Chapter One
Executive Summary

1.0 SUMMARY

This report details the second phase of the Office of Aviation Medicine (AAM) research program on Human Factors in Aviation Maintenance. This on-going research program enhances human performance in the aviation maintenance system to ensure continuing flight safety and operational efficiency. The research program, as reported in the Phase I report (Shepherd, et al., 1991) was initially planned to have 4 steps, with feedback mechanisms as shown in Figure 1.1. Phase I focused on preliminary investigation and problem definition of human performance in airline maintenance environments. This Phase II report describes research that centers on the development of hardware and software prototypes with potential to enhance human performance in aircraft maintenance. (In this report the activities subsumed under "inspection" are considered to be part of "aircraft maintenance").

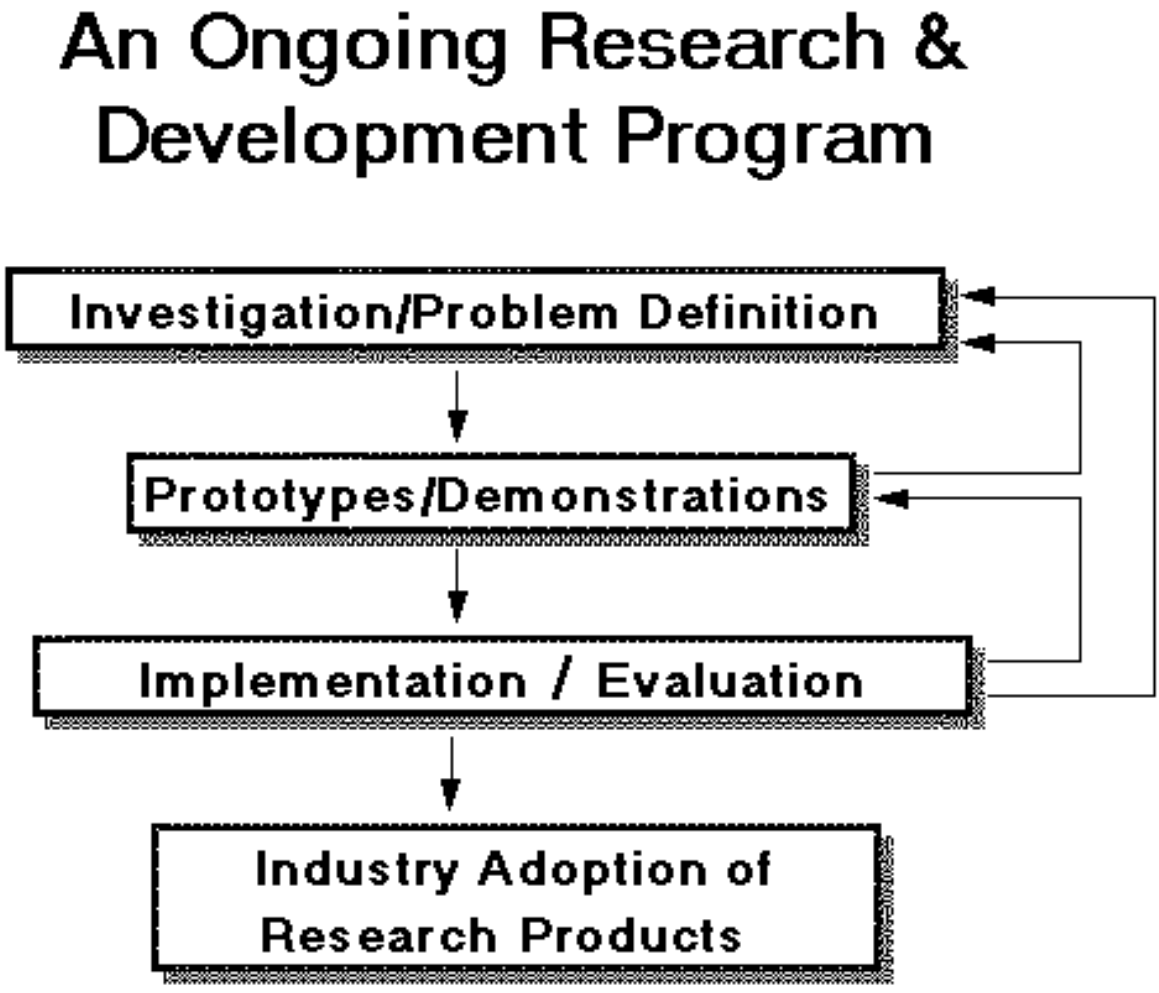

Figure 1.1 The Research Program

The research reported here has been conducted by a multi-disciplinary team of scientists and engineers from industry and academia. The research team has worked in very close cooperation with the international aviation industry, mostly with US airlines and aviation manufacturers.

