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16. Abstract

The third phase of research on human factors in aviation maintenance continued to look at the human's role in the aviation maintenance system via investigations, demonstrations, and evaluations of the research program outputs. This report describes the Office of Aviation Medicine's Hypermedia Information System, released on CD-ROM in early 1993. The report also offers an extended discussion of computer-based training (CBT) for maintenance and provides guidelines for CBT decision making. One chapter of the report identifies the "barriers" that have hindered the acceptance and success of nontraditional participants in aviation maintenance careers and offers recommendations to ensure a barrier-free work environment for all workers. The report also includes a chapter on the plan and pilot study to investigate relationships of a number of variables to nondestructive inspection performance. An evaluation of Maintenance Crew Resource Management is also reported on, as well as the development and status of the *Human Factors Guide for Aviation Maintenance*.

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The pragmatic nature of this research is attributable to the many FAA, airline, manufacturer, and vendor personnel who provided advice to the research team.

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LIST OF ABBREVIATIONS

AAM	Office of Aviation Medicine
AAUW	American Association of University Women
AICC	Aviation Industry Computer-based Training Committee
AMT	Aviation Maintenance Technician
ANOVA	Analysis of Variance
A & P	Airframe and Powerplant
ATA	Air Transport Association
ATCBI-4	Air Traffic Control Beacon Interrogator
BMP	bitmap
BRP	Blue Ribbon Panel
CALS	Computer-aided Acquisition and Logistical Support
CBT	computer-based training
CD-ROM	Compact Disc, Read-Only Memory
CMAQ	Cockpit Management Attitudes Questionnaire
CRM	Crew Resource Management
CRM/TOQ	Crew Resources Management/Technical Operations Questionnaire
DoD	Department of Defense
EAA	Experimental Aircraft Association
ECS	Environmental Control System
EIS	electronic library system
EPI	Eysenck Personality Inventory
EPS	encapsulated postscript
FAA	Federal Aviation Administration
FARs	Federal Aviation Regulations
FIMs	fault isolation manuals
GIF	graphics interchange file
GSC	Galaxy Scientific Corporation
HFL	Human Factors Laboratory
HIS	Hypermedia Information System
HR	human resources
ICAO	International Civil Aviation Organization
ID	identification
I-E	Internal - External
IETM	Interactive Electronic Technical Manual
ITS	intelligent tutoring system

JPEG . . . . Joint Photographic Experts Group
JTA. . . . . Job Task Analysis

kb . . . . kilobyte

Mb . . . . megabyte
MELs . . . . minimum equipment lists
MFFT . . . . Matching Familiar Figures Test

NASA. . . . . National Aeronautics and Space Administration
NDI. . . . . Nondestructive Inspection
NTIS . . . . National Technical Information Service

PC . . . . personal computer
PENS. . . . . Performance Enhancement System
PPSS . . . . Portable Performance Support System
PRF . . . . Personality Research Form

RON . . . . remain in station overnight

SGML . . . . Standard Generalized Markup Language
SME . . . . subject matter expert
SRS. . . . . Subjective Rating Scale
SUNY . . . . State University of New York

TEI . . . . Typical Experiences Inventory
TIFF . . . . targeted image file format

WAIS. . . . . Wechsler Adult Intelligence Scale
WP . . . . Working Paper

CHAPTER ONE
PHASE III OVERVIEW

1.0 INTRODUCTION

The Federal Aviation Administration (FAA) Office of Aviation Medicine (AAM) Human Factors in Aviation Maintenance research program has developed an industry reputation for maintaining an awareness for "where the rubber meets the road." The program combines solid human factors principles with the knowledge and active involvement of industry and government personnel. There have been extensive publications and presentations, as well as software distributed throughout the industry. **Table 1.1** offers a partial listing of the research products and publications. A detailed bibliography of the publications is included as Chapter Eight in this report.

Table 1.1 AAM Human Factors in Maintenance Products - A Partial Listing

• Seven workshops (nearly 1,000 total participants)
• Environmental Control System Trainer (distributed to more than 100 Part 147 schools and most of the U.S. airlines)
• CD-ROM (over 700 copies distributed)
• Publications (over 100 articles and scientific papers published)
• Performance ENhancement System (In Phase IV, a job aid will be fielded for FAA inspectors in all regions)
• Phase Reports (Four large technical reports like this one)

Since 1989 this research program was designed and executed according to the diagram in **Figure 1.1**. In the early stages of the research program the scientific team conducted extensive site surveys of airline maintenance organizations. That process not only prompted an enhanced understanding of the "real world" of airline maintenance but also identified numerous manufacturer, airline, and FAA partners who wanted to cooperate in this pragmatic research program.

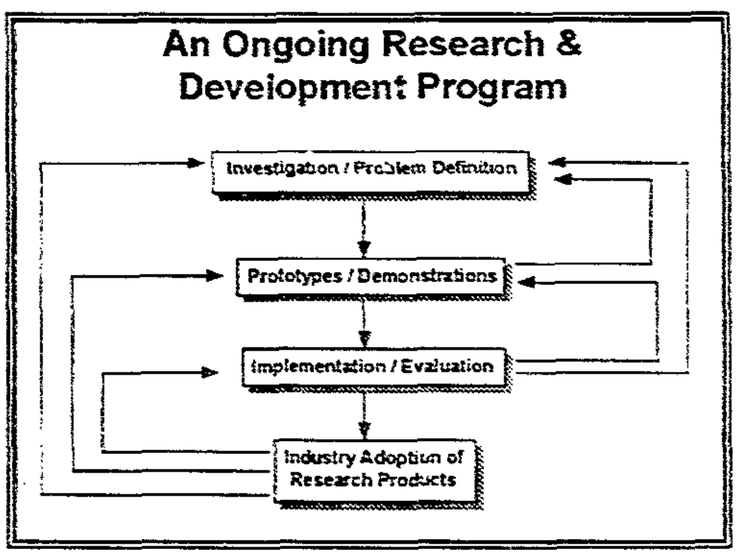

Figure 1.1 The Research Program

Figure 1.1 shows that the research proceeded from problem definition to the development, implementation, and evaluation of a variety of human performance enhancements in aviation maintenance. Examples reported on in past reports and in this volume include an operational example of intelligent tutoring using a B-767 environmental control system; a CD-ROM containing all the publications of the research program and a variety of multimedia and other software demonstrations; seven conferences on human factors in maintenance and inspection with over 1,000 total attendees; and a variety of other reports and demonstrations. **Figure 1.1** also shows that the industry adoption of research products provides feedback to all stages of the research.

When the research program began, in the late eighties, the concept of human factors in aviation maintenance was, for the most part, ignored. The National Plan for Aviation Human Factors recognized the importance of the aviation maintenance system by assigning maintenance human factors equal prominence with air traffic control and flight operations. The FAA AAM Human Factors in Aviation Maintenance research program has successfully demonstrated that attention to the human not only promotes safety but also affects maintenance efficiency, thus having a positive effect on maintenance costs.

As with the other reports from this research program, this volume begins with a sincere thanks to and acknowledgement of the many government and industry personnel who continue to cooperate with the research team. As the work, continues the number of contributors (FAA entities, air carriers, and consortiums of industry groups) has grown beyond a reasonable size to individually list all those who have provided guidance and cooperation.

The remainder of this overview chapter describes each chapter in this report.

1.1 THE AAM HYPERMEDIA INFORMATION SYSTEM (Chapter Two)

A prototype Hypermedia Information System (HIS) was developed in Phase II of the research program. This prototype demonstrated the tremendous potential of hypermedia technology for AAM research. Phase III work added eight documents to the framework provided by the prototype. The current HIS incorporates seven conference proceedings and two Phase Reports with over 1,700 pages of text and more than 500 graphics. It also includes two complete training simulations (ECS Tutor and ATCBI-4 Tutor), as well as a demonstration job aid for Aviation Safety Inspectors. **Figure 1.2** shows the HIS main menu.

In early 1993, the HIS was distributed on Compact Disc, Read-Only Memory (CD-ROM). The system was very well received in the research community and in the aviation industry as a whole.

In addition, Chapter Two discusses the changes to the HIS such as more powerful search and display tools, print functions, and an authoring system to allow a "hypermedia author" to transform paper documents into hypermedia documents. The chapter also describes how the HIS was integrated into a maintenance training environment and a job aid for aviation safety inspectors. Future needs of the HIS are also addressed.

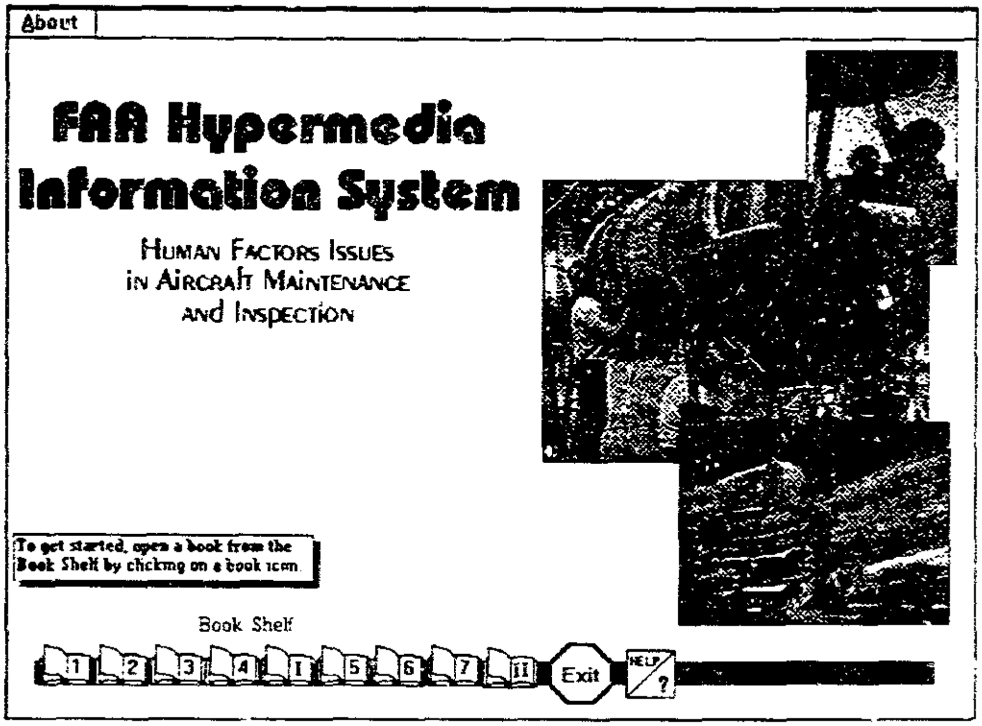

Figure 1.2 Main Menu from FAA Hypermedia Information System

1.2 GUIDELINES FOR DESIGNING AND IMPLEMENTING COMPUTER-BASED TRAINING FOR AVIATION MAINTENANCE (Chapter Three)

The application of advanced technology to training has been an important portion of the research program since its beginning in 1989. Industry and government personnel have looked to the AAM research for a glimpse of the cutting edge of instructional technology. The result has been demonstrations, development, and evaluation of simulation-based intelligent tutoring systems. The B-767 environmental control system training software has been distributed to many FAA-approved technician schools and to most U.S. airlines.

Chapter Three offers extensive discussion of computer-based training (CBT) for maintenance. The discussion is based on the knowledge gained through the research program, literature reviews, and reviews of off-the-shelf training systems. Written for managers, instructors, aviation safety investigations, and others associated with maintenance training, the chapter provides guidelines for CBT decision making.

1.3 IDENTIFICATION OF BARRIERS TO SUCCESS FOR NONTRADITIONAL PARTICIPANTS IN AVIATION MAINTENANCE CAREERS (Chapter Four)

Due to the changing demographics of the work force, an increasing number of new workers in aviation maintenance will come from nontraditional populations. Nontraditional members of the work force include females, Afro Americans, Asians, and Hispanics.

Chapter Four identifies the "barriers" that have hindered the acceptance and success of nontraditional participants in aviation maintenance career fields. Our changing society has removed many of the barriers; however, there is still opportunity for improvement. The chapter reports the results from a survey of nontraditional participants that was developed and distributed by a major U.S. carrier to its aviation maintenance work force. The chapter concludes with recommendations to ensure that the aviation maintenance work environment is barrier-free for all workers. Appendix 4 includes a demographic projection of future aviation maintenance technician (AMT) supply and demand.

1.4 A PILOT STUDY TO MEASURE CORRELATES OF INDIVIDUAL DIFFERENCES IN NONDESTRUCTIVE INSPECTION PERFORMANCE (Chapter Five)

An interim report (FAA/AAM & GSC, in press) reviewed previous research programs and studies in the area of nondestructive inspection (NDI). A repeated concern in the literature was the existence of substantial differences between inspectors' NDI proficiency. The report identified a number of variables which would appear potentially relevant to NDI inspector selection and/or proficiency. The variables can be grouped into the following categories:

- boredom susceptibility
- concentration/attentiveness/distractibility
- extraversion/ impulsivity
- motivation/perseverance
- decision making/judgement
- mechanical/electronics aptitude
- need for autonomy.

Chapter Five reports on the plan and pilot study to investigate relationships of these variables to NDI performance. The chapter discusses the tests and scales used to measure these variables, as well as the task employed in the study (NDI Task Simulation, **Figure 1.3**).

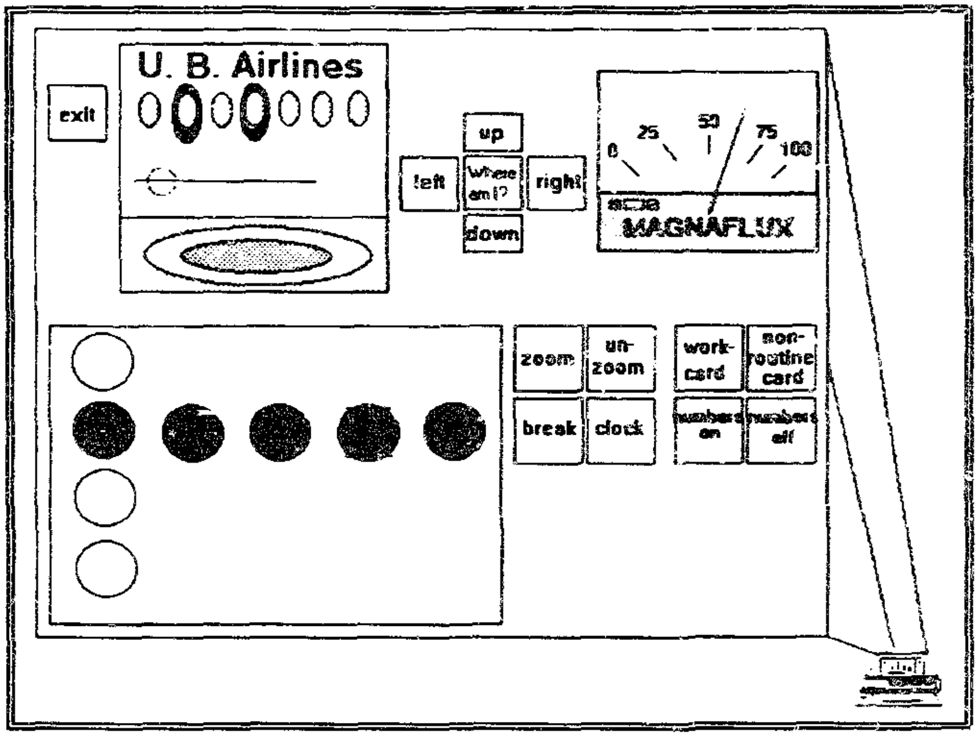

Figure 1.3 NDI Task Simulation

1.5 EVALUATION OF MAINTENANCE CREW RESOURCE MANAGEMENT (Chapter Six)

This project has co-developed and evaluated the effects of one airline's maintenance Crew Resource Management (CRM) training program (FAA/AAM & GSC, 1993). This training and evaluation focuses on maintenance managers' attitudes, their reported behaviors, and the maintenance performance of their units. The maintenance CRM program represents a long-term commitment to improving safe, dependable, and efficient performance through effective communication at all levels in airline maintenance operations. Extensive post-training questionnaires and on-the-job performance measures reveal a strong positive effect of the training.

As discussed in Chapter Six, the research examined maintenance performance changes and attitude changes that occurred following training. Maintenance performance changes occurred in the following areas: safety from ground damage, safety from injury, maintenance costs in overtime paid, delays in RON (remain in station overnight) aircraft departures, as well as dependability of on-time departures for other scheduled flights.

The analysis showed positive trends in a number of the company's overall maintenance performance measures for the 12 months after the onset of training compared with the previous 12 months. Comparisons of managers' attitudes before and after their training showed a significant improvement in three of the four attitude indicators: "willingness to share command responsibility," "usefulness of communication & coordination," and "recognition that stressors affect management decision making" (FAA/AAM & GSC, 1993).

The most important summary finding of the maintenance CRM training is that the concept works. As with cockpit CRM, improved attitude and communications result in a more productive, less error prone, and safer work environment.

1.6 A GUIDE TO HUMAN FACTORS IN AVIATION MAINTENANCE (Chapter Seven)

The operation of any system can only be optimized if every system element is working properly and if each element is carefully coordinated with every other element. The manager of a maintenance operation system should have all necessary information concerning maintenance technicians and, in particular, those features of the maintenance environment which serve either to enhance or to degrade technician performance. The manager or supervisor of a maintenance activity can be aided by the use of the *Human Factors Guide*, a handbook that provides this information in a form suitable for day-to-day reference.

Chapter Seven describes the *Human Factors Guide* development in Phase III. The *Human Factors Guide* presents established principles of job design and work that, if well applied, can contribute greatly to the control of human error in aircraft maintenance and inspection. Issues of communications, equipment utilization, work scheduling and load, work environment, and management relations are all important in determining worker effectiveness. The *Human Factors Guide* covers these and other human performance issues that can be applied in aviation maintenance. The *Human Factors Guide* is designed to address aviation maintenance and inspection needs. **Table 1.2** presents an outline of the *Human Factors Guide* sections.

Table 1.2 Outline for *Human Factors Guide* Sections

- Importance of Topic in Industrial Operations
    - Industrial Experience
    - Related Research
- Application in Aviation Maintenance
    - Industry Practices
    - Opinionnaire/Audit/Research Findings
- Human Factors Guidelines
    - Brief Discussion
    - Specific Guidelines
- Procedures for Evaluating the Situation

During Phase IV, the *Human Factors Guide* will undergo Beta testing with maintenance personnel in the United States. It is expected to be generally available in 1994 and will continue to be revised by the Office of Aviation Medicine. In addition to the hardcopy, a digital version of the Guide is planned.

1.7 BIBLIOGRAPHY - FORMAL PRESENTATIONS AND PUBLICATIONS (Chapter Eight)

Disseminating research results to the aviation industry is an important goal of the Human Factors in Aviation Maintenance research program. One effective way to do this is through presentations and publications for airlines, conferences, industry/government committees, schools, and magazines and journals. Chapter Eight provides a list of over 100 presentations and publications resulting from the research program to date.

1.8 CONTINUING RESEARCH

Future research will continue to emphasize the measurable impact of the research program on increasing maintenance effectiveness and efficiency with resultant cost control. In light of the serious financial trouble of the aviation industry, research dedicated to human-centered design and human resource development can have a wide-spread and immediate positive impact on the "bottom line." The research team will continue to interact with government personnel, airline management, and aircraft maintenance technicians to ensure the success and acceptance of research products by the aviation maintenance community.

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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.

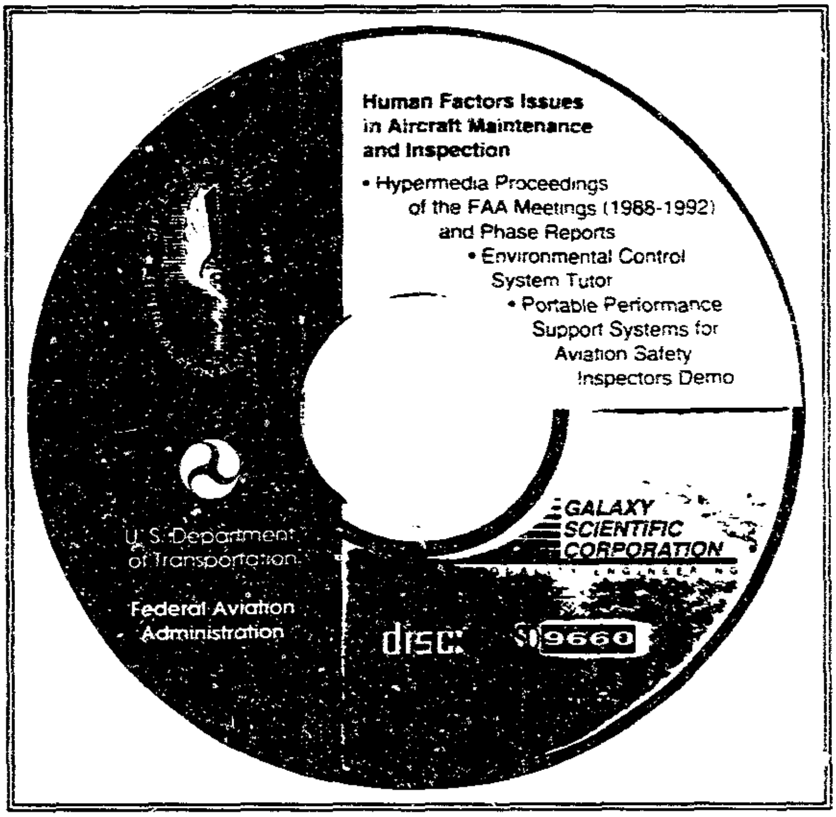

Figure 2.1 Human Factors Issues in Aircraft Maintenance and Inspection CD-ROM

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.

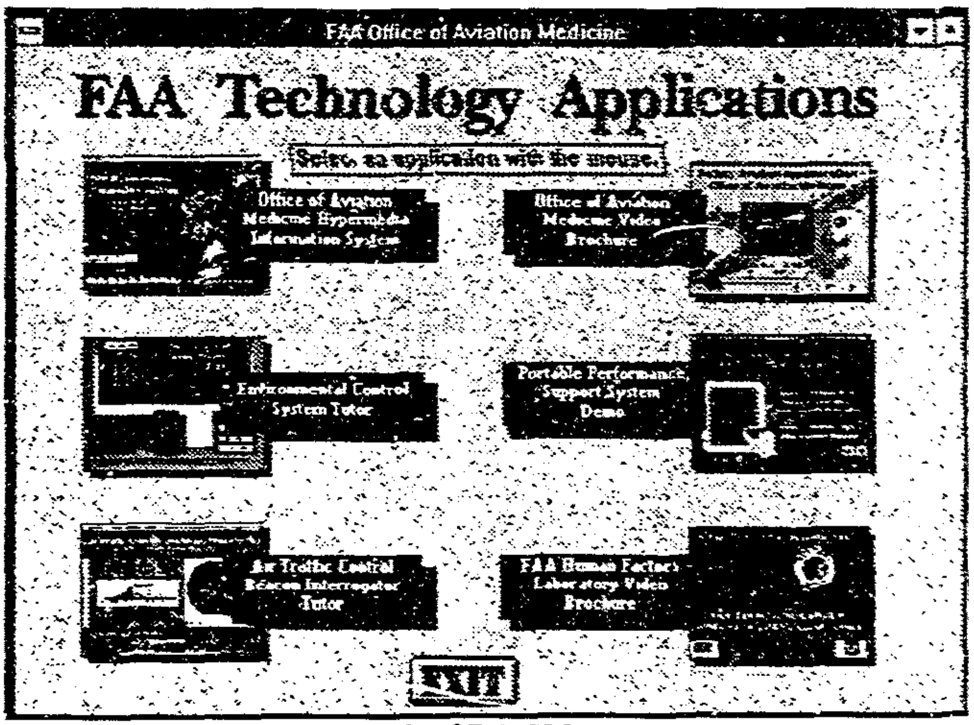

Figure 2.2 Applications on the CD-ROM

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 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.

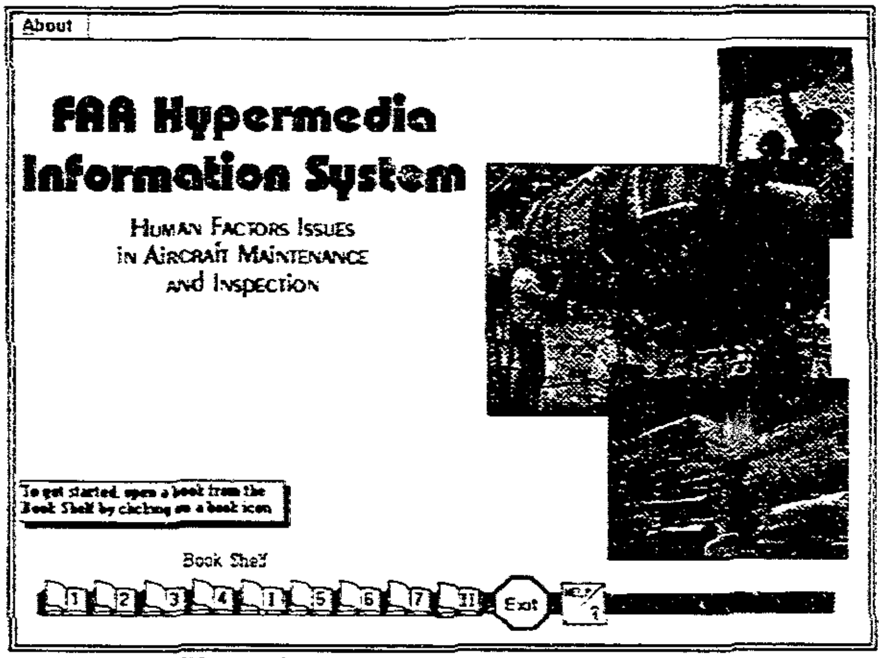

Figure 2.3 The HIS Bookshelf

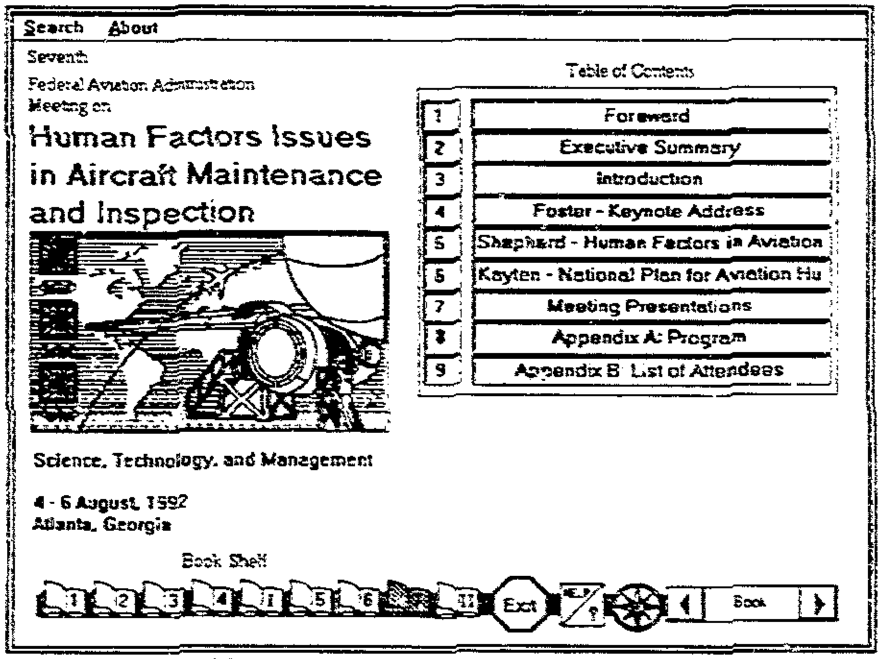

Figure 2.4 Table of Contents

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.

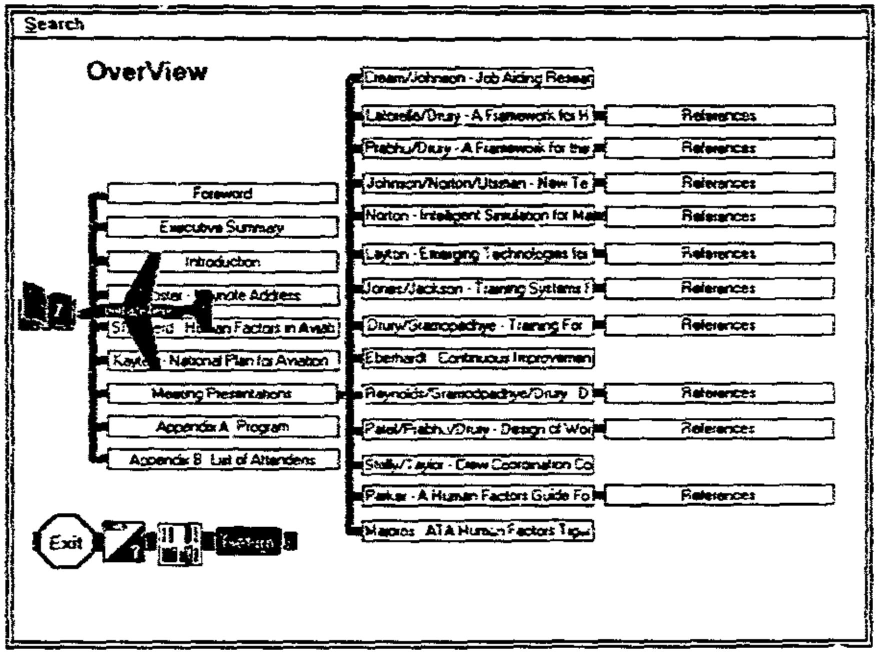

Figure 2.5 The HIS Overview Map

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.

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**.

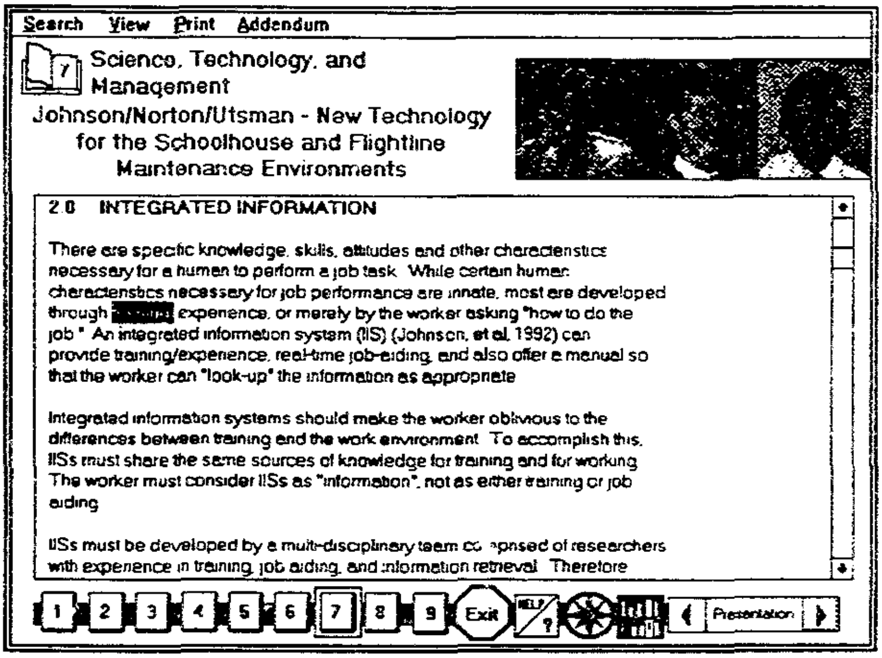

Figure 2.6 The Document Viewing Area

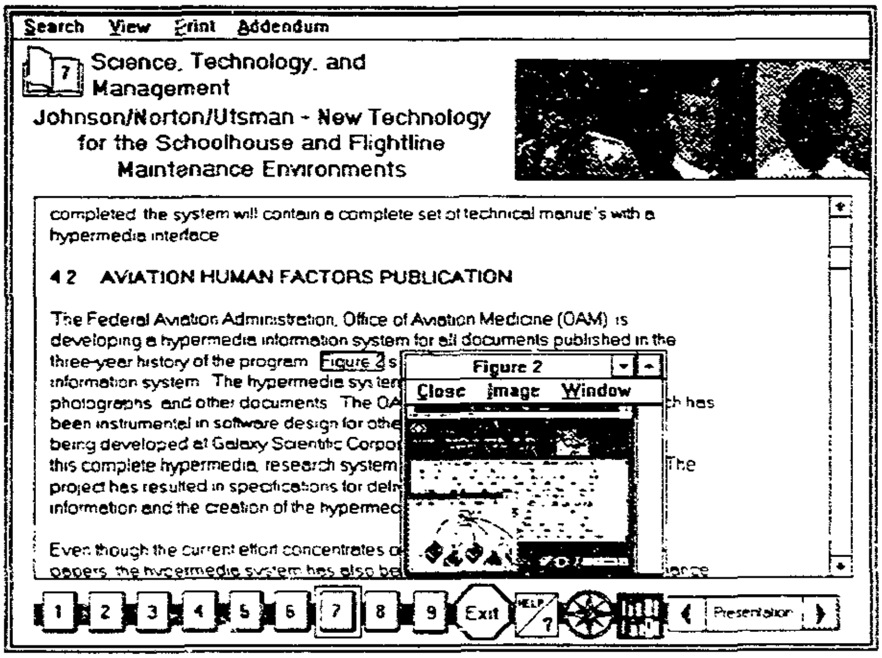

Figure 2.7 Hot Link to a Graphics Viewer

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**.

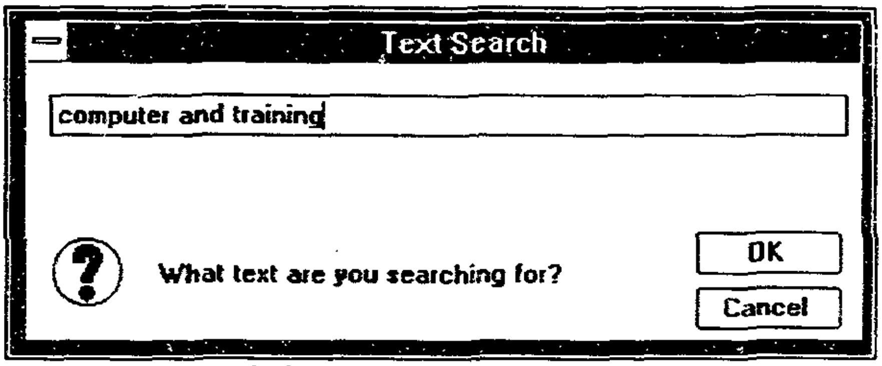

Figure 2.8 Search Query Dialogue Box

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 documents. 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*
4.0 A Plan to Support the Human Factors Guide	*3.1 Training for Aviation Maintenance Technicians*
5.0 The Future	*3.2 A Job Aid for Aviation Safety Inspectors*
	4.0 A Plan to Support the Human Factors Guide
	5.0 The Future

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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CHAPTER THREE
GUIDELINES FOR DESIGNING AND IMPLEMENTING COMPUTER-BASED TRAINING FOR AVIATION MAINTENANCE

3.0 ABSTRACT

This report is an overview of computer-based training (CBT) hardware, software, and instructional design. It will assist aviation maintenance training and FAA inspection personnel in making informed decisions about CBT. A central part of this report is the description of a process for analyzing the instructional requirements for a specific task and then selecting a CBT program or designing and implementing a program from scratch. The intended audience for this report includes FAA managers, aviation training managers and instructors, and others interested in CBT design and implementation. After reading this report, the reader will have a better understanding of the managerial, instructional, and technological issues involved in selecting or implementing CBT programs.

3.1 INTRODUCTION

Broadly defined, a computer-based training (CBT) system is a combination of computers and special software for training and education. Within this broad definition, there are many different approaches, systems, and technologies. Their common goal is to transfer skills and knowledge from an expert to the student via a computer system in such a way that the knowledge will develop and/or improve performance on a set of tasks. This goal is the same as that of instructional systems in general, including instructional aids, text books, and instructors. What differentiates a CBT system from traditional teaching methods is that CBT can be interactive, dynamic, and individualized. CBT does not require one-on-one interaction with an instructor. The computer program can be designed to simulate a piece of equipment, to react to user actions, and to provide useful feedback when the user makes mistakes. Sections 3.2 and 3.3 of this report describe CBT in detail.

3.1.1 Purpose of This Report

This report is for

- FAA managers
- Aviation training managers
- Aviation training instructors
- Those who are interested in designing and implementing CBT systems.

This report

- Provides an overview of CBT hardware, software, and instructional design
- Helps aviation maintenance training and FAA inspection personnel to make informed CBT decisions

- Presents a process for *designing and implementing* CBT systems
- Describes the issues that instructional design teams should consider in designing and implementing CBT systems.

The reader does not need to be familiar with CBT design and implementation to understand and apply this report but should be familiar with aviation training issues. The author assumes that the reader's organization does not currently have CBT capability. Additional information relevant to the topics covered in this report can be found in Section 3.9, "References."

3.1.2 Overview of Part 147 Changes Related to CBT

Appendix A of FAR 147 describes curriculum requirements. Recent revisions to that section under "(c) Teaching material and equipment," state the following:

> *The curriculum may be presented utilizing currently accepted educational* materials and equipment, including, but not limited to: calculators, computers, and audio-visual equipment.

While this revision is loosely worded, it is interpreted to mean that CBT can be a reasonable part of the approved Part 147 school curriculum. Explicit guidelines for FAA inspectors have not yet been issued. However, it is generally expected that student hours spent with CBT will become an approved portion of school curriculum. This report will contribute toward making CBT an approved part of the school curriculum.

3.2 OVERVIEW OF COMPUTER-BASED TRAINING

Before an organization attempts to produce or use a CBT system, it needs to examine its need for training and understand the issues involved in CBT design, production, and use. This includes knowledge of what makes CBT successful or unsuccessful. This section describes the issues involved in deciding whether CBT should be applied to aviation maintenance training tasks.

3.2.1 When to Use CBT

There are no strict rules for deciding when CBT should and should not be applied. The ability to judge the appropriateness of any training technology comes from knowledge of the technology, experience with previous applications of the technology, and knowledge of the training task. Each training technology has its own peculiarities that make it appropriate for certain types of tasks and domains, and inappropriate for others. In the case of CBT, these peculiarities include the interactivity of training, the ability to include several information types, and the individualization of instruction. **Table 3.1** lists situations when CBT is generally appropriate.

On the other hand, CBT does not currently provide support for all types of training. The lack of realism in current computer interfaces and the difficulty of providing intelligent human-computer dialog means that some training is better accomplished with other methods. **Table 3.2** lists situations when CBT is usually inappropriate.

Table 3.1 When CBT is generally appropriate

- Textbook teaching methods are used in current course curriculum
- Task requires strong problem-solving skills
- Students need to understand dynamic behavior of equipment
- Real equipment is too expensive for training
- Task is dangerous
- There are not enough human instructors available
- Flexibility of training schedule is desirable
- Training needs to be delivered to multiple, decentralized sites
- Students need extensive practice and review to accomplish task
- Students have wide range of experience and backgrounds
- Consistency of training is important

Table 3.2 When CBT is generally inappropriate

- Significant psychomotor or sensory skills are required for task
- Training requires significant instructor/student interaction
- Aesthetic judgement is required for task evaluation
- Extensive team skills need development
- Few students require training
- Training needs to be implemented quickly

As shown in **Figure 3.1**, there are two reasons for applying CBT to a particular task: reduced cost and improved performance (Kearsley, 1982). In the case of reduced cost, the goal is to provide training more cost effectively than the current method while maintaining the quality of training. Cost savings can come from reduced work force requirements, decreased travel cost, lower training equipment costs, and a decrease in the time required to attain knowledge or skill proficiency. For example, a CBT program that teaches a new maintenance procedure could be more cost-effective than teaching the procedure with an instructor because of money saved in travel and per diems. Improved performance, the second reason for applying CBT, results from the high-level of interactivity possible with graphical computer simulations. For example, a CBT program could improve technicians' troubleshooting abilities by allowing them to practice and improve their diagnostic skills. A CBT program can provide realistic simulation that rivals that of on-the-job experience, without the danger, equipment, and time required for on-the-job training.

There are financial tradeoffs to consider when comparing CBT to traditional training. **Figure 3.2** shows a generic trend comparing the development and delivery costs between the two methods. The initial development cost for CBT is often higher than for traditional instruction. However, over time the CBT delivery cost is likely to be less than that of traditional instruction. Financial considerations are also discussed in Section 3.4.1.3.

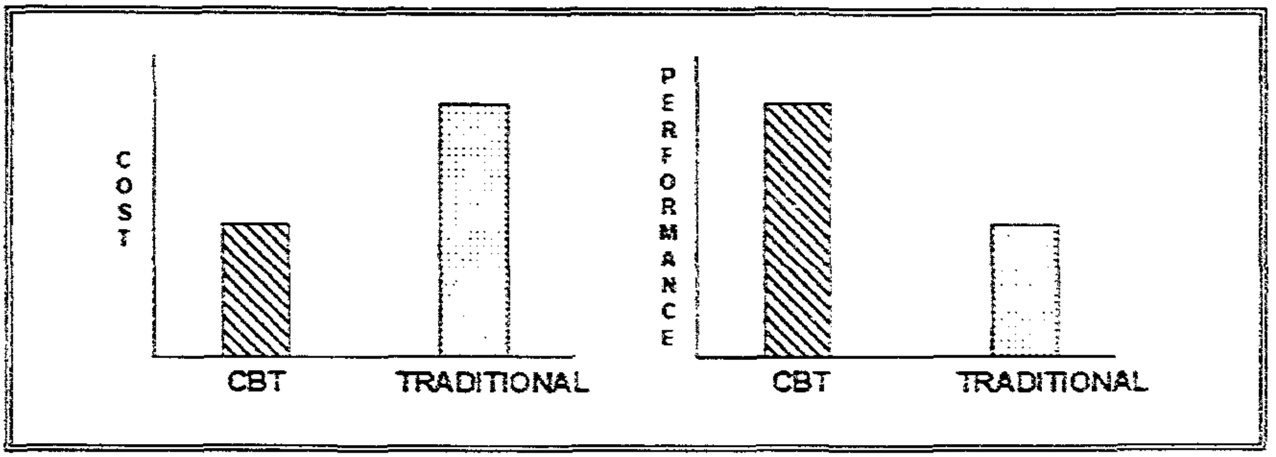

Figure 3.1 CBT goal to lower cost and increase performance

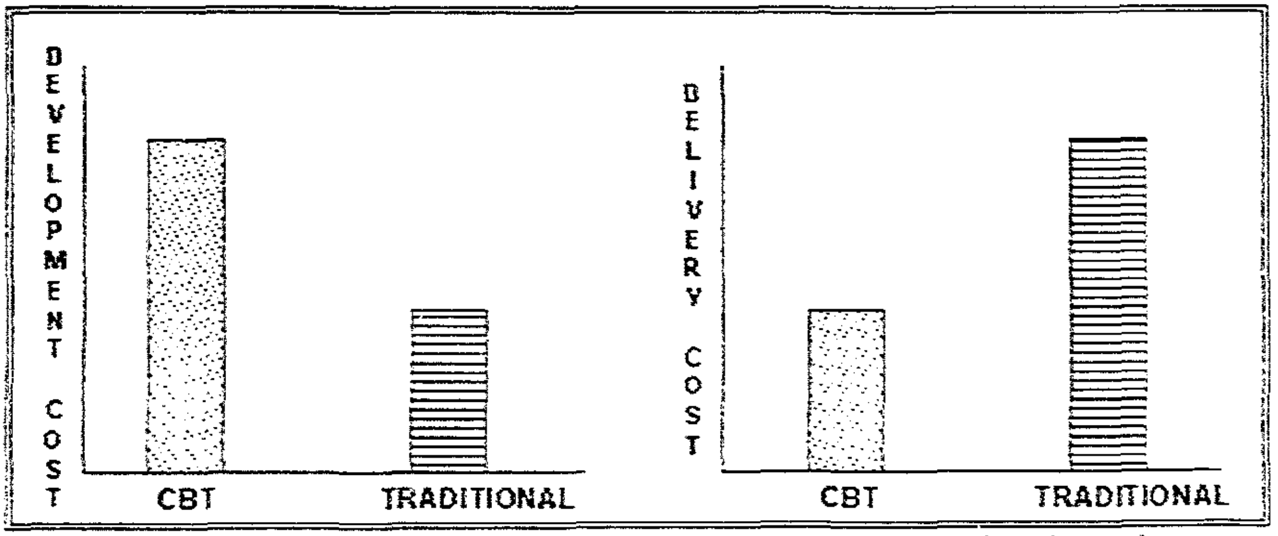

Figure 3.2 Comparison of development and delivery costs for CBT and traditional training.

3.3 CBT OPTIONS

There are many decisions to make in designing and implementing a CBT system. The selection of approaches and technologies should be based on the organization's instructional needs and budget. This section describes factors that must be considered when creating CBT programs.

3.3.1 Instructional Approach

Depending on the type of information and knowledge being taught to the student, there are usually several appropriate instructional approaches. For example, to teach the rules of the road, a standard present-and-test approach is appropriate. Actual driving (or a simulation) is appropriate for teaching the physical and coordination skills necessary for safe driving. This report lists several common approaches to instruction and gives examples of when each is appropriate. Note that a CBT program may combine several of these elements. For example, a "simulation-based" CBT could include an "intelligent training" component. **Table 3.3** lists four instructional approaches.

Table 3.3 Instructional approaches

	What is it?	When to use it?
Linear	Resembles book reading	Teaching facts and procedures
Simulation-Based	Simulates equipment or tasks	Teaching how to perform tasks
Intelligent Tutoring	Provides human-like response to user actions	Teaching a complicated task that requires reasoning
Microworld	Simulates context of problem solving	Teaching relationships between actions and outcomes

3.3.1.1 Linear Training

The linear training method of CBT presents the material in much the same way as a book. Users can "step" forward and backward through the material, and possibly jump to other topics and subjects. Typically, the instructional design is taken from a book or lesson plan that has been used to teach the course in the past. Linear training differs from a book in that the program can use multiple types of presentation methods, including graphics, audio, and video. Multiple types of media (multimedia) can make such a CBT system more interesting and instructive than a book or lecture.

Linear training is most appropriate when the material being taught consists of procedures, lists of items, or regulations that the student must memorize. One example of linear training is a CBT system that teaches the procedures for starting up an aircraft's engines. This type of task requires that the technician follow procedures in a specific order, so linear presentation of the material is appropriate. The testing unit of the CBT could then ask the user to order the procedures in the correct sequence. Linear training is usually the easiest to use, and it is also the least complex to design and implement. CBT that uses linear training has to be carefully designed to hold the user's attention, since linear presentations can quickly become monotonous.

3.3.1.2 Simulation-based Training

A simulation-based CBT system differs from a linear training system in that the former attempts to simulate some type of task through dynamic graphics. The software provides a realistic imitation of the necessary equipment and activities and behaves like the "real" world. For example, the CBT may require the student to troubleshoot a piece of equipment by inspecting, testing, and replacing its components. By simulating only the important features of a task, simulation-based CBT can provide cheaper, faster, and safer training than a real system, while requiring limited supervision from an instructor.

Simulation-based training should be used when the training task involves the manipulation of complicated equipment or when the equipment itself is too expensive to use for training. Examples of such training systems are a CBT that trains for avionics troubleshooting skills or a CBT that teaches the operation of NDI equipment. The way that a student uses a simulation-based system is much less constrained than the way a linear CBT works, since the student can perform the actions in any order.

3.3.1.3 Intelligent Tutoring

An intelligent tutoring system (ITS) mimics the instructional strategies of an instructor or domain expert. An ITS can give advice, provide feedback, and explain mistakes. The levels of intelligence in ITSs vary from "canned" text feedback to expert systems that understand the domain being taught. By automating some of the assistance that instructors usually have to repeat several times, ITS can provide consistent training to a large number of students.

An ITS cannot replace the role of the instructor because computer programs currently lack the intelligence and flexibility of human trainers. Computer intelligence in training should be seen as an instructional aid. An ITS can provide help for the simple, commonly asked questions, while the instructor provides the answers for the harder questions. These systems can perform some of the simple training and help tasks of the instructor, but the tasks requiring large amounts of interactivity and intelligence should be left to the instructor. By automating these tasks, the instructor has more time to answer the difficult questions and provide individualized instruction to students who need more help.

3.3.1.4 Microworld Training

Instead of simulating a piece of equipment or a particular task as a simulation-based trainer does, a microworld trainer models an entire job for a particular worker. The microworld trainer attempts to give a realistic context for problem solving, thus increasing the chance that the user will remember what he or she learned in the training while on the job. An aviation technician microworld CBT, for example, would simulate the cognitive tasks of troubleshooting, and allow the technician to replace parts and test the equipment.

Microworld training is most appropriate when the goal is to teach cognitive skills. Most text-based training systems attempt to teach the user a set of facts; a microworld trainer imbeds these facts in real-world problem solving. Microworld training provides the user with a context for problem solving, making it easier to remember when a similar situation occurs on the job.

Another advantage of microworld training is that it can be extremely engaging when designed correctly, thus motivating the student to use the CBT. Microworld computer games have high entertainment value, in comparison with other computer games, because the player has full control over the course of the game.

Remember: The instructional approaches described above are not mutually exclusive. Combine them to meet the students' instructional needs.

3.3.2 Presentation Formats

The training and instructional analysis provides a functional description of what information the CBT must provide to the user. Presentation media affects a CBT's cost so the media should be selected based on instructional criteria, rather than any aesthetic judgements or preferences. Common presentation formats are summarized in **Table 3.4**.

