DESKTOP SIMULATION FOR AVIONICS MAINTENANCE TRAINING

Scott D. Royse
Kevin J. Miller
Charles J. Zinsmeyer
Southwest Research Institute
San Antonio, Texas

ABSTRACT

The F-16 C/D Avionics Intermediate Shop Maintenance Procedures Trainer (AIS-MPT) represents a significant advance in the application of desktop simulation techniques to a training task that has previously been addressed only through interactive computer-based training (CBT). In order to meet requirements for a high-fidelity simulation of the AIS computer system using captured operational data, the simulator was designed using a digital multimedia representation of the four automatic test equipment (ATE) station types that is controlled by a simulation execution environment written in Ada. The result is a unique combination of real-time simulation programs and multimedia-based "simware" running on a networked, dual-CPU student station, and providing a true training simulator for the AIS and for F-16 line replaceable units (LRU).

The AIS-MPT provides the training environment for the development of new skills in the operation, familiarization, operational check-out, fault isolation and repair of AIS ATE and LRUs for the F-16 aircraft. The system provides a high-fidelity simulation of the AIS computer system, including a very detailed simulation of the software diagnostic tools used to debug complex AIS and LRU malfunctions, and a low-fidelity simulation, using digital multimedia images, of the four ATE station types of the AIS. The simulator uses actual AIS test data, obtained by using a data capture utility, to drive a simulation of the test equipment for 63 different malfunctions of both AIS equipment and aircraft LRUs. In addition, a courseware development utility provides the capability to create and modify the simulation presented at the computer bay and the multimedia simulation without having to modify trainer software.

This paper will provide an overview of the AIS-MPT software design, a description of the orchestration of the real-time simulation software and the multimedia presentation of test equipment, and an example of the unique development of "simware" materials that define student exercises.

ABOUT THE AUTHORS

Scott D. Royse is manager of the Training Systems Development Section at Southwest Research Institute. He has over 12 years of experience in systems engineering projects for automotive and missile electronics, and has developed simulator training systems for military and industrial clients. He has managed many training device development efforts including the Combined Arms Staff Trainer for the U.S. Marine Corps. He has a BSEE from Texas A&M University.

Kevin J. Miller is a senior staff member of the Training Systems Development Section at Southwest Research Institute. He has over 14 years of experience in the development of real-time software for automatic test equipment and simulator equipment for military clients. He has a BS degree in Computer Science from the University of Texas at San Antonio.

Charles J. Zinsmeyer is a Senior Research Analyst in the Instructional Systems Section at Southwest Research Institute. He has over seven years of experience in developing training systems and simulators for military and industrial clients. He has a BS/CS degree from St. Mary's University in San Antonio, Texas.

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INTRODUCTION

The F-16 Avionics Intermediate Shop (AIS) Maintenance Procedures Trainer (MPT) will provide a training environment for the development of new skills in the operation, fault isolation, and repair of AIS automatic test equipment (ATE) and F-16C/D aircraft avionics line replaceable units (LRUs). The trainer, designed to teach basic (3-level) and advanced (7-level) F-16 avionics maintenance courses to 300-350 students per year, presents exercises based on data captured during troubleshooting and repair activities of actual malfunctions experienced in the field. This data provides the baseline for a full-fidelity simulation of the test station computer bay and the ATLAS test language utilities. Students use the same technical order procedures that they will apply in the field to conduct troubleshooting and repair procedures using the test bay computer, and a digital video simulation of station test equipment and aircraft LRUs. The trainer is initially supplied with 63exercises based on malfunctions that require various levels of complexity in terms of diagnostic procedure and provides complete "simware" development utilities for the authoring of new exercises. The unique combination of real-time simulation programs and multimedia-based simware of the AIS-MPT provides a data-driven, desktop simulation for a training task previously addressed only by computer-based training (CBT).
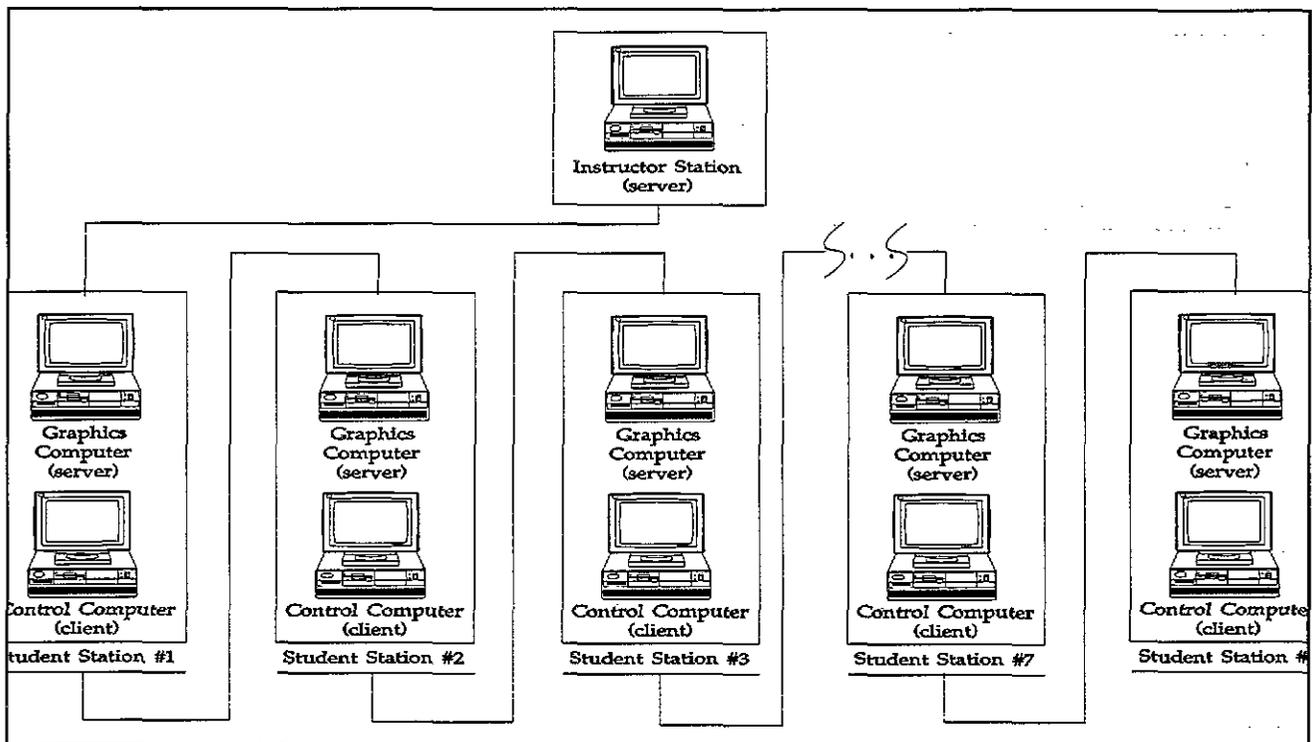