This report includes seven chapters and can be considered as an edited volume in that each chapter is written to stand alone as the work of each research group.

1.1 CONTINUING RATIONALE

Shepherd et al. (1991) and Shepherd & Johnson (1991), offered an extensive description of the rationale for the research program. These reports described the complexity of the total aviation maintenance system and the role of the human within the system. Increased maintenance workload, caused in part by an increased level of air carrier operations, is one reason to focus on improving aviation maintenance technician (AMT) performance. The challenge of providing continuing air worthiness of the aging fleet while developing knowledge and skills for maintaining new technology aircraft places a burden on airline maintenance organizations.

Phase I research investigated methods for enhancing human performance in aircraft maintenance. There are ample reasons for continuing these investigations. For example, operations will continue to increase. Airlines will fly more hours with the same fleet sizes. Thus, there will be less time for maintenance and greater stress on the fleet. Therefore, enhancing human performance in maintenance continues to be an important priority.

Resources are finite. Airlines, during 1991-92, have not been profitable. Since the Phase I report was published, major air carriers such as Pan Am and regional carriers such as Midway Airlines have gone out of business. Other carriers have suffered record financial losses and face uncertain futures. Airlines recognize the criticality of cost control in every aspect of their operation. However, cost control cannot jeopardize safety. This research program recognizes that the enhancement of human performance in maintenance is critical to the safety and efficiency of air carrier operations.

1.1.1 Integration of Human Factors Research Efforts

Research to enhance human performance in aircraft maintenance can focus on several dimensions, such as the human, the tools, the work place, work procedures, and management philosophies. The research must be useful to maintenance practitioners as well as to the human factors research community. This report, therefore, has practical as well as scientific value.

1.2 ADVANCED TECHNOLOGY TRAINING (Chapter Two)

Advanced technology training combines artificial intelligence technology with conventional computer-based training. The technology was described extensively in the Phase I report (Shepherd, et al., 1991) and elsewhere (Johnson & Norton, 1991 and Johnson & Norton, in press).

This chapter describes the continuing effort that has converted a Phase I training prototype to a fully operational advanced technology training system for the Boeing 767-300 environmental control system (ECS). The system is simulation-based in that it permits the user to access and operate all panels, controls, and built-in-test equipment of the ECS. Figure 1.2 shows the human-computer interface for the ECS.

