PROFICIENCY TRAINING SYSTEMS FOR AIRWAY FACILITIES TECHNICIANS

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1.0 ABSTRACT

Airway Facilities maintenance technicians are being challenged to maintain proficiency on old equipment while learning new equipment. The new equipment is both more complex and more reliable. Greater reliability leads to infrequent opportunities to troubleshoot. Infrequent practice means degradation of the knowledge needed to troubleshoot complex equipment. An intelligent simulator can help technicians to maintain proficiency by providing practice with the help of an expert advisor. This paper describes a "proof-of-concept" prototype advanced technology system for proficiency training of Air Traffic Control Beacon Interrogator (ATCBI-4) troubleshooting.

2.0 INTRODUCTION

Technicians receive initial training through resident courses which involve a combination of instructional methods (e.g., lecture, lab). After completing initial training for a particular piece of equipment, technicians ideally have the opportunity to practice and apply the newly acquired skills and knowledge on the job. However, sometimes technicians receive initial training several months (or years) before they are assigned responsibility for that specific piece of equipment. In such cases, by the time a technician is asked to apply classroom knowledge, much has been forgotten. Even when training is offered at the ideal time, technicians are responsible for several pieces of equipment; therefore, they are constantly being challenged to maintain proficiency on older systems while learning new systems.

Technicians spend most of their time performing preventative maintenance (PM) checks. Hence, they get frequent practice of these skills. Maintaining proficiency of troubleshooting skills, however, is more difficult. Problems do not occur on the real equipment with any regularity and practicing on the real equipment (by inserting problems) is not feasible. An advanced technology training system may help technicians maintain proficiency of troubleshooting skills by providing safe, on-site, individualized, training.

3.0 DISCUSSION OF ADVANCED TECHNOLOGY

In its broadest sense, advanced technology refers to all recent innovations in hardware and software technology. Only a small subset of such technology is applicable to technical troubleshooting training. In particular, this research focussed on advanced technology extensions of traditional computer-based instruction. Figure 1 shows the generic model for traditional computer based instruction (CBI). As the figure illustrates, a student interacts with an instructional environment on a computer through some type of interface (e.g., a monitor and keyboard).

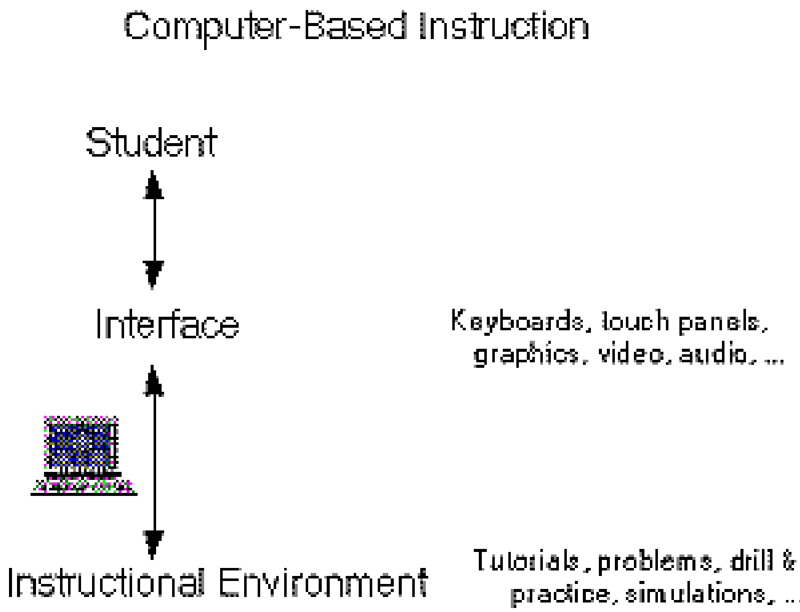

Figure 1 Generic CBI Architecture

In early CBI systems, the information presented by the computer was limited to monochrome text and simple line graphics. Today, there is a large amount of new (affordable) hardware and software technology that permits the capture, creation, display, storage and retrieval of high resolution color graphics, animations, text, and video. Such technology allows technicians to interact with high fidelity images of equipment and permits the storage of extensive amounts of information.

