental condition that is based upon the lack of perception of noticeable changes in temperature, and that results in a personal expression of satisfaction with the environment.

Discussion. The optimum temperature for personnel varies according to the nature of the tasks, the conditions under which the tasks are performed, and the clothing personnel are wearing. The optimum range of effective temperature for accomplishing light work while dressed appropriately for the season or climate is 21 - 27°C (70 -80°F) in a warm climate or during the summer, and 18 24°C (65 - 75°F) in a colder climate or during the winter. Effective temperature for the environment can be derived from Exhibit 13.3.

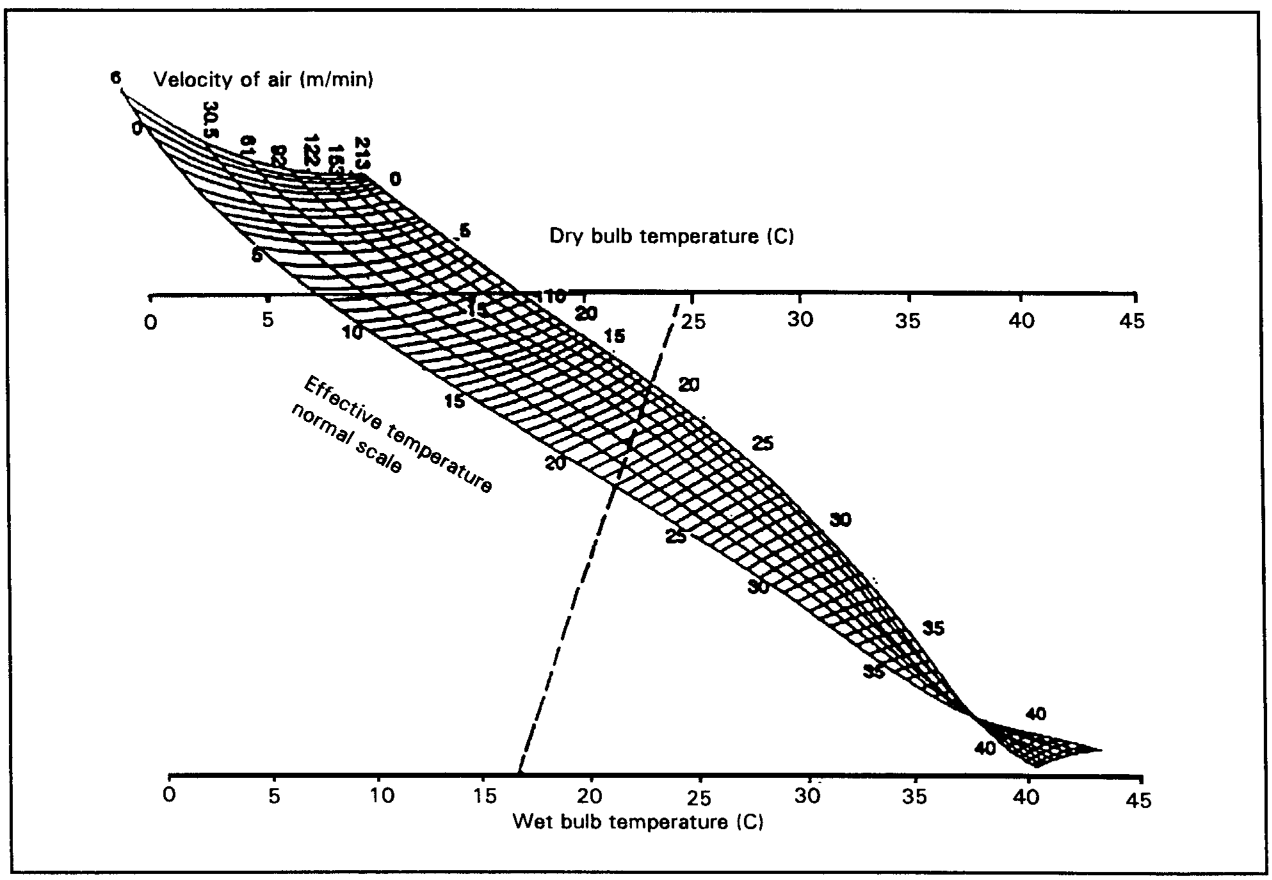


Exhibit 13.3.1 Deriving effective temperature

■ 13.3.2 **Hot air discharge.** Heating systems shall be designed so that hot air discharge is not directed at personnel. [Source: MIL-STD-1472D, 1989]

Definition. The **effective temperature** (ET) is an empirical thermal index that illustrates how combinations of dry bulb air temperature, wet bulb temperature, velocity of air, and clothing affect people. Numerically, it is equal to the temperature of still saturated air that would induce the same sensation, as shown in Exhibit 13.3.1. This chart assumes a worker wearing customary indoor clothing and doing sedentary or light muscular work. It does not include any additional heat stress from special purpose clothing such as chemically protective clothing. Likewise, it does not consider radiant heat sources such as the sun or equipment components.

Discussion. To use the chart above, draw a straight line between dry bulb temperature and wet bulb temperature. The effective temperature is indicated at the point where this straight line crosses the appropriate value for velocity of air. (In this example, the effective temperature is 21.5°C for a dry bulb temperature of 24.5°C, a wet bulb temperature of 16.5°C, and an air velocity of 30.5 mpm).

■ 13.3.3 **Cold air discharge.** Air conditioning systems shall be designed such that cold air discharge is not directed at personnel. [Source: MIL-STD-1472D, 1989]

■ 13.3.4 **Minimum effective temperature.** Minimum temperature requirements are dependent upon the tasks to be performed in specific applications. Within permanent and semi-permanent facilities, provisions shall be made to maintain an effective temperature (ET) not less than 18°C (65°F) (see Exhibit 13.3.1), unless dictated otherwise by workload or extremely heavy clothing. [Source: MIL-STD-1472D, 1989; MIL-HDBK-759B, 1992]

■ 13.3.5 **Maximum effective temperature.** The ET within enclosed workplaces for detailed work during extended periods shall be maintained at or below 29.5°C (85°F). This ET is considered the maximum limit for reliable human performance. [Source: MIL-STD-1472D, 1989]

□ 13.3.6 **ET ranges as a function of work activity.** The ET ranges are flexible because they vary according to the amount of work activity. In general, the ranges should be extended upwards for tasks requiring minimal physical effort and downward for tasks requiring continuous muscular exertion. Dry bulb temperature should be decreased by 1.7°C for each 29 watts per hour increase in metabolic rate above the resting 117 watts per hour level. Relative humidity should be kept at or below 60% to allow sufficient evaporation to avoid perspiration. [Source: MIL-HDBK-759B, 1992]

▫ **13.3.7 Arctic clothing.** A person wearing arctic clothing should not be exposed to temperatures higher than 15.5°C (60°F); a temperature of 1.5° to 7.0°C (32° to 45°F) is optimal. [Source: MIL-HDBK-759B, 1992]

▫ **13.3.8 Temperature of enclosed workplaces.** The temperature throughout enclosed workplaces should be relatively uniform. The temperature of the air at floor level and at head level should not differ by more than 5.6°C (10°F). [Source: MIL-HDBK-759B, 1992]

▫ **13.3.9 Side wall temperatures.** Side walls of enclosed workplaces should be kept at equal temperatures in so far as possible; however, temperature differences of 11°C (20°F) or less do not significantly degrade comfort. [Source: MIL-HDBK-759B, 1992]

▫ **13.3.10 Minimum relative humidity.** A minimum relative humidity of 15 percent should be maintained within all facilities to prevent irritation and drying of body tissues, for example, eyes, skin, and respiratory tract. [Source: MIL-STD-1800A, 1990]

▫ **13.3.11 Relative humidity.** Approximately 45% relative humidity should be provided at 21°C (70°F). This value should decrease with rising temperatures. [Source: MIL-STD-1472D, 1989]

Discussion. Humidity requirements may be driven by the requirement to maintain effective temperature levels.

▪ **13.3.12 Verification of humidity.** Humidity levels shall be verified by tests conducted during normal operations to ensure an acceptable level. [Source: MIL-STD-1800A, 1990]

Discussion. If humidity level requirements are imposed, estimating is inadequate. Direct measurement is the only means of providing the desired accuracy.

▫ **13.3.13 Humidity measurements.** Humidity measurements should be taken at all personnel work stations. [Source: MIL-STD-1800A, 1990]

13.4 Illumination

Criteria for appropriate illumination cannot be satisfied merely by providing a sufficient amount of light to perform tasks or by providing emergency lighting (approximately 32 lux) to enable personnel to operate important controls or to find the exit. The following factors need to be considered:

a. the brightness contrast between each visual task object and its background,

b. the glare from work surfaces and light sources,

c. the level of illumination required for the most difficult tasks,

d. the color composition of the illumination source and the equipment surfaces,

e. the time and accuracy required in task performance, and

f. the possible variations in operating conditions (such as outdoor panel blackout operation or outdoor panel visibility under bright sunlight) that may affect the lighting system, the task, or the personnel.

Design requirements are provided in this section for (1) illumination of specific tasks, (2) illumination for dark adaptation, (3) glare from light sources, (4) reflected glare, (5) brightness ratios, (6) lighting fixtures and controls, and (7) workstation illumination.

13.4.1 General

In addition to the following illumination rules, see the "Lighting Handbook from the Illuminating Engineering Society", for general lighting design footcandle levels and formulas. [Source: Illuminating Engineering Society of North America, 1993]

- 13.4.1.1 **General and supplementary lighting.** Both general and supplementary lighting shall be used as appropriate to ensure that illumination is compatible with each operation and maintenance task situation. [Source: MIL-STD-1472D, 1989]

- 13.4.1.2 **Dimming capability.** A light dimming capability shall be provided. [Source: MIL-STD-1472D, 1989]

▫ **13.4.1.3 Illumination in workplaces.** As a general rule, illumination in workplaces should eliminate glare and shadows that interfere with prescribed tasks. [Source: National Aeronautics and Space Administration (NASA-STD-3000A), 1989]

Definitions. Illumination is the amount of light (luminance flux) falling on a surface. Measured in lumen/m2 = lux = 0.093 ft-c. Illumination decreases with the square of the distance from a point source. **Luminance** is the amount of light per unit area emitted or reflected from a surface. Measured in candela per square meter (cd/m2), footlamberts (ft-L), or millilamberts (mL). 1.0 cd/m2 = 0.31 mL = 0.29 ft-L. The luminance of a surface does not vary with the distance of the observer from the surface being viewed.

13.4.2 Illumination for the workplace and specific tasks

▪ **13.4.2.1 Lighting level.** The lighting level shall be measured on the work surfaces, (30 inches above the floor in the absence of work surfaces), or at visual interfaces, (for example, CRT and panels), where appropriate. [Source: NASA-STD-3000A, 1989]

▪ **13.4.2.2 Illumination.** Workplace illumination shall be appropriate to the tasks to be accomplished. See Exhibit 13.4.2.2 for illumination requirements. [Source: NASA-STD-3000A, 1989]

Exhibit 13.4.2.2 Specific task illumination requirements

Work area or type of task	Illumination levels Lux (ft - C) Recommended		Minimum	
Bench work				
rough	540	(50)	325	(30)
medium	810	(75)	540	(50)
fine	1615	(150)	1075	(100)
extra fine	3230	(300)	2155	(200)
Business machine operation (calculator, digital, etc)	1075	(100)	540	(50)
Console surface	540	(50)	325	(30)
Corridors	215	(20)	110	(10)
Dials	540	(50)	325	(30)
Electrical equipment testing	540	(50)	325	(30)
Emergency lighting	NA		30	(3)
Gauges	540	(50)	325	(30)
Inspection tasks, general				
rough	540	(50)	325	(30)
medium	1075	(100)	540	(50)
fine	2155	(200)	1075	(100)
extra fine	3230	(300)	2155	(200)
Machine operation, automatic	540	(50)	325	(30)
Meters	540	(50)	325	(30)
Office work, general	755	(70)	540	(50)
Ordinary seeing tasks	540	(50)	325	(30)
Panels				
front	540	(50)	325	(30)
rear	325	(30)	110	(10)
Passageways	215	(20)	110	(10)
Reading				
large print	325	(30)	110	(10)
newsprint	540	(50)	325	(30)
handwritten reports in pencil	755	(70)	540	(50)
small type	755	(70)	540	(50)
prolonged reading	755	(70)	540	(50)
Recording	755	(70)	540	(50)

Exhibit 13.4.2.2 (continued) Specific task illumination requirements

Illumination levels

Work area or type of task	Recommended Lux	(ft - C)	Minimum Lux	(ft - C)
Repair work:				
general	540	(50)	325	(30)
instrument	2155	(200)	1075	(100)
Screw fastening	540	(50)	325	(30)
Service areas, general	215	(20)	110	(10)
Stairways	215	(20)	110	(10)
Storage				
inactive or dead	55	(5)	30	(3)
general warehouse	110	(10)	55	(5)
live, rough or bulk	110	(10)	55	(5)
live, medium	325	(30)	215	(20)
live, fine	540	(50)	325	(30)
Tanks, container	215	(20)	110	(10)
Testing				
rough	540	(50)	325	(30)
fine	1075	(100)	540	(50)
extra fine	2155	(200)	1075	(100)
Transcribing and tabulation	1075	(100)	540	(50)

- **13.4.2.3 Glare.** Lighting sources shall be designed and located to avoid creating glare from working and display surfaces, as viewed from any normal working position. [Source: NASA-STD-3000A, 1989]

13.4.3 Illumination levels to maintain dark adaptation

- **13.4.3.1 Maximum dark adaptation.** All transilluminated displays and controls shall be visible when all other lighting is turned off. If maximum dark adaptation is required, red lighting or low level white lighting [CIE color coordinates for x and y equals 0.330 +/- 0.030 (1932)] is acceptable. [Source: NASA-STD-3000A, 1989]

■ **13.4.3.2 Dark adaptation for task performance.** If dark adaptation is required for performance of tasks, the following steps shall be taken:

a. Low level lighting that minimizes loss of dark adaptation shall be provided for task performance.

b. Areas requiring low level illumination shall be protected from external light sources.

c. All external windows shall be provided with protective light shields (shades or curtains).

d. All doors shall be light-proof when closed. [Source: NASA-STD-3000A, 1989]

Definition. Dark adaptation is the process by which the eyes become more sensitive in dim light. The eyes adapt almost completely in about 30 minutes, but the time required for dark adaptation depends on the color, duration of exposure and intensity of the previous light.

Discussion. Ambient light is incompatible with dark adaptation. If it is dimmed enough so that it does not interfere with dark adaptation, it will not be bright enough by which to work. Minimum interference with adaptation is produced by brief exposure of the lowest intensity possible. Colors often appear different under different types of illumination, so unless a display will always be used under ambient light, do not use color coding.

□ **13.4.3.3 Ambient light and dark adaptation.** Where both ambient light and dark adaptation are required, the conflict should be resolved by evaluating the priorities of the operator's tasks. [Source: MIL-HDBK-759B, 1992]

13.4.4 Glare from light sources

One of the most serious illumination problems is glare from surfaces. Relatively bright light shining into the observer's eyes as he or she tries to observe a dim visual field, and reflected glare from work surfaces are common causes of reduced performance in visual tasks. Glare not only reduces visibility of objects in the field of view but causes visual discomfort.

Definition. Glare is produced by any luminance within the visual field that is sufficiently greater than the luminance to which the eye is adjusted. Glare causes eye fatigue, discomfort, and annoyance, as well as interfering with visual performance and visibility.

▪ **13.4.4.1 Glare from artificial light sources.** The following measures shall be taken to avoid glare from artificial light sources:

a. Locate light sources so that they do not shine directly at personnel. Light sources shall not be located within 60 degrees in any direction from the center of the visual field.

b. If additional lighting is needed, use dim light sources rather than bright ones.

c. Use polarized light, shields, hoods, lens, diffusers, or visors.

d. Use indirect lighting where possible.

e. Ensure that the maximum to average luminance ratio does not exceed 5:1 across the viewing area. Six test readings shall be taken in the work area to determine the average luminance of the area. [Source: NASA-STD-3000A, 1989]

Definition. Luminance ratio is the difference between the source of light of an object and its surroundings.

13.4.5 Reflected glare

- 13.4.5.1 **Specular reflectance from the task area and the surrounding area.** Luminance of specular reflectance from the task area shall not be greater than 3 times the average luminance of the surrounding area. [Source: NASA-STD-3000A, 1989]

  Definitions. A **Specular surface** is one that provides a specular reflection, a shiny surface. **Reflectance** is the ratio of luminous flux reflected from a surface to luminous flux striking it.

- 13.4.5.2 **Work surface reflection.** Work surface reflection shall be diffused and shall not exceed a reflectance of .2°. [Source: NASA-STD-3000A, 1989]

- 13.4.5.3 **Angle of incidence.** Direct light sources shall be arranged so their angle of incidence to the visual work area is not the same as the operator's viewing angle. [Source: NASA-STD-3000A, 1989]

- 13.4.5.4 **Polished surfaces.** Placement of smooth, highly polished surfaces within 60° of the user's normal visual field shall be avoided. [Source: NASA-STD-3000A, 1989]

- 13.4.5.5 **Light source behind user.** The placement of light sources behind users that reflect glare into the user's eyes shall be avoided. [Source: NASA-STD-3000A, 1989]

13.4.6 Brightness ratio

- 13.4.6.1 **Wall surface luminance.** Wall surface average luminance shall be within 50 to 80 percent of ceiling surface average luminance. [Source: NASA-STD-3000A, 1989]

- 13.4.6.2 **Maximum and minimum luminance ratio.** The maximum to minimum luminance ratio for any surface shall not exceed 10:1. [Source: NASA-STD-3000A, 1989]

- 13.4.6.3 **Brightness ratio.** The brightness ratios between the lightest and darkest areas or between a task area and its surroundings shall be no greater than specified in Exhibit 13.4.6.3. [Source: NASA-STD-3000A, 1989]

  Definition. Brightness is an attribute of visual sensation that is determined by the intensity of light radiation reaching the eye.

Exhibit 13.4.6.3 Required brightness ratios

	Environmental classification		
Comparison	**A**	**B**	**C**
Between lighter surfaces and darker surfaces within the task	5 to 1	5 to 1	5 to 1
Between tasks and adjacent darker surroundings	3 to 1	3 to 1	5 to 1
Between tasks and adjacent lighter surroundings	1 to 3	1 to 3	1 to 5
Between tasks and more remote darker surfaces	10 to 1	20 to 1	b
Between tasks and more remote lighter surfaces	1 to 10	1 to 20	b
Between luminaries and adjacent surfaces	20 to 1	b	b
Between the immediate work area and the rest of the environment	40 to 1	b	b

Notes:

A - Interior areas where reflectances of entire space can be controlled for optimum visual conditions.

B - Areas where reflectances of nearby work can be controlled, but there is only limited control over remote surroundings.

C - Areas (indoor and outdoor) where it is completely impractical to control reflectances and difficult to alter environmental conditions.

b - Brightness ratio control not practical.

13.4.7 Lighting fixtures

- **13.4.7.1 Emergency lights.** An independent, self-energizing illumination system shall be provided that will be automatically activated in the event of a major primary power failure or main lighting circuit malfunction resulting in circuit breaker interruption. If the back-up illumination system is a standby engine generator, it shall provide power within 15 seconds of a failure and shall be capable of sustained operation for a minimum of 72 hours. If the back-up illumination system is a standby battery system, it shall provide power immediately upon failure and shall be capable of sustained operation for a minimum of four hours. [Source: NASA-STD-3000A, 1989; Department of Transportation (FAA Order 6950.2C), 1985]

- **13.4.7.2 Controls location.** Lighting controls shall be provided at entrances and exits of enclosed workplace areas. [Source: NASA-STD-3000A, 1989]

- **13.4.7.3 Artificial illumination controls.** Lighting controls for artificial illumination of a workstation shall be located within the reach envelope of the user at the display and control panel or workstation affected. [Source: NASA-STD-3000A, 1989]

- **13.4.7.4 Control identification.** Lighting controls shall be illuminated in areas that are frequently darkened. [Source: NASA-STD-3000A, 1989]

- **13.4.7.5 Flicker.** Light sources shall not have a perceptible flicker. [Source: NASA-STD-3000A, 1989]

- **13.4.7.6 Protection from personnel activity.** Light sources shall be protected from damage by personnel activity. [Source: NASA-STD-3000A, 1989]

- **13.4.7.7 Portable lights.** Portable lights shall be provided for illumination of inaccessible areas or as supplemental lighting for tasks. [Source: NASA-STD-3000A, 1989]

13.5 Noise

Exposure to high levels of noise can cause hearing loss. The nature and extent of the hearing loss depends upon the intensity and frequency of the noise and the duration of the exposure. Noise induced hearing loss may be temporary or permanent. Temporary loss results from short-term exposure to noise; loss from prolonged exposure is irreversible. It can be arrested and prevented through administrative and engineering controls or through the use of ear protection.

13.5.1 Hazardous sound levels

- 13.5.1.1 **Reducing sound levels.** Administrative or engineering controls shall be used to reduce sound levels within the permissible exposure limit (PEL). These PELs are established in FAA Order 3910.4 and are given in Exhibit 13.5.1.1. [Source: Department of Transportation (FAA Order 3910.4), 1985]

Exhibit 13.5.1.1 Permissible exposure limits

Duration per day (hours)	Sound level (dBA slow)
8.0	90
6.0	92
4.0	95
3.0	97
2.0	100
1.5	102
1.0	105
0.5	110
0.25 or less	115

Maximum exposure to impulse or impact noise is 140 dB peak sound pressure level.

- 13.5.1.2 **Providing personal protection.** If administrative or engineering controls fail to reduce sound levels within the PELs, personal protective equipment shall be provided and a continuing effective hearing conservation program shall be administered in accordance with FAA Order 3910.4. [Source: FAA Order 3910.4, 1985]

▪ **13.5.1.3 Noise exposure**. Occupational noise exposure levels shall be predicted, tested, monitored, and computed in accordance with FAA Order 3910.4. [Source: FAA Order 3910.4, 1985]

Discussion. Monitoring the noise levels will identify users who are exposed to levels equal to or greater than:

a. the 90 dBA, 8-hour time-weighted average (TWA) (or 100 percent dose) PEL, or

b. the 85 dBA, 8-hour TWA (or 50 percent dose) action level.

Definitions. Action level is an 8-hour time-weighted-average noise level of 85 dBA or, equivalently, a noise dose of 50 percent, at which affected users will be provided hearing protection and placed in an audiometric testing program. **Dose** is the accumulated exposure to noise.

▪ **13.5.1.4 Monitoring results and corrective action.** If testing or monitoring reveals that the 8-hour TWA exposure level is:

a. less than 85 dBA (or 50 percent dose); no further action shall be required,

b. equal to or greater than the action level, 85 dBA (or 50 percent dose), the user(s) affected shall be provided hearing protection and placed in a hearing conservation program, or

c. equal to or greater than the PEL, 90 dBA (or 100 percent dose), the user(s) affected shall be provided hearing protection and placed in a hearing conservation program, and feasible administrative and engineering controls shall be used to reduce the noise to acceptable levels. [Source: FAA Order 3910.4, 1985]

13.5.2 Nonhazardous sound levels

▫ **13.5.2.1 Acoustical design objectives.** The acoustical design objectives for a work space should consider a balance of sound from all sources. [Source: American National Standards Institute (ANSI/HFS 100-1988), 1988]

Discussion. Where appropriate, the background noise level should be low enough to avoid interference with activity or speech, but high enough to mask intrusive sounds from adjacent spaces.

- **13.5.2.2 Personnel acoustical environment.** Personnel shall be provided with an acoustical environment that does not interfere with the performance of their tasks. They shall be protected from noise that could cause physical impairment. [Source: MIL-STD-1800A, 1990]

- **13.5.2.3 General noise levels.** Workplace noise shall be maintained at levels that do not: (1) interfere with necessary voice, telephone, and radio communication, (2) cause fatigue or injury, and (3) degrade overall system effectiveness. [Source: MIL-STD-1800A, 1990]

- **13.5.2.4 Noise criteria.** Noise criteria are defined by both the A-weighted sound level, dB(A), and the preferred speech interference level, PSIL-4. Use of the A-weighted sound level is preferable. Where it is not possible to meet the specified A-weighted sound level requirement, the corresponding PSIL-4 requirement shall be met. [Source: MIL-STD-1800A, 1990]

  Definitions. Preferred speech interference level (PSIL-4) is a measure of the effectiveness of noise in masking speech. **Speech interference level (SIL or SIL-4)** is the arithmetic mean, in dB, of sound pressure levels in the four octave bands with center frequencies of 500, 1000, 2000, and 4000 Hz. **A-weighted sound level (dB(A))** is a sound pressure level (in decibels) measured using a sound level meter with an A-weighting network. The A-weighted response is maximum at 2500 Hz, drops rapidly as frequency decreases below 1000 Hz, and gradually increases above 4000 Hz, thereby approximating the frequency dependent human response to moderate sound levels. ANSI S1.4 gives the definition of A-weighting filter characteristics. [Source: American National Standards Institute (ANSI/ASA S1.4-1983)), 1983]

- **13.5.2.5 Extreme quiet areas.** Ambient noise in areas requiring extreme quiet shall not exceed 35 dB(A) or 27 dB PSIL-4. [Source: MIL-HDBK-759B, 1992]

- **13.5.2.6 Small office spaces and special areas.** Ambient noise in areas requiring no difficulty with speech communication (for example, libraries and classrooms) shall not exceed 45 dB(A) or 37 dB PSIL-4; conference rooms and offices shall not exceed 38 dB PSIL-4. [Source: Department of Transportation (FAA-G-2100F), 1993; MIL-HDBK-759B, 1992]

- **13.5.2.7 Operational areas.** Ambient noise in areas requiring frequent phone use or requiring occasional speech communication (for example, operations centers, control rooms, tower cabs, and dynamic simulation rooms) at distances up to 4.6 m (15 ft) shall not exceed 55 dB(A) or 47 dB PSIL-4; shop offices and laboratories shall not exceed 48 dB PSIL-4. [Source: FAA-G-2100F, 1993; MIL-HDBK-759B, 1992]

- 13.5.2.8 **Equipment areas.** Ambient noise in areas requiring frequent telephone use or frequent speech communication (for example, computer rooms, engineering areas, equipment rooms, and telephone switching centers) at distances up to 1.5 m (5 ft) shall not exceed 65 dB(A) or 57 dB PSIL-4. [Source: FAA-G-2100F, 1993; MIL-HDBK-759B, 1992]

- 13.5.2.9 **High noise, remote areas.** High noise, remote areas that are normally unmanned shall not exceed 85 dB(A). [Source: FAA-G-2100F, 1993]

- 13.5.2.10 **Occupational noise exposure and control.** Administrative or engineering controls shall be used to reduce the sound levels to within permissible noise exposure levels listed in Exhibit 12.12.8. OSHA 29 CFR 1910.95 shall be used in determining equivalent A-weighted sound levels for daily exposure. A hearing conservation program shall be administered any time an employee's noise exposure equals or exceeds an 8-hour time weighted average of 85 db measure on the A scale (slow response) or equivalent without regard to attenuation that may be provided by personal protective equipment. OSHA 29 CFR 1910.95 shall govern the hearing protection program. [Source: 29 CFR 1910.95]

Glossary

Action level - An 8-hour time-weighted-average noise level of 85 dBA or, equivalently, a noise dose of 50 percent, at which affected users will be provided hearing protection and placed in an audiometric testing program.

Brightness: an attribute of visual sensation that is determined by the intensity of light radiation reaching the eye.

Comfort zone - That range of environmental conditions in which humans can achieve thermal comfort. It is affected by work rate, clothing, and state of acclimatization.

Dark adaptation - The process by which the eyes become more sensitive in dim light. The eyes adapt almost completely in about 30 minutes, but the time required for dark adaptation depends on the color, duration of exposure and intensity of the previous light.

Dose - The accumulated exposure to noise.

Effective temperature - An empirical thermal index that illustrates how combinations of dry bulb air temperature, wet bulb temperature, velocity of air, and clothing affect people.

Glare - Is produced by any luminance within the visual field that is sufficiently greater than the luminance to which the eye is adjusted. Glare causes eye fatigue, discomfort, and annoyance, as well as interfering with visual performance and visibility.

Illumination - The amount of light (luminance flux) falling on a surface. Measured in lumen/m2 = lux = 0.093 ft-c. Illumination decreases with the square of the distance from a point source.

Luminance - The amount of light per unit area emitted or reflected from a surface. Measured in candela per square meter (cd/m2), footlamberts (ft-L), or millilamberts (mL). 1.0 cd/m2 = 0.31 mL = 0.29 ft-L. The luminance of a surface does not vary with the distance of the observer from the surface being viewed.

Luminance ratio - The difference between the source of light of an object and its surroundings.

Preferred speech interference level (PSIL-4) - A measure of the effectiveness of noise in masking speech.

Reflectance - The ratio of luminous flux reflected from a surface to luminous flux striking it.

Specular surface - One that provides a specular reflection, a shiny surface.

Speech interference level (SIL or SIL-4) - the arithmetic mean of sound pressure levels in the four octave bands with center frequencies of 500, 1000, 2000, and 4000 Hz.

Thermal comfort - Defined as a mental condition that is based upon the lack of perception of noticeable changes in temperature, and that results in a personal expression of satisfaction with the environment.

Ventilation - The process of supplying air to or removing air from any space by natural or mechanical means. From the standpoint of comfort and health, ventilation issues involve both quantity and quality.

Weighted sound level (dB(A)) - a sound pressure level (in decibels) measured using a sound level meter with an A-weighting network. The A-weighted response is maximum at 2500 Hz, drops rapidly as frequency decreases below 1000 Hz, and gradually increases above 4000 Hz, thereby approximating the frequency dependent human response to moderate sound levels. ANSI S1.4 gives the definition of A-weighting filter characteristics.

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14 Anthropometry and biomechanics

Designers and human factors specialists incorporate scientific data on human physical capabilities into the design of systems and equipment. Human physical characteristics, unlike those of machines, cannot be designed. However, failure to take into account human physical characteristics when designing systems or equipment can place unnecessary demands and restrictions upon user personnel.

Definitions. Anthropometry is the scientific measurement and collection of data about human physical characteristics and the application (engineering anthropometry) of these data in the design and evaluation of systems, equipment, manufactured products, human-made environments, and facilities. **Biomechanics** describes the mechanical characteristics of biological systems, in this case the human body, in terms of physical measures and mechanical models. This field is interdisciplinary (mainly anthropometry, mechanics, physiology, and engineering). Its applications address mechanical structure, strength, and mobility of humans for engineering purposes.

This chapter of the HFDS provides additional anthropometric and biomechanics data beyond that used in other chapters. Previous data are cross-referenced, where appropriate. Unlike the other sections, this section provides more guidance about the nature of the data, its selection, and its proper use. It provides rules for applying the vast amount of human form data available to specific design fit, function, and human task performance.

The section also covers application principles and their resulting rules, human body measurement data (static and dynamic), range of motion and strength data, as well as comfort information.

14.1 General application of anthropometric and biomechanic data

In this document, body size, strength, and mobility data are presented. In the future, this population will include a wider range of ethnic backgrounds. Minorities and females are expected to increase. The average age is expected to decrease. These changes will be important for future systems design.

In this general section, design criteria and rules are given for: (1) ascertaining user population data, (2) using the design limits approach, (3) avoiding pitfalls in applying the data, (4) using distribution and correlation data, (5) solving design problems, and (6) using models.

14.1.1 User population

Anthropometric data are most appropriate when they are derived from a survey of the existing worker population of interest. Since the sub-population associated with the FAA has not been surveyed, information from substitute sources is used as a basis for design.

▪ **14.1.1.1 Use of data.** Anthropometric and biomechanics data shall be used in the design of systems, equipment (including personal protection equipment), clothing, workplaces, passageways, controls, access openings, and tools. [Source: National Aeronautics and Space Administration (NASA-STD-3000A), 1989]

> **Discussion.** The human's interface with other system components needs to be treated as objectively and systematically as are other interface and hardware component designs. It is not acceptable to guess about human physical characteristics or to use the designer's own measurements or the measurements of associates. Application of appropriate anthropometric and biomechanics data is expected.

- **14.1.1.2 Data to be used.** Designers and human factors specialists shall use the anthropometric and biomechanics data provided in this document. If additional data are needed, they shall use the more complete data given in DOD-HDBK-743A. If other reference or new data collections are considered, the contractor shall obtain the approval of the acquisition program office. [Source: NASA-STD-3000A, 1989; Department of Defense (DOD-HDBK-743A), 1991]

  Discussion. If this document does not present data needed for the problem at hand, the designer will have to select appropriate sample information from DOD-HDBK-743A. In that handbook, the 1988 military male and female survey distributions can be used to represent the FAA user population when needed, as it represents the most comprehensive samples available. Note that civilian working populations could be expected to have a larger range of sizes and ages than the military. Samples with comprehensive measures are not available.

- **14.1.1.3 Using population extremes.** Designers and human factors specialists shall draw upon the extremes of the larger male population distribution and the extremes of the smaller female population distributions to represent the upper and lower range values, respectively, to apply to anthropometric and biomechanics design problems. [Source: NASA-STD-3000A, 1989]

  Discussion. The use of separate male and female population data is a conservative approach that results in more inclusive design dimensions than the same percentiles would from a composite population.

14.1.2 Using design limits

Initial rules in this section address the design limits approach. To understand this approach, it is helpful to consider the overall steps and choices that one makes in applying anthropometric and biomechanics data. The design limits approach entails selecting the most appropriate percentile values in population distributions and applying the appropriate associated data in a design solution. These steps are listed in this introductory material and are explained in detail in the initial three rules of this subsection. If the reader has applied the design limit approach and understands it, the reader can skip the rest of this introductory material as well as the explanations associated with the first three rules. However the reader should not skip the rules.

Definition. The design limits approach is a method of applying population or sample statistics and data about human physical characteristics to a design so that a desired portion of the user population is accommodated by the design. The range of users accommodated is a function of limits used in setting the population portion.

To understand the design limits approach, it is helpful to consider step by step the choices that design personnel make in applying these human physical data.

a. Select the correct human physical characteristic and its applicable measurement characteristic (description) for the design problem at hand.

b. Select the appropriate population, representative sample, or rule information on the selected human physical characteristic and measurement description to apply to the design problem.

c. Determine the appropriate statistical point(s), usually percentile points from rule information or from the sample distribution(s) in order to accommodate a desired range of the human characteristic within the distribution of the user population.

d. Read directly or determine statistically the measurement value(s) that corresponds to the selected statistical point(s) relevant to the population distribution.

e. Incorporate the measurement value as a criterion for the design dimension, or in the case of biomechanics data, for the movement or force solution in the design problem.

- **14.1.2.1 Clearance dimension at the 95th percentile.** Design clearance dimensions that must accommodate or allow passage of the body or parts of the body shall be based upon the 95th percentile of the male distribution data. [Source: Department of Defense (MIL-STD-1472D), 1989]

- **14.1.2.2 Limiting dimension at the 5th percentile.** Limiting design dimensions, such as reach distances, control movements, display and control locations, test point locations, and handrail positions, that restrict or are limited by body or body part size, shall be based upon the 5th percentile of female data for applicable body dimensions. [Source: MIL-STD-1472D, 1989]

  Discussion. For example, the maximum height from floor level to an accessible part of any piece of equipment needs to be within reach of the 5th percentile female user, which will ensure that at least 95 percent of the user population can access this part of the equipment.

- **14.1.2.3 Adjustable dimensions.** Any equipment dimensions that need to be adjusted for the comfort or performance of the individual user shall be adjustable over the range of the 5th to 95th percentiles. [Source: MIL-STD-1472D, 1989]

- **14.1.2.4 Sizing determinations.** Clothing and certain personal equipment dimensions that need to conform closely to the contour of the body or body parts shall be designed and sized to accommodate at least the 5th through the 95th percentile range. If necessary, this range shall be accommodated by creating a number of unique sizes, where each size accommodates a segment of the population distribution. Each segment can be bounded by a small range of percentile values. [Source: MIL-STD-1472D, 1989]

- **14.1.2.5 Critical life support equipment.** Dimensions or sizes of critical life support equipment shall accommodate, at least, the range defined by the 1st through the 99th percentiles of the distribution. [Source: MIL-STD-1472D, 1989]

14.1.3 Avoiding pitfalls in applying anthropometric data

There are several common errors to be avoided by designers when they apply anthropometric data to design. These are: (1) designing to the midpoint (50th percentile) or average, (2) the misperception of the typical sized person, (3) generalizing across human characteristics, and (4) summing of measurement values for like percentile points across adjacent body parts.

- 14.1.3.1 **Misuse of the 50th percentile or of the average.** The 50th percentile or mean shall not be used as design criteria as it accommodates only half of the users. [Source:NASA-STD-3000A, 1989]

  Discussion. When the population distribution is Gaussian (normal), the use of either the 50th percentile or the average for a clearance would, at best, accommodate half the population.

- 14.1.3.2 **Misperception of the typically sized person.** Designers or human factors specialists shall not use the concept of a typically sized person where the same percentiles values are expected across many dimensions. A person at the 95 percentile in height is unlikely to measure at the 95th percentile in reach or other dimensions. A percentile value and its measurement value that pertains to a particular body part shall be used exclusively for functions that relate to that body part. [Source: Department of the Air Force (AFSC DH 1-3), 1980; NASA-STD-3000A, 1989]

  Discussion. When the middle 30 percent of a population of 4000 men was measured on 10 dimensions, only one-fourth of them were "average" in a single dimension (height), and less than 1 percent were average in five dimensions (height, chest circumference, arm length, crotch height, and torso circumference). Keeping in mind that there is not an "average person," one also must realize that there is not a "5th percentile person" nor a "95th percentile" person. Different body part dimensions are not necessarily highly correlated. An implication is that one can not choose a person who is 95 percentile in stature as a test subject for meeting 95 percentile requirements in reach or other dimensions.

- **14.1.3.3 Summation of segment dimensions.** Summation of like percentile values for body components shall not be used to represent any human physical characteristic that appears to be a composite of component characteristics. [Source: NASA-STD-3000A, 1989]

  Discussion. The 95th percentile arm length, for instance, is not the addition of the 95th percentile shoulder-to-elbow length plus the 95th percentile elbow-to-hand length. The actual 95th percentile arm length will be somewhat less than the erroneous summation. To determine the 95th percentile arm length, one must use a distribution of arm length rather than component part distributions.

14.1.4 Solving a complex sequence of design problems

In this section, rules are presented for approaching complex design problems that require the consideration of a sequence of relevant design reference locations (such as seat reference points and eye reference zones), human physical characteristics, statistical points, and measures. The recommended approach involves identifying the necessary human activities and positions and establishing reference points and envelopes for the necessary activities. These envelopes impact the location and design of controls and displays, as well as the placement of work surfaces, equipment, and seating accommodations. The effects of clothing or carried equipment are then used to expand the dimensions.

- **14.1.4.1 Design to body positions and motions of the tasks.** Design personnel shall base the necessary operator and user body positions and motions on personnel tasks to be performed during normal, degraded, and emergency modes of operations and maintenance. [Source: NASA-STD-3000A, 1989]

■ 14.1.4.2 **Construction or collection of unique position data.** If the common and mobile working positions data in Chapter 10 of this document do not represent the unique working positions associated with a design, then design personnel shall construct the applicable human physical characteristics and measures from the static and dynamic data provided later in Sections 14.3.2 and 14.3.3 or in DOD-HDBK-743A. If no applicable data can be found or calculated for important design measures, then, with the prior approval of the acquisition program office, sample measures shall be taken on appropriate personnel for the unique working positions. [Source: DOD-HDBK-743A, 1991; Roebuck, Kroemer, & Thomson, 1975]

Discussion. Anthropometric measurement needs to be done by professionals because there are many complexities and potential interactions among positions of body segments, as well as many technical points and pitfalls to avoid in measurement practice. Sample measurement methods can be found in Roebuck, Kroemer, and Thomson, 1975.