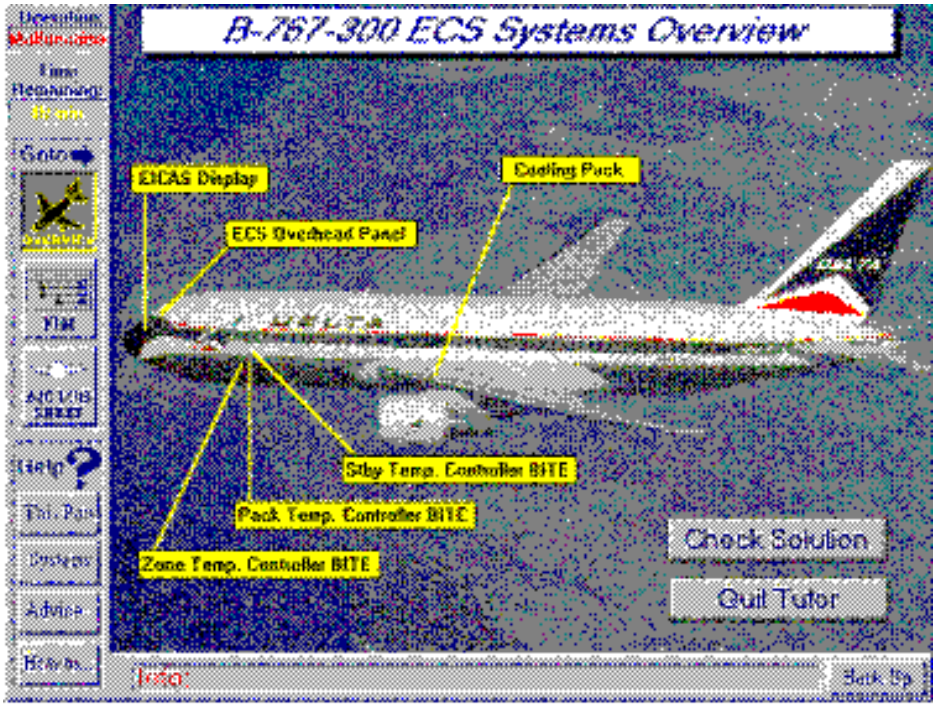

Figure 1.2 Environmental Control System Tutor

The ECS trainer is unique not only because of the simulation but also because of the robust software used for modeling student performance and providing feedback, explanation, and remediation. These modeling features are described in Chapter Two.

In addition to providing simulation, the ECS Tutor provides on-line access to the training manual for the ECS. The software makes it easy for the student to use the manual during training. This research is preparing for development of an integrated information system which can provide not only training but also real-time job aiding and maintenance documentation. Research related to the concept of on-line documentation is also described in Chapter Four.

The chapter also describes the process of formative evaluation that took place as the training systems underwent many iterations with software engineers and training professionals at Delta Air Lines and at Clayton State College. A substantive training effectiveness evaluation will be conducted at Delta.

Finally, as advanced technology training systems become more commonplace, it is likely that they can be used for AMT certification. Therefore, this chapter also reports on the research implications of the pending changes to Federal Aviation Regulation (FAR) Parts 65 and 147.

1.3 ADVANCED TECHNOLOGY MAINTENANCE JOB AIDS (Chapter Three)

This chapter addresses existing approaches to job aiding in maintenance, the drawbacks to such approaches, the prospects for using emerging technologies to develop maintenance job aiding systems, and the impact of emerging technologies on human performance. There were two major themes to the research: 1) many previous attempts at building maintenance job aids consisted of trying to replace human expertise with machine expertise; and, 2) problems with such approaches have led to a reconsideration of the skills and abilities of human operators and ways to capitalize on them.

Accordingly, the chapter calls for a `cooperative system' approach to designing such systems; a cooperative system is one in which a human and a computer are actively involved in the problem solving process. The chapter presents a study which used this approach in developing a job aid. Some of the results of the study that are relevant to designing maintenance job aids and integrated information systems (Johnson & Norton, 1992 a & b) are also presented. Finally, a research and development plan for building a maintenance job aid for aircraft maintenance is discussed.

1.3.1 Human Performance Implications of Artificial Intelligence Approaches

The bulk of the job aiding systems encountered in a literature review used artificial intelligence and expert systems techniques. While artificial intelligence techniques can provide a computer with powerful problem solving abilities, job aiding systems which rely solely on such techniques often meet with limited operational success. One of the reasons for such limited success is that the computer is supposed to embody the knowledge and abilities of a human expert, when, in fact, such systems are necessarily incomplete. Because builders of expert systems cannot capture all of the human expert's knowledge about a task, such systems often draw erroneous conclusions. Therefore, the operator must have enough expertise to realize that the computer is wrong; the problem is that the operator will not develop such expertise unless he/she is actively involved in the problem solving process. However, these problems do not exclude artificial intelligence techniques from use in operational job aids. Rather, the question is one of emphasis: instead of using artificial intelligence techniques as the foundation for a job aid, they should be used in conjunction with other methods of performance aiding (e. g., representation aiding).

1.3.2 Human Performance with a Cooperative System

A research study (Layton, 1992) which investigated human performance with three forms of a cooperative system provided some interesting insights into how such systems affect human behavior. This system was designed to assist commercial airline pilots and dispatchers in enroute flight planning. (Figure 1.3 depicts a portion of the system displays and controls.) This research has provided some interesting insights into the ways in which job aiding tools affect human performance.