Figure 1 System Overview

SYSTEM OVERVIEW

The trainer, shown in Figure 1, consists of 19 IBM-AT compatible computer systems, including a stand-alone, dual-computer courseware development station (CDS) and a local area network containing an instructor station (IS) and eight dual-computer student stations (SS). At each SS, the trainer provides the student with a simulation of the F-16C/D AIS ATE. Four ATE station types are simulated: the computers and inertial (CI) station (Figure 2), the displays and indicators (DI) station, the pneumatic and processors (PP) station, and the radio frequency (RF) station. All stations incorporate an identical computer bay; however, each station differs in the ATLAS test software executed at the computer bay, the test equipment mounted in the equipment bays, the LRUs tested by the station, and the common test equipment used to isolate test station faults.

The physical and operational fidelity of the simulation for each ATE station and each LRU varies depending on the stated specification requirements. In simple terms, the requirements are that the physical fidelity of the simulated

station computer bay shall be "high" and the physical fidelity of the test equipment bay, test accessory equipment, and LRUs shall be "low." Thus, each SS provides a full-fidelity physical mock-up of the ATE computer bay; and a multimedia simulation of the test equipment bay, the LRUs, and common test equipment is provided through the display of photographic images on a large color monitor. At the simulated computer bay, the student interacts with the equipment and ATLAS programs using the keyboard and station control panel (SCP) as he would at the actual stations. At the image monitor, the student interacts with equipment by touching the surface of the monitor while viewing equipment photographs and operator menus. The operational fidelity of the simulation is driven by a requirement to provide training exercises for the repair of 63 pre-defined ATE and LRU malfunctions. During each exercise, the student has the "freeplay" to perform maintenance actions that are not in accordance with the ideal troubleshooting path. However, the trainer does monitor student performance and will "freeze" the exercise when the student has significantly deviated (as defined by the exercise author) from the ideal path.
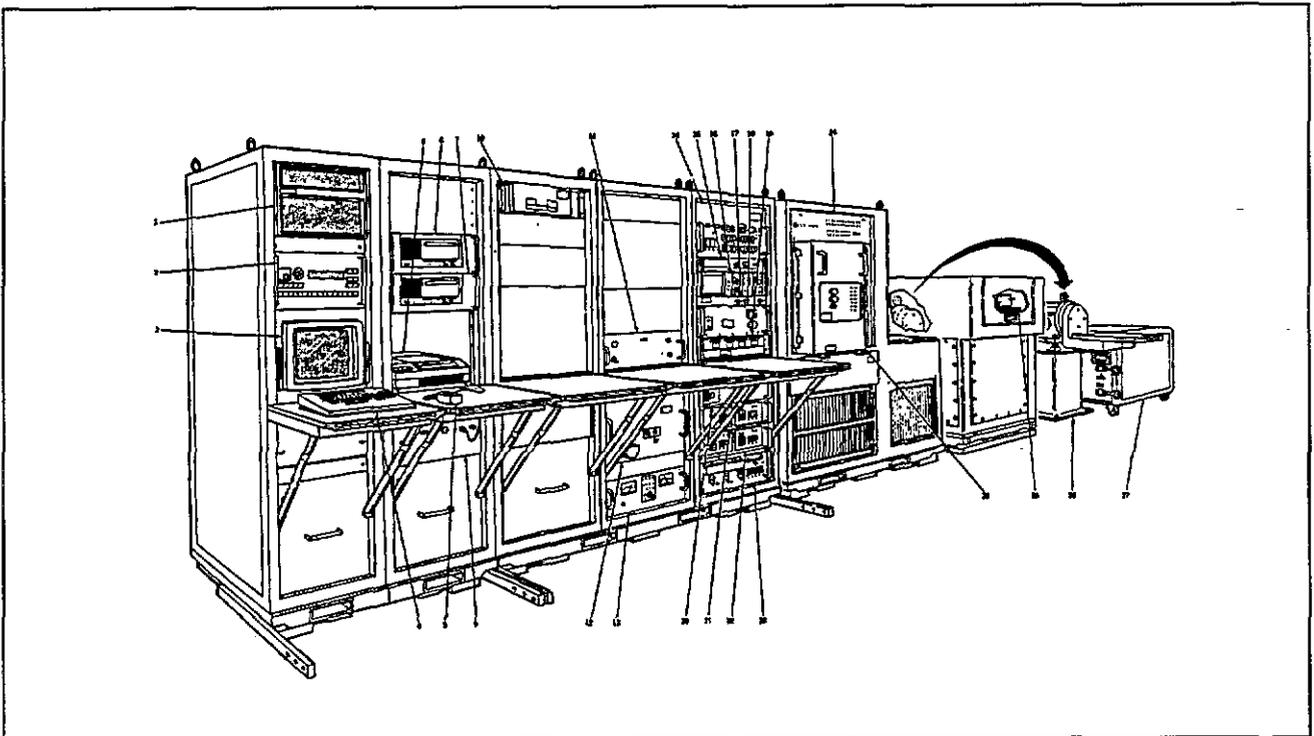

