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Operational Data Management System (ODMS)

Human Factors Plan

for the
Aeronautical Information Subsystem

Draft Report

Version 1.0

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Preface

Preparation of this initial Human Factors Plan for the Aeronautical Information Subsystem of ODMS, was managed by Dr. Judith Burki-Cohen of the Volpe Center's Operator Performance and Safety Analysis Division, DTS-45. Dr. Burki-Cohen, a human factors specialist at the Center, is active in other projects for FAA Air Traffic and the Research and Special Programs Administration. She displayed exceptional diligence and notable project management skills to overcome numerous contractual obstacles in the path to development of this comprehensive Human Factors Plan.

EXECUTIVE SUMMARY

This human factors plan covers the human factors effort for the development of the Aeronautical Information Subsystem (AIS) of the Operational Data Management System (ODMS). Broadly, the goals of the human factors effort are to provide a user interface design that can be implemented within the scope of the ODMS program and that is efficient, complete, and suitable to users (see section 2 for design goals).

A set of mutually reinforcing human factors activities and products is planned (described in section 4). The human factors activities proceed progressively from analysis, through implementation, and into system test and evaluation. (Linkages to test activities are indicated in section 3.) The schedule for the human factors activities (section 5) indicates an intensive initial effort which must provide user interface design and documentation for use in system implementation. Contributions are anticipated throughout the program including planning and conduct of initial training and planning for transition from current system operation to operation of ODMS.

A candidate set of issues has been identified (section 6). Timely resolution of the issues identified is needed. The resolution of the candidate issues should be provided early in the human factors effort since the resolution is likely to affect the form and content of the user interface design.

Activities for the ODMS Program Office and the Human Factors Coordinator are described (section 7). Since the human factors effort is initially intensive, the ODMS Program Office effort is likely to be initially intensive.

The primary risk for the human factors effort is schedule risk (section 8). A second major risk is the need to significantly change user interface design to account for operation after failures or during planned outages and to provide user interface design for integrated system monitoring and control.

Table of Contents

1. BACKGROUND.

As indicated in the Operational Data Management System (ODMS) Operational Requirements Document (ORD) section 1, development of ODMS will make significant improvements in the Traffic Flow Management and the Aeronautical Information functions of the Federal Aviation Administration (FAA). ODMS will provide a seamless automated system to manage the collection, validation, maintenance, and dissemination of aeronautical data.

ODMS is composed of three subsystems -- the Aeronautical Information Subsystem, the National Operational Data Archive subsystem, and the Data Management Tools subsystem. The human factors plan contained in this document covers the human factors effort associated with the Aeronautical Information Subsystem. The Aeronautical Information Subsystem replaces and extends the capability of two current systems -- the Aeronautical Information System and the U.S. Notice to Airmen System.

As indicated in ORD section 1.4.2, the Aeronautical Information Subsystem (AIS) must overcome current system deficiencies. From the standpoint of user interface design, key current system deficiencies to overcome are:

- Present methods and procedures for submitting, validating, and disseminating data are labor intensive, time consuming, and prone to error.
- The automated tools currently used are difficult to use.

AIS subsystem objectives (ORD section 1.4.3.1) directly relevant to the human factors and user interface design effort are:

- A standard user interface must be provided. The user interface must both support the Operational and Supportability Implementation Systems (OASIS) platform and be supportable using open system technology.
- The user interface must be easy-to-use and standard for all users.
- A reduction in data entry and coordination efforts must be achieved.
- The system must ensure consistency of data, in part, by aiding users and ensuring that procedural checks are applied.

The ODMS AIS will support a broad range of users (ORD, section 2). Broadly, the system will: support entry of data by the owners of the data, support a broad range of field users, and support the needs of ODMS administrators. ODMS products are provided to a broad range of recipients. Users affected by the introduction of the AIS (indicated in ORD section 2.2) includes:

- National Flight Data Center personnel,
- airport personnel,
- Flight Service Station personnel,
- FAA Technical Center users,
- Airways Facilities users,
- Flight Standards personnel,
- Military personnel,
- Air Route Traffic Control Center personnel,
- Flight Inspection Area Office personnel,
- Airport Traffic Control Tower personnel,
- terminal control (including Radar Approach Controls and Metroplex Control Facilities) personnel,
- various international users,
- system administrators, and
- National Ocean Service personnel.

2. USER INTERFACE GOALS AND REQUIREMENTS.

An acceptable user interface must meet at least the following high level requirements and must have at least the following characteristics:

1. Users must be provided with all the capability needed to complete tasks supported by the automation system. The Aeronautical Information Subsystem (AIS) must provide all the functionality of the current Aeronautical Information System (AIS) and the US Notice to Airmen System (USNS). ODMS must provide this capability with improved performance (ORD), section 1.4.3.1 and section 6). Current practices and procedures that cannot be changed must be supported by the system.

2. The design of the ODMS user interface must overcome the current system user interface problem of having specialized syntax that must be keyed and is very awkward to use (ORD, section 1.4.1.1).

3. A common, easy-to-use human computer interface must be provided for interacting with all ODMS subsystems (ORD, 1.1). End users will enter and update National Airspace System (NAS) Resources and Notice to Airmen (NOTAM) data through the human computer interface. This interface will be intuitively easy-to-use and will be standard for all users (ORD, 2.1, capability 1).

4. To meet ODMS objectives (ORD, section 1.4.3.1, item 1), user interface design must be consistent with and based on open system standards.

5. Chances for negative transfer of training must be contained by providing consistent conventions for: presentation of information, meaning of display attributes (e.g., color), presentation of feedback, command entry, meaning of labels, and use of parameters. Conventions for consistency must be followed across applications and within classes of users. Chances for negative transfer of training can also be reduced by understanding and minimizing inconsistency with current system nomenclature, use, and display of information. (See Characterization, section 4.4.)

6. Users must be able to complete tasks within time budgets. Cycle times for products must be analyzed to develop ODMS product time lines and time budgets for user tasks.

7. Users must receive adequate feedback through positive indications for actions, and, clear indications of states and modes affecting results. Guidelines and standards for feedback must be developed during user interface design activities.

8. Chances for user error must be reduced by provisions for error checking and feedback. The design of the ODMS user interface must overcome current system problems with procedures, methods of data submission, validation and dissemination that lead to unacceptable error rates (ORD, section 1.4.2, item 5). Error feedback must be easily understood by the user, indicate the consequences of the error, and indicate actions for error correction.

9. The system must ensure consistency of data, in part, by aiding users and ensuring that procedural checks are applied (ORD, section 1.4.3.1, item 11).

10. The system will support users of differing expertise (ORD, section 2.2). Provisions for help must span the range of user expertise and familiarity. The operational requirements for help (ORD, section 3.4.2.6) are broad and need to be made explicit as concepts of operation and user interface design.

11. Effects of changes in states and modes, including failures, of the system must be contained and must not adversely affect the integrity of transactions that were successfully processed. A user-centered examination of system modes and states must be performed as must a user-centered examination of a failure modes and effects analysis.

12. Training time must be within training effort budgets for preparation and conduct of training, and, within budgets for the participation of the trainees. Time budgets for training remain to be determined.

13. Time and effort needed to transition from the current system to the new system is within transition effort schedules and effort budgets for preparation, transition, and termination of capability no longer needed.

To design a user interface that meets requirements, is acceptable to users, and achieves ODMS program objectives, a series of human factors activities must be conducted. The results of the activities are a set of products that can be reviewed, validated, and then used by successor activities.

3. APPROACH.

A set of mutually reinforcing human factors activities and products is planned. Key Test and Evaluation Activities that provide vital input to human factors activities and products are the Operational Requirements Walk Through (ODMS Test and Evaluation Master Plan (TEMP), Test Activity 1), and, the Evaluation of Current Systems' Documentation (TEMP, Test Activity 3). Key review points for the user interface design include the System Level Design Review (TEMP, Test Activity 4) and Software Specification Inspections (TEMP, Test Activity 5). Joint Application Development (JAD) sessions of the Software Specification Inspections will both be points where human factors analyses and products can be used and where modification of human factors products or user interface design may be indicated. The Evaluation of Field Equipment Availability (TEMP, Test Activity 7) will serve as a good check of user interface functional completeness and assumptions about allocation of function.

Many of the later human factors products can contribute to the plans and procedures for Stage 1 System Test (TEMP, Test Activity 10), Stage 2 Alpha Test (TEMP, Test Activity 11), Stage 2 Beta Test (TEMP, Test Activity 12), Stage 1 NFDC Demonstration (TEMP, Test Activity 13), and Stage 2 Field Acceptance Test (TEMP, Test Activity 14). User interface design will be evaluated during Test Activities 10 through 14.

