United States Air Force Computer-aided Acquisition and Logistics Support (CALS)

Air Force Tech Order Management System (AFTOMS)

AUTOMATION PLAN - FINAL REPORT

February 1988 (Version 1.0)

DoD-VA 856-88-3

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United States Air Force
Computer–aided Acquisition and Logistics Support (CALS)

Air Force Tech Order Management System (AFTOMS)

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PREFACE

This report prepared by the Transportation Systems Center (TSC) concludes a Tech Order (TO) analysis which was undertaken as part of the U.S. Air Force Computer-aided Acquisition and Logistics Support Program (CALS). The Air Force Tech Order process has become costly and cumbersome and this report examines the need for automation of the procedures required to produce, manage and change TOs. The overall benefits of automation, including increased weapon system reliability, reduced costs and increased mission effectiveness, are explained.

The report describes the Air Force Tech Order Management System (AFTOMS) automation plan which evolved from bringing together TSC, Air Force and industry ideas. The plan is described in terms of system concepts, principal technical and organizational components, and the ability to meet present and projected requirements of the U.S. Air Force. Central to the AFTOMS concept is the creation of a modular four-tier hierarchy for general administration, acquisition and management, and ordering and distribution of Tech Orders. There will be a controlled transition from the present system (based on paper TOs) to a system based on TOs in digital format. The technologies required to effect this transition are presented as appendices to the report.

The work was performed under the direction of Dr. Robert Smith of the Systems Automation Division at TSC. TSC has drawn upon the skills and knowledge of several consultants. This has enabled the development of a multi-faceted team of experts each of whom has made a vital contribution. TSC would like to extend its gratitude to the following organizations: DYNATREND Inc., MIT Sloan School of Management, RJO Enterprises, and UNISYS Inc.

This report is an initial document which will help to establish the parameters of the implementation plan. Any comments or inputs are welcome so that the document will be current and useful for the program.

This document is a typical product of the documentation system that will evolve through the implementation of AFTOMS. For example, some of the system features that will be applicable for AFTOMS are integration of text and graphics, change control, electronic storage, and computer based printing on demand. A 300 dpi laser printer was used to print the final document.

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

INTRODUCTION

Computer-aided Acquisition and Logistics Support (CALS) is a Department of Defense (DoD) program designed to improve weapon systems support through digital automation. In June 1985, the joint industry/DoD Task Force on CALS issued a five volume report (IDA R-285) which presented the objectives and scope of the program, as well as a top-level management and implementation plan. The task force concluded that the following objectives can be met:

- Design more supportable weapon systems;
- Support transition from paper based to digital logistics and technical information for DoD operations;
- Routinely acquire and distribute logistics and technical information in digital form for new weapon systems.

The Joint Task Force recognized that to implement the target CALS system by 1990, efforts within the armed forces must be coordinated and focused on the CALS architecture. The DoD directed each service to create a permanent CALS Management Integration Office (MIO) as the official focal point for coordination of its logistics automation programs.

In response to this directive, the CALS Management Integration Office at HQ Air Force Systems Command (AFSC) was established in October 1985 to provide coordination within the Air Force for all existing and future CALS activity. In early 1986, the Transportation Systems Center (TSC) of the Department of Transportation (DOT) was contracted by the CALS/MIO to provide systems engineering support. The initial activity consisted of review and analysis of existing programs and standards. In 1987, the focus of this activity centered on developing a 7-10 year automation plan for Tech Orders (TOs) using the Modular Planning Process (MPP) developed at TSC.

The MPP, explained in more detail in the main report, has three distinct phases which are listed below with the time frame in which they were conducted:

Phase I. Examine existing environment - March to June 1987.

Phase II. Study opportunities - May to August 1987.

Phase III. Plan future direction and gain consensus - July 1987 to January 1988.

The TO planning team consisted of systems engineers and technical staff with strategic planning, and organizational skills. Team members met with many different groups within the Air Force and industry to discuss the existing system, (its characteristics, dimensions, problems, etc.), technology options, and viable alternatives.

The Air Force Tech Order Management System (AFTOMS) concept that evolved from this process was a result of melding TSC analysis with ideas received from the Air Force and industry to form a basis for the automation plan documented in this report.

OBJECTIVES

To develop an automation plan for Tech Orders, a set of clearly defined objectives were needed. The CALS/MIO, with guidance from Air Staff and the Major Commands (MAJCOM), established major objectives for the TO automation plan. These are to define:

- A realistic plan that could be operational by the mid 1990s.
- A modular strategy which allows phased introduction of automation and associated organizational changes.
- A system that addresses the major deficiencies of the current system while accommodating the need to effect a smooth transition by:
  a. Incorporating as many existing assets as possible (automation projects, organizations, facilities).
  b. Allowing parallel operations to proceed until the implementation is completed.
  c. Providing for conversion of the existing inventory of Tech Orders to digital form and subsequent management of these TOs in an automated fashion.

Long term goals have also been considered. These include:

- Developing a flexible, modular system concept to provide a strong foundation for the long term (25 years).
- Preparing the Air Force for paperless Tech Orders.
- Integrating TO data with other types of technical information, both from a system automation and organizational position.

KEY COMPONENTS OF THE PLAN

The AFTOMS plan addresses:

- Strategic issues such as the broad characteristics of the final system, the management of the transition process, and the establishment of centralized procedures for several activities.

- Organizational issues such as establishing an infrastructure for future system functions with responsibilities for each organizational layer.

- Technical issues such as types of automation systems, communication links, and level of automation.

Many of these issues are interdependent, and the plan defines priorities within the strategic, organizational, and technical areas identified.

This AFTOMS report is a synthesis of the tasks performed to date and includes:

- Analysis of existing Tech Orders and data flows;

- Examination of applicable technology trends and standards;

- Analysis of organizational and strategic issues;

- Description of the future TO system;

- Key organizational, technical, financial, and programmatic recommendations.

ANALYSIS OF TECH ORDERS AND DATA FLOWS

The current Tech Order system of the Air Force is characterized as follows:

- It is a manually oriented system with operating procedures that were defined in the 1940s.

- There are over 150,000 active TOs today. This inventory is managed by six centers, and divided by specific weapon systems or commodities.

- An average TO ranges between 100–150 pages with 60 percent text and 40 percent graphics.

- The total TO data base is approximately 20 million pages.

- Each year, about 2.3 million TO pages must be revised.

- There is a growing backlog of unfulfilled requirements, currently estimated to be as much as 2 million pages.

The current system needs to be updated to keep up with the growing workload and to eliminate backlogs.

TOs vary significantly in terms of their size, content, and frequency of revision. For the purpose of this report, TOs are broadly grouped into three categories:

- Type A: Page-oriented TOs that currently exist in paper form in the Air Force inventory.
- Type B: Page-oriented TOs that will be delivered to the Air Force by the Contractor in digital form, but will be presented to the end user in page-oriented form.
- Type C: Non-page-oriented TOs that will be delivered to the Air Force by the Contractor in digital form and presented electronically to the end user who will be able to search and retrieve required information. Access will be provided to related windows of information, regardless of their location in the TO. In reality, they have no page-orientation and are significantly different from Type A and Type B.

EXAMINATION OF TECHNOLOGY TRENDS AND STANDARDS

The new system (AFTOMS) for processing TOs is intended to meet present and future needs. A single weapon system, such as the B-1B, can generate approximately 3,500 new TOs, adding a million pages to the current TO data base. To meet these growing needs, it is appropriate to adopt leading edge technologies and standards that are likely to be in use over a relatively long period of time.

Some technologies that were investigated are presented as appendices to this report. They include the following:

- Automated reading of paper documents;
- Technology for mass storage;
- Computer based printing;
- Document management systems;
- Communication alternatives;
- Management of large information systems;
- Hypertext and videodisc systems;
- Natural language processing.

De facto industry standards which are gradually emerging in text, graphics, and other areas will be used until formal standards solidify. AFTOMS plans to incorporate, as fundamental building blocks, developing CALS data interchange standards as they are adopted.

ANALYSIS OF ORGANIZATIONAL AND STRATEGIC ISSUES

The process of generation and revision of TOs is coordinated by six fairly independent Regional Centers (ALCs). The TOs are dispatched to work groups at bases which, in turn, have some degree of autonomy in deciding what makes and models of computerized equipment they will buy and use. The decentralized environment complicates the process of introducing new technology. Successful application of new technology assumes a certain level of standardization of equipment capabilities, information exchange abilities, and categories of TOs.

There is a need for realignment of organizational structures and objectives to better suit the introduction of new technologies. Since new, automated technologies streamline processes, it may become necessary to reassign employees, and even to dispense with some organizational layers. It is also appropriate to examine the desirability and feasibility of operating existing and new systems on a parallel basis. Managing the transition period is usually the most difficult part of putting a new system in place.

HIGHLIGHTS OF THE FUTURE TECH ORDER SYSTEM

The plan advocates an implementation strategy that involves:

- Capturing Type A TOs on a limited basis by using scanners;
- Introducing Type B TOs in the short term;
- Introducing Type C TOs in a later phase;
- Using new technology for scanning, cataloging, storing, and retrieving information;
- Distributing TOs to users via optical discs;
- Supporting sophisticated entry, modification, and on-line retrieval capabilities;
- Supporting efficient document management;
- Distributing information based on profiles of individual user groups;
- Storing all types of information (numeric, textual, pictorial, and others) in a unified manner;
- Preparing TOs concurrent with the development of weapon systems and the review of TOs in progress;
- Establishing modified organizational and operating procedures.

In developing the automation plan, the emphasis has been on a 7–10 year planning horizon. The plan concentrates on the use of modular components, which can be readily substituted by later generations of similar components as they become available.

KEY RECOMMENDATIONS

The AFTOMS concept of operations calls for several major changes inherent in the following recommendations:

ORGANIZATIONAL

- Establish a Central Tech Order Administration (CTOA) which will direct and manage the TO modernization program.
- Approve the concept of Tech Order Centers (TOCs), with each TOC being assigned the exclusive responsibility for managing the complete suite of TOs for one weapon system.
- Deploy adequate technical personnel at various system tiers.
- Create a TOC at CTOA level to produce policy and procedure Tech Orders.
- Create new career paths for personnel involved in the automation of technical information.
- Train Air Force personnel in the use of the AFTOMS technologies.

TECHNICAL

- Support the use of a heterogeneous portfolio of TOs, since multiple types of TOs will need to co-exist for the next 10-15 years.
- Use state-of-the-art technologies for creating and storing TOs.
- Emphasize print on demand capability in Work Areas, instead of bulk batch printing by outside vendors at the ALCs.
- Use optical discs for distributing TOs to bases.
- Support gradual transition to digitized TOs and conversion of existing TOs to digitized form.
- Install and use contemporary Document Management Systems for efficient management of TOs.

FINANCIAL

- Allocate financial resources to implement the AFTOMS concept.
- Initiate administrative procedures to enable acquisition and installation of equipment at various stages in the implementation process.

- Provide resources, on an interim basis, to enable one or more user commands and TSC to collaborate in the demonstration of relevant technologies leading to a technical specification of AFTOMS Concept of Operations and Functions.

PROGRAMMATIC

- Examine the Automated Tech Order System (ATOS–I) installation and its potential incorporation into AFTOMS.

- Investigate the planned Improved Technical Data System (ITDS) user system for its interface requirements at the Work Area level, both at depot and base installations.

- Develop a strong link with the Integrated Maintenance Information Standards (IMIS) program and laboratory demonstrations in order to understand its concept of operations for potential integration into AFTOMS.

CONCLUSIONS

The AFTOMS approach will lead to many long term benefits to the Air Force including increased weapon system availability, reduced costs, and increased mission effectiveness. AFTOMS provides the flexibility needed to support the more complicated weapon systems of tomorrow. Specifically AFTOMS will:

- Reduce overall cost of TO acquisition, distribution, and maintenance;

- Improve the timeliness, accuracy, completeness, and currency of TOs;

- Provide a single CTOA agency which will have clear responsibility over the entire TO process;

- Provide specific management responsibility for suites of related TOs by weapon system;

- Provide clear lines of authority and accountability for all TO functional activities;

- Enhance control and impose standardization across TOs, especially at the stage of receipt from Contractors;

- Provide efficient management of all TOs.

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ACRONYMS

Government

AFCC	– Air Force Communications Command
AFHRL	– Air Force Human Resources Laboratory
AFLC	– Air Force Logistics Command
AFSC	– Air Force Systems Command
AFTOMS	– Air Force Tech Order Management System
AFTO	– Air Force TO
AFR	– Air Force Regulation
ALC	– Air Logistics Center
ATC	– Air Training Command
ATI	– Automated Technical Information
ATOS	– Automated Tech Order System
CALS	– Computer-aided Acquisition and Logistics Support
CTOA	– Central Tech Order Administration
CTOC	– Commodity TOC
DC	– Data Center
DCA	– Defense Communications Agency
DCS	– Defense Communications System
DDN	– Defense Data Network
DoD	– Department of Defense
DOT	– Department of Transportation
DSCS	– Defense Satellite Communications System
FLTSATCOM	– Fleet Satellite Communications System
GPO	– Government Printing Office
IMIS	– Integrated Maintenance Information System
IPR	– In-Process Review
ISO/OSI	– International Standards Organization/Open System Interconnect
ITDS	– Improved Technical Data System
LSA	– Logistics Support Analysis
LSAR	– Logistics Support Analysis Record
MAC	– Military Airlift Command

MAJCOM	- Major Command
MEITS	- Mission Effective Information Transfer System
MIO	- Management Integration Office
NWSTOC	- Non-Weapon System TOC
PD	- Product Data
PMD	- Program Management Directive
PMP	- Program Management Plan
PMRT	- Program Management Responsibility Transfer
SAC	- Strategic Air Command
SPO	- System Program Office
TAC	- Tactical Air Command
TDUS	- Task-Oriented Dialog Understanding System
TMP	- Technical Manual Plan
TO	- Tech Order
TOC	- Tech Order Center
TODMP	- TO Development Management Plan
TODO	- TO Distribution Office
TOMA	- TO Management Agency
TSC	- Transportation Systems Center
WSTOC	- Weapon System TOC

Technical

AI	- Artificial Intelligence
ANSI	- American National Standards Institute
ARPANET	- Advanced Research Projects Agency Network
CAD	- Computer Aided Design
CAE	- Computer Aided Engineering
CAM	- Computer Aided Manufacturing
CCD	- Charge Coupled Device
CD-I	- Compact Disc-Interactive
CD-ROM	- Compact Disc-Read Only Memory
DBMS	- Data Base Management System
DMS	- Document Management System

dpi	– Dots per inch
DS/DD	– Double Sided/Double Density (floppy disks)
GB	– Gigabyte
LED	– Light Emitting Diode
IEEE	– Institute of Electronics and Electrical Engineers
ISDN	– Integrated Services Digital Network
KB	– Kilobyte
Kbps	– Kilobits per second
LAN	– Local Area Network
MB	– Megabyte
Mbps	– Megabits per second
MPP	– Modular Planning Process
NIS	– National Information Standards
NIU	– Network Interface Unit
NLP	– Natural Language Processing
OCR	– Optical Character Recognition
OROM	– Optical Read Only Many Times
PBX	– Private Branch Exchange
PDL	– Page Description Language
PERT	– Program Evaluation and Review Technique
RF	– Radio Frequency
RLL	– Run Length Limited
SGML	– Standard Generalized Markup Language
ULANA	– Unified Local Area Network Architecture
ULCE	– Unified Life Cycle Engineering
WAN	– Wide Area Network
WASP	– Wait And See Parser
WORM	– Write Once, Read Many Times
WYSIWYG	– What-You-See-Is-What-You-Get

CHAPTERS 1–5

INTRODUCTION

SYSTEM CONCEPT

SYSTEM FUNCTIONS

IMPLEMENTATION STRATEGY

RECOMMENDATIONS

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The Air Force Computer-aided Acquisition and Logistics Support (CALS) Program was established to improve weapon system reliability and maintainability, and to reduce the costs of weapon system acquisition and support. One major objective of the CALS initiative is to streamline the flow of technical information by introducing automated techniques. The automation process is intended to improve the delivery and handling of large quantities of technical data. The program will significantly reduce the amount of paper and labor necessary to enter, manipulate, transfer, and interpret data.

On 18 October 1985, an Air Force Program Management Directive (PMD) established a CALS Management Integration Office (MIO) at HQ Air Force Systems Command (AFSC) to coordinate the CALS program. In addition, the PMD identified the following tasks:

- To plan for the integration of all existing Automated Technical Information (ATI) projects within and with a standard information systems framework; to determine the full range of CALS objectives and management concepts; and to plan large scale demonstrations and implementation of CALS technology for a weapon system acquisition program.
- To ensure system structures are consistent and comply with Air Force guidelines.
- To perform a cost analysis of replacing present technical information management methods with automated methods.
- To prepare and maintain an ATI and CALS Program Management Plan (PMP) addressing program integration and consolidation of CALS schedules as well as incorporation of improved ATI capabilities.

The MIO is responsible for planning, developing, and implementing the CALS initiatives, but is not responsible for the specific systems. The Transportation Systems Center (TSC) of the Department of Transportation (DOT) is providing the AFSC MIO with systems engineering support to create automation plans. The MIO identified three areas for review and improvement in the initial exercise: Tech Orders (TOs), Product Data (PD), and Logistics Support Analysis (LSA).

TSC developed and implemented a Modular Planning Process (MPP), an information engineering system approach, to perform the activities associated with the CALS initiatives. The principal requirements of the MPP are to:

- Focus on technical plans that would not be outdated before implementation;
- Incorporate existing transition systems;
- Meet the information distribution requirements of the user community;
- Interface with a variety of organizations responsible for weapon systems acquisition and logistics support.

The MPP has three phases:

(1) An examination of the existing environment;

(2) A study of opportunities;

(3) A plan of future direction.

An overview of the MPP is presented in Table 1-1 to give an indication of the steps needed to complete this process. Using the framework of MPP, TSC has developed an automation plan for Tech Orders. The first step was the examination of the current TO system environment, followed by a study of the opportunities and a plan for the future direction.

1.2 CURRENT TECH ORDER SYSTEM

The Air Force established the current TO system in the 1940s. This system provides the official medium for disseminating technical information, instructions, and safety procedures pertaining to Air Force systems and equipment. According to Air Force Regulation (AFR) 8-2, TOs are military orders issued in the name of the USAF Chief of Staff, by order of the Secretary of the Air Force, and require mandatory compliance. The current TO system is manually oriented and its structure is functionally illustrated in Figure 1-1.

Currently, there are over 150,000 Tech Orders in use. The TOs are managed by six centers, which are divided by specific weapon system or commodity. The size of a typical Tech Order ranges from 100-150 pages and is 60 percent text and 40 percent graphics. The total TO data base is approximately 20 million pages with about 2.3 million pages a year requiring revision. In addition, there is a growing backlog of unfilled requirements, currently estimated to be as much as 2 million pages.

1.2.1 Existing TO Generation and Distribution

The Air Force Systems Command (AFSC) is responsible for the acquisition and preparation of TOs. AFSC, through the System Program Office (SPO) for each major system acquisition, establishes a TO Management Agency (TOMA) to oversee the development and acquisition of TOs. The TO system division of the ALC, which has been designated

TABLE 1-1. MODULAR PLANNING PROCESS-OVERVIEW

EXAMINE THE ENVIRONMENT	STUDY THE OPPORTUNITIES	PLAN THE DIRECTION
<u>Initiate the Process</u> Perform Initial Assessment · Create Preliminary Description of Environment · Identify Organizational Expectations · Establish Priorities Develop Specific Procedures · Establish Management Plan · Identify Advisory Group · Prepare Project Plans <u>Conduct Structured Analysis</u> Describe Current Environment · Create Functional Model · Identify Major Data Elements · Describe the Organizational Infrastructure · Identify Major Information Flow Parameters Assess Transitional Projects · Identify Objectives · Describe Functions and Data · Identify Technologies · Identify Infrastructure Affected	<u>Assess Technology</u> Identify Existing Technologies · Review Current Environment · Review Ongoing Projects · Identify Existing Technologies Research Future Technology Opportunities · Select Technology Areas · Consult with Technology Experts · Examine Similar Applications · Review Development Trends Establish Technology Alternatives · Quantify Directions · Specification of Implementation Issues · Examine Benefits and Costs <u>Project Future Requirements</u> Forecast Requirements · Review Applicable Scenarios · Conduct Discussions with MAJCOMs · Forecast Process Changes · Assess Infrastructure Constraints Examine Feasible Alternatives · Determine Feasibility Issues · Review Industry Trends <u>Define Future State</u> Describe Future Environment · Define the Impact of Technology on Current State · Define Projected Organizational Responsibilities · Define Relevant Interface Requirements Create Future Functional Model · Develop a Description of Future State · Identify Projected Major Information Flow Parameters	<u>Formulate Alternatives</u> Assess Critical Issues · Examine Objectives · Identify Technologies · Review Organizational Issues Propose Initial Alternatives · Select Future Requirements · Identify Technologies · Structure Proposals Review and Modify Alternatives · Review Criteria · Identify Relationships with Transitional Projects · Define Policies and Organizations Involved <u>Develop Consensus</u> Review Progress with Advisory Group · Identify Discussion Topics and Priorities · Evaluate Current Environment · Establish Objectives · Provide Access to Information Develop Common Understanding · Review Future Requirements · Evaluate Recommended Solutions · Examine Feasibility Issues Expand Advocacy Network · Identify Implementation Agencies · Select Appropriate Forums · Communicate the Plans <u>Prepare Implementation Plan</u> Define Activity Descriptions · Establish Implementation Guidelines · Establish Evaluation Criteria · Develop Implementation Procedures Develop Organization Plan · Confirm Major Milestones · Establish Transition Plan · Identify Organizational Responsibilities Establish Constituency · Gain Management Acceptance of Plan · Obtain a Commitment for Execution Create Documentation · Establish Goals · Define Resource Requirements · Recommend Technologies · Define Organizational Impacts · Establish Financial Parameters

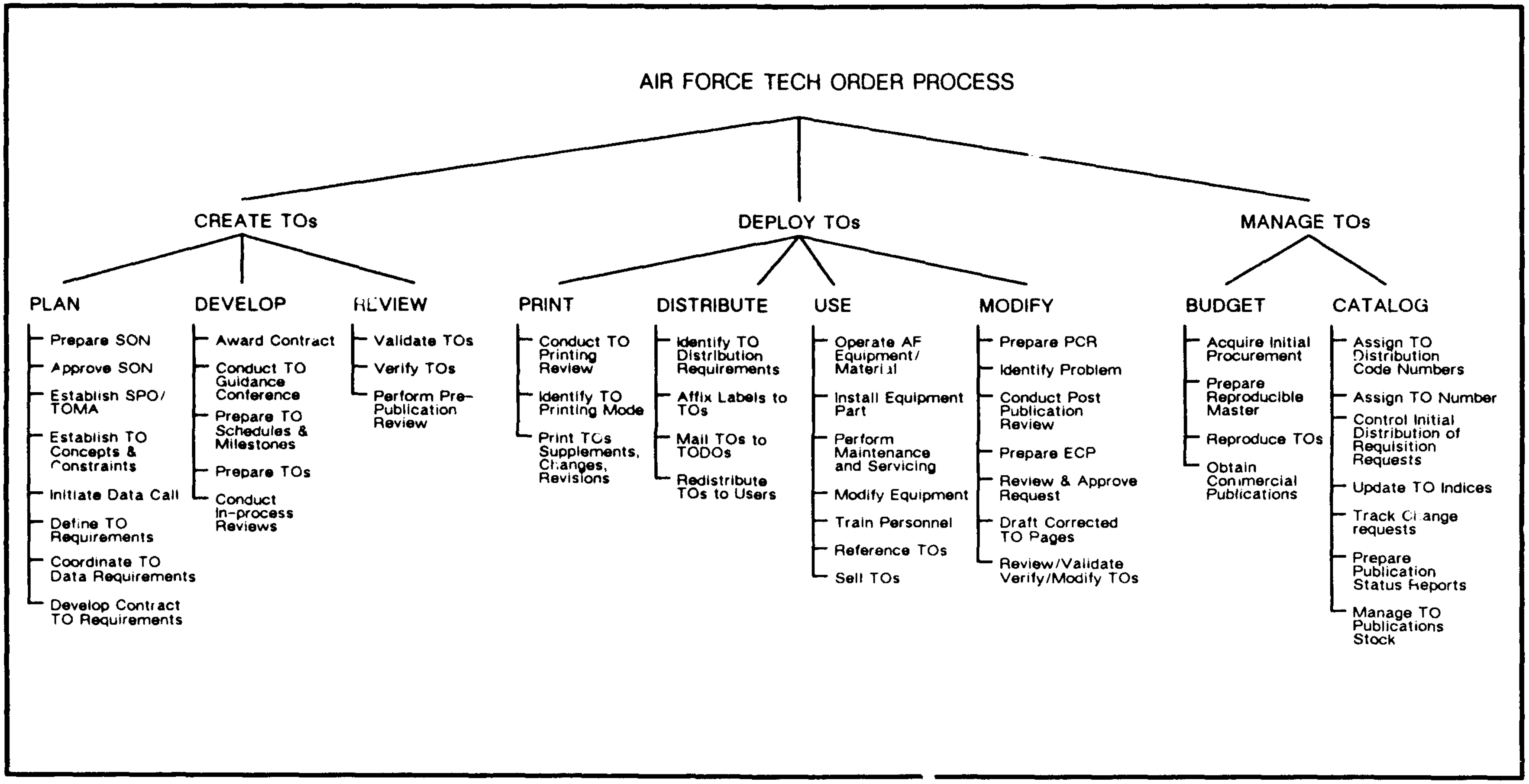


FIGURE 1-1 CURRENT TECH ORDER FUNCTIONAL STRUCTURE

as the prime support base for the weapon system, provides the technical support. The Contractor-prepared Technical Manual Plan (TMP), which is compatible with the Air Force TO Development Management Plan (TODMP), is used to produce a draft TO set. The TOMA conducts an in-process review. The final version of the TO set is validated by the Contractor and verified by appropriate Air Force commands such as, Military Airlift Command (MAC), Tactical Air Command (TAC), and Strategic Air Command (SAC). The ALC is responsible for storing, printing and distributing the finalized TO.

Four USAF Commands are involved in the creation, use, and management of TOs. Air Force Systems Command (AFSC) monitors the product development and the contracts associated with all new weapon systems. The Major Command (MAJCOM) that requires the weapon system provides technical specifications and reviews the weapon system, and is ultimately responsible for the operation of the weapon system. After the weapon system is fielded at Program Management Responsibility Transfer (PMRT), the Air Logistics Center (ALC) provides the operational logistics support required to field the weapon system. Air Training Command (ATC) uses TOs as an instruction tool for the proper use of weapons systems. Figure 1-2 illustrates the procedures for the production (generation and ordering) and distribution of TOs.

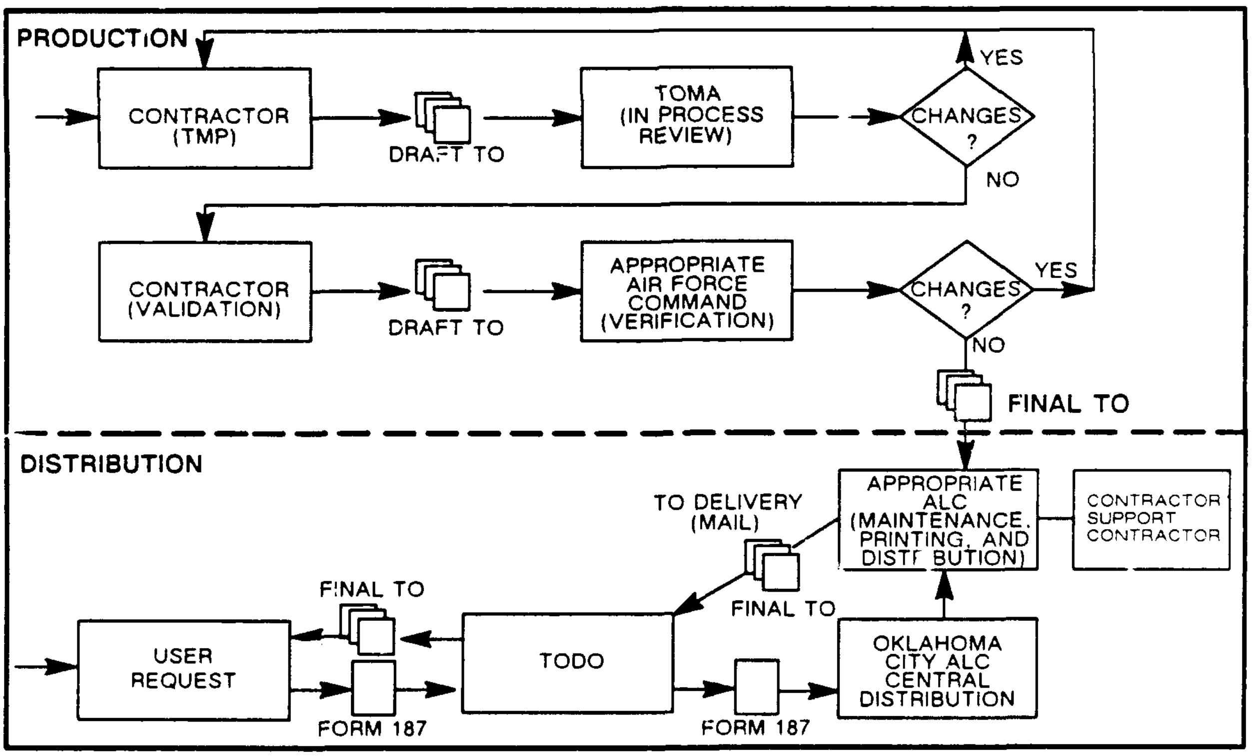


FIGURE 1-2. TECH ORDER PRODUCTION AND DISTRIBUTION

Users, who need specific TOs, send an Air Force TO (AFTO) Request, Form 187, to a TO Distribution Office (TODO). The TODO orders the requested TOs from the Oklahoma City ALC central distribution point. The Oklahoma City center sends a mailing label to the appropriate ALC who mails the TO to the TODO. Revisions and supplements follow a similar procedure. For a more detailed description of the TO system, see the companion document, "United States Air Force Computer-aided Acquisition and Logisitics Support (CALS) Tech Order System Description."

1.2.2 Existing System Deficiencies

A report of the Headquarters (HQ) Air Force Audit Agency cites several deficiencies in the existing system. These include:

- Contractors frequently fail to provide installation-level TOs in time for Air Force verification.
- At times, 500 days are needed to fully implement a routine change to a TO.
- Desk-top analysis and validation of TOs is frequently performed in lieu of actual performance of tasks.
- From 1977 to 1986, 47 percent of Cause Code 1 mishaps listed inaccurate TOs as a contributing factor with resulting equipment losses of about $86 million.
- The cost to develop and publish a TO is estimated to exceed $1,000 per page
- The Air Force does not separate the cost of TO preparation from the cost of a weapon system, making cost control difficult.

Therefore, the present paper-oriented system is inefficient in meeting the growing requirements of the U.S. Air Force. A single weapon system, such as the B-1B, generates approximately 3,500 new TOs, adding a million pages to the current TO data base. This additional volume cannot be managed by the present system in a timely fashion. All these facts motivate the formulation of a time-bound plan that will lead to a more efficient and powerful TO system, capable of meeting the present needs and the future requirements of the U.S. Air Force.

1.3 OBJECTIVES

Based on a consideration of the existing TO generation and distribution system and the problems existing within that system, TSC has developed an automation plan for TOs. The objectives of this automation plan are to:

- Reduce the overall cost of TO acquisition and maintenance;
- Improve the timely distribution of TOs;

- Improve the accuracy of TOs;
- Improve the level of completeness of TOs;
- Improve the currency of the TOs with existing weapon systems;
- Enhance the effectiveness of the overall system.

To meet these objectives, sophisticated technologies must be used to create, distribute, and update TOs on a regular basis. In addition, changes must be made at the strategic and organizational levels. Specifically, an automation oriented infrastructure must be created to handle the flow of TOs and associated information.

1.4 REPORT ORGANIZATION

This report describes the Air Force Tech Order Management System (AFTOMS) in terms of its system concept, its principal technical and organizational components, and its ability to meet present and projected requirements of the U.S. Air Force. The transition from the present system to AFTOMS is also described in this report.

This report consists of an executive summary, five chapters, and eight appendices. Chapter 2 highlights the AFTOMS concept. The ability of this system concept to serve all the functions relating to TOs is discussed in Chapter 3. Chapter 4 focuses on the details of a three-phase plan for the transition from the present system to AFTOMS. The last chapter contains a summary of key recommendations. The eight appendices present an overview of trends in different technologies relevant to the TO system:

Appendix A - Automated Reading of Paper Documents
Appendix B - Technology Assessment for Mass Storage
Appendix C - Computer Based Printing
Appendix D - Document Management Systems (DMS)
Appendix E - Communication Alternatives
Appendix F - Management of Large Information Systems
Appendix G - Hypertext and Videodisc Systems
Appendix H - Natural Language Processing (NLP)

Supplementary information is available in the following documents:

- U.S. Air Force CALS Technical Order System Description. Prepared by John LaPointe of Systems Automation Division, Transportation Systems Center, 1987 -- contains detailed information about the present TO system.

- Information Engineering for Large Organizations -- A Case Study of the Air Force, by Jay E. April, Richard I. Skolnick, Robert A. Smith, and

Robert E. Thibodeau presented at the First International Workshop on Computer-Aided Software Engineering, May 27-29, 1987 -- provides details of the modular planning process.

