Chapter Five
Job Performance Aids

5.1 INTRODUCTION

This research is designed to provide information that will enable maintenance managers in government and industry to more effectively manage the integration of technology into the work place. The information in this chapter will aid in assessing the capability of technologies and possible applications. It will provide a basis to judge various approaches of implementing technology. The information will contribute to efforts for estimating the time, expense, and utility of fielding Job Performance Aids (JPAs) and technology in maintenance operations. Principally, the information will help determine the return that can be expected from an investment in technology. A primary focus is on developing approaches for technology implementation that complement human capabilities (see Table 5.1). This is accomplished through research in two areas.

Summery of Research Objectives

Rank	Description
1.	Provide information to enable informed decisions on the integration of humans and technology.
2.	Provide information to increase the understanding of the capabilities and limitations of technology.
3.	Provide information that will simulate thought and awareness of avenues for increasing human performance through Human Factors considerations.

Table 5.1 Summery of Research Objectives

The first area seeks a commercial maintenance perspective of the issues. The research investigates current approaches to computerization and job aiding in aircraft maintenance. This includes a review of the relative level of automation at major airlines. The structure of completed systems is observed and work force reactions to the systems are determined. Trends are identified. The needs of the maintenance technician are assessed, and an overall understanding of the maintenance process is acquired.

The second area focuses on technologies. A survey was conducted to determine the capability of existing JPA systems. The state-of-the-art in computers and related technologies are assessed. The complexity and pragmatic considerations of designing databases, expert systems, and computer user interfaces are evaluated through experiments. Current approaches to system integration are identified. Expert assessments were obtained on the capabilities and limitations of various technological approaches.

5.2 PROBLEM DEFINITION

Research on Advanced Technology Job Performance Aids is included in a human factors research program in response to the concern that humans will not be able to meet the growing challenges of aircraft maintenance without the proper application of technology. The word "technology" is used broadly in this report to identify the tools available in science and engineering that may be applied to aviation maintenance. The growing challenges in commercial aviation maintenance are well documented (Parker and Shepherd, 1989, 1990 a. and b.). The challenges include aging aircraft, retiring work force, increasing maintenance capacity requirements, increasing aircraft complexity, increasing fleet diversity and size, diminishing pool of new technicians, and limited financial resources

Table 5.2 summarizes the researcher's understanding of the problem that originally motivated the research. Table 5.3 is the researcher's understanding of the problem at the completion of Phase I research.

Initial Motivation for Research

Rank	Description
1.	Technology is needed to help humans cope with growing challenges.
2.	Technology is needed to overcome the potential for human error.
3.	Technology is needed to overcome human limitations. (i.e. accuracy).
4.	Technology can make maintenance operations more efficient.
5.	Maintenance Technology should keep pace with aircraft technology.

Table 5.2 Initial Understanding of the Problem.

Final Motivation for Research	
Rank	**Description**
1.	Avenues for achieving peak human performance are under utilized.
2.	Implementing technology is more complex and expensive than accepted.
3.	The human factors of achieving user acceptance are not will understood.
4.	The human factors of system development (i.e. Developer/User communication are not well understood.)

Table 5.3 Understanding of the Problem at the end of the Phase I Research

If technology is to be used to meet new challenges it must complement existing human resources. Motivation to introduce technology might come from any of the areas described in Table 5.2. The relationship of technology and humans must be carefully planned.

The process of implementing Job Performance Aids is not straight-forward. It has proven difficult to predict the duration and costs of development. Development requires complete communication between the application experts (eventual users) and the system developers (who know what technology can do). This close working relationship is difficult due to the disparate backgrounds and languages of the two groups. The development process is a long series of trade-offs between reducing functionality to make development more feasible and adding functionality to make the system more useful. The final system is the system developer's interpretation of user needs, tempered by what is feasible.

Some JPAs are already in place, such as built-in test equipment (BITE). The fielding of these technologies is on-going, but guidelines that work in many environments are unsuccessful in aviation. For example, initial BITE systems fielded by Airbus had accuracy levels in the range of 90%. In the perspective of the design team this is a very successful system, but to a maintenance technician this was a very frustrating system. Repairs and component replacement in aviation are almost universally time consuming, so even one misguided recommendation in ten can waste an entire shift with some frequency. The BITE systems are improving and are now generally accepted as useful tools, but their implementation took time and considerable resources.

5.2.1 Computerization

The trend toward increased automation through computerization is well under way. Computers are already deployed in most of the "deterministic" tasks of maintenance operations such as tracking, scheduling, budgeting, and status reporting. Starting with mainframes in the 70's, most major airlines are now working on their second or third generation systems. While the mark of computers on maintenance operations is apparent and permanent, the implementation of the systems has not always been well received and their cost effectiveness is not always clear. Aviation maintenance is not necessarily an ideal application for computers, but during the 80's, as operations grew in complexity, computers seemed to be a solution for many problems. Computers in aviation maintenance usually achieved functional requirements, but sometimes failed to live up to the expectations of the user. This was due in part to the difficulty of fielding new technologies, and in part to the user's difficulty in specifying needs clearly. All involved are now sensitized to the criticality of assessing the user's needs, but it is not clear how this can be achieved satisfactorily. In any case, there is much more awareness of the difficulty of achieving objectives when humans are an integral part of the system (which is almost always the case.)

Computers solved some problems and created some new ones. Many difficulties had to be overcome to fit existing approaches to the nature of computer solutions. For example, many problems arose from the computer's affinity for numbers and the human affinity for symbols. Early on, technical considerations dominated and parts numbering, for example, became driven by computer requirements rather than maintenance requirements. One airline reported an air-turn-back when similar (but non-interchangeable) parts with like numbers were interchanged. This example and others highlight why the enthusiasm for computers diminished as workers lost control to the demands of the computer system.

Implementation of technology is an expensive, and to some extent experimental (trial and error) process. The Department of Defense expends enormous resources to bring ideas from concept to reality. Airlines rarely have the resources to carry out the same process. Maintenance operations are faced with mostly fixed expenses such as facilities, spares, and labor. Labor is not entirely fixed, but nearly so, given union agreements and the disruptions caused by layoffs. The volatility of repairs required in the fleet during any year are not reflected in the flexibility of annual budgets under which maintenance managers work. Financial resources are focused on the many expenditures encountered in maintenance, for example, in the process of swapping out or replacing parts in the aircraft. As a result, a very low percentage of the budget, if any, is available for computerization.

Computers will continue to become more adept at performing existing tasks, but the remaining avenues for computerization are more challenging. For example, communication of maintenance information is a central concern for every maintenance worker. Some technicians reported spending as much as 75% of their time obtaining the information needed to perform their duties. The problem is that this information is difficult to quantify. It is not simply a matter of having technical manuals available on-line. Subtle information such as the fact that a battery needs charging can make the difference between a successful engine run up or a wasted shift. Aircraft maintenance depends on a large number of interdependent events. The resulting complexity challenges the humans involved, and makes the process of computerization arduous.

5.2.2 Human Error

At the technician level there are consistent calls to automate elements of maintenance programs which are prone to human error. The heavy demands placed on inspectors to detect structural problems with aging aircraft motivate the pursuit of new Non-Destructive Inspection (NDI) equipment. The National Transportation Safety Board accident report on the Sioux City accident contains the following recommendation (NTSB, 1990):

"Intensify research in the nondestructive inspection field to identify emerging technologies that can serve to simplify, automate, or otherwise improve the reliability of the inspection process."

5.2.3 Human Limitations

Labor costs are a common concern of managers; thus the idea of tireless, efficient, and precise robots is appealing. JPAs are sought to overcome human limitations of attention span, endurance, and accuracy. This propensity is also motivated by the expectation that there will not be enough technicians available in the future, and the ones that are available will have difficulty working with increasingly complex aircraft.

5.2.4 Maintenance 2020

In the 40's and 50's it was likely that the aircraft mechanic was familiar with most aircraft systems, with the possible exception of the radio equipment. Today, only the most experienced aircraft technicians are familiar with a majority of the systems, and radio has been joined by a growing set of avionics equipment. The complexity of aircraft maintenance is expected to continue to increase. It is likely that computers and technology will play a larger role in the maintenance effort, but what are the characteristics of the role? How large will the role be, which technologies will be used, and when will they be used? If these questions could be answered, many false starts and considerable wasted effort could be prevented. Integration of technology is a long process and planning must be accomplished years in advance. The maintenance process has little margin for trial and error, and few resources are available to support extensive experimentation. Technology changes so rapidly that it often seems a new approach is obsolete as soon as it is successfully fielded. There may never come a time when maintenance programs or technology will arrive at a steady state. While it is not possible to see the future in a crystal ball, a great deal can be learned from past experience.

5.2.5 Technology

Technology has a lure of its own. Emerging technological capabilities seem to have "potential" to improve nearly everything. Pressure for change often comes from the promises of "technologists", eager to find applications for their inventions. It seems natural that as aircraft become more sophisticated, maintenance should follow. However, bias toward new technology should be tempered by a careful assessment of user needs. Designers are usually able to field hardware and software that works functionally, but compatibility with humans is more elusive.

Clearly "manual" methods are not sufficient forever. For example, technical documentation on aircraft systems has grown exponentially and a typical narrow body aircraft now arrives with 17,000 pages of documentation. Airlines usually maintain several different types of aircraft and must use unique procedures for each. A number of technological solutions are available to make the information more accessible, but more work is needed to facilitate the assimilation of the information. The point is that finding a technological solution does not replace the need for careful consideration of human factors.

5.3 METHODOLOGY

The research sought to obtain a rapid high level understanding of the issues. The primary task was to assess the implications of fielding technology to aid commercial aircraft maintenance. The information contained in this chapter is targeted for a reader who has considerable knowledge of aircraft maintenance, limited knowledge of computers and technology, and very little knowledge of Human Factors.

5.3.1 Aviation Maintenance Assessment

The research sought a first hand understanding of the challenges facing the aviation maintenance community and the current approaches for utilizing technology to meet those challenges. Basically, this knowledge is obtained from several sources:

- Aviation maintenance managers
- Aviation maintenance technicians
- Maintenance computerization specialists (MIS or DP)
- Aviation maintenance industry representatives
- FAA managers responsible for aviation maintenance
- Aircraft manufacturer representatives

5.3.1.1 Participation in Industry Forums

Participation in numerous industry forums from conferences to high level briefings provided access to most of the individuals listed above. Information was collected through informal unstructured interviews and discussions, as well as, through observation. The research objectives and approach were presented on these occasions, and feedback was used to focus and direct the effort.

5.3.1.2 Site Visits

Site visits lasting from several hours to one week were utilized to collect information on facilities, develop an understanding of the overall maintenance process, and to further talk with the individuals listed above. Information was collected through informal interviews and observation. When possible, the researchers participated on an non-interference basis in the normal conduct of aircraft maintenance. Technicians explained what they were doing as they performed their duties. All shifts of operation were observed. Training classes and morning management briefings were observed. The researchers reviewed documentation and procedures utilized in each aircraft maintenance organization. The Quality Control Department was normally the host, but time was spent with a cross-section of the maintenance organization. The research objectives and approach were always presented to verify that the results would be useful to the maintenance community.

5.3.2 Technology Assessment

5.3.2.1 Survey

A survey of existing JPA systems was conducted. A narrow definition of JPA was utilized, since there are existing sources of information on tooling, ATE, fixtures, and non-destructive inspection equipment. The focus of the JPA survey was on computer and microprocessor based systems utilized for information delivery, processing, or storage. In addition, a few applicable technologies, not yet incorporated in systems, were identified as part of the survey. Systems and technologies developed outside of aviation were included if they demonstrated a technology not already used in aviation. The military was the primary sponsor. Each aircraft manufacturer and large airline, as well as several other major industrial companies, had at least one JPA in development. The goal of the survey was not to find the system that would "revolutionize" aviation maintenance (although, if we had found one, it would have been included), but to assess the overall extent and characteristics of what is feasible and possible in Job Aiding. The systems were identified through database searches and the information was supplemented by contacting the developers. In addition, some systems were identified through site visits or at industry forums.

5.3.2.2 Technology Research

Research was conducted to assess the capabilities and limitations of the technologies that are most often proposed for implementation in aviation maintenance operations. Principally this effort focused on the application of computer technologies. Artificial intelligence and expert systems were given particular emphasis. Several "new" technologies were investigated in computer displays, microprocessors, storage, and input/output devices.

5.3.2.3 Experiments

Limited experiments were conducted to evaluate the pragmatic considerations involved in developing expert systems, databases, and computer user interfaces. The experiment in interfaces was principally software development task, but emerging technologies in the processor, packaging, and display were also tested. Database technology was used to organize the findings from the JPA survey, and a small expert system was developed with a commercial expert system development package.

5.4 FINDINGS

5.4.1 Overview

The findings are divided into three categories:

- Technological contributions
- Technological obstacles
- Implementation guidance

A working knowledge of each is needed to make successful decisions about applying new technologies in aviation maintenance. The findings apply to the industry, in general, but the reader can assess whether it is applies in their situation. The overall theme of the findings is the importance of a realistic assessment of the capabilities of technology. The section characterizes the present capabilities of technology and the likely capability of technology over the next ten years. The scope is limited to ten years, since predictions beyond ten years are highly speculative. In any case, few maintenance managers can afford to make decisions based on a theoretical potential 15 years in the future. Lessons learned from implementing technology over the last decade are documented throughout this section.

5.4.2 Technological Contributions

5.4.2.1 Automation in Aviation Maintenance

For a majority of the industry, maintenance automation means computerized maintenance information systems. Virtually all maintenance organizations have systems in place or anticipate implementing systems in the near future. Information systems provide indirect support of maintenance, but computers are also directly involved in maintenance in automatic test equipment or diagnostic support systems. The latter are covered in the next section on technologies.

The amount of information maintained on each aircraft has grown exponentially, but the basic structure of the paper methods are intact in today's information systems. This was necessary to ease the transition from manual methods and avoid extensive retraining. Most airlines developed maintenance information systems internally because each had unique maintenance programs. Even so, problems surfaced because computer applications were rarely able to do everything the same as manual methods and lacked flexibility. Further, it proved difficult to predict the magnitude of effort needed to develop systems or insure user acceptance.

Most maintenance operations now use computers to track parts and aircraft status, and more organizations are moving computers into forecasting and other decision aiding functions. Systems are justified based on promises to increase aircraft, engine, and component availability, or enable more production with existing resources. However, managers reported that unless an aircraft fleet was growing, labor savings in production were usually offset by increases in planning, production control, material, and data processing. The intensity of computerization efforts has slowed somewhat; only the largest (and profitable) airlines have data processing departments actively developing major new systems. All airlines continue to absorb and become accustomed to existing systems.

5.4.2.1.1 Why Automate?

The growth that airlines experienced in the post deregulation era provided motivation for most automation efforts. Tasks such as aircraft routing became too cumbersome as fleet size increased. Computerization offered increased capacity, faster turnaround without the need to develop an entirely new approach. Tangible and intangible benefits are achieved with automation. The intangible benefits out number the tangible ones.

The intangible benefits were often promoted as more important than the tangible benefits. The information needed by management to streamline operations is mostly intangible. Automation systems provide many more avenues than manual systems for tracking the technical performance of the organization. Management needs this information to recognize problems before they become critical. Automation systems make it easier to identify trends. The result is a more accurate control of resources and the efficiencies achieved can lead to increased maintenance capacity.

Cost control was frequently given as a reason for implementing automation systems. The computerization enables faster customer billing and closer tracking of costs. Detailed histories of existing costs improve forecasting and planning. In addition, comprehensive reliability information enables prompt acknowledgment of performance difficulties. The effectiveness of individual management decisions can be determined more readily with the additional information provided by the automation systems.

Tangible benefits are primarily found in increased aircraft (or engine or component) availability and additional capacity. The information from maintenance automation systems provides efficiencies that reduce turnaround times. Reduced turnaround time leads to increased aircraft revenue hours, fewer labor and material dollars for each service, and shorter AOG's. The information processing capability of the systems augment condition monitoring and enable more efficient stocking of spares. Stricter control of inventory and resulting efficiencies can lead to savings.

A couple of benefits that were sighted in the early years of automation never became reality. One area is manpower saving, as mentioned earlier. The other was the goal of a "paperless" system. There are a number of reasons for this failure including the fact that humans prefer to read hard copies and that computer information is updated so frequently. Combining these with the proliferation of copy machines and a visit to most maintenance facilities demonstrates that the goal of a "paperless" system has not been achieved.

5.4.2.1.2 What Can be Automated?

Computers are involved in most aspects of information management for maintenance, engineering, and materials. Airlines incrementally developed their systems over a number of years. Functionality and enhancements were added to a core capability. The difficulties not withstanding, the presumption is that each new piece or type of information added provides a more accurate and complete picture of the maintenance operation. As an example of the complexity involved, consider service scheduling. Scheduling depends on multiple constraints and has many ramifications. The service schedule has implications for labor, facilities, and materials requirements. The objective is to make efficient use of the first two and minimize the last element. In any case, in order to ensure all are available in sufficient quantity (and not in excess quantity) the service schedule must be carefully planned. The schedule is based on forecasts of expected demand. The unscheduled service requirements are anticipated from reliability information and the time condition of the aircraft. Ratable requirements, modification requirements, and deferred work all figure into the equation. The schedule requirements are meshed with resource availability to determine aircraft arrival and work scheduling.

Planning might utilize the computer for maintaining aircraft maintenance history, development of work packages, and work card generation. In addition, planners need access to service forecasting, service scheduling, and aircraft routing information. Computer support of work cards is increasingly common. Most organizations have computerized work card indexes and some systems generate the cards on demand.

Other than tracking parts, status information is one of the most widely implemented functions and represents a significant level of complexity on its own. The hours and cycles of every aircraft in the inventory must be known for tracking time limited parts and complying with regulations. The configuration of each aircraft is tracked for modifications and component serial numbers. Maintenance status includes pilot reports, discrepancies, deferrals, and history. Information necessary to support warranty claims is maintained, such as manufacturers requirements, time tracking, and flight history. Aircraft modifications might be tracked separately for the fleet, aircraft, and individual components.