3.3.2.1 Text

Text is the most common CBT presentation format, since all computers support text. Text can be used to identify and describe processes, objects, and procedures. While audio narration has a fixed rate of playback, text allows the reader to absorb information at his or her own pace. One drawback of text is that the low resolution of most computer monitors makes it difficult to read long text passages. CBT designers should take this into account by shortening the length of text and deleting unnecessary words and sentences.

Table 3.4 Presentation Formats

	When to Use	Guidelines for Use
Text	Identify and describe processes, objects, and procedures	• Limit word use, be clear • Use large fonts and readable colors
Graphics	Show what equipment looks like or how a system is organized	• Make as simple as possible and do not show unnecessary objects • Consider display resolution of computers
Animation	Explain a process or demonstrate the steps of a procedure	• Makes the program more engaging • Do not make longer than necessary • Give user control over playback
Audio	Add realism, increase entertainment factor, or communicate long text passages	• Do not overuse; have a reason for using it • Allow user to control volume, turn off
Video	Describe procedures or increase entertainment factor	• Give user control over playback • Match purpose with video quality

3.3.2.2 Graphics

When a CBT program needs to show what a piece of equipment looks like, or how a system is organized, a graphic is the best presentation method. Graphics can be pictures or line drawings of equipment or schematics showing connectivity and functionality of components. The CBT team must consider the resolution of graphics required for effective instruction, as this partially determines the type of computer display necessary to support the program. The required resolution is a function of the purpose of the graphics: teaching for recognition requires high resolution, while simple schematic drawings can be displayed in lower resolution. In cases where aesthetics or entertainment value is important, higher resolution may be desirable.

3.3.2.3 Animation

Motion is an effective method of drawing attention to a particular item. The simplest way of displaying motion is through animation, which is the movement of simple graphical objects along simple paths. Animations differ from video in that they capture the general content of an event while discarding some information, thus making it easier for the user to understand the relevant issues. An animation can be used to explain a process or to demonstrate the steps of a procedure. Examples include animations of flows in electrical and hydraulic systems and animations of the installation procedure for an avionics component.

3.3.2.4 Audio

Audio in CBT can add another level of realism to the training system, give more entertaining feedback, or make the communication of long text passages much simpler. CBT audio can be divided into three classes: narration, equipment sounds, and musical accompaniment. Narration allows the user to listen to a description while watching an animation or video; this is not possible with text annotations. Machine sounds such as jet engines are usually not needed for instruction but may increase the entertainment value of the program. Musical accompaniment makes the program more interesting or adds emphasis to a point. Before adding audio to a CBT program, remember that an audio sound board is required to play audio on PCs, and audio files can greatly increase the program's total size.

3.3.2.5 Video

Like animation, video can be used to describe a process or to show a procedure. Video differs from animation in that it is a more accurate representation of the "real world" and usually has an accompanying soundtrack. Since video is more realistic than animation, it is usually better for describing procedures such as test or installation steps that a technician will perform on the job. The viewer more easily understands the context of actions shown in a video than in an animation. There are several methods for displaying video on computers, with varying degrees of resolution and cost (Pearce, 1993). All current desktop full-motion video technologies require some type of high-end hardware and large amounts of data storage.

Remember: It is important to decide early in the design process which data types the CBT will use, since this partially determines the training application's hardware and software requirements.

3.3.3 Integrated Training and Job Aiding

Another important issue to consider before designing a CBT system is whether technicians could also benefit from a computer-based job aid. A job aid differs from a training system in that a job aid helps the technician when the task is performed, not before it is performed. This approach to training can also be called "just in time," borrowing from current "just in time" inventory and production management techniques. Some training is still necessary with a job aiding system, since workers need some background knowledge before starting to perform a task.

Because the knowledge and software required for training systems and job aids are usually very similar, it is more cost-effective to design a system that serves dual purposes than to design two separate systems independently. Integrated training and job aiding also implies active learning and on-the-job training. The chance of the user remembering an important fact or lesson is greater when the user is actually performing the job than when he or she is sitting in the training room. A job aid also decreases the need for "up- front" training, since the worker learns how to perform a task immediately before doing it.

3.4 HOW TO DESIGN AND IMPLEMENT COMPUTER-BASED TRAINING

The following section describes a process for designing and implementing CBT. The authors have used this process successfully. It maximizes the likelihood of producing successful CBT systems. **Figure 3.3** is a flow chart of the steps in and outputs of this CBT production approach.

3.4.1 Needs Analysis

The first step in designing a CBT system is to decide whether the system is really needed for a specific task, and to describe the expected benefits of implementing a CBT system. Note that this step is not specific to CBT; a needs analysis is necessary for all training systems and job aids. If a need is incorrectly identified or the nature of the problem is not understood, then the final product probably will not be useful. The needs analysis consists of three main steps: problem identification, current training methods analysis, and cost/benefit analysis. Each step is described below.

3.4.1.1 Problem Identification

The first step in needs analysis is to identify a task that needs improved performance or lower training costs. This can be done informally through interviews with technicians and managers. A more formal evaluation would include a description of the technicians' tasks, how long it takes technicians to perform these tasks, and any "bottlenecks" that delay completion. The final product of this step should be a list of technicians' tasks that may benefit from improved training methods.

Remember: The two reasons for using CBT are to increase efficiency for a task and to increase effectiveness of training.

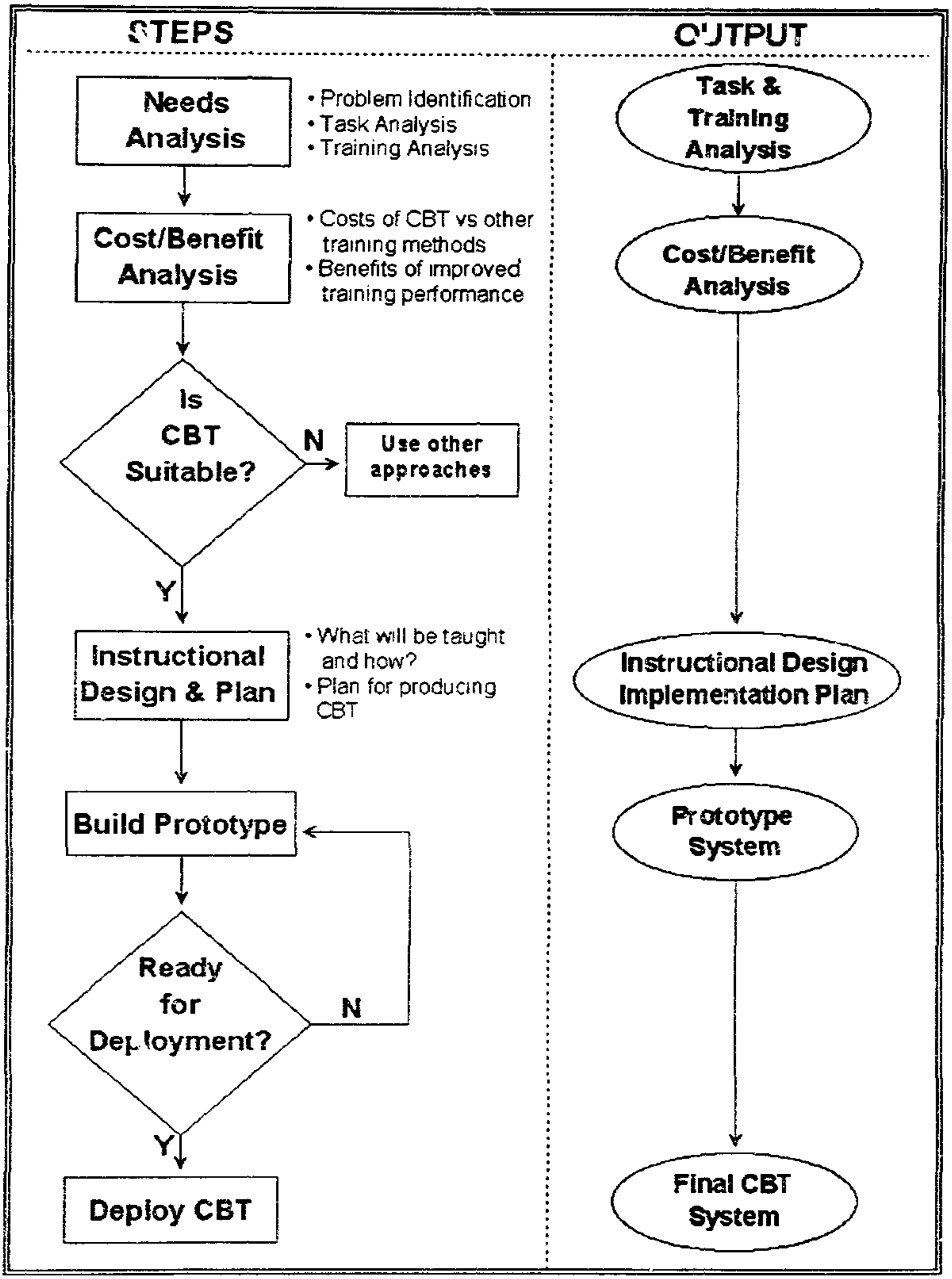

Figure 3.3 Typical CBT development process with outputs

3.4.1.2 Current Methods of Teaching the Task

The second step in needs analysis is to perform a training analysis to determine how the training for the task is currently conducted. This step helps determine if an improvement in the current method is possible and to identify strengths and weaknesses of present training methods. Once the current process is described explicitly, it is much easier to critique it and find its weak and strong points. Such a description should include what is taught, who teaches it, how long it takes, how it is taught, what resources are needed, and the students' performance before and after training.

The training analysis identifies one of the following possibilities: no formal training exists, training exists but could be improved, or current training is sufficient. Typically, workers learn many of their tasks on the job. When there is an existing training program, there are two more possibilities: the training could be made more effective (thus increasing technicians' performance and productivity), or efficiency could be increased (which decreases the training cost).

3.4.1.3 Pre-Production Cost/Benefit Analysis

The final step in needs analysis is to determine if training for the specified task will give an adequate return on investment. This is one of the hardest tasks in CBT production, because it is difficult to:

- Measure benefits of intangibles, such as safety and customer satisfaction
- Predict the actual performance improvement for a system that has not yet been built
- Predict the cost of building CBT systems (and computer programs in general).

Given all these unknowns, it is still possible to generate a rough estimate of a training system's effectiveness before it is produced. It is important to remember that these are rough estimates, so take this into consideration when planning resources and deadlines.

In deciding if CBT is appropriate for a specific task, look at other training methods and compare their costs and benefits. There are several methods for doing this, but this report will only mention them in passing, as most of the methods involve complex economic and mathematical analysis. One method is to compare the total "life cycle" costs of the CBT to that of other systems (Kearsley, 1982). Typically the costs are broken down into three categories:

- Research & development/start up costs - associated with planning and designing CBT
- Transition costs - one-time costs of implementing CBT hardware and software
- Steady state costs - continuing costs (such as maintenance) of using CBT.

The result of this step should be a description of the CBT system's goals and an estimate of its benefits (either improved efficiency and/or decreased cost). The goals provide a high-level summary of what the CBT system will do for the users.

3.4.2 Job Task Analysis

Job analysis is a process used to break a job into tasks and rate the tasks for further analysis. Task analysis is a process to determine how a task is performed and the factors that affect performance. Consequently, job task analysis (JTA) is a method used to identify what tasks are included in a particular job and how these tasks are supposed to be done. JTA identifies the knowledge, skill, and activity requirements necessary for job performance. The goal of the JTA is to explicitly describe the job so that the workers' efficiency, effectiveness, and error rates can be improved. There are many different methods for performing JTAs, ranging from detailed formats for describing each step in performing a task to more informal observational methods (Woods, 1993).

Formal JTA methods are used during system design or when there appears to be serious problems with the design of a system or the procedures used to operate it. In most cases, JTA need not be formal. JTA for instructional design can be as simple as a one-page description of what the workers do to perform the task. Particular attention should be paid to errors that repeatedly happen on the job and to inefficiencies that could possibly be eliminated through improved training.

Remember: Each organization will have to determine its acceptable level of JTA. JTA is merely a "means" to the "end" of developing CBT. The JTA process must not become the product.

3.4.3 Instructional Design and System Planning

Once the JTA is finished, the instructional design of the system must be created. Instructional design is concerned with understanding, improving, and applying instructional methods to specific problems (Reigeluth, 1983); it describes *how* certain material will be taught. This differs from curriculum design, which describes *what* will be taught. The goal of instructional design is to choose the best methods to achieve specific improvement in knowledge and skills for a given group of students. The description should summarize the training process to be implemented in the CBT program, including

- What the CBT will teach (its instructional goals)
- Knowledge students are assumed to know before using the system
- The instructional approach
- Structure of lessons, exercises, tests, etc.

- Types and number of questions
- How the information will be presented (text, graphics, video, etc.)
- How the CBT will be used with other instructional methods (instructor, books, etc.)
- How to evaluate the students' knowledge.

There are several common approaches to instructional design. Which approach is appropriate for a particular project depends on the training task. See Section 3.3.1 for more information on the various approaches to instructional design.

Once a particular instructional approach is chosen, the CBT team has a better idea of the time, skills, and resources necessary to complete the project. For example, simple training systems with text instruction do not require much effort to program and test; a large training project with complex equipment simulations and a multimedia presentation demands much more effort. The CBT team manager should apply standard planning methods, including

- Developing a program time line and Gantt chart
- Planning resource allocation, including people, computers, software, training, etc.
- Setting milestones for the development cycle.

Remember: The instructional design is one of the most important components of a successful CBT system. Poor instructional design will lead to poor training and possibly poor job performance.

3.4.4 Prototype System

Once the instructional design is finished, system implementation can begin. This is done by producing one or more prototypes of the CBT program. A prototype is a tool for critiquing the design of the system. The demo system can be evaluated by the designers, content experts, managers, users, and programmers to ensure that they all agree on the system's design before full-scale implementation begins. If there is not agreement that the prototype design is good, then it is unlikely that the organization will accept the final system.

The prototype demonstration is best done on a computer since this provides the interactivity that other methods lack. The demonstration program should include the "main" features described in the instructional design, with the secondary features (for example, student logging and multimedia) omitted. Also, some of the prototype computer program code can be used in the production version of the CBT program.

Although computer-based prototyping methods require more up-front effort than other approaches, they are often more efficient in the end. One advantage of computer-based prototyping is the ease with which the users can participate in program design. A user can suggest changes to the program, and the changes can be made while the user watches.

Another advantage is that the effort which goes into building the prototype can be applied to the actual CBT programming by using the prototype as the basis for the CBT program. The use of authoring systems in building CBT (covered in Section 3.6.3.2) makes the transition from prototyping to programming more manageable.

There are several prototyping approaches that do not require computers, and some find these methods easier to use. One method of producing a quick demonstration without computers is to produce a paper "storyboard" of how the screens will look. Each "frame" of the storyboard includes a rough sketch of what the screen will look like with a caption that describes the screen's purpose. Storyboarding can also be done on an erasable board, so that many CBT team members can participate in the design. A storyboard created before the computer prototype can act as a guide for the programmer.

3.4.5 Rapid Prototyping Software Development

The rapid prototyping approach to software production grew out of the observation that many computer programs do not meet the needs of the intended users. This often is the result of a divergence between what users need and what programmers think the users need. Often, users do not know what they want or do not want until they see it. Rapid prototyping helps solve this problem by including users in the software design process and by using their feedback to drive changes and improvements to the program (Sewell & Johnson, 1990).

The last two steps described in this CBT production process (prototype system creation and evaluation) are used as the basis for rapid prototyping. The instructional design is a definition of what requirements the designers want the software to meet and a high level description of how the program will meet the requirements. From this analysis, the programmers create a prototype program that can be critiqued by instructors, students, and administrators. The programmers then make changes to the software based on the users' feedback during the evaluation. The evaluation should include checks for

- Correctness of the information
- Ease of use of the program
- Spelling and grammar mistakes
- Graphical layout, user of color, and other aesthetic issues
- "Bugs" (programming errors) in the CBT program.

To ensure that the reported problems are addressed, it is best to have a formal reporting scheme. Such a scheme can be as simple as a written log of each problem found, the person who found it, the solution to the problem, and the person(s) who fixed it. Once all of the bugs have been fixed in the current version of the CBT, it should be tested again to ensure that previous problems were solved and that no new problems were introduced. This iterative process continues until the organization is satisfied that the software is suitable for its intended purpose. Because this step in CBT production is so unpredictable, set aside enough time to address both large and small problems that come up during the evaluations.

3.4.6 Evaluation of CBT System

Evaluate the CBT system to determine if any changes are needed to fulfill the goals of the CBT system and to provide data for future CBT systems. In the first case, the evaluation examines the instructional features of the CBT system and how the students use the system. Usually, any problems found may not have been known at the time the program was written and may arise from design decisions. For example, students without much computer experience may not understand how to use a control on the CBT program's interface that is familiar to experienced computer users. The other purpose of an evaluation, to help in developing future CBT systems, has the goal of using what was learned during the design and implementation of one CBT system to assist in the creation of other CBT systems. The data for this evaluation may include formal experiments or informal surveys of users' experiences with the training system.

One drawback of evaluations is that they can be very expensive. While one or two people can build a CBT system in several months, it takes numerous experimental CBT users to provide statistically significant data. Depending on what type of data are being collected, evaluation can require anywhere from several hours to several weeks of a CBT user's time. Also, it is difficult to collect "on-the-job" data, so written tests that may not measure actual learning and job performance improvements are often used as substitutes. Because of the expense of some types of evaluations, the CBT team should formulate specific issues that they want the evaluation to examine. When producing an evaluation, the CBT team should

- Develop a hypothesis about the training system(s)
- Collect data relevant to the hypothesis
- Analyze the data with respect to the hypothesis
- Apply the outcome of the evaluation to current and future training systems.

There are several common models for evaluating training. Models vary in the types of data needed for the analysis and the types of information that they produce. The appropriate method also depends on whether the CBT system was built to save money, to improve performance, or both. Sometimes a combination of models is appropriate to generate the information needed to make future decisions. **Table 3.5** summarizes the types of evaluations commonly used on CBT systems.

3.4.6.1 Questionnaires and Interviews

Cost and learning evaluations only tell part of the story. To judge users' opinions concerning a CBT system, the most appropriate tools are questionnaires and interviews. A questionnaire attempts to determine what users like and do not like about a CBT system. Make the questionnaire short (two pages or less) and simple, so that it can be filled out in a few minutes. The data can then be analyzed statistically to determine the system's strengths and weaknesses.

Table 3.5 Evaluation Methods

	Purpose	When to Use
Questionnaires and interviews	Collect information about users' opinions	After CBT is finished
Content verification	Ensure that information is correct	During development
Cost/benefit analysis	Determine the CBT's overall cost effectiveness	After CBT is finished
Usability testing	Evaluate the quality of the interface	During development

Interviews also attempt to collect data about users' opinions of a CBT system, but they are less formal than written questionnaires. An interview usually consists of a set of questions for the users and instructors, and they can also allow the subject to discuss unanticipated issues. Although interviews require preparation, data evaluation is often more difficult and subjective because the answers and comments tend to be more open-ended. Consequently, interviews are better for identifying specific problems with a CBT system than for determining general trends in acceptance and satisfaction.

3.4.6.2 Content Verification

The most important component of a CBT system is its content, since it is content knowledge that is being taught to the users. If the content is incorrect, then the students will not learn the correct information. This may lead to poor and/or unsafe job performance. A content validation verifies that the information contained in the CBT is correct.

Content evaluation is commonly accomplished by showing the CBT to experts and instructors and having them check for omissions and errors. Ideally, the people doing the content evaluation should not be the subject matter experts who provided the knowledge for the CBT program. It is possible that the subject matter experts have misconceptions about the domain. If multiple experts are to evaluate the content, it is likely that there will be conflicts and contradictions in the advice and suggestions they offer. Therefore, when analyzing the results of the content evaluation, differentiate between different styles of problem solving and training and significant errors in the domain knowledge.

3.4.6.3 Cost/Benefit Analysis

Cost/benefit analysis combines two separate measurements to determine the return on investment for the CBT. The cost analysis measures the total cost of designing, producing, and distributing the CBT. This data can be gathered from records of time and money spent on development. The benefit portion of the analysis focuses on changes in worker's performance. Benefits are measured from changes, or estimates of changes in on-the job performance.

If the benefits analysis concludes that the training is not effective, then other types of evaluations are necessary to pinpoint the source of the problem. This is because a benefits analysis "lumps" the good and bad features of a CBT into one measurement. Some common measures of success of CBT systems (and training systems in general) are:

- Higher achievement and productivity level
- Improved quality of work
- Decreased student training completion time
- Increased motivation level
- Increased safety and a lower accident rate.

The more abstract the measure of training success, the harder it is to correlate it with actual CBT features. For example, if there is an increase in productivity after the introduction of a CBT system, the increase may or may not be a result of the CBT. It is usually easier to eliminate other explanations such as the use of new equipment or new accounting methods than to prove that changes in performance are a result of the introduction of CBT.

3.4.6.4 Usability Testing

A usability test is conducted to ensure that students can operate and understand the system. This is necessary because the usability of a CBT system is an important factor in determining whether or not the users learn. Even if the information in the program is correct, users will not focus their attention on the lessons if the interface is poorly designed. For example, novice computer users may not understand conventions known to more advanced computer users. CBT designers need to keep this in mind when designing the interface. It is advisable to make the interface as simple as possible and to avoid cluttering it with unnecessary text and graphics.

Frequently, usability testing is done by observing a few potential users while they operate the program. It is best to have users who have not used the program before and who do not have much computer experience. These users will report problems such as not understanding what to do next. All users should be encouraged to report any difficulties before they start the usability testing. To identify other types of problems, it is best to watch the users and see what types of mistakes they make, keeping interruptions to a minimum. The problems in the interface should then be listed so that the CBT designers can discuss them. Once the interface problems have been fixed, the CBT team should conduct another usability test to ensure that the problems have been adequately fixed and that new problems have not been introduced.

Remember: Evaluation is part of the rapid prototyping software development method. The evaluations should be done frequently during CBT design and development. Ongoing evaluation eliminates surprises at the end.

3.4.7 Maintenance and Updates

A CBT system is not finished after the programming and evaluations have been done. The system needs to be kept up-to-date with changing technology, equipment, and procedures. For example, the maintenance procedures may change for a particular piece of equipment. If an existing training system refers to the old maintenance procedure, it will have to be updated to the current method. Also, students using a CBT program in the classroom usually uncover bugs that were not found during program testing. Instructors commonly request that new features such as automatic grade reporting be added to CBTs after they begin using them. These costs are called "steady state" costs because they remain somewhat constant after the CBT program has been finished and is being used.

Other "incidental" costs are rarely planned for, but commonly arise. Computer hardware maintenance costs vary widely, depending on the computers' quality and the amount of use. Public-access computers have higher levels of wear than computers used by individuals; so the budget should account for cleaning, maintenance, and repair. If the lab is to remain open for extended hours, security and lab personnel have to be budgeted. Also, such costs as those for printing paper and writing documentation are necessary for some types of CBT.

3.5 ASSEMBLING A CBT TEAM

One of the most important considerations in producing a successful CBT system is choosing the team members. Designing a CBT system requires skills in diverse areas such as training, graphics, computer software and hardware, and usability. The CBT team needs all the skills above, since the lack of even one skill can lead to significant problems with the CBT program. If the team does not have these skills, it should seek training in the unknown areas or hire consultants to fill the gaps. Sometimes one person may possess two or more of the skills, so the team does not always have to be large. **Figure 3.4** shows the makeup of a CBT team.

3.5.1 Instructional Designer

The instructional designer applies knowledge of training, learning, psychology, and other training systems to the design of the CBT system. Most instructional designers have advanced degrees in education or psychology and have the ability to apply their knowledge to the design of training systems. This person should also understand the training domain, the jobs and tasks of the workers, and how training principles and past experience apply to the current training system. Because instructional design is the most important consideration in CBT design, the instructional designer is often the team leader.

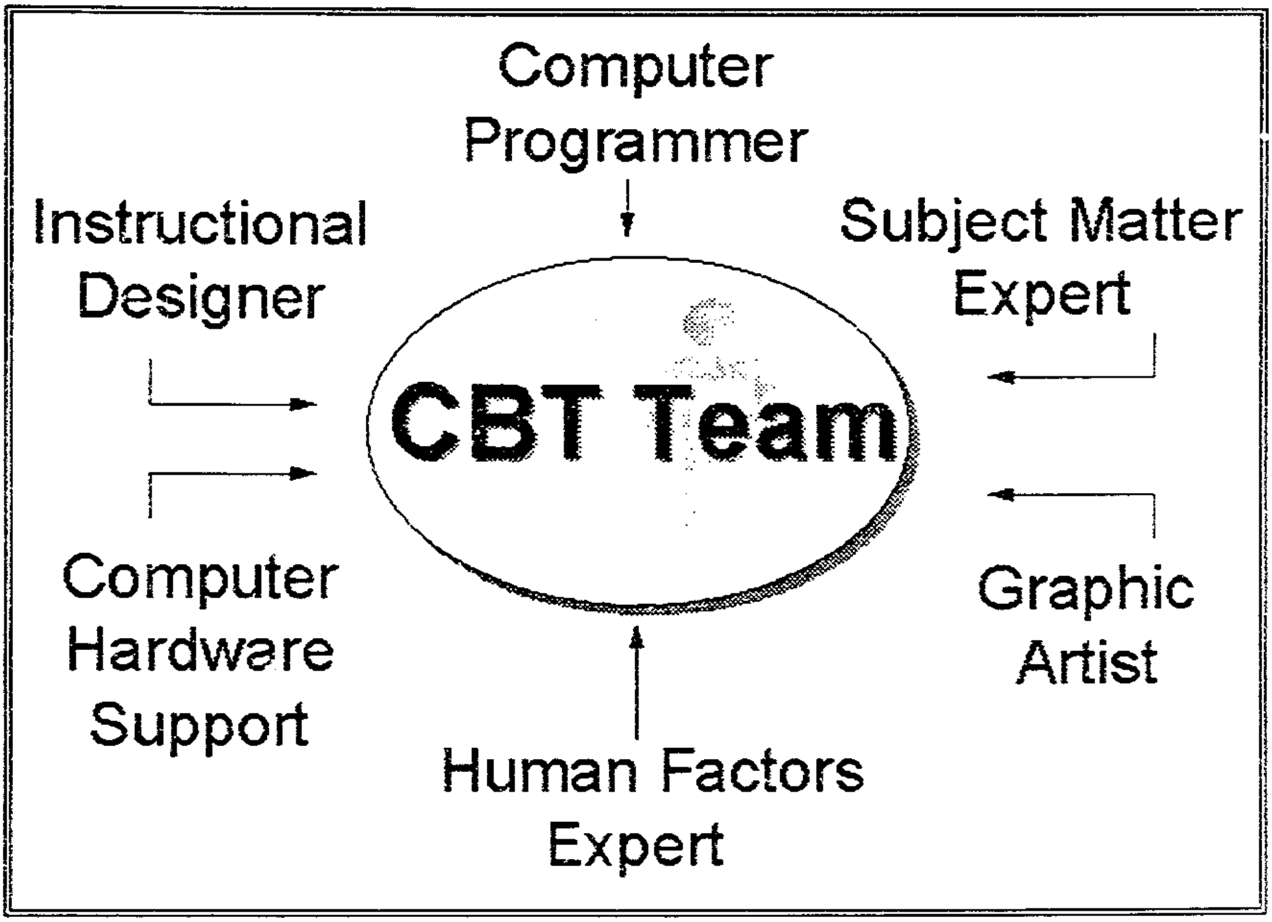

Figure 3.4 The CBT Team

3.5.2 Subject Matter Expert

The subject matter expect (SME) is key to the success of a CBT project because he or she is the source of the knowledge and information that the CBT system will teach to the students. If the SME does not understand the domain well enough to explain it to the instructional designer, then the chances of building a successful CBT system are slim Therefore, the SME is often an instructor or someone with much on-the-job experience. Johnson (1988) says that instructors are the best SMEs because they understand the subject and instructional principles and also know how to best explain the domain to programmers and other CBT developers.

A common problem in building CBT systems is difficulty in finding and retaining a knowledgeable SME. In aviation, as in most other domains, experts are scarce and are often committed to other projects. Experts may be pulled from a CBT project for more pressing tasks, leaving the CBT team with the difficult task of trying to bring a new SME up to speed on the project. In this case, there is a familiarization period before the new SME can contribute to the project, thus delaying any new work on the CBT. This problem can be avoided by having two or more experts working on the project, even if one or more of the additional experts are only secondary contributors. This approach has the advantage of allowing more than on person to verify the domain representation.

3.5.3 Computer Programmer

The programmer implements the instructional designer's training plan. An important part of a programmer's job is the ability to design a program that meets the constraints of time, money, performance, and computer hardware. The programmer should have some understanding of instructional design and software usability. The programmer must also be able to take users' feedback and convert it into changes making the software easier to use and more understandable.

Programming usually takes the largest portion of time in implementing a CBT system, and large projects require more than one programmer. Programmers' work load can be reduced by ensuring that they have adequate software tools, computer hardware, and design feedback from the rest of the team. Experience is the most important factor in determining a programmer's productivity; an experienced programmer can produce considerably more software than an equally intelligent but inexperienced programmer.

3.5.4 Computer Hardware Support

The computer hardware support person ensures all the computer hardware and software is working properly. If something is not working properly, the hardware support person should know how to test it and how to resolve hardware malfunctions. Another large part of the job is maintaining software configurations, making sure that the computers have the latest version of the CBT software. This person should be able to help the students use the software and to answer basic questions about the training program.

3.5.5 Human Factors Expert

When students cannot easily use a CBT system, chances are that they will not learn much. When students' attention is drawn away from content, they concentrate on trying to operate the software. The human factors expert ensures that the system is understandable and easy to use. The human factors expert can also provide design guidelines pertaining to program behavior, screen layout, colors, and fonts. It is important that the human factors expert be involved early in the design process so that he or she can critique the overall CBT approach. A human factors expert should have experience in the psychological issues of interface design and have practical experience in computer program design.

3.5.6 Graphic Artist

A good graphic artist is often vital to the timely completion of a CBT project. Graphics production is time-consuming. If the graphics are on paper, they must be scanned into the computer and then cleaned up with a paint program. If the graphics need to be drawn from scratch, the instructional designer or subject matter expert should sketch them so that the graphic artist does not have to guess at what is needed. The graphic artist should be familiar with issues of color selection, screen layout, design for readability, and usability, and should have some previous experience in designing graphics for the computer. When designing the screen layout and graphics, it is important to keep in mind the graphic limitations of the target computer configuration. For example, when graphics designed to be displayed on systems with 256 or more colors are displayed on computers that can only show 16 colors, the resulting graphics are not understandable or attractive.

Remember: The CBT team does not need one individual for each of the described tasks, but all of the skills should be included on the team.

3.6 CBT HARDWARE, SOFTWARE, AND SUPPORT

This section covers a variety of topics related to the budgetary and commercial issues in CBT. The material is not technical and presents enough information to allow managers to make informed decisions.

3.6.1 Hardware

Since they first became widely available, there has been a constant increase in the power of personal computers (PC). This increase in power has been followed by a constant increase in the computing power requirements of PC software. There is now much personal computer software that will not work (or works too slowly) on computers that are more than a few years old. Because of the high cost of installing and maintaining new computers, many older (and less powerful) computers are still in use.

When designing a CBT system, the CBT team must consider the type of computer that will be used for running the CBT program. If the hardware does not support the CBT software, then the students will not be able to make full use of the training. Computer hardware can vary along several dimensions, so the CBT team must consider all these dimensions when they design the CBT system. This section describes the various dimensions and also explains when special hardware may be needed, and what the hardware will add to the instruction

3.6.1.1 Processor Type and Speed

A PC's processor determines how "powerful" the computer is and how quickly it can do its computations. Because of improvements in processor technology, modern desktop computers are roughly 100 times more powerful than PCs of ten years ago. Processor speed is analogous to the thrust of an aircraft's engines, which determines the power of the aircraft. Some text-based applications can be used on an Intel 8088 computer, the first generation PC processor, although few of these are currently manufactured. The next step up is the Intel 80286 and 80386 processors which usually have clock speeds between 15MHz and 33MHz. For the most computer-intensive programs, the Intel 80486 with a 33MHz or higher clock speed is required.

3.6.1.2 Computer Memory

A PC's memory determines how much data it can work on at a single time. For text-based computer programs, 640 kilobytes (kb, or about 1,000 "words" of computer memory) is an acceptable amount of memory. For more complex programs, between 2 and 8 megabytes (Mb, or about 1,000,000 "words" of computer memory) is standard. With older computer operating systems (such as MS-DOS), extra memory does not make the computer significantly faster and is only a "minimum standard" that determines which programs the computer can run. With more modern computer environments (such as MS Windows), the speed of certain operations is affected by the amount of memory. Commercial CBT programs should be tested on one of the computers to be used for training to ensure that there is enough memory for the program. If software is being produced in-house, then programmers need to consider the amount of memory in the organization's computers.

3.6.1.3 Hard Disk Size

The hard disk is used to store data on the PC when the data is not being used. Most modern software programs are too large to store on floppy disks. The data stored on the hard disk can be either programs, which control what the computer does, or data which the programs process. For text-based applications, a 40 Mb hard disk is usually adequate. If multimedia data such as graphics, animation, and sound is part of the CBT program, then a larger hard disk should be considered. The size of hard disk required depends on the number of programs and the type and amount of data being stored on the computer. To store large amounts of data that does not change frequently, a compact disc read-only memory (CD-ROM) drive is preferred. Note that new data cannot be stored on a CD-ROM after it is manufactured, so another data storage mechanism is necessary for updates and student data.

3.6.1.4 Computer Display Quality

The computer monitor and the video adapter card work together to display the text, graphics, and video that the PC generates. The signals from the computer go through the "video adapter" which converts digital data to the signal the monitor displays. There are several dimensions along which the adapter/monitor combination can vary:

- Resolution of video adapter - number of vertical and horizontal "picture elements" (pixels) that can be displayed; usually ranges from 320 x 140 to 1024 x 768
- Size of the monitor - measure of diagonal size of the screen: between 12" and 27"
- Number of colors - how many colors can be displayed on the screen at once; from monochrome (black and white) to 16 million colors.

The appropriate combination depends on the type of data the CBT displays. For programs that display only text, the lower resolutions are appropriate. If a program displays graphics, video, and animation, then higher-end equipment is necessary. Use the prototype CBT program to evaluate resolution requirements.

3.6.1.5 Input Devices

An input device is a computer peripheral that allows the user to enter data into the PC. The most widely known input device is the keyboard which allows the user to enter text. However, most training approaches and tasks do not require the user to enter large amounts of text. Keyboards are not widely used in the newer CBT systems since it is easier to interact with the computer through a "selection" device such as a mouse, touchscreen, or light pen. These devices allow users to interact with the graphical elements on the display through gestures such as clicking/pressing, dragging and dropping, etc.

While the mouse is the device of choice for controlling most graphical environments, touchscreens and light pens are easier for novices to use. A touchscreen is sensitive to pressure, and the coordination of computer graphics and the user's actions allow for realistic simulation of equipment and tasks. A lightpen works in much the same way, but the user touches the screen with a special pen. Although touchscreens and lightpens are easier to use than mice, they cause arm fatigue when the user is required to perform a large number of selections.

3.6.1.6 Multimedia Accessories

Multimedia can be defined as the integration of several data types in a computer program. These data types include text, pictures, animation, sound, and video. Usually, *multimedia* assumes some level of sound and video, although both do not need to be present. In the case of a PC, the presentation of sound or full-motion video requires some hardware accessories, including a sound adapter with speakers and a motion video adapter board. Currently, the most widely used method for delivering video on a computer is through a videodisc player, but digital video technology is quickly becoming widespread. A CD-ROM drive is often used to store the large amounts of data associated with multimedia. Simple text-based training programs usually do not require these accessories. However, if multimedia is needed for training, the CBT team should plan for this when choosing the computer configuration. CD-ROM players are becoming increasingly common, and several software companies are delivering programs on this media.

3.6.1.7 Network Capability

A network connection enables a PC to transfer data to other computers. This allows for data sharing between isolated computers without having to transport a diskette or CD-ROM. Data can be transferred in either direction between the students' computers and the instructor's computer. Two applications for CBT are message sending and file sharing. Two examples of message sending are for the instructor to send a note to the students or for the students' grades from a CBT program to be sent to the instructor's computer. File sharing allows for more efficient use of computer resources such as keeping a single copy of the CBT program or multimedia data on the network server instead of maintaining a copy on each PC's hard disk.

3.6.2 Examples of Standard Computer Configurations

This section describes three broad classes of PCs and is designed to assist in selecting the correct computer configuration for a specific training application. The PC classes are derived from the various levels of processing power and hardware support required to manipulate different types of information. One thing to remember when choosing a computer configuration is changing training needs. Although the first CBT programs produced by an organization may be text-based, future training systems may require more computing power. It is possible to run text-based computer programs on multimedia computers, but not vice versa, so you should plan for future needs. **Table 3.6** summarizes the minimal hardware requirements for the three standard computer configurations described in this section.

Table 3.6 Minimal hardware requirements for standard computer configurations

	Text and simple graphics	**Partial Multimedia**	**Full Multimedia**
Processor	Intel 80286 processor 15 MHz clock speed	Intel 80386 processor 25 MHz clock speed	Intel 80486 processor 33 MHz clock speed
Memory	640 kb memory	1 Mb memory	4 Mb memory
Storage	40 Mb hard drive	80 Mb hard drive	150 Mb hard drive
Display	monochrome/ EGA monitor	VGA 256 color monitor	VGA 256 color monitor
Peripherals		mouse; sound board and speakers	mouse; sound board and speakers; digital video or overlay videodisc board; CD-ROM drive

3.6.2.1 Text and Simple Graphics

A text and simple graphics program has the lowest computing power requirements and can run on all first-generation IBM-PC compatible computers. Information the computer displays consists of blocks of text with some small graphics. Because such programs do not use many graphics, smaller displays with 2 or 16 colors are adequate. Also, very little computer memory or hard disk space is required because of the low storage space requirements for text and simple graphics. Multimedia peripherals are not needed. The standard configuration for this computer is

- Intel 80286 processor / 15 MHz clock speed
- 640 kb memory
- 40 Mb hard drive
- monochrome / EGA monitor.

3.6.2.2 Partial Multimedia

A partial multimedia machine adds the ability to display high-quality graphics, animation, and sound. Since this type of training applies emulations of equipment and job tasks, this level of computer hardware is required for simulation-based and microworld training. The higher data storage requirements of large graphics and sound make it necessary for the computer to have more memory and a larger hard disk. When the CBT program has significant data, it may be more cost effective to store the data on CD-ROM. The standard configuration for this computer is

- Intel 80386 processor / 25 MHz clock speed
- 1 Mb memory
- 80 Mb hard drive
- VGA 256 color monitor
- mouse or touchscreen
- sound card and speakers.

3.6.2.3 Full Multimedia

A full multimedia machine includes all the capabilities of the partial multimedia class and adds full motion video. Full multimedia is useful for showing technicians how a procedure should be carried out or for providing greater interactivity with the training. Special hardware is needed for the computer to process and display some types of multimedia data: sound cards to play sound and video cards to display full motion video. There are several computer programs that can display video without special hardware, but the video display is lower quality than that of hardware-assisted technologies. The standard configuration for this computer is

- Intel 80486 processor / 33 MHz clock speed
- 4 Mb memory
- 150 Mb hard drive
- VGA 256 color monitor
- mouse or touchscreen
- sound board and speakers
- digital video or overlay/videodisc board
- CD-ROM drive.

3.6.3 Software

Computer programs, collectively known as software, are sets of computer instructions that tell the computer hardware what to do. Without software, the computer would be useless. Software performs different functions. For example, one piece of software may control how keystrokes are interpreted, while another piece may control graphic display on the computer screen. Software is a central part of a CBT system, for it acts as a translation between the instructional designer's goals and the way the computer "acts."

There are several approaches to programming CBT; they vary in ease of use and flexibility. In most cases, the easier a program is to use, the less flexible it is. On the other hand, the more functions contained in the program, the more flexible it is. More effort is required for the user to learn to use a flexible program. Using the analogy of a car and a helicopter, it is easier to drive a car than it is to fly a helicopter, but the helicopter is more flexible with regard to the pilot's amount of control. Which one is appropriate depends on the needs, knowledge, and constraints of the traveller. **Table 3.7** outlines the advantages and disadvantages of programming systems.

Table 3.7 Advantages/Disadvantages of Programming Systems

	Advantages	**Disadvantages**
Programming languages	• Flexible; can make the program do what is needed. • Fastest programs.	• More time needed to implement programs. • Experienced programmers needed.
Authoring tools	• Both flexible and easy to use.	• Not as flexible as programming languages; some things not possible. • Slower than programming languages.
Off-the-shelf programs	• Program is ready to run; no need to hire development team.	• Doesn't always match need of users.

3.6.3.1. Programming Languages

A programming language is a set of conventions for specifying a sequence of operations a computer performs. The operations may include displaying graphics and text on the screen, monitoring the input devices, or computing a numerical value from a formula. Like the recipe that a cook follows to transform ingredients into a meal, a computer program tells the computer hardware how to transform input (from a keyboard, mouse, or data file) into meaningful output (text display, graphics, sound, or video).

Programming languages provide the most flexibility in producing CBT systems. It is possible to produce CBT systems with programming languages that cannot be produced with authoring tools. The cost for the flexibility of programming languages is the extra effort required to produce the program. This trade-off shows up in the experience required to become an expert programmer and the high cost of hiring experienced programmers.

There are several popular programming languages, including Pascal, FORTRAN, BASIC, and COBOL. The language of choice for most programmers and most commercial programs (word processors, spread sheets, etc.) for PCs is "C." The language expertise of the programmers, the existence of any previously written software, and company rules and preferences determine which language is most appropriate for a particular project.

3.6.3.2 Authoring Tools

Like a programming language, an authoring tool is a set of conventions for specifying a sequence of operations a computer performs. The form of an authoring tool's language is different from that of a programming language. In most cases, authoring tools are much easier to use than programming languages. Many authoring tools do not require extensive experience in computer programming and require little training for users to produce working systems. Sometimes the programming is done through "direct manipulation," i.e., drawing icons or objects that control how the program will act directly on the screen. Usually, the programming language for an authoring tool (called a "scripting language") is easier to understand and use than a true programming language.

The disadvantage is that authoring tools are not as flexible as programming languages. For example, consider writing a computer program that simulates a piece of equipment. It may not be possible to do this with some authoring systems because the authoring languages place constraints on the way that the program behaves.

There are different types of authoring tools. At one end of the spectrum are general purpose systems not designed for any particular domain. These systems combine the flexibility of programming languages with the flexibility of authoring tools.

At the other end of the authoring system spectrum there are authoring tools designed for a specific domain or for a specific instructional approach. The premise is that by including domain-specific information and structure in the authoring system, it is easier to produce new training systems. These systems often support standard CBT operations such as student login, test score gathering, and grade reporting. The biggest drawback is that flexibility is lost when more structure is added. Occasionally, it is not possible to make the CBT program do what is desired.

3.6.3.3 Off-the-Shelf Programs

The simplest way to apply CBT is to find an off-the-shelf program that meets the organization's training needs. This approach requires no computer programming or instructional design since the system has been designed and implemented by another company. The cost of pre-configured training systems is often lower than that of in-house CBT since the cost is distributed across several groups. Therefore, the break-even cost for off-the-shelf CBT as compared to instructor-led training is usually in the tens of students. Comparatively, the average break-even point for self-developed CBT is considerably higher.

See Section 3.5 for a list of aviation-specific off-the-shelf CBT programs. Another source of information on off-the-shelf aviation training software is the "CBT Courseware/Hardware Matrix" report from the Aviation Industry Computer Based Training Committee (AICC, 1992).

The biggest problem with off-the-shelf programs for aviation maintenance is the small number of systems on the market. If training is needed for a specific system, chances are that CBT does not exist for that system. On the other hand, it is not necessary that training be provided for all possible systems because of similarities between systems and equipment in the aviation industry. Some off-the-shelf CBT programs for aviation maintenance training are listed in Section 3.6.5, "Example CBT Applications."

Remember: The main tradeoff between these three programming approaches is ease of use vs. flexibility. The type of CBT being created and the programmers' experience determines which one is most appropriate.

3.6.4 CBT Computer Labs

There are two basic configurations for computer training rooms: individual carrels and classroom. In the individual training configuration, workstations are arranged so that there are partitions between the individual carrels. This prevents students from disturbing each other while using the computers. A problem with this configuration is that it is difficult for students to help one another with problems. In the classroom configuration, the computers are arranged on tables that face the front of the room, and there are no barriers between workstations. This allows for instructor-led CBT and for easy collaboration among students.

The CBT laboratory should be large enough to hold the computers and computer furniture. The computer furniture should be large enough for students to place their instructional and reference manuals while using the CBT. Lighting and window shades need to be designed so that there is not excessive glare on the computer displays. Computers produce large amounts of heat, so the CBT lab should have adequate cooling.

Before designing a CBT lab and ordering equipment, the CBT team should understand the students' training needs, budget (both for installation and maintenance) for the CBT lab, and the technology issues of maintaining and upgrading computer hardware. Such issues include

- Existing computer hardware and software versions
- Compatibility of hardware and software
- Special hardware requirements to simulate equipment
- Access times, lab security, lab assistants, fee collection, etc.
- Projection equipment for instructor-led training
- Networked vs. stand-alone computers, printer access.

3.6.5 Example CBT Applications

This section describes several currently available CBT programs for aviation technicians. These programs are either designed to teach procedures for specific aircraft models or to teach general troubleshooting skills.

3.6.5.1 General Troubleshooting Skills & Specific System Troubleshooting

These two programs produced by an aviation training CBT company typify the two main types of technical training. The general troubleshooting system program is an instructor-led CBT system that provides a simulation-based training program to teach general troubleshooting skills. This three-day course covers electrical circuits, tools, and test equipment. The goal of CBT systems that teach general troubleshooting skills is to teach knowledge and skills that are applicable to many different types of systems. For example, the troubleshooting skills applied to a general aviation aircraft are the same as those for a commercial aviation aircraft, but the systems are more complex on transport category aircraft.

The second CBT is specific to a single aircraft and was developed with a Canadian air carrier. The goal of this system is to teach the user to diagnose faults in the Challenger aircraft. Although the learning in system-specific training systems may transfer to other systems, such programs usually focus on the configuration and procedures specific to that system.

3.6.5.2 Aviation Training with Video

Courseware from another aviation training company ranges from the "Principles of Troubleshooting" course that teaches general troubleshooting skills to aircraft-specific CBT for the Gulfstream II, III, and IV, Falcon 50, King Air 200, and the Citation 500 and III. Although this company has begun taking advantage of digital video in their newer systems, many of its older CBT programs are videodisc-based.

3.6.5.3 Large Aircraft Training

Another CBT company has produced "off-the-shelf" maintenance CBT for the 747, 767, MD-11, and various other aircraft. The 767 training course includes 90 hours of CBT and covers most of the major aircraft systems. These training systems include multimedia, making the system much more interesting to the user. The videodisc system includes high-quality video, still pictures, and audio.

3.6.5.4 Fundamental Troubleshooting Skills Training

A large American CBT developer is working with a German air carrier to develop courseware teaching the fundamentals of jet aircraft. Material covered in this course such as avionics, hydraulics, and mechanics is common to most aircraft and is covered in each of the type ratings. The goal is to save time by teaching this material once, instead of having to teach it for each type rating. The whole CBT program, which is 100 hours of training, is scheduled for release in July 1995.

3.6.5.5 737 and 777 Training

One commercial airline has developed three courses covering several different systems and procedures related to the 737. These courses include the APUs, tagging procedures, and fueling regulations. These are mostly one-hour courses that can be used on low-end personal computers. The airline is also working with the manufacturer on developing an instructor-led course for the 777.

3.6.5.6 ECS Intelligent Tutoring System

The Environmental Control System (ECS) Tutor was produced for the FAA Office of Aviation Medicine. This is an intelligent tutoring system (ITS) that teaches general troubleshooting skills in the context of diagnosing and repairing malfunctions of the Boeing 767's ECS. The tutor contains a deep model of the ECS which allows the user to see the consequences of his or her actions on the system down to the sensor level. The tutor is also highly graphical, allowing for direct manipulation of ECS components and realistic pictures and animation of system components and schematics.

3.6.5.7 Part 147 Training

Two companies have produced jointly several multimedia training modules for A&P mechanics. Course material consists of integrated manual and CBT software. Existing courses cover eddy current inspections, electronic communication and navigation systems, and instrumentation systems. The course material is not specific to any particular equipment or system, but teaches general principles and methods of operation for the given task. The software runs on a "partial multimedia" computer and includes the ability to track student performance.

3.7. POTENTIAL PITFALLS IN CREATING CBT

In designing and producing CBT, the CBT team needs to be aware of several potential problems that are commonly encountered. These problems may be technical, instructional, planning, ergonomic, or organizational (**Table 3.8** summarizes these problems). The CBT process described in Section 3.4 minimizes the chance of these problems arising.

Table 3.8 CBT Pitfalls

Problem	Prevention/Solution
Additional training not required	Perform a thorough task analysis, including an analysis of the current training methods.
Poor instructional design	Perform a thorough task analysis and an instructional design based on this analysis.
Poor user interface	Conduct frequent user acceptance evaluations during development, follow interface design guidelines and conventions; know the target users
Poor computer programming of CBT	Apply standard software engineering and management techniques; use the right tools and programmers.
Unplanned organizational impact	Understand the shift in the instructor's role; design and evaluate a prototype course before starting school-wide use.
System not integrated with other training	Verify the whole instructional design; ensure that the students have all prerequisite knowledge, evaluate the CBT's integration with other courses
Oversell of CBT	Set realistic goals (cost effectiveness) that the CBT should meet.