- Series of technical reports on specific technologies prepared as background material for the TO automation project, excerpts of which are included as appendices to this report.
- MIL STD 1840A.

CHAPTER 2: SYSTEM CONCEPT

2.1 INTRODUCTION

In developing a system concept to manage the acquisition and distribution of digital TOs, consideration was given to a modular framework which easily maps to the existing Air Force infrastructure. Modularity allows phased implementation at a pace consistent with Air Force requirements and appropriations. To meet the objectives of more accurate, complete, timely, and cost effective TOs, clearly defined responsibilities and logical information flows must be established. A four-tier AFTOMS hierarchy was defined which places centralized control at the highest tier with top-down information distribution.

Several assumptions were made in the development of AFTOMS:

- The automation plan presented in this document should cover a 7–10 year period.
- The operational concept should be consistent with the present and projected USAF CALS requirements.
- All types of TOs should be managed and distributed by the system.
- State-of-the-art, commercially available, off-the-shelf technologies should be used, wherever possible.
- The system should evolve from the current system by integrating existing assets and future modules while the current system operates in parallel.
- The new system should facilitate future expansion.
- The resultant system must allow the Air Force to accept and efficiently use digital TO data from Contractors.

The AFTOMS concept meets the requirements embodied in these assumptions. This chapter describes the organization of AFTOMS. Since the concept is designed to serve all types of TOs, a brief description of TO types is presented first.

2.2 TYPES OF TECH ORDERS

From a functional view, the Air Force TOs are divided into the following application categories:

- Tech Manuals;

- Abbreviated Tech Orders;
- Time Compliance Tech Orders;
- Methods and Procedures Tech Orders;
- Index Tech Orders.

The basic characteristics of each category of TO are described in a companion document entitled "United States Air Force Computer-aided Acquisition and Logistics Support (CALS) Technical Order System Description". Appendix A of that document describes the sub-divisions within each kind of TO.

In formulating a system automation plan, it was necessary to create TO types based on digital delivery format versus paper delivery format rather than application categories. Presently all Air Force TOs are created, inventoried and distributed as paper documents. Although many of these documents are created and maintained by Contractor systems in digital form, they are delivered to the Air Force as paper copies since the current Air Force TO system is incapable of accepting digital delivery. The current Automated Tech Order System (ATOS-I) performs selective scanning of existing TO pages for digital storage and subsequent editing. However, digital change management by this technique is only a small portion of the entire process.

Once digital acceptance capabilities are provided by the Air Force, systems can be designed to display and manipulate the TO data in a variety of ways. A digital TO can simply be a computer based display of the paper document in which individual pages can be called up for display or printing. A more advanced concept would be to link individual TO data elements under the control of a data base manager which allows the user to assemble related TO information on the screen interactively as tasks require. To develop a system concept that serves all kinds of TOs (present and future) and these relevant automation issues, it was necessary to create broad categories into which all TOs could be subdivided.

- Type A - This refers to all TOs that currently exist or will be delivered in paper form in the Air Force inventory. Digitization of these TOs for computer applications will require selective scanning.

- Type B - This refers to TOs that will be delivered to the Air Force by the Contractor in digital form, but to the end user in page-oriented form. In other words, these TOs will be delivered and used in conventional page-oriented sequential format. A user, sitting in front of an electronic display, will be able to view and/or print any desired page(s) of the TO and to scroll across pages. The ability to directly access the required page on the electronic display will reduce both the need for and the volume of printed information.

- Type C – TOs of this type will offer the highest level of technological innovation. These TOs will be delivered by the Contractor to the Air Force in a digital format. The user will be able to use an electronic display to search and retrieve required information. Access will be provided to related windows of information, regardless of their location in the TO. In reality, they have no page–orientation and are significantly different from Type A and Type B.

2.3 ORGANIZATIONAL STRUCTURE

The AFTOMS organizational structure is designed to serve the natural functional entities that must reside in any documentation production and distribution system. These functional groupings include general administration, acquisition and production, ordering and distribution, and application use. AFTOMS has four–tiers in which each tier is mapped to a functional grouping.

2.3.1 Major Tiers

The four tiers are hierarchical, with centralized control coming from the top down. Each tier is subordinate in function and responsibility to the one above it. The functional groupings and their related AFTOMS tier–level organizations are listed below.

Function	Tier	Organization
General Administration	1	Central Tech Order Administration (CTOA)
Acquisition and Production	2	Regional Centers
Ordering and Distribution	3	Base Libraries
Application Use	4	Work Areas

- Tier 1. Central Tech Order Administration (CTOA) – This top tier is a single organization/facility within the Air Force that is responsible for the demonstration, implementation, and management of the entire Tech Order system. The CTOA establishes AF–wide TO policy and standards and provides coordination between Air Force commands and all participating organizations and users of AFTOMS.

- Tier 2. Regional Center – This tier consists of major Regional Centers that are responsible for the acquisition, planning, development and maintenance of TOs. Although specific system related TO duties are delegated to subfacilities called Tech Order Centers (TOCs), the Regional Center provides the overall management, facilities, and computer resources for all TOC functions. It is expected that Regional Centers will map to the existing ALCs and will continue to house specialized service points or depots.

- Tier 3. Base Libraries - The third tier represents Base Libraries, which are service organizations/facilities located at each base (geographic location) that provide centralized TO ordering and distribution services for an entire base regardless of its command orientation. The Base Library is a specialized facility, which is staffed, managed, and operated under CTOA control.

- Tier 4. Work Areas - Work Areas represent the end user community who requires TOs for the performance of their mission objective. Work Areas consist of command specific personnel and are not managed by the CTOA. Examples of Work Areas are: wing, squadron, shop, office, single user, and the aircraft itself.

Figure 2-1 shows the top-down arrangement of these functional tiers.

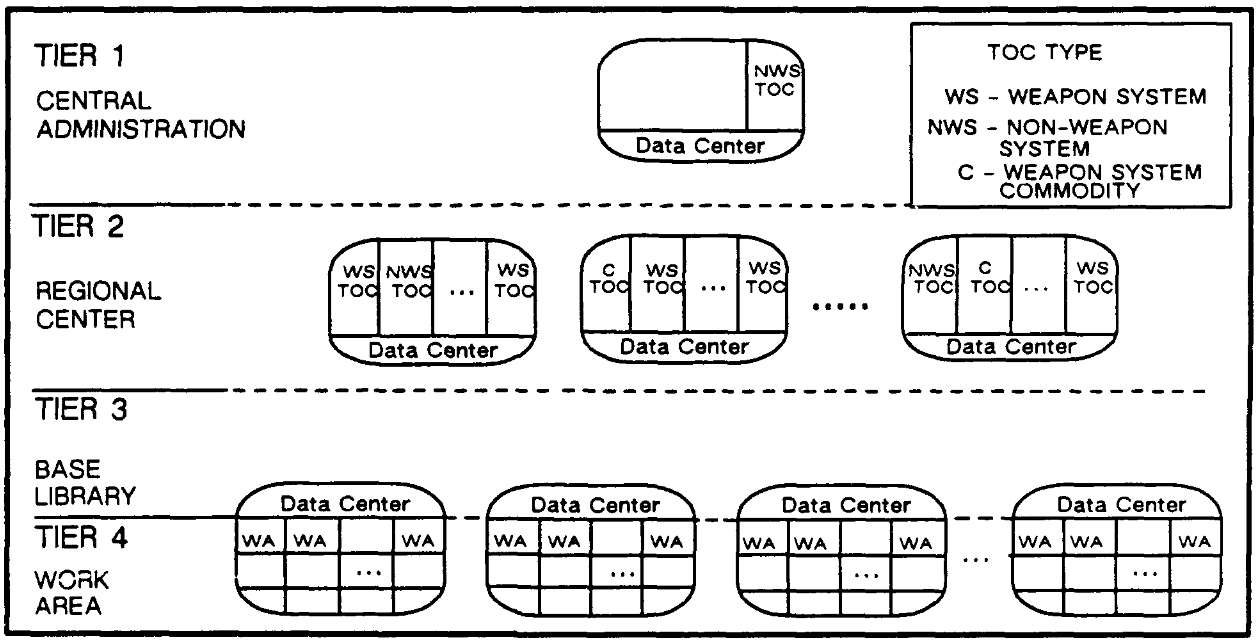


FIGURE 2-1. AFTOMS TIERS

2.3.2 Subfacilities

Tech Order Centers and Data Centers, subfacilities within the tiers, are established to consolidate staffing and equipment requirements, and add operational efficiency to the system.

Tech Order Centers (TOCs), Tier 2, are subfacilities of a Regional Center. Each TOC is responsible for the management (i.e. acquisition, planning, development, distribution, and updating) of the complete suite of Tech Orders for a single weapon system. It must be emphasized that the TOCs responsibility for the complete suite of weapon system TOs is a major departure from the existing organization. Currently, TOs for a weapon system are the responsibility of several ALCs, each with a different subsystem specialty. The TOC needs to acquire and distribute all TOs for a specified weapon system regardless of the source organization. Each weapon system will then be supported by a single TOC, which has all the TOs in one location and a clear mandate to manage that weapon system's Tech Orders.

Since weapon systems share many common equipment items, such as engines and avionics, there will be a need to create TOCs specializing in these commodities. Commodity TOCs will eliminate the duplication of effort that would occur if each weapon system TOC managed its own commodity TO inventory. A weapon system TOC will need to acquire commodity TOs directly from its respective commodity TOC. The weapon system TOC will then place these TOs into its suite for base distribution. Commodity TOCs will not distribute directly to the Base Libraries but only to weapon system TOCs requiring that commodity TO. However, all other functions (acquisition, management, production, etc.) remain the responsibility of the commodity TOC. In addition to weapon system and commodity TOCs there will also be TOCs to support non-weapon system related TOs for such items as support vehicles, policy and procedures, indices, etc. The CTOA will have a non-weapon system TOC to support its administrative TO requirements. A Regional Center will therefore house a mix of TOCs each with its own TO responsibilities. The types of TOCs defined are as follows:

Type	TO Responsibility	Distributes to
Weapon System TOC (WSTOC)	All TOs for a major weapon system (e.g. F-16, B-1B)	Base Libraries
Commodity TOC (CTOC)	Subsystem TOs (e.g. pneudraulics, engines)	Weapon System TOC
Non-weapon system TOC (NWSTOC)	Remaining TOs (e.g. policy, support vehicles, equipment, offices systems)	Base Libraries

Each of the top three tiers contain Data Center facilities designed to provide centralized computer services/resources at each physical location for tier level organizational processing, communications, production and distribution. At the CTOA and regional centers these Data Centers are relatively large installations, consisting of several mid-range computers, storage capabilities and printers networked via a Local Area Network (LAN), such as the AFLC LAN. Each TOC has its own LAN-based work stations which are bridged to the Regional Data Center. Since Base Libraries will support base-level requirements, the configuration of their Data Center will match required capacities. All Base Library Data

Centers will need to provide administrative processing, TO storage, high speed printing, and communication to CTOA. Configurations will range from LAN-based super-micro to mini-computer systems, file servers, and high-speed laser printers. Figure 2-1, page 2-4, shows the relationship of subfacilities within the tier level organizations.

2.4 INFORMATION FLOWS

Top-down data flow through the four tiers of AFTOMS is controlled by the Central Tech Order Administration (CTOA) and the associated hierarchy. The CTOA maintains a list of all active TOCs and their associated weapon systems responsibilities. Therefore, the CTOA is ideally positioned to be the control point for TO distribution and authorization. Once TO requests are registered by Work Area users in Tier 4, information flows up to the CTOA, Tier 1, and the response flows down through the tiers until it returns to Tier 4. This arrangement provides centralized control and distribution management.

Figure 2-2 shows the main information path flows from Work Area to Base Library, Base Library to CTOA, CTOA to TOC, and TOC to Base Library.

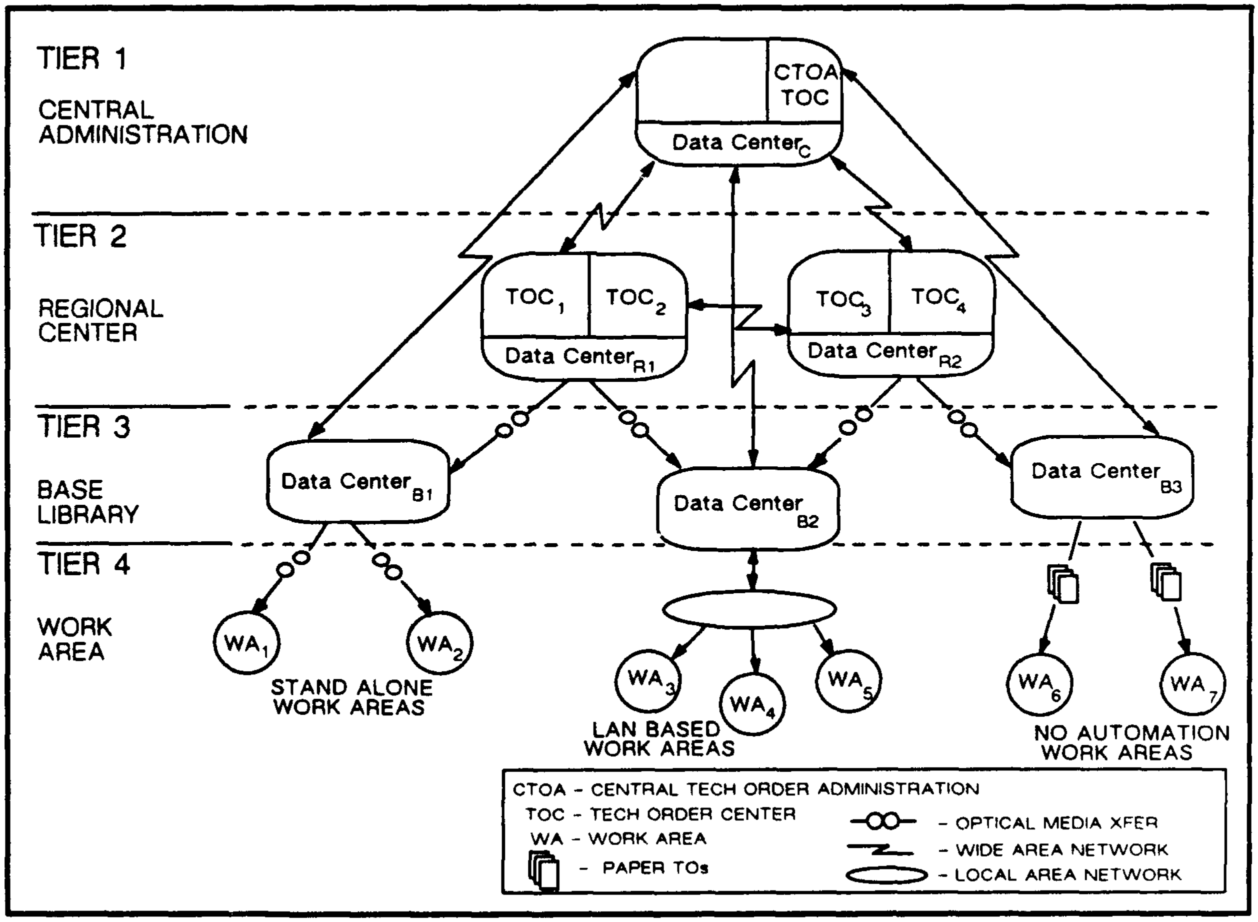


FIGURE 2-2. AFTOMS TRAFFIC FLOW

Work Areas request information in the form of task definition profiles from the Base Libraries which, in turn, send the request to CTOA. The CTOA either responds to a request directly or distributes the request to a specific TOC (Tier 2). TOCs may then pass requested data (usually TOs) back to the Base Library for distribution to the Work Area. It is important to note that, in this top-down flow strategy, Base Libraries do not request information directly from TOCs. The Base Library, therefore, need not know the location of TOs. This simplifies the ordering process, communications paths, and allows CTOA flexibility in assigning TOC responsibilities.

2.5 INTERCONNECTIVITY

The flow of information requires communication paths meeting the functional demands of the system to be defined as illustrated in Figure 2-3. The AFTOMS concept builds upon

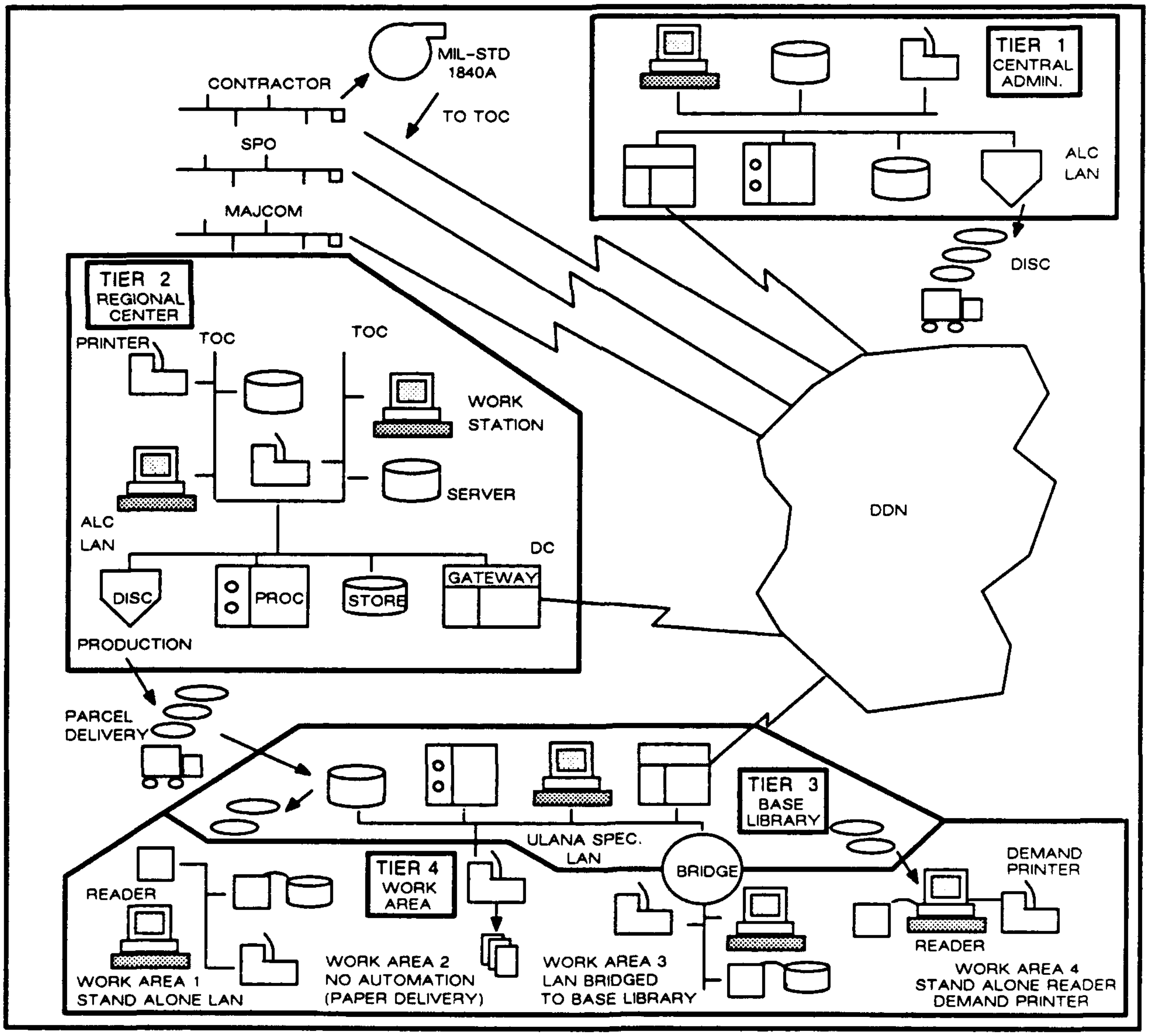


FIGURE 2-3. PROJECTED COMMUNICATION RESOURCES

the current implementation of Local Area Networks (LANs) taking place in the Air Force. Since the CTOA and TOCs are expected to reside at ALCs, the work stations and gateways to the Regional Data Centers will be supported by the AFLC LAN. Local base communications at the Base Library (required) and Work Areas (optional) will be provided by Unified Local Area Network Architecture (ULANA) specified LANs.

The figure shows the main points of interconnection and projected communication resources. Transfer of complete suites of TOs to the bases requires media exchange; for this type of transfer optical disc is recommended. Individual TO transfer among TOCs and the SPO/MAJCOM/Contractor community will be via the Defense Data Network (DDN), dedicated line, and media exchange. Communication of information other than TOs, such as change requests and user profiles, will be interactive transaction traffic, best served by a Wide Area Network (WAN) such as the Defense Data Network (DDN). Section 3-5 describes the distribution process and related resources in greater detail.

2.6 SUMMARY

AFTOMS is structured so that operational responsibilities for each system function is placed on discrete organizational units. Since Tier 4 Work Areas do not require a Data Center configuration, computer facilities can be provided at that level as needed without degrading the performance of AFTOMS. The control of the entire system's technical information by the CTOA and the assignment of single TOCs to each weapon system are key organization features of AFTOMS and provide accountability and control over the complete life cycle of a TO. TOCs are staffed by personnel with strong backgrounds in weapon system technical data. Data Centers are staffed by people highly skilled in computer disciplines.

CHAPTER 3: SYSTEM FUNCTIONS

3.1 OVERVIEW

In establishing the functional requirements of AFTOMS, an infrastructure was designed to serve the management and distribution of TOs regardless of their type. All TOs (Type A, B or C) need a system that can provide the core activities of acquiring, archiving, cataloging, distributing, and updating (change management). The activities were mapped to the AFTOMS concept according to the following basic functions:

- User Profile Registration and Maintenance;
- TO Cataloging and Archiving;
- Master Catalog Maintenance;
- Distribution;
- TO Planning, Development, and Review;
- Change Management.

These functions are explained, in detail, in the following sections.

Once TO data is brought into the system in digital form, the AFTOMS functions are the same for all TOs. Paper TOs (Type A) designated for AFTOMS automation, will be scanned and brought into the system as Type B, page-oriented TOs. Type C TOs, which will be delivered in digital form, will share the common system functions provided for Type B. From a high-level system function perspective, the difference between TO types remains transparent until actual distribution to a work station. Due to the difference in delivery formats, Type B TOs will require work stations configured with hardware and software that enable the user to display, scroll, and print TO pages, whereas full support of Type C TOs will require specialized delivery systems.

Figure 3-1 is a flowchart that shows the system functions shared by all digital TOs. This use of common functions to provide core applications will eliminate islands of automation. In addition, since the system is functionally modular, hardware and software updates to any given function can be made without disrupting or replacing the system as a whole. Paper TOs (Type A) that are not converted to Type B will be assigned to a TOC to be ordered, cataloged, and distributed through use of the AFTOMS common functional applications until their retirement.

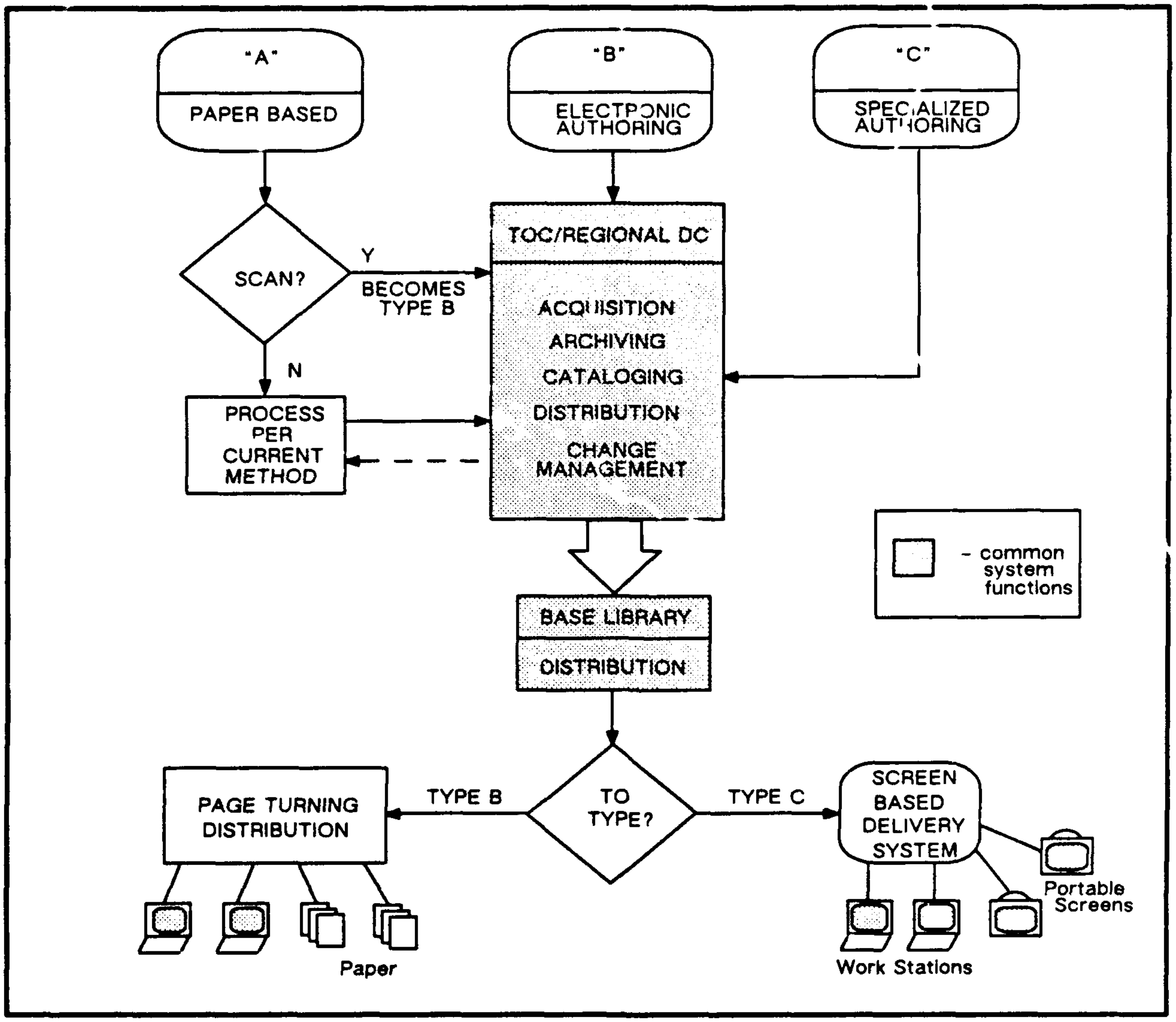


FIGURE 3-1. COMMON SYSTEM FUNCTIONS

3.2 USER PROFILE REGISTRATION AND MAINTENANCE

The profile registration and maintenance system function simplifies the ordering and subsequent distribution of TOs to the Work Areas. The Work Area user will simply log onto a terminal and provide a broad task description (such as landing gear maintenance) and weapon system (F-16). This profile information flows on-line through AFTOMS authorization checkpoints, until the Work Area is registered with the proper TOC. This process, which could be done in a matter of minutes, would position the Work Area user to receive regular, automatic delivery of the appropriate suite of TOs and changes from the TOC. A Work Area initiates the process by preparing a Work Area profile form. This profile will include, at a minimum, the following information:

- Work Area identifiers (wing, squadron, MAJCOM, base);
- Work Area personnel identifiers (billet, security class);
- Weapon system/subsystem (aircraft tail number, model, etc.);
- Task identifier (pneudraulics, hydraulics, electrical);
- Work Area configuration (LAN, stand alone, no automation);
- Delivery format.

In automated Work Areas, users complete an electronic Work Area profile form, while in non-automated Work Areas, they complete a paper version of the profile.

3.2.1 Operational Description

All Work Area profiles are transmitted or submitted to the Base Library Data Center. Paper based profiles are entered into the system by Data Center personnel. At the Base Library Data Center, the Work Area profiles are stored under Data Base Management System (DBMS) control. The DBMS sorts and merges the individual profiles to create a single master list called the base profile. The base profile, which contains all of the work area profile information at the base, is used to identify the TOs on a job function basis (e.g. F-16 engine overhaul) not on an individual, personnel or task basis. Work Areas with stand alone systems may request their own suite of TOs. Since the Base Library compiles the Work Area profiles, multiple ordering of TOs is eliminated. A single TO copy can be distributed by the Base Library Data Center to several Work Areas.

The Base Library transmits the base profile, via the DDN, to the CTOA Data Center. The CTOA reviews the TO requests and submits those that require special clearance or authorization to the appropriate CTOA administrator or MAJCOM. Once the request is approved, the CTOA performs two tasks: 1) the profiles are separated (parsed) into specific TO requirements by TOC; and 2) the updated profiles are added to the master CTOA data base.

After the profiles are parsed, the CTOA distributes, via the DDN, profile ordering information to the specific weapon system TOC located at one of six Regional Data Centers. Since the complete suite of TOs for a weapon system resides at a single TOC, registration of the Work Area is now completed. The Regional Data Center can now send the appropriate weapon system or subsystem TO suite to the base on a regularly scheduled basis. A frequent review and confirmation of TOs needed at the Work Areas is conducted by the Base Library. Shipments continue until profile registration is canceled by the CTOA. Figure 3-2 shows the information flows associated with profile registration and maintenance.

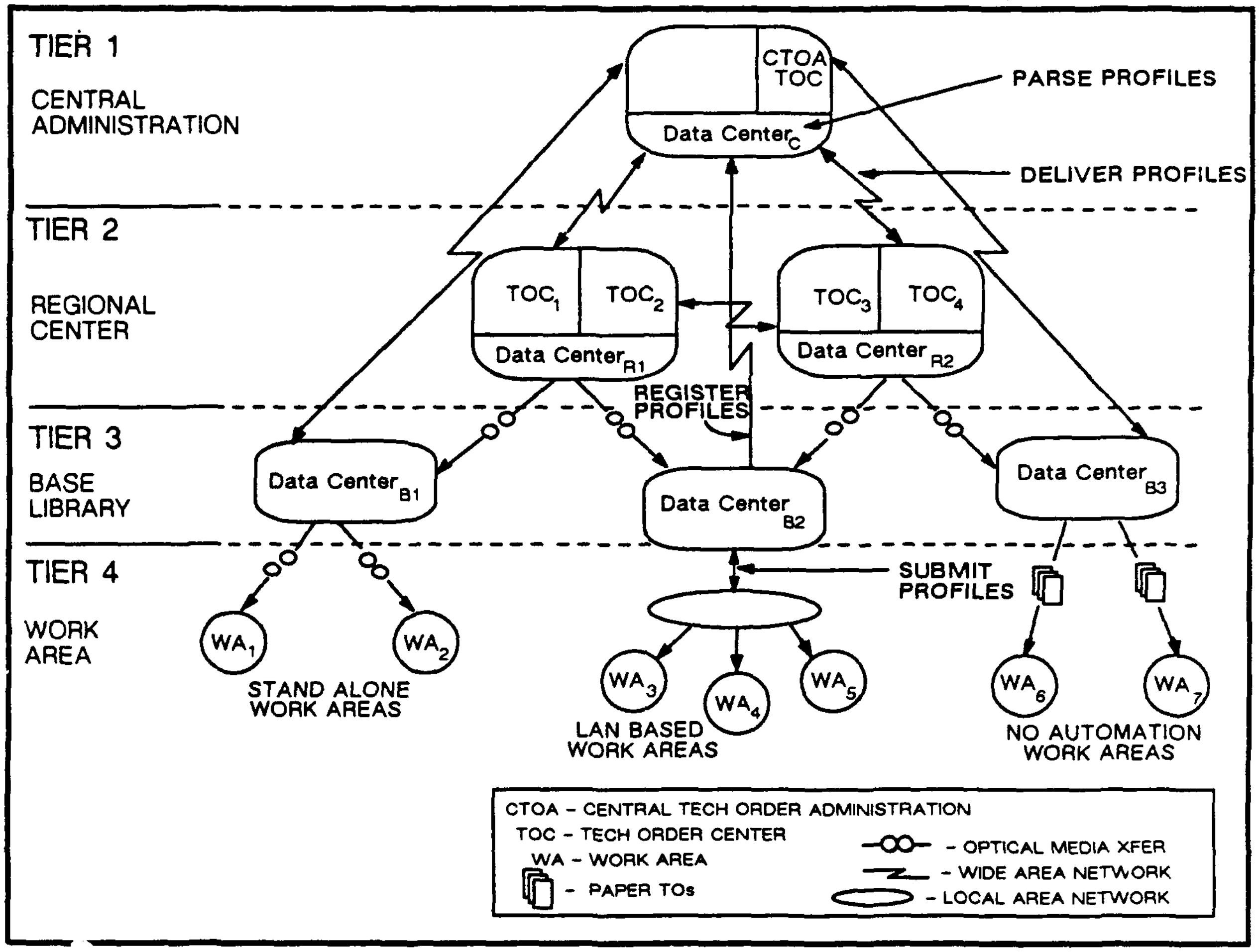


FIGURE 3-2. PROFILE REGISTRATION AND MAINTENANCE

3.2.2 Function Summary

Each work area receives TOs by registering its work group profile with the Base Library. Base profiles are sent to the CTOA, which authorizes requests and registers each base with applicable TOCs. The TOCs automatically deliver TOs to the Base Libraries who, in turn, distribute them to Work Area users based upon their profile requirements.

The key advantages of the AFTOMS profile registration and maintenance function are:

- The need for ordering individual TOs and updates is eliminated.
- Work Area activity is identified in the profile and provides delivery information for the relevant suite of TOs.
- Delivery of TOs (and revisions) is provided automatically by the system on a regular basis. Work Area profiles contain the Work Area configuration, thereby, determining the ultimate delivery form of the TOs (paper, disc, on-line, etc.).