Figure 2 AIS CI Station Graphic

AIS-MPT SOFTWARE DESIGN

Overview

Trainer requirements state that the simulation of ATLAS program execution at the AIS computer bay shall be provided through the replay of observable data captured from an actual ATE computer bay. In addition, a courseware developer shall have the capability to modify the simulation presented at the computer bay and the simulation presented on the image monitor without having to modify trainer software. Thus, the software at the the SS has been designed as shown in Figure 3 to use data contained in disk files to drive the simulation. To distinguish between trainer functions provided by software and functions provided by data, data has been organized into "exercises" and "simware." Exercises monitor student performance during a training situation and provide instructional feedback to the student. Simware provides a simulation of ATLAS program execution at the computer bay and the visual simulation of LRUs and test equipment on the image monitor. Simware includes the following types of data:

a. ATLAS test language simulation authoring files that control the presentation of observables at the simulated AIS computer bay. These files incorporate captured computer bay observable data for the bay's CRT terminal, printer, and station control panel (SCP).

b. Visual simulation authoring files that control the simulation of test bay equipment, LRUs and common test equipment through the presentation of photographs/menus on the image monitor.

c. Image files that contain a digital representation of a 35mm slide or a motion sequence.

Courseware Development Station (CDS)

Ada and commercial off-the-shelf (COTS) software at the CDS as shown in Figure 4 provide a development environment, using a pull-down menu interface, that allows a courseware developer to maintain exercises and simware to keep the trainer concurrent with the F-16 AIS ATE and LRUs. To provide a development environment that
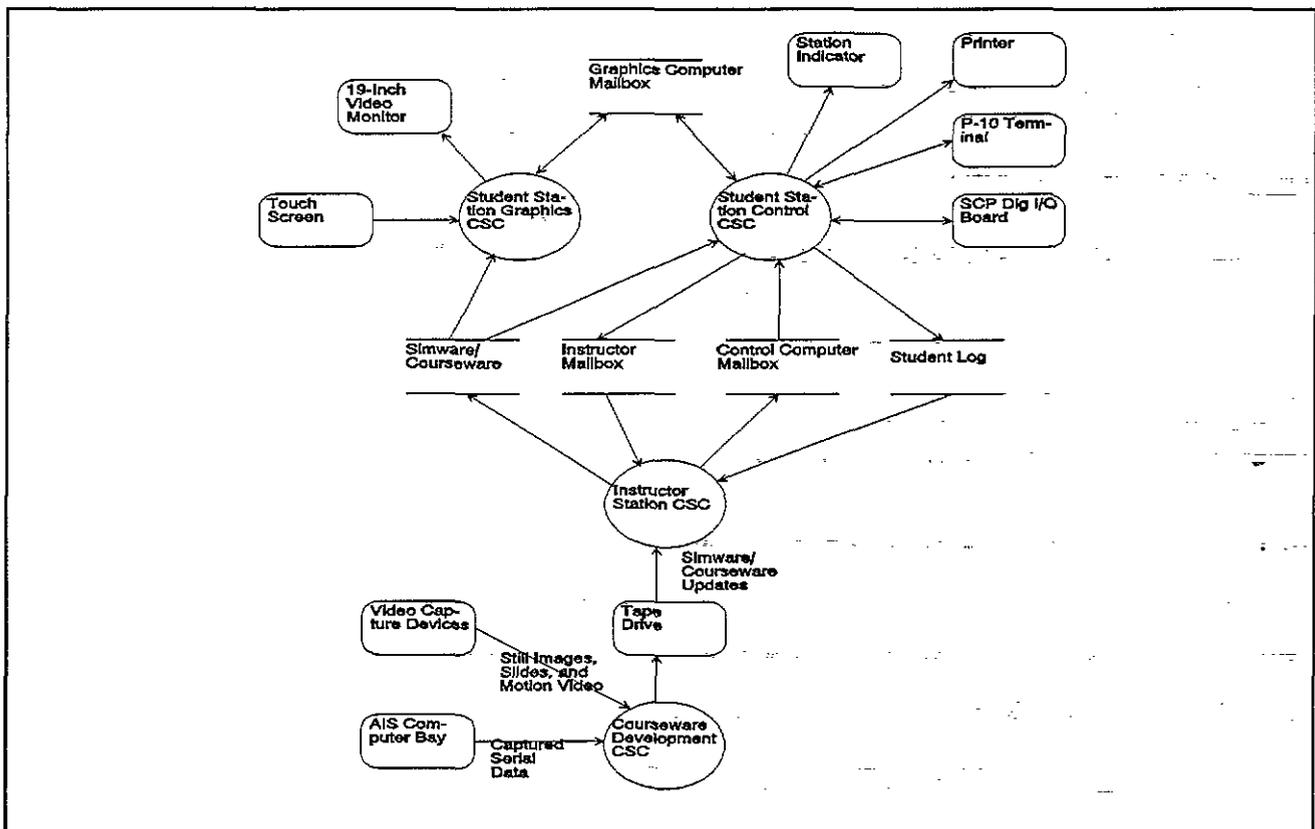

Figure 3 Software Design Overview

could be used by someone with little programming experience, three authoring systems were developed: an Exercise Authoring System (EAS), an ATLAS Simulation Authoring System (ASAS), and a Visual Simulation Authoring System (VSAS).

