Chapter One
Executive Summary

1.0 SUMMARY

The performance of aviation maintenance and inspection personnel is directly related to the design of their tasks, the training given to them, the tools they work with, and the nature of their work environment. The goal of the aviation maintenance system is to ensure the continued safe and efficient operation of aircraft. Toward that goal the Federal Aviation Administration instituted the Human Factors in Aviation Maintenance Research Team to focus on a variety of human factors aspects associated with the aviation maintenance technician and other personnel supporting the maintenance system goals.

The team was comprised of personnel from government, private industry, and academia with strong expertise in human factors. They were assisted by experienced industry maintenance personnel and certified airframe and powerplant technicians. The results of their efforts are included in five chapters, this first chapter being the combined executive summaries of the other four. Specifically:

In addition, information dissemination was achieved through the conduct of four conferences relating to the material of the four chapters. The results of these are also included in this summary.

Each of the chapters listed above, 2 through 5, have been treated so as to be a "stand alone" or independent research report. This chapter, the Overall Executive Summary, provides the rationale for the overall program and highlights the methods, primary findings, and subsequently planned research and development.

1.1 PROJECT RATIONALE

The work to date has identified numerous areas where human factors research and development is likely to improve efficiency and effectiveness in the maintenance system. Subsequent research, 1991 and beyond, will develop demonstrations for implementation and evaluation within operational maintenance organizations.

The aviation maintenance system is complex. It is influenced by a variety of entities and factors as shown in Figure 1.1. The system includes the aircraft manufacturers who design, build, and sell aircraft hardware, software, accessories, documentation, and a variety of support services. The airlines, and other operators, purchase, operate and maintain the aircraft and also supply equipment and services to other operators. Vendors supply aircraft components, maintenance equipment, and support services. Repair stations supply contract maintenance services and other support. Schools, private and public, offer training services.

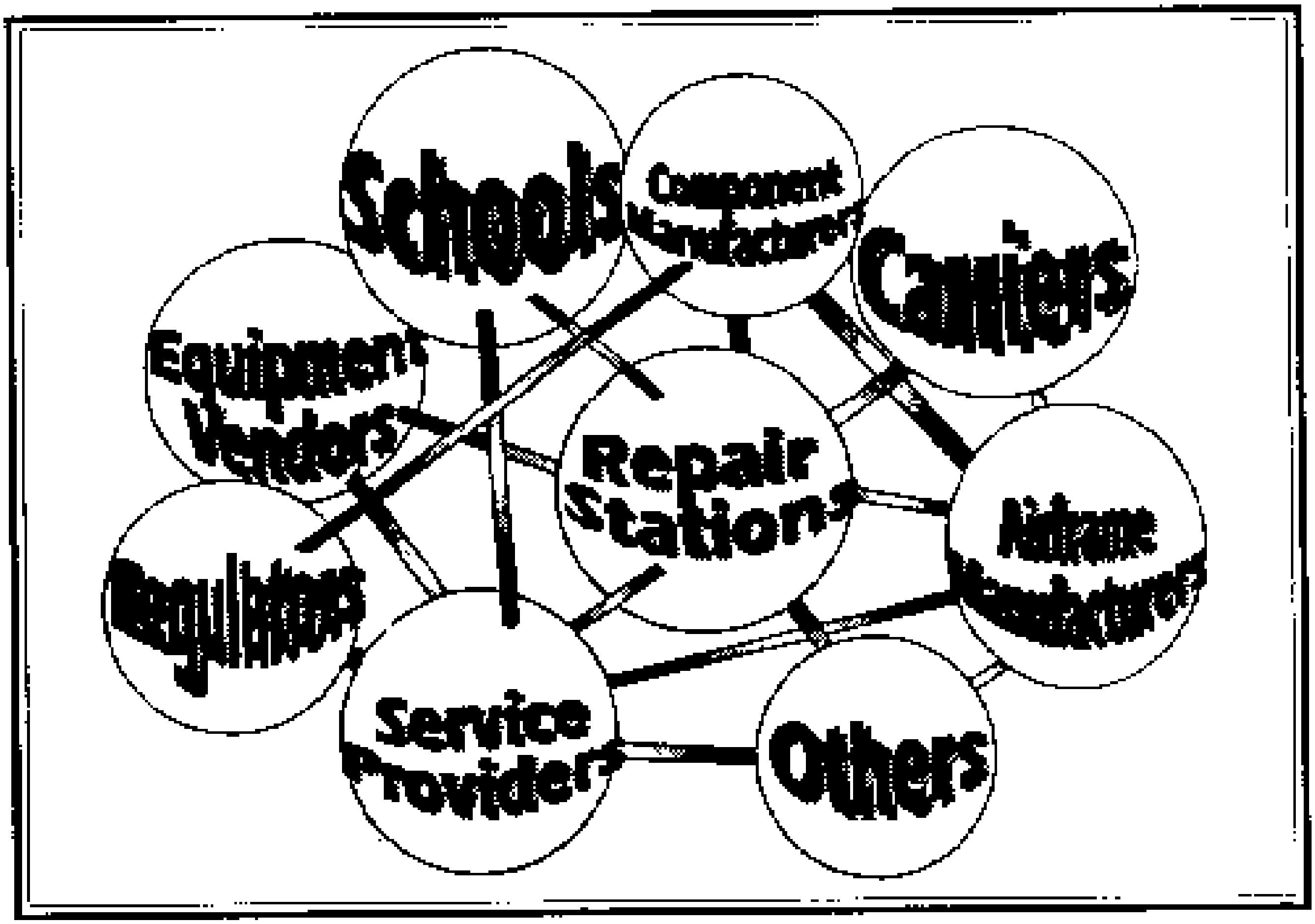

Figure 1.1 The Complex Aviation Maintenance System

Regulators, like the Federal Aviation Administration (FAA), the Occupational Safety and Health Administration (OSHA), and others, provide the regulatory environment in which the system operates. These independent entities exist in an integrated environment that the Air Transport Association (ATA) characterizes as a three-legged stool shown in Figure 1.2. The crossmembers between the legs of the stool represent the on-going cooperation, communication, and dependency among the three legs.