Advances in interface technology have lead to the use of graphical user interfaces (GUI) that allow direct manipulation of the objects on the screen. Such direct manipulation devices, in conjunction with an interactive simulation, permit technicians to "learn by doing." Instructional systems may also take advantage of hypertext (Horn, 1989) and hypermedia (Nielson, 1990) software that has been developed. In a hypertext or hypermedia system, users are not restricted to a single pre-specified learning sequence, but rather may use built-in links to rapidly browse the instructional content and to choose an individualized learning path through the content.

Advances in software technology have also addressed the issues related to making computer-based training more "intelligent". The work of cognitive scientists and artificial intelligence researchers over the past decades have focussed on such software technology, including simulations, expert systems, and Intelligent Tutoring Systems. Simulations model the functionality and behavior of equipment or systems and can be used as part of the instructional environment of a training system. Computer-based simulations have been shown to be effective for diagnostic training (Johnson, 1981, 1987; Maddox, Johnson, & Frey, 1986) Expert systems model the problem solving knowledge of a human expert in some specific area (Hayes-Roth, 1987). Intelligent Tutoring Systems (Polson & Richardson, 1988; Psotka, Massey, & Mutter, 1988) extend the basic CBI structure by adding three models: an expert model, a student model, and an instructor model.

Figure 2 illustrates the conceptual relationship between the generic components of an ITS. The expert model contains the domain specific knowledge that the student is to learn. The student model is a dynamic hypothesis of what the training system thinks that the student currently knows. This model is based on the observable actions that the student performs in the instructional environment. The instructor model typically compares the model of the student to the model of the expert in order to provide feedback to the student. The instructor model may also monitor the student model to decide when remediation is needed and to select future lessons or problems.

4.0 STATUS OF ADVANCED TECHNOLOGY IN AF MAINTENANCE TRAINING

An investigation was conducted to determine if advanced software technology is being applied to Airway Facilities (AF) maintenance training. The investigation was conducted via informal interviews and site visits at the FAA Academy AF Training Development Unit and a regional CBI training center. The investigation found that currently available Airway Facilities training does not take advantage of advanced software technology such as simulation, expert systems or Intelligent Tutoring Systems. Rather, the majority of the current computer-delivered training is based on the more limited computer-based instruction (CBI) architecture.

The investigation also found that the currently available AF CBI runs on outdated hardware (i.e., monochrome terminals connected to a remote mainframe via 1200 baud modem). However, a new delivery platform has recently been adopted called OATS (Office Automation Technical Support). The OATS platform will permit stand-alone CBI. That is, the courses will be delivered from the local OATS computer without being tied to a remote system through a network. The course material will be stored on CD-ROM and updated CDs will be distributed as needed. For security reasons, however, testing will still be handled over a network.

The AF Training Development Unit has already received positive feedback on the stand-alone course concept. In addition, the AF Developers are planning to augment the basic OATS system with special hardware and software to support multi-media learning including audio, video disk, graphics, and animation capabilities.

Transitioning to the new platform requires translation of existing courses so that they run on the new machines. The AF Training Development Unit has reviewed all existing CBI courses for instructional acceptability. Those found to be unacceptable are being discontinued, while the courses which have acceptable content are being upgraded during the conversion to the stand-alone format. The upgrading involves the use of the multi-media capabilities of the OATS platform as well as a break from the simple "page-turner" format. The AF Training Development Unit at the FAA Academy also indicated their plans to make use of expert systems technology for individualized instruction, refresher/proficiency training, and resident courses where appropriate. Given this interest in applying advanced technology to AF training, the research team proceeded with the development of a "proof-of-concept" prototype advanced technology training system.

5.0 PROTOTYPE ADVANCED TECHNOLOGY TRAINING SYSTEM

A prototype advanced technology training system was developed over a six month period. The development process involved iterations between knowledge acquisition, design, implementation and evaluation. Two important steps were taken prior to actual development: a) selection of the instructional domain and b) selection of the delivery and development hardware and software. This section briefly discusses each of these steps and then describes the prototype system as well as a preliminary evaluation of the prototype.

5.1 SELECTION OF THE INSTRUCTIONAL DOMAIN

The first step in developing a prototype advanced technology training system was to identify a piece of AF equipment that is appropriate for this type of training and for which additional training is needed. FAA personnel identified the following as candidates for the training system: the Paradyne modem, ATCBI-4, ATCBI-5, and Common Digitizer.

