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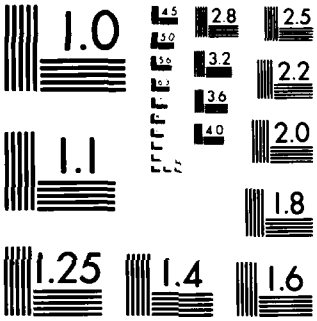

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INTERACTIVE GRAPHICS SIMULATOR: DESIGN, DEVELOPMENT, AND EFFECTIVENESS/COST EVALUATION

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This report covers the design, development, implementation, and evaluation of a new task and videodisc-based simulator, the Interactive Graphics Simulator (IGS). The test vehicle was the 6883 Converter Flight Control Test Station and its associated training course at Lowry AFB, Colorado. The computer-based simulator provided for task emulation of job planning tasks, as well as for equipment manipulation tasks. The simulation system provided a means of on-line task analysis, of simulation development from the task data base, of presenting simulations to students, and of adapting simulation presentation to the level of student achievement. Simulation lessonware covered both procedural equipment operation and troubleshooting activities.

A comparative study was performed with 22 students using the actual equipment trainer (AET) during training and 21 students using the IGS. Evaluation of the outcomes included training effectiveness analyses based on a conventional ATC block test, on a hands-on equipment operating procedures test, on a paper-and-pencil troubleshooting test, and on a predictive job performance test. The IGS-trained students performed significantly

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better on the troubleshooting test; however, no other significant performance differences were found. A comparison of the IGS and AET costs showed the IGS to be substantially less expensive in terms of acquisition and operating costs. Student attitudes toward the IGS were favorable, and the system operated extremely well in a standard ATC classroom environment.

SUMMARY

The objectives of this study were to design, develop, implement and evaluate a videodisc-based simulator system, the Interactive Graphics Simulator (IGS) for 6883 Converter Flight Control Test Station training at Lowry AFB, Colorado. The IGS was more than a functional replication of the actual equipment, it also specifically covered maintenance planning skills (i.e., decision making and problem solving) within the simulations. Setting controls and accessing test points on the IGS was done using a touch screen or touch pad to select areas of a video-disc-based visual.

The students in the training course (N=43) were assigned to either an actual equipment trainer (AET) or an IGS training mode. AET-trained students were given hands-on equipment manipulation training on the 6883 test station while IGS-trained students received equipment manipulation and troubleshooting training on the IGS system. Student performance was assessed using a battery of tests designed to measure troubleshooting ability, equipment operational procedures performance, and field assignment readiness. These scores were supplemented with conventional end-of-block test results and student attitudinal data. Costs of the IGS system and the AET were also compared.

Analysis of the scores showed the IGS system to be as effective as the actual equipment in training hands-on procedures and to be superior to the AET in training troubleshooting skills. The IGS also proved to be suitable for the training environment, providing for easy courseware development, requiring minimal maintenance, and operating efficiently in a standard classroom. Student acceptance of the IGS system was high. The IGS system not only provided training effectiveness advantages, but also substantial cost savings over the AET.

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PREFACE

This report is the final report for the design, development, implementation, and evaluation of the Interactive Graphics Simulator system for maintenance training. The project was conducted for the Air Force Human Resources Laboratory Technical Training Division, Lowry AFB, Colorado. This effort is documented under Project 2361 - Simulation for Maintenance Training. The goal for this effort was to utilize a computer-driven videodisc based training simulator in place of the actual equipment trainer normally used in one instructional block of the F-111 Integrated Avionics Computerized Test Station and Component Specialist training course.

This effort was conducted from April 1981 through August 1984. The services of Essex Corporation were obtained through contract AF33615-81-C-0006 for which Mr. William J. Pieper was the Principal Investigator and Project Director. Collaborative project effort was obtained through a subcontract with the Denver Research Institute for which Dr. J. Jeffrey Richardson was the Project Director. The Air Force contract technical monitor was Capt Randy H. Massey.

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The Essex Corporation and the Denver Research Institute (DRI) gratefully acknowledge the contribution of the Special Projects Office personnel in ATC for their assistance in lessonware development, IGS instruction, evaluation subject scheduling, test instrument development, and evaluation test monitoring. These personnel include SSgt M. Coley, SSgt J. Thomas, SSgt S. Schulte, SSgt D. Freund, SSgt P. Macalik and SRA T.K. Thomas. Additional personnel who provided assistance in evaluation subject scheduling and test instrument development include TSgt C. Libby and SRA L. Schmidt.

The authors also thank AFHRL personnel, Maj Dale Baxter, Mr. Brian Dallman, and Dr. Gerry Deignan for their ideas and assistance on this project.

Within DRI, the authors thank Dr. A. West, SSRE Division Head, and Dr. L. Cicchinelli, Assistant Division Head, for their review of the report. In addition, thanks to Mr. J. Kottenstette and Mr. D. Steffen for their early involvement and continued support of the project, Ms. C. Anselme for her contribution to lessonware development and student model investigations, and Mr. P. Manning for his tireless efforts in programming all the videodisc and student station software.

Ms. A. Montgomery of McDonnell Douglas Automation Company deserves special acknowledgement for programming the IGS design components which run on the AFHRL Cyber system.

Finally, the authors extend special thanks to Ms. D. Swanson of Essex Corporation for her many hours of effort in lessonware development, project documentation, and final report editing.

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I. INTRODUCTION

Background

Based on a recent study of simulators for maintenance training, a paraphrased definition is: training devices that replicate many, but not necessarily all, of the appearances and functions of actual equipment (Orlansky & String, 1983). Based on their external physical appearance, they are often characterized as two- or three-dimensional devices. The three-dimensional simulator bears the closest resemblance in physical form and function to the actual equipment. The two-dimensional simulator has less physical realism and represents the actual equipment through pictures presented on flat panels, augmented with selected functioning controls, displays, and test points. Although differing in the extent of realism, current maintenance training simulators attempt to replicate the physical appearance and functions of the actual equipment; they are equipment simulators. In general, the major advantages of simulators over actual equipment for maintenance training include increased reliability, improved safety, greater opportunity for troubleshooting practice, and reduced cost.

Several studies comparing training simulators and actual equi[illegible] trainers (AETs) were reviewed to determine the general finding[illegible] [illegible]ch regard to training effectiveness and cost (Orlansky & String, 198[illegible] In general, the studies indicated that equipment simulators could be used for training in place of AETs at substantial cost savings wi[illegible] sacrificing training effectiveness. At least two recent studies corroborated these findings (Cicchinelli, Harmon, & Keller, 1982; Cicchinelli, Keller, & Harmon, in press). Taken strictly as representations of actual equipment, equipment simulators used in maintenance training have done as well as can be expected, for they could not be expected to train any better than the actual equipment.

A newer generation of simulators, called here an Interactive Graphics Simulator(IGS), bears less physical resemblance to the actual equipment than either the two- or three-dimensional equipment simulators. An IGS represents the equipment layout, controls, and displays pictorially on a color video monitor using videodisc images as the source. Setting controls and accessing test points on the video monitor are done through the use of touch panels, light pens, or similar electronic selection devices. The challenge for a maintenance training IGS was to achieve a training effectiveness advantage over equipment simulators or actual equipment trainers. To do this, the IGS had to be more than a representation of the actual equipment. Specifically, it had to be a device which aided, with evaluation, the learner's emulation of maintenance tasks and skills; as, for example, diagnosing malfunctions; identifying, repairing, and replacing parts; and operating the equipment to verify proper functioning.

Achieving increased training effectiveness was taken to mean the incorporation of some form of computer-based instructional (CBI) technology; that is, the capability to prompt, evaluate, and remediate maintenance skills. The definition of maintenance simulation was broadened to include not only equipment representation but also task

emulation. The definition of an IGS for training was extended to: "A training device that (a) requires the user to emulate the tasks, skills, and knowledges of a trained maintainer and (b) simulates the physical appearances and functions of actual equipment." This orientation, along with the implied computer-based system, was anticipated to achieve the training effectiveness advantages desired and at the same time maintain the cost advantages expected of equipment simulators.

Project Goals

The goals of this project were to design, develop, implement, and evaluate an interactive computer-based IGS in support of avionics maintenance training. The required IGS system was to provide for the use of task analysis data, as well as equipment manipulation data. The task analysis data base was designed to be built on-line, representing all of the trained maintenance technician skills and knowledges. The task data base was also designed to serve simultaneously as the training data base and as the student model. The equipment manipulation data base was designed to be built on-line using videodisc picture information and digitized graphic overlays for presentation with the videodisc images.

During development, a set of program tools was built for use in implementing the graphics simulations. The tools captured a methodology of courseware development. The tools consisted of editors for the task and equipment manipulation data bases, a text and graphics editor for the task data base, and a graphics editor for the equipment data bases. In addition, run-time programs were built for the task and equipment manipulation elements that interfaced the data bases and the student model. The approach of using program tools as development aids provided an efficient means of courseware development, lessening the acknowledged labor-intensive nature of CBI materials development.

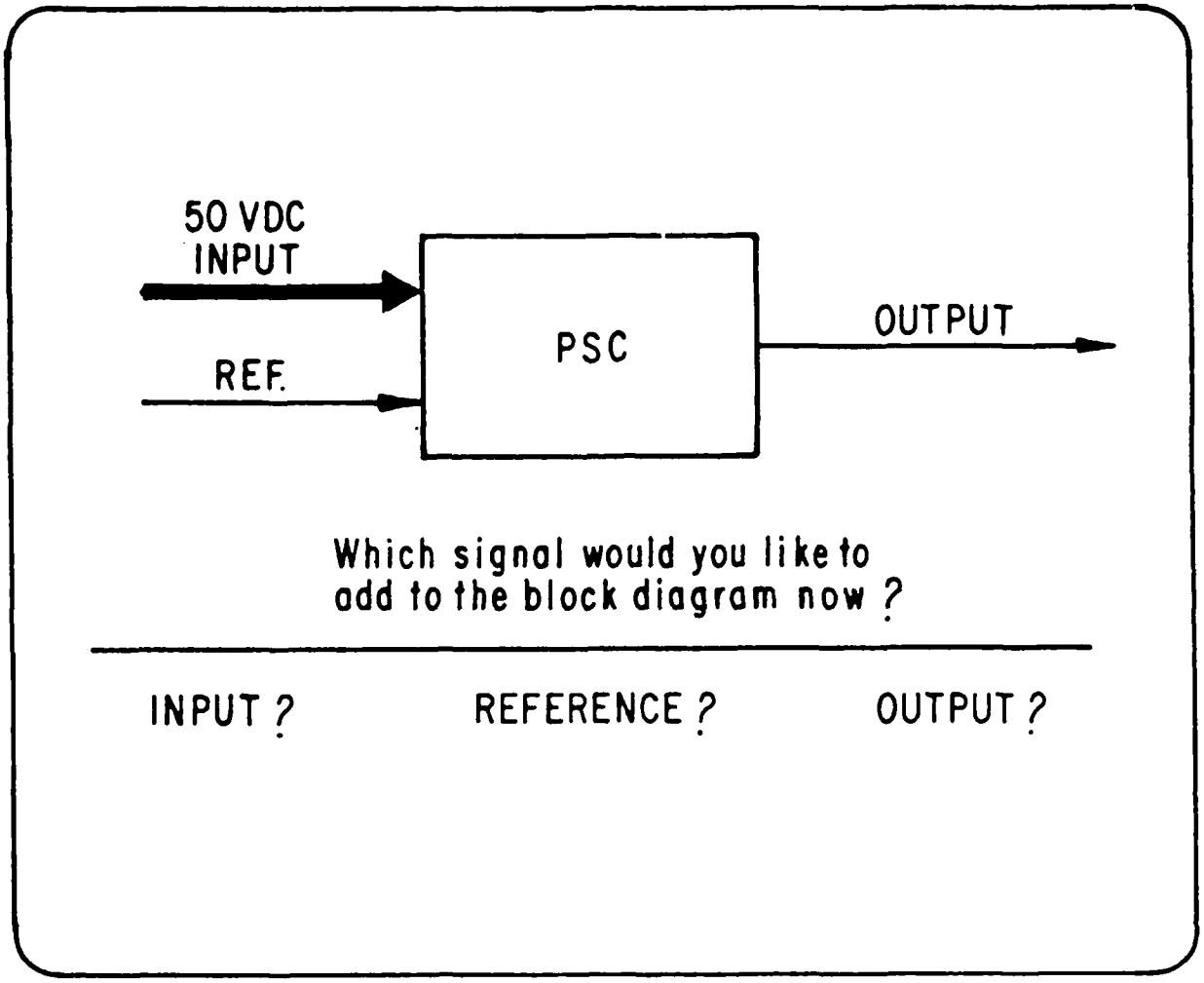
II. INTERACTIVE GRAPHICS SIMULATOR DESIGN AND DEVELOPMENT

Before the detailed design of the IGS is presented, the simulator will be described from the perspective of a trainee. The trainee sits before a keyboard, a touch-sensitive pad, and two displays. The video monitor presents videodisc images with graphic overlays providing actual equipment static and motion display. User interaction with the monitor is accomplished through the touch pad which provides selection of desired positions on the display. The terminal presents the problem-solving components of the tasks. User interaction with the terminal is accomplished through the keyboard.

Trainee interaction begins using the terminal display of the IGS. The terminal uses a medium-resolution graphics display on which text, diagrams, decision alternatives (menus), prompts, and feedback messages are presented. For example, suppose a trainee is developing a block diagram of the signal path involved in a troubleshooting problem. Figure 1 depicts one step in this process. At this point, the trainee will be focused on the inputs and outputs for one particular functional unit, the PSC (phase sensitive converter). The trainee has already identified that the input should be 50 volts DC (VDC) and has two more signals to identify. The terminal display shows a graphic representing the PSC with its two inputs and one output. The signal(s) already identified (in this case the 50-VDC input) is labeled and highlighted. A text prompt beneath the graphic asks, "Which signal would you like to add to the block diagram now?" At the bottom of the task display, the decision alternatives to be used in answering this question are presented. At this point in the example, the correct response is either "Reference" or "Output." Feedback messages associated with each incorrect response are displayed if that response is chosen. For example, if the trainee chooses "Input," the displayed feedback message is, "You have already identified this signal, pick another!" Interaction on the task display continues until an equipment action is required (e.g., Set up voltmeter). At that time, control is passed to the equipment display monitor.

The equipment display monitor is a regular TV color video monitor. This monitor is used in a fashion that has become almost standard in microform and videodisc simulations of equipment. The student accesses controls, readouts, test points, and components by selecting, through the touch pad, the portion of the picture to be displayed in greater detail. For example, if a voltmeter range control is to be set from 100 to 10, the trainee begins by selecting the voltmeter drawer in a rack of equipment pictured on the monitor. The rack picture is replaced by a picture of the voltmeter drawer. Next, the range control is selected and the voltmeter picture is replaced by a picture of the range control, currently positioned at 100. At this point, the 10 on the range scale is selected, and a picture of the range control set to 10 is displayed. Finally, when the equipment actions are complete, the trainee selects an area on the monitor screen labeled "Done."

When the voltmeter is correctly set up, control is again returned to the terminal display. In this way, a simulation proceeds through an initial sequence of task displays, setting the problem scenario to the



Depicted is an intermediate step in the development of a block diagram. Here the trainee has already identified that the INPUT should be 50 VDC and has two more signals to identify.

