CHAPTER TWO
HYPERMEDIA INFORMATION ON CD-ROM

2.0 INTRODUCTION

Aviation technicians, managers, engineers, and support personnel spend endless hours searching for information every day, not to mention the hours they spend creating and revising this information. Improvements in the way aviation personnel access information will lead to more reliable and more cost- effective air transportation.

Toward this end, the Federal Aviation Administration (FAA) Office of Aviation Medicine (AAM) Human Factors in Aviation Maintenance research program studied the challenges associated with creating, accessing, and maintaining digital documentation using a Hypermedia Information System (HIS). Hypermedia presents material in a fashion that encourages browsing and discovery by combining text, graphics, audio, video, and animation. This technology can be used solely as a tool to access information, or it can be integrated with job aiding and training systems (Johnson and Norton, 1992). The AAM hypermedia research developed and distributed the Compact Disc, Read-Only Memory (CD-ROM), shown in Figure 2.1, in early 1993.

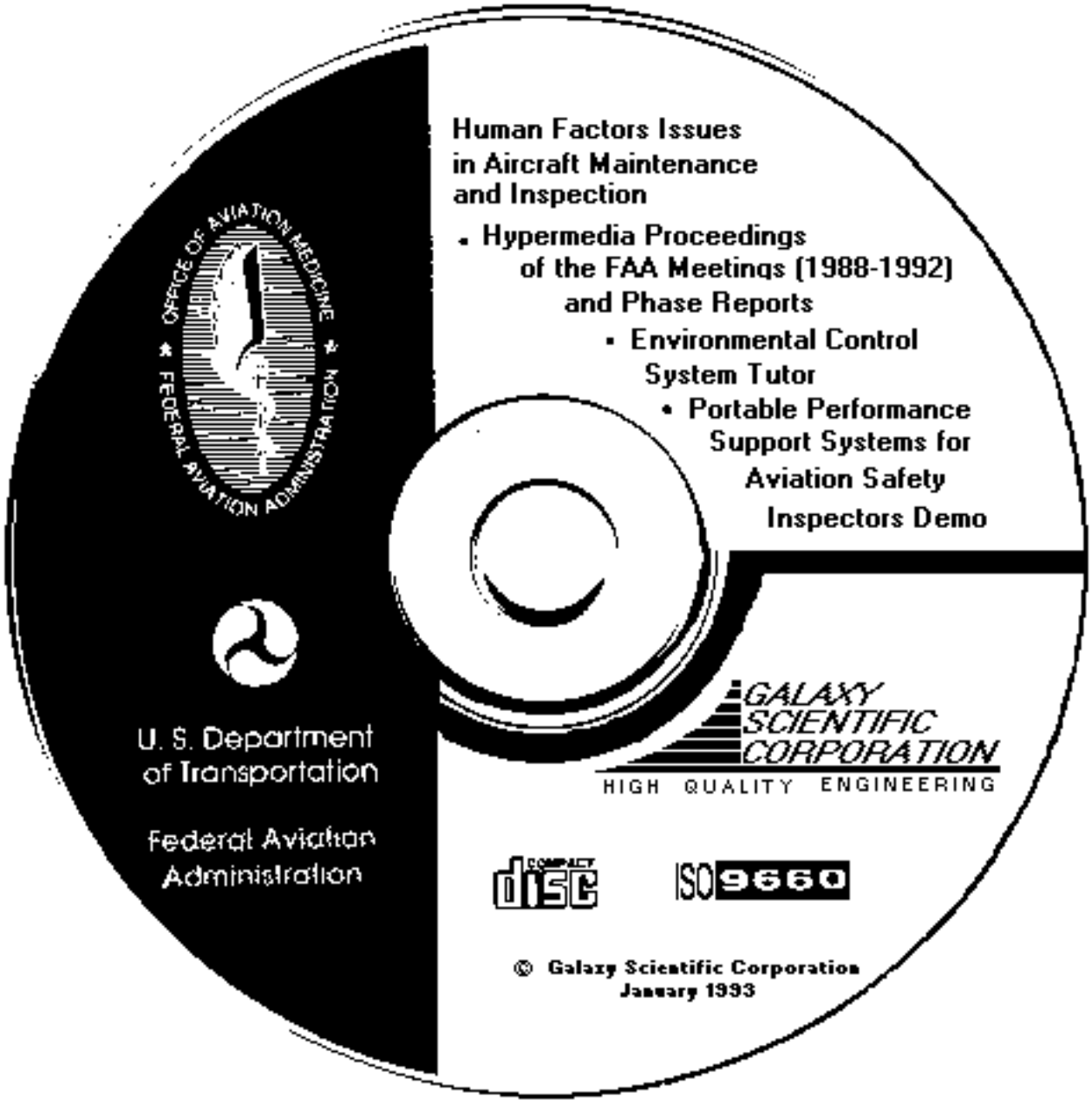

Figure 2.1 Human Factors Issues in Aircraft Maintenance and Inspection CD-ROM

This chapter focuses on designing and developing of a Hypermedia Information System for the AAM, and the CD-ROM on which the HIS was distributed. It describes the current and future technical challenges associated with the development of such a system.

2.1 ASPECTS OF HYPERMEDIA

Before delving into the specifics of the AAM HIS and the CD-ROM, it is first necessary to provide some background information about hypermedia and digital documentation.

2.1.1 Access to Technical Information

Technicians, depending on their experience and maintenance role, estimate that they spend as much as forty percent of their workday accessing technical information. This information usually spans many volumes. For example, the maintenance documentation for the Boeing 727 consists of multiple volumes with more than 33,000 pages each (Cruickshank, 1993). Trying to locate all references to a particular component or procedure within such a large collection of data is a daunting and time-consuming task. It requires hours of effort, with no guarantee of locating all the references.