□ 14.1.4.3 **Building and using reach envelopes.** If reach data provided in this document (see Section 14.4) do not apply to a specific design problem, then reach design dimensions or envelopes for design use should be constructed considering:

a. one-handed or two-handed operation,

b. grasp requirements which may affect the functional reach envelope,

c. positional relationship of a shoulder reference point or arm rotation point to the seat back, seat reference point, or other posture reference or design reference points, and

d. the appropriate samples and anthropometric measurements from the data provided in this document or in DOD-HDBK-743A, 1991 (see Paragraph 14.1.1.2). [Source: DOD-HDBK-743A, 1991]

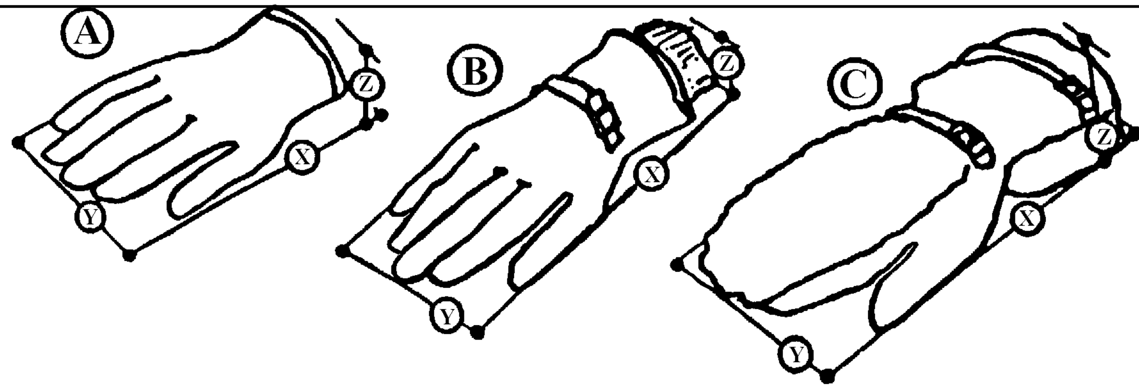
- **14.1.4.4 Effects of clothing.** Because most anthropometric data presented in this document and in other data sources represent nude body measurements (unless otherwise indicated), suitable allowances shall be made for light, medium, or heavy clothing and for any special protective equipment that is worn. Exhibit 14.1.4.4 illustrates the additive effects of clothing on static body dimensions and shows the 95th percentile gloved hand measures. If special items of protective clothing or equipment are involved, the effects shall be measured in positions required by the users' tasks. The effects on the extremes of the population distribution shall be determined. [Source: Department of Defense (MIL-HDBK-759B), 1992; Johnson, 1984]

  Discussion. Nude dimension and light clothing can be regarded as synonymous for practical purposes. Additional information on the changes in anthropometric measurement values imposed by different clothing ensembles is found in Johnson, 1984.

Exhibit 14.1.4.4 Additive effects of clothing on anthropometric measures

	Light clothing	Medium clothing	Heavy clothing
Abdomen depth	2.39 cm (0.94 in)	3.00 cm (1.18 in)	6.45 cm (2.54 in)
Buttock-knee length	0.51 cm (0.20 in)	0.76 cm (0.30 in)	1.78 cm (0.70 in)
Chest depth	1.04 cm (0.41 in)	2.44 cm (0.96 in)	3.91 cm (1.54 in)
Elbow breadth	1.42 cm (0.56 in)	2.64 cm (1.04 in)	5.38 cm (2.12 in)
Hip breadth	1.42 cm (0.56 in)	1.93 cm (0.76 in)	3.56 cm (1.40 in)
Hip breadth, sitting	1.42 cm (0.56 in)	1.93 cm (0.76 in)	3.56 cm (1.40 in)
Knee breadth (both)	1.22 cm (0.48 in)	1.22 cm (0.48 in)	4.27 cm (1.68 in)
Knee height, sitting	3.35 cm (1.32 in)	3.35 cm (1.32 in)	3.66 cm (1.44 in)
Shoulder breadth	0.61 cm (0.24 in)	2.24 cm (0.88 in)	2.95 cm (1.16 in)
Shoulder-elbow length	0.36 cm (0.14 in)	1.27 cm (0.50 in)	1.57 cm (0.62 in)
Shoulder height, sitting	0.41 cm (0.16 in)	1.47 cm (0.58 in)	2.03 cm (0.80 in)

Exhibit 14.1.4.4 (continued) Additive effects of clothing on anthropometric measures



Hand position	A Anti-contact glove X	Y	Z	B Wet-cold glove X	Y	Z	C Arctic glove X	Y	Z
Extended flat cm	26.7	11.9	6.4	27.2	14.5	7.6	42.2	13.7	9.1
(in)	(10.5)	(4.7)	(2.5)	(10.7)	(5.7)	(3.0)	(16.6)	(5.4)	(3.6)
Closed as fist cm	17.8	12.7	8.4	18.5	14.7	9.4	36.3	13.2	13.7
(in)	(7.0)	(5.0)	(3.3)	(7.3)	(5.8)	(3.7)	(14.3)	(5.2)	(5.4)
Grasping handle									
0.6 cm (0.24 in)	17.8	12.7	8.9	18.5	14.0	8.9	35.6	14.0	11.4
diameter	(7.0)	(5.0)	(3.5)	(7.3)	(5.5)	(3.5)	(14.0)	(5.5)	(4.5)
2.5 cm (1.0 in)	17.8	12.7	8.9	18.5	13.5	10.2	35.6	13.2	11.4
diameter	(7.0)	(5.0)	(3.5)	(7.3)	(5.3)	(4.0)	(14.0)	(5.2)	(4.5)
5.0 cm (2.0 in)	19.0	11.4	10.7	20.3	11.9	10.2	38.1	13.7	12.7
diameter	(7.5)	(4.5)	(4.2)	(8.0)	(4.7)	(4.0)	(15.0)	(5.4)	(5.0)
Grasping knob									
0.6 cm (0.24 in)	20.3	9.7	10.9	22.9	11.7	10.2	39.4	12.2	11.4
diameter	(8.0)	(3.8)	(4.3)	(9.0)	(4.6)	(4.0)	(15.5)	(4.8)	(4.5)
2.5 cm (1.0 in)	22.8	8.9	10.2	22.9	11.4	10.2	40.1	12.2	12.2
diameter	(9.0)	(3.5)	(4.0)	(9.0)	(4.5)	(4.0)	(15.8)	(4.8)	(4.8)
5.0 cm (2.0 in)	24.1	9.4	9.4	23.4	11.4	10.7	40.5	11.9	12.2
diameter	(9.5)	(3.7)	(3.7)	(9.2)	(4.5)	(4.1)	(15.9)	(4.7)	(4.8)

14.1.5 Use of distribution and correlation data

Complex uses of statistical data concerning human physical dimensions or capabilities are introduced in this section. Data and distribution information on a single physical characteristic and its measures provides no information about that characteristic's composite relationship with any other characteristic and its measures. For design, the relationship between two or more characteristics and how their measures vary together is important. Consider sizing clothing and designing seats. Bivariate distributions and correlation statistics can be used by knowledgeable professionals to determine design criteria.

□ 14.1.5.1 **Gaussian distribution of measurement values on a single human physical characteristic.** The relationship between the Gaussian distribution and the measurement value equivalent to the desired percentile statistic value should best be determined from a smoothed frequency distribution or from the formula presented in Exhibit 14.1.5.1 if the following conditions are met:

a. the percentile value is not given in applicable Human-machine-interface data, and

b. the population distribution for the applicable human physical characteristic is known to be Gaussian (normal) and the mean and variance are known. [Source: Israelski, 1977]

Exhibit 14.1.5.1 Percentile values

Percentile +	-		Formula* (SD)
70	and 30	%tile =	X ± (0.524)(X)
75	and 25	%tile =	X ± (0.674)(X)
80	and 20	%tile =	X ± (0.842)(X)
85	and 15	%tile =	X ± (1.036)(X)
90	and 10	%tile =	X ± (1.282)(X)
95	and 5	%tile =	X ± (1.645)(X)
97.5	and 2.5	%tile =	X ± (1.960)(X)
99	and 1	%tile =	X ± (2.326)(X)
99.5	and 0.5	%tile =	X ± (2.576)(X)

SD = (Standard deviation) X = mean or 50th percentile
* Do not use with skewed strength data.

▫ **14.1.5.2 Using bivariate distribution data.** Bivariate data should be professionally applied and interpreted since knowledge of the population distribution characteristics are necessary to project and extract design limits and to apply them to design problems. [Source: MIL-HDBK-759B, 1992]

Discussion. The variability of two body measurements and their interrelationship with each other may be presented in a graph or a table. Bivariate information includes the ranges of two measurements and the percentages or frequencies of individuals who are characterized by the various possible combinations of values of the two measurements. Knowledgeable professionals can tell about the relationships from the appearance and shape of the joint distribution of measures. Correlation statistics, when the relationship warrants, provide additional insight, and when appropriate samples are large enough, may provide predictions of population values.

▫ **14.1.5.3 Use of correlation and multiple correlation data.** When two or more human physical characteristics are applicable to a design problem, professionals should apply and interpret correlation statistics. Knowledge about distributions and intercorrelations among the distributions need to be factored into the use of these data. [Source: MIL-HDBK-759B, 1992; Kroemer, Kroemer, & Kroemer-Elbert 1990]

Discussion. The relationships or correlations between specific body measurements are highly variable among the various human characteristics and may differ across samples and populations. For example, breadth measurements tend to be more highly correlated with weight than with stature. The degree of the relationship may be expressed by a correlation coefficient or "r" value.

Although common percentile values may not be used to sum data across adjacent body parts, (see Paragraph 14.1.3.3), regression equations derived from the applicable samples can be used in constructing composite body measures.

Definition. The **correlation coefficient or "r" value** describes the degree to which two variables vary together (positive correlation) or vary inversely (negative correlation). The correlation coefficient, "r", has a range of values from +1.0 (perfect positive correlation) through -1.0 (perfect negative correlation). Multiple correlation involves the predictable relationship of two or more variables with another criterion variable (such as a composite measurement value). **"R"** is the **multiple correlation coefficient.** It is recommended that only correlations with strong predictive values be used (that is where r or R is at least or greater than |.7|). (Note: R^2 is the square of the multiple correlation coefficient and equates to the proportion of the variation accounted for in the prediction. An R of .7 would account for about 50 percent of the variation).

14.2 Anthropometric variability factors

There are many factors that relate to the large variability observed in measures of the human body. These factors include: (1) body position, (2) age, health, and body condition, (3) sex, (4) race and national origin, (5) occupation, and (6) evolutionary trends. These factors affect future population sampling and encourage the use of the most recent data on the populations of interest. If designers and human factors specialists need to draw upon other data or accomplish some special purpose sampling, the following rules related to data variability may assist.

□ 14.2.1 **Foreign populations.** If a specific use of the system or equipment involves operation or maintenance by foreign personnel in locations outside the United States, sample data should be obtained that represents the foreign work force. [Source: Israelski, 1977]

□ 14.2.2 **Body slump.** In determining body position and eye position zones for seated or standing positions, a slump factor which accompanies relaxation should be taken into account. Seated-eye height measurements can be reduced by as much as 65 mm (2.56 in) when a person sits in a relaxed position. Body slump, when standing, reduces stature as much as 19 mm (.75 in) from a perfectly erect position. These slump factors should be considered in designing adjustable seats, visual envelopes, and display locations. [Source: Israelski, 1977]

14.3 Anthropometric and biomechanics data

This section provides general guidance for the use of specific anthropometric and biomechanics data, static body characteristics data, dynamic body characteristic data, including range of joint motion and common and mobile working positions.

Dimensions of the human body which influence the design of personal and operational equipment are of two types: (1) static dimensions, which are measurements of the head, torso, and limbs in normal positions, and (2) dynamic dimensions, which are measurements taken in working positions or during movement. [Source: AFSC DH 1-3, 1980; NASA-STD-3000A, 1989]

14.3.1 Data usage

■ 14.3.1.1 **Use of anthropometric and biomechanics data.** Data throughout Section 14.3 are to be used for anthropometric issues that are not addressed in earlier sections of this document. If designers and human factors specialists need additional data to solve anthropometric design problems associated with human physical characteristics, they shall use the data presented in

DOD-HDBK-743A (see also 14.1.1.2). [Source: DOD-HDBK-743A, 1991]

▪ **14.3.1.2 Task considerations.** Designers and human factors specialists shall take the following task conditions into consideration when using the human physical characteristic data presented in this section:

a. the nature, frequency, and difficulty of the related tasks to be performed by the operator or user of the equipment,

b. the position of the body during performance of operations and maintenance tasks,

c. mobility and flexibility demands imposed by maintenance tasks,

d. the touch, grasp, torque, lift, and carry requirements of the tasks,

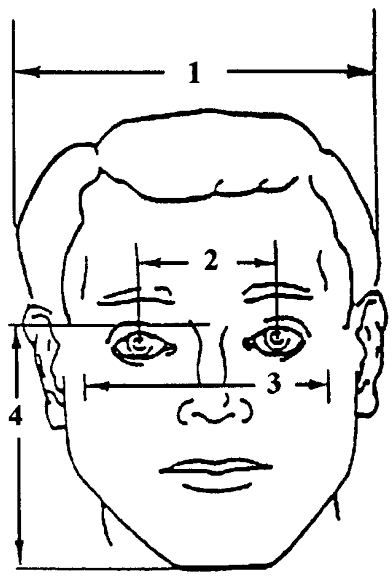
e. increments in the design-critical dimensions imposed by clothing or equipment, packages, and tools, and

f. increments in the design-critical dimensions imposed by the need to compensate for obstacles and projections. [Source: MIL-STD-1472D, 1989; MIL-HDBK-759B, 1992]

14.3.2 Static body characteristics

▫ **14.3.2.1 Static data.** Exhibit 14.3.2.1 presents static human physical characteristics and measurement values which should be used, as applicable, in design problems. Exhibit 14.3.2.1 addresses the following body parts: head, seated body, standing body, and hands. [Source: DOD-HDBK-743A, 1991]

Exhibit 14.3.2.1 Static human physical characteristics (head)



1 **Head breadth.** The maximum breadth of the head, usually above and behind the ears.

Sample			Percentiles 1st	5th	50th	95th	99th
A	Men	cm	13.9	14.3	15.2	16.11	6.5
		(in)	(5.1)	(5.6)	(6.0)	(6.3)	(6.5)
B	Women	cm	13.3	13.7	14.4	15.3	15.7
		(in)	(5.2)	(5.4)	(5.7)	(6.0)	(6.1)

2 **Interpupillary breadth.** The distance between the centers of the pupils of the eyes (the eyes are looking straight ahead).

Sample			Percentiles 1st	5th	50th	95th	99th
A	Men	cm	5.7	5.9	6.5	7.1	7.4
		(in)	(2.2)	(2.3)	(2.7)	(2.8)	(2.9)
B	Women	cm	5.5	5.7	6.0	6.9	7.0
		(in)	(2.8)	(2.2)	(2.4)	(2.7)	(2.8)

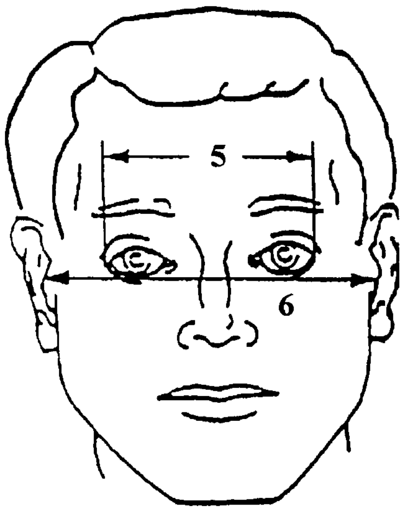
3 **Face breadth (bizygomatic).** The breadth of the face, measured across the most lateral projections of the cheek bones (zygomatic arches).

Sample			Percentiles 1st	5th	50th	95th	99th
A	Men	cm	12.8	13.2	14.0	15.0	15.4
		(in)	(5.0)	(5.2)	(5.5)	(5.9)	(6.1)
B	Women	cm	12.1	12.3	12.8	14.0	15.4
		(in)	(4.8)	(4.8)	(5.1)	(5.5)	(5.7)

4 **Face length (menton-sellion).** The vertical distance from the tip of the chin (menton) to the deepest point of the nasal root depression between the eyes (sellion).

Sample			Percentiles 1st	5th	50th	95th	99th
A	Men	cm	10.8	11.2	12.2	13.3	13.7
		(in)	(4.3)	(4.4)	(4.8)	(5.2)	(5.4)
B	Women	cm	10.1	10.4	11.3	12.4	12.9
		(in)	(3.4)	(4.1)	(4.5)	(4.9)	(5.1)

Exhibit 14.3.2.1 (continued) Static human physical characteristics (head)

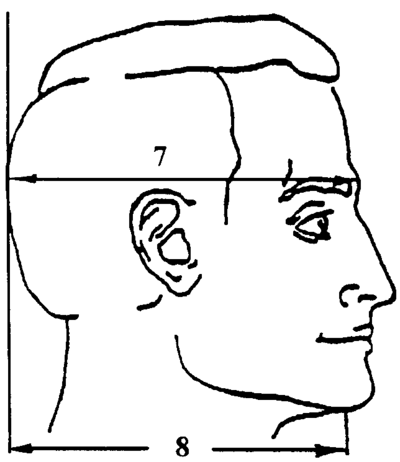


5 **Biocular breadth.** The distance from the outer corners of the eyes (right and left ectocanthi).

Sample			1st	5th	50th	95th	99th
A	Men	cm	11.0	11.3	12.2	13.1	13.6
		(in)	(4.3)	(4.5)	(4.8)	(5.2)	(5.4)
B	Women	cm	10.8	11.1	11.6	12.9	13.3
		(in)	(4.3)	(4.4)	(4.3)	(5.1)	(5.3)

6 **Bitragion breadth.** The breadth of the head from the right tragion to the left. (Tragion is the cartilaginous notch at the front of the ear).

Sample			1st	5th	50th	95th	99th
A	Men	cm	13.1	13.5	14.5	15.5	15.9
		(in)	(5.2)	(5.3)	(5.7)	(6.1)	(6.3)
B	Women	cm	12.5	12.8	13.3	14.3	15.0
		(in)	(4.3)	(5.4)	(5.4)	(5.7)	(5.9)



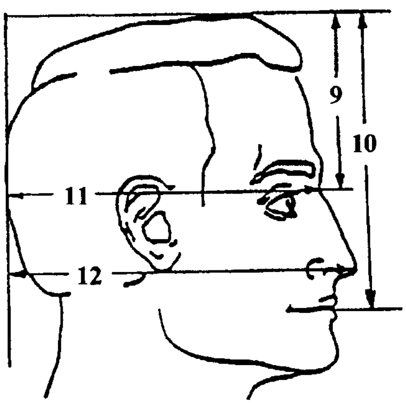
7 **Glabella to back of head.** The horizontal distance from the most anterior point of the forehead between the brow-ridges (glabella) to the back of the head, measured with a headboard.

Sample			1st	5th	50th	95th	99th
A	Men	cm	18.3	18.8	20.0	21.1	21.7
		(in)	(7.2)	(7.4)	(7.9)	(8.3)	(8.5)
B	Women	cm	17.5	18.0	19.1	20.2	20.7
		(in)	(6.9)	(7.1)	(7.5)	(8.0)	(8.1)

8 **Menton to back of head.** The horizontal distance from the tip of the chin (menton) to the back of the head, measured with a headboard.

Sample			1st	5th	50th	95th	99th
A	Men	cm	15.7	16.5	18.2	20.0	20.7
		(in)	(6.2)	(6.5)	(7.2)	(7.9)	(8.2)
B	Women	cm	15.2	15.8	17.3	18.9	19.6
		(in)	(6.0)	(6.2)	(6.8)	(7.4)	(7.7)

Exhibit 14.3.2.1 (continued) Static human physical characteristics (head)



9 Sellion to top of head. The vertical distance from the nasal root depression between the eyes (sellion), to the level of the top of the head, measured with a headboard.

	Sample		1st	5th	50th	95th	99th
A	Men	cm	9.7	10.1	11.2	12.4	12.9
		(in)	(3.8)	(4.0)	(4.4)	(4.9)	(5.1)
B	Women	cm	9.0	9.5	10.5	11.7	12.2
		(in)	(3.5)	(9.5)	(4.1)	(4.6)	(4.8)

10 Stomion to top of head. The vertical distance from the midpoint of the lips (stomion) to the level of the top of the head, measured with a headboard.

	Sample		1st	5th	50th	95th	99th
A	Men	cm	16.9	17.4	18.6	19.9	20.6
		(in)	(6.7)	(6.6)	(7.3)	(7.8)	(8.1)
B	Women	cm	15.7	16.3	17.5	18.8	19.4
		(in)	(6.1)	(6.4)	(6.9)	(7.4)	(7.6)

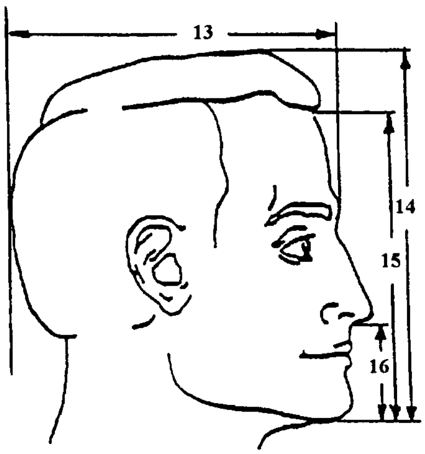
11 Sellion to back of head. The horizontal distance from the nasal root depression between the eyes (sellion), to the back of the head, measured with a headboard.

	Sample		1st	5th	50th	95th	99th
A	Men	cm	18.0	18.5	19.7	20.9	21.4
		(in)	(7.1)	(7.3)	(7.8)	(8.2)	(8.4)
B	Women	cm	17.4	17.8	18.9	20.0	20.5
		(in)	(6.6)	(7.1)	(7.4)	(7.9)	(8.4)

12 Pronasale to back of head. The horizontal distance from the tip of the nose (pronasale) to the back of the head, measured with a headboard.

	Sample		1st	5th	50th	95th	99th
A	Men	cm	20.0	20.5	22.0	23.2	23.9
		(in)	(7.9)	(8.1)	(8.7)	(9.1)	(9.4)
B	Women	cm	19.2	19.7	21.0	22.2	22.8
		(in)	(7.6)	(7.8)	(8.3)	(8.7)	(9.0)

Exhibit 14.3.2.1 (continued) Static human physical characteristics (head)



13 Head length. The maximum length of the head; measured from the most anterior point of the forehead between the brow-ridges (glabella) to the back of the head (occiput).

Sample			1st	5th	50th	95th	99th
			Percentiles				
A	Men	cm	18.0	18.5	19.7	20.9	21.3
		(in)	(7.1)	(7.3)	(7.8)	(8.2)	(8.4)
B	Women	cm	17.2	17.6	18.7	19.8	20.2
		(in)	(6.8)	(7.0)	(7.4)	(7.8)	(8.0)

14 Menton to top of head. The vertical distance from the tip of the chin (menton) to the level of the top of the head, measured with a headboard.

Sample			1st	5th	50th	95th	99th
			Percentiles				
A	Men	cm	21.2	21.8	23.2	24.7	25.5
		(in)	(8.4)	(8.6)	(8.6)	(9.1)	(9.4)
B	Women	cm	19.8	20.4	21.8	23.2	23.8
		(in)	(7.8)	(8.3)	(8.6)	(9.1)	(9.4)

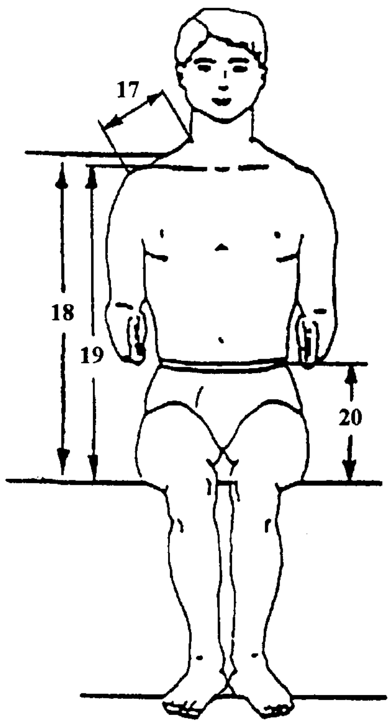
15 Menton-crinion length. The vertical distance from the bottom of the chin (menton) to the midpoint of the hairline (crinion).

Sample			1st	5th	50th	95th	99th
			Percentiles				
A	Men	cm	16.6	17.4	19.1	20.9	21.6
		(in)	(6.5)	(6.9)	(7.5)	(8.2)	(8.5)
B	Women	cm	15.5	16.1	17.7	19.2	19.9
		(in)	(6.1)	(6.3)	(7.0)	(7.6)	(7.8)

16 Menton-subnasale length. The distance from the bottom of the chin (menton) to the base of the nasal septum (subnasale).

Sample			1st	5th	50th	95th	99th
			Percentiles				
A	Men	cm	6.1	6.5	7.3	8.3	8.7
		(in)	(2.4)	(2.7	(2.9)	(3.3)	(3.3)
B	Women	cm	5.7	6.0	6.5	7.8	8.3
		(in)	(2.2)	(2.4)	(2.7)	(3.1)	(3.8)

Exhibit 14.3.2.1 (continued) Static human physical characteristics (seated)



17 Shoulder length. The surface distance along the top of the shoulder from the junction of the neck and shoulder to the point of the shoulder (acromion).

	Sample		Percentiles 1st	5th	50th	95th	99th
A	Men	cm	12.4	13.3	15.0	16.9	17.7
		(in)	(4.9)	(5.3)	(5.9)	(6.7)	(7.0)
B	Women	cm	12.0	12.7	14.5	16.2	17.1
		(in)	(4.7)	(5.0)	(5.7)	(6.4)	(6.7)

18 Mid-shoulder height, sitting. The vertical distance from the sitting surface of the shoulder halfway between the neck and the point of the shoulder, measured with the subject sitting.

	Sample		Percentiles 1st	5th	50th	95th	99th
A	Men	cm	56.3	58.3	63.0	67.7	69.4
		(in)	(22.2)	(23.0)	(24.9)	(26.7)	(27.3)
B	Women	cm	52.3	53.9	58.4	63.1	64.7
		(in)	20.6)	(21.2)	(23.0)	(24.8)	(25.5)

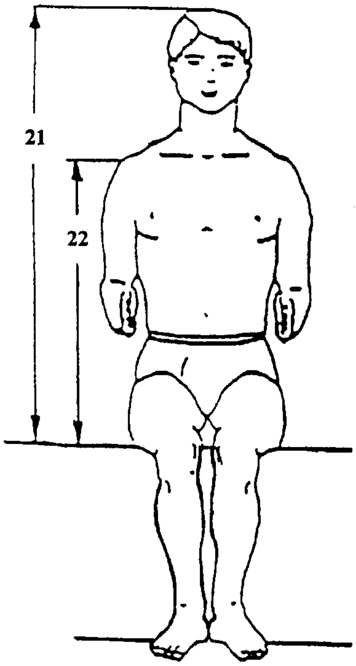
19 Trunk (suprasternale) height, sitting. The vertical distance from the sitting surface to the lowest point of the notch in the upper edge of the breast bone (suprasternale), measured with the subject sitting.

	Sample		Percentiles 1st	5th	50th	95th	99th
A	Men	cm	53.1	55.2	59.6	64.2	65.9
		(in)	(20.9)	(21.7)	(23.5)	(25.3)	(25.9)
B	Women	cm	49.8	51.1	55.3	59.6	61.2
		(in)	(19.6)	(20.1)	(21.8)	(23.5)	(24.1)

20 Waist height, sitting. The vertical distance from the sitting surface to the level of the waist (natural indentation), measured with the subject sitting.

	Sample		Percentiles 1st	5th	50th	95th	99th
A	Men	cm	24.8	26.0	28.7	31.5	32.9
		(in)	(9.8)	(10.2)	(11.3)	(12.4)	(13.0)
B	Women	cm	22.8	24.4	28.0	31.5	32.7
		(in)	(9.0)	(9.6)	(11.0)	(12.4)	(12.9)

Exhibit 14.3.2.1 (continued) Static human physical characteristics (seated)



21 Sitting height. The vertical distance from the sitting surface to the top of the head, measured with the subject sitting.

	Sample		Percentiles 1st	5th	50th	95th	99th
A	Men	cm	82.8	85.5	91.4	97.2	99.1
		(in)	(32.6)	(33.7)	(36.0)	(38.3)	(39.0)
B	Women	cm	77.5	79.5	85.1	91.0	93.3
		(in)	(30.5)	(31.3)	(33.5)	(35.8)	(36.7)

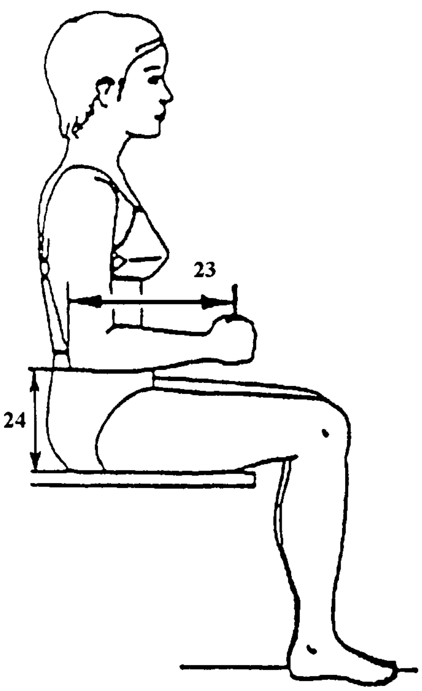
22 Shoulder (acromiale) height, sitting. The vertical distance from the sitting surface to the point of the shoulder (acromion), measured with the subject sitting.

Sample	Percentiles 1^{st}	5^{th}	50^{th}	95^{th}	99^{th}

14.....1 A Men cm 52.5 54.9
59.8 64.6 66.5
(in) (20.7) (21.6) (23.6) (25.4)
(26.2)

23 Elbow-grip length. The horizontal distance from the back of the elbow to the center of the clenched fist.

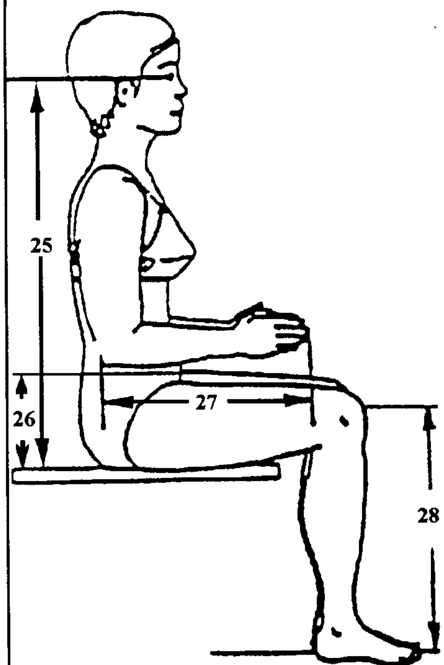
	Sample		Percentiles 1st	5th	50th	95th	99th
A	Men	cm	32.3	33.2	35.9	39.1	40.3
		(in)	(12.7)	(13.1)	(14.1)	(15.4)	(15.9)
B	Women	cm	28.9	30.0	32.8	35.8	37.2
		(in)	(11.4)	(11.8)	(12.9)	(14.1)	(14.7)



24 Elbow rest height. The vertical distance from the sitting surface to the bottom of the tip of the elbow, measured with the subject sitting and the forearm held horizontally.

	Sample		Percentiles 1st	5th	50th	95th	99th
A	Men	cm	16.8	18.4	23.2	27.4	29.2
		(in)	(6.6)	(7.2)	(9.1)	(10.8)	(11.5)
B	Women	cm	15.8	17.6	22.1	26.4	28.2
		(in)	(6.2)	(6.9)	(8.7)	(10.4)	(11.1)

Exhibit 14.3.2.1 (continued) Static human physical characteristics (seated)



25 Eye height, sitting. The vertical distance from the sitting surface to the outer corner of the eye (ectocanthus), measured with the subject sitting.

	Sample		1st	5th	50th	95th	99th
A	Men	cm	71.2	73.5	79.2	84.8	86.9
		(in)	(28.0)	(28.9)	(31.2)	(33.4)	(34.2)
B	Women	cm	66.4	68.5	73.8	79.4	81.6
		(in)	(26.1)	(30.0)	(29.1)	(31.2)	(32.1)

26 Thigh clearance. The vertical distance from the sitting surface to the highest point of the thigh, measured with the subject sitting.

	Sample		1st	5th	50th	95th	99th
A	Men	cm	14.1	14.9	16.8	19.0	20.1
		(in)	(5.6)	(5.9)	(6.6)	(7.5)	(7.9)
B	Women	cm	13.4	14.0	1.8	18.0	19.0
		(in)	(5.3)	(5.5)	(6.2)	(7.1)	(7.5)

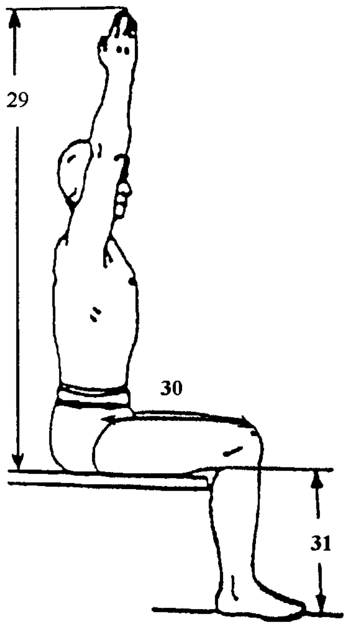
27 Elbow-fingertip length. The horizontal distance from the back of the elbow to the tip of the middle finger, with the hand extended.

	Sample		1st	5th	50th	95th	99th
A	Men	cm	43.4	44.8	48.3	52.4	54.2
		(in)	(17.1)	(17.6)	(19.2)	(20.6)	(21.3)
B	Women	cm	39.1	40.6	44.2	48.3	49.8
		(in)	(15.4)	(16.0)	(17.4)	(19.0)	(19.6)

28 Knee height, sitting. The vertical distance from the footrest surface to the top of the knee, measured with the subject sitting.

	Sample		1st	5th	50th	95th	99th
A	Men	cm	49.7	51.4	55.8	60.6	62.3
		(in)	(19.6)	(20.2)	(22.0)	(23.9)	(24.5)
B	Women	cm	45.4	47.4	49.8	56.0	57.8
		(in)	(17.9)	(18.7)	(20.2)	(22.0)	(22.8)

Exhibit 14.3.2.1 (continued) Static human physical characteristics (seated)



29 Vertical reach, sitting. The vertical distance from the sitting surface to the tip of the middle finger, measured with the subject sitting and the arm, hand, and fingers extended vertically.

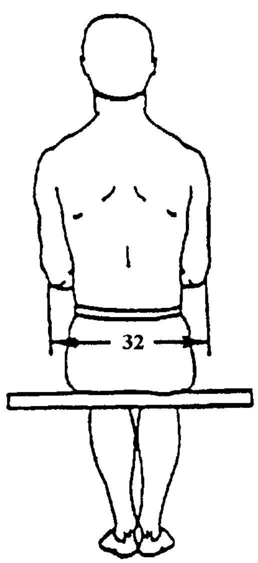
	Sample		Percentiles 1st	5th	50th	95th	99th
A	Men	cm	129.3	133.8	143.3	153.2	156.7
		(in)	(50.1)	(52.7)	(56.4)	(60.3)	(61.7)
B	Women	cm	119.7	123.3	132.7	141.8	145.4
		(in)	(47.1)	(48.5)	(52.2)	(55.8)	(57.2)

30 Abdominal depth, sitting. The depth of the abdomen, with the subject sitting.

	Sample		Percentiles 1st	5th	50th	95th	99th
A	Men	cm	18.6	19.9	23.6	29.1	31.4
		(in)	(7.3)	(7.8)	(9.3)	(11.5)	(12.4)
B	Women	cm	17.3	18.5	21.9	27.1	29.5
		(in)	(6.1)	(7.3)	(8.6)	(10.7)	(11.6)

31 Popliteal height, sitting. The vertical distance from the footrest surface to the underside of the lower leg, measured with the subject sitting.

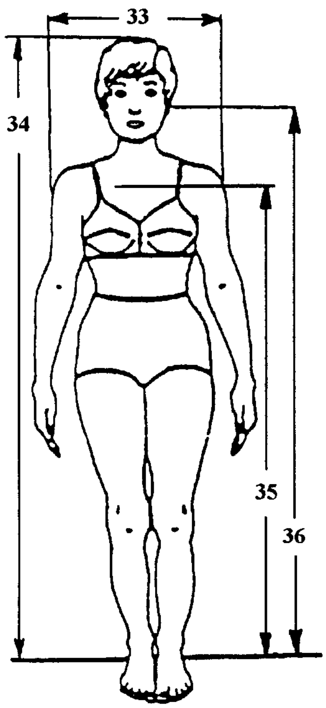
	Sample		Percentiles 1st	5th	50th	95th	99th
A	Men	cm	37.8	39.5	43.3	47.6	49.5
		(in)	(14.9)	(15.6)	(17.1)	(18.7)	(19.5)
B	Women	cm	33.7	35.1	38.9	42.9	44.6
		(in)	(13.3)	(13.8)	(15.3)	(16.9)	(17.6)



32 Forearm-forearm breadth, sitting. The horizontal distance across the body between the outer surfaces of the forearms, measured with the forearms flexed and held against the body.

	Sample		Percentiles 1st	5th	50th	95th	99th
A	Men	cm	45.1	47.79	54.5	62.1	65.3
		(in)	(17.8)	(18.8)	(21.5)	(24.5)	(25.7)
B	Women	cm	39.4	41.5	46.7	52.8	56.0
		(in)	(15.5)	(16.3)	(18.4)	(20.8)	(22.1)

Exhibit 14.3.2.1 (continued) Static human physical characteristics (standing)



33 Shoulder (bideltoid) breadth. The horizontal distance across the upper arms between the maximum bulges of the deltoid muscles; the arms are hanging and relaxed.

	Sample		1st	5th	50th	95th	99th
A	Men	cm	43.4	45.0	49.1	53.5	55.2
		(in)	(17.1)	(17.7)	(19.3)	(21.1)	(21.7)
B	Women	cm	38.0	39.7	43.1	47.2	49.2
		(in)	(15.0)	(15.6)	(17.0)	(18.6)	(19.4)

34 Stature. The vertical distance from the floor to the top of the head.

	Sample		1st	5th	50th	95th	99th
A	Men	cm	160.3	164.7	175.5	186.7	190.9
		(in)	(63.1)	(64.8)	(69.1)	(73.5)	(75.2)
B	Women	cm	148.3	152.8	162.7	173.7	178.0
		(in)	(58.4)	(60.2)	(64.1)	(68.4)	(70.1)

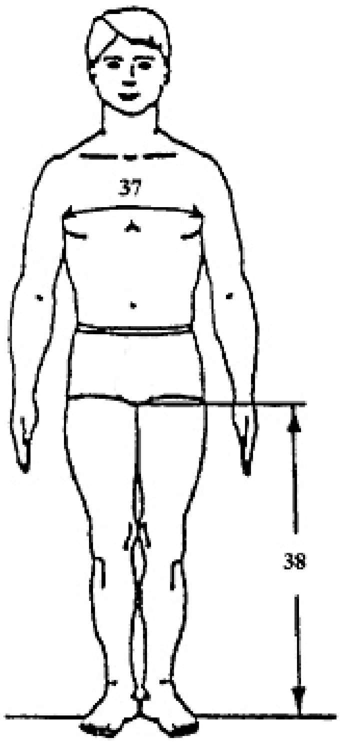
35 Suprasternale height. The vertical distance from the floor to the lowest point of the notch in the upper edge of the breast bone (suprasternale).