Figure 1. Typical task display.

first equipment action. Student activity continues through simulated equipment actions on the equipment display monitor and then returns to the next series of problem-solving activities on the terminal display. This process continues, alternating between the two instructional displays, until the problem is completed. The presented simulations are task-centered, in that the planning and problem-solving activities control access to the equipment display monitor.

IGS System Design

Quality in the development of task-centered simulations is impacted by (a) the accuracy and completeness of decision alternatives, (b) the consistency in problem-solving approach from simulation to simulation as reflected in the decision alternatives, (c) the cost incurred in developing comprehensive sets of decision alternatives for an entire set of simulations, and (d) the ability to chain together equipment actions that should be performed as a single, integrated equipment sequence -- given sufficient trainee expertise. The IGS system incorporated the development and use of an on-line task analysis technique in order to address these concerns.

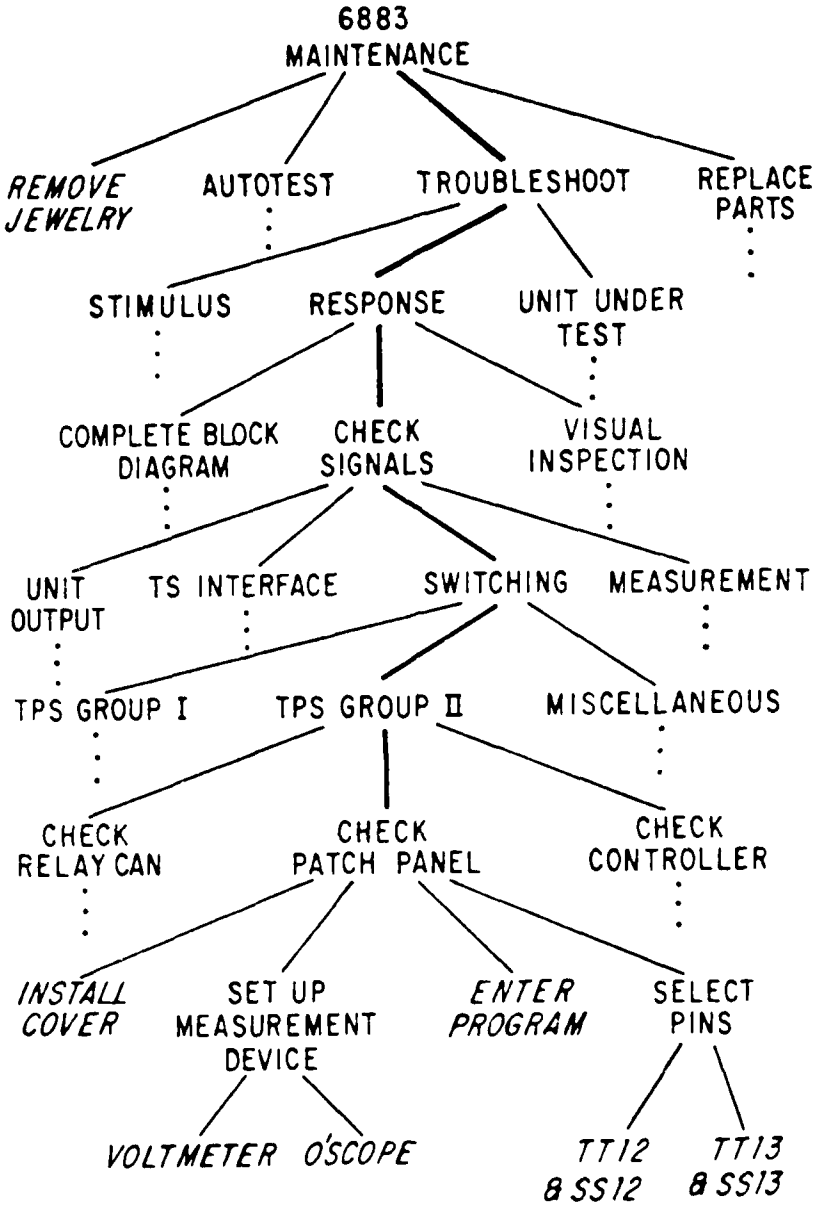
On-Line Task Analysis

The developed on-line task analysis technique was defined as the generation of a computer-resident task reduction data base containing the set of cognitive and manipulative actions required to accomplish a task. The technique captured the problem-solving strategy known as hierarchical decomposition or planning by abstraction. For any task, the strategy was to divide the task into more and more simple subtasks.

The approach taken in this task analytic technique was to continually ask, "What must be done to accomplish the task?" If three things had to be done (A, B, and C), the question was repeated for each of these. "What must be done to accomplish A?" The process was repeated until the answer to "What must be done?" was assumed to be part of the repertoire of the trainee or was in a sense "elemental." For example, changing the range on a voltmeter from 100 to 10 was considered elemental; i.e., the smallest level of behavior to be tracked in the system.

The nature of the relationship between the task and the equipment was neatly represented by the task analysis. The outcome of the task analysis had the form of a tree. The top or root node of the tree represented the most global description of the task. Several branches emanated from the root node to subordinate nodes representing the major subtasks. Each of the subtasks had branches emanating to nodes representing their subparts, and so on, until the task was decomposed into elemental equipment actions. Therefore, all equipment actions were terminal nodes in the tree.

The target task for IGS system development was the operation and maintenance of an 6883 Test Station (Dallman, Pieper, & Richardson, 1983). Figure 2 provides an abbreviated listing of the outcome of the analysis for this task. The full analysis tree is up to 16 levels deep and contains well over 1,000 nodes.



Only one line of decisions/actions is represented; all others have been pruned, as indicated by the ellipses. Task elements listed in italics are terminal nodes and entail equipment manipulation.

Figure 2. Task analysis tree for 6883 maintenance.

Detailed IGS Design Goals

Four detailed IGS design goals were addressed in the development of the on-line task analysis technique.

Design Goal 1: Focus the simulation on the tasks, not the equipment. The inherent structure of the developed on-line task analysis technique made equipment simulation an integral but subordinate portion of the decomposed task. This is graphically depicted by the fact that all equipment actions were terminal nodes in the resultant task analysis tree. Given this goal, the IGS was clearly defined as a task emulation device, not merely an equipment simulator.

Representation of the equipment was still a vital aspect of this approach to maintenance simulation. There had to be some way to practice equipment actions. Therefore, the videodisc representation of the equipment was a substantial element of the simulator.

Design Goal 2. Use the task data base to develop simulation courseware through an authoring editor. An authoring editor was designed to flag a correct path through the task analysis tree as the means of developing each unit of computer-based simulation courseware (i.e., problem protocol). The editor was built to do this by displaying the current node of the task tree along with each of its children (i.e., subordinate nodes). A subject-matter expert (SME) was to identify which child or children must be accomplished at this level of the tree for this protocol and in what order each must be done. The SME then selected one of the children as the new current node and the process was repeated. Through this mechanism, the task analysis tree was caused to serve directly as the basis for development of the simulation courseware which trains the job tasks.

Simulation protocols were built with the editor as follows. As the SME selected the subordinate nodes (children) to be performed at each level of the tree, the order of accomplishment was also determined. For example, the selected children could be assigned to be performed serially; that is, do A, then do B, then do C, etc. Alternatively, they could be assigned in various logical combinations of order; e.g., first do either A or C, then do B, and finally, do D and E in any order. Figure 3 illustrates the appearance of the editor screen after order assignment for the children of the "CHECK PATCH PANEL" node of the task data tree.

Once order was assigned for all of the nodes to be accomplished in a protocol, the task display associated with each decision alternative (e.g., first do A or C) was developed. Recall that the task display is what is presented to the trainee when that decision alternative is pending (see Figure 1). The SME would use graphics and text editors to develop the task displays which contained text and graphics summarizing the current state of the problem and/or presenting comment or prompts about the pending decision. Finally, textual feedback messages were created by the SME for each of the incorrect choices for the decision pending when the task display was presented. If, for example, the pending decision were "do either A or C," feedback messages would be prepared for choices B, D, and E. No feedback would be prepared for A

CHECK PATCH PANEL Subtasks:	TASK ACTIONS TO BE PERFORMED:
* Install cover	1. Install cover
* Set up measurement device	2. Set up measurement device
* Enter program	3. Select pins
* Select pins	4. Enter program
	5. Enter program

— menu of editor options normally appears here —

This display corresponds to the task structure depicted in Figure 2. Suppose "Check Patch Panel" was the method selected for checking the switching signals of TPS Group II relays (refer to Figure 2). When the "Check Patch Panel" node is expanded, the above display appears with the task components listed on the left and a blank screen on the right. The SME, using editor commands normally listed at the bottom of the screen, assigns the task components required to perform the patch panel check for this problem. The result is the list of task components shown on the right-hand side of the screen. At this point, if the SME entered a "2," this would cause the "Set Up Measurement Device" node to be expanded and the process of simulation courseware development would continue. Task displays are created by entering a command to "create task display" and the number (from 1 to 5 in this example) of the task action to associate with the display. Feedback messages are similarly constructed. The menu the trainee sees at the bottom of a task display is retrieved automatically from the task analysis tree and consists of all items listed on the left-hand half of the editor screen.

Figure 3. Simulation courseware development editor.

and C because these would be correct decision alternatives. A task display was considered complete when it contained the text and graphics for the pending decision and the feedback messages for the incorrect decision alternatives. Once developed, the task displays were stored as files until protocol run time.

The situation with regard to terminal nodes (i.e., equipment actions) was slightly different. Task displays were prepared for use when the equipment nodes were the pending decision alternatives. In addition, sequences of videodisc images and lists of touch pad inputs were also prepared for the actual equipment simulation components. The equipment action files (i.e., step files) were stored separately but were referenced to the node in the task data tree for which they were relevant. The example, setting the voltmeter range to 10, given near the beginning of this report, would require that a sequence of videodisc images and touch pad inputs be set up corresponding to the following actions: select the voltmeter in the rack of equipment, select the range control on the pictured face of the voltmeter, select the area labeled "10" on the picture of the range control, and select the "Done" area at the top of the display screen.

In summary, the task analysis tree provided a ready means of developing simulations. The decision alternatives for each step were provided directly by the data base. The SME identified the correct path through the tree for the protocol at hand and then associated task or equipment display information with each.

Design Goal 3: Promote consistency in the problem-solving approach while allowing for flexibility in simulation design. Since all simulations were developed from the same task analysis tree, they presented a consistent problem-solving approach. That is, any menu (list of decision alternatives) displayed in one simulation was exactly the same in all other simulations which needed to display that menu. The menus were not entered in the task display by the SME; they were provided by the task analysis tree. Only the correct choices for the specific simulation were provided by the SME. Consistency in the approach from simulation to simulation was inherent in the use of the task data tree for providing both the decision alternatives to the SME and menu choices to the trainees.

This approach to authoring supported a wide degree of latitude in constructing simulation problems. In particular, it supported the development of part tasks and the development of alternative troubleshooting approaches. An example will illustrate one way in which part tasks were developed. Suppose decision alternatives at some point in the simulation included: complete block diagram, perform visual inspection, and check signals. It may be that the SMEs wished at this time to focus on the check signals component of the task and to pass over completing the block diagram and performing a visual inspection.

In order to accomplish this, the SME might have assigned all three subnodes in sequence. At the same time, the detail correct alternative paths beneath the "Complete Block Diagram" and "Perform Visual Inspection" nodes would not be completed. Instead, task displays for

each of these two elements would have been created summarizing what the trainee would have accomplished had these subtasks been completed. Only the path beneath the "Check Signals" alternative would have been traced out completely. In this case, the scenario for the trainee would have gone as follows: "What would you like to do next--Complete Block Diagram, Perform Visual Inspection, or Check Signals?" Suppose the trainee had correctly selected, "Complete Block Diagram." In response to this, the trainee would have seen a summary task display showing a completed block diagram and a statement, "Here is your completed block diagram. Press NEXT to continue." The trainee would then be returned to the menu of decision alternatives: "Complete Block Diagram, Perform Visual Inspection, or Check Signals." Next, correctly selecting "Perform Visual Inspection" would have provided a summary task display of what that task would have yielded at its completion. The trainee would again have been returned to the menu: "Complete Block Diagram, Perform Visual Inspection, or Check Signals." Finally, correctly picking "Check Signals," would have provided a regular task display with a new set of decision alternatives appropriate to performing the next task in the decomposition of "Check Signals."

The authoring approach also supported the development of alternative troubleshooting strategies. For example, suppose any of three functional areas, X, Y, or Z, was to be explored next. Further, suppose the fault lies in region X. The author could have assigned these areas in at least two ways: X, Y, and Z may be performed in any order, or Y and Z are optional, and X is required. In the first of these assignments, the trainee would have had to explore all three areas even if X had been done first. In the second, once area X had been explored, neither of the others would have to be done. As a further example, suppose either of two methods for checking a certain signal was acceptable. Suppose that one method was the favorite of one SME and that the other was the favorite of another SME. If both methods were to be developed in detail, they could have been assigned as follows, "Do either Method A or Method B." The task analysis subtrees for both Method A and Method B would have been developed beneath their respective nodes. If development resources had not permitted building paths for both methods, and it was still perceived to be important to give the trainee the option of selecting either method, a summary scene could have been developed for Method B stating, "Yes, you could use Method B. It is a perfectly legitimate approach. However, today we would prefer you to try Method A."

The use of the task data tree for generation of the decision alternatives provided the desired consistency in problem-solving approach. In addition, the authoring editor with the task displays provided the desired flexibility in simulation design. Both of these goals were achieved simultaneously.

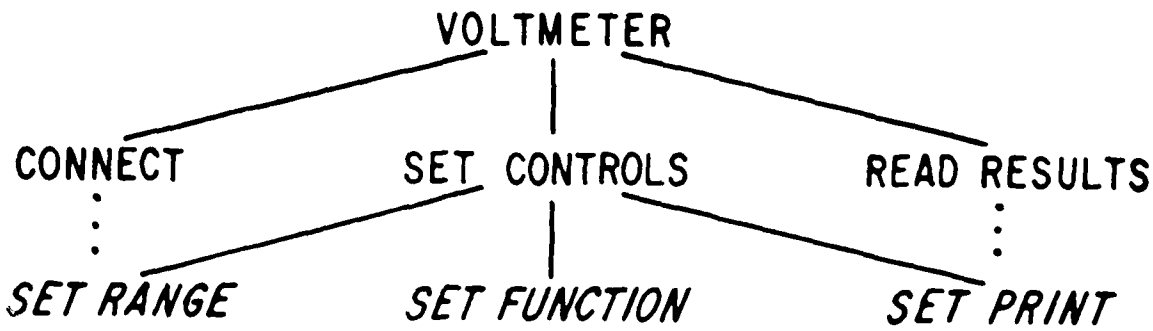
<u>Design Goal 4: Adapt the level of required interaction according to trainee achievement</u>. As a task was mastered, it became appropriate to support the chaining of common equipment actions. For example, consider the non-repertoire task of setting controls on a voltmeter to make a certain measurement. Assume the voltmeter had 10 controls and that three of these had to be set to make the measurement. Since the task

was not in the repertoire of the trainee, the task of setting the controls was represented in the task data base. That is, each control was treated as a separate equipment action and each control had to be selected explicitly on the task display before it could be set on the equipment display (see Figure 4).