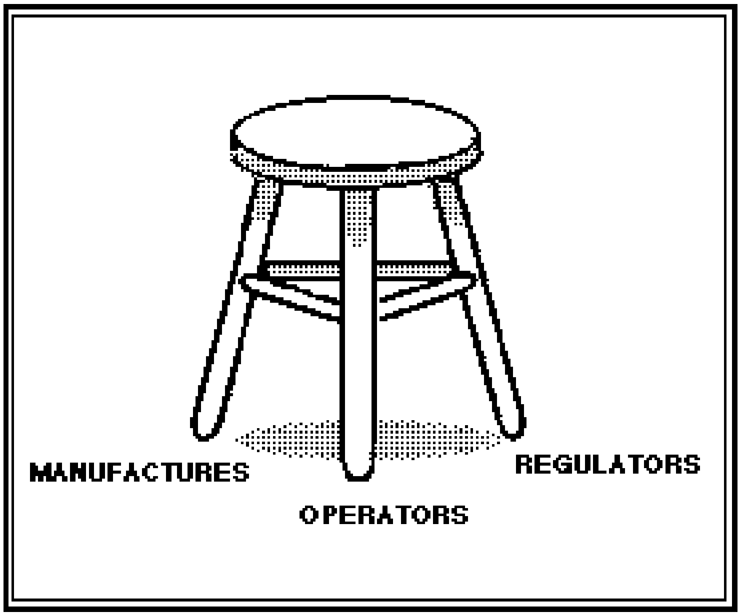

Figure 1.2 The ATA Three-Legged Stool

A research and development program in aviation maintenance is driven by the following facts:

1. Public sentiment demands a continuing, affordable, and safe air transportation system following national concern over recent maintenance-related incidents and accidents.
2. Maintenance workload is increasing due to such factors as:
   - increased traffic
   - increased maintenance requirements for continuing airworthiness of older aircraft
   - increased requirements for new technical knowledge and skills to maintain new technology aircraft
3. Demographic projections predict a shortage of qualified technicians.
4. Competitive pressures demand that maintenance organizations increase efficiency and effectiveness while maintaining a continuing high level of safety.

1.1.1 Public Demand for Continued Safe Public Air Transportation

Safe and reliable air transportation is a reasonable public demand. Commercial air transportation is, in fact, safe and reliable with trends toward ever-decreasing incidents per passenger mile flown (Office of Technology Assessment (OTA), 1988). Nevertheless, the infrequent incidents associated with air travel do influence public trust in the air transportation system. The 1990 crash of the United Airlines DC-10 in Sioux City, Iowa, raised questions about airline maintenance practices. The Aloha Airlines 737 accident showed that maintenance and maintenance training practices were the major cause of the explosive decompression and structural failure of major skin components (NTSB, 1989). While these incidents resulted in the loss of life, the overall safety and redundancy of the aircraft combined with the training of the crews prevented total catastrophe in both cases.

Since maintenance practices were involved in the examples above, as well as in other incidents, operators and the government are paying increased attention to the human in the maintenance system. The Aviation Safety Research Act of 1988 (PL100-591) mandated that research attention be devoted to a variety of human performance issues including "aircraft maintenance and inspection."

1.1.2 Increased Maintenance Workload

From 1980 to 1988 the estimated cost of airline maintenance increased from $2.9 billion to $5.7 billion (GAO, 1990). The increase is attributable to numerous factors including an increase in passenger miles flown, an increase in number of aircraft added to the fleet, and increased maintenance for continuing airworthiness on aging aircraft. Table 1.1 shows the increases in dollars spent on maintenance, passenger miles, number of aircraft, and number of maintenance technicians (GAO, 1990 and ATA, 1989 Summary Data) from 1980 through 1988. Figure 1.3 shows that the increase in the number of aviation maintenance technicians has the lowest percentage increase of all the categories in that eight-year period. These data suggest that workload on the individual technician has increased. Therefore, research attention to the human in the maintenance system is likely to have high potential to increase maintenance efficiency, effectiveness, and safety.

	1980	1988	% Increase
Maintenance Costs	$ 2.9 Billion	$5.7 Billion	96 %
Passenger Miles	255 Billion	433 Billion	65 %
Aicraft in U.S. Fleets	3,700	5,022	36 %
Number of Mechanics	45,000	55,000	22 %