Varying degrees of reliability information can be maintained on the fleet. A delay summary might be reviewed daily, where each delay is charged to a specific area of the airline or maintenance department. Unscheduled removal rate can be tracked to identify trends, perhaps from shop information. The management of materials and purchasing can be similarly information intensive, and there are several types of information of interest to manage rotables.

5.4.2.2 Industry Computerization

Virtually all major maintenance organizations utilize some form of computerized management information system. Relatively few utilize computer based job aiding systems for the technicians, other than tracking parts or automatic test equipment. Most of the systems were developed internally, although the current trend is to use outside consultants and off-the-shelf software. Some airlines are marketing their information systems to other maintenance organizations. It is difficult to gauge the cost benefits of the current generation of systems, but few consider it possible to go back to the old manual methods.

The following describes the level of automation at several airlines:

Air Canada has several types of mainframes, including Honeywell, IBM, and Unisys. They utilize networked HP and Wang mini-computers, as well as PCs. Most information utilized by management is maintained using the computers.

Alaska Airlines uses an Amdahl mainframe that is networked to the maintenance base. The system tracks aircraft and component history. Macintoshes are available for management reporting and other applications.

American Airlines has many management activities automated and is currently studying a major new automation plan.

America West uses a Unisys mainframe running software developed internally. The system performs tracking functions and supports planning.

British Airways has IBM mainframes handling all management information processing and storage requirements.

KLM uses several computerized systems. One is called CROCOS (computerized rotables control system) and another is called COMPASS (computerized material procurement and supply system.)

Northwest Airlines has an extensive automation system called SCEPTRE. It runs on IBM mainframes and was developed internally. The system addresses most management information needs, and is still growing.

Pan Am uses a system developed internally called AMIS (aircraft maintenance information system.) This is also a mainframe based system and performs functions such as maintenance scheduling, technical services, and retrieval of maintenance items.

TWA has applications running on an IBM 3090 mainframe to track aircraft status, maintenance requirements, and support reliability analysis. Capability has been added to track parts and labor using bar code technology.

United Airlines is one of the few airlines with a separate department devoted to developing maintenance automation systems. They review proposals received from vendors and develop systems in-house.

US Air uses a system developed internally called MERLIN. It is an integrated set of applications running on a IBM 3090 mainframe. Some of the details of this extensive system are included as a part of the JPA survey in the Appendix. Modules have been developed to perform numerous functions such as tracking maintenance activity, discrepancies, component times, and preparing repair shop schedules. US Air also has a robot controlled parts warehouse system.

5.4.2.3 JPA Survey

A survey of job performance aids was conducted to assess the application of technology in aviation maintenance over the last ten years. The focus was on computer or microprocessor based systems used to process, store, or deliver information to the maintenance technician. The systems currently in use in commercial maintenance tend to be the information systems discussed above. The survey concentrated on novel approaches to analysis, diagnosis, decision and job aiding, although a sample of other applications are included. Brief descriptions are included in the appendix, and a summary is included in the Chapter Appendix. In the interest of conserving space, the description of some systems is not included.

The survey was comprehensive, but some proprietary systems or recently announced systems might have been missed. In any case, the sample gives an overall sense of trends, typical applications, and the envelope of system capability. The findings demonstrated that application of technologies to aircraft maintenance is still an experimental process. Most of the systems identified did not survive beyond feasibility studies and prototyping. Active systems tended to be in the development cycle, and few systems were integrated into the day-to-day maintenance process. The long term impact of JPAs is unknown, but few experienced sponsors demonstrated eagerness to develop more systems or implement existing systems in critical applications.

It is difficult to generalize, but there seemed to be a 15 year lag between the time when an application is technologically feasible and when it is refined to the point of being cost effective. The process of implementing technology is a long term effort, and for now, except for a few specific applications (i.e.. engines, avionics), there is little evidence that the JPAs have had a major impact on the way aircraft maintenance is accomplished. In some cases, sponsors were withholding judgement until the completion of development. None-the-less, there are a few success stories and many lessons to be learned from past efforts.

Sixty percent of the systems identified were sponsored by the military, with the Air Force being the dominant sponsor. The remaining 40% were divided between commercial aviation and other commercial industries. Each of the aircraft manufacturers had at least one system in development, although often through their military divisions. Many airlines developed maintenance information systems internally, but only a few airlines were major players in JPA development. The dominant applications were systems that supported on-condition maintenance of aircraft engines.

Engines are a particularly good application, because maintenance involves collection and analysis of a lot of data. The analysis requires expertise, but can be computerized since it involves identifying trends in the data. Computers are particularly adept at reviewing vast quantities of numbers and comparing them to limits.

The recent generation of aircraft incorporates built-in test (BIT) for avionics. The early systems tended to generate numerous false alarms, but accuracy has increased over time. BIT seems to be here to stay since there are few alternatives given the growing complexity of avionics.

Thirty percent of the systems were used for fault diagnosis. Forty five percent of the systems were management information systems, 45% were used directly to support maintenance, and the rest were used for analysis. Some novel applications were identified. Several organizations are working on systems that have an imbedded self repair capability. One involves use of an expert system to reconfigure aircraft aerodynamics in the event of system failure or battle damage. A handful of efforts are tracking trend data on structures to anticipate maintenance needs, similar to what is already done for engines. The analysis involves reviewing the trends in vibration data collected from sensors. For example, the VSLED (vibration, structural life, and engine diagnostic) system developed for the V-22 tilt-rotor aircraft monitors data and generates reports that specify needed maintenance actions. Several voice recognition systems have been developed that could be used for data entry by inspectors. A product recently marketed by Lanier Voice Products receives voice inputs and automatically generates reports. Another application analyzes samples of engine lubricants taken at regular intervals. The levels of oxidation, sludge, viscosity, fuel dilution, dirt, glycol, water, and wear metals are recorded and tracked to predict when maintenance will be needed.

Forty percent of the systems identified incorporated expert system technology, 15% were portable and all used state-of-the-art hardware technology. Several new technologies made their debut in recent years. Fuzzy Logic is an approach to logic that incorporates characteristics of imprecise reasoning. Rather than being only "on" or "off", the Fuzzy methodology permits degrees of "on" or "off". This approach is used with some success to model human reasoning processes. It is a popular approach in Asia, but has not caught on in the United States. One technology that is receiving increasing attention is Virtual Reality (VR). VR combines three-dimensional graphics with sensors attached to the user to create an artificial environment. The sensors detect movement and modify the three-dimensional display accordingly. For example, the user wearing a set of goggles with miniature displays can walk through an environment created by the computer. The systems have potential to be the simulators of the future. CD-ROM has received a great deal of press, but the technology has not been widely implemented. It has very large information storage capabilities, but requires expensive hardware to store and retrieve the data. It reduces duplication costs, but it is not any more flexible than paper and humans are uncomfortable reading information from computer screens.

Several systems were portable, but portability did not appear to be as important as might be expected. It seems for the type of applications that are needed, it is not a problem to go to a terminal and get a hard copy. Portability is only a factor if each technician is given their own system, not a likely event, given current hardware and software costs. Even "dumb" terminals are currently too expensive to give one to everybody.

The principal criterion that separated the successful systems from others was the utility to the user. The successful systems are typically in applications where there is no alternative, such as engine monitoring or avionics testing. Overall, the most ambitious systems tended to get into the most trouble, unless the developer was very persistent and well funded. The systems developed by the automobile manufacturers, were well funded and had persistent developers, but still received slow acceptance until a manual mode was added. Further, it is very difficult to estimate development costs unless the application is very specific and the requirements are rigid. There is a tendency to make the system general in nature to spread the development costs across as many users as possible, but this inevitably lead to failure. The systems that targeted a very specific problem with a clear set of requirements fared best.

The road blocks to system development are establishing clear user requirements, software productivity, and the input/output required. Software is the principal expense in these systems and software development has been a long and arduous process. Several enhancements in software technology are beginning to address the problem. Computer Aided Software Engineering (CASE) tools are becoming more powerful. Object oriented programming is being implemented to facilitate the reuse of software. Authoring systems have the potential to enable users to develop their own systems. Currently, developing an application requires the developer to become an expert in the domain. Developing authoring systems is a major undertaking and no one has developed a JPA authoring system yet. Progress is being made in the I/O area in terms of graphical user interfaces, voice recognition, and computer vision. However, it will be some time (more than 10 years) before information can be communicated between humans and computers as rapidly as between humans.

5.4.3 Technological Obstacles

5.4.3.1 Technologies

The question might be asked, "What does technology have to do with human factors?" The answer is three fold. First, technology (especially "new" technology) is often sold as a solution for human factors problems. Secondly, observation shows that one of the greatest challenges of implementing technology is the human factors challenge in achieving the necessary communication between developers and users. Lastly, all systems ultimately interact with humans on some level and care must be addressed to human system interfaces.

Technology is a tool for developing systems that facilitate aircraft maintenance, but in itself does not solve any problems. For example, artificial intelligence is a tool for software development, but it is not a maintenance automation system. New technologies are developed at a rapid pace, and, in the fervor to find applications for technology, realism tends to be a casualty. Technologies are always "emerging", and industry often buys the "latest" technology. This aspect of the research seeks to diffuse this in favor of a more pragmatic assessment of the role of technology. Importantly, these findings are absent the salesmanship that often accompanies discussions of technology, as the researchers have no stake in any particular technology. A central effort in the research involved assessing the contribution already made. Comparison of past expectations and actual contributions provides insight into future contributions.

The Automated Intelligent Maintenance System (AIMS) is a typical example that illustrates the plight of many JPAs. AIMS was designed as a job aid for Army truck maintenance. It featured expert system and voice recognition technology, along with a computer screen that displayed schematic diagrams and installation drawings. It was wireless and packaged in a large briefcase. In addition to delivering technical maintenance information, AIMS was designed to track maintenance records, order parts, control inventory, maintain schedules, and support training. Over a million dollars went into development and a working prototype was fielded. However, the effort was ended when technicians were reluctant to use the prototype and the cost of updating the database was recognized. The system simply did not have the utility the technicians needed.

While not typical, the Air Force's Integrated Maintenance Information System (IMIS) serves as a model of how Job Performance Aid development efforts should proceed. It also gives a sense of the magnitude of the effort and perseverance needed to successfully implement a JPA. Table 5.4 identifies the time frame involved. IMIS is designed to be a single source of information for Air Force technicians. Technical data, diagnostics, training, historical data, and maintenance management information normally obtained from diverse sources is integrated by IMIS. IMIS has an interface for the aircraft maintenance data bus and can process information from BITE. The aircraft is identified through the interface and IMIS automatically provides aircraft specific information. In addition, IMIS has data entry capability and helps to generate necessary reports. IMIS was initiated by a concept paper in 1979 and a full up system demonstration is expected in 1993. Constant attention to the user, from assessing needs to final acceptance, is identified as the characteristic that leads this program to be more successful than others. It has proceeded in a phased manner from concept development using off-the-shelf hardware to field tests using custom hardware. The program has continually evaluated and enhanced the man-machine interface. The IMIS program is working on a complete set of specifications that could be adapted by others with similar objectives. The lessons learned by the Air Force during the development of IMIS can be utilized by the commercial industry. However, commercial and military approaches to maintenance are not the same, and IMIS technology may not transfer directly to commercial maintenance.

Example Development Cycle		
Rank	Description	% Total Time
1.	Indentification of need	-
2.	Feasibility study	3%
3.	Development plan and schedule	2%
4.	Definition of user requirements	15%
5.	Definition of user requirements	10%
6.	Initial system development	3%
7.	Small scale demonstration	2%
8.	Small scale test and evaluation	3%
9.	Final system development	22%
10.	Installation	10%
11.	Final integration-making changes to obtain user acceptance	30%
	Note: Steps are in order, but are largely interative	

Table 5.4 Development Time Frame for IMIS

Clearly maintenance will be different in thirty years and anything is possible, but the survey demonstrated that, for at least the next ten years, there is little evidence that technician job performance aids will be widely used in commercial aviation maintenance. The research reveals twelve reasons for this conclusion:

1. The Department of Defense is not planning to field systems until the middle of the decade. Commercial maintenance applications are at least five years behind the military in development.
2. Development of the systems in the automobile industry took nearly a decade and the application is more well defined. User acceptance has improved, but the cost effectiveness of the automobile systems are not clear.
3. Commercial aviation maintenance is performed by the users. Airlines and repair stations do not have the resources to undertake major development projects. Manufacturers have resources but insufficient motivation since they are not the primary maintainer of aircraft. Built-in Test systems are an exception and BIT will continue to be enhanced by manufacturers.

4. The per user cost of hardware stands at $3-5K. Although it is somewhat a function of utility, the margins in maintenance operations are not likely to support systems for every technician until system costs are under $100 per user. Acceptable costs are somewhat more at the supervisor level, but not more than $1000 per supervisor. Expensive equipment is often purchased to comply with regulations, but there seems to be no reason to regulate the use of JPAs.

5. Benefits of JPAs are primarily intangible.

6. Experience shows that user acceptance is difficult to achieve. The reasons vary from poor man-machine interface to a lack of utility. Contrary to conventional wisdom, distaste for technology was not a major reason for lack of user acceptance. Systems that did not facilitate the maintenance effort were not supported.

7. Hardware and software technologies advance so rapidly that fielded systems become obsolete over a relatively short period of time. Once an organization commits to using the systems, it is very difficult to avoid the expensive temptation to track technology changes.

8. Maintenance operations are still trying to integrate and justify automation systems implemented in the last decade. There seems to be little eagerness to start a new phase.

9. There are at least a dozen systems now looking for commercial maintenance sponsorship, none have found one.

10. The current approach to maintenance is working. As long as JPAs are not mandated by regulation or warranted due to a lack of capacity or manpower, there is little reason to try something new.

11. The utility of the systems is not clear. The types of information needed in maintenance are diverse and difficult to quantify. In the time it takes to enter a query into a computer, most questions can be resolved by talking with an experienced co-worker.

12. There are still enhancements possible in aviation maintenance through more effective use of existing resources, in particular human resources. Thus, there is little motivation to introduce new systems with new unknowns.

A few applications did seem to have potential. One was the use of expert systems to document the knowledge of experienced technicians that are retiring. These systems can be feasible if they are done for very specific applications. There are also opportunities to field technologies that give technicians better knowledge of the "big picture." Knowledge about the performance of the organization, priorities, successes, and anticipated workload does not always reach the people who actually work on the aircraft. This information, which is already used by management to assess the overall operation of the maintenance organization, would be useful to a technician on the floor.

5.4.3.2 Computers and Microprocessors

The enthusiasm about technological solutions to human factors problems revolves around the growing capability of information processing technologies. The fact that computers are becoming more powerful, smaller, and less expensive is widely covered. Computer processing speed, often measured in millions of instructions per second (MIPS), has doubled every three years for over twenty years. The price of each MIPS falls as more and more circuitry can be integrated on a single chip. The computer industry, in a very short time, has become one of the few trillion dollar industries that exist. It is safe to say the capabilities of computers will continue to increase, but additional considerations are necessary before it can be concluded that aviation maintenance needs more computers.

A basic understanding of how computers operate is useful in assessing where they can be applied. While the processing power of computers has increased many orders of magnitude, the architecture and the basic operation of computers has seen little change since 1946 when mathematician John von Neumann proposed a "Logical Design of an Electronic Computing System". He introduced the concept of stored programs and an architectural structure that remains the basis of computers today. This architecture has some basic features:

- Single Memory
    - sequentially addressed
    - common storage of data and program
    - unidimensional
- No hardware distinction between data and instructions
- No hardware meaning of data

When von Neumann proposed his architecture, many hardware limitations shaped his decisions. These constraints no longer exist, but his architecture has persisted. There is considerable momentum building in the area of parallel computing, but even this effort is based on parallel von Neumann architectures. The principal reason for the persistence of this architecture is the need for backward compatibility. In other words, the need for old programs to run on new computers. During any given generation of computers, there is a considerable investment in software. It is undesirable to lose this investment every time a new computer is fielded.

The reason for raising this issue is that a computer's architecture drives its inherent functionality and the amount of software effort necessary to achieve other functions (i.e.. not processing speed). A primary characteristic of the von Neumann architecture is its generality. All application characteristics must be specified in the software. This is true no matter how many MIPS a particular generation of computers can claim. One example is the constraints related to memory allocation. Computer programs must explicitly account for all anticipated memory needs. If a description is going to be associated with parts in a parts tracking application, a field must be defined for the description. The length of the field is fixed in the software, for example, perhaps 20 characters. Once this is done, 20 characters worth of memory will be allocated for every description. Even if a part has a short description, it will be stored with 20 characters worth of memory. If a part has a particularly long description (perhaps longer than anticipated during software design), its description still has to be limited to 20 characters. Additional flexibility could be achieved by setting aside 40 characters of memory, but memory is expensive in terms of purchase price and slowing down processing rates.

Even more important than memory allocation is the processing limitations associated with the Von Neumann architecture. It is often noted that computers process 1's and 0's, but what does this really mean? The 1's and 0's represent numbers in binary format (i.e.. 0101 is equivalent to 5). All of the processing done by the computer revolves around manipulating binary numbers. There are only a few ways in which numbers can be manipulated by computers. 1's and 0's can be added together, compared, decremented (or incremented), shifted (left or right), transferred and accessed from memory. Other arithmetic or logical functions can be achieved by adding several flavors of memory and instructions for combining the basic operations. Using these basic functions, computer programs can carry out an enormous variety of applications. However, the point is that computers only work with numbers, and there are inherent limitations to the non-numerical capabilities of computers. The numbers being manipulated might represent "numbers", but normally they represent various elements in the application. Computers do not inherently "know" anything except the meaning of numbers, as a result, everything else needs to be explicitly predefined in the software. For example, computers might represent an aircraft with the number 37889 and a wing by 98843. If the application requires knowledge about the relationship of aircraft and a wing, this must be explicitly stated in the software by other numbers. In contrast, the representation of aircraft and wings utilized by humans inherently represents their relationships. Once a human understands the meaning of "aircraft", they inherently understand wings. Therein lies the fundamental weakness of computers: everything and all relationships must be explicitly defined. This is not to say that all relationships cannot be defined, but that doing so is very often an enormous undertaking.