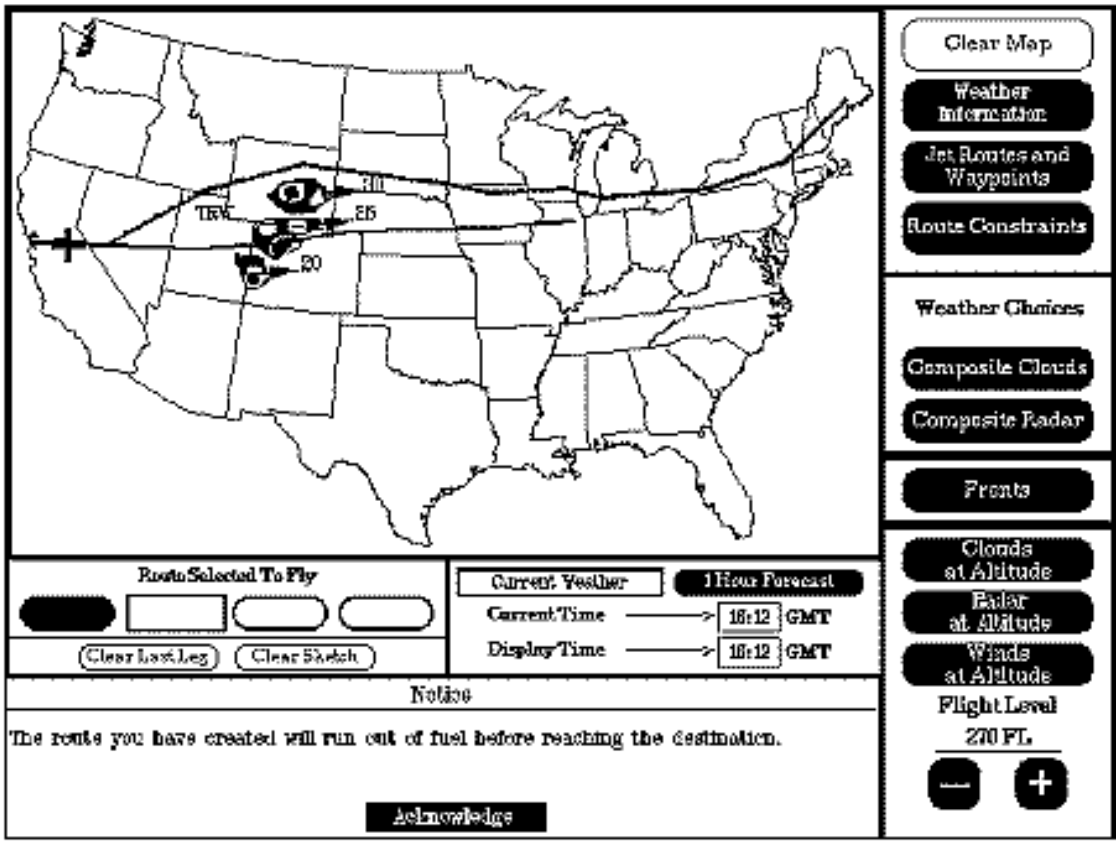

Figure 1.3 Enroute flight planning cooperative system

1.3.3 Research and Development Plan

A three-phase plan for developing an aviation safety inspector job aid using cooperative system techniques was developed. Initial interactions with the Flight Standards Service suggest that the job aid will assist inspectors in researching operator information and documenting inspection activities. The system will link inspection forms so that information that is entered into one form will automatically be entered into the other forms being used. The system will also provide the ability to search for information using on-line documentation. Such documentation may include the federal aviation regulations, advisory circulars, airworthiness directives, FAA policies, and operator-specific information. The system will have a cellular modem capability so that it can connect to the Flight Standards mainframe system and will likely use a CD ROM to store much of the on-line documentation.

1.4 DIGITAL DOCUMENTATION (Chapter Four)

Maintenance personnel are often overwhelmed with the amount of technical documentation necessary to accomplish a given task. The information comes from a variety of sources including company and manufacturer's manuals, and government documents, like advisory circulars or regulations. Currently most maintenance documentation exists as hard copy or microfiche. The task of keeping these databases current is very time consuming and expensive.

This research task, called the Hypermedia Information System, (HIS) shown in Figure 1.4, studies advanced technology software and hardware techniques for information storage and retrieval. The primary products of this research will be techniques for the development and use of large information sources on small portable computer systems.