3.3 CATALOGING AND ARCHIVING

The cataloging function provides TO descriptors that give each TO a myriad of identifying information for subsequent retrieval and cross referencing with all other related TOs. In addition, the Work Area user must be able to display or print the appropriate TO version for any model of a weapon system. To meet this requirement, AFTOMS archives will hold each TO in a historical form that enables base level systems to access and produce any version of a TO. A complete audit trail of revisions to each TO will be kept on both non-editable archive copies and distribution copies. Figure 3-3 shows conceptually how the revision history of a TO will be stored. The large storage capacity of the optical disc makes it possible for this history to be accumulated and distributed to the Work Areas.

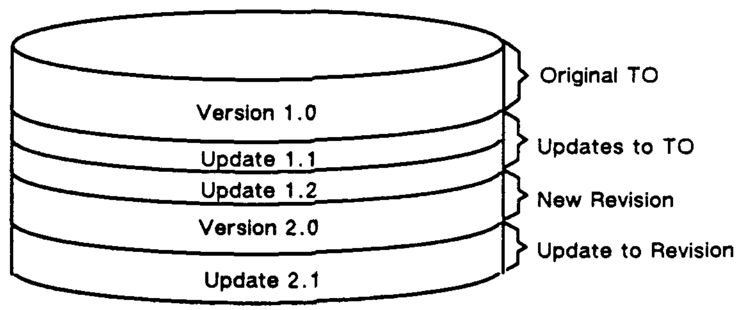


FIGURE 3-3. STORAGE OF TECH ORDER REVISIONS

3.3.1 Operational Description

After accepting digital TOs from the Contractor, the cataloging and archiving function will be performed by the Data Centers at the Regional Centers. This internal function provides a method for TO access and storage for subsequent functions (e.g. distribution).

After a TO has been approved by the weapon system SPO, it becomes the management responsibility of the TOC assigned to that system. The Regional Data Center (DC), which supports that TOC, catalogs the TO into the Air Force inventory. This catalog function supplies a set of attributes (i.e. ID, weapon system affiliation, Contractor, model number, etc.) that uniquely describes the TO. Once cataloged, the TO and its revisions are accessible to the Work Area users through the system functions. When a catalog change has occurred, the Regional DCs transmit updates to the CTOA DC where the master catalog/ index will be prepared and distributed.

In archiving, the Regional DC places a source or working copy of the TO into TOC on-line storage. This copy can be accessed for change management by document management work stations residing on the TOC LAN. A second non-editable copy of the TO is placed into the weapon system archive suite. Master optical discs are made from this archive suite of weapon system TOs. After an optical disc master has been created, production copies are sent to the CTOA, which maintains a permanent and complete archive of all USAF TOs. In addition, the Base Library Data Center is responsible for storing archive copies of TO suites that it receives for distribution to its Work Area population. AFTOMS, therefore, has three levels of archiving, which increases local availability of TOs as well as the survivability of the system during conflict.

The information flows associated with the cataloging and archiving function are shown in Figure 3-4.

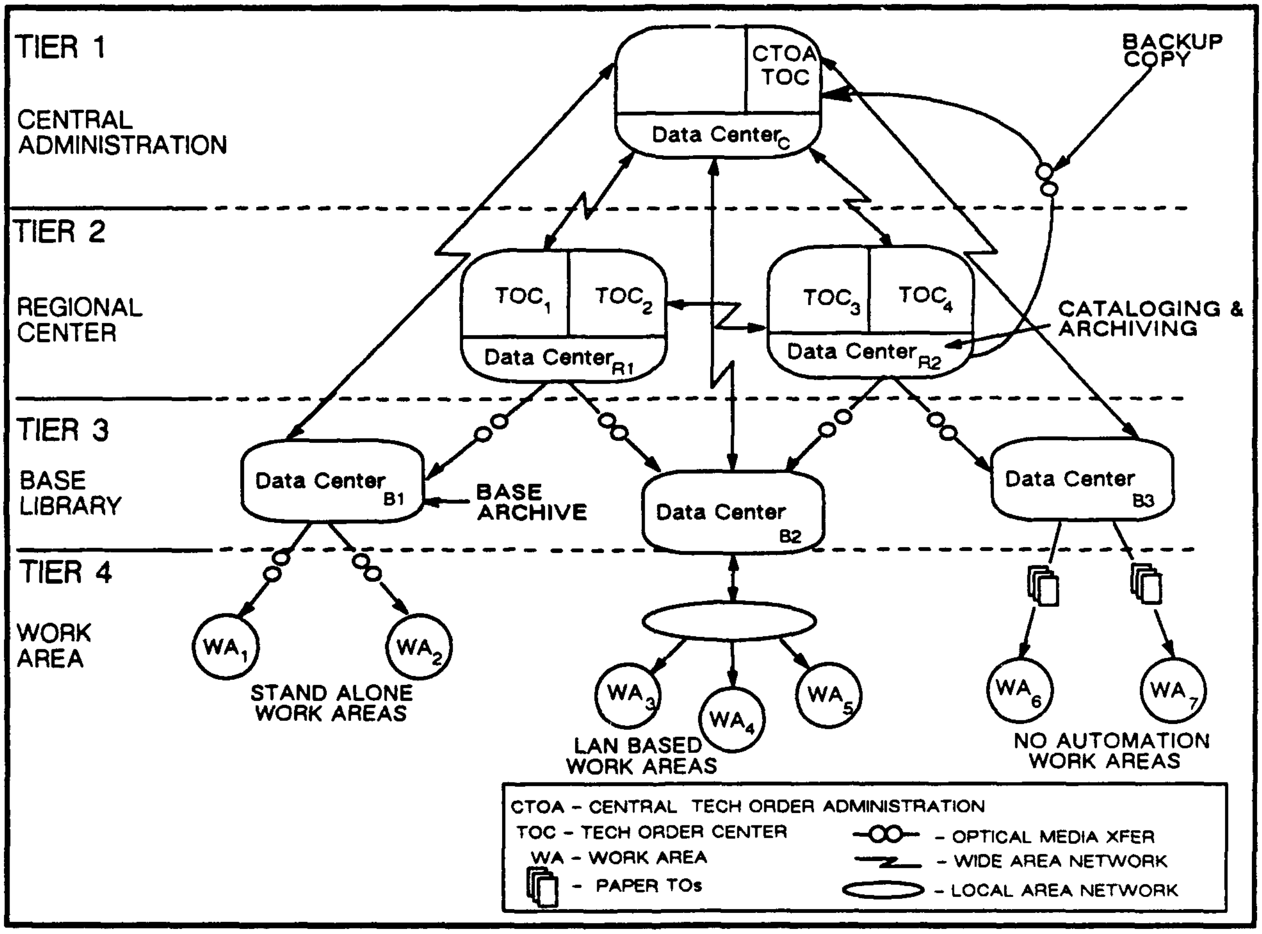


FIGURE 3-4. CATALOGING AND ARCHIVING INFORMATION FLOWS

3.3.2 Function Summary

TOs are cataloged under TOC control and archived at the Regional Data Center. Backup copies of all USAF TOs and catalog identifiers are kept at the CTOA. Work Area TOs are backed up at the Base Libraries.

The key features of this function are:

- The TO archiving strategy provides a complete audit trail or revision history.

- The archived TOs are in non-editable, non-volatile form. New TO revisions can be added to the archives but no changes can be made to the existing archived copies.
- The CTOA maintains backup copies of all Air Force TOs to provide a single central source of all TOs.
- Base Libraries maintain backup copies of all TOs required by their respective Work Areas.
- TO catalog maintenance is performed by the Regional Data Center for its TOC population.

3.4 MASTER CATALOG MAINTENANCE

The master cataloging function is analogous to indexes used in current operations and is designed to maintain and to provide an automated listing and cross-reference of all Air Force TOs. The master catalog allows users to log onto their local system and locate individual TOs that may or may not be in their local inventory. Figure 3-5 shows the information flows associated with master catalog maintenance.

3.4.1 Operational Description

The master catalog is prepared, managed and distributed by the CTOA DC. This catalog is copied onto optical discs and follows the same distribution path as TOs (see Section 3.5). Since CTOA has TOC responsibility of its own for the planning, development, and review of policy and procedural TOs, the CTOA DC has the same optical disc production and communication facilities as Regional Data Centers.

As described in Section 3.3, Cataloging and Archiving, each TOC maintains the catalog descriptions of its TO suite at the Regional Data Center. Up-to-date catalogs are transmitted to the CTOA DC at defined intervals. At the CTOA, a master catalog is regularly compiled from these inputs. The master catalog lists and cross references all Air Force TOs by system and subsystem.

On a regular and as needed basis, the master catalog is delivered to the CTOA DC disc production facility where it is written to optical disc. The master catalog is distributed to all Base Libraries where it is mounted on the base LAN file server. Work Area users may access the catalog information on-line via a gateway from the Work Area LAN or via remote terminal access. In addition, master catalog discs may be ordered for large Work Areas equipped with their own optical disc readers and file servers. Non-automated Work Areas may request the Base Library to print parts of the master catalog for paper distribution.

3.4.2 Function Summary

Individual TO catalog maintenance activity for a weapon system is performed by the TOC at its Regional Data Center. TO catalog information is transferred to CTOA where a

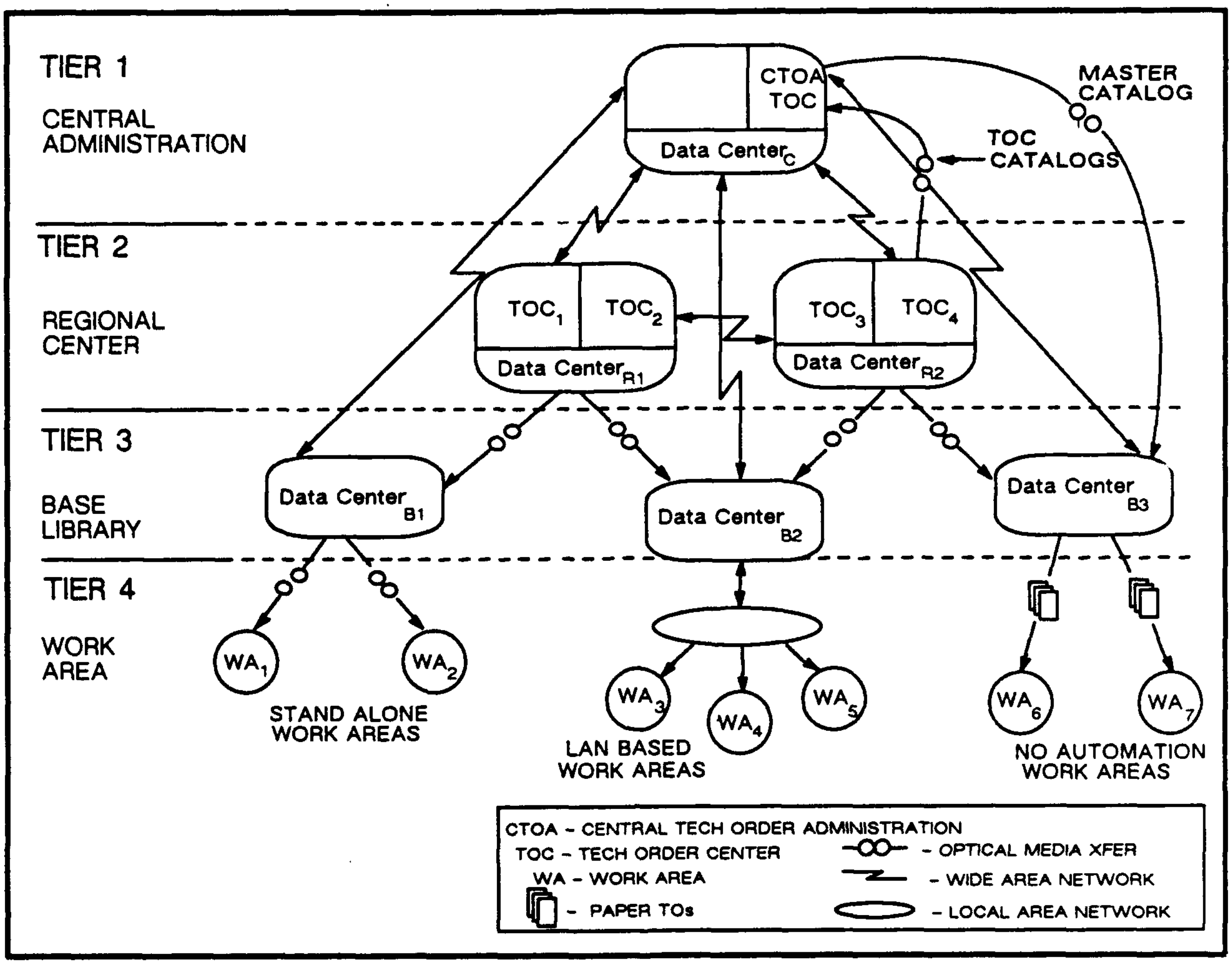


FIGURE 3-5. MASTER CATALOGING INFORMATION FLOWS

master catalog of the entire Air Force TO inventory is managed and maintained. The CTOA distributes the master index, on a regular basis, to the Base Libraries on optical disc where it is made available to the Work Areas.

The key features of this function are:

- The master catalog is compiled by the CTOA from inputs received from Regional Data Centers.
- The master catalog is archived by the CTOA Data Center.
- The master catalog is distributed to the Base Libraries on optical disc.
- Base Libraries have sort/retrieval software that enables Work Area users to produce customized index information from the master catalog.
- Work Areas may receive master catalog information in paper, optical media, or on-line form.

3.5 DISTRIBUTION

The distribution function of AFTOMS is designed to provide a timely, efficient, secure, and cost effective delivery of TOs to the end user. The Work Area users will regularly receive the appropriate TOs on medium that matches the computer resources available at that level. Therefore, AFTOMS distribution will allow the Work Area to receive printed copies (paper), on-line document files over LAN connected Work Areas, or optical disc for Work Areas with stand alone systems. Optical disc is the prime medium for the physical storage and distribution of TOs to the Base Libraries. Analysis of telecommunications facilities including the Defense Data Network (DDN) and dedicated high speed circuits result in either over-utilization or cost prohibitive solutions for on-line transfer (see Appendix E). Since receipt of TOs within a 24-hour period is considered acceptable to Work Areas, physical delivery by parcel express was chosen. Such response is much quicker than the current process, which requires several days to several weeks to accomplish. Optical disc is cost effective since it doubles as the storage and delivery media. Transmission of shorter time-compliant TO data will take place over the DDN and be followed up by optical disc distribution at the next regular interval.

Optical disc technology has matured to the point that today a single disc can store up to 800 TOs. It is projected that, by 1993, an average of 2,335 TOs can potentially be stored on a single disk. The complete suite of F-16 TOs (750,000 pages), which represents a very large weapon system, can presently be stored on approximately 12 optical discs. The large storage capacity of optical discs makes the overhead associated with retaining the complete revision history of TOs practical. Based on this research, AFTOMS uses physical delivery of discs to distribute TOs. For more information on optical disc technology, see Appendix B.

3.5.1 Operational Description

The Data Centers located at CTOA and the Regional Centers are responsible for producing optical discs for their respective TOCs. After a number of revisions have been made, the TOC requests the Data Center to distribute the updated suite of archived TOs (most likely according to a regular interval schedule). The specific suite of subsystem TOs that reside on each disc is determined during the Planning and Development phase discussed in Section 3.6. The Data Center moves the updated TO suite from on-line storage to the optical disc mastering system (formatting software). The information stored on the mastering system is used to produce two master copies, one of which is kept for archival storage and the other is sent to the Air Force optical disc production facility.

The production facility returns the master as well as the requested optical discs to the Regional Data Center. The master and archival discs are kept at the Regional Data Center until the next update. Optical discs are then distributed via US mail or 24-hour carrier to those Base Libraries registered with the TOC. The CTOA receives a copy of each optical disc for its archive.

Large Base Libraries, with LAN capabilities, mount a copy of each optical disc on their system file servers or jukeboxes for on-line access by high speed system printers (see Appendix C), terminal display, and bridged Work Area LANS (see Appendix E). Stand alone automated Work Areas receive optical discs of their own for system access, display and printing. Non-automated Work Areas receive printed copies of TOs prepared by the Base Library printers. Base Libraries serving small user communities may use optical disc players to display and print TOs on demand. Publishing software residing at print server locations enables the user to print any version of the TO from the historical data residing on the optical disc. Figure 3-6 shows the optical disc production and delivery system.

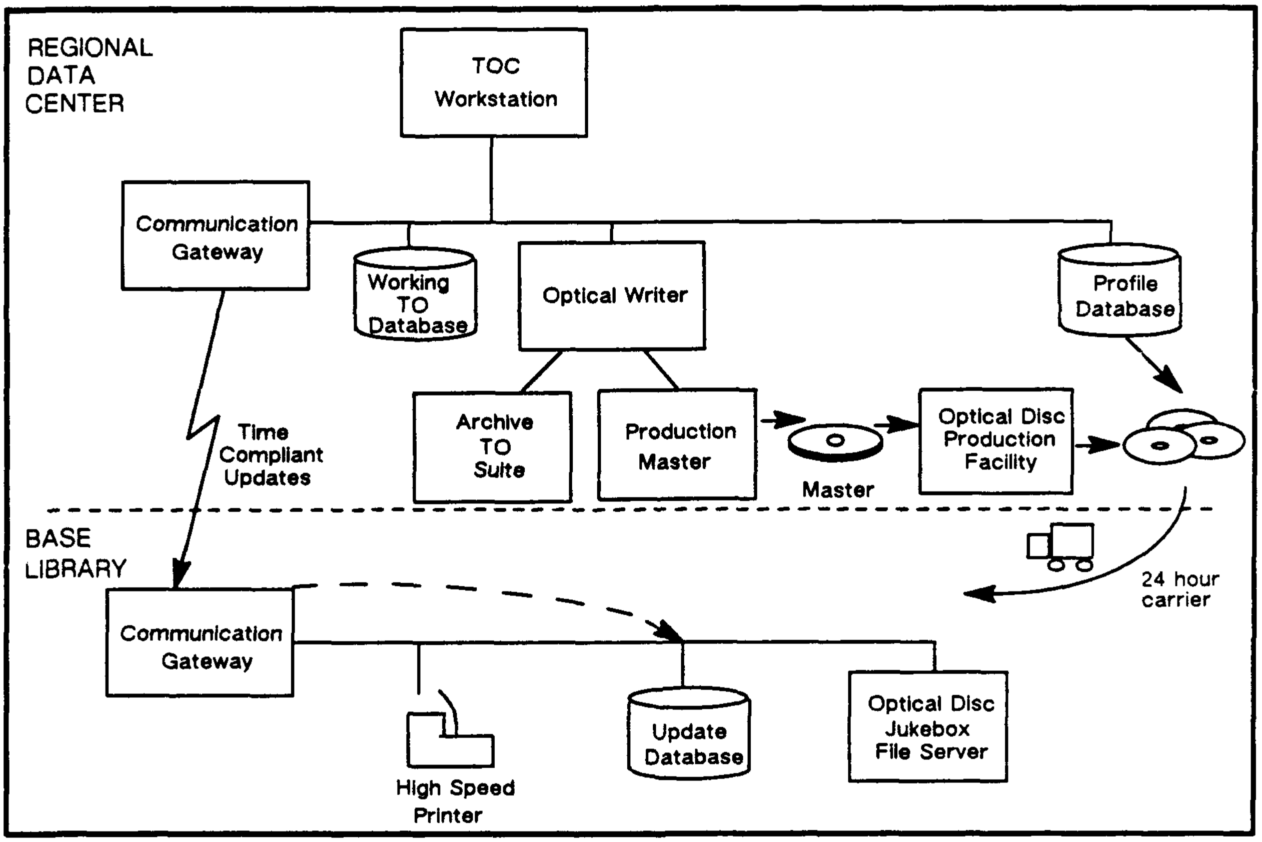


FIGURE 3-6. OPTICAL DISC PRODUCTION AND DELIVERY SYSTEM

3.5.2 Distribution of Updates

Since the production of optical discs occurs only when a sufficient number of TO changes have accumulated to warrant its expense, a method must be developed to distribute timely updates. TO updates, approved by the TOC for distribution, are transmitted via wide area communications (e.g. DDN) to the Base Library. The Base Library Data Center writes this data locally to various storage media. When queried, the sort and retrieval software that operates on the Base Library file server automatically checks the supplemental storage media for updates before calling up the TO from the optical disc. In this manner, integration and distribution of updates (change packages) is performed automatically by AFTOMS, thereby eliminating manual posting of updates.

3.5.3 Function Summary

In summary, TOs are distributed by TOCs to the Base Libraries on optical disc media. The Base Libraries then provide the TOs to individual Work Areas in paper, optical disc, or on-line (LAN) form. The end user uses the print-on-demand or display capabilities of the Base Library or Work Area to print or display the TO.

The key features of this function are:

- Production of optical discs containing TOs is the responsibility of the Regional TOC Data Center.
- Optical discs contain the complete revision history of each TO.
- Retrieval software enables any version of the TO to be printed from the historical data residing on the disc. Thus, the tedious task of "posting" is eliminated.
- The large storage capacity of optical disc media allows users to receive the complete suite of TOs for that weapon system or subsystem. This eliminates incorrect or incomplete distribution.
- The Base Library has the ability to distribute TOs to the Work Areas in any of three forms: paper, disc, or on-line.

3.6 PLANNING, DEVELOPMENT, AND REVIEW

Currently, the acquisition of new TOs involves a lengthy paper based planning, development, and review process involving the prime Contractor, SPO, ALC, and the MAJCOM. The prime Contractor is the defense Contractor who is the main developer of the weapon system. The SPO is the AFSC contract manager and the MAJCOM is the AF Command for which the weapon system is being developed (e.g. the C-17 for MAC, the ATF for TAC). The existing process involves many meetings, paper document exchanges, and In-Process Review (IPR) conferences organized under the direction of the SPO TOMA. Due to the time constraints involved in coordinating meeting schedules, TOs are often delivered after the weapon system has been commissioned for duty at Program Management Responsibility Transfer (PMRT). At PMRT, the TO management function is transferred from AFSC to AFLC.

AFTOMS significantly changes this process by making the TOC responsible for providing centralized control of TO acquisition at weapon system program inception. A TOC is identified for overall management during weapon system development and it remains in this role through its entire life cycle. To streamline the acquisition process, the TOC uses the resources of its Regional Data Center. Telecommunications, Data Base Management Systems (DBMS) and Document Management Systems (DMS) are the key technologies to be used (see Appendices D, E, and F).

3.6.1 Operational Description

The TOC creates a weapon system TO planning data base at its Regional Data Center. This common data base is made available via telecommunications to the authorized Contractor, SPO, and MAJCOM staff responsible for the development and review process. The TO document itself is reviewed and edited under the control of a DMS (Document Management System). By using DMS, the automation and control of TO development begins at the planning stage. The DMS is sophisticated technical publication software that allows both engineering and configuration management data bases to be tapped for integration into a single document. Changes to an engineering drawing are automatically reflected in the document. DMS provides a complete audit trail of all pending and accepted changes. One powerful feature of DMS is the capability for the TOC-based editor to distribute multiple copies of a TO for on-line IPR review. Each participant can mark-up the document, make margin notes and review the edits of others. Submitted changes can be called up by the TOC and integrated or distributed as the review process requires. Figure 3-7 presents a planning, development, and review configuration.

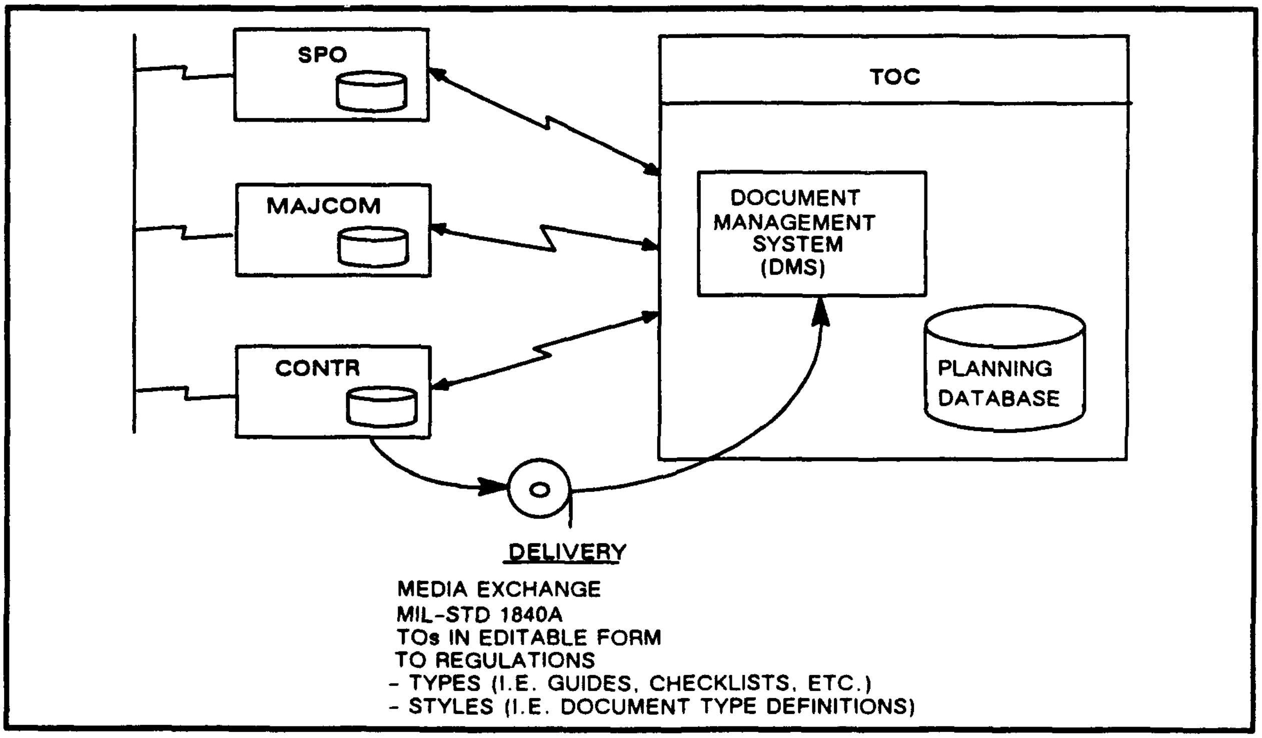


FIGURE 3-7. PLANNING, DEVELOPMENT, AND REVIEW CONFIGURATION

3.6.2 Skeletal TOs

To initiate the acquisition process, the TOC calls up a standardized screen listing requirement categories and format specifications (skeletal TO). The TOC can modify the standards at the beginning of the planning effort. As the TOC coordinates various participants (MAJCOM, TOC, SPO, Contractor) in retrieving and reviewing requirements, the skeletal TOs evolve into a package to be used for proposal and subsequent evaluation of the Contractor's responses. Much of this information can be acquired from the contractual documents and entered automatically into the Planning Data Base

3.6.3 Requirements Review

Interactive review via electronic mail and DMS software allows participants to work effectively with the TOC to identify, define, review and establish TO requirements. Using the skeletal TO concept, participants can enter their own individual requirements, propose and review changes, and even vote on disagreements. While not expected to displace all face-to-face or table top meetings, interactive review performed on-line provides inexpensive access to preparation materials and permits frequent review, thus shortening the time for this step in the cycle.

3.6.4 Numbering and Indexing

Once the Technical Manual Plan (TMP) has been completed and accepted by all parties, the numbering and indexing of TOs can begin concurrently with TO development. Number selection is triggered by the contract award and the approval process is done via a terminal. Once a number is assigned, it is automatically recorded in the planning data base index and transmitted to all groups.

3.6.5 In-Process Review, Validation and Verification

In-Process Reviews are carried out under the control of the TOC based DMS. Reviewers can submit their proposed document changes to the TOC. Using a DMS, the TOC editor can view all suggested changes simultaneously. Once a set of changes has been approved, the TOC editor can command the DMS to commit them to the TO. The DMS automatically updates all references to any item that changes throughout the TO and provides a document change audit trail.

Both validation and verification of TOs are performed using this computer support. As the Contractor is developing the TOs, the TOC and other designated participants are able to monitor the progress interactively. As the TOs move from validation by the Contractor to verification by the Air Force, an on-going review process can be maintained and controlled by computer processes, as opposed to manual means.

3.6.6 Contractual Acceptance

After changes based on verification activities are made, the Air Force reviews the final TO interactively. Readability and comprehensibility are evaluated by participants processing digitized TOs from their terminals. Pre and post publication reviews will be simplified due to computer support.

3.6.7 Digital Delivery

The final transfer of the weapon system suite of TOs is accomplished when the Contractor delivers the final TO to the Air Force. All digital TOs are delivered in MIL-STD-1840A format. The TO digital data received by the TOC is then moved into the TOC source (working) data base.

3.6.8 Function Summary

Planning, development, and review functions comprise the creation activity for new TOs. There is a high degree of interaction between the TOC, prime Contractor, SPO, and MAJCOM. These functions are conducted in a more automated, interactive manner than the current means (meetings, paper document exchange, review conferences, etc.) and result in high quality TOs produced in a more timely, cost efficient manner.

The key points of this function are:

- Major contributing organizations are linked via telecommunications and participating facilities can access a common planning data base at the TOC.
- At any stage, each organization can independently perform reviews on-line. Therefore, most issues can be resolved prior to the formal review conference.
- Exchange of relevant information among organizations occurs without delay.
- Electronic mail and wide area communications, planning data base, standard delivery interface and regulations, and Document Management Systems are major technologies that streamline this process.

3.7 CHANGE MANAGEMENT

The change management function, as illustrated in Figure 3-8, automates the revision of TOs. The Document Management System (DMS), used by the TOCs in the development stage, continues to provide the control vehicle for making TO changes.

3.7.1 Operational Description

Upon noting a deficiency in a TO, a Work Area user completes an automated version of the current Air Force Tech Order (AFTO) Form 22. For non-automated Work Areas this form is completed by the Base Library Data Center. All Work Area change requests are sent to the Base Library where they are logged and transmitted to the CTOA Data Center.

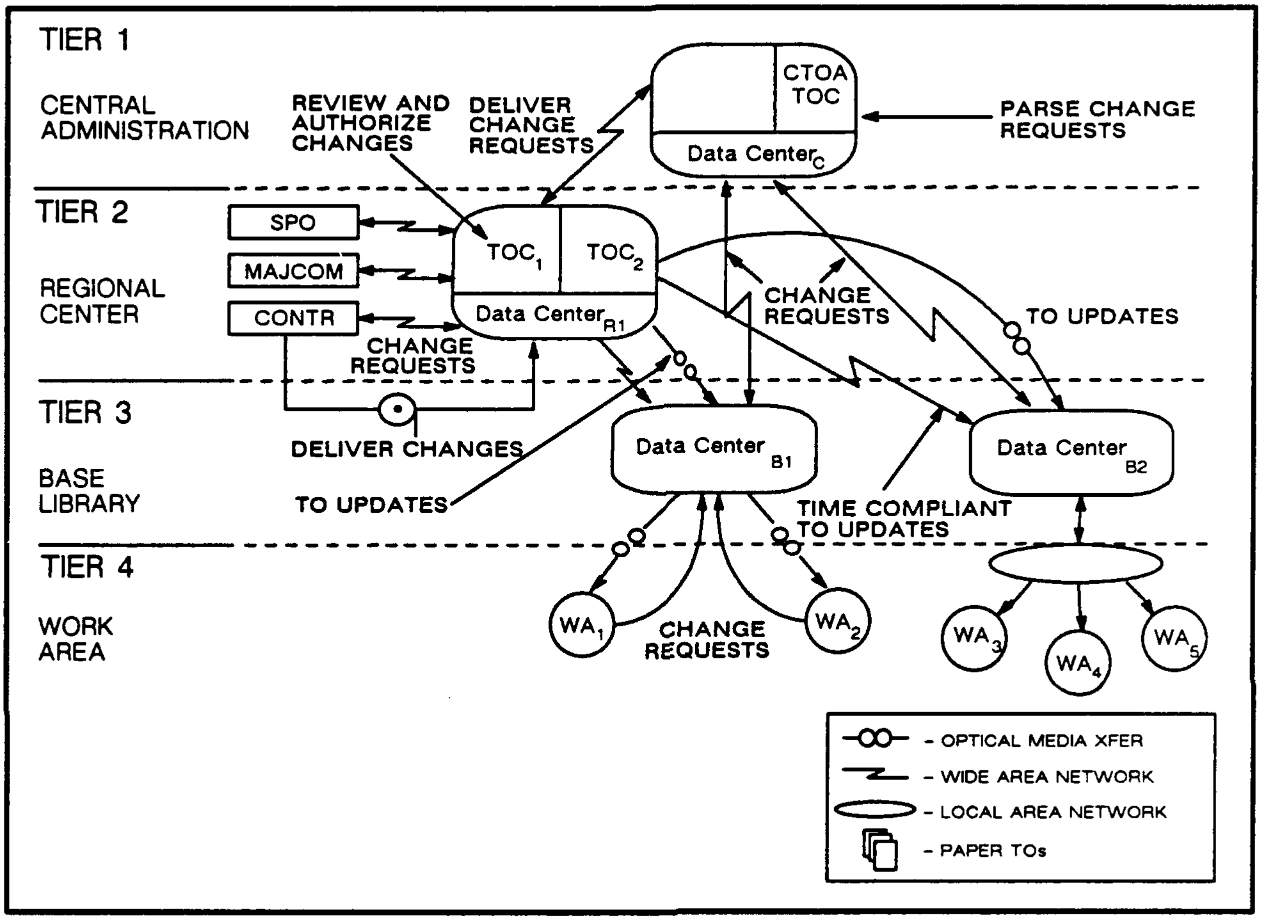


FIGURE 3-8. CHANGE MANAGEMENT CYCLE

The CTOA Data Center logs the incoming requests and parses them out to the responsible TOC. At the TOC, change requests received from Air Force users are merged with those generated by the Contractor (e.g. change design request). The TOC places the requests into a change data base for review. TOC and MAJCOM staff view the requests on-line and determine what action should be taken.