3.7.1 Additional Training not Required

Sometimes training systems are built when there is no need for them. This usually happens when a needs analysis is not conducted. Some tasks do not require formal training because they are easy to learn, and on-the-job training is the appropriate instructional method. In other cases, instructor-led training or self-study instruction are adequate for the material being covered.

To determine if additional training is required, the instructional designer needs to perform a thorough needs analysis, including an analysis of the current training methods. The task analysis will determine if there is an opportunity for improving on-the-job performance. A needs analysis may identify ways of restructuring the task for improved performance and efficiency. If a CBT is proposed to lower training costs, then a cost/benefit analysis needs to be performed to determine if the CBT system will actually result in lower training cost.

3.7.2 Poor Instructional Design

Another pitfall in creating CBT systems is poor instructional design resulting from a mismatch between the target users' instructional needs and the training system's design. Occasionally, such a mismatch can hinder users' job performance if they are trained to perform the task incorrectly.

An important part of instructional design is making the CBT software interesting to the users. Many failed CBT programs are "page turners" that are little more than books that have been transcribed to the computer: these systems do not hold most users' attention. A program cannot be made engaging simply by tacking on pretty pictures and animation; user interest must be designed into the system from the project's beginning.

The best defense against poor instructional design is, again, a thorough job task analysis and instructional design based on this analysis. Instructional design is the bridge between the students' instructional needs and the CBT program's design. Without a thorough job task analysis, it is unlikely that the CBT program will be useful. If the program is being done in-house, iterative reviews help ensure that it will meet its instructional goals. A thorough analysis of the system's instructional design is necessary for programs built by a contractor or bought off-the-shelf.

3.7.3 Poor User Interface Design

A CBT system should be designed so that it is easy to use. The text should be readable, the controls should be intuitive, and the user should be able to determine what the program is doing and what he or she can do with the program. If this is not true, users become frustrated with the system and avoid using it. If students are forced to use a poorly designed program, they usually do not pay attention to what the program is trying to teach. A program can also be unusable and frustrating if the computer is not powerful enough for the software or does not have all of the features (such as multimedia accessories) the software requires. The net effect of poor user interface design may be a decrease in training and work motivation, so this type of failure requires special consideration.

User interface design problems can be avoided by performing frequent user acceptance evaluations during CBT development. The best way to do this is to have intended users operate the program and report any problems they have understanding its content or usage. Someone uninvolved in the CBT's programming should observe the users to record reported problems and to look for problems that users do not report. Data gathered from these evaluations should drive CBT design changes.

The CBT team should understand the target users. The team should know the users' level of computer experience, background knowledge, and learning styles. For example, if the CBT program requires a mouse and the students are unfamiliar with using a mouse, the instructor should give a short lesson on its use (possibly by letting the users play a computer game). With knowledge of user backgrounds, CBT software and hardware can be evaluated for "fit" with the students, and changes can be made, if necessary. Users have a variety of experience and knowledge, and CBT systems should be designed to be usable by the largest number of students. There is always a number of students who need extra help with any system.

3.7.4 Poor Computer Programming of CBT

A needed and properly designed CBT system will not be successful if it is poorly programmed. If the computer program does not do what it was intended to do, then it is unlikely that it will meet its instructional goals. Poor programming can result in incorrect or missing data, or programs that mysteriously "lock up" the computer. A program with too many errors is not instructionally effective because the user pays too much attention to trying to make the program work. Poor computer programming can result from several planning or management problems:

- Poor planning or resource allocation
- Wrong choice of programming tools for the task
- Insufficient training in the use of the programming tools
- Insufficient management of programming tasks, testing, or deadlines
- Personality conflicts between CBT team members.

These problems can be avoided by applying standard software engineering and management techniques to administering the programming project. Although team management is not a concern for organizations buying off-the-shelf CBT, it is still important to ensure that the training software being bought is error-free. This can be done by conducting a pilot program with a small group of students before buying the CBT program.

Because computer programming is still more of an art than a science, it is often difficult to predict how much time it will take to complete a program. On the average, it takes between

200 and 500 hours of development to produce one hour of CBT. The time for any particular project depends upon many factors, including the system's complexity, the CBT team's experience, and the amount of cooperation with management and instructors. It is important to allocate time for evaluation and testing to ensure that the CBT program is useful and usable.

3.7.5 Unplanned Organizational Impact

When applying any technology to a task, it is important to consider the impact that the technology will have on the organization. This is not often done with computer technology since it is usually assumed that the "new" method will improve efficiency and productivity. Sometimes lack of planning for the introduction of new technology results in a refusal to use the new technology. Organizational rejection of technology may be caused by poor training, confusion about the purpose of the technology, or users' feelings that the technology is being imposed on them.

When using CBT in an organization for the first time, it is important to understand and account for the shift of the instructor's role from a presenter of information to that of a student assistant. This can best be done by conducting a trial CBT course. This trial course should explicitly describe the roles of instructors, students, administrators, and support personnel. Testing a prototype in a classroom also provides useful information before the CBT course is implemented school-wide. The students should be familiar with the behavior and operation of computers and the reason for using computers in training.

3.7.6 System not Integrated with Other Training

Just as there is no single tool for all tasks, there is no single technology appropriate for all training. A CBT system should be applied to meet specific training goals for which it is appropriate. Since there are other training methods to teach other knowledge, an instructional designer must consider how to integrate CBT with other types of training. For example, a CBT system that teaches non-destructive inspection may be integrated with classroom lectures that explain the theory behind magnetic and ultrasonic NDI and textbook material that describes different NDI systems. When dividing a training course among several instructional techniques, the instructional design must be well-planned to ensure that students have all the prerequisite knowledge before proceeding to new lessons.

3.7.7 Oversell of CBT

A CBT program is an asset to technical training because it enhances traditional classroom training. CBT systems have sometimes failed because they were oversold to school management, instructors, and/or students. CBT is not the "end" in training technology; it is rather a "means" in the effort to meet the overall goal of effective and efficient technical training. The broad category of oversell includes optimistic predictions of cost effectiveness, performance improvements, development time, or user acceptance.

A good CBT system requires time, money, and other developmental resources. If sufficient resources are not allocated to building the system, it will be inadequate and will probably fail to meet its goals. If the finished CBT is ineffectively utilized, it is unlikely to be cost-effective. Another common misconception is that CBT solves all of an organization's training problems. As with any training approach, some students will have problems learning from CBT. This may result from poor CBT design or from some students' insufficient background knowledge or poor learning habits. Instructors should prepare for this eventuality.

To avoid this problem, set realistic goals for CBT. The goals should describe expected changes in training costs and effectiveness. Remember that both of these do not have to improve; in some cases, a CBT that increases effectiveness may cost more than the current training method. Finally, make sure that others in the organization understand the goals for the CBT system.

3.8 CONCLUSION

The design and implementation of CBT systems present many options to aviation training managers. While the decisions may seem complicated, they can be greatly simplified by using a proven systems approach to manage CBT selection, development, and implementation.

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CHAPTER FOUR
IDENTIFICATION OF BARRIERS TO SUCCESS FOR NONTRADITIONAL PARTICIPANTS IN AVIATION MAINTENANCE CAREERS

4.0 INTRODUCTION

The challenge to improve air safety through employment and retention of an appropriate maintenance work force is extremely diverse. Many factors determine the composition of any air carrier's maintenance team. These factors include Federal Aviation Administration (FAA) regulations, area demographics, pay scales, union rules, and availability of personnel, to name a few. The FAA Office of Aviation Medicine, in conjunction with Aviation Education Consultants, has compiled the information in this report in an effort to ensure that a plentiful supply of appropriately qualified persons will be available to meet anticipated Aviation Maintenance Technician (AMT) needs into the 21st century. For the purpose of this investigation, an Aviation Maintenance Technician (AMT) is any person directly involved with the repair or restoration of aircraft. AMT personnel includes Airframe and Powerplant (A&P) technicians, Avionics technicians, non-certified technicians employed by repair stations and does not include supervisory, educational, or administrative personnel.

It is anticipated that highly skilled blue collar workers will become increasingly in demand by various trades; therefore, the aviation industry may find it difficult to employ those persons needed for many specialized maintenance operations such as non-destructive testing, composite refabrication, and electronics troubleshooting and repair. The changing role of the U.S. military may also have a dramatic impact on the availability of AMTs. Current data from research studies suggests that the supply of white male workers, who have traditionally populated this field, will prove inadequate to meet future work force needs. It will be important, therefore, not only from an equity perspective, but also because of employment demands, to emphasize recruitment, training, and placement of nontraditional populations for AMT careers.

4.1 THE OBJECTIVES

The primary objective of this study was to delineate effective strategies for meeting the emerging AMT work force needs through recruitment, training, placement, and retention of nontraditional workers. Research has shown that historically under represented populations such as females, blacks, Hispanics, displaced homemakers, and reeducated older workers, while representing the greatest hope for meeting work force shortfalls, present unique employment challenges. In most cases, individuals in these populations lack adequate training and/or FAA certification to allow them to enter an AMT career.

In order to prepare effective strategies for meeting the emerging needs of the aviation industry, demographic data was collected to determine the populations most in need of assistance. This portion of the study was also used to predict future supply and demand for AMT employees. The methodology was an extensive demographic review of currently employed AMTs, Bureau of Labor Statistics, FAA and census data, as well as various industrial sources. The historic demographic composition of the AMT work force can also have a profound effect on future employees. Historically, AMT career fields have been dominated by white males, but, by what percentage and are those percentages changing? The demographic portion of this study examines both the composition of the AMT work force, now and in the future, as well as the predicted number of AMTs available to fill the emerging positions in the aviation maintenance industry.

In order to identify effective strategies to combat the lack of employment diversity in the aviation maintenance fields, one must first identify the barriers which inhibit nontraditional populations from choosing aviation maintenance as a career. During this study, the research team conducted a thorough literature review and site visitations to AMT schools and work facilities. Barriers to nontraditional employment and existing recruitment and retention strategies in airline, general aviation institutions, training, and other related environments were identified and cataloged. With assistance from a commercial airline, the International Association of Machinists, and the Aviation Technical Education Council, information was gathered to identify other delimiters to AMT career selection, retention, and post-training articulation into AMT career fields. The research team was able to identify several strategies which are potentially helpful in encouraging nontraditional individuals to choose AMT careers, succeed in training, and then to entice them to remain in the field.

4.2 DEMOGRAPHIC PROJECTIONS

This section of the report re-examines the results of the 1991 *Working Paper* (FAA, in press) on Aviation Maintenance Technician (AMT) shortages prepared by the Federal Aviation Administration. The 1991 paper produced projections of pilot and AMT work force needs in Civilian Aviation for 1992-2003. This section of the report addresses only the projections of future AMT work force needs. A re-examination of civilian commercial pilot work force projections is beyond the scope of this project. A summary of the complete demographic study is in Appendix 4.

4.2.1 Background

The re-examination of future AMT work force needs was called for in response to questions from aviation officials, union leaders, and others about the large shortages of AMTs that were projected in the 1991 working paper. The 1991 working paper states that "numerous sources predict that there will be a need for 100,000-120,000 AMTs by the year 2000. This number is based on the current number of technicians combined with new positions related to new aircraft and increased attention to continuing airworthiness of older aircraft." The 1991 report projects the shortage of AMTs to be between 65,000 and 85,000 new AMTs by the year 2000. Many felt that the shortfalls were too large; others, that the projected shortfalls were too conservative.

The shortages projected were accompanied by supporting information and arguments that seemed to provide a rationale for the expected large shortfalls. In the report, the projected decline of the population in the 16-24 and 25-34 age groups by the year 2000, a declining pool of potential AMTs coming from the military, a low retention rate of AMTs in the aviation industry (only 45% of AMT school graduates remain in aviation after 2 years), and other reasons are offered to explain why the supply of AMTs is not expected to keep up with demand. All of these reasons and rationales focus on the supply of AMT work force into the aviation industry. However, the FAA report does not offer specific yearly projections of AMT work force supply to accompany their detailed yearly projections of AMT work force demand. As a result, precise yearly shortages remain unclear.

This study examines the report's projection of AMT work force need. The projections are re-calculated using much of the original study's methodology but with some variation where the assumptions of the original projections have been questioned. These variations in assumptions and methodology are described in Appendix 4. This study also offers yearly projections of work force supply using data that was not used in the working paper study. This study projects supply by using FAA data on estimated active AMTs reported in the *FAA Statistical Yearbooks*. The yearly projections of AMT work force supply and demand can be compared to produce projected yearly shortages or surpluses.

4.2.2 Projected Demand and Supply of AMTs

The projections of AMT demand from **Tables 4A-4** through **4A-6** (Appendix 4) are combined with projections of AMT supply from **Tables 4A-8** and **4A-9** (Appendix 4). Projections of AMT shortages can be calculated by comparing the supply and demand projections. Only where 40% of active AMTs are employed in aviation and where it is assumed that 14 AMTs/transport category aircraft, 4.2 AMTs/commuter aircraft and .15 AMTs/general aviation aircraft are needed do we find that there will be substantial AMT shortages (see **Figure 4.1**). However, for circumstances where greater than 40% of active AMTs remain employed in aviation and where fewer AMTs are needed to maintain each class of aircraft, we do not project

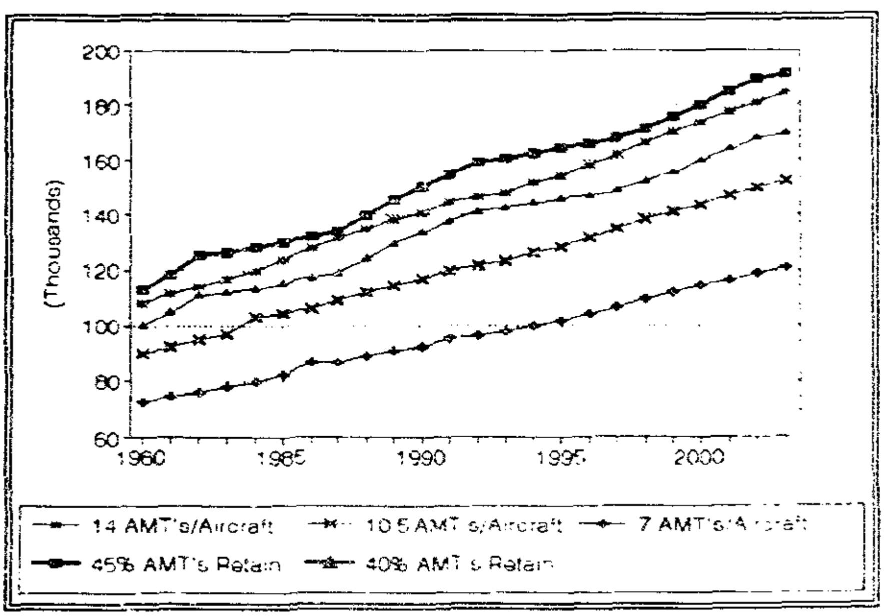

Figure 4.1 AMT Supply & Demand

shortages (**Figure 4.1**). In general, the supply of AMTs will meet the aviation industry's demand.

Another factor to be considered when projecting future shortages is the large pool of AMTs who are certified but who are not employed in aviation. These AMTs could return to aviation employment at some point if circumstances warrant it. However, it is to the aviation industry's advantage not to draw upon this supply of AMTs. It is much more cost-effective to continue to fill positions with entry-level AMTs, rather than to pay higher wages to more senior people. The comparatively low wages, nighttime work schedules, and uncertain job security in the aviation industry create retention problems within the industry, especially for more experienced and senior workers.

There may be short-term shortages of entry-level AMTs in the aviation industry, given the cyclical nature of increase in the number of annually certified AMTs who remain active in aviation maintenance each year (see **Figure 4.2**). Short-term shortages in the industry may indeed be the stimuli that AMT schools and prospective students react to, at least until it becomes difficult for newly trained AMTs to find jobs. The schools then react by reducing the scope of their programs. Individuals then may also become less interested in AMT training due to a perceived or real lack of jobs in the industry. Given the nature of the aviation industry, it seems to be quite difficult to create any long-term balance between the training of new AMTs and the availability of jobs. Assuming that the aviation industry is tied to the overall economy, in the long-term (more than a few years), the number of AMTs needed will continue to show cyclical changes as the economy goes through its typical upturns and downturns.

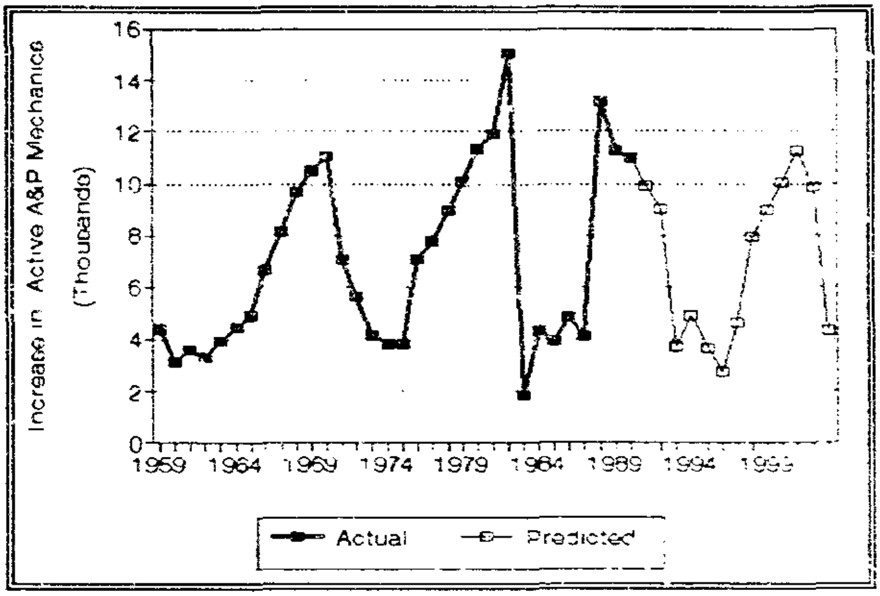

Figure 4.2 Change in Active A&P Mechanics

Another trend that may substantially reduce demand for AMTs in the U.S. aviation industry is the movement of aviation maintenance facilities to foreign countries. As more of these facilities become realities, the growth in the number of jobs available to AMTs trained in the United States will slow.

The overall conclusion of these analyses is that AMTs are available to meet today's demand and that future shortages seem unlikely. There may be short-term shortages of entry-level AMTs as the aviation industry fluctuates with the economy. However, the massive shortages suggested by the working paper seem unlikely. For a more detailed look at the demographic portion of this study, see Appendix 4.

4.3 BARRIERS AND MOTIVATORS TO NONTRADITIONAL CAREER INVOLVEMENT

In order to prepare effective strategies for meeting the emerging employment needs of the aviation industry, barriers which inhibit the recruitment and retention of nontraditional populations into the AMT work force must be identified and cataloged. Successful motivators which encourage diversity in aviation work force populations must also be examined. Ultimately, the federal government and the aviation industry must strive to ease the barriers and increase the motivators which will stimulate the involvement of nontraditional populations in AMT careers.

4.3.1 Review of Previous Research

The research literature and previous studies of nontraditional employees in aviation suggest that there are many reasons that women and minorities fail to select aviation careers. From an expansive view, these delimiting factors can be grouped into several general categories: societal and cultural indoctrinations and expectations; disparity of treatment; individual development; vocational awareness; and real or perceived discrimination and bias. The summative effect of these variables is central to an individual's predisposition to select and his or her ability to survive and prosper in nontraditional careers.

The literature suggests that minorities and women with an interest in nontraditional careers place as much emphasis on career goals as do white males (Bianchi, 1990; Goldberg & Shiflett, 1981). What, then, discourages women and minorities from entering white male dominated career field preparation and pursuits? The literature suggests that there are many barriers limiting or discouraging these individuals from selecting nontraditional activities. Factors such as the individual's socioeconomic status, the amount and type of parental encouragement the individual received, the aspirations of peers, and the employment status of their close friends and family members are a few contributing variables (Carr & Mednick, 1988; Ott et al., 1979). The literature groups delimiters limiting the entry of women and minorities into traditional white male occupations into three distinct barrier types: institutional, situational, and dispositional (Denbroeder & Thomas, 1980; Thomas et al., 1979).

4.3.1.1 Institutional Barriers

Institutional barriers are those delimiters which are intrinsic to white male dominated educational or industrial organizations into which female or minority integration is desired. Examples of institutional barriers are admission policies, financial aid policies, institutional regulations and policies, and staff attitudes (Bianchi, 1990; Denbroeder & Thomas, 1980; Thomas et al., 1979). Many educational, industrial, and societal factors influence and limit career aspirations and success for minorities and women in white male dominated training or career fields.

4.3.1.1.1 Industrial Bias

Legislative mandate has substantially reduced institutional barriers for women and minorities. Federal laws such as the Equal Pay Act, the Civil Rights Act, the Equal Employment Opportunity Act, and the Equal Rights Amendment establish industrial guidelines aimed at integrating minorities and women into historically under represented career fields (Aburdene & Naisbitt, 1992; Biles & Pryatel, 1978). Thus, many institutional barriers associated with educational and industrial policies have been removed for females and minorities interested in nontraditional pursuits.

The imposition of Congressional mandate does not assure equal treatment in the work place. The literature suggests that women and minorities in supervisory positions are viewed by their subordinates less favorably than white males in those positions, despite the subordinates' race or gender (Faludi, 1991: Haccoun, Haccoun, & Sallay, 1978). Research also indicates that minorities and women generally perceive that they are discriminated against as a population. However, when these same individuals were asked if they themselves were discriminated against, they generally indicated that they were not (Crosby, 1984; Eiff, 1989). Many institutional barriers can and have been successfully addressed and controlled through legislation in order to equalize vocational opportunities for men and women of all races (Thomas et al., 1979). In the current study, workers of both genders and various races reported that many industrial barriers, biases, and discriminatory activities have been controlled or neutralized by legislation or by fear of legal action precipitated by judicial precedent.

4.3.1.1.2 Educator Bias

Institutional barriers associated with educational organizations have proven formidable to the process of integrating equitable numbers of minorities and women into white male dominated career fields. While the Civil Rights Act and Title IX of the Education Amendments propose to ensure the elimination of bias and race- and sex-role stereotyping in both employment and career preparation, both overt and covert bias remain entrenched in our educational institutions (AAUW, 1992; Denbroeder & Thomas, 1980). Unfavorable comments and behaviors by teachers, counselors, and peers have been shown to be discouraging influences on women and minority students with nontraditional interests

(Bianchi, 1990; Eko & Brown, 1981). Legislative mandate has neutralized most overt forms of discrimination in educational institutional admissions, financial aid, and regulations policies (Orr, 1983). However, successful remediation of biases associated with staff attitudes and actions has not been realized. The influences of teacher, counselor, and textbook biases on minority and female students still pervade our educational institutions (AAUW, 1992; Cronenwett, 1983).

Teachers and counselors consciously and/or unconsciously convey bias to students by "sending verbal and non-verbal messages to students" discouraging the selection of a nontraditional career field (Cronenwett, 1983; Stitt, 1988). Since counseling experiences seem to influence career decision-making in young people, counselors must question the quality and equity of the service they provide (Sauter, Siedl, & Karbon, 1980). The literature shows that counselors hold sex-and race-stereotypical attitudes and often show disapproval toward students with an interest in nontraditional or, as they perceive it, "deviant" program or career interests (Bianchi, 1990; Ott et al., 1979). Most agree that counselor bias and awareness level are important variables in the pursuit of an equitable counseling experience (Sauter et al., 1980). Most also agree that counselors need to reduce their open and subtle biases in an effort to facilitate equity in educational programs and career pursuits (Lewis et al., 1976; Stitt & Stitt, 1990).

The literature implies that counselors are "agents of conformity, rather than vehicles of change" (Hawley, 1972; Stitt, 1988). Research indicates that counselors tend to suggest only traditional options to undecided students and discourage nontraditional interests. Teachers in areas like technology are somewhat reluctant to include nontraditional students in their courses. While these influences may be presented most subtly, they can effectively discourage nontraditional choice among under represented populations (Harrison, 1980). Attitudes among educators toward the suitability of vocational courses for various individuals were demonstrated to be associated with the educator's sex and educational level, but not their race or teaching longevity (Handley & Walker, 1978). Male teachers were more influential than female teachers in female students' decisions to select nontraditional courses and careers. Female teachers tended to encourage female students to maintain a traditional educational and career interests. White educators, both male and female, are more biased regarding nontraditional work preferences of men and women than are black educators (AAUW, 1992; Handley & Walker, 1978).

Educational institutional barriers must be changed from within. The key to implementing such changes is the teacher (Farris, 1980). Research indicates that teachers exhibit differential treatment of students according to the student's race and gender (AAUW, 1992, Ott et al., 1979). It is suggested that this treatment disparity occurs because teachers ascribe different characteristics to gender and race and prefer certain types of behavior in members of certain populations (Ott et al., 1979; Stitt, 1988). While teaching faculty have not been implicated as directly influencing traditional choices in students' majors, they seem to have an indirect influence through classroom experiences (Bianchi, 1990; Carr & Mednick, 1988; O'Donnell & Andersen, 1978). Teachers and counselors disclose that they do not encourage or discourage students' consideration of nontraditional career interests. They do indicate, however, that when a student indicates a nontraditional interest they "probe" to insure that the student's interest is genuine. This "probing" could discourage many students from pursuing nontraditional interests (Lewis et al., 1976; Stitt, 1988).

4.3.1.1.3 Educational Material Bias

While teachers and counselors may covertly convey bias, there are many overt forms of bias in the educational environment. Chief among these influences are instructional language and textbook bias. Subtle forms of racist or sexist language significantly affect students social perceptions. (Briere & Lanktree, 1983; Stitt, 1988). The use of guidance materials (Eiff, 1989; Rohfeld, 1977) and textbooks which project overt or covert sex- or race-stereotyping or utilize racist or sexist language can greatly deter students' consideration of nontraditional interests (Lewis et al., 1976; Stitt & Stitt, 1990).

Research suggests that a student's perception of career attractiveness and his or her willingness to move into specific career fields follows sex- and race-stereotypical directions as a function of the degree of exposure to racist and sexist language. These findings support recent demands for non-sexist and non-racist language in guidance material and textbooks. (Briere & Lanktree, 1983; Faludi, 1991). In addition to language bias, textbooks have also been found to project stereotypical race and gender attributes. Textbooks often present females as passive, fearful, or incompetent. Males are often portrayed as active, brave, and resourceful (Ott et al., 1979). Minorities are often projected to be criminal, lazy, or offensive In order to remove biases generated by educational materials, it is imperative that teachers and counselors guard against the use of sex- or race-typed material (Lewis et al., 1976).

4.3.1.2 Situational Barriers

While legislation and programmatic changes have alleviated many institutional barriers, neutralizing institutional barriers will not, in and of itself, result in greater representation of women and minorities in white male dominated career fields. There remains a sizable array of personal-social barriers which create conflicts for minorities and women who would like to enter nontraditional careers (Thomas et al., 1979). Among these barriers are influences related to the individual's environmental and life contextual limitations Situational barriers are those constraints experienced by the individual due to the circumstances in which they find themselves. Situational barriers include family responsibilities, financial needs, and societal pressures (Denbroeder & Thomas, 1980; Leach & Roberts 1988; Thomas et al., 1979). An individual's social and family context has a significant impact on his or her career aspirations.

4.3.1.2.1 Career Training Costs

Principle among situational delimiters is the cost of training necessary for career participation. Many minorities and women require more career preparation in order to enter many white male dominated fields than do white males Weak prerequisite skills in mathematics and science often dictate additional training in these disciplines before entering career training. Many women and minorities fail to consider nontraditional career fields because of their need for career preparation and the cost of that training (Drake, 1990; Rodriguez, 1986). In aviation career fields, career preparation training costs are a barrier which must be surmounted before minorities and women can enter these nontraditional careers. Socioeconomic background may predispose low aspirations among these individuals if they perceive parental reluctance or inability to support career-preparation costs (Carr & Mednick, 1988; Danziger, 1983). Despite a desire to pursue such training, these individuals may also find it difficult to secure loans for training and often lack information on how to obtain money for career training (Bianchi, 1990; Thomas et al., 1979). In order for individuals from low-income backgrounds to have an opportunity to enter nontraditional careers, it is necessary for them to identify sources of money for training costs (Bianchi, 1990; Fralick, 1984). These individuals often find it difficult to secure financial aid due to their special needs (Thomas et al., 1979).

4.3.1.3 Dispositional Barriers

Legislative removal of institutional barriers has not changed pervading attitudinal barriers preventing students from choosing nontraditional career pursuits (Albrecht, 1976; Duo & Yuen, 1985; Leach & Roberts, 1988). Dispositional barriers are those attitudinal attributes of an individual which preclude his or her involvement in nontraditional careers. Individual dispositions may create dispositional barriers such as the fear of failure, fear of success, attitudes toward intellectual activities, role preference, level of aspiration, dependence, and feelings of inferiority (Denbroeder & Thomas, 1980; Thomas et al., 1979). For many minorities and women, race- and sex-role stereotyping, occupational race- and sex-typing, and self-concept have a significant impact on their occupational aspirations (Eiff, 1991; Ruble et al., 1984). Attitudinal barriers effectually eliminate serious consideration of nontraditional career pursuit. It has been shown that an individual's level of education affects the impact of such barriers on career aspirations. Lower levels of education in combination with socialization presents an ominous barrier for nontraditional career aspirations. The "lack of an adequate education which would prepare one for certain occupations combines with attitudes developed during socialization that, in effect, define these occupations as inappropriate choices anyway" (Albrecht, 1976).

4.3.1.3.1 Self-Esteem

Research has indicated that there appears to be a significant relationship between an individual's self-esteem and whether or not the individual's attitudes are nontraditional or traditional (Harrison et al., 1981). The literature reports that many women and minorities have a lower self-concept than white males in the realm of occupational performance. This may lead to lower self-confidence and an expectancy of failure (Sleeter, 1991; Soldwedel, 1989; Thomas et al., 1979). Women are more self-conscious and, therefore, more vulnerable to criticism than males, especially in occupationally related terms (Faludi, 1991; Rosenberg & Simmons, 1975). Women facing the reality of pursuing male-dominated careers agree that they are discouraged by their lack of self-confidence (Eko & Brown, 1981). Women with higher self-esteem are more likely to pursue nontraditional occupations (Harrison et al., 1981).

4.3.1.3.2 Fear of Success

Females and minorities who gain success in environments where their employment is considered traditional or where there is an equality of representation elicit favorable white male reaction. When the success is associated with careers or actions considered "deviant" for minorities or females, these same males react punitively. Successful nontraditional workers may manifest a "motive to avoid success" in an effort to avoid disfavor among white male peers (Lockheed, 1975). Thus, women and minorities may become underachievers when competing with white males, especially in environments where white males dominate, in order to avoid a perceived compromise in their relationship with these men (Carr & Mednick, 1988; Dole, 1989; Thomas et al., 1979).

4.3.1.4 Socialization

The effects of social expectations are most apparent in the career and life aspirations of women. Women are socialized into diverting their attention away from themselves as workers and toward seeking identity from their spouse or potential spouse (Thomas et al., 1979). Socializing forces not only inhibit the development of women but also impede the national interest to maximize human resources (Aburdene & Naisbitt, 1992; O'Donnell & Andersen, 1978). Socialization is a process "whereby implicit standards of social conduct are conveyed to and acquired by children" (Bearison, 1979). As an example, parents, teachers, and media socialize women from infancy to seek their fulfillment in the wife/mother role and at the same time motivate men toward occupational success (Orr, 1983). Social scientists assert that this differential in socialization patterns exists throughout an individual's life, guiding males and females in different directions (Carr & Mednick, 1988; Rosenberg & Simmons, 1975). Traditional societal sex-role socialization promotes achievement motivation in men but is antagonistic to the development of such motives in women (Carr & Mednick, 1988).

Members of minority populations are similarly affected by cultural and social expectations dictated by their backgrounds. These influences give stark evidence that paramount among socializing forces is the family. The family is the first and foremost influence in our lives (Auster & Auster, 1981; Eiff et al., 1986). Research indicates that the socialization process within the family was the greatest factor affecting the occupational choices of women and minorities (Eko & Brown, 1981). As the primary agent of socialization, the family's influence on career choice is a result of a complex interplay of active and passive, formal and informal, social, psychological, and economic factors. Career choice among women is influenced by such family socioeconomic factors as parental education levels and occupational status, income, and number, birthing order, and sex of siblings (Auster & Auster, 1981) as well as parents' attitudes toward traditional roles (Leach & Roberts, 1988; Thomas et al., 1979).

The literature indicates that despite their racial or ethnic background, parents differentially socialize sons and daughters (Bearison, 1979; Carr & Mednick, 1988). Seemingly benign behaviors by parents can translate into covert sex-role stereotyping. Factors such as the type and frequency of handling in infancy, the numbers and kinds of toys, and the encouragement of dependence or independence can have dramatic implications on children's sex-role perceptions (Schlossberg & Goodman, 1972). The classic "Baby X" research demonstrated the pervasive and inadvertent nature of parental sex-role socialization. By using the same baby and representing it as male or female, researchers were able to demonstrate that adults interact different with the same infant in accordance with the child's perceived sex (Seavey, Katz, & Zalk, 1975). Thus, the literature suggests that women from all backgrounds are adversely affected by familial socializations.

Many family attributes and constraints also affect the career aspirations of minorities and women. The educational levels of parents, especially that of the mother in the case of women aspirants, and the work history of parents have been strongly implicated as factors in an individual's nontraditional career pursuit (Crawford, 1978; Danziger, 1983; Drake, 1990; O'Donnell & Andersen, 1978; Sauter et al., 1980). Both boys and girls appear to be influenced by the occupation of the opposite sex parent (Kane & Frazee, 1989; Nelson, 1978). The financial resources of the family are also linked to parental expectations and individuals' aspirations. Families with limited financial resources may be more sensitive to the cost and duration of career preparation and the uncertainty of occupational returns (Bianchi, 1990; Danziger, 1983).

Other prominent socializing forces are the influences of race- and sex-typing in the media and advertising. Television abounds with sex- and race-typed information concerning role appropriateness in its program and advertising content. The media, including magazines, songs, newspapers, and radio, reinforce traditional sex and race roles (Schwartz & Markham, 1985). Children learn about jobs and work settings from television, but such programming strongly promotes the "appropriate" race and sex of the worker (O'Bryant & Corder-Bolz, 1978; Stitt & Stitt, 1990).

The race- and sex-typing of toys has also contributed to role socialization. Such socializations are strongest for females. Toys "for girls" are strongly oriented toward domestic pursuits and do not encourage construction and manipulation like "boys' toys" do (Schwartz & Markham, 1985). Toy advertisements project the toy's appropriate sex, thus promoting sex-role socialization. Research has demonstrated that toy advertisers portray their toys with "appropriate" sex children in the pictures (Schwartz & Markham, 1985). In toy use experiments, however, researchers have found that there is no significant relationship between a child's sex and the use of boys' or girls' toys (Karpoe & Olney, 1983). Children, instead, universally used the toys by toy-defined criteria, rather than by perceived sex-typing

Another example of sex-typed expectations are those predicting that women are not mechanically inclined and lack the ability, strength, dexterity, and aptitude to perform many maintenance-related tasks. Research studies of mechanical skills demonstrate that this perception is contrary to demonstrated abilities. When tested for technical aptitudes and abilities, women were found to excel in six aptitudes: finger dexterity, graphorrhea, ideaphoria, observation, silograms, and abstract visualization. Men excelled over women in only two areas, grip and structural visualization. (Orr, 1983). Thus, commonly held beliefs that women are not adept or capable of performing mechanical tasks as well as men have been demonstrated to be erroneous.

4.3.1.4.1 Role Stereotyping

Role stereotyping is one of the most frequently cited sources of bias in the literature (Faludi, 1991; Ruble et al., 1984). Role stereotypes are oversimplified judgments about people's capabilities and interests based on their race, ethnic background, or sex (Farris, 1980, p. 19). Role stereotyping is a deeply rooted and pervasive aspect of our culture which affects career, educational, and occupational choices (Aburdene & Naisbitt, 1992; Faludi, 1991; Alden & Seiferth, 1980). Sex- and race-role identification is a central aspect of the social learning process and has profound effects on a child's expectations, self-image, and behavior (Schwartz & Markham, 1985).

Traditionally, masculinity and femininity have been viewed as dichotomous (Yanico, Hardin, & McLaughlin, 1978). It has been a cultural precept that if an individual endorses a position which projects masculinity, there is simultaneous non-endorsement of femininity (Faludi, 1991; Urbonas-Bendikas, 1981). The analysis of sex-roles brings with it a perception of threat since it asks us to question our own personal sense of identity. This is because our identities have been based upon socialization as males or females through constant and frequent overt and covert reinforcements of sex-stereotyped characteristics (Farris, 1980). Sex-role socializations are problematic in that they block human understanding, communication, and potential (Alden & Seiferth, 1980).

The acquisition of sex- and race-role identities are usually attributed to one of three factors: innate biological differences, cognitive-developmental parameters, or social influences (Bardwell, Cochran, & Walker, 1986). The third factor is derived from social learning theory and, thus, is central to the current study. The process of stereotyping involves classifying or categorizing groups or individuals according to dispositional traits, attitudes, or intentions (Carr & Mednick, 1988; Ruble et al., 1984). In the current context, a stereotype centers around normative role expectations. Relative to gender, for men, these normative expectations are that they will be economically independent, that they will work all their adult lives, and that they will be the principle breadwinner and achiever. Women, on the other hand, are expected to be successful in marriage, to assign their priorities to child rearing and homemaking, and are less exposed to social pressure to achieve. Career pursuits and economic independence are conceived of as secondary considerations for women (Danziger, 1983). Socialization of women turns them toward being pleasing to others; socialization of men turns them to accomplishment and achievement (Stitt & Stitt, 1990, Rosenberg & Simmons, 1975).

Society identifies certain traits as representative of male and female attributes. The male is considered to be independent, active, objective, confident, ambitious, assertive, logical, and aggressive (Ruble et al., 1984; Shinar, 1975). Female attributes include gentleness, emotionality, interpersonal sensitivity, tactfulness, neatness, and quiet (Ruble et al., 1984; Shinar, 1975). When compared to men, women are considered less competent, less independent, less objective, less logical, and less organized (Broverman, Vogel, Broverman, Clarkson, & Rosenkrantz, 1972; Rosenberg & Simmons, 1975).

Individuals acquire role stereotyping from a variety of social forces: parents, schools, peers, and the media (Schwartz & Markham, 1985). Since stereotyping begins at infancy, it is set by the age of three and defined by the age of six. Parents are the first and primary source of role-bias (Duo & Yuen, 1985). The role stereotypes imposed by parents during early childhood become a formidable barrier during later years (Thomas et al., 1979). Parents subconsciously pass sex- and race-role traditions on to their children through both overt and covert actions and language. Parents teach children to play with race- and sex-appropriate toys, assign them sex-appropriate household tasks, and treat them differently (Ott et al., 1979). Many times, differential treatment is conscious and deliberate (Seavey et al., 1975). During adolescence, parental expectations that daughters will marry and have children is an important barrier to career pursuit (Carr & Mednick, 1988; Thomas et al., 1979).

Many other social forces contribute to role expectation reinforcement. Schools nurture stereotypical behavior through their expectations of different behaviors for boys and girls, and for members of different races. Girls are expected to be obedient, docile, and dependent; boys, to be aggressive, active, achieving, and independent (Carr & Mednick, 1988; Faludi, 1991). Another influence on role identification is the bias imparted by television (O'Bryant & Corder-Bolz, 1978). In general, women are portrayed in less liberal, more sex-role differentiated roles in television commercials than is the case in real life. Television commercials generally depict women in maternal, housekeeping, and aesthetic roles (Mamay & Simpson, 1981).

4.3.1.4.2 Occupational Stereotyping

Occupations and professions are highly segregated by race and gender (Bielby, 1978). Occupational race- and sex-stereotypes are developed in much the same way as individual stereotypes (Ruble et al., 1984) and are extensions of the generalized segregation which characterizes all aspects of Western society (Lipman-Blumen, 1976). These stereotypes are but one reflection of a pervasive society-wide system of sex and race differentiation which manifests itself in differing roles, temperaments, and opportunities (Faludi, 1991; Mason, 1976; Schlossberg & Goodman, 1972). As with other Western cultures, occupational segregation has been a constant feature of the work place in the United States throughout its entire history (Deaux, 1984; Duo & Yuen, 1985).

Two methods of occupational sex- and race-typing are apparent in the literature: 1) the use of the race or gender ratio of workers in an occupation and, 2) by a classification of the nature of the work (Standley & Soule, 1974). Research suggests that the most commonly held perceptions of occupational stereotyping relate to the majority sex or race working in a career being perceived as the occupation's appropriate sex/race (Krefting, Berger, & Wallace, 1978; Ruble et al., 1984; Thomas et al., 1979). Often, minorities and women are discouraged from seeking employment in white male dominated careers because of such occupational stereotyping (Drake, 1990; Kane & Frazee, 1989; Thomas, 1981).

Historically, there has been a tendency to channel women and minorities into a few socially acceptable, low-status, traditional occupations (Leach & Roberts, 1988). Segregation by race- and sex-typed occupation constitutes a major waste of natural talent (Aburdene & Naisbitt, 1992). Despite purported efforts to infuse greater numbers of women into nontraditional occupations, research indicates that occupational segregation by sex is nearly as prevalent today as it was almost one-hundred years ago (Alden & Seiferth, 1979). An individual's perception of occupational sex- and race-appropriateness has been found in early childhood (Rosenthal & Chapman, 1982). Studies suggest that students in elementary grades limit their career interests to race- and sex-typed career fields (Alden & Seiferth, 1980; Papalia & Tennent, 1975; Tremaine, Schau, & Busch, 1982). Career aspiration gains in liberality through pre-adolescent (Tremaine et al., 1982). Females express more varied, nontraditional, and sophisticated vocational preferences during pre-adolescence than they do when entering college (Eiff, 1989). By the time women enter college, they exhibit clearly defined perceptions of sex-typed occupations (Shinar, 1975). These perceptions of race- and sex-appropriate career fields prevent many minorities and women from considering white male dominated occupations.

4.3.1.5 Informational Barriers

Informational barriers have proven to be a major force working to limit the involvement of women and minorities in white male dominated aviation career fields. Research has repeatedly demonstrated that a generalized lack of awareness and the unavailability of career information and career guidance with regards to atypical careers are significant factors in the discouraging the nontraditional participant from entering white male dominated career fields.

4.3.1.5.1 Lack of Awareness

Many minorities and women fail to perceive the myriad of nontraditional career opportunities as viable career options simply because they are unaware of them. A campaign of general publicity and efforts to inform high school counselors has been listed as the most important strategy to improve the representation of nontraditional workers in white male dominated occupations (Deaux, 1984; Leach & Roberts, 1988; Occupational Competencies, 1991).

Race and socioeconomic status are important factors in career awareness. Occupational knowledge is associated with an individual's socioeconomic status, family size, and race. Race, in particular, has been demonstrated consistently to have a dramatic impact on an individual's occupational knowledge (Howell, 1978). Blacks are less familiar with job titles than other populations and have a more restrictive view of occupational possibilities. They also have a lower inclination to explore career possibilities (Alden & Seiferth, 1980).

Women are generally less aware than men of both the availability of nontraditional careers and of information about employment openings (Drake, 1990; Leach & Roberts, 1988; Stitt, 1988). In aviation career fields, specifically, the general lack of awareness among women and minorities concerning the diversity of aviation career opportunities was cited as the single most important reason for the low levels of representation by these populations in aviation career fields (Eiff, 1989; Occupational Competencies, 1991). It has been suggested that making these individuals aware of atypical career opportunities and encouraging them to explore those opportunities will have a dramatic impact on the integration of women and minorities into white male dominated careers (Drake, 1990; Harrison, 1980; Leach & Roberts 1988).

4.3.1.5.2 Lack of Career Information

Many women and minorities to select traditional careers because they do not have access to information concerning atypical occupational opportunities (Kane & Frazee, 1989; Stitt & Stitt, 1990). Individuals and counselors lack important information about nontraditional careers which would enable minorities and women to make intelligent choices with regards to occupational selection and preparation (Eko & Brown, 1981; Stitt, 1988). Information concerning career preparation, potential salaries, job opportunities, working conditions, and promotional opportunities is critically lacking (Lewis et al., 1976).

4.3.1.5.3 Lack of Career Guidance

The literature indicates that there is a dramatic need for greater career counseling for women and minorities (Alden & Seiferth, 1980; Leach & Roberts 1988). When workers were asked if career counseling was influential in their nontraditional career decision, many indicated that it was of little or no help (Eiff et al., 1986; Rohfeld, 1977). It has been suggested that this may indicate that counselors either do not have adequate information about individuals in nontraditional occupations or that their own biases regarding race- and sex-roles directly limit the information they offer women and minorities. In either case, it is important that counselors increase their knowledge about career opportunities for women and minorities, as well as their awareness of and sensitivity to bias (Drake, 1990; Occupational Competencies, 1991).

4.3.2 Nontraditional Career Motivators

The literature also gives insight as to what factors influence or motivate minorities and women to consider nontraditional careers. Motivation is a function of two elements: expectancy and value. Expectancy is "the individual's subjective sense of probability that a certain event will occur" (Laws, 1976). Value can be viewed, from the cognitive perspective, as the "positive or negative incentive value a particular event has for the individual" or, from a behavioral perspective, "in terms of an organism's tendency to approach or avoid a given state of affairs" (Lewis et al., 1976). Together, expectancy and values are the framework of an individual's aspirations and career motivations. Aspiration, from a psychological or social learning theory perspective, is "an integral part of a dynamic cycle involving goal-setting, effortful striving, events that provide feedback about success or failure, and the adjustment of aspirations" (Lewis et al., 1976). Some of the more important motivating influences encouraging women and minorities to choose nontraditional careers include the promise of economic gain, the presence of role models, interactions with career professionals, visits to job sites, experiential career experiences, and appropriate career information.

4.3.2.1 Economic Gain

In career selection and pursuit, several factors influence the decision process. Salary, social prestige, nature of the work, individual characteristics of the job seeker, and educational and skill levels are concomitants of occupational preferences (Aburdene & Nausbitt, 1992, Dole, 1989; Ruble et al., 1984). Earning potential is a major influence in career decision making (Cronenwett, 1983) Women and minorities in traditional careers have consistently made less money than men in traditional white male career fields. This persistent 60% ratio in female to male earnings exerts pressure on many women to pursue higher-paying career opportunities (Deaux, 1984). Often, nontraditional career consideration is directly related to an individual's perception of better earning potential (Walshok, 1976). A motivation to maximize earning potential causes many minorities and women to avoid or leave traditional careers in favor of nontraditional career opportunities (Scott, 1980).

4.3.2.2 Role Models

The influence of "significant others" has been attributed a paramount importance in career decision making (Eiff et al., 1986; Eko & Brown, 1981; Handley & Walker, 1978). Significant others include parents, teachers, and influential role models (Handley & Walker, 1978) The shortage of female and minority role models in nontraditional career fields, it has been suggested, results in nontraditional workers being afraid to enter white male dominated fields (Orr, 1983; Thomas et al., 1979).

Research indicates that material which portrays minorities and women in white male dominated jobs reduces female and minority reluctance to enter those fields (O'Bryant & Corder-Bolz, 1978; Orr, 1983; Stitt & Stitt, 1990) Identifying role models actively employed in under represented fields can help overcome their habitual feelings of self-doubt and self-defeat (Fletcher, 1980). Women and minorities are less likely to aspire to an occupation when the representation of same race and same gender workers in that field is low. Evidence of few role models in a career field gives the impression that the career is "off-limits" (Deaux, 1984). Career information and activities involving role models "who are actually doing it" can be an effective tool in neutralizing barriers to alternate careers (Alden & Seiferth, 1980, Burge, 1983; Dolan, 1980; Eko & Brown, 1981, Lewis et al., 1976, Ott et al., 1979, Stitt & Anderson, 1980).

Career information and posters should display nontraditional role models (Carney & Morgan, 1981), eliminate race- and sex-restrictive labels, and drop sex-biased semantic markers for traditional, stereotyped occupations (Rosenthal & Chapman, 1982). Many researchers have suggested that, as the number of minorities and women in a career field grows, the numbers of nontraditional workers who aspire to that career will increase (Jackson, 1978; Ruble et al., 1984). One researcher has even speculated that the entry of more women and minorities into white male dominated career fields will have a "snowballing effect," resulting in greater numbers of these populations aspiring to that field (Thomas et al., 1979). The more frequently females and minorities can be portrayed as incumbents in jobs previously held primarily by white males, the more likely the sex- and race-type assessment of the occupation is to change (Krefting et al., 1978; Soldwedel, 1989).

4.3.2.3 Meeting Career Professionals

Many studies have indicated the importance of personal contact with role models (Eko & Brown, 1981). Programs which allow for a free and unstructured information exchange between women and minorities in nontraditional careers and individuals aspiring to those careers will provide for successful neutralization of barriers to career involvement (Brunner, 1981). Men realize early in life that they will spend the majority of their adult lives in paid employment. Men, therefore, consciously or unconsciously build informal mentoring relationships which help them to develop requisite skills for success (Lynch, 1980). Women, on the other hand, limit their involvement in such networks.

Meeting and discussing career concerns with professionals from aviation career fields would allow minorities and women interested in nontraditional aviation careers with a quasi-mentoring environment. Such a mentoring environment should provide knowledge about the specific conditions encountered in the field, provide the opportunity to meet people who might be able to provide career and occupational preparation information, and to provide support in matters relative to career decision making (Lynch, 1980). These mentoring activities give interested individuals the opportunity to develop an individual, personal perception of what it is like to be in that particular career (Eiff, 1989; Eiff et al., 1986). Participants find it very helpful to discuss career opportunities with someone who can "tell it like it is." Some participants, after a candid and close examination of the career, may decide the occupation is not for them (Fowler, 1981). An optimal mentoring program maintains the age difference between the mentor and the participants at a half-generation, roughly 8 to 15 years (Lynch, 1980).