To determine the final selection, discussions were held during site visits to the General National Airspace Sector (GNAS) office in Atlanta, GA and the Air Route Traffic Control Center (ARTCC) in Hampton, GA. Based on these discussions, the Air Traffic Control Beacon Interrogator - Model 4 (ATCBI- 4) was selected as the best choice for prototype development. The Paradyne Modem was rejected due to the lack of available troubleshooting expertise. The Common Digitizer was rejected because the need for training was not as great as for the ATCBI- 4. The ATCBI-5 was rejected because the research team was located in close proximity to an ATCBI-4 system and expert technicians.

5.2 DELIVERY AND DEVELOPMENT HARDWARE AND SOFTWARE

In order for the prototype training system to be of value to the technicians in the field, it had to be developed for a hardware delivery system that would be available to the technicians. Given that the FAA had selected OATS machines as the new standard, the prototype advanced technology training system was targeted for delivery on an OATS machine in the Microsoft Windows environment. The prototype requires the following minimal configuration: 386/25MHz machine, Microsoft Windows 3.0, 4MB of memory, VGA monitor, a run-time version of Asymetrix Toolbook, and a mouse input device.

The initial prototype development, however, began in the DOS environment in order to make use of rapid prototyping tools: Microcomputer Intelligence for Technical Training (MITT) and MITT Writer. Both MITT and MITT Writer run in the DOS environment and use EGA graphics. Figure 3 illustrates the relationship between these two tools. MITT Writer (Wiederholt, 1991, 1991, November) is a development environment for producing a description of training without the need to write computer code. MITT (Johnson, Norton, Duncan, & Hunt, 1988; Norton, Wiederholt, & Johnson, 1991) uses the training description files to deliver simulation-oriented troubleshooting training.

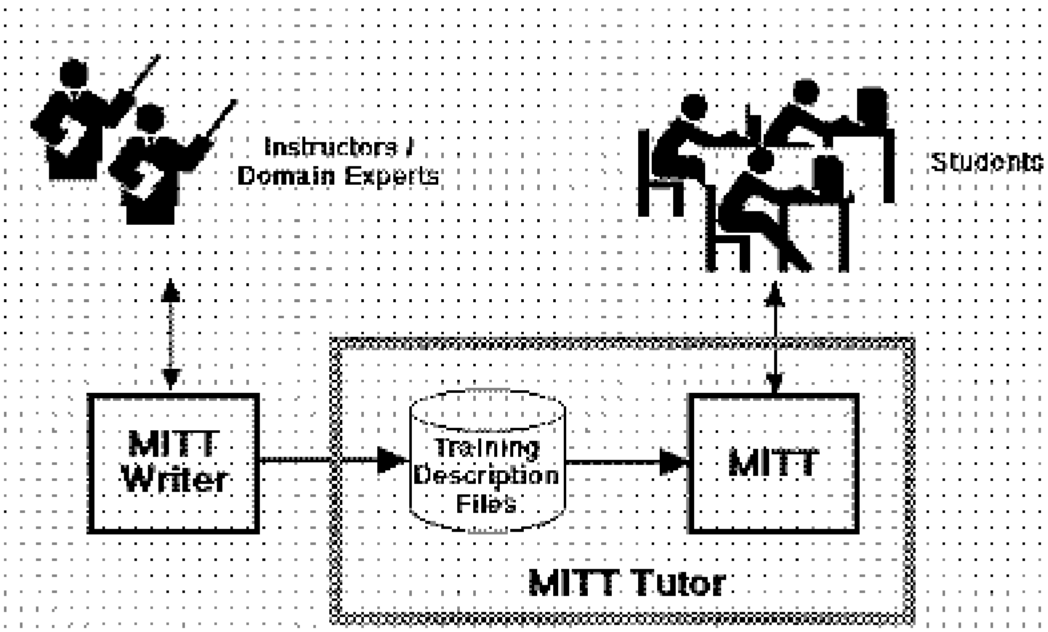

Figure 3 Relationship Between MITT and MITT Writer

In addition to its rapid prototyping capability, the MITT system is an Intelligent Tutoring System which provides two types of advice: procedural and functional. MITT's functional advice is based on the simulation model which represents the connections between parts. MITT's procedural advice is based on documented troubleshooting procedures and the experience of expert technicians.