New automated technical systems are referred to by many names, including electronic library systems (ELS), hypermedia, digital documentation, and electronic documents. They attempt to reduce the amount of time required to access information. Initial studies have found that time required to search a maintenance manual is reduced by as much as forty percent when the manual is on a CD-ROM rather than on paper or microfiche (Cruickshank, 1993). With such technology, technicians spend less time accessing information, which allows for more time directed toward maintenance. Thus, aircraft will be available to produce revenue more quickly.

New aircraft such as the Boeing 777 are incorporating ELSs at design time. Since ELSs are only available for the newer aircraft, older aircraft do not offer this advantage. Therefore, the AAM research program has been exploring issues involved in creating digital documentation to support older aircraft, as well as the other documentation needs in the aviation maintenance system. The Hypermedia Information System applies hypermedia technology to these needs. The HIS and other results of the AAM program are contained on the Human Factors Issues in Aircraft Maintenance and Inspection CD-ROM.

2.1.2 New Terms for New Technologies

New technology leads to the need for a new vocabulary. Creating a hypermedia document is more than scanning hard-copy into digital format. That process would be similar to the creation of microfiche, searchable only by an index. The reader would have to refer to the index, then manually go to the appropriate page. Hypermedia documents are far more powerful than that, and the additional power requires a new vocabulary. This section defines common terms used to describe electronic documents: *hypertext*, *hot words*, and *hypermedia*.

A useful digital document capitalizes on *Hypertext* technology. Using a computer's assistance, hypertext makes it possible to establish connections (called *Links*) within and between documents. Hypertext links are usually denoted by *Hot Words*, using different colors, fonts, or outlining to differentiate them from the rest of the text. With hypertext, for example, a maintenance technician can link the Maintenance Manual to the Minimum Equipment List.

Hypermedia extends a hypertext document to include such media as animation, video, and audio. For example, with hypermedia in a Maintenance Manual, the reader could click on a hot word to see a video clip that demonstrates a selected maintenance procedure. (For more on the basics of hypertext and hypermedia, see Howell, 1992.)

2.2 THE CD-ROM

Figure 2.2 shows the main screen on the CD-ROM. Each of the six programs shown in the figure is described in this chapter. One is an intelligent information retrieval system; two are intelligent tutoring systems; one is a demonstration; and two are kiosk programs. The first one -- the HIS -- is the focus of the chapter and is discussed first and in the most detail.