4.3.2.4 Job Site Visitation

Another technique suggested by previous research as motivating nontraditional career selection is for individuals to visit job sites not traditionally occupied by minorities or women. Visitation of career facilities which allow students to meet and observe workers was rated "very helpful" by high school students (Eiff et al., 1986; Leach & Roberts, 1988; Rohfeld, 1977). Research indicates that minorities and women with traditional interests participate in job site visits more than those with nontraditional career interests (Orr, 1983). Such visits promote a clearer understanding of what the career entails and a more realistic picture of the working environment (Harrison, 1980). During such visits, nontraditional employees should be evident in order to promote role models which are associated to the specific occupation (Lewis et al., 1976). Examples of involvement of women and minorities in nontraditional careers will project the career field's movement toward a more balanced race and sex ratio within the field. This perception will encourage greater numbers of nontraditional persons to consider the exhibited career field (Heilman, 1979).

4.3.2.5 Experiential "Hands-on" Experiences

Career exploration utilizing experiential work simulation has proven to be very effective. Studies have demonstrated the effectiveness of having individuals learn about career opportunities through experiential activities related to actual career tasks or in actual career environments. Students seldom have the opportunity to engage in realistic, hands-on experiences. Performing realistic work tasks using real tools provides an environment in which work-related skills and interests may be tried and explored (Fifield & Petersen, 1978). Viewed as a learning experience, hands-on training activities optimize knowledge acquisition: "According to the American Audio-Visual Society, people remember only 11% of what they hear, 30% of what they see, 50% of what they see and hear, and 70% of what they *do*" (Bradley & Friedenberg, 1986). Hands-on experiences emphasize the application of skills, rather than a vicarious skill experience. The experiential aspects of the experience are uniquely effective at capturing the interest of participants and motivating them to learn (Fifield & Petersen, 1978). Cognitive learning, participants' attitudes about the job, participants' interest, and participants' valuation of work all increase significantly (Fifield & Petersen, 1978). This success appears to be linked to the fact that students tend to perceive themselves as actually involved in authentic work problems. This perception results in a higher degree of motivation and facilitates a realistic exploration of the participant's interests, aptitudes, and special abilities (Eiff et al., 1986; Fifield & Petersen, 1978).

The use of experiential "hands-on" activities generates intense occupational interest. Participants in hands-on activities report that they felt particularly positive about the activity. Educators report that such experiential activities result in a high degree of student motivation. This motivation causes the student to seek additional information about the career. Educators have found that hands-on experiences are extremely interesting and effective ways for students to learn about occupations and to increase their interest in the world of work in general and the career explored in particular (Fifield & Petersen, 1978).

4.3.2.6 Career Education and Information

The literature is emphatic about the need to re-examine career guidance and education if equitable numbers of women and minorities are to be integrated into white male dominated career fields. The quality and availability of career information is critical to neutralizing barriers against involvement of women and minorities in nontraditional occupations. One of the most important influences on students is information about careers; career literature is a major influence in perceived career attainability and in occupational selection (Sauter et al., 1980; Stitt, 1988). Unfortunately, much of the career information currently available contains racially and sexually biased information (Yanico, 1978) and categorizes occupations as race- and sex-role appropriate (Ott et al., 1979). Great care must be taken to select or generate career guidance information which is not sex-stereotyped (Lewis et al., 1976).

Studies indicate a need for an intensive effort to provide career information addressing career issues and to make that information available to parents, students, teachers, and counselors (Alden & Seiferth, 1980; Occupational Competencies, 1991). To be effective, such information should include trends in the world of work, realistic information on working conditions, potential for employment, and earnings potential (Cronenwett, 1983). Material must be developed to increase the visibility of white male dominated occupations and awareness among minorities and women of nontraditional opportunities (Orr, 1983). This material should provide a more egalitarian perspective on the role of women and minorities and should provide a non-stereotyped representation of career opportunities (Sauter et al., 1980).

4.4 SPECIFIC AVIATION CAREER BARRIERS

While the research literature identifies many generalizable barriers for women and minorities seeking to pursue nontraditional careers, central to the concerns of this study are those specific to aviation career pursuits. Also, the last decade has seen aggressive efforts by the aerospace industry to encourage the participation of greater numbers of nontraditional workers in various aviation careers. Recent research studies indicate that these efforts have begun to result in increased numbers of women and minorities selecting and pursuing nontraditional aviation professions. Therefore, an important facet of the study was to review efforts currently used by aviation industries, schools, and organizations in order to determine what programs and methodologies are best at causing women and minorities to consider aviation career pursuits.

4.4.1 Career Selection Barriers

The research literature indicates that the generalized lack of awareness among women and minorities concerning nontraditional career opportunities is a major reason that few of these individuals select those careers. Earlier research demonstrated that most young people and high school career counselors are unaware of the diversity of aviation career opportunities available to potential employees. The same study indicated that these individuals do not understand the requisite knowledge and skills necessary for entry into such careers or know how or where to obtain career training (Eiff et al., 1986).

The generalized lack of familiarity of aviation career opportunities remains the single most prominent barrier to diversifying the aviation work force. Numerous research efforts have demonstrated that individuals from all age groups have almost no understanding of the workings of aviation commerce and the variety of careers it represents (Eiff et al., 1986).

This has been proven to be especially true among young people. When questioned about aviation careers, few young people exhibited a knowledge of career opportunities other than those of pilot and air traffic controller (Occupational Competencies, 1991). This leaves little doubt as to why these particular careers have realized the greatest gains in nontraditional workers over recent years.

From discussions held with various administrators within the aviation industry, it appears that there have been significant gains in the representation of minority populations, other than women, in aviation maintenance careers. This improved minority hiring appears especially true within major industrial settings. An evaluation of this trend suggests that the dramatic increase in numbers of minority workers in aviation maintenance professions is most attributable to aggressive education and recruitment efforts by the military, major airlines, government agencies, and other aviation and educational organizations.

4.4.1.1 The Military Influence

One of the most significant factors influencing the current trend toward more equal representation of nontraditional aerospace maintenance professionals has been the relatively successful diversification of the military. The dramatic success by all branches of the military in recruiting, training, and placing large numbers of women and minorities in aerospace career fields has had a dramatic residual effect on civilian industries. When aviation maintenance technicians currently working in the industry were asked where they received their training, military training and experience constituted the greatest source of career preparation for Blacks, Hispanics, and women (see **Tables 4.1** and **4.2** and **Figure 4.3** and **4.4**).

Table 4.1 Aircraft Mechanics and Technicians Career Preparation by Gender

Population	Military	FAA 147	Work Exp	Other	N
Females (Aggregate)	6 30%	5 25%	5 25%	4 20%	20
Males (Aggregate)	73 37%	92 46%	23 12%	10 5%	198

Table 4.2 Aircraft Mechanics and Technicians Career Preparation by Race

Population	Military	FAA 147	Work Exp	Other	N
Asian	2 17%	8 67%	1 8%	1 8%	12
Black	12 46%	9 35%	5 19%	0	26
Hispanic	6 67%	1 11%	1 11%	1 11%	9
Caucasian	57 35%	76 47%	19 12%	11 6%	163

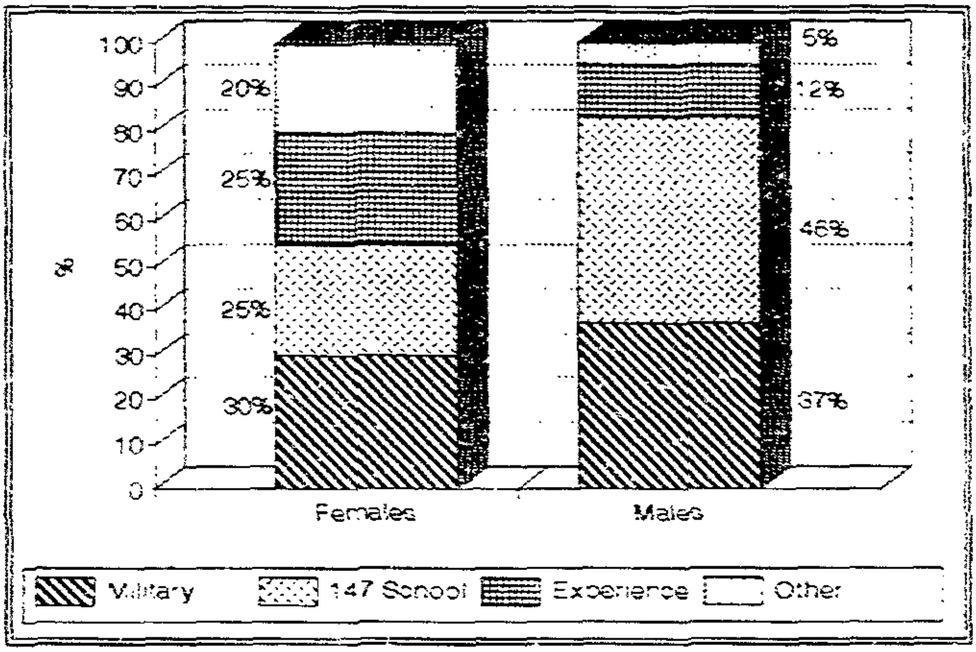

Figure 4.3 Career Preparation by Gender

The military has a long history of successful outreach programs. Active recruitment in high schools, technical schools, and colleges has been a mainstay for diversity in today's military. Youth activities such as the Civil Air Patrol, Young Astronauts Program, Star Base, and Boy and Girl Scout groups have been a keystone for diversity recruitment efforts. The military has also played an important role in supporting aerospace education efforts at numerous grade levels throughout the country. College tuition programs have also proven instrumental in drawing minority populations into military aerospace fields.

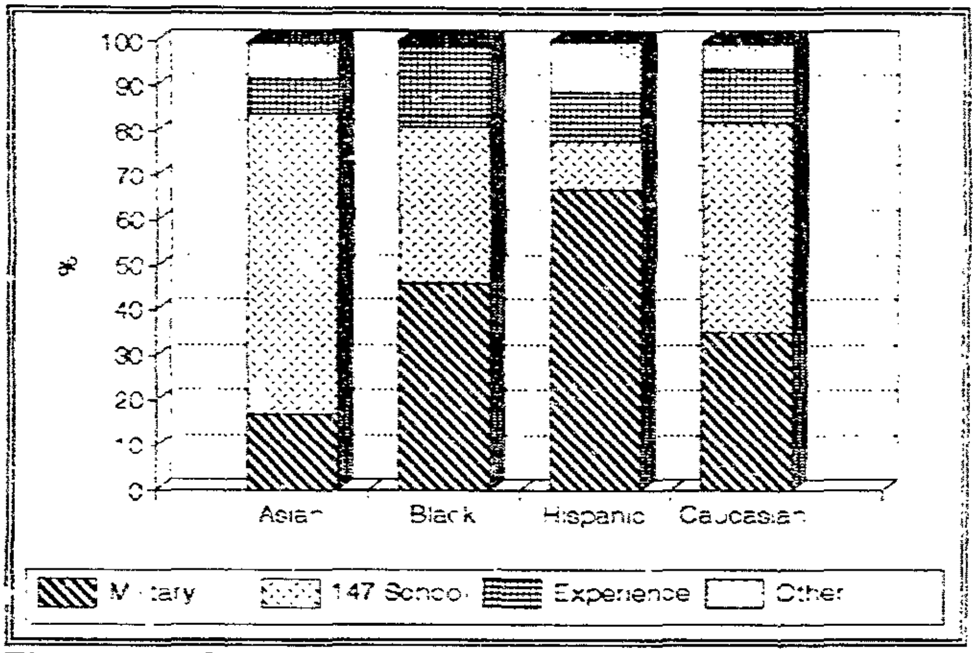

Figure 4.4 Career Preparation by Race

In an effort to provide for an all-volunteer military, all branches of the armed services have engaged in aggressive recruitment and advertising programs. To a large extent, armed services' advertising projects an unbiased and gender- and race-fair image of aerospace professionals. Their extensive use of race and gender role models in advertising fosters larger participation by under represented populations.

The movement toward greater world peace and the demise of the Soviet Union has precipitated a feeling among many that the military in many areas has become obsolete. Increasing concerns over the national deficit will most assuredly result in dramatic reductions in the defense budget These reductions in military spending promise to limit, if not curtail, many of the beneficial spin-offs reaped by civilian aerospace industries. Reduced budgets will most likely result in diminished support of educational and youth activities. The predicted reduction in technical staffing in the military will result in fewer trained minority aviation professionals for articulation into civilian careers. Most importantly, the military's aggressive gender- and race-fair advertising of aerospace careers will most likely be reduced dramatically.

In light of the fact that working aviation maintenance technicians indicate that the largest percentage of women and minority workers received their career interest and training through the military, the reduction of military spending and the downsizing of our military forces will most assuredly affect the representation of nontraditional workers in aviation technical careers. According to the working AMTs questioned in this study, 27% of the female, 46% of the Black, and 75% of the Hispanic maintenance professionals now employed in civil aviation industries were trained in the military. In each case, this number represents the largest contributor to the representation of each population. As the military loses its much needed influence, it is incumbent upon the civil aviation industry and schools to renew their efforts to recruit and retain women and minorities in aviation professions.

4.4.1.2 Other Government Agency Efforts

Several other governmental agencies have promoted aerospace career and education outreach programs as a part of their activities. Prominent among these agencies are the FAA and the National Aeronautics and Space Administration (NASA). Both agencies have devoted significant resources to developing educational material and programs, as well as sponsoring educational grants and projects. Many of these efforts have proven quite successful.

The FAA has developed a wide variety of aviation career education materials. The most significant are documents which discuss various aviation career opportunities, the education and training necessary to qualify for each career, and the need for such professionals in today's aerospace industry. The care and effort expended to make these documents race- and gender-fair has resulted in career brochures which, for the most part, are not only fair but project an atmosphere which encourages women and minorities.

The FAA has also developed an extensive array of education materials, videos, and programs which promote aviation and aviation careers. Much of this material is designed to be integrated into educational environments as supplemental materials for normal educational activities from elementary to high school and college. In an effort to distribute these materials, each FAA region has an aviation education specialist who serves as a contact point for individuals seeking assistance with aviation education materials. In addition, the FAA has established a network of aviation education resource centers. Teachers and other individuals interested in obtaining educational materials or assistance in materials or program preparation can utilize the centers' vast array of materials. The FAA also promotes programs such as aviation art contests, Aviation and Space Education Conferences, and state, regional, and national awards for aviation educators.

While the FAA has expended considerable effort and resources in preparing and distributing aviation educational materials and in developing educational programs and awards, these efforts have not attained their maximum effectiveness for several reasons. First, regional aviation education specialists are normally collateral duty assignments. These individuals perform educational activities in addition to other duties. Often, their other responsibilities take precedence over educational matters, resulting in reduced effectiveness. Most prominent among the reasons that the FAA programs have not realized their potential is a lack of continuity and follow-through. Frequent changes in administration result in shifting focuses and changes in programmatic emphasis, as well as wide fluctuations in funding for such programs.

The FAA Administrator's Award for Aviation Education Excellence is a prime example of an exemplary concept developed by the FAA which has fallen by the wayside. For two years, the FAA awarded state, regional, and national "Excellence in Aviation Education" awards to individuals who had made significant contributions to aviation education. This award caused a great deal of excitement among educators and aerospace education proponents, resulting in many individuals' renewed efforts to develop and promote aviation education projects. Unfortunately, just as the award was realizing significant results, the awards were discontinued.

NASA has committed significant funds, personnel, and facility space to developing, producing, storing, and disseminating public educational materials. Unfortunately, NASA's narrow focus on math and science subject material has limited the materials' effectiveness at generating greater awareness for aerospace career opportunities among nontraditional populations. This intense focus is also reflected in their educational grant programs. National Space Grant Consortium programs are generally aimed at high school and college math and science students who have already demonstrated an interest in and an aptitude for these subjects.

4.4.1.3 Aviation Industry Out-Reach

Due to the declining aviation industry economy, industry-sponsored programs have been scarce over the past troubled decade. In times past, major aviation and aerospace companies expended considerable effort and resources in promoting aviation education and career awareness. Beech, Cessna, and Piper aircraft companies each had very active aviation education programs several decades ago, producing many types of career and general education materials promoting aviation concepts. As aviation suffered from its rapid decline in the late 1970's, one of the first areas to receive significant cuts were the aviation education programs. As a result, much of this material is unavailable at the present time.

Currently, Beech Aircraft is the only manufacturer distributing aviation educational material. The Aircraft Electronics Association recently formed an Education Foundation to help promote aviation education. The General Aviation Manufacturers Association prepares and distributes material in behalf of aircraft manufacturers. One of the most significant efforts to be fronted by the aviation industry in recent years is the renewed efforts by the Experimental Aircraft Association and the Aircraft Owners and Pilots Association. The Young Eagles program, for example, is a breath of fresh air in an otherwise mostly stagnant aviation education environment.

4.4.1.4 Aerospace Education Out-Reach

As has been noted, governmental agencies and aviation industry corporations and organizations have and continue to produce quality aerospace educational materials for infusion in regular class subjects. Recent research, however, demonstrated that most educators are not aware of this material and are not using it in their educational activities (Eiff et al., 1986). Despite efforts by these agencies and the establishment of networks of resource centers, the material is just not getting to most educators.

In an effort to help alleviate this problem, aerospace educators have initiated a series of outreach programs to make educators aware of the abundant material available to them for aviation and space education and to provide aviation and space examples for regular class. Numerous packaged aviation and space programs, such as "Come Fly With Me," "Back to Basics Through Aviation," and "Fantastic Flight," have been developed in a "teacher-ready" format for use in public school classrooms. Teacher education classes have been offered throughout the nation in order to provide encouragement and guidance to teachers wishing to utilize aviation materials in their classrooms. Most of these programs have been highly successful.

4.4.1.5 Early Aerospace Education

Research literature suggests that most individuals make generalized career decisions by the time they leave elementary school. Therefore, one of the best long-term strategies for encouraging young people to consider aerospace careers is to use aviation and space examples in learning activities starting in kindergarten and continuing through all elementary grades. Iris Harris promoted this concept in the "Fantastic Flight" program developed in Alabama and subsequently promoted by the FAA.

A similar concept started in Illinois, known as the "Harvard Park School" project, has demonstrated that it can not only enhance the learning of regular subject material but also stimulate and motivate both teachers and students. The program includes a teacher education class that provides teachers with "instruction-ready" material and explores innovative instructional methodologies. A central element of the teacher education program is an in-depth exploration and demonstration of how aviation materials meet state mandated goals for learning and produce increased learning and student motivation.

The adoption of the concept in a school-wide program offered an invaluable opportunity to measure the concept's effectiveness. A post-unit evaluation of the program showed significant increases in student motivation and learning. An unforeseen benefit was the reported motivation of teachers who used the material. Additional benefits of the program included increased parental participation in learning activities and measurable increases in community, industrial, and school administrative support and involvement. In its fourth year, school officials report that the program is still producing measurable gains in motivation and learning. More importantly with regards to this study, students have demonstrated a pronounced increase in their understanding of the aviation industry and aviation careers.

4.4.1.6 Lack of Visible Role Models

The literature strongly identifies the need for like-race and like-gender role models in encouraging nontraditional populations to select under represented career opportunities. Aviation advertisement and literature significantly lacks these types of role models.

Researchers reviewed aviation advertising in trade journals, popular publications, on travel posters, in career placement advertisements, and on television. The vast majority of the material projected strongly traditional role models. Notable exceptions included military advertisements and FAA public service announcements. Unfortunately, the beneficial impact of these exceptions was dramatically reduced by the fact that military advertisement is becoming less prevalent and that FAA public service announcements are often played during broadcast periods when few impressionable young people are watching.

The importance of a significant other or role model is evidenced by the fact that almost 90% of the women maintenance professionals interviewed for this study had a family member or close friend active in aviation. Most minorities also identified same-race individuals in aviation as influential in their selection of an aviation career. While numerous informal race/gender role model strategies have been used to encourage nontraditional workers to enter under represented careers, little has been done to formalize role modeling or networking activities with one notable exception.

In 1990, Dr. Peggy Baty held the first of what has become an annual conference for women in aviation careers. The National Women in Aviation Conference has been held each year since 1990 and has enjoyed a dramatic increase in participation every year. The conference is a highly effective means of promoting female aviation role models and providing a network for women pursuing aviation careers. As such, it represents a vehicle which could prove very beneficial at encouraging women to enter nontraditional aviation careers.

4.4.1.7 Changing Aviation Environment

Dramatic changes in the aviation environment over the past several decades have contributed significantly to limiting the visibility of aerospace careers and access to information concerning career preparation. Much of the difficulty currently experienced in encouraging young people to consider aviation careers is directly attributable to barriers resulting from changes in the aviation environment. The reduction in the per capita pilot population, declining numbers of airports, reduced access to airport facilities and workers, increased cost of career preparation, and increased exposure and sensitivity to liability issues are among the most notable barriers delimiting the recruitment of new aviation workers from diverse populations.

Discussions with numerous aerospace workers who have been working in aviation careers for more than 10 years revealed that many became interested in aviation careers through early exposure to aircraft or aviation enthusiasts at local airports. Many said that as youth they frequently visited local airports and freely wandered about the facilities. This open accessibility allowed them to meet and interact with many aviation professionals and hobbyists with varied backgrounds and interests. Such encounters provided these individuals with much of the information necessary to stimulate their aerospace career interests and provide the necessary background information to chart the path of aviation career preparation.

For many aviation professionals, their spark of aviation interest was kindled by observing activities at local airports. Stories of walking ramp areas or airport hangars and talking to pilots or mechanics were common among these professionals. Many related how they were allowed to help "rib stitch" wings, wash and wax airplanes, or participate in other aviation activities. Today, young people have little opportunity to participate in such learning activities since airport security provisions have virtually "locked-out" all unauthorized individuals from airport facilities. Gone are the opportunities for young people with an aviation interest to visit airport facilities and cultivate their own aviation contacts. This "lock-out" has progressed to such a level that at most airports individuals with a sincere desire to observe airport operations are kept at such a distance that meaningful observation is impossible. Airport observation decks and areas have, for the most part, disappeared. Most individuals who attempt to gain access to airports for individual or group observation of aviation operation and career activities reported receiving "hostile" receptions and "extreme negativism" from airport managers and facilities operators.

The initiation to aviation for many aviation enthusiasts and professionals often involved a chance encounter with an individual or a relationship with a friend who is a pilot. Such relationships often result in "first flight" opportunities and significant exposure to aviation operations, careers, and airport environments. Recent Experimental Aircraft Association (EAA) statistics suggest that the opportunity for such encounters may be declining. The shrinking fleet of general aviation aircraft coupled with the reduced population density of pilots will inexorably mean fewer opportunities for individuals to be introduced to aviation in this traditional fashion. According to a recent EAA publication, in 1953, there was one pilot for every 262 people in the United States. Today, there are now fewer than one pilot for every 371 individuals. When this trend is viewed within the context of the drastically reduced access to airport facilities precipitated by the airport security "lock-out," the few individuals fortunate enough to have such encounters or acquaintances will most likely not be from the diverse populations targeted by this study. Probability would imply that aviation mentors would most likely be white males and access would be limited to traditional populations. The result is a perpetuation of the same populations in aviation professions

Compounding the effects of reduced access to existing airports and the dwindling numbers of pilots is the dramatic reduction in the number of local airports and small aviation business operations. Severe shifts in aviation commerce over the past few decades have resulted in the disappearance of many smaller airports and operations. For example, the Chicago area boasted 52 airports immediately following the Second World War. By the mid-eighties, only 26 of those airports remained in operation. The economics of aviation commerce at many smaller airports make it impossible to support maintenance and flight operations. In Illinois alone, more than 40 of the 135 airports throughout the state have no operator on the field. Illinois is not alone in this dramatic reduction of airport operations. A review of aviation business statistics indicates that the number of airports and aviation businesses throughout the country are significantly lower than those of two decades ago. As the cost of maintaining and operating aircraft increases exponentially and the number of general aviation aircraft and pilots dwindles, small aviation operations are finding it increasingly more difficult to remain in business.

Another factor limiting access to airport facilities, aviation professionals, and opportunities for flight experiences is the increased concern about liability. Discussions with individuals and organizations which attempt to provide aviation education and career experiences for young people, teachers, and potential aviation professionals indicate a pronounced reluctance on the part of aviation industries, organizations, professionals, and hobbyists to provide such experiences. When approached to provide tours or opportunities to meet and observe aviation professionals in their work environment, many aviation businesses cite liability concerns as precluding their participation. Many youth, teacher education, and aviation education groups try to provide opportunities for program participants to fly in general aviation aircraft as a learning experience. Providing an opportunity to participate in a flight experience was once relatively easy to arrange. Most groups now report, however, that national organizational restrictions or concerns by potential pilots over liability issues make such opportunities nearly impossible to arrange.

Another factor which limits the consideration of aviation careers by prospective professionals is the rapidly rising costs of career preparation. Most notable among aviation career costs are those for flight career preparation. It is not uncommon for individuals to spend upwards of $20,000 to obtain the necessary flight ratings to obtain the minimum qualifications necessary to begin a professional flight career. Even individuals aspiring to aviation maintenance professions find career training and tool costs a formidable barrier to career consideration. Since many minority populations come from economically disadvantaged backgrounds, these career preparation costs may severely limit the involvement of these target populations. In fact, tool and career training costs were identified by both males and females of all populations as a barrier to aviation career selection in this study.

4.4.2 Technical School Bias

Central to the research study was an evaluation of the preparedness of aviation maintenance and technical programs to foster the recruitment, retention, and placement of women and minorities in aviation maintenance professions. Also of concern was the ability of technical programs to promote a learning environment where bias and discrimination against members of these populations was minimized.

4.4.2.1 Recruitment and Retention

Several previous research studies have indicated an imperative for informational and recruitment strategies in order to encourage more women and minorities to pursue aviation careers (Eiff et al., 1986; Rodriguez, 1986; Eiff, 1991). FAA certified mechanics schools were questioned in an effort to determine their level of involvement in recruitment and retention efforts. As show in **Figure 4.5**, only about one-third (34.6%) of the schools questioned had recruitment programs of any type. Of the schools with recruitment programs, the vast majority (65.4%) of the programs consisted of a broad- based strategy aimed at encouraging both women and minorities to pursue aviation maintenance careers. Approximately a quarter

(26.9%) of the schools with recruitment programs had strategies structured primarily for recruiting women. Only 7.7% of the programs were exclusively aimed at minority populations other than women.

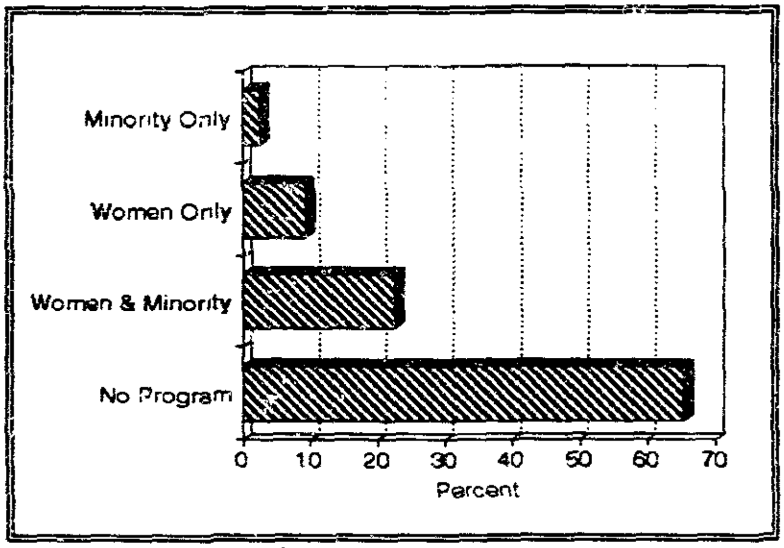

Figure 4.5 Schools with Recruitment Programs (by type of program)

A principle concern of the research team was that many FAA certified Mechanic Schools may present a hostile learning environment for female and/or minority students. Attitudinal concerns include perceptions of school administrators and faculty concerning the potential success of minority and female students. Environmental concerns centered around possible race- and gender-bias of textbooks, instructional bias, institutional barriers, discriminatory materials and language, and the generalized lack of support to remediate skill, tool familiarity, and knowledge requisite expectations.

School officials and faculty were questioned to determine their perception of the likelihood for successful completion of aviation technical training programs by women and minority students. Seventy-six (76) FAA Part 147 certified Mechanic Schools were questioned to determine the representation of women and minorities in their student population (**Figure 4.6**). Results indicated that minority students represented 24.9% of the aggregate student body, while women constituted only 3.4% of the total number of students enrolled in aviation maintenance career preparation.

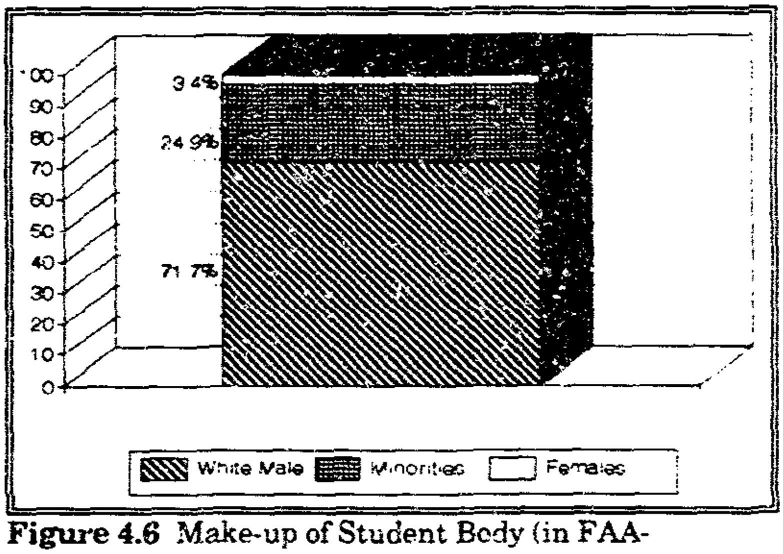

Figure 4.6 Make-up of Student Body (in FAA-approved mechanic schools)

When asked to predict the average success rate for their women and minority students, school officials and faculty in these programs reported widely different completion rates. As an aggregate, the schools felt that women and minority students were about equally likely to succeed in maintenance training programs. On the average, they felt that 77.3% of the minority students would complete their training. Women were thought to be successful 78.6% of the time.

These same schools were asked to report the number of students who graduated from their schools in 1992 and to project the number of 1993 graduates. Of the 5,783 students graduated from these schools in 1992, 570 (9.9%) were minority students and 200 (3.4%) were female students. The predicted number of students to graduate in 1993 was 5,394. Of these, 667 (12.4%) were minority students and 454 (8.4%) were women. On close examination, these figures constitute a paradox. While school officials and faculty predict that women and minority students possess an equal probability of success from their programs, in actuality, this equality is not evident in completion rates.

If the reported population representations are compared with the 1992 graduation statistics, we note some interesting relationships. In the case of minority students, only 40% of the students graduated. Women, on the other hand, graduated in the same proportion as their representation in the population. Predictions for the 1993 graduation of these populations suggest that school officials predict that women and minorities will have twice the representation in the graduating class as they did during the previous year.

While these statistics could be attributable to specific class representation anomalies, they could also indicate subtle bias on the part of school officials and faculty at aviation technical schools. The 1992 graduation statistics and predicted success for women in 1993 suggests that perhaps women are more successful than these school representatives perceive. This could indicate a subliminal belief by school officials and faculty that women will not be successful in aviation maintenance careers and training. A similar evaluation of the statistics for minority populations suggests that perhaps these same officials are overly optimistic about their success rate.

It is interesting to note that some of the schools studied predicted completion rates as low as 20% for female students. The lowest predicted completion rate for other minority students was only 33%. In 20.7% of the reporting schools, the same school reported that the success rate for females was much lower than for minorities. In several cases, the difference between completion rates for the two populations was predicted to be as great as 50% and 70%. On the average, these schools indicated that women were 28% less likely to complete the program than their minority male peers. These predictions do not seem to be supported by the graduation statistics. This difference may indicate bias against female students participating in these particular training programs because school officials and faculty believe that women are not successful in aviation maintenance training.

With the perception that women and minorities are less successful than white male students in aviation maintenance training programs, one would think that the schools would establish strong programs designed to promote retention of these populations. To identify the level of support offered by certified mechanic schools for female and minority students, reporting schools were asked if they had special retention programs for students. Only one-third of the schools had any retention program at all. Of those schools with programs, 72% were generic programs designed for all populations including, both female and minority students (see **Figure 4.7**). Of the reported retention programs 22% were structured to address the specific needs of minority populations. Only 16% of the schools with programs (5% of the reporting school aggregate) had special retention programs designed especially for female students' needs. Thus, the researchers conclude that little is being done to meet the specific retention needs of women and minority students in aviation maintenance training.

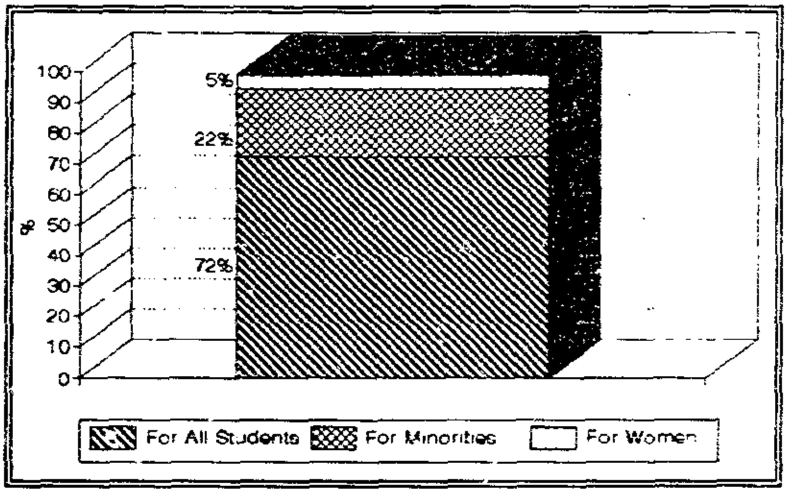

Figure 4.7 Type of Student Retention Programs (for those schools which have programs)

4.4.2.2 Learning Environment

School site visitations by researchers identified what appeared to be a genuine interest by school officials and most faculty in providing a bias- and discrimination-free environment for female and minority learners. However, while many of the most blatant and overt forms of bias and discrimination were not evident in the vast majority of schools visited, the researchers identified many subliminal and covert barriers to learning.

A review of the most popular aviation maintenance textbooks demonstrated that little has been done to project a race- or gender-fair image of aviation maintenance professionals. Pictures almost always depict white male maintenance professionals. Even line drawings and "stick people" project a male persona. Much of the textbook material reflects material used in older military manuals. Little has been done by current authors and publishers to remove the strong male engenderment of this material.

The proliferation of male attributes throughout aviation literature, communications, and terminology has a dramatic impact on women aspiring to aviation careers. These terms are so entrenched in the aviation environment that it becomes difficult, if not impossible, to communicate without being bombarded by gender specific terms, including the use of gender-specific terminology by governmental agencies. Most significant among these influences is the gender specific terminology used in the Federal Aviation Regulations (FARs). Terms such as "repairman" project to women aspiring to these positions that they are outsiders, anomalies, or aberrations. The FAA is slowly rectifying these deficiencies which will have a lasting effect on improving the equity in the AMT industry. We applaud these efforts.

Historically, aviation environments have been inundated with pictures, posters, calendars, and cartoons with ethnic, racial, and sexual overtones. This discriminatory and harassing material was offensive and detrimental to members of these populations who worked in such environments. The diversification of the aviation work force coupled with the enactment of legislation and fear of litigation has precipitated the general elimination of much of this material. Researchers engaged in school site visitations were especially vigilant in seeking materials which might be offensive to minority and female students. While material which might be perceived as demeaning or offensive to minority populations was not evident in any school visited, many had sexually suggestive or degrading materials. Most of these materials were tool or parts suppliers' advertising posters or calendars. While these materials were not nearly as suggestive or offensive as material common throughout the environment a decade ago, the message was still very clear.

Some specific examples include the following. A postcard with a woman sun bathing topless was taped to the wall above the desk of the faculty member responsible for the development and retention programs for female students in an aviation maintenance technology program. Another school's flight maintenance department had two posters mounted in the work area which depicted women clad in small bikini swimwear holding the advertiser's tools. At another school, a toolbox sported the large poster for an aircraft parts distributor which showed a woman "mechanic" in front of what appears to be her toolbox holding a wrench. This could have been a positive image of a woman aviation professional except that the woman was wearing a small bikini nightgown. Such portrayal of women undermines the perception of women as maintenance professionals and reinforces their perception as sexual objects. Objectionable material leaves many women wondering if they will be respected and accepted should they select aviation maintenance careers. Each of these examples depicts a demeaning attitude toward females in aviation maintenance and is likely to have a negative effect on self perception and esteem of female students.

Researchers were also cognizant of institutional barriers impeding the success of minorities and women in maintenance career preparation. The facilities of most visited schools were not adequate for female students. Inequality of facilities, especially the lack of adequate restroom facilities, was evident at all of the schools. Many schools were trying to cope with their changing student populations, but their attempts have, in most cases, fallen short.

For example, one of the schools visited has been training aircraft mechanics for over 25 years and is a well-respected technical program associated with a major university. An evaluation of the building's restroom facilities for students found that the main "men's" restroom had 2 showers, 35 lockers for students to store a change of clothes or tools in, 15 urinals and stalls, and 5 sinks with heavy-duty, mechanic's hand cleaner dispensers. The women's restroom had one stall, one sink, and no lockers, shower, or hand cleaner dispensers. These differences send the message that women are not expected to be at this school as aircraft maintenance personnel who use tools or get dirty hands.

4.4.2.3 Classroom Interactions

During site visitation, researchers observed classroom and laboratory instructional sessions whenever possible. The researchers sought to evaluate the content and presentation methodology for biases, discrimination, or disparity in learning activities for affected populations. While the researchers found little in the form of open discrimination or bias, a strong subliminal bias and disparity of educational treatment was noted for both minority and women students.

Aviation educators may not realize that despite their best intentions, not all students are receiving equal instruction in their classrooms. There is considerable research supporting the contention that teachers may unconsciously display behavior limiting the nontraditional students. This may be even more likely to occur where the instructor has generally worked with traditional (white male) students. When this trained cultural influence colors teacher attitudes toward students, then teacher expectation begins to mold student behavior to fit the expectation (Sadker & Sadker, 1982).

Gender bias manifests itself in unintentional differential treatment of students based on teacher expectation. It is important to note that differences in teacher interactions toward students based on their gender was found by the Klein (1985) study to occur in both male and female teachers, regardless of their race, at all levels of education from kindergarten through college instruction. Site visits indicated a strong, verbalized support from teachers to the researchers for the minority and female student, but closer observation proved that the these students received little teacher attention. They were often found working alone, not interacting with the teacher or other students. According to a recent report from the American Association of University Women (AAUW, 1992), researchers report that females receive significantly less attention from classroom teachers than do males, and African American females have fewer interactions with teachers than do white females. Teachers also were reported to call on male students in class eight times as often as on female students. And, according to Sadker (1986), when the males talk, teachers listen. Clearly, at visited sites, the males were doing the talking both with the teacher and with each other.

The kinds of tasks and groupings teachers assigned are often based on stereotyped notions about appropriate female and male behavior. Therefore, males are asked to perform more strenuous or mechanical tasks while females are asked to do simpler tasks involving cleaning up or note taking. A study of science classes found that when teachers needed assistance in carrying out a demonstration, 79% of the demonstrations were carried out by male students (Tobin & Garnett, 1987). Similarly, at visited sites, the researchers noted that the male students appeared to be completing teacher-requested tasks during open lab times. The female students, on the other hand, appeared to be relegated to observation, note taking, or clean-up chores and not included in the maintenance-related laboratory tasks under consideration.

A possible cause for disparity of educational treatment among white, minority, and female students may be a generalized lack of awareness on the part of the instructional staff that such differences are occurring. This could be due, in part, to the fact that few of the instructors in aviation maintenance training programs have formal training in the educational process. Unfamiliarity with the precepts of educational psychology and instructional methodologies may leave well-intentioned instructors with the feeling that they are treating all students equally while, in fact, they are discriminating against some populations.

Few of the schools examined require their instructors to be well-versed in the foundations of the learning process. In fact, 36% of the schools reported that they had no requirement for faculty to have any formal education or degree at all (**Figure 4.8**). A few schools (6%) required a local or state vocational teaching certificate but no college education. About a quarter of the schools (26%) required prospective instructors to have an Associate Degree in any discipline. An additional 25% of the schools indicated that they require a Bachelors Degree. Only 7% of the schools require a Masters Degree. In each case, the degree could be in any discipline. None of the schools reported that they required training beyond a Masters Degree or that the degrees earned must be in an educational discipline.

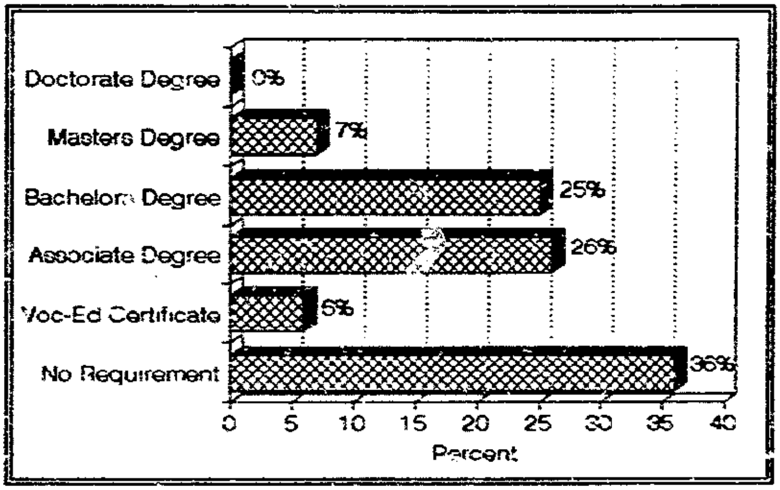

Figure 4.8 Formal Education Requirements for Instructional Staff at A&P Schools

The research team was also interested in the level of representation of minorities and women on school faculty. Research in related nontraditional career fields suggests that gender and race "role models" are very important for recruiting and retaining nontraditional students. The schools in this study were asked how many of their A&P certified faculty were women and minorities. The schools employed a total of 759 A&P certified instructors. As shown in **Figure 4.9**, 66 were minorities (8.6%) and 14 were

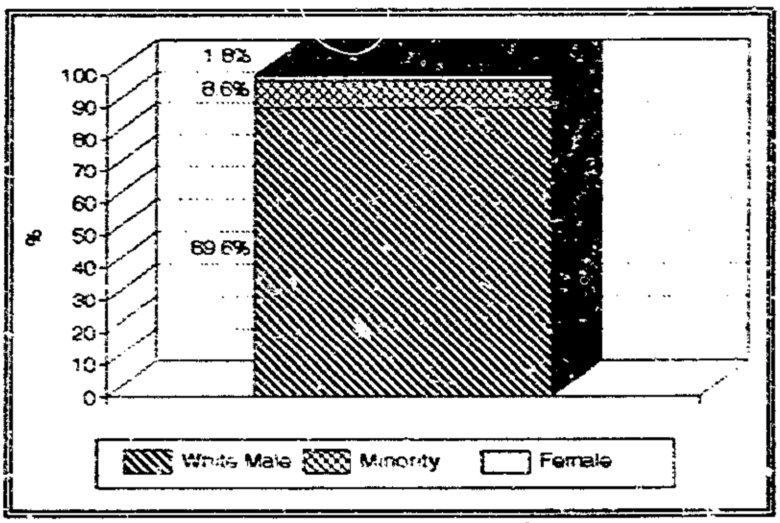

Figure 4.9 Composition of A&P Faculty (at FAA approved mechanic schools)

females (1.8%). Close examination of the data revealed that female faculty had been on the job for an average of only 3.8 years. Obviously, recruitment of women for faculty positions is a relatively new concept. In fact, of the 14 female faculty reported to be on the instructional staff of these schools, 12 had been on the job for 5 years or less.

The research literature strongly suggests that role models among the faculty of nontraditional programs greatly enhances both the recruitment and the retention of under represented students in such programs (Eliason, 1981). For this reason, schools should recruit as many minorities and women into faculty positions as possible. As a facet of the research project, 214 active aviation mechanics working in aviation maintenance fields were questioned to explore the availability of women with the educational and work experience requirements necessary to qualify as instructional faculty in maintenance training programs. Of the female mechanics who responded to the study, 68.8% responded that their highest level of educational preparation was a high school certificate. An additional 25% of the female respondents indicated that they had attained a college Associate Degree. Only 6.3% of the working female mechanics and supervisors indicated that they had achieved a Bachelors Degree in a college program. None of the respondents indicated education beyond a Bachelors Degree.

The limited educational backgrounds of working minority and female mechanics has the potential to severely limit their qualification to serve as faculty in many schools. When schools were asked if they were willing to "waive or defer" some educational requirements for otherwise qualified female or minority faculty candidates, 22.7% of the schools reported that they would consider such a waiver or deferment.

Although the literature indicated that faculty and minority role models increased nontraditional students' recruitment and retention, the question remained as to whether or not this would be true of aviation maintenance nontraditional students. The representation of minorities in aviation maintenance training programs seemed little affected by the presence of minority faculty. The average number of minority students in aviation maintenance training for all of the schools sampled was 39.4 students per school. For schools with minority instructors, the average number of students was 39.8 per school. This lack of correlation among student representation and the presence of an instructor role model did not hold true for females, however. For the schools sampled in this study, the presence of a female instructor seemed to have a dramatic effect on the participation rates of female students. Viewing the aggregate school sample, the average number of female students participating in aviation maintenance career preparation was 5.4 females per school. When compared to the average number of female students in schools with female faculty, the contrast was dramatic. Schools with female faculty averaged 13 female students per school, more than twice the average for schools with no female faculty. Though not conclusive, these figures strongly suggest that the presence of female faculty increases participation by women interested in pursuing an aviation maintenance career.

Work place role models are also very beneficial in encouraging nontraditional students to pursue under- represented careers. Many schools have promoted or established close working relationships with industry which may include work experience or cooperative education opportunities for students. The schools were asked if their students had an opportunity to participate in work experience or cooperative education programs as a part of their educational experience. About one third (34%) of the schools reported that students in their programs have opportunities to participate in work experience or cooperative education programs with aviation industries. Of those schools reporting such opportunities, only 19% reported making any attempt to place the students in a work environment with appropriate race and gender role models. As a result, few nontraditional students have the opportunity to experience same-race or same- gender mentors as they prepare for their chosen career

Finally, national research on educational environments has reported that incidents of males sexually harassing females in schools are increasing at a high rate. One study by Kane and Frazee (1989) found that 65 percent of female high school students in nontraditional courses reported harassment by male classmates and by some teachers. Researchers found no evidence of sexual harassment during site visits. However, candid discussions with female graduates of aviation maintenance programs disclosed several instances of peer and instructor harassment. It is important to remember that despite its frequency, sexual harassment is rarely reported, tallied, investigated, or systematically documented (AAUW Report, 1992).

4.4.3 Work Place Barriers

Key to retaining women and minorities in the aviation maintenance work place is determining what barriers might deter these populations from completing training or remaining in an aviation career. A survey instrument was developed and distributed by a U.S. air carrier and the International Association of Machinists; the research team provided assistance in analyzing the results of the survey. The focus of the instrument was to determine the perceptions of AMTs concerning various possible barriers to successful employment as aircraft technicians.

The barriers were categorized as economic, physical, social, emotional, life experience/education, and work-related. Respondents were asked to describe the degree to which the items listed in each category were perceived to be a barrier for women and minorities seeking training or employment as AMTs. Barriers were assigned a value of 5 for "a high degree;" 4, "some degree;" 3, "undecided;" 2, "a small degree;" and 1, "not to any degree." In all, 65 barriers were listed for evaluation with a space for optional comments. The barriers were selected based on their identification by other researchers conducting studies with nontraditional workers (*No way out*, 1989; Cho, 1983; Stitt & Stitt, 1990; Deaux et al., 1984).

A total of 242 aircraft maintenance employees responded to the survey. Analyses of the data were done by race and by sex. Some of the respondents did not complete all parts of the survey; therefore, there were missing data in the analyses.

Of the total sample, listed in alphabetical order there were 13 (5.4%) Asian, 27 (11.2%) Black, 165 (68.2%) Caucasian, 10 (4.1%) Hispanic, 11 (4.5%) Other. Sixteen (6.6%) did not identify their race. Of the total sample, 20 (8.3%) respondents identified themselves as Female, 216 (89.3%) as Male, and 6 (2.5%) did not identify their gender. The majority of the respondents were male Caucasians. Females constituted less than 10 percent of the total sample. Although the majority of respondents were Caucasian males, their responses were important because they were asked for **their perceptions of possible barriers to women and minorities pursuing AMT training or employment**. This permitted comparison of what Caucasian males perceive to be barriers with what women and minorities perceive as barriers.

The factors used as dependent variables in the analyses were Economic Barriers, Physical Barriers, Social Barriers, Emotional Barriers, Life Experience/Education Barriers, and Work-Related Barriers. Race and sex were the only independent variables analyzed.

Table 4.3 and **Figure 4.10** show the average responses by race for each of the six categories of barriers. The higher the score, the more often employees of that race identified the items in that category as significant barriers to training or employment as aircraft maintenance employees.