	Sample		1st	5th	50th	95th	99th
A	Men	cm	130.2	134.3	143.7	153.7	157.5
		(in)	51.3	(52.9)	(56.6)	(60.5)	(62.0)
B	Women	cm	120.7	124.1	132.9	142.5	146.4
		(in)	(47.5)	(48.9)	(52.3)	(56.1)	(57.6)

36 Tragion height, standing. The vertical distance from the floor to the tragion, the cartilaginous notch at the front of the ear.

	Sample		1st	5th	50th	95th	99th
A	Men	cm	147.4	151.9	162.4	173.4	177.5
		(in)	(58.0)	(59.8)	(63.9)	(68.3)	(69.9)
B	Women	cm	136.3	140.7	150.4	161.2	165.4
		(in)	(53.7)	(55.4)	(59.2)	(63.5)	(65.1)

Exhibit 14.3.2.1 (continued) Static human physical characteristics (standing)

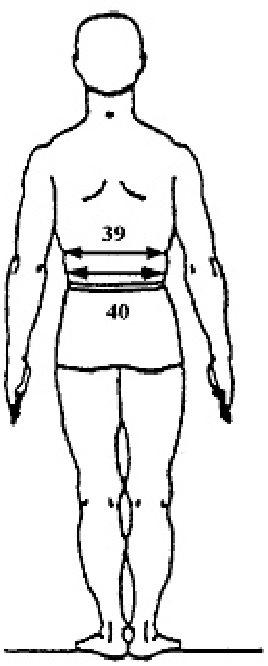


37 **Chest (bust) circumference.** The circumference of the torso measured at the level of the nipples.

Sample			Percentiles 1st	5th	50th	95th	99th
A	Men	cm	84.5	88.6	98.7	111.3	116.8
		(in)	(33.3)	(34.9)	(38.9)	(43.8)	(50.0)
B	Women	cm	78.1	81.4	90.1	102.2	107.7
		(in)	(30.8)	(32.1)	(35.5)	(40.2)	(42.4)

38 **Crotch height.** The vertical distance from the floor to the midpoint of the crotch.

Sample			Percentiles 1st	5th	50th	95th	99th
A	Men	cm	73.2	76.4	83.5	91.6	94.6
		(in)	(28.8)	(30.1)	(32.9)	(36.1)	(37.2)
B	Women	cm	67.0	70.0	77.0	84.6	88.1
		(in)	(26.4)	(27.6)	(30.3)	(33.3)	(34.7)



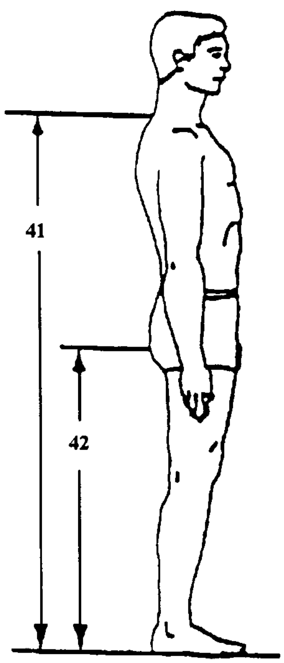
39 **Waist circumference (natural indentation).** The horizontal circumference of the torso at the level of the natural indentation of the waist.

Sample			Percentiles 1st	5th	50th	95th	99th
A	Men	cm	69.9	73.0	83.4	97.1	102.9
		(in)	(27.5)	(28.7)	(32.8)	(38.2)	(40.5)
B	Women	cm	60.7	63.7	71.7	84.3	91.0
		(in)	(23.9)	(25.1)	(28.2)	(33.2)	(35.8)

40 **Waist circumference (omphalion).** The horizontal circumference of the torso at the level of the navel (omphalion).

Sample			Percentiles 1st	5th	50th	95th	99th
A	Men	cm	70.0	73.3	85.6	101.6	107.7
		(in)	(27.6)	(28.9)	(33.7)	(40.0)	(42.4)
B	Women	cm	64.4	67.6	78.1	94.6	102.6
		(in)	(25.4)	(26.6)	(30.8)	(37.2)	(40.4)

Exhibit 14.3.2.1 (continued) Static human physical characteristics (standing)

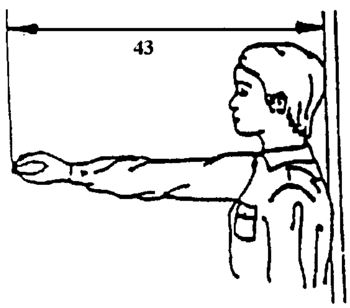


41 Cervicale height. The vertical distance from the floor to the cervicale, the tip of the spine of the seventh cervical vertebra at the base of the neck.

	Sample		1st	5th	50th	95th	99th
A	Men	cm	137.4	141.8	151.8	162.4	166.1
		(in)	(54.1)	(55.8)	(59.8)	(63.9)	(65.4)
B	Women	cm	127.3	131.4	140.6	150.8	154.8
		(in)	(50.1)	(51.7)	(55.4)	(59.4)	(60.9)

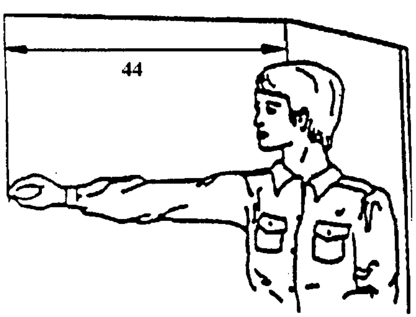
42 Buttock height. The vertical distance from the floor to the maximum posterior protrusion of the buttock.

	Sample		1st	5th	50th	95th	99th
A	Men	cm	78.4	81.5	88.5	96.9	100.5
		(in)	(30.9)	(32.1)	(34.8)	(38.1)	(39.6)
B	Women	cm	73.9	76.7	83.7	91.5	94.9
		(in)	(29.1)	(30.2)	(33.0)	(36.0)	(37.4)



43 Functional (thumb-tip) reach. The horizontal distance from the wall to the tip of the thumb, measured with the subject's shoulders against the wall, the arm extended forward, and the index finger touching the tip of the thumb.

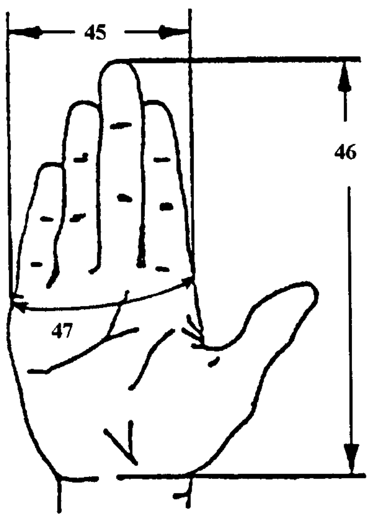
	Sample		1st	5th	50th	95th	99th
A	Men	cm	72.0	73.9	80.0	86.7	89.7
		(in)	(28.4)	(29.1)	(31.5)	(34.1)	(35.3)
B	Women	cm	65.8	67.7	73.4	79.7	82.4
		(in)	(25.9)	(26.7)	(28.9)	(31.4)	(32.4)



44 Functional (thumb-tip) reach, extended. Measured similarly to functional (thumb-tip) reach, except that the right shoulder is extended forward as far as possible, while the left shoulder is kept pressed firmly against the wall.

	Sample		1st	5th	50th	95th	99th
A	Men	cm	77.9	80.5	87.3	94.2	97.7
		(in)	(30.7)	(31.7)	(34.4)	(37.1)	(38.5)
B	Women	cm	71.2	73.5	79.6	86.2	89.0
		(in)	(28.0)	(28.9)	(31.3)	(33.9)	(35.0)

Exhibit 14.3.2.1 (continued) Static human physical characteristics (hand)



45 Hand breadth. The breadth of the hand, measured across the ends of the metacarpal bones (metacarpal-phalangeal joints).

	Sample		Percentiles 1st	5th	50th	95th	99th
A	Men	cm	8.1	8.4	9.0	9.8	10.0
		(in)	(3.2)	(3.3)	(3.5)	(3.9)	(3.9)
B	Women	cm	7.1	7.3	7.9	8.6	8.9
		(in)	(2.8)	(2.9)	(3.1)	(3.4)	(3.5)

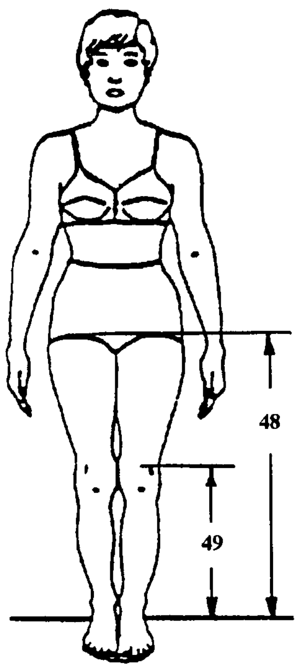
46 Hand length. The distance from the base of the hand at the wrist crease to the tip of the middle finger.

	Sample		Percentiles 1st	5th	50th	95th	99th
A	Men	cm	17.3	17.9	19.3	21.1	21.9
		(in)	(6.8)	(7.1)	(7.6)	(8.3)	(8.6)
B	Women	cm	15.9	16.5	18.0	19.7	20.5
		(in)	(6.3)	(6.5)	(7.1)	(7.8)	(8.1)

47 Hand circumference. The circumference of the hand, measured around the knuckles (metacarpal-phalangeal joints).

	Sample		Percentiles 1st	5th	50th	95th	99th
A	Men	cm	19.2	19.9	21.3	23.0	23.7
		(in)	(7.6)	(7.8)	(8.4)	(9.1)	(9.3)
B	Women	cm	16.7	17.3	18.6	20.0	20.7
		(in)	(6.6)	(6.8)	(7.3)	(7.9)	(8.2)

Exhibit 14.3.2.1 (continued) Static human physical characteristics (standing position)



48 Hip (trochanteric) height. The vertical distance from the floor to the level of the maximum posterior protrusion of the greater trochanter of the femur (trochanterion).

Sample			1st	5th	50th	95th	99th
A	Men	cm	82.1	85.3	92.7	100.9	104.0
		(in)	(32.3)	(33.6)	(36.5)	(39.7)	(40.9)
B	Women	cm	76.1	78.9	86.0	93.8	97.5
		(in)	(30.0)	(31.1)	(33.9)	(36.9)	(38.4)

49 Knee height, midpatella. The vertical distance from the footrest surface to the top of the knee, measured with the subject sitting.

Sample			1st	5th	50th	95th	99th
A	Men	cm	44.3	46.1	50.4	55.2	56.8
		(in)	(17.4)	(18.2)	(19.8)	(21.7)	(22.4)
B	Women	cm	39.9	41.7	45.8	50.3	52.3
		(in)	(15.7)	(16.4)	(18.0)	(19.8)	(20.6)

14.3.3 Dynamic (mobile) body characteristics

This section presents: (1) information concerning the range of whole body motion characteristics, and (2) design rules and data on joint and body motion. Where such data are in other sections with application topics such as design for use and workplace design, cross references are provided.

14.3.3.1 Range of whole body motion

Efficiency and accuracy of task performance can be maintained only if required body movements are within safe and comfortable limits. Human variability in range of body and joint movement is attributable to many factors, including the following:

a. Age becomes a factor after age 60, at which time mobility has decreased 10 percent from youth.

b. Sex differences favor greater range in females at all joints except the knee.

c. Body build is a significant factor. Joint mobility decreases significantly as body build ranges from the very slender, through the muscular, to the obese.

d. Exercise increases movement range. Weight training, jogging, and the like may tend to shorten certain muscle groups or increase their bulk so movement is restricted.

e. Fatigue, disease, body position, clothing, and environment are other factors affecting mobility. [Source: NASA-STD-3000A, 1989; AFSC DH 1-3, 1980; Israelski, 1977]

This section provides introductory definitions related to the angular motion of skeletal joints. Knowledge of the range of joint motion helps the designer determine the placement and allowable movement of controls, tools, and equipment.

▪ **14.3.3.1.1 Trunk movement.** Workplace designs based upon design-driven body positions shall allow enough space to move the trunk of the body. The design shall be based upon:

a. the required tasks and human functions,

b. the need for optimal positions for applying forces, and

c. the need for comfortable body adjustments and movements. [Source: MIL-HDBK-759B, 1992]

- **14.3.3.1.2 Whole body movement.** If large forces that are greater than 13.6 kg (29.98 lb) or large control displacements that are more than 380 mm (14.96 in) in a fore-aft direction are required, the user shall be given enough space to move his or her entire body. [Source: MIL-HDBK-759B, 1992]

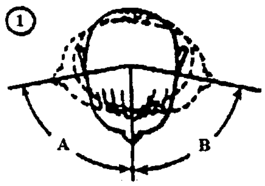
14.3.3.2 Joint motion

Joint motion capabilities make body movements possible. Joint movement is measured at the angle formed by the long axes of two adjoining body segments or at the angle formed by a body segment and a vertical or horizontal plane. The total range of motion is measured between the two extreme positions of the joint. The types of movement are defined below and are illustrated in Exhibits which follow.

Definitions. **Abduction** is movement away from the midline of the body. **Adduction** is movement toward the midline. **Circumduction** is a continuous circular movement of a limb. **Depression** is the lowering of a body member from its normal position. **Elevation** is the raising of a body member from a normal position. **Extension** is the straightening of a limb or an increase in the angle between parts of the body. **Flexion** is the process of bending a limb or decreasing the angle between parts of the body. **Lateral rotation** is turning away from the midline of the body, while **medial rotation** is turning toward the midline of the body. **Pronation** is the downward turning of the palm, or lying face down. **Supination** is the upward turning of the palm, or lying face up.

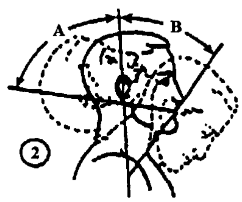
- **14.3.3.2.1 Single joint movements.** Designers and human factors specialists shall use the data in Exhibit 14.3.3.2.1 for design problems involving the movement of a single joint. This Exhibit presents single joint movement ranges for males and females. [Source: NASA-STD-3000A, 1989; MIL-HDBK-759B, 1992; Department of Defense (MIL-STD-1800A), 1990]

Exhibit 14.3.3.2.1 Joint movement ranges



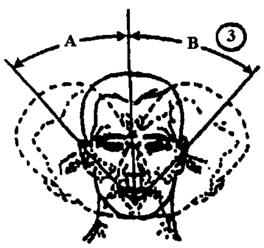
Neck Rotation,
Right (A), Left (B)

Joint movement	Range of motion (degrees) Males 5th percentile	Males 95th percentile	Females 5th percentile	Females 95th percentile
Neck, rotation right	73.3	99.6	74.9	108.8
Neck, rotation left	74.3	99.1	72.2	109.0



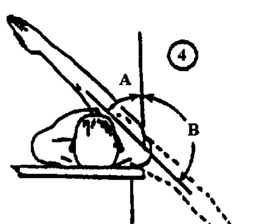
Neck Extension (A)
Flexion (B)

Joint movement	Range of motion (degrees) Males 5th percentile	Males 95th percentile	Females 5th percentile	Females 95th percentile
Neck, flexion	34.5	71.0	46.0	84.4
Neck, extension	65.4	103.0	64.9	103.0



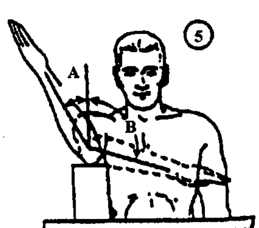
Neck Lateral Bend
Right (A), Left (B)

Joint movement	Range of motion (degrees) Males 5th percentile	Males 95th percentile	Females 5th percentile	Females 95th percentile
Neck, lateral right	34.9	63.5	37.0	63.2
Neck, lateral left	35.5	63.5	29.1	77.2



Horizontal Adduction (A)
Horizontal Abduction (B)

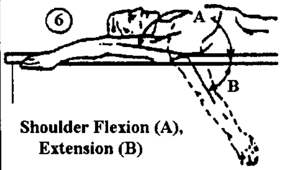
Joint movement	Range of motion (degrees) Males 5th percentile	Males 95th percentile	Females 5th percentile	Females 95th percentile
Shoulder, abduction	173.2	188.7	172.6	192.9



Shoulder Rotation,
Lateral (A), Medial (B)

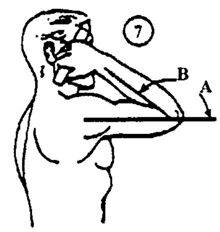
Joint movement	Range of motion (degrees) Males 5th percentile	Males 95th percentile	Females 5th percentile	Females 95th percentile
Shoulder, rotation lat	46.3	96.7	53.8	85.8
Shoulder, rotation med	90.5	126.6	95.8	130.9

Exhibit 14.3.3.2.1 (continued) Joint movement ranges



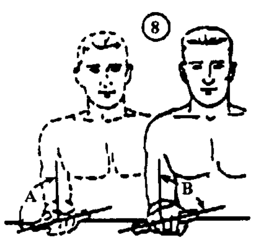
Shoulder Flexion (A), Extension (B)

Joint movement	Range of motion (degrees) Males 5th percentile	Males 95th percentile	Females 5th percentile	Females 95th percentile
Shoulder, flexion	164.4	210.9	152.0	217.0
Shoulder, extension	39.6	83.3	33.7	87.9



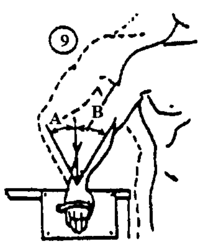
Elbow Flexion (B), Extension (A)

Joint movement	Range of motion (degrees) Males 5th percentile	Males 95th percentile	Females 5th percentile	Females 95th percentile
Elbow, flexion	140.5	159.0	144.9	165.9



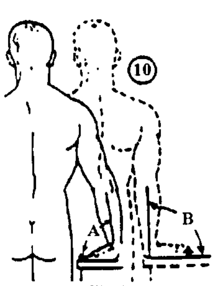
Forearm Supination (A), Pronation (B)

Joint movement	Range of motion (degrees) Males 5th percentile	Males 95th percentile	Females 5th percentile	Females 95th percentile
Forearm, pronation	78.2	116.1	82.3	118.9
Forearm, supination	83.4	125.8	90.4	139.5



Wrist Ulnar Bend(A), Radial Bend (B)

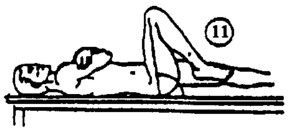
Joint movement	Range of motion (degrees) Males 5th percentile	Males 95th percentile	Females 5th percentile	Females 95th percentile
Wrist, radial	16.9	36.7	16.1	36.1
Wrist, ulnar	18.6	47.9	21.5	43.0



Wrist Flexion (A), Extension (B)

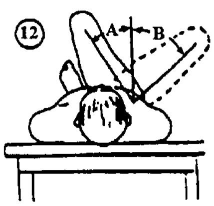
Joint movement	Range of motion (degrees) Males 5th percentile	Males 95th percentile	Females 5th percentile	Females 95th percentile
Wrist, flexion	61.5	94.8	68.3	98.1
Wrist, extension	40.1	78.0	42.3	74.7

Exhibit 14.3.3.2.1 (continued) Joint movement ranges



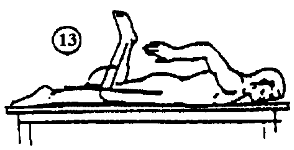
Hip Flexion

	Range of motion (degrees)			
	Males		Females	
Joint movement	5th percentile	95th percentile	5th percentile	95th percentile
Hip, flexion	116.5	148.0	118.5	145.0



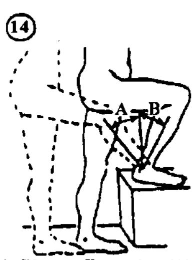
Hip Adduction (A), Abduction (B)

	Range of motion (degrees)			
	Males		Females	
Joint movement	5th percentile	95th percentile	5th percentile	95th percentile
Hip, abduction	26.8	53.5	27.2	55.9



Knee Flexion, Prone

	Range of motion (degrees)			
	Males		Females	
Joint movement	5th percentile	95th percentile	5th percentile	95th percentile
Knee, flexion	118.4	145.6	125.2	145.2



Ankle Plantar Extension (A), Dorsi Flexion (B)

	Range of motion (degrees)			
	Males		Females	
Joint movement	5th percentile	95th percentile	5th percentile	95th percentile
Ankle, planar	36.1	79.6	44.2	91.1
Ankle, dorsi	8.1	19.9	6.9	17.4

- **14.3.3.2.2 Range of motion for two joints.** Exhibit 14.3.3.2.2 shall be used for design problems involving the motion of two joints. Designers shall avoid using single joint movement data for adjacent joints because they are usually not additive. [Source: NASA-STD-3000A, 1989; MIL-HDBK-759B, 1992; MIL-STD-1800A, 1990]

  Discussion. The range of joint movement is drastically reduced by movement of the adjacent joint. Exhibit 14.3.3.2.2 defines the change in range of motion of a given joint when complemented by movement of the adjacent joint.

  Example. The following illustrates how Exhibit 14.3.3.2.2 is to be used. The first entry is read: the average shoulder has a full range of extension of 59.3 degrees with the elbow in a neutral position (locked in hyperextension). When shoulder extension was measured with the elbow flexed to one third of its full joint movement range (these movements can be determined from illustrations six and seven in the previous Exhibit), the mean value of shoulder extension was found to increase by 1.6 degrees, or approximately 103 percent of the base value. The results for other movements and adjacent joint positions are presented in a similar manner.

Exhibit 14.3.3.2.2 Change in range of joint movement with movement in an adjacent joint

		Change in range of movement of 1st joint (degrees)				
		Movement of 2nd joint (fraction of full range)				
Two-joint movement	Full range of 1st (degrees)	Zero	1/3	1/2	2/3	Full
Shoulder extension (1) with elbow flexion (2)	59.3		+1.6 deg (102.7%)		+0.9 deg (101.5%)	+5.3 deg (108.9%)
Shoulder flexion (1) with elbow flexion (2)	190.7		-24.9 deg (86.9%)		-36.1 deg (81.0%)	-47.4 deg (75.0%)
Elbow flexion (1) with shoulder extension (2)	152.2			-3.78 deg (97.5%)		-1.22 deg (99.2%)
Elbow flexion (1) with shoulder flexion (2)	152.2		-0.6 deg (99.6%)		-0.8 deg (99.5%)	-69.0 deg (54.7%)
Ankle plantar flexion (1) with knee flexion (2)	48.0		-3.4 deg (92.9%)		+0.2 deg (100.4%)	+1.6 deg (103.3%)
Knee flexion (1) with ankle planar flexion (2)	127.0			-9.9 deg (92.2%)		-4.7 deg (96.3%)
Knee flexion (1) with ankle dorsiflexion (2)	127.0					-8.7 deg (93.9%)
Knee flexion (1) with hip flexion (2)	127.0			-19.6 deg (84.6%)		-33.6 deg (73.5%)

14.4 Reach

Reach limits are clearly dependent on the task, motion, and function to be accomplished by the reach action. Limited reach data on standard anthropometric positions are available in sources of static and dynamic anthropometric data. Reach envelopes need to be constructed for actual working positions and for explicit design purposes. Reach envelopes may be related to a body reference point (such as the shoulder joint), to a measurement apparatus point, or to a design point (such as a seat reference point). This section provides design criteria and rules for using reach data and constructing reach envelopes. [Source: NASA-STD-3000A, 1989]

▪ 14.4.1 **Task and body position effects.** The following task considerations shall be taken into account in order to establish reference points and to obtain the reach information needed to construct a reach envelope:

a. the nature and requirements of the task to be performed (see also Paragraphs 14.3.1.2 and 14.4.3 for the nature of the reach task),

b. body position while reaching (standing, seated, seat back and seat pan angles, and others),

c. whole body movement capabilities and restraints (seat belts, harnesses, necessary and permitted movements of the torso),

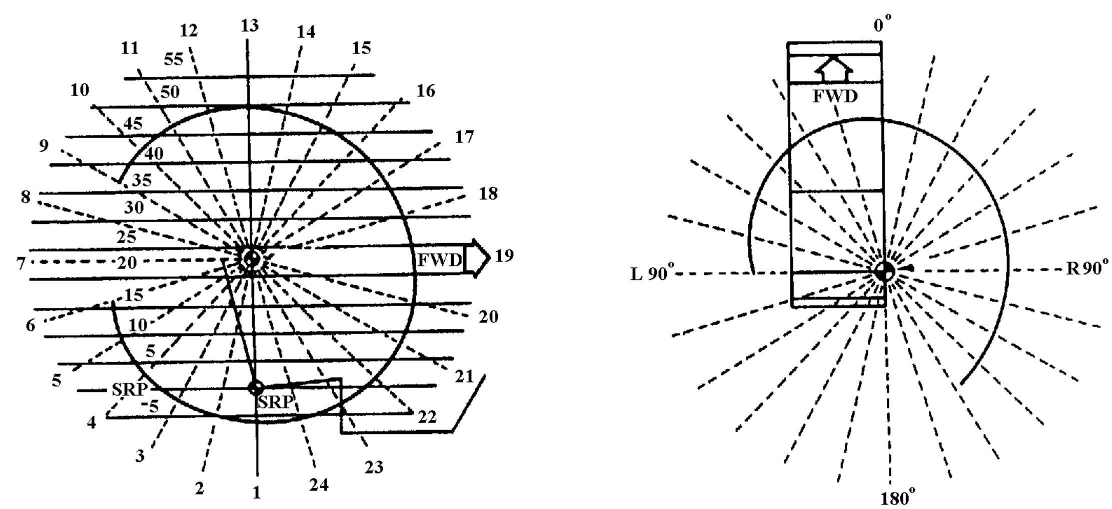
d. design purposes such as: to accommodate the appropriate portion of the population, to enhance task performance, or to avoid striking reachable surfaces, and

e. equipment locations that interfere with reach, vision or intercommunications. [Source: NASA-STD-3000A, 1989]

□ **14.4.2 Reach envelope data collection.** Designers and human factors specialists should understand that reach envelope measurement data are often related to the data collection procedures and apparatus. Often data can be found or should be collected to relate the design reference point of concern to the reach capabilities of the actual users. Another factor in data collection is the amount of whole body movement allowed. For example, consider bending the torso forward so that one or both shoulders no longer touch the seat back. [Source: Roebuck, Kroemer, & Thomson, 1975]

> **Example.** Exhibit 14.4.2 shows an example in which reach measurement is related to the seat reference point from a restrained shoulder level. In the left graph, a side view reference plane is shown, and in the right graph, a top view is shown in terms of reach angles. All measures and dimensions are relative to the apparatus.

Exhibit 14.4.2 Reach envelopes in vertical and horizontal planes



Discussion. An issue surrounding the application of reach data is how to relate static anthropometric reach dimensions, shoulder joint points, data collection procedures and apparatus reference points, and design reference points. Most reach measurements are made relative to an apparatus reference point. A further complication is that the apparatus and design seat reference point may not be the same or may not reflect the same seat configurations (back and pan angles).

> **Definition. Seat reference point** is a point in the mid-sagittal plane where the seat back and seat pan intersect.

- **14.4.3 Reach envelope interaction with the reach task.** Reach envelope data shall be collected or modified for the tasks, motions, or functions to be accomplished by the reach. Exhibit 14.4.3 (a) defines some task demands (touch, grip, and grasp) that affect reach characteristics and measures. [Source: Kroemer, Kroemer, & Kroemer-Elbert, 1990]

Exhibit 14.4.3 (a) Touch, grip, and grasp functions

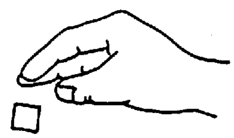
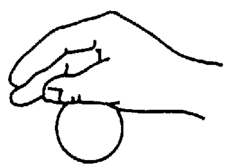
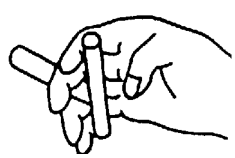
	**Finger touch**. One finger touches an object without holding it.
	**Palm touch**. Some part of the inner surface of the hand touches the object without holding it
	**Finger palmer grip** (hook grip). One finger or several fingers hook(s) onto a ridge or handle. This type of finger action is used if thumb counterforce is not needed.

Exhibit 14.4.3 (a) (continued) Touch, grip, and grasp functions

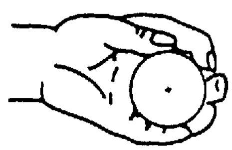
Thumb-fingertip grip ("tip grip"). The thumb tip opposes one fingertip.

Thumb-finger palmar grip ("pinch grip"). Thumb pad opposes the palmar pad of one finger, or the pads of several fingers near the tips. This grip evolves easily from coupling the thumb-fingertip grip.

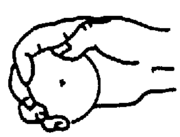
Thumb-forefinger side grip (lateral grip or "side pinch"). Thumb opposes the (radial) side of the forefinger.

Thumb-two-finger grip ("writing grip"). Thumb and two fingers (often forefinger and index finger) oppose each other at or near the tips.

Thumb-fingertips enclosure ("disk grip"). Thumb pad and the pads of three or four fingers oppose each other near the tips (object grasped does not touch the palm). This grip evolves easily from the thumb-two-finger grip.



Finger-palm enclosure ("enclosure"). Most, or all, of the inner surface of the hand is in contact with the object while enclosing it.

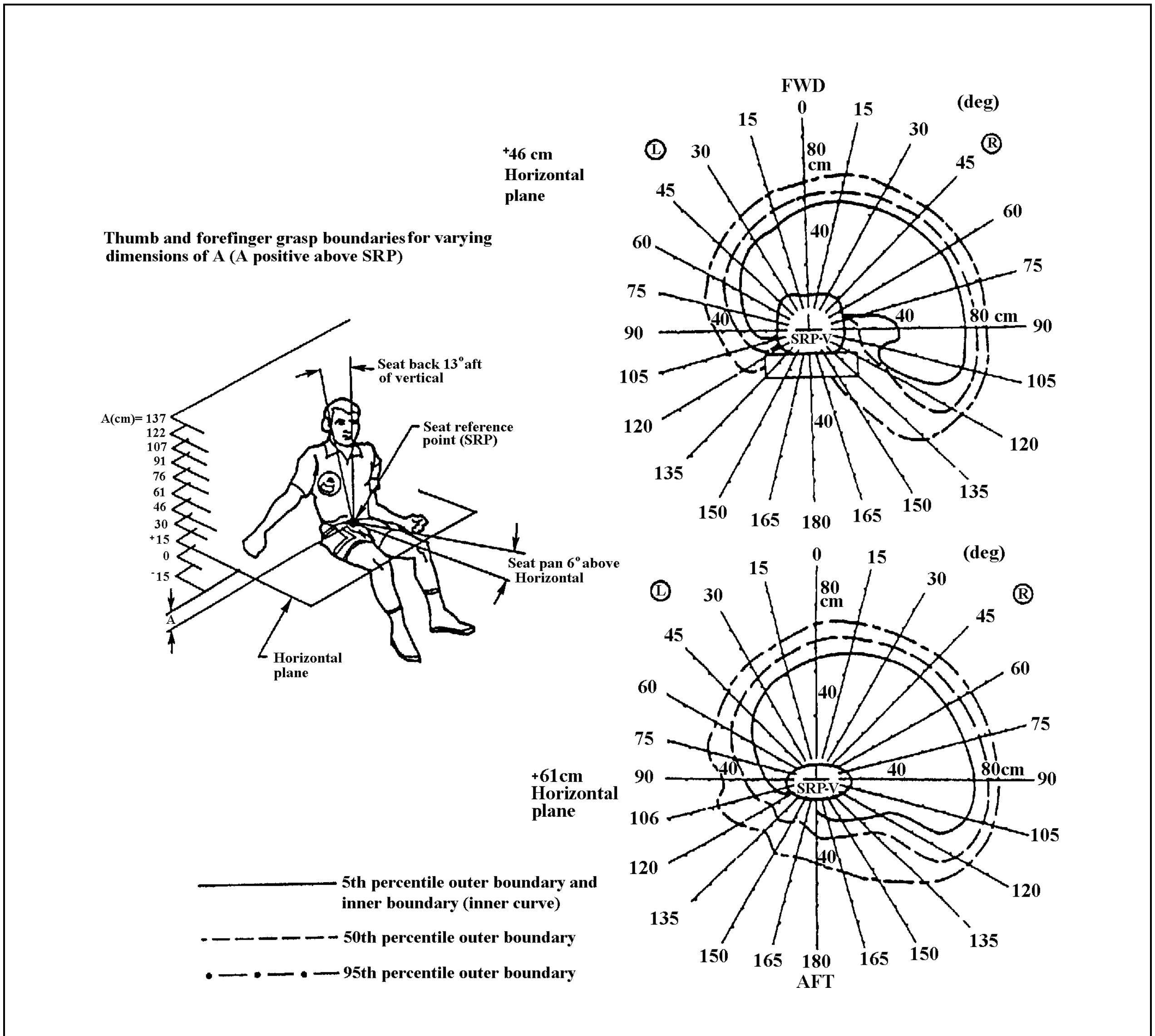


Grasp ("power grasp"). The total inner hand surface is grasping the (often cylindrical) handle which runs parallel to the knuckles and generally protrudes on one side or both sides from the hand.

Discussion. Fingertip touch results in the largest reach dimensions appropriate for touch controls. Other grasp functions would reduce the reach envelope. Two-handed operations, greater precision, and frequent or continuous operation would necessitate locating the task closer to the body. Bulky clothing could affect reach capabilities.

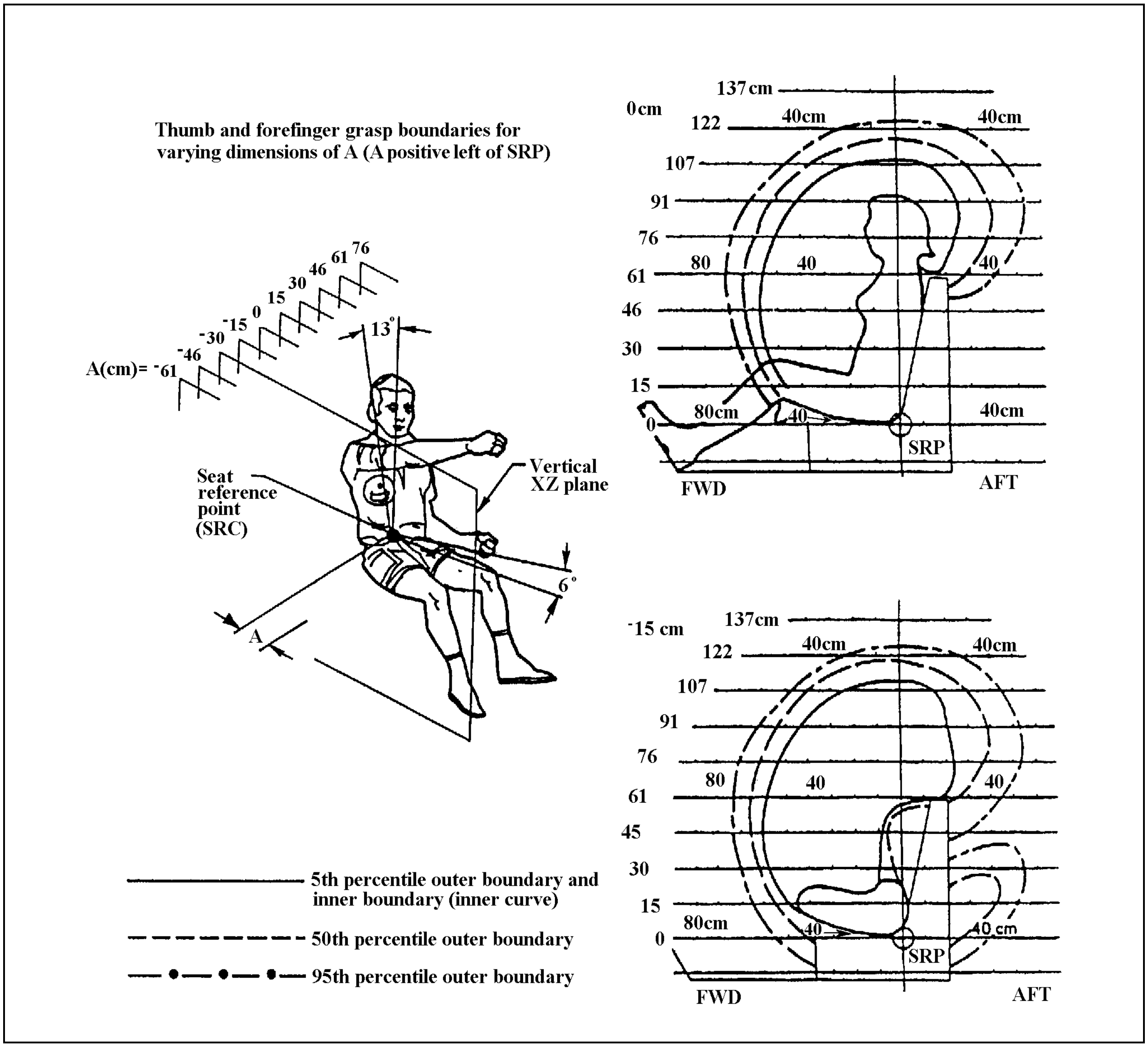
Examples. Exhibits 14.4.3 (b) and (c) present 5th percentile female reach envelope data as examples of one possible presentation for such data. The data represent right hand reach for a fingertip grasp task. In Exhibit 14.4.3 (b) horizontal contours are shown at the 46 and 61 cm levels.

Exhibit 14.4.3 (b) Thumb and forefinger grasp boundary data for females in the 46 cm and 61 cm horizontal planes



In Exhibit 14.4.3 (c) vertical planes are shown for the 0 and -15 cm planes. For design use, data would be presented for other horizontal and vertical planes. For this example, shoulders were restrained against the seat.

Exhibit 14.4.3 (c) Thumb and forefinger grasp boundary data for females in the 0 and -15 cm vertical planes



Three factors can affect three-dimensional reach envelopes: the effects of different hand manipulation tasks, the effects of permitting torso and shoulder movement, and the effects of the seat back angle of the data collection apparatus. For instance, the Exhibit shows thumb and forefinger grasp. Not shown is that fingertip touch reach would increase by 7.0 cm (2.8 in) and full hand grasp reach would decrease by -5.5 cm (2.2 in) from their fingertip grasp reach values.

Additional data also not shown in the Exhibit reveals that if the seat back angle were changed from 13 degrees rearward (as shown in the Exhibits) to the vertical position, that is to 90 degrees, then reach measures in a horizontal plane from 0 degrees (arm straight forward and horizontal) to 90 degrees to the right increase as follows:

a. at 0 degrees, by 1.02 cm (.40 in);

b. at 15 degrees, by 1.27 cm (.50 in);

c. at 45 degrees, by .94 cm (.37 in);

d. at 60 degrees, by .66 cm (.26 in); and

e. at 90 degrees, by .25 cm (.10 in).