Table 1.1 Percentage Increase in U.S. Airlines 1980-1988

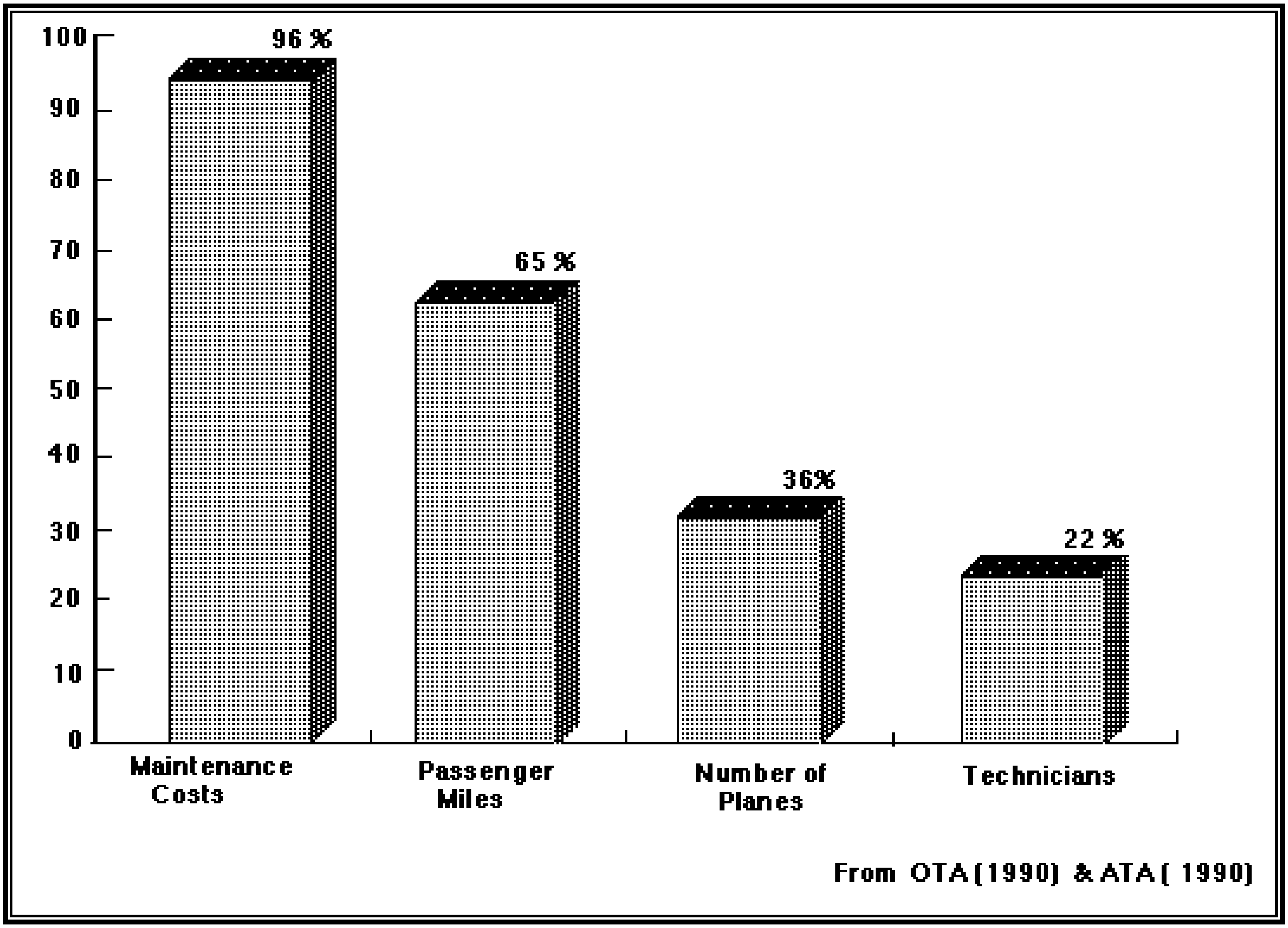

Figure 1.3 A Graph of Table 1.1

1.1.3 Demographics

The OTA, the U.S. Department of Labor, the Air Transport Association, the Future Aviation Professionals Association, the Aviation Technician Education Council, the Professional Aviation Maintenance Association, and numerous other groups maintain estimates regarding the projected shortage of aviation maintenance technicians (AMT) over the next ten years. There is unanimous agreement that there will be a need for 100,000 - 120,000 AMTs by the year 2000. The 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. Using those estimates and the estimates of the numbers of new AP certificates, the shortage will range from 65,000 to as many as 85,000 new AMTs needed by the year 2000. Table 1.2 depicts the estimates.

Projected AMT Requirement through 2000	100,000 - 200,000
AMTs Employed in 1988	55,000
Estimated New Positions	45,000 - 65,000
Estimated Attrition Through 2000	45,000
Estimated Training Completions	25,000
Projected Shortage of AMTs By 2000	65,000 - 85,000

Table 1.2

Aviation Maintenance Manpower Requirements Through the Year 2000

(Dept of Labor (1990), ATA (1990))

Most of the new AMT workforce will be different that the current AMT workforce, which is comprised of males over 30 years old (69% in 1988 (Dept. of Labor)), with nearly a third of this population having over 20 years experience. As these experienced technicians retire their positions will be largely filled by inexperienced personnel. The new work force will require greater training and job support systems, both of which will be products of a human factors research program.

1.1.4 Competition for Resources

With increasing passenger miles flown and increasing numbers of flights per day there is considerable competition for resources, especially between operations and maintenance. The operations departments need more airplanes, for more routes, for longer periods each day. The increased flight hours and emerging requirements for continuing airworthiness on aging aircraft require more maintenance. The finite resources include, as examples, time, shop floor space for maintenance, equipment for inspection and maintenance, and AMT personnel. The limited resources are competing to match aircraft availability with the transportation system demands. The increasing fleet size, matched with the fact that by 1995 nearly 65% of the aircraft will be over 20 years old (National Council on Vocational Education, 1991), suggest that there is a serious potential shortage of the resources (human, equipment, and space) to inspect and repair aircraft (GAO, 1990). There is a need to increase resources across the board. In addition, there will be a special need to help the technician work "smarter" and generally increase the overall capability of the human, as well as the system, to service the growing numbers of aircraft.