After an adequate amount of practice, the task became familiar and it was no longer appropriate to force the trainee to plan separately for and then to make each control setting. It was appropriate to allow the trainee to select the goal "Set Voltmeter Controls" and then to go directly to the equipment display and make, in an integrated fashion, each of the control settings needed. In other words, the level of detail or graininess of the simulation had to be adapted to the trainee's level of competence. This was achieved through the use of a student model and run-time adaptation rules.

An individualized student model was built from a copy of the task names in the on-line task analysis data base; one for each trainee. The model was designed to be annotated with a record of trainee performance on each node and an indication of the current state of the node. After the trainee had correctly accomplished a node a given number of times, the state value for the node was increased. For nodes with task displays, the state values were specified as recognition, recall, performance, and summary. The run-time adaptation rules treated each of the nodes differently. For nodes in recognition, the menu was presented on the task display (i.e., decision alternatives were explicit). In recall, the menu was not displayed (i.e., alternatives had to be retrieved from memory). A node in the performance state caused all subordinate task display nodes to be ignored, while the subordinate terminal nodes (the equipment actions) had to be accomplished. Once a node reached the summary state, no further actions needed to be performed by the trainee; the results of the actions which would have been required were summarized.

In the example above, each time a trainee set a voltmeter control, performance on that task was recorded. Once the task was performed correctly a given number of times, the state of the control's node was changed and the task display changed. At first the student had to recognize from a list of controls the correct ones to set, select each control in turn, and perform the associated equipment action on the equipment display. As each control's node entered the recall state, each control still had to be selected, but its name had to be recalled from memory. In each of these states, the associated equipment action was taken only after the control was selected. Recording of student performance continued and after the criterion number of correct performances was reached, the state of the "Set Controls" node changed to performance. The next time the task "Set Controls " would have been encountered with its associated task display, no task display was presented; instead, all equipment displays under this node were run as a single, integrated equipment display without intervening task displays. Finally, when the set controls node reached the summary state, on selecting "Set Controls" the trainee received the message, "The voltmeter controls have been set properly for measuring the desired signal."



Training Sequence Before

1. Enter "Set up voltmeter"
2. Enter "Set range control"
3. Set range to 10
4. Enter "Set function control"
5. Set function to KOHMS
6. Enter "Set print control"
7. Set print to TRACK

Training Sequence After

1. Enter "Set up voltmeter"
2. Set range to 10
3. Set function to KOHMS
4. Set print to TRACK

As a consequence of demonstrated proficiency in setting voltmeter controls (left-hand training sequence), the system automatically adapts and subsequently permits the separate equipment manipulations to be chained together as one integrated equipment action (right-hand training sequence).

Figure 4. Chaining equipment manipulations.

To summarize, the task of setting the voltmeter controls was originally four separate task decisions, each followed by an equipment action. As soon as mastery of the separate component processes was demonstrated, the task of setting the controls became one single task decision followed by one single equipment action. Finally, no action at all was required since the trainee had already demonstrated complete competence. Figure 5 provides a picture of the nature of this adaptive approach. The overall effect of the student model was to adapt the level of required interaction according to trainee achievement, thus focusing trainee attention on unmastered portions of the task. This provided the potential for enhanced training effectiveness and reduced training time for completing a set of simulations.

Development of the IGS System

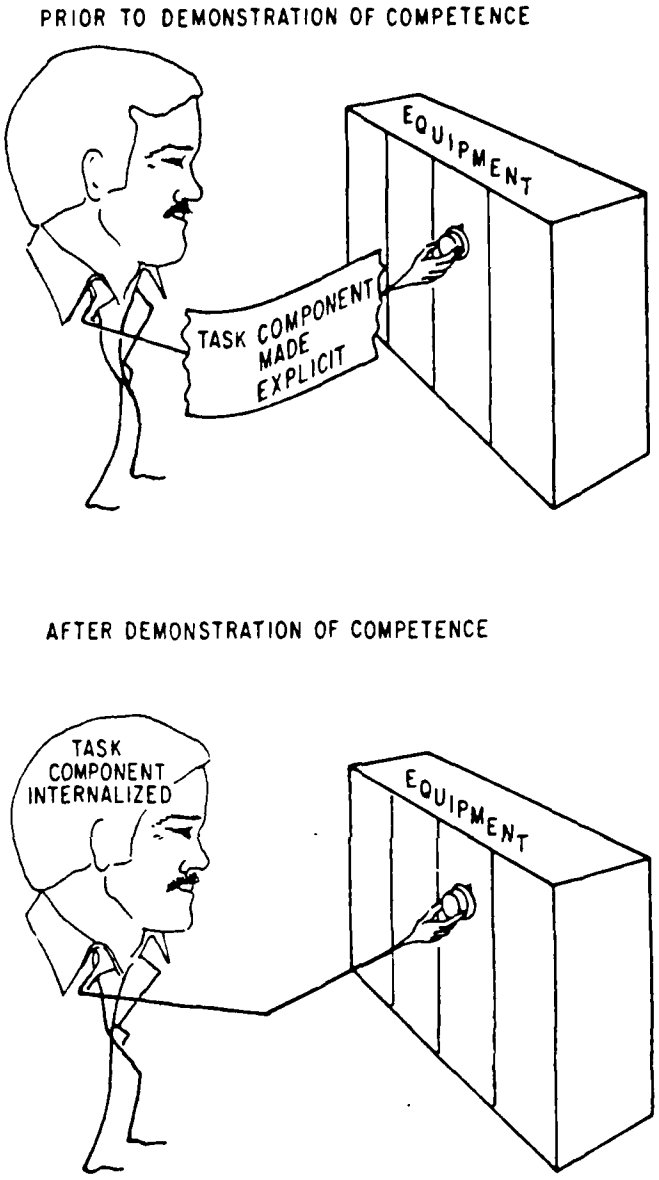
The IGS system developed in response to the design goals, consisted of two major equipment components, several software tools, and the initial task data base. The overall development philosophy was to develop the system on a large-scale computer and then, after determining exactly what equipment and tools were required, specify the characteristics of a stand-alone system. Conceptually, the system was organized into the problem-solving component and the equipment-manipulation component (i.e., the terminal and video monitor, respectively). The problem-solving component consisted of those system elements devoted to building, maintaining, and running all the items associated with the on-line data base except the simulated equipment manipulation actions. The equipment manipulation component consisted of only those items required for simulating the equipment actions.

The IGS Problem-Solving Component

The computer used for this component was a Control Data Corporation (CDC) Cyber system located at the Air Force Human Resources Laboratory (AFHRL), Training Systems Division, on Lowry AFB, Colorado. Some of the software tools already available on that system were used simply to avoid unnecessary duplication of development effort. The tools used included the existing text editor and the existing graphics editor. The tools developed specifically for the IGS system included a data base and simulation editor, a simulation run-time program, a student enrollment and data analysis program, and several print and report utilities. All of these programs were written in the CAMIL programming language.

The Global Task Hierarchy (GTH) editor program performed the functions of entering, deleting, renaming, and classifying tasks in the hierarchical data base. In addition, the program permitted the SMEs to specify which tasks were relevant to a particular simulation (i.e., problem protocol) and the order in which the tasks should be accomplished for that protocol. Finally, this editor was used to build the task displays with feedbacks and equipment displays. In essence, the GTH editor was the heart of the system.

The simulation run-time program used the task data base, the specific protocol task orderings, the task and equipment displays, and the student model to present the simulations to the trainees. The run-



Prior to demonstration of competence on a task component, the adaptive model requires the trainee to verbalize explicitly task planning and decisions before making the associated equipment manipulations. After competence has been demonstrated, the planning and decision structure has been internalized by the trainee, who may now interact with the equipment directly.

Figure 5. Adaptive simulation.

time program also updated the student model information and was the link to the videodisc-based equipment component.

The student enrollment program was used to specify courses and the set of problem protocols that made up each course. It was also used to specify whether or not the protocols were ordered and whether or not a protocol was required or optional. Finally, this program was used to enroll students, assign protocols to the student for each simulation session, and maintain total time and score records by student for each protocol worked.

Print utilities were developed for the task data base as well as the task choices for each protocol. In addition, a screen dump utility was developed for the detailed student performance records. Finally, a screen print routine was developed for the graphics used in the task and equipment displays.

The Equipment-Manipulation Component

This component of the IGS was assembled entirely of off-the-shelf commercial hardware. The computer used for the equipment-manipulation component was an Apple II microcomputer. This computer was augmented with five special cards to interface to other peripheral devices. The devices included a laser videodisc, a 15-inch color video monitor, a graphics overlay generator, a touch pad, and a medium-resolution color terminal. The software for this component was entirely originally built software. The primary programs included a system picture editor, a step file builder, a video graphics/text editor, two run-time programs, and several picture file utilities. All programming for the equipment component was done in assembly language and Pascal.

The system picture editor was used to develop a data base describing the contents of the videodisc. This data base was a structured data base reflecting the relationship of the separate pictures on the disc to one another. Each entry contained the name and the frame number of the picture, and the names of the pictures that were closeups of the elements of this picture. The program was used to create, delete, and name picture records and to identify touch pad coordinates of picture elements.

The step file builder was used to create files describing the sequence of touch pad coordinates and picture usage for a particular step associated with an equipment node used in a protocol. This program was not an editor, but simply a file creation program. The program took as input the system picture file and author touch sequences to build the desired step file. The program could specify both picture and motion sequences as elements of a step. In addition, a digitized graphic overlay could be specified by file name for use with a particular disc image.

The video graphic text editor was used to create and modify digitized graphic overlay files that could be superimposed on a video image using the graphic overlay generator. The generated files contained text and simple graphics and were stored on the microcomputer floppy disks.

The two run-time programs were the author run-time and IGS run-time. The author run-time program was used to check each of the step files for accuracy and completeness before using the step with trainees. This program took all input from the terminal keyboard and touch pad and ran the step without the associated problem-solving terminal displays. The IGS run-time program performed exactly as the author run-time except action was controlled by the problem-solving component in place of the keyboard. Both programs scored the student's performance on each step, noting whether the correct touch areas were used in the required sequence. The author program displayed the results on the terminal screen whereas the IGS run-time program transmitted the result to the Cyber computer system for use in updating the student model.

The file utilities included print programs for both the system picture file and the step files. In addition, a system picture check program and a fix program were developed for checking and maintaining the integrity of the system picture file. The remainder of the available file-handling utilities were those supplied with the Pascal operating system.

Development of the Task Data Base

The approach taken in the development of on-line task analysis was to build a skeleton task tree through traditional front-end analysis, employing the technique of hierarchical problem decomposition. The initial data base was then refined and filled out as a consequence of using it to build simulations.

After entering the skeleton tree into the task data base using the authoring editor, an attempt was made to create a simulation using what was available on-line to that point. The top node provided the first set of decision alternatives, which were adequate for assigning the first correct choices. As each correct choice was selected to be the new current node, new sets of decision alternatives were available and assigned as correct choices. Eventually a current node was reached for which one or more decision alternatives (i.e., children) were missing. At this point, the authoring editor was used to add children to the list of alternatives for the current node.

For example, suppose the only existing decision alternatives for the current node were "Complete Block Diagram" and "Check Signals." Further, suppose the protocol being developed required that a visual inspection be performed after completing the block diagram and before checking signals. Using the authoring editor, the new child "Perform Visual Inspection" was added to the list of decision alternatives for the current node. Once "Perform Visual Inspection" was available as a decision alternative, it was assigned as the second correct choice.

When "Perform Visual Inspection" was selected as the current node, no decision alternatives were available because it was a new node. At this point, new decision alternatives were added as children of "Perform Visual Inspection". Once the alternatives were added, they were assigned as correct choices, and the process was repeated. Through this

iterative process, the task data base was filled out and refined as a direct consequence of developing new problem protocols.

Since the menus that appeared at the bottom of each task display were read at simulation run time from the task data base, all changes to the data base affected even simulations previously developed. Each new decision alternative appeared automatically on the appropriate task display.

This approach to the development of the task data base for simulation had the major advantage of ensuring that the task data were always relevant to the simulations developed. The strategy was to let the demands of the simulations cause the on-line task analysis to grow. The task analysis represented by the task data base and the tasks emulated by the trainees were exhaustive and representative of the job to the same extent that the set of problem protocols used to develop the simulations was complete and representative of the job.

Summary of IGS System Design

The design and development of the IGS system was an attempt to successfully produce a training effectiveness advantage over traditional instructional approaches involving actual equipment and equipment simulators. The main feature of the system was focusing the simulations on the emulation of job tasks as opposed to equipment operation. A second feature of the IGS system was adapting the simulation presentations to student achievement. To do this, the structure of the simulations was altered in a way that focused trainee attention on unmastered tasks, eliminating unnecessary repetitive practice of learned skills.

The IGS system also provided instructional development assistance to the SMEs. Simulations were simply created by flagging a path through an on-line task data base representing the set of goals and actions employed in accomplishing the job tasks. This approach was robust enough to support the development of part-task simulations and alternative troubleshooting approaches.

III. IGS SYSTEM IMPLEMENTATION

Training Analysis

The purpose of the training analysis was to determine the most suitable role of the graphics simulator, considering the nature of the course in which it would be used and the instructional potential of the graphics simulator. The present section describes the rationale and impetus for many of the IGS design features presented in the previous chapter. It also presents the rationale for what was considered the optimal role for the IGS within the existing course structure.

The target block of instruction was Block IX of the F-111 Integrated Avionics Computerized Test Station and Component Specialist course (3ABR32634A) at Lowry AFB. This block taught the maintenance and operation of the 6883 Test Station, an intermediate level automatic test equipment stand.

The training analysis was performed using the standard Air Force course documents as a starting point. These included the course Plan of Instruction (POI), the Specialty Training Standard (STS), and the Lesson Plans. An outline of instructional topics was constructed identifying the training tasks addressed in the course documents. In the course of instruction, all of the test station and most of its associated Line Replaceable Units (LRUs) were covered. The two major areas of instruction were related to the two major types of LRU signals (i.e., analog and digital).

The organization of the curriculum featured presentation of theory followed by hands-on practice at the end of the block. Theory, function, and signal flow of Test station Replaceable Units (TRUs) were presented first for the analog units and then for the digital units. Hands-on practice in running the maintenance tapes for the test station (TS), the Feel and Trim (F&T) LRU, and the Multiplexer Converter Set (M/S) LRU was provided near the end of the block. The F&T was largely analog; the M/S, largely digital. See Table 1 for an overview of the time spent in the various Block IX units as listed in the course POI. Units 1 through 9 are the units covering the TRUs, while 10 through 13 contain practical exercises for the test station, as well as theory and practical exercises for the LRUs. The total course length was 72 hours or 9 days, with a total of 16 hours of practical excercises.

A series of interviews was held with the course instructors to identify the instructional process and ways the test station was used instructionally. The instructors also provided protocols for test station operation, including descriptions of the rationale for various steps.

