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Using Intelligent Simulation to Enhance Human Performance in Aircraft Maintenance [1]

William B. Johnson
Jeffrey E. Norton
Galaxy Scientific Corporation
2310 Parklake Drive, Suite 200
Atlanta, GA 30345

ABSTRACT

Human Factors research and development investigates the capabilities and limitations of the human within a system. Of the many variables affecting human performance in the aviation maintenance system, training is among the most important. The advent of advanced technology hardware and software has created intelligent training simulations. This paper describes one advanced technology training system under development for the Federal Aviation Administration.

1.0 INTRODUCTION/BACKGROUND

A myriad of human factors challenges associated with aircraft maintenance exist. Maintenance and inspection are essential to ensure continuing airworthiness on the aging fleet. New advanced technology procedures for aircraft further complicate the aviation maintenance system. The human is a critical component of the maintenance system. Therefore, research and development must address a variety of issues affecting the human in maintenance. Figure 1 depicts a few of the factors that can affect human performance in the maintenance system.

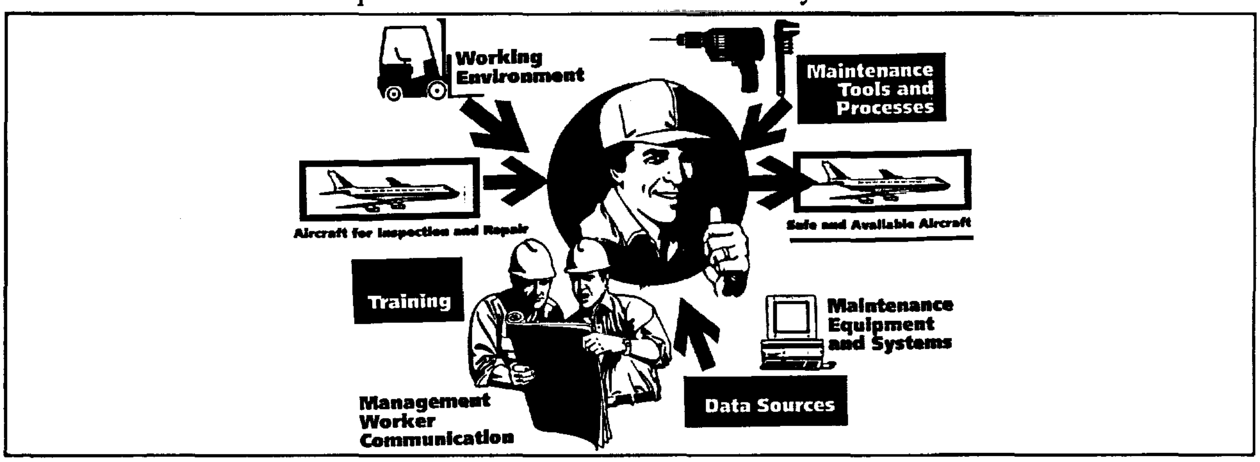

Figure 1. The Human in the Maintenance System

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The "work environment" includes not only physical characteristics such as noise, temperature, and illumination levels, but also less tangible measures associated with management-labor communications, corporate goal setting and attainment, and individual decision making by maintenance personnel. "Data sources" include the variety of technical information that a technician must access to perform and record maintenance actions. "Training" includes the many activities that prepare the human to perform a given maintenance task. Training must also help the human maintain an appropriate level of technical proficiency for safe, efficient, and effective job performance.

Human factors research and development is recognized as a critical component of aviation safety. *The Aviation Safety Act of 1988* (PL100-591) (ref.1) mandates that research attention be devoted to a variety of human performance issues including aircraft maintenance and inspection. Similarly, *The Aviation Security Improvement Act of 1990* (PL101-604) (ref. 2) states that the FAA "shall review issues relating to human performance in the aviation security system with the goal of maximizing such performance." *The National Plan for Aviation Human Factors* (ref. 3) is but another official recognition that the human is a most critical factor in aviation safety.

The Biomedical and Behavioral Sciences Division of the FAA Office of Aviation Medicine is engaged in a research program entitled "Human Factors in Aviation Maintenance." The program is conducting research in the areas listed in Table 1.