□ **14.4.4 Strength or fine manipulation.** Tasks which require strength or fine manipulation, as well as repetitious tasks should be located well within the perimeter of the reach limit envelope. [Source: NASA-STD-3000A, 1989]

Discussion. The strength that can be exerted varies considerably throughout the reach envelope. As was noted in the previous example, the reach envelope varies with the type of grasp required in defining the envelope. This rule points out that one may need to further accommodate the task location by the strength, fine manipulation, or repetitive nature of the tasks to be performed. In these cases, consider the capabilities of the small (1st or 5th percentile) female user and also provide sufficient space and adjustability to accommodate the large male.

14.5 Human strength and handling capacity

The designer and human factors specialist needs to know the limits and ranges of human strength to create designs that are within the capabilities of potential users. If demands on human strength are too high, inefficient and unsafe worker performance will result. If the designer underestimates strength, unnecessary design effort and expense may be incurred.

This section introduces muscle strength factors and provides criteria and rules on control forces, as well as push and pull forces. This section also provides supplemental criteria and rules on lifting and carrying.

14.5.1 Muscle strength factors

The forces delivered by the human body depend on the contractile strength of the muscles, and the mechanical advantages of the body lever system with the joints serving as fulcra and the long bones serving as levers.

Knowledge of some of the many factors that relate to muscular strength may aid design personnel in understanding human physical capabilities. In addition to the strength capabilities of various body members, other factors include: (1) age, (2) endurance, (3) gender, (4) body build, (5) body position, (6) handedness, (7) exercise, (8) diet and drugs, (9) diurnal variation, and (10) emotional and fatigue states. Gender and handedness are discussed below while strength limit factors are presented in the criteria and rules throughout Section 14.5.
[Source: Israelski: 1977]

Discussion. In general, females are about 35 to 85% as strong as males with varying differentials for various muscle groups. Gender differences favor greater range in joint motion in females at all joints except the knee. The preferred hand and arm are approximately 10% stronger than the non-preferred hand and arm.

Definitions. There are three basic categories of strength: (1) **static strength**, also known as isometric strength, which is steady force exerted while the limbs are in a stationary or static position, (2) **dynamic strength**, which is a force exerted by limbs moving in a smooth manner over time, such as while lifting an object, and (3) **explosive strength**, which is the application of peak amounts of strength for short periods of time, usually periodically, such as in running or sprinting.

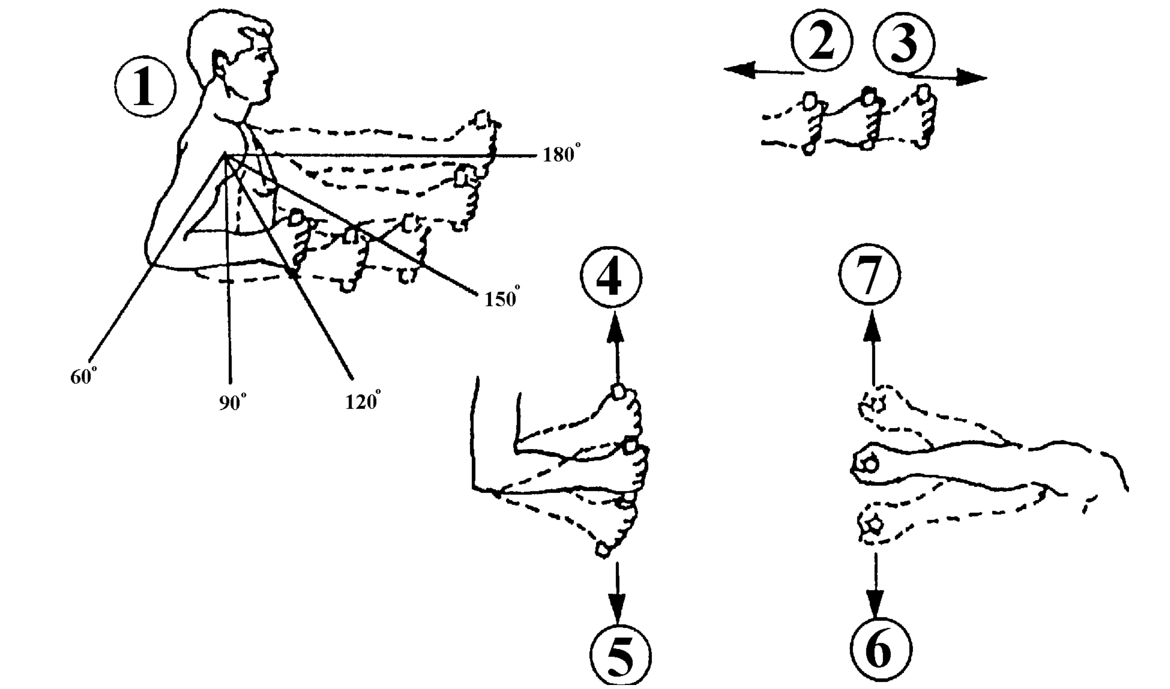
14.5.2 Exerted forces

▫ **14.5.2.1 Maximum young male force or resistance for a control.** The maximum amount of force or resistance designed into a control should be determined by the greatest amount of force that can be exerted by the weakest person likely to operate the control. Control force limits, like most strength design limits, should be based upon the 5th percentile (or, for critical tasks, the 1st percentile) of the female user population. [Source: MIL-HDBK-759B, 1992; AFSC DH 1-3, 1980]

Exhibit 14.5.2.1 represents 80% of the maximum exertion forces for the 5th percentile male for the arm, hand and thumb. Since the experimental conditions used to collect the source data yielded maximum possible exertion values for young men, these values are were too high for design purpose. For design, one does not want to deliberately or consistently require maximum exertions. Thus these source values were reduced by 20% before applying them as design criteria. Male data should be selected based upon the body components involved in the specific exertion task. To estimate female strength, male data should be further reduced according to Paragraph 14.5.2.3. Females can apply most strength when torso, back, and legs are major contributors. Female upper body and arm strength are weakest (see also comparative lifting strength information Paragraph 14.5.2.3).

Discussion. The maximum force that can be applied will depend on such factors as the type of control, the body member used to operate it, the position of this body member during control operations, the general position of the body, and whether or not support is provided by backrests.

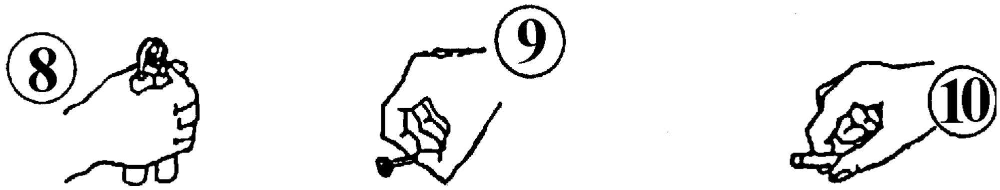
Exhibit 14.5.2.1 Male muscle strength of the arm, hand, and thumb for control forces (5th percentile values)



Arm strength N (lb) Design criteria levels

1	2		3		4		5		6		7	
Degree elbow flexion	Pull L	Pull R	Push L	Push R	Up L	Up R	Down L	Down R	In L	In R	Out L	Out R
180°	177.6 (40)	184.8 (41.6)	149.6 (33.6)	177.6 (40)	32 (7.2)	49.6 (11.2)	46.6 (10.4)	60.8 (13.6)	46.6 (10.4)	71.2 (16)	28.8 (6.4)	49.6 (11.2)
150°	149.6 (33.6)	199.2 (44.8)	106.4 (24)	149.6 (33.6)	53.6 (12)	64 (14.4)	64 (14.4)	71.2 (16)	53.6 (12)	71.2 (16)	28.8 (6.4)	53.6 (12)
120°	120.8 (27.2)	149.6 (33.6)	92.8 (20.8)	128 (28.8)	60.8 (13.6)	85.6 (19.2)	74.4 (16.8)	92.8 (20.8)	71.2 (16)	78.4 (17.6)	36 (8)	53.6 (12)
90°	113.6 25.6)	132 (29.6)	78.4 (17.6)	128 (28.8)	60.8 (13.6)	71.2 (16)	74.4 (16.8)	92.8 (20.8)	56.8 (12.8)	64 (14.4)	36 (8.)	56.8 (12.8)
60°	92.8	85.6	78.4	120.8	53.6	71.2	64	71.2	60.8	71.2	42.4	60.8

Exhibit 14.5.2.1 (continued) Design criteria for male muscle strength of the arm, hand, and thumb for control forces (5th percentile values)



Hand and thumb-finger strength N (lb)

	8		9	10
	Hand grip		**Thumb-finger grip (palmer)**	**Thumb-finger grip (tips)**
	L	**R**		
Momentary hold	200 (44.8)	208 (47.2)	48 (10.4)	48 (10.4)

- **14.5.2.2 Increasing strength values.** Strength values shall be slightly increased if:

a. a lifting yoke or other special harness is to be used,

b. the object is unusually easy to handle,

c. the required force must be applied infrequently or only for a few seconds, if more than one per 30 seconds, decrease by .30 or

d. the working body parts are provided with suitable support. [Source: MIL-HDBK-759B, 1992; MIL-STD-1472D, 1989; MIL-STD-1800A, 1990; AFSC DH 1-3, 1980]

▫ **14.5.2.3 Comparative strength.** Research has produced little insight into the strength of women relative to men. The following strength relationships developed by the US Army Research Institute of Environmental Medicine should be used until better data becomes available:

a. For upper extremities, females strength is 56.5% of men.

b. For lower extremities, female strength is 64.2% of men.

c. For trunk extremities, female strength is 66.0% of men.

Explanation. These numbers may serve as a design rule until more information becomes available.

▫ **14.5.2.4 Preventing tremor in positive control performance.** Tremor is important in activities in which a body member is maintained in a precise position or motion (tasks involving fine continuous control, detailed drawing, tracking, tracing, cutting, or painting). The following features should be designed into systems or equipment, where applicable, to help reduce tremor and ensure positive control performance of fine detailed tasks:

a. ensure that visual reference can be used,

b. provide support of the body and the member involved, for example, the hand or arm,

c. support the hand because tremor is less if the hand is 203.2 mm (8 in) above or below the heart level, and

d. provide mechanical friction in the control device to add enough resistance to movement to partially counteract the energy of the vibrations of the body member. [Source: Israelski, 1977]

Definition and discussion. Tremor is the oscillation of a body extremity which may occur along with an effort to maintain a fixed position or direction. The degree of tremor is measured by the distance or number of departures from the fixed path or position per unit of time. Tremor increases when (1) effort is made not to tremble, and (2) fatigue is present. It is greatest in vertical motion, less in front-to-back motion, and least in side-to-side motion.

14.5.3 Push and pull forces

□ 14.5.3.1 **Horizontal direction of force.** Manual horizontal push and pull forces that are initially necessary to set an object in motion, or to sustain the motion over a period of time, should not exceed the values given in Exhibit 14.5.3.1. For the second or third person applying horizontal forces, the value in the Exhibit's first column should be doubled or tripled, respectively. For each additional person (beyond the third) another 75 percent of the force value in the first column should be added. [Source: MIL-HDBK-759B, 1992]

Explanation. The Exhibit shows maximum push and pull forces that a designer would be expected to use when appropriate body positions, support, and traction conditions are provided. Use of the maximum values shown in the Exhibit is predicated upon a suitable surface for force exertion (vertical with rough surface approximately 400 mm (15.75 in) wide and between 0.51 - 1.27 m (1.673 - 4.167 ft) above the floor) to allow force application with the hands, shoulders, or back.

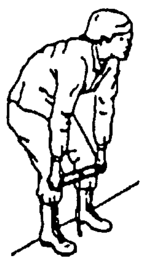
Exhibit 14.5.3.1 Horizontal push and pull forces that can be exerted

Exertable horizonal force	Applied with	Condition (μ: coefficient of friction)
110 N (24.7 lbf) push of pull	both hands or one shoulder or the back	with low traction $0.2 < \mu$ 0.3
200 N (45.0 lbf) push or pull	both hands or one shoulder or the back	with medium traction $\mu \approx 0.6$
240 N (54.0 lbf) push	one hand	if braced against a vertical wall 510-1520 mm (20.08-59.84 in) from and parallel to the push panel
310 N (70.0 lbf) push or pull	both hands or one shoulder or the back	with high traction $\mu > 0.9$
490 N (110.2 lbf) push or pull	both hands or one shoulder or the back	if braced against a vertical wall 510-1780 mm (20.08-70.08 in) from and parallel to the panel or if anchoring the feet on a perfectly non-slip ground (like a footrest)
730 N (164.1 lbf) push	the back	if braced against a vertical wall 580-1090 mm (22.83-42.91 in) from and parallel to the push panel or if the anchoring the feet on a perfectly non-slip ground (like a footrest)

▫ **14.5.3.2 Vertical direction of force.** Required manual vertical static lift forces should not exceed the applicable 5th percentile peak or mean force values given in Exhibit 14.5.3.2. [Source: MIL-HDBK-759B, 1992]

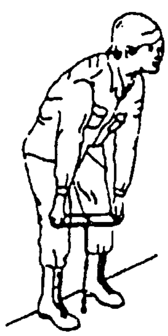
Explanation. Based upon NIOSH experience, the forces found in the source that studied young military personnel have been reduced by 20 percent (Exhibit 14.5.3.2). The mean forces given represent force over a three second interval, beginning two seconds after it reached a minimum value of 45 N provided that it continued to exceeded this minimum. Exhibit 14.5.3.2 reflects the higher of two trials for each condition.

Exhibit 14.5.3.2 Static muscle strength data for vertical pull exertions



A. Standing two-handed pull: 38 cm (15.0) level. Standing with feet 45 cm (17.7 in) apart and knees bent; bending at the waist, grasping both sides of a 45 cm (17.7 in) handle located directly in front, 38 cm (15.0 in) above standing surface, and pulling, using primarily arms, shoulders, and legs

Strength measurements	5th percentile Male	5th percentile Female	95th percentile Male	95th percentile Female
Mean force (N)	737.5	330.9	1354.5	817.6
Mean force (lbf)	(165.80)	(74.39)	(304.50)	(183.80)
Peak force (N)	844.7	396.9	1437.2	888.3
Peak force (lbf)	(189.90)	(89.23)	(323.10)	(199.70)



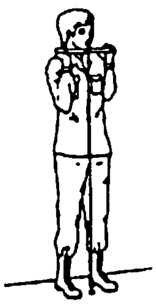
B. Standing two-handed pull: 50 cm (19.7 in) level. Standing with feet 45 cm (17.7 in) apart and knees straight; bending at the waist, grasping both sides of a 45 cm (17.7 in) handle located directly in front, 50 cm (19.7 in) above standing surface, and pulling, using primarily arms and shoulders

Strength measurements	5th percentile Male	5th percentile Female	95th percentile Male	95th percentile Female
Mean force (N)	758.0	326.1	1341.6	840.7
Mean force (lbf)	(170.41)	(73.31)	(301.60)	(189.00)
Peak force (N)	830.9	374.1	1441.7	905.2
Peak force (lbf)	(186.79)	(84.10)	(324.11)	(203.50)

C. Standing two-handed pull: 100 cm (39.4 in) level. Standing erect with feet 45 cm (17.7 in) apart, grasping both sides of a 45 cm (17.7 in) handle located directly in front, 100 cm (39.4 in) above the standing surface, and pulling, using the arms

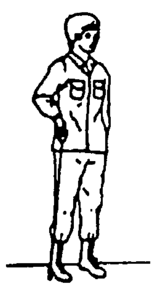
Strength measurements	5th percentile Male	5th percentile Female	95th percentile Male	95th percentile Female
Mean force (N)	444.4	185.0	931.0	443.0
Mean force (lbf)	(99.91)	(41.59)	(209.30)	(99.59)
Peak force (N)	504.0	218.0	988.4	493.3
Peak force (lbf)	(113.30)	(49.01)	(222.20)	(110.90)

Exhibit 14.5.3.2 (continued) Static muscle strength data for vertical pull exertions



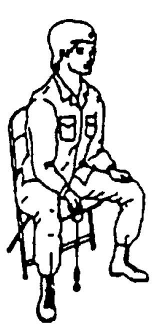
D. **Standing two-handed push: 150 cm (59.1 in) level.** Standing erect with feet 45 cm (17.7 in) apart grasping from below, both sides of a 45 cm (17.7 in) handle located directly in front, 150 cm (59.1 in) above standing surface, pushing upward using arms and shoulders

	5th Percentile		95th Percentile	
Strength measurements	Male	Female	Male	Female
Mean force (N)	408.8	153.5	1016.9	379.9
Mean force (lbf)	(91.9)	(34.51)	(228.61)	(85.41)
Peak force (N)	472.8	187.7	1094.3	430.1
Peak force (lbf)	(106.29)	(42.20)	(246.02)	(96.69)



E. **Standing one-handed pull: 100 cm (39.4 in) level.** Standing erect with feet 15 cm (5.9 in) apart dominant hand grasping underside of D-ring located directly to the side, 100 cm (39.4 in) above standing surface, pulling upward while keeping shoulder square and other arm relaxed at side

	5th Percentile		95th Percentile	
Strength measurements	Male	Female	Male	Female
Mean force (N)	214.8	102.8	627.6	283.8
Mean force (lbf)	(48.29)	(23.11)	(141.09)	(63.8)
Peak force (N)	258.9	131.7	724.2	322.5
Peak force (lbf)	(58.20)	(29.61)	(162.81)	(72.50)



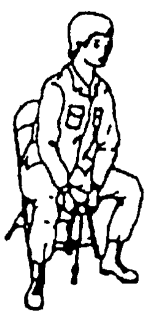
F. **Seated one-handed pull: seat centerline 45 cm (39.4 in) level.** Sitting erect with feet 55 cm (21.7 in) apart, dominant hand grasping underside of D-ring located directly to the front, 45 cm (17.7 in) above the floor, pulling upward while keeping shoulder square and other arm resting in lap

	5th Percentile		95th Percentile	
Strength measurements	Male	Female	Male	Female
Mean force (N)	222.3	106.3	678.4	391.9
Mean force (lbf)	(49.98)	(23.90)	(152.51)	(88.11)
Peak force (N)	273.1	127.2	758.4	450.6
Peak force (lbf)	(61.40)	(28.60)	(170.50)	(101.30)

Exhibit 14.5.3.2 (continued) Static muscle strength data for vertical pull exertions

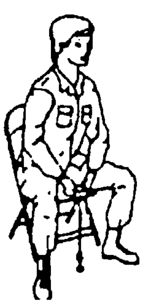
G. Seated one-handed pull: side of seat, 45 cm (17.7 in) level. Sitting erect with feet 55 cm (21.7 in) apart, dominant hand grasping underside of D-ring located a short distance to side, 45 cm (17.7 in) above the floor, pulling upward while keeping shoulders square and other arm resting in lap

Strength measurements	5th percentile Male	Female	95th percentile Male	Female
Mean force (N)	408.8	153.5	1016.9	379.9
Mean force (lbf)	(91.90)	(34.51)	(228.61)	(85.41)
Peak force (N)	472.8	187.7	1094.3	430.1
Peak force (lbf)	(106.29)	(42.20)	(246.02)	(96.69)



H. Seated two-handed pull: centerline of seat, 38 cm (14.96 in) level. Sitting erect with feet 55 cm (21.7 in) apart, bending slightly at waist, grasping both sides of 15 cm (5.9 in) handle located directly to the front, 38 cm (15.0 in) above the floor, pulling upward using arms and shoulders, keeping arms off thighs

Strength measurements	5th percentile Male	Female	95th percentile Male	Female
Mean force (N)	214.8	102.8	627.6	283.8
Mean force (lbf)	(48.29)	(23.11)	(141.09)	(63.80)
Peak force (N)	258.9	131.7	724.2	322.5
Peak force (lbf)	(58.20)	(29.61)	(162.81)	(72.50)



I. Seated two-handed pull: centerline of seat, 50 cm (19.7 in) level. Sitting erect with feet 55 cm (21.7 in) apart, bending slightly at the waist, grasping both sides of 15 cm (5.9 in) handle located directly to the front, 50 cm (19.7 in) above the floor, pulling upward using arms and shoulders, keeping arms off thighs

Strength measurements	5th percentile Male	Female	95th percentile Male	Female
Mean force (N)	222.3	106.3	678.4	391.9
Mean force (lbf)	(49.98)	(23.90)	(152.51)	(88.11)
Peak force (N)	273.1	127.2	758.4	450.6
Peak force (lbf)	(61.40)	(28.60)	(170.50)	(101.30)

14.5.4 Lifting and carrying

There are three major muscular components of weight-lifting: (1) the legs, (2) the arms-back, and (3) the arms. In efficiently lifting objects to different heights, these components are combined in different ways. Specifically, lifting objects to about knee height involves primarily the use of the leg component, while objects lifting to about waist level involves a combination of leg and arm-back components. Lifting objects to shoulder level or higher requires the use of all three components.

- 14.5.4.1 **Lifting and carrying limits.** Data, criteria, and rules in Chapter 4 shall be used to establish recommended maximum weights to be lifted and carried by one and two people. [Source: AFSC DH 1-3, 1980; Israelski, 1977; NASA-STD-3000A, 1989]

14.6 Wheelchair anthropometrics

- 14.6.1 **Maximum high forward reach in a wheelchair**. If the clear floor space only allows forward approach to an object, the maximum high forward reach allowed shall be 48 in (1220 mm)(see Exhibit 14.6.1), unless there is an obstruction projecting 20 to 25 in (510 to 635 mm), in which case it is 44 inches (1120mm). [Source: UFAS, 1988]

- 14.6.2 **Minimum low forward reach in a wheelchair**. If the clear floor space only allows forward approach to an object, the minimum low forward reach shall be 15 in (380 mm)(See Exhibit 14.6.1). [Source: UFAS, 1988]

- 14.6.3 **Maximum reach over obstruction in a wheelchair**. The maximum forward reach over an obstruction with knee space below shall be 635 mm (25in) (see Exhibit 14.6.1). [Source: UFAS, 1988]

Exhibit 14.6.1 Forward reach from a wheelchair.

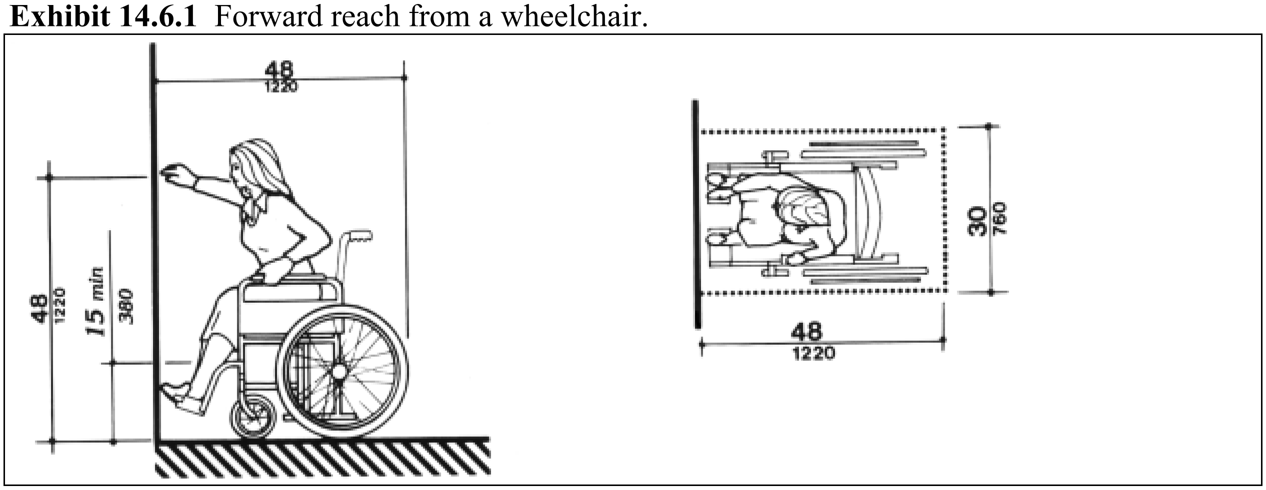
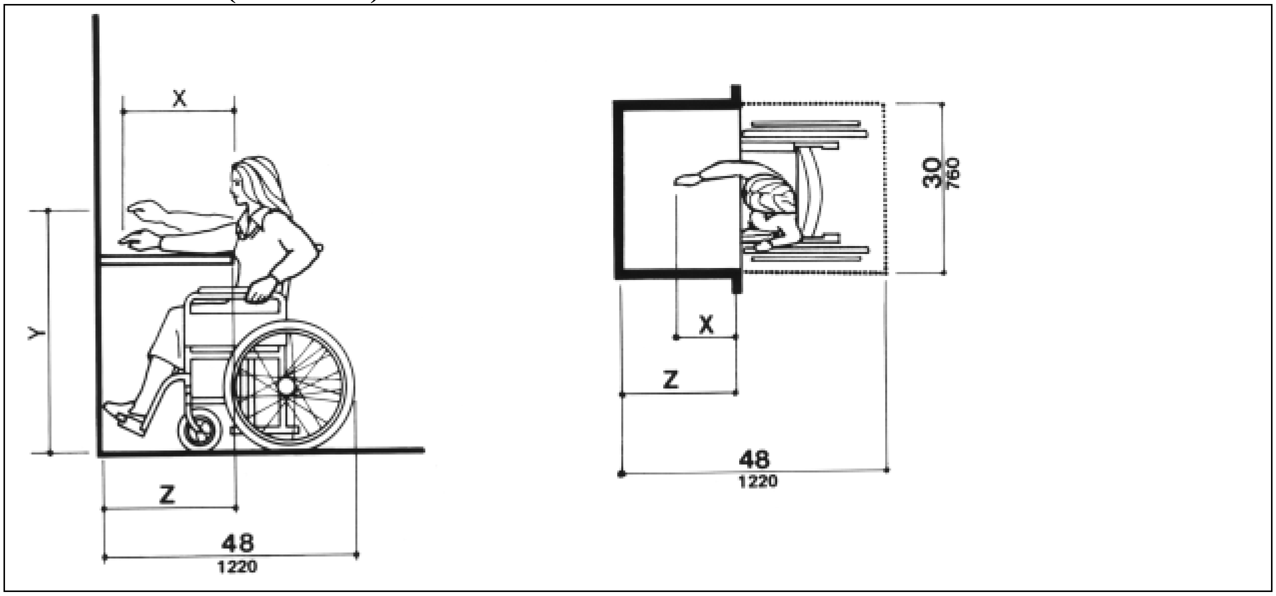


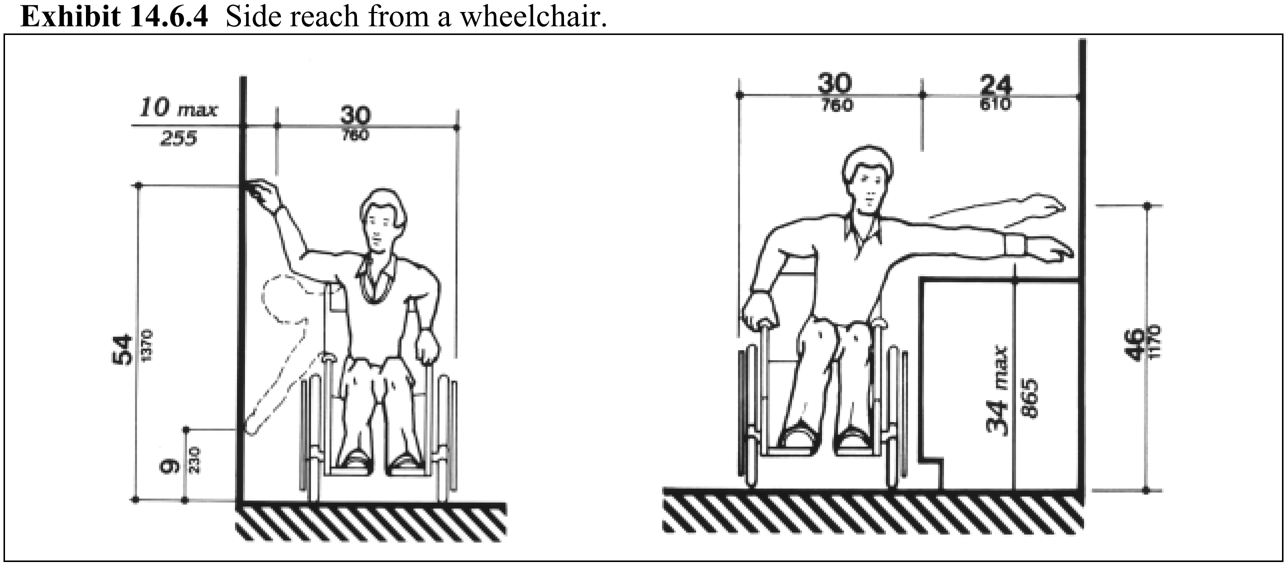
Exhibit 14.6.1 (continued) Forward reach from a wheelchair



- 14.6.4 **Maximum side reach in a wheelchair**. If the clear floor space allows only parallel approach to an object by a person in a wheelchair, the maximum high side reach allowed shall be 54 in (1370 mm)(see Exhibit 14.6.4), unless there is an obstruction projecting 20 to 25 in (510 to 635 mm), in which case it is 46 inches (1170mm). [Source: UFAS, 1988]

- 14.6.5 **Minimum side reach in a wheelchair**. If the clear floor space allows only parallel approach to an object by a person in a wheelchair, the minimum side reach allowed shall be no less than 9 in (230 mm)(see Exhibit 14.6.4) above the floor. [Source: UFAS, 1988]

Exhibit 14.6.4 Side reach from a wheelchair.

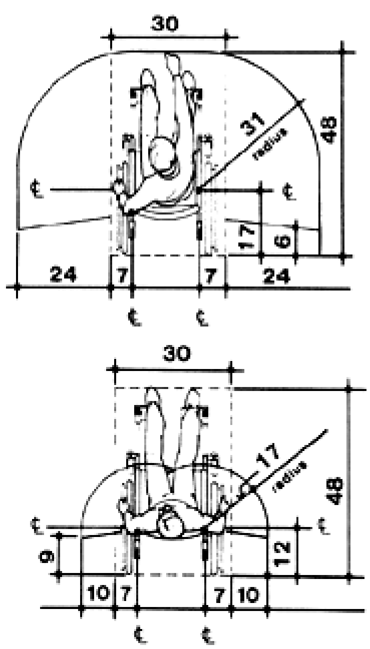


- **14.6.6 Wheelchair dimensions.** Designers and human factors specialists shall use the data in Exhibit 14.6.6 for design problems involving wheelchair users. This Exhibit presents wheelchair dimension data. [Source: UFAS, 1988]

Exhibit 14.6.6 Wheelchair dimensions.

The height of the handle is at 36 inches (915 mm). The armrest is 30 inches (760 mm) high. Eye level is between 43 and 51 inches (1090-1295 mm). The lap is at 27 inches (685 mm). The seat is at 19 inches (485 mm). The toe is at 8 inches (205 mm). The width of a wheelchair measured from the outer edges of the back wheels is 26 inches (660 mm); the length is 42 inches (1065 mm); the width measured from the outer edges of the footrests is 18 inches (455 mm). The toes extend 6 inches (150 mm) beyond the edge of the footrests.

Note: Footrests may extend further for very large people.



Glossary

Abduction - Movement away from the midline of the body.

Adduction - Movement toward the midline.

Anthropometry - The scientific measurement and collection of data about human physical characteristics and the application (engineering anthropometry) of these data in the design and evaluation of systems, equipment, manufactured products, human- made environments, and facilities. Biomechanics describes the mechanical characteristics of biological systems, in this case the human body, in terms of physical measures and mechanical models. This field is interdisciplinary (mainly anthropometry, mechanics, physiology, and engineering). Its applications address mechanical structure, strength, and mobility of humans for engineering purposes.

Biomechanics - Describes the mechanical characteristics of biological systems, in this case the human body, in terms of physical measures and mechanical models.

Circumduction - A continuous circular movement of a limb.

Correlation coefficient or "r" value - Describes the degree to which two variables vary together (positive correlation) or vary inversely (negative correlation). The correlation coefficient, "r", has a range of values from +1.0 (perfect positive correlation) through -1.0 (perfect negative correlation). Multiple correlation involves the predictable relationship of two or more variables with another criterion variable (such as a composite measurement value).

Depression - The lowering of a body member from its normal position.

Design limits approach - A method of applying population or sample statistics and data about human physical characteristics to a design so that a desired portion of the user population is accommodated by the design. The range of users accommodated is a function of limits used in setting the population portion.

Dynamic strength - A force exerted by limbs moving in a smooth manner over time, such as while lifting an object.

Elevation - The raising of a body member from a normal position.

Explosive strength - The application of peak amounts of strength for short periods of time, usually periodically, such as in running or sprinting.

Extension - The straightening of a limb or an increase in the angle between parts of the body.

Flexion - The process of bending a limb or decreasing the angle between parts of the body.

Human physical and associated measurement characteristics - Refers to specific physical, mobility, or strength features of human users and to the explicit way that a human feature or capability is measured for use as general anthropometric or biomechanics data or as data for a specific design.

Lateral rotation - Turning away from the midline of the body.

Medial rotation - Turning toward the midline of the body.

Percentile statistic - Determined by ranking all data values (using the applicable measurement values related to the selected human physical characteristic) in the sample and determining the percentage of data that fall at or below a specific datum value.

Percentile value (or point) of the selected datum - The percentage of data that fall at or below a specific datum value.

Pronation - The downward turning of the palm.

"R", The multiple correlation coefficient – Is a statistical number that indicates the strength of the relationship between sets of data. The correlation coefficient can be between –1 and +1 with a correlation of |1| indicates a perfect correlation. The closer the number is to |1|, the stronger the relationship between the two sets of data. It is recommended that only correlations with strong predictive values be used (that is where r or R is at least or greater than |.7|).

Seat reference point - A point in the mid-sagittal plane where the seat back and seat pan intersect.

Static strength - Also known as isometric strength, which is steady force exerted while the limbs are in a stationary or static position.

Supination - Is the upward turning of the palm, or lying face up.

Tremor - The oscillation of a body extremity which may occurring along with an effort to maintain a fixed position or direction. The degree of tremor is measured by the distance or number of departures from the fixed path or position per unit of time. Tremor increases when (1) effort is made not to tremble, and (2) fatigue is present. It is greatest in vertical motion, less in front-to-back motion, and least in side-to-side motion.

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15 User documentation

This section provides criteria and rules for the development of documents that will be used by operators and maintainers in the performance of routine and corrective use of systems and equipment. User documentation includes user guides and manuals, user handbooks and technical instructions, job performance aids, quick reference guides, and instruction placards.

To be successful, a document must be appropriate to the knowledge and skills of its users, to the tasks they will perform using the document, and to the environment in which the users will perform these tasks. To ensure success, document development might include the following steps: (a) determine the relevant characteristics of the users of the document, in particular, their existing knowledge and skills, (b) determine the environment in which the document will be used, (c) determine the tasks to be covered by the document, (d) determine the users' information requirements, (e) determine the appropriate types of documentation, (f) create draft documents, (g) perform technical review(s), (h) perform usability tests, and (i) prepare documentation for release.

User documentation is part of the interface between the users and other system components. It contributes to the user's cognitive understanding of the hardware, software, and human interactions with these other components of the system. It can serve as a job aid and as a supplement to (but not a substitute for) system training. Thus, this section contributes to the usability and effectiveness of the operational system and is to be applied to new systems and equipment acquisitions and modifications as a part of development and procurement.

The first part of this section is devoted to criteria and rules for the development of printed user documentation in general. These general topics include organizing the document, writing the text, and laying out the page. These topics are followed by criteria and rules for the individual components that comprise a user document, such as the title page, figures, instructions, and indexes.

15.1 General

The users of a document want the document to help them perform their tasks quickly and efficiently. However, these users differ from each other in many ways in level of expertise, in motivation, in time constraints, in work styles, in reading abilities, in attitudes, in personal preferences, in age, and so on. The more these differences are accommodated, the more effective a document will be to its individual users. This section recommends some ways to match documentation to users and ways to make the documentation appear easy to use.

15.1.1 Matching documentation to users

- 15.1.1.1 **Description of expected users.** The procuring agency shall provide a description of the expected users of the document to the document contractor. The description would include the following sorts of information: (a) aptitude profile, (b) reading level, (c) time in job, (d) job-related training, (e) job-related work experience, and (f) job-related skills, knowledge and duties. This description could be iterated between the procuring agency and the technical writers until they mutually agree that it is sufficient. [Source: Joyce, R.P., Chenzoff, Mulligan, & Mallory (AFHRL-TR-73), 1973; Department of Transportation (FAA-D-2494/b), 1984]

  Example. FAA-D-2494/b, Technical Instruction Book Manuscript: Electronic, Electrical, and Mechanical Equipment, Requirements for Preparation of Manuscript and Production of Books, provides a general level description of some of these user characteristics, as well as instruction and maintenance environments.

- 15.1.1.2 **Documentation for people at different skill levels.** If the users of a document are expected to vary widely in their skills and levels of experience, the document shall permit use in different ways by people at different levels, or different versions of the document shall be prepared for people at different levels. If a single document is designed for use by people with different skill levels, use by people at one level shall not be hindered by the material relevant to a different level. [Source: FAA-D-2494/b, 1984, Department of Defense (MIL-M-87268), 1995]

  Examples. Beginning users can be guided to a tutorial, help process, or an entry-level document. Separate reference documents can be written for beginners, advanced users, and experts. A document intended for "novices" and "power users" of computer applications programs may give a procedure to select a sequence of windows for the novices and keyboard codes for direct control selection by the power users. Novice users might be given detailed, step-by step instructions to complete a procedure, while expert users might simply be given the name of the procedure to be completed -- a sort of checklist.

  Another approach is to code information for different skill levels. Font size and type, opposite or alternative pages or paragraphs, shaded or color-coded boxes or borders, and position location on a page can be used to indicate applicable skill levels. For instance, location coding is typically used when multiple languages are presented for identical instructions.

15.1.2 Making documentation appear easy to use

Some components of a document affect users' perceptions of its attractiveness and its apparent ease of use. These components are listed here in their order of importance to users' perceptions.

□ **15.1.2.1 Tabs.** If a document has many divisions (5 or more), it should have tabs for each major division or for each frequently used division. [Source: Angiolillo and Roberts, 1991; Simpson and Casey, 1988]

Examples. This document uses an edge tab on the side of the insert page. A bleed-through marking at the same edge location on each page in a section, chapter, or topic can mark and divide topics.

□ **15.1.2.2 Guides to organization.** User documents should have informative titles and, if applicable, a discernable, hierarchical system of section headings. Different levels of headings should be differentiated with typographic cuing, for example, size and boldness of the type (see Sections 15.2.1.1 and 15.3.3). White space, color, font type, and font sizes can be used judiciously if they aid in locating and categorizing information and contribute to readability and appearance of the document. They then result in a usable and friendly document. [Source: Angiolillo and Roberts, 1991]

■ **15.1.2.3 Table of contents.** A user document shall have a table of contents unless it has fewer than three divisions or fewer than six pages. The table of contents shall not appear crowded, that is, it shall have a liberal amount of white space, and it shall use typographic cuing to differentiate among levels of headings. [Source: Angiolillo and Roberts, 1991; FAA-D-2494/b, 1984; Simpson and Casey, 1988]

□ **15.1.2.4 Figures and examples.** User documents should be generous in providing figures and examples. Information that can be effectively presented as a figure or exhibit, should be. [Source: Angiolillo and Roberts, 1991]

15.2 Writing user documentation

This section contains criteria and rules for organizing a document, for writing and presenting paragraphs and sentences, and for choosing and using words and symbols, including abbreviations and acronyms.