Table 4.3 Average Response for Each Barrier Category by Race

Category	Asian	Black	Caucasian	Hispanic	Other
Economic	2.60	2.51	2.51	3.06	2.27
Physical	2.08	1.82	2.18	2.42	2.07
Social	1.87	2.50	2.03	2.37	2.06
Emotional	1.89	2.36	2.19	2.46	2.28
Life Exp./ Education	1.65	2.45	2.40	2.77	2.11
Work-Related	2.31	2.89	2.80	3.24	2.44

It is important to note that respondents were asked to identify items that are possible barriers to minorities. Therefore, the Caucasian responses were reports of their perception of barriers for minorities, not for themselves. The Hispanic race scores were the highest in each category of barrier items. These respondents indicated that they perceive barriers in every category except Social more frequently than Asian, Black, or Caucasian races. The categories with the highest scores by the Black respondents were Economic, Social, and Work-Related Barriers. The Black race response to Social Barriers was the only score higher than the Hispanic race response. The category with the highest score by the Asian respondents was Economic Barriers. Black, Caucasian and Hispanic respondents saw Life Experience/Education Barriers more frequently than Asian respondents.

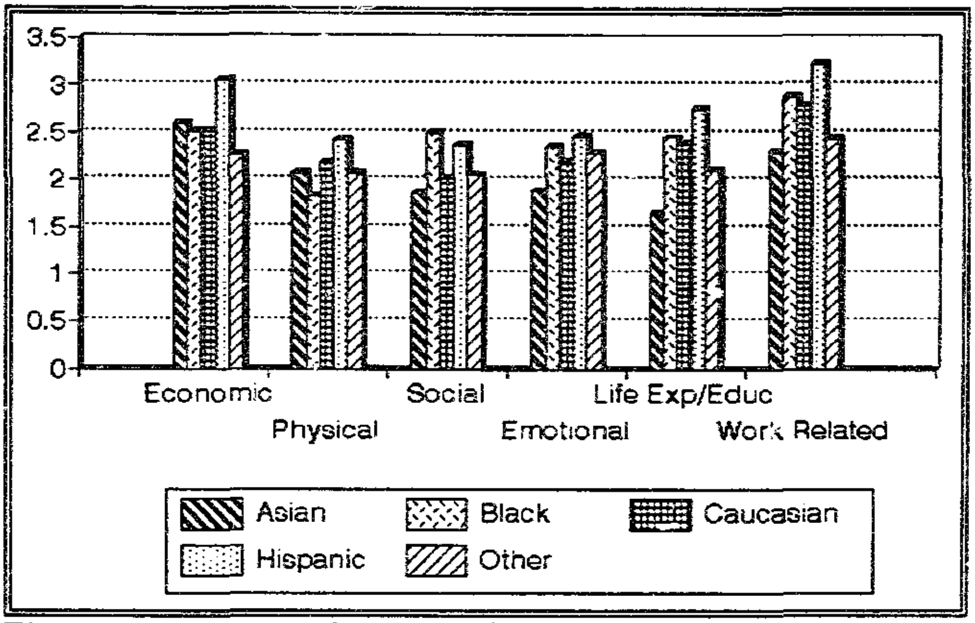

Figure 4.10 Response for Barrier Categories by Respondent's Race

Similarly, **Table 4.4** and **Figure 4.11** give the response among male and female aircraft maintenance employees on the six categories of barriers. The scores displayed in the table indicates by category the frequency that items in that category were perceived as significant barriers.

Table 4.4 Average Response for Each Category by Gender

Category	Females	Males
Economic	2.40	2.50
Physical	1.90	2.15
Social	2.40	2.07
Emotional	2.20	2.18
Life Experience/ Education	2.50	2.35
Work- Related	2.28	2.70

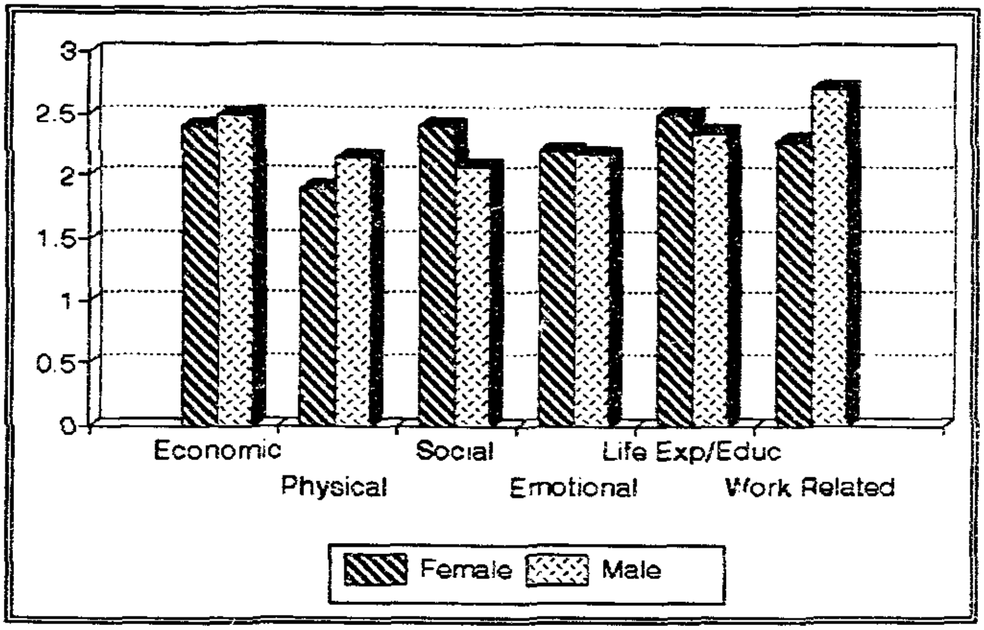

Figure 4.11 Response for Barrier Categories by Respondent's Gender

Work-Related Barriers were identified with the highest frequency by males as possible barriers to females. This category also had the greatest difference in frequency between male and female respondents. In other words, females disagree with males more frequently concerning this barrier. Economic Barriers were frequently identified by both males and females. Equally significant by females were Social Barriers and Life Experience/Education Barriers. Physical Barriers were identified by females least frequently.

Analysis of Variance (ANOVA) were carried out to determine if there were differences by race and gender on the various factors (Economic Barriers, Physical Barriers, Social Barriers, Emotional Barriers, Life Experience/Education Barriers and Work Related Barriers). The results of the analysis showed significant differences by both race and gender at the .05 level of significance. However, there was only one category of barriers identified as significant for race and one category for gender. The Life Experience/ Education category was identified as significantly different (.02) by race. In other words, there were significantly different responses among races in their perceptions of Life Experience/Education Barriers for females pursuing an AMT career. This category of barriers included the following items among others:

Know nontraditional employees
Concern about level of verbal and writing skills
Concern about level of math and technical skills
Familiarity with tools
Solid level of self-confidence
Time and stress management skills.

Work-Related Barriers was the only category identified as significantly different (.02) by gender. Female respondents differed in their perceptions of work-related barriers from male respondents. This indicates that males perceive more barriers than females did for females pursuing AMT careers. This category of barriers included the following items among others:

Concern about getting a job
Concern about keeping a job
Concern about moving up on the job
Travel requirements
Concern about working outside in inclement weather
Dislike for late shift work schedule.

The level of significance was set at an Alpha of .10 for the remainder of the analysis. An Alpha of .10 (rather than .05) is commonly preferred when there is no control group in the study. It should be noted that at a significance level of .05 there were only minimal differences by gender and race.

The results of the analyses showed that there were differences among the races on Social Barriers, Life Experience/Education Barriers and Work Related Barriers. **Table 4.5** shows the average response among the different races to the individual items in the Social Barriers category.

Table 4.5 Individual Item Response of Social Barriers by Race

	Caucasian	Black	Hispanic	Asian	Other
Communicating with peers of the opposite sex or other race or culture.	2.1	2.3	2.5	1.5	2.5
Cooperating with peers of the same sex, race or culture.	1.9	2.0	2.1	1.7	1.8
Being the only person of your race or sex in a work team.	2.0	2.6	2.3	1.5	1.8
Hazing or being teased by peers.	1.9	2.1	1.6	1.5	2.4
Availability to socialize with peers and feeling accepted socially by peers.	2.0	2.4	2.5	2.0	1.7
Being accepted by and feeling a part of the work team.	2.3	3.0	2.9	2.2	1.7
Sex or race discrimination in training or on the job.	2.1	3.3	2.7	2.7	2.5

The barrier items listed in **Table 4.5** were significant in the ANOVA analysis. The specific Social Barrier items that received the most frequent identification as possible barriers to training or employment were:

Being the only person of your race or sex in a work team
Being accepted by and feeling a part of the work team
Sex or race discrimination in training or on the job.

The Black and Hispanic races reported the highest number of responses in these items. The Asian race responded with a high frequency (2.7) on only the item involving discrimination.

Table 4.6 shows the average response to individual items in the Life Experience/Education Barriers category.

Table 4.6 Individual Item Response of Life Experience/Education Barriers by Race

	Caucasian	Black	Hispanic	Asian	Other
Know people who are in nontraditional jobs.	1.9	2.3	3.3	1.7	1.8
Concern about level of verbal and writing skills.	2.4	2.4	2.4	1.9	2.0
Concern about level of math and technical skills.	2.6	2.5	2.8	1.8	2.3
Familiarity with tools.	2.5	2.4	2.9	1.5	2.2
Solid level of self-confidence.	2.6	2.3	3.1	2.0	2.0
Played with kids of opposite sex as a child.	1.7	2.1	2.0	1.2	1.4
Familiarity with the aircraft maintenance occupation.	2.6	2.6	3.3	1.5	2.0
Time and stress management skills.	2.5	2.7	3.4	1.8	2.8
Physical health.	2.8	2.3	3.2	1.7	2.7
Personal contacts (important contacts in the field).	2.4	2.8	2.7	1.7	2.5
Knowledge of job openings and fringe benefits.	2.9	2.9	3.0	2.0	2.4
Family or friends employed in aviation industry.	2.1	2.2	2.2	1.4	1.6
Jobs in aircraft maintenance require a good understanding of math and science.	2.9	2.7	2.6	1.8	2.5
Had a same-sex or same-race role model.	1.8	2.4	2.1	1.4	1.6

There was agreement among the Caucasian, Black, and Hispanic respondents that knowledge of job openings and fringe benefits was perceived as a possible barrier to minorities. The frequency of response was consistent (2.9, 2.9, 3.0). Asian respondents did not identify that item with as much frequency (2.0). Both Black and Hispanic respondents identified personal contacts as a possible barrier with scores of 2.8 and 2.7. However, there were no other items where there was agreement among the respondents by race as to the level of significance of a barrier item. The most obvious information to draw from this table is the high number of items that were identified as possible barriers by Hispanic respondents. These items were:

Know people who are in nontraditional jobs **(3.3)**
Concern about level of math and technical skills **(2.8)**
Familiarity with tools **(2.9)**
Solid level of self-confidence **(3.1)**
Familiarity with the aircraft maintenance occupation **(3.3)**
Time and stress management skills **(3.4)**
Physical health **(3.2)**
Personal contacts (important contacts in the field) **(2.7)**
Knowledge of job openings and fringe benefits **(3.0)**.

Table 4.7 shows the average response to individual items in the category Work Related Barriers.

Table 4.7 Individual Item Response of Work-Related Barriers by Race

Category Item	Caucasian	Black	Hispanic	Asian	Other
Concern about getting a job.	3.4	2.7	3.8	2.5	2.6
Concern about keeping a job.	3.5	2.5	3.9	2.1	3.4
Concern about moving up on the job.	2.9	3.3	3.4	2.6	2.5
Travel requirements.	2.4	2.3	3.0	2.3	2.1
Concern about effort required to succeed in a nontraditional career.	2.3	2.3	3.1	2.3	2.4
Concern that most new labor force entrants will be nontraditional.	2.3	2.1	3.1	1.7	2.3
Concern about working outside or in a hangar or in inclement weather.	2.4	2.7	2.9	1.9	2.0
Dislike for late shift work.	3.3	3.0	2.7	3.0	3.3

The Asian respondents identified the items less frequently than any other race including Caucasian. There was general agreement among the races as to a dislike for late shift work schedules and its potential as a possible barrier. Again, the noticeable information is the high level of frequency by the Hispanic respondents to many of the items. Those items were:

Concern about getting a job (**3.8**)
Concern about keeping a job (**3.9**)
Concern about moving up on the job (**3.4**)
Travel Requirements (**3.0**)
Concern about more effort required to succeed in a nontraditional career (**3.1**)
Concern that most new labor force entrants will be nontraditional (**3.1**)

The results of the ANOVA indicated that there were significant differences among the sexes on Work Related Barriers only. **Table 4.8** gives the average responses by sex to the individual items in the category Work Related Barriers.

Table 4.8 Individual Item response of Work Related Barriers by Sex

	Female	Male
Concern about getting a job.	2.6	3.3
Concern about keeping a job.	2.6	3.3
Concern about moving up on the job.	2.6	2.9
Travel requirements.	2.6	2.9
Concern about more effort required to succeed in a nontraditional career.	2.5	2.3
Concern that most new labor force entrants will be nontraditional.	1.7	2.3
Concern about working outside or in a hangar or in inclement weather.	2.1	2.5
Dislike of late shift work schedule.	2.7	3.3

Males and females in this study did not agree on the significance of Work-Related Barriers for females and minorities. In fact, males identified every Work-Related Barrier item as more likely to be a barrier than did females with the exception of one item: Concern about more effort required to succeed in a nontraditional career.

It is important to note that males were not responding to items they found to be barriers for themselves. Rather, they were identifying items they thought to be barriers for females. In other words, males find these items to be barriers for females, but females say they are not barriers. The only item agreed upon as a barrier was concern about more effort required to succeed in a nontraditional career.

There were some items that crossed several barrier categories which women consistently identified as possible barriers that were not identified by men. These items are also consistently identified by females in other nontraditional careers as barriers. Those items are listed below:

> Expense of child care **(2.85)**
> Communicating with peers of the opposite sex **(2.55)**
> Being the only one like me on the work team **(2.80)**
> Sex and/or race discrimination **(2.90)**
> Need to prove self **(3.0)**
> Biased language, jokes, pictures **(2.35)**
> Concern about being accepted by management **(2.50)**
> Stress/time management **(3.05)**
> Personal contacts in the field **(3.15)**
> Knowledge of job openings and fringe benefits **(3.30)**.

With the exception of the figures reported in these tables, aviation maintenance personnel do not differ significantly in how they perceive barriers to the training and employment of women and minorities as aviation maintenance technicians. However, the barrier categories and items that were reported in the tables provide information that can be helpful in removing these barriers.

The aviation maintenance industry in its determination to more evenly balance the work force by race and gender has endeavored to seek out possible barriers to training and employment for women and minorities. This study has shown that while women and minorities perceive some barriers, there exists no long list of barriers. Certainly, barriers alone are not enough to be the total cause of the disparity in the numbers of women and minorities in the AMT work place.

Hispanic and Black races perceived the greatest number of barriers to employment and training. Hispanics perceived barriers in all categories, and Blacks perceived Work-Related Barriers most significant for their race. There is also general agreement by Caucasians that these barriers may exist for these specified populations. Asians perceive few barriers as compared to the other races; however, Economic Barriers were most often identified as possible barriers for this population.

Females identified Life Experience/Education Barriers most often as the most problematic category of barriers. Men identified Work-Related Barriers most often as barriers for females in aviation. It is important to note that contrary to stereotypical perceptions, women do not perceive Physical Barriers as frequently as any of the other barrier categories.

The results of the ANOVA indicated there were significant differences among the races on Social Barriers, Life Experience/Education Barriers, and Work-Related Barriers. Blacks and Hispanics identified the most Social Barriers. Hispanics identified the most items in the Work-Related category. The results of the ANOVA indicated significant differences by sex on Work-Related Barriers only. In general, males perceive nearly all Work-Related Barrier items as possible barriers for females.

Of course, the aviation industry cannot be held responsible for all the barriers perceived to be significant for women and minorities. Our society as a whole must bear some of the burden for the Social Barriers perceived by women and minorities. Our families and educational systems must assume responsibility for the entrenchment of many of the Life Experience/Education Barriers.

The aviation industry is to be applauded for the steps it has already taken to encourage social and educational change to eliminate many of these barriers. It is also to be encouraged and supported in its continuing efforts to look into the possibility of reducing the remaining Work-Related Barriers.

Some specific recommendations for reducing barriers for women and minorities include:

1. Conduct workshops or training seminars for all employees in team building, communication skills, time and stress management, and sexual harassment issues - particularly language, jokes, pictures, and discrimination.

2. Provide a more accessible or directed method for informing employees about in-house job openings and fringe benefits.

3. Conduct workshops or training seminars in job-seeking and job-keeping skill development.

4. Alert employees that there may be differences in perceptions about barriers and encourage open discussion of solutions to possible barriers.

5. Provide all supervisory personnel with the findings of this study and provide the avenue for them to participate fully in workshops and training seminars on the above topics.

The aviation industry is recognized for its determination to eliminate any remaining barriers to increase the representation of women and minorities in aviation careers.

4.5 CHANGES IN REPRESENTATION

While parity of representation has not been established in most career fields, significant gains in the representation of women and minorities in many under represented aviation careers have been realized (Eiff et al., 1986). Most under represented minority populations have made dramatic gains in numbers from those of a decade ago. While no historical data exist on the levels of representation of minority populations, it is generally agreed that few members of these populations were included in the aviation maintenance work force as recently as two decades ago. By contrast, the FAA has compiled data on the representation of women in the maintenance field for several decades.

Although no official data exist, either historic or current, on the representation of minorities in the aviation work place, it is generally agreed that their numbers were very low two decades ago, but the level of representation for all minority populations has grown appreciably during the intervening years. While it is difficult to determine the exact representation of these populations in the current work place, the current study gives evidence that significant changes have occurred and that representation levels are dramatically improved. As nearly as can be determined, the current work force of aviation maintenance professionals in airline careers is comprised of approximately 11% Hispanic, 12% Asian, and 20% Black workers.

The representation of women, on the other hand, remains quite low. Current estimates place their representation at approximately 2% of airline maintenance professionals. As mentioned before, historic data are available for women mechanics. Although current research indicates that women have made dramatic strides toward equal representation in aviation career fields such as air traffic control and as flight crew professionals, the number of women in aviation maintenance technical fields has demonstrated little propensity for change and remains very low.

A decade of proactive effort by the aviation industry, governmental agencies, and special interest groups has resulted in increasing representation of women in many male-monopolized aviation careers. Aviation maintenance, however, remains the slowest career field in aviation to realize any trend toward greater representation. The most current available FAA statistics suggest that the representation of women among the ranks of certified mechanics remains very low. Current estimates place the number of active female aircraft mechanics at 3,901. While this is a dramatic increase over the number of active female mechanics of a decade ago, this number represents only just over 1% of the number of active mechanics (airlines and general aviation, combined) in the work force.

While the actual number of women in aviation maintenance careers remains quite low, there is reason for optimism about the future of women in this male-dominated field. A complex model for predicting the number of maintenance professionals needed in the years ahead was formulated for the demographic aspects of this study. As a result of this model, the anticipated levels for women could be predicted for the next several years. The model's prediction for the representation of women in aviation maintenance careers in **Figure 4.12** is represented by the line extending to the year 2003. Statistical data from FAA records for the three most current years strongly suggest a marked deviation from the predicted levels of representation.

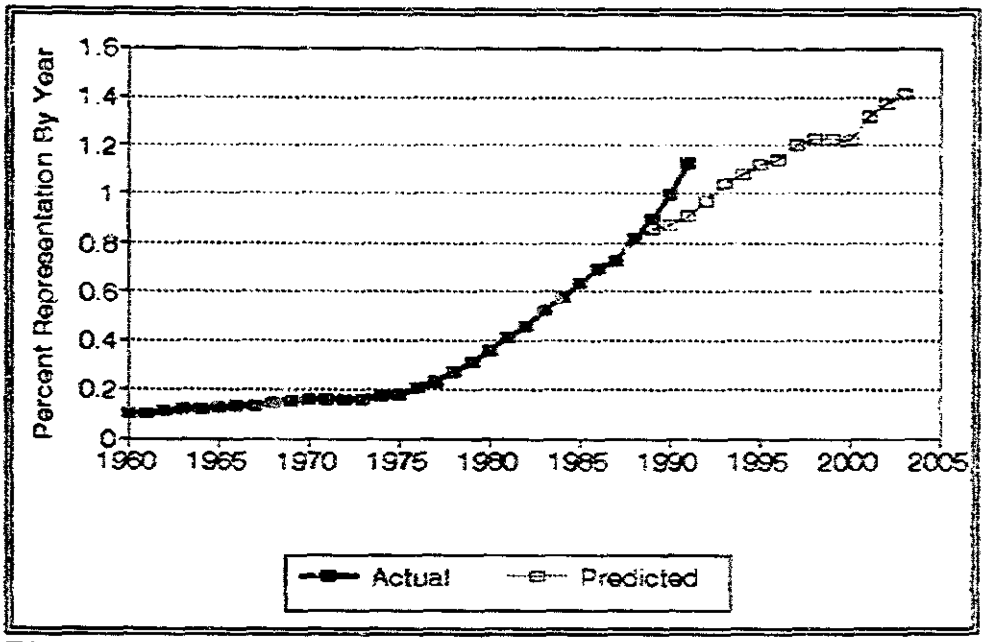

Figure 4.12 Percent Representation of Active Female Aircraft Mechanics

When viewed from a "rate-of-change" in representation prospective (**Figure 4.13**), the change in the level of representation of women in maintenance careers seems on the verge of dramatic growth. As suggested by the demographic model and as realized in actual data, the change in the representation of women in maintenance careers was relatively constant for the years between 1960 and 1975. From 1975 to 1988, an increase in the rate of change in this representation was noted. Instead of the predicted steady growth, this period demonstrated a yearly increase in the rate of change in representation of women mechanics in the work force. In the period from 1988 to that of the most current available data, there has been a very sharp increase in the rate at which women are selecting aviation careers. Thus, the data for the representation of women in aviation maintenance careers suggest that we may be on the verge of dramatic increase in the number of women in aviation maintenance career fields.

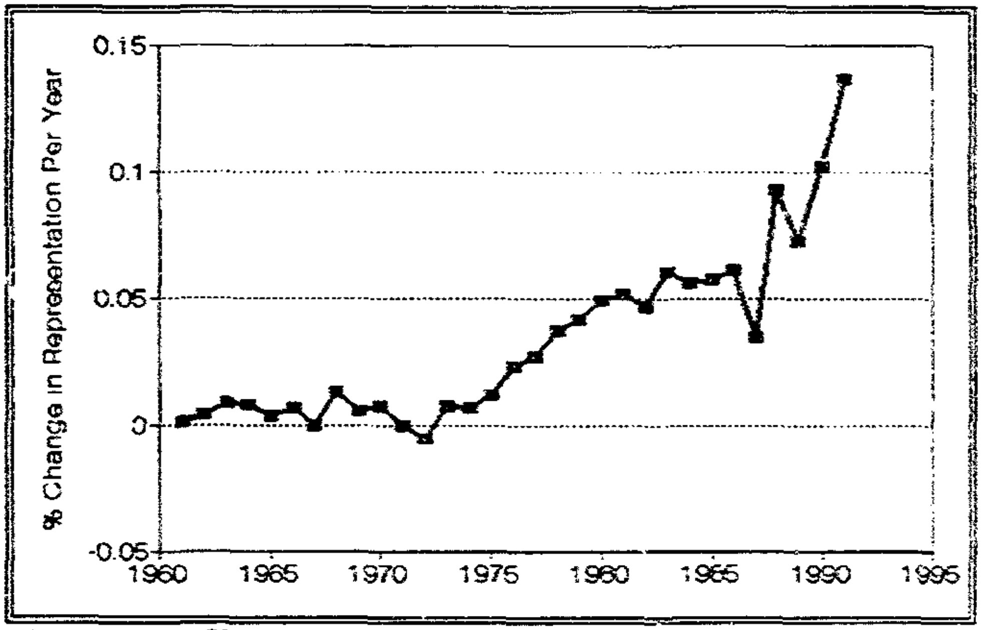

Figure 4.13 Change in Percent Representation of Active Female Aircraft Mechanics

4.6 SUMMARY

The aviation maintenance professional will continue to be a valuable asset to air safety well into the 21st century. Modern aircraft promise to bring greater reliability and maintainability to the aviation industry; yet, the complexity of these craft will bring new challenges to AMTs. The aviation industry must take a proactive approach if it expects to employ a competent work force which will meet equal opportunity standards while simultaneously maintaining the productivity of aviation maintenance technicians. Through the efforts of many individuals, learning institutions, and corporations, diversity in the AMT work force has begun to emerge. Current legislation helps to promote these efforts; however, much is yet to be done if true equity for both gender and race is to be accomplished. Improving diversity in the AMT work force and the relations between genders and the various races currently employed as AMTs will build a strong foundation for improved maintenance and future air safety.

The data collected in this study suggests that over the past several decades minorities have made dramatic progress in aspiring to AMT careers. Females, however, are still extremely under represented in the aviation maintenance industry. According to one major US air carrier, females currently make up approximately two percent of their AMT work force and minorities constitute approximately 26 percent. The lack of female role models, inadequate physical facilities at AMT schools, subliminal bias by teachers counselors and supervisors, and a general lack of career awareness comprise major barriers to females entering an AMT career.

This study points out that today's youth are for the most part unaware of the exciting well paid careers which exist in the aviation maintenance industry. With the liability and security problems of today's aviation environment it is very unlikely that young people will have a chance to explore a career in civil aviation. The changing military environment will assuredly supply less publicity and training aimed toward aviation. These factors leave a void which must be filled and enhanced if we hope to have a plentiful, diverse supply of competent AMTs in the future. Industry, AMT schools, and governmental agencies must join together to promote aviation in a gender and race fair manner.

Currently many programs exist which are helping to improve the diversity of the aviation maintenance industry. These programs must be amplified and used in conjunction with gender- and race-fair role models to help reach under represented populations. **Table 4.9** shows several strategies which can be used to help eliminate the barriers which limit the employment of nontraditional populations in AMT careers. The data collected in this study suggests that women must be a primary focus group if significant change is to occur. There are two simple strategies which continue to emerge as primary methods to achieve equity: (1) *promotion of aviation maintenance as an exciting and rewarding career*, and (2) *improving* the image of the aviation maintenance professional. These strategies focused at the youth of America and enhanced for minorities and females will ensure a plentiful supply and diverse work force needed to meet the future challenges of the aviation maintenance industry.

Table 4.9 Strategies to Help Eliminate Barriers

IDENTIFIED BARRIERS		STRATEGY TO ELIMINATE BARRIERS
Recruitment (career selection)	• Lack of information concerning AMT careers • Lack of adequate role models	• Increase gender/race fair outreach programs • Better promotion of AMT careers by major air carriers • Increase awareness of AMT careers to elementary and high school students
Educational	• Recruitment • Retention • Learning environment	• Increase the number of female and minority AMT instructors • Promote gender/race fair educational practices for faculty and staff • Improve AMT school facilities to be more gender fair • Improve texts and other educational materials to be more gender/race fair • Increase and improve female and minority recruitment
Work place	• Economic • Emotional • Environmental	• Improve grant/loan programs to help disadvantaged individuals with cost of education and tool purchases • Increase and improve worker and administration awareness programs to promote gender/race fair interactions • Improve facilities to be more gender fair

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CHAPTER FOUR - APPENDIX

Projections of Future Need of Aviation Maintenance Technicians (AMTs) in Civilian Aviation

Introduction

This section of the report re-examines the results of the 1991 FAA Blue Ribbon Panel (BRP) report on Aviation Maintenance Technician (AMT) Shortages prepared as a working paper (WP). The 1991 paper produced projections of pilot and AMT work force needs in Civilian Aviation for the 1991-2003 time period were produced. This section of the report addresses only the projections of AMT future work force needs. A re-examination of civilian commercial pilot work force projections is beyond the scope of this project.

The re-examination of future AMT work force needs was called for in response to questions from aviation officials, union leaders, and others about the large shortages in AMTs projected in the 1991 working paper. The 1991 working paper states "numerous sources predict that there will be a need for 100,000-120,000 AMTs by the year 2000. This number is based on the current number of technicians combined with new positions related to new aircraft and increased attention to continuing airworthiness of older aircraft." The 1991 report projects the shortage of AMTs to be between 65,000 and 85,000 new AMTs by the year 2000. Many felt that the shortfalls were too large; others, that the projected shortfalls were too conservative.

The shortages projected were accompanied by supporting information and arguments that seemed to provide a rationale for the expected large shortfalls. In the report, the projected decline of the population in the 16-24 and 25-34 age groups by the year 2000, a declining pool of potential AMTs coming from the military, a low retention rate of AMTs in the aviation industry (only 45% of AMT school graduates remaining in aviation after 2 years), and other reasons are offered to explain why the supply of AMTs is not expected to keep up with demand. All of these reasons and rationales focus on the supply of AMT work force into the aviation industry. However, the BRP report does not offer specific yearly projections of AMT work force supply to accompany their detailed yearly projections of AMT work force demand. As a result, the precise yearly projected shortages remain unclear.

This study examines the working paper's projection of AMT work force need. The projections are recalculated using much of the original study's methodology but with some variation where the assumptions of the original projections have been questioned. This study also offers yearly projections of work force supply using data that was not used in the BRP study. This study projects supply by using FAA data on estimated active AMTs reported in the *FAA Statistical Yearbooks*. The yearly projections of AMT work force supply and demand can be compared to produce projected yearly shortages or surpluses.

Projection of AMT Demand

The projection of AMT demand by civilian aviation in this study follows the general assumptions and definitions used in the BRP study, with several exceptions. These exceptions are pointed out in the following discourse on how the working paper's projection methodology compares with this study's methodology. Using the definition of AMTs from page 6 of the working paper, an AMT in this study is defined as "any person who works to maintain an aircraft, aerospace vehicle, or component thereof in an airworthy condition." Thus, an AMT performs daily maintenance work to keep the civilian airfleet flying efficiently and safely. AMTs perform tasks from line maintenance to airframe modification.

WP Projections of AMT Demand

In the WP report, the projection of AMT demand revolves on several fundamental assumptions and pieces of information. Future AMT demand was argued to be closely tied to changes in the civilian airfleet, i.e. as the number of aircraft of various types increases or decreases, demand for AMTs would be affected. Projections of the number of aircraft in three areas of civilian aviation (large jet-commercial, commuter and general aviation) were taken from the FAA Aviation Forecasts report (Feb. 1992) which covered the years 1992-2003. The methodology for these projections is reported in the 1992 FAA report. The WP study combined estimates of the number of aircraft with assumptions concerning how many AMTs are necessary to service each class of aircraft project of how many AMTs are needed to service the airfleet in any one year. The large jet-commercial class of aircraft (which is composed of commercial 2, 3, and 4 engine narrow body and wide body turbojets) was assumed to require an average of 14 AMTs per aircraft for maintenance. The commuter class (which includes 2 and 4 engine turboprop; 2, 3, and 4 engine piston; and rotary wing turbine aircraft) was assumed to require an average of 4.2 AMTs per aircraft for maintenance. General aviation aircraft (which includes 1 engine, 2 engine, and other piston; 2 engine and other turboprops; piston and turbine rotary wing; 2 engine and other turbojet; and all other aircraft) was assumed to require an average of .15 AMTs per aircraft for maintenance. Multiplying the number of aircraft projected by the number of AMTs needed for maintenance per aircraft produces yearly projections of the number of AMTs needed to maintain the entire fleet.

A fourth category of AMTs was also included in the WP study's projection of AMT need. In the WP projection table, the category "Other" was included. The "Other" category included AMTs employed outside of aviation maintenance, but within aviation. The other category included AMTs employed in manufacturing, at repair stations, and as federal technicians. In 1988, the base year, it was deduced that about 43,000 AMTs were employed in the "Other" category. The WP report assumes a 2% yearly growth in "Other" AMT employment.

Of course, the AMT workforce is subject to attrition due to a variety of causes, including retirement, death, transfers, and leaving aviation employment. In the WP report, a 7 percent attrition rate was assumed for large jet, 20 percent for commuter, and 10 percent for general aviation AMTs. As jobs become available in large jet and commuter aviation, a number of transfers between the classes of aviation were anticipated. It was assumed that 60% of commuter attrition and 20% of general aviation and "Other" attrition were transfers to large jet aviation. It also assumed that 10% of general aviation and "Other" attrition were transfers to commuter aviation.

A rough estimate of the number of net vacant positions in each class of civilian aviation is calculated by subtracting the number of transfers into the type of aviation from the vacancies created due to attrition. For example, in the WP report, there were 2538 large jets in 1980 which yielded 35,532 jobs (2538 X 14). Attrition, which was 7% for the year, yielded 2487 vacant positions (35532 X .07). There were 1912 transfers into large jet maintenance from other aviation employment. Thus, after taking transfers into account, there were 575 (2487 - 1912) net vacant positions in large jet maintenance in 1980.

The WP report's procedure yielded projections of total AMT jobs in aviation maintenance for each year, as well as estimates of the total of net vacant positions in each year. The reader is directed to the WP report for a detailed summary of the findings.

Projection of AMT Demand in This Study

As stated earlier, the projection of AMT demand in this study follows the WP study's methodology, with some exceptions. One change is that this study does not use FAA projections of the number of aircraft reported in the February 1992 *FAA Aviation Forecasts* document. This study employs a different projection methodology than that used in the *FAA Aviation Forecast*. This was done to provide an independent confirmation of the projections of aircraft numbers. This is important since projected AMT demand relies directly on the aircraft projections.

The projection of the number of each type and class of aircraft uses FAA data on yearly estimates of each type of aircraft. In the *FAA Statistical Yearbooks*, estimates of the number of 2, 3, and 4 engine turbojets; 1, 2, 3, and 4 engine piston; 2 and 4 engine turboprops, and piston and turbine rotary wing aircraft are available for each year back to 1958. Using the 1958-1989 time series of data for each aircraft type, projections were made through the year 2003 using the Box-Jenkins time series analysis technique. This procedure examined a variety of long-term time series models to identify which particular time series model best fits the 1958-1989 data. It then used the model that best fits the data to produce the projections through 2003. Of course, a different time series model may fit each time series of data. For example, as will be seen in the analyses, some aircraft types show systematic increases and some show decreases across time. For other aircraft types, the change is cyclical, e.g., increase, decrease, then increase.

The results of the time series analyses of FAA aircraft estimates are reported in **Tables 4A-1** through **4A-3**. **Table 4A-1** gives estimates and projections for large jets. Estimates and projections for commuter aircraft are given in **Table 4A-2**. **Table 4A-3** gives estimates and projections of general aviation aircraft. These tables all give estimates for 1980 to 2003. The numbers of aircraft for the years 1980-1989 are estimates derived from the best fitting Box-Jenkins time series model while the numbers of aircraft for the years 1990-2003 are projections based on the best-fitting models. Again, it is important to emphasize that these numbers were generated by time series models which analyzed FAA data on aircraft numbers of each aircraft type from 1958-1989 to establish long-term trends in the increase or decrease of each aircraft type. These estimates and projections of aircraft numbers serve as the basis for projecting AMT demand.

Table 4A-1 *Estimated and Projected Number of Commercial, Large Jet Aircraft*[1]

	4-engine	3-engine	2-engine	Total Large Jet
80	437	1358	751	2538
81	397	1386	847	2630
82	364	1414	939	2717
83	346	1434	1061	2841
84	338	1451	1204	2993
85	337	1481	1362	3180
86	360	1485	1538	3383
87	376	1484	1715	3575
88	389	1490	1864	3743
89	412	1500	2005	3917
90	427	1495	2110	4032
91	437	1505	2295	4237
92	452	1510	2342	4304
93	462	1515	2359	4336
94	467	1521	2511	4499
95	471	1529	2597	4597
96	472	1537	2772	4781
97	475	1552	2933	4960
98	481	1562	3149	5192
99	484	1574	3311	5366
00	48.	1582	3429	5494
01	489	1597	3579	5665
02	492	1609	3716	5817
03	496	1622	3812	5930

[1]Projections and estimates based on FAA estimates taken from the *FAA Statistical Yearbooks*.

Table 4A-2 Estimated and Projected Number of Commuter Aircraft[1]

	Piston			Turbo-Prop		Rotary Wing	Total
	4-eng	3-eng	2-eng	4-eng	2-eng	Turbine	Commercial
1980	58	0	419	93	521	3	1094
1981	62	0	513	99	641	4	1319
1982	60	0	491	104	71.	5	1373
1983	53	0	497	107	788	7	1423
1984	44	2	436	106	880	7	1475
1985	42	4	410	103	966	6	1531
1986	39	4	374	102	1068	8	1595
1987	36	3	359	99	1174	9	1680
1988	38	3	341	97	1271	7	1757
1989	35	3	328	98	1315	8	1787
1990	36	5	303	96	1367	8	1815
1991	36	4	298	94	1439	7	1878
1992	34	4	289	96	1493	7	1923
1993	30	5	281	97	1544	8	1965
1994	29	5	273	98	1619	8	2032
1995	27	4	267	99	1689	9	2095
1996	23	4	261	101	1741	9	2139
1997	21	3	259	102	1773	9	2167
1998	20	3	254	103	1797	11	2188
1999	17	3	251	105	1827	11	2214
2000	17	3	247	107	1867	12	2253
2001	15	2	243	109	1897	12	2278
2002	13	2	231	108	0929	11	2294
2003	11	2	227	107	1964	11	2322

[1]Projections and estimates based on FAA estimates taken from *FAA Statistical Yearbooks*

Table 4A-3 Estimated and Projected Number of General Aviation Aircraft[1]

Year	Piston			Turbo-Prop		Rotary Wing			TurboJet		Total General Aviation
	1 engine	2 engine	Other	2 engine	Other	Piston	Turbine	Other	2 engine	Other	
1980	166310	24481	183	4016	111	2881	3182	4805	2618	331	208918
1981	167029	34873	167	4464	129	2825	3484	5184	2855	365	211375
1982	167735	24954	174	4894	145	2788	3268	5485	3179	439	213061
1983	166925	24813	161	5749	154	2804	3834	5749	3452	457	213498
1984	167701	24486	168	5400	164	2739	3894	6141	3697	496	214886
1985	169073	24171	163	5404	177	2817	3848	6451	3816	500	216420
1986	168776	23729	154	5354	189	2826	3813	6638	3890	450	215819
1987	167991	23101	121	5232	194	2758	3771	6763	3894	415	214240
1988	168514	22778	114	5183	200	2683	3853	6900	3881	373	214479
1989	167959	22201	105	5062	200	2675	3868	6894	3914	367	213245
1990	168142	21340	101	5049	198	2657	3899	6928	3926	361	212601
1991	168146	21229	100	5051	199	2671	3902	6992	3961	359	212610
1992	167563	21119	101	5047	193	2673	3911	7003	3970	358	211938
1993	167762	21097	99	5092	191	2677	3921	7009	3972	354	212174
1994	167928	21073	97	5089	189	2682	3943	7031	3968	352	212352
1995	168820	21069	98	5083	187	2677	3957	7052	3974	350	213267
1996	169527	21053	95	5081	183	2673	2964	7077	3978	348	213979
1997	170328	21047	97	5073	184	2669	3982	7091	3991	346	214808
1998	171572	21039	98	5069	181	2652	4001	7099	4001	344	216056
1999	172503	21021	99	5081	173	2637	4027	8123	4122	341	218127
2000	173609	21038	101	5079	177	2621	4052	8177	4157	329	219340
2001	174834	21042	100	5083	179	2611	4073	8197	4269	320	220708
2002	176221	21057	94	5129	193	2579	4138	8371	4412	311	222505
2003	177816	21059	79	5147	195	2538	4297	8419	4502	304	224366

[1]Projections and estimates are based on FAA estimates reported in the FAA Statistical Yearbooks

Two things are worth noting about the estimates and projections in **Tables 4A-1** through **4A-3**. First, when one considers the projections for each of the three classes of aircraft, the projections of this study do not substantially differ from the *FAA Forecasts*. This can be seen by comparing the numbers in **Tables 4A-1** through **4A-3** with Tables 15, 20, and 21 in Chapter X of the *FAA Aviation Forecasts* (1992-2003) document. Second, there are substantial differences in the two sets of forecasts for some particular types of aircraft. For example, the projections of this study forecast more 3 engine turbojets and fewer 2 engine turbojets than does the FAA study. These particular differences in estimates and projections may be important in other contexts. However, since only the projections and estimates for three broad classes of aircraft are used to project AMT demand, the differences in the projections for particular types of aircraft are relatively unimportant in the overall context of this study.

A second major departure from the WP study's methodology is that assumptions concerning the number of AMTs necessary to maintain each class of aircraft are re-assessed in light of comments and criticism from a variety of sources in civilian aviation. Most thought that the assumptions of 14 AMTs per large jet, 4.2 AMTs per commuter aircraft, and .15 AMTs per general aviation aircraft were unrealistically high. The sources' estimates ranged from a high-end which reflected the WP assumptions to a low-end which was about half the level the WP assumed.

In response to these questions, varying assumptions concerning the number of AMTs needed per class of aircraft were employed to estimate and project AMT demand in civilian aviation One set of projections was made using the assumptions of the WP report, i.e. 14 AMTs per large jet, 4.2 per commuter, and .15 per general aviation aircraft. Two additional sets of projections were generated. The first assumed 10.5 per large jet, 3.15 per commuter and .1125 per general aviation. The second assumed 7 per large jet, 2.1 per commuter, and .075 per general aviation aircraft. These three sets of projections and estimates are presented in **Tables 4A-4** through **4A-6**. Each table presents projections based on a different set of assumptions concerning the number of AMTs needed per aircraft for maintenance.

The projections in **Tables 4A-4** through **4A-6** employ the WP study's assumptions concerning attrition and transfer rates, as well as the size and growth of the "Other" category. The "Other" category -- AMTs employed outside of aviation maintenance -- includes AMTs employed in manufacturing, at repair stations, and as federal technicians. The WP's assumptions in these areas are recognized to be somewhat arbitrary; but, in the absence of better or contradictory information, there are no compelling reasons to change them. The specific assumptions are the following. The attrition rate for all causes among large jet workers is 7%, 20% for commuter AMTs, and 10% for general aviation/"Other" workers. The transfer rates are that 60% of commuter attrition plus 20% general aviation/"Other" attrition are assumed to be caused by AMTs transferring to large jet maintenance. Transfers into commuter maintenance account for 10% of general aviation/"Other" attrition. Finally, it was estimated that 43,000 AMTs were employed in the "Other" category in 1988 (base year) and that this number grew by 2% each year. The 2% growth assumption is pegged to an assumed 2% annual economic growth.

Table 4A-4 Additional Aviation Technicians Needed by Year

	Large Jets[1]				Net	Commuters[4]			
Year	Aircraft	Technicians	Attrition[2]	Transfers[3]	Vacant	Aircraft	Technicians	Attrition[5]	Transfers[6]
1980	2538	35532	2467	1912	575	1094	4595	919	680
1981	1630	26820	2577	2047	530	1319	5540	1108	691
1982	2717	38038	2663	2094	569	1373	5767	1153	701
1983	2841	39774	2784	2136	646	1423	5977	1195	709
1984	2993	41902	2933	2182	751	1475	6195	1239	719
1985	3180	44520	3116	2231	885	1531	6430	1286	730
1986	3383	47362	3315	2277	1038	1595	6689	1340	737
1987	3575	50050	3504	2332	1172	1680	7056	1411	743
1988	3743	52402	3668	2389	1279	1757	7379	1476	752
1989	3917	54838	3839	2418	1421	1787	7505	1501	759
1990	4032	56448	3951	2448	1503	1815	7623	1252	766
1991	4237	59318	4152	2497	1655	1878	7888	1578	775
1992	4304	60256	4218	2536	1662	1923	8077	1615	782
1993	4336	60704	4249	2577	1672	1965	8253	1651	793
1994	4499	62986	4409	2630	1779	2032	8534	1707	803
1995	4597	64358	4505	2684	1821	2095	8799	1760	814
1996	4781	66934	4685	2728	1957	2139	8984	1797	825
1997	4960	69440	4861	2764	2097	2167	9101	1820	836
1998	5192	72689	5088	2799	2269	2188	9190	1838	848
1999	5366	75124	5259	2840	2419	2214	9299	1860	862
2000	5494	76916	5384	2884	2500	2253	9463	1893	874
2001	5665	79310	5552	2923	2629	2276	9568	1914	887
2002	5817	81438	5701	2958	2743	2294	9635	1927	901
2003	5930	83020	5811	3000	2811	2322	9752	1950	915

	Net	General Aviation[7]			Combined with other Attrition[9]	Total	Added from	Total Net	Total
Year	Vacant	Aircraft	Technicians	Other[8]		Technicians	Last Year	Vacant Positions	Attrition
1980	239	208918	31338	36670	6801	108135		7615	10207
1981	417	211325	31699	37404	6910	111463	3328	7857	10595
1982	452	213061	31959	38152	7011	113916	2453	8281	10827
1983	486	213496	32025	38914	7094	116690	2774	8228	11073
1984	520	214886	32233	39693	7193	120022	3332	8663	11365
1985	556	216420	32463	40487	7295	123900	3878	8910	11697
1986	603	215819	32373	41297	7367	127731	3831	9008	12022
1987	668	214240	32136	42140	7428	131382	3651	9268	12343
1988	724	214479	32172	43000	7517	134953	3571	9520	12661
1989	742	213245	31987	43860	7585	138190	3237	9746	12925
1990	759	212601	31890	44737	7663	140698	2508	9925	13139
1991	803	212610	31892	45631	7752	144729	4031	10210	13482
1992	832	211938	31791	46543	7833	146667	1938	10347	13666
1993	858	212174	31826	47473	7930	148256	1589	10460	13830
1994	904	212352	31853	48422	8028	151795	3539	10711	14144
1995	946	213267	31990	49390	8138	154537	2742	10905	14403
1996	972	213979	32097	50377	8247	158392	3855	11176	14729
1997	948	214808	32221	51384	8361	162146	3754	11442	15042
1998	990	216056	32408	52411	8482	166697	4551	11619	15408
1999	998	218127	32719	53459	8618	170601	3904	12035	15737
2000	1019	219340	32901	54528	8743	173808	3207	12262	16020
2001	1027	220708	33106	55618	8872	177602	3794	12528	16336
2002	1026	222505	33376	56730	9011	181179	3577	12780	16639
2003	1035	224366	33655	57864	9152	184291	3112	12998	16913

[1] 14 technicians per aircraft
[2] 7% per year for all causes
[3] 60% of commuter attrition + 20% General Aviation Other attrition
[4] 4 2 technicians per aircraft
[5] 20% per year for all causes
[6] 10% of C neral Aviation/Other attrition
[7] 15 technicians per aircraft
[8] Base year 1988 - assumes 2% annual growth. Includes manufacturing, repair stations, federal technicians
[9] 10% per year for all causes

Table 4A-5 Additional Aviation Technicians Needed by Year

	Large Jets				Net	Commuters			
Year	Aircraft	Technicians	Attrition	Transfers	Vacant	Aircraft	Technicians	Attrition	Transfers
1980	2538	26649	1865	1617	248	1094	3446	689	602
1981	2630	27615	1933	1722	211	1319	4155	831	612
1982	2717	28529	1997	1761	236	1373	4325	865	621
1983	2841	29831	2088	1796	292	1423	4482	896	629
1984	2993	31427	2200	1835	365	1475	4646	929	639
1985	3180	33390	2337	1876	461	1531	4823	965	648
1986	3383	35522	2487	1915	572	1595	5024	1005	656
1987	3575	37538	2628	1960	668	1680	5292	1058	662
1988	3743	39302	2751	2007	744	1757	5535	1107	671
1989	3917	41129	2879	2033	846	1787	5629	1126	679
1990	4032	42336	2964	2059	905	1815	5717	1143	687
1991	4237	44489	3114	2101	1013	1878	5916	1183	696
1992	4304	45192	3169	2135	1028	1923	6057	1211	704
1993	4336	45528	3187	2170	1017	1965	6190	1238	713
1994	4499	47240	3307	2214	1093	2032	6401	1280	723
1995	4597	48269	3379	2260	1119	2095	6599	1320	734
1996	4781	50201	3514	2298	1216	2139	6738	1348	745
1997	4960	52080	3646	2330	1316	2167	6826	1365	755
1998	5192	54516	3816	2361	1455	2188	6892	1378	767
1999	5366	56343	3994	2397	1597	2214	6974	1395	780
2000	5494	57687	4038	2435	1603	2253	7097	1419	792
2001	5665	59483	4164	2470	1694	2278	7176	1435	805
2002	5817	61079	4275	2502	1773	2294	7226	1445	816
2003	5930	62265	4359	2540	1819	2322	7314	1463	831

	Net	General Aviation			Combined with other	Total	Added from	Total Net	Total
Year	Vacant	Aircraft	Technicians	Other	Attrition	Technicians	Last Year	Vacant Positions	Attrition
1980	87	208918	23503	36670	6017	90268		6352	8571
1981	219	211325	23774	37404	6118	92948	2680	6548	8682
1982	244	213061	23969	38152	6212	94975	2027	6692	9074
1983	267	213496	24018	38914	6293	97245	2270	6852	9277
1984	290	214886	27175	39693	6387	102941	5696	7042	9516
1985	317	216420	24347	40487	6483	105047	2106	7261	9785
1986	349	215819	24279	41297	6558	106122	1075	7479	10050
1987	396	214240	24102	42140	6624	109072	2950	7688	10310
1988	436	214479	24129	43000	6713	111966	2894	7893	10571
1989	447	213245	23990	43860	6785	114608	2642	8078	10790
1990	456	212601	23918	44737	6865	116708	2100	8226	10972
1991	487	212610	23919	45631	6955	119955	3247	8455	11252
1992	507	211938	23843	46543	7039	121635	1680	8574	11413
1993	525	212174	23870	47473	7134	123061	1426	8676	11559
1994	557	212352	23890	48422	7231	126003	2942	8881	11818
1995	586	213267	23993	49390	738	128251	2248	9043	12037
1996	603	213979	24073	50377	7445	131389	3138	9264	12307
1997	610	214808	24166	51384	7555	134856	3467	9481	12566
1998	611	216056	24306	52411	7672	138125	3269	9738	12866
1999	615	218127	24539	53459	7800	141315	3190	10012	13189
2000	627	219340	24676	54528	7920	143988	2673	10150	13378
2001	630	220708	24830	55618	8045	147087	3099	10369	13644
2002	627	222505	25032	56730	8176	150067	2980	10576	13896
2003	632	224366	25241	57864	8311	152684	2617	10762	14133

10 5 technicians per aircraft
60% of commuter attrition + 20% General Aviation/Other attrition
20% per year for all causes
15 technicians per aircraft
Base year 1988 - assumes 2% annual growth Includes manufacturing, repair stations, federal technicians
10% per year for all causes
7% per year for all causes
3 15 technicians per aircraft
10% of General Aviation/Other attrition

Table 4A-6 Additional Aviation Technicians Needed by Year

	Large Jets				Net	Commuters			
Year	Aircraft	Technicians	Attrition	Transfers	Vacant	Aircraft	Technicians	Attrition	Transfers
1980	2538	17766	1244	1322	-78	1094	2297	459	523
1981	2630	18410	1289	1397	108	1319	2770	554	533
1982	2717	19019	1331	1429	-96	1373	2883	577	541
1983	2841	19887	1392	1457	-65	1423	2988	598	549
1984	2993	20951	1467	1488	-21	1475	3098	620	558
1985	3180	22260	1558	1520	38	1531	3215	643	567
1986	3383	23681	1658	1522	6	1595	3350	670	575
1987	3575	25025	1752	1588	164	1630	3528	706	582
1988	3743	26201	1834	1625	209	1757	3690	738	591
1989	3917	27419	1919	1648	271	1787	3753	751	599
1990	4032	28224	1976	1671	305	1815	3812	762	607
1991	4237	29659	2076	1705	371	1878	3944	788	616
1992	4304	30128	2109	1734	375	1923	4038	808	624
1993	4336	30352	2125	1763	362	1965	4127	825	634
1994	4499	31493	2205	1789	406	2032	4267	853	644
1995	4597	32179	2253	1836	417	2095	4400	880	654
1996	4781	33467	2343	1867	476	2139	4492	898	664
1997	4960	34720	2430	1896	534	2167	4551	910	675
1998	5192	36344	2544	1924	620	2188	4595	919	686
1999	5366	37562	2629	1954	675	2214	4649	930	698
2000	5494	38458	2692	1987	705	2253	4734	946	710
2001	5665	39655	2776	2018	756	2278	4784	957	722
2002	5817	40719	2850	2046	804	2294	4817	963	734
2003	5930	41510	2906	2079	827	2322	4876	975	747

	Net	General Aviation			Combined	Total	Added from	Total Net	Total
Year	Vacant	Aircraft	Technicians	Other	with other Attrition	Technicians	Last Year	Vacant Positions	Attrition
1980	-64	208918	15669	36670	5234	72402		5092	6937
1981	21	211325	15849	37404	5325	74433	2031	5238	7166
1982	36	213061	15980	38152	5413	76034	1601	5351	7321
1983	48	213498	16012	38914	5493	77801	1767	5477	7483
1984	62	214886	16116	39693	5581	79858	2057	5622	7668
1985	76	216420	16232	40487	5672	82194	2336	5786	7673
1986	95	215519	16166	41297	5748	86514	4320	5849	8076
1987	124	214240	16068	42140	5821	86761	247	6109	8279
1988	147	214479	16086	43000	5909	88977	2216	6265	8481
1989	152	213245	15993	43860	5965	91025	2048	6408	8655
1990	155	212601	15945	44737	6068	92718	1693	6528	8506
1991	173	212610	15946	45631	6158	95150	2462	6702	9023
1992	184	211938	15895	46543	6244	96604	1424	6803	9161
1993	191	212174	15913	47473	6339	97865	1261	6892	9289
1994	209	212352	15926	48422	6435	100108	2243	7050	9493
1995	226	213267	15995	49390	6539	101964	1856	7182	9672
1996	234	213979	16048	50377	6643	104384	2420	7353	9864
1997	235	214808	16111	51384	6749	106766	2382	7518	10089
1998	233	216056	16204	52411	6862	109554	2788	7715	10325
1999	232	218127	16340	53459	6962	112100	2546	7889	10541
2000	236	219340	16451	54528	7098	114168	2068	8039	10736
2001	235	220708	16553	55618	7217	116610	2442	8210	10950
2002	229	222505	16688	56730	7342	118954	2344	8375	11155
2003	228	224366	16827	57864	7469	121077	2123	8524	11350

7 technicians per aircraft
60% of commuter attrition + 20% General Aviation/Other attrition
20% per year for all causes
.075 technicians per aircraft
Base year 1988 - assumes 2% annual growth. Includes manufacturing, repair stations, federal technicians
10% per year for all causes

7% per year for all causes
2.1 technicians per aircraft
10% of General Aviation/Other attrition

Results of Demand Analysis

Tables 4A-4 through **4A-6** give the results of the analyses of AMT demand in civilian aviation through the year 2003. To aid the reader in understanding the information and calculations presented in the tables, it is useful to work through an example. In **Table 4A-4**, consider the row of information and calculations for 1993. In column 1 is reported the projected number of large jets for 1993 (4336). Assuming 14.2 technicians are needed to service each large jet -- yields column 2 -- the number of technicians needed to service large jets (4336 X 14 = 60704). In the third column is the estimated attrition for large jet technicians (60704 X .07 = 4249.28), i.e the number of jobs that will become available due to attrition. In the fourth column is the estimated number of AMTs transferring to large jet maintenance from other aviation maintenance jobs. It is calculated as 60% of commuter attrition plus 20% of general/"other" aviation (.60 X 1651 plus .20 X 7930 = 2577). The Net Vacant column is the difference between available jobs and transfers (4249 - 2577 = 1672). The same general procedure is followed for commuter and general aviation/"Other" calculations. Since it is assumed that general aviation/"other" jobs represent entry level positions (BRP assumption), no estimate of transfer into general aviation/"other" is made. Rather, the attrition number represents available jobs in general aviation/"other" which are ultimately filled by newly certified AMTs.