Human factors activities and products can and must serve as a basis for transition planning. Transition planning is expected to include training plans. Human factors activities and products must serve as an important basis for the development of training methods and materials.

4. HUMAN FACTORS ACTIVITIES AND PRODUCTS.

The human factors activities and products needed to support the design, implementation, and testing of the Aeronautical Information Subsystem of the Operational Data Management System consist of a broad range of work. The basis for the ODMS user's interface must be developed in a manner that progressively provides a basis for user interface design, implementation, test, and transition. Human factors activities must be structured to capture and document user interface requirements in time for use during software design and implementation. The results of the human factors activities must be rigorously documented to serve as a basis for software requirements, test plans and procedures, and planning for transition from the current system to ODMS.

Human factors activities that require customer participation or field observation should be conducted in a manner that is efficient and effective for both the system developer's team and the FAA. Generation of multiple products from single visits, as was obtained from observations of Flight Service Station specialists at St. Petersburg is strongly encouraged (see sections 12 and 13).

4.1 Companion Human Factors Plan.

A detailed companion human factors plan must be provided by the system developer. The plan must indicate the system developer's understanding of human factors activities, products, schedules for product delivery, participation in other program activities (e.g., reviews, demonstrations, and evaluations), resources needed and personnel assigned, dependencies, and risks.

4.2 Analysis of Constraints.

Constraints on the design of the user interface for ODMS must be analyzed and documented. The description of constraints must be sufficiently rigorous to serve as user interface evaluation criteria that can be used during the analysis, design, demonstration, and evaluation phases of the program. The analysis of constraints can be used for technology selection, design tradeoffs, and formulation of test objectives and criteria.

The set of factors that constrain the design or operation of the user interface must be captured and documented. Candidate factors will be drawn from organizational, procedural, and technological considerations. For each factor, a constraint must be developed. Where possible, constraints must be specified in quantitative terms. Some constraints may be expressed in qualitative terms. Constraints must be expressed in a form that can subsequently serve as a basis for system test evaluation criteria.

Organizational and procedural constraints must be validated. The results of the analysis of constraints must be used to develop user interface requirements and evaluation criteria.

4.3 Determine Operations Concept.

An operations concept document will serve as: a source of issues, a guide to scenario generation, a guide to user interface designers, and a first point of validation by users or their representatives. The operations concept must be based on ORD section 2 and subordinate sections, concepts gained from field observations, analysis of government documents, completion of the Operational Requirements Walk Through (TEMP Test activity 1), and the high level system design. The operations concept must be updated as needed to serve as a record of the results of the Software Specification Inspection Joint Application Development sessions (TEMP Test activity 5). The operations concept must include organizational factors that affect which users perform which actions.

The operations concept must describe:

- significant changes compared to current capability,
- additional capability and intended use of capability,
- additional information available for display or distribution,
- unifying user interface design concepts that are applied throughout the system,
- use of capability for the major activities of: changing data, coordination change approval, verification and validation of change, and distribution of data,
- provisions for error prevention and correction,
- provisions for training and help,
- capability provided during system maintenance,
- operation of the system in failure modes,
- capability provided for monitoring and controlling the system, and,
- anticipated set of skills needed to operate, monitor and control, and maintain the system.

The operations concept must provide descriptions of the use of the system for each class of user for frequent and critical activities. The descriptions need to be sufficiently detailed to allow initial assessments of the completeness and the suitability of the emerging user interface design. Review of the operations concept must identify unaccounted for capability and activities.

4.4 User Characterization.

The characterization of users must include: types of users, and characteristics of users that affect their population stereotypes. A hierarchical catalog of user characteristics must include type of user, title, role, and use of system elements, interfaces with other organizations, and characteristics. A suggested hierarchy starts with the major distinction between system users -- sources of information and recipients of information. (See ORD section 1.4.1 for primary sources and recipients of information and section 2.2 for user impacts.)

One purpose of the user characterization activity is to collect information needed to design an intuitive and easy-to-use interface to the system. A user's judgment of ease of use will be made from their frame of reference. A designer who is unaware of the frame of reference may design an interface that is complete, consistent, compact and that will, nevertheless, be judged difficult to use. If legacy or incumbent systems have conventions that the designer is unaware of the designer may, inadvertently, give a function key a meaning that is the opposite of the user's current convention. For example, if a key that currently effects an insert is redefined to effect a delete, users who respond out of habit will inadvertently effect a deletion instead of an insertion and will judge the system unacceptable. If rules of operation (current compared to new system) are different, the user must maintain two sets of rules during the transition period. If the rules are easily confused or not easily learned, error rates can be higher, productivity can be lower, and user resistance to change can be significantly higher. The resulting difficulty in training is referred to as negative transfer of training. Generally, negative transfer of training is indicated when the trainee's skills interfere with learning new skills. Consideration of negative transfer of training leads to the guideline that it is often better to create a new convention rather than change an existing convention. The reasoning is that learning a new rule is easier than learning when to ignore the old rule, learning the new rule, and then learning when the old rule applies and when application of the old rules leads to unintended results.

Alternatively, if the user interface designer is aware of the rules and conventions of the users, a much more effective user interface can be designed. An interface that maintains and extends current conventions reduces training and transition effort by preserving the value of current skills and extending them to new capability. The user, in this case, retains knowledge they have gained and approaches the new capability from a known base. When rules and conventions are already understood, training and transition efforts are reduced.

A challenge facing ODMS user interface designers is that ODMS will serve sets of users who currently operate independently developed systems and who have different skills. To provide an effective user interface, the characteristics of the users, including the systems they use, have to be examined to establish the rules and conventions of different user groups. Rules and conventions can come both from skills acquired in operating automation equipment and from organizational factors. An important activity will be synthesizing a nomenclature that is acceptable to different sets of users. A shared nomenclature becomes a basis for object names, names for states, labels, command names, parameter names, and conventions for presentation of messages, alerts, and alarms.

The user characterization must be used both to guide user interface design and to contribute to the System Level Design Review (TEMP Test Activity 4, Method, item 14). User characteristics must be recorded in sufficient detail to be useful when designing the user interface to minimize opportunities for negative transfer, and, when designing help applications.

4.5 Information Flow and Process Analysis

The results of the Evaluation of Current System's Documentation (TEMP Test Activity 3) must provide the set of government documents and information needed to derive a user oriented information flow and process analysis. ORD section 2 provides the high level functions that will be performed by the AIS. These high level functions must be detailed to gain the information needed to develop the: operations concept, catalog of objects and operations, scenarios, and parts of the characterization of users. Process flows must identify customers, internal and external products, customer product requirements, product schedules and time constraints, quality checks, and monitoring and supervision mechanisms (provided by system administration services).

Consideration of system utilization leads to consideration of number of users, input workload, throughput workload, response times, and availability. The distribution of cycle times for products obtained from the constraint analysis needs to be decomposed to steps within processes supported by ODMS.

Current procedures and methods of data submission, validation and dissemination are prone to error (ORD, section 1.4.2, item 5). The developer must analyze previous studies of the current AIS and USNS (cited in ORD, section 1.4.2), and, the documentation for the ODMS program, to uncover potential causes of error or factors leading to higher than acceptable error rates. Barring formal study of errors, subject matter experts can be interviewed to determine which errors could be avoided with a better user interface or with better error checking and feedback. The analysis of errors must identify parts of processes that are prone to error. The results of this analysis must be used to develop user interface requirements and design to reduce chances for error.

4.6 User Interface Scenarios

Scenarios showing complete threads through the system from entry of new information, to modification of information, to distribution of the information (including on request) to various internal and external consumers must be developed and documented. The scenarios must include the data verification, validation, and certification activities. User interface scenarios can be very effectively generated in a top-down and iterative fashion. The first level of scenario development catalogs the activities performed by system users. Activity statements can be very high level statements and must be consistent with and drawn from the emerging operations concept. Scenarios can be progressively detailed until they account for actions taken by users (for example key presses and use of a cursor control device).

The scenarios must use the results of the information and process flow analysis and the formation of operations concepts. The information and process flow analysis must indicate the structure and sequence of high level scenarios.

Scenarios have broad use throughout system design, implementation, and test.

4.7 Catalog of Objects and Operations

A catalog of all displayed objects and operations must be developed. The catalog will serve as a basis for designing the displays presented to users. The catalog of objects and operations must be consistent with and may be part of the ODMS data base design. The catalog must include object identity, source, units, representation (e.g., text or graphic), transformations, operations applied to the object, object states or attributes, and destination and class of distribution. The catalog of objects and operations also needs to indicate access limitations. It is anticipated that access, distribution, and use of data will vary as a function of the state of the data (e.g., data are unvalidated or validated). Availability of operations will most likely vary by class of user (e.g., some commands associated with data configuration control may be privileged). Due to the anticipated size of the catalog of objects and operations, the catalog must be organized hierarchically. (See ORD section 1.4.1 for high level object descriptions, and section 3.1.3 for major data groups and object states.)