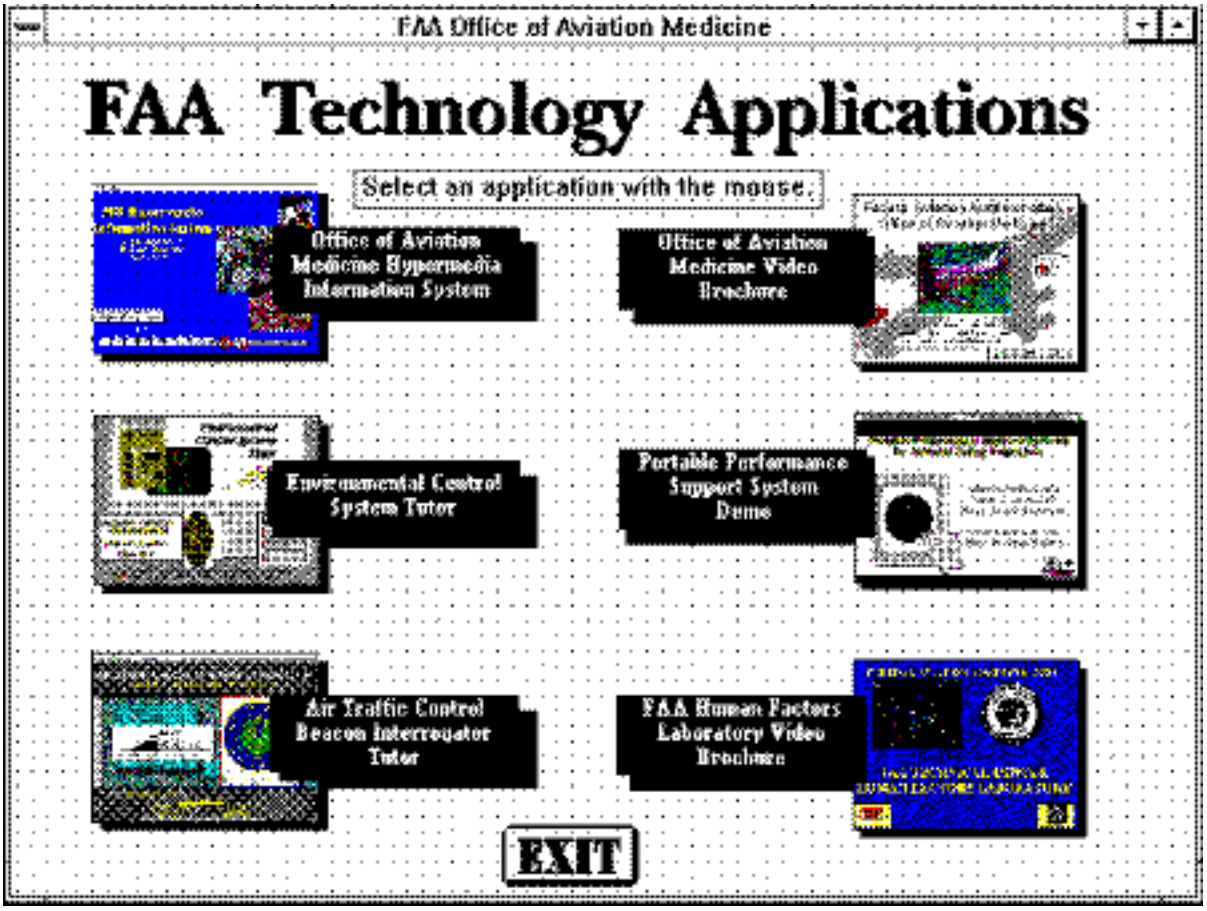

Figure 2.2 Applications on the CD-ROM

2.2.1 The AAM Hypermedia Information System

The goal of the AAM Hypermedia Information System (HIS) research program is to investigate hypermedia technology and how it can help the aviation community. The research strives to create new tools and methods for information storage and retrieval. The hypermedia research to date has been conducted over a two-year period.

During the first year of the research, a prototype hypermedia information system was developed. This is reported in detail elsewhere (FAA/AAM and GSC, 1993). For this system, a selected subset of publications from the AAM research program were put on-line. Links to graphics were then added to the documents. The prototype HIS provided a mechanism for viewing and searching these documents. The product was distributed on floppy discs to over 100 persons with either aviation and/or human factors expertise. An opinionnaire and informal interviews elicited user feedback on the HIS interface. The feedback was positive and supported further development of the HIS.

With user feedback from the prototype, as well as on-going user evaluation of the software, the prototype was enhanced during the second year of the research and is described herein. The enhancements to the HIS made it a turn-key system. It has been used in a research setting, as well as in aviation maintenance and inspection tasks. These applications are described below, followed by an in-depth discussion of the HIS.

2.2.1.1 The HIS Supports the Aviation Maintenance System

The HIS has proven its ability to benefit all facets of the Aviation Maintenance System: air carriers, schools, aviation maintenance technicians, researchers, etc. The version of the HIS presented on the CD-ROM addressed the needs of aviation researchers. It was also successfully incorporated into both a maintenance training environment, as well as a job aid for aviation safety inspectors.

2.2.1.1.1 The Research Community

The development of the first AAM CD-ROM presented most of the challenges that the industry would face in production of digital data. Documents were selected for the HIS library based on the following criteria: (1) documents that would have value for the FAA, the aviation industry, and the research program and (2) documents in the public domain so that the end product could be distributed at no charge. With these criteria, it became obvious that the CD-ROM document library should include the products of the Aviation Medicine Human Factors in Aviation Maintenance research program. These products include reports and conference proceedings which encompass over 1,700 pages of text and over 500 graphics.

2.2.1.1.2 Training for Aviation Maintenance Technicians

Using hypermedia technology, a version of the Environmental Control System (ECS) Tutor (described in more detail below) provides links from the Tutor to the HIS. The library for this new Tutor uses text and graphics directly from the cooperating airline's training manuals, allowing direct access to information in a format familiar to those using the Tutor. This replaces the abridged format presented in earlier versions. With the data in the HIS, the student can browse the information or search for specific topics while troubleshooting with the Tutor.

2.2.1.1.3 A Job Aid for Aviation Safety Inspectors

The HIS also supports a Job Aid for Aviation Safety Inspectors. The Job Aid (described in FAA/AAM & GSC, 1993) supports the Aviation Safety Inspector in a variety of regulatory activities. The Inspector accesses various manuals and guidelines throughout the work day. A version of the HIS modified the interface to meet inspectors' special requests.

To demonstrate the power of the HIS for job aiding, several key FARs were incorporated into a new library. The HIS allows the Inspector to browse and search the FAR library for specific information related to the particular inspection task.

2.2.1.2 HIS Features

The prototype HIS, developed in the first year of research, demonstrated the tremendous potential of hypermedia technology for AAM research, but it was just a prototype. Over the last year, the functionality of the HIS has been increased to give readers more power to browse and search through the hypermedia documents. The HIS' features that support the reader in navigating the system, viewing and searching a document, and printing text and graphics are described below.

2.2.1.2.1 Navigation

The HIS provides the reader with multiple ways to navigate through a collection of documents, or a library: the Bookshelf, the Table of Contents, and the Overview Map. The Bookshelf, shown in Figure 2.3, is the first display the reader sees in the HIS. The reader chooses a library to view from the Bookshelf. The numbered icons in the bottom left of the screen represent nine different libraries in this example.

Once the reader selects a library, the Table of Contents for that library appears, as shown in Figure 2.4. When the reader selects one of the displayed chapters, that chapter's text then appears.