The final four columns of **Table 4A-4** present some summary measures. Again, for 1993, the Total Technicians column represents the number of jobs available in the three classes of civilian aviation [60704 (large jet) + 8253 (commuter) + 31826 (general aviation) + 47473 (other) = 148256]. The next column is the number of jobs added during the year (148256 - 146667 = 1589). The Net Vacant column is a summation of the net vacant jobs in the three aviation classes (1672 + 858 + 7930 = 10460). The final column sums attrition across the aviation classes.

Table 4A-4 gives projections using assumptions identical to the WP report. The results are quite similar to those reported to the DOT's Blue Ribbon Panel. The differences are due to the different projections of the number of aircraft used in each study. The two columns of interest in **Table 4A-4** are the Total Technician and the Added from Last Year columns. The Total Technician column is a projection of AMT demand in aviation. The Added column is a projection of job increase in aviation. The Vacant Position column is not of particular interest since this report uses a direct measure of AMT supply. In a later section, projections of AMT demand (from **Tables 4A-4** through **4A-6**) are compared to projections of AMT supply. It is on the basis of a table similar to **Table 4A-4** that the WP report projected a future shortage in AMTs.

Tables 4A-5 and **4A-6** give projections computed similarly to those in **Table 4A-4**. However, **Tables 4A-5** and **4A-6** are based on somewhat different assumptions than **Table 4A-4**. In **Table 4A-5**, the average number of AMTs needed to service each class of aircraft were assumed to be 10.5 per large jets, 3.15 per commuter, and .1125 per general aviation/"Other" aircraft. In **Table 4A-6**, the assumed AMTs per aircraft were 7 per large jets, 2.1 per commuter, and .075 per general aviation/"Other". As can be seen by comparing the Total

Technician and Added Jobs columns across the three tables, it is obvious that the differing assumptions produce significantly reduced projections of AMT demand.

Projection of AMT Supply

The FAA publishes estimates of the number of active AMTs in its *Statistical Yearbooks*. Estimates of active AMTs are available from 1958. Separate estimates are available for females. The FAA estimates include all those who are employed in the various components of aviation, plus those who hold certification but who are no longer active in aviation. It is assumed that the FAA estimates adjust yearly for newly certified AMTs, as well as for retirements and deaths. This time series of data can be subjected to the same time series analysis used earlier to project active AMTs to the year 2003.

Table 4A-7 gives the results of such a time series analysis. Column 1 reports the FAA *Statistical Yearbook* estimates of AMTs for the 1958-1988 period. Column 2 estimates and projects figures for active AMTs generated by a Box-Jenkins time series model for the 1958-2003 period. In column 3 are the yearly increases in AMTs. Column 3 clearly shows that the supply of AMTs tends to follow a 10 year cyclical pattern. Roughly every ten years there is a significant increase in AMT production. More will be said about this pattern in the discussion of **Table 4A-8**. Column 4 contains FAA estimates of active female AMTs. In column 5 are estimated and projected numbers of female AMTs which were generated by a time series model. The female AMT model is clearly not as cyclical in nature as the total AMT model.

Since the concern in this study is only with AMT demand in civilian aviation, the projected numbers of AMTs in **Table 4A-7** will have to be adjusted to account for the fact that the majority of certified AMTs are not employed in civilian aviation. The WP report provides some information on which to base an assumption concerning the percentage of active AMTs employed in aviation. On page 7 of the WP report, it is stated that less than 4,500 of 10,000 graduating AMTs can be found in U.S. aviation 2 years later. In an August 11, 1992, memo to the Blue Ribbon Panel from Phaneuf Associates Incorporated, it was estimated that 43 percent of entry level AMTs went directly to jobs in non-aviation industries. Thus, any assumption concerning the percent of AMTs employed in aviation is somewhat subjective. As a result, two different assumptions are used in this report to estimate AMTs active in aviation. These assumptions are generally consistent with those reported to the BRP. The two assumptions are that 40 and 45 percent of AMTs remain active in aviation. Again, these assumptions are only loosely empirically based. Better information on retention in aviation jobs would adjust these assumptions. If anything, the percentage retention in aviation jobs is probably lower than 40 percent. These numbers reflect what many in the aviation industry point to as a significant problem, i.e. AMTs leave aviation maintenance jobs seeking more conventional hours, better working conditions, and better pay. Also, given the increasing volatility of the commercial aviation industry, job security of aviation employees has suffered.

Table 4A-7 FAA Estimates and Time Series Projections of Active AMTs

	Estimated Active AMTs[1]	Projected Active AMTs[2]	Added From Last Year	Estimated Active Female AMTs[1]	Projected Active Female AMTs[2]	Added From Last Year
1958	107072	107932	-	118	115	-
1959	113520	112323	4391	119	116	1
1960	115688	115425	3102	110	120	4
1961	118689	119000	3575	117	125	5
1962	122160	122323	3323	137	134	9
1963	124945	126255	3932	141	148	14
1964	130131	130677	4422	166	164	16
1965	135351	135559	4882	182	176	18
1966	140799	142213	6654	197	194	18
1967	146572	150330	8117	196	204	10
1968	158211	150189	9680	229	238	34
1969	170716	170688	10499	269	263	25
1970	184647	181713	11025	302	294	31
1971	193295	188739	7026	322	305	9
1972	201700	194366	5629	349	314	9
1973	193337	198526	4158	284	325	12
1974	198863	202327	3801	318	346	20
1975	205436	206141	3814	360	377	31
1976	212303	213222	7081	422	440	63
1977	220768	220972	7750	505	516	76
1978	228743	229916	8944	600	622	106
1979	237611	239996	10080	695	748	126
1980	250157	251330	11340	890	907	159
1981	262705	263249	11919	1051	1085	178
1982	277436	278278	15029	1298	1276	191
1983	288335	280121	1843	1493	1455	179
1984	298028	284428	4307	1649	1636	181
1985	274100	288376	3948	1775	1824	188
1986	284241	293193	4817	1964	2038	214
1987	297178	297279	4086	2237	2218	180
1988	312419	310419	13140	2565	2545	327
1989	-	323677	13258	-	2769	224
1990	-	334666	10989	-	2927	158
1991	-	344535	9869	-	3139	212
1992	-	353504	8968	-	3427	288
1993	-	357202	3698	-	3728	311
1994	-	362098	4896	-	3922	194
1995	-	365756	3658	-	4107	185
1996	-	368454	2698	-	4203	96
1997	-	373106	4652	-	4469	266
1998	-	381002	7896	-	4672	203
1999	-	389925	8923	-	4783	111
2000	-	399950	10025	-	4872	89
2001	-	411208	11258	-	5427	555
2002	-	421055	9847	-	5773	346
2003	-	425353	4298	-	5983	210

[1] Estimates are taken from FAA Statistical Yearbooks
[2] Time series estimates and projections based on FAA estimates

Table 4A-8 gives the projected number of active aviation maintenance technicians (AMTs) for the 1980-2003 period. In column 1 are the estimated and projected numbers of active AMTs generated by a Box-Jenkins time series model. In column 2 are the numbers of AMTs being added each year. As was commented on earlier, there is clearly a cyclical pattern in the production and certification of new AMTs. Roughly every ten years, there is a two or three year period marked by significantly higher AMT production. It also should be pointed out that this cyclical pattern occurs in the FAA data on active AMTs (see **Table 4A-7**). Why this cyclical pattern occurs is open to conjecture. There are any number of possible explanations. The pattern could represent variations in the production of AMTs by the schools. It could represent varying availability of potential AMTs coming from the military. It could also represent some cyclical pattern of retirements within the industry. What is most likely is that aviation maintenance schools tend to react to the volatility of the aviation industry, i.e. as aircraft orders increase with short-term expansion in aviation, schools react to perceived increased demand, and so on.

Table 4A-8 Projected Number of Active
Aviation Maintenance Technicians (AMTs) 1980-2003

Year	Estimated #	Added from last year	Estimated AMTs in Aviation[1]	Estimated AMTs in Aviation[2]
1980	251330	11340	113099	100532
1981	263249	11919	118462	105300
1982	278278	15029	125225	111311
1983	280121	1843	126054	112048
1984	284428	4312	127993	113771
1985	288376	3948	129769	115350
1986	293193	4817	131937	117277
1987	297279	4086	133776	118912
1988	310419	13140	139689	124168
1989	323677	11258	145655	129471
1990	334666	10989	150599	133866
1991	344535	9869	155040	137814
1992	353504	8968	159077	141402
1993	357202	3698	160741	142881
1994	362098	4896	162944	144839
1995	365756	3658	164590	146302
1996	368454	2698	165804	147382
1997	373106	4652	167898	149242
1998	381002	7896	171450	152401
1999	389925	8923	175466	155970
2000	399950	10025	179978	159980
2001	411208	11258	185044	164483
2002	421055	9847	189475	168422
2003	425353	4298	191409	170141

[1]Assumes 45% of active AMTs work in aviation maintenance
[2]Assumes 40% of active AMTs work in aviation maintenance

Columns 3 and 4 in **Table 4A-8** report the estimated active AMTs in aviation assuming that 45% of active AMTs are employed in aviation (Column 3) and that 40% of active AMTs are employed in aviation (Column 4). The estimates and projections in Columns 3 and 4 will be used as rough indicators of AMT supply in the next analysis which attempts to answer the question, "Will there be AMT shortages in the future?"

Projected Demand and Supply of AMTs

To determine if there will be a future shortage of AMTs, the projections of AMT demand from **Tables 4A-4** through **4A-6** are combined with projections of AMT supply from **Table 4A-8** and **Table 4A-9**. Projections of AMT shortages can be calculated by comparing the supply and demand projections. Only the situation where 40% of active AMTs are employed in aviation (Column 2) and where it is assumed that 14, 4.2 and .15 AMTs are needed to maintain each aircraft of each class of aircraft (Column 3) are there predicted to be substantial AMT shortages. However, for circumstances where greater than 40% of active AMTs remain employed in aviation and where fewer AMTs are needed to maintain each class of aircraft, shortages are not projected. In general, the supply of AMTs will meet the aviation industry's demand for them.

Another factor that has to be considered in projecting future shortages is the large pool of AMTs who are certified but who are not employed in aviation and who conceivably could return to aviation employment at some point. The aviation industry could draw upon this relatively large pool of available AMTs if circumstances warrant it. However, it is to the aviation industry's advantage not to draw upon this supply of AMTs. It is much more cost-effective to continue to fill positions with entry-level AMTs rather, than to pay higher wages to more senior people. The comparatively low wages, nighttime work schedules, and the uncertain job security in the aviation industry create retention problems within the industry, especially for more experienced and senior workers.

There may be short-term shortages of entry level AMTs in the aviation industry, given the cyclical nature of increase in the number of AMTs certified each year (see **Table 4A-7** and **Table 4A-8**). Short-term shortages in the industry may indeed be the short-term stimuli that AMT schools react to, at least until it becomes difficult for newly trained AMTs to find jobs. The schools would then react by reducing the scope of their programs. Individuals then may also become less interested in AMT training due to a perceived or real lack of jobs in the industry. Given the nature of the aviation industry, it seems to be quite difficult to create any long-term balance between the training of new AMTs and the availability of jobs. Assuming that the aviation industry is tied to the overall economy, in the long-term (more than a few years), the number of AMTs needed will continue to show cyclical changes as the economy goes through its typical upturns and downturns.

Another trend that may substantially reduce demand for AMTs in the U.S. aviation industry is the movement of aviation maintenance facilities to foreign countries. As more of these facilities become realities, the growth in the number of jobs available to AMTs trained in the United States will slow.

The overall conclusion of these analyses is that AMTs are available to meet today's demand and that future shortages seem unlikely. There may be short-term shortages of entry-level AMTs as the aviation industry fluctuates with the economy. However, the massive shortages the WP suggested seem unlikely.

Table 4A-9 Projected Demand and Supply of AMTs in Non-Military Aviation, 1980-2003

Year	Supply Active AMTs in Aviation		Demand AMTs needed in Aviation		
1980	113099[1]	100532[2]	108135[3]	90268[4]	72502[5]
1981	118462	105300	111436	92948	74433
1982	125225	111311	113916	94978	76034
1983	126054	112048	116690	97245	77801
1984	127993	113771	120022	102941	79858
1985	129769	115350	123900	405047	82494
1986	131937	117277	127731	106122	86514
1987	133776	118912	131382	109072	86761
1988	139689	124168	134953	111966	88977
1989	145655	129471	138190	114608	91025
1990	150599	133866	140698	116708	92718
1991	155040	137814	144729	119955	95180
1992	159077	141402	146667	121635	96604
1993	160741	142881	148256	123061	97865
1994	162944	144839	151795	126003	100108
1995	164590	146302	154537	128251	101964
1996	165804	147382	158392	131389	104384
1997	167898	149242	162146	134856	106766
1998	171450	152401	166697	138125	109554
1999	175466	155970	170601	141315	112100
2000	179978	159980	173808	143988	114168
2001	185044	164483	177602	147087	116610
2002	189475	168422	181179	150067	118954
2003	191409	170141	184291	152684	121077

[1]Assumes 45% AMTs remain in aviation. See Table 4A-8.
[2]Assumes 40% AMTs remain in aviation. See Table 4A-8.
[3]Assumes 14 AMTs per large jet, 4.2 per commercial and .15 per general aviation aircraft. See Table 4A-4.
[4]Assumes 10.5 AMTs per large jet, 3.15 per commercial and .1125 per general aviation aircraft. See Table 4A-5.
[5]Assumes 7 AMTs per large jet, 2.1 per commercial, and .075 per general aviation aircraft. See Table 4A-6.

Description of Time Series Models

The Box-Jenkins procedure (described in Box and Jenkins, *Time Series Analysis: Forecasting and Control*, Holden-Day, 1976) is used to fit and project time series data by means of a general class of statistical models. An observation at a given point in time is modelled as a function of its past values and/or current and past values of random shock, both at seasonal and nonseasonal time logs. The Box-Jenkins technique will model a single variable with observations equally spaced in time with no missing values. Many times it is necessary before modelling the time series to transform the data (usually by taking the log or power transformation of the series) or by differencing the series on a seasonal or nonseasonal basis.

The modelling of time series data is usually done in three steps. First, a tentative model is identified for the time series. Second, the parameters of the model are estimated and diagnostics statistics and plots are examined to determine the adequacy of the model. Third, if the model is deemed adequate, projections based on the model can be made. If one model is determined to be inadequate, then other models are examined till one is found with an acceptable fit. Once the best-fitting model is formed, forecasts can be made. Fitting and forecasting a given time series of data usually requires multiple computer runs.

Thus, the specific best-fitting model for each series of data projected in this study differs from each other model in terms of its parameters. The clearest example of these differences can be seen by comparing the projection of AMT supply (clearly cyclical) with the projection e.g,. of the number of large jet aircraft. The best-fitting model for each time series of data was used to make the projection for that time series, but the best-fitting model was different for each time series.

Finally, the Box-Jenkins model allows for the calculation of three separate forecasts for each time series. The two additional sets of projections are based on the upper and lower confidence interval limits about the estimated model parameters. These additional projections were generated, but are not reported in this report. The use of the alternate projections would not alter the major conclusions of this analysis.

CHAPTER FIVE
A PILOT STUDY TO MEASURE CORRELATES OF INDIVIDUAL DIFFERENCES IN NONDESTRUCTIVE INSPECTION PERFORMANCE

5.0 INTRODUCTION

An interim report examined previous research programs and studies in the area of nondestructive inspection (NDI) conducted by the Air Force, by the nuclear power industry, and by various academic and industry investigators (FAA/AAM & GSC, in press). A repeated finding and concern in these studies was the existence of substantial differences among inspectors' NDI proficiency. Those few studies that have attempted to examine correlates of NDI proficiency have been generally unsuccessful in establishing significant relationships with performance.

As noted in the interim report, however, there are a number of variables, measures of which appear potentially relevant to NDI selection and/or proficiency. This conclusion is based on the findings of studies of individual differences in the areas of inspection and vigilance, on the opinions of experts in the NDI field, and on the results of interviews with NDI inspectors and training supervisors. These variables can be roughly separated into the following categories:

- Boredom Susceptibility
- Concentration/Attentiveness/Distractibility
- Extraversion/Impulsivity
- Motivation/Perseverance
- Decision Making/Judgement
- Mechanical/Electronics Aptitude
- Need for Autonomy.

Each of these categories and the measures used for them is discussed in greater detail under Section 5.1, Methodology.

The pilot study reported here represents the initial phase of an effort to investigate relationships of these variables to NDI performance. A second aspect of this effort is to investigate possible task-induced fatigue resulting from sustained performance and to examine possible interactions between performance changes and the above subject variables. The task employed in this study was a computer-simulated NDI eddy-current task developed by Dr. Colin G. Drury and his colleagues at the State University of New York (SUNY) at Buffalo. The task has been described in studies by Drury, Prabhu, Gramopadhye, and Latorella (1991) and Latorella, Gramopadhye, Prabhu, Drury, Smith, and Shanahan, (1992). In essence, the task utilized a SUN SPARC workstation and incorporated a standard keyboard and optical three-button mouse as input devices. As Latorella et al. (1992) have emphasized, the aim in developing this task was neither to develop a simulator for training on actual NDI tasks nor to develop a task to measure absolute values of the probability of detecting particular types and sizes of faults. Rather, their aim was to devise a task that closely approximated the characteristics and requirements of eddy-current inspection tasks to enable laboratory investigation of factors that may influence NDI performance.

Of the two previous studies that have used this task, neither has extensively evaluated possible predictor measures or possible fatigue effects resulting from sustained performance over successive task sessions. As noted above, the primary intent of this research program, of which the pilot study reported here is only the initial phase, is to investigate both the relationship of individual difference variables to NDI performance and the possible effects of sustained task performance on NDI efficiency .

The following sections more fully describe the criterion task, the tests and measures used, the procedures employed, and the results obtained. Preliminary observations and directions to be taken in the primary study are also discussed.

5.1 METHODOLOGY

5.1.1 Subjects

A total of 6 subjects, 3 males and 3 females, participated in the pilot study. All were right-handed, had normal near visual acuity (as determined from an Orthorater screening test), reported normal hearing, and were between 18 to 29 years of age. None had prior training or experience in aircraft maintenance or inspection. All had completed at least 12 years of school. Subjects were obtained through an existing Federal Aviation Administration (FAA) subject contract and were paid $10.00 an hour for their participation. Summary characteristics of the subjects are given in **Table 5.1**.

Table 5.1 Characteristics of Subjects

Subject Number	Age	Gender	Occupation	Education Level
1	21	male	roofer	12 years
2	21	female	medical aid	14 years
3	18	male	student	13 years
4	22	male	janitor	13 years
5	22	female	student	15 years
6	29	female	store manager	13 years

5.1.2 Apparatus

As indicated earlier, the basic apparatus consisted of a SUN SPARC Model 4/50GX-16-P43 workstation, a 19 inch color monitor, and a 3-button optical mouse. Since the nature of the task and its physical characteristics have been described in detail previously (Drury et al., 1991; Latorella et al., 1992), only characteristics relevant to the present study are reviewed here.

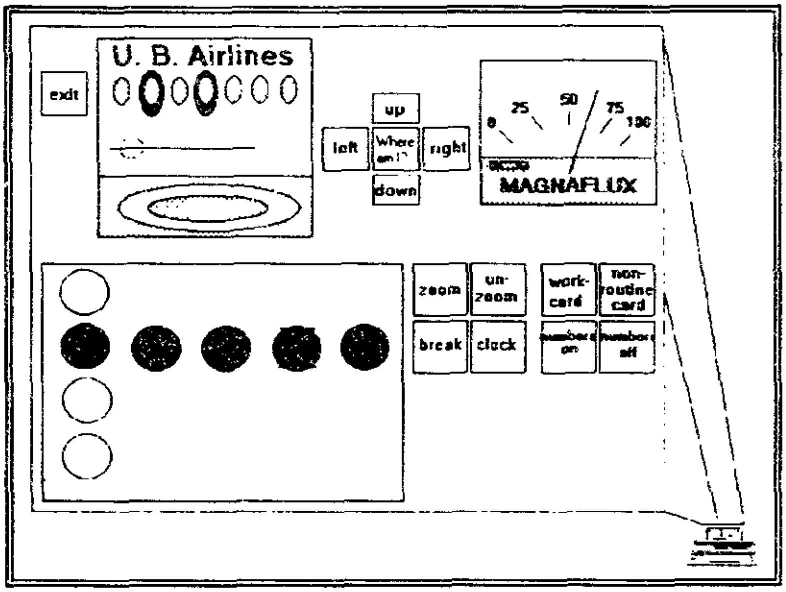

Figure 5.1 NDI Inspection Task Simulation (Drury et al., 1992)

The display itself consisted of four basic task elements (windows). These are shown in **Figure 5.1** and are described below.

5.1.2.1 Inspection Window

The lower left portion of the screen displayed the inspection window and contained the actual rivets to be inspected. Although it was possible to present more than one six-rivet row of rivets to the subject, only a single row was used in this study. An optical mouse was used to move a cursor around the circumference of each simulated rivet. The subject was free to examine the rivet until a decision was reached as to whether or not a crack was present. If it was decided that a rivet was defective, the right mouse button was pressed which caused a red cross to appear over the "defective" rivet and the words "rivet marked bad" appeared on the screen. If the rivet was judged to be nondefective, pressing the middle button caused the appearance of the words "rivet marked good." If a subject realized that an incorrect response had been made, it could be corrected by pressing the appropriate button.

When all six rivets had been inspected, the left mouse button was clicked on the directional block labeled "right." This caused a black marker ring to circle the last rivet inspected, and the next six rivets appeared in the inspection window.

5.1.2.2 Macro-View and Directionals

A macro-view in the upper left of the screen displayed a side view of the aircraft fuselage and the row of rivets being inspected. Since only a small portion of this row was being inspected at any given time during the task, the subject could move the cursor over the words "Where am I?" in this area and a momentary circle would appear over that portion of the rivet row currently being examined.

5.1.2.3 Eddy-Current Meter

The upper right segment of the display contained a simulated analog meter that served as the eddy-current output indicator. Deflections beyond a set point on the meter produced an audible alarm as well as a red flash on an indicator light. Meter deflections could be caused by:

- touching a rivet edge with the cursor or moving the cursor onto the rivet
- the cursor passing over a crack (All cracks were invisible and of varying length.)
- the cursor passing over or near simulated corrosion, scratches, or paint chips (These were simulated by 2 mm jagged lines at random locations adjacent to a rivet. Not all rivets contained such "noise," and no rivet contained more than one such noise spot.)

5.1.2.4 Lower Right Window

The subject could use the lower right area of the display to exercise a number of options (e.g., "zoom" to take a closer look at a rivet being inspected, stop task in order to take a break, display elapsed time). Only one feature was used in the present study; this feature caused a number to appear on each rivet and was only used by the experimenter during training feedback sessions to enable subjects to locate and re-check rivets incorrectly classified.

5.1.3 Predictors and/or Task Correlates

As noted earlier, the interim report (FAA/AAM & GSC, in press) identified a number of variables, measures of which appear potentially relevant to NDI selection and/or proficiency. These variables can be roughly separated into the following categories:

- Boredom Susceptibility
- Concentration/Attentiveness/Distractibility
- Extraversion/Impulsivity
- Motivation/Perseverance
- Decision Making/Judgement
- Mechanical/Electronics Aptitude
- Need for Autonomy.

The following sections describe the tests and scales that were employed as measures of the above to identify possible correlates of performance on the NDI task.

5.1.3.1 Subjective Rating Scale (SRS)

The Subjective Rating Scale (SRS) is a simple self-rating scale that the author has used in several previous studies (e.g., Thackray, Bailey, & Touchstone, 1977; Thackray & Touchstone, 1991) to assess the current disposition of the subject, with measures generally taken before and after periods of task performance. The basic instrument consists of five 9-point scales measuring the dimensions of attentiveness, tiredness, strain, boredom, and annoyance. Two additional scales measuring perceived effort and perceived difficulty were used in the more recent study by Thackray and Touchstone (1991) and were included here as well. The SRS was studied most extensively in the early study by Thackray, Bailey, and Touchstone (1977). In that study, subjects falling at the extremes of rated boredom following performance of a simulated radar monitoring task were compared with respect to several performance and subjective variables. In general, those subjects who rated the task as quite boring showed the greatest decline in rated attentiveness and the largest performance decrement.

5.1.3.2 Bennett Mechanical Comprehension Test

One of the recommendations of a Southwest Research Institute study of ways to improve NDI technician proficiency was to select individuals who scored high on mechanical/electronics aptitude (Schroeder, Dunavant, and Godwin, 1988). This recommendation was also echoed in interviews with NDI instructors who expressed the belief that individuals who were above average in mechanical aptitude made better inspectors (Galaxy Scientific Corporation, in press). For these reasons, the Bennett Mechanical Comprehension Test was included in the test battery. This test appears to be one of the better measures of mechanical aptitude, and its norms include those for aviation mechanical jobs and electrical inspector trainee jobs. Unfortunately, the norms for aviation mechanical jobs, although updated in 1980, still do not include separate normative data for women.

5.1.3.3 Typical Experiences Inventory (TEI)

The ability to resist distraction, if it can be measured, would appear to have at least face validity in selecting inspectors (Wiener, 1975). A scale developed for use in several previous studies (Pearson and Thackray, 1970; Thackray, Jones, and Touchstone, 1973) and titled "Typical Experiences Inventory" consists of a series of statements designed to measure ability to work under conditions of (a) time stress, (b) threat of failure, (c) distraction, (d) social stress, and (e) physical stress. In the study by Thackray et al. (1973), subjects were selected who scored high, as well as low, on the distractibility subscale of this inventory. The high scorers showed significantly greater lapses of attention during performance of a repetitive task than did those scoring low. Because of these findings, it was decided to examine the relationship of scores on this subscale to possible performance decrement on the NDI task.

5.1.3.4 Arithmetic, Digit Span, and Digit Symbol Tests of the Wechsler Adult Intelligence Scale (WAIS)

Scores on these three subtests of the WAIS have been shown in numerous factor analytic studies to measure a factor that has been variously named "Freedom from Distractibility," "Attention-Concentration," or "Concentration-Speed" (e.g., Goodenough and Karp, 1961; Karp, 1963). Some or all of these WAIS tests have been found to relate significantly to inspection performance (Gallwey, 1982; Wang and Drury, 1989). Consequently, these tests were included as another measure of attention/concentration or, conversely, distractibility.

5.1.3.5 Eysenck Personality Inventory (EPI)

The Eysenck Personality Inventory is a short inventory that measures extraversion and neuroticism. The extraversion dimension has been studied extensively in the context of vigilance research because of the hypothesis, originally formulated by Eysenck (1967), that extraverts should have more frequent lapses of attention and hence more omission errors than would introverts. Reviews of the use of this personality dimension in vigilance research (Berch and Kantor, 1984; Wiener, 1975) have lent some support to the belief that extraverts generally do not perform as well on vigilance tasks as do introverts. Much less research has been conducted on personality variables in the area of inspection, and no studies of extraversion and inspection performance had been conducted at the time of Wiener's 1975 review. Since then, the author is aware of only one inspection study that has incorporated a measure of extraversion. Using a visual search task, Gallwey (1982) found that introverts, as measured by the EPI scale, had fewer search errors.

A factor analysis of the EPI scale has shown that it is comprised of two factors: sociability and impulsivity (Eysenck & Eysenck, 1963). Several studies have shown that the impulsivity dimension of extraversion is most clearly related to performance changes (Revelle, Humphreys, Simon, & Gilliland, 1980; Thackray, Jones, & Touchstone, 1974). In the latter study, extraverts showed a greater increase in lapses of attention during performance of a monotonous, repetitive task than did introverts. Further, it was determined that it was impulsivity, rather than the sociability dimension of extraversion, that was responsible for the obtained decrement.

Although a recent meta-analysis of vigilance studies over a 30-year period has concluded that evidence for the superiority of introverts is considerably less than previously believed (Koelega, 1992), Koelega feels that there is enough consistency in the findings to warrant continued research. Because of this, it was decided to include extraversion as measured by the EPI and the subscales measuring impulsivity and sociability in the present study.

5.1.3.6 Boredom Proneness Scale (Life Experiences Scale)

NDI inspection is typically a repetitive task and is frequently considered boring and monotonous (Schroeder, Dunavant, & Godwin, 1988). While the evidence relating experienced boredom to poor performance is tenuous at best, at least one study demonstrated a significant relationship of reported boredom and monotony to vigilance performance. As noted earlier, subjects falling at the extremes of rated boredom following performance of the simulated radar monitoring task showed the greatest decline in rated attentiveness and the largest performance decrement (Thackray et al., 1977).

Boredom in the above study was measured following task performance and thus can be considered a "state" assessment of boredom. The only scale specifically developed to assess the general construct of boredom proneness (i.e. a "trait" measure of boredom susceptibility) was developed by Farmer and Sundberg (1986). To the author's knowledge, this scale has not been used in studies of inspection performance. For this reason, it was included in the present study.

In order to somewhat disguise the intent of the scale, it was relabeled "Life Experiences Scale." Besides yielding a measure of boredom proneness, a recent factor analysis of the scale revealed that it was comprised of two factors, "apathy" and "inattentiveness" (Ahmed, 1990). Scores on these two subscales were also obtained. Ahmed's analysis revealed that the last item of the Farmer and Sundberg scale (item # 28) contributed to unreliability of the total test score, so this item was removed from the scale administered in this study.

5.1.3.7 Matching Familiar Figures Test (MFFT)

The MFFT is a test developed by Kagan and his associates (Kagan, Rosman, Day, Albert and Phillips, 1964) and consists of a series of 12 "stimulus" pictures each associated with 8 "response" pictures. Except for one picture in each set of the 8 response pictures, all differ from the stimulus in some minute detail. Subjects point to the picture they believe to be the correct one in each set and continue to point until the correct one is identified. Both the time to first response and the number of errors are scored. According to the above authors, the test measures a cognitive style known as reflection-impulsivity. Those who make quick inaccurate decisions on the test are said to have an impulsive cognitive style; those who make slow accurate decisions are said to have a reflective cognitive style.

This test has been considered to measure the tendency of subjects performing inspections tasks to opt for speed or accuracy in their speed/accuracy tradeoff (Drury, Gramopadhye, Latorella, Patel, Prabhu, and Reynolds, 1992). Presumably, impulsive subjects would tend to opt for speed at the expense of accuracy; conversely, reflective subjects would opt for the opposite. In a recent study, scores on the MFFT were found to be significantly related to several measures of inspection performance (Latorella et al., 1992). Since the task used in this latter study was the NDI simulation developed by Drury et al. and used in the present study, it seemed desirable to investigate further the relationship of MFFT scores to performance on this task.

5.1.3.8 Internal-External Locus of Control Scale

Rotter's (1966) Internal-External (I-E) Locus of Control Scale was developed to measure differences between individuals in the extent to which they believe either that rewards and reinforcements are contingent on or independent of their own behavior. The internal person believes that rewards are contingent on his own effort, attributes, or capacities; the external person believes that rewards result largely from luck, chance, fate, or forces outside of his control.

In a study of vigilance performance, Sanders, Halcomb, Fray, and Owen (1976) hypothesized that "internals," by constantly striving for mastery of a situation and by exhibiting a belief in their own ability to determine the outcome of their efforts, would perform better on a vigilance task than would an "external" person. The results supported this hypothesis in that internals, relative to externals, missed significantly fewer signals. Also, the internal subjects continued to progress in the monitoring task with a very small decline in performance, while the externals showed a consistently increasing performance decrement.

Because the Rotter scale has apparently not been used previously in inspection research, it seemed important to determine whether relationships similar to those found in vigilance would apply to inspection performance.

5.1.3.9 Jackson Personality Research Form (PRF)

The PRF is a widely used test designed to yield a set of scores for personality traits broadly relevant to the functioning of individuals in a wide variety of situations. It is a personality test that focuses primarily upon areas of normal functioning, rather than psychopathology.

The Form E (PRF) used in this study consists of sixteen scales, of which nine were actually employed. The included scales were (a) Achievement, (b) Endurance, (c) Understanding, (d) Cognitive Structure, (e) Autonomy, (f) Change, (g) Impulsivity, (h) Infrequency, and (i) Desirability. A brief description of each and the reason(s) for its inclusion are as follows:

- *Achievement.* A measure of the willingness to put forth considerable effort to accomplish difficult tasks. This was included as a possible measure of intrinsic motivation or perseverance in task performance and was mentioned in the interim report as a desirable quality of NDI technicians (Galaxy Scientific Corporation, in press).

- *Endurance.* A measure of the willingness to work long hours and to be patient and unrelenting in work habits. This trait appears somewhat related to the above measure, and, in fact, loads on the same factor in a factor analysis of the test. It was included for the same reasons as the Achievement trait.

• *Understanding.* A measure of intellectual curiosity and the desire to understand many areas of knowledge. This was included because it was felt that it might correlate negatively with performance on a task as constrained and repetitive as eddy-current testing.

• *Cognitive Structure.* A measure of the need to make decisions based upon definite knowledge with a dislike of ambiguity and uncertainty. It was felt that this trait might be positively related to decision time, i.e. the time spent searching each rivet for possible faults.

• *Autonomy.* This is a measure of the need to be independent and not to be tied down, restrained, confined, or restricted in any way. This was mentioned in the interim report as a trait characterizing the most proficient inspectors (FAA/AAM & GSC, in press). This trait was also mentioned by some of the NDI instructors interviewed by the present author.

• *Change.* A like of new and different experiences, with a dislike and avoidance of routine activities. Inclusion of this trait is self-evident, since NDI tasks are so often referred to as boring and monotonous.

• *Impulsivity.* A measure of the tendency to act on the "spur of the moment" and without deliberation. This was included as an additional measure of impulsivity to compare with similar measures obtained from the EPI and from the MFFT described previously.

• *Infrequency and Desirability.* These were two scales included as measures of carelessness and response bias in taking the test.

The various tests and measures described in the preceding sections were included because it was felt that each might serve to measure some aspect of the categories mentioned under Section 5.1.3 as predictors and/or correlates of NDI performance. It should be apparent that a number of these tests and measures bear similarities to one another and may indeed be measures of the same trait, aptitude, or ability. However, one cannot always tell from test titles and descriptors whether or not they measure similar things, and some were included to determine empirically the extent of their interrelationships, or lack thereof.

5.1.4 Procedure

Each subject was tested over two successive days. The morning of the first day was devoted to administration of the various tests and measures; during the afternoon, subjects practiced using the mouse and were required to read and be tested on a document describing eddy-current testing. They then practiced the NDI simulation task. The afternoon training procedures were essentially the same as those used and reported by Drury et al. (1991). Subjective rating scales were administered at various times during the course of both days.

Training in the use of the mouse was provided by a display program consisting of an enlarged picture of a rivet head with a training circle surrounding it. The subject practiced using the mouse and cursor to circle the rivet while staying within the circle. After each pre-selected block of training trials, feedback was provided consisting of average times required to circle the rivet, and averages of the number of times the cursor head touched the rivet or went outside the circle. Training continued until the subject reached a consistent level of performance. This usually required approximately 30 minutes of practice.

Training on the task began with a short (20-rivet) demonstration session in which the basic elements of the NDI task were explained. This was followed by three training sessions each 60 rivets long. Thirty percent of the rivets in each of the three training sessions contained faults (cracks). In addition, the second and third sessions also contained small, but visible (2 mm) "noise" spots at various locations at or near a rivet. Frequency of "noisy rivets" was also thirty percent. Locations of faults and noise were randomly assigned for each task session (both training and subsequent test tasks). Performance feedback was automatically provided after each block of 10 rivets. In the first and second sessions, training circles were provided around each rivet to assist the subject in keeping the cursor in the appropriate region while circling the rivets; no training circles were used in the third session.

On the morning of the second day, subjects performed a short (20-rivet) "refresher" version of the NDI task and then performed two lengthy (180-rivet) test sessions. Since these sessions were self-paced, test durations for each subject varied from 60 to 90 minutes. There was a fixed 10-15 minute rest break between each session, although subjects were told that they could take short (10-20 second "stretch" breaks as needed during any session. Following a 60-minute lunch break, this same procedure (two 180-rivet sessions), minus the short practice session, was followed in the afternoon. No feedback was provided following test sessions and the frequency of both faults and noise was held at 30 percent each. At the end of the second day, subjects were debriefed and questioned about various attitudes about and approaches to the NDI task.

5.2 RESULTS

5.2.1 Criterion Performance

Figure 5.2 shows mean values for misses and false alarms across the three training sessions. Visual examination of this figure reveals an apparent increase in false alarms during the second training session. However, subjects typically made no errors (misses or false alarms) during these training sessions and the increase noted above was caused by two subjects making two false alarms during this second session. The only

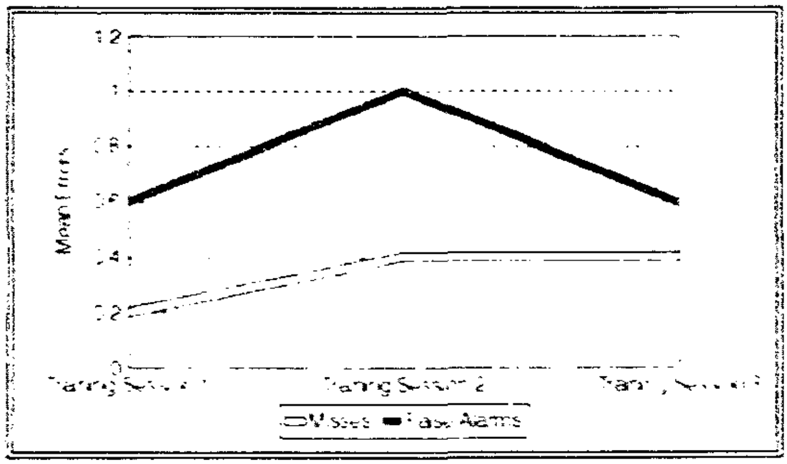

Figure 5.2 Mean Misses and False Alarms Across Training Sessions

important information to be gained from this figure is that miss rate remains level during the last two training sessions and false alarm rate returns to its initial level.

Raw data for misses and false alarms during the four test sessions are given in **Tables 5.2** and **5.3** respectively. Mean values obtained from these two tables are plotted as bar graphs in **Figure 5.3**. In addition, this figure also plots miss and false alarm data for the first and second half of each test session shown in **Tables 5.2** and **5.3**. Notice the general increase in both misses and false alarms across sessions and the general increase in both types of errors within sessions. Analyses of variance revealed the differences between sessions to be significant for both misses ($F(3/15)=4.90$, $p=.014$) and false alarms ($F(3/15)=3.72$, $p=.035$), while differences between first and second halves of the sessions approached significance at the .05 level for both misses ($F(1/5)=5.79$, $p=.061$) and false alarms ($F(1/5)=4.65$, $p=.084$). The Interaction of Session Halves with Sessions was not significant for either misses or false alarms.

Table 5.2 Frequency of Missed Faults Over the Four Test Sessions

Misses		**Session 1**		**Session 2**		**Session 3**		**Session 4**		
Subject Number	Gender	1st 1/2	2nd 1/2	1st 1/2	2nd1 /2	1st 1/2	2nd 1/2	1st 1/2	2nd 1/2	Total
01	Male	1	5	3	2	2	2	5	10	30
02	Female	0	1	5	2	3	1	1	0	13
03	Male	5	11	5	16	19	13	10	11	90
04	Male	3	6	6	7	5	5	6	8	46
05	Female	2	5	6	13	12	9	2	13	62
06	Female	3	4	1	1	4	4	7	18	42

Table 5.3 Frequency of False Alarms Over the Four Test Sessions

False Alarms		Session 1		Session 2		Session 3		Session 4		
Subject Number	Gender	1st 1/2	2nd 1/2	1st 1/2	2nd 1/2	1st 1/2	2nd 1/2	1st 1/2	2nd 1/2	Total
01	Male	0	0	0	1	4	8	6	7	26
02	Female	0	0	0	1	0	0	0	2	03
03	Male	3	4	6	14	6	16	19	15	83
04	Male	0	1	1	1	0	3	12	14	32
05	Female	0	0	0	1	1	0	0	1	03
06	Female	2	0	0	2	0	0	0	1	05

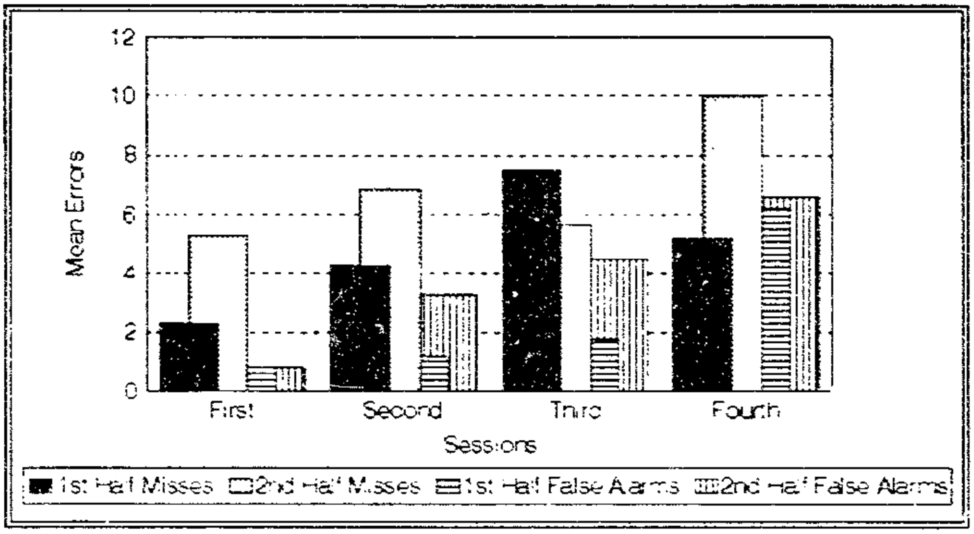

Figure 5.3 Mean Misses and False Alarms Across Test Sessions

Total task time and mean time per rivet are shown in **Table 5.4**. As can be seen in this table, there was a general decrease in both total task time and mean time per rivet during training as well as during the test sessions. Analysis of variance revealed the decline in total task time to be nonsignificant both during training and test sessions ($p>.10$). Mean time per rivet, however, decreased significantly both during training ($F(8/2)=4.27$, $p=.05$) and during test sessions ($F(3/15)=8.22$, $p=.002$). The increase in mean time per rivet from the last training session to the first test session can probably be attributed to the fact that the larger number of rivets in the test sessions caused the meter in the simulation to be slightly more sluggish in its response. This aspect was explained to subjects before the first test session, and subjects characteristically began the session by circling the rivets with greater care and deliberation.

Table 5.4 Mean Total Task Time and Mean Time per Rivet

Task	Mn Total Time (min)	Mn Time Per Rivet (sec)
Training Session 1	29.7	23.4
Training Session 2	27.9	23.6
Training Session 3	26.3	20.3
Test Session 1	92.7	28.8
Test Session 2	82.8	24.1
Test Session 3	93.1	24.9
Test Session 4	78.6	19.4

Estimates of task reliability were obtained by comparing the combined data of test sessions 1 and 2 with the combined data of sessions 3 and 4. The correlation between combined sessions was r=.82 (p<.05) for false alarms and r=.81 (p<.05) for missed events. Total false alarms across sessions was also compared with total misses across sessions. The obtained correlation was r=.73 (p=.10) which, although failing to reach the .05 level, suggests that the two measures might be significantly related, given a larger sample size.