If a change is to be made, the TOC distributes electronic copies of the change request and the TO to the appropriate AF and/or Contractor engineering staff. The DMS allows Contractor, MAJCOM, and TOC staff to submit changes interactively, on-line to the TOC data base. Under the direction of the TOC editor, reviewers can then access draft changes for on-line review, acceptance, or revision. The technical content manager approves/disapproves a change to the TO. Once approved, the Contractor delivers the revised TO to the TOC, similar to the process for new TOs.

The TOC places the revision into the source data base where it is appropriately numbered, indexed, and cataloged. When the change is time critical, the change package is transmitted via the telecommunication facility to all Base Libraries registered for the affected TO(s). Normally, the changes are distributed on optical disc.

3.7.2 Function Summary

The change management function deals with filing change requests, review and authorization of change requests, preparation of (draft) changes and review of the changes. This process involves a high degree of interaction among the TOC, SPO, MAJCOM, and Contractor. A change request data base, telecommunications, and Document Management System are used to automate the function. The key points are:

- The major organizations (SPO, MAJCOM, TOC, and Contractor) are linked via telecommunications and can conduct change request/authorization processes interactively.
- The TOC maintains an approved change request data base, which can be accessed by other participants.
- Exchange of relevant information among organizations can occur without delay.
- Time critical TOs can be distributed on–line.

3.8 CONVERSION OF EXISTING TECH ORDERS

The AFTOMS concept maps activities into six basic functions. In this chapter, each of these functions were described based on the premise that the Tech Orders were page–oriented and entered AFTOMS in digital form (Type B). This would be a typical scenario for Tech Orders created in the 1990s. However, approximately 150,000 Tech Orders already exist in paper form (Type A) and will fall under the management responsibility of AFTOMS. This section deals with the technical, managerial, and economic options for Type A Tech Orders.

Conversion of Tech Orders into digital form is a desirable objective since it will allow AFTOMS to perform the six major functions on these Tech Orders in the exact, automated fashion as if they entered in Type B fashion. Simply stated, conversion takes place once and from that time on, AFTOMS is unaware that they were previously Type A Tech Orders. While this is the optimal objective with respect to the management of Type A Tech Orders, it cannot always occur for a variety of technical and economic reasons. Therefore, other options must be identified.

CONVERSION OPTIONS

The AFTOMS concept proposes management of Tech Orders by weapon system (TOC). Each TOC will choose a Type A conversion approach, from the four options listed below, based on factors unique to that weapon system program and its associated Tech Orders.

OPTION 1 - Full Weapon System Document Conversion To Type B

All the Tech Orders are document scanned and converted into a digital form so that they can be packaged and delivered into AFTOMS according to MIL-STD-1840A format.

OPTION 2 - Partial Weapon System Document Conversion To Type B

Some of the Tech Orders are document scanned, as described in Option 1, and the remaining TOs are image scanned. All the Tech Orders are delivered in hybrid digital form to AFTOMS, however, change management cannot be automatically conducted on the image scanned Tech Orders. Digital delivery of TOs allows for automated distribution.

OPTION 3 - No Weapon System Document Conversion To Type B

All the Tech Orders are image scanned, as described in Option 2.

OPTION 4 - No Scanning

None of the Tech Orders are document scanned or image scanned, nor are they digitally delivered to AFTOMS. Only the ordering, management and cataloging information for these Tech Orders reside in AFTOMS.

A more detailed breakdown of the Type A processing shown in Figure 3-1, "Common System Functions", is presented in Figure 3-9.

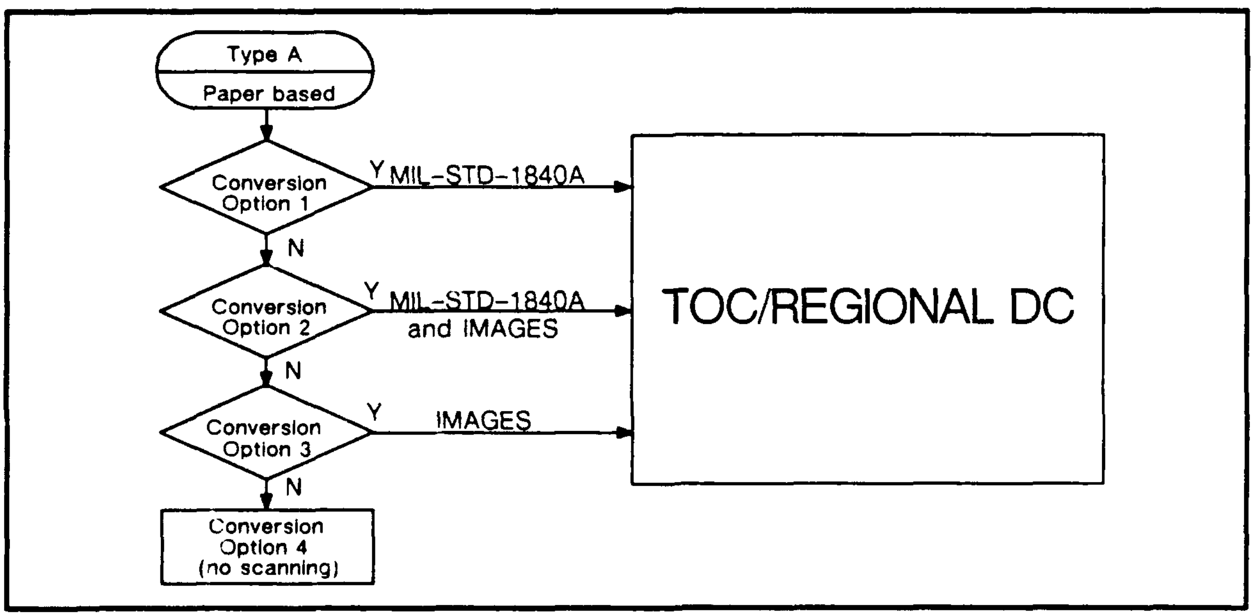


FIGURE 3-9. TYPE A CONVERSION PROCESSING

Depending on the Conversion Option selected by a TOC, the degree of automation that can be applied to the subsequent management of the Tech Orders will vary. Table 3-1 compares the Conversion Options by function.

FUNCTION	CONVERSION OPTIONS			
	1	2	3	4
PROFILE REGISTRATION/ORDERING	X	X	X	X
ACQUISITION	X	X	X	
CATALOGING	X	X	X	X
ARCHIVING	X	X	X	
OPTICAL DISTRIBUTION	X	X	X	
PAPER DISTRIBUTION				X
DEMAND PRINT	X	X	X	
SCREEN DISPLAY	X	X	X	
CHANGE MANAGEMENT	X	Partial		

TABLE 3-1. CONVERSION OPTIONS BY FUNCTION

3.9 TYPE C INTEGRATION

The AFTOMS functions described in this section are designed to manage and distribute Type C TOs when they become available. Type C TOs will be delivered to the Air Force by the Contractor in digital form but presented to the end user via electronic display in the form of discrete "information units". Type C TOs will present material, tailored to the user's technical skill and reading level, in a dynamic on-screen fashion.

The Air Force Integrated Maintenance Information System (IMIS) program, run by the Air Force Human Resources Laboratory (AFHRL), is conducting a research program which will lead to Type C TO capabilities. It is anticipated that these TOs will be implemented with the use of emerging technologies that include hypertext and videodisc (see Appendix G). Creation of Type C TOs will require specialized authoring/development systems which allow trained authors to build user directed branching and stop points and to simulate the way users will interact with the system.

The common functions of AFTOMS will integrate all types of Air Force TOs. Since Type C TOs are received and used in digital form, the computer systems provided by all tier level Data Centers will be capable of managing and distributing these TOs in the same fashion as Type B. TOCs that have Type C TOs in their inventory will require specialized authoring systems for the planning, development, review and change of this suite of TOs. All Data Center functions, such as registration, cataloging, archiving, and distribution on optical disc remain the same.

It is not until Type C TOs are used at the Work Area that specialized work stations with sophisticated human interfaces may be required. Therefore, other than the specialized authoring and delivery systems, the management of Type C TOs remain transparent to AFTOMS. Due to the complexity of the technology, presentation, and training issues related to these TOs, the Air Force should not expect to achieve routine production of Type C TOs for at least ten years.

3.10 SYSTEM SUMMARY

The AFTOMS concept was designed to be an integrated solution that can accommodate all types (A, B, and C) of TOs. It allows the automation of each type to proceed at the pace of technological advances. Conversion of paper (Type A) TOs via scanning to Type B TOs can be decided on a weapon system life cycle basis. The system concept is designed to accept Type C TOs when they become available.

The four-tier architecture supports the automation of all major functions from planning through support without major infrastructure changes. The simplification and streamlining of TO life cycle management is based on selected use of optical disc media, document management systems, publishing systems, and telecommunications, which are today's emerging technologies. This use of automation returns some of the maintenance and operations personnel of the Commands to their work specialties. A career path is established within the Air Force for computer management and operational specialists supporting technical publications expanding into technical information.

With AFTOMS, the acquisition process is standardized and the management and the operations of the CTOA and TOCs are consistent. The system, as a whole, provides a simple user interface for interacting with the TO process. Work Areas are able to automate at their own discretion and within their respective budgets. Automation flexibility at the Work Area level allows various commands to proceed at their own pace and to select configurations that best suit their needs. Common system configurations end at the Base Library tier. The major strengths of the AFTOMS are:

- An intelligent distribution strategy is based on user Work Area profiles.
- Planning, review, and change management occur on-line.
- Common TOC system configurations provide one uniform method of manufacturing and distributing TOs.
- The modular architecture is designed to support automated systems of today and tomorrow.
- The infrastructure to accept and integrate digital TO data from the Contractor is in place.

CHAPTER 4: IMPLEMENTATION STRATEGY

4.1 INTRODUCTION

This chapter presents organizational framework and an outline of the recommended implementation strategy for AFTOMS. Based on the technological and organizational components of the automation plan, the key steps involved in implementing the proposed concept are developed.

The operation of the AFTOMS concept will have a major impact on the organizational and management processes within the Air Force. Its significance derives not only from the changes in the use of technology for processing Tech Order information, but also from the corresponding organizational changes required to support the proposed plan. Increased operational efficiency in information flows and strategic benefits to the Air Force in achieving its overall objectives (increased weapons system readiness and aircraft availability) are expected benefits of AFTOMS.

Successful implementation of new information technology involves three major components: strategy, technology, and organization. Technology without adequate organizational infrastructure cannot succeed. Similarly, availability of technological and/or organizational resources alone cannot lead to planned change. By carefully delineating the strategic, technological, and organizational aspects, the likelihood of success will increase. The interrelationship of these components in the TO Automation Plan is depicted in Figure 4-1.

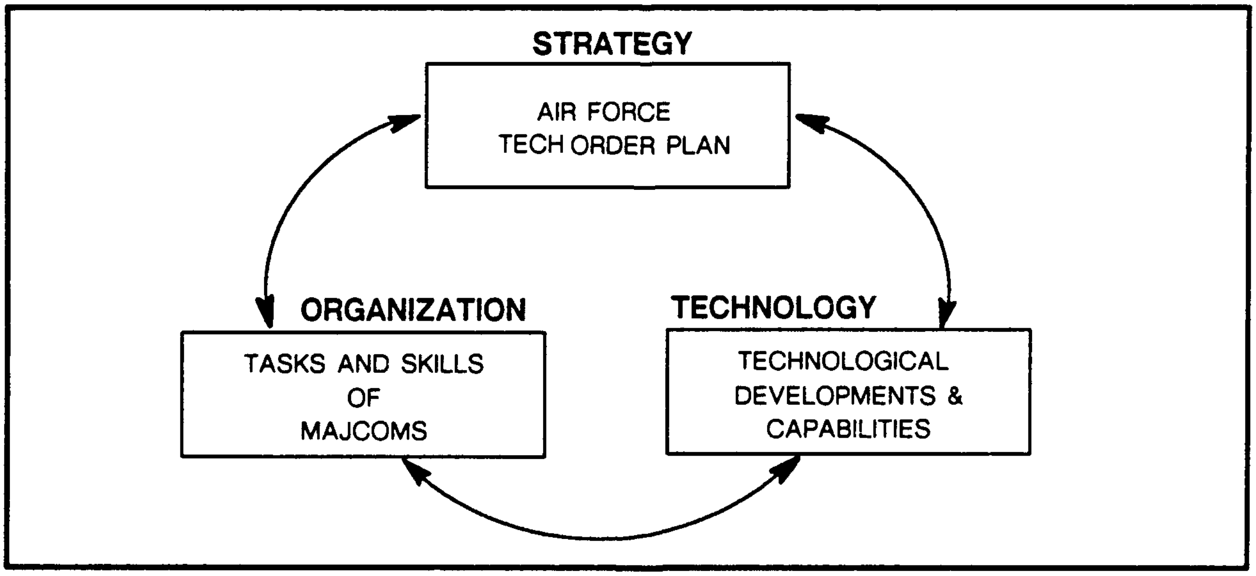


FIGURE 4-1. ALIGNMENT FOR TECH ORDER AUTOMATION

Given the strategic potential of this activity, the AFTOMS concept requires new levels and types of technical capabilities, as well as appropriate changes in the tasks and skills of the

MAJCOMs. The experience of the private sector in dealing with significant technological changes has shown that new technological initiatives without appropriate organizational adjustments (changes in the skills of the staff, shifts in the management processes, and adjustments in reporting relationships and responsibilities) rarely meet with success. Recognizing that organizational changes in the Air Force are difficult, and carry high levels of hidden costs, an automation scheme which minimizes organizational changes should be emphasized. It is essential to identify a central administrative authority, as early as possible, to monitor the alignment of technological and organizational changes.

4.2 IMPLEMENTATION GOALS

The specific set of goals for AFTOMS implementation are:

- *Adapting Relevant Technologies*. Adapt relevant technologies which will enable digital production, management, and distribution of Tech Orders. This effort should be based on emerging and mature technologies to allow timely, low-risk implementation.

- *Deploying the System in a Modular Fashion*. The system concept should be both flexible and modular, and permit incremental improvements and enhancements over a 20–30 year timespan. As new technologies become commercially available on an off-the-shelf basis, it must be feasible to incorporate these innovations into the continuously evolving Tech Order system in a responsive and cost effective manner.

- *Fitting the System to Air Force Organization*. This goal is to match technological capabilities and organizational requirements. The focus should be neither on adapting a single configuration for the entire Air Force, nor on the creation of an entirely new organization to accommodate newly implemented technologies.

- *Handling Existing and Future Technical Information*. The AFTOMS automation plan permits current TOs to co-exist with future TOs. The implementation strategy should include the management of all three types of TOs. Further, the process of converting one type of TO to another must also be facilitated.

4.3 IMPLEMENTATION STRATEGY, STAGES AND SCHEDULES

Implementation of AFTOMS involves acceptance of a new conceptual approach, acquisition of adequate off-the-shelf hardware and software, selection and adoption of pilot programs, and reorientation of organizational and technological resources that currently relate to TOs. These factors and procedures have been taken into account while formulating the implementation strategy.

4.3.1 Establishing a Central Tech Order Administration

The most important requirement for the successful implementation of AFTOMS is the identification of a specific authority for managing and coordinating the implementation process. This is necessary to ensure that the initial, critical steps in the implementation plan are carried out as efficiently as possible. In addition, the establishment of the coordinating and administering agency signals the level of commitment to this activity relative to other activities within the Air Force. A single, centralized body should be responsible for overseeing the implementation and the operation of AFTOMS in the next decade. A centralized authority is required because:

- The strategic :mportance of this plan is such that an organizational unit should be created that is exclusively responsible for implementing the automation plan.
- Specific responsibility for the completion of the plan can be identified. This reduces the potential of deviating from the plan because of coordination lapses and diffused authority.

The need for an early establishment of a Central Tech Order Administration (CTOA) cannot be overemphasized in the context of the implementation process.

4.3.2 Major Steps in AFTOMS Implementation

The creation of the new TO system, and the transition from the present system to the new system needs to be conducted in a manner that ensures adequate testing of key components and allows the development activities to be carefully controlled and monitored. The system development of AFTOMS has therefore been o' anized into three distinct system phases:

DEMONSTRATION SYSTEM

This system involves linking a small suite of hardware and software components for: (a) determining technology feasibility and effectiveness; (b) examining the viability of automation and user interface from a technical perspective; and (c) providing first-cut cost benefit data. The demonstration system development will be conducted in a controlled environment by designers and developers, and not by end users.

PILOT SUBSYSTEM

This stage involves installing a significant suite of hardware and software components for: (a) simulating real world use; (b) identifying and resolving operational problems; (c) identifying training needs and developing a training plan for the users; and (d) obtaining user feedback. Implementation is to be carried out along a complete vertical thread of the organization (from the CTOA in Tier 1 to Work Areas in Tier 4). This vertical set of activities is necessary to understand operational issues such as, the effectiveness of user interfaces, changes in tasks and roles, and shifts in coordination and management roles. The task will be conducted in the user environment by a team consisting of designers, developers, and users.

PRODUCTION SYSTEM

This system represents the extension of pilot activities into a fuller, operational mode. It involves fielding the full configuration and conducting operations using the new configuration. The single vertical thread of the pilot system is expanded to multiple, inter-connected vertical threads that cover the entire Air Force.

All systems should be developed in accordance with the above descriptions. However, it is not necessary that all demonstration systems or pilot systems be developed simultaneously. In fact, some systems should be developed prior to others. For example, the demonstration system for converting Type A Tech Orders to Type B Tech Orders can be developed earlier than the demonstration system for creating Type C Tech Orders.

4.3.3 Initial Schedule for Implementation Activities

The implementation schedule for AFTOMS should be guided by the evolutionary growth of management responsibilities of the CTOAs. Since the CTOA consolidates several major functions within its span of control, it must gradually expand its responsibilities to effectively oversee the development and operations of AFTOMS and align the organizational infrastructure with technological capabilities. The major implementation activities and schedules are as follows:

Time Period	Implementation Phase	Activities	System	CTOA Responsibility
1988–1990	Initial Development	Mission Element Needs Statement (MENS) Functional Requirements Organizational Requirements	Demonstration	Centralized Guidance
1991–1992	Final Development	Develop/Test Operational Test	Pilot	Centralized Control
1993–1995	Installation	Incremental Deployment	Production	Centralized Control

Figure 4-2 illustrates the timeframe for major activity implementation.

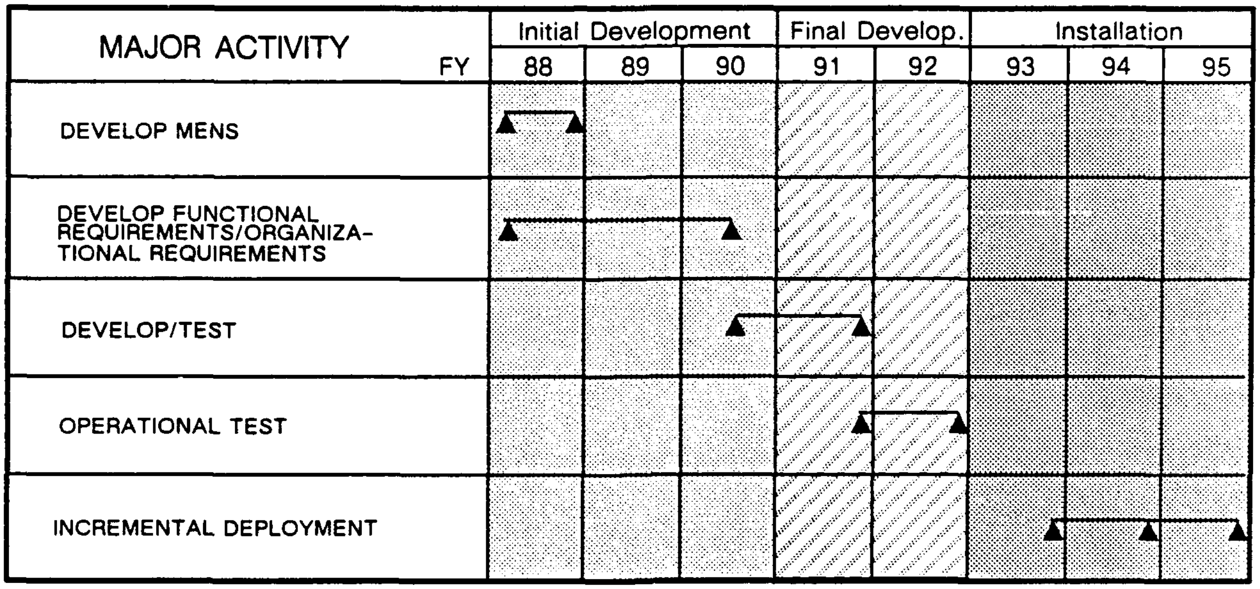


FIGURE 4-2. AFTOMS IMPLEMENTATION SCHEDULE

4.4 INITIAL DEVELOPMENT: CENTRALIZED GUIDANCE (1988-1990)

During Initial Development, a Mission Element Needs Statement (MENS) will be written in which both the functional and organizational requirements will be defined. To support these activities, several technological and organizational activities will begin. The technical capabilities of converting Type A Tech Orders to Type B Tech Orders will be demonstrated. Although there is strong evidence that the required technological capabilities are available, it is important that such capability be demonstrated within the context of the Air Force requirements. Development of a Type B demonstration system as well as initial design of a Type C demonstration will also occur.

The organizational activities will focus on providing a centralized guidance to the technical activities in terms of resource allocation (both financial and physical) and ongoing management and review of the technical activities. More specifically, the organizational activities in this phase will be aimed at efficient management of the key resources which enable the creation of a TO conversion prototype for Type A Tech Orders and a concept prototype for Type B Tech Orders. This efficient management of resources includes the assessment of different options available in technological areas and their appropriateness in the context of Tech Order automation.

4.4.1 Technological Activities

This section offers a synthesis of the technological activities necessary for initial development of the demonstration systems.

TYPE A CONVERSION DEMONSTRATION

This task involves selecting a candidate weapon system that presently maintains its Tech Order inventory in Type A form and is considered to be appropriate for conversion into Type B. Two of the key criteria that are important in this selection decision are the number of distinct Tech Orders (less than 100); and the anticipated life of the weapon system (at least 20 years). It is recommended that the entire suite of Tech Orders for this weapon system be converted to Type B. This will show the effectiveness of the latest technology and ensure that there are minimal coordination problems in the subsequent stages.

This conversion demonstration activity is expected to result in the following:

- *Proof of Technological Capability.* During this activity, it should be possible to demonstrate the capability of scanning technology to convert paper based TOs to digitized document form employing a scanning system linking to a document pagination system.

- *Guidelines for Future Conversions.* Based on this demonstration, it should be possible to develop a set of criteria to evaluate the appropriateness of various weapon systems for conversion to Type B. It is recommended that a document stating the key criteria for the conversion from Type A to Type B be developed.

- *Cost–Benefit Analysis.* The conversion demonstration activities will assist in a systematic calculation of costs and benefits of conversion. It is recommended that this assessment be carefully examined before continuing with further TO conversion.

TYPE B CONCEPT DEMONSTRATION (INCLUDES COMMON SYSTEM FUNCTIONS)

To cover the functional areas described in Chapter 3, this demonstration integrates a wide variety of technological improvements. The requirements of this demonstration are to:

- Test the six major functions of the system concept from an operational and ease of use perspective, as well as proving the technology exists and can be integrated into a system.

- Integrate hardware, software, and communication components. The To-Be Concept Demonstration is based on the ability to integrate relevant pieces of hardware, software, and communication capabilities. Implementation of the demonstration within a controlled environment is expected to provide a preliminary evaluation of these requirements that subsequently can be tested for the functional activities of the Final Development phase.

- Test compatibility and distribution of converted TOs. The converted TOs (from Type A to Type B) must be compatible with the Type B TOs obtained in digital page-oriented format. This compatibility is critical if the overall scheme of TO automation is to succeed. The gradual integration of present TOs with new TOs will lessen the potential problems that can be created by the co-existence of multiple technologies.

TYPE C WEAPON SYSTEM DEMONSTRATION SPECIFICATION

During Initial Development, the CTOA will coordinate the final functional definition and specification of Type C TOs. At this time, the Type C TO strategy is aligned with the current Air Force Integrated Maintenance Information System (IMIS) requirements. However, clearly focused functional objectives, enabling Type C TOs to provide an integrated expert systems approach in accessing technical information need to be established. From these objectives, specifications for a Type C demonstration will be written.

4.4.2 Organizational Activities

In conjunction with the specific technical tasks, key organizational tasks as discussed below, must be carried out. Specific organizational issues and activities during initial development are:

ESTABLISHMENT OF A CENTRAL TECH ORDER ADMINISTRATION

Establishment of a CTOA is the primary and perhaps the most significant organizational activity during initial development. This should be done as early as possible and at a level that reflects the importance attached to this project. Establishment of a CTOA requires:

- *Approval of a CTOA Charter.* A new organization must initially function as a parallel organization (for demonstration activities) without disturbing the existing organizational infrastructure. This is similar to an R&D effort conducted without any appreciable link to ongoing operations. If the feasibility is established, then the new organization needs to be shifted from a parallel operating mode towards consolidation into a single unified organization. Approval of a charter is intended to solidify this authority of the CTOA.

- *Authorize Resources for CTOA.* The successful implementation of this phase requires appropriate resources. While the requirements of technical and financial resources may be straightforward, it is important to emphasize managerial resources. These managerial resources imply institutional support for the overall endeavor. They provide critical encouragement for a set of activities that are bound to encounter an array of operational problems given the scope of the project and the diversity of the user community.

CTOA OPERATIONS

The second set of organizational activities relates to the operations of the CTOA. These are:

- *Completion of Phase I Planning and its Execution.* The AFTOMS concept has been developed in sufficient detail to understand and to appreciate its merits and its role within the Air Force. However, the concept has not been developed to the level of detail necessary to provide a blueprint for action. Concepts and rationale have been introduced without translating them into operational activity details. The CTOA management must translate this plan into detailed operational tasks, with schedules, milestones, costs, and responsibility areas defined.

- *Demonstration Management.* The development of a demonstration system involves both technical and management issues. It is the task of the CTOA to manage development of the demonstration according to the planned schedule.

- *Demonstration Evaluation.* The demonstration system must be evaluated by designated AF commands coordinated by the CTOA. This evaluation will enable the CTOA to recommend continuation, modification, or restructuring of the TO automation plan after Initial Development.

CTOA PLANNING AND ADMINISTRATION

If the demonstrations are considered successful, planning for the Final Development must be carried out. This requires: organizing internal CTOA activities, obtaining resources, and conducting organization planning.

GAIN MAJCOM COMMITMENT

The CTOA must gain the support of the using Major Commands. Since it is the ultimate objective of AFTOMS to provide increased weapon system availability while reducing costs, it will be the MAJCOMS that inevitably judge its success and advocate for base-level implementation.

4.5 FINAL DEVELOPMENT: CENTRALIZED CONTROL (1991-1992)

During Final Development, AFTOMS will be developed and operationally tested. The CTOA will begin control of AFTOMS activities at all four major tiers as the Type B prototype moves from a controlled environment to a full vertical thread implementation with the Type B weapon system pilot. In addition, selected weapon systems with Type A paper based TOs are converted to Type B and the Type C specification develops into a system demonstration.

4.5.1 Technological Activities

TYPE A CONVERSION

In Initial Development, pilot activity for the Type A system focuses on proving the capability of modern scanning technology and document conversion to bring paper TOs into digital files that are managed and updated by Type B, DMS-based systems. Contingent upon the success of this effort, Final Development will expand the Type A demonstration to include additional paper based weapon system TO conversions. The costs and capabilities associated with this process will allow the USAF to establish cost benefit criteria for selecting weapon systems in this category.

TYPE B WEAPON SYSTEMS PILOT

During Final Development, at least one weapon system will be selected for a Type B Pilot and a vertical line of activities will be implemented. As shown in Figure 4-3, all tiers from CTOA to work area levels, will be involved. This represents a major shift from a demonstration (laboratory-type) operation towards implementation of technological changes and the necessary organizational changes. This phase involves the adaptation of both technology and organization to each other in the light of the results of Initial Development.

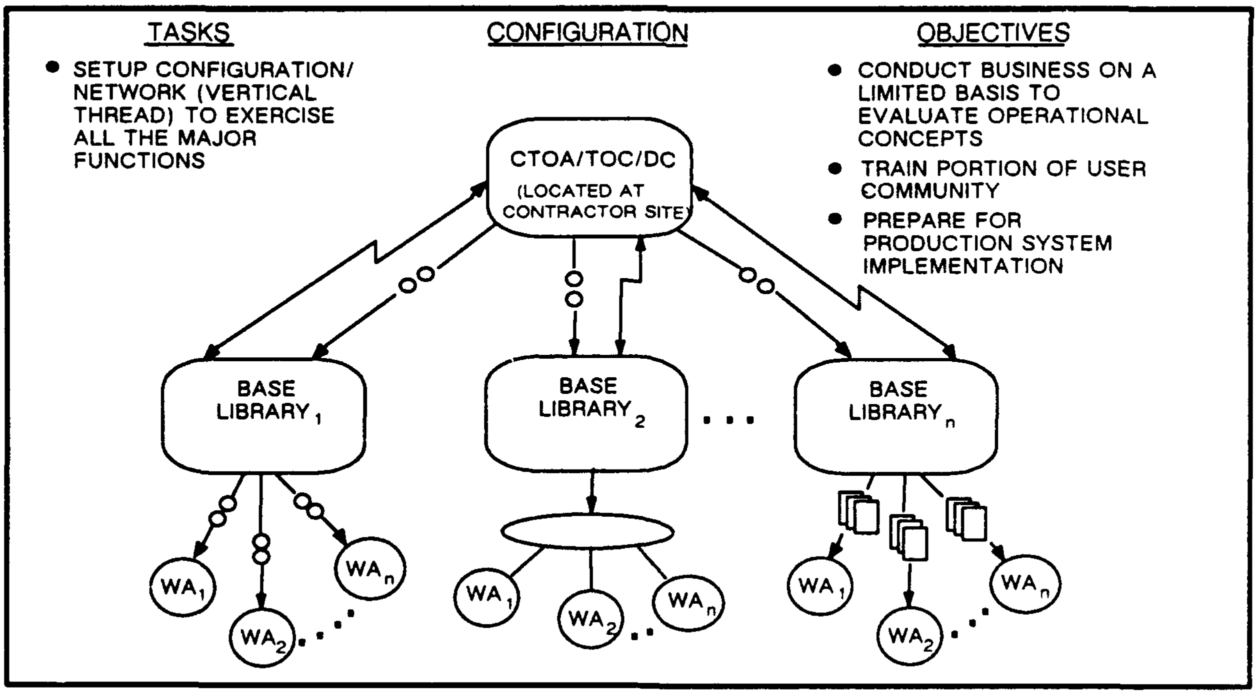


FIGURE 4-3. WEAPON SYSTEM PILOT

The main tasks of the Type B weapon system pilot are related to setting up the required network configuration that would tie the vertical thread together. They are:

- Establishing a TOC and supporting Data Center for a weapon system at the Prime Contractor site.
- Establishing Base Libraries at those operating bases supporting the weapon system.
- Developing Work Area computer facilities that enable on-line access to Base Library functions.
- Providing training to personnel at each tier that guarantees recognition of responsibilities and functional objectives.
- Establishing communication interfaces, capacities, and performance for Wide Area and Local Area Networks.
- Operating all AFTOMS functions for capability assessment.

A limited pilot experiment needs to be conducted to evaluate the operational issues and problems in moving the plan from the demonstration system to the pilot system. It is critical to identify coordination and management problems and issues before implementing the AFTOMS approach on a larger scale within the USAF. Final Development provides an opportunity to test the organizational concepts of centralized control of management and administration activities with the technological goals established for Type A and B Pilot programs.

TYPE C DEVELOPMENT SYSTEM DEMONSTRATION AND TESTING

Type C TOs represent a need for specialized delivery systems. Since this category of TOs uses related information units rather than page-oriented information, the TOC support systems may require additional capabilities for proper review and production. The Type C demonstration will allow evaluation of the effectiveness of Type C TOs and the capability of AFTOMS to provide the common functions with or without modification. Given that the Type C category is a critical component of the AFTOMS plan, it is important to develop a Type C demonstration by the end of the second phase.

4.5.2 Organizational Activities

The specific organizational issues during Final Development are:

FORMALIZE ORGANIZATION

Given the shift from demonstration activities towards pilot activities, it becomes essential to formalize organizational changes. This involves:

- Specification of the organization structure in terms of the new roles and linkages to the existing organization.
- Articulation of roles and responsibilities as well as reporting relationships.

- Specification of systems and procedures for key activities including major areas of resource allocation as well as technical and organizational issues.

CTOA OPERATIONS

The CTOA will expand its functional operation from a focus on guidance to a focus on control. The CTOA will add policy, procedures, and operation to supporting functions that include user profile registration, cataloging, and archiving. The full suite of AFTOMS functions must be benchmarked before full scale implementation can begin.