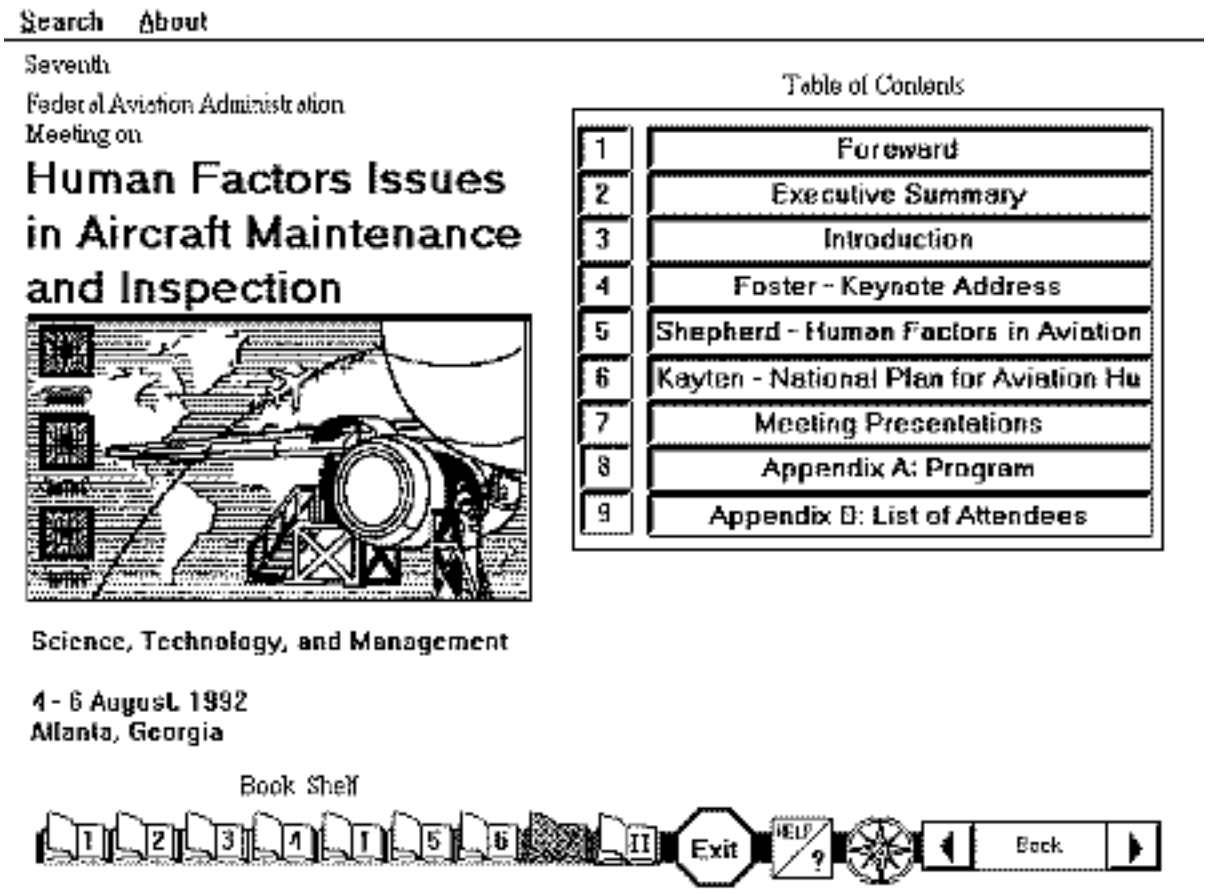

Figure 2.4 Table of Contents

Another way to choose a chapter is to use the Overview Map, as shown in Figure 2.5. The Overview Map provides a more detailed list of a library's contents than the Table of Contents. When the reader selects a rectangular document icon, that document's text then appears.