4.8 User Interface Design Review

The user interface design must, as with other aspects of the system design, be reviewed. Evaluation of the user interface design must include considerations of completeness, consistency, correctness, and suitability. Specific evaluation criteria can be developed from the required characteristics contained in the ORD and the analysis of constraints. User interface design considerations must be part of the System Level Design Review (TEMP, Test Activity 4) and Software Specification Inspections (TEMP, Test Activity 5). Review of the user interface design must include tradeoff analyses conducted for selection of commercial off-the-shelf software and hardware. A review of user interface design guidelines and standards must be conducted. Design documentation must be revised as modified by the results of Joint Application Development sessions (TEMP, Test Activity 5).

The design of the interface for users must be consistent with operations concepts, the catalog of objects and operations, and the emerging system data base design. The design of user interfaces must reflect the needs of different classes of users identified in the user characterization document. The emerging user interface design must be recorded in user interface design documentation.

4.9 User Interface Design and Documentation

The user interface must be designed to be complete, consistent and correct. The user interface design must be acceptable to each class of user. Evaluation criteria can be formed from requirements contained in the ORD and user interface characteristics indicated in section 3.0 of this document. The user interface design must be based on the results of analysis of: functional requirements, constraints, information flow and process, scenarios, user needs, and the needs of internal and external product recipients. Completeness and consistency must be checked against the results of the characterization of users and the evaluation of current systems' documentation (TEMP, Test Activity 3). The consistency of the user interface design must be maintained by the application of design guidelines and standards. The completeness, correctness, and consistency of the user interface design will be reviewed (TEMP, Test Activities 4 and 5) and evaluated (TEMP, Test Activities 10 through 14). The suitability of the user interface will be evaluated (TEMP, Test Activities 10 through 14).

User interface design documentation must be detailed and rigorous to allow use for system implementation and test. System implementers must be able to use the user interface design documentation as a basis for software design. System testers must be able to use user interface design documentation as a basis for test case construction. The documentation can also serve as a basis for training materials and system documentation.

Documentation provided by vendors of software used in ODMS may be referenced or supplied to meet display and command language documentation needs if the vendor supplied documentation is complete and acceptable to system testers and users.

4.9.1 User Interface Design Guidelines

Guidelines for design of display content, format, and control of attributes must be provided. Conventions for object (e.g., windows, window objects, menus) format and presentation must be provided. Conventions for command language semantic, syntactic, and lexical design must be provided. Evaluation criteria based on the guidelines must be documented and provided to system designers and implementers. Conventions for use of terminology must be documented and validated by the customer. Guidelines and evaluation criteria may be based on existing design guidelines (e.g., *Human Factors in the Design and Evaluation of ATC Systems: A handbook for FAA User Teams,* Volpe National Transportation Systems Center, 1994). To meet ODMS objectives (ORD, section 1.4.3.1, item 1), user interface guidelines and design must be consistent with and based on open system standards.

4.9.2 User Interface Display Design

The content, layout, and attributes of every window and object must be designed to meet the goals for user interface design. The design must incorporate the results of other human factors activities and the resolution of issues. The design must be documented. The display design documentation must follow the organization of the catalog of objects and operations.

The display language can be developed in an iterative manner proceeding from the semantic level, through the syntactic level, and to the lexical level of design. Completeness of the command language and the availability of objects should be first be assessed at, but is not restricted to, the semantic level of design. At the semantic design level, conventions for formatting, use of display attributes, characteristics of application independent objects, and provisions for messages must be established. Consideration of object state must be part of the user interface display design. It is quite likely that attributes of displayed objects should be related to object state. Conventions and rules for display content, layout, and use of attributes are established at the syntactic level of design and carried through to the lexical level of design. Consideration of consistency within applications, between applications, across classes of users, and within displays design must be considered at all levels of display language design.

The design documentation must indicate:

- display language rules and conventions for format, layout, use of symbols, and use of display attributes (e.g., color, brightness, texture),
- rules and conventions for use of audible alarms,
- the content and layout of every display,
- formatting characteristics (e.g., justification, positioning, treatment of numeric data, treatment of graphic data),
- provisions for display customization,
- object identity, minimum and maximum size, units, representation (e.g., text or graphic), object states or attributes, format exceptions, and destination and class of distribution must be indicated.

The design documentation must also indicate:

- mapping of display objects to display attributes (e.g., color, brightness, texture),
- provisions for messages including error messages and status messages, messages displayed which are asynchronous to user input, and
- provisions for intermittently displayed objects (e.g., menu items, intermediate feedback).

4.9.3 User Interface Command Language Design

The command language must be designed to meet the goals for user interface design. The design must incorporate the results of other human factors activities and the resolution of issues.

The command language, like the display language, can be developed in an iterative manner proceeding from the semantic level, through the syntactic level, and to the lexical level of design. The semantic level of design establishes the set of commands and their meaning. The syntactic level of design establishes command names and the structure of the command language (e.g., command name and parameter order, conventions for defaults). The lexical level of design details the actions a user takes to enter a command. Completeness of the command language and the availability of commands should be first be assessed at, but is not restricted to, the semantic level of design. Conventions and rules for the command language are established at the syntactic level of design and carried through to the lexical level of design. Consideration of consistency within applications, between applications, and across classes of users, and within the command language design must be considered at all levels of command language design.

The design documentation must indicate:

- command language rules and conventions,
- command availability (e.g., indication of privileged commands, indication of availability by system mode and state),
- provisions for error prevention and handling,
- provisions for editing and data entry,
- types of dialog and provisions for controlling dialog (e.g., query based dialog),
- command names and aliases,
- alternative methods of command invocation,
- parameters, parameter defaults and alternative methods of supplying parameters,
- provisions for intermediate feedback,
- results, and indications provided by exception processing.

4.9.4 Data Entry and Display Device Requirements

Documentation containing the data entry and display device requirements need to support the user interface design (display resolution, display extent, color capability, support for audible alarms, data entry device (mouse, keyboard, other data entry devices for entry of graphics)) needed by system users. The document must indicate differences in requirements by user categories if such differences exist.

4.10 Failure Modes and Effects Analysis

ORD section 3.4.2.2, System Management, contains requirements for maintaining system integrity after hardware or software failures. System monitoring, control, and operation in various modes and states must be examined.

The need for integrated system monitoring and control should be considered. A system monitoring and control capability is a key element in mitigating the effects of failures and in restoring capability in an orderly and predictable manner. Examination of the results of a system failure modes and effects analysis should indicate the set of failures whose effects can be mitigated or controlled through manual intervention. Capabilities must be provided to allow the user to detect conditions requiring intervention, to recognize the condition, to decide which corrective action must be taken, and to take corrective action. Capability must also be provided to allow users to monitor the progress of corrective actions or transitions between system states and system modes that affect capability provided to the user.

The set of failures should be examined to find those failures that change capability provided to users. Given a failure, the set of surviving capability should be examined to determine if adequate capability remains to continue operation at an acceptable level. It is quite possible that new applications or changes to capability operating in reduced capability will be needed to maintain productivity and responsiveness at an acceptable level. Provisions must be made for indicators that alert users to changes in modes and states that affect the set of capability available for use (see section 6.5). Provisions must also be made to alert users when processing of transactions has been suspended or when scheduled processing cannot be completed.

The effort must indicate the functions provided to users in different modes and states. Indications of changed state or mode in each state and mode must be provided and must be included in the user interface display design. The effort must indicate the user activities required to achieve system synchronization and completion of transitions of states and modes. Added capability must be included in the user interface command language design.

The results of the analysis must be used to design a user interface for users who monitor and control the system. The results of the analysis must also be used to provide any additional display objects and capability initiated by users through the command language.

4.11 Demonstration Plans, Procedures, and Reports

User interface and workstation mockups and prototypes should be integrated into a program as early as possible. Mockups and prototypes of the functional aspects of the user interface can be thought of as following the progression used for physical design. Initially, large constraints are taken into account to form an envelope in which the system must fit. For system prototyping, there are the dimensions of architecture, platform (hardware and SW), load, and dynamics. Dynamics include user interaction during scenarios, mode and state changes, and transient events. The progression on all dimensions must be from low resolution, low fidelity, and low realism mockups to high resolution, high fidelity, and high realism mockups and prototypes.