CTOA PLANNING AND ADMINISTRATION

During Final Development, CTOA planning and administration must be centered on operations and facilities. The CTOA is no longer striving for legitimacy through charter. The CTOA is now developing and managing regional, base, and work area level organizations. Assuming that the Pilot program is proceeding towards a successful conclusion, preparation and planning for full scale deployment of AFTOMS must be completed in this phase.

CAPABILITY ASSESSMENT

Evaluation of both technological capability and organizational appropriateness must be a continuous effort. The CTOA must be ready to adopt new requirements as they arise and dismiss those that prove ineffective.

4.6 INSTALLATION: CENTRALIZED CONTROL WITH DECENTRALIZED OPERATIONS (1993-1995)

Installation marks full production implementation of the Type B system. The complete administration and operational infrastructure must be in place to allow AFTOMS to function as described in this plan. At this point, the USAF has the capability to accept, manage, and use digital technical information from the Contractor for all future weapon systems. The Type C system moves into a pilot program for full evaluation. Sub-tier organizations below the CTOA mature and begin operation on a decentralized basis.

4.6.1 Technological Activities

TYPE B PILOT SYSTEM ENHANCEMENT TO A PRODUCTION SYSTEM

Refinements are made to the Type B Pilot, which allow full implementation. In changing to a production system, Regional Data Centers are installed and configured to support Tech Order Centers (TOCs). It is expected that TOCs will be established individually as the Air Force accepts new weapon systems with Type B TOs and when existing systems are chosen for Type A to Type B conversion. TOCs for Type A TOs (partially automated) also need to be established. Contractor supported TOC activity will be moved to a Regional Center based TOC.

Base Libraries will be established at all bases and configured to match expected Work Area loads. Hardware and software to support Base Library functions and communication links with the CTOA will be installed.

TYPE C WEAPON SYSTEM DEMONSTRATION MOVES TO PILOT

The Demonstration Type C system will answer questions that determine the specialized authoring and delivery systems required by these interactive, expert system type TOs. As the demonstration system is moved to the pilot system, the capability of the production system (Type B) to accommodate common AFTOMS functions for Type C will be tested. The Type C Pilot will provide a complete vertical implementation for the weapon system used during the demonstration stage.

A Type C TOC will be created at a Regional Center and a pilot installation of Type C end user equipment will be performed at Base Libraries and Work Areas that support this weapon system.

4.6.2 Organizational Activities

Installation will drive full development of the four tier AFTOMS organizational infrastructure. As Regional Centers, TOCs, and Base Libraries are configured and become operational, the CTOA will transfer relevant responsibilities to those organizations. The CTOA will position itself as the central management organization. It will be incumbent upon the CTOA to continually evaluate the performance of the system and the integration of Type C TOs into the system.

During this phase the USAF will have a complete top-down organization and system architecture that allows acceptance and delivery of digital TOs to occur regardless of the pace set by Type C innovation.

4.7 SUMMARY

Implementing AFTOMS involves an evolutionary approach which matches technological activity with appropriate organizational support. Integrating technologies into system development involves incremental milestones which progress from controlled laboratory demonstration to a top-down pilot followed by full Air Force production. Organizational activity recognizes the need to establish the CTOA as a fully chartered agency before any AFTOMS implementation can begin. Once established, the CTOA will provide centralized guidance in demonstration projects. This guidance will evolve into full centralized control of AFTOMS administration in subsequent pilot and production phases.

CHAPTER 5: RECOMMENDATIONS

5.1 INTRODUCTION

The AFTOMS plan provides a means by which Air Force Tech Order production, distribution and maintenance can be modernized by the mid 1990s. The automation plan incorporates a modular strategy so that new technology can be introduced within the system in the out-years without changing the new TO management infrastructure. In the short term, co-existence with the current TO technology is facilitated by taking paper TOs into the system for management and distribution or converting them to a digital type. To bring all of the ensuing benefits to the Air Force in a timely, orderly manner, certain organizational, technical, financial and programmatic recommendations are made.

5.2 ORGANIZATIONAL RECOMMENDATIONS

The automation plan covers a 7-10 year period during which a mix of paper based (Type A), digital page-oriented (Type B), and digital discrete information unit Type C TOs co-exist. In the plan, specific duties of acquisition, planning, development and maintenance are designated to Tech Order Centers (TOC). The TOCs are subfacilities within the Regional Centers which provide overall management, facilities, and computer resources for all TOC functions. The creation of the new TO system and the departure from the present system necessitates careful control and monitoring which should come from the centralized authority responsible for planning, developing, demonstrating and managing the TO system. The need for an early establishment of the Central Tech Order Administration (CTOA) as that centralized authority cannot be over emphasized. It is necessary to create and approve the CTOA Charter and authorize the appropriate resources, both technical and managerial, for the CTOA and TOCs. Therefore, organizational recommendations are:

- Establish a Central Tech Order Administration which will direct and manage the TO modernization program.
- Approve the concept of Tech Order Centers, with each TOC being assigned the exclusive responsibility for managing the complete suite of TOs for one weapon system.
- Deploy adequate technical personnel at various tiers.
- Create new career paths for personnel involved in the automation of technical information.
- Train Air Force personnel in the use of the AFTOMS technologies.

5.2 TECHNICAL RECOMMENDATIONS

A primary goal for the AFTOMS implementation endeavor is to adapt relevant technologies which will enable digital production, management and distribution of Tech Orders. This effort should be based on emerging or mature technologies which allow responsive and low-risk implementation. As new technologies become commercially available, it will be feasible to incorporate them. The system concept will permit incremental improvements and enhancements. The automation plan permits current Tech Orders to co-exist with future Tech Orders. The implementation strategy includes the generation of page-oriented, digitized Tech Orders. Further, the process of converting one type of TO to another must be addressed. Specific technical recommendations for the short term are:

- Support the use of a heterogeneous portfolio of TOs, since multiple types of TOs will need to co-exist for the next 10-15 years.
- Use state-of-the-art technologies for creating and storing TOs.
- Emphasize print-on-demand capability in base Work Areas, instead of bulk batch printing by outside vendors.
- Use optical discs for distributing TOs to bases.
- Support a gradual transition of existing and future TOs to digitized form.
- Install and use contemporary Document Management Systems for efficient management of TOs.

5.3 FINANCIAL RECOMMENDATIONS

It is imperative to fund a single, centralized body to be responsible for overseeing the implementation and the operation of the Tech Order automation plan throughout the next decade. In addition, there are technological components that must be proven. A proof-of-concept demonstration needs to be conducted in a controlled environment by designers and developers. A pilot subsystem should be installed that will involve a significant suite of hardware and software components for: a) simulating real world use; b) identifying and resolving operational problems; c) identifying training needs and developing a training plan for the users; and d) obtaining user feedback. Implementation should be carried out along a thread of the organization from CTOA to the Work Area. This involves several financial commitments:

- Allocate financial resources to implement the AFTOMS concept.
- Initiate administrative procedures to enable acquisition and installation of equipment at various stages in the implementation process.

- Provide resources, on an interim basis, to enable one or more user commands and TSC to collaborate in the demonstration of the relevant technologies leading to a technical specification of AFTOMS Operation and Functional requirements.

5.4 PROGRAMMATIC RECOMMENDATIONS

Since AFTOMS is a comprehensive system spanning the entire Tech Order life cycle and will be prepared to manage all three types of Tech Orders, it will be important to take advantage of the programs and direction currently established within the Air Force. Two such programs, ATOS–I and Improved Technical Data System (ITDS) are already underway and in the process of creating a foundation upon which improvement and enhancement can be made. ATOS–I, a system already installed in the ALCs, is capable of dealing with changes to Tech Orders. ITDS, although in the development stages, projects the deployment of a user system which will present Tech Orders at the Work Area level. Another program, Integrated Maintenance Information System (IMIS) is an R&D project involving a future, highly integrated concept of operations and appropriate technologies.

By employing the preplanned product improvement program approach, significant benefits can be achieved through the expected upgrade of existing assets. The following programmatic recommendations are based upon this expectation:

- Examine the ATOS–I installation and its planned ECP for potential incorporation into AFTOMS.
- Investigate the planned ITDS user system for its interface requirements at the Work Area level, both at depot and base installations.
- Develop a strong link with the IMIS program to understand its concept of operations and laboratory demonstrations for potential integration into AFTOMS.

5.5 CONCLUSIONS

The AFTOMS approach will lead to many long–term benefits for the Air Force including, increased weapon system availability, reduced costs and increased mission effectiveness. Specifically, AFTOMS will:

- Reduce the overall cost of TO acquisition, distribution, and maintenance.
- Improve the timeliness, accuracy, completeness, and currency of TOs through the use of new technologies.
- Optimize utilization of expertise and resources, as the CTOA and the TOCs will have clear responsibility over entire TO systems and individual weapon systems respectively.

- Provides clear lines of authority and accountability for all TO functional activities.

- Enhance control and impose standardization across TOs, especially at the stage of receipt from Contractors.

- Provide efficient management of all documents relating to TOs. AFTOMS provides the flexibility needed to support the more sophisticated weapon systems of tomorrow.

In view of the above, it is recommended that the Air Force accept AFTOMS as the approach for modernization of its current TO system.

APPENDICES

AUTOMATED READING OF PAPER DOCUMENTS

TECHNOLOGY ASSESSMENT FOR MASS STORAGE

COMPUTER BASED PRINTING

DOCUMENT MANAGEMENT SYSTEMS

COMMUNICATION ALTERNATIVES

MANAGEMENT OF LARGE INFORMATION SYSTEMS

HYPERTEXT AND VIDEODISC SYSTEMS

NATURAL LANGUAGE PROCESSING

APPENDIX A

AUTOMATED READING OF PAPER DOCUMENTS

A.1 INTRODUCTION

Optical Character Recognition (OCR) devices and image scanners can be used for direct, efficient, and cost effective conversion of text and graphics from paper to electronic media.

The AFTOMS automation plan includes an implementation strategy for gradually converting existing TO pages into an electronic form. To facilitate the conversion of TO information, the AFTOMS concept requires the new technical capabilities that OCR devices and image scanners offer. These devices will eventually enable the storage of 20 million existing TO pages in an electronic form that is highly efficient, less expensive, and more manageable. This appendix discusses current and future technical capabilities of recognition and scanning devices, and suggests a number of recommendations for incorporating this technology into AFTOMS.

Almost all commercial image scanners capture character images using an array of Charge-Coupled Devices (CCD). A CCD is a light sensitive semiconductor device which produces an electrical charge on its surface. This charge is determined by the differing amounts of light reflected off the inked characters on the page. The optical image captured by the CCD array is converted into a two-dimensional matrix of picture elements. Each picture element is either white, black, or more frequently, some shade of gray. The collection of these dots, in varying shades of gray, is a representation of the original image. The information about the shade of each dot is converted and stored in digital form. With the CCD technique, colors in the original image generate differing shades of gray.

Irrespective of whether the scanned page consists of text or graphics, the scanning mechanism generates a two-dimensional, bit-mapped representation. Systems designed to recognize textual information are called Optical Character Recognition (OCR) devices. Systems geared towards recognizing graphic and pictorial information are called image scanners. As more sophisticated software is developed, the distinction between OCR devices and image scanners will gradually erode. Individual scanners will have the capacity to recognize and integrate both text and graphics.

A bit-mapped representation requires a large storage space. At a resolution of 300 dots per inch (dpi), there are about 9 million dots to be digitally represented on one sheet of

8.5" x 11" paper. In the event that no information about the shade is stored (a dot is either black or white), more than 1 MB of storage space is required without data compression. This is called raster scanning. If the page consists entirely of text with information stored in the form of characters (in ASCII, for example), then only 5 kilobytes (KB) of storage is required. Graphic information can be stored more efficiently when it is represented in the form of vectors. For example, a circle described in vector form can be stored in terms of simply a point and a radius rather than as a description of each point on its circumference thereby reducing the storage space required for this figure. Vector graphics reduce the required storage space and enable graphic changes to be made more readily. Discussion of data compression techniques can be found in Appendix F.

A.2 TYPES OF READERS

Readers are usually classified into three functional categories. The three major categories of character readers are as follows:

- *Document Readers.* These machines are oriented towards transaction processing such as billing and form processing. The source document is prepared in a stylized type font with restrictions on the character set.
- *Process Automation Readers.* These systems control particular processes such as letter sorting.
- *Page Readers.* These machines read typewritten and typeset documents. This category of readers is most relevant for scanning TOs.

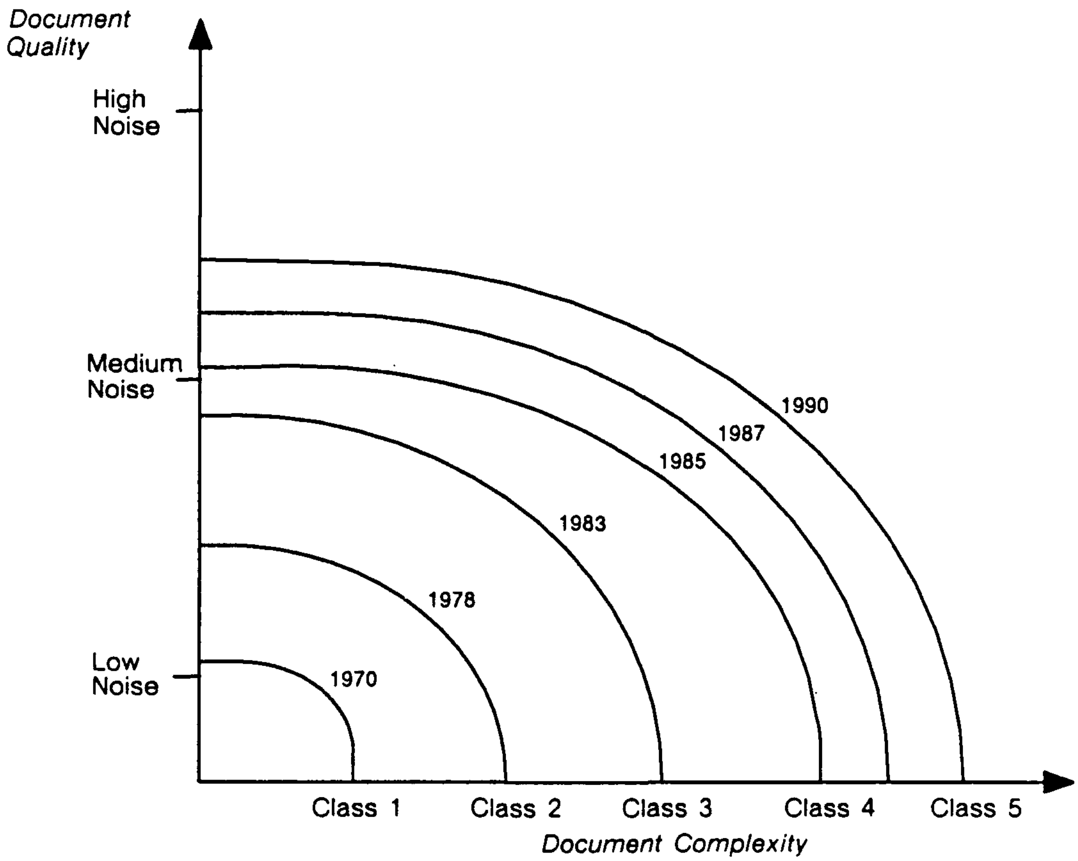
Readers can also be classified by their document reading mechanism. With camera-based systems, the distance between the paper and the camera may be adjusted to allow smaller objects to be scanned with greater resolution. In flatbed systems, the paper is placed face down on a glass plate and scanned by a moving bar of light. In paperfeed scanners, the page is conveyed through the unit while the scanning mechanism remains fixed.

A.3 RECOGNITION TECHNOLOGIES

Recognition is the process whereby the CCD array scans paper based images and transfers these images to computer based media. The quality of the scanned image is determined by its spatial resolution (number of dpi) and the shades of gray recognized. The latter parameter is more important for graphic information than it is for text.

A.3.1 Document Standards

Documents can be categorized in terms of their complexity and quality to determine the level of difficulty in converting their information into digital form. For the purposes of comparing the capabilities of different scanning devices, standards have been established which describe the complexity of a document from Class 1 to Class 5. Class 1 is a single column, mono spaced, single pitch document and Class 5 is a multicolumn document with mixed text and graphics. Standards describe document quality in terms of noise level. Low noise is an original clean typewritten page and high noise is a poor reproduction with characters both broken and touching. Figure A-1 shows the evolution of scanning machines to the point where poor quality (high noise) documents with a high degree of complexity (Class 5) can be processed. This figure also shows that most documents can be successfully scanned by Readers which are available today.



DOCUMENT COMPLEXITY
Class 1: Single column, monospaced, single pitch
Class 2: Single column, multifont, mixed spacing
Class 3: Single column, some images, any formatted text
Class 4: Multicolumn document, tables
Class 5: Multicolumn, mixed text and images

DOCUMENT QUALITY
Low Noise: Original typewritten or typeset document, clearly separated characters, no skewing
Medium Noise: Easily readable photocopy or original laser print, characters not touching
High Noise: Broken and touching characters, fading ink, skewed text

FIGURE A-1. EVOLUTION OF SCANNING CAPABILITIES

A.3.2 Character Recognition

For text, recognition begins with location of character images. With the exception of some high-end scanners, which employ Natural Language Processing (NLP) as a tool for contextual analysis, all readers are character-oriented. Briefly, NLP employs Artificial Intelligence (AI) to interpret user input regardless of its format (for a full description refer to Appendix H). In character recognition, each character is treated as a single unit, and recognized independently. These units are transmitted sequentially to a single character recognition subsystem. Units that differ significantly from the supported character sizes are either flagged or skipped. Note that this design makes text oriented OCR devices unsuitable for dealing with graphic information.

A.3.3 Methods of Recognition

There are two methods available today for recognizing the identity of individual character units. They are the following:

TEMPLATE MATCHING

Template matching (matrix matching) is the most commonly used technique. In this technique, exact bit-mapped images of all the characters are initially stored in the memory. After scanning, each character unit is compared with the dictionary of supported characters. The identity of the character is made based on the comparison that possesses the highest degree of overlap. This strategy works most effectively when only one type of font, and one size of characters are permitted. Large variations in document fonts and character sizes require increased memory capacity and time to interpret the characters.

FEATURE EXTRACTION

This technique focuses on detection of specific components within the character, such as pronounced angles, junctions, crossings, slopes and inflection points. These components are determined for each character and compared with values in a reference table. Since these features are relatively independent of style and size of the character, this technique is relevant for documents that contain multiple fonts and sizes of characters. On the negative side, feature extraction is especially sensitive to quality. Broken characters caused by poor printing or repeated photocopying are usually misread.

A.3.4 Character Recognition Problems

Text that contains merged characters presents additional problems. The breaking of page images into character units is based on the assumption that adjacent characters are separated by a horizontal or sloped line of blank space. However, in the case of tight kerning, inadequate resolution of the scanner, poor quality of the document, or high brightness threshold, adjacent characters may spread into each other.

After initial recognition, the identity of characters can be corrected using stored information such as a spelling checker, and empirical rules (for example, the letter "q" is always followed by "u"). Contextual analysis can also assist in character recognition.

A.4 NEXT GENERATION TECHNOLOGIES

Today, the scanning speed of readers is typically 100 characters per second. The error rate is less than 0.1 percent for an average page. Over the last five years, this error rate has decreased by a factor exceeding ten and a similar reduction is expected within the next five years. The price of an off-the-shelf omnifont reader is in the range of $10,000–$75,000 depending on the make, the model, and the options. As shown in Figure A-2, prices have declined every year and this decline is expected to continue. The current generation of readers is able to read most printed documents, including documents containing both text and graphics.

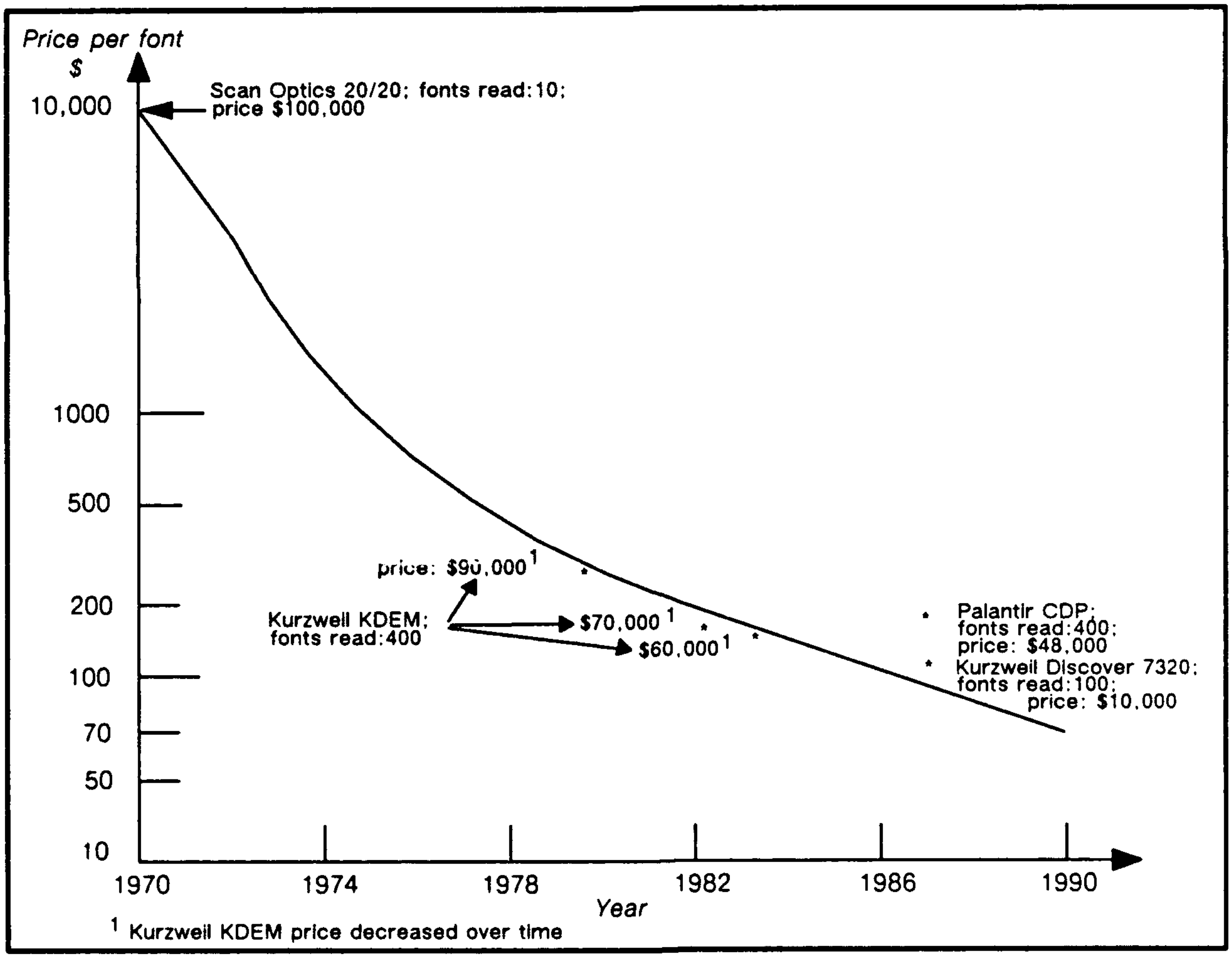


FIGURE A-2. DECLINING COSTS OF READING MACHINES PER FONT RECOGNIZED (1970-87)

Table A-1 summarizes the evolution of scanning devices since 1975, and the projected developments over the short term (1-3 years) and long term (5-8 years).

TABLE A-1. SCANNERS - TRENDS AND PROJECTIONS

	1975	1982	1987	PROJECTED (within 1-3 years)	PROJECTED (within 8 years)
PROCESSING CAPABILITY	Text (characters)	Text plus images (ASCII text and bit maps)	Text plus images (ASCII text and bit maps)	Text and images; Separate abilities to deal with vector graphics	Text and images plus vector graphics (vector graphics files)
FONTS	Typewritten text only	Most printed as well as typewritten fonts	Virtually all printed material	All printed material	All printed fonts including some handwritten text
PAGE ANALYSIS	Matrix matching for character recognition of selected fonts	Feature analysis of letters within the text, and matrix matching techniques for identifying characters	Context analysis spelling checking (lexicons), feature extraction for identifying characters	Natural language syntax analysis based techniques for text recognition; aids for distinguishing text and graphics	Semantic analysis, natural language parsing aids for context analysis and correct interpretation of letters and automatic identification of text and image areas
EDITING	Simple editors for correcting correcting errors within data scanned	Text editors and word processors for editing pages	Separate editing facilities for text (text) editors/word processors) and images (through graphic editors)	Limited degree of integrated editing	Integrated editor for text, images, and vector graphics with interface for other packages like DBMSs
UTILIZATION AREAS	Document processing with no editing requirements	Documents with text processed through text editors	Pages scanned and processed through word processors, and graphic editors	Documents with text and graphics processed	Customization of printed page processing software
ERROR RATES	2-3 percent for a good quality document	2-3 percent for a typewritten page	0.1 percent for a typewritten page	0.5 percent for a typewritten page; 1 percent for a typeset page	0 percent for a typewritten page; 0.1-0.4 percent for a typeset page

A.4.1 Short Term (1–3 years)

- *Automatic separation of text and graphics*: OCR systems will be able to automatically differentiate between text and graphics areas. This ability will significantly reduce the need for operator intervention and the time for processing. In addition, new software will be able to recognize and restore tabular formats.

- *Raster to vector conversion*: As mentioned earlier, an image is scanned bit by bit to create a raster file. For robust editing capability to exist, raster files must be replaced by vector graphics files. Primitive software for converting raster files into vector graphics files has already become available. There is a trend towards the convergence of vector graphic techniques and OCR technology. This convergence will greatly ease the editing process and lead to the emergence of integrated editors for text, images, and vector graphics.

- *Local Area Networks*: The process of networking OCR scanners has already begun. Today it is possible to interconnect a scanner and several work stations. The feasibility of sharing additional resources such as storage devices and high performance peripherals is expected to occur in the near future. This will lead to more efficient operation and faster access to all types of information.

A.4.2 Long term (5–8 years)

Within a 5–8 year time frame, significant advances will occur. Superior page analysis techniques and faster scanning speeds are areas in which these advances are expected.

- *Minimal user intervention*: Advanced techniques from the fields of Artificial Intelligence (AI) and expert systems will increasingly be applied to reading machines. With the use of NLP aids for contextual analysis, scanners will achieve near-perfect accuracy in the recognition of virtually all types of printed matter. Further, editing time will be significantly reduced. Overall, the need for manual intervention will dramatically decrease in the next 5–8 years.

- *Faster speeds*: In addition to faster processors, multiple processors are being used in the same system. Using multiple processors within scanning devices offers the benefit of performing successive recognition operations. This development will significantly increase operating speeds and reduce time needed in transition from one type of document to another.

- *Reduced error rates*: New reading machines will be able to read typewritten documents with 99.5 percent accuracy within the next three years.

and the accuracy level will further improve to 100 percent for good quality documents within 8 years.

Both short term and long term technology forecasts are summarized in Table A-1.

A.5 RECOMMENDATIONS

In the case of Tech Orders, the pages of a TO must be scanned with perfect or near-perfect accuracy and concatenated into a unified document in order to make the document sufficient for subsequent steps in the TO process (i.e., digital editing, distribution manufacturing, and digital delivery). This capability is a requirement for Conversion Option 1 as stated in Section 3.8, and will become a reality in the near future.

Apart from rapid production, updating, and distribution of TOs, significant cost savings will occur through the use of scanning technologies. Off-the-shelf products will enable conversion of all weapon system documents to Type B (Conversion Option 1 of Section 3.8). In view of these facts, it is suggested the Air Force consider:

- Investing in a limited number of off-the-shelf scanners as prototype systems for demonstrating the ability to convert existing TOs to Type B.

- Integrating the scanners with other hardware, software, and communication components in AFTOMS.

- Testing compatibility of converted TOs with Type B TOs obtained in digital page-oriented format.

- Acquiring additional scanners after the prototype stage to support full conversion of all documents when appropriate Weapon Systems are identified for this purpose.

To summarize, the acquisition and use of powerful, off-the-shelf conversion technologies will enable quicker and more cost effective support of the TO functions.

APPENDIX B

TECHNOLOGY ASSESSMENT FOR MASS STORAGE

B.1 INTRODUCTION

The storage and distribution of Tech Orders (TOs) is costly and time consuming. The size of a typical TO ranges from 100–150 pages. At 30 Kilobytes (KB) per page a 100 page TO requires 3 Megabytes (MB). Existing TOs are estimated to comprise approximately 20 million pages. Roughly translated, existing TOs would occupy 600 Gigabytes (GB) of computer based storage space, or the equivalent of 1,700,000 double-sided, double density (DS/DD) floppy disks. There are about 2.3 million pages of additions and changes to the existing TOs per year. The conversion of TOs into physically secure digitized storage and distribution form can provide substantial cost savings and improved distribution and timeliness of TOs.

Today, the standard means of mass storage is the magnetic hard disk, which was introduced in the early 1970s. Recently, optical technology has increased the number of alternative high-capacity and extendible forms of storage. These new storage media offer cost effective and safe distribution of information.

This appendix presents an assessment of various commercially available data storage technologies potentially applicable to the storage and distribution of TOs. The applicability of these media to mass storage, their distribution, cost ratio, compatibility and future trends are examined. Table B-1 presents a comparison of several mass media storage techniques.

B.2 EXISTING TECHNOLOGIES

The most commonly used forms of magnetic storage are floppy disks, magnetic tapes and hard disks (Winchester disks). The floppy disk, which is most often used for small-scale distribution, offers storage capacities from 180 KB to 1.2 MB. A medium-size, mainframe, magnetic tape can store 100–1,000 MB of data. Microcomputer hard disks, which are the most popular and fastest growing form of magnetic storage, have storage capacities ranging from 10–60 MB. Large hard disks range from 1,000 to 500,000 MB with an average storage cost of $9 per MB. Within the hard disk family is the Bernoulli machine, which differs from the Winchester disk in that it is not enclosed in a hermetically sealed environment and its read/write head does not achieve the same proximity to the media of the hard disk head. Bernoulli drives store 10–20 MB of data on removable media, allowing for easier distribution and unlimited storage in 10 or 20 MB segments.

TABLE B-1. MASS STORAGE MEDIA COMPARISON

	Floppy Disk	Bernoulli Machine	Small Hard Disk	Large Hard Disk	Mainframe Magnetic Tape	CD-ROM	12" WORM Double-Sided
Storage (MB)	0.3-2.4	10 - 20	10-350	1,000-500,000	100-1,000	550	2,400
Access Time (ms)	100-300	100-300	20-150	10-20	50-200	700	195
Access Mode	Random	Random	Random	Random	Sequential	Random	Random
Transfer Rate (Kb/sec)	100-500	-	500-10,000	1,000-10,000	500-1,000	150	220
Replaceable or Fixed (R/F)	R	R	F	F	R	R	R
Read/Write (R/W)	R-W	R-W	R-W	R-W	R-W	R	R-W
Drive-Unit Cost ($)	50-300	500-2000	300-8000	20,000-1,000,000	10,000-100,000	600	4,350
Media Cost ($)	0.3-3	30-100	N/A	N/A	500-2000	2.75-5.50	400
Cost/MB($)	1-8*	5-6*	23-30**	2-20**	2-5*	.09-.14*	.017*

* based on media cost
** based on drive unit cost

The above-mentioned technologies are vulnerable both mechanically and electromagnetically. When any read/write head becomes misaligned through movement of the drive or tape feeder, it crashes to the disk or tape surface, and can damage the disk or tape. Magnetic storage is also vulnerable to damage by heat, by bending, by liquid contamination and by exposure to magnetic fields. Magnetic tapes are also susceptible to damage by the tape feeder drive, which pulls and pushes the tape past the read/write head. Due to these vulnerabilities, the hard disk and magnetic tape are neither physically reliable nor practical means of distributing information.

B.3 MAGNETIC MEDIA ADVANCES

Technological advancements, which increase the storage capacity and decrease the access time of magnetic media, are being made. Three design features that have recently been introduced are thin-film technology, perpendicular recording, and Run Length Limited (RLL) coding. Thin-film technology features a spiral film of electrical conductor deposited on a silicon substrate, which provides better response to the changes in the magnetic field enabling the data to be read or written faster. The thin-film process for disks gives the magnetic layer of the disk a more uniform composition that provides a more reliable, durable, greater recording density than can be achieved with an oxide disk (about 12,000 bpi versus 10,000 bpi for oxide platters). In perpendicular recording, the magnetized regions of the disk lie at right angles to the disk surface rather than parallel to the disk surface, allowing a 300 percent increase over conventional recording. The RLL coding techniques of data storage depends on the controller or interface, as well as the disk, are being adopted. This technique records three bits of data in the space normally occupied by two. In other words, a disk that normally stores 62 MB of data will store as much as 93 MB of data using the RLL technique.

B.4 OPTICAL TECHNOLOGY

There are four types of optical discs: CD-ROM (Compact Disc-Read Only Memory), OROM (Optical Read Only Many Times), WORM (Write Once, Read Many Times), and Erasable (Write Many, Read Many). Presently, the CD-ROM disc is the only medium with established standards for disc capacities, formats, speeds, and densities. The final approval of any proposed standards lies with the American National Standards Institute (ANSI) and the National Information Standards (NIS). Standards must be established among the media and drive manufacturers and accepted by ANSI for WORM and Erasable technologies to become feasible alternatives.