The process of detailing such an analysis is always personnel intensive and time-consuming. The first tasks analyzed revealed that several of the equipment and decision steps were repeated across problems. For example, the oscilloscope was repeatedly set up to make time delay measurements and the digital voltmeter was repeatedly set up to make voltage measurements. The planning steps leading to the

Table 1. Block IX Units and Time Allocation

Unit	Title	Unit	Title
1.	Test Station (TS) Introduction T - 1 hour	8.	Signal Converter Unit T - 1.5 hours
2.	Switching Complex T - 6 hours	9.	Digital Interface Unit T - 1.5 hours
3.	Switching Control Unit T - 4 hours	10.	Test Station P - 12 hours *
4.	Flight Control System Adapter T - 4 hours	11.	Terminology T - 2 hours
5.	Signal Converter Simulator T - 8 hours	12.	Feel and Trim T - 8 hours P - 2 hours *
6.	Serial Digital Adapter T - 4 hours	13.	Multiplexer/Converter Set T - 9.5 hours P - 2 hours *
7.	Parallel Digital Adapter T - 1.5 hours		Misc Training and Testing 5 hours

T = Theory and Function P = Practical
* = AET and IGS training, totaling 16 hours

selection of these devices and the measurement of these signals were also analyzed in order to integrate commonly recurring steps in separate problems into a global, overall representation of the job. One outcome was the identification of the overall job logic (See Figure 6). The flow depicted has implicit decision points which became explicitly represented in the various simulations.

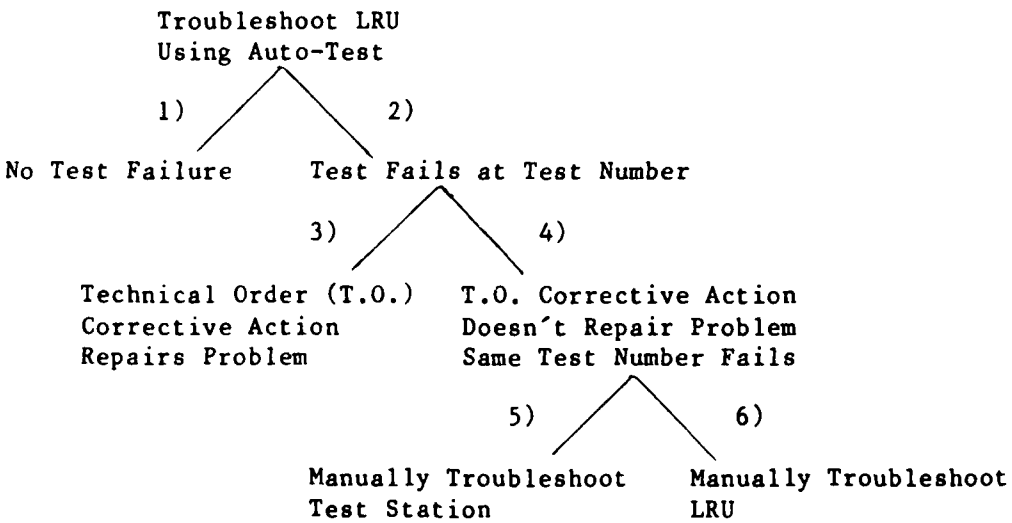


Figure 6. Job Logic.

A major organizing principle for the development of the troubleshooting simulations was discovered during the in-depth analysis of the equipment and instructor protocols. This was the concept of a test loop. A test loop consisted of the parts of the test station and LRU (if any) involved in a specific test. It covered the stimulus source, the stimulus switching, the stimulus switching logic, the test station/LRU interface, the LRU components, the response signal interface, the response logic, the response switching, and the measurement device. If a programmed test failed and the indicated repair action did not fix the problem, the technician usually began by determining which area of the test loop was involved. The test loop guided the manual troubleshooting process. Although the words "test loop" were identifed with regard to the 6883 Test Station, the test configuration implied above is common to many automatic test sets and is useful when manually isolating malfunctions.

In order to reinforce the test loop concept, the capability to color-code task displays by region of the test loop was added as a feature of the IGS system. This coloring scheme associated a unique color with each region on the test loop. The colors were presented as borders or frames around the task displays. For example, when a trainee was troubleshooting the stimulus portion of the test loop, task displays were bordered with a red frame. Task displays shown when troubleshooting the measurement device portion of the test loop were framed with blue. In the first simulation, the color-coding scheme was explained when trainees first saw the representation of the test loop and its seven regions.

A loose coupling of theory and practice was seen in the temporal ordering of units in the POI (See Table 1). As indicated above, the job logic involved two distinct types of activity: one consisting mainly of known sequential actions, requiring little or no understanding of the test station, and another being mainly problem solving, requiring great amounts of test station understanding. As the block was taught, the theory portions of the block were applicable to the problem-solving activities and were reinforced in workbook exercises. However, no formal practice involving the test station in these problem-solving activities was provided. Formal hands-on practice was largely limited to the fixed procedure activities. A Burtek Patch Panel Trainer (PPT) offered some part-task training in signal tracing in the switching components of the 6883 Test Station. Practice in the activities requiring knowledge of job logic was randomly available on the actual equipment (when it failed on its own accord), but could not be structured or organized for the purposes of training.

The lack of formal problem-solving instruction in daily classroom training indicated a need to support troubleshooting practice on a daily basis. If the IGS was to have an impact on training effectiveness, it had to do more than simply represent the equipment actions. It also had to represent the cognitive activity needed for troubleshooting competence on the job. Improvement in the course was judged achievable if the identified omissions in the course organization could be filled with simulator lessons. Operating within the constraints of the identified role of the simulator required that these lessons be

available within the course's current curriculum and daily activity plans.

The theory part of the block was augmented with simulations which provided part-task practice with the TRUs under study. This practice was provided using a troubleshooting problem scenario in which a failure had been isolated to a particular TRU. Hence, practice in situations involving the need for theoretical/functional understanding was provided at the time theory was taught. Formal maintenance tape practice sessions, at the end of the block, were augmented to include both fixed procedures and problem-solving activities.

The requirement of daily work on the IGS precipitated a study of classroom time allocation. The analysis included classroom activities and equipment utilization. The instructors were asked to reply to an informal survey of how their time was spent each day in an average classroom week. The instructors indicated that the principal activities were reviewing, lecturing, and demonstrating. They reported the approximate proportion of time devoted to each of their activities (see Table 2).

Table 2. Overall Percentage of Classroom Time Use in Block IX

Lecture and Review	30%
Practical	20%
Homework Review	18%
Workbook	15%
Break	12%
Other	5%

From the percentages in Table 2, the necessary time for IGS use could be obtained during the normal 8-hour classroom day. Using the "Practical" time (approximately 90 minutes) and some of the "Homework Review" time (approximately 10 minutes), a total of approximately 100 minutes would be available each day. Over the 9-day block, this would amount to approximately 900 minutes or 15 hours, the same amount of time set aside in the regular course for hands-on AET experience. Assuming a nominal 20 minutes per simulation, four students per class (the average), and two IGS systems in the classroom, each student could take two simulations each day within the available time. Maintaining the overall 15 hour time limit for practical exercises was the desired goal; therefore, adjustments to insure that a slow IGS student did not get more time on the simulations would be made by reducing the number of simulations worked. Conversely, an IGS student who was quick would be permitted to work additional simulations in the remaining available time. Additional information on time usage in the IGS treatment is presented in Section IV, Evaluation.

Simulation Development

Based on the training analysis presented in the previous section, a set of simulations was developed to support the existing POI, and to replace the hands-on AET experience normally given at the end of block IX. The simulations began with part-task protocols supporting the training of theory and functions emphasized in the early portion of the block. The simulations ended with whole-task protocols supporting the practical training emphasized near the end of the block.

A team of Air Force instructors was asked to cover each objective in the POI by selecting a set of faults on which representative simulations would be based. For each fault, the instructors were asked to write out a troubleshooting protocol. These protocols were paper-and-pencil "story boards" of the problem scenarios and model diagnostic procedures to be followed in isolating the respective faults. Initially, contract personnel used these protocols to begin building the on-line task analysis data base, and from it, the sequence of decision points which constituted the core of the simulations.

Just exactly what the correct or preferred diagnostic procedures were for a given protocol was often the subject of heated debate among the members of the Air Force team. In general, differing points of view held by the SMEs were brought into a consensus through extensive discussion, argument, and counterargument. Soon after contractor personnel developed the initial on-line hierarchical task data base for 6883 Test Station maintenance, Air Force instructors began generating new protocols on-line rather than with pencil and paper. The process of on-line task decomposition and data base development was previously described in Section II.

In addition to the sequence of decision points which defined each simulation; text displays, feedback messages, and associated videodisc sequences were developed. The Air Force SMEs were the only sources of information for most of this material and were responsible for quality assurance, both in terms of the logical consistency of the on-line task analysis and in terms of editorial modifications to input text. Table 3 summarizes, by day, the series of simulations developed in support of the POI objectives. Appendix A contains screen prints of a representative simulation.

Development Effort

The effort needed to develop each new simulation consistently decreased. The main reason for this was that the on-line task analysis, which supplied the decision points for all simulations, became more and more complete as each simulation was developed. As a result, less and less effort was needed to expand the on-line task analysis data base. Since each new simulation used major portions of the hierarchy already developed, less and less new material needed to be added. For the early simulations, the majority of the simulation development effort was expended in building the task data base. This required much more effort than did the creation of the associated presentation material (i.e., text displays, feedback messages, and videodisc image sequences).

Table 3. Simulations for IGS Instruction

Day	POI Topics	Simulations
1	Introduction and Switching	PRTCL10: Part-task, Fault = Switching Relay II/044 PRTCL12: Part-task, Fault = Stimulus Relay 10/1
2	Switching Control Unit, Flight Control System (FCS) Adapter	PRTCL7: Part-task, Fault = Switching Relay I/031 PRTCL4: Part-task, Fault = Stimulus Relay 02/1 PRTCL11: Part-task, Fault = Switching Control Unit PRTCL15: Part-task, Fault = FCS Adapter
3	Signal Converter Simulator (SCS)	PRTCL13: Part-task, Fault = 3-wire Test Point Relay
4	Serial/Parallel Digital Adapter, Signal Converter Unit Controller, Digital Interface Unit(DIU)	PRTCL14: Part-task, Fault = SCS A41 Card PRTCL16: Part-task, Fault = SCS Decoder or Transfer Board PRTCL17: Part-task, Fault = Digital Interface Unit Output Card PRTCL18: Part-task, Fault = Serial Digital Adapter
5	Maintenance Tapes I and II	PRTCL19: Whole-task, Fault = Micrologic P/S A1 Card PRTCL20: Whole-task, Fault = DATAC PRTCL21: Whole-task, Fault = Test Point/Stim Relay PRTCL22: Whole-task, Fault = A2/A9 12vdc Breaker PRTCL23: Whole-task, Fault = Digital Drawer PRTCL24: Whole-task, Fault = A2A3A21
6	Feel and Trim	PRTCL1: Part-task, Fault = Test Point Controller A37 PRTCL2: Part-task, Fault = Phase Sensitive Converter PRTCL5: Part-task, Fault = Stimulus Relay 03/8 PRTCL8: Part-task, Fault = Signal Generator A28
7	Feel and Trim Maintenance Tapes	PRTCL6: Whole-task, Fault = Center Relay Package K48 PRTCL25: Whole-task, Fault = None PRTCL9: Whole-task, Fault = Signal Generator TB3 PRTCL26: Part-task, Fault = Lower Relay Panel
8	Converter Set Maintenance Tape	PRTCL27: Whole-task, Fault = None PRTCL28: Whole-task, Fault = Converter Set
9	Converter Set	PRTCL3: Whole-task, Fault = Converter Set PRTCL29: Whole-task, Fault = Converter Set

The effort required to develop the presentation material was basically constant since it needed to be newly developed for each step in each simulation. Overall, the development effort was split approximately 50-50 between task data base and presentation material development.

To summarize, the effort required to build a series of simulations had two basic parts. The effort associated with building the on-line task data base continually decreased as more and more simulations were developed. The effort associated with flagging the correct path through the task hierarchy and annotating the path with associated text displays, feedback messages, and videodisc display sequences remained almost constant.

Videodisc Data Base Development

The equipment display used a combination of videodisc images and graphic overlays to represent actual equipment. The videodisc medium was chosen for its large, random access storage capacity at reasonable cost. The graphic overlays were added to represent specific equipment states as required by individual lessons; for example, to change the value of a digital voltmeter display. The videodisc image base was composed of over 20,000 still frames and appropriate motion sequences used to represent various test station states and to demonstrate the attachment of LRUs, adapters, and cables.

In addition to the equipment images accessible from the videodisc, several internal equipment processes, which the instructors "picture" when working on a problem, were needed to complete the image data base. Many of these added images were dynamic in nature and were better suited to representation on the interactive graphics terminal (e.g., wave shapes) rather than the videodisc. These images covered both process visualizations and dynamic equipment interactions and, therefore, were constructed on the graphics terminal using a graphics editor.

The images included in the videodisc image data base were selected by experienced Air Force Training Command (ATC) instructors considering the proposed IGS content. A filming schedule of test station and LRU component images was developed. This schedule included images of the overall test station, of the four test station bays or racks, and of individual TRUs. Switches, dials, meters, display windows, representative fuse holders, and test points on the TRUs were also included. In addition, LRU adapters, cables, and "black boxes" were scheduled to be photographed. Finally, components within TRUs and LRUs (replaceable boards as well as components attached to the boards) were included as necessary.

A 16-mm movie camera, set on single-frame exposure except for a few motion sequences, was used to photograph the test station according to the filming schedule. The 6883 Test Station located on Lowry AFB was used for all photography. Multiple exposures of each shot were taken to bracket calculated exposures. A photographer, schedule coordinator, and SME (i.e., an ATC instructor) accomplished all photography.

The resulting 16-mm film was processed and run on film editing machines to inventory each frame. A picture catalog of numbered frames was prepared for use during development of the simulations. The film was then transferred to video tape and finally, to videodisc.

A videodisc image data base was built using the picture catalog with frame numbers. Simulated equipment manipulation sequences were built from the data base for use by the students at various points in the lessons (i.e., problem protocols). Graphic overlays were added as needed. These overlays allowed lesson developers to add meter readings, switch settings, light bulb and fuse holder illumination, and other visual cues onto videodisc images as appropriate for specific lessons.

Simulation Adequacy

Several attributes of the simulations and their development provided confidence in the adequacy of the simulations. First, the simulations were developed by Air Force SMEs and were closely tied to an approved course POI. In addition, the SMEs reached consensus concerning the appropriate diagnostic approach employed in each simulation.

There are two basic ways to establish the acceptability of instructional material. By far the most common is to have the material reviewed and critiqued by a panel of SMEs and to arrive at a group consensus about the form and content of the material. The second way to establish acceptability, in accordance with ISD procedures, is to:

1. articulate, in advance, the objectives for the material
2. develop an independent measure of objective mastery
3. use the material to train naive subjects
4. test after training for objective mastery

In the case of the IGS materials, SME group consensus was considered adequate for determining materials acceptability.

IV. EVALUATION

Overview

Evaluation of the IGS system covered three major areas: Training Effectiveness, Environmental Suitability, and Cost. The first part of this section describes the evaluation components and the second section presents the evaluation results.

Training block IX of the Integrated Avionics Computerized Test Station and Component Specialist (3ABR32634A) course of instruction was assigned as the target of this study. This 9-day block covered operation and maintenance skills for the 6883 Test Station. The training emphasized development of diagnostic and procedure-following competence. This block of instruction was administered to two treatment groups, instructionally similar except for the training device used.