If commercial-off-the-shelf (COTS) software (SW) is used, demonstrations become the means for assessing completeness, consistency, and operation within constraints.

Demonstration plans should indicate the objective of each demonstration. Demonstration procedures should be reviewed to remove possible invalid display objects, commands, or results. Reports written after each demonstration should summarize demonstration procedures, issues resolved or identified, and plans for the next demonstration.

4.12 Training Plan

A training plan must be developed to meet the objective of having users (National Flight Data Center (NFDC) personnel) become the "resident expert" trainers. The plan must include the effort needed to train the trainers and the effort needed to provide supporting materials for the trainers (ORD, section 2.2). The plan must include the tailoring of products from human factors activities (such as developing an operations concept, providing user characterization, designing the user interface, and developing scenarios) to support the training effort.

4.13 Transition Analysis

This analysis must include consideration of: parallel operation of the current system and the new system (as indicated in ORD section 1.4.3.10), and, synchronization of the current system and the new system as parallel operation is conducted. The basis for the transition analysis include user interface design and system design documentation. The results of the analysis should indicate capability that has to be provided to successfully complete transition from the current system to ODMS.

4.14 Human Factors Action Item Report.

The report must contain but is not restricted to: action item identifier, action type, priority, date identified, originating organization, description of action needed, consequences of failure to close action item, activity that closes the action, product description, dependencies, planned closure date, item owner, status, and disposition. The action items report must be maintained for the duration of the program. The issues report must be reviewed on a regular and continuing basis by the Human Factors coordinator (or designee) and the system developer.

4.15 Human Factors Issues Report.

The report must contain but is not restricted to: issue identifier, issue type, priority, date identified, identifying organization, issue description, consequences of failure to resolve issue, issue resolution activity, product describing resolution, resolution dependencies, planned resolution date, resolution verification procedure, issue owner, status and disposition. The issues report must be maintained for the duration of the program. The issues report must be reviewed on a regular and continuing basis by the Human Factors coordinator (or designee) and the system developer.

4.16 Human Factors Risk Report.

The data base must contain but is not restricted to: risk identifier, type, severity, date identified, identifying organization, risk description, expected program impact if the risk is realized, risk mitigation activity, product mitigating risk, planned date of risk mitigation, dependencies for risk mitigation, risk monitoring procedure, risk mitigation owner, and status and disposition.

5. SCHEDULE.

The resources required to support human factors activities will be based on the schedule presented below. The activities are described in section 4.

ACTIVITY	Q1 FY95	Q2 FY95	Q3 FY95	Q4 FY95	Q1 FY96	Q2 FY96
Detailed Human Factors Plan	X	X				
Analysis of Constraints	X	X				
Operations Concept	X	X				
User Characterization	X	X				
Information Flow and Process Analysis	X	X				
User Interface Scenarios	X	X	X	X		
Catalog of Objects and Operations	X	X				
User Interface Design Review	X	X				
User Interface Design Documentation	X	X	X	X	X	X
Failure Modes and Effects Analysis	X	X	X			
Demonstration Plans				X	X	X
Training Plan					X	
Transition Analysis					X	X
HF Action Item Report	X	X	X	X	X	X
HF Issues Report	X	X	X	X	X	X
HF Risk Report	X	X	X	X	X	X

6. CANDIDATE ISSUES

Five candidate issues have been identified and are described in separate sections. These issues cover: user interface completeness, user interface consistency, the presentation of alerts and alarms, provisions for help, and, operation of the system after failures or planned outages.

Activities that can contribute to issue resolution are: evaluation of current system's documentation (TEMP, Test Activity 3), development of operations concept, information and process flow analysis, development of the catalog of objects and operations, development of scenarios, generation and review of the user interface design documentation, software specification inspection (TEMP, Test Activity 5, particularly Joint Application Development sessions). The adequacy of issue resolution will be evaluated during stage 1 system test (TEMP Test Activity 10), stage 2 alpha test (TEMP Test Activity 11), stage 2 beta test (TEMP Test Activity 12), stage 1 NFDC demonstration (TEMP Test Activity 13), and state 2 field acceptance test (TEMP Test Activity 14).

6.1 Completeness.

There are sources of user need that will be harder to discover, describe, and document. Some system requirements are inherent in activities users currently perform without using an automation system. To reveal these requirements, user activities that will be supported using ODMS unique capability must be analyzed.

The activities performed, the exceptions handled, and the results obtained are implicit in the way tasks are completed rather than explicitly contained in current system documentation or organizational operating procedures. For example, addition, modification, or deletion of NAS resource data may require coordination with other users and classes of users. The manual process of coordination is rich. For example, an initiator notifies other parties, continues to attempt to make contact if contact is not established, can tailor the presentation for information to the recipient, conveys information that indicates the priority of the change, can respond immediately with clarifications or corrections, and can relay the status of the change. An examination of the flow of information during coordination must account for and allocate functions to user or to system. The evaluation of current systems' documentation (TEMP, Test Activity 3) may reveal many other activities (e.g., preparation and distribution of data using electronic forms) that will need further analysis.

Some system user needs are inherent in capability that is currently not available or that will be substantially enhanced. To reveal these requirements, analysis of scenarios or use of prototype or initial capability is indicated. For example, use of graphical representations to present changes to NAS resources may, on examination, reveal requirements for control of object states and attributes to provide highlighting and reveal requirements for filtering to reduce clutter and improve search times. The need to discriminate between archived, current, and, pending change data may lead to requirements for control of object attributes based on object state.

Compromising completeness could lead to problems attaining some user interface objectives. These objectives include:

- A user must be provided with all the capability needed to complete tasks supported by the automation system.

- The AIS must provide all the functionality of the current AIS and USNS with improved performance (ORD, section 1.4.3.1 and section 6).

Inadequate examination of activities not supported by current system automation or not indicated in current system procedures can lead to:

- incomplete requirements with the customer revealing new requirements to meet user needs as the project proceeds,
- evaluations that reveal unanticipated serious operational suitability problems,
- difficulty training for use of the new system,
- continued reliance on current methods of operation and failure to fully achieve system objectives and benefits,
- suitability problems encountered during transition to the new system.

Steps for problem resolution may include:

- field observation, interviews supported by subject matter experts, and interaction with users to explore, define, and document user needs,
- working with system developers to share and refine documented user needs,
- translating the expression of user needs into requirements,
- validating, with subject matter experts and user representatives, the understanding of user requirements as part of a design review,
- working with the customer to document and validate a system concept of operation,
- developing user interface design concepts that are validated by the customer,
- and prototyping the user interface and conducting demonstrations for decision makers and evaluations for representative users.

6.2 Consistency.

The design of the user's interface must be consistent. Lack of consistency in the user interface can have many adverse affects. An inconsistent user interface can lead to:

- longer than anticipated or acceptable training time due to the need to train many different rules of operation or different conventions,
- higher than anticipated or acceptable error rates due to errors of commission and substitution, and,
- longer than anticipated task completion time due to users taking time to use help facilities, reference material, or seeking help from support personnel,
- judgment by users that the interface is excessively complicated and not suitable which can lead to the judgment that the system is not acceptable.

Compromising consistency could lead to problems attaining some user interface objectives. These objectives include:

- The design of ODMS must overcome the current system user interface problem of having specialized syntax that must be keyed and is very awkward to use (ORD, section 1.4.1.1).
- A common, easy-to-use human computer interface will be used for interacting with all ODMS subsystems (ORD, 1.1).
- End users will enter and update NAS Resource and NOTAM data through the human computer interface. This interface will be intuitively easy-to-use and will be standard for all users (ORD, 2.1, capability 1).

Several forms of consistency must be examined. Rules and conventions for operation must be consistent across applications provided by the system. Previously independent systems will be integrated into a single system so there is a chance that current system rules and conventions are not consistent. The rules and conventions for operation of incumbent systems must be characterized. Special care must be taken to examine rules and conventions across the different categories of users (as indicated in the ORD, for example, section 1.4.1). The conventions to be examined include: object names, units of objects, object representation, format, object attributes and states, command names, parameter names, command language syntax, and defaults for command entry. Incumbent system rules and conventions must be examined in preparing the catalog of objects and operations.

The user interface design must be consistent with current system rules and conventions where possible. If current system rules and conventions are not consistent, new and substantially different rules and conventions must be developed. This approach must minimize the chances for negative transfer of training associated with inconsistent rules and conventions in the current systems.

The number of conventions and rules for object names, units of objects, object representation for format, object attributes and states, command names, parameter names, command language syntax, and defaults for command entry must be held to a minimum. The compactness of user interface conventions and rules, like other aspects of user interface consistency, must be examined.