1.2 HUMAN FACTORS DEFINED

1.2.1 What is Human Factors

Human factors studies the performance of the human as an operating element within a goal-directed system. In the design and use of a system, the human is viewed in the same manner as any system component. If the system is to function effectively and efficiently, the designer must understand the operating characteristics of each component, including the human. Human Factors research seeks information on laws of human behavior, the capabilities and limits of humans, effects of environmental factors, and rules for optimizing the use of humans in present-day systems. The research team recognizes that it is not always possible to treat the human as a predictable element in a system. Human nature, work ethic, and a variety of such innate behavioral variability threatens a classical engineering treatment of the human in a system.

The broad goals of human factors research require a multi-disciplinary effort drawing on information from specialties such as psychology, physiology, ecology, engineering, medicine, education, computer science, and others. Information from these sources is used to develop procedures for system design, for operational system use, and for ongoing evaluations of system effectiveness. In all cases, primary attention is given to the human operator.

1.2.2 Why Human Factors Research in Aviation Maintenance

The human in aviation maintenance can be conceptualized as a person-machine system, as shown in Figure 1.4. Input and output variables can be clearly specified. The process itself, as shown, is labor-intensive, with the Aviation Maintenance Technician being, by far, the most important system element. In order to achieve the desired system output, an understanding is required of the many factors (working environment, training, etc.) which affect the performance of technicians. Human factors examines all of these variables, their effect on technician performance, and the resulting quality of system output. Using this information, a maintenance system can be designed to minimize system error and to ensure that aircraft are available as needed and are fully safe for flight.

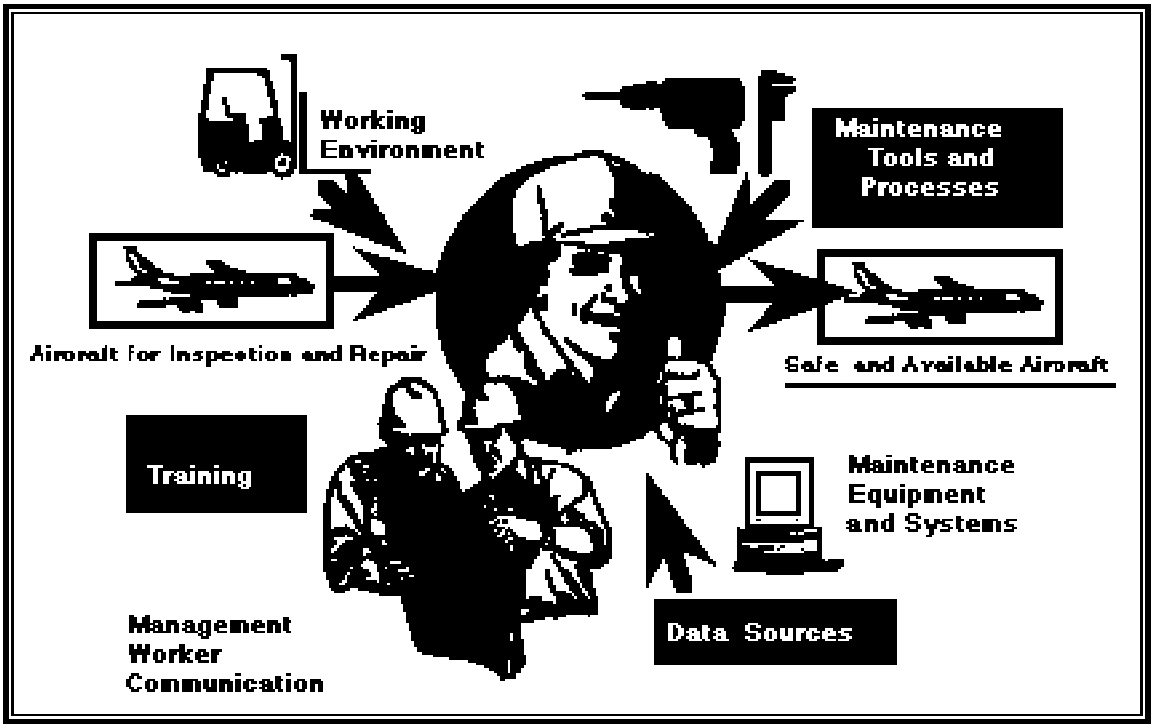

Figure 1.4 The Human in the Maintenance System

Human factors can have significant effect on the performance of the total aviation maintenance system. Human factors can affect hardware design and manufacture; the design and implementation of maintenance tools and procedures; and the selection, training and overall support of the human as a critical component of the aviation maintenance system.

Human factors provides approaches to make efficient use of human resources, while at the same time maintaining margins of safety. Importantly, while only two to three percent of accidents are attributed to pilot error, Weiger and Rosman (1989) have data which indicates that about 40% of all wide-body aircraft accidents attributed to human error begin with an aircraft malfunction. Reducing aircraft malfunction is a primary goal of maintenance programs and the humans who carry out those programs.

1.3 STUDY OF THE MAINTENANCE ORGANIZATION (CHAPTER 2)

This research was a study of maintenance organizations from an organizational psychology and systems engineering perspective. The intent was to identify how communication is accomplished within a maintenance organization. The research also focused on how maintenance organizations set and accomplished technical goals.