15.2.1 Organization

Good documentation has a clear conceptual organization. The organization needs to be compatible with its purpose and understandable to its users. The organization helps the users find relevant information in order to carry out their functions and tasks. There are three major ways to help the user understand the conceptual organization: (a) the use of titles and headings, (b) the visual appearance of the document, and (c) a hierarchical numbering system.

Discussion. The features of the document can be reviewed for input by a user group early in its development. These users can contribute to its conceptual organization.

This section includes rules on the use of a variety of techniques that can help users use a document more effectively.

15.2.1.1 Titles and headings

Titles and headings are of major importance to users; they help users find relevant information, understand the organization of the document, and maintain awareness of their location in the document.

Definitions. A **title** is a word or phrase that describes or identifies the contents of a document or a portion of a document. A **heading** is the title of an organizational subdivision of a document, that is, a title that has hierarchical significance.

Discussion. Headings are usually set apart from the text to which they refer in a way that indicates the hierarchical structure of the document. This may be accomplished with the use of horizontal and vertical spacing. In addition, headings are usually differentiated from text typographically, for example, by the use of larger type size or increased boldness, or both.

- **15.2.1.1.1 Titles.** A document shall have a title, and its major subdivisions shall have headings. These titles and headings shall be brief, descriptive, and distinctive. That is, within the constraint of being as brief as possible, a title or heading shall identify the contents of the document or division with sufficient detail to distinguish it from similar documents or divisions. [Source: FAA-D-2494/b, 1984; MIL-STD-962B, 1988]

- **15.2.1.1.2 Paragraph titles.** If practical, each paragraph shall have a title that identifies its contents. Paragraph titles are practical if they help users in finding relevant information, if they contribute to understanding the paragraph contents, or if the users desire them. [Source: FAA-D-2494/b, 1984; Department of Defense (MIL-STD-962B), 1988; Department of Defense (MIL-STD-490A), 1985]

- **15.2.1.1.3 Uniqueness of titles.** Titles and headings shall not be repeated within a major division of a document. [Source: FAA-D-2494/b, 1984; MIL-STD-490A, 1985]

15.2.1.2 Numbering of sections and subsections

- **15.2.1.2.1 Decimal numbering.** The subdivisions of a document should be numbered in a way that reflects the organization of the document. This can be accomplished by: (a) assigning consecutive numbers to the major divisions of the document, beginning with 1 for the first, 2 for the second, and so on, (b) following this number with a period, (c) assigning consecutive numbers beginning with one to each subdivision, if any, of each major division and appending this number to that of the preceding division, (d) following this number with a period, and (e) continuing this process with any additional subdivisions until the paragraph level is reached. The final number should not be followed with a period. [Source: FAA-D-2494/b, 1984; MIL-STD-490A, 1985]

- **15.2.1.2.2 Itemization within a paragraph.** If it is necessary to identify individual items within a paragraph, they should be identified with lower case letters in parentheses so that they are not confused with the decimal numbering system. [Source: MIL-STD-962B, 1988; MIL-STD-490A, 1985]

- **15.2.1.2.3 Number of levels**. If possible, the numbering system should not exceed five levels, that is, the number of subdivisions from the document as a whole to its numbered paragraphs should not exceed five. When the material and its potential organization lend itself to fewer levels, four or three would be preferable. [Source: MIL-STD-962B, 1988; MIL-STD-490A, 1985]

  Discussion. There is no "right" number of subdivisions for a document; whatever makes sense to the user is right as long as he or she can use it without difficulty. However, any numbering system becomes increasingly unwieldy as the number of subdivisions increases. Five levels is considered a reasonable limit. A rule of thumb from memory research is that people can generally remember five plus or minus two items or chunks of information. From a design point of view, the preference is to accommodate many people, thus, use fewer categories.

15.2.1.3 Advance organizers

Advance organizers have been shown to improve comprehension and retention of material that is unfamiliar to readers.

Definition. An **advance organizer** is supplementary information that is presented prior to the main body of information in which a user is interested.

Examples. Tables of contents, introductory summaries, flow charts, and adjunct questions are all advance organizers as long as they occur before the targeted information.

- **15.2.1.3.1 When to provide advance organizers.** If users are likely to be relatively unfamiliar with the contents of a document, one or more advance organizers should be included. [Source: MIL-STD-962B, 1988; MIL-STD-490A, 1985]

  Examples. An introductory summary that states the main points or provides a framework for a document or a division of a document can be an effective advance organizer. A bulleted, advanced summary provides the user with a list of topics that can be easily scanned. Headings in the form of questions are also effective advance organizers. Any document of more than a few pages will probably benefit from a table of contents.

  In this document, introductory textual information, and in some instances even exhibit information, is given in the right hand column and is associated with high level (first and second section level) headings. This introductory information is presented to give some advanced organization, orientation, or usage limitations for the section contents. Such information is optional for lower level headings.

15.2.1.4 Internal cross references

- ▫ **15.2.1.4.1 Minimize internal cross referencing.** Internal cross referencing should be minimized. Ways to do this include: (a) repetition of material, (b) sequential organization of the document, and (c) use of foldout pages so that needed material is visible simultaneously with any preceding material. [Source: MIL-STD-490A, 1985; Simpson and Casey, 1988]

- ▪ **15.2.1.4.2 Form of internal cross references.** Internal cross-references shall refer to subdivision or paragraph numbers, or, if numbering is not used, to the title of the subdivision or paragraph. Cross-references shall not be made to page numbers. [Source: MIL-STD-490A, 1985; MIL-STD-962B, 1988; Zaneski, 1982]

15.2.1.5 Task versus list orientation

Most user documents will probably be organized to facilitate the performance of one or more tasks. Others might be intended to provide quick access to specific information, and thus might be organized as ordered lists. For some documents, a hybrid of the two organizations might be appropriate (see Section 15.5.1).

- ▫ **15.2.1.5.1 Task orientation.** If a task orientation is appropriate for a user document, the organization of the document should reflect the steps of the task as determined by a task analysis. If the document covers more than one task, the sequence of coverage should reflect the sequence in which the tasks are performed to the extent possible (see Section 15.5.1 for procedural instructions). [Source: Simpson and Casey, 1988]

- ▫ **15.2.1.5.2 List orientation.** If a list orientation is appropriate for a user document, the document should be organized in a meaningful way, such as listing the topics in sequential, logical, or alphabetic order. [Source: Gribbons, 1992]

15.2.2 Paragraphs

- ▫ **15.2.2.1 Content of paragraphs.** In general, the content of a paragraph should be limited to a single idea. All of the material in the paragraph should relate to and develop that idea. [Source: MIL-M-87268, 1995]

- ▫ **15.2.2.2 Topic sentences.** In general, a paragraph should have a topic sentence, that is, a sentence that announces the topic of the paragraph. If present, a topic sentence should follow an initial linking sentence if there is one; otherwise, it should be the first sentence of the paragraph. [Source: Spyridakis & Wenger, 1992]

  Definition. A **linking sentence** is a sentence that connects the paragraph it is in to the paragraph that precedes or follows it. The connection is usually accomplished by repeating a word or phrase or referring to a concept.

□ **15.2.2.3 Length of paragraphs.** The average length of paragraphs in technical writing should not exceed six sentences. [Source: MIL-M-87268, 1995]

Discussion. The preferred length of paragraphs is three or four sentences, but five or six sentences are acceptable.

15.2.3 Sentences

The ideal sentence states directly what is meant, using familiar words, and without using any excess words; it states explicitly all information that is to be communicated, leaving nothing to be inferred. [Source: Simpson and Casey, 1988]

15.2.3.1 Choice of wording

■ **15.2.3.1.1 Clear, simple language.** The text of a document shall be written in clear, simple language, free of vague, ambiguous, unfamiliar, and unnecessary words. [Source: FAA-D-2494/b, 1984; MIL-STD-490A, 1985; MIL-STD-962B, 1988]

□ **15.2.3.1.2 Technical terms.** The text of a document should contain a minimum number of technical terms that require specialized knowledge to be understood unless those terms are needed to convey precise meaning. See Section 15.2.4.6.1 for rules regarding the definition of such terms when they are used. [Source: FAA-D-2494/b, 1984]

15.2.3.2 Writing level, readability

There are a number of formulas that derive a measure of the readability of text from word difficulty (usually based on word length and familiarity) and sentence complexity (usually based on sentence length). These summary metrics are useful in categorizing and evaluating reading levels of instructional materials. They do not provide specific suggestions to help in the writing of a unique technical document as they are usually calculated after the writing is done. Unfortunately, comprehendability metrics are not yet available.

Discussion. These summary metrics include the Flesch formula for reading ease, the Dale-Chall formula, the Devereaux formula, The US Army FORECAST readability formula, and the Gunning Fog Index. Readability is usually expressed as a reading grade level. For example, a text might be said to be readable at the eighth grade level.

□ **15.2.3.2.1 Writing level.** The writing level of a document should be appropriate to the users of that document. In addition to editorial review, draft review by a user group will provide insight into a document's readability and ability to be comprehended. [Source: FAA-D-2494/b, 1984, Boff and Lincoln, 1988]

15.2.3.3 Length

The typical sentence in user documentation expresses a single thought. The length of the sentence will be whatever is appropriate to the adequate expression of the thought. In some literary styles and subjects, very long sentences that maintain clarity are acceptable.

▫ **15.2.3.3.1 Average length.** Generally speaking, in technical writing, the length of sentences (without lists) should not, on the average, exceed 20 words. [Source: MIL-M-87268, 1995]

Discussion. The preferred average sentence length is 17 words or less, but up to 20 is acceptable. Shorter sentences are desirable if they express the intended message clearly and completely and comply with grammar rules.

Very long sentences often include lists; these lists can usually be presented vertically, that is, with each item on a separate line, greatly reducing the apparent difficulty of such sentences. Lists are especially appropriate for ordered series of items such as the sequential steps needed to perform a task.

15.2.3.4 Complexity

Complex and compound sentences are more difficult for users to comprehend than are simple sentences.

▫ **15.2.3.4.1 Single thought.** In general, a sentence should express a single thought. [Source: MIL-M-87268, 1992]

▫ **15.2.3.4.2 Subordinate clauses.** A user document should contain relatively few sentences that have more than one or two subordinate clauses. In general, short, simple sentences should be substituted for complex and compound sentences. [Source: MIL-STD-490A, 1985; Hartley, 1978]

15.2.3.5 Word order

▫ **15.2.3.5.1 Normal order.** In general, the elements of a sentence should be arranged in the following order: (a) subject, (b) verb, (c) object, (d) predicate object, and (e) indirect object. [Source: AFHRL-TR-73, 1973]

Example. "Human factors specialists want well-written documentation for the system users."

15.2.3.6 Voice

- ▫ **15.2.3.6.1 Active, not passive voice.** In general, sentences should be written in the active, not the passive voice. That is, the subject acts upon the predicate rather than the more complex arrangement where the subject is acted upon by the predicate. [Source: FAA-D-2494/b, 1984; Department of Defense (MIL-HDBK-761A), 1989; Simpson and Casey, 1988; Spyridakis & Wenger, 1992]

  Examples. "Lively sentences move readers" (active) versus "The readers are moved by lively sentences" (passive).

15.2.3.7 Person and mood

- ▪ **15.2.3.7.1 Second person imperative.** The second person verb form and the imperative mood shall be used in all sentences that direct the reader to do something. Examples are: "Remove test set from carrying case," and "Turn R15 fully clockwise." [Source: AFHRL-TR-73, 1973; FAA-D-2494/b, 1984]

15.2.3.8 Positive, not negative wording

- ▫ **15.2.3.8.1 When to use positive wording.** Most of the time, positively worded sentences should be used because they are more definitive, less confusing, and less evasive than negatively worded statements. [Source: Hartley, 1978; Simpson and Casey, 1988; Spyridakis & Wenger, 1992]

  Examples. "Often writers will not use negative sentences since these statements may not always be correctly interpreted" (negative) versus "Writers often choose the clarity of the positive over the confusion of the negative" (positive). Consider: "The operator monitoring for errors did not see the alarm nor solve the problem" (negative) versus "The operator failed to see the alarm or to act upon the problem" (positive).

- ▫ **15.2.3.8.2 When to use negative wording.** Negative wording should be used to state prohibitions and to correct existing or potential misconceptions. [Source: Hartley, 1978]

  Examples. An example of a prohibition is: "Do not remove the cover until the power cord has been unplugged." An example of correcting a potential misconception is: "The highest voltage is not present in the largest wire; it is present in the red wire." Also consider: "The alarm display was beyond the visual envelopes of the operators, thus the problem could not be detected by the operational system."

15.2.3.9 Standard phrases

- **15.2.3.9.1 Consistent phrases.** The same phrase should be used to express the same meaning throughout a document. For example, the phrase "conforming to" should not be used in one place and "in accordance with" in another if the same meaning is intended. [Source: MIL-STD-490A, 1985; MIL-STD-962B, 1988]

- **15.2.3.9.2 Task steps.** If a task step occurs more than once in a user document, the same words shall be used in all occurrences, except for any unique variables that need to be included in the different occurrences. [Source: AFHRL-TR-73, 1973]

15.2.3.10 Capitalization and punctuation

- **15.2.3.10.1 Capitalization.** The United States Government Printing Office *Style Manual* shall be used as a guide for capitalization. If the *Style Manual* does not provide the guidance needed, Merriam-Webster's *New International Dictionary* shall be used. [Source: MIL-STD-490A, 1985; MIL-STD-962B, 1988]

- **15.2.3.10.2 Capitalization of phrases for emphasis.** Capitalization shall not be used to emphasize phrases (see Section 15.3.3.7 for the recommended way to emphasize text). [Source: MIL-STD-490A, 1985]

  Discussion. Text other than single words is easiest to read and comprehend when it is presented in mixed case letters. Single words are recognized better when printed in all upper case letters.

- **15.2.3.10.3 Punctuation.** The United States Government Printing Office *Style Manual* shall be used as a guide for punctuation. If the *Style Manual* does not provide the guidance needed, Merriam-Webster's *New International Dictionary* shall be used. [Source: MIL-STD-490A, 1985; MIL-STD-962B, 1988; FAA-D-2494/b, 1984]

  Discussion. Punctuation is an aid to accurate reading. Well-planned sentences need little punctuation. If a sentence seems to need extensive punctuation, it may need to be rewritten.

15.2.4 Words and symbols

15.2.4.1 Consistency

- **15.2.4.1.1 Terminology.** Technical lexicons should be developed within and between system and subsystems acquisition programs that include common human components (individual users or work groups). This terminology should reflect user inputs and shall be consistently used in system design and in user document development. Consistency of nomenclature, operational, and maintenance terminology is necessary to ensure that human communication is feasible, straight forward, and clear. Lexicon development should be done as early as possible in an acquisition. It is best done before the writing of the user documentation has begun. Terminology should be consistent throughout a user document and among related documents. For example, the name of a part, including any modifying words, should be the same in explanatory text, in procedural steps, and in parts lists. [Source: FAA-D-2494/b, 1984; MIL-STD-490A, 1985; Simpson and Casey, 1988]

  Discussion. Variations in words and phrases, whether they occur intentionally for stylistic reasons or unintentionally through carelessness, incur a strong risk of confusing the reader. Consistent use of words and phrases may incur a slight risk of boredom, but it is not likely to cause confusion. If consistency is ensured in design, it is more likely to be reflected in the documentation. However, inconsistent use of lexicon among design components is likely to result in confusion and increase training burden for the users. This is particularly problematic when standard and accepted practice is not used in NDI or COTS subsystems and components. Such consistency needs to be considered as a criterion in the selection of COTS subsystems and in evaluating its hidden human and monetary costs for operations and maintenance. This consideration argues for closer relationships between the production and selection of user documentation and component selection and design and development.

15.2.4.2 Short, high-frequency words

Short, simple, and frequently used words are easier for readers to recognize and comprehend than are long, complex, and infrequently used words. [Source: Spyridakis & Wenger, 1992]

- **15.2.4.2.1 High-frequency words.** If equivalent high frequency (familiar) and low-frequency (unfamiliar) words exist for a desired use, the high-frequency word should be used. For example, use would be a better choice than employ. [Source: Spyridakis & Wenger, 1992]

- ▫ **15.2.4.2.2 Short words.** If equivalent short and long words exist for a desired use, the short word should be used. For example, use would be a better choice than utilize. [Source: Spyridakis & Wenger, 1992]

- ▫ **15.2.4.2.3 Simple words.** If equivalent simple and complex words or terms exist for a desired use, the simple word or term should be used. [Source: Spyridakis & Wenger, 1992]

15.2.4.3 Concrete, non-ambiguous words

- ▫ **15.2.4.3.1 Concrete versus abstract words.** Concrete words and terms should be used rather than abstract words and terms. [Source: Spyridakis & Wenger, 1992; Hartley, 1978]

  Examples. Consider: "Maintenance for this system is poor" (abstract) versus "Maintenance records show that four computer components fail to meet reliability standards and the depot can not repair them. Expensive replacement components remain on back order. The system has been down for three weeks" (concrete).

- ▪ **15.2.4.3.2 Ambiguous words.** Ambiguous words and terms shall be avoided. [Source: FAA-D-2494/b, 1984]

  Example. The word replace could mean either "remove an existing item and install a different one" or "reinstall an item." Thus replace by itself is ambiguous and must have additional or different words to make the meaning clear.

- ▫ **15.2.4.3.3 Indefinite words and terms.** Indefinite words and terms such as and/or, suitable, appropriate, and etc. should not be used. [Source: MIL-STD-962B, 1988]

- ▪ **15.2.4.3.4 Variations on flammable.** The words inflammable and uninflammable shall not be used. Flammable shall be used to describe a combustible object, and nonflammable shall be used to describe a noncombustible object. [Source: MIL-STD-490A, 1985; MIL-STD-962B, 1988]

15.2.4.4 Standard words

- ▫ **15.2.4.4.1 If, when, and where.** The word if should be used at the beginning of phrases that state conditions in which the passage of time and spatial location are not important, for example, "If a fuse is blown, perform the tests prescribed for the circuit it protects." The word when should be used at the beginning of phrases in which the passage of time is important, for example, "When the motor reaches a speed of 200 RPM." The word where should probably not be used to introduce a conditional phrase unless spatial location is important. [Source: MIL-M-87268, 1995]

- **15.2.4.4.2 Shall, should, may, and will.** If the sentence structure permits, the word "shall" shall be used in sentences that state something the user must do. The word "should" shall not be used in instructions to users. The word "may" shall be used to express permission or non-mandatory options. The word "will" shall not be used for any of these purposes. [Source: FAA-D-2494/b, 1984; MIL-STD-490A, 1985; MIL-STD-962B, 1988]

15.2.4.5 Pronouns

- **15.2.4.5.1 Unambiguous referents.** Whenever a pronoun is used, the noun to which it refers shall be clear and unambiguous. [Source: FAA-D-2494/b, 1984]

  Example. The following demonstrates an ambiguous sentence: "Whenever the author knows the reader, he or she benefits." The following statement is clearer: "Whenever the author knows the readers, he or she can write to meet their needs."

15.2.4.6 Definitions

- **15.2.4.6.1 What to define.** Technical terms, uncommon words, and common words that are used in unusual or special ways shall be defined in the text and also in an alphabetically-ordered glossary, if one exists. Using one such section assists the user in navigating to this reference information. [Source: FAA Order 1700.8D, 1992]

  Discussion. In FAA technical document practice, when several (about 10) new terms or abbreviations are used a glossary or, as applicable, a list of acronyms would be included.

- **15.2.4.6.2 When to define.** Words or terms that must be defined shall be defined immediately following their first occurrence in the text. [Source: FAA Order 1700.8D, 1992]

15.2.4.7 Abbreviations and acronyms

The benefit of abbreviations and acronyms is the saving of space; they are shorter, more compact versions of the words or phrases they represent. The cost of abbreviations and acronyms is a reduction in reader comprehension and an increase in reader effort. [Source: Simpson and Casey, 1988]

Definitions. An **abbreviation** is a shortened version of a word or group of words formed by omitting one or more letters. An **acronym** is a word formed from the initial letter or letters of a group of words.

Examples. "ft" is an abbreviation of foot and "CAM" is the acronym for Computer-Aided Manufacturing.

- **15.2.4.7.1 Keep abbreviations and acronyms to a minimum.** Abbreviations and acronyms shall be kept to a minimum that is appropriate to the technical understanding and usage of the intended users. After its initial definition, an abbreviation or acronym shall be used whenever the term occurs. [Source: FAA-D-2494/b, 1984]

Discussion. Judgment is necessary to determine the technical understanding and when to use the technical vernacular appropriate to the target users. For example, if a technical document for maintenance personnel used the terms "very high frequency omni-directional radio" and "baby N connector" instead of VOR and BNC, the full names would be inappropriate. The full names may be appropriate for a lay audience, but they would be gibberish and distracting to the target users. There is no substitute for knowing or finding the users.

▪ **15.2.4.7.2 Definition of abbreviations and acronyms.** Abbreviations and acronyms shall be defined immediately following their first occurrence in the text. Their definitions shall consist of presenting the word or term fully spelled out, followed by the abbreviation or acronym enclosed in parentheses. Examples are: "...abbreviation (abbr)...", and "...Government Printing Office (GPO)...." [Source: FAA-D-2494/b, 1984]

▪ **15.2.4.7.3 Glossary.** The abbreviations and acronyms used in a document shall be listed alphabetically and defined in a glossary. [Source: FAA-D-2494/b, 1984]

▪ **15.2.4.7.4 Standard abbreviations and acronyms.** To the extent possible, abbreviations and acronyms shall be those given in:

a. FAA Order 1000.15A, Glossary,

b. FAA Order 7340.1H, Contractions, and

c. ASME Y1.1, Abbreviations for Use on Drawings and in Text. [Source: FAA-D-2494/b, 1984; Department of Transportation (FAA Order 1000.15A), 1975; FAA Order 1700.8D, 1992; Federal Aviation Administration (FAA Order 7340.1H), 2000]

▫ **15.2.4.7.5 Nonstandard abbreviations.** If a word or term to be abbreviated does not appear in any of the sources listed in paragraph 15.2.4.7.5, the word or term should be abbreviated in accordance with the United States Government Printing Office *Style Manual*. In specific specialized technical areas, technical sources, standards, and practice should be followed. [Source: MIL-STD-962B, 1988]

Discussion. In certain operating systems, upper and lower case letters can mean different things. For example, grep, Grep, and GREP have a different meaning in the UNIX operating system.

- **15.2.4.7.6 Units of measurement.** The abbreviation and punctuation of units shall conform to ANSI/IEEE Standard 260 for standard letters and symbols for units on measurement. For additional abbreviation guidance conform to the United States Government Printing Office *Style Manual*. [Source: FAA Order 1700.8D, 1992]

15.2.4.8 Spelling

- **15.2.4.8.1 Spelling.** The United States Government Printing Office *Style Manual* shall be used as a guide for spelling. If the *Style Manual* does not provide the guidance needed, Merriam Webster's *New International Dictionary* shall be used. In equivalent spelling, the first citation shall be used. [Source: FAA-D-2494/b, 1984; MIL-STD-490A, 1985; MIL-STD-962B, 1988]

15.2.4.9 Numbers

- **15.2.4.9.1 Numerals versus words.** Numbers representing measurements or time shall be expressed in numerals. Numbers (both cardinal and ordinal) representing quantities of 10 or more shall be expressed in numerals; those representing quantities less than 10 shall be expressed in words. If a number is the first word in a sentence, it shall be expressed in words. Other cases and exceptions to these rules shall conform to the United States Government Printing Office *Style Manual*. [Source: FAA-D-2494/b, 1984; U.S. Government Printing Office (USGPO Style Manual), 1984]

  Discussion. This rule pertains to the decimal (base 10) numbering system, but in specific industry and technical areas other base systems may be used (for example: binary, hexadecimal, and octal systems).

- **15.2.4.9.2 Arabic numerals.** In general, Arabic numerals should be used, not Roman numerals. [Source: USGPO Style Manual, 1984]

  Exception. Roman numerals are recommended for numbering the pages of any front matter a document might contain (see Paragraph 15.3.2.6.3).

- **15.2.4.9.3 Decimals versus fractions.** Non-whole numbers should be expressed as decimals, not fractions. [Source: MIL-STD-962B, 1988]

- **15.2.4.9.4 Decimals and leading and trailing zeroes.** Decimals of less than one shall be written with a zero preceding the decimal point. Zeroes following a decimal shall be omitted unless they indicate exact measurement. [Source: USGPO Style Manual, 1984]

15.2.4.10 Units of measurement

- **15.2.4.10.1 Dual units.** Both the International System of Units (the Metric system) and the customary inch-pound units of measurement shall be included in text and exhibits. The customary units shall be given first, followed by the International System units in parentheses, for example, 36 in (91 cm). This document follows the accepted style for metric standards, which places metric values first. The abbreviation and punctuation of units shall conform to ANSI/IEEE Standard 260 and to the United States Government Printing Office *Style Manual*. [Source: FAA Order 1700.8D, 1992]

- **15.2.4.10.2 Conversion of units.** The conversion of units between the International System and the customary inch-pound system shall conform to ANSI/IEEE Standard 268, Metric Practice, and to FED-STD-376. [Source: MIL-STD-962B, 1988]

15.2.4.11 Letter symbols and mathematical signs

- **15.2.4.11.1 Letter symbols and mathematical signs.** Letters used as symbols for objects and mathematical signs shall be in accordance with ANSI/IEE 260. [Source: FAA-D-2494/b, 1984]

15.2.4.12 Graphic symbols

- **15.2.4.12.1 Standard graphic symbols.** Graphic symbols used for circuit elements shall be those contained in ANSI Y32.2 and ANSI/IEEE 315A with the following additional provisions: (a) in those cases in which ANSI Y32.2 gives different symbols for electronic and electrical elements, the symbols for electronic elements shall be used, (b) under items 4.3.1 to 4.3.3, 4.3.5 to 4.3.7, 4.25.3, and 4.30.2, the parallel line contact symbols shall not be used, and (c) under items 11.2.7 and 11.2.7.1, the circular symbol for indicator lights shall not be used. Designations for electrical diagrams, power switches, and controls shall conform to ANSI Y32.16, Reference Designations for Electrical and Electronic Diagrams and MIL-STD-27A, Designations for Electrical Power Switch Devices and Industrial Control Devices. [Source: FAA-D-2494/b, 1984]

- **15.2.4.12.2 Mechanical diagram symbols.** Graphic symbols designating mechanical parts on diagrams and line drawings shall be in accordance with MIL-STD-17B as applicable. [Source: FAA-D-2494/b, 1984]

- **15.2.4.12.3 Logic diagram symbols.** Graphic symbols used in logic diagrams shall be in accordance with ANSI/IEEE 91. Graphic symbols not listed in ANSI/IEEE 91 shall not be used without approval of the acquisition program office. [Source: FAA-D-2494/b, 1984]

15.2.4.13 Other symbols

- **15.2.4.13.1 Flow chart symbols.** Symbols used in flow charts shall be in accordance with ANSI/ISO 5807. [Source: FAA-D-2494/b, 1984]

  Discussion. Flow charts are seldom used in present software development which use pseudo code and other charts.

- **15.2.4.13.2 Special symbols.** Special symbols used in diagrams shall be explained as follows: (a) if the use of a special symbol is limited to a diagram, the symbol shall be defined in the diagram in which it appears, (b) if special symbols are used extensively, the symbols shall be defined in a chart on a separate page in a section that provides support data, and (c) preexisting charts that define symbols in addition to those that actually appear in the document shall not be used. [Source: FAA-D-2494/b, 1984]

15.3 Layout and formatting

The most appropriate physical structure for a document depends upon how it will be used. Who will use the document? In what environment will it be used? For what tasks or purposes will it be used? Another important consideration is the handling of updates to the document.

15.3.1 Document-level considerations

15.3.1.1 Size

The optimum size for the pages of a document depends primarily upon the circumstances of its use. For example, a good size for a simple job performance aid might be a size that would fit in a pocket, or a good size for a user's guide to a large, complex system might be 8.5 by 11 inch (21.6 by 27.9 cm) pages.

- **15.3.1.1.1 Basic size.** The basic page size for user documents should be 8.5 inches (21.6 cm) wide by 11 inches (27.9 cm) high. If these pages are trimmed prior to binding, the finished size should be at least 8.25 by 10.75 inches (21.0 by 27.3 cm). [Source: FAA-D-2494/b, 1984]

- **15.3.1.1.2 Avoidance of odd sizes.** Odd sizes and shapes should be avoided, for example, pages that are very large or very small, pages that have extreme height-to-width ratios, and pages that are wider than they are high. [Source: Simpson and Casey, 1988]

15.3.1.2 Binding

The type of binding appropriate for a document depends largely on the user's priorities and on the way in which the document will be used. The primary considerations are whether or not users will want the document to lie flat when opened (see Paragraph 15.3.1.2.2) and whether or not individual pages of the document will be removed and new pages inserted (see Paragraph 15.3.1.2.3).

Definitions. In **mechanical binding**, the pages are punched with either round or slotted holes and then placed in a ring binder or bound with a comb or spiral binder. In **perfect binding**, the pages are assembled, the left side is cut and roughed, glue is applied, and the cover is attached to the pages. In **pamphlet binding**, the pages are stitched or stapled together. There are two types of pamphlet binding, saddle stitched and side stitched. **Saddle stitching** permits the document to lie flat.

- ▫ **15.3.1.2.1 Page orientation.** Unless special considerations warrant a different orientation, pages should be bound at the left side, not at the top. [Source: Simpson and Casey, 1988]

- ▫ **15.3.1.2.2 Flat-lying.** The binding should permit the document to lie flat when it is open. [Source: Simpson and Casey, 1988]

  Discussion. Ring binders and comb or spiral binding are probably the best choices in this respect for large documents; saddle stitching, for small documents. Spiral and comb bindings are cheaper; ring binders permit easy access for copying as well as updates.

- ▫ **15.3.1.2.3 Easy updating.** If it is likely that a document will be updated frequently, a ring binder should probably be selected. [Source: Simpson and Casey, 1988]

15.3.2 Page-level considerations

It is desirable that the visual structure of a document, that is, its cues and format, is reflected and complemented by the structure in the table of contents. The primary objective of the text designer is to create a visual hierarchy that distinguishes major concepts from sub-concepts and one category of information from another. Ways to do this include varying the size of type and the position of the material on the page. Visual cues are most effective when used sparingly.

15.3.2.1 Margins

- ▪ **15.3.2.1.1 Consistency.** Margins shall be consistent throughout a document, or, conversely, the portion of the page used to present information shall be consistent. [Source: Houghton-Alico, 1985]

- ▪ **15.3.2.1.2 Pages 8.5 by 11 inches (21.6 by 27.9 cm) or larger.** On pages 8.5 by 11 inches (21.6 by 27.9 cm) or larger, the margins shall be at least 1 inch (2.54 cm) on all sides. [Source: FAA-D-2494/b, 1984; FAA Order 1700.8D, 1992; Simpson and Casey, 1988]

Discussion. This margin recommendation permits room for binding or for punched holes for loose-leaf ring binders on all pages without the necessity of special or offset margins for reference documents. FAA Order 1320.1.D sets the text line presentation area as 7 in (18.8 cm) width for directives. FAA-D-2494/b (for instruction books with right and left hand pages) sets margins at .75 in (1.9 cm) on the outside edges and 1 in (2.5 cm) on the inside edges as margins for instruction books.

■ 15.3.2.1.3 **Offset for binding.** If the pages are to be bound on the left, the left margin shall be increased by 0.5 inch (1.3 cm) for 8.5 by 11 inch (21.6 by 27.9 cm) pages or by an amount proportional to the ratio of the page width to 8.5 inches (21.6 cm) for pages of other sizes. [Source: Simpson and Casey, 1988]

15.3.2.2 Headers and footers

Page headers and footers can be used to present a variety of potentially useful information to the reader, for example, page numbers, the name of the section and possibly also the subsection of the document, and the date of issue of the page or document.

□ 15.3.2.2.1 **Use of headers and footers.** If only a few elements of information are to be presented, they should probably be presented in a header only; that is, a footer should be omitted. If more elements are to be presented than fit comfortably in a header, then the information should be divided between a header and a footer. [Source: Simpson and Casey, 1988]

□ 15.3.2.2.2 **Location of information within a header or footer.** The elements of information included in headers and footers should be located in accordance with their importance to the reader. The most important elements should be located at the outside ends. The next most important elements should be located either centered or near the outside end of the header or footer. The least important information should be presented at the inside end. [Source: Simpson and Casey, 1988; Houghton-Alico, 1985]

- **15.3.2.2.3 Headers, footers, and margins.** Headers and footers should be located within the space reserved for top and bottom margins, that is, they should not take space away from that reserved for the body of the document. [Source: FAA-D-2494/b, 1984]

15.3.2.3 White space

The spatial formatting of text can be extremely effective in communicating the structural hierarchy of information. The consistent and logical allocation of vertical and horizontal white space creates a visual hierarchy that separates major headings from minor headings, headings from text, and so forth. The judicious use of spacing can convey information about the structure of a document to users more easily and effectively than can typographic cues. White space can be used in combination with typographical cues. Reduced line lengths and associated horizontal white space can make skimming, searching, and reading easier. [Source: Gribbons, 1992; Hartley, 1978]

- **15.3.2.3.1 Representational vertical spacing.** The vertical space that precedes a text element should indicate that element's level in the document's structural hierarchy, with the amount of space increasing at each level. [Source: Gribbons, 1992]

  Example. A logical point to start in determining vertical spacing is the smallest vertical unit, the space between two lines of text. If this space is taken to be one unit of spacing, the resulting representational spacing might be two units between paragraphs, four units between a subheading and a paragraph, and eight units between a major heading and a subheading. This document uses vertical white space to set off text paragraphs in the right-hand text columns. In the left column, white space combines with typographical cues to differentiate subsection heading levels.

- **15.3.2.3.2 Horizontal spacing (indentation).** Horizontal spacing (indentation) is an alternative to vertical spacing as a means for showing the hierarchical structure of a document. If horizontal spacing is used, the left-most position should represent the highest level of the hierarchy, with subsequent indentations representing successively lower levels. [Source: Gribbons, 1992]

  Discussion. Horizontal spacing is not as straightforward as vertical in indicating hierarchical levels. While successive indentation would seem to imply successively lower hierarchical levels, readers perceive centered headings to be more important than headings at the left margin.

15.3.2.4 Right-and left-hand pages

The printing of pages on both sides introduces the possibility and desirability of treating the fronts of pages differently from the backs. If offsets for binding are necessary, left- and right-hand pages will have different margins (see Paragraph 15.3.2.1.3).

> **Definitions.** The terms **right-hand page** and **left-hand page** have meaning only if pages are printed on both sides. In that case, a right-hand page is the page printed on the front, and a left-hand page is the page printed on the back. Thus, when the pages are bound, and the document is open, the right-hand page appears on the right, and the left-hand page appears on the left.

□ **15.3.2.4.1 Major divisions of the document.** Major divisions of the document should begin on right-hand pages. This will occasionally result in a blank left-hand page. [Source: FAA-D-2494/b, 1984]

> **Discussion.** In large frequently-used reference documents with many pages and divisions, one consistently begins each new major division on a right-hand odd-numbered page. This practice permits one to number pages within each section and to insert tabs between sections.

■ **15.3.2.4.2 Page numbering of left and right handed pages.** Right-hand pages shall be odd-numbered pages, and left-hand pages shall be even-numbered pages. [Source: FAA-D-2494/b, 1984]

15.3.2.5 Page numbering

There are two common methods for numbering the pages in a document, (a) numbering the pages sequentially from the beginning to the end of the document, and (b) numbering the pages independently within each major division of the document.

This second method incorporates a designation for the division into the page number, for example, 3-9 would be the number of the ninth page of the third division.

> **Discussion.** Numbering within divisions has two advantages: (a) it provides the reader with an additional location cue as to which division one is looking at, and (b) it makes updating easier in that fewer pages need be renumbered when material is added or deleted.

■ **15.3.2.5.1 Arabic numerals.** Arabic numerals shall be used for the page numbers of the main body of a document. [Source: FAA-D-2494/b, 1984; MIL-STD-962B, 1988]

□ **15.3.2.5.2 Numbering style - body.** The page numbering style for the main body of documents containing three or more major divisions or having an average division length of six or more pages should be the division designation followed by a dash followed by the number of the page within the division, for example, 4-7 is the divisional page number of the seventh page of the fourth division. [Source: FAA Order 1700.8D, 1992; Simpson and Casey, 1988]

□ **15.3.2.5.3 Numbering style - front material.** The pages of material at the beginning of a document, such as a foreword or a table of contents, should be numbered sequentially with lower case Roman numerals. [Source: FAA Order 1700.8D, 1992; FAA-D-2494/b, 1984; MIL-STD-962B, 1988]

□ **15.3.2.5.4 Numbering style - Appendixes.** Appendixes should be designated using consecutive letters beginning with A. Pages within an appendix should be numbered using the designation of the appendix followed by a dash followed by the sequential number of the page within the appendix, for example, A-3 would be the third page of Appendix A. [Source: FAA Order 1700.8D, 1992]

■ **15.3.2.5.5 Location.** If compatible with other information displayed in headers and footers, page numbers shall be located at the bottom outside edge of the page, that is, at the right edge of right-hand pages and the left edge of left-hand pages. [Source: FAA-D-2494/b, 1984]

15.3.2.6 Columns

■ **15.3.2.6.1 Number of columns.** The number of columns of text on a page of user documentation shall not exceed two. [Source: FAA Order 1700.8D, 1992]

Discussion. The use of columns may seem to complicate word processing in certain software packages. However, the benefits of location coding permitted by appropriate white space to the user navigation and readability warrant consideration of columns from a human factors usability standpoint.

Discussion. Since the division of the page into two columns halves the horizontal distance available for successive levels of indentation without affecting the vertical space available, the vertical spacing method will usually work more effectively than the horizontal.

15.3.2.7 Foldout pages

Foldout pages are relatively expensive to produce and relatively difficult to handle. Still, there are advantages to their use; in particular, the larger size may be necessary to display detail legibly. They can also permit a drawing or table to be visible while the user looks at other parts of the document.

□ **15.3.2.7.1 Minimize use.** The use of foldout pages should be minimized to those necessary to legible display of the information and necessary to understanding and tracing location and relational information. [Source: MIL-STD-490A, 1985; MIL-STD-962B, 1988]

Discussion. One way to reduce their use is to divide a large figure or table and display it on facing pages rather than printing it on an oversize page. When facing pages or fold out pages are used it may be necessary to aid the reader in tracing lines across the gaps or folds. For instance, when a large number of parallel lines transition across folds or gap, color coding of each continuing line may help a user trace and maintain the identity of the lines. Giving lines number or letter identifiers at places throughout each line may help.

■ **15.3.2.7.2 Foldout to the right.** Foldout pages shall fold to the right only; they shall not fold out to the top or bottom. [Source: FAA Order 1700.8D, 1992]

■ **15.3.2.7.3 Visibility of page number and caption.** Each foldout page shall be folded so that the page number and the page caption are visible without unfolding. [Source: FAA Order 1700.8D, 1992]

■ **15.3.2.7.4 Visibility of entire exhibit.** If it is necessary that a user see an entire exhibit while reading another part of the document, the exhibit shall be printed with a blank area the size of a normal page at the left of the foldout page so that when the page is unfolded, the entire exhibit will be visible. [Source: FAA Order 1700.8D, 1992]

- **15.3.2.7.5 Location of foldout pages.** If the ratio of text to foldout pages is reasonably balanced, a foldout page should be the next page after the one on which it is mentioned. If doing this would result in an excessive amount of white space on text pages, the foldout pages should be grouped together in a single section immediately preceding any appendixes. [Source: FAA Order 1700.8D, 1992; MIL-STD-490A, 1985; MIL-STD-962B, 1988]

  Discussion. If a document contains both foldout and non-foldout exhibits of the same type and the foldout exhibits are grouped at the end of the document, users may have difficulty finding a particular exhibit. Treating the foldout exhibits as a separate category of exhibits will help alleviate the difficulty. For example, exhibits that are integrated into the text might be called "exhibits" and oversize exhibits that are grouped at the end might be called "foldouts."