- Advanced Technology Training Systems
- Advanced Technology Information Systems
- Analysis of Human Error in Maintenance and Inspection
- Communications in Maintenance Environments
- Development of Human Factors Guide for Maintenance
- Human Factors Work Site Evaluations

Table 1. Human Factors in Aviation Maintenance Research Topics

The comprehensive research program is described elsewhere (ref. 4). This paper will describe only the research and development task associated with advanced technology training systems.

2.0 TRAINING TECHNOLOGY

Demographic data (ref. 5) indicates that there will be a distinct shortage of qualified aviation maintenance technicians (AMTs) by the year 2000. The obvious solution is to create methods that permit less qualified personnel to conduct maintenance and inspection by using advanced technology job aiding equipment (i.e., make the tools smarter and the job easier). A second way would be to devise new methods that will train, efficiently and effectively, more personnel as AMTs (i.e., make the human smarter). Of course, a hybrid of these two approaches would be to create job aids that also train (i.e., smarter tools and smarter people).

The suggested hybrid approach requires research and development on the use of artificial intelligence technology for both training and job aiding systems. The research must address issues associated with interface design and software optimization for portable computer systems. The advanced technology training system is called an "intelligent simulation". It is "intelligent" because it contains software components that provide extensive modeling and feedback that approach what might be provided by a human simulation instructor.

The advanced technology training project reports the current status of maintenance training, develops a prototype training system, and evaluates the system in maintenance training environments (ref. 6). The training is described in the following sections.

3.0 Environmental Control System (ECS) Trainer

The ECS Trainer (Figure 2) permits the student to interact with a simulation of the Boeing 767-300 air conditioning portion of the ECS. The system is designed to train for troubleshooting - the most complex of maintenance tasks. The student can operate the system under normal or malfunction conditions.

To troubleshoot the malfunction, the student looks at displays, manipulates controls and switches, and tests, inspects and replaces components. While troubleshooting, the student has access to operational information for the equipment. The student may also ask for advice on how to solve the problem most effectively.

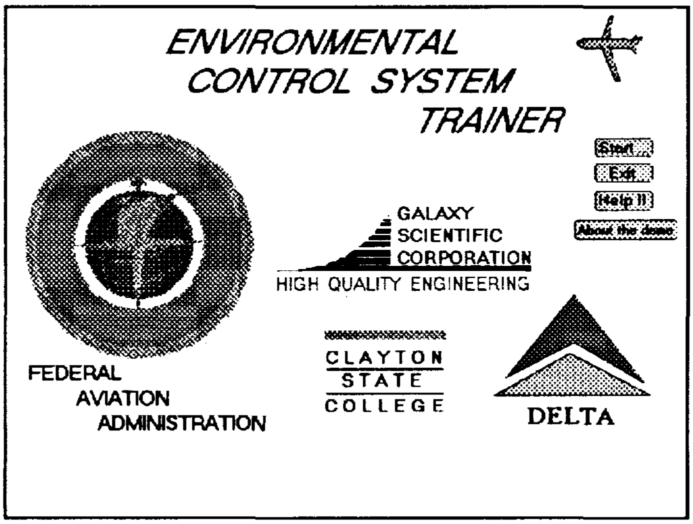

Figure 2. Environmental Control System Trainer

The following sections of the paper will familiarize the reader with the ECS Trainer from several different viewpoints. First, the interface design is discussed. Then, the general instructional design is addressed. Finally, the implications and possible future directions of the system are discussed.

3.1 Interface Design

Figure 3 shows the primary (Overview) display used by the student. The system was designed so that the majority of relevant troubleshooting information is only one display away from the primary display. This design prevents the student from getting "lost" while in the Trainer.