The result is that less expensive, more powerful computer hardware does not necessarily warrant application of more computers in aviation maintenance. The largest task involved in applying computers is independent of processing speed, it is explicitly understanding and documenting all of the information needed to accomplish the application. New techniques being are identified to facilitate this process. Standards are increasingly being established to facilitate the reuse and portability of software. Computer Aided Software Engineering (CASE) tools are further increasing the productivity of programmers. Artificial Intelligence is an example of a software technology that makes efforts to develop human reasoning applications more productive and well defined. Expert System and Database technologies also fall into the category of approaches to make the software process more productive. None-the-less these technologies do not change the fundamental need to define all application elements and relationships explicitly.

Solutions based on computer technology must also address security, configuration, and the threat of computer viruses. Passwords usually provide sufficient security, but configuration can be a major challenge. The primary issue is that, once a program is written and distributed to different locations, each location can make changes in the software. The result is a variety of versions of the software and some confusion. As a result, it is normally necessary to have a configuration manager to track the integrity of the code. Computer viruses are more of an unknown. These are software programs that can sabotage applications and stored information. Viruses are primarily a problem for computers that communicate with remote locations, but the possibility of overt or accidental contamination is always possible. Techniques and expertise exist to address these issues, but all of these issues represent additional considerations involved in computer applications.

5.4.3.3 Artificial Intelligence

Artificial Intelligence (AI) has achieved "buzz word" status, and is frequently advocated as the heart of automation systems of the future. Although AI has not produced a machine that can think, the field has developed several new software development techniques. Expert Systems are the most successful example of these techniques. The aim of research in AI still includes the pursuit of machine intelligence, but for practical purposes, few believe this will be achieved any time soon. AI does have some applications in aviation maintenance, but it is important that these efforts are initiated without any illusions about machines becoming intelligent. AI is warranted if an application would benefit from "human-like" reasoning. AI provides a structured methodology for incorporating this reasoning into programs. Remember, however, that all elements and relationships must be specified, computers do not have intuition. It is helpful to keep this in mind when assessing the feasibility of a particular activity. The more information (knowledge) necessary to carry out the application, the more complicated, time consuming, and expensive the project will be. This includes knowledge that seems obvious to humans, such as the relationship between an airplane and a wing. Nothing is obvious to computers!

The field of Artificial Intelligence has developed structured methodologies for accomplishing several types of capabilities. There are techniques for voice recognition, speech understanding, computer vision, text understanding, robotics, and decision aiding. Researchers continue to work on automatic programming and learning. All have capabilities far short of humans and require major development efforts. For the most part, it will remain economical to utilize humans for applications that require human capabilities.

5.4.3.4 Expert Systems

Expert Systems now enjoy wide popularity. Expert Systems achieve intelligent functionality in a straight forward manner. They are based on "if-then" rules. For example, "if the object is a 747, then it has wings". The heart of expert systems are rules that address every relationship of interest in the application. While the concept sounds simple, developing an effective approach to implementing these systems took considerable time.

The process is now facilitated by the use of software packages called "expert system shells". Developers no longer need to spend large amounts of time coding the structure of the expert system. These packages normally contain development environments that facilitate building the knowledge base and designing a user interface. There are many shells on the market to suit different needs, but large complicated expert systems are often customized. Shells have limitations of functionality and flexibility, but there are few (if any) aviation maintenance applications that can be implemented cost effectively by a custom expert system.

When a shell is utilized, roughly 50% of the effort is planning and documenting the knowledge to be represented by the expert system. Figure 5.1 shows the overall structure of an expert system. This process requires two kinds of people, one is frequently labeled the "knowledge engineer" and the other is the domain expert. It is the knowledge engineer's job to develop the rules that will be the basis of the expert system. This is as much of an art as a science, since it is never possible to be sure the knowledge is complete. Domain experts do not readily think in terms of explicit rules so these need to be drawn from answers to questions. Expert systems can not be developed from technical manuals, live experts are needed. Much of the power of an expert's knowledge is in terms of nuances that are not contained in manuals.

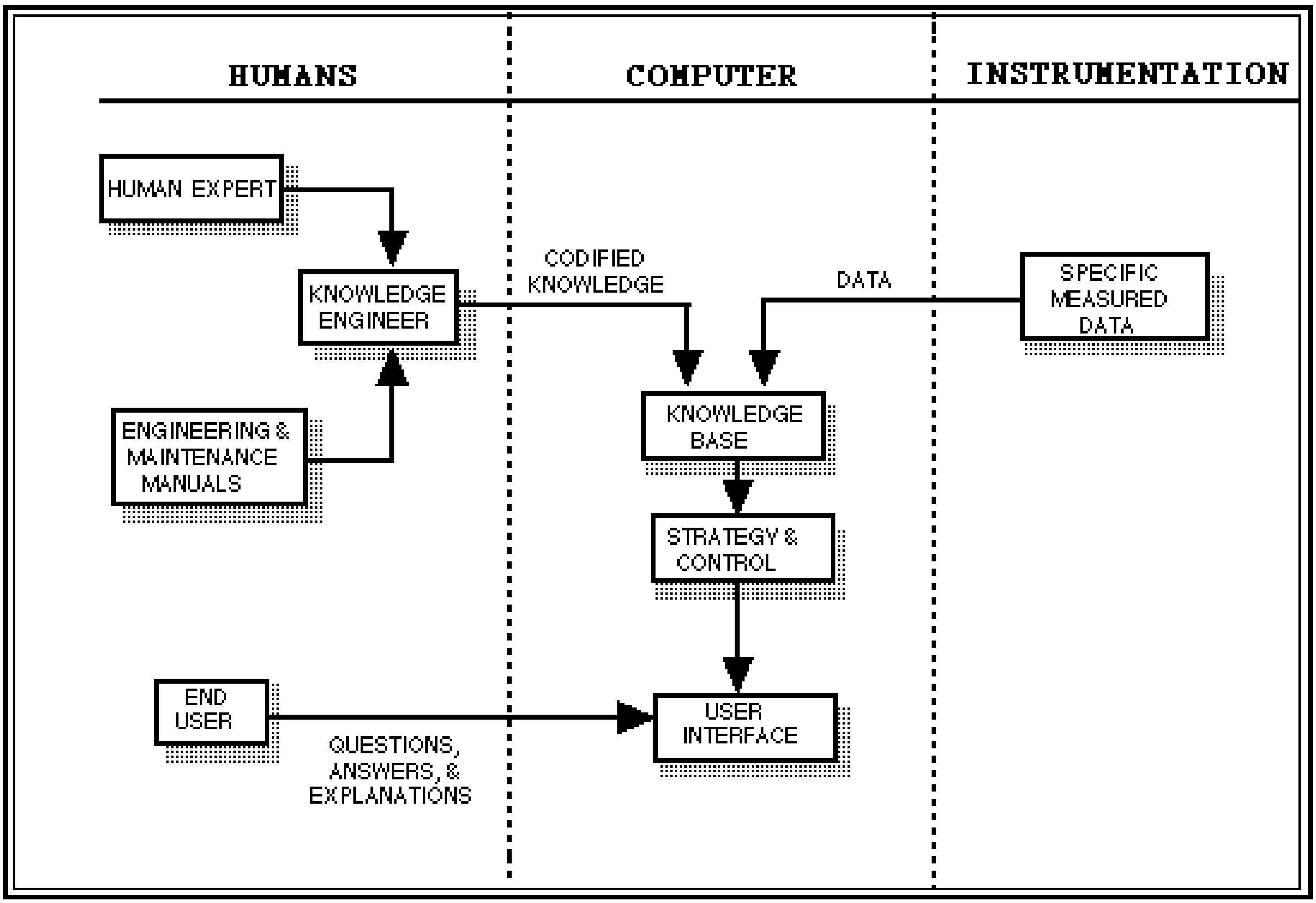

Figure 5.1 Expert System Diagram

The process starts by assessing the types of issues that will be encountered by the final product. Likely scenarios are identified, and the expert is asked how they might respond to a given scenario and why. The difficulty is that there is no way of knowing for sure if all scenarios the operational expert system will experience have been addressed. Thus, it is never possible to know if the rules obtained from the expert are sufficient. Unfortunately, as with most computer applications, changes once the system is operational are not easy. The reason is that rules entered into the program are written in terms of models of the system and possible interaction between the elements of the system. Adding to the existing rules is not a major undertaking but, if the model must be changed, it can have implications for many rules.

It is not possible to know how the system will respond in an operational environment because only known scenarios can be tested. This uncertainty leads to a critical criterion for determining the feasibility of an expert system. The problem has to be very well defined. The success of the project will be further jeopardized if the problem is not rigid and changes during the project cycle.

The final expert system is usually implemented with a menu interface. The user navigates through the system by selecting items on menus. Data is entered in a similar manner by selecting one of several possibilities offered by the computer. The interfaces are becoming more graphical and intuitive, but the computer still only understands numbers. The software associates each element in the menu with a number. For example, if the observation to be considered is that there is a "blue stain on the fuselage" it would be too difficult for the software to associate a number with each of the words. In addition, there are numerous ways in which the same message can be conveyed in natural language. This problem is avoided by creating menus of options, each of which is assigned a number. This is an additional limiting factor, since it may not be possible to know ahead of time all of the possible conditions that should be addressed in menus.

Once an initial question is asked by the user, the expert system will prompt the user with questions until it has the information necessary to satisfy the rules. The rules in the expert system are normally given associated confidence factors. For example, if two conditions exist there is some amount of confidence that a third condition exists. This information is presented to the user along with conclusions and the list of rules that were applied to reach the conclusion.

One of the steps of expert system development is the thorough documentation of knowledge in a particular area. This can be a useful product in itself if an expert is nearing retirement. This is not an unusual situation, since the expertise we value most is that gained over a life time. The aviation maintenance industry is facing the retirement of a large percentage of its work force over the next decade. Expert systems might be warranted in some specific, well defined areas.

5.4.3.5 Databases

There is a science to collecting and maintaining information with computers. The primary task is to ensure that information will be readily accessible when it is needed. Numerous software packages are available to facilitate this process for most applications, including packages specifically designed for aircraft maintenance. The task of database development involves three steps. The steps and percentage of total time required are listed below:

Planning 30%

Implementation 60%

Data entry 10%

The most deterministic step is the data entry effort. If you can assess how long the data entry will take, it gives you some idea of the magnitude of effort involved in the other steps. The implementation stage is a matter of learning the particular software package involved and carrying out the steps required. The planning stage is the most critical and the least defined. Databases are essentially made up of numerous small databases with links between them. The planning process involves predicting the characteristics of all of the types of information that are to be included in the database. In addition, all the possible uses of the information need to be known ahead of time. This is usually done by developing input screens and reports with the help of the user.

The person that enters information into the database, enters information into one or more fields. These fields correspond to the possible classifications of the information. The fields explicitly link the new information to information already in the database. For example, a maintenance database might have a field for part number, aircraft type, part description, quantity available, or other designations. The number of ways information can be accessed is a function of the number of fields, but each field takes data entry time and the number of fields should be minimized. The final database is the developer's interpretation of the user's needs. For the interpretation to be accurate, developing a database requires careful communication between the user and the developer.

As with other efforts to implement technological solutions, it makes sense to start small. A demonstration database should be built to test assumptions and obtain additional input from the user. Databases can not be easily modified once they are complete, so it is important that the process not get too far ahead of the user (i.e.. entering vast amounts of data without obtaining user acceptance of the approach).

There are other considerations once the database is complete. Data entry should be carefully controlled to maintain the integrity of the information (i.e.. two people entering different versions of the same information). Once again, major applications are likely to need a specialist to support and maintain the database.

5.4.3.6 Peripheral and Supporting Technologies

Storage media. Data storage is currently accomplished with magnetic and optical technologies. The vast majority of memory devices use magnetic technology, for example floppy disks, hard disks, tape, cassette, and most mainframe memory peripherals. The major advantages lie in its cost, physical size, power requirements, and speed in accessing data. Industry manufacturers such as Conner Peripherals, Seagate, and Toshiba continuously identify enhancements.

Optical Technology, which is used in compact disk read-only memory (CD-ROM) and write once read many (WORM) systems, is relatively new. The major advantages of optical storage technology is its large capacity and the reliability of the data (i.e.. it is not as susceptible to magnetic fields or physical contamination). The major disadvantages are in data access times which are long due to data file format and the lack of standardization found in WORM technology. In addition, the hardware is more expensive than that used with magnetic storage mediums. The advent of rewriteable optical storage based on magneto-optical technology, may increase the utility of optical systems.

Input methods. The keyboard remains the primary input device for computers, however, a number of other options are becoming available. These include touch-screen, voice recognition, mouse, bar code readers, stylus and handwriting recognition software. Touch-screen is currently used in applications such as manufacturing environments where keyboard input is not feasible. It is mainly integrated in CRT displays with some use in flat-panel displays. Voice recognition systems have made considerable progress to the point where vocabularies of 60,000 words have been achieved. The systems are probably still not practical for the maintenance environment for cost reasons, their tendency to require words to be repeated, and the problems caused by extraneous noises. Data entry by mouse or joy stick is relatively routine. Bar code readers are finding increasing application. TWA uses bar code technology to track labor and parts. The first commercial portable computer to accept handwritten input is expected in December 1991. The hardware for this system will cost around $5000 and there are a numerous constraints about how the handwritten inputs are made; however, handwritten input may eventually be useful for specific maintenance activities.

Output methods. There are several display technologies, including Cathode Ray Tube (CRT), Flat-panel, and miniature displays. CRT display technology has progressed from monochrome, low resolution displays to multi-colored, high resolution systems as the industry standard. Current trends indicate resolutions will continue to improve for greater picture quality. Flat-panel displays offer a low-profile alternative to the CRT. The three major technologies offered in flat-panel displays are the liquid crystal display (LCD), the gas plasma display, and the electro-luminescent (EL) display. The major challenge in developing these displays is to make the screen readable in virtually all lighting conditions, at high resolutions, and produce it at reasonable costs. Currently this flexibility is still elusive. This is complicated even further if a color screen is desired. Currently, displays are being produced in all three technologies with the LCD technology dominating most of the flat-panel market (i.e.. for PC laptops.)

A flat-panel display technology currently under development is called field-emission displays. They take advantage of the basic principle of the CRT, but rather than using a bulky, high voltage electron gun, it uses a micron-size cone-shaped structure called a "field-emission cathode" which can produce the same results as a CRT, at much lower voltages.

A display developed by Reflection Technology called the "Private Eye" is worn by the user on a headset. It is a miniature display (1x1 inch) that is placed in front of the users dominant eye, and creates the illusion of a full (10x12 inch) display. It costs around $600, but it is not yet practical for aviation maintenance. Use of the system demonstrated that the head set is awkward and keeping the display in the right location for viewing requires constant attention. In addition, looking at the display for any length of time becomes uncomfortable.

Printers increase in quality and become less expensive each year. Printers remain the principal form of computer output. Voice synthesis as output has found some applications in telecommunication systems, but are as yet too expensive and inflexible to be applied in more than a few aviation maintenance activities.

5.4.4 Implementation Guidance

5.4.4.1 System Integration

This section relates lessons learned from a decade of implementing technology in aviation maintenance and other applications. Technical functionality is normally the focus of development efforts, but experience demonstrates that Human Factors issues are the principal barrier to success. Humans remain the engine for most complex systems. For example, even automatic test equipment (ATE) is dependent on humans for planning, design, manufacturer, installation, and maintenance. Aircraft maintenance in thirty years will be different than today, and automation will certainly have a larger role. The question is how do we get to that future system with a minimum of trial and error? The answer seems to favor the "tortoise" over the "hare". Development efforts in the 1980's demonstrated that implementing new technologies is an expensive and largely experimental process.

Overall, the findings indicate that unless an organization has the resources to experiment with technology, it should wait for others to work out the "bugs". If a system development project is undertaken, it should be done with "eyes wide open" and not based the fact that it is "technologically feasible". There are numerous lessons to be learned from past efforts on this account. Finally, it our finding that for the foreseeable future, humans will remain central to maintenance, and implementation of technology should be centered on supporting human activities.

5.4.4.1.1 Planning an Automation System

There are numerous reasons for needing a system and even more functions the system can perform, but once management recognizes the need for a system more details need to be considered. Table 5.5 list the typical steps in a feasibility study. Many early systems were developed without sufficient input from the end user and, in some cases, the final system was rejected (or ignored) by the users. Maintenance organizations are now very sensitized to the importance of incorporating user requirements. Large airlines have internal data processing departments and some large and small airlines use consultants to help in system development. The process requires a close working relationship between user and system developer. Often user organizations are surprised to learn that system development requires the full-time involvement of one or more staff members, and the part-time involvement of many staff.

Example Feasability Study

Step	Description	% Total Time
1.	Rapid needs assessment	5%
2.	Survey of management support & team building	5%
3.	Airline analysis-existing verses needed resources	10%
4.	Definition of requirements	25%
5.	Definition of approach to design	20%
6.	Reassess requirements and design with users	10%
7.	Justification- benefits	5%
8.	Justification- costs	10%
9.	Overall development approach	10%
10.	Report - written and oral presentation	ongoing

Note: The steps are listed in the order that they will be carried out, however, most steps are iterative in nature.

Table 5.5 Steps Involved in a Feasibility Study

Once a team has been assembled from the two groups the planning can begin. Three types of information must be obtained during the planning process. The first is determination of system requirements and the functions the system will perform. The objective might be to computerize the current system, in which case research is probably needed to identify existing types and flow of information. Requirements might also go beyond the current system in specific areas. It was noted that ineffective manual approaches remain ineffective when done on a computer, thus existing approaches should be carefully scrutinized before they are computerized. The requirements process might also involve a number of visits to different locations to assess what others have done.