These tools are described as follows:

- **Exercise Authoring System (EAS).** A text editor is used to create an exercise file that initializes the simulation and defines the ideal troubleshooting procedure. Each step in the procedure "waits for" the student to perform a specific maintenance action (e.g., run an ATLAS test, reseat a circuit card) that will transition to the next step. In each step, the author can test student actions and display instructional feedback messages. A compiler is provided that checks EAS files for syntax errors and converts the file into an efficient format for execution at a student station.

- **ATLAS Simulation Authoring System (ASAS).** A text editor is used to create ASAS files that control the presentation of observables at the full-fidelity computer bay. Commands allow the author to display text on the terminal, the

printer, and the SCP display in response to student actions. Input processing commands allow the author to easily simulate the characteristics of ATLAS test control menus. A compiler is provided that checks ASAS files for syntax errors and converts the file into an efficient format for execution at a student station. To automate ASAS development, the CDS provides a program to capture observable data from an AIS station. Capture requires the author to connect cables to AIS station serial ports, then exercise all ATLAS functions targeted for simulation. The capture program stores data being transmitted to the station terminal and station control panel in temporary disk files. After capture is complete, the author executes a program that converts the captured data files into ASAS authoring command files. Approximately 75 percent of the ASAS authoring process can be automated by the capture software.
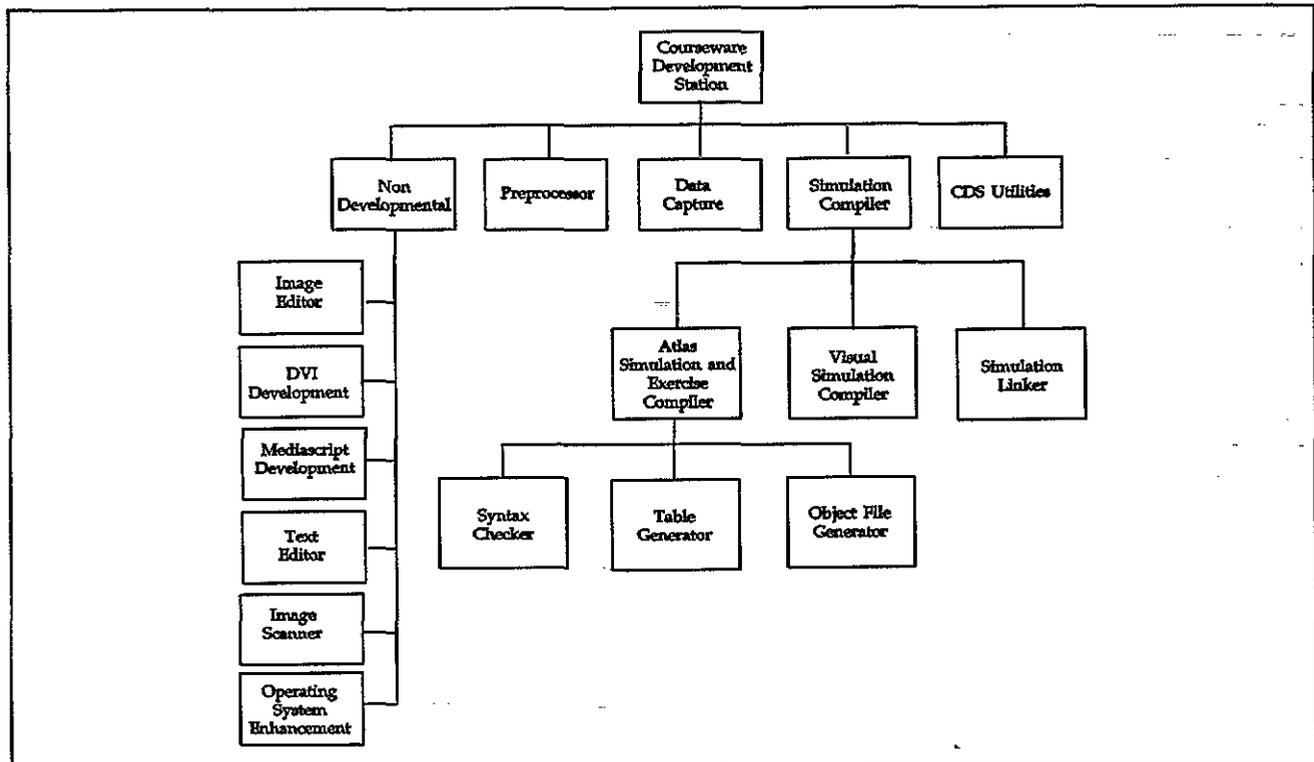
- **Visual Simulation Authoring System (VSAS).** A text editor is used to create visual authoring files that control the presentation of images and menus on the image monitor. Commands allow the author to define pull-down menus,

Figure 4 Courseware Development Station Software

define active touch areas, and display menus/ images in response to student actions. A compiler is provided that checks the VSAS files for syntax errors and converts the file into an efficient format for execution at a student station. In support of VSAS development, the CDS provides the capability to digitize 35mm slides and motion sequences stored on SVHS tape. A COTS program is used to convert slides to image files and then edit the image files. Edit capabilities include cut/paste from multiple images, sharpening, blurring, color changes, and text overlays.

The application of these tools to the authoring of exercises, and of ATLAS and visual simware to the creation of new training scenarios, is described below.