A rapid but systematic assessment of aviation maintenance technician interaction in eight U.S. companies was undertaken in early 1990. Over 200 AMTs, their foremen, and maintenance managers were interviewed and observed during two to four day visits of heavy maintenance checks of aging aircraft. The data from these visits were coded and classified using socio-technical systems (STS) concepts to identify organizational purpose, values, environment, product, and patterns of communication (Taylor, 1989). STS principles (Cherns, 1987) were then used to help assess the compatibility among those various components.

1.3.1 Awareness of Maintenance Goals

The survey suggested that individual AMTs did not always have a complete understanding of the company purpose regarding the role of maintenance. The maintenance personnel need to be able to individually describe their role in concert with the company purpose.

1.3.2 Competence of the Workforce

The survey, albeit not all encompassing, indicated a shortage of experienced AMTs. Several factors are responsible for this situation. In the late 1960Us, the maintenance force was comprised of AMTs with experiences gained during military service, supported by skilled general foremen, scheduling cadre, and instructors to broaden the AMT knowledge as newer aircraft such as the Douglas DC-9 and Boeing 727 joined the established fleet of Boeing 707Us and Douglas DC-8Us. The oil crisis of 1972-73, increased fuel costs resulting in increased fares. Increased fares caused a reduction in load factors, causing airlines to lay off newer mechanics. Unfortunately, as the crisis eased, these mechanics were not rehired, to a large degree. The slow economic times of 1979-83, coupled with deregulation, generated a cost-conscious industry, a sign of which is reduced inventories of aircraft parts and leaner staffing.

Finally in 1988 through the present the "new" fleet of 1970 aircraft are now the aging aircraft, exhibiting the need for increased inspection and repair. The AMT workforce however, with the experienced AMTs retiring, being promoted and transferring, currently exhibits a bimodal distribution with the AMTs either being very experienced, or having little (3 years or fewer) experience.

With the aging fleet problems involving extensive sheet metal repair, the newer AMTs are working to develop skills and experience to complete repairs which are compatible with commercial transport damage tolerance practices. This learning process can result in delay and often in re-repair, a situation that is not acceptable to the time pressure type of maintenance operation.

1.3.3 Teamwork

The survey clearly indicated that above-average coordination, cooperation, and communication produced less frustration and improved work performance. Where communication was not a high priority, high turnover, low morale, and concerns about the high maintenance workload resulted. Contributing to this problem was the complexity of coordination among maintenance, planning, stores and shops.

1.3.4 Commitment

The overwhelming majority of AMTs contacted during the survey expressed enjoyment in maintenance and mechanical repair. A strong desire to see the "big picture" was exhibited throughout the mechanic, inspector, planner and managerial workforce. Regarding intent to remain in the maintenance operation, the planning force was the group considered most likely to move on to other areas.

1.3.5 Phase II Plan

In the second phase the researchers will develop a document that will be a guideline for effective communication within maintenance organizations. The document will be designed with, and written for, all levels of maintenance management. The document will address issues related to maintenance management style, the structure of the maintenance organization, job design for application of new technology, defining purpose and goals within a maintenance organization, and other topics related to the pursuit of excellence within maintenance organizations. This written guideline will be available to the industry at the completion of Phase II, in late 1992.

1.4 STUDY OF THE MAINTENANCE TECHNICIAN IN INSPECTION (CHAPTER 3)

The Federal Aviation Administration policy regarding aircraft structural design is that of damage tolerance. This approach accepts that cracks and corrosion in metal aircraft do, by definition, exist through the life of the aircraft. The inspection interval applied to the damage tolerant design is that which will detect the defect before it presents a hazard to safe flight. The inspection interval is maintained by humans doing the job manually or with some form of inspection device. In either case, humans and machines are fallible. Ways are needed to make the system components less error-prone, and the system itself more error tolerant.

The approach in this chapter is to determine typical human/system mismatches to guide both future research and short-term human factors implementation by system participants. Also, by providing a human factors analysis of aircraft inspection, it is intended to make human factors techniques more widely available to maintenance organizations, and to make aircraft maintenance more accessible to human factors practitioners.

Error-prone human/system mismatches occur where task demands exceed human capabilities. The necessary comparisons are made through a procedure of task description and task analysis. Task description enumerates the necessary task steps at a level of detail suitable for subsequent analysis. Task analysis uses data and models of human performance to evaluate the demands from each task step against the capabilities of each human subsystem required for completion of that step. Examples of subsystems are sensing (e.g., vision, kinesthesis), information processing (e.g., perception, memory, cognition), and output (e.g., motor control, force production, posture maintenance).

Table 1.3 shows a seven-task generic task description with examples from each of the two main types of inspections: Visual Inspection (VI) and Non-Destructive Inspection (NDI).

TASK DESCRIPTION	VISUAL EXAMPLE	NDI EXAMPLE
1. Initiate	Get workcard, read and understand area to be covered	Get workcard and eddy current equipmemn, calibrate.
2. Access	Locate area on aircraft, get into correct position.	Locate area on aircraft, position self and equipment
3. Search	Move eyes across area systematically. Stop if any indication.	Move probe over each rivet ahead. Stop if any indication.
4. Decision Making	Examine indication against remembered standards, e.g. for dishing or corrosion.	Re-probe while closely watching eddy current trace.
5. Respond	Mark defect, write up repair sheet or if no defect, return to search.	Mark defect, write up repair sheet, or if no defect, return to search.
6. Repair	Drill out and replace rivet.	Drill out rivert, NDT on rivet hole, drill out for oversize rivet.
7. Buyback Inspect	Visually inspect marked area.	Visually inspect marked area.