Once the requirements of the system are determined, the approach for implementing the requirements is developed. Naturally, it is desirable to build on existing systems. The approach should be divided into modules that can be developed and fielded incrementally. Benefits should not wait for the entire system, each module should add value. Anticipated screen layouts and report formats might be identified at this stage. The next step is to bring the requirements and the design concept together in an implementation plan.

This is the stage that requires the closest cooperation between user and developer. Numerous tradeoffs are always needed to make implementation feasible. Users need to ensure that priority of various functions are known by the system developer. Otherwise, facilitating hardware and software development will drive trade-offs and the result may not be acceptable to the user. Once the planning stage has been completed, it is possible to make a more realistic assessment of the advantages of automation. Cost estimates should be balanced with promised benefits.

5.4.4.1.2 Human Factors

The objective may be to implement technology, but the success or failure of system integration very often comes down to Human Factors issues. The development task is basically one of reconciling the needs of two groups. The group developing the system knows what needs to be done to achieve a particular functionality. The group that will use the system knows what functions they want implemented. Unfortunately, approaches that are easier for the developers often produce unsatisfactory results for the user and vice-versa. The tradeoffs must be negotiated between the groups and there-in lies the Human Factors challenge. The groups have disparate languages and perhaps even disparate goals. The system developer is usually judged by the cost and the rate of development progress, and the user's focus is on maintaining aircraft. The process requires constant communication between these groups. The user is usually interviewed to determine his requirements, but unless there is a constant exchange of information, the final product ends up being the developers interpretation of what the user needs. Thus, a primary lesson of efforts to date is that there is a need for increasing consideration of human factors in system design. A paradigm that centers system integration on humans (end users and those that participate in system development) and not on emerging technologies is warranted. There is an enhanced awareness of the need to focus on the user, but the current paradigms still focus on technology.

5.4.4.1.3 Alternatives

The least expensive approach to implementing technology is not to do it at all. Organizations can get hooked into competing based on who uses the most advanced technology, but given that the product is aircraft maintenance this can be an expensive diversion. Implementation of technology is not the only avenue for addressing the increased complexity of aircraft maintenance. The research program on ***Human Factors in Aviation Maintenance***, of which this technology study is a part, is designed to develop approaches to make more effective use of the human resources. Peak human performance is a function of a number of factors and current management techniques do not address them all. Quality Circles and similar employee involvement programs were a start, but there is a need for additional creativity in increasing worker production. Aircraft maintenance organizations focus on the factors that make humans capable of doing the job (training, tools, support equipment), but many do not adequately address factors affecting human willingness to do tasks (participation in decision making, economic incentives, recognition programs).

Alternatives should be considered before system development is attempted. The availability of new technologies is not in itself a reason to implement technology. One factor that characterizes successful use of technology is that they are in applications where there are no alternatives. Examples include systems that support on-condition maintenance of aircraft engines and tracking parts.

5.4.4.1.4 System Development

If there are no alternatives and the decision is made to implement a technological solution, there are a number of things to consider:

1. **It is never easy the first time.** If an application is particularly suited to a technological solution, there will eventually be numerous off-the-shelf packages available. If the proposed application is the first of its kind, beware. Systems are built from numerous individual technologies for everything from wire to metal cabinets. The system is dependent on all of these elements working together. Failures can occur anywhere. Successful implementation of technology requires explicit consideration of every possible outcome. Once similar systems have been built, knowing all of the possible things that can go wrong is easier. One way to address this is to build a small scale version of the application and test assumptions.
2. **Use the most experienced talent available.** Nothing replaces experience when it comes to developing complex technical systems. The experienced person will cost more hourly, but the job will be completed much more thoroughly and rapidly. If experienced help seems to be too expensive, it should raise questions about whether there is sufficient resources to undertake the task at all.
3. **Whatever can go wrong will go wrong.** Canceling a project because of problems encountered can be very disappointing and expensive. The project should not be initiated without recognizing that numerous difficulties will be encountered. The difficulties will be proportional to the maturity of the technology and the experience of the individuals involved. Installing dedicated ATE from a manufacturer may have a few unexpected problems, but internal development of unique ATE which incorporates voice recognition can expect many.
4. **Requirements should be specific and rigid.** In effect, system development requires predicting the anticipated use of equipment and the operating environment. This is nearly impossible as applications become more general. Avoid the tendency of requiring equipment to be more general in order to spread the development costs across more applications. Rigid requirements are necessary, since changes become more expensive to incorporate as development proceeds. Figure 5.2 illustrates the increase in cost as the project proceeds.

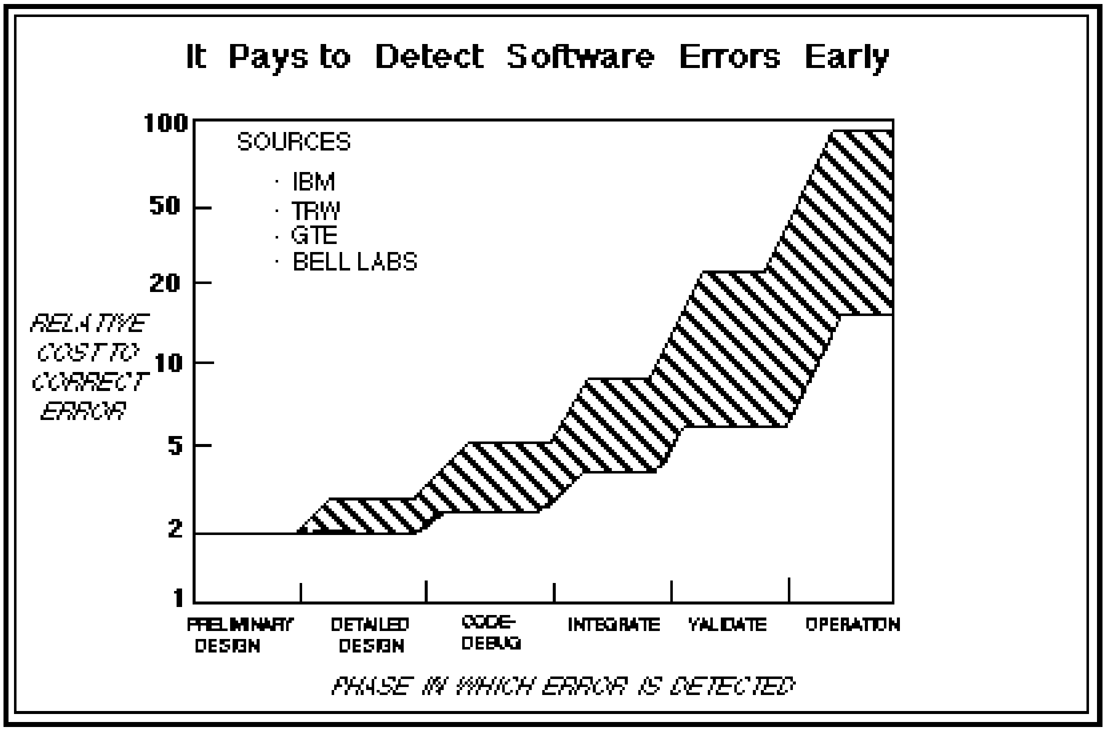

Figure 5.2 Cost of Correcting Software

5. **The system should be fielded incrementally.** Each element should add value, and the changes to the current approach should be made slowly. This permits an ongoing process of evaluation and enables users to provide inputs and become accustomed to the system. Waiting until all resources have been expended is not a good time to discover the success or failure of a system.
6. **Assume technology will continue to change.** The three or four year cycle needed to implement technology corresponds with the three or four year cycle in which major new technologies are developed. The result is that by the time a program to implement the last generation of technology is done, a new generation of technology will be available.

5.4.4.1.5 Maintenance Automation

Automation system development is normally controlled by data processing personnel. The users will usually assign one person to act as a liaison to insure their interests are incorporated. Problems can arise in several areas. Technological considerations that simplify system design are often incompatible with features that simplify use. The computer's affinity for numbers versus human affinity for symbols is in constant conflict. Unless the design team has considerable experience in the application area, they very often underestimate the effort required. When deadlines approach, user requirements are vulnerable.

Neither group may have a strong understanding of human factors considerations, and human factors specialists are often not a part of the design team. Approaches that facilitate the incorporation of human factors exist and should be considered. The MANPRINT (manpower and personnel integration) program at the Army has developed a very specific process to incorporate human factors considerations in system integration of large systems. They have also accumulated over 70 resources that are available for addressing human factors, including the following (Booher, 1990):

- Analytic Techniques
- Computer Software
- Data Bases
- Handbooks/Guides
- Military Standards/Specifications

Maintenance data processing professionals and managers learned the following from experience:

Ensure user involvement and support during all phases; there should be no surprises in the end.

It might even be necessary to ensure the users have a realistic knowledge of the challenges of the process to avoid excessive expectations.

Do not chase the latest technology, and be conservative on the number of functions automated.

The definition of the functions automated should be very precise.

Design in flexibility and anticipate future needs.

Build the system in an incremental manner where each module can return value as soon as it is complete.

Do not lose sight of the fact that maintenance is the mission of interest and computerization should not become an end in itself.

The original justification of automation systems can be lost in the "heat" of implementing the system. Evaluations and expectations should be verified on a continuous basis from proposal throughout the life of the system.

5.4.4.1.6 User Requirements

It has not been productive to compel humans to use automation systems, thus success depends on obtaining user acceptance. The problem does not seem to be a general reluctance to use technology, but resistance to systems that do not have adequate utility. System developers are now well sensitized to the importance of considering the user, and will always claim advocacy of user needs. The problem is that addressing the users needs is not easy, and simply asking users what they want rarely suffices. The users know and understand the current approaches for getting the job done, but not to the level of detail needed for computerization. In any case, if the most appropriate approach is different from the current approach, users may not be the best source for requirements. The criterion of "user friendly" might suffice as an objective, but is too vague to be a useful design criterion. Developing a system that addresses user requirements is difficult not only because user requirements are hard to define, but because technologies can only be implemented in a limited number of ways. Implementation must be accomplished within a long series of constraints.

Achieving user acceptance requires system developers to take a broader view of design objectives. The system must be designed to achieve functionality so that the human is capable of using the system to achieve a task, but additional considerations are necessary before humans will be willing to use the system. Much can be accomplished by simply asking, as long as the developer is willing and able to give priority to even seemingly minor considerations. The design should account for the following:

> Control should remain with the user. Humans are naturally uncomfortable in situations where they do not have control over progress. In most cases this is not just whim, but the frustration that results from identifying a more efficient approach and not being able to enact it.
>
> Gaining user input should be more than a one step process at the project's beginning. Often users don't know what they really want or need and don't know what is possible. User input must be an interactive and iterative process explicitly scheduled and evaluated throughout the development stages. Involve users in the decision waiting process when considering alternatives and options. Let users test the proposed system and see if they really like the approach. Often the user does not, for reasons they were unable to predict from a concept description.
>
> Humans should not be expected to assimilate vast quantities of data or information. Computers have the capability to keep vast amounts of information on-line, but the information should not be presented to humans all at once. The challenge of serving as a source of information is not just to provide access, but to provide rapid access to needed information and nothing more.
>
> Single data entry should serve all parts of the system. Data entry is a "bottleneck" for computer based systems and is made worse if disparate systems can not share data. Applications that are input or output intensive should be avoided.
>
> Systems should provide tangible benefits for the work force. It seems obvious, but there should be some clear benefit in using the system. If the benefits are in terms of greater profitability of the organization, then that should be communicated to the users. Humans are naturally reluctant to use systems that increase their workload with no clear benefits.

Computers should serve humans. Computer systems depend on humans for data entry, maintenance, and upgrades, so it can start to be confusing who is serving who. Humans usually need to adapt their approach to fit the computer. The use and benefits of computer systems should be clearly stated and clearly demonstrated, so that humans will know why they should want to adapt.

Users should be allowed to optimize the system. System development may end with a working system, but there are always enhancements to be made. Users are the best source for identifying these enhancements.

There are several general considerations that apply to technology in commercial aircraft maintenance:

Cost - few maintenance organizations can afford to pay for the development of new technology applications. Some can afford to purchase systems developed by others. In any case, the vision of every technician walking around with a portable job performance aid is some time off, unless the benefits become more tangible. A system that provided access to maintenance manual information would be worth less than $100/technician in tangible benefits.

Hostile environment - technology is fragile, and making it durable can be expensive. While most maintenance activities are not greasy or done in the rain, things do get dirty or dropped. Experience with microfilm readers and computer terminals demonstrates durability is important.

Information needs of technicians - the information needed by technicians is not easily quantified. It is not simply a matter of placing technical manuals on-line. Technicians need numerous types of information:

- Location of tooling and fixtures
- Work completed on previous shift
- Location or arrival time of aircraft
- Relative urgency of repair
- History of particular aircraft
- Remote effects of local actions
- Alternative repairs
- Procedural nuances

Portability - given current per user costs, it is likely that systems will have to be shared between many technicians. As a result, they need only be located in a central location.

Graphics - Graphics are expensive to display and store, so there is some motivation to minimize them. However, illustrating what has to be done is much more effective than text instructions, so graphics are essential to user acceptance.

Training - All new systems will have implications for training. These should be anticipated and planned. Training will have initial and ongoing elements.

5.5 RECOMMENDATIONS

5.5.1 Overview

This research is part of a larger research program on Human Factors in Aviation Maintenance Inspection. The interest is in strategies for enhancing current practice that might not be apparent from the perspective of maintenance professionals performing their day-to-day duties. The recommendations that follow are based on the first phase of Job Performance Aid research. The last two phases of research will demonstrate, validate, and develop approaches to implement the recommendations.

5.5.2 Recommendation 1

Make more effective use of human resources and realistically examine the utility of technology.

5.5.2.1 Description

Additional consideration should be given to approaches that use human resources more effectively before new technologies are implemented. The process of fielding technology is largely experimental, and although initially appealing, it often requires more resources and produces less satisfactory results than anticipated. Fielding technology is important for long term competitiveness, but it is a long and expensive process. It is not a practical alternative to making more effective use of human resources today. Management of human resources should use a broader perspective when considering the issues involved in attaining peak human performance. The current focus is on elements that make humans capable of performing the work, but there are other considerations such as obtaining their willingness to do the work:

- Clear and concise goals
    - ownership
    - cooperation
- Job satisfaction
    - recognition of contribution
    - realistic expectations
    - adequate working environment
- Respect, trust, and loyalty
- Competence
    - physical
    - cognitive

Few would admit to placing more faith in technology than people, but the research demonstrated that low faith in the capabilities of humans was a large part of the motivation for system development. There is some discomfort with addressing issues such as job satisfaction, and technology appears to be more predictable. However, if humans are used more effectively and technology is viewed more realistically, a different picture arises.

Research in this area and others addressed by the ***Human Factors in Aviation Maintenance and Inspection Research*** demonstrated that there is a potential for increasing human performance in aircraft maintenance. The untapped potential of existing human resources should be utilized and existing technologies should be completely integrated before new systems are fielded. Experience demonstrates that each new system introduces unknowns into the maintenance process.

5.5.2.2 Interventions

Maintenance managers are often too busy meeting the demands of the day-to-day maintenance effort to have time for reflection on alternative approaches to make more effective use of human resources. Changes can not be initiated bottom up, and no one person can change the philosophy of an organization. Affecting changes will not be easy. ***The Human Factors in Aviation Maintenance*** research effort is designed to increase awareness from the top down. Once it is recognized that further consideration of human factors might provide avenues to achieving more effective use of human resources, the next step is to test the idea. A pilot program can be initiated to provide a model of how human factors can contribute to the maintenance effort. Perhaps work on a particular type of aircraft or particular shop can serve as the test case. The effort should be carefully planned and the expected benefits should be tangible to include the following:

- Reduced turn-around time
- Increased quality
- Reduced parts costs

5.5.3 Recommendation 2

Avoid user acceptance and system utility problems by centering system development on humans.

5.5.3.1 Description

A decade of user acceptance problems has led to an enhanced sensitivity of user needs. No developer will risk being perceived as insensitive to the user. However, sensitivity does not mean developers know how to effectively incorporate user needs in system design. Implementation of technology is still easier if the user is ignored. Developers need the expertise, resources, and staying power to end up with a system that is compatible with humans. The expertise exists, but a shift in thinking is needed to insure future systems will be accepted by the user. The perspective needed is one that centers system development on humans.

Many claim to work closely with users during system development, but not all are successful. Implementation decisions still tend to be dominated by a given technology's facility for achieving a given function. For example, most on-line work card systems do not incorporate pictures of the task described, because graphics are memory intensive and much more difficult to create than text. Perhaps, work-arounds can be identified such as pasting in graphics, after the fact, but this leads to other difficulties. For example, if the graphics and text come from two sources, the terminology may not correlate sufficiently. A system development perspective centered on humans might lead to a decision to hold off putting work cards on-line until pictures can be adequately incorporated. Care should be addressed to elements that seem to be minor inconveniences. Parts are no longer tracked by their name and description, but by numbers. If two parts look similar and have similar numbers, technicians might use a part without taking the time to track down the descriptions that indicate why the parts are not interchangeable.

In other words, once the conclusion is reached that more effective utilization of humans is not sufficient for a particular problem and a technology solution is warranted, humans should not be forgotten. So far there is no structure to insure this. This process can be facilitated by establishing up front that humans (users) are more important than technology. The process should revolve around helping humans maintain aircraft, and not the existence of a particular emerging technology. Tradeoffs during the development process should carefully consider the technological alternatives for increasing the utility of the system for the human users, and should not be dominated by eliminating functionality simply because it is technically inconvenient to implement. The reverse is also true; functions should not be added because they are technologically convenient. Developers and users should have shared goals.

5.5.3.2 Interventions

Boeing Corporation has taken the step of assigning a maintenance expert to a leading role in the development of their next generation aircraft (Boeing 777.) This individual has the clout to insure that ease of maintenance is a primary consideration in system design. Boeing was motivated to do this to increase customer satisfaction with their product. Equivalent steps can be taken in any system development effort. It is a matter of establishing from the top down that consideration of the user is paramount. If technology has not progressed enough to provide an approach that will provide the functionality needed by humans, the development project should not be started until it does.