Student Station (SS)

Software at the SS, illustrated in Figures 5 and 6, executes on two different computers and provides a simulation of the ATLAS operating system and an execution environment for simware and exercises. The primary SS computer, the control computer, executes Ada code and serves as an interpreter for EAS and ASAS files. The secondary SS computer, the graphics computer, executes 'C' code and serves as interpreter for VSAS files. Intel's Digital Video Interactive (DVI)® hardware/ software is used to present images and motion sequences for a real-time simulation.

Although the ASAS and VSAS files are executed on separate computer systems, the simulation must perform as an integrated system. Student actions on the image monitor directly affect ATLAS program execution. Likewise, ATLAS test execution has a direct effect on image monitor displays. In addition, the EAS needs access to ASAS and VSAS execution to monitor student actions. Thus, the authoring systems use a common pool of variables to communicate with each other. Maintenance of the common variable pool and communications to the IS are implemented using a COTS peer-to-peer network.

Instructor Station (IS)

Ada software at the IS, shown in Figure 7, provides database maintenance functions and a student station monitor/control environment using
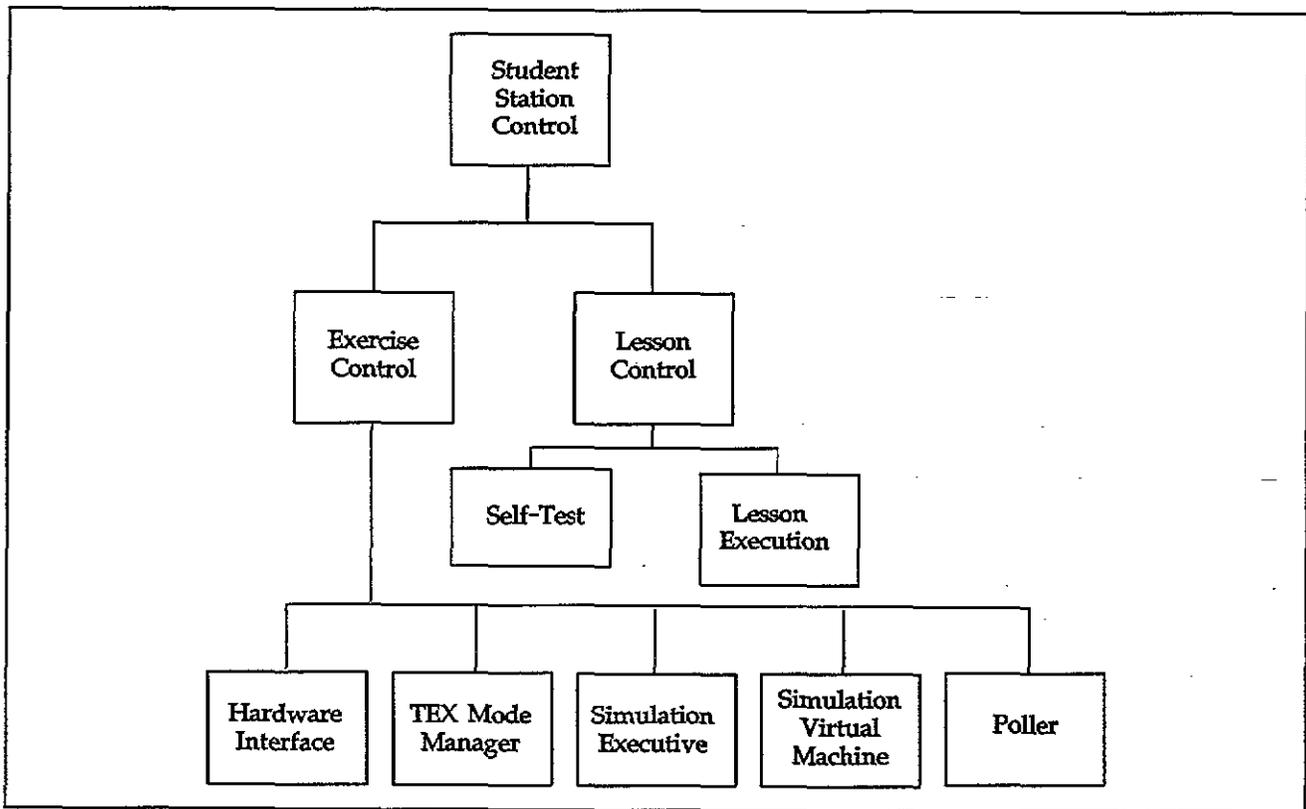