6.3 Presentation of Notification, Alerts, and Alarms.

ODMS must provide notification, alerts, and alarms to users. To provide an effective user interface, the presentation and prioritization of notification, alerts, and alarms must be considered in an integrated fashion. Examples of the diverse requirements are:

- ODMS will support the coordination and approval of changes, where appropriate, by alerting other users of pending changes requiring their attention (ORD, section 2.1, capability 1). The presentation of alerts must be carefully considered. The system response to lack of acknowledgment of key alerts must be considered.
- New NOTAMs will be indicated to users as they sign onto the system or immediately if they are already signed onto the system (ORD, section 2.1, capability 3).
- Users will be notified when NAS Resource Data Maintenance additions for modifications are received, held, accepted/rejected, or approved (ORD, section 3.1.2.1)
- ODMS will initiate automated notification to appropriate users of specified rule making actions (ORD, section 3.1.2.2, item 16).
- The system must alert users who are responsible for a piece of data that a change has been initiated (ORD, section 3.1.2.2, item 25).
- The system will alert system administrators when repeated session activation with an incorrect user identifier or password is attempted (ORD, section 3.4.2.2).
- The system will provide notification of failure, degradation, or loss of system function and will provide alerts or alarms when workstations or critical functions become inoperable (ORD section 3.4.2.2).

Failure to design an integrated approach to presentation of notification, alerts, and alarms could lead to:

- missed notification leading to late or missing user actions which adversely affects subsequent processing,
- user actions taken on a first noticed, first completed basis rather than on the basis of priority or importance, and
- missed alarms or alerts leading to late or no corrective action.

6.4 Provisions for Help.

The system will support users of differing expertise (ORD, section 2.2). The system will be used by expert users (e.g., NFDC and site personnel) and by more occasional users (e.g., airport personnel, military offices). Provisions for help must span the range of user expertise and familiarity. Help provided for expert users is typically more condensed while help provided for less expert users is typically more voluminous. Less expert users are also the most likely to be remote from more expert users. The operational requirements for help (ORD, section 3.4.2.6) are broad and need to be made explicit in the form of concepts of operation and user interface design.

Inadequate provisions for help can lead to:

- longer than anticipated or acceptable training time,
- higher than anticipated or acceptable error rates due to errors of commission and substitution, and,
- longer than anticipated task completion time due to users taking time to use help facilities, reference material, or seeking help from support personnel,
- judgment by users that the interface is excessively complicated and not acceptable and the judgment that the system is not acceptable.

Inadequate provisions for help could compromise the objective of providing an easy-to-use human computer interface for interacting with all ODMS subsystems (ORD, 1.1).

6.5 Provisions for Operation After Failure or During Planned Outages.

ODMS will provide a seamless automated system to manage the collection, validation, maintenance, and dissemination of aeronautical data. ODMS will manage numerous data sets of the NAS and will provide interfaces and services to users of these data (ORD, section 1.1). To provide seamless operation, operation of the system must be understood for system states and modes that affect services provided to users and services provided to collect, process, and disseminate data. Transitions between states and modes may occur in response to failures or in response to planned events (e.g., maintenance).

To operate the system in an orderly manner, users must be provided with indications of states and modes that limit or change their interaction with the system. Feedback must be provided for all user initiated actions that cannot be completed due to a change in state or mode. Users must be provided with an indication of any scheduled process that cannot be completed due to a change in state or mode.

To provide for efficient system operation, certain transitions in state or mode may require special processing to restore synchronization of data and resumption of suspended processing. Users must be provided with an indication of state or mode transitions that change their interaction with the system. Users must be provided with an indication of the set of data or transactions that is subject to special processing to effect a successful state or mode transition. Users must be prompted if user intervention is required to effect or complete a transition in state or mode.

To control the system, integrated monitoring and control capability must be provided. Monitoring generally requires access to state, mode, performance, and load information. Controlling generally requires an ability to change state, mode, load, and tasking.

Failure to design a user interface taking into account changes in states and modes could lead to:

- excessive workload associated with state or mode transitions,
- excessive error rates caused by errors of omission,
- inability to provide for continued operation around detected faults (ORD, section 3.8),
- missed indications of state transition leading to delayed or omitted control actions,
- inability to monitor or control the system in an integrated way, and
- loss of productivity due to avoidable loss of system capability.

The primary activity used to resolve the issue of operation after state or mode transition is a user-centered failure modes and effects analysis. The results of the failure modes and effects analysis may be broad and affect a wide range of human factors activities.

7. ODMS PROGRAM OFFICE ACTIVITIES

A Human Factors Coordinator should be designated. The Human Factors Coordinator will be responsible for supervising the review and approval of the results of human factors activities and coordinating participation in the test and evaluation of the ODMS user interface. The Human Factors Coordinator will serve as the focal point for human factors issue resolution.

The companion human factors plan (see section 4.1) is the product that indicates the system developer's approach to integration of human factors into the analysis, design, and evaluation phases of the program. The companion human factors plan serves as a key tool for monitoring and controlling human factors activities. The plan should be reviewed by the Human Factors Coordinator to assess the developer's understanding of the analysis and design work, and, to assess integration of human factors efforts into the implementation, test, and evaluation efforts.

The Human Factors Coordinator should be the system developer's initial interface for requests for information, requests for issue resolution, or requests for site visits. The Human Factors Coordinator should participate in planning for training and transition to both provide products to support these efforts, and, to ensure the products resulting from human factors activities are useable for training and transition.

The product of human factors activities must be evaluated against several criteria.

- The human factors analyses should be verified and validated by the controlling agency. Verification and validation prior to use of the analyses in design efforts will reduce the risk of errors being propagated throughout the user interface design.

- The human factors analysis and user interface design efforts should be internally consistent, consistent from analysis to design, and consistent with the emerging system design.

- The user interface design must be functionally complete and must be developed to a sufficient level of detail to be used by system developer's and testers. The user interface design must support user activities that are both explicit and implicit in the conduct of their work (see Completeness, section 7.1).

- The results of human factors analysis and user interface design must be available for review prior to their use by system developers and testers.

The timely resolution of issues must be ensured. If an issue is valid it is likely that the resolution of the issue is a dependency for another activity in the program. If timely resolution of issues is not achieved, there is a risk that interim resolutions will be formed to maintain activity schedules and that the interim issue resolutions will be in error. Propagation of inadequate issue resolutions can lead to greater than acceptable corrective efforts.

There is a need for the anticipated benefits of system introduction to be stated in terms that apply to and can be understood by system users. The anticipated benefits can be used to formulate user interface evaluation criteria. While the criteria are likely to be qualitative rather than quantitative, agreement on criteria will contribute to more consistent and reliable evaluation of human factors products and user interface design.

To effectively control and facilitate the design of ODMS user interfaces, the ODMS Program Office should conduct reviews and evaluations of products resulting from human factors activities.

- The set of human factors activities and products contained in the human factors plan should be examined. The ODMS Program Office should determine which activities are complete or have been delivered and are acceptable.

- The system developer's user interface design evaluation criteria must be verified and validated.

- Review and comment should be provided on all deliveries of user interface analysis and design products. User interface design documentation should be evaluated against criteria that take into account completeness, consistency, correctness, and suitability. User interface design documentation must be evaluated to ensure it supports the development of plans for training and transition. User interface design documentation must be suitable for supporting user training.

- NFDC Subject matter experts should participate in the Operational Requirements Walk Through (TEMP, Test Activity 1), Evaluation of Current Systems' Documentation (TEMP, Test Activity 3), System Level Design Review (TEMP, Test Activity 4), Software Specification Inspection (TEMP, Test Activity 5), and system test and evaluation activities (TEMP, Test Activities 10 through 14).

The effectiveness of human factors analyses can be facilitated through several early actions by the ODMS Program Office.

- The set of government documents (e.g., relevant policies, procedures, standards, orders, and performance criteria) needed for human factors analyses should be prepared for distribution. Use of government documentation will facilitate preparation the operations concept, user characterization, information flow and process characterization, and the object and operations catalog. It is anticipated that many or all of the documents needed will be used during the Evaluation of Current Systems' Documentation (TEMP, Test Activity 3).

- The set of government documents containing constraints affecting the design, operation, or operation the user interface should be prepared for distribution. Constraints to be specified include: staffing levels (how many system users by organization and site), current practices and procedures which cannot be changed, retained hardware or software capabilities, floor space and environmental factors, training time available (by type of user, organization, and site), and product cycle times. The analysis of constraints can be used for technology selection, design tradeoffs, and formulation of test objectives and criteria.