Although MITT Writer was designed to aid an instructor or domain expert in developing a MITT tutor, this tool was used by a member of the research team to quickly produce and modify an initial prototype system. The MITT program was then used to run the training system to obtain input and feedback from technicians. Technicians who reviewed the initial prototype system reacted favorably to the MITT approach to troubleshooting training. Thus, the research team decided to capitalize on the MITT technology to develop a similar ITS system that would run in the Windows environment. The final prototype system was developed using Asymetrix Toolbook and Borland C++.

5.3 DESCRIPTION OF THE PROTOTYPE

The prototype investigates the use of advanced technology in proficiency training for AF maintenance technicians in the area of troubleshooting. As discussed above, the instructional domain for the prototype is the ATCBI-4. The ATCBI-4 is a complex electronics system which provides controllers with identification and altitude information about aircraft in the surrounding airspace.

The prototype training system is divided into four major sections: Introduction to Training, Understand the Simulation, Understand the System, and Practice Problems. Figure 4 shows the main screen of the training system. The four buttons at the bottom of the screen allow the user to access any of the four sections. The Practice Problems section is the primary focus of the proficiency training system, while the first three sections provide background and support information. A description of the Practice Problems section follows.

The Practice Problems section allows the technician to practice the mental skills of troubleshooting with the help of an expert advisor. When the technician starts a practice problem, a scenario is given which states the initial conditions of a problem. Figure 5 shows an example of a problem scenario. The technician is then free to begin troubleshooting. The technician's goal is to identify the malfunctioning component as quickly as possible without making unnecessary or illogical tests.

Figure 5 Example Scenario

In general, the technician can go to the simulation displays or functional flow diagrams (Figure 6) and begin choosing tests to perform. There are two levels of information that can be accessed. Tests performed on the functional flow diagrams (or through the use of the Tests menu) always state the summarized test result, i.e., whether the part or output is normal or abnormal. By reducing the complexity of the information, the technician can focus on learning more generalized troubleshooting skills.