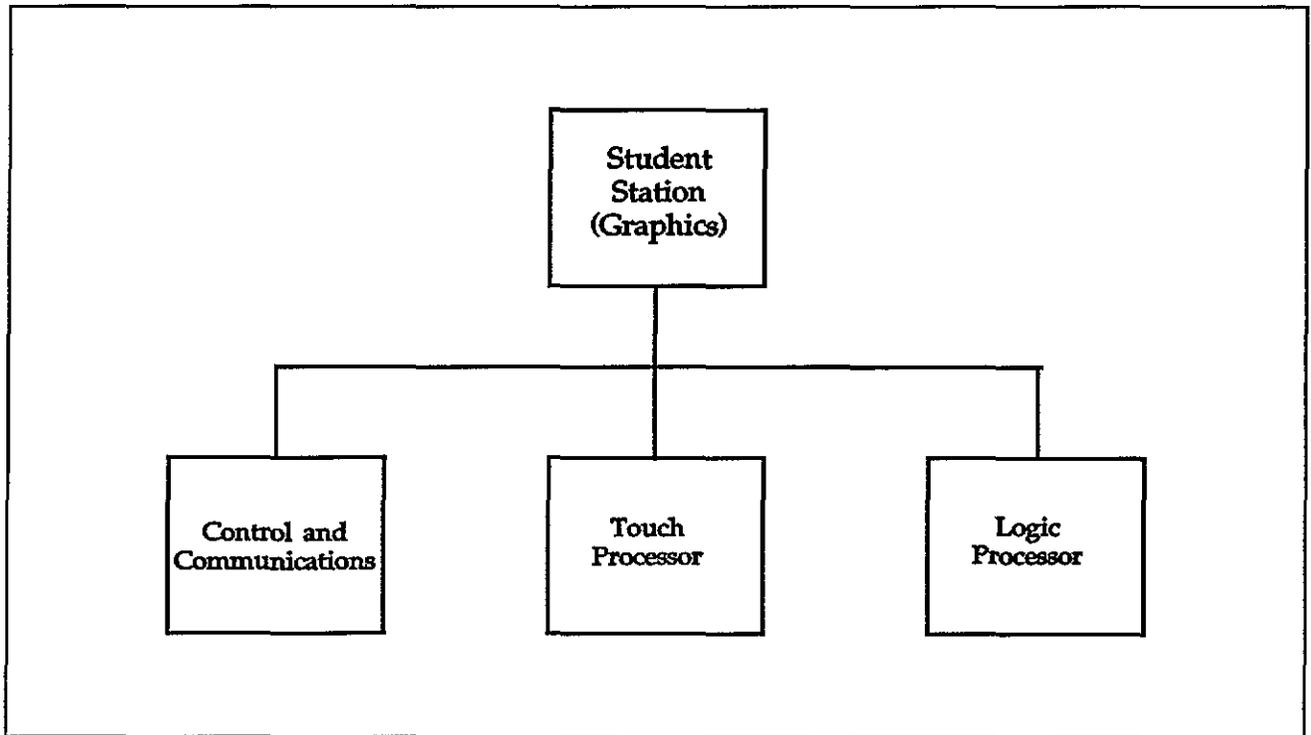**Figure 5 Student Station Control Software**
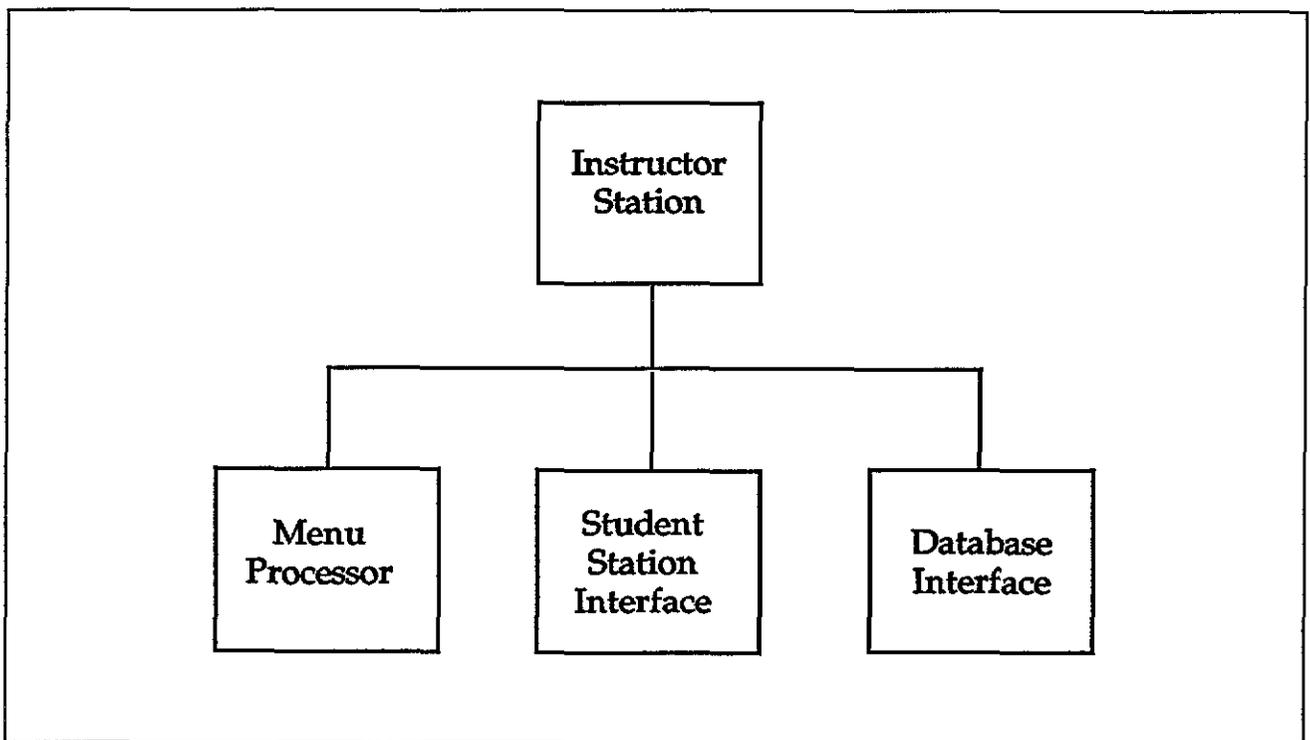
Figure 6 Student Station Graphics Software

Figure 7 Instruction Station Software

a pull-down menu interface. To aid in the development of student curriculum, a lesson database is maintained at the IS. Lessons specify up to five exercises that a student will perform during a day of trainer use. In the student database, students are organized into classes and assigned an identification number. At the start of each day, an instructor assigns each student a lesson at the IS. At the SS, a student logs into the trainer with his identification number and the trainer presents the assigned lesson to the student.