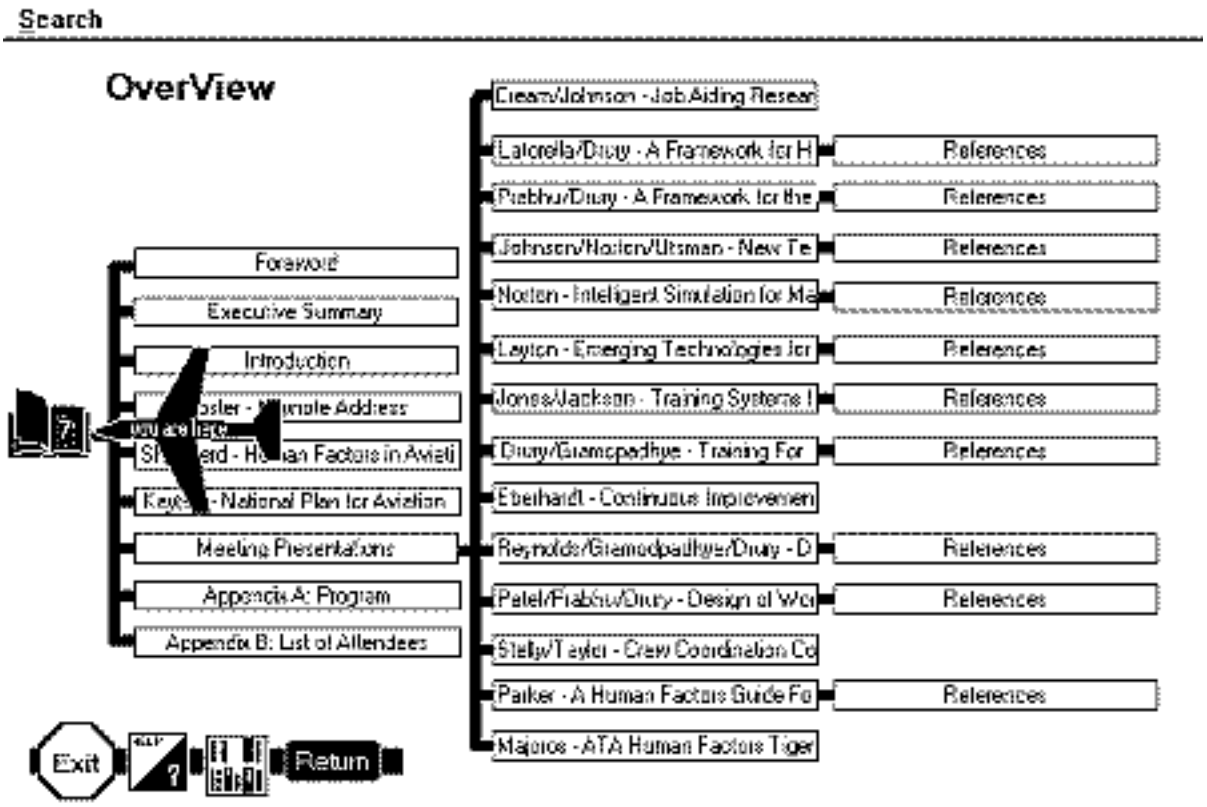

Figure 2.5 The HIS Overview Map

The system also maintains internal bookmarks to aid navigation. An internal bookmark remembers the reader's place in a document in the same way that a paper bookmark keeps the reader's place in a paper book. For example, if the reader is viewing the "Foreword," goes to the Overview Map, and then wants to return to the "Foreword," the HIS returns to the last location in the "Foreword," instead of returning to the first line of the "Foreword."

2.2.1.2.2 Viewing Area

The document viewing area shown in Figure 2.6 allows a reader to scroll through and read a hypermedia document. Text formatting such as boldface, italics, and underlining enables the on-line document to resemble the original.

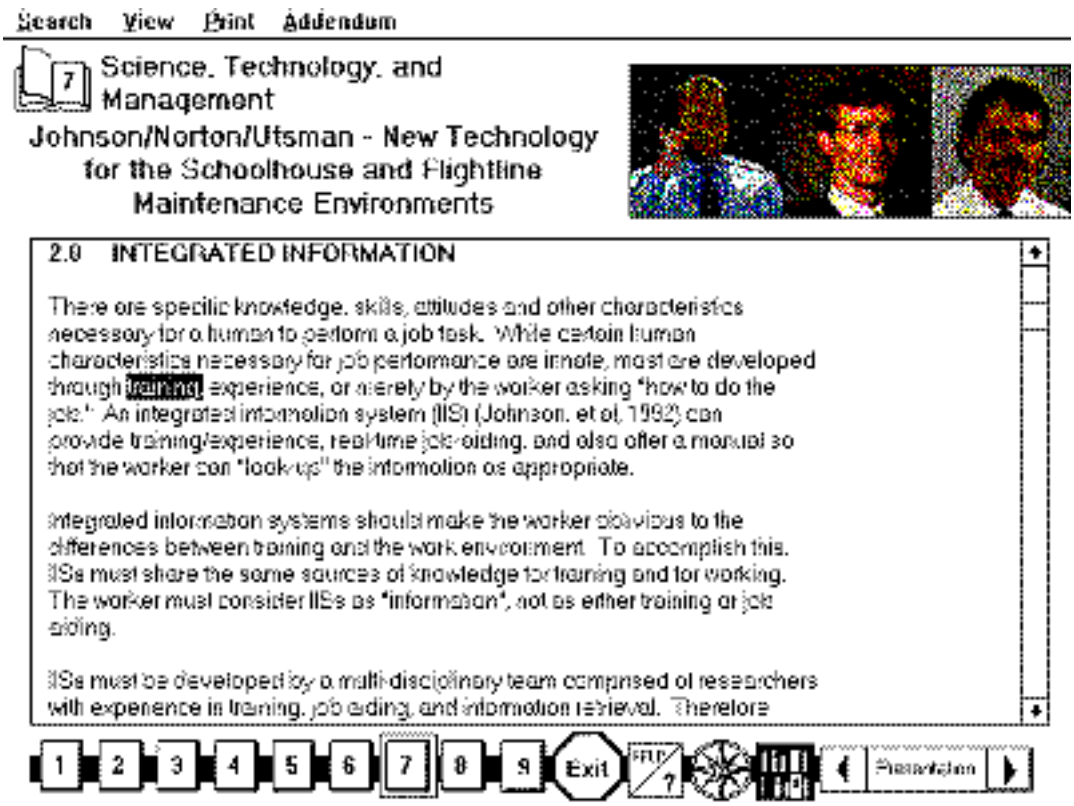

Figure 2.6 The Document Viewing Area

While viewing a document, a reader may come across a hot word, indicating a link. The hot word is enclosed in a rectangle. When selected by the reader, some hot words will link to a graphic. A Graphics Viewer will display the figure, as shown in Figure 2.7.