The control group used an actual equipment trainer (AET) as prescribed by the course POI. During the last 2 days of the 9 days of instruction, the AET was used to provide approximately 15-16 hours of hands-on experience in performing prescribed procedures and diagnostic testing.

The experimental group used the IGS in place of the AET. The IGS was used throughout the 9-day block, to provide practice in following prescribed procedures and solving troubleshooting problems. Instructors limited IGS contact time to approximately 100 minutes per day, as described in Section III. Any adjustments, required to stay within the time limit, were made by reducing the number of simulations worked. Therefore, both IGS and AET students received a total of approximately 16 hours of training on their respective training devices.

Two tests, unique to this study, were specially developed to measure the capabilities of the two treatment groups: an actual equipment hands-on test of precedure-following capability, and a paper-and-pencil test of troubleshooting reasoning competence for equipment-specific fault isolation problems. A projected job proficiency test from a previous study and the normal end-of-block test were also used to measure each student's competence. Finally, student opinions were surveyed. AET and IGS equipment costs were compared and IGS suitability to the training environment was evaluated.

Evaluation Components

This section presents descriptions of the two experimental treatments, of the evaluation test instruments, of the subject assignments to treatment groups, of the testing schedule, and of the data collection.

Experimental Treatments

The AET control treatment included, classroom training using the standard instructor POI and AET (i.e., the 6883 Test Station) hands-on training during the last two days of instruction block IX.

The IGS experimental treatment included classroom training using the standard instructor POI and hands-on training using the IGS system (i.e., both the problem solving and equipment manipulation components). The primary difference, other than the nature of the practice simulations on the IGS, was the IGS daily distributed practice (100 minutes for 9 days) rather than the AET massed practice (8 hours for the last 2 days).

The number of trainees available for the study in the avionics maintenance career path (AFSC 3ABR32634A) was 43. Because of the low number of trainees, the experimental treatments were limited to: AET training with no IGS system contact and IGS training with no AET system contact.

Training Modes

AET training. AET training for the 3ABR32634A course instructional block (Block IX) consisted of 7 days of classroom instruction and 2 days of practical instruction on the 6883 Test Station (Table 4). The 7 days of classroom instruction consisted of stand-up lecture, chalkboard diagramming, and workbook problem assignments. During this instruction, the students were taught about the test station Replaceable Units (TRUs) and the aircraft Line Replaceable Units (LRUs) that the test station checked. The lecture and chalkboard instruction focused primarily on the electronic circuitry, programming, and component identification of the TRUs and LRUs. The workbook problems stressed troubleshooting procedures and processes. Samples of the workbook troubleshooting problems are included in Appendix B.

Table 4. Instructional Approach by Training Mode

Objective		Training Mode: Actual Equipment		Training Mode: IGS
Instruction in equipment familiar	7 days	Stand-up lecture Chalktalk Workbook assignments	9 days	Stand-up lecture Chalktalk Workbook assignments
Instruction in troubleshooting techniques	7 days	Workbook assignments	9 days	Workbook assignments IGS simulations
Instruction in equipment operation	2 days	Hands-on operation of 6883 test station	9 days	IGS simulations

The practical portion of the AET training consisted of 2 days of equipment operation. Due to restrictions on inducing failures in the 6883 Test Station and to the fact that operational equipment was not designed to function as training equipment, the role of the AET during the practical instruction was primarily one of performing equipment operational checks without failures. Although the actual equipment is operated by a single technician in the field, the limited number of test stations in the classroom (only one), together with safety and cost considerations, necessitated a group approach to the practical exercises. This approach was used by the AET group during the entire evaluation period.

The AET 7-day classroom/2-day practical training approach was selected by ATC after considering other alternatives. At one point, classroom training was conducted in the test station equipment laboratory in order to permit distributed practice on the AET over the entire Block IX training period. This distributed-practice approach was subsequently rejected in favor of the current 7-day/2-day massed-practice approach. In addition, the massed-practice approach was used in all AET related blocks of instruction prior to Block IX. The AET massed-practice approach was considered by ATC to be the most practical and was the approved approach.

IGS training. A similar standardized IGS format was implemented for Block IX training. IGS training was identical to AET training in several ways. The same POI served as the guide to sequencing the training topics and activities. Also, the IGS students had the same overall time in instruction (9 days), used the same study guides and technical orders, received the same chalktalk for programming and diagramming examples, used the same workbook problems for troubleshooting procedures and processes, and had the same amount of time per class for practical test station instruction (16 hours or 2 days).

The principal difference between IGS and AET training, besides the use of the IGS to replace the AET, was in the content of the practice problems and their usage pattern. As described in Section III, the simulations were part- and whole-task job samples containing both the cognitive elements and the equipment manipulation aspects of 6883 Test Station operation and maintenance. In general, the problems were troubleshooting problems typical of those found on the job. Usage of the problems was distributed throughout the 9-day training period instead of being massed during the last two days. This approach was selected to make optimum use of the IGS system capabilities and to effectively integrate them into the training curriculum.

Initially, 27 simulation protocols were developed. After pilot testing the protocols, it was determined that the average protocol would take approximately 45 minutes. Assuming two students per IGS class (i.e., one-half of the usual 4 students per class), each student could work only one protocol per day in the 100 minutes available. This would mean that a total of only nine protocols could be worked during the 9-day block. Since a consistent set of protocols was desired for all IGS students, 11 of the 27 were chosen for use during the evaluation

period. The 11 protocols were chosen to maximize coverage of the test station components, to support daily teaching objectives, to include both part- and whole-task protocols, and when there were conflicts, to support instructor preferences. Once chosen, the protocols were sequenced in accordance with daily teaching objectives and all students took the problems in the same order.

Two IGS student stations were installed in the classroom to insure that each student would receive 45 minutes of simulation practice each day even if there were four students in an IGS class. Students operated the IGS stations on an individual basis. No contact with the 6883 Test Station was permitted for the IGS trainees. While two students each operated a separate IGS station, the remaining students (maximum of two in any class) solved workbook problems at their desks until it was their turn to use the stations. Using this approach, IGS-trained students could be perceived as having had more troubleshooting training than AET students. However, no IGS students had any actual equipment operational procedures training. IGS student practical training consisted of 6883 simulated equipment manipulation and troubleshooting exercises using the IGS.

The number of students who took IGS training was 21. Of these, classroom training data was lost on three students due to a computer crash and backup failure. Of the remaining 18 students, one completed only the first three protocols (PRTCL10, PRTCL11, and PRTCL14) of the eleven available. Four students completed three additional protocols (PRTCL18, PRTCL19, and PRTCL8), for a total of six. Approximately one-half of the IGS students (10) completed a seventh protocol (PRTCL6). One student completed the eigth protocol (PRTCL17) and two students completed all protocols through the ninth protocol (PRTCL1). The maximum number of protocols worked by any student was nine.

As discussed in the intoductory chapter, this project adopted the goal of using simulators to emulate not only the equipment but also the task decisions made by the skilled maintenance technician. Thus, the optimal role of the IGS system was seen as providing both troubleshooting and simulated equipment manipulation training distributed over the 9-day period of the block. In this format, the IGS simulations were enhancements to the daily objectives of the POI (ref. Table 3).

Test Instruments

In the training effectiveness analysis, several measurement instruments were used. These included existing measurement instruments developed and administered by the Air Force and measures developed by the Denver Research Institute (DRI). This section describes all the measurement instruments, including the rationale behind their development.

Air Force test instruments. The following test instruments were developed either by the Armed Services or by the Air Force. Administration of these measures to evaluate subjects was the sole responsibility of the Armed Services or the Air Force.

The Armed Services Vocational Aptitude Battery (ASVAB). The ASVAB is a DoD multiple-choice paper-and-pencil test instrument developed jointly by all the Armed Services. The ASVAB is composed of 10 subtests that measure various types of aptitudes. The services combine these subtests in different ways to form composite scores used for selecting and classifying enlistees. The Armed Forces Qualification Test (AFQT) composite test score was designed to assess the general training potential of military enlistees and is primarily used for initial service selection by all services.

The Air Force uses the following ASVAB composite or aptitude index scores for job selection and classification: General, Mechanical, Administrative, and Electronics. Students entering the 3ABR32634A course generally require a minimum electronics score of 80, although waviers are permitted for cross-trainees and other special cases. The ASVAB is administered by a trained test administrator from one of the military services at the time of initial enlistee screening. A detailed description and development of ASVAB Forms 8,9, and 10 is found in Ree, Mathews, Mullins, and Massey (1982) and in Ree, Mullins, Mathews, and Massey (1982).

Instructional Block Test. This end-of-block test is designed to measure how well students have learned the material presented in the classroom during specific instructional blocks. It is a pencil-and-paper, multiple-choice test developed by ATC instructor personnel. This test is normally administered by the classroom instructor on the last day of each instructional block.

IGS evaluation test instruments. Test instruments were designed and developed by DRI to measure performance of Air Force subjects involved in this study. Although DRI personnel were involved in the design, development, and evaluation of the IGS system, those individuals involved in developing the measurement instruments and conducting the evaluation were not involved in the design or development of the IGS system or its simulations. The DRI test instruments were administered to all evaluation subjects on the day after the Block IX end-of-block test.

Procedures Test. This measurement instrument is a hands-on test designed to determine the extent of the students' facility in operating the 6883 Test Station. The test was developed by assembling a pseudo-operational procedure for the test station. Elements of many different technical order procedures were combined into a single procedure which the student follows. The elements were chosen in a way which maximized the number of TRUs operated, and required both front-panel actions (i.e., setting controls, reading meters, etc.) and internal test station operations. In addition, the student is required to interface an LRU to the test station as though an actual checkout were being performed. Every effort was made to incorporate a representative sample of all possible field-type operational actions for the test station.

This test is most closely associated with the practical portion of AET training and with many of the equipment display interactions of IGS training. No troubleshooting was required or intended in this test. The test is composed of 12 distinct segments, each requiring the student to perform a set of equipment manipulations, and then to identify and explain the resultant equipment indications (meter readings, visual discriminations, etc.). Of the 55 test items which comprise the Procedures Test, 19 of them, are unique to the 6883 test station (i.e., require equipment manipulations related to TRU and LRU components found only on the 6883 test station). The remaining 36 test items require programming, switch setting, meter reading and other basic activities related to common TRUs such as DATAC, digital voltmeter, and oscilloscope. A 45-minute maximum time to completion was set for this test (see Appendix C).

Troubleshooting Test. This 2-hour pencil-and-paper test was designed to measure how well subjects can troubleshoot test station malfunctions, by logically analyzing problems and applying their understanding of test station operation (including signal flow and component TRUs). In a recent report (Cicchinelli, Harmon, Keller, & Kottenstette, 1980), 24 avionics maintenance personnel identified these skills as highly relevant to 6883 Test Station training and job performance. The 2-hour time period was considered sufficient for sampling troubleshooting skills and knowledges typical of the operational field environment.

The test was developed by DRI staff with assistance from experienced ATC instructors. The test consists of six separate problems with a varying number of subparts, for a total of 31 items. During development of the items, care was taken to pattern the problems after those presented in the student workbooks (See Appendix B for samples of workbook troubleshooting problems.) This was done in order to ensure that the problems were of a type and in a format that both the actual equipment and IGS trainees had worked during training. Care was also taken to ensure that none of the items duplicated workbook problems or problems presented in IGS simulations. Finally, every effort was made to ensure that the problems did not include an explicit troubleshooting methodology taught in either the AET or IGS training regimes.

In place of the pencil-and-paper test, troubleshooting competence could also be measured by a hands-on AET troubleshooting test. This approach was not used for two reasons. First, it is desirable to separate the physical performance tasks (equipment familiarity and equipment procedures proficiency) from the highly cognitive troubleshooting skills. Hands-on AET/IGS troubleshooting confounds these. Second, in the limited time available for testing subjects, very little data on troubleshooting competence could be collected from an AET hands-on troubleshooting test. The set-up and testing of six faults on the actual equipment would have taken up much more time than the students had available for testing. AET troubleshooting testing would have forced consideration of fewer troubleshooting problems, possibly only one, which would have greatly reduced the amount of data collected and the test reliability. The paper-and- pencil test allowed the testing of troubleshooting reasoning on six distinct problems, rather

than just one or two available with an AET hands-on troubleshooting test. The 2-hour maximum time for completion was set for this test in order to stay within the testing time requirement provided by the school. (See Appendix C-1.)

Projected Job Proficiency Test (PJPT). This test was used in a previous 6883 simulation evaluation study (Cicchinelli et al., 1982). The PJPT was designed to assess the possible impact of training on actual job performance. Since a field follow-up of subjects could not be incorporated into the evaluation plan, due to cost and time limitations, this test was included. The primary rationale for this test was to determine whether students are knowledgeable about basic electronics to the level expected by field personnel. Development of the test was based on a job proficiency criteria analysis which had been used to solicit questions from field supervisors reflecting the level of knowledge expected of new technicians. From 75 items received, a 35 item pencil-and-paper multiple-choice test was developed. The PJPT was administered with a 45-minute time limit (See Appendix C-3).

All performance evaluation test instruments were administered to a limited number of Air Force students before initiation of the evaluation effort. The full battery of tests was administered to a Block IX class (N=4) to identify problems in test administration or in test item clarity.

Student Sample and Assignment to Groups

The total subjects included 1 female and 42 male students, of which 22 were AET trained and 21 were IGS trained. Sex distribution across treatments was not an issue in treatment assignment.

Two early classes (total number of students = 5) were randomly assigned by class to each of the two treatment conditions. Once it was determined that the anticipated student flow would be low, all other experimental subjects were assigned to treatment groups on an individual basis. Each entering class was divided into two separate treatment conditions -- AET training and IGS training -- each with its own instructor. Assignments were made in proportions required to maintain treatment assignment equivalency. For example, an entering class of 4 students resulted in 2 students each being randomly assigned to the AET and IGS treatment conditions.

No attempt was made to match students to experimental treatments based on aptitude test scores or prior instruction block scores. Previous analyses of these measurement instruments (e.g., Cicchinelli et al., 1982) showed that performance on these measures has only modest correlation with performance in the 6883 Test Station block of instruction. However, as part of the data analysis, scores on these measurement instruments and scores on the prior block tests were analyzed to confirm that student comparability or random subject sampling did exist in subject assignment to treatment groups.

Instructor Assignment to Groups

Some of the 6883 Test Station instructors at Lowry AFB were assigned to the ATC Special Projects Office. Personnel in this office were involved in the IGS project throughout the design, development, and evaluation phases. Instructors from this office taught the IGS treatment during the evaluation. Other ATC 6883 Test Station instructors, with no connection to the Special Projects Office, taught Block IX using the AET. Therefore, in both treatments, training delivery to students was provided by instructors highly familiar with and partial to the training approach used. Two Special Projects Office instructors each taught one-half of the 21 IGS students (11 students and 10 students). One of the four AET instructors taught 12 of the 22 students. The other three instructors taught the remaining 10 AET students (4, 4, and 2).

Testing Schedule

All evaluation performance measurement instruments were administered on a day specifically set aside for this purpose. This day immediately followed completion of the 6883 Test Station block of instruction (Block IX) and the ATC end-of-block test. Students were given the two pencil-and-paper tests (PJPT and Troubleshooting Test) according to a schedule that permitted ongoing administration of the Prodedures Test to students on an individual basis. This schedule was approved by both ATC and AFHRL.