15.3.3 Typographic issues

Typographic cues are useful for conveying to readers the importance and organization of textual material. Type size is easily the most important cue. The position of material such as headings is another potential cue, as is the use of all capital letters. The use of color and varied intensity (boldness) of printing are additional potential cues.

Definition. A **point** is a measure of the height of type; there are 72 points in an inch (2.54 cm).

15.3.3.1 Type size

- **15.3.3.1.1 Basic size.** The basic size for text should be 10 point type. If the document will be used under dim illumination, the size should be increased to 11 or 12 points. [Source: FAA Order 1700.8D, 1992; FAA-D-2494/b, 1984; Zaneski, 1982]

  Discussion. This rule assumes that the document will be composed and reproduced with good quality equipment resulting in sharp, clear images, and that it will be viewed under satisfactory conditions, including illumination, reading distance, and viewing angle.

  Examples. The text of this document is 12 point type. Newspaper text is 10 point. Eight point type is often used in car advertisements. Smaller sizes are used in phone book listings and tabular materials.

- **15.3.3.1.2 Minimum size.** The minimum size for text should be 8 point type. This size should be used only when viewing conditions, particularly illumination, are satisfactory. [Source: FAA-D-2494/b, 1984]

- **15.3.3.1.3 Unequal spacing of sizes.** If more than two type sizes are used to indicate the importance of material, for example, the level of a heading, the difference in size from one level to the next should increase as the size of the type increases; that is, the differences should not be equal. [Source: Gribbons, 1992; Williams & Spyridakis, 1992]

  Example. If three type sizes are used to indicate three levels of headings, the smallest size might be 12 points; the middle size, 14 points; and the largest size, 18 points, rather than sizes of 12, 14, and 16 points.

15.3.3.2 Line length

Most readers prefer line lengths within the range of 14 to 36 picas for type sizes in the range of 8 to 12 points, and lines varying within this range are approximately equal in legibility. [Source: Simpson and Casey, 1988]

Definition. A **pica** is the unit of measurement used in printing. It is equal to 0.17 inch (4.23 mm).

- **15.3.3.2.1 Line length.** For type sizes in the range of 8 to 12 points, line length should not be less than 14 picas or more than 36 picas. [Source: Simpson and Casey, 1988]

  Discussion. Lines longer than 36 picas become increasingly difficult to read.

15.3.3.3 Line spacing

- **15.3.3.3.1 Minimum spacing.** The spacing between lines using type sizes in the range of 8 to 12 points should be at least two points. [Source: Simpson and Casey, 1988]

  Discussion. If the space between lines is too small, reading difficulty is increased.

15.3.3.4 Justification

The alignment of the starting point of lines of text is generally agreed to aid reading, probably by providing a predictable place for the eye to move to. Most typeset text and much of the text produced with word processors incorporates variable spacing within and between words so that lines are of equal length and the right ends of the lines are also aligned. In addition to variable spacing, words are often broken (hyphenated) in the process of constructing equal length lines. There is no evidence that the use of equal length lines aids reading, however, hyphenation can cause reading difficulties.

Definitions. In **left-justified text**, lines of text are aligned at the left, but spacing within and between words is not varied, resulting in a ragged right margin. In **right-justified text**, lines of text are aligned at the right, but spacing within and between words is not varied, resulting in a ragged left margin. In **center-justified text**, lines are centered on the page, with both right and left margins ragged. In **fully-justified text**, spacing is added within and between words so that all lines are the same length, resulting in alignment of both right and left margins.

- **15.3.3.4.1 Justification of text.** For extended text, the type of justification used should be either left- or full-justification. Center- and right-justification should not be used for text. [Source: Simpson and Casey, 1988]

- **15.3.3.4.2 Appropriate use of right-justification.** If right-justification is used, its use should be restricted to such items as headings and information in headers and footers. [Source: Simpson and Casey, 1988]

- **15.3.3.4.3 Avoiding hyphenation.** The breaking of words between syllables at the ends of lines should be avoided. The only hyphens at the ends of lines of text should be those that properly signify compound words. [Source: Simpson and Casey, 1988]

15.3.3.5 Type style (font)

Most type fonts fall into one of two categories, those having serifs and those that do not (sans serif fonts). Readers seem to prefer fonts with serifs and seem to read them more easily. [Source: Cooper, Daglish, and Adams, 1979; Simpson and Casey, 1988]

Definitions. **Serifs** are decorative elements (short lines, knobs, and balls) at the ends of the strokes that form letters. Sans serif fonts do not have these decorative elements. A **type family** is a collection of fonts that are similar in design but vary in size and boldness. A family can include *italic* versions.

Discussion. By far the majority of books and newspapers use fonts with serifs for the body text. Helvetica, Arial, and Univers are common sans serif fonts. Sans serif fonts are often used for labels and headings.

▫ **15.3.3.5.1 Serifs for basic font.** The basic font for a document body should be a font that has serifs. [Source: Simpson and Casey, 1988]

▫ **15.3.3.5.2 Minimize different fonts.** The number of different fonts used in a document should be kept to a minimum. [Source: Simpson and Casey, 1988]

Discussion. One family of fonts can be used for text, including different sizes of type, boldface fonts, and italic fonts. Another family might be used to make another type of information stand out from the basic text.

15.3.3.6 Upper versus mixed case text

Text that is written using both upper and lower case letters is both preferred by users and more legible to them. In the case of isolated letters and words, however, capital letters are more legible than lower case letters. Logically this implies that all text, including titles, headings, headers, and footers, would best be printed in mixed case. However, the use of all upper case letters can make individual words stand out and thus aid comprehension. [Source: Gribbons, 1992; Simpson and Casey, 1988]

▪ **15.3.3.6.1 Words to be typed in upper case letters.** If the following words are used as headings, they shall be displayed in all upper case letters: (a) WARNING, (b) CAUTION, and (c) NOTE. [Source: AFHRL-TR-73, 1973; FAA-D-2494/b, 1984]

▫ **15.3.3.6.2 Minimize use of upper case letters.** The use of upper case letters for words and phrases in text should be minimized; upper case letters should not be used to emphasize a word or phrase. [Source: MIL-STD-962B, 1988; Hartley, 1978]

15.3.3.7 Typographic emphasis

There are a variety of ways in which portions of text can be emphasized typographically. The use of upper case letters has already been discussed. Other commonly-used ways include: (a) the use of **boldface** type, (b) the use of *italic* type, and (c) the use of underlining. The intent of all of these is to make a portion of text stand out from its surroundings. [Source: Simpson and Casey, 1988]

Judicious use of typographic emphasis can help readers locate and remember things, but emphasis is probably most effective when it is used sparingly. For emphasis to be effective, the reader must (a) be aware of the intent of the emphasis, and (b) know enough about the task to judge the importance of the emphasized words.

▪ 15.3.3.7.1 **Inform the reader.** If typographic emphasis is used, the reader shall be informed of what it is and what it means. [Source: Simpson and Casey, 1988]

▪ 15.3.3.7.2 **Use boldface type for emphasis.** If typographic emphasis is used, it shall be boldface type. [Source: Hartley, 1978; Simpson and Casey, 1988; Zaneski, 1982]

▪ 15.3.3.7.3 **Use typographic emphasis sparingly.** Typographic emphasis shall be used sparingly. [Source: Hartley, 1978; Simpson and Casey, 1988]

▫ 15.3.3.7.4 **Do not use underlining for emphasis.** Underlining should not be used for typographic emphasis. [Source: FAA-D-2494/b, 1984; MIL-STD-490A, 1985; MIL-STD-962B, 1988; Gribbons, 1992; Hartley, 1978; Simpson and Casey, 1988]

Discussion. Underlining actually makes the underlined text more difficult to read, at least for some readers; it reduces the white space between lines, and it disrupts the characteristic shape of the underlined word or words. The same is true for numbers.

Sometimes underlining is use to indicate changes in a document. Other typographical cues such as redlining, asterisks, or vertical lines in the margin may be used to indicate changes. FAA order 1320.1D calls for the use of asterisks or vertical lines in the margins to indicate change. Whatever the method, the notation for change should be explained in the text. In a directive, it is explained in a paragraph entitled explanation of changes.

▪ **15.3.3.7.5 Do not use italics for emphasis.** Italic type shall not be used for typographic emphasis. [Source: Hartley, 1978]

Discussion. Italic type fonts are usually drawn with relatively thin lines, which tend to make these fonts recede rather than stand out from the surrounding text. This is the opposite of emphasis. Italic type is appropriate for the titles of books when they appear in text and in bibliographic references.

▫ **15.3.3.7.6 Do not use upper case letters for emphasis.** All upper case letters should not be used for typographic emphasis in text. [Source: MIL-STD-490A, 1985; Simpson and Casey, 1988]

Discussion. The use of all upper case letters in text slows reading and appears to interfere with memory of the unemphasized material. Individual words can be recognized faster when they appear in upper case letters, so, if used sparingly and wisely, upper case letters can be effective for emphasis. However, because boldface type has fewer actual and potential problems, it seems a better choice for typographic emphasis. FAA Order 1320.1D addresses the use of underlining and capital letters when standard typewriting is used for document preparation. It also notes that word processing equipment offers bold and other typographical cues which, when appropriately used, enhance reading and navigation in a document.

15.3.3.8 Print contrast, quality

Typesetting and competent offset printing produce print of adequate quality for documents that may be used in a range of viewing conditions. Modern laser printers can also produce print of this quality. Mechanical or dot matrix printers generally do not produce print of this quality. [Source: Simpson and Casey, 1988]

Definition. Print contrast is the ratio of the difference in brightness between the printing and its background to the brightness of the background (assuming dark print on a light background). It is defined by (B1-B2)/B1, where B1 is the brighter of the two.

▪ **15.3.3.8.1 Adequate print contrast.** The print contrast of a document shall be high enough so that users can read it without eyestrain under the expected viewing conditions. [Source: Simpson and Casey, 1988]

15.3.3.9 Color and shading

Color can be a very effective cue, especially when it is used to aid users who are searching for something. However, users perceive color as less significant than other types of typographic cuing, particularly size and boldness. In addition, the existence of deficiencies in the color vision of some users limits the applicability of color as an effective cue. [Source: Gribbons, 1992]

- 15.3.3.9.1 **Color as a typographic cue.** If color is used as a typographic cue, it shall be redundant with another typographic cue, such as size. [Source: Gribbons, 1992]

- 15.3.3.9.2 **Text in color.** If color is used for either print or background, it shall satisfy the print contrast criterion, Paragraph 15.3.3.8.1. [Source: Gribbons, 1992]

- 15.3.3.9.3 **Subsequent reproduction.** If a document is likely to be photocopied, colors and shadings shall be selected so that their meanings do not become lost or distorted when photocopied. [Source: Hartley, 1978; FAA-D-2494/b, 1984]

  Discussion. Colors that are clearly different in their original reproduction may change during photocopying in black and white in ways that change their meaning. For example, the lighter of two colors may become the darker of two shades of gray. Similarly, gradients of colors or shadings that are clear in the original production may be lost in photocopying.

15.4 Components of documents

This section contains rules for the various components that might be contained in a user document, such as the cover page, table of contents, and figures. Exhibit 15.4 lists FAA directives associated with certain types of documents that are oriented to FAA users and lists the components and the sequence for components, when applicable for each type. These directives and related specifications listed in Exhibit 15.4 also call for mandatory items: forms to identify and control changes and some explicitly required paragraphs and text. These mandatory policies are to be followed for each applicable type of document.

Discussion. FAA Order 1320.1D addresses directives in general and includes long orders (more than 25 pages) which may be called handbooks. The order describes the orders development process and prescribes some formal formatting details for organizational-level orders or supplements. FAA Order 1320.58 addresses Maintenance Technical Handbooks and equipment modification directives. These are exempted from 1320.1D formatting provisions.

There are two kinds of user-oriented documents that apply to the implementation of specific modification programs: modification manuals and modification instructions. The manuals are to have similar components to those listed in the exhibit under Maintenance Technical Handbooks. When either of these modification program documents are manufacturer's documents, they may be treated as technical issuances as is explained later. FAA-D-2494/b, 1984 addresses instruction books for operation and maintenance of new or modified systems and equipment. With FAA permission, instruction books may also be technical issuances. In such cases, writers and publishers may use other formats and organizations. FAA-D-2494/b includes an appendix that addresses a general evaluation of commercial instruction books.

Definition. Technical Issuances, according to FAA Order 1320.1D, are publications acquired from non-agency sources or developed within FAA that directly concern installation, maintenance, or modification of equipment, equipment systems, facilities, or aircraft. Manufacturers' instruction books for plants and equipment are included in this category. A basic objective of using this category is to permit the merging of internally-developed and externally-acquired technical manuals and publications into consolidated, single source documents. Because of necessary deviations from standard directive format and issuance procedures, they are designated technical issuances.

The detailed guidance of this user-interface guide represents advisable practice to help design-in and facilitate human performance as a component of new or changed operational systems. Its provisions may be selectively applied to user-documentation of new and modified systems. It may be used to help evaluate user documentation on NDI and COTS procurements.

Exhibit 15.4 FAA directives and order of document components

Source	FAA Order 1320.1D	FAA Order 1320.58	FAA Specification FAA-D-2494/b Appendix 1	
Document types	Generic Long Orders	Maintenance Technical Handbooks, Modification Manuals & Instructions	Technical Instruction Books	Commercial Instruction Book Contents
Document components				
Cover	x	x	x	
Contractor guarantee			x	
List of modifications to specifications (drafts only)			x	
List of effective pages			x	
Content assurance page			x	
Record or order of changes	x	x	x	
Foreword	x	x	x	
Table of contents	x with tables, figures	x	x	
List of tables		x	x 2nd in order	
List of illustrations, figures		x	x 1st in order	
Family tree chart			x	
General information and requirements	x	x	x	x
Technical characteristics or description		x	x	x
Operations			x	x
Standards and tolerances		x	x	x
Periodic maintenance		x	x	x
Maintenance procedures		x	x	x
Corrective maintenance			x	x
Flight inspection		x		
Parts list			x	x
Installation and checkout			x	x
Computer software			x	x
Troubleshooting			x	x
Miscellaneous	x			
Appendixes	x	x	x	
Glossary	x	x		
Index	x	x	x	
Feedback	x	x	x	

15.4.1 Cover page

- **15.4.1.1 Contents of cover page.** The cover page of a user document shall contain the explicit identifying information for the document including a document title, number, and date. [Source: FAA-D-2494/b, 1984]

  Example. An instruction book cover has the following elements: (a) the national stock number of the document, (b) the publication number, (c) a phrase specifying the type of document, for example User's Guide, (d) the name of the equipment or system to which the document applies, (e) if applicable, "TYPE" and the type number of the equipment or system, (f) if applicable, "SERIAL NOS." and the range of serial numbers to which the document applies, (g) "U.S. DEPARTMENT OF TRANSPORTATION," and (h) "FEDERAL AVIATION ADMINISTRATION."

- **15.4.1.2 Type style and size, 8.5 by 11 inch (21.6 by 27.9 cm) pages.** The type style used on the cover page shall be bold, and it shall not be italic. The point size for each element for an instruction book is given in Exhibit 15.4.1.2. [Source: FAA-D-2494/b, 1984]

Exhibit 15.4.1.2 Type sizes for cover page elements

Element	Point size
National stock number	14
Publication number	14
Type of document	18
Name of equipment or system	30
“TYPE” and type number	18
“SERIAL NOS” and serial numbers	18
“U.S. DEPARTMENT OF TRANSPORTATION”	18
“FEDERAL AVIATION ADMINISTRATION”	14
All other printing	12

15.4.2 Table of contents

A table of contents serves to reveal the organization of a document as well as to guide the user to a desired topic.

- **15.4.2.1 When to include a table of contents.** A user document shall have a table of contents unless it has fewer than three divisions or fewer than six pages. [Source: FAA-D-2494/b, 1984; Angiolillo and Roberts, 1991; Simpson and Casey, 1988]

- **15.4.2.2 Labeling the table of contents.** The single word "CONTENTS" shall appear at the beginning of the table of contents. [Source: MIL-STD-962B, 1988]

- **15.4.2.3 What to include in the table of contents.** A table of contents shall include: (a) at least two levels of the headings and subheadings of the document, (b) appendixes if they exist, (c) the glossary and index if they exist, (d) lists of exhibits, illustrations, figures, and tables if they exist, and (e) the initial page number of each item listed. [Source: FAA-D-2494/b, 1984; MIL-STD-962B, 1988]

- **15.4.2.4 Right-hand page.** The table of contents shall begin on a right-hand page. [Source: FAA-D-2494/b, 1984]

15.4.3 Lists of exhibits

Lists of exhibits (figures, tables, or any other illustrations) may follow or may be part of the table of contents; this section contains additional rules pertaining to lists.

> **Discussion.** In this guide, exhibits which contain either or both graphics and tabular materials are used. Such exhibits enable the user to have the graphic and tabular data that are used together, located together. This practice aids the user's task performance by eliminating cross referencing between separate table and figure information.

- **15.4.3.1 Lists of exhibits.** If a document contains one or more instances of a type of exhibit, such as a figure or table, all instances shall be listed by type in the table of contents. That is, all figures shall be listed in a list of figures, and all tables shall be listed in a list of tables. [Source: FAA-D-2494/b, 1984]

- **15.4.3.2 Contents of lists of exhibits.** Lists of exhibits shall include: (a) the identification of the exhibit, for example, "Exhibit 6-1," (b) the title of the exhibit, and (c) the page number on which the exhibit appears or begins. [Source: FAA-D-2494/b, 1984]

- **15.4.3.3 Location and precedence of lists.** Lists of exhibits shall be placed at the end of the table of contents. Each type of exhibit shall be listed separately, and the lists shall be placed in the following order: (a) exhibits labeled "exhibit," (b) figures (or other types of illustration), (c) foldout figures, (d) tables, and (e) foldout tables. [Source: Simpson and Casey, 1988]

15.4.4 Figures

This section contains rules for the use, identification, location, style, content, and orientation of figures.

> **Definition.** A **figure** is an exhibit that is primarily graphical or pictorial in nature, as opposed to verbal or numerical.

15.4.4.1 General

▪ **15.4.4.1.1 When to use.** Figures shall be used when they are likely to increase a reader's understanding in ways that words cannot. [Source: FAA Order 1700.8D, 1992]

▪ **15.4.4.1.2 Relationship to text.** Figures shall be clearly related to, consistent with, and referred to in the text of the document. [Source: MIL-STD-490A, 1985; Simpson and Casey, 1988]

15.4.4.2 Identification

▪ **15.4.4.2.1 Number and title.** Each figure shall have a unique identifying number and a title. Numbers shall be assigned consecutively, beginning with one, either for the document as a whole, or within divisions. If they are assigned within divisions, the division's identifying number shall form part of the figure's identifying number. The figure's title shall describe concisely what the figure contains. [Source: FAA Order 1700.8D, 1992; FAA-D-2494/b, 1984; MIL-STD-490A, 1985; MIL-STD-962B, 1988; Simpson and Casey, 1988; Zaneski, 1982]

▪ **15.4.4.2.2 Caption.** Each figure shall have a caption that consists of the word "Figure" followed by its unique identifying number, two spaces, and its title. The caption shall be centered below the figure. [Source: FAA-D-2494/b, 1984]

15.4.4.3 Location

▫ **15.4.4.3.1 Preferred location.** A figure that is smaller than a page should be placed on the same page as its first reference, either within or following the paragraph that contains the reference. If the space following the reference is too small, the figure should be located at the top of the following page. A figure that fills a page should be placed on the page following the page containing its reference. [Source: FAA Order 1700.8D, 1992; MIL-STD-490A, 1985; MIL-STD-962B, 1988; Simpson and Casey, 1988]

- ▫ 15.4.4.3.2 **Consistent location.** The location of a figure relative to its first reference in the text should be consistent. If for some reason the preferred location specified in Paragraph 15.4.4.3.2 is not satisfactory, all the figures should be grouped together near the end of the document. An example of this would be a document in which the space devoted to figures far exceeds the space devoted to text. [Source: FAA Order 1700.8D, 1992; MIL-STD-490A, 1985]

15.4.4.4 Style

- ▪ 15.4.4.4.1 **Consistent style.** The figures for a document shall be prepared so that in their final state, that is, after any reduction or enlargement, they are consistent in terms of such characteristics as line width, shading, and style and size of type. [Source: Simpson and Casey, 1988; FAA Order 1700.8D, 1992]

- ▫ 15.4.4.4.2 **Preferred pictorial style.** Pictorial figures should consist of line drawings rather than photographs. [Source: AFHRL-TR-73, 1973]

  Discussion. While there may be circumstances in which photographs might be preferable, in general, line drawings have several advantages. In particular, they permit omission of distracting and irrelevant details, and they can be reproduced without significant loss of detail.

- ▫ 15.4.4.4.3 **Consistent pictorial style.** All the comparable figures in a document should be prepared in the same style, for example, all line drawings, or all photographs. [Source: Simpson and Casey, 1988]

- ▪ 15.4.4.4.4 **Minimal distraction.** Decorative elements such as borders and background shading shall be avoided. Photographs shall be cropped or masked to remove irrelevant or unimportant portions unless those portions are helpful in orienting the reader. Photo masking with high reproducible quality may be an economical alternative to line drawings. [Source: FAA Order 1700.8D, 1992; Simpson and Casey, 1988]

- ▪ 15.4.4.4.5 **Alphanumeric information.** All alphanumeric information contained in figures shall be created mechanically or electronically; it shall not be hand drawn. The size shall be at least 8 points in the figure's final size, that is, after any reduction or enlargement. [Source: FAA-D-2494/b, 1984]

- ▪ 15.4.4.4.6 **Line width.** The width of lines when the figure is in its final size, that is, after reduction or enlargement, shall be at least 0.01 inch (0.25 mm). [Source: FAA-D-2494/b, 1984]

- ▪ 15.4.4.4.7 **Color.** Color shall not be used in figures unless it is meaningful and authorized by the acquisition program office. [Source: FAA Order 1700.8D, 1992]

  Discussion. The use of shadings and patterns is usually as effective as the use of color.

15.4.4.5 Content

- ▪ **15.4.4.5.1 Amount of detail.** Figures shall contain only necessary and useful detail, that is, they shall contain the detail necessary to the task being performed and additional detail that provides helpful context. [Source: AFHRL-TR-73, 1973]

- ▪ **15.4.4.5.2 Callouts.** Specific features of interest in a figure shall be identified with callouts. The text of a callout may be located adjacent to the feature, or the feature may be identified by a number, and the text located elsewhere. A callout shall consist of: (a) an arrow with its head pointing at the feature and its tail leading to a block of text or to a number, (b) a number that is keyed to a block of text, if applicable, and (c) a block of text that gives information about the feature. Numbered callouts shall be numbered consecutively, starting with one and beginning with the feature nearest "three o'clock" on the figure and proceeding clockwise around the figure. [Source: AFHRL-TR-73, 1973; FAA Order 1700.8D, 1992]

- ▪ **15.4.4.5.3 Specific types of diagrams.** If a document contains any of the following specific types of diagrams, the diagrams shall conform to FAA-D-2494/b, 1984: (a) block diagrams, (b) major function diagrams, (c) schematic diagrams, (d) diagrams for analog equipment, (e) diagrams for functional entities, (f) functional circuit diagrams, (g) photographs, (h) continuous-tone illustrations, (i) printed circuit board illustrations, (j) power distribution diagrams, (k) wiring diagrams, (l) cabling diagrams, (m) mechanical drawings, and (n) piping diagrams. For developing directives, FAA 1320.1D recommends that figures which are sample forms should be a filled out as an example to help the user. Rather than dividing form-filling instructions between the figure and the main text or an appendix, the writer should include instructions on the sample form and, where feasible, show variances for completion in marginal notes. [Source: FAA-D-2494/b, 1984]

15.4.4.6 Orientation

- ▫ **15.4.4.6.1 Preferred orientation.** Figures should be oriented so that the reader can read them without rotating the page, that is, all text, including the figure's identification and title, should appear horizontally when the page is in its normal orientation. [Source: FAA Order 1700.8D, 1992; MIL-STD-962B, 1988]

- ▪ **15.4.4.6.2 Alternate orientation.** If it is not possible to display a figure in the preferred orientation, it shall be oriented so that the top of the figure is at the left side of the page. [Source: FAA Order 1700.8D, 1992; MIL-STD-962B, 1988]

15.4.4.7 Oversize figures

- ▫ **15.4.4.7.1 Facing pages.** If a figure is too large to fit on a single page, if possible, it should be divided into two parts that are presented on facing pages. [Source: FAA Order 1700.8D, 1992; MIL-STD-962B, 1988]

- ■ 15.4.4.7.2 **Captions for divided figures.** If a figure is divided and displayed on two pages, the figure's caption, that is, its identifying number and title, shall be repeated below each portion, with the word "Continued" in parentheses following the title. [Source: MIL-STD-962B, 1988]

- □ 15.4.4.7.3 **Foldout pages.** If a large figure cannot be divided and displayed on facing pages, it shall be displayed on a foldout page. [Source: FAA-D-2494/b, 1984]

15.4.5 Tables

15.4.5.1 General

- □ 15.4.5.1.1 **Use.** Tables should be used: (a) when data or text can be displayed more clearly than can be done otherwise, or (b) to show large amounts of data or text more compactly than could be done otherwise. [Source: FAA Order 1700.8D, 1992; MIL-STD-490A, 1985; MIL-STD-962B, 1988; FAA-D-2494/b, 1984]

  Definition. A **table** is an array of data or text in rows and columns. Usually at least one dimension, either the rows or the columns, is labeled; sometimes both are labeled.

  Examples. Some examples of information that might be presented in tables are: (a) performance standards and operating tolerances, (b) functions of controls and indicators, (c) operating parameters, (d) turn-on and checkout procedures, (e) performance checks, and (f) procedures for preventive and corrective maintenance, alignment, and calibration.

15.4.5.2 Identification

- ■ 15.4.5.2.1 **Number and title.** Each table shall have a unique identifying number and title. Numbers shall be assigned consecutively, beginning with one, either for the document as a whole, or within divisions. If they are assigned within divisions, the division's identifying number shall form part of the table's identifying number, for example, "Table 2-1" would indicate the first table in division two. The table's title shall describe concisely what the table contains. [Source: FAA-D-2494/b, 1984; FAA Order 1700.8D, 1992; MIL-STD-490A, 1985; MIL-STD-962B, 1988]

- ■ 15.4.5.2.2 **Caption.** Each table shall have a caption that consists of the word "Table" followed by its unique identifying number, two spaces, and a title. The caption shall be centered above the table. [Source: FAA-D-2494/b, 1984]

15.4.5.3 Location

- **15.4.5.3.1 Preferred location.** A table should be placed on the same page as its reference, either within or following the paragraph that contains the reference. If the space following the reference is too small, the table should be located at the top of the following page. A table that fills a page should be placed on the page following the page containing its reference. [Source: FAA Order 1700.8D, 1992]

- **15.4.5.3.2 Consistent location.** The relative location of a table to its first reference in the text should be consistent. If for some reason the preferred location specified in Paragraph 15.4.5.3.2 is not satisfactory, all the tables should be grouped together near the end of the document. An example of this would be a document in which the space devoted to tables far exceeds the space devoted to text. [Source: FAA Order 1700.8D, 1992; MIL-STD-490A, 1985]

15.4.5.4 Formatting

- **15.4.5.4.1 Organization.** Tables shall be organized to show the significance and relationships in their contents as clearly and simply as possible. [Source: FAA Order 1700.8D, 1992; MIL-STD-490A, 1985]

- **15.4.5.4.2 Type size.** The size of type used within a table shall be at least 8 points when the table is in its final form, that is, after any reduction or enlargement. [Source: FAA Order 1700.8D, 1992; FAA-D-2494/b, 1984]

- **15.4.5.4.3 Units of measurement.** If the entries in a row or column consist of some sort of quantity, the unit of measurement, such as inches or degrees, shall be given in the row or column label; it shall not be repeated after each quantity. [Source: FAA Order 1700.8D, 1992]

- **15.4.5.4.4 Ease of reading.** It shall be easy for the reader to follow rows and columns visually. [Source: FAA-D-2494/b, 1984, 3.1.7.3; Simpson and Casey, 1988]

  Discussion. There are three common ways to help readers follow rows and columns: (a) the use of white space, for example, a blank line after every four or a maximum of five rows and generous spacing between columns, (b) the use of vertical and horizontal lines, and (c) the shading of alternate rows or columns. Contemporary practice is to use white space and shading rather than vertical and horizontal lines.

15.4.5.5 Content

- **15.4.5.5.1 Useful and relevant.** The information presented in a table shall be limited to information that is likely to be used by a reader. Tables shall contain only information that is relevant to the associated text. [Source: FAA-D-2494/b, 1984; MIL-STD-490A, 1985; MIL-STD-962B, 1988]

■ **15.4.5.5.2 Non-redundant information.** Tables and text shall not be redundant; that is, tables shall not simply restate information that is presented in the text. [Source: MIL-STD-490A, 1985; MIL-STD-962B, 1988]

Discussion. This rule is not intended to prohibit text from quoting, summarizing, or commenting upon the information in a table. In general, the purpose of the associated text is to make the purpose of the table clear, and the purpose of the table is to present data relevant to the associated text.

15.4.5.6 Orientation

▫ **15.4.5.6.1 Preferred orientation.** Tables should be oriented so that the reader can read them without rotating the page, that is, all text, including the table's identification and title and any row and column labels, should appear horizontally when the page is in its normal orientation. [Source: FAA Order 1700.8D, 1992]

■ **15.4.5.6.2 Alternate orientation.** If it is not possible to display a table in the preferred orientation, it shall be oriented so that the top of the table is at the left side of the page. [Source: FAA Order 1700.8D, 1992; MIL-STD-490A, 1985; MIL-STD-962B, 1988]

15.4.5.7 Oversize tables

▫ **15.4.5.7.1 Facing pages.** If a table is too large to fit on a single page, if possible, it should be divided into two parts that are presented on facing pages. [Source: FAA Order 1700.8D, 1992; MIL-STD-962B, 1988]

■ **15.4.5.7.2 Captions for divided tables.** If a table is divided and displayed on two pages, the table's caption, that is, its identifying number and title shall be repeated above each portion, followed by the word "Continued" in parentheses. [Source: MIL-STD-962B, 1988]

■ **15.4.5.7.3 Foldout pages.** If a large table cannot be divided and displayed on facing pages, it shall be displayed on a foldout page. [Source: FAA-D-2494/b, 1984]

15.4.6 Lists

It is often convenient to present information in the form of a list.

Definition. As used in this section, a **list** is a series of similar or related items in which each item is marked and displayed on a separate line or lines. The markings can be graphic symbols, such as bullets (•) or squares (▫), or sequential identifiers, such as numbers or letters. An item can be a word, a phrase, a sentence, or a group of sentences.

- **15.4.6.1 Marks.** If the items in a list have no precedence over each other and there is no need to refer to them individually, they should be marked with graphic symbols, such as bullets. If the items do have precedence, for example, if they are sequential steps in a procedure, or if they need to be referred to individually, they should be marked with numbers or letters. [Source: Rubens, 1992]

- **15.4.6.2 Punctuation items.** If an item consists of one or more complete sentences, it should be followed by a period. If an item is not a complete sentence, it should be followed by a comma, with two exceptions: (a) the next to last item should be followed by a comma and either the word "and" or "or," and (b) the last item should be followed by a period. [Source: Rubens, 1992]

15.4.7 Formulas and equations

- **15.4.7.1 Identification.** Formulas and equations that occur in user documents shall be numbered consecutively, in Arabic numerals, beginning with one. The number shall appear in parentheses at the right margin on the last line of the formula or equation. [Source: FAA Order 1700.8D, 1992]

- **15.4.7.2 Location.** Short formulas and equations that are not part of a series should be placed in the text rather than displayed on a separate line. Formulas and equations that are longer or that are part of a series shall be displayed either indented or centered in a line immediately below the text that refers to them. A group of separate but related formulas or equations should be aligned on their equal signs, and the group as a whole should be indented or centered on the page. [Source: FAA Order 1700.8D, 1992]

- **15.4.7.3 Format.** If a formula or equation includes a numerator and denominator, they shall be separated by a line equal to the length of the longer term; both terms shall be centered with respect to the line. [Source: FAA Order 1700.8D]

15.4.8 Warnings, cautions, and notes

This section contains criteria governing the use of warnings, cautions, and notes.

Definitions. A **warning** is a written notice given to a reader when a situation might result in personal injury or loss of life; a **caution** is a written notice given when a situation might result in damage to or destruction of equipment or systems; a **note** a written notice given to draw the reader's attention to something or to supply additional information.

- **15.4.8.1 When to use.** Warnings shall be provided whenever a step or procedure or the failure to perform a step or procedure correctly might result in personal injury to, or loss of life of, the user or anyone else. Cautions shall be provided whenever a step or procedure or the failure to perform a step or procedure correctly might result in damage or destruction of equipment or systems. Notes shall be provided whenever it seems appropriate to call the reader's attention to something or to provide additional information. [Source: FAA-D-2494/b, 1984]

- **15.4.8.2 Warnings.** Warnings shall consist of (a) the word "WARNING" in upper case letters, enclosed in a border, and centered on the page, and (b) the text of the warning, indented from both margins and centered on the page. The text of the warning shall include (a) a brief description of the hazard, (b) the likely result if the warning is ignored, and (c) specific steps to take to avoid the hazard. Warnings shall precede the information to which they apply. [Source: FAA-D-2494/b, 1984; MIL-M-87268, 1995]

- **15.4.8.3 Cautions.** Cautions shall consist of (a) the word "CAUTION" in upper case letters and centered on the page, and (b) the text of the caution, indented from both margins and centered on the page. The text of a caution shall include (a) a brief description of the hazard, (b) the likely result if the hazard is ignored, and (c) specific steps to take to avoid the hazard. Cautions shall precede the information to which they apply. [Source: FAA-D-2494/b, 1984; MIL-M-87268, 1995]

- **15.4.8.4 Notes.** Notes shall consist of (a) the word "NOTE" in upper case letters and centered on the page, and (b) the text of the note, indented from both margins and centered on the page. The text of a note shall include the information that is to be given to the reader. Notes shall either immediately precede or immediately follow the information to which they apply, depending upon the content of the note and the text to which it applies. [Source: FAA-D-2494/b, 1984; MIL-M-87268, 1995]

- **15.4.8.5 Precedence of warnings, cautions, and notes.** If more than one type of notice applies at the same place in a document, for example, if a hazard exists to both people and equipment, the order in which the notices appear shall be warnings, cautions, and notes. [Source: FAA-D-2494/b, 1984; MIL-M-87268, 1995]

- **15.4.8.6 No procedural steps.** Warnings, cautions, and notes shall not contain procedural steps. [Source: FAA-D-2494/b, 1984; MIL-M-87268, 1995]

15.4.9 Appendixes

This section contains rules for appendixes.

> **Definition.** An **appendix** is a body of supplementary information collected, labeled, and placed at the end of a document.

- **15.4.9.1 When to use.** Information that supplements, but is not integral to, the main body of a document should be placed in one or more appendixes. Examples of such information include illustrations, applications, calculations, and formulas. Appendixes should be used only if the information is essential. [Source: FAA Order 1700.8D, 1992]

- **15.4.9.2 Relation to main body.** The content of an appendix shall be within the scope of the document and shall not be inconsistent with the document itself. An appendix shall be referred to in the main body of the document. [Source: FAA Order 1700.8D, 1992; MIL-STD-962B, 1988]

- **15.4.9.3 Identification.** Each appendix in a document should have an identifying letter and a title. Identifying letters shall be assigned consecutively, beginning with "A." The title shall be brief but descriptive. [Source: FAA Order 1700.8D, 1992; MIL-STD-962B, 1988]

> **Discussion.** FAA Order 1320.1D requires that appendixes of directives be identified by an Arabic numeral designator with pages numbered within each appendix (for example 1- page 1, 1- page 2 and so on). FAA-D-2494/b, 1984 for instruction books uses Roman numerals for appendix designators. The present guidance document recommends alphabetic designator for appendixes and page numbering within each appendix (for example, A-1, A-2, ... B-1, B-2, and so forth). This designation helps the users of reference type documents to distinguish between main chapters and appendixes and aids them in navigating through the document.

- **15.4.9.4 Page numbering.** Each page of an appendix shall have a number that consists of the letter that identifies the appendix followed by a dash followed by the number of the page within the appendix. For example, B-2 would indicate the second page of Appendix B. Page numbers shall be located in the same relative position on the page as page numbers in the main body of the document. [Source: FAA Order 1700.8D, 1992]

- **15.4.9.5 Pagination.** Each appendix shall begin on a right-hand (odd-numbered) page. Appendixes shall not have title pages; rather, the title shall appear at the top of the first page of the appendix. [Source: FAA Order 1700.8D, 1992]

15.4.10 Glossary

- **15.4.10.1 Terms.** Special terms and words used in technical or unusual ways shall be defined where they first appear in the text. If there are many such terms, they shall also be collected in a glossary located near the end of the document. [Source: FAA Order 1700.8D, 1992]

- **15.4.10.2 Format.** The glossary shall consist of (a) an alphabetic listing of all the special or unusual terms that appear in the document, and (b) their definitions. The definitions shall be the same as those that appear in the text where the terms are first defined. [Source: Zaneski, 1982]

15.4.11 Index

An index can greatly enhance the usability of a document, increasing both the speed and the likelihood of a user's finding the desired information.

- **15.4.11.1 When to use.** Documents that are lengthy or complex shall have indexes. [Source: FAA Order 1700.8D, 1992]

- **15.4.11.2 Format and content.** An index shall consist of an alphabetic listing of the terms and topics that exist in the document and the pages on which they can be found. Each alphabetic group shall be preceded by the initial letter of the group. This letter shall appear in upper case type that is larger and bolder than the entries. [Source: FAA Order 1700.8D, 1992; Zaneski, 1982]

- ▫ **15.4.11.3 Level of detail.** An index should contain more levels of detail than does a table of contents. [Source: Simpson and Casey, 1988]

- **15.4.11.4 Location.** An index shall be the last division of a document. [Source: MIL-STD-962B, 1988]

15.4.12 User feedback forms

- **15.4.12.1 When to use.** All user guides and manuals shall include forms inviting feedback from users. [Source: FAA-D-2494/b, 1984]

- **15.4.12.2 Location.** User feedback forms shall be the very last pages in the document, that is, they shall be bound just before the back cover. [Source: FAA-D-2494/b, 1984]

- **15.4.12.3 Content.** The form shall solicit from users of the document at least those categories of information illustrated in Exhibit 15.4.12.3 (a). The fields for the document identifier and title shall be printed on the form, that is, the user shall not have to write them in. The form shall be self-addressed and shall have an "Official Business" postage permit, as illustrated in Exhibit 15.4.12.3 (b). Appendix 15 of FAA Order 1320.1D shows a sample feedback form for users of formal directives. This form encourages users to suggest subject matter for future additions. [Source: FAA-D-2494/b, 1984; MIL-STD-962B, 1988]

Exhibit 15.4.12.3 (a) User Feedback form – Front

(Fold along this line)

(Fold along this line)

Federal Aviation Administration

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

BUSINESS REPLY MAIL

Postage will be paid by the
Federal Aviation Administration

[Addressee]

Exhibit 15.4.12.3 (b) User feedback form - Back

Instructions. This form is provided as part of the FAA's continuing effort to improve documentation. Users of this document are invited to submit comments and suggestions, especially if they are aware of any difficulty associated with its use. To submit comments or suggestions: (1) remove this form from the document, (2) complete the applicable sections, (3) fold this form in thirds, using the lines on the reverse side as a guide, and (4) mail. No postage is necessary if the form is mailed in the United States.