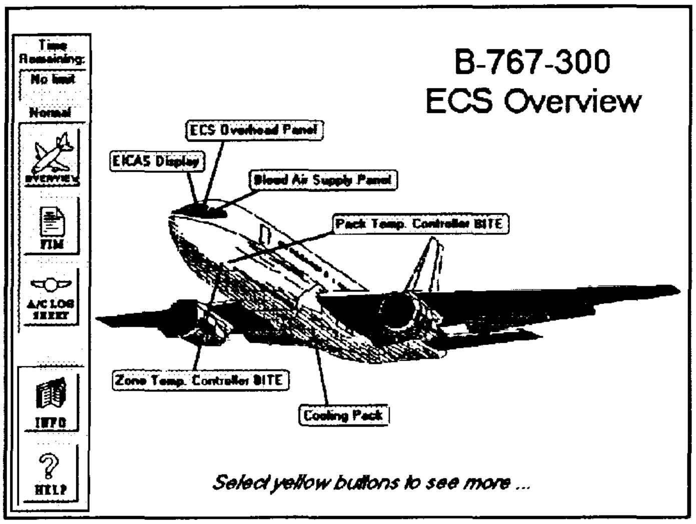

Figure 3. Primary ECS Display

From the Primary ECS display the student may access the displays, controls, and components that are required to troubleshoot a malfunction. For example, if the student selects the overhead panel there are two modes of operation. The first mode, shown in Figure 4, will provide basic instruction on how the equipment operates. The second mode, shown in Figure 5, provides a simulation of the system which the student can use for real-time operational practice. An expert system, embedded in the simulation, advises the student on system operation as needed or requested.

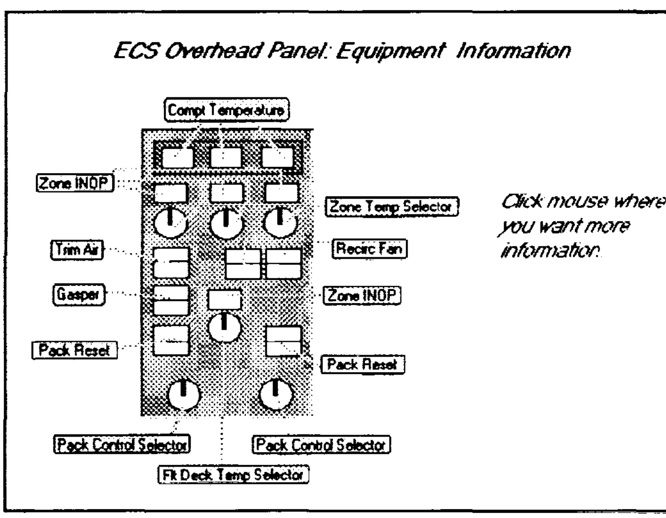

Figure 4. Equipment Information

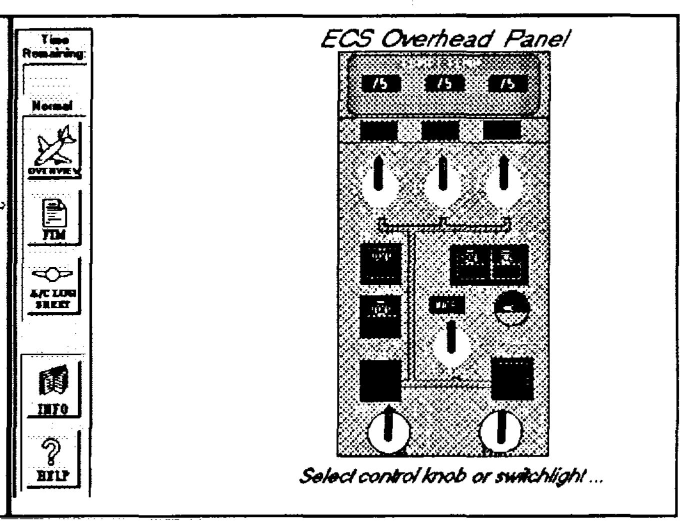

Figure 5. Equipment Operation

From the Primary ECS display the student can access the Fault Isolation Manual (FIM). The FIM, shown in Figure 6, is taken directly from the airline's training documentation. In the training system the FIM becomes a dynamic troubleshooting display that provides advice and feedback.