The Army's MANPRINT (manpower and personnel integration) program provides the largest scale demonstration of how human factors can be incorporated in system integration Booher (1990). Their program integrates consideration of human factors into the many phases of the acquisition process (request for proposal, proposal, award, design, implementation, test, and evaluation.) Consideration of human factors is a primary component in the award of contracts. For example, a soldier's lack of skills can not be faulted for system failure during test and evaluation. Designers are aware of the soldier's skills during the entire design process, thus there is no room for this justification. The initial apprehension of contractors about a heavy focus on human factors is usually diminished by the end of the process, and the results have been excellent. For example, the tools required to maintain one type of engine was reduced from 140 specialized tools and fixtures to a little over a dozen that can be found in most homes.

5.6 CONCLUSION

The conclusion of the research is that Job Performance Aid Technology is less mature and more expensive than generally accepted. Developing applications for new technology is important in the long term, but in the short term it should be secondary to increasing the effectiveness of existing resources, in particular human resources. Technology should continue to be applied in areas where there is no alternative. If a technological solution is chosen, the development process should center on humans. Most implementation efforts to date were successful in achieving a promised technical functionality, but few performed satisfactorily with the human user. Additional attention should be addressed to human factors in the development effort (i.e.. communication between developers and users) and human factors in the application (i.e.. user requirements and compatibility).

This is not the conclusion anticipated when the research was initiated. It was expected that a survey of technologies and Job Performance Aids would identify numerous systems that could make important contributions to aviation maintenance. At most, it was anticipated that some additional guidance might be needed in the design of the man machine interface. The research rapidly demonstrated that while projects were initiated with great expectations, few sponsors claimed the final product would have a major impact or were actively pursuing new development efforts. This is not to say there were no bright spots, as some programs such as the Air Force's Integrated Maintenance Information System (IMIS) can serve as models for future efforts. Efforts got into trouble when they underestimated the magnitude of the undertaking or tried to implement technology in place of better utilization of human resources. Increasing the efficiency of human resources is a lot more appealing when technology is well understood and viewed realistically.

The conclusion does not reflect the lack of capability of the system development community, but respect for the magnitude of the challenge involved in implementing technological solutions. It is the complexity of technology that warrants caution in promoting it as a near term solution. It is recognized that technology will be important for long term competitiveness, however, implementing technology is a long, expensive, and largely experimental process.

The mission of maintenance organizations should remain maintenance, and managers should not be lured by the seeming excitement of implementing systems at the leading edge of technology. No one expects a better version of humans to be available in the near future, and advocates of technology can always claim something new and wonderful is "just around the corner." However, commercial maintenance organizations should be pragmatic and expect technology to be accountable in the same way humans are accountable - "what can you do for me today?" Organizations should take additional advantage of what is known about achieving peak human performance. Technology is good and important, but it is not a "silver bullet".

5.7 REFERENCES

Booher, H.R. (Ed.). (1990). *MANPRINT: an approach to systems integration,* New York, New York: Van Nostrand Reinhold.

National Transportation Safety Board. (1990). *Aircraft accident report, United Airlines Flight 232 McDonnell Douglas DC-10-10, Sioux City, Iowa, July 19, 1989,* (NTSB/ AAR-90/06). Washington, DC: NTSB

Parker, J., & Shepherd, W.T. (Eds.) (1989). *Human factors issues in aircraft maintenance and inspection.* (DOT/FAA/OAM-89/9). Washington, DC: Federal Aviation Administration, Office of Aviation Medicine

Parker, J., & Shepherd, W.T. (Eds.) (1990a). *Human factors issues in aircraft maintenance and inspection, information exchange and communications.* (DOT/FAA/OAM-90/14). Washington, DC: Federal Aviation Administration, Office of Aviation Medicine

Parker, J., & Shepherd, W.T. (Eds.). (1990b). *Human factors issues in aircraft maintenance and inspection:* Office of Aviation Medicine. (DOT/FAA/OAM-90/x). Washington, DC: Federal Aviation Administration, Office of Aviation Medicine

APPENDIX A: Summary of Job Performance Aid Survey

Appendix A1 Summary of Job Performance Aid Survey

Appendix A2 Summary of Job Performance Aid Survey

Appendix A3 Summary of Job Performance Aid Survey

APPENDIX B

1. ADE-AUTOMATIC DATA ENTRY FOR AIRCRAFT MAINTENANCE

FUNCTION Facilitate data entry

SPONSOR US Air Force

DEVELOPER Lockheed

INITIATED 1975

DESCRIPTION An automatic data entry system which encompasses all mechanical devices. This system replaces the manual entry of data into the information system.

2. AEM-AUTOMATED ELECTRIFIED MONORAIL

FUNCTION To deliver replacement parts used in maintenance at high-speed.

DEVELOPER United Airlines

LIFE Present.

DESCRIPTION Electrified monorail parts delivery system moves product at high speed thus improving efficiency.

3. AFTA-AVIONIC FAULT TREE ANALYZER

FUNCTION Performs automatic testing of avionics equipment in its' operational environment

SPONSOR U.S. Navy

DEVELOPER Douglas Aircraft Company, St. Louis, Mo.

DESCRIPTION The Avionics Fault Tree Analyzer, AFTA, is a suit-case sized microprocessor-based computer system which performs automatic testing and fault isolation of F/A-18 avionic systems. It is capable of fault analysis to the Shop Replaceable Assembly level. The fault isolation programs are referred to as fault trees; analysis of these trees include analyzing, sorting, comparing, examining, and manipulating data from the system being tested. The effectiveness of this system is contingent upon the effectiveness of the avionics system built-in-test (BIT) equipment and the knowledge and practical expertise of the fault tree designer. In addition to the lightweight, portable computer, the AFTA requires removable magnetic tape cassette cartridges. The system connects to the aircraft MUX BUS and aircraft power. Once the program is initiated, the fault diagnosis is illuminated on the flat screen display. A hard copy can be generated.

4. AGILE EYE, and AGILE EYE PLUS-HELMET MOUNTED DISPLAY BUILT IN TEST EQUIPMENT

FUNCTION Helmet-mounted display

SPONSOR US Air Force

DEVELOPER Kaiser Electronics

LIFE 1990

DESCRIPTION This system modifies the "Private Eye" miniature display, also called Agile Eye and Agile Eye Plus. The display is incorporated with a helmet in order to significantly increase a pilot's situational awareness. It is possible using this apparatus to project television monitor information or other computer information. The image is directed to the visor of the pilot's helmet, thus keeping the information in front of his eyes at all times. It is a monocular presentation to the pilot's dominate eye. It displays only information needed. The system can also be tailored by the pilot, i.e., "decluttered" so that it can include only what the pilot wants to see.

5. AGTR-AVIONICS GROUND TRAINING RIG (RAF)

FUNCTION To train aircraft maintenance personnel in fault diagnosis and service of advanced avionic systems.

SPONSOR United Kingdom Royal Air Force (RAF)

DEVELOPER Essams

LIFE 1985

DESCRIPTION The Avionic Ground Training Rig, AGTR, is a maintenance trainer and simulator designed to train ground crews in advanced avionic fault diagnosis and servicing methods. The system is composed of a life-size cock-pit and a PDP 11/55 and VAX 11/70 computer-based system. The ground crew can accurately diagnose aircrew reported system deficiencies through simulated flight. This system was developed for the UK Royal Air Force, Tornado F2 interceptors.

6. AIDS-AIRBORNE INTEGRATED DATA SYSTEM

FUNCTION On-line integrated data systems for use in work areas by technical and engineering personnel.

SPONSOR Trans World Airlines

LIFE Operational in 1986

DESCRIPTION Satisfies the need for dedicated computers for maintenance and engineering functions.. The system uses an ARINC Communications and Reporting Systems (ACARS) data link.

7. AIDAPS -AUTOMATIC INSPECTION DIAGNOSTIC AND PROGNOSTIC SYSTEM, also referred to as, UH-AIDAPS TEST BED PROGRAM

FUNCTION Engine monitoring instrument that performs automatic in-flight inspection, diagnostic and prognostic procedures to detect mechanical malfunctions and warn of failure-conditions.

SPONSOR US Army Aviation Systems Command, St. Louis, MO.

DEVELOPER Test Bed Program Developer: Hamilton Standard; Analysis, Procedures and Trade-Off Concept Formulation Study, Computer Tabulations, Computer Models, Computer Output Data, Northrop Corporation.

LIFE 1972. Computer modelling 1972 through 1975.

DESCRIPTION Automatic data-acquisition and data analyzer systems to inspect, diagnose malfunctions, and predict failure of in-flight aircraft engines and fuel systems. AIDAPS was designed for the US Army helicopter, UH-1H.

8. AIMES-AVIONICS INTEGRATED MAINTENANCE EXPERT SYSTEM

FUNCTION Monitors engine functions and performs real-time diagnostic procedures.

DEVELOPER McDonnell Douglas

LIFE Flight tested January 1986

DESCRIPTION In-flight, automatic test system for use in US Army F/A-18 Hornet aircraft which utilizes artificial intelligence. Data acquisition and diagnostic operations are performed while the craft is airborne which eliminates the need for maintenance personnel to re-create the conditions once on the ground. The knowledge of the mechanic is coded on the computer in the form of operating rules.

9. AIMS-AUTOMATED INTELLIGENT MAINTENANCE SYSTEM

FUNCTION Portable interactive computer system used for maintenance testing and repair of US Army vehicles.

SPONSOR US Army

DEVELOPER Analytics Corporation, King of Prussia, PA.

LIFE 1987

DESCRIPTION AIMS is a portable, light-weight, expert system for use in maintenance, repair and training arenas. It uses expert system and voice recognition technologies, and computer screen displays of schematic diagrams and installation drawings. System may also be used for inventory tracking parts requisition and maintenance-history records of vehicles, and schedules. Interchangeable software will accommodate to other type vehicles including aircraft and rotorcraft.

10. AMES-AIRCRAFT MAINTENANCE EFFECTIVENESS SIMULATION MODEL

FUNCTION Project to develop simulation of operation and maintenance of an aircraft squadron.

SPONSOR Navy

DEVELOPER XYZYX Information Corporation, Canoga Park, California

LIFE 1977-1979.

DESCRIPTION A computer-based program of Aircraft Maintenance Effectiveness Simulation (AMES) which is able to develop and test maintenance performance and operational readiness in an aircraft squadron. This program can quantify the cost of human errors and maintenance accuracy and its impact on other factors of maintenance (i.e., consumption of spares, missed gate-times, delay, aborted missions.) This information is helpful since human errors are difficult to measure and evaluate since they are interactive with other types of errors, and not easily traced by conventional analysis.

11. AMICAL

FUNCTION Computer program to automate and perform economical scheduling of maintenance tasks.

SPONSOR KLM Royal Dutch Airline

LIFE 1986

DESCRIPTION Airline-developed computer program with applications for aircraft maintenance task scheduling, uses mini-computer based system.

12. APU MAID-AUXILIARY POWER UNIT MAINTENANCE AID and MAIDEN

FUNCTION Auxiliary Power Unit Maintenance Aid (APU MAID) software assists the flightline technician in performing test, fault detection, fault isolation and repair of the C-130 APU. Software is hosted on a portable, computer called, MAIDEN, which is specifically designed for this use.

DEVELOPER Allied-Signal Aerospace Co., Teterboro, NJ

LIVE 1987

DESCRIPTION The APU MAID is an expert system based job performance aid which uses heuristic and logical reasoning. It was developed for the C-130 aircraft auxiliary power unit. System is designed to be useful on the maintenance flight-line in APU diagnostic, fault detection, isolation and repair. It is used in conjunction with a specifically designed computer, called MAIDEN (Maintenance Aid Engine). The computer is light-weight, portable, and battery operated.

13. ASMT - AIRCRAFT SIMULATION MAINTENANCE TRAINERS

FUNCTION Computer driven simulator to train and certify C-17 maintenance personnel.

SPONSOR USAF

DEVELOPER ECC International Corporation

LIFE 1989

DESCRIPTION Air Force Aeronautical Systems Division awarded a $138-million contract for 5 C-17 Aircraft Simulation Maintenance Trainers. These will provide computer-aided instruction to the maintenance trainee personnel. Each trainer will have twelve separate training devices that replicate the C-17's systems.

14. ATEOPS

FUNCTION Expert systems used to direct automatic test equipment for testing of F-15 fighter hardware.

SPONSOR USA

LIFE 1985

DESCRIPTION ATEOPS, ATEFEXPERS and ATEFATLAS are three expert systems used to control Automatic Test Equipment (ATE) by troubleshooting the converter programmer power-supply card on the F-15 aircraft. Each system uses a specific knowledge base with tests particular to the specific circuit being tested and the test requirements. Each includes a constraint propagated frame system that allows enhanced control by creating code in the Atlas programming language, checking the code for good form, controlling the ATE and changing the test sequence as needed.

15. ASTROLOG

FUNCTION Early demonstration to integrate ground based computers and airborne data recorders for engine maintenance.

SPONSOR American Airlines, Maintenance and Engineering Center, Tulsa, OK

LIFE 1967

DESCRIPTION Astrolog is an integrated system for engine maintenance. The engine maintenance recorder portion of the data system consists of four major components: airborne magnetic data recorders, conventional long distance telephone data transmission links, centralized ground based computer complex, and computer programming which permits automatic diagnosis of engine health, fault identification and measurement of the urgency of such corrective action.

16. ATE's for AH-64 HELICOPTERS for use at AVIM-AVIATION INTERMEDIATE MAINTENANCE UNITS.

FUNCTION Automatic testing units designed to test and diagnose faults on components removed from Army helicopter AH-64.

SPONSOR Army

DESCRIPTION Computer-driven automatic test equipment designed for shop use to test and diagnose faults in Line Replaceable Units removed from the helicopter.

17. AUTOMATIC TEST PROGRAM GENERATOR (ATPG)

FUNCTION Knowledge-based interactive editor

SPONSOR Warner Robins Air Logistics Center (WRALC)

DEVELOPER Air Force Institute of Technology, School of Engineering

LIFE 1986

DESCRIPTION A prototype knowledge-based automatic test program generator (ATPG) has been developed which uses a special language to operate automatic test equipment. The ATPG is an interactive editor that will enable the software analyst to write codes effectively and efficiently. It will also aid the software development process by reducing the amount of time used in software maintenance and modification. The ATPG prototype is used in selected tests performed on a component of the F-15 aircraft.

18. ATSJEA III -AUTO TEST SYSTEM FOR JET ENGINE ASSEMBLIES

FUNCTION System to test overhauled engines.

SPONSOR Air Force

DEVELOPER Advanced Technology and Testing, Inc., Michigan

LIFE 1989

DESCRIPTION This system is designed to test overhauled fuel assemblies from Allison T56 turboprop engines powering USAF C-130K transports. This product, presently in its third generation includes a new software generated programming technique to perform necessary adjustment diagnostics and prompt the operator as necessary.

19. AVID-AUTOMATIC VIBRATION DIAGNOSIS SYSTEMS

FUNCTION Vibration data extraction from gas turbine engines.

SPONSOR USAF

DEVELOPER Mechanical Technology, Inc., Latham, New York

LIFE 1983

DESCRIPTION Automated vibration data extraction system was developed for jet transport overhaul centers. AVID automates trouble shooting procedures for fully assembled gas turbine engines. High frequency vibration data is extracted from existing standard instrumentation and provides input to a specialized symptom/fault matrix. Malfunctions are detected and assigned to a particular data set, with corrections detailed.

20. BRAD -BRILLIANT REUSABLE ADA DIAGNOSTICIAN (REUSED SOFTWARE)

FUNCTION To assist a novice munition maintenance technician in various system and components.

SPONSOR Air Force Munitions Systems Division

LIFE 1989

DESCRIPTION System in development which intends to demonstrate the applicability of model based reasoning and the concept of software reuse. The goal of the work is to enable a novice maintenance munitions technician to perform fault isolation and diagnostics in electronic, electro-mechanical, and mechanical faults using schematics and design data.

21. CAD-COMPUTER AIDED DESIGN

FUNCTION To streamline aircraft maintenance and repair.

SPONSOR US Naval Aviation Depot, Cherry Point, NC

DEVELOPER McDonnell Aircraft

DESCRIPTION This system aids US Marine personnel to troubleshoot maintenance functions by having direct access to drawings and engineering information of the builder/designer of the AV-8B Harrier II short take-off and vertical landing aircraft. Computer drawings and data for structural repairs are updated every three months, as is stress analyses and wiring diagrams.

22. CADS-COMPUTER AIDED DIAGNOSTIC SYSTEM

FUNCTION Demonstration of diagnostic system application to the H-34 helicopter.

SPONSOR US Navy

DEVELOPER Naval Postgraduate School , Monterey, California

LIFE 1987

DESCRIPTION Prototype to demonstrate feasibility of applying expert systems technology to the H-46 helicopter maintenance process. This is known as a micro computer based prototype called CADS, Computer Aided Diagnostic System. The complexity of the helicopter system diagnosis, inadequacies of the maintenance manuals often result in unnecessary removal of system components. The diagnostic system for the H-34 is proposed to add a comprehensive, stable knowledge base not dependent upon particular personnel for capable repair.

23. CALS-COMPUTER ACQUISITION AND LOGISTIC SUPPORT

FUNCTION DOD and industry strategy for the transition from paper-intensive acquisition and logistic processes to a highly automated and integrated mode of operation for the weapon systems of the 90's.

SPONSOR US Department of Defense and Industry

DEVELOPER US Department of Defense

LIFE In September 1985, Deputy Secretary of Defense approved recommendations of a DOD-industry task force on CALS. MIL-M-28001 was published February 1988. In August, 1988, another memorandum was issued stating that major steps had been taken towards routine contractual implementation of CALS through out DOD and industry. The memorandum upheld the issuance of standards for digital data delivery and required technical data in digital form for weapons systems in development in FY 1989 and beyond.