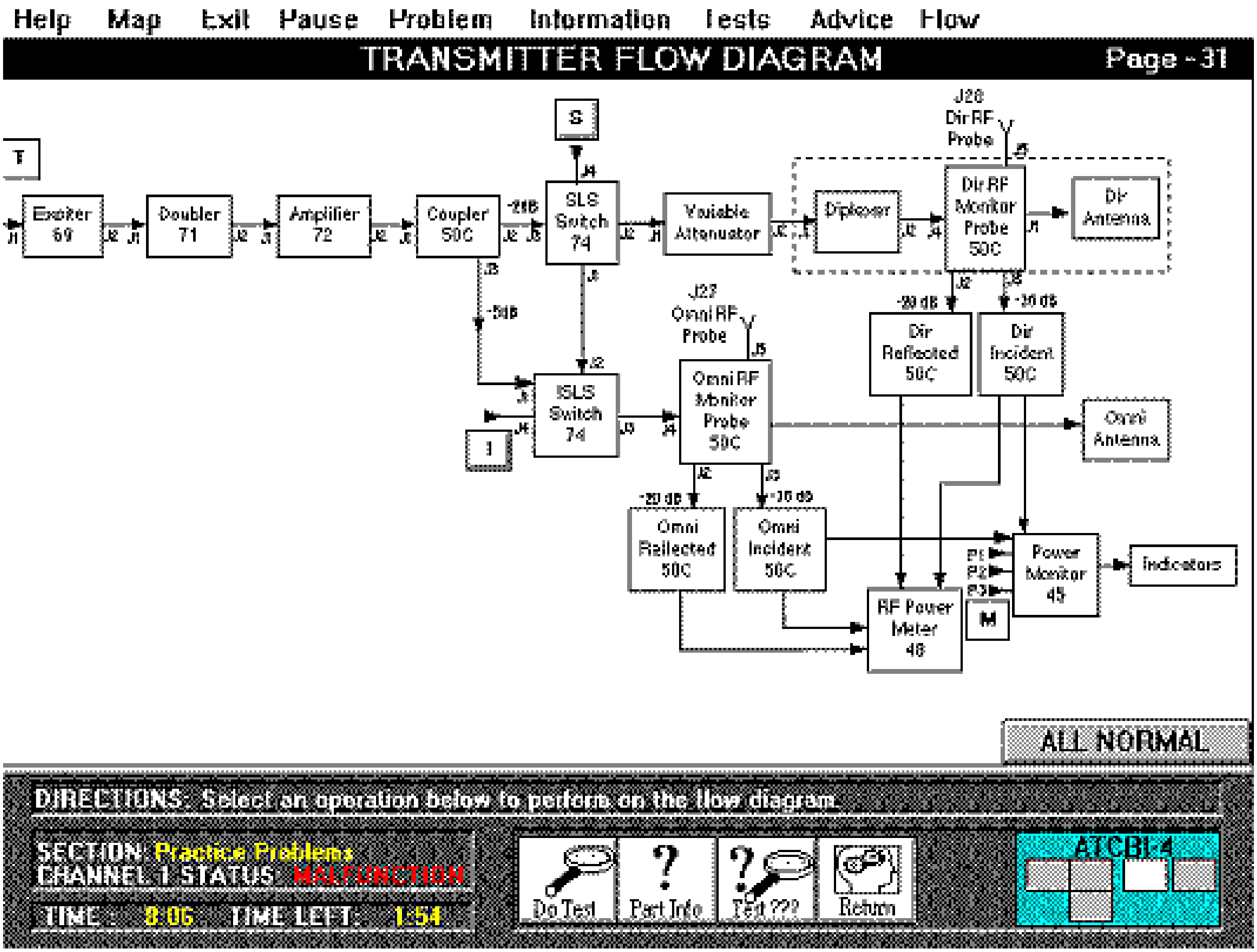

Figure 6 Example Flow Diagram

Technicians who want a higher fidelity simulation may use the simulation displays which provide a more realistic decision environment. On the simulation displays, the test results are given as actual data values which must be interpreted as being normal or abnormal. For example, the oscilloscope simulation display is shown in Figure 7. The technician selects a test point and the waveform is displayed. The technician must then decide if this is normal output for the selected test point. If needed, the technician may request an explanation of the waveform which describes the waveform and states whether it is normal or abnormal.