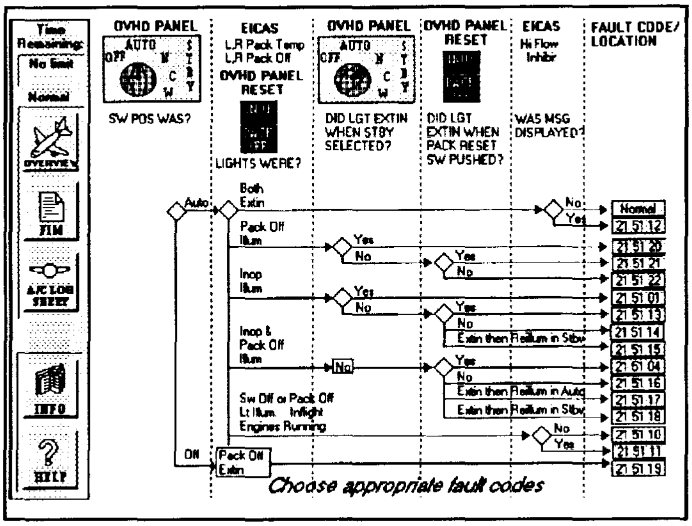

Figure 6. Page from Fault Isolation Manual

The student can also select "Help" from the Primary ECS display. The "Help" button provides three kinds of assistance. Help on the "current screen" describes how to use the features that are specific to the current display. The "advice" option provides hints to the student on how to troubleshoot a malfunction. The advice is based on the information contained in the FIM. The "how to use the system" option describes how to use the features that are common to all displays.

3.2 Instructional Design

The ECS intelligent simulation is designed with the instructional philosophy that "adult learners learn best by doing". The instructional design, therefore, permits the learner to operate the equipment in any way. The student can ask for help and advice at any time and is provided advice when it is badly needed. The intelligent simulation does not force the learner to follow any specific order. Essentially, the system adapts to the needs and learning characteristics of the student. This type of training system is not like a book, which must be accessed in a linear fashion, page after page. Instead, it is like having an airplane and an instructor for each student.

The general design used to develop the ECS Trainer is shown in Figure 7. The system is designed to include an instructional environment, a student model, an expert model, and an instructor model. This general architecture is called an Intelligent Tutoring System (ITS). The ITS monitors student performance (through the student model) and compares these actions to the subject matter expert actions (the expert model). Based on the difference between the student and expert actions, the ITS provides remediation and instruction accordingly (the instructor model). When the ITS technology is combined with the simulation-based instructional environment the power of the instruction is very high. It is similar to providing each learner with a full-time simulator instructor.

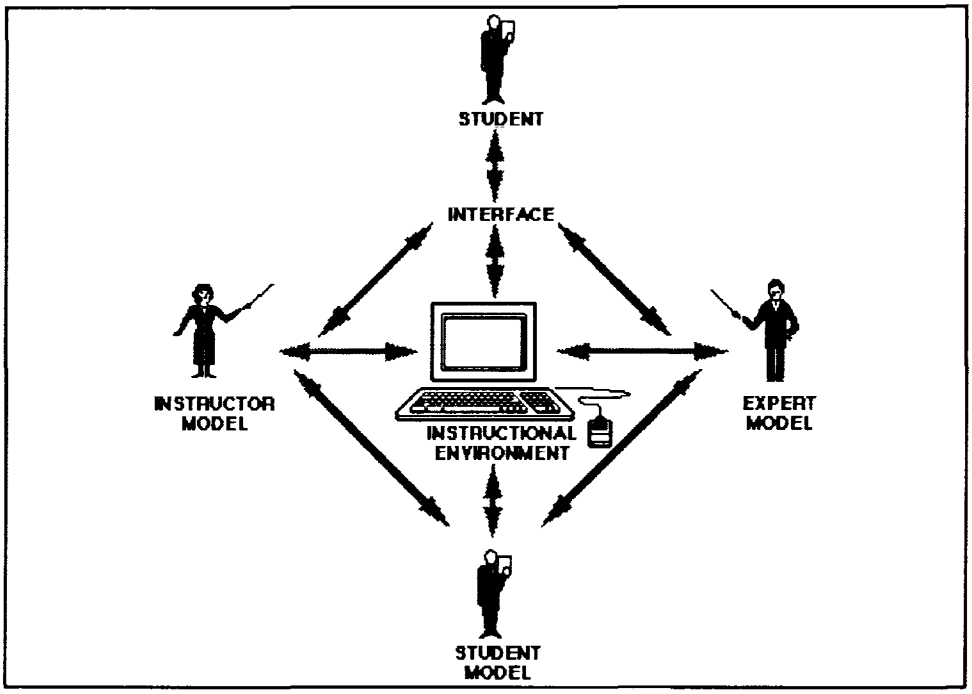

Figure 7. Intelligent Tutoring System

The remainder of this section will explain each of the components of an ITS and how each is implemented for the ECS Trainer.