DESCRIPTION CALS addresses the generation, access, management, maintenance, distribution and use of technical data associated with weapon systems. This includes engineering drawings, product definition, and logistic support analysis data, technical manuals, training materials, technical plans and reports, and operational feedback data. The CALS system will facilitate data exchange and access, and reduce duplication of the data preparation effort. Additionally, CALS provides the framework for integration of other automation systems within DOD. The cornerstone standard for the interchange of textual technical in formation is MIL-M-28001.

24. CAMS-COMPUTERIZED AUTOMOTIVE MAINTENANCE SYSTEM

FUNCTION Automotive diagnostic system which can interface with a remote mainframe computer.

SPONSOR Commercial

DEVELOPER General Motors, Buick Division

LIFE 1987

DESCRIPTION A computer with diagnostic capability using the car computer, built-in sensors, and circuits. The system can retrieve and store a portion of data so that intermittent problems may be analyzed, sometimes with the aid of a small portable monitor hook-up. This system can interface with the Buick mainframe in Michigan by telephone hook-up, if required.

Locally, the CAMS machine consists of a touch screen command system, so that it may be used by persons without computer background. Buick claims that 48% of cars repaired without the system would return for the same type of repair; with the CAMS system, Buick claims that this was reduce to 8%, since the machine is particularly successful with small circuit analysis. This system is similar to Ford Motor OASIS system, and will soon be followed by Chevrolet, Pontiac, and GMC, and Oldsmobile. It is noted that maintenance personnel were at first reluctant to use the machine because it did not have a manual operation mode; the maintainers wanted to assert control. Its' use became more widespread as the manual mode was introduced.

25. CATS-1

FUNCTION A portable computerized troubleshooting system developed for large locomotive repair.

SPONSOR Commercial.

DEVELOPER General Electric Research and Development Center

LIFE Current

DESCRIPTION This electrical and mechanical diagnostic system uses expert systems technology combined with portable computers for use on the maintenance floor. The system initiates diagnostic technique by supplying a menu of possible symptoms and then prompts a series of detailed queries. At appropriate point in the interaction, the user may call up from the computer memory, displays and drawings, photos or movies of the locomotives various components, locations and functions. As malfunctions are determined, repair instructions are provided on the video screen.

This system uses a standard 16-bit microcomputer for information processing, additional memory for storing expert knowledge, a CRT, a printer, a video disc player and monitor for demonstration of repair procedures.

CAT-1 is currently in use at GE locomotive repair facilities nationwide.

26. CCP-CONTAMINATION CONTROL PROGRAM

FUNCTION To reduce unnecessary maintenance and heavy-equipment downtime through progressive analysis of various non-engine lubrication and maintenance schedules.

SPONSOR Mobil Oil

DESCRIPTION Samples of engine lubrications are mailed to Mobil's Kansas City Laboratory and analyzed for levels of oxidation and sludge, viscosity, fuel dilution, dirt and glycol, water and wear metals. Lubricants are not changed until contaminated which also indicate the presence of or incipient maintenance actions.

27. CCS-COMPONENT CONTROL SYSTEM

FUNCTION To improve communication between aviation maintenance, inventory and scheduling departments without increasing data entry time.

DEVELOPER USAir

LIFE 1986.

DESCRIPTION The Component Control System, part of the USAir publicly marketed Merlin System, is used for time control processing, removal/installation and history processing for components, major assembly processing of subassemblies and forecasting removal requirements.

28. CEMS IV-COMPREHENSIVE ENGINE MANAGEMENT SYSTEM increment IV

FUNCTION To support the on-condition maintenance philosophy, combined with portable decision support devices using diagnostics and trending analyses.

SPONSOR Air Force

DEVELOPER Systems Control Technology, Inc., Palo Alto CA

LIFE 1988

DESCRIPTION A fielded expert system automates equipment for fault isolation, diagnosis, and trend analysis, and recommends corrective maintenance action. This program is the standard to the Air Force base level maintenance. CEMS IV will be enhanced and fielded under the umbrella of Core Automated Maintenance System.

29. CEPS - CITS EXPERT PARAMETER SYSTEM

FUNCTION Maintenance diagnostic system

SPONSOR Air Force

DEVELOPER Boeing Military Airplane Development

LIFE 1987

DESCRIPTION CEPS couples expert system technology and conventional programming with a large data base to provide a system which will assist maintenance diagnostics. This system incorporates avionics design knowledge, avionics maintenance expertise, and statistical analysis of past and present failure indicators to improve fault detection and isolation. A prototype is under development for the B-1B.

30. CITEPS -CENTRAL INTEGTRATED TEST - EXPERT PARAMETER SYSTEM

FUNCTION System to utilize monitoring systems and built-in test systems on the B1-B to perform fault solation.

SPONSOR US Air Force

DEVELOPER Wright Patterson Aeronautical Laboratory.

DESCRIPTION This system is built upon previous technological systems developed for Air Force maintenance procedures, such as the Central Integrated Test and Comprehensive Engine Monitoring System. This system receives data from these other systems and combines it with expert technology derived directly from the experience of mechanics. It enables a less experienced mechanic to perform advanced diagnostic analysis and maintains a higher production standard.

31. CITS - CENTRAL INTEGRATED TEST SYSTEM

FUNCTION On-board central diagnostic system developed for the B1-B aircraft.

SPONSOR USAF

DEVELOPER Rockwell International Corporation, Los Angeles, California.

LIFE 1981

DESCRIPTION The B1-B Central Integrated Test System (CITS) is the on-board test system for the B1-B aircraft and the avionics subsystems. The CITS operates continuously and automatically in flight and on the ground to display performance and faults to the aircrew. It records approximately 19,600 parameters. Failed modes of operation are detected/recorded on all subsystems and faults are isolated to the line-replaceable-unit (LRU) level. Three snapshots of all CITS data parameters is recorded on magnetic tape for maintenance troubleshooting. The CITS performs pre-flight and postflight tests automatically. Reverification of systems and ground readiness tests are conducted on individually selected subsystems at the operators' request. This system was first developed for the B1-A aircraft, and refined for the B1-B aircraft.

32. CMS-COMPUTERIZED MAINTENANCE SYSTEM

FUNCTION Serving 26 US Coast Guard airstations and repair and supply facilities in the United States and Puerto Rico.

SPONSOR US Coast Guard.

LIFE 1988

DESCRIPTION The Computerized Maintenance System uses a relational database running on a Digital Equipment Corporation VAX 8530. Real-time information is provided on the status of more than 200 aircraft, in addition to the identification of trends and problems. It is used for assistance in troubleshooting, system reliability analysis the recording and reporting of aircraft data and the maintenance of records on airframes and components. The system functions by users entering data into a commercial off the shelf terminal which is then transmitted via telenet to the VAX 8530 located at Tamsco. Data integrity is maintained by a data entry system that automatically provides validation and cross checking.

33. COMPASS - CONDITION MONITORING AND PERFORMANCE ANALYSIS HOST SOFTWARE SYSTEM

FUNCTION This is a ground-based engine monitoring program for general application to engines in service after 1989, which integrates other engine monitors. This product is available from third party vendor respect the proprietary information required to implement the software.

DEVELOPER Rolls Royce

LIFE Developed for use on new engine types entering service in 1989.

DESCRIPTION Maintenance functions, including reduced cost of operation, increased utilization of resources, improved procedures and increased visibility of engine and fleet condition are all more efficient due to built-in instrumentation to monitor performance of the unit, and more sophisticated computer system capabilities on the ground. The system supplies trend and operational monitoring information from four main areas (on-wing, ground, test cell, and maintenance action data) to a ground base, thus enabling early warning and maintenance decision and scheduling functions to be determined ahead of condition failure. Information regarding the operational parameters of the host engines and users must be fed into the system.

34. DC-9 REFRIGERATION SYSTEM DIAGNOSIS

FUNCTION Early method of computer diagnosis in aircraft maintenance

DEVELOPER Eastern Airlines, Inc., Miami, Florida

LIFE 1973 PA, 1973.

DESCRIPTION An early method of instantaneous diagnostics DC-9-30 refrigeration systems using readily obtainable data, suitable algorithms of component performance comparing performance to performance standard. Variable conditions are factored in such as hot day conditions, and effects of preventative maintenance procedures.

35. DCS-DIGITAL CONTROL SYSTEM

FUNCTION Telecommunications-based diagnostic and support system

DEVELOPER Kearney & Trecker, Milwaukee, WI

DESCRIPTION The DCS Analyst is a telecommunications-based diagnostic and support tool available to users of Gemini controls. This includes equipment manufactured by Kearney & Trecker, Cross, Swasey, Warner for milling, boring, and machining equipment and lathes.

Used in conjunction with a modem, communication may be established to DCS analysts at the firms' headquarters in Milwaukee, and any Gemini-controlled machine, and thus control or monitor any machine function. The control system can set, alter, program software uploaded/downloaded, condition of the machine checked, and maintenance levels established.

Support is established by using the particular units' own service history as well as the history of other machines stored in the DCS database. The users computer may be interrogated and control may be bypassed to test sections of the control individually. In addition, a specific machine will be analyzed for its' own fingerprint, which will enable the customer to develop an appropriate preventative maintenance program.

36. DECISION SUPPORT SYSTEM FOR DIAGNOSIS OF A/C EMERGENCIES

FUNCTION System designed to show the feasibility of expert systems technology utilizing existing on-board sensors to aid diagnosis of single and compound emergencies.

SPONSOR US Navy

DEVELOPER Naval Postgraduate School, Monterey, California

LIFE 1986

DESCRIPTION This system was developed to demonstrate the feasibility of using on-board sensors, specific knowledge bases with personal computer implementation, to assist the aircraft crew to respond to single and compound emergencies. The platform for the demonstration was the AH-1T attack helicopter. This system quantifies the information and respondent knowledge required to define emergencies.

37. DIAGNOSTIC DATA RECORDER

FUNCTION On-Line computerized diagnostic tool used in the automotive industry.

SPONSOR General Motors -Buick

DESCRIPTION An on-line diagnostic tool installed on certain cars. This system records various indicators of 26 engine functions. When the auto is referred for service of an intermittent or other problem, the data recorder may be hooked up by modem to enable the data log to be examined, compared to heuristic data and fault diagnosed. Such items as engine temperature, O2 sensor, timing, and air-fuel mix control, are checked.

38. DIAGNOSTIC EXPERT SYSTEM FOR AIRCRAFT GENERATOR CONTROL UNIT

FUNCTION A generic, diagnostic expert system for generator control units.

DEVELOPER Westinghouse Electric Corporation, Lima, OH

LIFE 1988

DESCRIPTION This system may be applied to different devices. Modular variable-speed/constant frequency generators families are organized by standard modules to enable expert system technology to be applied. A general diagnostic expert shell is developed that will guide troubleshooting procedures of modules and line-replaceable units. System is applied to the generator control unit and may be applied to other types of units by incorporating device-specific rules from expert personnel.

39. DMMIS-DEPOT MAINTENANCE MANAGEMENT INFORMATION SYSTEMS

FUNCTION To improve Air Force maintenance depot planning and control functions.

SPONSOR US Air Force, Wright Patterson AFB, OH

DEVELOPER Grumman Data Systems, Grumman Aerospace Corporation

LIFE 1988, still in development

DESCRIPTION This Grumman product will support Air Force maintenance depots engines, all types of aircraft, cargo, instruments, avionics, landing gear and accessories, and communication systems. It endeavors to improve planning and control functions of scheduling, workload planning, inventory control, productivity and planning and operational readiness. In addition, it will provide on-line data access and user interaction.

The DMMIS system is software intensive using commercial off-the-shelf software management systems to replace an existing 1500 computer programs. It will cluster all systems of management (material requirements, work order generation, logistics, budgeting, time and attendance, job cost, quality management, etc.) to reduce repetitive data entry and systems, increase amounts and variety of available information.

40. DODT-DESIGN OPTION DECISION TREE

FUNCTION A method for systematic analysis of design problems and integration of human factors data.

SPONSOR US Air Force AFHRL, Brooks Air Force Base, TA.

DEVELOPER Systems Research Laboratories, Dayton, OH.

LIFE 1974.

DESCRIPTION This method is represented by a schematic format termed the Design Option Decision Tree. It displays the various design options available at each decision point in the design process. Note that this system is not only applicable to aircraft systems, although the system is modelled on aircraft design problems. The user specifies design goals, and among the various design parameters are human factors considerations.

41. EASTERN AIRLINES COMPUTER SYSTEM

FUNCTION Maintenance planning and scheduling

DEVELOPER Eastern Airlines

DESCRIPTION Use of a combination of mini and mainframe computers have improved.

Eastern's productivity and costs, allowing a reduction of three aircraft assigned to periodic service. This system was particularly useful when the company had a known parts shortage-so that unnecessarily assigning the wrong aircraft this part would cause canceled flights.

Computer information is transferred directly to the shop floor, and in bases where the maintenance operations do not have a designated computer, information may be sent via the computers used at ramp and customer service departments.

Capacity planning chores are also performed. Management can calculate the effects of line slippage, schedule constraints and workload/manpower planning, as well as modification impact assessment. This computer system follows the recommendations of the ATA which specified that maintenance and engineering must have dedicated computers and staff using fully integrated systems available at the work areas using on-line data systems.

42. ED/CEMS ENGINE DIAGNOSTICS/COMPREHENSIVE ENGINE MGMT SYSTEM IV

FUNCTION Platform used for applications such as XMAN, used in jet engine diagnostics to support on-condition maintenance philosophy.

DEVELOPER Systems Control Technology, Palo Alto, California

LIFE 1986.

DESCRIPTION An expert system that automates equipment used for diagnosis of anomalies in engine operations based upon prescriptive parameters. Fault diagnosis, trend analysis and recommended corrective actions are features of this system. This system is a knowledge-based system composed of three modular software element: a knowledge base, a data base, and a control system.

43. EDS (ENGINE DIAGNOSTIC STS) FLT EVALUATION AIR FORCE

FUNCTION Engine diagnostics and trend monitoring

SPONSOR Air Force Aero-Propulsion Laboratory, Wright-Patterson AFB, OH.

DEVELOPER McDonnell Aircraft Co.

DESCRIPTION In the F15/F100 Engine Diagnostic System Flight Evaluation, data was collected to verify gas turbine engine fault detection/isolation and health trending algorithm employing gas path analysis.

44. ELATS-EXPANDED LITTON AUTOMATED TEST SET

FUNCTION Automated test systems for various flight functions.

DEVELOPER Litton Systems Canada

DESCRIPTION The Expanded Litton Automated Test Set is a comprehensive automated test system for radar, communications, microwave, electronic warfare systems and advanced depot-level support maintenance. It is designed as an inexpensive means for intermediate and depot-level support maintenance, combining existing instrumentation with a general design approach. The RF-ELATS can automatically simulate a variety of scenarios, modulation and noise and diagnose faults on the weapons replaceable assemblies. It also has built-in test routines and transfer standards and test subroutines.

45. EM/PA-MOBIL OIL ENGINE MAINTENANCE THROUGH PROGRESSIVE ANALYSIS

FUNCTION To reduce unnecessary maintenance and heavy-equipment downtime through progressive analysis of engine oils and maintenance schedules.

DEVELOPER Mobil Oil

DESCRIPTION Samples of engine lubrications are mailed to Mobil's Kansas City Laboratory and analyzed for levels of oxidation and sludge, viscosity, fuel dilution, dirt and glycol, water and wear metals. Lubricants are not changed until contaminated which also indicate the presence of or incipient maintenance actions.

46. ETTR - ENGINE TIME TRACKING RECORDER

FUNCTION Part of larger system that monitors time and temperature of engine operation.

SPONSOR Air Force

DEVELOPER General Electric Co., Aircraft Engine Business Group, Lynn, MA.

LIFE 1979.

DESCRIPTION This system is one component of the Parts Life Tracking System is an engine time-temperature recorder system. Based on the on-condition maintenance, the recorder monitors operations and compares it to a set of designated parameters of satisfactory operation. The Parts Life Tracking System manages the TF34-100 engine in USAF/A10 aircraft.

47. EXPERT SYSTEM FOR MAINTENANCE DIAGNOSIS

FUNCTION Self repair of digital control systems.

SPONSOR US Air Force, Air Force Flight Dynamics Laboratory, Wright Patterson AFB, Ohio

LIFE 1983.

DESCRIPTION Using statistics collected from battle damaged repair history, i.e., from Southeast Asia, Falkland Islands, and Israeli data, the self-repairing concept was explored toward development of the diagnostic data /expert knowledge systems for maintenance diagnosis.

48. FAMIS - FIELD ASSET MANAGEMENT & INFORMATION SYSTEM

FUNCTION CD-ROM based information retrieval system

DEVELOPER Image Storage/Retrieval Systems IS/RS

LIFE 1989

DESCRIPTION FAMIS is a field support tool for the gas, electric, telecommunications and nuclear utility industry. Data is stored on CDs and enables field support personnel to access information such as maps, manuals, work orders and bulletins. It also collects data from the field for transfer to the home office via floppy disk or through the built-in modem.

49. FAULT ISOLATION-BITE

FUNCTION Next generation of built-in test equipment.

SPONSOR US Air Force

DEVELOPER Boeing Commercial Airplane Company, Seattle

LIFE 1982

DESCRIPTION Built-in test equipment developed for the Boeing 757 and 767 aircraft allows faults to be detected to the line replaceable unit level of maintenance. This extension to beginning fault isolation test equipment is designed for the mechanic's needs, as opposed to the engineer's. Intermittent faults will be detected. This is expected to lead to greater maintenance bay productivity, improved schedule reliability and decreased maintenance cost.

50. FCMDS-FLIGHT CONTROL MAINTENANCE DIAGNOSTIC SYSTEM

FUNCTION Diagnostic system for maintenance of flight control systems.