Table 1.3 Generic Task Description of Incoming Inspection with Examples from Visual and NDI Inspection

Given a generic task description, the next requirement is to bring human performance models to bear on the tasks, and hence form a task analysis. Two ways were found to perform this. First, the critical human subsystems were checked at each task step. Second, observations of likely errors, human factors improvements, and error-related issues were made from observations taken. These led to a composite task description/task analysis form as an in-project working document.

To document the human and system error potential, the approach taken was to have the analysts visit several maintenance/inspection sites and work with inspectors to complete task descriptions of representative tasks. Inspectors were observed, questioned, photographed and interviewed, often on night shifts and under typical working conditions. (The degree of cooperation, enthusiasm and professionalism of all of our "subjects" was remarkable, and reassuring to the travelling public.)

1.4.1 Summary Findings

There are many places where Human Factors interventions can be effective. This Chapter describes experience in applying Human Factors to inspection tasks in manufacturing industry. In summary these include:

- Changing the system to fit the operator:

1. Improving visual aspects - lighting, contrast, target enhancement, optical aids, false colors on video.
2. Improving search strategy - briefing/feed forward, aids to encourage systematic search.
3. Enhancing fault discriminability - standards at the workplace, rapid feedback.
4. Maintaining correct criterion - recognition of pressures on inspection decisions, organization support system, feedback.
5. Redesigning the aircraft and its systems to improve access, search and decision, i. e. Design for Inspectability (Drury, 1990).

- Changing the operator to fit the system:
  1. Selection/placement - visual function, perceptual style (Drury and Wang, 1986).
  2. Training/retraining - cuing, progressive part training schemes, controlled feedback (Drury and Gramopadhye, 1990).

When applied specifically to aircraft inspection, Table 1.4 shows a summary of the potentially-useful strategies. They range from the simple (such as improved flashlights and mirrors for visual inspection and safe, easily-adjustable work stands) to the complex and costly (such as pattern recognition-based job aids, restructuring of the organization to provide feedforward and feedback).

	STRATEGY	
	Changing Inspector	**Changing System**
Initiate	Training in NDI Calibration (Procedures Training)	Redesign of Job Cards Calibration of NDI Equipment Feedfoward of Ecpected Flaws
Access	Training in Area Location (Knowledge and Recognition Training)	Better Support Stands Better Area Location System Location for NDI Equipment
Search	Training in Visual Search (cueing, progressive-part)	Task Lighting Optical Aids Improved NDI Templates
Decision	Decision Training (cueing Feedback, Understanding of Standards	Standards at the Work Point Pattern Recognition Job Aids Improved Feedback to Inspection
Action	Training Writing Skills	Improved Fault Marking Hands-free Fault Recording

Table 1.4
Potential Strategies for Improving Aircraft Inspection

The FAA recognizes that communications and training need immediate attention. The aviation maintenance information environment (Drury, 1990) complicates communication between inspectors and their co-workers (e.g., feedforward information), between inspectors at shift change, and between inspectors who find a problem and those who must reinspect and approve ("buy-back") that repair. Training is largely on-the-job, which may not be the most effective or efficient method of instruction. In subsequent years, the National Aging Aircraft Research Program (NAARP) and, hopefully, the maintenance/inspection providers need to pursue both short-term interventions based on solutions proven effective in manufacturing, and longer-term research to give definitive, implementable solutions.

1.4.2 Phase II Plan

Phase II of this research task will pursue the overall program goal to create demonstrations of techniques to improve human factors in aviation maintenance. The first subtask will identify, implement, and measure the effect of specific lighting improvements used in an inspection task. This research task will assess the lighting change with respect to potential elimination of error and with respect to cost effectiveness.

A second task under this research topic will address methods to reduce error in the calibration and operation of a variety of non-destructive inspection test equipment. This research will study the human factors aspects of NDI equipment design and various aspects of training and retraining of NDI personnel. Finally, this subtask will continue to identify human factors issues that should be addressed in the continuing effort to improve human performance in inspection.

1.5 STUDY OF ADVANCED TECHNOLOGY FOR MAINTENANCE TRAINING (CHAPTER 4)

Advanced technology training refers to the combination of artificial intelligence technology with conventional computer-based instructional methods (Johnson, 1990).

This chapter reports the status of a project to support the application of advanced technology systems for aircraft maintenance training. The first phase of the research was to survey the current use of such technology in airlines, manufacturers and approved aviation maintenance technician schools. The second phase of the research is building a prototype intelligent tutoring system for aircraft maintenance training. The chapter defines intelligent tutoring system technology and presents the specifications for the prototype. The chapter also describes example constraints to the rapid design, development and implementation of advanced technology for maintenance training.

The human is an important component in the commercial aviation system that provides safe and affordable public air transportation. Much attention to the "Human Factor" in the aviation industry has focused on the cockpit crew. However, the FAA and the airlines recognize that aircraft maintenance technicians (AMTs) are equal partners with pilots to insure reliable safe dispatch. The job of the AMT is becoming increasingly difficult as discussed in Section 1.1.2. This is a result of the fact that there are increasing maintenance tasks to support continuing airworthiness of the aging aircraft fleet while, at the same time, new technology aircraft are presenting complex digital systems that must be understood and maintained. Sheet metal and mechanical instruments have given way to composite materials and glass cockpits. These new technologies have placed an increased training burden on the mechanic and the airline training organizations. The advanced technology training research, reported here, is exploring alternatives for the effective and efficient delivery of a variety of aircraft maintenance training.