Document Number: Document Title:

Your name, address, and telephone number: (optional) Date:

Please describe any difficulty associated with use of the document and add any comments or suggestions that might be helpful. (Please include the section or paragraph number, recommended changes, and your rationale for the recommendations, as applicable.)

- **15.4.12.4 Number of copies.** Three copies of the user feedback form shall be bound with the document. [Source: FAA-D-2494/b, 1984]

15.4.13 Tabs

- **15.4.13.1 When to use.** Tabs should be provided if a document has many divisions. If a document has tabs, it should have a tab for each major division, for each frequently-used division, or both. [Source: Simpson and Casey, 1988]

  Discussion. Some sort of balance is needed between the number of tabs in a document and the number of pages between tabs. If there are a few long divisions, tabs might be used within divisions; on the other hand, if there are many short divisions, one tab might serve several divisions. A rule of thumb might be that three or four tabs is so few that they would not be helpful and that more than 20 or 30 tabs might be so many that they would interfere rather than help.

15.4.14 Footnotes

Footnotes, like appendixes, are used to present information that is not properly a part of the text. The difference is that footnotes tend to be much shorter and more closely related to the specific text than are appendixes.

- **15.4.14.1 Minimize use of footnotes.** The use of footnotes shall be minimized. [Source: MIL-STD-490A, 1985, 3.2.11.1; MIL-STD-962B, 1988; Hartley, 1978]

  Discussion. Footnotes may be distracting and often are ignored. If the information is important, it properly belongs in the text; if the information is not important, it is probably not necessary. Extensive supplemental information belongs in an appendix.

- **15.4.14.2 Identification.** Footnotes to text shall be numbered consecutively throughout a document or throughout a division of a document. The reference to a footnote in the text shall consist of the footnote's number in superscript Arabic numerals immediately following the word or phrase to which it applies. The footnote itself shall be preceded by its identifying number, also in superscript. Footnotes to figures or tables shall be numbered consecutively or otherwise identified (see the following Exception) independently for each figure or table. [Source: MIL-STD-962B, 1988]

  Exception. If footnotes occur in tables or figures, and the use of numbers to identify them might lead to confusion with numerical data in the table or figure, letters and symbols are acceptable alternatives for identifying footnotes.

- **15.4.14.3 Location.** Footnotes to text shall be located at the bottom of the page on which their reference in the text occurs. Footnotes to figures or tables shall be located immediately following the figure or table. [Source: MIL-STD-490A, 1985; MIL-STD-962B, 1988]

15.4.15 Copyright and patent issues

- **15.4.15.1 Copyrighted documents.** If a user document is or will be copyrighted, the copyright information shall be placed on the back of the title page. [Source: Zaneski, 1982]

- **15.4.15.2 Inclusion of copyrighted or patented material.** Copyrighted or patented material shall not be included in user documents without the prior consent of the owner of the copyright or patent. When such consent has been obtained, and if the owner requests it, an acknowledgment of the permission shall be placed in the document near the material. [Source: MIL-STD-962B, 1988]

15.4.16 Publication date

- **15.4.16.1 Location.** The date of publication shall appear at the center of the bottom of the front cover. [Source: FAA-D-2494/b, 1984]

15.5 Specific user document contents

This section contains rules for two specific types of user document contents, proceduralized instructions and interactive electronic technical manuals.

15.5.1 Proceduralized instructions

Proceduralized instructions tell users how to complete tasks. They may be used for (a) mechanical procedures, such as assembling, servicing, and repairing units of equipment, (b) operating procedures, such as starting, operating, and shutting down systems or units of equipment, and (c) test procedures, such as periodic maintenance tests and alignments. The instructions are presented as a series of steps.

> **Definition.** A **proceduralized instruction** is a set of step-by-step instructions a procedure intended to ensure the successful completion of a task.

15.5.1.1 General

- **15.5.1.1.1 Procedures, tasks, subtasks, and steps.** A proceduralized instruction shall apply to a single task and shall present instructional information as a series of steps. A lengthy or complicated procedure may be divided into a series of related subtasks as long as each subtask accomplishes a distinct, recognizable objective. [Source: Department of Defense (MIL-M-87268, 1995]

- **15.5.1.1.2 Level of detail.** Proceduralized instructions shall include a level of detail that is appropriate to the intended users. [Source: Wieringa, Moore, & Barnes, 1993]

- **15.5.1.1.3 Completeness.** Each proceduralized instruction shall contain all the steps and supporting information required to successfully complete the task. [Source: AFSC DH 1-3, 1980; MIL-HDBK-761A, 1989]

- **15.5.1.1.4 Safety considerations.** The performance of all procedures shall be made as safe as possible by including all of the following safeguards that apply:

  a. If possible, actions shall be performed with equipment shut down and isolated.

  b. At the completion of a task or subtask, no portion of a unit of equipment shall be left in a dangerous state unless the procedure includes the posting of adequate warnings.

  c. Steps that tell a user to remove voltage or pressure shall also tell the user to label or tag the switches, circuits, or valves involved.

  d. If components capable of holding a charge are involved, the procedure shall tell the user how to discharge these components safely.

  e. Procedures shall include steps to restore equipment to a safe operating condition.

  f. Procedures shall include warnings, cautions, and notes as appropriate. [Source: MIL-HDBK-761A, 1989]

- **15.5.1.1.5 General safety instructions.** A proceduralized instruction shall include a summary of any general safety information that applies throughout the task. [Source: MIL-HDBK-761A, 1989]

15.5.1.2 Organization and content

- **15.5.1.2.1 Hierarchical, logical, and consistent.** A proceduralized instruction shall be organized in a hierarchical, logical, consistent manner that is apparent to the user. [Source: Wieringa, Moore, & Barnes, 1993]

- **15.5.1.2.2 Identifying information.** Information identifying the procedure shall be displayed on the cover page of the procedure and in a header or footer on each page. [Source: Wieringa, Moore, & Barnes, 1993]

- **15.5.1.2.3 Title.** A proceduralized instruction shall have a title that is concrete, specific, and terse, and that uniquely identifies the task to be performed. [Source: MIL-HDBK-761A, 1989]

- **15.5.1.2.4 Headings.** If a proceduralized instruction contains distinct parts, each part shall have a heading. Headings shall conform to the requirements for titles (see Paragraph 15.2.1.1.1). [Source: Wieringa, Moore, & Barnes, 1993]

- **15.5.1.2.5 Numbered steps.** Steps shall be numbered, using Arabic numerals, in a way that provides useful information to users without being overly complex. [Source: MIL-HDBK-761A, 1989; Wieringa, Moore, & Barnes, 1993]

  Discussion. A complex step might be divided into a number of substeps, and the numbering might reflect this. For example, if step 6 has three substeps, the substeps might be numbered 6.1, 6.2, and 6.3.

- **15.5.1.2.6 Supporting information.** A proceduralized instruction shall include all of the following supporting information that is applicable:

  a. An applicability statement that specifies the equipment or systems to which the procedure applies (for example, the applicability statement might list equipment model numbers and a range of serial numbers);

  b. Any initial setup or input conditions required for the procedure;

  c. A list of test equipment required;

  d. A list of tools required;

  e. A list of materials, consumable or expendable items, and mandatory replacement parts required;

  f. A list of support equipment required;

  g. If more than one, the minimum number of personnel required;

  h. A system preparation checklist; and,

  i. A list of any special environmental conditions required (for example, ventilation, lighting, temperature, noise level, electromagnetic interference, cleanliness, and humidity). [Source: MIL-HDBK-761A, 1989]

- **15.5.1.2.7 Appendixes and attachments.** Information that is important and useful but not easily incorporated into a procedure should be presented in an appendix or attachment to the procedure. However, the use of appendixes and attachments should be minimized. [Source: Wieringa, Moore, & Barnes, 1993]

  Examples. Types of information presented in appendixes or attachments might include contingency actions, actions performed by someone other than the user of the procedure, and periodic steps.

15.5.1.3 Format

- **15.5.1.3.1 Step numbers and text.** The text of a step shall begin on the same line as its number, separated from the number by two spaces. If the text fills more than one line, the additional line or lines shall begin under the first letter of the first line, not under the number. [Source: Department of Defense (MIL-M-38784, 1992]

- **15.5.1.3.2 Check off provision.** If appropriate, the proceduralized instruction should provide a line or box adjacent to a step so that a user can check off the step when it has been completed. [Source: Wieringa, Moore, & Barnes, 1993]

  Discussion. The provision of a check off can serve a variety of functions; it can serve as a placeholder in cases in which a user refers to another part of the procedure or another procedure; it can serve as a record of the completion of the step; and it can be used to identify the applicable condition in a conditional step.

- **15.5.1.3.3 Lists.** If a step contains a sequence of three or more items (for example, actions, conditions, or units of equipment), the items should be presented in a list format (see Section 15.4.6). [Source: Wieringa, Moore, & Barnes, 1993]

- **15.5.1.3.4 Illustrations.** If a step refers to an illustration, it shall be possible for the user to see both the step and the illustration simultaneously. This may be accomplished by placing the illustration (a) within the step in which it is used, (b) on the same page as the step, (c) on a facing page, or (d) on a foldout page (see Section 15.3.2.7). [Source: AFSC DH 1-3, 1980]

15.5.1.4 Wording of steps

- **15.5.1.4.1 Completeness.** Each step shall contain all the instructions and supporting information required to successfully complete the step. [Source: AFSC DH 1-3, 1980]

- **15.5.1.4.2 Grammar.** The steps in a proceduralized instruction shall be comprised of grammatically correct sentences. [Source: Wieringa, Moore, & Barnes, 1993]

▪ **15.5.1.4.3 Action statements and indication statements.** If appropriate, a step in a proceduralized instruction shall be comprised of an action statement followed by an indication statement. The indication statement shall include any applicable values or tolerances. [Source: MIL-HDBK-761A, 1989]

> **Definitions.** An **action statement** is an action verb followed by the object or item acted upon. An **indication statement** states the name of an indicator that the user reads or observes and the indication expected to result from the action. The **stated indication** is what is expected if the equipment or system is operating normally.

▪ **15.5.1.4.4 Standard steps.** If the same (or highly similar) action or indication occurs more than once in a procedure, a standard wording shall be adopted and used consistently throughout the procedure. Such standard wording shall, as appropriate, accommodate different objects and indicators. [Source: MIL-HDBK-761A, 1989]

▪ **15.5.1.4.5 Conditional steps.** Steps that are to be performed only if a specified condition exists shall begin with the word "if" or "when" and a statement of the condition, followed by the word "then" and the action statement. If and then shall be emphasized typographically (see Section 15.3.3.7). If the condition is negative, the word not shall be used and emphasized. [Source: Wieringa, Moore, & Barnes, 1993]

> **Examples.** Examples of conditional steps are: "If the status light is green, then press the override button," "When engine speed reaches 2000 RPM, then engage the clutch," and "If the status light is not green, then press the power switch."

▪ **15.5.1.4.6 No calculations.** If possible, no step shall require a user to make a calculation. If a calculation is necessary, the step shall include a calculation aid, for example, a series of step-by-step instructions for carrying out the calculation. [Source: Wieringa, Moore, & Barnes, 1993]

▫ **15.5.1.4.7 Numerical precision.** If a step contains numerical information that relates to an indicator, the precision of the information in the step should not exceed the precision of the indicator. For example, if an instrument dial can be read only to the nearest five units, the step should not require a reading to the nearest single unit. [Source: Wieringa, Moore, & Barnes, 1993]

▪ **15.5.1.4.8 Numerical ranges.** If a step specifies a range of numerical values, the range shall be stated as the upper and lower values, not as the middle value plus and minus an increment. For example, a temperature range might be stated as 75-85°F, not as 80°F ±5°. [Source: Wieringa, Moore, & Barnes, 1993]

15.5.1.5 Branching and cross-references

Not every procedure is a simple, sequential series of steps. Some require branching depending upon conditions (for example, "If the condition is *A*, then go to step *X*; if the condition is *B*, then go to step *Y*"), and some require a temporary reference to another step or procedure followed by a return to the current procedure (for example, "If the condition observed in step *N* is *C*, then perform procedure *Z* before performing step *N+1*").

▪ **15.5.1.5.1 Minimize use.** The use of branching and cross-referencing in proceduralized instructions shall be minimized. [Source: Wieringa, Moore, & Barnes, 1993]

▪ **15.5.1.5.2 Explicit instructions.** Branching and cross-referencing shall be explicit, not implicit. [Source: Wieringa, Moore, & Barnes, 1993]

▪ **15.5.1.5.3 Content.** Branching and cross-referencing instructions shall provide all necessary information and shall be worded consistently. [Source: Wieringa, Moore, & Barnes, 1993]

> **Examples.** Branching instructions might be worded: "If ..., then go to step ..." A cross-referencing instruction might be worded: "Refer to steps ... then return to step ..."

15.5.1.6 Miscellaneous

▪ **15.5.1.6.1 Simultaneous actions or indications.** If a procedure includes actions that must occur simultaneously or indications that occur simultaneously, the actions or indications shall be included in the same step. [Source: MIL-HDBK-761A, 1989]

▫ **15.5.1.6.2 Format for diagnostic steps.** The format of a diagnostic step should be appropriate to the immediate task. [Source: Wieringa, Moore, & Barnes, 1993]

▫ **15.5.1.6.3 Nonsequential steps.** Steps that need not be performed in a fixed sequence should be presented in a way that makes clear when they should be performed and that ensures they are not omitted. [Source: Wieringa, Moore, & Barnes, 1993]

> **Discussion.** In some cases, a number of steps must be performed, but the order in which they are performed does not matter. In others, a step must be performed when a condition is met, for example, shutting a valve when a tank becomes full. In still others, a step must be performed at specified intervals or at a specified time after an action has been taken.

▫ **15.5.1.6.4 Verification steps.** Steps that require a user to verify that a stated condition is met should be presented in an appropriate format, for example, with a check box. If a procedure contains more than one verification step, the verification steps should have a consistent format. [Source: Wieringa, Moore, & Barnes, 1993]

▫ **15.5.1.6.5 Equally-acceptable steps.** Steps that tell a user to perform one of a number of equally acceptable actions should be presented in a format that makes clear exactly what the user is to do, for example, to select and perform one and only one action. [Source: Wieringa, Moore, & Barnes, 1993]

▪ **15.5.1.6.6 Actions performed from memory.** If a procedure includes one or more steps that a user is expected to perform from memory, the written procedure shall include those steps. [Source: Wieringa, Moore, & Barnes, 1993]

Example. The first step(s) in an emergency procedure may have to be done from memory. Whenever the total procedure is written out, the memorization steps are assumed to be necessary and are included.

▪ **15.5.1.6.7 Procedures involving more than one person.** A procedure that involves more than one person shall be presented in a way that assigns actions and observations to individuals and integrates the actions and observations of all the individuals into a single series of steps. [Source: MIL-HDBK-761A, 1989]

15.5.2 Interactive electronic technical manuals

Interactive electronic technical manuals are technical manuals designed for interactive use on an electronic display system. This medium has many advantages, such as (a) tailoring the presentation to the user, for example, presenting highly detailed information to novice users and condensed information to experienced users, (b) tailoring the presentation to the situation, for example, following one branch rather than another based on a user input, (c) permitting the manipulation (such as movement or enlargement) of diagrams, and (d) permitting easy access to information, such as parts information.

15.5.2.1 General

▪ **15.5.2.1.1 Access to contents.** A user shall be able to access directly any portion of the manual that appears in a list of its contents. [Source: MIL-HDBK-761A, 1989]

▪ **15.5.2.1.2 Help information.** The system shall provide at the user's request additional information relating to the technical content of all sections of the electronic technical manual. This help shall include both context-sensitive help applicable to the user's current activity and situation, and descriptive information on a specific term, technical point, or process. Help information shall include:

a. administrative information about the manual itself, for example, the title and identification, the version number, the date of the latest change, and the preparing organization;

b. an easily noticeable applicability statement that specifies precisely the equipment or system to which the manual applies, including model numbers and serial numbers, if applicable;

c. an introduction that states the purpose, scope, contents, organization, and range of tasks covered by the manual;

d. information on how to use the help information;

e. information about the computer system being used to view the manual;

f. instructions on the use of any utility functions provided, for example, the automatic preparation and submission of reports;

g. information about function keys and other keyboard features;

h. general information about the task being performed or the portion of the manual being used;

i. specific, context-sensitive help;

j. an index of help information; and,

k. definitions of abbreviations and unusual terms. [Source: MIL-HDBK-761A, 1989]

Discussion. The above rule does not imply that an electronic technical manual or a help subsystem can merely be a paper manual transposed to a help role by its presentation or availability through a computer system monitor. To the contrary, such a practice may produce a nearly useless help system or electronic technical manual. Help systems and electronic technical manuals need to be designed along with the system, especially along with software systems.

Such systems and electronic manuals need to be based upon human understanding of technical information related to human tasks, processes, interfaces, and other subsystem that they use and maintain to enable their individual and collective purposeful endeavors. Using computer technology to turn pages is a questionable practice. Hypertext help is much more appropriate than a paper manual transposed to be a help system.

- 15.5.2.1.3 **Safety summary.** If an interactive electronic technical manual contains one or more warnings or cautions, it shall also include a safety summary. [Source: MIL-HDBK-761A, 1989]

15.5.2.2 Text

- 15.5.2.2.1 **Applicable information.** The system shall present to users only information that applies to the specific equipment or system configuration and situation. [Source: MIL-HDBK-761A, 1989]

- 15.5.2.2.2 **Level of detail.** An interactive electronic technical manual shall contain all the information necessary for a user (a) to perform the task involved without error or loss of time due to insufficient information, or (b) to comprehend a description. It shall not contain unnecessary detail. [Source: MIL-HDBK-761A, 1989]

- 15.5.2.2.3 **Procedures in steps.** If a step includes a procedure that is specific to the equipment or system, the procedure shall be included in the step. If a step includes a general-purpose procedure that is likely to be performed without reference to technical information by an experienced technician, the user shall be given the option of bypassing presentation of the procedure. [Source: MIL-HDBK-761A, 1989]

- 15.5.2.2.4 **Accommodating novice and expert skill levels.** If specified by the acquisition program office, an interactive electronic technical manual shall offer two levels of detail, one for a novice skill level, and one for an expert skill level. The novice skill level shall contain all information necessary for an inexperienced user to perform the task involved or to comprehend a description. The expert level shall function as a checklist, presenting only the steps required to complete a task or providing a description in broader terms, requiring a higher level of theoretical knowledge. Both levels shall contain all pertinent warnings and cautions. The expert user shall be able to access information at the novice level, but the novice user shall not be able to access information at the expert level unless otherwise specified by the acquisition program office. [Source: MIL-HDBK-761A, 1989]

15.5.2.3 Graphics

The types of graphic displays that might appear in an interactive electronic technical manual include, but are not limited to, locator diagrams, functional block diagrams, general support graphics, schematics, wiring diagrams, flow diagrams, graphs, and charts.

- 15.5.2.3.1 **Minimum quality.** Graphic displays shall meet the general requirements of Paragraph 15.5.2.3.1 when displayed on the least capable device (for example, the smallest screen) on which the manual is intended to be used. [Source: MIL-HDBK-761A, 1989]

- 15.5.2.3.2 **Interaction with graphics.** A displayable graphic may or may not be designed to be used interactively. If a graphic is not interactive, it shall be displayed in full detail; if it is interactive, a user shall be able to (a) manipulate the graphic for a better view, for example, by moving or re-sizing it, (b) choose selectable areas within the graphic, or (c) both. [Source: MIL-HDBK-761A, 1989]

  Discussion. An interactive graphic would be appropriate if the graphic is so large or detailed that it cannot be displayed in full detail in the space available, and thus requires the use of scrolling or zooming.

- 15.5.2.3.3 **Detail and context.** Graphics shall present only the equipment items to which action statements refer and enough of their surroundings to permit a user to locate and isolate an item without error. Unnecessary details that reduce the comprehensibility and clarity of the graphic shall be omitted. [Source: MIL-HDBK-761A, 1989]

- 15.5.2.3.4 **Citations of equipment nomenclature.** If a graphic contains labels or citations that refer to controls, control positions, test points, and indicating devices that are labeled on the equipment, the graphic labels shall appear exactly as they appear on the equipment (for example, using all capital letters if the equipment label does). [Source: MIL-HDBK-761A, 1989]

- 15.5.2.3.5 **Angle of view.** Graphics shall be drawn from the same general angle of view that the equipment presents to a user. Cutaways and hidden lines shall be used as necessary in conjunction with details that are accessible but not visible to a user. In situations in which a user is able to view the equipment from more than one angle, the view that provides the most pertinent and necessary information in the simplest fashion shall be used. An item or part removed from the equipment may be rotated to show important features, but, if so, the axis, direction, and degrees of rotation shall be indicated in the graphic. Perspective and isometric projections shall be used rather than orthographic projection, unless the view is head-on. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.3.6 Use of a human figure.** If it is necessary to illustrate an operation or procedure, a graphic shall include a human figure or the relevant body parts. Jewelry shall not appear in graphics. The human figure or part shall not obscure details of the equipment necessary for a complete understanding of its operation. The human figure shall be clothed as specified by the acquisition program office. A cross section of races and sexes shall be used. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.3.7 Callouts.** Callouts shall be provided to identify specific features of interest on graphics. Callouts shall be in accordance with Paragraph 15.4.4.5.2. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.3.8 Schematic and wiring diagrams.** Unless specified otherwise by the acquisition program office, a wire list, schematic, or wiring diagram that is displayed in association with text shall be simplified to contain only the information referred to in the text. However, a user shall have access to the entire wire list, schematic, or wiring diagram. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.3.9 Functional flow diagrams.** Functional flow diagrams shall be drawn as flowcharts indicating the direction of system interaction. The information shall flow from left to right and top to bottom on diagrams. The diagrams shall indicate the detail referenced by the accompanying text. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.3.10 Locator graphics.** Locator graphics shall enable a user to find specific hardware items (for example, parts, switches, controls, or indicators) referred to in the technical information. A locator graphic shall consist of a labeled graphic together with required callouts. The locator graphic shall show what a particular item looks like and illustrate its relationship to its immediate surroundings on the equipment illustrated. Locator graphics, if used, shall either be included as an option for selection by a user, or as an automated part of the presentation of procedural or descriptive information. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.3.11 Placement of locator graphics.** Locator graphics shall be integrated with their associated technical information as follows:
  a. Individual equipment items (for example, parts, switches, controls, and indicators) shall be shown in the physical context of major equipment components. The nomenclature of major equipment components shall be shown on the graphic.

  b. Index numbers on callouts shall be assigned on the equipment item locator graphic either (a) in clockwise sequence, or (b) in the sequence that items are discussed in procedural steps.

  c. If a procedural step includes a reference to an illustrated equipment item, the reference shall cite either a callout or an index number with a leader line pointing to the referenced item. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.3.12 Exploded item views.** Exploded views of items shall be used as locator graphics only if further disassembly is required. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.3.13 Minimum size of a locator graphic.** The minimum size of a locator graphic shall enable a user to quickly identify the surroundings and the item to be located with respect to the surroundings. A callout shall be used to emphasize the item to be located. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.3.14 Animated information.** The motion of animated information shall be easily discernable by a user and clearly differentiated from its background and from static information on display. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.3.15 Video controls.** If an interactive electronic technical manual includes an animated or motion video sequence, the sequence shall repeat automatically after completion. A user shall be able to pause, repeat, and exit the sequence. [Source: MIL-HDBK-761A, 1989]

15.5.2.4 Audio

- **15.5.2.4.1 Redundant visual information.** Audio information shall always be accompanied by redundant visual information so that the information presentation is effective even if its audio output device is not available. Audio information shall be in accordance with Chapter 7 of this document. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.4.2 When to use nonverbal auditory signals.** Nonverbal auditory signals shall be limited to applications in which immediate discrimination is not critical to personnel safety or system performance. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.4.3 When to use computer-generated and electronically-stored speech.** Computer-generated and electronically-stored speech shall be limited to the presentation of procedural information. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.4.4 Audio controls.** If an interactive electronic technical manual includes either verbal or nonverbal audio signals, it shall provide users the ability to (a) request a repetition of any signal, (b) adjust the volume of the signals, and (c) turn the audio signals on and off. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.4.5 Pronunciation of abbreviations.** Computer-generated and electronically-stored speech shall pronounce the entire word or phrase an abbreviation represents unless the abbreviation is pronounced as individual letters in common usage. Acronyms in common use shall be pronounced as the acronym. [Source: MIL-HDBK-761A, 1989]

  Examples. The abbreviation "mm" would be pronounced "millimeter." The abbreviation "SSE" would be pronounced "south south east." The abbreviation SFO (for Sector Field Office) would be pronounced "S" "F" "O." The acronym "TELCO" (for telephone company) would be pronounced "telco."

- **15.5.2.4.6 Pronunciation of alphanumeric strings.** Strings of digits or alphanumeric characters that are not ordinarily pronounced as a unit shall be pronounced as a series of single letters or digits. [Source: MIL-HDBK-761A, 1989]

15.5.2.5 Warnings, cautions, and notes

- **15.5.2.5.1 When to include warnings and cautions.** If it is impossible to avoid the use of or exposure to hazardous materials, conditions, or equipment, the technical information shall be supplemented with a warning or caution designed (a) to attract the user's attention to practices, procedures, and conditions that could lead to injury or equipment damage, (b) to warn the user about the performance of certain hazardous actions, and (c) to state how the procedure can be performed safely. Warnings, cautions, and notes shall be in accordance with Section 15.4.8. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.5.2 Readable and comprehensible.** Warnings, cautions, and notes shall be easy to read and understand in the work environment in which they are likely to appear. [Source: MIL-HDBK-761A, 1989]

  Note. If more than one type of danger may be present, or if danger can come from more than one source, or if one type of danger may require more than one remedial action, the dangers and actions may be referred to once in a single, combined warning or caution.

- **15.5.2.5.3 Association of warnings and cautions with text.** A warning or caution shall be directly associated with and precede in logical sequence the text or procedural step to which it applies. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.5.4 Location of warnings, cautions, and notes.** Warnings, cautions, and notes that are presented in dialog boxes shall be displayed in the approximate center of the display area, and normal operation of the system shall not resume until a user acknowledges the message. Upon acknowledgement, the box shall be removed and normal operation resumed. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.5.5 Color in warning, caution, and note displays.** If color is used in interactive electronic technical manuals, the color red shall be associated with warnings, yellow with cautions, and cyan with notes. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.5.6 Borders for warnings, cautions, and notes.** Warnings, cautions, and notes presented in dialog boxes shall be enclosed in borders consisting of diagonal bars, alternating between the background color or white and the designated message color. The text shall be displayed within the border. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.5.7 When to use notes.** Notes shall be used to supply needed information that is not a step in a procedure. Information in notes shall be limited to necessary specifics. Required tolerances and clearances shall not be given in notes; they shall be included in procedural steps. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.5.8 Association of notes with text.** A note shall either directly precede or directly follow the applicable text depending upon the point to be emphasized. A note shall precede a procedural step to which it applies. [Source: MIL-HDBK-761A, 1989]

15.5.2.6 Interaction style

- **15.5.2.6.1 Dialog boxes.** If windowing is used, a dialog box shall be the principal means by which a user interacts with an interactive electronic technical manual. The box shall be displayed in a separate window and shall contain a heading and one or more control push buttons. All boxes shall have an **OK** push button and, if appropriate, a **Cancel** push button. Dialog boxes shall appear in a consistent and prominent part of the display, and shall be easily distinguishable from other types of displayed information. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.6.2 Dialogs.** Dialogs shall be formulated as prompting questions that are presented to the user and that require a response from the user. The system response shall be appropriate to the user's response. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.6.3 Prompts.** A standard symbol or layout shall be used with prompts to indicate to a user that an explicit response is expected. The symbol or layout shall be used exclusively for this purpose. The user's response shall be displayed adjacent to the prompt. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.6.4 Changing responses to prompts.** A user responding to a series of prompts in a single portion of a procedure shall be able to change any previously entered response as long as that change does not alter the logic of the procedure. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.6.5 Navigation operations.** Users shall have at least the following navigation functions:

  a. **Next**. This operation shall display the next section of information appropriate to the context.

  b. **Back**. This operation, the opposite of **Next**, shall display the previous section of information appropriate to the context.

  c. **Return**. If the manual provides branching, this operation shall return the user from a branch to the branching point, resetting any temporary system state information relative to the branch.

  d. **Browse back, Browse next,** and **Browse exit**. If the Next and Back operations set interactive system variables that affect subsequent navigation through the manual, browse functions shall be available that act as **Next** and **Back** but without affecting the system variables. Once the **Browse next** or **Browse back** operation has been selected, the normal **Next** and **Back** operations shall not be available until the user invokes the **Browse exit** operation. The system shall provide a distinct visual indication when the system is in the browse mode. [Source: MIL-HDBK-761A, 1989]

  Definitions. Browse back is the action of moving to the previous window without permanently resetting system variables; however, system variables in the temporary state table will be reset. **Browse next** is the action of moving to the succeeding window without permanently setting system variables; however, system variables will be set to a temporary state table. **Browse exit** is the action of leaving browse mode.

- **15.5.2.6.6 Data access operations and features.** An interactive electronic technical manual shall provide users at least the following access operations or features:

  a. **Marking.** Users shall be able to mark a displayed information element for later recall. "Marking" shall include the ability to create, name, delete, modify, and go to a mark.

  b. **Outline and index.** Users shall have access to information through a hierarchical outline of the manual, an index, or both.

  c. **Functional diagrams.** If a manual includes a functional diagram or graphic, users shall be able to gain access to information by selecting the appropriate portion of the diagram.

  d. **Search.** Users shall be able to gain direct access to information by entering selection information in a Search operation.

  e. **Cross-references.** If a displayed information element has a cross-reference or other related information associated with it, the element shall include a clear indication of that fact, and a user shall be able to display the related information and then return to the original display using the Return operation (see Paragraph 15.5.2.6.6.c). [Source: MIL-HDBK-761A, 1989]

15.5.2.7 User interface

- **15.5.2.7.1 Consistency.** The user-manual interaction and the display formatting of an interactive electronic technical manual shall be consistent across all devices upon which the manual can be presented. [Source: MIL-HDBK-761A, 1989]

15.5.2.8 Special requirements for proceduralized instructions

- **15.5.2.8.1 Form and content.** Procedural information in an interactive electronic technical manual shall be directive in form. It shall instruct a user how to operate, test, maintain, or repair a system. It shall contain the directive information (for example, the steps) and any additional supporting material needed or helpful in the successful completion of a procedure. [Source: MIL-HDBK-761A, 1989]

15.5.2.9 Special requirements for troubleshooting information

- 15.5.2.9.1 **Troubleshooting logic.** The fundamental logic for interactive troubleshooting shall be specifically designed and shall include, but not be limited to, predefined fault isolation sequences and dynamically generated fault isolation recommendations based on system or user inputs. [Source: MIL-HDBK-761A, 1989]

- 15.5.2.9.2 **Contents.** Troubleshooting information shall include, but not be limited to (a) symptoms, (b) procedures, such as tests, repairs, and scheduled maintenance, (c) graphics, locator diagrams, and schematics, (d) parts and test equipment information, (e) equipment failure history, and (f) theory of operation. In addition, after a fault has been isolated, the manual shall permit direct access to relevant corrective maintenance procedures. [Source: MIL-HDBK-761A, 1989]

- 15.5.2.9.3 **User inputs.** Users shall have the following capabilities:

  a. the ability to enter symptom information (a) by typing or (b) by initiating automatic retrieval from the system or equipment under observation,

  b. the ability to enter and change test results, if appropriate,

  c. the ability to confirm conditions or states if necessary to continue a user action,

  d. the ability to review and browse through previous actions and test results, and

  e. the ability to access information needed to troubleshoot the system or equipment in an efficient and clearly defined manner. [Source: MIL-HDBK-761A, 1989]

- 15.5.2.9.4 **Predefined fault isolation sequences.** Each step in a predefined fault isolation sequence shall be based on the reporting of an observed symptom or the result of a previous test and shall specify the next procedure, test, or corrective user action. [Source: MIL-HDBK-761A, 1989]

  Definition. A **predefined fault isolation sequence** is a sequence of fixed procedures and tests that leads to a suspected fault. It is similar to a fault tree in a fault isolation manual.

- 15.5.2.9.5 **Presentation of a predefined fault isolation sequence.** Predefined fault isolation sequences shall be presented as procedural steps that prompt users to perform tests, make observations, or perform corrective repair actions. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.9.6 Dynamically-generated fault isolation recommendations.** Dynamically-generated fault isolation recommendations shall be derived from user inputs along with stored information and automated inputs. The system shall provide users recommendations of tests to perform or actions to perform to aid in the fault isolation process. Results of the tests or actions shall be used to update the system status and shall result in further recommendations, as appropriate. [Source: MIL-HDBK-761A, 1989]

  Definition. A **dynamically-generated fault isolation recommendation** is a recommendation made by a computer system based on stored information and information received from user inputs, automated system inputs, or both. The information used by the system may include historical information, heuristics, probability factors, and cost factors. The recommendation may be derived using model-based reasoning, dependency models, fault-based reasoning, rule-based logic, information theory, or advanced artificial intelligence schema.

- **15.5.2.9.7 Presentation of dynamically-generated fault isolation recommendations.** The starting point for dynamic troubleshooting shall be depicted in some representational form, for example, a functional or connectivity block diagram. These depictions shall convey information about the current components under investigation and any suspected faults. By interacting with the depictions, users shall be able to obtain additional information, such as lower levels of system detail, theory of operation, and parts information. Information presentation shall not be limited to a single set of troubleshooting recommendations, but shall permit users to view additional information such as a "best test" or "best repair list," previous actions performed during the troubleshooting process, test results, and block diagrams. [Source: MIL-HDBK-761A, 1989]

15.5.2.10 Presentation of parts information

- **15.5.2.10.1 Information available.** An interactive electronic technical manual shall include a data base of supporting parts information that (a) permits unambiguous identification of all parts that are replaceable or repairable at the current level of maintenance, (b) shows the precise physical relationship of each part to other parts of the system, and (c) provides the user the information needed to order parts through the use of an automatically-generated parts ordering form. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.10.2 Accessibility of parts information.** Users shall be able to access information about a part at any time that part is identifiable in a display. Relevant displays include:

  a. locator diagrams.

  b. logic flow diagrams or circuit diagrams.

  c. portions of text that cite the part using any valid designation of the part.

  d. a dialog prompt for parts information. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.10.3 Direct access.** Users shall be able to obtain parts information directly by specifying a part using any applicable part identification or numbering system. [Source: MIL-HDBK-761A, 1989]

15.5.2.11 Descriptive information

- **15.5.2.11.1 Information available.** An interactive electronic technical manual shall include descriptive information to assist a user in the comprehension of procedural information. Descriptive information shall include, but not be limited to, theory of operation, diagrams, and general knowledge. [Source: MIL-HDBK-761A, 1989]

- **15.5.2.11.2 Presentation of descriptive information.** Descriptive information need not conform to any specified format, but shall be easily understandable and usable (see Section 15.2). Section and paragraph headings shall be employed as needed to assist users in identifying or understanding the organization of descriptive information (see Section 15.2.1). [Source: MIL-HDBK-761A, 1989]

15.6 Accommodating people with disabilities

Accessibility in design extends general design principles to cover those individuals who are faced with either temporary or permanent limitations in some dimension of human ability (e.g., sight, hearing, physical mobility, etc.). Although these rules are meant to make systems more accessible and thus make systems available to an increased number of users, it is not possible to design everything for use by everyone. However, there are often adaptations that can significantly increase system accessibility and usefulness. The goal of this section is to make systems more accessible and thus maximize the number of potential users.

Definitions. A **disability** is a physical or mental impairment that substantially limits one or more of a person's major life activities. A **reasonable accommodation** is any modification or adjustment to a job or the work environment that will enable a qualified person with a disability to participate in the application process and to perform essential job functions.

15.6.1 Document readability and handling

People with visual disabilities may have difficulty reading printed documentation, and people with physical disabilities may have difficulty handling documentation. The following rules provide information that can be used to design documentation that will maximize the number of people who can read and handle it. [Source: Vanderheiden & Vanderheiden, 1991]

- **15.6.1.1 Electronic and printed form.** Manuals and other important documentation intended to be accessible should be available in electronic and printed form and include both text and graphic information.

  Discussion. This will enable the material to be presented on an assisting device such as an enlarged display, a speech synthesizer, or a Braille reader. [Source: Scadden & Vanderheiden, 1988]

- **15.6.1.2 Convertible format.** Documentation should be available in formats that can be converted easily. (for example ASCII format for normal text) [Source: Ladner, 1988]

- **15.6.1.3 Alternate formats.** Documentation should be provided in alternative formats such as electronic, large-print, audiotape, and Braille. [Source: Vanderheiden & Vanderheiden, 1991]

- **15.6.1.4 Type size.** Documentation should be provided in the largest type that is practical. [Source: Vanderheiden & Vanderheiden, 1991]

- **15.6.1.5 Alternate coding devices.** Color coding should not be the only coding device used. [Source: Vanderheiden & Vanderheiden, 1991, D-1]

- **15.6.1.6 Graphic information.** A textual description should be provided of all graphical information. [Source: Vanderheiden & Vanderheiden, 1991]

- **15.6.1.7 Placement of basic instructions.** Basic instructions for operation should be provided on the applicable device and in the documentation. [Source: Vanderheiden & Vanderheiden, 1991]

- **15.6.1.8 Compatible documentation.** Documentation should be compatible with electronic scanning and optical character reading devices. [Source: Vanderheiden & Vanderheiden, 1991]

15.6.2 Cognitive or language disabilities

People who have cognitive or language disabilities may have particular difficulty understanding documentation. The following rules provide information that can be used to design documentation that will maximize the number of people who can understand it. [Source: Vanderheiden & Vanderheiden, 1991]

- **15.6.2.1 Illustrations.** Descriptions should not require illustrations. [Source: Vanderheiden & Vanderheiden, 1991]

  Discussion. This is especially true for descriptions provided for the basic operations. [Source: Vanderheiden & Vanderheiden, 1991]

- **15.6.2.2 Key information.** Key information should be highlighted and placed near the beginning of the document. [Source: Vanderheiden & Vanderheiden, 1991]

- **15.6.2.3 Instructions.** Step-by-step instructions should be provided that use numbers, bullets, or check boxes. [Source: Vanderheiden & Vanderheiden, 1991]

- **15.6.2.4 Directional terms.** When providing instructions, directional terms, such as left, right, up, and down should not be used. [Source: Vanderheiden & Vanderheiden, 1991]

- **15.6.2.5 Initiation of basic features.** A section of the document should be provided that offers information on how to initiate the basic features of the system or equipment. [Source: Vanderheiden & Vanderheiden, 1991]

  Discussion. Consider using audio or videotapes in place of printed documentation to assure that the user is provided the information needed to operate the basic features. [Source: Vanderheiden & Vanderheiden, 1991]

Glossary

Abbreviation - A shortened version of a word or group of words formed by omitting one or more letters.