SPONSOR US Air Force, Wright Patterson Aeronautical Laboratories, Wright-Patterson AFB, Ohio

DEVELOPER Honeywell Systems and Research Center, Minneapolis, MN

LIFE 1988

DESCRIPTION Determination of maintenance diagnostic approaches has led to the development of flight control system diagnostics which will enhance the organizational-level technicians. Maintenance productivity improves as shop reliability and work load scheduling are able to improve. The system is composed of two parts: imbedded diagnostic sensors on the aircraft, and a computerized ground base system to extrapolate and test on-board generated data.

51. FLIGHT DATA RECORDING SYSTEM TECHNOLOGY-FAULT TOLERANT MULTIPROCESSOR FOR AIRCRAFT SYSTEMS

FUNCTION Computer architecture

LIFE 1988

DESCRIPTION FTMP, Fault Tolerant Multiprocessor is a digital computer architecture evolved over a ten year period. Its application to several life-critical aerospace system, notably, as the fault tolerant central computer for civil air transport applications. The design is based upon independent processor-cache memory modules and common memory modules which communicate via redundant serial buses. All information processing and transmission is conducted in triplicate so that local voters in each module can correct errors. Modules can be retired and/or reassigned in any configurations. Reconfiguration is carried out routinely from second to second to search for latent faults in the voting and reconfiguration elements. Job assignments are all made on a floating basis, so that any processor triad is eligible to execute any job step. The core software in the FTMP will handle all fault detection, diagnosis, and recovery in such a way that applications programs do not need to be involved.

52. FUZZY DIAGNOSTICS

FUNCTION System to assist diagnosis of faults difficult to describe in aircraft hydraulic systems.

SPONSOR Peoples Republic of China

LIFE 1986

DESCRIPTION Aircraft hydraulics systems, the drive systems which control attitude, extension and retraction of landing gear, and wing flaps, are composed of many parts. These are complex systems and often give rise to puzzling faults that are difficult to reenact and difficult to describe. The applications of computers in fault diagnosis can increase precision and speed so as to conveniently array the prerequisites which create the fault. The causes of system faults and the appearance of symptoms have a random or fuzzy nature. This system takes natural language and transforms it into machine language and crystallize human experience to simulate a fuzzy inference system. The characteristic nature of the system is first to select from events a set of symptoms and causes of model fault events and store them in a computer. Then during diagnosis a symptom is matched to a known fault to determine cause.

53. GATEKEEPER (PROGRAM), TEXAS AIR

FUNCTION Helps airline managers coordinate and maintain gate schedules in response to changing flight schedules, aircraft routings, weather and airport conditions.

SPONSOR Texas Air

DEVELOPER Texas Air System One, Houston, TX

LIFE 1989

DESCRIPTION This is a VAX-based expert system designed to alleviate effects of, and causes of, airport congestion. This is an intelligent, LISP-based distributed system that is operated on a UNIX-based workstation in the X-windows environment. It is connected via Ethernet to a relational database management system from Oracle on a VAX or 30386 database server.

GateKeeper coordinates flight operations and gate assignments in such locations as Continental (Houston, Newark and Denver), and Eastern (Miami). It is currently being marketed world-wide. The objective of the program is to improve efficiency and reduce operating costs. It uses artificial intelligence and incorporates four types of information: monthly and up-to-the-minute flight schedules, routing of aircraft for maintenance, flight information from each airline, and passenger information. The system is fault tolerant with triple redundancy and designed to reduce an airline's dependence on mainframe networks.

The system has predictive capability and may therefore avert potential crises by showing a manager the consequences of certain assignments.

54. IEIS - INTEGRATED ENGINE INSTRUMENT SYSTEM

FUNCTION Computer driven display and processing instrumentation system used to monitor aircraft engine conditions.

SPONSOR Naval Air Development Center, Warminster, PA

DEVELOPER GE, Wilmington Mass Aerospace Instruments

LIFE 1973

DESCRIPTION The Integrated Engine Instrument System (IEIS) is primarily concerned with the monitoring of aircraft engine conditions in response to the needs of flight crews and maintenance personnel.

55. IFL-INTELLIGENT FAULT LOCATOR

FUNCTION Designed to diagnose problems with the AH-64A Attack Helicopters.

SPONSOR US Army

DEVELOPER McDonnell Douglas Helicopter Co.

LIFE 1988

DESCRIPTION US Army's expert system used on the AH-64A helicopter diagnosed faults on four of the eighteen systems with 96.3% accuracy, and reduced by half the time required to locate faults. The system was developed on a Texas Instruments Explorer symbolic processing workstation.

56. IMIS - INTEGRATED MAINTENANCE INFORMATION SYSTEM

FUNCTION Integrates technical data collected from several sources and delivers that information in a practical form to the flight-line maintenance technician performing fault isolation procedures in a convenient and portable mode.

SPONSOR US Air Force Human Resources Laboratory

LIFE 1982, ongoing

DESCRIPTION It uses a hand-held rugged computer for use during diagnostic maintenance, an aircraft maintenance panel connected to on-board computers and sensors, a maintenance workstation connected to various ground based computers systems, and sophisticated integration software which combines information from these various sources and presents data and conclusions to the maintenance technician in a consistent and practical manner. Functionally, this system includes technical data, training, diagnostics, management, scheduling and historical data bases, and transmits such data to the flight-line.

This system is consistent with technologies developed as Core Automated Maintenance System (CAMS), Automated Technical Order System (ATMOS) Phase IV, Integrated Turbine Engine System (ITEMS) and a variety of Automatic Test Equipment.

57. INS-FAAMS-INERTIAL NAVIGATION SYSTEM

FUNCTION Inertial system fault analysis and management system to enhance US Army avionics.

SPONSOR US Army

DEVELOPER McDonnell Aircraft Company, St. Louis, Mo.

LIFE 1984

DESCRIPTION The purpose of the Inertial Navigation System-Fault Analysis and Management System is to implement artificial intelligence in fighter aircraft avionics. This has the effect of enhancing the availability to mission and accuracy of the inertial navigation system. Inertial Navigation System failures are often difficult to isolate because the are related to incorrect procedures or non-repeatable conditions. The expert system identifies failures through the analysis of key failure paths, field maintenance data, and simulation testing of various mission profiles. The system is based upon blackboard architecture and has three divisions: current hypothesis and permanent knowledge, knowledge source demons searching for an antecedent to be true, and a priority based scheduler.

58. IN-ATE - INTELLIGENT AUTOMATIC TEST EQUIPMENT

FUNCTION A fault diagnosis expert system environment.

DEVELOPER Automated Reasoning Corp. New York

LIFE 1987

DESCRIPTION IN-ATE is a fault diagnosis expert system software environment that is designed to reduce test-program development-time and test program run-time.

59. INTEGRATED TURBINE ENGINE MONITORING SYSTEM

FUNCTION Complex engine diagnostic system.

SPONSOR US Air Force Wright Patterson Aeronautical Systems Division

LIFE 1986

DESCRIPTION Successor to the Turbine Engine Monitoring System, used on the TF34 and the F-15 Engine Diagnostics System, and the T-38 trainer Engine Health Monitoring System.

60. INTERFACE II - ADVANCED DIAGNOSTIC SOFTWARE

FUNCTION Software appends software capabilities of various systems.

SPONSOR US Air Force.

DEVELOPER General Electric Co., Cincinnati, OH.

LIFE 1988

DESCRIPTION Interface II is a system of software designed to enable other systems to extend capability into new domains. An example of this system is JET-X, a system developed to coordinate Turbine Engine Monitoring Systems and Comprehensive Engine Monitoring Systems (TEMS and CEMS, respectively) to extend its diagnostic and troubleshooting capabilities and to allow use of the machine for training purposes.

61. IRAN-INSPECT AND REPAIR AS NECESSARY

FUNCTION Maintenance philosophy and management framework.

SPONSOR US Army

DEVELOPER Rand Corporation

DESCRIPTION The Inspect and Repair as Necessary concept demonstrated in the early phases of computerized maintenance planning and aircraft inspection capabilities. The system was demonstrated on the F-106 aircraft, and performance effects of the program were measured on the ADCM 66-28 parameters. The system was shown to have ambivalent effect; aircraft was neither received in a state of necessity, and procedures did not augment its reliability or in-service time.

62. INTEGRATED TESTING AND MAINTENANCE TECHNOLOGIES

FUNCTION To receive and extract from data information required to troubleshoot interactive aircraft systems.

SPONSOR Air Force, Wright Patterson Air Force Base, Ohio

DEVELOPER Boeing Aerospace, Seattle, Washington

LIFE 1988

DESCRIPTION Technology which will enable coordination of various on-board and ground support systems. The multitude of systems covered partially or entirely by particular avionics leads to a vast amount of replication of processing and software unless integrated. Maintenance ground support diagnosis also entails replication.

63. IUSM - INTEGRATED UTILITIES SYSTEM MANAGEMENT SYSTEM

FUNCTION Integrates aircraft utility systems onto a common data bus.

SPONSOR US military

DEVELOPER Smiths Industries

LIFE 1986

DESCRIPTION The ISUM was developed on the Experimental Aircraft Program (EAP). The system combines the fuel management, hydraulics, engine control, and environmental control systems onto a common military standard data link. This system reduces system complexity and also provides a method by which a CRT display could be integrated, thus giving the pilot quick access to data via soft keys or menus. The system can be configured so that any parameter which is out of tolerance is displayed as it arises. One of the main advantages of this system is a weight savings of 50% and volume savings of 25% when compared to other systems. This in turn eases maintenance.

64. JET-X

FUNCTION Expert system works interactively with other systems.

SPONSOR US Air Force

DEVELOPER General Electric Co., Cincinnati, OH

LIFE 1988

DESCRIPTION Jet-X is a knowledge based expert system used to diagnose and aid maintenance of the TF-34 jet engines installed on the USAF A-10A aircraft/ This system uses input from the Turbine Engine Monitoring System (TEMS) installed on the airplane, and combines it with information retrieved from the CEMS (Comprehensive Engine Management System) database that is part of the computer ground support system. This combination generates alarms which activates the JET-X analyses. Troubleshooting procedures are imbedded in the system for each type of alarm. In addition, "help" will assist the inexperienced technician so that it may be used both as a flight line tool and a training tool.

65. LAMP-LOGISTICS ASSESSMENT METHODOLOGY PROTOTYPE

FUNCTION Computer model developed to assess technology effects of advanced USAF aircraft supportability and logistics requirements.

SPONSOR US Air Force Integrated Logistics Technology Office

DEVELOPER Dynamics Research Corporation

LIFE First analysis performed in June 1986 investigated an advanced self-repairing flight control system. In August, 1986, the system demonstrated the effects of the incorporation of a particular radar system in an advanced aircraft.

DESCRIPTION This computer model is designed on the premise that supportability of an item (such as advanced fighters) is as important as such factors as cost, performance and schedule. Embedded in the LAMP software are models for cost, manpower, sortie generation and airlift support models. The USAF F-16 data is used as the reference system. The LAMP system runs on the logistics assessment workstation (LAWS).

66. LEADER

FUNCTION Automatic, real-time diagnostic system

DEVELOPER Textron Lycoming

LIFE 1988

DESCRIPTION LEADER is an expert system that supports acceptance testing functions of gas turbine engines. The system aids in problem diagnosis by automatically analyzing engine parameters for fault identification. It models the reasoning of an experienced engineer for a specific steady-state testing procedure with several hundred rules.

67. LEADS 200

FUNCTION Flight data recording system

DEVELOPER Technische Hochschule, Aachen Instrumentation for Jet Propulsion and Turbomachinery.

LIFE 1983

DESCRIPTION The LEADS 200 flight data recording system was introduced into a F104G wing of the German Air Force in order to monitor aircraft and engine maintenance. The main software routines in the system for engine data performance monitoring and fault diagnosis.

68. LIPS - LIST PROCESSING LANGUAGE

FUNCTION Prototype Maintenance Expert System for the CH-47 Flight Control Hydraulic System.

SPONSOR U.S. Army Research Office Dept. of Mechanical and Aerospace Engineering

LIFE 1986

DESCRIPTION List Processing Language, or, LIPS, is a computer language used to facilitate data processing during the hydraulic flight control system inspection of Boeing CH-47 helicopters.

69. MACPLAN-MILITARY AIRLIFT COMMAND PLAN

FUNCTION Logistics support

SPONSOR US Air Force Military Airlift Command, Wright Air Force Base

LIFE 1989

DESCRIPTION This plan was developed with cost-containment specifically in mind. It is designed to help the Military Airlift Command move large cargo quantities between the US and overseas bases. Factors include types of available aircraft, numbers of flights, routes, refueling and other adverse contingencies. Possible extrapolation to the commercial aviation field as logistics support for parts and replacement kit movement for all types service business.

70. MACSPEC PGW - PORTABLE GRAPHICS WORKSTATION

FUNCTION CD-ROM based catalog.

DEVELOPER Image Storage/Retrieval Systems IS/RS

LIFE 1989

DESCRIPTION PGW is a CD-ROM based system that is used by Mack Trucks and their dealers to store their parts catalogs on CD-ROM. The system was to help the dealer find an specific part in less time. It was designed with a touch-sensitive screen, packaged for a hostile environment, portability for use on the road, and expandability for enhancements such as inventory control. The system contained images and text.

71. MADARS-MALFUNCTION DETECTION ANALYSIS AND RECORDING SYSTEM

FUNCTION To provide engine analysis.

SPONSOR US Air Force, Wright Patterson AFB, Ohio

DEVELOPER Lockheed-Georgia, Marietta, Georgia

DESCRIPTION C5A malfunction detection analysis and recording system for on-board flight isolation of several functions including engines.

72. MACH-MAINTENANCE ACTIVITY COMMUNICATIONS HISTORY

FUNCTION To minimize aircraft maintenance downtime and improve communications between maintenance, scheduling, and inventory without increasing data entry time.

SPONSOR USAir, Pittsburgh, PA.

DESCRIPTION The Maintenance Activity Communications History system is used for aircraft history reporting and data collection, aircraft reliability reporting and control, and an interface for line planning functions. It also functions as a communications network for maintenance and engineering. The system is an adjunct to the existing Merlin system.

73. MAINTENANCE ANALYST

FUNCTION System which uses Artificial Intelligence to troubleshoot an avionics subsystem on Sikorsky Blackhawk helicopters.

SPONSOR US ARMY

LIFE 1986

DESCRIPTION The Maintenance Analyst is a portable real-time consultant for field-level troubleshooting the SAS-1 avionics subsystem aboard the Sikorsky Blackhawk helicopter. This system runs on IBM compatible computers in LISP (an artificial intelligent programming language) and is designed to reduce the time required to troubleshoot the system under test.

74. MAINTENANCE DATA BUS MONITOR AND RECORDER (MIL-STD-1553b)

FUNCTION Technology of data transmission which enables continuous data flow from a monitor system to the receiving recorder system.

SPONSOR National Aeronautics and Space Administration, Washington

DEVELOPER Normalair-Garrett Ltd., Yeovil, England

DESCRIPTION The use of data buses for communication creates the need for the monitoring and collection of data for a variety of purposes including trend data for analysis of databus or subsystem performance, as well as diagnostic data relating to continuous or intermittent failures. The technology also created the need for data monitoring and recording systems with redundant data buses.

75. MCS-MODIFICATION CONTROL SYSTEM

FUNCTION Used for aircraft modification and development, status update and reporting, workload planning and scheduling.

DEVELOPER USAir, Pittsburgh, PA.

LIFE 1986

DESCRIPTION This system part of the larger Merlin System developed by USAir to improve efficiency and communications between all phases of maintenance.

76. MDC-USAF MDC-US AIR FORCE MAINTENANCE DATA COLLECTION SYSTEM

FUNCTION Provision of a limited number of measures to access fleet condition and identify likely candidates for reliability and maintainability improvement.

SPONSOR US Air Force

DEVELOPER RAND Corporation, Santa Monica, California

DESCRIPTION The Air Force has determined that the maintainability of products and systems is as important as other utility and cost factors; hence, the development of a set of parameters, organized into the MDC system, to enable the user to determine which areas of the purview are likely candidates for improvement in reliability and maintainability. Since the program looks at subsystems, a better-than-average understanding of maintenance data collection and base-level maintenance systems is required to manage this complex system. The system provides the user with condensed organized data so that decisions and actions may be further determined.

77. MDIS-MAINTENANCE AND DIAGNOSTIC INFORMATION SYSTEM

FUNCTION Generic model-based expert system for use in maintenance.

SPONSOR US Air Force

DEVELOPER Boeing Aerospace Co., Boeing Military Aircraft Div.

LIFE 1986

DESCRIPTION Software system with capability of building a description of any type of equipment, currently used in the Portable Computer-Based Maintenance Aid System (PCMAS) being built by Boeing for the US Army.

78. MERLIN SOFTWARE

FUNCTION Software package marketed by USAir to improve the efficient performance and communication among operating departments of aviation maintenance organizations. These departments include maintenance, overhaul, scheduling, shops, and inventory.

DEVELOPER USAir, Pittsburgh, PA.

LIFE Since 1986.

DESCRIPTION The Merlin software package developed by USAir is composed of five management information systems which integrate various aspects of aviation maintenance. These include MACH (Maintenance Activity Communications History), CSS (Component Control System), MCS (Modification Control System), MSCS (Material Services Control System). Several carriers have acquired this software. Among them are Federal Express, Aeromexico, Kuwait Airways, Cameroon Airlines, BWIA International Airline, Ansett Airlines, Turkish Airlines, UTA and Flying Tigers.

79. MICROFICHE MAINTENANCE MANUAL STORAGE AND RETRIEVAL

FUNCTION To store maintenance manuals in microfiche form for delivery to maintenance areas and airline shops throughout the US.

SPONSOR Delta Airlines

DEVELOPER Minolta Corp.

LIFE 1985

DESCRIPTION Job performance aid which supplies bulky compendia such as airplane maintenance manuals in microfiche form. Readers used by Delta are the RP407 and RP407E reader-printers located in maintenance areas or airline shops and repair stations, allow standard, complete, and easy distribution of information which may need to be needed by various departments.