5.2.2 Subjective Measures

As indicated earlier, subjective ratings of attentiveness, tiredness, strain, boredom and annoyance were obtained at various times during the two-day period. Measurements of each were obtained at the beginning of each morning and afternoon of the two-day periods each subject was tested. These same measures were obtained at the end of the first day's training session and at the end of the morning and afternoon test sessions of the second day. In addition, items relating to perceived task difficulty and to the amount of effort required to maintain alertness were also administered at the end of the above three sessions. Data for the subjective ratings are given in **Table 5.5**.

Comparing the pre- and post-session data of **Table 5.5**, it is apparent that attentiveness decreased, while tiredness, strain, boredom, and annoyance all increased. Analyses of variance, however, revealed that only those changes associated with tiredness and strain were significant ($F(1/4)$=7.90, p=.048 and $F(1/4)$=11.0, p=.029 respectively). The increases in perceived effort and perceived difficulty were nonsignificant (p>.10).

Table 5.5 Mean Pre- and Post-Session Subjective Ratings

Variable	Mn Pre-Session Ratings	Mn Post-Session Ratings
Attentiveness	7.0	5.7
Tiredness	4.3	5.3
Strain	3.5	4.3
Boredom	3.2	3.9
Annoyance	1.2	1.8
Effort	4.4	5.1
Difficulty	2.7	3.9

5.2.3 Predictor Measures

Means and standard deviations for the various predictor tests and measures used are shown in **Table 5.6**. Because of the small sample size used in the pilot study, with the attendant risk of obtaining spurious correlations, no attempts were made to correlate or compare any of these measures with performance variables. Where normative data were available, most measures appeared to fall within one standard deviation of the reported mean values. Several deviations are worth mentioning, however: The sample as a whole scored relatively low on impulsivity as measured by the PRF and EPI scales, on boredom susceptibility as measured by the Boredom Proneness Scale, and relatively high on endurance as measured by the PRF scale.

5.3 DISCUSSION

Discussion of the findings of this pilot study is not extensive for two reasons. First, the essential purpose of this initial study was simply to test and evaluate the various tests, scales, procedures and task used in order to determine whether changes were necessary for the major study of which this was only the initial phase. Second, the small size of the sample used increases the risk of obtaining spurious results and makes any conclusions drawn from the data risky at best. However, some comment on the findings is necessary and appropriate.

The significant increase in misses (faults) obtained over the four test sessions suggests a boredom and/or fatigue effect resulting from the repeated testing, perhaps causing the subjects to become less careful or attentive in examining the rivets. This decline in performance efficiency was accompanied by an increase in ratings of both boredom and fatigue. However, only the increase in tiredness was found to be significant. There was also a significant increase in strain, suggesting that continued task performance over the four successive sessions was not only tiring, but emotionally demanding as well.

Table 5.6 Means and Standard Deviations of the Predictor Measures

Variable	Mean	Standard Deviation
Typical Exper Inv	22.00	6.90
Bennett Mech Comp	40.67	2.88
LES Boredom Prone	5.33	4.03
LES Inattentiveness	2.33	2.58
LES Apathy	3.83	2.32
MFFT Mn Error	1.23	0.37
MFFT Mn Time	59.80	23.40
EPI Extraversion	12.50	1.52
EPI Impulsivity	3.83	1.47
EPI Sociability	7.33	1.37
WAIS Digit Symbol	56.17	14.18
WAIS Digit Span	13.00	2.83
WAIS Arithmetic	7.83	2.93
PRF Achievement	12.50	2.59
PRF Autonomy	6.83	2.48
PRF Change	8.50	1.64
PRF Cog Structure	10.17	2.71
PRF Endurance	13.33	1.97
PRF Impulsivity	3.50	3.39
PRF Understanding	7.00	4.34
I-E Scale	8.33	3.61

While an increase in fatigue (tiredness) across sessions seems a plausible explanation for the increase in missed faults, it is somewhat puzzling to see how increasing tiredness could also result in an increase in false alarms as **Figure 5.3** shows. The possible increase in carelessness and inattentiveness with fatigue could again be a contributing factor. Recall that **Table 5.4** showed a significant decrease during the test sessions in mean time spent examining rivets. While this could merely be an indication of increased skill in the use of the mouse, it seems more likely that it indicates less careful examination of the individual rivets by at least some of the subjects, especially during the last session. Less careful examination would likely increase the number of times a rivet edge was touched or "noisy" area was crossed. The resulting meter deflections might then be erroneously interpreted as faults.

One should also not overlook the possibility that the increase in false alarms might simply be an artifact of the particular sample used. Examination of **Table 5.3** reveals that half of the subjects (subjects 2, 5, and 6) showed essentially zero false alarms across all four sessions. The increase in false alarms was essentially the result of subjects 1, 3, and 4. Thus, whether the larger, more representative sample to be used in the primary study to follow this one will show an increase or no increase in false alarms across sessions cannot really be predicted from these data. Likewise, one should not attribute much significance to the fact that the three subjects of **Table 5.3** showing no increase in this type of error were all females. Whether or not a gender difference exists in this respect again must await the findings of the subsequent study.

Of the remaining data, there is little more that can be discussed. Reliability of the NDI task, in terms of both misses and false alarms, was shown to be acceptable, and one would hope that these reliability estimates will approximate those to be obtained in the primary study. As noted earlier, the particular sample used scored somewhat below average on measures of impulsivity, on measured boredom susceptibility, and above average on the PRF measure of task endurance. Also, the sample appeared to show a gender difference in frequency of false alarms on the NDI task. Whether any or all of the above characteristics of this sample will be reflected in the larger sample of the primary study remains to be determined. The experiment protocol of the pilot study proved to be workable with testing and training occurring on the first day and with the second day devoted to successive test trials. No problems were encountered in administration of the various psychometric tests and measures and all will be used in the primary study.

As indicated in the Introduction, the pilot study reported here represents the initial phase of a larger effort (the primary study) to investigate relationships of selected subject variables to NDI performance. A second aspect of this effort is to investigate possible task-induced fatigue resulting from sustained performance on the NDI task and to examine possible interactions between performance changes and the various subject variables examined in the pilot study. Approximately 25-30 subjects will be tested in the primary study, but the basic procedures and approach will remain essentially those incorporated in this pilot study.

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CHAPTER SIX
THE EFFECTS OF CREW RESOURCE MANAGEMENT (CRM) TRAINING IN AIRLINE MAINTENANCE: RESULTS FOLLOWING ONE YEAR'S EXPERIENCE
(Report of Work Completed through 6-30-92)

6.0 SUMMARY

This report describes the first full year's evaluation of the effects of one airline's Crew Resource Management (CRM) training program. This evaluation focuses on maintenance managers' attitudes, their reported behaviors, and the maintenance performance of their units. The results reveal a strong positive effect of the training.

The overall program represents a long-term commitment to improving safe, dependable, and efficient performance through effective communication at all levels in airline maintenance operations (Appendix A contains the current syllabus). The initial findings described in a previous progress report (Galaxy Scientific Corporation, 1992) are reinforced and elaborated here. The current results benefit from a larger sample size. Additional months of performance data and results from six- and twelve-month follow-up questionnaires[1] also contribute to the value of this data set.

In the present report, we examine maintenance performance changes following training, as well as the relationships noted between the post-training attitudes and performance. Maintenance performance reported here includes safety from ground damage, safety from injury, maintenance costs in overtime paid, delays in RON (remain in station overnight) aircraft departures, as well as dependability of on-time departures for other scheduled flights. We further describe these measures in **Table 6.1**.

The analyses reported here examine training effects on performance, on attitudes and on indicators of behavior. In particular, we compare managers' immediate post-training attitudes with their follow-up attitudes about a variety of management and organizational factors. We also test the relationship of attitudes with maintenance performance measures. Highlights of results from this training program include increased safety and improved costs from management of stress, and improved on-time performance from the application of more assertive communications. More specific results are as follows:

1) We noted positive trends in a number of the company's overall maintenance performance for the 12 months after the onset of training, compared with the 12 months before. The two performance categories of Efficiency (**Figure 6.3**) and Safety (**Figures 6.4-6.5**) improve after the training. In addition, most of the overall results of Dependability performance remain stable in the 12 months after the onset of training (**Figures 6.6-6.10**)

[1]All surveys and questionnaires were distributed by the airline to airline employees. The survey instruments were not developed or distributed by the FAA

2) Comparisons of managers' attitudes immediately after their training with their attitudes months later confirm that the effects of training on beliefs are stable. Comparison of managers' attitudes before and after their training showed a showed significant improvement in three of the four attitude indicators. Improvement took place in attitudes about "willingness to share command responsibility," "usefulness of communication & coordination," and "recognition that stressors affect management decision-making" (Galaxy Scientific Corporation, 1992). The present report goes beyond that examination of pre-post test comparison of attitudes to look at the same attitudes shown by these managers months later. This test of the questionnaire data shows that the favorable post-training attitudes remain at those high levels two months, six months, and twelve months after the training. The influence of the training on managers' attitudes is thus a stable and robust change and not merely a brief "honeymoon effect." We present these comparisons graphically in **Figures 6.1** and **6.2**.

3) Another analysis of the data looks at the relationships between the post-training attitudes and maintenance results over several months. In this "time-lagged" analysis, we test the effects for performance before the training, performance at the same time as the training, and performance months after the training. As we describe in the main body of this report, we found a pattern of significant relationships (in the expected direction) between the managers' **immediate post-training attitudes** and performance. Specifically, some attitudes are associated with concurrent performance of work units, as well as performance several months later. Effective performance, as measured by the dependability measures, in the months before the training are associated with favorable post-training feelings about communication and coordination and the importance of work stresses in management decision-making (cf., **Tables 6.7-6.11**). Furthermore, these two attitude measures are also significantly related to on-time performance in the months following the training (**Table 6.7**).

4) The pattern of relationships between **attitudes assessed two months after training,** and performance is somewhat different. These "follow-up attitudes" have more sustained relationships with performance over the several months examined than attitudes immediately following the training. A low rate of ground damage incidents before and during the period of the two-month follow-up survey is most related to three indices in the follow-up measure. Those three are the "recognition of stressor effects on decision-making," and the participant reports of "work goal sharing" within and between work groups (**Table 6.13**). Measures of assertiveness and of sharing command responsibility are consistently related to on-time performance (**Table 6.15**) and to the other measures of dependability (**Tables 6.16-6.18**).

5) Managers' self-reports of their behavior for the six- and twelve-month follow-up surveys confirm change from more passive behaviors to more active and interactive behaviors. Passive behaviors can be accomplished by oneself and do not require the cooperation of others. It is for that reason that we find those self-reports consistent with our expectations. The passive behaviors of "better listening" and "being more aware of others" are reported as most used two months after the training, but they do not increase appreciably in the six-month and twelve-month surveys. On the other hand, the active

behaviors of "communicating" and "dealing better with others" increase markedly in written descriptions by participants twelve months after the training (**Figure 6.12**). This latter result offers powerful implications for the long-term effects of the training. It appears that during the CRM training these managers learn some skills that they begin to use right away, and others that they apply only months afterward.

Methods used in the study

Maintenance managers' attitudes are measured based on a questionnaire developed a decade ago by NASA and The University of Texas. The NASA/UT program has used that questionnaire to evaluate the results of CRM flight crew training in a large number of U.S. and foreign carriers (Helmreich, Foushee, Benson, & Russini, 1986). Questionnaire data for the present study were collected before, and immediately after, the training, as well as two months after, six months after, and twelve months after. The managers were requested to choose an identification number (known only to them) and to use that number on all questionnaires they completed. Using these numbers, it was possible to match the same managers' answers to the same questions over the various time intervals.

All questionnaires used here included 26 separate multiple choice questions, which we later collapsed into six composite index measures. Of these six composites, four are measures of attitudes which the CRM training should influence, and two are perceptions of goal attainment behavior that the training should not predictably change. The first four composites measure attitudes about "sharing command responsibility," "communicating & coordinating," "managing stressors," and "assertiveness." The other two composites measured managers' attitudes about sharing work goals within their own groups, and between work groups.

In addition to the multiple choice questions, all questionnaires administered after the training included several open-ended questions. Those open-ended questions explore how the managers expected to use what they learned from the training, how they did use it, and what they thought would improve the training. This report describes the results, using the six questionnaire composite measures and the four open-ended items.

6.1 BACKGROUND

The CRM training reported here is first-time training in several team-related concepts, including communication skills, self-knowledge, situational awareness, and assertiveness skills for maintenance management personnel in one large U.S. airline (hereafter called "the company"). Maintenance in this company includes engineering, quality assurance, technical planning, systems & procedures, contracts administration and purchasing, as well as the more direct maintenance functions of line- and base-maintenance, inspection, shops, and material services. It is the company's intention to train all of its 1,800 maintenance directors, managers, supervisors, and assistant supervisors.

CRM training in airline maintenance operations is unique to the present organization. This exceptional example has been intensively studied during its first 18 months. The first reports (c.f. Taylor, 1991a, 1991b) were limited to a relatively small sample of participants and a small number of months of post-training maintenance performance data. A summary report of the first six months was published in the FAA Office of Aviation Medicine's Second Annual Human Factors Research and Development Progress Report (Galaxy Scientific Corporation, 1992). The present report continues to document the company's CRM training efforts and particularly examines the effects of training-related attitudes on subsequent performance, as well as the stability of post-training attitude changes.

The effectiveness of this training, as measured by its ongoing evaluation, can help direct the airline industry's maintenance human resources practices in the future and guide the development of future ATA and FAA training policies and regulations.

The analyses reported below assess the relationships among managers' post-training attitudes about a variety of management and organizational factors and maintenance unit performance.

6.2 THE PURPOSE OF THE PROGRAM AND OF THE COURSE

The program's champion is the company's Senior Vice President for Maintenance. He has stated that his aim for the training and evaluation program is to improve human resource (HR) management. This HR progress, he believes, will be hastened by using science-based tools and techniques for evaluating the training outcomes and using those results for continuously improving the program's effectiveness.

This particular training program originally began with help from the company's flight operations training group who had nearly a decade's experience with their own CRM program. Now, however, the training is a maintenance program entirely. The program is managed and administered by maintenance people, and the trainers (in conjunction with professional human factors consultants) are maintenance people too.
The purpose of the training, as stated by trainers on the first day of each training session, is "To equip all maintenance personnel (management first) with the skill to use all resources to improve safety and efficiency."

6.2.1 Course Objectives

The objectives (the more specific goals of the training) are also clearly stated during the trainers' introductory remarks. They are as follows

1. Diagnose organizational "norms" and their effects on safety
2. Promote assertive behavior
3. Understand individual leadership styles
4. Understand and manage stress

5. Enhance rational problem-solving and decision-making skills
6. Enhance interpersonal skills

6.2.2 The Course as Designed for the Objectives

The aims and objectives of the training are achieved by following a course syllabus containing 12 modules (Chapter Six Appendix contains the current syllabus).

6.2.3 State of Training Completed

At the time of this writing more than 1000 maintenance Managers have attended the CRM training course. Thus, the present analysis uses data from over half of the whole maintenance management staff who will eventually complete the training. By September 1992 all of senior management had attended the course. The people remaining to complete the course are maintenance management personnel, mainly maintenance supervisors and assistant supervisors located in the company's three largest cities.

6.2.4 Maintenance Work Units as the Focus of the Analyses

The analyses described in this report illustrate the effect of changes in management attitudes upon the maintenance performance of their work-units. In order to achieve this examination of attitude correlations with performance, the individual manager's data are combined into averages for the units to which they belong. The maintenance performance data (classified into categories of "safety," "quality," "dependability," and "efficiency") are also constructed into measures for the same work units.

6.3 THE "CREW RESOURCE MGT/TECH OPS QUESTIONNAIRE" (CRM/TOQ)

6.3.1 Prior Experience in Measurement of Attitudes Related to CRM Training

The Cockpit Management Attitudes Questionnaire (CMAQ) has long been a recognized measure for assessing flight crew attitudes. It is useful as a training, evaluation and research tool (Helmreich et al., 1986). The CMAQ questionnaire contains 25 items measuring attitudes that are either conceptually or empirically related to CRM. Taggart (1990) revised the CMAQ for use in a maintenance department, and reported positive initial results following CRM training conducted for maintenance managers in late 1989.

Two recent studies involved the close analysis of the CMAQ instrument through the use of Factor Analysis, a technique to explore for a consistent internal structure (Gregorich, Helmreich, & Wilhelm, 1990; Sherman, 1992). In these studies the authors showed, for separate samples of flight crews and air traffic controllers, that the relationships among the 25 CMAQ items were clustered into the following four constellations of attitudes:

Sharing Command Responsibility
Value of Communication & Coordination
Recognizing Stressor Effects
Avoidance of Interpersonal Conflict.

Those authors combined the individual CMAQ items into the four composite indices to obtain more stable indicators of each concept. Such index scales permit a more detailed assessment of the separate but related attitudes than a single total score for the entire questionnaire. They also provide more accurate and reliable results than are available from each of the individual questionnaire items alone. Although Gregorich, et al. (1990) eventually reduced the set from four to three composites by dropping "Avoidance of Interpersonal Conflict," Sherman found a much more robust fourth factor, which he titled "Advocacy and Assertiveness."

6.3.2 Measurement of Attitudes in the Present Study

The "Crew Resources Management/Technical Operations Questionnaire" (CRM/TOQ) used in the present study is a modified version of Taggart's revised CMAQ. In obtaining a "good" measure of the complex concepts of CRM training, the present company's goal was to start with a proven survey shown to be valid with CRM training in the airline industry. In following the lead of the CMAQ, the CRM/TOQ is a short questionnaire with enough items to provide convergence to a smaller set of concepts.

The CRM/TOQ contains 26 multiple response items. The company's modifications of the CMAQ involved removing five questions and adding six others. The five questions were removed because they either lacked predictive validity as reported by earlier flight crew studies (Helmreich, et al., 1986) or, in the company's opinion, lacked relevance to maintenance.

A confirmatory Factor Analysis was undertaken for the data obtained with the CRM/TOQ in the present study (Taylor, 1991a). Results for the items drawn from the revised CMAQ were similar to those of Gregorich, et al. (1990) and Sherman (1992). As in the latter study, the CRM/TOQ's fourth composite was statistically strong, and was therefore retained as the reflected index "Willingness to Voice Disagreement."

Attitude change from pre-training to post-training using the CRM/TOQ was examined in the previous progress report (Galaxy Scientific Corporation, 1992). "Sharing Command Responsibility," "Communication & Coordination," and "Recognizing Stressor Effects," all increased significantly following training. "Willingness to Voice Disagreement" decreased (non-significantly) for the whole sample following training, but it rose significantly for the supervisors (the largest single group in the sample to that date) when they were viewed separately from assistant supervisors and directors.

Six questions were added to the CRM/TOQ, based on items intended to measure respondents' perceptions of behaviors dealing with attainment of work goals (Geirland & Cotter, 1990).

These six items were considered important to add because the work of maintenance managers differs from that of flight crew officers (as managers) in the typically longer time required for technical operation's goal attainment and the relatively greater ambiguity of those goals. In addition, because goal setting and attainment were not covered in the CRM training they could act as "control questions" which were not predicted to change in a consistent or positive way following the training. These items loaded onto two factors in the Factor Analysis: "Goal Attainment in Own Group" and "Goal Attainment with Other Groups." The goal attainment scales were not expected to change because goal attainment was not a topic covered in the training, and because there would not be time, during the training, to change the behaviors that were the focus of the measures. Similar to attitudes, these perceptions can be influenced by exposure to new information or by reconsidering initial assessments. These perceptions did change during the CRM training and they have proven to be also related to maintenance performance.

There are four versions of the CRM/TOQ questionnaire that have been used in various phases of this project. Although the first two versions are not part of the present analysis, they are described with the latter versions below.

1. A "Baseline Questionnaire" was mailed to all 1,800 maintenance managers, supervisors, and assistant supervisors in the company in May 1991 before the training was announced. The results of this baseline assessment of management attitudes were factor analyzed and were also used to assess the reliability and validity of the CRM/TOQ (Taylor, 1991a). The Baseline version will not be further discussed.

2. A "pre-training" questionnaire is completed by all participants in the first minutes of the workshop. Respondents place a confidential identification (I.D.) number or code on the questionnaire so that their responses can be compared with their responses on subsequent, follow up questionnaires. These pre-training attitudes have been compared with post-training attitudes to test the effects of the training (Galaxy Scientific Corporation, 1992). Further results using the pre-training questionnaire will not be discussed here.

3. A "post-training" questionnaire is completed by all participants at the workshop's conclusion. Respondents write their I.D. code on the questionnaire, and are asked to note the number in their course workbook to help them remember it for later "follow-up" questionnaires (see version 4 below). The training facilitators collect and mail the completed pre-training and post-training questionnaires to the University for processing. Data from this post-training version of the CRM/TOQ have been compared with the pre-training questionnaire data, as noted above. The present report will discuss responses from the post-training questionnaire and will compare these matched responses with the participants matched responses to version number 4, the "follow-up" questionnaires.

4. "Follow-up" questionnaires are individually mailed by the company to all past participants two, six, and twelve months following their CRM training. Respondents are asked to include their I.D. code so that these follow-up questionnaires can be matched with the earlier questionnaires and to return the questionnaires to the University for confidential

processing. Although the two, six, and twelve month follow-up surveys are all identical in form, they measure the respondents' thoughts, assessments, and attitudes over increasingly remote periods from the training.

6.3.3 Sample Size and Response Ratio

The following is the ratio of post-training and follow-up CRM/TOQ questionnaires processed by July 1992, to those distributed:

1,040 post-training questionnaires, (93%)
365 two-month follow-up questionnaires, (44%)
255 six-month follow-up questionnaires, (42%)
76 twelve-month follow-up questionnaires, (40%).

6.4 RESULTS SECTION 1: COMPARISON OF POST-TRAINING ATTITUDES WITH TWO-MONTH, SIX-MONTH, AND TWELVE MONTH FOLLOW-UP SURVEYS

Figures 6.1 and **6.2** present the comparisons for the four attitude scales and the two goal-attainment scales respectively using all the responses available without regard for matched responses. No significant differences were found among the post-training, two, six and twelve-month surveys. All four attitude scales and the two "Goal Attainment" measures remain high in the year following CRM training. The tests shown in **Figures 6.1** and **6.2**, in turn, have been compared with survey data which were *directly matched*, by individual respondent I.D. number, among the several follow-up questionnaires, and the results are remarkably similar. In this way, the potency of examining the responses from the same individuals matched over time, was combined with the power of the larger unmatched sample of responses for comparison.

6.4.1 Matched Questionnaires and Sample Size

For the remainder of the analyses in this report the results for the CRM/TOQ will be reported in terms of the largest number of **matched** individual responses available, i.e., those that can be matched by I.D. code number across the various surveys. The practical implication of this matching is that the total size of the matched sample is limited by the number of smallest wave of data. For example, by July 1992 (13 months after the onset of the training) there were 74 people who returned the twelve month follow-up questionnaire, 64 of whom included an I.D. number that could be matched to their earlier questionnaires. Any statistical tests of comparisons between post-training and twelve-month follow-up questionnaires would necessarily be based on that limiting twelve-month sample size of 64. Using, instead, only the two-month follow-up questionnaires, the number of respondents whose I.D. numbers matched to their post-training questionnaires could rise much higher.

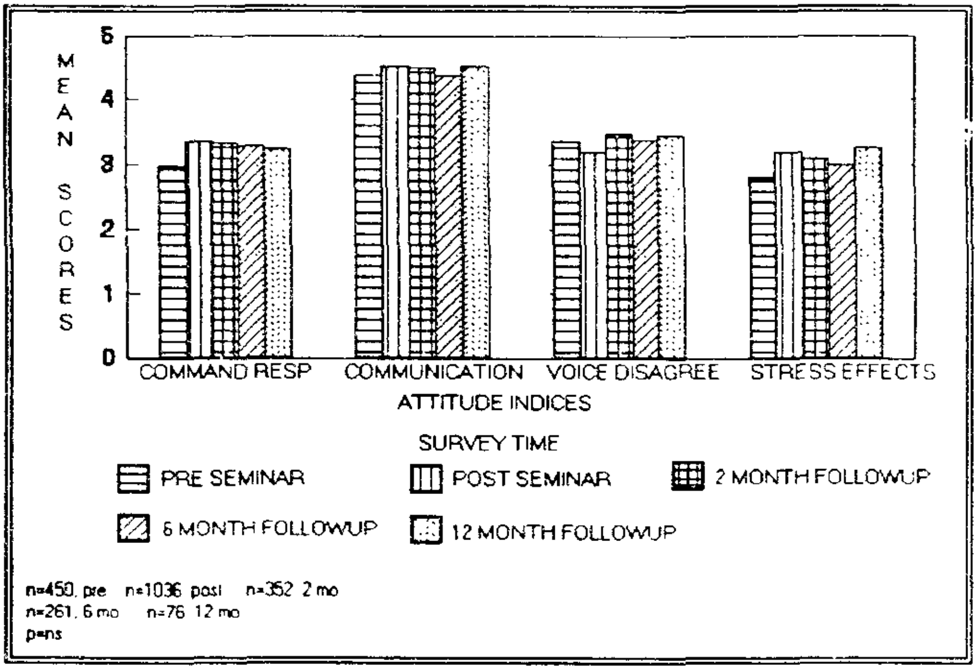

Figure 6.1 Attitude Indices Pre, Post, Two, Six, Twelve Months

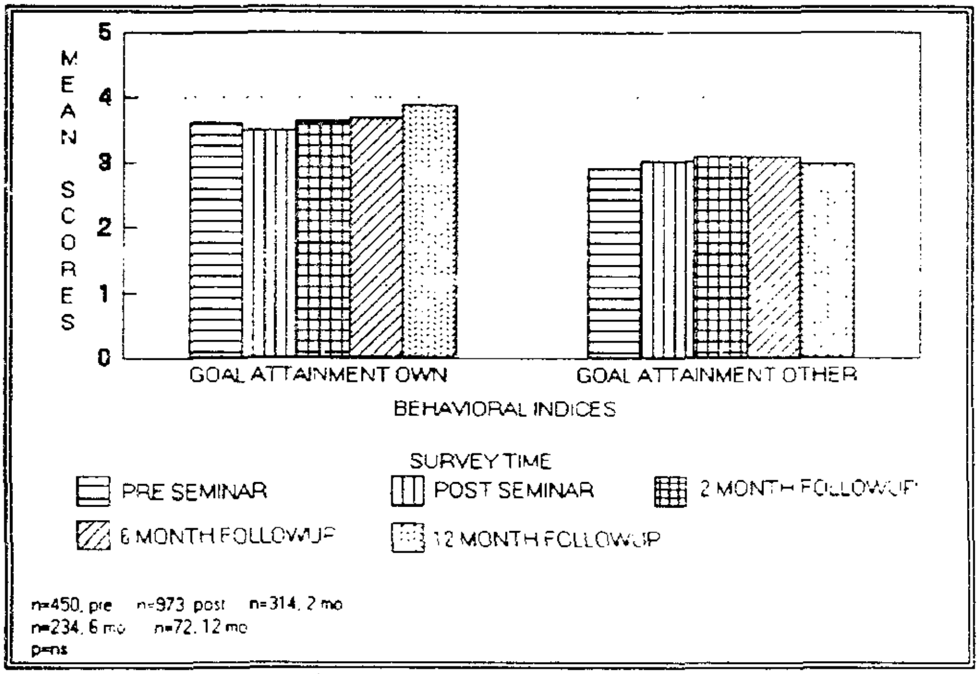

Figure 6.2 Behavioral Indices Pre, Post, Two, Six, Twelve Months

6.5 PERFORMANCE DATA DESCRIBED

Maintenance managers in the company already collect performance data in abundance. **Table 6.1** presents the eight measures used as end-result criteria in the present study. Three conditions were met in order to include these measures in the work-unit analysis reported here. First (and obviously), the performance measures need to be available by work unit (i.e., line station, shop, warehouse, etc.), and not just by department or function. Second, the measures must be ones that people in the work unit can affect by their actions, and not merely ones that are conveniently assigned to a unit, but for which it can do little. The third condition applied was that the measures not be directly related to (or completely determined by) other measures in the set. The eight performance measures used in the present analysis are included in the company's categories of "safety," "dependability," and "efficiency." The "quality" measures used by the company cannot at this time be applied to the specific maintenance units, so they are not included in this present analysis.

The trainers and administrators of the CRM course evaluated the performance measures and predicted which of them would be more sensitive to effects of CRM training. The results of their evaluation are footnoted in **Table 6.1**. Their conclusions were that five measures were the most readily improved by the training. These five performance measures included the two aircraft safety items ground damage and days lost to occupational injury, and dependability measures, based on departures within 5 and 15 minutes and delays due to maintenance error. Their second ranked performance measures likely to improve in response to training included the dependability of departures within 60 minutes and the efficiency of overtime paid. A performance indicator rated least likely to improve as a function of the training was departures later than 60 minutes.

6.5.1 Performance Measures and Attitudes

The present analysis examines the impact of pretraining performance on management attitudes, and those attitudes' lagged effects on the measures of concurrent and subsequent maintenance performance. We are focused mainly on the training's longer-term effects on attitudes, which are related to performance **following** the training **as well as occurring at the same time.** Therefore, the sample selected included as many matched responses to follow-up questionnaires as possible, yet left the months between January and July 1992, to permit a test of "lagged" performance effects.

Table 6.1 Technical Operations Performance Measures Available by Work Unit (maximum number of work units possible are in parentheses)

I. MEASURES OF EFFICIENCY

A. Cost

1. % Overtime paid to total wage bill[b] (60)

II. MEASURES OF SAFETY

B. Safety of Aircraft

2. Number of Ground Damage Incidents[a] (44)

C. Personal Safety

3. % Occupational Injury Days Lost[a] (60)

III. Measures of Dependability

D. Departure Performance (Line Station data only, n=31)

4. % Departure within 5 minutes[a]
5. % Departure within 15 minutes[a]
6. % Departure within 60 minutes[b]
7. % Departure over 60 minutes, but not canceled[c]
8. Number of Delays due to late from Maintenance[a] (n=35)

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a = Measures evaluated **most** sensitive to effects of CRM training
b = Measures evaluated **moderately** sensitive to effects of CRM training
c = Measures evaluated **least** sensitive to effects of CRM training

6.5.2 The Sample Used for the Present "Lagged Attitude-Performance Analysis"

By January 1, 1992, 570 of the 573 managers attending one of the CRM workshops had completed an immediate post-training questionnaire. Four-hundred four of those 570 managers were employed in one of the five maintenance-oriented departments in the Maintenance Division -- line maintenance, base maintenance, inspection, shops, and materials service. The data file containing the 404 maintenance managers was matched, by confidential identification number, to the file containing the 2-month follow-up questionnaires, 225 of which had been completed and returned. The total actually matched by I.D. number was 181. This sample represents the direct maintenance managers who attended the CRM workshop during June through December 1991 and who answered the two month follow-up questions. The sample provided the two-month time interval between measurements of attitudes and up to six months between measures of attitudes and performance. The demographic characteristics of this sample are presented in **Tables 6.2** and **6.3**, below. The tables show that this sample includes mainly line maintenance supervisors, who are in their 30's, male, many of whom have some college education.

Table 6.2 Demographics of CRM Managers Attendees (June-December, 1991) Matched with Their Two Month Follow-up Survey (n=181), Categorical Percentages

Job Title	Assistant Supervisor	Super-visor	Manager	Director	Engineer	Co-ordinator	Quality Assurance
	29%	47%	17%	2%	1%	1%	3%
Dept.	Line	Base	Quality	Shop	Material		
	54%	10%	12%	11%	13%		
Total Years Working at the Company	2-6 yrs	7-10 yrs	11-17 yrs	21-25 yrs	26-48 yrs		
	52%	20%	7%	8%	13%		
Years Working in Present Position	0-5 yrs	6-10 yrs	11-20 yrs	21-30 yrs	31-45 yrs		
	79%	10%	3%	6%	2%		
Years Working with Other Airlines	0-5 yrs	6-10 yrs	11-15 yrs	16-25 yrs	26-35 yrs		
	68%	7%	8%	13%	4%		

Table 6.3 Demographics of CRM Managers Attendees (June-December, 1991) Matched with Their Two Month Follow-up Survey (n=181), Categorical Percentages

Age	20-29 yrs	30-39 yrs	40-49 yrs	50-60 yrs	61-70 yrs
	6%	42%	23%	21%	8%
Sex	Male	Female			
	98%	2%			
Years in Military	0-5 yrs	6-10 yrs	11-20 yrs	21-30 yrs	
	93%	3%	1%	3%	
Years in Trade School	0-1.5 yrs	2-4 yrs	5-10 yrs	15-20 yrs	
	55%	41%	4%	01%	
Years in College	0-1.5 yrs	2-3.5 yrs	4-5 yrs	6-7 yrs	
	52%	31%	17%	.01%	
Company	Company 1	Company 2			
	99%	1%			

6.6 RESULTS SECTION 2: TESTING RELATIONSHIPS OF POST-TRAINING ATTITUDES WITH PERFORMANCE

The first associations examined here are among post-training attitudes measured at the end of each training session and maintenance performance for seven combined two-month intervals (Jun/Jul'91; Aug/Sept'91; Oct/Nov'91; Dec'91/Jan'92; Feb/Mar'92; Apr/May'92; Jun/Jul'92). Performance measures are analyzed for the periods prior to and concurrent with the training (Jun-Dec'91), and two, four and six months following training (Jan-July '92). The individual months of performance are combined into two-month increments to improve the distribution characteristics.

The distributions of the performance measures require that non-parametric statistical tests be used for optimal analytic power (cf., Taylor, 1991b). Therefore, the relationships between the attitude indices and the performance measures are indicated by the Spearman Rank-order Correlation ("Rho"), as presented in **Tables 6.4-6.11**.

6.6.1 The Relationships Between the Post-Training Questionnaire Scales and Maintenance Unit Performance Measures

The overtime performance measure described here was rated by the trainers as only moderately likely to improve as a result of the training. We will start with that one, to explain the way these tables are set up and to provide a contrast with the more interesting and/or consistent results in the remaining tables.

6.6.1.1 "Percent of Overtime to Total Wages"

The six rows of **Table 6.4** are comprised of the four attitude scales and the two goal-attainment scales. The seven columns represent performance in overtime costs for seven different time periods. Jun/Jul, Aug/Sept, and Oct/Nov 1991 represent the concurrent performance, while Dec/Jan, Feb/Mar, Apr/May, and Jun/Jul 1992 represent performance following training. The cell entries in **Table 6.4** are Rho coefficients testing the degree of relationship between the six questionnaire scales and the overtime measure at the seven different times. The calculations are derived from work-groups. Even a large company like this one has only 60 work units in maintenance that report overtime used. **Table 6.4** shows that 39 of those 60 work units were included in this analysis. The missing ones were dropped for a variety of reasons, including the fact that less than one third of all the managers had been through the training by January 1992.

There is only one statistically significant relationship and no consistent pattern of results in **Table 6.4**, as there are <u>negative relationships</u> as well as positive ones. In fact, this efficiency measure of labor costs was rated by the trainers to be less influenced by the training than would be other performance measures. Thus, this table is essentially an example of an absence of training effect.

Table 6.4 Spearman-Rho Correlations between Post-training CRM/TOQ Results and Maintenance Efficiency Performance for % Overtime Paid to Total Wagebill[1]

	Jun/Jul 1991	Aug/ Sep	Oct/ Nov	Dec/ Jan	Feb/ Mar	Apr/ May	Jun/Jul 1991
Sharing Command Responsibility	-.12	.05	-.15	-.06	-.05	-.10	-.06
Communication and Coordination	-.03	-.08	-.03	.19	-.16	-.07	.04
Recognition of Stressor Effects	.16	-.10	.09	.08	-.24	-.03	.02
Willingness to Voice Disagreement	-.10	00	.04	.11	-.12	-.12	**-.37***
Goal Attainment with Own Group	.11	.02	-.08	.16	-.01	.03	.05
Goal Attainment with Other Groups	.03	-.02	-.23	.12	-.12	.01	.14

n = 39 Shaded area are months concurrent with the training (and the measurement) and unshaded area are the months following training
Note: These items score lower when performance is positive, thus the direction of the statistics should be negative
* $p < .05$ ** $p < .01$

6.6.1.2 "Number of Ground Damage Incidents"

In **Table 6.5** the safety measure of Ground Damage incidents shows one significant association, in the expected direction, between assertiveness ("Willingness to Voice Disagreement") in one period following training. This result, taken with the others in the same row displaying the same direction of relationship, suggests that people intervene and speak up more when aircraft may be damaged in those groups with higher scores for this attitude. There are two other significant relationships in the expected direction between the goal attainment scales and concurrent ground damage performance.

Table 6.5 Spearman-Rho Correlations between Post-training CRM/TOQ Results and Maintenance Safety Performance for Ground Damage[1]

	Jun/Jul 1991	Aug/ Sep	Oct/ Nov	Dec/ Jan	Feb/ Mar	Apr/ May	Jun/Jul 1992
Sharing Command Responsibility	.14	.07	.13	-.21	-.30	-.16	-.23
Communication and Coordination	-.06	-.07	-.06	.12	-.14	.06	-.01
Recognition of Stressor Effects	.28	.30	.26	.13	.04	-.14	-.10
Willingness to Voice Disagreement	-.22	-.20	-.26	-.19	**-.38***	-.14	-.31
Goal Attainment with Own Group	-.22	-.11	**-.38***	-.22	-.09	-.11	.00
Goal Attainment with Other Groups	-.36	**-.42***	-.22	-.20	-.21	-.16	-.07

n = 21 Shaded area are months concurrent with the training (and the measurement) and unshaded area are the months following training
Note These items score lower when performance is positive thus the direction of the statistics should be negative
* $p < .05$ ** $p < .01$

6.6.1.3. "Occupational Injury Days Lost"

"Occupational Injury Days Lost" is the second safety-related performance indicator to be examined. **Table 6.6** shows the pattern of results indicating that the two goal attainment scales account for most of the significant differences in performance. Occupational injury rates are consistently lower, both concurrently with training and subsequent to it, in work units where managers and supervisors believe that team goals are shared within their units, and between them. Although goal attainment shows a strong association with this performance, it is not a specific management value addressed by the CRM training. Of the attitude improvements intended to be affected by the training, Willingness to Voice Disagreement is again significantly related to later safety performance. Other post-training attitudes don't show much uniformity of pattern in relationships with this performance indicator.

Table 6.6 Spearman-Rho Correlations between Post-training CRM/TOQ Results and Maintenance Safety performance for Occupational Injury Days Lost[1]

	Jun/Jul 1991	Aug/ Sep	Oct/ Nov	Dec/ Jan	Feb/ Mar	Apr/ May	Jun/Jul 1992
Sharing Command Responsibility	-.09	-.14	.09	-.13	-.03	.03	-.10
Communication and Coordination	-.24	-.25	-.20	.06	-.13	-.09	-.13
Recognition of Stressor Effects	-.02	.07	-.03	.20	-.18	.05	-.17
Willingness to Voice Disagreement	-.03	-.02	-.25	.04	-.10	-.10	-.28*
Goal Attainment with Own Group	.10	-.20	-.32*	-.20	-.30*	-.14	-.41**
Goal Attainment with Other Groups	.06	-.14	-.30*	-.16	-.50**	-.20	-.34**

n = 42 Shaded area are months concurrent with the training (and the measurement) and unshaded area are the months following training.
[1]Note. These items score lower when performance is positive, thus the direction of the statistics should be negative.
* $p < .05$, ** $p < .01$

6.6.1.4 "Aircraft Departures Within Five Minutes of Schedule"

This dependability measure involves only the line maintenance stations. **Table 6.7** contains 27 data points. One relationship between concurrent, on-time performance and sharing command responsibility is significant. Several concurrent and subsequent measures of departures within 5 minutes are related to communication and to recognition of stressor effects. This is not surprising, as managers of large line stations, during the busiest hours, must relinquish moment-to-moment decisions or they will slow things down. Likewise, they must ensure communication among everyone involved and recognize that the adverse consequences of stress are also related to dependable performance. Work in line stations creates some of the highest levels of work-related stress in maintenance. Relationships in **Table 6.7** signify that there are differences in management attitudes toward sharing their power, communicating, and managing stress such that the more these attitudes improve, the more the on-time departures.

With respect to the pattern of results for all of **Table 6.7**, the proportion of significant and directional relationships between six immediate post-training attitudes and the seven maintenance performance measures, to the total number of tests conducted, is substantially better than that expected by chance alone. Eight Spearman "Rhos" of the 42 total were significant p.05 (8/42 = 19% > 5%), and three of those were significant p<.01 (3/42 = 7% > 1%).

Table 6.7 Spearman-Rho Correlations between Post-training CRM/TOQ Results and Maintenance Dependability Performance for Departures within Five Minutes

	Jun/Jul 1991	Aug/ Sep	Oct/ Nov	Dec/ Jan	Feb/ Mar	Apr/ May	Jun/Jul 1992
Sharing Command Responsibility	.20	.17	.36*	.28	.19	.00	,24
Communication and Coordination	.36*	.24	-.05	.35*	.41**	.26	.09
Recognition of Stressor Effects	.32*	.25	.25	.36*	.41**	.23	.15
Willingness to Voice Disagreement	.28	.17	.17	.15	.25	.19	.13
Goal Attainment with Own Group	.25	.15	.06	.28	.45**	.26	.28
***Goal Attainment* with Other Groups**	.21	.08	.01	.13	.35	.23	.01

n = 27 Shaded area are months concurrent with the training (and the measurement) and unshaded area are the months following training
* p< .05, ** p< .01

Tables 6.8 through **6.11** present relationships between the six questionnaire items and further measures of dependability.

6.6.1.5 "Departures Within Fifteen Minutes"

Table 6.8 shows that command responsibility, communication & coordination, and assertiveness are all significantly and positively related to departures within 15 minutes of schedule during the period concurrent with the training. The two goal attainment scales are related to this performance measure subsequent to the training.

Table 6.8 Spearman-Rho Correlations between Post-training CRM/TOQ Results and Maintenance Dependability Performance for Departures within Fifteen Minutes

	Jun/Jul 1991	Aug/ Sep	Oct/ Nov	Dec/ Jan	Feb/ Mar	Apr/ May	Jun/Jul 1992
Sharing Command Responsibility	.23	.20	.42**	.29	.18	.06	.29
Communication and Coordination	.36*	.21	-.05	.18	.23	.19	.03
Recognition of Stressor Effects	.24	.15	.18	.29	.29	.15	.16
Willingness to Voice Disagreement	.36*	.09	.08	.17	.23	.08	.17
Goal Attainment with Own Group	.21	.10	.06	.36*	.48**	.07	.31
Goal Attainment with Other Groups	.31	.11	.06	.19	.36*	.17	.04

n = 26 Shaded area are months concurrent with the training (and the measurement) and unshaded area are the months following training

* p < .05, ** p < .01

6.6.1.6 Departures Within Sixty Minutes"

Table 6.9 displays only two significant relationships to departures within 60 minutes. This performance measure was one of those the trainers felt would be only moderately sensitive to training effects. In fact the two significant relationships represent a proportion we could expect by chance alone (2/42 = 5%).

Table 6.9 Spearman-Rho Correlations between Post-training CRM/TOQ Results and Maintenance Dependability Performance for Departures within Sixty Minutes

	Jun/Jul 1991	Aug/ Sep	Oct/ Nov	Dec/ Jan	Feb/ Mar	Apr/ May	Jun/Jul 1992
Sharing Command Responsibility	.17	.22	.30	.16	.11	-.14	.14
Communication and Coordination	.33*	.07	-.02	.25	.09	.06	.21
Recognition of Stressor Effects	.45**	.22	.17	.07	-.01	.11	.06
Willingness to Voice Disagreement	.21	.13	.05	-.04	.02	-.05	.09
Goal Attainment with Own Group	.06	.08	-.14	.14	.07	-.08	.02
Goal Attainment with Other Groups	.19	-.06	-.09	.26	.32	-.09	-.01

n = 27 Shaded area are months concurrent with the training (and the measurement) and unshaded area are the months following training

* p < .05, ** p < .01

6.6.1.7 "Departures Over Sixty Minutes, Not Canceled"

The measure, "departures over 60 minutes, but not canceled," (**Table 6.10**) is one that the trainers felt would be least sensitive to training effects. Although **Table 6.10** shows three significant positive correlations (only slightly above a chance expectation for the table overall), it also contains one significant negative relationship (opposite to that expected). Given the absence of any pattern to the relationships in **Table 6.10**, we may conclude that post-training attitudes and perceptions do not have an effect on this performance.

Table 6.10 Spearman-Rho Correlations between Post-training CRM/TOQ Results and Maintenance Dependability Performance for Sixty Minutes, Not Canceled

	Jun/Jul 1991	Aug/ Sep	Oct/ Nov	Dec/ Jan	Feb/ Mar	Apr/ May	Jun/Jul 1992
Sharing Command Responsibility	.03	-.04	-.20	.05	.00	-.19	.36
Communication and Coordination	(-.44**)	-.11	.39*	.00	.00	.24	.16
Recognition of Stressor Effects	-.25	-.21	.40*	-.19	.00	-.25	.39
Willingness to Voice Disagreement	.06	.03	-.30	-.03	-.30	-.20	.30
Goal Attainment with Own Group	-.19	-.03	.02	.19	-.26	.08	.25
Goal Attainment with Other Groups	-.29	.17	.13	.04	-.27	.47**	.28

n = 27 Shaded area are months concurrent with the training (and the measurement) and unshaded area are the months following training

* $p < .05$, ** $p < .01$

6.6.1.8 "Delay Due to Late from Maintenance"

Table 6.11 presents relationships between post-training questionnaire responses and delays due to late from maintenance. This is a measure of the number of aircraft, either scheduled to remain in station overnight (RON) or on the ground (AOG) for repair, which are not ready for morning flights. "Communication & Coordination" is significantly correlated and in the expected direction with this performance measure concurrently with training and subsequent to it. These results indicate that as more managers communicate and coordinate among themselves and with mechanics, the lower the number of delays due to the aircraft being late from maintenance.

Table 6.11 Spearman-Rho Correlations between Post-training CRM/TOQ Results and Maintenance Dependability Performance for Delay Due to Late from Maintenance[1]

	Jun/Jul 1991	Aug/ Sep	Oct/ Nov	Dec/ Jan	Feb/ Mar	Apr/ May	Jun/Jul 1992
Sharing Command Responsibility	-.15	-.37*	-.27	-.12	-.33*	-.17	-.28
Communication and Coordination	-.38*	-.48**	-.52**	-.40*	-.37*	-.37*	-.24
Recognition of Stressor Effects	-.09	-.23	-.20	-.30	-.21	-.14	-.40*
Willingness to Voice Disagreement	-.16	-.22	-.20	-.18	-.16	-.11	-.20
Goal Attainment with Own Group	-.16	-.22	-.20	-.18	-.16	-.11	-.20
Goal Attainment with Other Groups	.08	-.22	-.12	-.39*	-.27	-.09	-.13

n = 18. Shaded area are months concurrent with the training (and the measurement); and unshaded area are the months following training.
[1]Note: These items score lower when performance is positive thus the direction of the statistics should be negative.
* $p < .05$, ** $p < .01$

6.7 RESULTS SECTION 3: THE RELATIONSHIPS BETWEEN THE TWO-MONTH FOLLOW-UP QUESTIONNAIRE SCALES AND MAINTENANCE UNIT PERFORMANCE MEASURES

The same eight performance measures are examined again, using the matched group of maintenance managers' two month follow-up questionnaires. Although **Tables 6.12** through **6.19** are arranged in the same manner as **Tables 6.4** through **6.11** above, they differ in the performance periods preceding, concurrent with, and subsequent to the survey. Because the follow-up surveys (for the present sample) took place between October 1991 and February 1992, the first two performance periods (Jun/Jul, Aug/Sept'91) are "pre-survey," Oct'91-Mar'92 are "concurrent" with the survey, and Apr-Jul'92 are subsequent to the training. As in the preceding section the performance measures will be examined for "Efficiency," "Safety" and "Dependability," respectively.

6.7.1 "Overtime Paid to Total Wages"

Table 6.12 shows a similar absence of results for two-month follow-up attitudes as those presented above for post-training attitudes and overtime performance. Only one significant relationship is noted in **Table 6.12**, between recognition of stressor effects and June/July 1992 overtime. In fact, the trainers had rated overtime as only moderately sensitive to the training effects. A more powerful impact on overtime may originate from upper management policy and dictum. Using the data from both **Tables 6.4** and **6.12**, that assumption seems substantiated.

Table 6.12 Spearman-Rho Correlations between Two Month Follow-up CRM/TOQ Results and Maintenance Efficiency Performance % Overtime Paid to Total Wage[1]

	Jun/Jul 1991	Aug/ Sep	Oct/ Nov	Dec/ Jan	Feb/ Mar	Apr/ May	Jun/Jul 1992
Sharing Command Responsibility	.00	.00	.03	-.06	.09	-.07	-.12
Communication and Coordination	-.09	-.16	-.01	-.09	-.19	-.11	.07
Recognition of Stressor Effects	.09	.21	.25	-.02	-.21	-.12	-.38*
Willingness to Voice Disagreement	-.15	-.09	-.07	-.13	.09	-.18	-.15
Goal Attainment with Own Group	-.03	-.07	-.05	-.09	.00	.03	.30
Goal Attainment with Other Groups	-.11	-.14	-.17	-.19	-.15	-.21	.20

n = 32. Shaded area are months concurrent with the two month follow-up survey for the sample of training participants examined.
[1]Note: These items score lower when performance is positive, thus the direction of the statistics should be negative.
* $p < .05$, ** $p < .01$

6.7.2 "Number of Ground Damage Incidents"

This safety measure in **Table 6.13** shows ten significant associations, in the expected direction, between "Recognition of Stressor Effects," "Sharing Command Responsibility," and goal attainment, after the CRM training, but concurrent with the two month follow-up survey. Recognition of the effect of stressors on decision making is also related to the performance prior to the two month follow-up questionnaire, as are the two goal attainment scales.