Figure 1.4 Hypermedia Information System

The term "hypermedia" refers to a combination of text, graphics, animation, audio, and video to convey information. Such information bases are designed to be accessed easily, usually in a non-linear fashion. This hypermedia research will make it possible for a technician to access a manual for all media and information to complete a job. The research fosters co-development of integrated information systems (Johnson & Norton 1992, a & b) that provide training, job-aiding, and on-line documentation.

A by-product of the research is the development of a hypermedia information system for all technical publications from the Aviation Medicine Human Factors in Aviation Maintenance research program. Ultimately this digital source of information will be published on a CD-ROM (Compact Disc-Read Only Memory).

The proceedings of one of the first six conferences on aviation maintenance human factors has already been prepared for distribution as a digital document. The seventh conference will be the first time that the meeting proceedings will be distributed in digital format at the meeting. The software developed through this research effort has facilitated the timely publication of such digital documentation.

1.5 HUMAN RELIABILITY IN AIRCRAFT INSPECTION (Chapter Five)

The research related to improving human reliability in aircraft inspection built upon the solid task analytic foundation derived under Phase I. The chapter describes two studies: one study related to the re-design of workcards for inspection and the other a study of the lighting environment for inspection. Both studies offer practical human factors guidelines applicable to these topics. The chapter also describes a plan to consider human-computer interface issues applicable to computer-based maintenance aids.

This chapter also describes a series of laboratory experiments that evaluate the effects of time pressure on inspection and the improvement of training techniques for visual inspection. The chapter describes a study of the classification of human error in inspection. The classification is particularly valuable in its review of many scientific studies of human error. These studies form the basis for the team's development and presentation of system models of human error in inspection. These models provide the means to understand, predict, report and manage inspection errors.

Inspection is information processing. The chapter reports research on the design of information flow in the inspection environment. The research helps to determine what, when, and how to present information to the inspector. Experimental results are presented regarding optimal methods of information presentation in inspection tasks.

Chapter Five also describes a joint study of inspection practices in the UK and USA. The comparative study observed that management structures of maintenance and inspection are more closely intermeshed in the UK than in the US. Other differences and rationales are reported.

1.6 GUIDELINES FOR HUMAN FACTORS IN MAINTENANCE (Chapter Six)

Human Factors principles are often derived in laboratory studies of procedures, equipment, effects of time, temperature, lighting and other variables. Much of the information derived from these studies is reported for scientists, psychologists, and engineers for academic applications. This task is reviewing the human factors literature from a wide variety of parallel and similar areas to aircraft maintenance. All of the research results from the Aviation Medicine Aircraft Maintenance Human Factors program will be combined with this information base to produce a Human Factors Guide for Aircraft Maintenance. This guide promises to be useful to airline maintenance management system designers, FAA oversight personnel, and others as they strive to improve human performance in the maintenance system. Chapter Six offers an example chapter from the Human Factors Guide.

1.7 CREW RESOURCE MANAGEMENT FOR MAINTENANCE: EVALUATION OF A TRAINING PROGRAM (Chapter Seven)

Phase I (Shepherd, et al., 1991) reported on management-worker communications in the aviation maintenance environment. Phase II research has shifted focus to the effects of crew resource management (CRM) training in an airline maintenance environment. The research has concentrated on communication among maintenance crews. The researcher participated in the evaluation of the effectiveness of a particular airline's CRM training for maintenance personnel and in the post-training performance effects on maintenance managers and technicians.

The CRM course acceptance has been very high. In fact maintenance crews have demonstrated greater acceptance of the CRM principles than have flight crews. The research indicates that relevant attitudes about CRM improved immediately after training. Course attendees have reported that the CRM principles have caused them to be more actively involved in all maintenance decision making.

The CRM evaluation research is valuable in that it has created instruments and criteria to measure post-training maintenance performance. These measures will be helpful to assess the training and cost effectiveness of such human performance enhancement courses.

1.8 CONTINUED COMMUNICATION

The seven workshops that have been conducted to date under the Aviation Medicine research program have facilitated communication between researchers and industry. The immediate application of some of the research activities described above will allow the industry to increase reliability and lower costs. The Office of Aviation Medicine (AAM) intends to continue sponsorship of the workshops throughout the duration of the research program.

The participation and cooperation of the airline industry has been instrumental to the AAM research program. Air carriers, manufacturers, and schools have been extremely cooperative and helpful. This cooperation is gratefully acknowledged.

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