Associated with each lesson conducted at the student station is an activity log. Student maintenance actions and exercise step events are recorded in the log to assist the instructor during student evaluation. From the IS, the instructor can browse through an active log for any of the eight student stations. After lesson completion, logs are archived in the student database to provide a permanent record of student performance. The IS also provides the instructor with a display indicating the status at all eight student stations. Status includes station state (e.g., idle, freeze), and a performance summary for each student (e.g., time in exercise, number of errors).

SOFTWARE-SIMWARE INTERACTION

Software at the SS is hosted on two computers that work together as an integrated system to provide a simulation of AIS equipment operation. The computers communicate using the local area network system to send and receive messages in real time. The SS control computer is connected to the simulated AIS operator's terminal, SCP, and printer. The control computer executes software written in Ada that:

(1) provides the student with a simulation of the computer bay ATLAS operating system at the terminal,

(2) presents an ATLAS program execution simulation on the terminal, SCP, and printer controlled by ASAS authoring files, and

(3) monitors student performance in accordance with EAS authoring files.

The SS graphics computer uses DVI® hardware/software to present images and motion sequences of aircraft LRUs and AIS equipment items on a 20-inch monitor with touch screen. The graphics computer executes software written in 'C' that:

(1) provides a trainer-unique user interface for students/instructors, and

(2) presents the visual simulation controlled by VSAS authoring files.

Presentation of student exercises requires the current revision of exercise and simware authoring files to reside at each SS. When a student logs in at a SS, the IS downloads a message defining the student's assigned lesson, and the first specified EAS file is executed by the control computer. File commands initialize the simulation by specifying the AIS station and equipment malfunction to be simulated. EAS execution then proceeds to the first exercise step and waits for the student to perform the required maintenance action. The AIS computer bay simulation begins by presenting the student with the ATLAS operating system prompt on the AIS operator's P-10 terminal. When the student enters an "EXECUTE" command, the appropriate ASAS authoring file is executed on the control computer to simulate ATLAS program execution. The control computer is able to execute EAS and ASAS files in parallel using Ada's tasking capabilities.

After the EAS file has initialized the simulation, the control computer signals the graphics computer to begin the visual simulation. The visual simulation begins by executing the main VSAS file for the specified station. Visual simulations always begin with an image of the entire station equipment bay displayed on the monitor. The student selects a piece of equipment to manipulate by touching it. Equipment can be extended from the bay, covers can be removed, and internal components can be adjusted, reseated, substituted and replaced.

Although the ASAS and VSAS files are executed on separate computers, the simulation performs as an integrated system. Student actions on the image monitor directly affect ATLAS program execution. Likewise, ATLAS test execution has a direct effect on image monitor displays. Together, the two coordinated presentations provide a full-fidelity simulation of the AIS computer bay, and a digital multimedia simulation of aircraft LRUs and AIS station equipment.

SIMWARE DEVELOPMENT

An important characteristic of the AIS-MPT is the inherent capability to add new training scenarios, based on data-driven simulation, without changing the simulation software. Although simware development is a complicated process, the primary skill required is that of AIS subject matter expertise, not software development. New training scenarios are created according to the process shown in Figure 8 by using the EAS, ASAS, and VSAS authoring tools described above to author exercises, ATLAS simulation files, and visual simulation files.

Exercise Authoring

The development cycle for creation of a new student exercise that will train AIS equipment fault isolation procedures begins with exercise author-ing. An exercise monitors student performance during a training situation and provides instructional feedback. Exercise authoring consists of identi-fying the sequence of actions that constitute successful isolation and correction of a fault condition, identifying how much deviation from the 'optimal' troubleshooting procedure will be allowed, and identifying what instructional feedback will be provided in response to student actions.