Table 6.13 Spearman-Rho Correlations between Two Month Follow-up CRM/TOQ Results and Maintenance Safety Performance for Ground Damage[1]

	Jun/Jul 1991	Aug/ Sep	Oct/ Nov	Dec/ Jan	Feb/ Mar	Apr/ May	Jun/Jul 1992
Sharing Command Responsibility	-.22	-.25	-.03	-.10	-.44*	-.19	-.16
Communication and Coordination	-.37	-.21	-.16	.09	-.27	-.37	-.26
Recognition of Stressor Effects	.13	-.47*	-.18	-.49*	-.43*	-.26	-.11
Willingness to Voice Disagreement	.05	-.04	.19	-.05	-.18	-.30	-.00
Goal Attainment with Own Group	-.10	-.53**	-.28	-.46*	-.45*	-.22	-.37
Goal Attainment with Other Groups	-.23	-.62**	-.18	.43*	-.44*	-.01	-0.4

n = 18. Shaded area are months concurrent with the two month follow-up survey for the sample of training participants examined.
[1]Note: These items score lower when performance is positive, thus the direction of the statistics should be negative
* $p < .05$, ** $p < .01$

6.7.3 "Occupational Injury Days Lost"

Only three significant relationships are seen in **Table 6.14**, which is only barely above chance probability. "Willingness to Voice Disagreement" is correlated with this performance, both before and after the survey period. One of the goal attainment scales is also significantly correlated with this safety-related performance indicator.

Table 6.14 Spearman-Rho Correlations between Two Month Follow-up CRM/TOQ Results and Maintenance Safety Performance for Occupational Injury[1]

	Jun/Jul 1991	Aug/ Sep	Oct/ Nov	Dec/ Jan	Feb/ Mar	Apr/ May	Jun/Jul 1992
Sharing Command Responsibility	.06	.08	.17	.29	.18	.07	.03
Communication and Coordination	-.04	-.15	-.27	.16	.17	.05	-.22
Recognition of Stressor Effects	.03	.02	.07	.29	-.18	-.08	-.19
Willingness to Voice Disagreement	-.38*	-.12	-.13	.09	-.14	-.42**	-.17
Goal Attainment with Own Group	-.06	-.20	-.17	.00	.00	-.07	.04
Goal Attainment with Other Groups	-.10	-.15	-.33*	-.04	-.18	-.09	.01

n = 28. Shaded areas are months concurrent with the two month follow-up survey for the sample of training participants examined.
[1]Note: These items score lower when performance is positive, thus the direction of the statistics should be negative.
* $p < .05$, ** $p < .01$

6.7.4 "Departures within Five Minutes"

This pattern of results for departures within 5 minutes in **Table 6.15** differs from that shown for the immediate post-training survey. This two-month follow-up shows "Sharing Command Responsibility" is still positively related to 5 minute departures. The relationship between departures within 5 minutes and both assertiveness and goal attainment within ones' own group, though, is much more sustained over time. There is very clearly an effect of assertiveness ("Willingness to Voice Disagreement") and goal attainment within work units, upon on-time departures.

6.7.5 "Departures within Fifteen Minutes"

Table 6.16 Departures within 15 minutes shows the same pattern of results as departures within 5 minutes. That is, command responsibility, assertiveness, and shared goals within the group are positively and significantly related to this "dependability."

Table 6.15 Spearman-Rho Correlations between Two Month Follow-up CRM/TOQ Results and Maintenance Dependability Performance for Departures within Five Minutes

	Jun/Jul 1991	Aug/ Sep	Oct/ Nov	Dec/ Jan	Feb/ Mar	Apr/ May	Jun/Jul 1992
Sharing Command Responsibility	**.54****	.27	.30	.28	.14	**.49***	.40
Communication and Coordination	-.06	-.18	-.16	.10	-.08	-.21	-.02
Recognition of Stressor Effects	.33	.17	.11	.19	-.04	.27	.26
Willingness to Voice Disagreement	**.64****	**.69****	**.69****	**.62****	**.57****	**.69****	**.55****
Goal Attainment with Own Group	**.43***	.53	**.51***	**.65****	**.64****	.32	**.49***
Goal Attainment with Other Groups	-.03	.10	.20	.25	.21	.04	.24

n = 17 Shaded area are months concurrent with the two month follow-up survey for the sample of training participants examined.
* $p < .05$, ** $p < .01$

Table 6.16 Spearman-Rho Correlations between Two Month Follow-up CRM/TOQ Results and Maintenance Dependability Performance for Departures within Fifteen Minutes

	Jun/Jul 1991	Aug/ Sep	Oct/ Nov	Dec/ Jan	Feb/ Mar	Apr/ May	Jun/Jul 1992
Sharing Command Responsibility	**.42***	.21	.34	.23	.05	**.45***	.34
Communication and Coordination	.31	-.23	-.17	.00	.10	-.30	.11
Recognition of Stressor Effects	.31	.13	.21	.19	-.07	.10	.33
Willingness to Voice Disagreement	**.62****	**.65****	**.74****	**.57****	**.46***	**.70****	**.47***
Goal Attainment with Own Group	**.42***	**.52***	**.51***	**.62****	**.57****	.31	**.48***
Goal Attainment with Other Groups	.01	.12	.19	.24	.25	.07	.32

n = 17. Shaded area are months concurrent with the two month follow-up survey for the sample of training participants examined
* $p < .05$, ** $p < .01$

6.7.6 "Departures within Sixty Minutes"

Similar to the other dependability measures, departures within 60 minutes continues to show significant positive correlations with command responsibility and assertiveness as shown in **Table 6.17**. Shared goals, however, is no longer strongly associated with dependability performance. In addition, the communication & coordination scale shows a significant <u>negative</u> relationship with 60 minute departures following the survey, that is, favorable attitudes toward communication and coordination two-months after training, are correlated with poor 60 minute departure performance.

Table 6.17 Spearman-Rho Correlations between Two Month Follow-up CRM/TOQ Results and Maintenance Dependability Performance for Departures within Sixty Minutes

	Jun/Jul 1991	Aug/ Sep	Oct/ Nov	Dec/ Jan	Feb/ Mar	Apr/ May	Jun/Jul 1992
Sharing Command Responsibility	.46*	.23	.40	.31	-.14	.61**	.36
Communication and Coordination	-.25	-.16	-.27	-.23	-.26	-.53*	.16
Recognition of Stressor Effects	.35	.22	.21	.11	-.33	.03	.39
Willingness to Voice Disagreement	.56**	.53*	.70**	.43*	.26	.58**	.31
Goal Attainment with Own Group	.38	.37	.23	.40	.43	-.13	.25
Goal Attainment with Other Groups	-.10	.07	.02	.10	.41	-.36	.28

n = 17. Shaded area are months concurrent with the two month follow-up survey for the sample of training participants examined.
* $p < .05$, ** $p < .01$

6.7.7 "Flight departures not Canceled, but over Sixty Minutes Late"

The pattern is consistent <u>and negative</u> for sharing command responsibility depicted in **Table 6.18**. Anecdotal evidence suggests that the maintenance control department often directs line maintenance to hold an aircraft and its passengers and to require periodic updates of departure times, resulting in delays of over an hour. This protracted and indirect arrangement for holding a flight causes local maintenance employees and managers to feel impotent, and probably obliged to provide unrealistic departure time estimates regardless of their ability to do so. The negative, largely concurrent, relationships in **Table 6.18** suggest that as more aircraft are held over one hour in an attempt to repair them, line station management feel that command responsibility is not shared; rather, it is usurped by others.

Table 6.18 Spearman-Rho Correlations between Two Month Follow-up CRM/TOQ Results and Maintenance Dependability Performance for Departures within Sixty Minutes, Not Canceled

	Jun/Jul 1991	Aug/ Sep	Oct/ Nov	Dec/ Jan	Feb/ Mar	Apr/ May	Jun/Jul 1992
Sharing Command Responsibility	(-.64**)	-.21	.00	(-.44*)	(-.55**)	(-.57**)	.36
Communication and Coordination	.24	-.06	-.05	.34	.31	.29	.16
Recognition of Stressor Effects	-.31	.09	.12	-.33	-.30	-.32	.39
Willingness to Voice Disagreement	-.14	-.30	-.02	-.17	-.31	-.40	.31
Goal Attainment with Own Group	.07	-.18	-.19	.08	-.01	-.09	.25
Goal Attainment with Other Groups	.23	-.10	.05	.23	.04	.37	.28

n = 17. Shaded area are months concurrent with the two month follow-up survey for the sample of training participants examined
* p < .05. ** p < .01

6.7.8 "Flights Delayed Due to Late from Maintenance"

Like its counterpart (**Table 6.11**) for the immediate post-training questionnaire data, **Table 6.19** shows a pattern of significant correlations in the expected directions. Differences between the two, however, are revealed in an increase in effect of "Recognition of Stressors" for this follow-up measure, and the disappearance of any effect of follow-up "Communication & Coordination" with this dependability indicator. "Goal Attainment with Own Group" measured two months after training is also significantly correlated with this performance index.

6.7.9 A Note on the Different Patterns

The patterns of relationships with maintenance performance between the post-training surveys and the two-month follow-up questionnaires for this same sample are different. These differences have been noted, but they require some explanation. Whereas the post-training survey represents virtually all the CRM training participants in 1991, the two-month survey was returned by approximately 55% of participants, and I.D. codes could be matched with the post-training set for about 80% of those. Although this is a very good return for such surveys, it is nonetheless limited. Examination of the demographic characteristics of the two-month follow-up sample reported here shows that some station (city) locations are over-represented, and some occupations and hierarchical levels are under-represented whereas others are over-represented. In particular the proportion of assistant maintenance supervisors for several large cities is lower for the two-month follow-up than for the post-training questionnaire. These proportions, in turn, contribute to the differences in the work unit mean scores on the "assertiveness" and "command responsibility" scales between the two surveys.

Table 6.19 Spearman-Rho Correlations between Two Month Follow-up CRM/TOQ Results and Maintenance Dependability Performance for Delays Due to Late from Maintenance[1]

	Jun/Jul 1991	Aug/ Sep	Oct/ Nov	Dec/ Jan	Feb/ Mar	Apr/ May	Jun/Jul 1992
Sharing Command Responsibility	-.61**	-.25	-.58	-.22	-.18	-.47	-.44*
Communication and Coordination	-.05	-.01	-.09	-.39	-.09	.00	-.30
Recognition of Stressor Effects	-.56**	-.38	-.39	-.33	-.27	-.65**	-.45*
Willingness to Voice Disagreement	-.33	-.40*	-.23	.08	-.20	-.43	-.13
Goal Attainment with Own Group	-.57**	-.59**	-.62**	-.40	-.55	-.27	-.45*
Goal Attainment with Other Groups	-.19	-.31	-.49*	-.24	-.40	-.20	-.30

n = 18. Shaded area are months concurrent with the two month follow-up survey for the sample of training participants examined
[1]Note. This performance item scores lower when performance is positive, thus the direction of the statistics should be negative
* $p < .05$. ** $p < .01$

6.8 RESULTS SECTION 4: TRENDS IN MAINTENANCE PERFORMANCE TWELVE MONTHS BEFORE AND TWELVE MONTHS AFTER THE ONSET OF CRM TRAINING

To study the trends in the eight maintenance performance indicators 12 months before and 12 months after the commencement of the CRM training, comparisons are presented here. There are two trend lines in each of the **Figures 6.3** through **6.10**. Each figure presents one of the eight performance indicators. One line in each figure estimates the trend for the 12 months preceding CRM training and the other line shows the trend after the onset of training. The discussion below will focus on the post-training trends for the performance categories of efficiency, safety and dependability.

6.8.1 Efficiency

6.8.1.1 Overtime Wages Paid

One trend analysis was conducted for efficiency concerning the performance measure of overtime. **Figure 6.3** shows that the trend of overtime expenses for the 12 months following

June 1991 (the onset of the CRM training) improves at a faster rate than it had in the 12 months preceding. Improved cost performance appears coincident with the training, and may be affected by it.

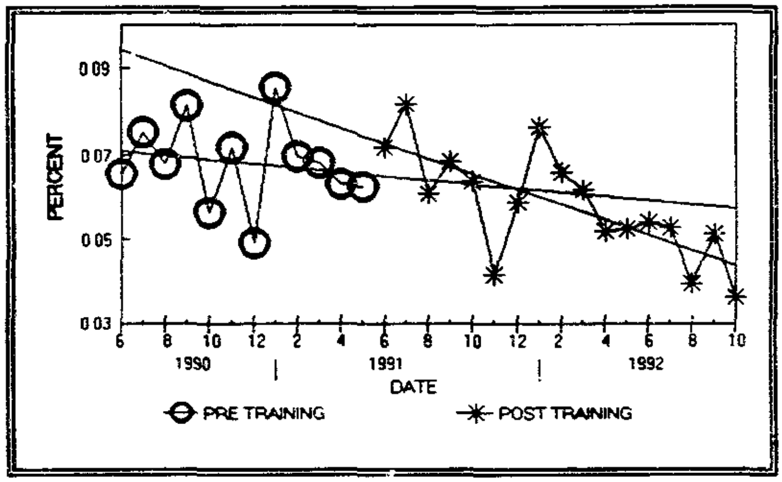

Figure 6.3 Efficiency Overtime (Time Series)

6.8.2 Safety

Two trend analyses were performed for the safety performance measure consisting of ground damage and occupational injury. These are shown in **Figures 6.4** and **6.5**.

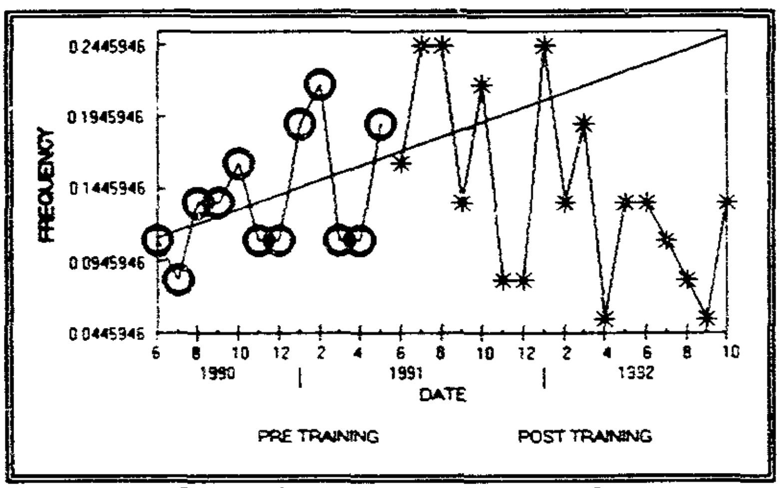

Figure 6.4 Safety Ground Damage (Time Series)

6.8.2.1 Number of Ground Damage Incidents

Figure 6.4 shows a clear reversal of trends for the number of ground damage incidents, in the year before and the year after June 1991. Reduced ground damage incidents is clearly related in time to the CRM training.

6.8.2.2 Occupational Injury Rates

Occupational injury rates, shown in **Figure 6.5**, already show a sharp decline in the year preceding the training, but the injury rates remain low during the following year. The training may have some effect on keeping these rates low.

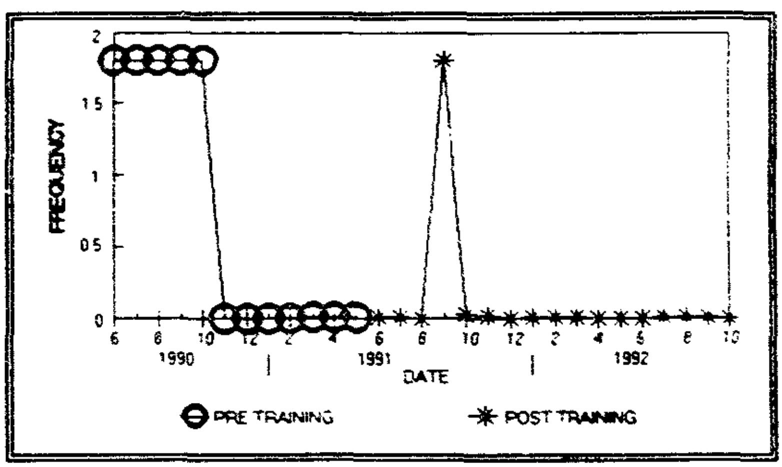

Figure 6.5 Safety Occupational Injury (Time Series)

6.8.3 Dependability

Five trend analyses were conducted for the dependability performance measures regarding departure times and delays due to maintenance. These are shown in **Figures 6.6-6.10**.

6.8.3.1 "Departures within Five Minutes of Schedule"

Figure 6.6 shows a slightly higher level of performance, overall, in the post-training year, but the performance was trending up in the year preceding the training. The apparent effect of the CRM training on 5 minute performance overall is to maintain pretraining performance levels.

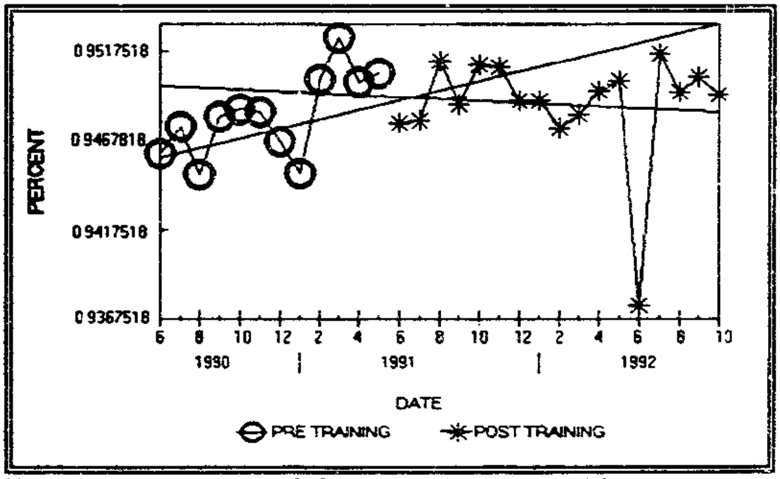

Figure 6.6 Dependability Departure in 5 Minutes (Time Series)

6.8.3.2 "Departures within Fifteen Minutes of Schedule"

The pattern in **Figure 6.7** shows a similar trend to departures within 5 minutes. That is, performance improves (the trend is up) in the year preceding the onset of CRM training, and that performance remains high and stable in the year following. Like departures within 5 minutes, the overall effect of the CRM training on 15 minute performance is cloudy, although results from the follow-up survey demonstrates the relationship between assertiveness and dependability (cf., **Tables 6.15-6.16**).

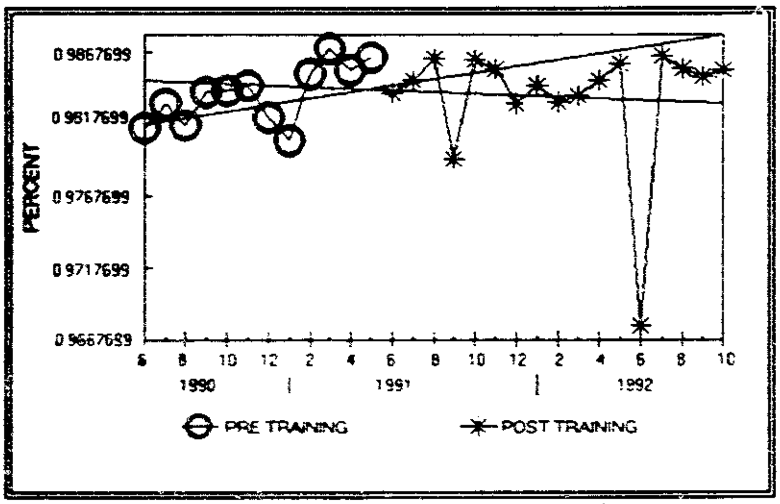

Figure 6.7 Dependability Departure in 15 Minutes (Time Series)

6.8.3.3 "Departures within Sixty Minutes of Schedule"

In **Figure 6.8**, the performance remains the same (quite undifferentiated) between the year preceding and the year following the onset of CRM training. The training appears to have no impact on this performance.

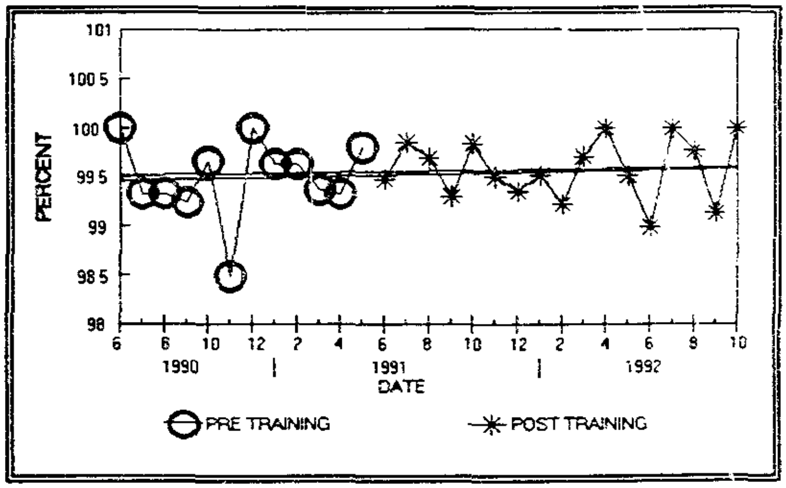

Figure 6.8 Dependability Departure in 60 Minutes (Time Series)

6.8.3.4 "Flights Delayed over Sixty Minutes, but not Canceled"

The trend lines in **Figure 6.9** show a very similar slope between the before- and after-training time periods. Here also the training appears to have neither positive nor negative impact on this performance indicator.

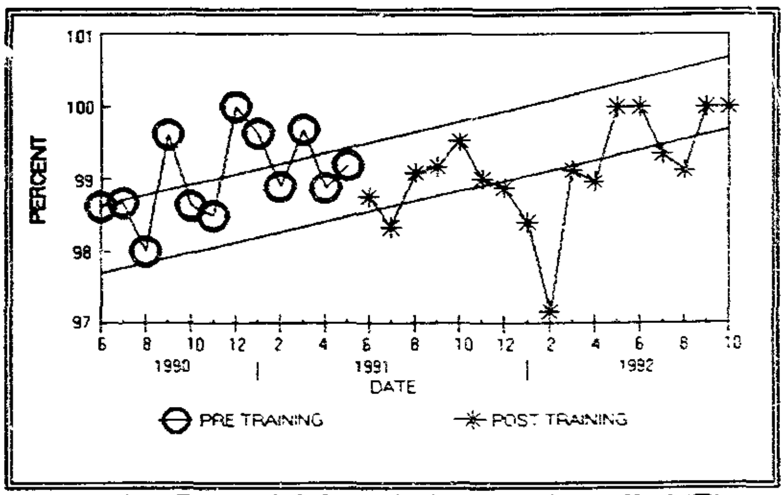

Figure 6.9 Dependability Flights Not Cancelled (Time Series)

6.8.3.5 "Frequency of Late Flights due to Maintenance."

No appreciable improvement in "Late from Maintenance" is noted in **Figure 6.10** for the year following the onset of CRM training, although the trend is toward improved performance during both years.

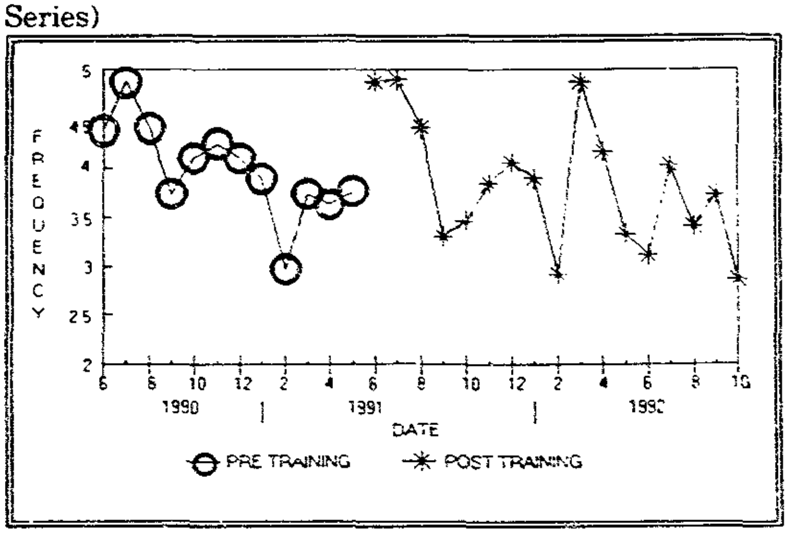

Figure 6.10 Dependability Late From Maintenance (Time Series)

6.9 RESULTS SECTION 5: MANAGERS SELF-REPORTS OF BEHAVIOR CHANGE: WRITTEN COMMENTS FROM THE POST-TRAINING AND FOLLOW-UP CRM/TOQ

Two open-ended questions were ask d of the maintenance managers concerning the intended use of the CRM training and its app. cation to the job. What follows are the results of these two questions. The full sample available by July 1992 is employed in the following analysis.

6.9.1 Intended Use of CRM Training

On the post-training, two, six, and twelve month follow-up questionnaires, participants were asked to write their responses to a question concerning how they expected to use the CRM training on the job. Content coding of the answers to this question resulted in four categories of response: "Better listening;" "More awareness of others;" "Dealing better with others;" and "Better communication." These categories represent two types of self-perception of potential behavior change: the first two categories show a "passive" improvement made within the person, while the last two categories show an "active" transfer of information by direct interpersonal approaches.

6.9.1.1 "How will You Use the CRM Training"

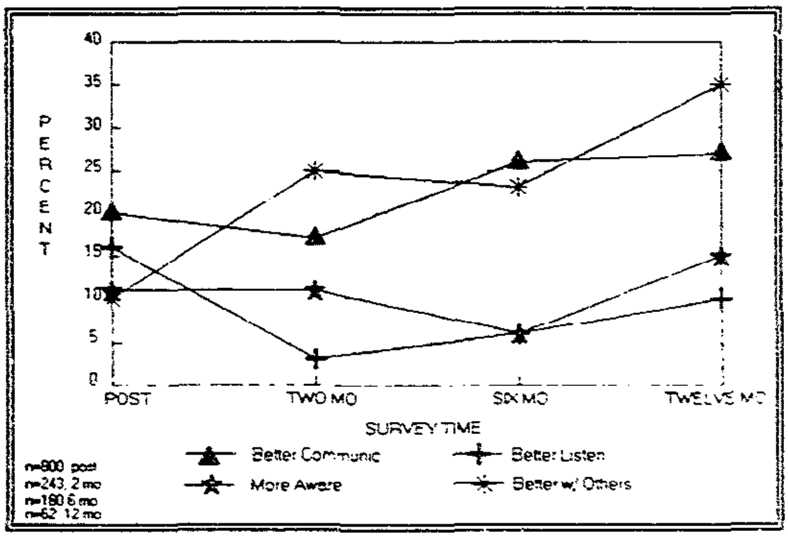

Figure 6.11 Percent Written Responses - How Training will be Used: Post, Two, Six, and Twelve Months

Figure 6.11 presents the results of the question, coded into the categories, for all four measurement waves. As the figure shows, expectations for all four categories are low in approbation as measured by frequency of response (none of the four categories accounts for as much as 25% of those answering) immediately following the training. In the subsequent waves of measurement in the months following, the two "passive" categories show a flat and low pattern, while two "active" categories (dealing better with others and better communication) increase. "Dealing better with others" includes statements such as more "problem solving activities," "team work," and "group consensual decision making." The shifting pattern from passive and reactive involvement, to more active information transfer and working with others is clearly shown in **Figure 6.11**.

6.9.2 How Training was Used on the Job

For the sample of participants who returned the two, six and twelve month follow-up questionnaires, responses to the question of how they actually used the CRM training on the job were content coded. The trainees' self-perception of behavior responses were coded in the same four categories as the other open ended question regarding the intended use of the CRM training.

6.9.2.1 "How did you Use the CRM training?"

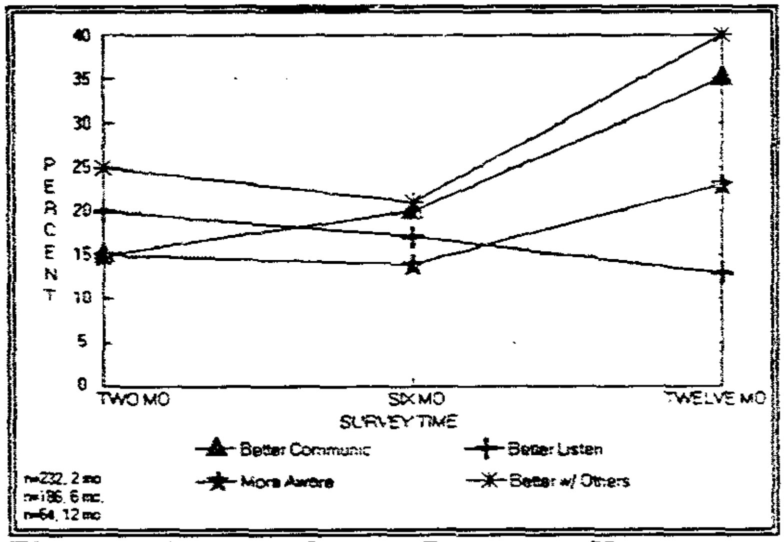

Figure 6.12 Percent Written Responses - How Training was Used: Two, Six, and Twelve Months

Figure 6.12 presents the graphed percentages of how the training was used on the job for the survey periods of two, six and twelve months. Better listening tended to decrease in reported percentage from 20% for two months to 17% for six months and 13% for twelve months. The other passive category, "be more aware of others," showed a stable pattern over time for the two and six month survey periods and increased to 23% for the twelve month survey period. The active category of "deal better with others" displayed high percentages for both two and six months (25% and 21% respectively) and rose substantially for twelve months with 40%. Better communication also showed a high percentage of use, for all three follow-up questionnaires. These open-ended responses appear to confirm that improved interpersonal behaviors have resulted from the positive attitudes that followed the training. Furthermore, the preferred behaviors tend to have shifted from those people could do by themselves (e.g., "be a better listener" and "being more aware of others"), to behaviors that involve others, such as "communicating better" and "dealing better with others."

6.9.3 Other Evidence for Improved Behavior Patterns Following Training

6.9.3.1 Anecdote Concerning Behavior Change

The use of anecdotal data for reporting trainees' behavior change on the job and the application of the knowledge learned from the training is recommended by Blakeslee (1982) and Ford (1989). One such anecdotal case involves a long-term employee who was planning to quit due to the supervisor's management style. After attending the CRM training course and returning to work, the boss's style changed considerably. The supervisor was apparently actively applying the concepts of the CRM training to the work environment. Only after this supervisor had actively committed to this new management style, did the employee decide not to quit the company. After this incident occurred, and the employee's turn to attend the CRM came, the change in the supervisor's behavior was described to the training facilitators. The employee commented that what had happened to the supervisor must be attributable to the CRM training. The employee stated that the boss's behavior had obviously changed after the training and now reflected many of the CRM principles and concepts in daily work.

6.9.4 Specific Reactions to the Course Itself -- Suggestions for Its Improvement

6.9.4.1 Good Aspects of the Training

On the post-training and two, six and twelve month follow-up CRM/TOQ, there was an open ended question consisting of "what aspects of the training were particularly good?" The participants written-in responses were content coded and the categories of comments with the highest frequencies were selected and percentages calculated. The five resulting categories include specific CRM course topics and they are shown in **Table 6.20**. All four survey periods including post-training, two, six and twelve month participants responses are presented in **Table 6.20**. Results for these four survey periods indicated that the Strength Development Inventory or personality (behavioral) style self-analysis exercise had the highest reported enthusiasm for all four survey periods.

Table 6.20 Written-in Responses Indicating Particularly Good Aspects of Training for Post-training, Two, Six and Twelve Month Follow-up

	SURVEY PERIOD			
Response	**Post-training**	**Two Month Follow-up**	**Six Month Follow-up**	**Twelve Month Follow-up**
Strength Development Inventory	17%	11%	18%	19%
Communication	9%	3%	14%	16%
Listening Skills	8%	3%	5%	6%
Assertiveness	11%	4%	2%	5%
Stress Management	10%	7%	10%	8%

For the post-training survey period, the assertiveness module was rated as the second highest, (particularly good) aspect of the CRM training. Also, for the post-training survey results, the stress management training module was rated nearly the same by the participants, followed by the communication and listening skills modules.

6.9.4.2 Training Improvements

The open-ended question "what do you think could be done to improve the training?" was asked in order to gain information to make the CRM training course better. All of the participants' written-in responses were content coded and the categories of comments with the highest frequencies were selected and percentages calculated. Results of the content coding indicating how the training might be improved for the three survey periods of post-training, two, six and twelve month are shown in **Table 6.21**. For the post-training survey period, the largest category of responses was that the training does not need any improvements; "do nothing" or "it's fine as it is." Second in order was the comment that the participants would like more training similar to this or "bring us back for follow-up training." As **Table 6.21** shows, the other four categories for the post-training survey were all similar in frequency.

Table 6.21 Percentage of Written-in Responses Indicating How Training Might be Improved for Post-training, Two, Six and Twelve Month Follow-up

	SURVEY PERIOD			
	Post-training	**Two Month Follow-up**	**Six Month Follow-up**	**Twelve Month Follow-up**
Response				
Needs Nothing	35%	16%	12%	14%
More Training & Follow-up	11%	27%	28%	29%
More Role Playing	7%	11%	4%	7%
Add Time to Training	7%	5%	4%	5%
More Case Studies	6%	7%	7%	8%
Better Mix of Participants	6%	5%	7%	6%

Results of the participants' responses for the two, six and twelve months follow-up survey period showed that the largest single category of comments was for recurrent training and ("bring us back for follow-up training"). The next largest response category for all three surveys was the "needs nothing" responses. These comments seem to indicate that most respondents showed approval of the program and perhaps more important, wanted more training like it. Participants in roughly similar proportions to their post-training responses, suggested more role playing and case studies, adding more time to the training and having a better mix of participants.

6.9.4.3 General Analysis of Open Ended Responses

Analysis of the open ended question pertaining to the particularly good aspects of the CRM training seminar, indicates that for all four survey time periods the participants found the strength development inventory or analysis of ones' behavioral style to be particularly good. In this training module, the participants were given information concerning their behavioral style with the implications of that style for human interactions and management practices. Furthermore, it appeared that learning ones' behavioral style under various workloads and conflict situations heightens the awareness and appreciation of how people will react and manage. Many maintenance managers wrote that having understood ones' behavioral style brought a sense of clarity of how other people were responding to them under various leadership and working situations. Also, understanding one's boss's behavioral style alerted them of why the boss was managing the work units in a particularly way. The stress management, assertiveness and communication training modules were all mentioned as particularly good aspects of the CRM training. It follows from this that after the trainees understood their own behavioral style and their boss's behavioral style, learning how to become more assertive, manage stress better and communicate more effectively under stressful conditions was deemed important. Active listening skills assisted the technical manager in better communicating and understanding the working situation.

Over time, the design of the CRM training program was still considered as "fine" and it "needs nothing." What was clearly being stated by the participants was the need for more training and follow-up courses that incorporated more role playing exercises, along with more case studies. It appears, by what they report to practice over time, that the technical managers have attempted to apply as much as they can to their work environment; now they want some more constructive practice and study on how to further improve their resource management skills. A refresher course on crew coordination concepts skills seems to be important to these maintenance managers. Many of them indicated that they would like to work more with the professionals in this area of CRM and interact with other technical managers in practicing and applying these skills. These data are consistent with developments in the company to produce a follow-up CRM course for these managers, including a broader mix of participants, more "real life" case studies and more role-playing exercises.

Other written-in comments reinforce the generally positive response to the training. Several of the participants wrote that because this course was well designed and delivered, it was the first time they did not fall asleep in the training seminar! The authors observed several of the training sessions, and noted a high level of activity and involvement of the participants. We observed that everyone was actively participating and interacting with others during the course exercises. Many of the managers were taking notes in their training manual and studying the material during breaks. Several of the participants stated that they went home and discussed the material with their family members and commented on how the course material could be reasonably easy in applying it to their home situation as well as at work.

6.10 CONCLUSIONS

The combined results of the five major analyses reported here reveal a strong and positive effect of the maintenance management CRM training after its first full year of implementation. Although all maintenance management personnel have not yet been trained, a sizable portion of them have. Additionally, a full 12 months of post-training performance data provide a good sample of performance effects following the onset of training.

The stability of the follow-up measures for individual respondents is established, although there appears to be some sampling effect in the follow-up data caused by a variable return rate by station and hierarchical level.

Many individuals report changing their behavior to take advantage of what they learned in the CRM training. Most measures of maintenance performance improve in the year following the onset of the training when compared with the same period before the training. Furthermore (despite the sampling effect noted above), the improved attitudes toward sharing responsibility, coordinating, speaking up, and recognizing stressor effects are significantly related to concurrent and subsequent maintenance performance.

Additional survey data have been, and continue to be, collected in the months following training. Larger sample sizes and longer time periods will become available for analysis in the coming months and we expect some of the variability in longitudinal group data to decrease. Based on the time-lagged results shown in the present report we can expect to see even stronger evidence for the power of the CRM training in improving safety in the future.

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Technical Operations Division
Crew Coordination Concepts Syllabus

Module	Time	Facilitator	Method	Objective
Day 1				
Introduction	8:15am (30 min)	TO	Introduce self. Cover facilities, restrooms, telephones, breaks, lunches, closing time. What have you heard about course? Review PURPOSE, OBJECTIVES, WORKING AGREEMENTS. Collect Pre-seminar questionnaire. Explain purpose & importance of ID #. Group introduces themselves.	Position program as helpful in dev. mgt. skills. Get group talking and energized. Set the tone of the workshop. Clarify expectations, yours/theirs. Remove teacher-student relationship.
Portland Video	8:45am (45 min)	HF	Show video; identify resource mgt. problems; relate Portland problems to work place. Prepare flipchart	Attention getter. Identify mgt. problems faced; problems become course focus/overview.
Expectations	9:30am (15 min)	HF	Develop expectations of individuals in course. Write on chart. Compare to course objectives.	Get expectations from group, compare to course, illustrate differences if any.
Break	9:45am (15 min)			
Testing Assumptions/ DC-10 Video GUM	10:00am (120 min)	TO	Introduce concept of Perception vs. Reality. Show DC-10 Video GUM. Tablework: What were "Chain of Events" that led to the accident? Discuss "ASSUMPTIONS" that led or contributed to accident. How can we test our assumptions? What could each person have done differently?	Test Assumptions by: Advocacy - "Speaking Out" Inquiry - "Ask Questions" Active Listening - "Listening"
Lunch	12:00pm (60 min)			

Technical Operations Division
Crew Coordination Concepts Syllabus

Module	Time	Facilitator	Method	Objective
Behaviors	1:00pm (75 min)	HF	Discuss use of instruments; admin. SDI; develop Behav Dim Model; discuss concept of "Assertive Behavior."	Understand behavior differences; understand strengths and weaknesses of behavior styles; assertiveness using a variety of styles (positively).
Break	2:15pm (15 min)			
Behaviors Cont'd	2:30pm (60 min)	HF	Score SDI; Interpret SDI; draw arrows; discuss/apply "Assertiveness"	People are different; behaviors influence communication, values, perceptions of others, decision making & conflict resolution methods. Behavior modification approp. for effective supervision.
Break	3:30pm (15 min)			
Stress Management	3:45pm (60 min)	TO/HF	TO - Introduce/understand stress What are sources of stress in our jobs? Develop list of Stressors. HF - Identify body's reaction to stress. Ways to deal with stress. TO - Work on how to deal with 2 examples. ETR'S MANPOWER, PARTS AVAILABILITY	Stress is normal; stress can be managed; Recognize signs of excess stress. Effects of safety & efficiency. Application of CCC to reduce stress.

Technical Operations Division
Crew Coordination Concepts Syllabus

Module	Time	Facilitator	Method	Objective
Day 2				
Opening DC-10 Video GUM 041	8:15am (30 min)	TO	Show GUM 041 video with breakfast. Address loose ends from Day 1; Outline schedule for Day 2. Review lessons learned in context of video (GUM 041).	Transition and clarification; group at ease with where they've been and are heading; NOT A REVIEW!
Sub Arctic Survival	8:45am (60 min)	TO	Purpose of simulation. Make individual decisions (step 1). Make group decisions (step 2).	Tie into Day 1; position as a competition This is fun!
Break	9:45am (15 min)			
SAS II	10:00am (60 min)	HF	Define/develop rational decision process; apply process to simulation; complete SAS: critique team effect; develop lessons learned/appl to job.	Problem solving involves a rational process; concensus decisions are better than individual decisions. Interpersonal skills impact decision-making.
Break	11:00am (15 min)			
Norms/ EAL 855	11:15am (45 min)	TO	Identify role of norms in Tech Ops. Introduce concept, give examples. Allow time to review EAL 855. Assign each table a role. What were norms that led to accident? Groups develop lists of good/bad CO norms. Discuss how to manage norms and prevent accidents.	Norms play powerful role in organizations. Have a direct impact on safety & efficiency. Assumptions must be tested. Norms are unwritten rules enforced by the group. Mgt & FAA are powerless to change norms.
Lunch	12:00pm (60 min)			

Module	Time	Facilitator	Method	Objective
Listening & Communicating	1:00pm (60 min)	HF	Tie into SAS; Sleep excercise. Communication model; listening barriers; listening tips.	Listening is a learned skill. Poor listening limits quality decision making.
Break	2:00pm (15 min)			
Supporting/ Confronting	2:15pm (60 min)	TO/HF	Use interactive dilemas. Conduct 1st dilema. Critique/lessons learned from 1st. Conduct 2nd dilema. How was second different from first?	Application of behavioral skills/style. Understand the variety of approaches; language is important. Use role play to demonstrate skills/lack of and need of practice.
Break	3:15pm (15 min)			
Wrap-up Evaluations/ Questionnaire	3:30pm (45 min)	TO/HF	Take home concepts? USC/CAL Questionnaire explanation I.D. #s on questionnaires	Pledge to do something different/better. Feedback for program enhancement; participants feel good about experience.

CHAPTER SEVEN
A HUMAN FACTORS GUIDE FOR AVIATION MAINTENANCE

7.0 INTRODUCTION

Maintenance for air carriers is conducted under a myriad of pressures caused by strict flight schedules, new aircraft technologies, aging aircraft issues, personnel working conditions, and economic factors. Irrespective of these pressures, the quality of maintenance must be high if industry safety standards are to be achieved. Also, the efficiency of maintenance must be high if the airline industry is to remain economically viable. These industrial imperatives can only be met with a maintenance workforce that is both productive and rigorous. Maintenance tasks must be accomplished expeditiously and accurately. A Human Factors Guide can be valuable in supporting and enhancing the performance of aviation maintenance personnel and thereby aid in meeting the industry's goals.

The Federal Aviation Administration (FAA) program on Human Factors in Aviation Maintenance is developing, as one end product, a guidebook presenting human factors information to support the work activities of maintenance technicians. The philosophy of the guide is that a maintenance technician represents one operating element in a "maintenance system," with other elements being the aircraft, the maintenance facility, supervisory forces, and maintenance equipment. In this context, we need to know the "operating characteristics" of the technician just as we would those of any other operating element. Information is necessary concerning the capabilities and limits of humans, the effect of environmental factors, and the way in which humans operate most effectively in a human-machine relationship. In short, we need to understand the "human factors" of aviation maintenance.

The Human Factors Guide was prepared on the basis of stated preferences of maintenance personnel. This was done to ensure that the guide is usable and that its potential for helping maintenance is not degraded by problems of acceptance or by its physical characteristics. Selection of topics and the presentation of materials was guided by information obtained through a series of FAA-sponsored human factors meetings as well as input gained from a participatory panel of maintenance personnel.

7.1 STATUS OF HUMAN FACTORS GUIDE

During the past twelve months, the *Human Factors Guide for Aviation Maintenance* has progressed through the following stages: (1) **Concept Definition**; (2) **Methodology Development**; (3) **Data Collection and Analysis, Data Synthesis and Abstraction, and Draft Section Authoring**; (4) **Advanced Technical Data Solicitation**; and (5) **Preliminary Draft Review**. Copyright and Permission Approvals are being obtained as required.

Concept Definition was addressed through two means that involved key members of the air carrier maintenance community: (1) A topic selection meeting and (2) a data gathering phase.

The topic selection meeting was held in January 1992 prior to the convening of the Sixth FAA Meeting on Human Factors Issues in Aircraft Maintenance and Inspection. Attendees included invited individuals representing the interests of experienced Air Transport Association Inspection Panel Members, manufacturers, carriers, unions, universities, the FAA and FAA support contractors. The topic selection meeting resulted in preliminary recommendations relative to the Guide's scope and purpose, primary target audience, writing style and tone, and suggested topical sections.

During June-July 1992, a **concept definition** for the guide was sought from 60 key members of the air carrier maintenance community. Information solicited was designed to ensure that the real needs of aviation maintenance personnel would be met and that the Guide would be authored and constructed consistent with likely end-user needs. The information obtained addressed issues of target audience identification, as well as Guide content, size, and style.

A detailed analysis of information obtained from the air carrier representatives was presented in August 1992 at the Seventh FAA Meeting on Human Factors Issues in Aircraft Maintenance and Inspection: "Science, Technology and Management, A Program Review." Also included as part of the presentation was a **methodology development** strategy, along with a prototype topical section on Area and Task Lighting. Subsequently, draft Guide sections have been developed using the outline shown in **Table 7.1**.

Table 7.1 Outline for *Human Factors Guide* Sections

- Importance of Topic in Industrial Operations
    - Industrial Experience
    - Related Research
- Application in Aviation Maintenance
    - Industry Practices
    - Opinionnaire/Audit/Research Findings
- Human Factors Guidelines
    - Brief Discussion
    - Specific Guidelines
- Procedures for Evaluating the Situation

Also, as part of **methodology development**, a broad outline for the entire Guide was established, including the following:

Part I:	Introduction
Part II:	Maintenance and Inspection
Part III:	Workplace Design
Part IV:	The Human Operator
Part V:	Workplace Issues.

Data Collection and Analysis, Data Synthesis and Abstraction, and **Draft Section Authoring** has progressed sequentially for all sections of the Guide. Primary data sources are shown in **Table 7.2.**

Table 7.2 Primary Data Sources

- Proceedings from the FAA Meetings on Human Factors Issues in Aircraft Maintenance and Inspection
- Aviation maintenance manufacturers and carriers
- Professional journals and publications
- Copyrighted human factors and performance enhancement textbooks and publications
- Professional society and/or association conference proceedings
- Government and Professional guidelines and standards
- National Research Council, Committee on Human Factors
- University human factors and behavioral technology research laboratories and aviation maintenance programs

Information was abstracted and synthesized, with concepts and ideas condensed to present key information concisely. Relevant information is presented in either a bullet format or in short listings and statements. Illustrations are used to support textual material, as appropriate.

Advanced Technical Data. Because of the technical nature of some Guide sections, data were solicited from organizations such as the Industrial Engineering Laboratory, State University of New York at Buffalo; ATA Committees on Standardized/Simplified Language and Maintenance Manual Data/Format; the Equal Employment Opportunity Commission; and the U.S. Department of Health and Human Services.

A **preliminary review of draft** Guide sections was held at BioTechnology on 9 March 1993. The meeting's purposes were to (1) review the draft Guide and (2) to discuss efforts needed to bring the Guide to completion. Issues addressed at this review meeting included a final discussion of target audience to ensure that sponsor and contractor personnel were in full agreement; illustrations and photographic support; Guide size, cross referencing, and format; copyrights and approvals; air carrier and air manufacturer aviation maintenance technical review comments; and publication, printing, and distribution issues.

Many, but not all, **copyright and permission** requirements have been identified (e.g., for scanned images, photographs and quoting/abstracting more than 500 words of copyrighted textual material). A complete audit of each Guide section relative to copyright obligations continues. To date, letters have been sent to 35 publishers. Fourteen have responded positively.

Not all copyright and permission letters have been prepared. Of those copyright and approval letters for which responses have been received, **Table 7.3** is a composite summary of permission requirements established by publishers:

Table 7.3 Permission Requirements

- Publishers require copyright credit lines.
- Permissions typically:
    - Are restricted to print reproduction only and *do not include electronic media or any type of electronic format*
    - Are limited to the English language distribution (some publishers restrict distribution to the U.S., its territories and dependencies, the Philippines, and Canada; other publishers allow distribution in the English language world-wide)
    - Do not extend to any copyrighted materials credited to other sources
    - Are non-exclusive and are not transferable
    - Require one copy of the final work to be provided to the publisher
    - Require that any changes to the draft submission be approved
    - Require a signed agreement.

The *Human Factors Guide for Aviation Maintenance* will undergo final review by the Federal Aviation Administration during 1994. The Guide will be available to the air carrier maintenance industry upon completion of the review cycle and subsequent publication. Distribution of the Guide will be controlled through the Office of Aviation Medicine, Federal Aviation Administration.

CHAPTER EIGHT
Bibliography - Formal Presentations and Publications for the FAA Office of Aviation Medicine Human Factors in Aviation Maintenance and Inspection Research Program, 1989-1993

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3rd	"Training Issues"	June 12-13, 1990
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