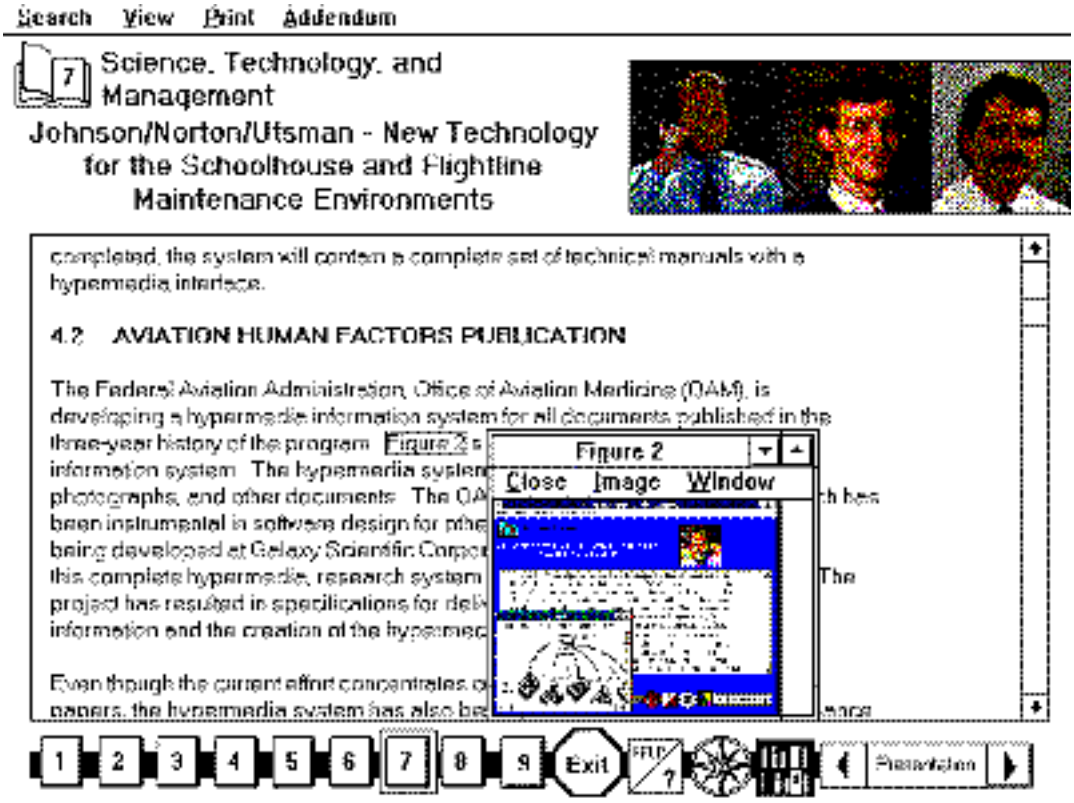

Figure 2.7 Hot Link to a Graphics Viewer

2.2.1.2.3 Searching

One of the most powerful features of a hypermedia system is its ability to quickly locate specific words in large amounts of text without the reader having to scan each line of text. A reader performs a search by typing in a query, as shown in Figure 2.8. The HIS then rapidly searches all documents in the library and highlights the document icons on the Overview Map which satisfy the query. From that point, the reader can select a document for viewing that contains the "search hits." Once the selected document is loaded, the reader can use menu items to find the exact locations of the search hits. Search hits are highlighted to provide the context, as shown in Figure 2.6.

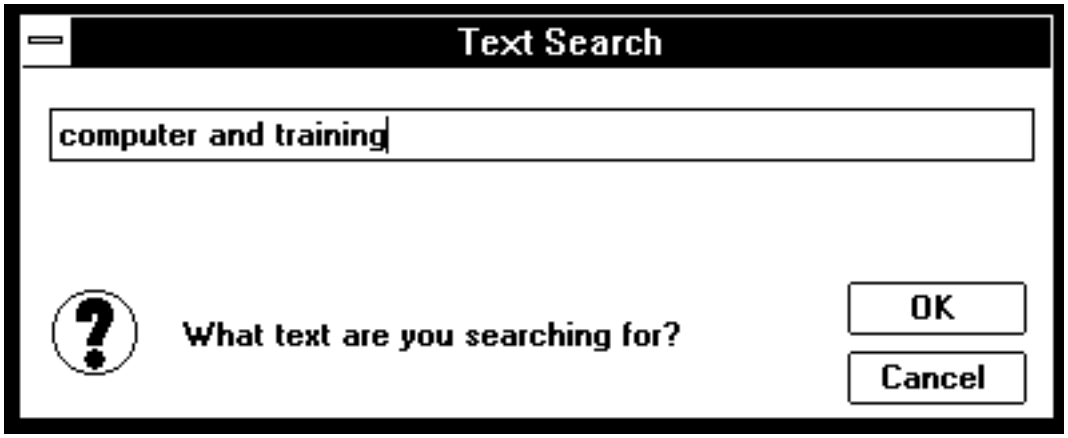

Figure 2.8 Search Query Dialogue Box

The HIS supports four types of searching: term, wildcard, phrase, and Boolean. "Term" search, the simplest, is a search for one specific term, such as *computer*. Every document which contains this term will be highlighted on the Overview Map.

The "wildcard" search allows the reader to look for variations of a term, e.g., computer, computers, computing. For example, *compute** would highlight all documents containing any variation of "compute". A document with "compute" (or "computer", or "computer-based", etc.) would match the search, but a document with "computing" would not.

"Phrase" searching enables the reader to specify the order and adjacency of multiple terms. For example, phrase searching for *"computer training"* will only display places where that exact phrase appears. The reader specifies a phrase search by placing quotes around the phrase.

The "Boolean" search combines any of the above types with Boolean operators (AND, OR, NOT). For instance, *computers or "computer training"* will identify documents which contain either the word "computers" or the phrase "computer training".

2.2.1.2.4 Printing

The second year HIS also provides several ways to print information. Two menu items, "Print Selected Text" and "Print Document", are available from the document viewing screen. "Print Selected Text" allows the reader to highlight text as small as a single word using the mouse and to send that portion of the document to the printer. "Print Document" prints the entire current document.

As text might not provide the only pertinent information in a hypermedia system, a printing capability exists in the Graphics Viewer as well. This allows the reader to print any graphic that is referenced by a document.

2.2.1.2.5 On-line Help

An extensive, on-line help program exists in the HIS. It describes the features of the HIS and assists a reader in navigating through the HIS.

2.2.2 Other CD-ROM Applications

The CD-ROM showcases software developed in support of the Federal Aviation Administration. In addition to the HIS, the applications include two intelligent tutoring systems, two video kiosk programs, and one demonstration of a job aid currently under development.