For example, an AIS subject matter expert (SME) may begin the process of exercise authoring by selecting a shop replaceable unit (SRU) that will be listed in a confidence program error message as the probable cause of station failure (PCOF). The SME will then run the fault scenario on an actual AIS station to develop an Exercise Description (ED) document containing each troubleshooting step required for fault isolation and correction. The
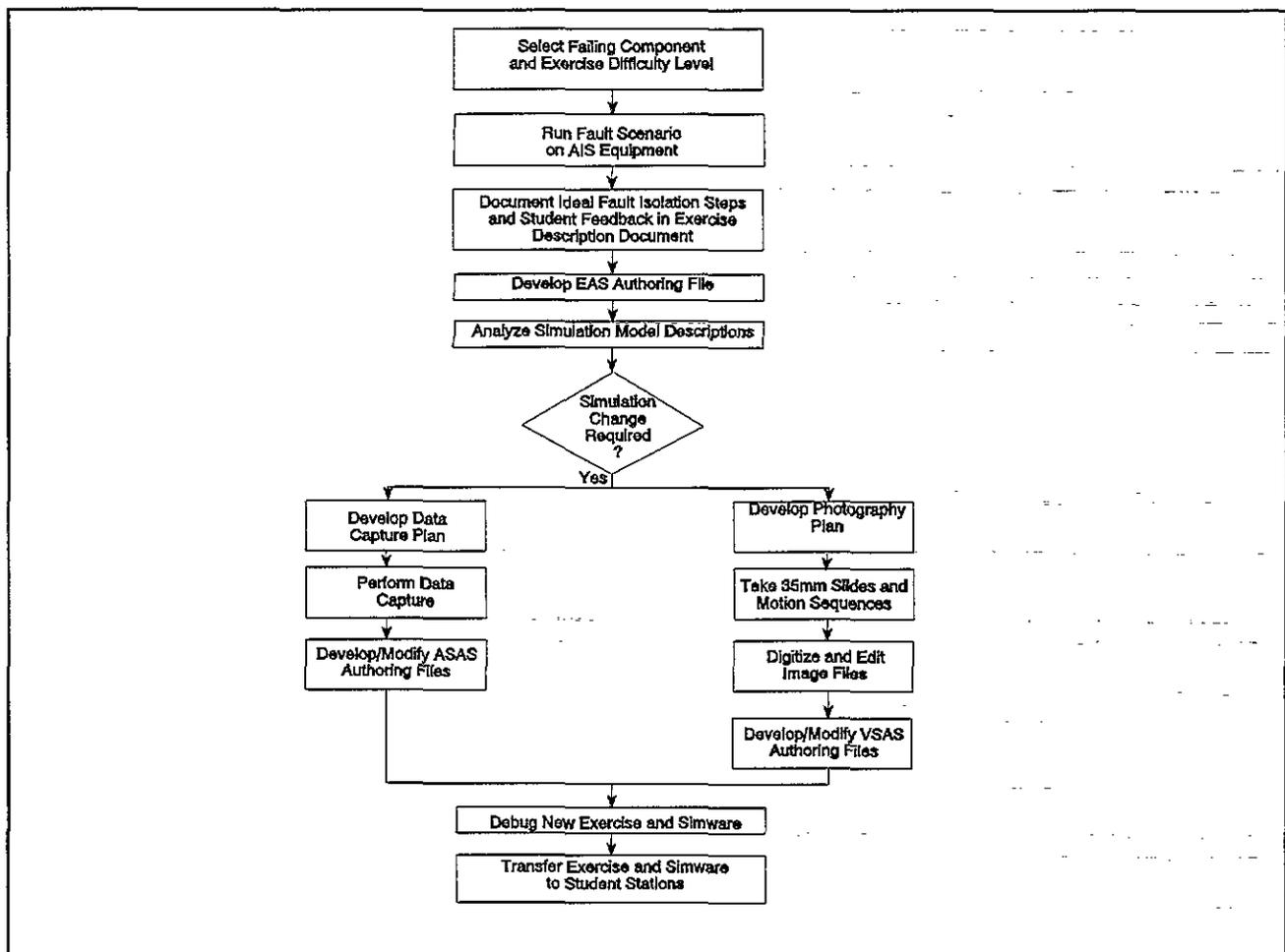

Figure 8 Simware Authoring Process

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SME then adds to the Exercise Description document the instructional feedback parameters that define how the trainer will respond when the student deviates from the optimal path of corrective action. Typically, the exercise will allow the student to perform up to three significant actions that are not the next troubleshooting step of the ideal procedure before instructional feedback is provided. However, the exercise author may elect to provide feedback immediately on deviation from the preferred procedure, or may elect not to provide any instructional feedback at all. The exercise author may also choose to provide instructional feedback upon completion of each step in the troubleshooting procedure.

Once the Exercise Description document has been completed, the EAS text editor is then used to create an exercise file for execution on the Student Station Control computer.

Simulation Authoring

Once the exercise authoring is completed, the existing Simulation Model Description (SMD) documents must be analyzed to determine if simulation authoring is required to support the exercise. The SMD documents describe in detail how the simulated computer bay, test equipment and LRUs respond to specific student actions in order to provide an accurate simulation of actual equipment. For new exercises, it is likely that new ATLAS observables will be needed, thus requiring data capture activities. It is also likely that new digital image materials will be required for the visual simulation of test equipment items. Once the SMD modifications are complete, ATLAS program data capture and equipment photography plans are developed.

The flowchart shows that the ASAS and VSAS developments can be performed in parallel. ASAS development begins with data capture of actual AIS operating data performed in accordance with the data capture plan. ASAS authoring files to be modified are checked out of the configuration management (CM) system, and the data capture results are integrated into the authoring files using the ASAS development environment. The main authoring task at this point is the control logic associated with simulation of the computer bay, and the main skill required of the simware author is that of AIS subject matter expertise.

In a similar manner, VSAS development begins with photography performed in accordance with the photography plan. The resulting 35mm slides and motion sequences are digitized and slide image files are edited to produce the final still frame images. The VSAS is then used to define active touch areas and pull-down menus, and to add the control logic associated with visual simulation of the test equipment and LRUs. Once again, the primary skill involved on the part of the author is that of subject matter expertise. Finally, existing ATLAS and visual simulation files are checked out of the CM system and modified to display the new images and allow the student to perform additional maintenance actions.

Debug and Validation

The final stage of exercise development is the debug and validation of new and modified authoring files at the CDS. This is accomplished at the CDS by selecting the debug state from pull-down menu choices and selecting the exercise to debug. The CDS is temporarily reconfigured to operate as a student station executing the new exercise. Simulation or exercise errors that are encountered during execution may be corrected by returning to the CDS development environment to effect the necessary changes. Exercise validation is accomplished by comparing proper exercise execution with the ED and SMD documents, and with actual test station operation. Once all debug and validation activities at the CDS are complete, the author transfers the modified files to the IS using tape media. The IS is then used to (1) transfer EAS and ASAS files to each SS control computer, and (2) transfer VSAS authoring files to each SS graphics computer.

CONCLUSION

The F-16 Avionics Intermediate Shop (AIS) is an expensive and extremely complicated device combining aircraft components under test with an array of electronic test equipment and sophisticated software diagnostic tools. Furthermore, as the hardware and software configuration of the aircraft changes, it impacts the test equipment and the procedures for troubleshooting and maintenance of aircraft components. The AIS Maintenance Procedures Trainer addresses this situation by providing a desktop simulation of the AIS equipment, along with the tools required for avionics maintenance experts to update and maintain existing training exercises, and to provide new training exercises without changing the simulation software of the trainer.