Acronym - A word formed from the initial letter or letters of a group of words.

Action statement - An action verb followed by the object or item acted upon.

Advance organizer - Supplementary information that is presented prior to the main body of information in which a user is interested.

Appendix - A body of supplementary information collected, labeled, and placed at the end of a document.

Browse back - The action of moving to the previous window without permanently resetting system variables; however, system variables in the temporary state table will be reset.

Browse exit - The action of leaving browse mode.

Browse next - The action of moving to the succeeding window without permanently setting system variables; however, system variables will be set to a temporary state table.

Caution - A written notice given when a situation might result in damage to or destruction of equipment or systems.

Center-justified text - Lines are centered on the page, with both right and left margins ragged.

Disability - A physical or mental impairment that substantially limits one or more of a person's major life activities.

Dynamically-generated fault isolation recommendation - A recommendation made by a computer system based on stored information and information received from user inputs, automated system inputs, or both. The information used by the system may include historical information, heuristics, probability factors, and cost factors. The recommendation may be derived using model-based reasoning, dependency models, fault-based reasoning, rule-based logic, information theory, or advanced artificial intelligence schema.

Figure - An exhibit that is primarily graphical or pictorial in nature, as opposed to verbal or numerical.

Fully-justified text - Spacing is added within and between words so that all lines are the same length, resulting in alignment of both right and left margins.

Heading - The title of an organizational subdivision of a document, that is, a title that has hierarchical significance.

Indication statement - States the name of an indicator that the user reads or observes and the indication expected to result from the action.

Left-justified text - Lines of text are aligned at the left, but spacing within and between words is not varied, resulting in a ragged right margin.

Linking sentence - A sentence that connects the paragraph it is in to the paragraph that precedes or follows it. The connection is usually accomplished by repeating a word or phrase or referring to a concept.

List - A series of similar or related items in which each item is marked and displayed on a separate line or lines. The markings can be graphic symbols, such as bullets (•) or squares (▫), or sequential identifiers, such as numbers or letters. An item can be a word, a phrase, a sentence, or a group of sentences.

Mechanical binding - The pages are punched with either round or slotted holes and then placed in a ring binder or bound with a comb or spiral binder.

Note - a written notice given to draw the reader's attention to something or to supply additional information.

Pamphlet binding - The pages are stitched or stapled together. There are two types of pamphlet binding, saddle stitched and side stitched.

Perfect binding - The pages are assembled, the left side is cut and roughed, glue is applied, and the cover is attached to the pages.

Pica - The unit of measurement used in printing. It is equal to 0.17 inch (4.23 mm).

Point - A measure of the height of type; there are 72 points in an inch (2.54 cm).

Predefined fault isolation sequence - A sequence of fixed procedures and tests that leads to a suspected fault. It is similar to a fault tree in a fault isolation manual.

Print contrast - The ratio of the difference in brightness between the printing and its background to the brightness of the background (assuming dark print on a light background). It is defined by (B1-B2)/B1, where B1 is the brighter of the two.

Proceduralized instruction - A set of step-by-step instructions a procedure intended to ensure the successful completion of a task.

Reasonable accommodation - Any modification or adjustment to a job or the work environment that will enable a qualified person with a disability to participate in the application process and to perform essential job functions.

Right hand page/Left hand page - The terms right-hand page and left-hand page have meaning only if pages are printed on both sides. In that case, a right-hand page is the page printed on the front, and a left-hand page is the page printed on the back. Thus, when the pages are bound, and the document is open, the right-hand page appears on the right, and the left-hand page appears on the left.

Right-justified text - Lines of text are aligned at the right, but spacing within and between words is not varied, resulting in a ragged left margin.

Saddle stitching - A type of pamphlet binding that permits the document to lie flat

Serifs - Decorative elements (short lines, knobs, and balls) at the ends of the strokes that form letters. Sans serif fonts do not have these decorative elements.

Stated indication - What is expected if the equipment or system is operating normally.

Table - An array of data or text in rows and columns. Usually at least one dimension, either the rows or the columns, is labeled; sometimes both are labeled.

Technical Issuances - According to FAA Order 1320.1D, are publications acquired from non-agency sources or developed within FAA that directly concern installation, maintenance, or modification of equipment, equipment systems, facilities, or aircraft. Manufacturers' instruction books for plants and equipment are included in this category. A basic objective of using this category is to permit the merging of internally-developed and externally-acquired technical manuals and publications into consolidated, single source documents. Because of necessary deviations from standard directive format and issuance procedures, they are designated technical issuances.

Title - A word or phrase that describes or identifies the contents of a document or a portion of a document.

Type family - A collection of fonts that are similar in design but vary in size and boldness.

Warning - A written notice given to a reader when a situation might result in personal injury or loss of life; a caution is a written notice given when a situation might result in damage to or destruction of equipment or systems; a note is a written notice given to draw the reader's attention to something or to supply additional information.

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Index

Glossary

Abbreviation - Any shortened form or abridgment of a word, expression, or phrase used to conserve space or time including initializations, contractions and acronyms.

Abduction - Movement away from the midline of the body.

Accelerators - Keyboard commands that can be used instead of pointing and clicking on menu options. They are indicated by underlining the proper character and placing the keyboard alternative in parenthesis after the option (e.g., <u>B</u>old (Ctrl+B)).

Accreditation - The authorization and approval granted to an AIS or network to process sensitive data in an operational environment.

Acronym - A word formed from the initial letter or letters of a group of words.

Action level - An 8-hour time-weighted-average noise level of 85 dBA or, equivalently, a noise dose of 50 percent, at which affected users will be provided hearing protection and placed in an audiometric testing program.

Action statement - An action verb followed by the object or item acted upon.

Active Help - A form of "Help" that senses an inappropriate entry and interrupts the task to ask users what they are attempting and if they are sure they want to complete the operation they have just initiated. Depending upon the user's response to the question, active "Help" then suggests the correct action.

Adaptive automation - Is the real time allocation of tasks to the user or automated system in a flexible manner, changing the automation to meet current situational demands. Adaptive automation may benefit user performance by allowing the user to remain in active control of the system instead of becoming a passive observer.

Adduction - Movement toward the midline.

Advance organizer - Supplementary information that is presented prior to the main body of information in which a user is interested.

Advice - An interactive, context-sensitive "Help" source that indicates what entry to make at the current location in the application, the required keystroke(s), or which steps to take to complete the task.

Advisory - A signal that indicates a safe or normal configuration, condition of performance, or operation of essential equipment, or attracts attention and imparts information for routine action purposes.

Alarm filtering - A technique by which unnecessary alarms are eliminated.

Alarm suppression - Alarm messages are not displayed but are available to the user upon request.

Alert - A signal that indicates a condition relating to the effective performance of duties. The condition or message requires the operator or maintainer to take immediate action or indicate that a significant update in information necessary for the effective performance of duties is available.

Alert boxes - Applied to display messages to users to inform them of situations that may require their attention or are possibly dangerous.

Alphanumeric keys - The letters of the alphabet, numerals, and punctuation symbols (numeric keypads may be separate on portable computers).

Anthropometry - The scientific measurement and collection of data about human physical characteristics and the application (engineering anthropometry) of these data in the design and evaluation of systems, equipment, manufactured products, human- made environments, and facilities. Biomechanics describes the mechanical characteristics of biological systems, in this case the human body, in terms of physical measures and mechanical models. This field is interdisciplinary (mainly anthropometry, mechanics, physiology, and engineering). Its applications address mechanical structure, strength, and mobility of humans for engineering purposes.

Appendix - A body of supplementary information collected, labeled, and placed at the end of a document.

Attributes - Instructions that change the characteristics of a selected item. An example of an attribute is changing text from standard to bold type.

Authentication - The act of identifying and confirming the eligibility of a station, originator, or user to access specific categories of information. Authentication is a measure designed to provide protection against fraudulent entry or transmissions by establishing the validity of a transmission, message, station, or originator.

Authorization - Granting to a user or user group, the right of access to a program, a process, or information.

Automatic test equipment - Checks two or more signals in sequence without the intervention of a maintainer. The test usually stops when the first out-of-tolerance signal is detected.

Automation - A device or system that independently carries out a task that was formerly carried out by a human.

Automation bias - When users rely on automated decision aids in a heuristic manner.

Biomechanics - Describes the mechanical characteristics of biological systems, in this case the human body, in terms of physical measures and mechanical models.

Brightness - An attribute of visual sensation that is determined by the intensity of light radiation reaching the eye.

Browse back - The action of moving to the previous window without permanently resetting system variables; however, system variables in the temporary state table will be reset.

Browse exit - The action of leaving browse mode.

Browse next - The action of moving to the succeeding window without permanently setting system variables; however, system variables will be set to a temporary state table.

Built-in test equipment - An integral part of a unit of equipment, can range from a simple voltmeter to a complex automatic checker.

Cable - A number of lines bound together within a single, permanent sheath.

Cascading menu - A type of hierarchical menu in which a submenu is attached to the right side of a menu item. Cascading menus can be added to drop-down menus, pop-up menus, or even other cascading menus.

Case - The part of a unit of equipment that encloses and protects the equipment from its surroundings. It may also serve to protect the surroundings - including maintainers - from the equipment.

Cathode Ray Tube (CRT) - A vacuum tube of a television or computer monitor in which the inner surface is coated with phosphors which glow and produce light when hit by an electron beam. CRT is often used as a generic term for a computer monitor.

Caution - A signal that indicates the existence of a condition requiring attention but not immediate action or a written notice given when a situation might result in damage to, or destruction of, equipment or systems.

Center-justified text - Lines are centered on the page, with both right and left margins ragged.

Central visual field - Central visual field (sometimes referred to as the focal area) is the central 30° of the visual field. This is the area that people use to look at objects in the world, moving their eyes as needed to bring images of the object onto the fovea, which is the area of highest acuity. When an object is outside of the focal area, a person will usually turn their head rather than simply move their eyes.

Certification - The technical evaluation that supports the accreditation process and establishes the extent to which a particular computer system or network design and implementation meets a pre-specified set of security requirements.

Circumduction - A continuous circular movement of a limb.

Client area (or working area) - The main area of the window that users employ to do their operational or application tasks. It is the area where users make their inputs and receive their outputs.

Collating test equipment - Presents the results of two or more checks as a single display; for example, a light might come on only if a number of different signals are in tolerance.

Color fringes - Are the pixels along the border of an object that contain a combination of the selection and background colors.

Combo box - A special type of text box with an attached list of options. Combo boxes allow the user to either select from the given list or type in an alternative response. There are two types of combo boxes, standard and drop-down.

Comfort zone - That range of environmental conditions in which humans can achieve thermal comfort. It is affected by work rate, clothing, and state of acclimatization.

Command entries - A type of control entry that enables the user to initiate a message to the system that will specify desired functions.

Command language - A limited programming language used strictly for executing a series of commands (e.g., Linux, any DOS shells).

Commands - Instructions that cause a device to perform some action.

Component - A subdivision of a unit of equipment that can be treated as an object by the maintainer, but which can be further broken down into parts. A mounting board together with its mounted parts is an example of a component.

Connector - A piece of hardware that joins or attaches lines or cables to other lines or cables or to units of equipment. The term is used rather loosely to refer to either of the two parts that mate with each other and to the plug that mates with a receptacle.

Consistency - Consistent means adhering to the same principles with minimal variation.

Contrast - The range between the lightest tones and the darkest tones. The lower the number value, the more closely the shades will resemble each other. The higher the number, the more the shades will stand out from each other.

Contrast ratio - The luminance of the foreground divided by the luminance of the background. It indicates how much brighter a pure white output would be than a pure black output. The greater the contrast, the sharper the image will be. It is also called luminance ratio.

Control automation - When an automated system executes actions or control tasks with some level of autonomy.

Control entries - User input for sequence control, such as function key activation, menu selection, and command entry.

Copy - Instructs the computer to copy selected data.

Correlation coefficient or "r" value - Describes the degree to which two variables vary together (positive correlation) or vary inversely (negative correlation). The correlation coefficient, "r", has a range of values from +1.0 (perfect positive correlation) through -1.0 (perfect negative correlation). Multiple correlation involves the predictable relationship of two or more variables with another criterion variable (such as a composite measurement value).

Corridors - Walkways that are physically restricted by walls or the like.

Cover - A part of a unit of equipment that closes an access opening.

Critical function - Is a function that can cause system failure when a malfunction is not attended to immediately.

CRT - See Cathode Ray Tube.

Cursor - A marker on the display screen that indicates the position where the computer expects the next input or will display the next output. The cursor may be positioned by the computer or by the user.

Dark adaptation - The process by which the eyes become more sensitive in dim light. The eyes adapt almost completely in about 30 minutes, but the time required for dark adaptation depends on the color, duration of exposure and intensity of the previous light.

Database - A set of interrelated data stored in a computer.

Data-entry window - A window that contains a set of labeled fields for entering, changing, and deleting data. It may also contain labeled data display fields, which a user cannot change.

Decision aids - (sometimes referred to as decision support systems) Automated systems that provide support to human decision-making processes, either unsolicited or by user request. Decision aids can narrow the decision alternatives to a few or suggest a preferred decision based on available data.

Dedicated formatting keys - Keys for text formatting operations such as a **Space** bar, a **Tab** key, and a **Return** or **Enter** key.

Depression - The lowering of a body member from its normal position.

Design limits approach - A method of applying population or sample statistics and data about human physical characteristics to a design so that a desired portion of the user population is accommodated by the design. The range of users accommodated is a function of limits used in setting the population portion.

Diffuse glare - A type of glare caused by the general ambient luminance, which effectively reduces the display contrast without producing significant specular reflection.

Direct manipulation - When the user controls the interaction with the computer by acting directly on objects on the display screen. An object may be an icon, menu option, symbol, button, or dialog box. An example of direct manipulation is a GUI.

Disability - A physical or mental impairment that substantially limits one or more of a person's major life activities.

Disparity - The computation of depth values based on the lateral distance between corresponding picture elements in both image planes of stereo vision.

Displacement joystick - A joystick that moves in the direction it is pushed. Displacement joysticks are usually spring-loaded so that they return to their center position.

Display sequencing - A means of reducing clutter by displaying a series of partial displays (e.g., a map and a series of overlays) or of displaying data sequentially. It can also be used as a form of animation.

Dose - The accumulated exposure to noise.

Drop-down combo box - A combo box that has a down arrow button, and a drop-down list.

Dwell emphasis - When the pointer comes to rest for a predetermined time on a selected object, the computer tells the user which object it perceives the user is about to select.

Dynamic strength - A force exerted by limbs moving in a smooth manner over time, such as while lifting an object.

Dynamically-generated fault isolation recommendation - A recommendation made by a computer system based on stored information and information received from user inputs, automated system inputs, or both. The information used by the system may include historical information, heuristics, probability factors, and cost factors. The recommendation may be derived using model-based reasoning, dependency models, fault-based reasoning, rule-based logic, information theory, or advanced artificial intelligence schema.

Effective temperature - An empirical thermal index that illustrates how combinations of dry bulb air temperature, wet bulb temperature, velocity of air, and clothing affect people.

Effective watt - Equal to 1.84 watts.

Effectively - Carrying out a task effectively means producing the desired result.

Efficiently - Carrying out a task efficiently means that the desired result is produced with a minimum of waste (usually in relation to time).

ELD - See electroluminescent displays.

Electroluminescent displays (ELD) - A flat-panel display, the type typically used for laptop computers, that works by placing a thin phosphorescent film between one plate coated with vertical wires and another plate with horizontal wires, to form a grid. When an electrical current passes through a horizontal and a vertical wire, the phosphorescent film at this intersection glows, creating a point of light (pixel).

Elevation - The raising of a body member from a normal position.

Ellipses - Visual indicators, such as three dots (...), used to distinguish menu options that branch to other sub-menus, from menu options that will immediately perform an operation.

Exclusive buttons (option buttons or radio buttons) - Single, two-state choices, which are mutually exclusive from each other.

Explosive strength - The application of peak amounts of strength for short periods of time, usually periodically, such as in running or sprinting.

Extension - The straightening of a limb or an increase in the angle between parts of the body.

Fasteners - Devices that join, attach, and mount parts, components, cases, covers, and units of equipment. They include quick fastening and releasing devices, screws, bolts, latches, catches, rivets, retainer rings, and retainer chains.

Figure - An exhibit that is primarily graphical or pictorial in nature, as opposed to verbal or numerical.

Fixed-function key - Keys provided for extra or general functions, typically labeled **F1, F2,** and so on.

Flexion - The process of bending a limb or decreasing the angle between parts of the body.

Flicker - The appearance of flashing that occurs in a computer display when the display is not refreshed frequently enough causing the phosphor to begin to decay prior to being refreshed.

Focal vision - The central 30° of the visual field. It is the area that people use to look at objects in the world, moving their eyes as needed to bring images of the object on to the fovea, which is the area of highest acuity.

Foot lamberts - Is a measure that has been corrected for the visual system's differential sensitivity to different wavelengths, giving an approximation to perceived brightness.

Fovea - The small central region of the retina that exhibits the greatest sensitivity to detail and color.

Fully-justified text - Spacing is added within and between words so that all lines are the same length, resulting in alignment of both right and left margins.

Function keys - Labeled keys that serve as keyboard short cuts (e.g., F1, F2, F3, or with the function name such as Delete or Insert) by combining in one key the actions of a sequence of individual keys.

Gas plasma display - Is a type of flat-panel display that works by placing neon gas between one plate coated with vertical conductive print and another plate coated with horizontal conductive print to form a grid. A point of light (pixel) is created at the intersection of a horizontal and vertical line that has been charged with an electric current.

Glare - Is produced by any luminance within the visual field that is sufficiently greater than the luminance to which the eye is adjusted. Glare causes eye fatigue, discomfort, and annoyance, as well as interfering with visual performance and visibility.

Go, no-go test equipment - Provides one of two alternative answers to any question. For example, it tells whether a given signal is in or out of tolerance.

Graphic menus (palettes) - A set of unlabeled symbols, typically presented within small rectangles. Symbols may be icons, patterns, characters, or drawings that represent an operation. Palettes are used widely in drawing and painting packages but are commonly found in word-processing applications as well.

Grid lines - Horizontal lines, vertical lines, or both, extending from the scale divisions of one or both axes of a graph and intended to aid users in locating and reading data points.

Group - On a pull-down menu, a group is any set of menu items between two separators or the whole list if there are no separators on the pull-down menu.

Guard - An enclosure or barrier intended to prevent inadvertent or unauthorized operation of a control.

Hard function key - The physical function key on the keyboard.

Hazardous condition - The presence of energy or a substance which is likely to cause death or injury by reason of physical force, shock, radiation, explosion, flames, poison, corrosion, oxidation, irritation, or other debilitation. Biological and chemical hazards can have debilitating effects through disease or interference with physiological functions.

Hazardous location - A space within a facility, room, or open environment where a hazardous condition exists or is accessible or exposed within the system or equipment located within the space.

Heading - The title of an organizational subdivision of a document, that is, a title that has hierarchical significance.

Hierarchical menu - A large series of options or menus that is organized as a multi-level, branching structure in which an option in a higher-level menu is the name of another menu at the next lower level. The options in the lowest level menus are not the names of other menus. They are commands or selectable values, such as color squares on a palette or specific Auto Text choices (e.g., Dear Sir, or To Whom It May Concern).

Hot spot - The selectable area in which a user can place the pointer and successfully select an icon.

Human physical and associated measurement characteristics - Refers to specific physical, mobility, or strength features of human users and to the explicit way that a human feature or capability is measured for use as general anthropometric or biomechanics data or as data for a specific design.

Identification - The process that enables the security safeguards to recognize a user name (usually through a machine-readable name) as an identical match to a name previously listed in an authorized user file.

Illumination - The amount of light (luminance flux) falling on a surface. Measured in lumen/m2 = lux = 0.093 ft-c. Illumination decreases with the square of the distance from a point source.

Impairment - A loss or abnormality of physiological or anatomical structure or function.

Indication statement - States the name of an indicator that the user reads or observes and the indication expected to result from the action.

Information automation - Includes information acquisition and integration. This type of automation would include filtering, distributing or transforming data, providing confidence estimates and integrity checks, and enabling user requests

Input focus - The notion that only one window and usually only one object in a window at a time is capable of accepting input from a pointing device or the keyboard.

Interlaced - A display that produces a video image by displaying alternate scan lines.

Interlocks - Devices (for example, switches) connected with a cover, shield, or case that disable the associated internal hazard (usually electrical) when the cover, shield, or case is opened. OSHA regulations discuss lockout and tagout procedures to be used in the workplace during maintenance or operations to protect from electrical hazards.

Interocular crosstalk - When the left eye can see the images intended for the right eye, and vice versa.

Irradiance - The radiant flux density on a given surface.

Isometric joystick - Responds to the amount and direction of pressure applied to it, but it does not move. Displacement joysticks usually require less force than isometric joysticks and are thus less fatiguing over long operating periods.

Item - A nonspecific term used to denote any product, available or in design or development, including parts, components, modules, and units of equipment.

Jitter - A departure from geometric stability which occurs when pixels in displayed objects move instead of remaining in a fixed position.

Keyboard accelerator - A key or simultaneous combination of keys that a user can type to select an option in a menu without having to display the menu.

Keyboard lockout - A state determined by an application in which the application does not accept input from the keyboard.

Keyguard - A keyboard cover with holes over keys.

Label - Alphanumeric information that identifies or describes an object. Labels can be printed directly on or adjacent to the object, or they can be printed on a card or plate that is attached to the object or adjacent to the object.

Lateral rotation - Turning away from the midline of the body.

Layout - The physical arrangement of the parts and components that make up a module or a unit of equipment.

LCD - See liquid crystal display.

Left-justified text - Lines of text are aligned at the left, but spacing within and between words is not varied, resulting in a ragged right margin.

Legibility - The extent to which the user can decipher or read alphanumeric characters or text.

Levers - Controls having the same size and shape, but that allow continuous adjustment.

Limit stops - Mechanical mechanisms designed to restrict a moving object or part by stopping it at predetermined (limit) positions.

Line - Any single length of pipe, wire, or tubing.

Linking sentence - A sentence that connects the paragraph it is in to the paragraph that precedes or follows it. The connection is usually accomplished by repeating a word or phrase or referring to a concept.

Liquid crystal display (LCD) - Is a flat-panel display that works by suspending liquid crystals between two transparent sheets of polarizing material. An electric current passes through the liquid causing the crystals to act like a shutter, either permitting light to pass through or blocking the light so that it cannot pass through.

List - A series of similar or related items in which each item is marked and displayed on a separate line or lines. The markings can be graphic symbols, such as bullets (•) or squares (▫), or sequential identifiers, such as numbers or letters. An item can be a word, a phrase, a sentence, or a group of sentences.

Lockout - Uses a mechanical mean to disable a control or switch in its safe position (for example, electricity disconnected) and to prevent its activation without the use of undue force or tools.

Luminance - The amount of light per unit area emitted or reflected from a surface. Measured in candela per square meter (cd/m2), footlamberts (ft-L), or millilamberts (mL). 1.0 cd/m2 = 0.31 mL = 0.29 ft-L. The luminance of a surface does not vary with the distance of the observer from the surface being viewed. Luminance is expressed in candela per meter squared or foot lamberts.

Luminance contrast - The contrast between a figure and its background.

Luminance ratio - The luminance of the foreground divided by the luminance of the background. It indicates how much brighter a pure white output would be than a pure black output. The greater the contrast, the sharper the image will be. It is also called contrast ratio.

Marking - Nonverbal information, such as colors or symbols, that identifies or describes an object. Marking can appear directly on or adjacent to the object, or it can be printed on a card or plate that is attached to the object or adjacent to the object.

Mechanical binding - The pages are punched with either round or slotted holes and then placed in a ring binder or bound with a comb or spiral binder.

Medial rotation - Turning toward the midline of the body.

Mental model - An individual's understanding of the processes underlying system operation.

Menu - A list of options from which a user makes a selection or selections.

Menu bar - A narrow panel, usually at the top of a computer screen in menu-based computer systems, that continually displays the highest-level menu options for selection by the user. The options on a menu bar are usually the names of other menus**.**

Menu function - Causes the appearance of a menu appropriate to the location of the pointer.

Message window (**message box**) - A secondary window that provides users with non-critical information, progress information about lengthy processes, alerts to unusual events, and/or warnings of potential dangers. Message windows may be modal or modeless.

Minimize – The operation that reduces a windows presence into a standby icon button on the information line at the bottom of the screen.

Mnemonic - A single letter that a user can type to select an option in a menu.

Modal window - A window with which a user must interact before being able to interact with any other windows. A user cannot interact with other windows as long as the modal window is displayed.

Modeless window - A window that allows a user to interact with other windows.

Modifier keys - Keys that modify or qualify the effects of other keys for as long as they are held down, for example, **Shift, Ctrl,** and **Alt.**

Modular - To be modular means to be designed with standardized or uniform components.

Modularization - The separation of equipment into physically and functionally distinct units that can be easily removed and replaced.

Module - An assemblage of two or more interconnected parts or components that comprise a single physical and functional entity. It is this singular functionality that defines a module.

Motion artifacts - The after images that appear to follow a moving display object because the images of the previously drawn object have not yet decayed enough to disappear. They often look like the tail of a comet following the object in motion.

Mounting - The positioning and attachment of parts, components, and modules.

N - Is a metric term for the force measure called a Newton. One pound force in the English measurement system is equal to 4.4482 Newton (1 lbf = 4.4482 N).

Navigation keys - Keys that move a cursor, for example, **Arrow** keys, **Home, End, Page Up,** and **Page Down,** which are dedicated to keyboard navigation

Newton - A one pound force in the English measurement system is equal to 4.4482 Newton (1 lbf = 4.4482 N).

Non interlaced - A display that produces a video image by displaying all lines in a frame in one pass from top to bottom before the next frame appears.

Note - A written notice given to draw the reader's attention to something or to supply additional information.

On-line Help - Primarily an interactive, context-sensitive source of information that can prompt a user what entry to make at the current location in an application, what keystrokes are required, or what steps are required to complete a task. Secondarily, on-line Help is a form of on-line documentation and reference information.

Option - One of the selectable items in a menu.

Option buttons (exclusive buttons or radio buttons) - Single, two-state choices, which are mutually exclusive from each other.

Outline selection - An extended form of drag selection that is particularly useful for graphical objects when normal drag selection conflicts with moving objects with the mouse.

Packaging (of a unit of equipment) - The assembling, mounting, and enclosing of the items it includes.

Paging - The process of scrolling through data one page at a time.

Palettes (graphic menus) - A set of unlabeled symbols, typically presented within small rectangles. Symbols may be icons, patterns, characters, or drawings that represent an operation. Palettes are used widely in drawing and painting packages but are commonly found in word-processing applications as well.

Pamphlet binding - The pages are stitched or stapled together. There are two types of pamphlet binding, saddle stitched and side stitched.

Panes - The separate viewing areas in a split window.

Panning - An orientation of display framing in which a user conceives of the display frame as moving over a fixed array of data.

Part - An object that cannot normally be broken down further without destroying its designated use. Fuses, resistors, and capacitors are examples of parts.

Passageways - Areas across which people must pass for work purposes.

Passive Help - A form of Help that simply responds to user requests for information. The information may be in the form of on-line system documentation, such as a user's guide or a list of functions performed by combinations of key presses.

Percentile statistic - Determined by ranking all data values (using the applicable measurement values related to the selected human physical characteristic) in the sample and determining the percentage of data that fall at or below a specific datum value.

Percentile value (or point) of the selected datum - The percentage of data that fall at or below a specific datum value.

Perfect binding - The pages are assembled, the left side is cut and roughed, glue is applied, and the cover is attached to the pages.

Phosphor - A luminescent substance, used to coat the inside of a CRT, which emits visible light when illuminated by electrons within an evacuated glass tube.

Pica - The unit of measurement used in printing. It is equal to 0.17 inch (4.23 mm).

Point - A measure of the height of type; there are 72 points in an inch (2.54 cm).

Pointer - A symbol displayed on the screen that is controlled by a pointing device. Its shape may change depending on the function that is invoked at a particular moment or its location on the screen.

Pointing device - A non-keyboard device that allows a user to navigate rapidly around the screen and to specify and select objects for manipulation and action. Examples include a mouse, trackball, stylus and grid, and light pen.

Polarity - The relationship between the brightness of the background and an image. Bright images on a dark background is negative polarity and dark images on a bright background is positive polarity.

Pop-up menus - Menus that only appear on user demand. They are often associated with a particular object on a display (e.g., a pop-up menu listing acceptable command options close to the immediate work area). Because pop-up menus are not displayed all of the time, they do not take up valuable screen space. They provide an efficient way to access commands because they eliminate the need for the user to navigate to a menu bar or control bar. A pop-up menu typically contains 5 to 10 options presented in a vertical listing.

Predefined fault isolation sequence - A sequence of fixed procedures and tests that leads to a suspected fault. It is similar to a fault tree in a fault isolation manual.

Preferred speech interference level (PSIL-4) - A measure of the effectiveness of noise in masking speech.

Primary colors - Are Red, Green, and Blue (RGB) for light emitting displays such as CRTs. This is different than the primary colors for subtractive color mixture (like mixing paints), which are Yellow, Red and Blue.

Primary window - A top or high-level window in an application. It is the main location of user interaction and functions independent of other primary windows in the application.

Print contrast - The ratio of the difference in brightness between the printing and its background to the brightness of the background (assuming dark print on a light background). It is defined by (B1-B2)/B1, where B1 is the brighter of the two.

Proceduralized instruction - A set of step-by-step instructions for a procedure intended to ensure the successful completion of a task.

Pronation - The downward turning of the palm.

Public entrances - Any entrances that are not loading or service entrances.

Pull-down menu - A menu associated with an option on a menu bar that appears when a menu bar option is selected.

Query - The process of specifying, locating, and retrieving data matching specified characteristics from a database.

"R," The multiple correlation coefficient - Is a statistical number that indicates the strength of the relationship between sets of data. The correlation coefficient can be between –1 and +1 with a correlation of |1| indicating a perfect correlation. The closer the number is to |1|, the stronger the relationship between the two sets of data. It is recommended that only correlations with strong predictive values be used (that is where r or R is at least or greater than |.7|).

Radio buttons (exclusive buttons or option buttons) - Single, two-state choices, which are mutually exclusive from each other.

Reasonable accommodation - Any modification or adjustment to a job or the work environment that will enable a qualified person with a disability to participate in the application process and to perform essential job functions.

Reflectance - The ratio of luminous flux reflected from a surface to luminous flux striking it.

Refresh rate - The rate (in cycles per second or Hz) at which the displayed contents of a computer screen are regenerated.

Resolution - The number of pixel elements per square inch on a monitor.

Right hand page/Left hand page - The terms right-hand page and left-hand page have meaning only if pages are printed on both sides. In that case, a right-hand page is the page printed on the front, and a left-hand page is the page printed on the back. Thus, when the pages are bound, and the document is open, the right-hand page appears on the right, and the left-hand page appears on the left.

Right-justified text - Lines of text are aligned at the right, but spacing within and between words is not varied, resulting in a ragged left margin.

Saddle stitching - A type of pamphlet binding that permits the document to lie flat.

Saturation - The relative amount of whiteness in a chromatic color.

Save - A command that causes the computer to save the data.

Scrolling - A method used to move through the contents of a window or list in a dialogue box using the scroll-bar or scroll arrows.

Scrolling menu - A menu, usually containing many options, that does not display all of the options at once. It includes a scroll-bar that permits the sequential display of all options. Scrolling menus are also called list boxes and scrolling lists.

Seat reference point - A point in the mid-sagittal plane where the seat back and seat pan intersect.

Secondary colors - Secondary colors are Cyan, Magenta, and Yellow (CMY) for light emitting displays such as CRTs.

Secondary window - A window that is displayed from within a primary window or another secondary window. Secondary windows are sometimes called child windows.

Security architecture - A subset of the overall system architecture that protects the automated system, telecommunication, physical, and informational assets through denial of service and unauthorized (accidental or intentional) disclosure, modification, or destruction.

Security safeguards - The protective measures and controls that are prescribed to meet the security requirements specified for a system. Those safeguards may include but are not necessarily limited to: operational procedures, physical security, or hardware and software features.

Select function - Selects or activates objects on the screen or sets the location of the cursor.

Selection - The action a user makes in choosing a menu option. Selection may be accomplished by pointing, by typing, or by pressing a function key.

Serifs - Decorative elements (short lines, knobs, and balls) at the ends of the strokes that form letters. Sans serif fonts do not have these decorative elements.

Service points - A means for lubricating, filling, draining, charging, and performing other service functions. They permit the routine performance of these services on all equipment and components requiring them.

Shield - An enclosure or barrier intended to protect components that are susceptible to damage or to protect maintainers from possible injury.

Slider - A control used to set a value and give a visual indication of the setting.

Soft function key - An area on the screen that represents a function key.

Special purpose keys - Keys that have a special function, such as **Help, Delete,** and **Backspace.**

Specular glare - The appearance of unwanted images (reflections) on the display surface.

Specular surface - One that provides a specular reflection, a shiny surface.

Speech interference level (SIL or SIL-4) - A measure of the effectiveness of noise in masking speech. It is the arithmetic mean of the same pressure levels of interfering noise in the four octave bands centered on the frequencies 500, 1000, 2000, and 4000 Hz, respectively. The unit of speech interference is the decibel (dB).

Spin box (also known as a **spin button**) - A variation of the scrolling menu or list. A spin box is made up of a text box and two arrows and displays a sequence of mutually exclusive choices.

Spin button (also known as a **spin box**) - A variation of the scrolling menu or list. A spin button is made up of a text box and two arrows and displays a sequence of mutually exclusive choices.

Split bar - The divider placed across the middle of the window that separates the panes.

Split box - A rectangular indicator located inside the scroll-bar of a split window or immediately above the scroll-bar of a split-able window. Note, however, that in some rules, the split box is called the split bar.

Stacking - The stringing together of commands so that they can all be executed with a single command.

Standard combo boxes - A special type of text box that includes a standard list of options with all options visible to the user.

Standardization - Standardization refers to common user-interface features across multiple applications.

Stated indication - What is expected if the equipment or system is operating normally.

Static strength - Also known as isometric strength, which is steady force exerted while the limbs are in a stationary or static position.

Status bar - A special type of message bar used to present information about the current status of the application.

Stereopsis (also called **stereoscopic vision**) - Three-dimensional depth perception based on retinal disparity. As the eyes are slightly separated, each eye sees a slightly different image, when these images are fused in the brain. The result is a perception of depth or stereoscopic vision.

Stereoscopic display - A method used to generate the sensation of three dimensions within the human visual system. Three-dimensional display technology may be "stereoscopic," which requires that users wear special glasses that provide different images to the two eyes, or "auto stereoscopic," which does not require any special viewing aids.

Stereoscopic vision - See Stereopsis.

Stroke width - The thickness of the lines used to make up the number or letter.

Supination - Is the upward turning of the palm, or lying face up.

Syntax - The set of rules governing the language of a command language. Examples would be rules about the order in which parts of a command occur or rules about punctuation in commands.

Table - An array of data or text in rows and columns. Usually at least one dimension, either the rows or the columns, is labeled; sometimes both are labeled.

Tagouts - Tags that are attached to a control or place of hazard to identify the required control condition and hazard associated with an ongoing mode of operation or maintenance.

Tailoring - The process of selecting and evaluating individual standards to determine the extent to which they apply to a specific system or piece of equipment. It includes the process of modifying these standards to ensure that there is an optimal balance between operational needs and cost.

Tear-off menu - A menu that can be removed from the menu bar and moved to another location on the screen where it can remain on display. Tear-off menus are also called "tacked" or "pushpin" menus.

Technical Issuances - According to FAA Order 1320.1D, are publications acquired from non-agency sources or developed within FAA that directly concern installation, maintenance, or modification of equipment, equipment systems, facilities, or aircraft. Manufacturers' instruction books for plants and equipment are included in this category. A basic objective of using this category is to permit the merging of internally-developed and externally-acquired technical manuals and publications into consolidated, single source documents. Because of necessary deviations from standard directive format and issuance procedures, they are designated technical issuances.

Test points - A means for conveniently and safely determining the operational status of equipment and for isolating malfunctions.

Text boxes - Edit controls into which the user types information. Most text boxes are one line tall, but applications can also use multi-line text boxes.

Text frame - A sizable field into which the user can type text. This is a dynamic form of an edit field and should not be confused with the text box. Although text frames are generally rectangular, other shapes may also be used.

Thermal comfort - Defined as a mental condition that is based upon the lack of perception of noticeable changes in temperature, and that results in a personal expression of satisfaction with the environment.

Title - A word or phrase that describes or identifies the contents of a document or a portion of a document.

Toggle switch - A switch with discrete positions operated by a lever.

Toggled menu options - Options that are used to issue commands as a binary selection of one of two opposite commands.

Tonal coding - Coding based on different shades of the same hue or different patterns or textures.

Transilluminated display - A display in which light passes through the element being viewed.

Tremor - The oscillation of a body extremity, which may occurring along with an effort to maintain a fixed position or direction. The degree of tremor is measured by the distance or number of departures from the fixed path or position per unit of time. Tremor increases when (1) effort is made not to tremble, and (2) fatigue is present. It is greatest in vertical motion, less in front-to-back motion, and least in side-to-side motion.

Type family - A collection of fonts that are similar in design but vary in size and boldness.

Unit of equipment - An assemblage of items that may include modules, components, and parts that are packaged together into a single hardware package. For example, a computer, its keyboard, and its visual display are all units of equipment, as are radio transmitters and receivers.

User-centered perspective - A user-centered perspective involves focusing on the needs and requirements of the end user throughout the design, acquisition, or development process.

Utility window - A supplementary window that provides the users with additional tools or controls, such as a tool palette or a set of text attributes.

Viewing angle - The angle off the center line from which a display will be viewed.

Ventilation - The process of supplying air to or removing air from any space by natural or mechanical means. From the standpoint of comfort and health, ventilation issues involve both quantity and quality.

Visual angle - The angle subtended by objects measured in minutes of arc. It represents an apparent size of an object based on the relationship between an object's distance from the viewer and its size (perpendicular to the viewer's line of sight). For example, if an object that is size $\boldsymbol{h}$ is at a distance $\boldsymbol{d}$ from the retina, the visual angle subtended, $\boldsymbol{x}$, is: $\boldsymbol{x} = \arctan(\boldsymbol{h}/\boldsymbol{d})$.

Walkways - Areas designated for walking.

Warning - A written notice given to a reader when a situation might result in personal injury or loss of life; a caution is a written notice given when a situation might result in damage to or destruction of equipment or systems; a note is a written notice given to draw the reader's attention to something or to supply additional information.

Weighted sound level (dB(A)) - A sound pressure level (in decibels) measured using a sound level meter with an A-weighting network. The A-weighted response is maximum at 2500 Hz, drops rapidly as frequency decreases below 1000 Hz, and gradually decreases above 4000 Hz, thereby approximating the frequency dependent human response to moderate sound levels. ANSI S1.4 gives the definition of a-weighting filter characteristics.

Working area (or client area) - The main area of the window that users employ to do their operational or application tasks. It is the area where users make their inputs and receive their outputs.

Workplaces - An area, room, or establishment where work is done.

Workstations - A place designed for a specific task or activity from where work is conducted or operations are directed. Desks, offices, repair benches, tools, equipment, and computer terminals are examples of these special accommodations and equipment. Workstations are designed as areas for one or more workers to use in accomplishing purposeful tasks or jobs.

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