- Expected productivity rates for users need to be established. Productivity rates will be used to determine expected user task completion times and serve both as design constraints and evaluation criteria.

- A plan for providing NFDC subject matter experts is needed. The experts must be capable of representing and interpreting user needs for the system developer. The subject matter experts can be expected to answer system developer questions about mission and operations concepts. Use of the subject matter experts in concept evaluation, requirements validation, issue resolution, tradeoff analyses, evaluations of demonstrations, prototype evaluations, and operational test and evaluation must be anticipated.

- A plan for developing scenarios for system developer use is needed. Scenarios will be needed during the analysis, design, developmental test and evaluation, and operational test and evaluation phases of the program.

- A plan for developing a transition strategy is needed. The transition plan must serve as the basis for determining the set of capability the system developer must provide to successfully transition from current to system operation to full ODMS operation.

8. RISKS

The main risk for the human factors portion of the program is schedule risk. The time required for the large amount of human factors work to be performed appears to be greater than the time available to meet development and test schedules. Addition of resources will not completely mitigate the schedule risk since much of the work involves synthesis and design. Addition of resources can, if not properly coordinated, decrease the consistency and cohesiveness of the resulting user interface design. If human factors analyses are not completed, issue resolution will be adversely affected. The risks of incomplete issue resolution are discussed in Candidate Issues (see section 7).

Program phasing to provide initial operating capability followed by a planned product improvement will reduce the risk of fielding a system that is judged not suitable. Some analysis, design, and implementation can be prudently deferred to the product improvement phase. A key part of the risk mitigation strategy is providing an initial operating capability, that while not final or complete, is sufficiently acceptable to warrant further test and evaluation by field personnel. A judgment that initial capabilities are not adequate can have adverse consequences for the further conduct of the program. Human factors analyses, activities, and products contribute to providing an initial operating capability that is sufficiently acceptable. Lack of adequate human factors analyses, activities, and products contributes to the risk that initial operating capability is not sufficiently acceptable to warrant further test and evaluation. Careful selection of the analysis and design that can be deferred is warranted.

A second major risk is the possible need to significantly change or add user interface design to account for operation after failures or during planned outages. The introduction of capability providing for continued operation in the face of failures or planned outages is likely to add to the human factors effort. Consideration of user roles in synchronization and restoration of capability appears to be at initial stages and is likely to add to the human factors effort. The requirement to ensure the integrity of ODMS products makes consideration of roles in synchronization and restoration critical. Similarly, consideration of capability for integrated system monitoring and control appears to be less than well advanced. Capability for system monitoring and control is needed to mitigate the risks of failures, to effect system synchronization and the restoration of capability, and is needed to support system maintenance.

9. PRELIMINARY ODMS OPERATOR TASKS AND HUMAN FACTORS CONCERNS

Table 1: ODMS functions listed by user group.

Function No.	User Group	Description	Human Factors Concerns
1.0	National Flight Data Center (NFDC) Personnel		
1.1	NFDC	Validate data products	Product sampling methods
1.2	NFDC	Enter data	Data entry methods. Form design
1.3	NFDC	Prepare standard data products (56 day cycle)	Electronic calendar. Automatic report control
1.4	NFDC	Train field users in source entry techniques	
1.5	NFDC	Manage contractors performing system administration, database management, and ODMS applications maintenance and improvements	
2.0	Airport Personnel		
2.1	Inspectors	Prepare, review, and enter airport inspection information	Data entry methods. Form design
2.2	Airport Personnel	Query AIS to obtain data and reports	Query dialog Report defaults

3.0	Flight Service Station (FSS) Personnel		
3.1	FSS	Enter FSS and communications outlet information	Data entry methods. Form design
3.2	FSS	Query AIS to obtain automatic NOTAM distribution	Query dialog
3.3	FSS	Enter data on behalf of small airports	Data entry methods. Form design
3.4	FSS	Obtain NOTAMs from the Flight Service Automation System (FSAS) in the FAA Standard format	Query dialog
3.5	FSS	Use FSAS to filter, sort, and retrieve NOTAMs appropriate to a specific preflight or inflight briefing	Query dialog Default queries
3.6	FSS	Query (interactively) the database in support of a briefing	Query dialog
4.0	FAA Technical Center (Tech Ctr) Users		
4.1	Tech Ctr	Support the Flight Service Automation System (FSAS) and other applications using automated AIS data input	
4.2	Tech Ctr	Query the AIS database	Query dialog
4.3	Tech Ctr	Receive reports	Report format/frequency
4.4	Tech Ctr	Support Advanced Automation System (AAS) static data updates through the System Support Computer Complex (SSCC) for automatic seeding and updates to the HOST en route and terminal adaptation databases	Automation monitoring

5.0	Airway Facilities (AF) Users		
5.1	AF	Enter NAVAID, Instrument Landing System (ILS)	Data entry method. Form design
5.2	AF	Query the database	Query dialog
5.3	AF	Receive required reports automatically	Distribution list maintenance
6.0	Flight Standards (Flt Stds) Personnel		
6.1	Flt Stds	Enter NAS Resource data within scope of effort	Data entry method. Form design
6.2	Flt Stds	Query the database	Query dialog
6.3	Flt Stds	Receive reports as authorized	Distribution list maintenance
7.0	Military Offices		
7.1	Military	Enter military and joint use airport information	Data entry method. Form design
7.2	Military	Enter NOTAMs	Data entry method. Form design
7.3	Military	Receive customized reports	Report specification and request methods
7.4	Military	Enter Special Use Airspace activity for military training routes, aerial refueling tracks, and military operations areas	Data entry method. Form design

7.5	Military	Submit Special Use Airspace activity to Regional Office via automated approval process	Data entry method. Form design. Electronic coordination. Procedures
7.6	Military	Forward NOTAM information on status of the Global Positioning System via ODMS for proper system wide distribution	Data entry method. Form design
8.0	Air Route Traffic Control Center (ARTCC) Personnel		
8.1	ARTCC	Enter data on ARTCC boundaries	Data entry method. Form design
8.2	ARTCC	Enter ARTCC sector frequencies	Data entry method. Form design
8.3	ARTCC	Enter Fixes, Preferred Routes, SIDs, STARs and other special data elements	Data entry method. Form design. Default data entries
8.4	ARTCC	Perform circle searches for five-letter names and other pertinent data	Query dialog. Search result dialog
8.5	ARTCC	Receive AIS NOTAMs and reports automatically	Distribution list maintenance
8.6	ARTCC	Distribute NOTAMs in FAA Standard format to appropriate sectors automatically	Distribution list maintenance
8.7	ARTCC	Deliver NOTAM information to pilots in flight when required	Query dialog. New NOTAM alerts
8.8	ARTCC	Review Letters of Agreement and track changes in boundaries or other parameters contained in these letters	Online document review method. Electronic text file formats

9.0	Flight Inspection Area Office (FIAO) Personnel		
9.1	FIAO	Enter airway flight check data	Data entry method. Form design
9.2	FIAO	Enter instrument approach changes and other related information	Data entry method. Form design. Graphic annotation method
9.3	FIAO	Enter data needed to produce regulatory NOTAMs	Data entry method. Form design
9.4	FIAO	Enter resource data within scope of responsibility (e.g., Instrument Approach Procedures)	Data entry method. Form design
9.5	FIAO	Enter NOTAMs and information on NAVAIDs, ILS, etc.	Data entry method. Form design
9.6	FIAO	Enter permanent changes in AIS database as authorized	Data entry method. Form design. Security access procedure
9.7	FIAO	Query database	Query dialog
9.8	FIAO	Receive authorized reports	Distribution list maintenance
9.9	FIAO	Initiate automatic processing to generate and distribute an Flight Data Center (FDC) NOTAM if AIS business rules determine that a regulatory NOTAM is required {?}	

10.0	Airport Traffic Control Tower (ATCT), Radar Approach Control (RAPCON), and Metroplex Control Facilities (MCF) personnel		
10.1	ATCT, RAPCON, MCF	Enter information about service and frequencies within facility control	Data entry method. Form design. Default data entries
10.2	ATCT, RAPCON, MCF	Enter NOTAMs if information regarding the airspace under the facility's control requires	Data entry method. Form design
10.3	ATCT, RAPCON, MCF	Receive NOTAMs electronically	New NOTAM alerts. Message queue management
10.4	ATCT, RAPCON, MCF	Review incoming NOTAMs for applicability to the facility surrounding airspace	NOTAM format
10.5	ATCT, RAPCON, MCF	Include NOTAM information in the Automatic Terminal Information Service (ATIS) broadcast	Digital ATIS and NOTAM system workstation integration and compatibility
10.6	ATCT, RAPCON, MCF	Deliver NOTAM information directly to pilots as required	New NOTAM alerts
11.0	International Users		
11.1	AIS Automation	Automatically return unreadable foreign NOTAMs to their originators (international agreements permitting)	Auditing procedures. Revision to ICAO procedures and international agreements
11.2	AIS Automation	Automatically review U.S. NOTAMs for criteria requiring international dissemination	