1.5.1 Summary Findings

The industry survey showed that there are many applications of traditional computer-based training being used for maintenance training. However, there are very few applications of artificial intelligence technology to maintenance training. Nearly all airline personnel indicated that current computer-based training was not sufficient to meet all of the demands associated with maintenance training. The survey also suggested that managers of maintenance training are becoming increasingly articulate about specifying their requirements for computer software and hardware. Numerous industry committees are creating standards that will increase compatibility across the maintenance training industry.

The FAA is in the process of modifying the regulation affecting the AMT schools. Part 147 of the Federal Aviation Regulations now recognizes that computer-based training systems are, in selected cases, as valuable for training as the use of real equipment. This change in policy is likely to create an increased marketplace for development of advanced technology training systems.

During Phase I a prototype training system was built for an aircraft environmental control system. Development of the environmental control system training prototype demonstrated that rapid prototyping is a very effective means to involve system users in the earliest stage of the system design. The software tools for rapid prototyping make it relatively easy to create reasonable examples of the final system interface. However, this prototyping effort reinforced the researchers' opinion that the "easy to use" tools are good for rapid prototyping but have limited potential with respect to building the completed training system. Subsequent development must be accomplished with programming languages rather than interface development tools.

1.5.2 Phase II Plan

During Phase II the environment control system training prototype will be written in a programming language. The simulation, specified in Phase I, will be written. The knowledge engineering process and formative evaluation will continue with the technical personnel. The prototype will be converted to a fully operational turn-key training system. The training system will be the key focus for the extensive evaluations planned for Phase III.

1.6 STUDY OF JOB PERFORMANCE AIDS (CHAPTER 5)

This research was designed to provide information for government and industry managers in their efforts to assess the utility and implementation of job-aiding technology. There were two areas in this research task - aviation maintenance assessment and technology assessment.

The first research area sought a user's perspective on job performance aids (JPAs). Current approaches to computerization and job aiding in aircraft maintenance were investigated. A survey was conducted to determine the relative level of automation at 25 airlines. Systems were observed during various phases of development and work force reactions were determined. The needs of the maintenance technician were assessed and an overall understanding of the maintenance process was obtained.

The second area focused on technologies. A survey was conducted to determine the capability of existing JPA systems. The state-of-the-art in computers and in related technologies was assessed. Current approaches to system integration were identified.

The research documented the challenges facing aviation maintenance and the current approaches to utilize technology in meeting those challenges. This information was obtained from four sources:

- Airlines - managers, data processing specialists, AMTs
- Industry representatives - groups such as the ATA
- FAA - maintenance managers and inspectors
- Manufacturers - customer support, designers

Access to these individuals was obtained through participation in numerous industry forums and site visits. The site visits lasted from two hours to one week. Information was collected through informal interviews and observation. The researchers participated on a non-interference basis in the normal conduct of aircraft maintenance. All shifts of operation were observed.

Information was collected through surveys, expert assessment, and literature research. A survey of existing JPA systems was conducted. The focus of the JPA survey was on computer and microprocessor-based systems used for information delivery, processing, or storage. In addition, applicable technologies not yet incorporated in systems were identified in anticipation of future systems. The goal of the survey was not to find the system that would "revolutionize" aviation maintenance, but to assess the overall extent and characteristics of what has been done and what is possible in terms of job aiding. The information was collected through extensive database searches, telephone discussions, and site visits. Several "new" technologies were investigated in computer displays, microprocessors, storage, and input/output devices. Finally, two small experiments were conducted to assess the realities of developing databases and graphical user interfaces (GUI) for job performance aids.

1.6.1 Summary Findings

The findings are divided into three areas:

- Maintenance automation
- Technology assessment
- Systems integration

The areas represent what exists, what is possible, and how to transition between the two. The findings on maintenance automation systems describe the status of maintenance automation, how they are designed, justified, lessons learned, and trends for the future. The technology assessment findings provide a realistic assessment of the utility of technologies in terms of cost, function, availability, and complexity. The focus of the systems integration findings is information on how to integrate humans into the various systems.

1.6.1.1 Maintenance Automation

The process of fielding maintenance automation has largely been one of computerization. The statistics maintained on aircraft have grown exponentially. The basic structure used for the paper methods has been transferred intact to the computer approaches. This was necessary to ease transition and avoid extensive retraining that might be needed with a new approach. Most maintenance operations now use computers to track parts and aircraft status, and many organizations are moving computers into forecasting and other decision aiding functions. Efforts to computerize have reached a plateau, and only the most profitable airlines have data processing people actively developing major new systems for maintenance.

1.6.1.2 Technology Assessment

The survey of JPAs identified over 150 job performance aids developed during the last ten years. More than half of the developments were sponsored by the Department of Defense (DoD). Fewer than twenty systems are still in active use or development, and another twenty were searching for a sponsoring application. The remaining were shelved for reasons that usually involved lack of funding.

There are several successful JPAs, and the survey findings do not imply that JPA development is unfeasible. The survey did support the need for a more realistic assessment of how soon JPA technology can be applied to commercial aviation maintenance.

1.6.1.3 Systems Integration

Based on technical functionality, most of the computerization efforts for aircraft maintenance and JPA development efforts by the DoD were successful. Unfortunately, technical functionality is not good enough. Humans remain the engine for most complex systems. Even automatic test equipment (ATE) is dependent on humans for planning, design, manufacturer, installation, and maintenance. Approaches exist that incorporate Human Factors and these should be considered.