Data Collection

Data collection and analysis were planned and managed by DRI personnel. The troubleshooting and PJPT pencil-and-paper tests were administered and monitored by ATC instructor personnel, while DRI personnel administered the hands-on 6883 procedures test. All test scoring and data analyses were performed by DRI personnel. This approach ensured consistency of presentation and scoring, as well as, evaluation testing and course instruction independence.

Evaluation Results and Discussion

The results of the evaluation are presented for training effectiveness, environmental suitability, and cost. The emphasis of the evaluation was on the effects of differences in training approaches on student performance. This section focuses on analysis of student performance on the three primary test instruments.

Training Effectiveness

Based on the goals of this study, the design of the IGS system, the simulations developed, and the manner in which the IGS simulations were integrated into and coordinated with the course and its POI, several hypotheses were investigated:

Hy 1 - IGS and AET training result in equivalent student performance on the standard ATC block test.

Hy 2 - IGS and AET training result in students' acquiring an equivalent ability to perform operational procedures on the 6883 Test Station.

Hy 3 - IGS and AET training result in students acquiring an equivalent ability to solve common troubleshooting problems.

Hy 4 - IGS and AET training result in students solving common troubleshooting problems with equivalent speed.

Hy 5 - IGS and AET training result in students acquiring equivalent job-related experience.

No performance difference was expected a priori on any of the criterion measures.

Background and pre-6883 training measures. Aptitude tests (ASVAB and AFQT) did not show significant differences between training modes. This was not surprising since students in the 3ABR32634A career field had been preselected according to these test instruments. Therefore, varability among students on these measures was diminished. (See Table D-1, Appendix D for a summary of aptitude test results.)

Prior instructional block performance scores did not reveal significant differences between training modes either. This was also to be expected, since the 6883 Test Station instructional block is the ninth block of instruction in the course. Slower students who might have provided performance variability would likely have been reassigned to another career field by this point in the training program. In addition, the avionics electronics career field is especially difficult; therefore, those students who are admitted are, overall, students of comparably high ability. (See Table D-2, Appendix D for a summary of Block I - VIII end-of-block test scores.)

Block IX training. Several measures were employed to identify potential performance differences based on the training treatment. The end-of-block test administered by ATC personnel, the pencil-and-paper Troubleshooting Test, and the hands-on Procedures Test comprised the 6883 training performance assessment battery.

The end-of-block test results analysis addressed the question of whether students received comparable training regarding the 6883 Test Station and its theoretical operation, the issue addressed in Hypothesis 1. Results of this test did not reveal significant differences between training modes (Table 5). Mean scores for AET-trained students (84.4) and IGS-trained students (86.3) did not differ significantly [$t(41)=0.70$, $p<.49$].

The Procedures Test was developed to assess student ability to manipulate the actual equipment. Analysis of the results of this test addressed Hypothesis 2. The difference in mean scores for AET trainees

Table 5. Evaluation Test Instruments Results

Performance Measure		Training Mode AET	IGS	t-Value
Converter Flight Control End-of-block Test	N	22	21	0.70
	X	84.4	86.3	NS
	s	9.79	8.16	
Procedures Test Performance Score	N	22	21	1.10
	X	41.8	43.5	NS
	s	5.11	5.30	
Procedures Test Performance Time (in minutes)	N	22	21	0.50
	X	38.9	40.8	NS
	s	7.10	15.21	
Troubleshooting Test Performance Score	N	22	21	3.00
	X	14.95	17.76	p<.005
	s	3.03	3.11	
Troubleshooting Test Performance Time(in minutes)	N	22	21	0.24
	X	82.19	83.89	NS
	s	20.91	22.91	

(41.8) and IGS trainees (43.5) revealed no significant difference between training modes [t(41)=1.10, p<.28; Table 5]. Results of the analysis indicate that the students showed no detectable difference in their ability to manipulate actual equipment, regardless of training mode. This finding was consistent with the expectation that AET-trained students and IGS-trained students would perform similarly on this measure. The implication is that generic experience with actual equipment (e.g., on prior test stations) and equipment manipulation training via interactive videodisc were sufficient conditions for students to gain procedural familiarity with actual equipment.

Time to completion was also tracked for the Procedures Test. Mean times for AET students (38.9 minutes) and IGS students (40.8 minutes) showed no significant difference between training modes [t(39)=.50, p<.62]. Although the means were not significantly different, the IGS students showed somewhat greater variability in time usage than the AET students. This result is not unexpected since the AET students had consistent exposure to the equipment during their practical exercises, while the IGS students had not seen the physical device prior to taking the test. The relatively equivalent Procedures Test performance, on score and time measures, for both student groups; indicates that the

groups were not detectably different in their ability to operate the 6883 Test Station.

The Troubleshooting Test was developed to measure the ability of students to diagnose electronic faults in 6883 test station TRUs and LRUs. The analysis of student performance on this measure addressed Hypotheses 3 and 4.

Analysis of the Troubleshooting Test scores revealed a significant difference between the two training modes in solving troubleshooting problems (Table 5). The mean scores were 14.95 for AET students and 17.76 for IGS students. The significant finding [$t(41)=3.00$, $p<.005$] permits rejection of the hypothesis that the two training regimes produce graduates of equivalent troubleshooting ability.

Time to completion was also recorded for the Troubleshooting Test. Mean times for AET and IGS trained students (82.2 minutes and 83.9 minutes, respectively) were not significantly different [$t(41)=.24$, $p<.81$]. Therefore, performance of the AET and IGS students was not detectably different in terms of the time required to solve the problems.

Several possible explanations for the significant performance difference in troubleshooting accuracy were considered. First, troubleshooting practice problems were available to IGS-trained students from two sources: the student workbooks and the IGS system lessons. AET students received troubleshooting problem practice from student workbooks and diagnostic testing practice during the practical excerises at the end of Block IX. Still, IGS-trained students could be perceived as receiving more troubleshooting practice than did AET students.

Second (as described in Chapter II and illustrated in Appendix A), decision making (i.e., the cognitive component of troubleshooting) and equipment manipulation continually alternated in the IGS simulations (as is the case in actual troubleshooting performance). Students get a chance to apply their problem-solving conclusions (e.g., that a certain measurement should be made based on a just-completed line of reasoning) as soon as they are reached. Thus, cognitive problem solving and equipment manipulation mutually reinforce each other, and do so in context. This may have yielded a degree of reality or relevance to the troubleshooting problems that was lacking when troubleshooting problems were worked out in a workbook in isolation from the equipment, as was done in the AET training.

Third, the IGS system was interactive, providing reinforcement, feedback, and prompts. This means that the system required the active participation of the student in order to progress through a simulation. Active engagement was enforced. In the first class of the IGS treatment, it was noticed that some students were merely entering the decision alternatives (presented in recognition mode), one after another, until they found the correct one. This is a low-effort strategy, not requiring the active participation of the student. The IGS software was then modified to cause the terminal bell to ring when a student made a wrong selection. At this signal, the instructor would

come over and ask if the student needed help. After this bell was installed, the students applied themselves to figuring out the correct alternative at each choice point (i.e., guessing stopped). This had the effect of increasing the students' level of participation.

Fourth, the IGS treatment employed an individualized training approach during use of the simulations (vs. the group training approach for AET training). The individual approach to IGS system operation for problem analysis and solution may reinforce development of a troubleshooting strategy better than, solving workbook problems through individual effort with group rewiew and critique followed later by group training on the AET, the approach used for AET training.

Beside treatment considerations, test format and content were considered as possible explanations of the difference in troubleshooting mean scores. One possibility was that, the problems developed for the Troubleshooting Test reflected the types of practice problems encountered by IGS students better than those encountered by AET students. However, this explanation was rejected for several reasons: (a) further analysis of student performance on the Troubleshooting Test showed that IGS students performed consistently better on each of the six test problems than did the AET students; (b) the Troubleshooting Test was developed by individuals, from both ATC and DRI, who had no familiarity with the content of IGS lessonware; and (c) student workbook problems (see Appendix B) were found to be more similar to Troubleshooting Test problems (see Appendix C-2) than to IGS problems. IGS lessons (see Appendix A for an example) emphasized the development of test loops and other tools for troubleshooting. No test loop development or related troubleshooting tool was required or suggested by the Troubleshooting Test problems. Therefore, a high degree of similarity between IGS lessons and Troubleshooting Test items was not considered to be the source of the difference in mean troubleshooting scores.

Further, it was considered possible that, IGS students were so concerned about the quality of training available with the experimental system that they studied the instructional material to a greater degree than did their AET student counterparts. In fact, student comments to IGS instructors throughout the study indicated concerns about their performance on the end-of-block test (the only test which would count toward their class and overall averages). If extra study by IGS students did account for the Troubleshooting Test performance difference, a performance difference would also be expected on the end-of-block test. The results of that test have already been discussed; no significant difference was found.

Another possible explanation of the difference in troubleshooting scores was the distributed nature of the IGS training, as opposed to the massed, 7-day classroom/2-day hands-on, training of the AET approach. However, troubleshooting training for both the AET and IGS students was received through workbook problems distributed over 7 days for AET and 9 days for IGS students. Thus, with respect to much of the troubleshooting training, both treatment groups received distributed workbook problem training.

The significant performance difference on the Troubleshooting Test between training modes is most likely due to the following combination of characteristics of the IGS training approach: troubleshooting practice beyond that of workbook problems, consistency of IGS lesson presentation, alternating cognitive planning steps and videodisc-based equipment manipulations, and delivery of training on an interactive, individualized student basis. These are characteristic, key features of the IGS training approach.

The Projected Job Proficiency Test (PJPT) was developed to estimate performance in a field environment, based on equipment familiarity and basic electronics knowledge. Mean scores on this test were 18.95 and 18.76 for AET and IGS trainees, respectively. This difference was not statistically significant [$t(40)=.14$, $p<.89$]. (See Table D-4, Appendix D.)

Post Block IX training. Post-6883 instructional block end-of-test scores were analyzed to identify differences that may have resulted from IGS and AET training on subsequent instructional blocks. No significant findings resulted from this analysis. (See Table D-4, Appendix D.)

Summary of training effectiveness results. No significant differences were revealed between treatment groups prior to Block IX, as evidenced by aptitude scores and prior instructional block scores. No significant differences were found between treatment groups at the end of Block IX for the end-of-block test, for the Procedures Test, or for the PJPT. In addition, no significant differences were found between the groups on end-of-block test scores for blocks after Block IX. These results would imply that IGS and AET training provided the students with similar skills as measured by these instruments. Only the pencil-and-paper Troubleshooting Test showed significant performance differences in favor of IGS training.

Attempts to explain the difference in troubleshooting accuracy identified several key characteristics of the IGS training approach. These included troubleshooting practice over that of workbook problems, individualized interactive training, alternating cognitive and equipment manipulation activities in each simulation, consistency of problem presentation, and reinforcement of a developing troubleshooting strategy. The most probable explaination is that this combination of factors (not any one alone) was the key to the difference in performance. Removing any one of these factors from the IGS approach could possibly result in a detectable performance loss.

IGS Environmental Suitability

This section of the report treats issues related to hardware compatibility with the training environment, maintenance requirements, lessonware authoring capability, and student acceptance of the training system. Instructor acceptance was not measured in this effort because the two ATC Special Projects Office instructors had a developmental investment in the IGS system and were felt to be biased in favor of the system.

Hardware suitability. The IGS student/author station rests on a table top and in a small cabinet. All components of the IGS station are portable and easily removed or replaced as needed. The station produces very little noise and requires only a standard 110 volt circuit for operation. The IGS station does not require air conditioning beyond that of normal facilities systems.

In the training environment that existed for the evaluation study, installation of telephone lines was necessary to interconnect the IGS station with the AFHRL Cyber computer for system program execution and student record storage. With the IGS system in a stand-alone configuration, the telephone lines would not be required.

Maintenance. Unscheduled maintenance was minimal on the IGS stations during the evaluation period. Alignment of graphics overlays with videodisc images and alignment of touch points on the touch screens with generated graphics or videodisc images were two recurring problems. However, these problems were corrected early in the evaluation period through component repairs, and replacement of the touch screens with touch pads. A problem endemic to the training environment throughout the study period was the random loss of the IGS-Cyber interconnect. While the interconnect could be restored quickly in most instances, the disruption to training was an irritation. However, student completion of IGS lessons was not significantly affected. The problem was determined to reside in the Cyer system; therefore, further discussion of it is not included. An IGS stand-alone system configuration would eliminate this problem.

Lessonware authoring. Due to the hierarchical structure of the on-line task analysis employed in the IGS, lessonware authoring was relatively easy for ATC instructor personnel. All existing menu items appeared as elements which could be selected from the authoring menu at appropriate levels in the hierarchy. As additional items were included in the hierarchy, these items appeared on all appropriate menus. As a result, consistency of lesson structure and item selection was automatic. The existing IGS lessonware was developed by contractor, subcontractor, and ATC personnel (see Chapter III).

The issues involved in establishing the acceptability of the developed lessonware were discussed near the end of Chapter III. Initially, lessonware relevance was established on the basis of SME group consensus. At this point, lessonware relevance has been demonstrated by the Performance Test and Troubleshooting Test results discussed above. Since Air Force personnel were largely responsible for lessonware development and since lessonware relevance has been established, it is justifiable to conclude that the IGS is useable by Air Force ATC instructors for the development and presentation of instructional simulations. Using the simulations in an IGS training regime produces graduates, who perform similarly on procedural tasks on the actual equipment but perform better on troubleshooting tasks when compared to conventionally trained graduates.

Student acceptance. A brief Student Interview form (see Appendix C-4) was given to all students regardless of training mode. The first page of the form used a 5-point scale (where 5 corresponded to a highly favorable rating) for questions about 6883 training in general. The second page specifically addressed use of the IGS system through open-ended questions. AET students did not complete the second page. Results of the Student Interview analysis revealed some interesting significant results. Although most of the differences in response were not significant, those that were showed that the IGS students perceived that their regime:

* included greater variety of training
  IGS (4.4) - AET (3.5)
  [$t(38) = 3.75$, $p < .01$]

* provided a good understanding of how to operate the equipment
  IGS (4.0) - AET (3.5)
  [$t(38) = 2.38$, $p < .05$]

* included more troubleshooting time
  IGS (4.1) - AET (3.3)
  [$t(38) = 4.08$, $p < .01$]

A review of the comments on the second page of the Student Interview revealed that students who used the IGS equipment found several characteristics to their liking. Most commonly mentioned were; (a) instruction in developing a troubleshooting approach (9 of 24 comments), (b) the step-by-step process of the lessons (5 of 24 comments), (c) the individual training format, and (d) the self-paced approach (3 of 24 comments). Favorable comments were also received regarding the use of videodisc imagery, color enhancement for test loops, feedback and prompt messages, and the fact that working on the system was fun.

Negative comments focused on the interconnect problem between IGS and the Cyber system (7 of 11 comments). Additional negative comments included cursor problems (point drift on touch screens) (2 of 11 comments), lessons which were too long, and long warm-up time.

A few suggestions were offered including suggestions for expansion of the IGS approach to other test station instruction blocks and for expanded explanations of why an incorrect answer was incorrect. The suggestions for using IGS in other blocks of instruction were surprising in light of the students initial concern about the quality of instruction with the IGS replacing the AET. Expansion of the IGS approach and system capabilities to other blocks could improve the training effectiveness in content areas other than troubleshooting.