2.2.2.1 The Environmental Control System (ECS) Tutor

This software was sponsored by the FAA AAM as part of the Human Factors in Aviation Maintenance research program and is described in Phase II (FAA/AAM & GSC, 1993) and Phase III Volume 1(FAA/AAM & GSC, 1993). The ECS Tutor investigates the use of advanced technology in maintenance training. This intelligent simulation compares models of the student, the instructor, and the ECS expert to provide remediation to the student and uses the student's previous performance to decide when the student requires assistance in troubleshooting a malfunction.

The ECS Tutor software simulates the operation of the Air Conditioning portion of the Environmental Control System (ECS) for the B-767-300 and assumes some background knowledge of this system. The system can operate in two modes: normal operating mode and malfunction mode. Normal operating mode lets the students manipulate the switch lights and control knobs as needed to observe normal ECS operation. The ECS will respond as demanded, just like in the "real" world. Malfunction mode presents component malfunctions to the student. The ECS displays data values corresponding to the current malfunction.

2.2.2.2 Portable Performance Support System Demo

This software demonstration was sponsored by the FAA Office of Aviation Medicine. The Portable Performance Support System (PPSS) demo provides an overview of the FAA's efforts to apply pen computer and hypermedia technology to provide real-time job aiding and information retrieval for Flight Standards Activities. The PPSS has since been renamed the Performance Enhancement System (PENS). The initial target users are Aviation Safety Inspectors.

Aviation Safety Inspectors perform a variety of tasks, including accident and incident investigation, certificate management, and aircraft inspection. Aviation Safety Inspectors must document their activities on forms. The FAA would like the inspectors to record their data in a format that can be directly stored in the database.

Not only must inspectors maintain their records, but they must have access to the large amounts of information relevant to their jobs. Such information includes Federal Aviation Regulations, Airworthiness Directives, Advisory Circulars, and other documentation. PENS will use the HIS to provide ready access to such information. (An in-depth description of this system is found in FAA/ AAM & GSC, 1993.)

2.2.2.3 Office of Aviation Medicine Video Brochure

This software was sponsored by the FAA Office of Aviation Medicine. It describes the goals, organization, and work of the FAA AAM by allowing the user to browse through a series of short video clips.

2.2.2.4 The Air Traffic Control Beacon Interrogator Tutor

This software was sponsored by the FAA Technical Center, Advanced System Technology Branch (ACD- 350). This proof-of-concept tutor investigates the use of advanced technology in Airways Facilities maintenance training. The goal of the training system is to help experienced technicians maintain proficiency.

This tutor contains a simulation of the Air Traffic Control Beacon Interrogator (ATCBI-4) and references information about the ATCBI-4, including part/output descriptions, test/adjustment/ replacement explanations, preventive maintenance procedures, standard and tolerance values, and functional block schematics.

2.2.2.5 The FAA Human Factors Laboratory Video Overview

This software was sponsored by the FAA Technical Center. It introduces the goals and facilities of the Human Factors Laboratory (HFL) at the FAA Technical Center in New Jersey through a series of short video clips and still images. The mission of the HFL is to ensure optimum safety as greater demands are placed upon the National Airspace System. As a facility featuring state-of-the-art technology and an innovative structural configuration, the HFL will have a great impact on the movement of aviation into the next century.

2.2.3 Production of the CD-ROM

The HIS and other applications were distributed on CD-ROM for two reasons: a CD-ROM holds large amounts of data and it is a cost effective means of distribution. This section describes how much data a CD-ROM holds, how one is produced, and how much production costs.

2.2.3.1 How Much a CD-ROM Holds

A CD-ROM disc contains approximately 650 Megabytes of storage, the rough equivalent of 325,000 pages of text. The HIS and the library together used 40 Megabytes of storage, leaving ample disc space for other applications.

Because of the volume of data, any other means of distribution would be costly and cumbersome. The potential of a CD-ROM disc to store vast amounts of information ensures its continued use for distributing the HIS and any application libraries. Even if a CD-ROM disc eventually reaches capacity, the system can be distributed over multiple CD-ROM discs.

2.2.3.2 How One is Produced

A CD-ROM is a storage medium similar to floppy and hard discs. It holds digital data like floppy and hard disks, with one important distinction: once the CD-ROM is produced, a user can only **read** from it. Therefore, the creator of a CD-ROM must take special care in its preparation.

In order to produce the CD-ROM, Galaxy contracted with a disc manufacturing company. The first step in the process was to gather all of the data files for the CD-ROM and to send them to the disc manufacturer for premastering. During this process, the manufacturer put the files into a special format along with error detection and correction codes to produce a proof disc that was returned to Galaxy.

Galaxy thoroughly tested the proof to ensure that neither the disc manufacturer nor Galaxy had inadvertently left data files off the disc. From the proof, a master disc was produced. The master disc was duplicated, producing the CD-ROM discs that were distributed to the aviation maintenance community.

2.2.3.3 How Much a CD-ROM Costs to Produce

Table 2.1 shows the production costs for the AAM CD-ROM. The CD-ROM package contained the disc, an 8-page booklet describing each application, and an inlay card for the CD-ROM jewel case. The CD-ROM discs, holding 650 Megabytes of data, cost approximately $1.75 each in lots of 1000. These 1992 prices are expected to drop in the future. The accompanying 9 pages of paper documentation cost as much as the CD-ROM disc! This clearly illustrates the cost advantage of digital documents over paper documents.