1.6.2 Phase II Plan

The next phase of the research on job aiding will identify a candidate technical domain in which a computer-based intelligent job aid can have potential to increase maintenance effectiveness and efficiency. During Phase Two the research team will work with an airline to identify a candidate domain and construct a system prototype. Current plans are aimed at using a portable, expert system-based job aid that has been developed in a non-aviation industry. The next phase of the research will focus more on the specification and development planning than on completion of the job aid for an operational aviation maintenance environment. Sewell and Johnson (1990) have described how prototype systems can be used for system design and development. The intelligent job aid prototype will be used for concrete systems specification for Phase III development.

1.7 HUMAN FACTORS IN AVIATION MAINTENANCE - THE CONFERENCES

The combination of factors described in Section 1.2 highlights the importance of communication among all entities involved in the aviation maintenance system. Broderick (1990) suggested that industry communication "ties the maintenance operation together and, in fact, is the thread that runs through aviation safety from any point of view...." This project was a direct intervention to present Human Factors information to the aviation maintenance community, and to provide a forum for direct interchange of relevant information between system participants. This sub-project organized a series of Human Factors seminars for personnel associated with aviation maintenance.

As noted in Section 1.1, the air carrier industry in the United States can be viewed as a three-legged stool consisting of the aircraft manufacturer, the airline operator, and the regulatory agencies, principally the Federal Aviation Administration. For carrier maintenance to work as it should, communications among these three elements must be efficient and meaningful. The cross braces in the stool represent the communication.

The FAA and industry have noted a need to develop some other mechanisms to foster ready communications among airline operators, aircraft manufacturers, and the FAA. This should exist in some form that would allow members within each of these three groups to understand the current thinking of members of the other two groups. A free exchange of information should be allowed concerning maintenance technologies, procedures, and problems.

The Federal Aviation Administration, on reviewing the success of the 1988 meeting, established a series of meetings to address "Human Factors in Aircraft Maintenance and Inspection." The purpose was to foster communications among all segments of the aviation maintenance community. To date, four meetings have been held. While the first meeting in 1988 explored the full range of maintenance problems, each subsequent meeting focused on a specific Human Factors issues in order to obtain greater depth of coverage.

The four meetings in this series held thus far are:

Human Factors Issues in Aircraft Maintenance and Inspection Alexandria, Virginia, October 1988.

Presentations were made concerning maintenance issues and human factors ramifications by representatives of aircraft manufacturers, airline operators, the FAA, technical training schools, and others. Three presentations described the discipline of human factors and its potential contribution to aviation maintenance.

Human Factors Issues in Aircraft Maintenance and Inspection - Information Exchange and Communications Alexandria, Virginia December 1989.

This meeting focused on problems in the exchange of maintenance information and possible improvements in information management and industry communications. Considerable attention was given to new technologies which might support industry communications.

Human Factors Issues in Aircraft Maintenance and Inspection - Training Issues Atlantic City, New Jersey, June 1990.

The purpose of this meeting was to review the status of maintenance training for the air carrier industry, to consider problems facing those responsible for this training, and to learn of new training technologies under development. Some of the presentations illustrated new technologies now being brought into use in aviation maintenance.

Human Factors Issues in Aircraft Maintenance and Inspection - The Aviation Maintenance Technician Alexandria, Virginia, December 1990.

The meeting dealt with the aviation maintenance workforce. Presentations dealt with acquiring, training, and maintaining an effective workforce. The likely impact of changing national work force demographics was explored. The impact of organizational factors on aviation maintenance was reviewed.

Attendees at each of these meetings have commented on the value of the meetings as a communications medium for the air carrier maintenance community.

1.7.1 Phase II Plan

There will be two workshops conducted during Phase II. The first, scheduled for June 1991 in Atlanta, Georgia, will address Human Factors in the aviation work environment. The second meeting will be in Washington, DC, during January of 1992.

1.8 ADDITIONAL RESEARCH ACTIVITIES

The research program is committed to be responsive to Human Factors issues related to proposed rule changes, new policies, Airworthiness Directives and/or Service Difficulty reports.

1.8.1 Electronic Document

One of the projects scheduled for Phase II is the development of an electronic database of all publications and presentations from Phase I of the program. The electronic document will capitalize on hypertext software technology. This research will go beyond the mere digitization of documents. The project will emphasize a document format and electronic interface that will provide greater capability than is available with hard-copy documentation. The project will create specifications for the electronic publishing of all past and new project-related documents. At the completion of the project the documentation will be available on one compact disc read only memory (CD ROM) disc.

1.8.2 Handbook on Aviation Maintenance Human Factors

During Phase II the research team will outline and prototype a handbook on aviation maintenance human factors. The handbook will offer basic and applied principles covering all issues of human performance in aviation maintenance. The handbook will be useful to all who are responsible for planning, managing, and conducting maintenance. It will include, as an example, the following kinds of topics: workplace requirements, workplace environment, human capabilities, workplace design principles, training design and practices, and other topics. The handbook will follow formats used in other such compendia (Boff and Lincoln, 1988; Parker and West, 1973).

1.8.3 The National Plan for Aviation Human Factors

The Federal Aviation Administration, in conjunction with the National Aeronautics and Space Administration (NASA) and the US Department of Defense, conducted an extensive series of workshops, during 1990, to create a National Plan for Human Factors. One of the subgroups of the Scientific Task Planning Group was dedicated to Human Factors in aircraft maintenance.

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