General comments stressed that the IGS system should not replace the AET; hands-on time on the actual equipment trainer was perceived to be an important part of training. However, empirical evidence from the Procedures Test results indicate that this AET perception may not be warranted.

Summary of IGS environmental suitability. The IGS system was determined to be a highly mobile, easily accommodated, low maintenance system. The development and updating of valid lessonware was found to be easily accomplished by ATC personnel. Student acceptance was found to be favorable regarding the variety of training, the explanation of 6883 equipment operation, the development of a troubleshooting strategy, the amount of troubleshooting practice, the step-by-step instructional process, and the individualized operation.

IGS/AET Cost Evaluation

In the evaluation of the IGS and AET costs, a simple cost model, similar to the one used in previous simulator studies (Cicchinelli et al., 1982; Cicchinelli et al., in press) was employed. Eight major cost categories were considered (Table 6). These included three types of hardware and software breakdowns, plus the documentation and administrative costs incurred by the contractor.

The costs incurred by the Air Force Special Projects Office personnel were not included. However, the hours they spent on courseware development were added into the total hours spent and were represented in the development dollars shown for software.

Cost figures for both the hardware and software components of the IGS system were based on contractor records. One hardware cost item was estimated: the central computer. The computer required was sized on the basis of the amount of resources used in the AFHRL Cyber system. The cost was based on vendor quotes for a computer of that size. No attempt was made to determine the reduction that might occur in these cost as packaging densities, availability, and competition increase. The quoted prices were simply used as given. Costs for the AET were taken from previous 6883 simulator cost studies (Cicchinelli et al., 1982) and adjusted to 1984 dollars based on Consumer Price Index figures.

The three types of hardware and software costs were: I - Off-the Shelf, II - Standardized, and III - Unique. For hardware, the distinction between Types I and II was somewhat arbitrary. All Type I and Type II hardware was off-the-shelf equipment; however, Type II included modems, multiplexers, etc. Only modems were used with the IGS system. In addition, no Type III hardware items were developed or purchased for this effort.

For software, the operating system for the peripheral computer was the only off-the-shelf item. The system included a text editor, file manipulation tools, an assembler, and a high-level-language compiler. For an operating environment only, a software development system would not be required. In addition, the programs developed would not need to be redeveloped for subsequent use in preparing new courseware and simulations. Type III software was considered to be the specific simulations and courseware developed for student use in the classroom. This is the only software which needs updating and revision based on course and equipment changes, or on additional classroom material as desired for expanded training objectives.

Table 6. IGS/AET Cost Comparison
(in 1984 dollars)

Cost Category	IGS Investment Cost	IGS Recurring Cost	AET Investment Cost	AET Recurring Cost
Type I Hardware				
Central Computer	30,000	2,500		
Student Station				
Peripheral Computer with monitor	4,200	200		
Video Disc w/ Controller	1,100	100		
Graphic Overlay w/ Cont.	3,000	100		
Touch Screen w/ Cont.	900	100		
Color Monitor (NTSC)	500	100		
Subtotal - (x2)	19,400	1,200		
Type II Hardware				
Modems - two per station	1,500	0		
Subtotal (X2)	3,000	0		
Type III Hardware	0	0		
Hardware Total	$ 52,400	$ 3,700	$ 2,398,900	$ 244,900
Type I Software				
Operating System (Dev.)	1,000	100		
Type II Software				
Editor Programs	200,000	0		
Instructional Features	50,000	0		
Type III Software				
Courseware (29 simulations with text and graphic tutorials, feedback, and prompt screens including videodisc based simulated equipment action)	250,000	3,000		
Courseware evaluation	50,000	100		
Software Total	$ 551,000	$ 3,200	$ 0	$ 2,300
Documentation				
System user handbooks	10,000	0		
New printings		200		
Administrative				
Contract	40,000		15,000	0
Totals	$ 653,400	$ 7,100	$ 2,413,900	$ 247,200

Two major cost areas were considered for each of the eight categories. The first was investment costs which included acquisition, installation, and start-up costs. The second cost area was that of recurring costs: operation, maintenance, updating, and modification or revision costs. The recurring costs shown were for 1 year.

Finally, no cost estimate for the Centeral Processor and Controls (CENPAC) computer, used to drive the 6883 Test Station, was included due to the unavailability of cost records. Inclusion of just the maintenance costs for this equipment would serve to increase the costs for the actual equipment. Thus, the difference between AET and IGS costs is probably much larger than indicated by the current estimate.

Comparison of system costs between the IGS and the actual equipment shows the investment cost of the IGS system to be significantly less than the initial investment cost of the AET ($653,400 vs. $2,413,900, respectively). Recurring costs for a full year were also significantly less for the IGS system than for the AET ($7,100 vs $247,200, respectively).

Expansion of these costs to reflect a 5-year or longer life cycle was considered; however, it seemed unwarranted, given the rate at which costs in this industry are changing. A case can be made for a straight-line expansion or an escalating expansion or a diminishing expansion for development of the estimate. In short, estimates beyond the first year are far more tenative and would vary according to the costing assumptions and the rapidly changing industry costs. The reader is free to make whatever estimate appears warranted if projections beyond the first year are desired.

V. STUDY IMPLICATIONS

Conclusions

IGS trained students performed significantly better on a written troubleshooting test than did the AET students. The troubleshooting test consisted of a 2-hour test of six problems which represented the domain or types of problems found in the operational field. The mean troubleshooting test scores were 14.95 for the AET-trained students and 17.76 for IGS-trained students [$t(40)= 3.00$, $p< .005$]. Differences in student performance on all other measures were not significant, regardless of training mode.

It is interesting to note that the IGS students (who were not exposed to the 6883 actual equipment) performed as well on the hands-on equipment procedures test as did those who received their training on the actual 6883 Test Station. The mean test scores were 41.8 for AET-trained students and 43.5 for IGS-trained students. However, the difference was not significant [$t(40)= 1.10$, $p< .28$]. SMEs designed the hands-on procedures test to determine how well students could effectively perform basic equipment manipulations required to properly operate the 6883 Test Station.

Also interesting is the finding that, IGS students expressed greater acceptability and perceived a higher effectiveness for their training regime than did AET students. IGS students were also favorably disposed toward the troubleshooting approach reinforced by the IGS courseware. This study suggests that high task fidelity simulation (i.e., decision making combined with equipment manipulation) appears to be more important than high physical fidelity simulation when considering training effectiveness and student acceptance of a maintenance trainer.

The IGS system proved suitable for the existing Air Force technical training environment, providing easy development of task-based maintenance lessonware. In addition, the system required low maintenance and operated extremely well in a standard classroom environment. Finally, the IGS system was substantially less costly as compared with the AET.

Recommendations

Based on the preceeding conclusions, the following recommendations are presented:

1. The IGS system should be used in the 6883 classroom training curriculum as long as an equipment-specific training approach is in use.

Use of the IGS system to reinforce daily POI training objectives has been shown to be at least as effective as actual equipment training for meeting ATC requirements as evidenced by end-of-block test results.

2. The IGS system should be used in place of actual equipment to provide avionics equipment operation training.

The IGS system can provide equipment operation procedures training at least as well as training currently presented on the actual equipment. Incorporating necessary lessonware and videodisc/graphics image changes, the IGS system can meet the ATC needs for equipment operation training for a wide variety of different types of actual equipment trainers.

3. The IGS system should be used for troubleshooting training in avionics electronics maintenance training.

The IGS system and training approach have been shown to deliver troubleshooting training better than does AET training. Troubleshooting knowledge and skill were identified by field personnel as critical to the avionics maintenance mission. Reinforcement of a consistent troubleshooting approach was identified, by students who were trained on the IGS system, as a desired feature of the IGS training approach. The apparent significant transfer of training, criticality of the maintenance task, and high user acceptance suggest that the role of the IGS system, as a troubleshooting trainer, should be established and expanded to other avionics electronics instructional blocks and maintenance curriculums.

4. The use of the IGS system in courses of instruction should be accompanied by appropriate efforts to convince instructors (and, therefore, students) of its value as a replacement for actual equipment in meeting training objectives.

The cost effectiveness of the IGS system has been demonstrated, and the system's worth has been accepted by the instructors and students who used it. However, the IGS instructors in this study had "ownership" of the IGS system through their involvement with its design and development. A larger-scale institutionalization of the IGS system will need to be accompanied by appropriate efforts to win instructor acceptance and, in turn, student acceptance. Since the IGS system is suitable for use by Air Force personnel in lessonware development, an excellent route to acceptance should be through instructor involvement in the lessonware development process.

5. The IGS system adaptive student learning model should be more fully developed and tested.

Comments by students who had contact with the IGS system identified the step-by-step, self-paced approach of the IGS lesson structure, and the feedback and prompt features, as particularly pleasing. With the activation of the adaptive menu feature, training more appropriate to a student's skill level could be realized.

6. The IGS system should be integrated with a tutorial computer-based instruction capability.

The IGS system provides practice in applying troubleshooting skill and theory-of-operation knowledge to diagnosing faults; it plays no role in the direct instruction (e.g. tutoring) in a toubleshooting approach or in theory of operation. In the IGS evaluation, the tutorial role was played by the instructor. Although this may be optimal, the use of the IGS system to provide more background instruction should be investigated. This is particularly desirable, since the existing IGS hardware and software are completely compatible with a Computer Based Instruction (CBI) system. The extent of the potential benefits from IGS are as yet unexplored.

7. The IGS lessonware development editors should be more fully developed.

Air Force personnel did the bulk of the lessonware development for this project. However, contract personnel played an important role in the development of the initial on-line task analysis and in overall quality assurance. The feasibility of embedding a default approach to electronics troubleshooting within the IGS system and articulating this approach as a series of prompts and help messages to the developer should be investigated.

8. The IGS system should be developed into a stand-alone system.

Numerous complaints by students who were trained on the ISG system and the record of IGS system maintenance focus on the fragility of the IGS/Cyber system interface. A stand-alone IGS system would correct this problem.

9. The use of the IGS system as a performance measurement device should be investigated.

It is very easy to work through a fault isolation exercise with the IGS system, an exercise which incorporates an equipment-specific troubleshooting approach and a reasonable simulation of equipment manipulation. Utilizing the adaptive model menu feature of the IGS system, personnel being tested could begin a simulation running in "performance mode," and the system would appropriately transition to recall and recognition modes in order to focus and direct the completion of the exercise, once errors were made. A metric of performance could be derived from the before-test and after-test changes in the student model over the course of a series of fault isolation exercises. Moreover, performance measurement could also be prescriptive, in that errors could be mapped into areas of the on-line task analysis needing further study.

10. The feasibility of the IGS system as a performance aid should be investigated.

The value of the IGS system as a training aid has been established. There are several characteristics of the IGS system and task modelling approach which would be highly adaptable to a performance aiding role.

These include the on-line task analysis (in which fundamental elements of the avionics electronics maintenance task are included); the highly flexible and easily updateable videodisc/graphics imagery base; the decision menu approach, which, with the adaptive feature developed, could interface with the user at the appropriate level of knowledge and skill; and the system of prompts and feedback messages, which would help the user refine the problem approach. The physical mobility of the IGS system and its limited facilities requirements make it an appropriate aid for the intermediate shop or even the flightline environments.

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APPENDIX A:

IGS Simulation Example

Welcome to this simulation...

Before we go into any detail at all about the problem or anything else, there is something you ought to do first.

Please enter what this is . . .

1 REMOVE RINGS & WATCH 4 TROUBLESHOOT TL
2 AUTOTEST
3 REM & REP PARTS
Enter response> REMOVE RINGS & WATCH_____

Press RETURN

In this simulation we are only going to deal with part of a troubleshooting problem. Since this is your first simulation, you must be very careful in your troubleshooting technique.

Read all information provided and make notes of important data, just as you would if you were troubleshooting an actual test station.

Most important of all: think logically!!

Press RETURN.

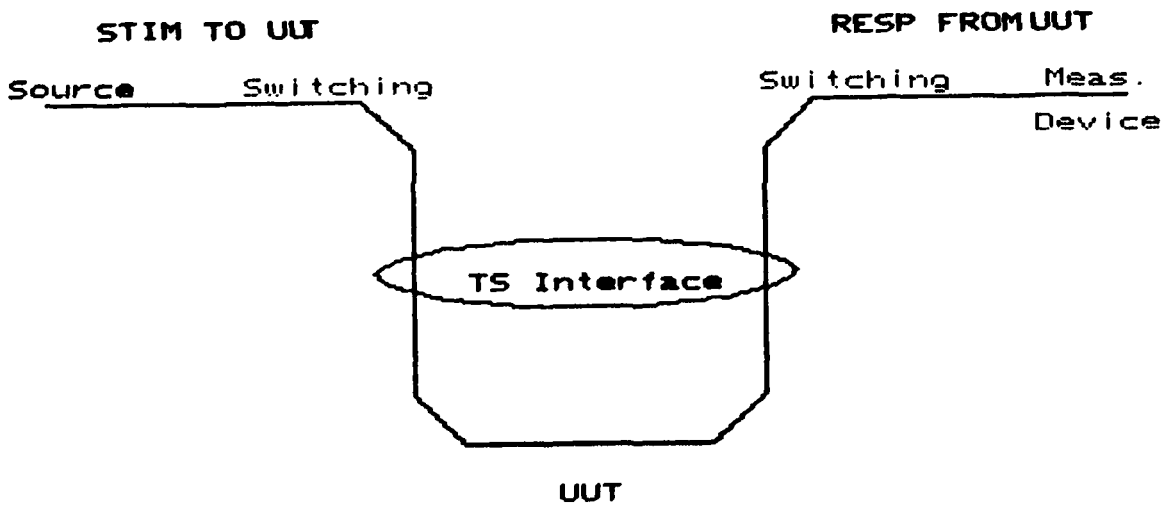
Assume that you were testing a Feel & Trim LRU and the autotest failed at TN 302350. Before removing and replacing any parts, you ran the shop standard F&T LRU known to be in perfect working order. The autotest failed again--at the same TN.

This means your next action is to troubleshoot the test loop. Please enter "TROUBLESHOOT TL".

```
1 REMOVE RINGS & WATCH 4 TROUBLESHOOT TL
2 AUTOTEST
3 REM & REP PARTS
   Enter response> TROUBLESHOOT TL____________________
```

Pictured below is a general diagram of the test loop. It is intended to help you visualize the signal flow through the test station.