B.4.1 CD-ROM

The Compact Disc-Read Only Memory (CD-ROM) is the most advanced laser storage technology. CD-ROM discs are prerecorded material, having an average capacity of 550 MB per disc, that can be read but not written to. A 550 MB CD-ROM will store the equivalent of 1,527 DS/DD floppy disks. The 4.7" diameter discs are composed of a substrate of plastic, which supports an aluminum reflective layer, over which another plastic layer has been laid for protection. The composition of these discs makes them resistant to the magnetic disruption and the typical wear that plagues hard disk drives. CD-ROM discs are a physically secure and efficient means of storing and transporting multiple copies of data bases.

Several important parameters must be considered when using CD-ROM as a form of mass storage. The number of pages that can be stored on one CD-ROM varies widely based on the compression ratio and overhead (indices and search techniques) imposed by the application and data management software used. The raw data error rate of a new optical disc is still much higher than that of inductive magnetic media even though error correction devices are used in the manufacturing of CD-ROM discs. There is presently an uncorrectable error on 1 of every 2,000 discs.

A cost estimate of a single CD-ROM process is presented in Table B-2.

TABLE B-2. CD-ROM COST ESTIMATE

	1987	1988	1990	1993	1995
Cost per drive*	$800	$600	$220	$80	$50
Cost per disc*	$6.50 **	$3.75 **	$1.40 **	$ .70 **	$ .50**
Mastering cost	$3,500	$2,200	$1,500	$1,000	$750
TOTAL	$4,306.50	$2,803.75	$1,721.40	$1,080.70	$350
Storage capacity	550 MB	680 MB	780 MB	-	-

* based on presentation by Steven B. Weissman at the Microsoft Second International Conference March 4, 1987, Seattle
** cost per single disc

CD-ROM is an inexpensive, standardized method of storing or distributing large stable data bases (approximately 10 cents per MB, depending upon the model used for the cost estimate and number of copies, versus $2 per MB for a large hard disk). It is a commercially produced technology whose price is spiraling downward. As the number of discs replicated increases, the cost per disc decreases, making mass distribution a viable alternative. Optical discs are resistant to damage by the player read mechanism, by heat, by bending, by liquid contamination, and by exposure to magnetic fields. However, there are limitations. CD-ROM has a standard disc size of 4.7", which cannot presently store more than 680 MB. This size limitation is a possible disadvantage with large data bases. The data stored on a CD-ROM cannot be altered for updates and changes.

B.4.2 OROM

Similar to the CD-ROM in data storage/reading and composition is the Optical Read Only Many Times (OROM). The larger OROM disc size (8"-14") permits more data (1.2 GB) to be stored on a disc. The major drawback of the OROM is that it must be specially ordered from a manufacturer. Presently, there are very few companies who have OROM manufacturing capabilities, and projections do not suggest that it will be a high growth technology. There is no cost information available because of its special order status.

B.4.3 WORM

The Write Once Read Many Times (WORM) technology involves one-time recording with multiple read back. The WORM discs are primarily used for audit trails, archival storage and on-line storage of large data bases. WORM technology has not been standardized. The disc size varies from manufacturer to manufacturer, ranging from 5.25" to 12" discs. A 5.25" double-sided disc stores approximately 800 MB of information and a 12" stores 1.2 GB single-sided and 2.4 GB double-sided.

The WORM disc can be written on one time by the user and does not require expensive manufacturer-based mastering, though it does require expensive user equipment ($15,500 per optical writer). Once an area has been written to, it cannot be written over or erased, though unused areas can be written to at a later date. For subsequent copies of the data, another disc must be copied by the read/write machine.

As with CD-ROM technology, the number of pages that can be stored on one WORM disc varies widely with compression ratio and overhead. Error correction is achieved with the use of error correcting and detecting codes similar to CD-ROM. The availability of various WORM disc sizes provides more flexibility in the size of the data base stored on one disc.

WORM technology is a secure, inexpensive method of storing and distributing data, (approximately 25 cents per MB, depending upon the models used for the cost estimate), and the price will continue to decrease. WORM technology allows the user to store a large document (approximately 83,900 pages) on a 12" double-sided disc. The predicted standardization of WORM technology in the next several years will make it a viable option for mass storage and distribution of data. However, it also has several problems. Lack of standardization allows experimentation by the manufacturers, but decreases the stability and compatibility of the product for the user. Information recorded on a WORM read/write system must be read by an identical system. The information written on a WORM disc cannot be altered, but additions can be written, if storage space is available. Table B-3 shows a cost estimate for 12" WORM technology.

TABLE B-3. 12" WORM COST ESTIMATE

	1987	1988	1990	1993	1995
Cost per drive	$15,500	$15,000	$11,000	$8,000	$5,000
Cost per disc	$400	$400	$250	$150	$100
Mastering Cost	-	-	-	-	-
TOTAL	$15,900	$15,400	$11,250	$8,150	$5,100
Storage Capacity	1.2 GB	2.2 GB	5 GB	7 GB	10 GB

B.4.4 Erasable

The newest technology, in this area, is the Erasable optical disc. This technology will allow the user to write and erase information on a laser disc. Presently, ANSI is considering a standardization proposal for a 3.5" disc, which holds approximately 50-70 MB on a single side and the storage capacity is predicted to increase.

Semiconductor lasers are used to record information, erase previously made recordings, and play back recorded information. There are two types of laser systems being used in the erasable optical disc memory systems; single-head and two-head. In the single-head system the same laser beam is used to erase previously made recordings, record new information, and play back prerecorded information. The two-head system is equipped with an erase head and a recording head. In this system, the erase head's laser beam traces the surface of an optical disc slightly ahead of the recording head's beam so that new information can be recorded as the old information is erased. As a result, it takes less time to record new information.

There is very little information presently available on Erasable disc technology. It offers considerably less storage capacity than CD-ROM and WORM, though it appears to be a valuable storage device for personal computers and for dynamic data storage.

B.5 SUMMARY

The discussion of storage and distribution devices presented in this appendix is intended to point out mass storage alternatives and the accelerated pace at which they change. There are several technologies that are workable depending upon the size, stability, use, and distribution of the stored data.

Magnetic media storage capacity will continue to increase with advances in technological methods while the prices decrease. For a medium size, dynamic data base that requires frequent updates and small, bursty distribution, magnetic media is one form of mass storage that is practical. However, magnetic media is subject to physical damage and is costly in comparison with optical storage.

Over the next five years, as the sales of optical discs and disc players increase, the costs will decrease at a marked rate. For example, 65.5 thousand CD-ROM disc players were sold in 1986 and it is estimated that 1,048.1 thousand players will be sold in 1991; the current cost for a CD-ROM system (drive, disc, mastering cost), $4,306, will decrease to approximately $1,540 by 1991. Table B-4 compares four major storage and distribution methods: paper, removable cartridges, CD-ROM and WORM optical discs. The F-16 Air Force Weapons System is used as an example.

TABLE B-4. F-16 WEAPON SYSTEM STORAGE AND DISTRIBUTION COST COMPARISON (1987 PRICES)

	# OF DISCS/ PAPER RE-QUIRED PER SET	UNIT COST	PRODUCTION COST PER SET	SUBTOTAL PER SET	DELIVERY COST ** (UPS)	TOTAL
PAGES	750,000	$21,300	-	$21,300	$750 (Trucking) Cost)	$22,050
CARTRIDGE DISK	1,098	$70	$1,235	$78,095	$240	$78,135
CD-ROM	39	$275	$859*	$966	$4	$870
12" DOUBLE SIDED WORM	12	$400	$180	$4,980	$12	$4,992

* production cost based on 100 sets
** calculated for 500 miles

Table B-5 shows a typical example of the predicted price reduction in the technology of optical disc storage. As the technology matures the number of optical discs required to store a weapon system suite of Tech Orders will diminish from 12 optical discs to 3 optical discs and the unit cost per disc will decrease from approximately $400 to $100. The combination of these two factors will reduce costs by a factor of 10.

TABLE B-5. OPTICAL DISC STORAGE - PROJECTED PRICE REDUCTION (1987 -1995)

YEAR	OPTICAL STORAGE SIZE	# OF DISCS REQUIRED PER SET	UNIT COST	PRODUCTION COST PER SET*	SUBTOTAL PER SET	DELIVERY COST ** (UPS)	TOTAL
1987	2.2GB	12	$400	$180	$4980	$12	$4992
1991	5GB	6	$250	$180	$1680	$12	$1692
1995	10GB	3	$100	$180	$480	$12	$492

* production cost based on 100 sets based on 1987 prices
** calculated for 500 miles based on 1987 prices

Depending on the data to be stored and the scope of distribution, optical storage is a practical and highly desirable method for distribution and storing information-intensive data bases such as cartography, library information, static data bases, and technical manuals. Optical technology is a physically safe and easily transportable medium for archiving these large data bases.

It is recommended that several issues be addressed before choosing a storage and distribution method for Tech Orders:

- The amount and compressed size of the data that must be stored together;
- The indexing and search methods to be used;
- The size and frequency of updates;
- The advantage of writeable versus non-writeable media;
- The ease of application for the users.

The best approach to the storage and distribution of the data may not be the choice of a single mass storage technology, but rather the integration of two or more types into a complete system.

APPENDIX C

COMPUTER BASED PRINTING

C.1 INTRODUCTION

Computer based printing technologies will be used to support the automation of TOs in the AFTOMS project. All TOs will eventually reside on optical or magnetic media and must be printed if a hard copy is needed. Traditional printing methods will be eliminated and all printing will be computer based.

Computer based printing technology offers several advantages over conventional methods. They include:

- There is no need for repeated typesetting.
- Both text and figure changes can be made quickly and cost effectively.
- Changes in styles, fonts, and sizes can be made virtually instantaneously.
- Copies can be generated as needed, instead of having to print large numbers of copies in advance.
- The manual step of substituting new pages for old pages in all copies (posting) can be totally eliminated for all TOs.

C.2 TYPES OF PRINTERS

Computer based printing devices are generally divided into two categories: impact printers and non-impact printers. In the former category, which includes dot matrix and daisy wheel printers, the character is generated on the paper through direct contact. In general, impact printers have limited graphics capability and produce lower quality print than non-impact printers. In addition, since impact printing involves the coming together of paper, ribbon and molded character, the printing speed is much slower, and as such will not provide the necessary support for TO operations.

With non-impact printers, electrostatic forces form a full page bit-mapped image from digital information and transfer that image in the form of toner to the page. Non-impact printers offer higher speeds and lower noise levels than impact printers. One disadvantage of non-impact printers is that they can print only one copy at a time whereas impact printers can print multiple copies simultaneously. A need for multiple copies makes it necessary to repeat the printing cycle many times. This, however, is not a problem due to the high printing speeds of non-impact printers.

C.3 TECHNOLOGIES FOR NON-IMPACT PRINTING

The imaging technologies that are used for non-impact printing include laser, electrostatic, ion deposition, LED and ink jet. The pertinent features of each are discussed below.

LASER PRINTING

The most commonly used non-impact printer is the laser printer. A laser beam is used to charge a photoconductive surface with the latent image of the characters to be printed. The charged surface attracts a special powder which sticks to the paper to produce visible characters. By controlling the intensity of the laser beam, one can print characters and shade areas in varying levels of intensity. The laser technology produces excellent quality outputs using a complex lens system. The laser system, however, has a lower overall reliability than other technologies. The expenditure involved in recurring maintenance, supplies, and parts result in a high cost per page.

ELECTROSTATIC PRINTING

The basic principle of the laser printer is used in the electrostatic printer, where characters are generated by impressing static charges of electricity on special paper. The charged spots attract a toner and produce a darker impression. By using 200 dpi or more, the image looks much like a newspaper halftone image. This technology offers higher reliability than laser technology. However, the electrostatic process requires specially coated dielectric paper, resulting in high operating costs.

LED PRINTING

The LED technology uses Light Emitting Diodes to create the image. There is one LED per pixel or character area. LED Printers use an array of fixed light sources making them easier to maintain compared to laser printers which incorporate moving mechanisms. Because of their simpler design and their ability to use ordinary paper, LED technology offers lower initial cost and lower recurring costs compared to laser and electrostatic printing. However, this approach usually offers lower resolution. Typeset quality resolution (1500 dpi) may not be available within the next ten years. Also, a failure of a single LED makes the entire system inoperational.

INK JET PRINTING

In principle, ink jet printing resembles spray painting. In the ink jet process, tiny droplets are extracted from an ink reservoir by a piezoelectric crystal vibrating at high frequency. These droplets are then bonded to the paper in a high heat system and form the desired character. Maintaining the flow and controlling the size of each dot of ink are two areas requiring careful design. Among the various methods available for ink jet printing, bubble ink jetting is considered to be the most promising. This method permits fast, high resolution printing.

ION DEPOSITION

Ion deposition imaging is a relatively new printing technology. With ionography technology, ions are extracted from a triode electron tube and a basic image is created on a dielectric cylinder. This image is developed using a special magnetic toner. The image is then transferred to paper using a cold fusing mechanism and the cylinder surface is cleaned. The formation of the electrostatic image by extracting ions and the use of cold fusion are the unique characteristics of this technology. At present, resolutions of 600 dots per inch (dpi) are available, and the overall reliability appears to be superior to other technologies.

The advantages and disadvantages of the five technologies are summarized in Table C-1.

TABLE C-1. COMPARISON OF DIFFERENT IMAGING TECHNOLOGIES

Imaging Technology	Advantages	Disadvantages	Max. Resolution (in dpi)		
			1987	1990	1993
Laser/ Electrophotography (xerographic)	Good to excellent quality output	Requires maintenance and expensive supplies and parts Fair to low reliability High cost per page	600	1200	1500
Electrostatic	Does not use parts that need to be replaced periodicaly	Require specially coated dielectric paper	300	400	600
Inkjet	Good to excellent image quality on plain paper Low cost	Low speed Problems in controlling the size of the dot of ink Reliability problems due to dried ink clogging the nozzle	300	400	400
LED	Low cost and good reliability as they do not use mechanical or moving part	Possible drop in quality due to LED aging Potential reliability problems due to LED elements burning out	300	400	400
Ion deposition	High speed (30-120 ppm) Simple process Cold fusing Good reliability	Expensive technology Some quality problems; for example, paper looks too shiny	300	600	1000

This table extrapolates technological enhancements expected to become available on a commercial basis within the next five years. The price and performance of a representative sample of non-impact printers is depicted in Figure C-1.

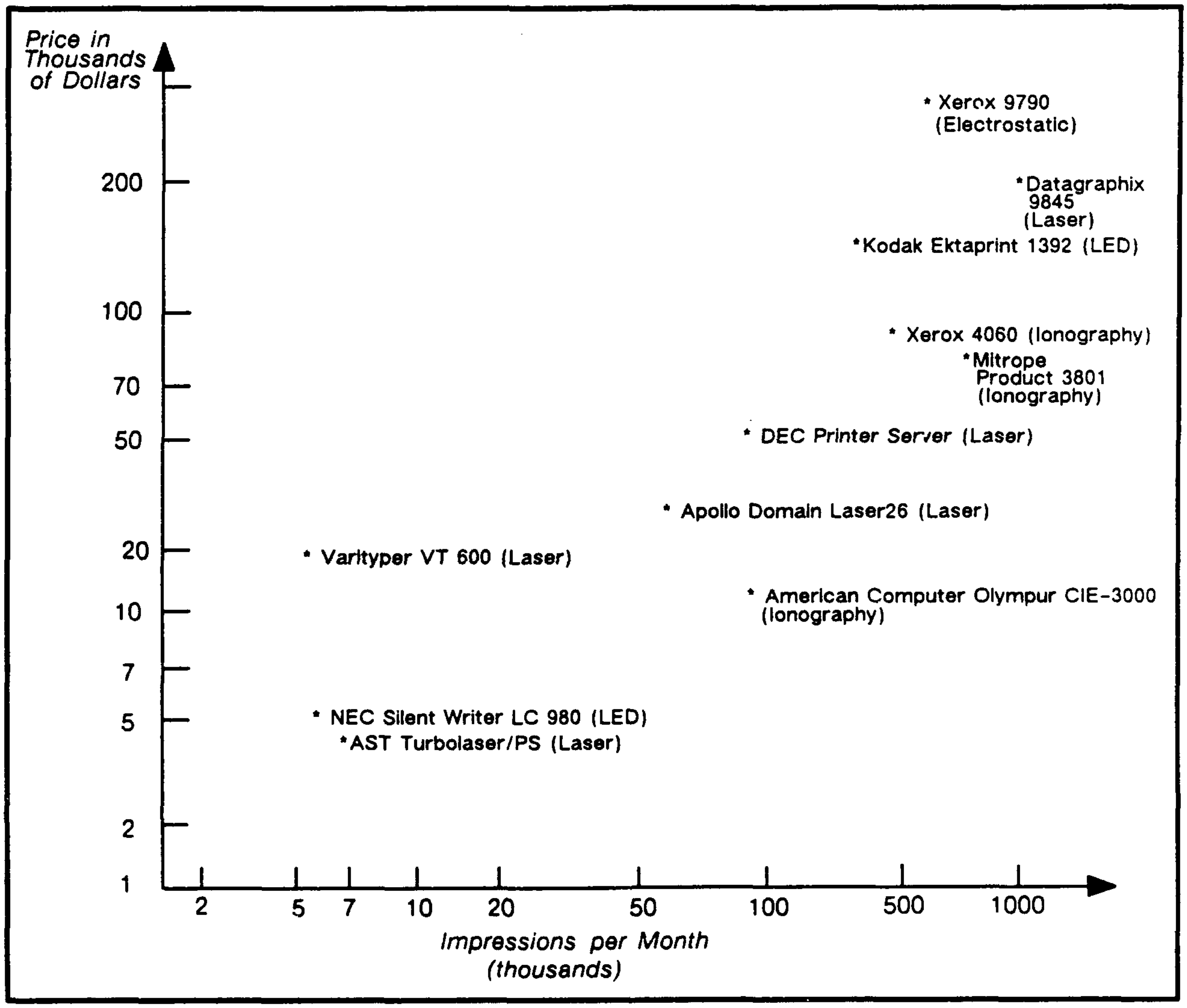


FIGURE C-1. PRICE PERFORMANCE OF A REPRESENTATIVE SAMPLE OF NON-IMPACT PRINTERS

C.4 PAGE DESCRIPTION LANGUAGES

A Page Description Language (PDL) is an elegant language which tells a printer what information to print, where to print it, which resolution to use, and what special effects to produce. A PDL uses mathematical descriptions of graphic and symbolic elements to compose a page containing images.

Sequences of commands transmitted from the computer to the printer relay information about each element to be inked. In the case of bit-mapped operations, frequently used in printing graphic information, the computer transmits information about each bit. At 300 dpi resolution, there are nearly 9 million dots on a single 8.5" x 11" page. Sending instructions for each dot on the page is a time consuming process. A PDL overcomes this problem by radically reducing the volume of information that needs to be transmitted to the printer. It also permits changes in information and hardware configuration to be readily accommodated. Characters and pages can be magnified, skewed, and rotated with extreme precision. A PDL allows horizontal and vertical dimensions to be easily altered. More significantly, the same file can be sent to any printer or other output device that supports the PDL approach, thus allowing for a broader use of commercial equipment.

Examples of PDLs include Postscript by Adobe, Interpress by Xerox, and DDL by Imagen. In order to derive maximum benefits, it is important to standardize on one PDL. Documents can be transmitted to diverse systems in a common format. This means that the systems can be independently configured at central sites and at base sites. For example, a TO composed on a mainframe can be output on any printer connected to a microcomputer at any base. Using a single PDL will reduce storage and distribution costs. The same document can be printed at varying resolutions using different printers without modifying the document in any way. Thus, a single PDL enables the tailoring of print operations to suit the needs of different users.

C.5 PRINTING TECHNOLOGIES FOR AFTOMS

There is a direct correlation between printing speeds and the cost of printers. The capital investment required to produce each page of output on a high-speed printer is greater than the equivalent figure for a low-speed printer. Over time, costs will decline according to the pattern shown in Figure C-2. Each curve in this figure represents the prices of printers with different capabilities in a particular year.

Currently within the Air Force, paper copies of TOs are generated in a batch mode using offset printing techniques. These paper copies are distributed by conventional modes. As better printers are introduced, there will be a growing trend towards on-demand printing at the user site. Such printing offers the advantage of giving users the latest version of information where it is needed. On-demand printing can be done at the Base Level and at the Work Area level. The printing volume will be higher at the Base Level. The vertical line in Figure C-2 indicates that a printer with a speed of less that 30 pages per minute will be appropriate for use in Work Areas and that faster printers will be needed at the Base Level.

In order to determine what printing technologies are optimal for use in AFTOMS, it is pertinent to look at advances expected to occur in the forthcoming years. Advances in printer technology can be projected for the short term (1-3 years) as well as for the long term (5-8 years).

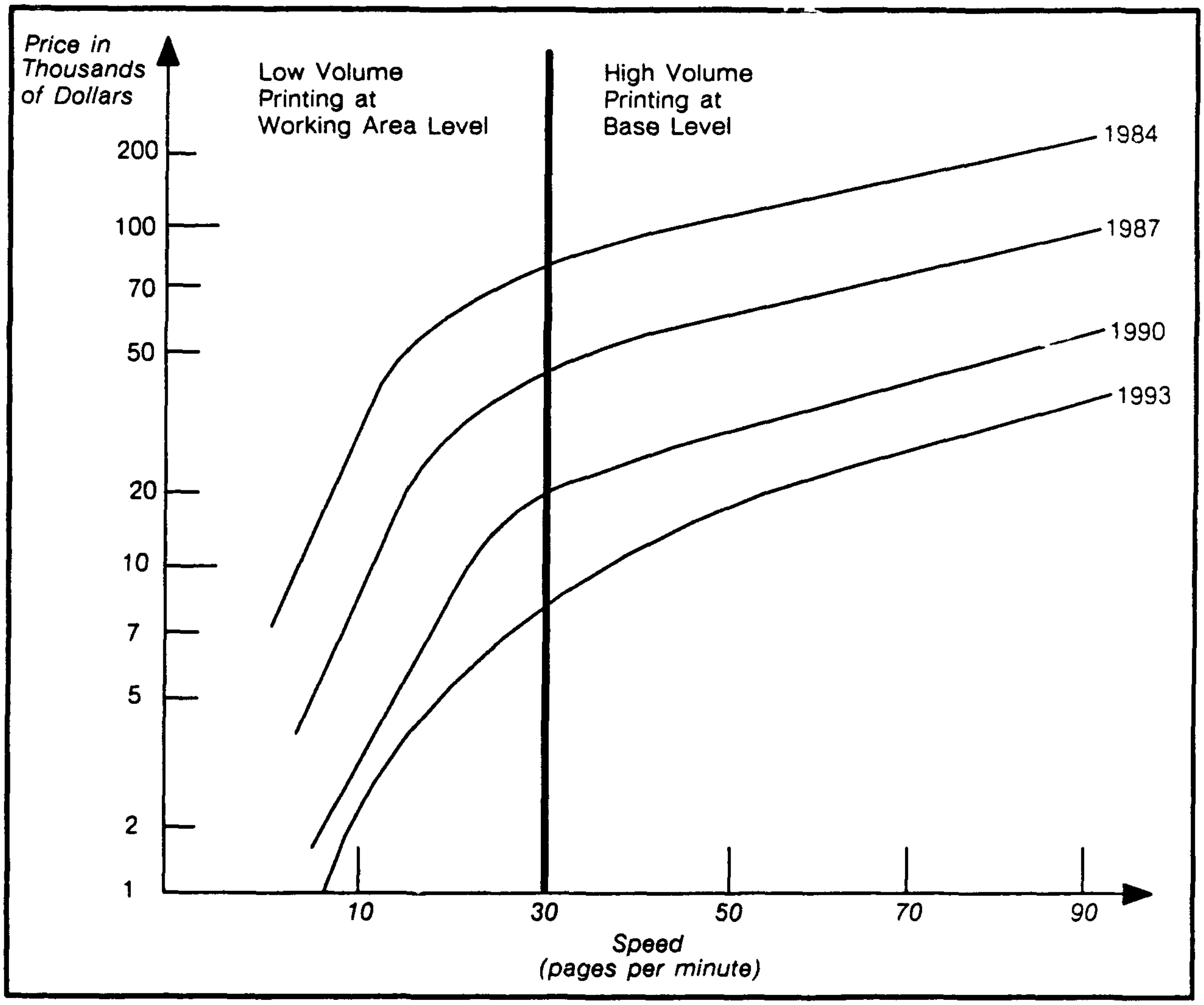


FIGURE C-2. EVOLUTION OF NON-IMPACT PRINTERS

C.5.1 Short Term (1–3 years)

- *Improved Ion Deposition Technology*: This technology is expected to attain resolutions of 600 dpi by 1990. Costs will decline by 40 percent during the same period. The highest percentage increase in overall usage will most likely occur in ion deposition technology due to its superior resolution and reliability.

- *Semi-Intelligent Printing*: The new generation of printers will be able to adapt readily to PDL commands embedded in the data stream. With the use of a PDL, the printer will be able to change from text mode to graphics mode and vice versa, as well as make appropriate changes in sizes, styles, and resolutions.

C.5.2 Long Term (5–8 years)

- *Integration of printing, photocopying, and facsimile technologies*: The linking of processors and modems with printers is gradually making it possible to receive information in compressed form over communication links and to print multiple copies at the desired resolution.

- *Support of Intelligent Updates*: Instead of transmitting the entire document, it will be necessary to communicate only the changes. The microcomputer associated with the printer will be able to edit the earlier version of the document based on these changes.

C.6 RECOMMENDATIONS

In developing future TO processing systems, it is suggested that the following factors should be considered:

- One type of printer technology is unlikely to meet the needs of all users. Printers using ion deposition technology are recommended for use at the Base Level, given their high printing loads. Low speed xerographic laser printers appear to be most appropriate for disposable printing in Work Areas;

- After completion, documents should be stored and distributed in Page Description Language form. Postscript, which is the current de facto standard, should be used until the new Standard Page Description Language (SPDL), being developed at the National Bureau of Standards, is finalized and gains industry acceptance;

- An acceptable level of quality should be clearly defined. A resolution of 300 dpi, generated by all of the aforementioned printing technologies, appears to be adequate for all TOs (this document is printed at a resolution of 300 dpi);

- Printers should be selected with adequate concern given to interfacing capabilities with various computers and peripherals such as scanners and facsimile machines. High levels of compatibility will allow integrated work stations to be set up in Work Areas;

- Printers should be selected only if they can operate with standard paper stock.

APPENDIX D

DOCUMENT MANAGEMENT SYSTEMS (DMS)

D.1 INTRODUCTION

This appendix outlines the current Tech Order review and revision procedure, and explains the concept of a Documentation Management System (DMS). This information is related to the Air Force environment to illustrate how a DMS system can contribute to the current and projected needs of the TO system.

D.2 CURRENT TECH ORDER REVIEW AND REVISION PROCEDURES

Tech Orders provide information for the operation and maintenance of a weapon system. The majority of TOs are produced by the Contractor as part of the data requirements for that weapon system. Changes to a TO can occur while it is being drafted by an in-process review, or after the TO is turned over to the Air Force through a formal change request. Both the review and revision procedures are lengthy and time consuming.

In-process review of a TO usually occurs only twice, at the 40 percent and 80 percent completion points. In an in-process review, draft copies are printed and distributed. Reviewers meet at a central location, such as a plant or source facility, to edit and comment on the draft TO. When a consensus is reached, the individual comments must be manually correlated and turned over to the Contractor.

Formal change requests can come from end users in the field (e.g. MAC, SAC, TAC) correcting errors in the manuals, or from engineering departments to reflect changes in the weapon systems design. Tracking a change is important; because of the interdependence of TO information, one change can affect several different TOs. In the case of engineering changes, different versions of the TOs must be maintained to support both modified and unmodified equipment.

D.3 NEAR FUTURE DEMANDS ON THE TO SYSTEM

Demands on the TO system are increasing. Planned weapon systems are becoming more complex and sophisticated, requiring more pages of documentation. Figure D-1 shows the amount of documentation needed for previous and future weapon systems. The figure illustrates that the documentation needs for a weapon system have increased from about 600,000 pages for the C-5 weapon system in the 1960s to a projected 2 million pages for the ATF in the late 1980s. The cost per page of documentation has also increased, as

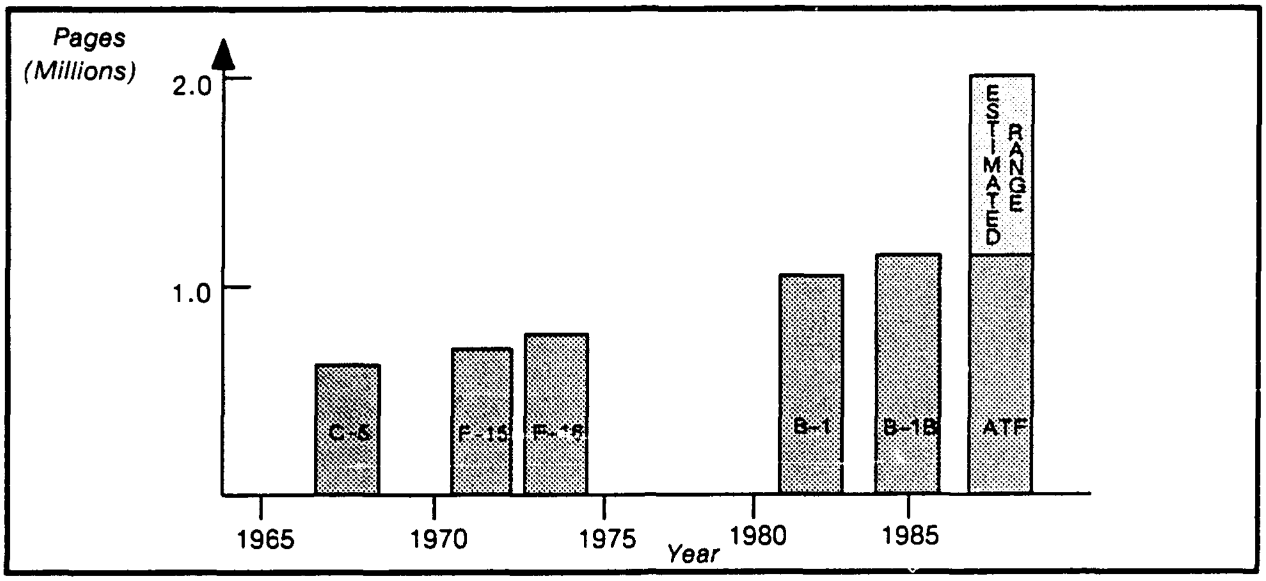


FIGURE D-1. DOCUMENTATION REQUIREMENTS FOR SELECTED WEAPON SYSTEMS

shown in Figure D-2, from $95 per page for the C-5 to $500 to $1000 per page for the B-1 bomber. In certain worse case scenarios, costs can rise to $2000 a page. Aerospace executives cite labor required to review and maintain the TOs as the major cost factor.

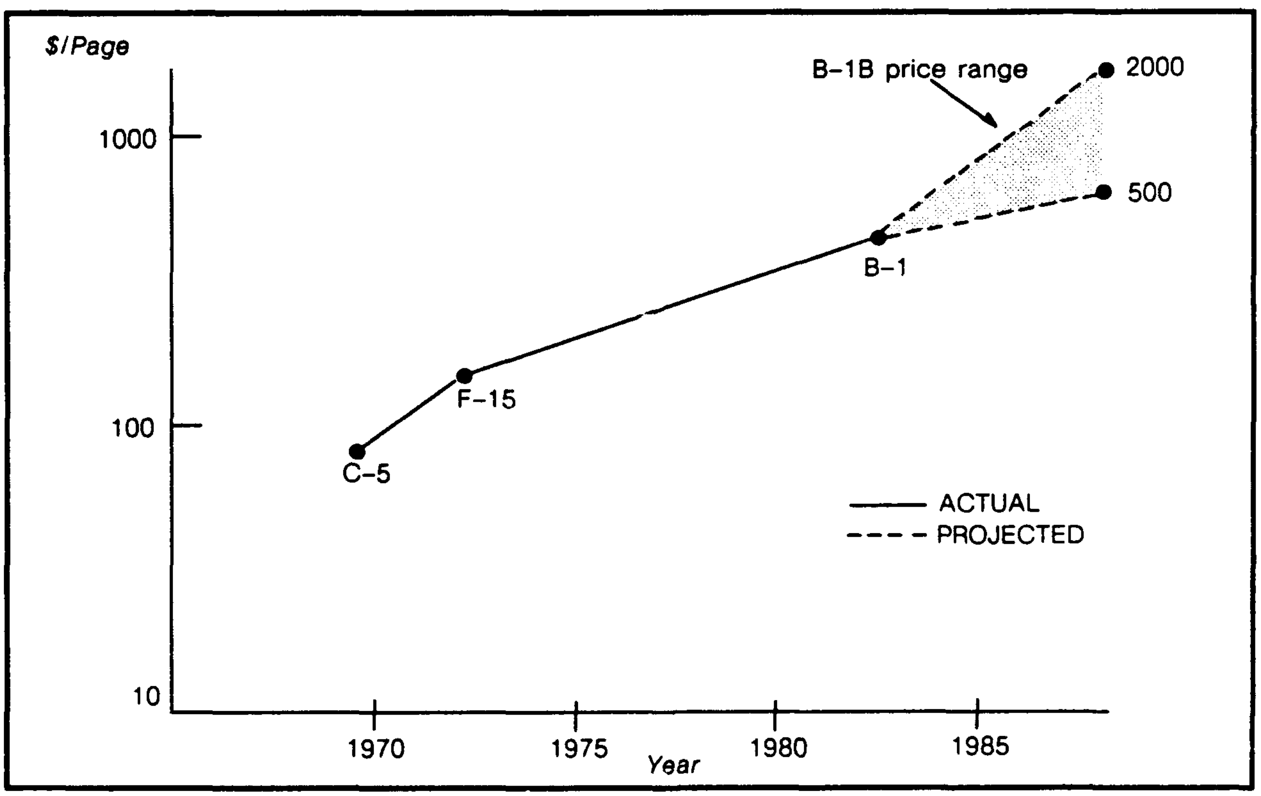


FIGURE D-2. COST PER PAGE OF DOCUMENTATION

D.4 DOCUMENT MANAGEMENT SYSTEMS (DMS)

DOCUMENT MANAGEMENT SYSTEMS

One of the major roles of traditional and electronic publishing systems has been the publication of end user manuals. This is only a small portion of the documentation required for project development. Recognizing the need to support the entire documentation and publications system, engineering-oriented application companies such as the manufacturers of CAD/CAE/CAM systems have begun developing DMSs. Manufacturers of Document Pagination (Technical Publications) Systems are now also adding this capability to their systems.