11.3	AIS Automation	Automatically distribute international class NOTAMs to appropriate international users without human intervention	
12.0	System Administrators		
12.1	System Administrators	Ensure integrity of the Aeronautical Information Subsystem database	Auditing procedures. Database sampling and verification methods
12.1.1	System Administrators	Control system security and data access	Security and access procedures
12.1.2		Access administrative functions for maintaining various processes, database files, and tables	Database security and configuration management protocols
12.1.3		Control of backup and recovery of the database	System administration procedures
12.1.4		Monitor performance by displaying system statistics (message traffic and peak load) in tabular and graphic form	System administration procedures. Data formats
12.1.5		Control data structure and data validation parameters	System administration procedures
12.1.6		Monitor AIS automated validation and update processes to ensure that no invalid or inconsistent data are used to update the database	Database sampling and validation protocols

13.0	Distribution Points		
13.1	Distributors	Direct User Access Terminal (DUAT) vendors, the National Ocean Service, and other organizations serving as approved distribution points for AIS data will be able to access the system and prepare information for other end-user organizations	Query dialog. Output formats. User access controls
13.2	National Ocean Service (NOS)	NOS will have access and the authority to update certain data such as NOS field surveys and Airport Datum Monument Program (ADAM) survey information	
13.3	NOS	Broadcast (automatically) message of proposed/pending change to subscribers designated to access and use the particular data element	Electronic communication
13.4	Other users (airlines, pilots, other government agencies)	Access the database and regular reports and publications which incorporate this data using standard computer and communications interfaces	Modem access procedures

Table 2. Representative ODMS Capabilities and Inferred Human Operator Tasks

Number	Description of ODMS Capability	Affected User Group(s)	Description of Inferred Operator Task	Human Factors Concerns
1.0	Manage Location Identifiers	NFDC		
1.1	Maintain unique three, four, and five character identifiers for aeronautical facilities and other NAS entities using assignment rules incorporated into the system		Obtain location identifier from system for assignment to new NAS entity	Query dialog
1.2	Track status of each identifier using 'active,' 'available,' 'reserved,' or 'inactive' to enable selection of new identifiers based on naming rules		Confirm that intended location identifier is available for assignment	Query dialog
1.3	Code a deleted identifier for potential reuse and future data available for use			
1.4	Validate an identifier when adding a new record, checking that the identifier does not already exist and that it conforms to rules for that facility type			
1.5	Maintain the set of ICAO facility indicators which are already in use internationally			
2.0	Assign unique numbered fixes for boundaries and turning points on airways	NFDC	Modify airspace boundary or airway definition	Data entry method Graphic annotation method

3.0	Calculate which FSSs are associated with a Military Training Route (MTR) (within 150 NM) when MTR coordinates change	NFDC Military	Modify a Military Training Route (MTR) definition	Data entry method Graphic annotation method
4.0	Reassign to an Automated FSS (AFSS) responsibilities for NAS resources of those FSSs that the AFSS is replacing	FSS AF	Modify status reporting responsibility for a NAS resource	Data entry method User access control
5.0	Automatically compute the NAVAID radials and distances off MTR points	NFDC Military	Identify degree/distance waypoints for an MTR route	Query dialog
6.0	Ask ODMS user if an entered bearing is in degrees true or magnetic. Convert a user-entered magnetic bearing to a true bearing and store the result as the bearing	NFDC Military FSS	Enter a magnetic bearing as part of a new AIS database entry	Data entry method Default data formats
7.0	Issue a message that a Parachute Jumping Area (PJA) is a candidate for charting based on time since commissioning, continuity of operation, and number of jumps	NFDC	Enter information about a newly commissioned parachute jumping area	Data entry method Default data formats
8.0	Maintain the legal description of Special Use Airspace (SUA) in the database, including natural features which describe limits of the SUA through the Geographical Information System (GIS)	NFDC Military	Enter the legal description of a new section of Special Use Airspace	Data entry method Graphic annotation method
9.0	Increment the sequence portion of a SID or STAR name when there is a change in definition of the segments	NFDC	Change the definition of a SID or STAR segment	Data entry method Graphic annotation method

10.0	Accept and store the International Air Transport Association (IATA) codes for airports	NFDC	Enter the IATA code for an airport	Data entry method
10.1	Search for selected location identifiers		Find the location identifier associated with a particular NAS resource	Query dialog
10.2	Check airport data elements (e.g., runway numbers, lengths, airport elevations) for validity using available data and the Geographic Information System		Enter airport data	Data entry method Default data
11.0	Process changes to facility operating hours and produce a list of affected facilities		Enter a change to facility operating hours	Data entry method
12.0	Translate values for coordinates from radian measure to decimal measure and vice versa upon demand		Request the radian measure equivalent of a decimal coordinate measure	Query dialog
13.0	Automatically maintain facility components in their correct order (e.g., airways, preferred routes, and boundary points)			
14.0	Assign the transmission frequency of a Remote Communications Outlet (RCO) as that of the NAVAID collocated with that communications outlet when the RCO frequency is receive-only	FSS NFDC	Enter data on a new receive-only RCO	Data entry method
15.0	Track the previous name-codes (identifiers) for each fix whose name-code changes	FSS NFDC	Select a new name-code for a fix	Query dialog

16.0	Initiate automated notification to appropriate users regarding a rule making action if a relocation or name change occurs to a NAVAID on an airway in FAR Part 95, the legal description of airways	NFDC	Enter a proposed airway relocation or name change	Electronic communication Electronic text/graphic annotation method
16.1	Accept a new airway number and maintain its status relative to the review process		Enter a new airway number	Data entry method
16.2	Make the proposed airway record available to all eligible users in the system for review and comment		Review proposed airway record and enter comments about the proposed change	Electronic communication Electronic text/graphic annotation method
16.3	Display the new airway graphically using a GIS		Request a graphic display of a new airway	Query dialog Graphic format
16.4	Facilitate coordination with the Air Traffic Procedures (ATP) organization on NPRM issues		Enter comments on NPRM	Electronic communication Electronic text/graphic annotation method
17.0	Regarding data that are known to take effect in the future		Enter data which will take effect in the future and the date/time it is to take effect	Data entry method Default data
17.1	Store data in the database			

17.2	Issue a notice that an update to that particular record already exists and display data to prevent duplicate entries if a user should attempt to enter or modify future data that are already stored in the system		Attempt to update a record that already exists or attempt to enter duplicate updates	Redundancy checks Error checking Data entry method Query dialog
17.3	Automatically process data on the date that future data are to become effective by updating the current database		Query the system to verify that entries with future effective dates become updated on the effective date	Query dialog Data sampling method Verification procedures
17.4	Indicate which facilities in the system will be affected by future data			
18.0	Maintain a record of, and on-line access to, a set of all changes to the database	NFDC	Query the system to obtain a list of changes affecting a given facility	Query dialog Default queries
19.0	Provide a capability to view the database as it existed at the end of any previous system-defined date, using COTS/GOTS mechanisms like the standard SQL	NFDC	Review database records to determine facility status for a given date in the past	Query dialog Archival report format Report customization method
20.0	Provide a capability to view the database as it will exist at any system-defined future date using data about planned changes to NAS resources, using COTS capabilities like the standard SQL	NFDC	Review database records to determine projected facility status for a given date in the future	Query dialog Prospective status report format Report customization method

21.0	Maintain a record of letters of agreement, memoranda of agreement, and memoranda of understanding between air traffic control facilities, and when appropriate, require the concerned ARTCCs to "sign off" on changes to data that require their approval	ARTCCs ATCTs FSSs MCFs RAPCONs		
22.0	Highlight NAS Resources which have pending or active NOTAMs	FSSs NFDC	Review active or pending NOTAMs for particular facilities	Query dialog
23.0	Provide a capability to store graphic data associated with Instrument Approach Procedures (IAPs), Standard Instrument Departures (SIDs), and Standard Terminal Arrival Routes (STARs), and to display the graphic data on properly equipped workstations	FSSs ARTCCs ATCTs RAPCONs	Review the graphic data for an IAP, SID, or STAR	Query dialog Graphic display formats
24.0	Provide a capability to store GPS information by space vehicle number and/or by pseudo random noise number			
25.0	Provide a capability to store proposed changes to AIS data and electronically alert users responsible for authorizing the change.	ARTCCs	Change a preferred route in the system database and forward to region for approval.	Electronic communication Graphic annotation method
25.1		Regional Office	Receive electronic notification from initiating ARTCC of proposed change to a preferred route	Electronic communication Change request alerts Message queue management