80. MIMS-MAINTENANCE INFORMATION MANAGEMENT SYSTEMS

FUNCTION To bridge the information assimilation gap between data acquisition and maintenance operations.

SPONSOR US Air Force

DEVELOPER Systems Control Technology, Inc., Palo Alto, California

LIFE 1981

DESCRIPTION The Turbine Engine Fault Detection and Isolation Program Model Development resulted in the Maintenance Information Management System in 1981. Although the acquisition of engine monitoring systems has been effective in prototype and operational modes, it was determined that the acquisition of data, although reliable, was not formulated in a manner in which it could be utilized by the maintenance management. There were no procedures for integrating the data into the maintenance process. This systems attempts to resolve the complexity of integrating data received. The system establishes standards for managing information flow effectively in the standard Air Force maintenance units.

81. MSCS-MATERIAL SERVICES CONTROL SYSTEM

FUNCTION Computer software system to facilitate communication between material control, purchasing, planning, receiving and issuing functions in an aviation maintenance organization.

DEVELOPER USAir, Pittsburgh, PA

LIFE Since 1986.

DESCRIPTION This software system is a component of the Merlin package, which include MACH, CCS, and MCS. This phase of the system is used in material control, planning, purchasing, receiving and issuing functions in aviation organizations.

82. MAINTENANCE TRAINING SIMULATOR-US ARMY

FUNCTION Efficient, complete training for specified aircraft or maintenance systems.

SPONSOR US Army

DEVELOPER BBN Laboratories

LIFE 1988

DESCRIPTION Maintenance training simulators are designed to reduce training costs, reliance upon certain types of equipment availability, and condense training time with increased training effectiveness. As an example, the simulator developed for the F-16 fighter aircraft environmental system has reduced eleven days overall training with one day hands-on, to seven days hands-on. This simulator, developed by BBN Laboratories for the US Army is for the Sikorsky Black Hawk air defense system radar. Using artificial intelligence, the trainer embodies the knowledge of an expert. It can be used to train or function as a diagnostic tool.

83. MULTIPLE FAULT DIAGNOSTIC GAS PATH ANALYSIS SYSTEM

FUNCTION Demonstration of Hamilton Standard's Gas Path Analysis Technique.

SPONSOR Naval Air Propulsion Test Center, Trenton, Nj

DEVELOPER United Technologies, Windsor Locks, CT

LIFE 1975

DESCRIPTION System demonstrates the results of Hamilton standard's gas path diagnostic system for a complex twin-spool mixed flow, variable geometry turbofan engine. Possible diagnostic routines are specified with sensor and control uncertainties.

84. NASA/US AIR FORCE SELF-REPAIRING FLIGHT CONTROL PROGRAM

FUNCTION Aircraft self-diagnostics system.

SPONSOR NASA/US Air Force

DEVELOPER General Electric

LIFE 1989

DESCRIPTION The Self-Repairing Flight Control Program was developed to assist fault failure detection and maintenance. The program detects and identifies failures as they occur in-flight, thus eliminating the difficulty of replicating failures in ground tests after the aircraft lands. General Electric has developed an aircraft maintenance self-diagnostic system that will perform these in-flight tests on an F15 research aircraft.

85. ORION 4400 AUTO TEST SYSTEM

FUNCTION To maintain inertial navigation and aircraft management system.

SPONSOR Japan Air Lines

DEVELOPER GEC Avionics

LIFE 198

DESCRIPTION The Orion 4400 is a system used to help maintain inertial navigation systems and aircraft management systems. The equipment is of modular design and has self-diagnosing and self-repair capabilities. These systems are used in production control and maintenance applications.

86. PCMAS -PORTABLE COMPUTER BASED MAINTENANCE AID SYSTEM

FUNCTION Portable maintenance expert system

SPONSOR US Air Force

DEVELOPER Boeing Military Aircraft Company

LIFE 1986

DESCRIPTION Portable Computer-Based Maintenance Aid System, PCMAS, is maintenance system which utilizes expert systems called MDIS.

87. PLTS-PARTS LIFE TRACKING SYSTEM

FUNCTION System designed to manage on-condition maintenance.

SPONSOR US Air Force

DEVELOPER General Electric Corp., Aircraft Engine Business Group, Lynn, MA.

LIFE 1979.

DESCRIPTION The system is designed to support the philosophy of on-condition maintenance. The system manages maintenance of USAF/A10 aircraft. Included in the overall system are Parts Tracking Systems, and Engine Time-Temperature Recorder systems. The central data base includes a parts master file encompassing all designated parts entered into the system either as spares or as a part of the engine data. The PLTS requires data from the mechanic responsible for changing parts (engine serial number, part serial number, location of part and date, for example) and periodic reading and recording of information taken from the units at other times.

88. PRISM - PRODUCTIVITY IMPROVEMENTS IN SIMULATION MODELING PROJECT

FUNCTION To provide a proof of concept for an integrated model development environment.

SPONSOR USAF Air Force Human Resources Laboratory

LIFE 1988

DESCRIPTION Event simulation models have been, and continue to be, major decision support aids in logistics capability assessment. Results of a survey conducted by the Air Force Human Resource Lab indicate a large amount of user dissatisfaction with various aspects of many of these decision support aids. The Prism project was created to address these problems by providing a proof of concept via a software environment.

89. Q-GERT SIMULATION LANGUAGE

FUNCTION Simulation language

SPONSOR USAF

LIFE 1983

DESCRIPTION Q-GERT is a simulation language that was used to develop a model that would determine B-1B automatic test equipment station quantities required to support the B-1B avionics components at base level. Two techniques were developed to determine test station quantities based on the model output. The first technique was to buy sufficient test stations to achieve a four day maximum base repair cycle time for the avionics components. The second technique was to conduct a cost-benefit analysis by comparing the costs of additional test stations (benefits of a shorter repair cycle times) to the benefits of fewer test stations (the costs of longer repair cycle times). The research effort provides a range of management options for consideration by the B-1B System Program Office.

90. RADstation

FUNCTION Speech recognition-based radiology reporting system.

DEVELOPER Lanier Voice Products

LIFE 1990

DESCRIPTION The RADstation is a radiology reporting system that is based on an IBM-compatible PC and Dragon Systems' speech recognition technology. The software package is menu driven and contains an on-line vocabulary of 30,000 words. This system enables the radiologist to read the X-ray and call out a particular finding. This will trigger the system to produce a complete and formatted report on that finding. The report can be written into one of the three available levels of detail. This report can be sent to physicians quickly via computer network interface or by fax using a fax/modem.

91. RF-ELATS -RADIO FREQUENCY EXPANDED LITTON AUTOMATED TEST SETS

FUNCTION Test various systems/equipment of F/A-18 aircraft

SPONSOR Royal Australian Air Force

DEVELOPER Litton Systems Canada

LIFE 1987

DESCRIPTION Radio Frequency Expanded Litton Automated Test Sets (RF-ELATS) performs comprehensive tests and fault diagnosis on radar, communications, microwave and Electronic Warfare (EW) equipment. The system utilizes a touch-sensitive screen, a keyboard a printer and a plotter.

92. RMMS - REMOTE MAINTENANCE MONITORING SYSTEMS

FUNCTION Monitor, control and verify remote equipment.

SPONSOR FAA

LIFE 1989

DESCRIPTION The RMMS monitors, controls, and verifies the performance of National Airspace System equipment and sites. The program to modernize this is designed to centralize and automate the systems' activity. Presently, the system is setup up in a master/slave relationship. By 1995, the setup should be changed so that the controller transparently accesses the remote facilities through the main Advanced Automation System (the host system for air traffic).

93. SAIFE-STRUCTURAL AREA INSPECTION FREQUENCY EVALUATION

FUNCTION To assist in the evaluation of proposed structural inspection programs for commercial jet transport aircraft.

DEVELOPER Technology, Incorporated, Dayton, Ohio

LIFE 1978

DESCRIPTION SAIFE is a computer program developed to assist management in the evaluation of alternative structural inspection and modification programs. Its logic simulates various structural defects, failures and inspections and their ramifications in five areas of control: (1) aircraft design analysis; (2) fatigue testing; (3) production, service, and corrosion defects; (4) probability of crack or corrosion detection; (5) aircraft modification economics. The goal of this program is to quantify the evaluation process currently used to establish and modify inspection intervals for commercial jet transport.

94. SAMT - SIMULATED A/C MAINTENANCE TRAINING

FUNCTION To increase effectiveness of maintenance procedure instruction.

SPONSOR USAF

DEVELOPER Honeywell Training and Controls Systems Operations

LIFE 1982

DESCRIPTION The F-16 engine diagnostic SAMT is comprised of simulated aircraft cockpit and test equipment control panels, an instructor station, and a computer simulation of the Pratt & Whitney F-100 engine. Computer simulation seeks to provide realistic engine performance for maintenance training. Use of this vehicle allows students to practice engine trimming procedures, and diagnosis of a variety of engine component failures.

95. SELF-REPAIRING FLIGHT CONTROL SYSTEMS

FUNCTION Flight control system

SPONSOR USAF - Aeronautical Systems Division

DEVELOPER Honeywell & McDonnel Douglas

LIFE 1985

DESCRIPTION This is a reconfigurable or Tself-repairing' flight control system that continually evaluates the aerodynamic conditions of aircraft, and reconfigures itself in the event that certain control surfaces are unavailable due to damage or malfunction. A reconfiguration module contained in the system is capable of choosing the correct combination of control surface deflections to execute certain maneuvers. The system will also provide instructions to the pilot to compensate for the alteration in control surface. This reconfiguration computer technology might be adapted to future civilian aircraft.

96. SEMSA WEAPON SYSTEM AND MAINTENANCE SIMULATOR

FUNCTION Weapon system and maintenance simulator

DEVELOPER Sogitec

LIFE 1988

DESCRIPTION The SEMSA weapon system and maintenance simulator is designed to train technicians in Mirage 2000 maintenance methods. The simulator is used to familiarize technicians with weapon system operation, fault-finding and diagnosis of malfunctions. SEMSA contains four elements: a cockpit cabinet with a display of the pilot's station; and aircraft cabinet with another display of the stores system and test equipment; an instructor's station; and a data processing suite.

97. SERVICE BAY DIAGNOSTIC SYSTEM I

FUNCTION Computer to guide automobile maintenance technicians through repair of Ford's electronic engine control unit (EEC-IV) and the many components with which that unit interacts.

SPONSOR Ford Motor Company, Ford Parts and Service Division

DEVELOPER Hewlett-Packard Co.

DESCRIPTION This diagnostic system incorporates a touch screen computer and printer, and a portable engine analyzer that may be operated during a road test. Functionally, it taps into the EEC-IV system through the data link, and talks to other modules in the system. It can activate other sensors and actuators. It can also communicate with Ford's OASIS (On-Line Automotive Service Information System) to receive technical information, updates and manual information and service bulletins. The computer will also display diagrams and drawings of parts and sensors, which may be otherwise difficult to locate or discern.

98. SERVICE BAY DIAGNOSTIC SYSTEM (SBDS) II

FUNCTION Auto diagnostics expert system using hypertext capability.

DEVELOPER Ford Motor Company

LIFE Operation by December 1989 in 2000 dealerships

DESCRIPTION Hypertext is a method of organizing related information via computer systems. Hypertext-based automobile diagnostics and repair workstation helps mechanics repair cars. The Service Bay Diagnostic System has an expert system in the diagnostic mode to analyze the meter readouts, symptoms data entered into the computer by the technician.

99. SPS-SHOP PLANNING SYSTEM

FUNCTION To reduce the amount of duplicated effort and improve accountability and control of shops parts tracking and shop planning systems.

DEVELOPER USAir

LIFE Since 1986.

DESCRIPTION This is a software tool, part of the larger Merlin package, to improve aviation maintenance management and staff function efficiency. This portion of the Merlin package governs shop planning, scheduling, and parts inventory control. A combined system such as this reduces paperwork without reducing efficiency.

100. STAR-PLAN

FUNCTION To help satellite control operators identify and resolve system faults in orbiting spacecraft.

DEVELOPER Ford Aerospace & Communications Corporation, Sunnyvale

LIFE 1986

DESCRIPTION Increasing complexity of spacecraft systems and the unavailability of technical advisors in some remote ground stations and mobile control facilities, has emphasized the need for automation of these satellites diagnostic and advisory functions. Satellite expert control systems must accommodate multiple disciplines and complex relationships between subsystems. The prototype system will be a ground based decision aid to replace or augment the work of the technical analyst who monitors incoming telemetry data stream from a satellite and compares that data with expected conditions (heuristic reasoning). Models for incorporating procedures for automating the knowledge acquisition process are also included.

101. STEMS -STRUCTURAL TRACKING AND ENGINE MONITORING SYSTEM

FUNCTION Monitoring system for aircraft structures.

SPONSOR USAF

DEVELOPER Northrop

LIFE 1983

DESCRIPTION STEMS is a system that determines inspection and repair schedules for individual aircraft, determines aircraft surface life expectancy, provides data for future specifications, and establishes operational limitations. It consists of an on-board processor, diagnostic display unit and a data collection unit.

102. THREE-DIMENSIONAL TRAINING SIMULATOR

FUNCTION Training Simulator

SPONSOR Commercial. Used by NASA and General Motors and others.

DEVELOPER Autodesk, Salsaulito, California VPL Research, Redwood City, California

LIFE 1989

DESCRIPTION The simulation is accomplished through tiny computer monitor goggles which users wear over each eye. The goggles deliver coordinated messages to the user's brain. The computer linked to the user through a sensor glove. Use of the glove creates and guides perceived movement, thus creating an artificial reality. This is called Cyberspace. It puts the user in a simulated, realistic 3-D world. This is being used and developed for use in training helicopter pilots and other types of applications by GE, NASA and the Army.

103. TEDS-TURBO ENGINE DIAGNOSTIC SYSTEMS

FUNCTION To electronically monitor various engine conditions and functions.

SPONSOR US Air Force, and others.

DESCRIPTION A generic term for systems using electronic means to determine engine conditions and satisfactory functions. The first system was called, Events History Recorder, developed for the Air Force F100 engine. Other systems using same and developing technology include that for the T-38 trainer J85 engine, the A-10 ground support aircraft's TF34 turbofan engine, and those installed in the KC-135, B1-B, and F-16 aircraft. Representative systems are known as Integrated Turbine Engine Monitoring System and Joint Advanced Fighter Engine diagnostic system.

104. TEMS-TURBINE ENGINE MONITORING SYSTEMS

FUNCTION Generic term for a variety of engine monitoring systems.

SPONSOR USAF

DESCRIPTION TEMS is representative of one of the earliest applications of technology to the maintenance process. This system focuses on engine monitor parameters seeking to predict when and what maintenance is required on the engine to achieve on-condition maintenance. TEMS is a generic name for a variety of early systems which use different means of collecting data. Some data is collected manually, others automatically. Recent systems collect data and in real-time transmit it to the ground station. All systems collect this data to spot anomalies, leading to increased aircraft availability, reduced overall engine maintenance costs.

105. TEXMAS -TURBINE ENGINE EXPERT MAINTENANCE ADVISOR SYSTEM

FUNCTION Used in conjunction with a system such as TEMS, TEXMAS uses human-like reasoning to achieve reduced maintenance costs and increase aircraft availability.

DEVELOPER Textron, Inc., Avco Lycoming Textron, Stratford, CT

LIFE 1988.

DESCRIPTION TEXMAS takes raw data and carries out functions such as engine performance measurement, event monitoring, and life monitoring, and fault isolation and diagnosis. It can also be used to walk an inexperienced mechanic through the diagnosis process. TEXMAS is based on expert system technology, implemented on a laptop computer.

Developed for the T53 engine. This is an engine with few sensed parameters (two rotor speeds, torque, exhaust gas temperature, oil pressure and oil temperature. With no other measurements available, the diagnosis process requires the knowledge of an expert.

106. TROUBLESHOOTER

FUNCTION Training tool to aid aviation mechanics in learning troubleshooting and diagnostic skills utilizing simulation oriented computer-based instruction methods.

DEVELOPER Flight Safety International

LIFE First introduced in 1986, successive developments in 1988 with anticipated additional developments.

DESCRIPTION Flight Safety International has developed a series of simulation oriented computer-based instruction aids for virtually all major subsystems of Cessna Citation 500, Dassault Falcon 50 and the Sikorsky S-76. First introduced in 1986, the diagnostic courses are being expanded to a wide range of business aircraft. This system uses actual pilot write-ups of service difficulty reports, manufacturers service write-ups, with cockpit indicators programmed into the software. Students review subsystems individually or in teams in order to develop and critique solutions. Review of the steps taken to diagnose the problem and the components replaced determine the effectiveness of the recommended procedures. Use of the system does not require previous computer experience.

107. VSLED- VIBRATION, STRUCTURAL LIFE AND ENGINE DIAGNOSTIC

FUNCTION Monitoring system for V-22 tiltrotor aircraft, this system is representative of the latest generation of performance aids, distinct by its integration into the aircraft itself. It extends the monitoring process to the aircraft structure.

DEVELOPER Bell Aerospace

LIFE 1989

DESCRIPTION Vibration, Structural Life and Engine Diagnostics (VSLED) is a monitoring system developed for the V-22 tiltrotor aircraft. This system seeks reduce maintenance costs by 50% By monitoring the structure of the aircraft and analyzing trends and parameters as do engine monitoring systems, VSLED integrates several systems, and uses automatic detection of exceeded limits. This data is analyzed and fault isolation analysis is performed. It monitors the aircraft's vibration, temperatures, structural life, and engine events, and can generate reports that specify needed maintenance actions.

108. XMAN-EXPERT MAINTENANCE TOOL

FUNCTION An expert maintenance system designed to be a user interface to the maintenance data base created by systems such as TEMS.

SPONSOR US Air Force

DEVELOPER System Control Technology Corporation

DESCRIPTION XMAN was developed for use on the USAF A-10A. It uses expert systems technology and builds upon other related technologies (such as TEMS) to automate diagnostic and troubleshooting procedures. Since this tool can communicate to the user the sequence of conclusions in the diagnostic procedure, it may be used for training.