3.2.1 Instructional Environment

The instructional environment in which the student operates is an interactive simulation of the ECS. The model of the ECS is based on changes in inputs to the system. For example, as the demand on the cooling pack changes, the change is propagated from component to component and reflected on the equipment displays. This simulation gives the student the look and feel of the real maintenance environment.

The student is allowed to manipulate the displays, test equipment, and control panels in any order. When parts are replaced, the simulation will change accordingly. As in the "real world", the student must observe current indications to determine whether the malfunction has been eliminated.

3.2.2 Student Model

The student model tracks student performance (ref. 7) within the instructional environment. The student model logs information about what the student has seen and what actions the student has taken for each malfunction. Also, the student model records the amount of time and/or dollars expended to correct a malfunction and the number of errors made.

Some of the types of information stored in the student model are the types of tests performed, which parts were inspected, which parts were replaced and which errors were made. This information is then passed along to the expert and instructor models.

3.2.3 Expert Model

As the student troubleshoots a malfunction, the student's actions are compared against those of an ECS expert. This expertise is contained in the expert model. The ECS expert model knows the procedural and/or logical steps that are required to troubleshoot the system. This knowledge is represented in the form of component connectivity diagrams, fault trees, and operational procedures.

3.2.4 Instructor Model

When the student's actions are compared against the expert's actions, the instructor model gauges the difference between these two set of actions and decides how to act upon the difference. For example, the student may respond to a Warning light on the ECS Overhead Panel incorrectly. The instructor model must decide whether to let the student make this error and continue, or let the student know of the error immediately. The way that the instructor model responds is usually dependent on the severity and consequences of the inappropriate action.

The instructor model also is responsible for problem selection. The instructor model will analyze the historical information about the problems already completed by the student. The instructor model looks for deficiencies on previous malfunctions to determine which malfunction to present to the student next.

4.0 Future Considerations of Advanced Technology for Aviation Maintenance

4.1 AMT Schoolhouse Training and Testing

Advanced technology is becoming more widely available for aviation maintenance training. Planned changes to Federal Aviation Regulation (FAR) Part 147, Aviation Maintenance Technician Schools, will permit the use of educational technology in the classroom and laboratory. It is reasonable to expect that computer simulations may supplant requirements to operate certain turbine engines. Such a substitution is critical for schools located in the heart of a city. The use of computer simulations will also be critical in controlling equipment costs for all FAR Part 147 schools.

Technical instructors always customize their materials to meet the needs of their students. Advanced Technology training must be capable of such modification if it is to gain wide acceptance. Most AMT instructors are not computer programmers or computer-based training developers. Therefore tools, usually called authoring systems, must be designed so that AMT instructors can make changes to the advanced technology software. A U.S. Air Force research program called Microcomputer Intelligence for Technical Training (ref. 7) has shown that such authoring systems are possible.

As AMT certification procedures (FAR Part 65) evolve with the new training technology, it is likely that some practical testing may also use computer simulation. Many portions of the General, Airframe, and Powerplant practical exam present the examinee with system troubleshooting problems. Computer simulation is an ideal method to evaluate an individual's system understanding through troubleshooting.

4.2 Training and Job Aiding

This paper has focused on the application of advanced technology to maintenance training. The same technologies can be applied to intelligent job aids. The development of the expert system knowledgebase, for training or for aiding, is labor intensive; therefore, it is very expensive. By designing systems that can be used in training environments and on the job, the cost can be easier to justify. When students became familiar with the system for training, they are more likely to use the system when in the job environment.

4.3 More Technology - Not the Only Answer

This paper has discussed advanced technology from the standpoint of what it can do to enhance human performance in maintenance and inspection. The focus has been on function more than on form. Hardware systems such as digital video interactive, CD-ROM storage, notebook color computers, voice input/output devices, and other such devices have not been discussed. Hardware technology is very important. However, attention to software design and interface design, combined with a knowledge of the capabilities of the human maintainer, are the key ingredients to effective advanced technology applications. Human factors research and development will ensure important attention to the human as advanced technology is introduced to the maintenance system.

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