OVERVIEW

The fundamental concept behind the design of a DMS is to make a project's documentation an integral part of the development process by networking all contributors to the documentation. Contributors can include design engineers, contractors, technical writers, review and approval committees, and users. Figure D-3 shows a project where DMS is used to propose, specify and document the project simultaneously with its development. The figure also shows how DMS provides a mechanism for tracking changes. DMS systems are oriented toward large multiple document projects found in aerospace, electronic systems, and government industries.

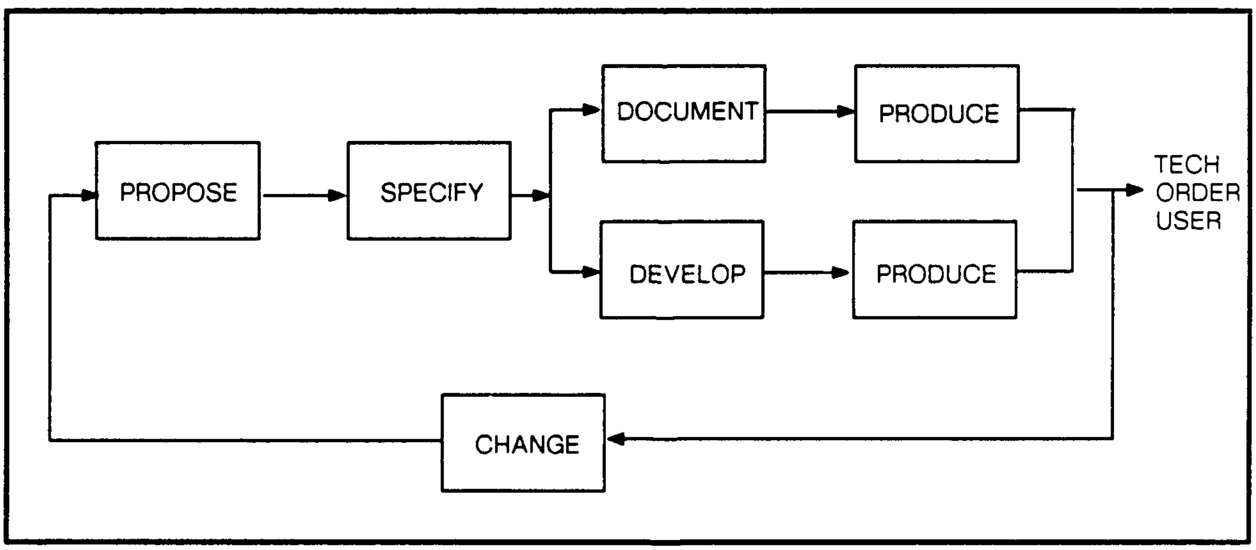


FIGURE D-3. PRODUCT AND DOCUMENT DESIGN PROCESS USING DMS

DMS goes beyond the current generation of electronic publishing systems in that it manages a distributed network of users and data bases and decentralized document production. DMS provides a set of tools to produce, manage, and cross index related documents. Specifically:

- DMS will aid in the creation of a document and allow several users to edit and change the document concurrently;
- Information can be shared using a DMS between design data bases from CAD/CAE systems, and from other documentation sources;
- DMS provides a change control mechanism by displaying the document with changes suggested by different authors, in any combination; it can also manage and track changes so that related documents can be kept up to date
- DMS can navigate through a series of related documents to get specific information on a particular topic or aspect of a design.

DMS are designed to run on a network of engineering work stations. They offer a what-you-see-is-what-you-get (WYSIWYG) document editor similar to the current generation of electronic publishing systems. However, unlike electronic publishing systems, DMSs have the ability to reference or import other text and graphics from many sources such as CAD/CAE design data bases, other documents, and technical reviews. Imported information is not just copied into the current document. Instead, the information is retrieved and formatted every time it is referenced, guaranteeing that any changes made in the original data base are reflected in the document.

DMS - CHANGE MANAGEMENT

DMS supports multiple users accessing the same document by using the concept of a baseline document. A baseline document cannot be directly altered. Instead, users place margin notes within the document for their own use, or propose changes to the document identifiable by a unique marker known as a logical change name. Several people can edit and comment on the document simultaneously. The impact of those changes can be viewed by selecting different combinations of the changes made by other users, which overlay the original document. This feature makes it possible to re-edit previous modifications simultaneously.

Changed versions of a document can be distributed either on-line or in hardcopy form. A changed document can have the changes directly incorporated into it, or have a changed page format which alerts the reader to the changes made since the original document. In a change page format, the changed segments will be automatically highlighted or marked with change bars. This technique provides obvious pointers to changes that occurred since the document was last released.

The ability to view the same baseline document with different logical changes can also be used to make several (variant) versions of the same document. Documents for similar but different products can be supported without duplication of effort.

DMS can support a formal change process. All logical changes to a document can be maintained as a complete history, forming an audit trail. A change request, with the associated changes, is identified by a change request number. A change request committee can review all of the proposed changes at the same time. They have the option of incorporating changes by revising logical changes, merging in accepted changes as they are or creating new changes made up of parts of existing logical changes and new edits. The approved, altered version can be formed into a new baseline document.

DMS - INDEXING

DMS also supports automatic document indexing and creation of table of contents. A potential use of the indexing and referencing capabilities of a DMS is to create an index that cross references other documents. This index, known as a super index, is used to locate information within a series of related documents and browse to related subjects. This information would be associated with related information elsewhere in the document data base. A user could look up a subject in the super index, and by following a thread either more information or related information would be made available. For example, a technician calibrating equipment would use the index to reference the actual procedure. Related information on how to use the calibration equipment and the theory of operation would also be made available to the user without the technician explicitly having to look for the information in several documents.

NEAR TERM DOCUMENT MANAGEMENT SYSTEMS

DMS technology is closely linked to improvements in telecommunication networks, distributed data bases, and mass storage technologies. With the present communications technology, the rate that text and graphics can be transferred limits the interactive use of a DMS to local area networks (LANs). A remote user can conceivably access a DMS through a packet switched network such as ARPANET (Advanced Research Projects Agencies Network) or DDN, although this may be too slow for practical use.

Presently, DMSs can reference only a few CAD/CAM/CAE data bases whose formats are supported. With time, the number of formats supported for referencing and importing of information will increase. Implementation of a standard interchange format such as the Initial Graphics Exchange Specification (IGES) will enable the DMSs to reference all CAD data bases, through the translation of graphic parameters into a common language.

D.5 APPLICATION OF DMS TO THE TECH ORDER PROCESS

The Contractor is not the only supplier of TOs. The Air Force itself generates TOs on policies and procedures. A DMS can be used to create and edit these documents. References to information such as policies or procedures from other documents (provided that they are available to the system) will be automatically updated should changes occur in the original.

DMS allows documentation to be prepared at the same time as a product is being developed. This gives the advantage of speed (TO is completed with the completion of the project) and accuracy. The increase in accuracy is due to the fact that TO information will come from designers during the design stage. In addition, DMS aids designers in viewing projects as a whole rather than merely a microcosmic section.

IN-PROCESS REVIEW

A DMS can streamline the in-process review of Contractor TOs. If reviewers can access the DMS over a communications network, the TO can be reviewed interactively while being written. Formal reviews can still occur at the 40 percent and 80 percent points, where all logical changes are formally reviewed, and frozen into a fresh baseline document. If the reviewers can not directly access the Contractor's DMS, draft versions of the TO can be shipped via electronic media to reviewers. The reviewers, using their own DMS work stations, can propose changes. The drafts with the reviewers comments can be sent back to the Contractor, or consolidated and distributed to a formal review committee for approval, then shipped back to the Contractor.

CHANGE REQUESTS

Change request reporting and the change request process can be combined and streamlined by use of a DMS. Proposed changes can be drafted as a logical change, and assigned a formal change proposal number. Members of the change management committee can review the proposed changes on their own work stations. The impact of the proposed changes can be assessed and comments made. Approved changes can then be incorporated into the baseline document and change pages or the updated version of the TO printed. A change history can thus be established by electronic storage of each version. Any documents that refer to the changed TO will automatically be updated.

D.5 RECOMMENDATIONS

In the present system, all changes made to the document in reviewing and revising are tracked manually. Use of a Document Management System is recommended to automate the TO revision and review procedures, resulting in improved timeliness and accuracy of the revised document. Specifically, it is recommended that a DMS can be used in the TO process for:

- Creation of policy and procedural TOs generated by the Air Force;
- In-process review of Contractor TOs;
- Change request reporting; and
- Processing change requests.

APPENDIX E

COMMUNICATION ALTERNATIVES

E.1 INTRODUCTION

This appendix presents local and long-haul communication resources and technologies which can meet the performance and availability requirements of the AFTOMS concept. The major focus of this appendix is to investigate DoD communication systems which may support the CALS automation plan for Tech Orders.

E.2 CALS COMMUNICATION RESOURCES AND REQUIREMENTS

Communication among bases that are widely dispersed (interbase) as well as among facilities within each base (intrabase) will be required to support an automated TO distribution system. Communication facilities within this system must accommodate two types of data: bulk data files and messages resulting from interactive processes. Bulk data is a large file such as a TO, which requires lengthy communication time. Interactive messages are generally less than a full screen in length and usually represent queries, requests and electronic messages.

Wide Area Network (WAN) and Local Area Network (LAN) communication alternatives will be evaluated for their support of the specified requirements for both interbase and intrabase distribution of TO data.

E.2.1 Wide Area Networks

DoD Wide Area Networks provide interbase communication among major operating bases, located throughout the world using packet switched services, satellite services or dedicated leased lines. The USAF has several DoD networks and subnetworks available to support its activities. Chief among these is the Defense Data Network (DDN).

Defense packet networks, such as the DDN, use datagram adaptive routing, which allows individual packets of data to detour around portions of a network that are congested or damaged. Packet switching is particularly well suited to military data communications, because of its speed, inherent redundancy, and ability to handle robust, "bursty" traffic. Because it was developed specifically for computer communications, it can support real time communications as required by computer systems and CALS interactive applications.

Presently, the Air Force uses Defense Satellite Communications System (DSCS) and Fleet Satellite Communications System (FLTSATCOM) to provide secure command and control communications. These systems are designed to remain functional at all levels of tactical and strategic warfare, except for a direct attack on orbiting satellites. During peace time, the DSCS carries over half the DoD overseas telecommunications traffic. The Air Force has developed fixed and transportable earth stations to satisfy specific combat requirements.

Since the restrictions on satellite communications have their greatest effect on interactive data transmissions, satellite service appears to be best suited to bulk data transfer. However, use of satellite communications has, at this point, been restricted to high priority mission critical transmissions.

E.2.2 Local Area Networks

Local Area Networks (LANS) provide intrabase communications linking diverse systems including PBXs, terminals, computers and video displays. A LAN is either baseband (a single digital channel) or broadband (multiple data channels); these channels are in the radio frequency (RF) range. Transmission media include twisted pair, coaxial cable, and optical fiber. Data rates range from approximately 1 Mbps on base band twisted pair, to more than 300 Mbps on wideband fiber optic cable.

Air Force LANs will provide the intrabase data transmission facilities for CALS. CALS data, including TOs, engineering drawings, and Logistics Support Analysis Record (LSAR) data, will be distributed to CALS servers and terminals. Because of the diverse nature of the CALS user community, the LANs must support various terminal types, including ASCII terminals, personal computers, graphic work stations, and CAE/CAD/CAM devices.

The Mission Effective Information Transfer System (MEITS) effort is developing a ULANA specification to satisfy the need for interaction between the LAN and the local information transfer system. This interaction requires the system to accommodate multiple protocols. The ULANA specification will include the International Standards Organization Open System Interconnect (ISO/OSI) protocol. This protocol will open communication between simple and complex computer devices and will provide application-to-application multilevel data integrity. It is expected that ULANA phase I equipment and vendor listings will be available by March of 1988, with field testing of a testbed system to begin by early 1989. The Air Force is developing several LANs for specialized command operations.

The AF Logistics Command is installing LANs at each of the AFLC Air Logistics Centers (ALCs) to support its programs (See Figure E-1). The AFLC LAN will provide the transmission medium for the automated management systems which record and document AFLC functions. It will also provide intrabase communication services for logistics management.

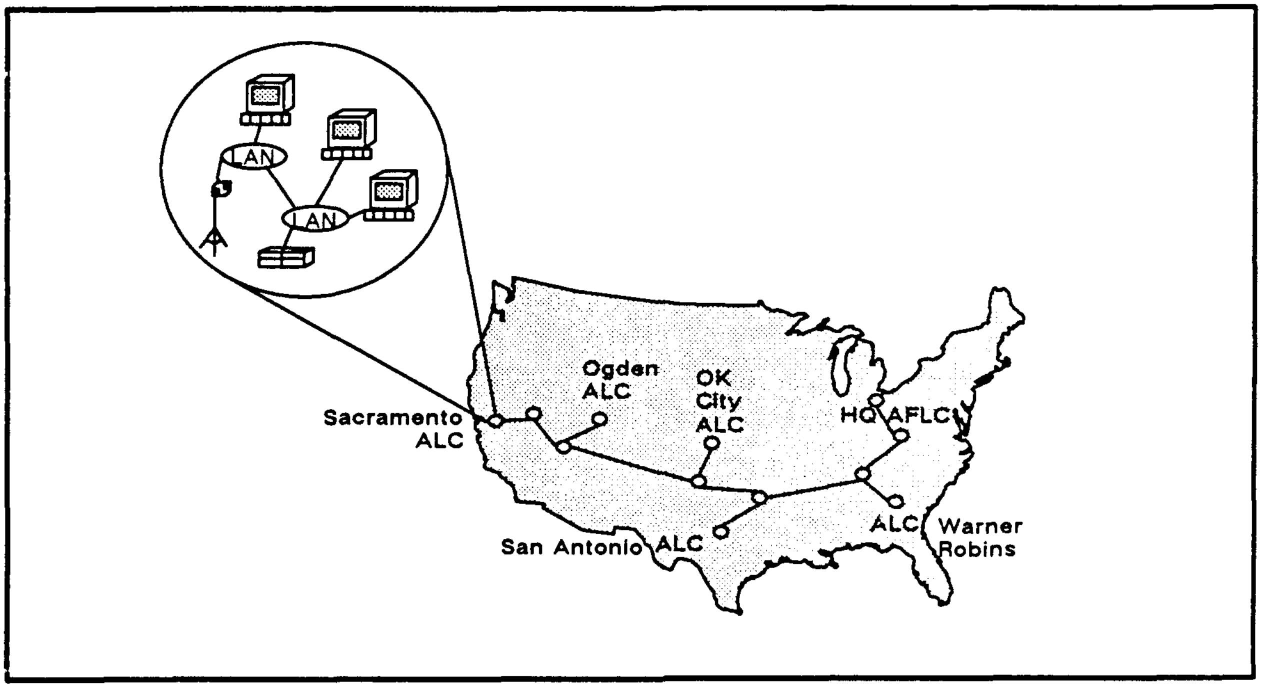


FIGURE E-1. AFLC LAN SITES

The AFLC LANs are designed to support multiple subnetworks. These LANS are broadband buses using specific channel frequencies within the bandwidth for generic functions including Network Interface Unit (NIU) traffic, graphics, modem, host, growth and emergency functions.

E.3 LONG RANGE PLANNING

Since interbase communications is a principal requirement of CALS, emphasis must be placed on WAN communication. The Air Force Communications Command (AFCC) and the Defense Communications Agency (DCA) are planning for the expected increase in traffic, produced by CALS, on the Defense Communications System (DCS). The plan will require the expansion and modernization of DCS WANs to support the CALS project. This plan must involve the expansion of existing networks and the development of new data networks, as well as the implementation and integration of the OSI protocol and Integrated Services Digital Network (ISDN) communications system to support the multifunction requirements of the DoD and CALS.

E.4 NETWORK CAPACITY PLANNING

Appropriate sizing of communication links to support the transfer of Tech Orders and supporting system documentation depends on the accurate collection of expected data traffic. This process involves identifying all forms to be used in the Tech Order system concept of operation and determining their expected message lengths and volume.

E.4.1 Tech Order Message Lengths

Since the system concept is a proposal, there are no available statistics that reflect real world implementation. However, a traffic loading study was performed for the Automated Tech Order System (ATOS-I) project. Although the information contained in the study is preliminary, it does provide sufficient numerical data to project estimated traffic on the proposed system. Such estimation will validate the feasibility of various communication resources to meet system demands.

The standard planning factor for TOs, (as established in CALS Technical Order System Description, Report No. DoD-VA856-87-29, prepared by TSC, October 1987), estimates the average TO to vary from 100-150 pages. The contents of the TO is comprised of 60 percent text and 40 percent graphic information. Using current scanning and digital storage techniques, each page is expected to have an average size of 30,000 bytes (30 KB). The estimated size of a 100 page TO is 3 MB.

Currently, more than 30 forms are used to support the TO process. These forms include those used by Air Force Tech Order (AFTO), Air Force Logistics Command (AFLC), Department of Defense (DoD) and the Government Printing Office (GPO). The AFTO Form 22 is one of the larger forms. The smaller forms include the AFTO Form 110, AFLC Forms 103, 186, 540, 541, and AFLC history forms. For a worst case scenario, the size of data flows required by the paper system will be used for forecasting. User-entered data is expected to be three pages for a change request (AFTO 22) and a minimal amount of all other forms. Therefore, message lengths for change requests and support forms are expected to be 15 KB (3 pages at 5 KB per page) and a 2 KB (a single screen at 1920 bytes) respectively. Profiles are estimated to be 5 KB (one page) and queries/responses to be 0.5 KB (half-screen). These numbers are based on similar commercial applications.

E.4.2 Traffic Volumes and Data Flows

The volume of TO related transmissions and the flow directions must be quantified to determine adequate network capacities. In the AFTOMS concept, intersite (long-haul) traffic will be generated and flow among Central Tech Order Administration (CTOA), Tech Order Centers (TOCs) located at Regional Centers, and Base Libraries located at each operating base. Figure E-2 shows estimated long haul traffic.

Intrasite traffic at each TOC will be transmitted on the ALC-LANs as they become available. Base Library and Work Area traffic will initially be served by a centralized Base Library host system, which will eventually be served by base LANs such as those outlined in the ULANA specification.

Current concept plans call for the CTOA to transfer a master index to each TOC on a monthly basis. In addition, profile registration will be parsed and distributed to the ap-

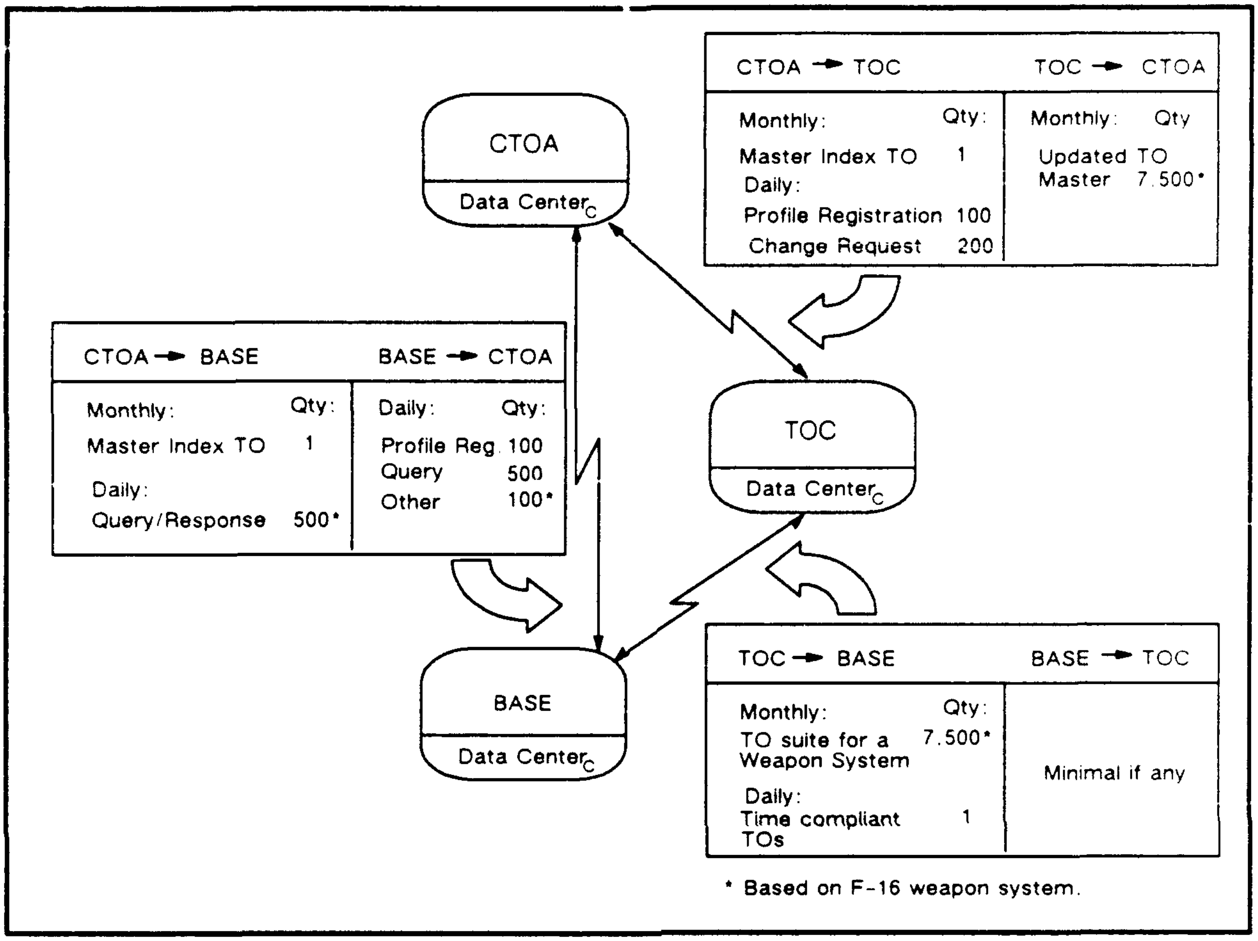


FIGURE E-2. ESTIMATED TECH ORDER LONG-HAUL TRAFFIC

propriate TOC as they arrive at the CTOA. After updating its complete suite of TOs for a weapons system, the TOC will forward a copy of the new masters to CTOA for archival purposes. New master copies are expected to be produced on a regular basis, perhaps as frequently as monthly.

The system concept was designed to eliminate direct communication from the bases to the TOCs so that the Base Libraries would not need to know the actual location and routing of requests. All requests would first go to the CTOA which, in turn, would forward this information to the appropriate TOC. Therefore, direct communication from the TOC to a base is one way; the TOC will transfer its complete suite of weapons system TOs to the base library on a regular (monthly) basis. In addition, special or time-compliant TOs must be transferred. The projected number of these special transfers is one per day.

The CTOA will transfer the master index TO on a regular (monthly) basis to each Base Library. It is estimated that queries regarding the status of TO changes, authorizations, and locations will account for approximately 500 transactions per day. The Base Library will register users for receiving TOs through profile registrations, which will account for an estimated 100 transactions on a daily basis. Supplementary support form traffic is not expected to exceed 100 requests per day per base.

Since the CTOA produces and reviews TOs related to USAF TO policy and procedures, it will have the same functional requirements for data transfer as the TOC. There will be a need to perform routine downloads to configure TO specialist work stations for new users or to reconfigure a work station for a previously defined user. These configurations will involve transferring approximately 20 TOs on the LAN daily.

Using ATOS projections, large form traffic such as change requests (AFTO 22) is expected to consist of 500 per day. Approximately 1500 support forms will also be served by the system on a regular daily basis.

The long range objective is to distribute TOs via the base LAN to multiple Work Area locations. The system concept allows Work Areas to be served by the Base Library regardless of their degree of automation. A Work Area served by a LAN will require a gateway or bridge to the Base Library LAN. Non-automated Work Areas will acquire their TO data from the library in paper form.

It is estimated that the Base Library LAN will need to serve a minimum of 100 profile registrations, 500 queries, 100 support forms and as many as 100 TOs per day.

E.4.3 Estimated Performance Characteristics

All data traffic flows identified must be served. Modeling and simulating these data transmission requirements involves an analysis of each part of the system which includes physical links, Wide Area Networks (WANs) and LANs. It is at this point of the process that the traffic volume and message length data collection become useful. Raw data as well as protocol and security overhead are considered. The effects of transmission errors and propagation delays are included since they have an overall effect on projected network capacity.

INTERSITE PERFORMANCE

Lengthy modeling calculations are not required to determine that downloading a complete suite of weapons system TOs would swamp any of the current long haul resources including the DDN.

The DDN backbone links operate at 56 Kbps. A host can also connect to the DDN at 56 Kbps. Even if the route(s) for each packet were dedicated for TO use, it would be optimistic to think actual TO data throughput would exceed 70 percent utilization. Therefore, it would take approximately 10.2 minutes to transmit a TO using the DDN. This does not include overhead or recovery from transmission errors. With the same assumptions, at T1 rates (1.544 Mbps) the time would be approximately 22.2 seconds. For

750,000 TO pages (F-16 TO suite) the time would total 53 days at 56 Kbps and 46.3 hours at T1 rate.

It is easy to see that, at the current DDN transmission rate, trunks which are not dedicated to the TO requirement would be swamped. Furthermore, T1 rates do not currently exist in the DDN and are still a rather expensive solution. Table E-1 shows the transmission times for the F-16 TOs.

TABLE E-1. F-16 TECH ORDER SUITE TRANSMISSION TIMES

Document	# Pages	File Size (MB)	Transmission Rate		Time Units		Utilization (%)
					56Kbps	1.544Mbps	
F-16 Weapons System's TOs	750,000	22,500	56Kbps	1.544Mbps	53 days	46.3 hrs	70
1 Average TO	100	3	56Kbps	1.544Mbps	10.2 min.	22.2 sec.	70
3 Page Profile/ Change Req.	3	0.015	56Kbps	1.544Mbps	3.1 sec.	0.11 sec.	70

This example shows that, presently, it would be best to use the DDN or dedicated point-to-point lines to serve only special and time compliant TO requests as well as daily TO support form traffic during peak hours. Off peak availability of the DDN could be used for some portion of larger TO file transfers if necessary.

The DDN performance is expected to closely match these results. Since intersite daily traffic, other than the complete TO suite download, primarily consists of change request traffic, profile registrations and an occasional special request Tech Order, it would be feasible to use the DDN resources for the lesser load. Furthermore, packet networks are more efficient with short bursty traffic than with long continuous transmissions. An alternate method of moving the full suite of applicable TOs to the Base Libraries warrants further investigation (refer to Appendix G).

INTRASITE TOC PERFORMANCE

The AFLC broadband LANS provide 10 Mbps 802.3 (Ethernet) subchannels. Realistic throughput is expected to be 40-60 percent of the 10 Mbps. Ethernet (CSMA-CD), which is based on contention, becomes inefficient at higher levels of utilization (greater than 60 percent). With a dedicated subchannel, these rates are capable of handling the initial projection of intrasite traffic. To maintain server availability during the peak hours, TO file transfers to work stations should be accomplished during off-peak hours. If the Ethernet channels are shared, then additional traffic studies must be performed to determine the impact of this additional traffic on the performance of the LAN.

INTRASITE BASE LIBRARY PERFORMANCE

The base libraries are anticipated to install Local Area Networks based on the MEITS-ULANA specification. This specification includes Ethernet (10 Mbps) IEEE 802.3 compatibility. At this time, there has been little TO traffic projection performed at the base level. Furthermore, the method of delivery of TOs to work area print stations and/or CRTs remains to be determined. The ability of the LAN to meet this TO requirement will depend on the base LAN architecture as it relates to TO storage. TO storage at a centralized file server would cause greater daily traffic than distributed servers that meet the needs of individual work areas. However, Ethernet configurations used in the engineering drawing (CAD/CAM) community have performed well in similar environments. By careful placement of servers and subnetworks, it is safe to assume that base LANs will be able to handle the loads specified.

E.4.4 Alternatives to On-Line Transmission

Since emergency and time-compliant TO information can be placed on-line for quick response, the need for all TO revisions to be transferred on-line is eliminated. Distribution within days is quite acceptable and far more reasonable then the current process which takes months. Therefore, it would be advantageous to consider physical delivery of TOs. State-of-the art mass storage devices such as optical discs allow the storage of hundreds of TOs per disc. Using optical discs for distribution and storage eliminates the need for magnetic storage devices at each end of a communications facility. Table E-3 shows the comparative costs and performance for transferring and storing a TO via the DDN, 56 leased lines, T1 leased lines and optical disc. Magnetic storage costs of $1.50/MB were used in pricing the storage for the on-line alternatives.

TABLE E-2. MEDIA PERFORMANCE AND COST

		DDN*	56 Kbps**	1.544Mbps **	Optical Disc
TO (3MB)	Transfer Time	10.2 MIN	10.2 MIN	22.2 SEC	24 HOURS
	Storage Cost	$3.03 +	$1.38	$0.18	$0.0005
	Transfer Cost	$9 ++	$9 ++	$9 ++	$0.13
	Total Cost	$12.03	$10.38	$9.18	$0.13

* Air Force Information Systems (AFIS) Guidelines State That, Unless a Waiver From Air Force Communications is Granted, the DDN is the Primary Distribution Network for Data Transfer
** Based on Line Utilization of 70%, 15% Protocol Overhead, at AT&T Private Line Rates
\+ Based on 1024 BYTES per Packet, 15% Protocol Overhead, and a Rate of $0.90 Per Kilopacket
++ Based on $1.50/MB Storage Cost and 3 MB of Storage at the Receiving and Sending Ends

E.5 CONCLUSIONS

The research of existing communication technologies, services, standards, and issues as they apply to the support of CALS Tech Order automation offers the following findings.

- Transfer of all Tech Order information solely over existing communications technology and services would be costly and inefficient.
- The traffic profiles of interactive and special time–compliant communications appear to suit existing DoD and USAF packet–switched data networks.
- The Defense Data Network should be used as the long–haul network of choice for interactive communications.
- The AFLC LAN and ULANA specifications should be used to acquire LAN capabilities at Tech Order Centers (TOCs) and base libraries, respectively.
- Connectivity between Contractors, Systems Program Offices, MAJCOMS, and Tech Order Centers should be provided by the DDN.
- Transfer of complete suites of TOs should be accomplished via alternate means, such as physical distribution of optical discs.

APPENDIX F

MANAGEMENT OF LARGE INFORMATION SYSTEMS

F.1 INTRODUCTION

Storage, manipulation, and retrieval of large amounts of information involves the use of sophisticated Data Base Management Systems (DBMS). These systems make optimal use of available processing resources, and enable the best utilization of available storage space. Both DBMS and data compression techniques are discussed in this appendix.

F.2 DATA BASE MANAGEMENT SYSTEMS

DBMS store information and provide quick access to a particular subset of that information based on a set of criteria specified by the user. An operation that retrieves information is called a query. An operation that stores or modifies existing information is called an update. Queries and updates are collectively referred to as transactions.

F.2.1 Retrieval of Data

DBMS were originally designed to handle large volumes of data resident on a single mainframe computer. In such centralized systems, there was no consideration given to the parallel processing of queries by multiple computers. Further, since information was stored in a single format, the design of the DBMS was relatively simple.

The need for retrieving data from multiple computer systems resulted in the development of distributed DBMS. These systems require special mechanisms, called locks, to prevent simultaneous access to the same data element by more than one processor. Because of the requirement to support parallel operations in a controlled manner, distributed DBMS are more complex than centralized DBMS.

In a distributed system, all computing elements can be identical to each other. Such a system is characterized as a homogeneous system. The more general and complicated situation involving dissimilar computers is called a heterogeneous environment. Distributed heterogeneous DBMS are still at an evolutionary stage. Integrated retrieval of data stored in multiple systems (homogeneous or heterogeneous) requires the establishment of common standards and protocols for passing information. These standards still have to be defined and accepted.

Overall, technology relating to storage and retrieval of numerical and textual information is more mature than technology for storing graphic and pictorial information. The latter types of information are stored simply as arrays of bit-maps, and examples of retrieval based on specification of patterns or images are rare. Image data base management techniques are still at an infant stage.