25.2		Regional Office	Coordinate with other ARTCCs	Electronic communication
25.3		Regional Office	Submit approved change to preferred route to ATCSCC for authorization	Electronic communication Electronic authorization method
25.4		ATCSCC	Receive electronic notification from Region of request for change in preferred route	Electronic communication Electronic authorization method
25.5		ATCSCC	Authorize or deny change in preferred route	Electronic authorization method
25.6	Provide a capability to store proposed changes to AIS data, circulate change notices, and store comments from interested parties.	NFDC ARTCCs FSSs ATCTs RAPCONs	Enter proposed changes to AIS data, comments about proposed changes, and replies to comments	Electronic communication Data entry method Electronic text file annotation method

10. OBSERVATIONS CONCERNING CURRENT USNS AND AIS OPERATIONS AT AN AUTOMATED FLIGHT SERVICE STATION

Flight service station (FSS) specialists were observed performing their duties at the NOTAM position during a brief site visit at the St. Petersburg automated FSS. Procedures observed were as specified in facility order PIE AFSS 7220.6A (appended) and FAA Order 7930.2E Notices to Airmen. These procedures included:

- Creation of NOTAM D
- Cancellation of NOTAM D
- Creation of NOTAM L for lighting outage on a tower/obstruction
- Cancellation of NOTAM L for lighting outage
- Review of NOTAM entries for delinquent cancellations
- Call back verification of posted lighting outages.

Forms used to create and track NOTAMs which were reviewed included:

- PIE AFSS Form 7930-4A, NOTAM FORM
- FAA Form 7230-4, DAILY RECORD OF FACILITY OPERATION
- FAA Form 7930-1, STATION NOTAM ACCOUNTABILITY LOG
- Model 1 Full Capacity (M1FC) View Sequence (VS) 240-TWROTG, OBSTRUCTION LIGHT OUTAGES

Observations.

FSS personnel were extremely helpful. They explained and demonstrated several operations they routinely perform to create, access, and delete NOTAM data.

FSS Specialist Currency on the NOTAM Position. Regulations require one hour per month to maintain currency on the NOTAM position. Current practice at this automated flight service station provides each specialist between 3 to 4 hours per month on the position, with no more than 1 hour at the position in a single day.

Equipment Interface. The Model 1 Full Capacity (M1FC) system that AFSS specialists use provides a preformatted monochrome textual display. Data entries and queries can be made using a standard (QWERTY) keyboard and labeled backlit function keys. The workstation also includes peripheral systems which are used for communications (direct access and indirect access communication lines). Specialists advised that all operator stations at the FSS are configured alike, and all FSSs have much the same equipment and configuration. The software interface uses an abbreviated command syntax and form-fill for data entries. All databases are accessed from the common interface and command language.

Job Aids. The NOTAM position has separate notebooks for tracking D and L NOTAMs, and obstruction lighting reports. There are several quick reference cards posted around the position.

Data Processing Functions. In addition to accessing and entering weather, flight plan information, and FDC NOTAMs, the specialists can submit D (distant dissemination) NOTAMs and L (local dissemination NOTAMs). Ds are submitted to NFDC for a format check and assignment of a NOTAM number. Observed NFDC response was about 5 minutes for a NOTAM creation message on "Circuit B." L NOTAMs are controlled entirely at the FSS with locally generated NOTAM numbers. The FSS also tracks lighting outages on obstructions. This information is stored in paper and on-line files, but on-line entries can only be accessed by visually scanning the entire list (no query is available). Determining which obstruction light outages apply to a proposed flight is not possible because the system does not automatically correlate these with NAS route structures or airports. Therefore, this information is not routinely issued to pilots or used in preflight briefings. Apparently, the sole purpose of collecting this information is to report outages to the enforcing agent, the Federal Communications Commission, if the outage is not corrected within 15 days.

Workload. Work is not time critical, but incoming phone calls (landline traffic) concerning reports of NAS Resource outages and obstruction lighting outages, as well as coordination calls to other air traffic facilities can keep the NOTAM operator busy. The practice at this AFSS is to write notes on scratch paper, and copy the information to the appropriate NOTAM Forms later. Computer entries are made based on the information written on NOTAM forms. It appears that the speed of data entry is not at all critical, but that accuracy is very important because of requirements to adhere to prescribed message (NOTAM) syntax. ODMS will probably not reduce the number of incoming outage reports, but the automation may reduce the amount of coordination traffic that must occur between facilities.

Operations Require Accuracy. Accuracy of data entries is especially critical for Service B NOTAM deletion messages, because it is possible to accidentally delete the wrong NOTAM by entering an incorrect NOTAM number. Since the current system does not prompt the specialist or provide other forced confirmation for deletions, it would be unlikely that the specialist would detect the error until after the NOTAM was accidentally deleted.

Pending NOTAMs Cannot be Entered in Advance. The system cannot hold NOTAMs for later posting, so procedures require that pending NOTAMs be entered on the day they are to become active. This could conceivably cause task overload if numerous NOTAMs were to be entered on the same day. However, no one recalled any problem of that sort.

Maintenance Concept. There are approximately 10 excess workstations in the facility, so when equipment fails, specialists simply move to another position and the position remains unused until corrective maintenance is accomplished. Airway Facilities personnel perform all remove/repair/replace and preventive maintenance functions. Hardware failures ("gripes") are reported on the daily operations log with an "E" notation. There is limited built-in-test and fault reporting capability for such things as failed firmware (EPROMs), circuit cards, modem connections, and disk drives. There are also weekly, quarterly, and annual preventive maintenance actions. NAFEC occasionally installs new programs, but most upgrades are handled by the AF personnel. Maintenance personnel complete a five week course on the M1FC system equipment.

Human Factors Concerns

Problems with Duplicate Entries. Contrary to the report of widespread duplicate NOTAMs in the System Safety and Efficiency Review, there was no apparent problem with duplicate entries at the AFSS. However, the specialists are required to search for all locations which might have issued a NOTAM for a common NAS Resource, such as a navigational aid (NAVAID). The ODMS planned tie-in to the Aeronautical Information Subsystem will enable rapid identification of affected facilities (e.g., when an NDB (NAVAID) is used for approach procedures at different airports). This will reduce specialists' requirements to memorize which facilities may be affected by a common NAVAID, and to scan the active NOTAM file for other possible deletion candidates when a NOTAM is to be canceled.

Graphic Presentation of Instrument Approach Procedure Changes and Airspace NOTAMs. Specialists will benefit from the capability to view graphic presentations of FDC NOTAMs about airway, instrument approach procedure, and SID/STAR changes. This will enable them to better visualize/ explain changes to pilots during briefings.

Electronic Coordination and Comment. The existing system does not permit electronic coordination. Thus, the planned ODMS capability to electronically generate, route, coordinate, and record comments on proposed changes to NAS Resources will be new to these FSS users.

Adaptation to a Paperless Operation. FSS specialists rely heavily on a notebook system for tracking NOTAMs and their associated facility accountability logs. The planned implementation of ODMS automation may provide a conceptual and procedural challenge to FSS specialists who are not accustomed to a paperless data management environment. The interface design will have to accommodate specialists expectations concerning layout of data and organization of NOTAM entries, perhaps in an "electronic notebook" format. Their notebook system of "accountability logs" seems to work well for them. Depending on the dialog design, it may be necessary to continue in parallel with the paper system until specialists become accustomed to the electronic replacement.

International (ICAO Format) NOTAMs. These specialists were not observed to work with international NOTAMs. It is possible that such NOTAMs are more of concern at other FSS facilities, or perhaps where they are received (National Flight Data Center (NFDC)).

11. ACRONYMS.

AIS: Aeronautical Information Subsystem

COTS: Commercial-Off-The-Shelf

JAD: Joint Application Development session

NAS: National Airspace System

NFDC: National Flight Data Center

NOTAM: Notice To Airmen

ODMS: Operational Data Management System

ORD: Operational Data Management System - Operational Requirements Document

SW: Software

TEMP: Operational Data Management System - Test and Evaluation Master Plan

USNS: US Notice to Airmen System

12. REFERENCES

Operational Data Management System - Operational Requirements Document, version 1.0, DOT-VNTSC-FAA-93-14, April 1994.

Operational Data Management System - Test and Evaluation Master Plan for the Aeronautical Information Subsystem, version 1.0, DOT-VNTSC-FAA-93-14, May 1994.