Table 2.1 CD-ROM Production Costs

PRODUCT	QUANTITY	COST
Premastering Disc	1	$ 500.00
Proof Discs	2	$ 400.00
Master Disc	1	$ 500.00
CD-ROM Replicas	950 (+ 50 free)	$ 1710.00
Total		$ 3110.00
8 Page Booklet	1000	$ 1512.00
Inlay Card	1000	$ 265.00
Total		**$ 1777.00**

2.3 THE FUTURE

The HIS shows great promise in all areas of the Aviation Maintenance System and will continue to evolve. The HIS developers look to the following goals for guidance with future enhancements:

- To support a wider variety of media.
- To support a wider range of users by offering more methods for navigating documents.
- To provide tools for the creators of hypermedia documents.
- To support existing and emerging documentation standards.

The following sections describe plans to enhance the HIS in support of these goals.

2.3.1 Additional Media

The HIS Graphics Viewer allows the reader to view a PCX-formatted picture - enlarging, reducing, or printing the picture as needed. A PCX-formatted picture is the only medium other than text which the HIS supports. Because a computer-based document can incorporate many different types of media, future HIS enhancements will support new media and graphics formats.

Possible graphics formats include, among others, bitmap (BMP), encapsulated postscript (EPS), graphics interchange file (GIF), targeted image file format (TIFF), and Joint Photographic Experts Group (JPEG). Additionally, more innovative types of media for computer presentation, e.g., sound, video, animation, etc., will be supported. A Multimedia Viewer will be added to play audio, video, animation, CD, etc. A reader will be able to access the media through a hot word in the manner currently used for static graphics.

2.3.2 Navigating Documents

A traditional paper book provides several methods for navigating its contents: a Table of Contents, an Index, and simple page turning. Likewise, a hypermedia information system must provide multiple methods for navigating a hypermedia document. This is important because different readers access information in different ways. As mentioned earlier, the HIS currently provides a Bookshelf, a Table of Contents, an Overview Map, and Internal Bookmarks. Future enhancements to the HIS will add a more flexible Table of Contents and user-definable Bookmarks.

The improved Table of Contents will act as a textual representation of the library, similar to its graphical counterpart, the Overview Map. A reader will be able to view the sections as a "collapsed" Table of Contents, as is done now, or to expand a section to see what subsections fall within it, as shown in Table 2.2.

Table 2.2 Collapsed and Expanded Table of Contents

Collapsed Table of Contents		Expanded Table of Contents	
1.0	Introduction	1.0	Introduction
2.0	Continued Growth of the HIS	2.0	Continued Growth of the HIS
3.0	The HIS Supports the Aviation Maintenance System	3.0	The HIS Supports the Aviation Maintenance System
		3.1	Training for Aviation Maintenance Technicians
		3.2	A Job Aid for Aviation Safety Inspectors
4.0	A Plan to Support the Human Factors Guide	4.0	A Plan to Support the Human Factors Guide
5.0	The Future	5.0	The Future

Table 2.2 Collapsed and Expanded Table of Contents

The current HIS provides system-defined internal bookmarks. However, it is sometimes desirable for a reader to mark a place in a document. A bookmarking capability will be added to the HIS to create multiple bookmarks for a document.

2.3.3 Tools for Creating Hypermedia Documents

As mentioned earlier, a hypermedia document is more than just a digital version of a paper document. It may contain links to other documents, graphics, animation, and even other software programs. Before a digital document can be called a hypermedia document, someone must transform it from its original form into a form by the HIS can use. Just as a "reader" views, or reads, the hypermedia document, an "author" creates the hypermedia document. The author's job is similar to that of an editor, i.e., to gather source material into a cohesive form. A hypermedia author does the same, but also defines the relationships among the different sources (text, graphics, audio, video, and animation).

Example: An author wants to transform a maintenance manual (already in digital format) into a hypermedia document. The manual has wiring diagrams and pictures of components. Also, the manual describes certain removal and installation procedures for which the manufacturer has supplied video.

Using this example, the author would first access three different source materials: the *text* of the maintenance manual, the *graphics* files containing the pictures and diagrams, and the *video* files of the procedures. The author must bring these three types of information to a common destination -- the hypermedia library. By adding references in the text to link information with other source materials, the author transforms the digital document into a hypermedia document.

In order to facilitate the creation of hypermedia documents, future work will provide support tools for the author. The research will investigate ways to make the conversion from existing source documents to their hypermedia counterparts less time-consuming. One solution will be to provide filters for existing word processing packages. The filters will translate the source documents into hypermedia documents, preserving all previously formatted text. Additionally, the authoring process will be streamlined, integrating all such authoring tools into one seamless authoring environment.

2.3.4 Documentation Standards

The HIS proved that hypermedia technology is useful to the aviation community. For the HIS to continue to succeed, it must adhere to aviation documentation standards, such as Air Transport Association Specification 100 (ATA Spec 100) and Standard Generalized Markup Language (SGML) (Goldfarb, 1990).

Also, because commercial and military aviation have many similarities, the HIS must consider Department of Defense (DoD) standards as well. The DoD mandates that the Federal Computer-aided Acquisition and Logistical Support (CALS) program adhere to SGML. Also, new weapons systems are using Interactive Electronic Technical Manual (IETM) Specifications. The HIS will consider these and other emerging standards in future versions.

2.4 CONCLUSIONS/SUMMARY

Tough economic times in the aviation industry have forced air carriers to find ways to reduce costs without sacrificing safety. Hypermedia technology provides such a way. Advanced technology information systems such as the HIS showcased on the AAM CD-ROM save time and money (Johnson, in press). In addition, by providing a complete search of the information, these systems support safer maintenance. The HIS is an important part of safer, more cost-effective maintenance. Continued, enthusiastic cooperation from the aviation industry will make further progress with hypermedia technology possible.

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