F.2.2 Performance Trends

Since conventional single-processor computer systems can provide neither the speed nor the capacity required to manage large information systems, designers have adopted several approaches to overcome this performance barrier. These systems have resulted in major increases in the speed of processing queries and updates to data bases. In 1980, the most powerful systems were able to process only 25 transactions per second, now it is feasible to process more than 1,000 transactions per second. By the early 1990s it will be possible to process 10,000 transactions per second. This surge in processing capability, accomplished by the use of parallel processing technology, is reflected in Figure F-1.

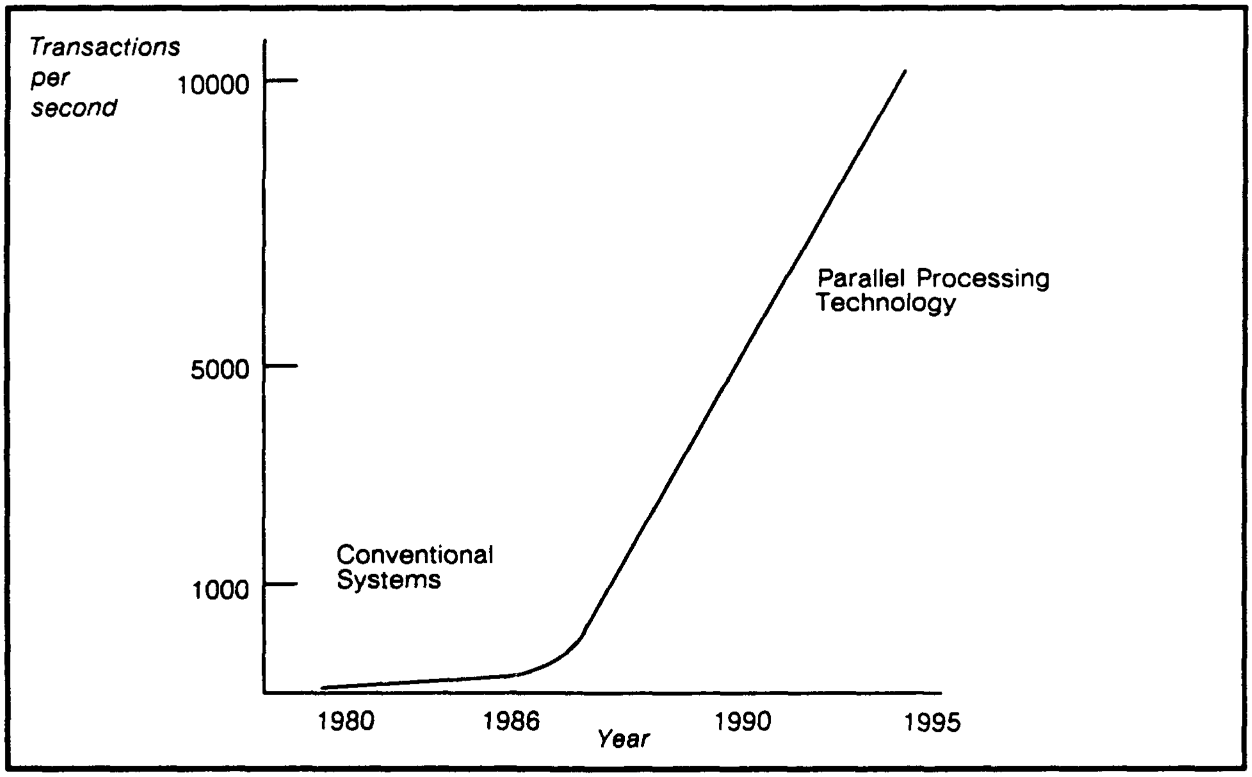


FIGURE F-1. EVOLUTION OF DATA BASE CAPABILITIES

Apart from retrieving or storing the desired piece of data, contemporary data base systems automatically perform consistency checking and automatic backup functions. The spectrum of these functions has increased over time, and so has the overhead involved in the performance of these functions. As such, the amount of effort involved in processing a transaction has increased over time.

F.3 DATA COMPRESSION

There are two methods of data compression: approximate and exact. Only the latter is relevant to the TO environment.

Data compression involves taking a piece of information, purging redundancies, and storing it in the most compact manner. For example, on this printed page, there is more white area than black (printed) area. To store this page as a two-dimensional matrix of very small dots, it would be advantageous to store information on those dots that are black, as opposed to those that are white.

Another method of data compression is to store information about boundary points only. Instead of saying "white, white, white, white, black, black," one could say "3 white, 2 black." Note, however, that the raw data stream is in the former format, and computational time is involved in converting the data to the latter format. There is a corresponding overhead at the time of decompression.

The effectiveness of data compression is measured in terms of the following:

- *Compression ratio* – the ratio between the memory required to store uncompressed data to the memory required to store compressed data.
- *Error rate* – the number of errors introduced by the compression/decompression algorithm.
- *Computation overhead* – the amount of additional computational effort involved in compression and decompression.
- *Buffer size* – the minimum memory size required for performing the tasks of compression and decompression.

With advances in the size and the memory capacity of computers, compression techniques once considered unacceptable because of their long processing times can now be implemented. Also, higher compression ratios are not feasible. For example, if this printed sheet is scanned at 300 dpi, all the information on this page can be stored in just 80 Kilobytes. This reflects a compression factor exceeding twelve. This factor will more than double within the next three years.

F.4 TECHNOLOGY TRENDS

Broad technology trends are highlighted in Table F-1. Projections are made on a short term (less than three years) and long term (3-8 years) basis.

TABLE F-1. EVOLUTION IN DBMS

	1970-1980	1980-1987	PROJECTED (within 1-3 years)	PROJECTED (within 8 years)
DBMS RESEARCH DIRECTION OR STANDARDIZATION ATTEMPTS	DBTG (1971, 1975) COBOL Specification (1974); ACM TODS (1976); DDLC Specification; ANSI/X3/Sparc Framework Report (1978)	DAPLEX; Entity-relationship model	Sharing of information generated by different sources; ANSI/X3/SPARC	Object oriented approach to Data Modeling; Data Sharing Standards
DBMS TECHNOLOGY	Hierarchical, Relational, Codasyl DBMS Models (1977)	Relational DBMS model	Knowledge based tools to support user activity	Knowledge Based Management Systems
USER INTERACTIONS	Simple user queries; programming language interfaces	User friendly interfaces through prompt menus and forms processing	Customized software support	Fully reliable systems with automatic backup and reconfiguration capabilities
DATA HANDLING	File management systems; database management systems	Database Machines; Distributed DBMSs; Heterogeneous Distributed DBMSs	Data sharing through Computer Networks; Request-and-service links	High volume, integrated access systems for text, images, and data
DBMS CAPACITY MEMORY:	64KB-4MB	0.5MB-16MB	2MB-24MB	16MB-30MB per system
DISK SPACE:	2.5 GB (Max.)	10GB(Max.); 200MB Hard Disk; Optical Disks	30GB (Max.)	100 GB (Max.) per system
DBMS UTILIZATION	Managerial and accounting applications Data 60%; Text 35%; Images 5%	Scientific and engineering applications Data 20%; Text 70%; Images 7%; Voice Data 3%	Office automation applications Data 20%; Text 65%; Images 10%; Voice Data 5%	Industrial automation applications Data 20%; Text 50%; Images 20%; Voice Data 10%

F.4.1 Short Term (1-3 years)

INTEGRATION OF INFORMATION FROM DISTRIBUTED RESOURCES

At present, there is virtually no efficient mechanism for automated integration of information which is scattered across several existing systems. Tools for facilitating this process, especially in the case of homogeneous or near-homogeneous environments will become available in the near future.

KNOWLEDGE BASED TOOLS

The distinct fields of DBMS and Artificial Intelligence (AI) are gradually merging together into Knowledge Base Systems (KBS). The first generation of commercial products will enable queries to be entered in qualitative, rather than in strict quantitative terms. Responses will also be tailored to meet individual requirements.

DATA COMPRESSION CAPABILITIES

A single 8.5" x 11" document scanned at a resolution of 300 dots per inch requires in excess of 1 Megabyte of storage space. This space can be reduced through data compression. By the year 1990, integration of various compression techniques will enable this document to be stored in only 20 kilobytes, as shown in Figure F-2. This is a compression factor of 25.

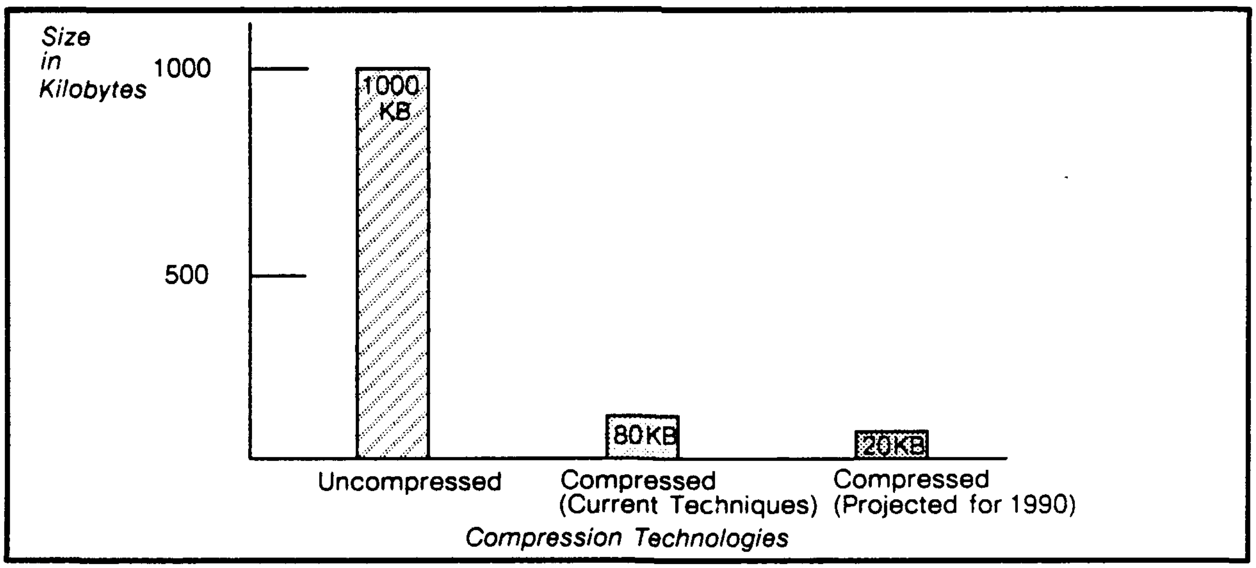


FIGURE F-2. STORAGE REQUIREMENTS FOR A SINGLE 8.5" x 11" SHEET

F.4.2 Long Term (3-8 years)

HETEROGENEOUS, DISTRIBUTED DATA BASE MANAGEMENT SYSTEMS

It will become feasible to intelligently access and integrate information resident in heterogeneous systems. Such systems will allow answers to ad hoc queries to be generated with what-you-see-is-what-you-get (WYS/WYG) acceptable response times.

INTEGRATED ACCESS

Future systems will be able to offer integrated access to numerical, textual, pictorial. and other types of data, with very fast response times, using multiple processing elements.

F.5 RELEVANCE TO THE TO SYSTEM

The operational characteristics of the TO system will be enhanced by the application of new DBMS technologies to manage large information systems. The process of data gathering, data maintenance, data utilization and/or the distribution and use of TOs at bases will all be more efficient. Figure F-3 illustrates how the development of an automated TO data base, which combines text, data, images and voice, will support the creation, storage, revision and distribution of TOs. The center of this figure represents the core of

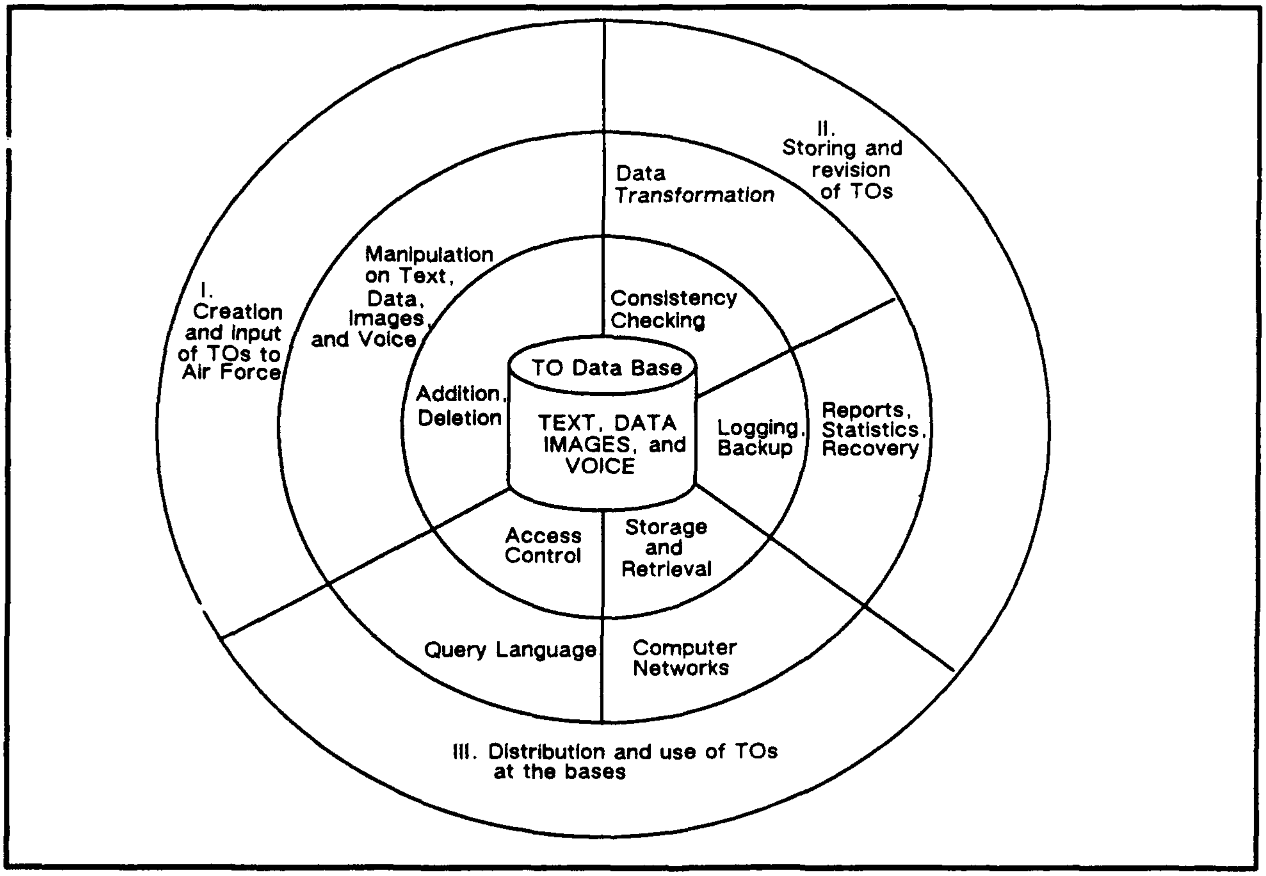


FIGURE F-3. OPERATIONAL CHARACTERISTICS OF A TECH ORDER DBMS

the DBMS, the area outside the outermost circle refers to the user world, and the set of the three concentric circles signify the layers of software that interact between the two. Starting at the outermost circle, there are three functions: (i) Creation of TOs; (ii) Storage of TOs; and (iii) Distribution of TOs. Each of these functions is indicated in a separated wedge. Looking inwards from that wedge is a set of activities related to that function. For example, creation of TOs requires manipulation of textual, numerical, pictorial, and other forms of information. In designing a data base system for the TO application, all the activities depicted in this figure must be addressed.

F.6 RECOMMENDATIONS

Apart from the efficient storage, management, and retrieval of actual TOs, both existing and new, there is a need to automatically update and distribute TOs and related information. There is also a need to generate statistical reports, as well as to respond to queries based on various parameters, such as weapon systems, contractors, and type of component. In order to meet all these requirements, it is suggested that the Air Force consider:

- The establishment of a single integrated computer-based information system for TOs (AFTOMS) with integrated data base management capabilities;
- The feasibility of incorporating existing systems within the framework of the integrated system;
- The creation of a phased timeplan for setting up the new system;
- The option of establishing common standards to enable implementation of the highest possible level of data compression and optimal storage and retrieval techniques.

APPENDIX G

HYPERTEXT AND VIDEODISC SYSTEMS

G.1 BACKGROUND

Hypertext and videodisc systems are new technologies that will be highly applicable to the Type C Tech Order which is defined in the main report. Type C refers to those TOs delivered to the Air Force by the Contractor in digital form, but presented to the end user via electronic display in the form of discrete information units. Type C TOs will be designed for delivery and use, from a screen, in a fashion adapted to the specific needs of a user for a specific task.

From the user's point of view, there are four advantages to a well-designed Type C Tech Order system as compared to the traditional page-oriented sequential Tech Order documents (Type B when in digital form). These advantages are:

- The right amount of information is presented for the task. The system clears away extraneous or excessively detailed instructions.
- The material can be dynamically tailored to the user's reading level, technical skill, and information needs at that particular point in time, according to instructions from the user.
- Illustrated job guides and check lists can be dynamically prepared and displayed on the screen for a particular task at a particular point in time. They may also be prepared by the system and printed out for convenience of technicians on the flight line and at remote sites.
- Material can be presented, text on one-half of the screen and an illustration on the other half, with the text and illustration always keyed to each other.

The Air Force Integrated Maintenance Information System (IMIS) program, run by the Air Force Human Resources Laboratory (AFHRL), is conducting a research program which will lead to Type C Tech Order capabilities. In addition, the program will create Standard Generalized Markup Language (SGML)-based interchange standards for accepting Type C Tech Order information into the Air Force from Contractors.

This appendix indicates how the emerging technologies of hypertext and videodisc can be applied to the future development and use of Type C Tech Orders within the Air Force.

G.2 REQUIREMENTS

The following general requirements will be necessary for a computer system to support a suite of Type C Tech Orders to the satisfaction of both authors and users.

AUTHORING

In addition to the usual automated authoring tool package which would include word processing, spelling, style conventions, and easy import and manipulation of graphics, the author should have an easy-to-use shell. This shell allows for the creation of a series of notecards, each containing a unit of instruction (i.e., a definition or a step in machine assembly would be on a notecard). Further, the shell enables the author to link the notecards in a logical manner corresponding to the way the user will follow the instructions. Lastly, it allows insertion of break points enabling the user to skip material and navigate through the network of notecards as needed. In short, the shell allows trained authors to readily simulate the way users are likely to interact with the system and create the appropriate network of text and illustration elements.

DATA BASE

The structure of the data base should allow the author to easily define instruction units (notecards), and define the identification, retrieval, and storage of these units. Retrieval of a given unit, while the system is in use, should be as rapid as possible.

DISPLAYS

Since the TO user will rely almost exclusively on the information in a screen display, the display must be easy to read with large, clear type and line definition. Improvements will be required over the CRT-type displays now familiar to computer users. Flat screens now under development may be moving toward the level needed by the users.

PRESENTATION

At a minimum, authors must prepare clear, concise presentations of illustrated job guides and check lists for each job to be done. These must be capable of retrieval by the users in response to simple, logical navigation through the network of linked notecards (information units) as the task is defined.

PRINTING

The capability should exist for printing job guides or checklists displayed on the screen as needed. Occasional printing of other kinds of brief information units, such as definitions, flow charts, outlines and sets of illustrations, will be required.

G.3 HYPERTEXT

Hypertext has been defined as, "a combination of natural language text with the computer's capacity for interactive branching, or dynamic display of a nonlinear text which cannot be printed conveniently on a conventional page." In its simplest form it is a data base containing discrete information units as objects. Windows on the screen are associated with these objects to display their contents. Links are provided between the objects, both graphically as labeled arrows and in the data base as pointers. Nonlinear refers to the capability to go from one topic to another as desired rather than in a predetermined fashion.

More specifically, the following features are represented in the typical hypertext system:

a. The data base is a network of nodes, each of which is an information unit of text and/or graphics.

b. Windows on the screen correspond to nodes on a one-to-one basis, and each has a name or title. However, only a small number of nodes are ever open as windows on the screen at the same time.

c. Standard window system operations are supported. Windows can be positioned, opened, resized, closed, and put aside as small window icons. A mouse is almost essential for efficient use of windows.

d. Windows can contain any number of link icons which represent pointers to other nodes in the data base. The link icon contains an abbreviation which suggests the contents of the node to which it points. Tagging a link icon with the mouse causes the system to find the referenced node and to open a new window for it on the screen.

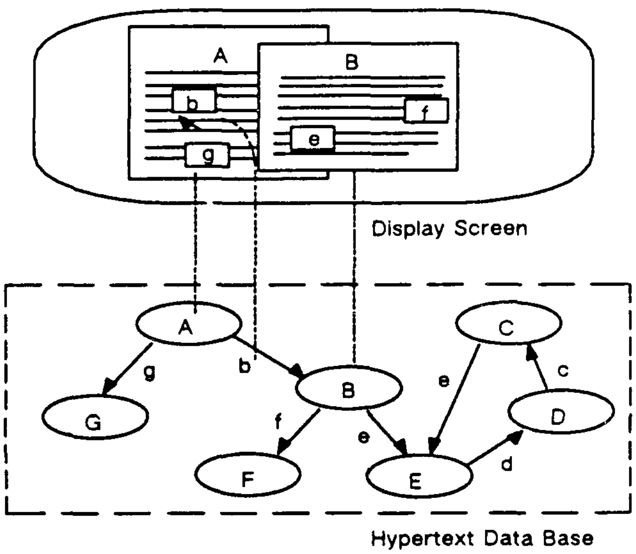
e. Users can create new nodes as new objects are defined, and new links to new or existing nodes to reflect new relationships.

f. The data base can be navigated in three ways. First, the user may follow links and open windows successively to examine their contents; second, the network may be automatically searched for keywords or attribute values; third, a graphic display of the network is placed on the screen and the user examines it, using node and link labels to direct a search.

Hypertext systems have been under development for about twenty years, primarily in research laboratories. The computer science problems involved in setting up such systems have been substantial. Recently, two simple hypertext products appeared on the market: Guide, from Owl International Inc., and HyperCard for the Apple MacIntosh.

Hypertext systems in the research environment are addressing most of the requirements for Type C Tech Orders as described above. Much remains to be done to develop fully capable prototypes and subsequently, proven commercial systems. Beyond establishing a technology base, effective utilization will be paced by the technical authors learning how to use the new approach, and by availability of efficient authoring and production tools. The Air Force should not expect to achieve routine production of Type C Tech Orders, within an acceptable standard, for at least ten years.

Figure G-1 illustrates how information units can be brought to the screen by activating link icons.



Note: User can create a window containing information in unit B by tagging link icon b on window A

FIGURE G-1. CORRESPONDENCE BETWEEN DISPLAY WINDOWS AND LINKS, AND DATA BASE NODES AND LINKS

G.4 VIDEODISC

Videodisc is a technology that stores and allows retrieval of a mixture of audio, video, and digital data.

The videodisc is an optically pitted plastic disc with enough independently addressable locations to be able to play 30 to 60 minutes of continuous video motion accompanied by sound track. Video and audio information may be interspersed with conventional computer data. The player rotates the disc continually and uses a low-power laser to read the data. A microprocessor-based controller can access any desired frame address. It may also branch to encoded picture stops or chapter initiation points. Scan, search, forward/reverse, speed, and index options can be applied.

An integrated system includes a computer, videodisc player, and display. It is physically closely analogous to the WORM mass storage technology. A different physical system to perform the same function called Compact-Disc Interactive (CD-I) is in a similar way, closely analogous to the CD-ROM mass storage technology. Levels of interactivity have been defined as follows:

1. Play only, no random access.
2. User-directed branching and stop points.
3. Preprogrammed control of user interaction, as in a training routine.
4. Computer-resident programs that can generate on the same output display:
   a. Video and still images from the disc player;
   b. Computer text and graphics from the computer;
   c. A mixture of these.

The Level 4 capability is required for effective integration of videodisc-based instructions with hypertext for application to Type C Tech Orders. Figure G-2 shows the schematic of a videodisc system.

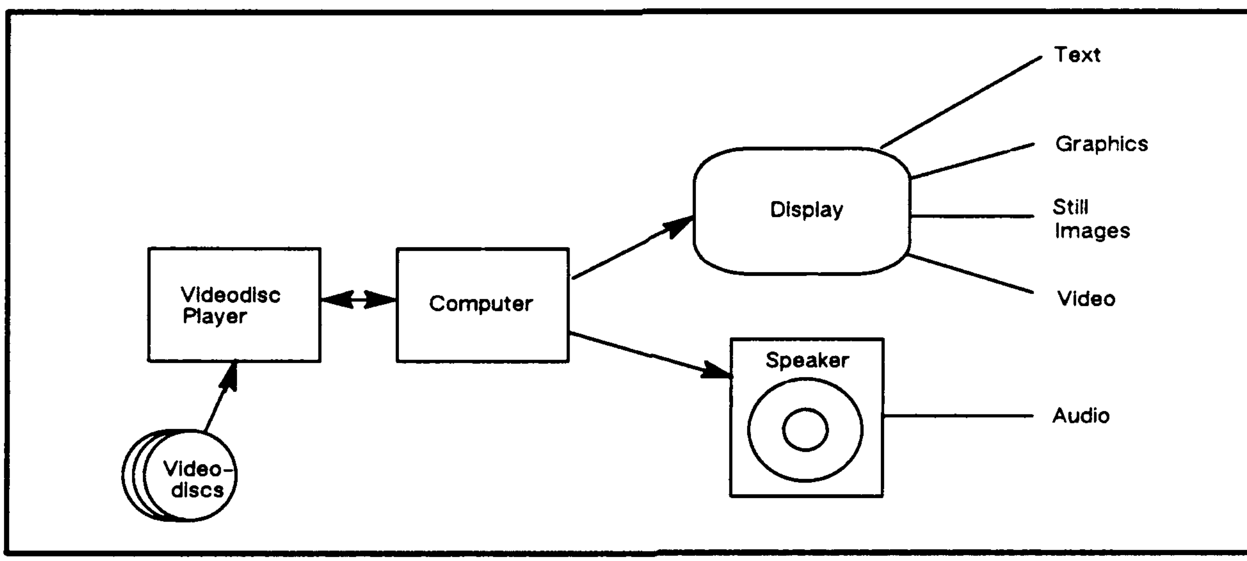


FIGURE G-2. SCHEMATIC OF VIDEODISC SYSTEM

Two videodisc products are now on the market: Sony's View System and IBM's InfoWindow System. As with hypertext, technical authors must learn how to use the new approach and have available efficient authoring and production tools. Videodisc has a level of complexity beyond hypertext, in that a variety of skills, including photography, graphic design, filming, and editing are needed for production. In addition, the tools must be available to smoothly integrate videodisc sequences into the information units of the hypertext document. Based on all these factors, effective implementation and integration of videodisc technologies into Type C Tech Orders, in a routine production mode, is more than ten years away.

G.5 CONCLUSIONS AND RECOMMENDATIONS

Hypertext and videodisc are new technologies that will, in time, make possible the smooth development of Type C Tech Orders for the Air Force. However, these applications have significant barriers which remain to be overcome in the next ten years. In addition to further technological development in both areas, training must be developed and applied, for the end users and Tech Order authors. Since this kind of document is not standard in industry, the Air Force will be breaking new ground with such a training program. Creating videodisc components of Type C Tech Orders requires the production of video sequences, which in turn requires the application of a variety of special skills comparable to those used in the television industry. An additional delay to the effective implementation of this technology may be anticipated.

Based on these conclusions the following recommendations are made for best use of these technologies over the next ten years:

- The Prototype Type C authoring and user systems which emerge from the IMIS program should be evaluated, and lessons learned applied to later implementations.
- The Air Force Human Resources Laboratory (AFHRL) should conduct research on Type C user systems to better understand how they can become accepted by the technician work force.
- The Air Training Command (ATC) should develop training programs for Type C authors, beginning perhaps in five years and based on the best commercial products at that time. User training programs also must be developed and in place prior to implementation of Type C Tech Orders on a specific weapon system. These training programs must be frequently updated as better products become available.
- The commercial market should be continuously monitored for progress in state-of-the-art of hypertext and videodisc, and other prototypes developed within the next ten years to continually gain experience prior to full replacement of Type B Tech Order systems by Type C.

APPENDIX H

NATURAL LANGUAGE PROCESSING (NLP)

H.1 BACKGROUND

Transforming of Tech Orders from paper documents to electronic ones raises the question of how these documents will be made available and interacted with at the flight line and the workbench.

Large on-line text and image data bases are relatively new phenomena, and associated query and retrieval techniques are the subject of current research. Yet a system can be envisioned that allows the rapid query and/or browsing of pertinent Tech Orders to find the critical materials required to solve a problem. This system would be based on a more or less English-style problem statement or query from the user. The system would parse the request, i.e., transform the request from natural language into a program in the formal language of the machine that carries out the action requested by the user. The capability just described is called Natural Language Processing (NLP).

The Tech Order data base, once electronically generated, allows many possible additional scenarios to be envisioned. These include:

1) Walking the user through the task using multi-media documents that would include text, diagrams and drawings, video step-by-step instructions, review of instruments and equipment techniques and calibration.

2) Detailed queries in how to carry out a task. In this case, the NLP must be interfaced to a detailed knowledge domain for the specific tasks.

3) Interfaces to expert systems for diagnosis and repair procedures.

Achievement of these three scenarios is not going to follow trivially by converting the old paper documents to electronic ones. To achieve Scenario 1 would require reorganization of the Tech Order and the addition of considerable video material to the original text. Scenarios 2 and 3 would require the creation of expert systems and knowledge bases about each specific application domain. This would be a major effort.

NLP permits a user to interact with a computerized system in the most natural and familiar method, the written language of the user or some restricted subset. The advantages of using English (in the United States) over other user friendly modes such as menus and command line scripts is the NLP's ability to understand input regardless of its format and content. Its major drawback is that the inherent ambiguities of natural language require the costly development of a complex set of Artificial Intelligence (AI) tools to have even a marginally useful NLP.

H.2 SUMMARY OF RELATED WORK

While progress can be expected to be slow and to have a history of promising leads that fail to produce major breakthroughs, there has been and will continue to be major progress. A project by T. Winograd in the early 1970s demonstrated a program called SHRDLU that could manipulate blocks in a graphic simulation and understand and answer queries about the world and the nature of its actions using an NLP. University of Lowell research has recently shown that robotic assembly of real objects is feasible using an expanded dictionary of machinery and assembly terms based on WASP (Wait And See Parsers).

Probably the closest research directly applicable to the Tech Order user is the SRI International TDUS (Task-Oriented Dialog Understanding System) which had the goal of advising a human apprentice on repair operations on electro-mechanical equipment. TDUS maintained information about how tasks were to be accomplished using a partially ordered list called a procedural network. The procedural network is similar to the familiar PERT network, i.e., both maintain task precedence relations. The project, while successful in many of its goals, also illustrated many problems with this approach. The lack of understanding of the apprentice's goals and world knowledge, and cost of development showed that this area is still in need of further research.

LADDER is an SRI International project that allows the Navy to query the nature and location of ships at sea in a flexible natural language format. The data base has over 40,000 ships and has been used for air/sea search and rescue. A major breakthrough was INTELLECT, a program written by the Artificial Intelligence Corp. This NLP was designed for front end Data Base Management Systems found in the IBM series of mainframes. It allowed users to request data in a very normal question format, i.e., "List all New England sales personnel who have exceeded their quota by more than 50 percent and sort by highest performance." This query in the formal query language would be cumbersome and require an advanced programmer to provide the correct answer. Perhaps, INTELLECT's major impact was that IBM agreed to market the product and thereby give its stamp of approval to NLPs. Over the last several years there have been a variety of new and promising NLP products for querying relational data bases.

The NLP sophistication and robustness of the level of understanding is increasing rapidly. Systems exist that can use a 10,000 word dictionary; map a query of words not strictly in the data base relations into close approximation to the desired response; and, deal with spelling errors and ellipses (omitted words).

H.3 NATURE OF INTERFACES

During the 1950s and 60s computers grew in size and complexity and required a dedicated cadre of computer professionals to program and maintain them. Now the microcomputer has made itself part of the office and shop floor. While the microcomputer is becoming a universal tool, research and development is still needed in the area of man–machine interfaces. Many frustrating hours are spent in classes reading ambiguous manuals and learning the details of a new operating system. The price of becoming an expert is seen as too high and prohibitive for the casual user.

The following criteria can be used to indicate the direction for creating the user model of any interface:

- The user's knowledge of the functionality of the system.
- The long term commitment of the user to the system.
- The expected user population's range of sophistication.
- The ability to personalize the interface for sophisticated users.
- The ability of the system to provide help at any point in the interaction.

In general, unless the user community is very experienced and knowledgeable and the commitment is for the long term, a NLP approach will be preferred over a fixed, terse, formal interaction.

H.4 CRITERIA FOR NLP INTERFACES

There are several criteria for NLP interfaces:

- Syntactic coverage of any natural language system. Fortunately, most task–oriented systems contemplated for the Tech Order application are invariably simple dialogs using current theory and tools, and hence will probably yield success.
- Task–oriented semantic coverage implies that by appropriately limiting the scope of these tasks and information domains, a reasonably robust and flexible system can be constructed. However, like expert systems, NLPs break down in unexpected ways as they approach the edges of their domains.
- Flexibility in the presence of errors in grammar. Many studies have shown that more than half of the dialog typed by users is ungrammatical. Misspellings, missing punctuation, ellipses, interjection, and transposed word order are just some of the errors that a NLP must be expected to handle if it is to be a useful tool.