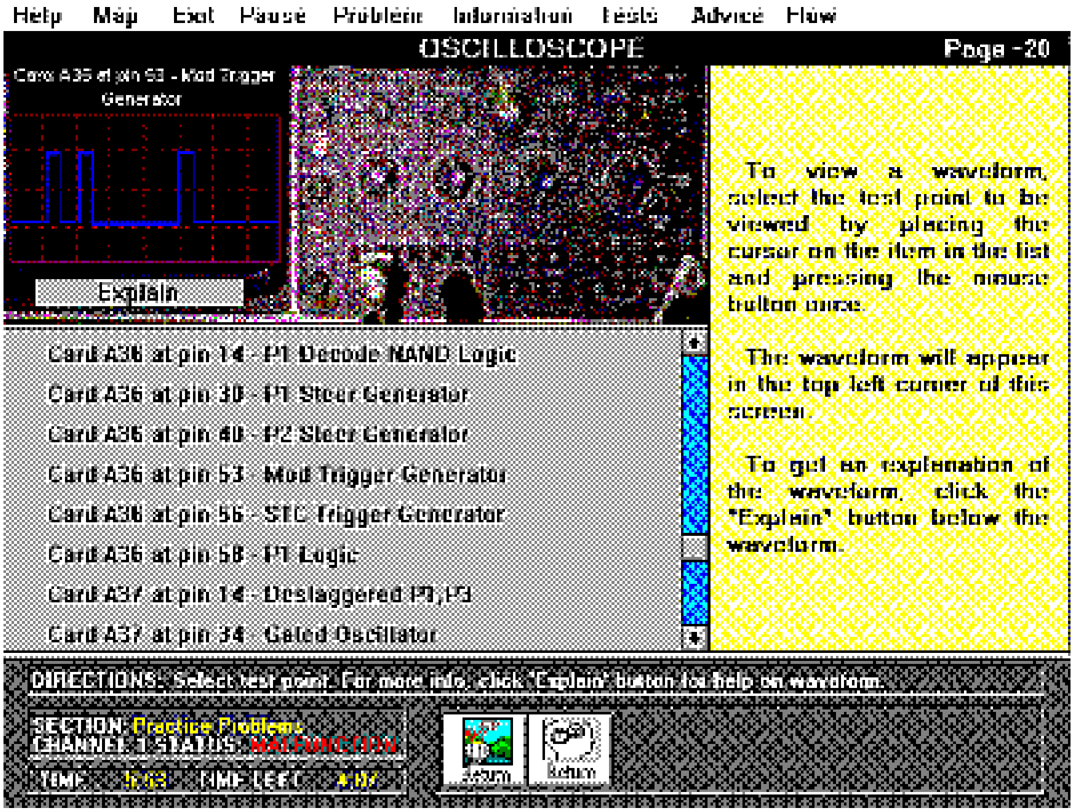

Figure 7 Example Oscilloscope Test

If the technician does not know what test to perform, he can request either functional or procedural advice. The functional advisor will suggest that the technician perform a test on the part that has the potential for eliminating the most parts from consideration as the malfunctioning part. Functional advice is based on the functional flow connections between parts contained in the simulation of the equipment and logical troubleshooting principles. For example, if a part has bad output, then any part "downstream" of that part cannot be causing the malfunction and can be eliminated from the set of feasible parts. Similarly, if a part has normal output, then any part "upstream" from that part cannot be the malfunctioning part and therefore can be eliminated from the set of feasible parts.

The procedural advisor, on the other hand, will suggest a test based on the experience of an expert technician. A recently retired AF technician was consulted to develop the procedural advice for each practice problem. The expert suggested realistic tests for quickly isolating the malfunctioning part. However, it must be emphasized that there is no single "correct" procedure in terms of which part to test in what order. Therefore, the technician is not forced to follow the exact steps suggested by the expert.

There are times when the technician is penalized, however. The system tracks the students actions and provides unsolicited instructional advice when the technician does one of the following: a) tests a part which is "upstream" from a part that was tested and shown to be normal, b) tests a part which is "downstream" from a part that was tested and shown to be abnormal, and c) identifies a normal part as the malfunctioning part. These three actions count as troubleshooting errors that are tallied and reported at the end of a practice problem session.

5.4 DISCUSSION OF THE PRELIMINARY EVALUATION

An informal preliminary evaluation was conducted with the prototype software. Three technicians were observed while interacting with the prototype training system during approximately one hour sessions. None of the technicians had used the prototype prior to this session.

Each session began with the first screen of the training system already displayed. The developers informed the technician that the purpose of the session was to interact with the training system to determine what they like and dislike about the system. Each technician was also informed that there would be an evaluation sheet provided at the end of the session to solicit such feedback.

In general, the three technicians were able to use the system with little input from the observers. No major errors were encountered, however, minor changes to the interface were made in response to user comments. The technicians all gave positive verbal comments about the system and each was able to successfully complete a practice troubleshooting problem. Two of the three technicians indicated that they would use this system for proficiency training. (The technician who indicated that he would not use this system is a supervisor and is no longer responsible for troubleshooting the ATCBI-4 equipment.)

6.0 FUTURE PLANS

In the next phase of this research, the prototype system will be extended into a complete proficiency training system for troubleshooting the ATCBI-4. There are four major tasks involved in this effort. First, input will be obtained from the AF Development Unit and AF technicians to guide development of the complete training system. Based on this input, changes will be made to the instructional environment, student model, instructor model, and the expert model. Third, knowledge engineering work will continue in order to extend the set of simulated practice problems. Finally, the knowledge base of domain specific data will be restructured to improve the access time and facilitate the development of similar systems.

Upon completion and review of the final ATCBI-4 training system, work will begin on an authoring system for the development of additional AF Maintenance ITSs. The research team will work with personnel at the FAA Academy to develop a functional specification that meets the needs and desires of training development personnel. A demonstration development system will be developed to provide a concrete basis for the discussion.

In addition, work will begin on the development of a plan and preliminary specification for an advanced technology AF Information System. The AF Information System will integrate three components into one system: training, job-aiding, and information storage and retrieval. The completed training system will serve as the initial basis for the training component of the AF Information System. The research plan will detail how the knowledge base of the training system will be extended to support real-time job aiding. In addition, the plan will describe the development tasks for including additional documentation in the system.

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