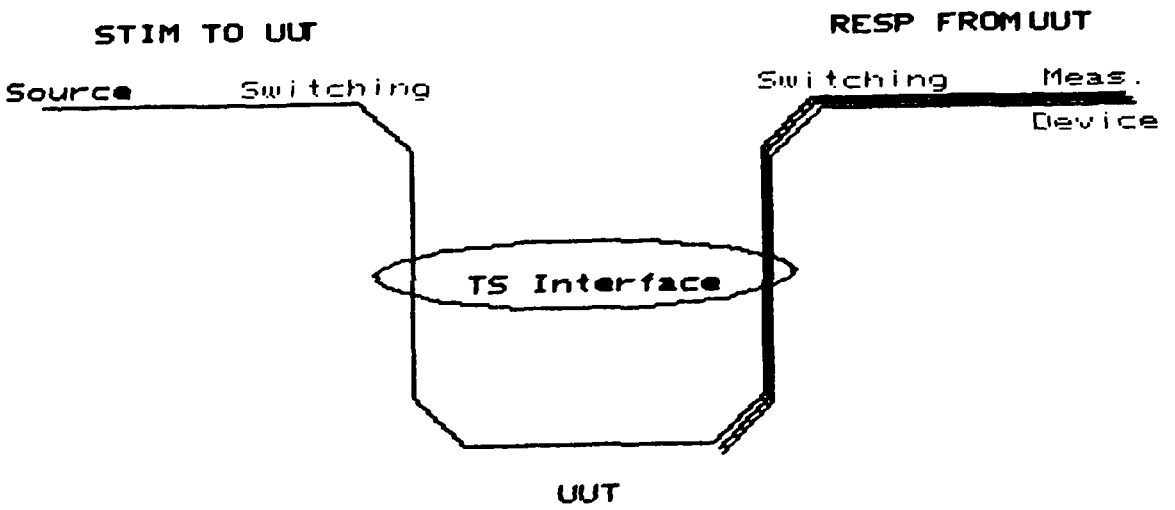
Please notice that each region of the test loop has been assigned a color. We'll be using these colors to remind you of which region of the test loop you are trouble-shooting. More about this in a few minutes.



Press RETURN.

From your visual inspection, it appears the stimulus signals are getting to the LRU properly. This indicates that the stim source is good. You have decided to begin troubleshooting in the response leg of the test loop.

Select "RESP FROM UUT" as your next task.



1 T/S CENPAC
2 T/S STIM
3 STIM TO UUT
4 RESP FROM UUT
5 UUT

Enter response> RESP FROM UUT_____

Press RETURN

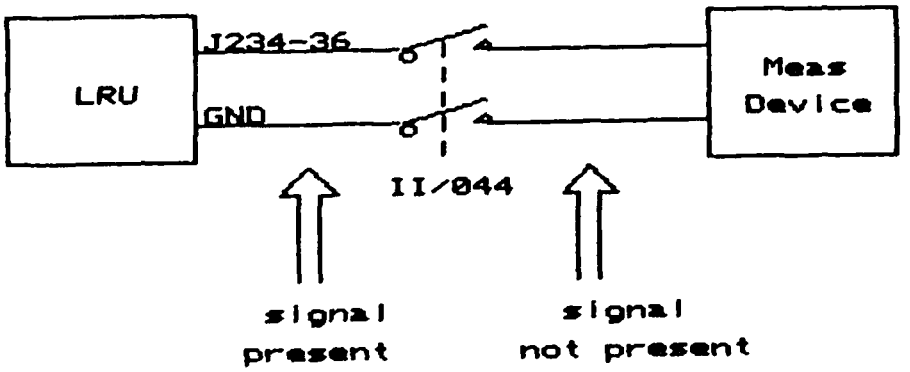
Assume that you have checked the input to the measurement device and found that the signal is not present. You have also checked the output of the LRU and found it to be good. This means the signal from the LRU is not being routed to the measurement device.

If you refer to the test title and instructions column in the Feel & Trim tape T.O. for test number 302350 you will find this program:

120F14* 203444

This program routes the LRU output (response) to the measurement device and refers specifically to TPS relay II/044. Your next step is to check this relay.

Press RETURN.



Please enter 'CHECK SIGNALS' as your next task.

1 COMPLETE BLOCK DIA 4 ID FAULTY COMPONENT
2 VISUAL INSPECTION
3 CHECK SIGNALS
  Enter response> CHECK SIGNALS_____

Press RETURN

```
You have already decided to concentrate your
efforts in the area of response switching.
In order to begin checking signals in that area,
please select "SWITCHING" as your next task.


1 UUT OUTPUT            4 MEAS DEVICE
2 TS INTERFACE
3 SWITCHING
   Enter response> SWITCHING___________________________


                                        Press RETURN
```

At this time, please take a moment to notice the blue border which has appeared on the screen. This is the 'color coding' which was referred to when you first saw the test loop diagram. This color will remain on the screen as long as you continue to check signals in the 'Response Switching' region of the test loop.

When this border changes color, you will have selected another region of the test loop to troubleshoot.

Press RETURN.

The relay you want to check is a TPS relay.
To which group does it belong?

1 TPS GROUP-I RELAY 4 TPD RELAY
2 TPS GROUP-II RELAY 5 STPS GROUP-I RELAY
3 MISC RELAY 6 STPS GROUP-II RELAY

Enter response> TPS GROUP-II RELAY_____

Press RETURN

When you are trying to isolate a fault, you want to get the most information in the fastest and least complicated way.

Right now you want to check a test point relay. Which of the three devices listed below will yield the best information to help you determine if the test point relay is functioning?

1 PATCH PANEL
2 RELAY CAN
3 TPS CONTROLLER

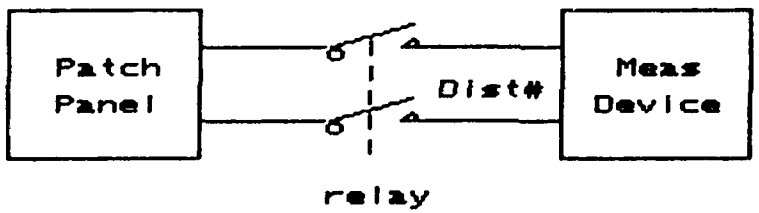
Enter response> PATCH PANEL_____

Press RETURN

That`s right! Since the test point relay you want to check is wired to the patch panel you can use the patch panel as a troubleshooting aid.

At this point you are preparing to make a continuity check of the test point relay. Here is what you should do:

As you recall, the outputs of all test point relays are wired to the distribution relays. If you select the proper distribution, the patch panel pins will be routed directly to the DVM.



Press RETURN.

What is the first thing you should do
to check the relay at the patch panel?

1 INSTALL PP COVER 4 SELECT PINS
2 SET UP MEAS DEVICE
3 ENTER PROGRAM
Enter response> INSTALL PP COVER_____

Press RETURN

Before you can install the patch panel cover, you must locate the patch panel on the test station.

To do this you must first select the quarter of the test station which has the patch panel in it - the upper right quarter of the test station.

When that quarter is on the screen, you must select the patch panel to indicate the panel you wish to work on.

To install the patch panel cover you must remove the Adapter and then put the checkerboard cover in its place. In this simulation, the Adapter is already removed so that when you select the label you will next see the checker-board cover being installed.

If you wish to see the motion sequence again, just select 'SEQ' at the top left of the screen. When you are finished, select 'DONE' to continue with the simulation.

Equipment simulation INSTALL PP COVER performed.
Is it performed correctly? <yes or no>>

```
The patch panel is ready...
What should you do next?

1 INSTALL PP COVER      4 SELECT PINS
2 SET UP MEAS DEVICE
3 ENTER PROGRAM
   Enter response> SET UP MEAS DEVICE_________________

                                  Press RETURN
```

Which measurement device should you
use to check the patch panel?

1 DVM
2 O-SCOPE
Enter response> DVM_____

Press RETURN

In accordance with paragraph 4-51 on page 4-7 of T.O. 33D7-17-15-2, assume you have reset all registers in test point selector A3A5 by entering 14, depressing ADDRESS pushbutton, entering 15, and depressing ADDRESS pushbutton. Failure to comply could result in damage to DVM A1M1.

First select the quadrant containing the DVM and then select the DVM. You need to adjust the following controls:

PRINT to Track, FUNCTION to K Ohms, RANGE to 10.

To adjust a control, select the control and then select the setting for that control. Select 'DONE' to continue. Do the next controls in the same manner. When you are finished, remember to select 'DONE'.

Equipment simulation DVM performed.
Is it performed correctly? <yes or no>>

Now that both the patch panel
and the measurement device are
set up, what should you do?

1 INSTALL PP COVER 4 SELECT PINS
2 SET UP MEAS DEVICE
3 ENTER PROGRAM
  Enter response> SELECT PINS

Press RETURN

Which pins are you going to jumper?

1 TT12 AND SS12
2 TT13 AND SS13
3 TT14 AND SS14
4 TT15 AND SS15
5 TT16 AND SS16

Enter response> TT13 AND SS1^_____

Press RETURN

Referring to figure 9-242 of the Shop Systems T.O., you find that relay II/044 is wired to Patch Panel pins TT13 and SS13.

In this case you want to jumper two pins together to measure the signal on them. You already located the patch panel when you installed the cover. Select the portion of the patch panel where the pins you want are located. Then select the area of the pins you want to jumper. Notice that they are outlined for you.

Install the following jumpers: TT13 to SS13

You are now reading the results of having jumpered the pins on the patch panel. You did not have to indicate that you wanted the DVM in order to read the results, since the DVM is what you set up a short while ago. No program has been entered on DATAC to energize the relay, so you are trying to see if the relay contacts are open. Remember you set the DVM to read K ohms.

When you are finished reading the results, and wish to continue, select "DONE" on your screen.

Equipment simulation TT13 AND SS13 performed.
Is it performed correctly? <yes or no>>

You have jumpered the pins and verified
that there is an open.

Now what?

1 INSTALL PP COVER 4 SELECT PINS
2 SET UP MEAS DEVICE
3 ENTER PROGRAM
Enter response> ENTER PROGRAM_____

Press RETURN

You are to enter an address into DATAC: 120F14*.
You must locate DATAC on the test station by first selecting the quadrant containing DATAC, and then selecting the DATAC panel. Next, select the MODE switch and set it to 'Keyboard' by selecting that setting.

Select the keyboard to get a close-up. Then enter the information by selecting the keys in the right order. If you make a mistake, press the 'CLEAR' button to begin again.

Now enter the address 120F14*, and you will see the results on the DVM in K ohms. When you are ready to go on, select 'DONE'.

You now need to enter an info word: 203444. You will start at the keyboard, and enter the info word in the same manner as you did the address. The results will appear on the DVM. Again, select 'DONE' when you are ready to go on.

Equipment simulation ENTER PROGRAM performed.
Is it performed correctly? <yes or no>>

At this point, it might seem that since you have concluded the relay isn't functioning properly, you should now replace it. However, replacing the relay is both difficult and time-consuming. For that reason, you should be VERY sure that the relay itself is bad before attempting to replace it.

There is a better way: The Test Point Controller decodes programmed information and in turn energizes or de-energizes the appropriate test point relay.

Front panel test points and major test points located in the controller offer easy access to determine if the fault is in the TPS Controller. Since this is an easier 'next step' than replacing the relay, the next thing for you to do would be to check the TPS Controller.

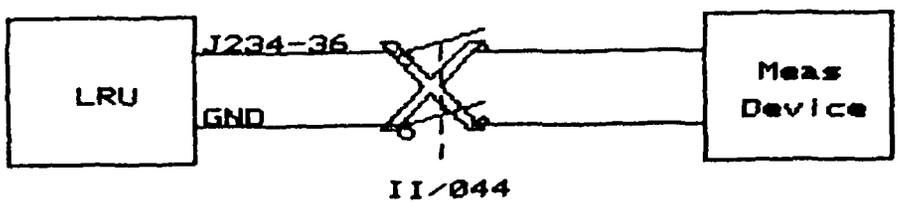
Press RETURN.

Checking the TPS Controller will tell you one of two things: either the Controller is malfunctioning or the relay/circuits are malfunctioning.

If the controller were functioning properly, you would next check the logic circuits in the relay can. It might be that the circuits are okay, too. In that case you would know for sure that the relay is bad, and it would have to be replaced.

Press RETURN to continue.

II/044 appears to be at fault here:



As you may recall, your objective was to check the response switching. Specifically, you were to check for a short circuit when the relay was programmed to set. However, you found an open circuit indicating a fault.

CONGRATULATIONS! You have successfully completed your assignment!

Press RETURN.

APPENDIX B:

Sample Workbook Problems
for Block IX

PROJECT IV

Answer the following questions pertaining to each test number given.

1. Test number 301138

a. On what A3A2A15 pins should the measured signal be found?

b. What test point relay must be energized to test this signal?

c. On what relay subassembly of the Switching Complex is the relay found?

d. To which output pins are the wipers connected?

e. At what Feel and Trim jack and pin can the measured signal be probed? What should this value be?

f. What would you first check if the output from the Feel and Trim was not within tolerances?

2. Test number 301003 displays a NO-GO in the results window of DATAC.

a. What will be the first step in verifying the failure?

b. What is the most probable cause for this failure?

c. Assume that the proper Feel and Trim subassembly has been removed and replaced. What must be done before repeating the test that failed?

d. Test number 301003 passes but test number 301010 fails. What is the most probable cause and how would it be checked?

e. Where should the output of the Feel and Trim be probed with the DVM lead?

(1) If the signal is <u>not</u> present at this point, how would you determine if the failure is caused by the test station or the LRU?

(a) What in the test station would cause this test to fail?

(b) What in the Feel and Trim could cause this test to fail?

(2) If the signal <u>is</u> present at this point, what should be checked?

(a) At what A3A2A15 pins could this be checked?

(b) How would this be checked for a malfunction?

3. Test number 300180 fails. The DVM reads 28 VDC.

a. What circuit is being tested?

b. After repeating the test to verify the failure, what action should be taken?

c. What is the most probable component causing the fail?

d. How should this be checked?

PROJECT V

Answer the following questions.

1. A 28 VDC Nose Right Command will energize which relay in the Yaw Trim Circuit? What will be felt at J200-J?

2. What causes K8 of the Lower Relay Panel (12C1154-855) to energize? What will this do in the Roll Trim Circuit?

Answer the questions following each given test configuration for tape #830701.

1. Test number 000633 displays a NO-GO in the results window of DATAC.

a. What will CENPAC do?

b. What is the first step in verifying the malfunction?

c. What TO and figure # would you use to physically locate this failure?

d. In what Converter Set area is this located?

e. What should be done to verify that the component you suspect is causing the test failure?

2. Test number 000302 displays a NO-GO LO in the Results window of DATAC.

a. What should be done immediately?

b. Which area of the power supply is being checked?

c. What Converter Set plug and pin numbers can be checked?

d. What should be measured there?

e. On what routing diagram sheet number will you find the test loop diagram?

f. If you measure the proper voltage out of the Converter Set, what in the test station could also cause the test to fail?

g. If test number 000300 passed, would the answer to question "f" be valid?

h. What should be checked next? Why?

(1) How would you go about this?

(2) What patch panel pins should be checked?

i. If this is functioning properly, what is the next logical problem?

3. Test number 002342 displays 005A2A in the Measurement Window of DATAC.

a. The test should be repeated by going back to which test number?

b. What is the name of the signal being checked?

c. What type of signal is this?

d. On what Converter Set jack and pin number(s) can this signal be found?

e. In what area of the C/S is this signal processed?

f. What should be displayed in the Measurement Window of DATAC?

g. What does this represent? (Use figure 4-4, Table B of Shop Systems).

h. What is the most probable cause of the failure?

i. What other SRUs are used in this test?

4. Test number 2880 displays E00002 in the Measurement Window of DATAC.

a. What test number should you request in order to repeat this test?

b. What is the name and code of the signal being tested?

c. What type of signal is being measured? What should this be?

d. On which C/S jack and pin number(s) can this signal be measured?

e. What will CENPAC do when this test fails?

f. Test number 9882 displays a GO in the Result Window of DATAC. What does CENPAC do?

g. Test number 9886 displays a PROG STOP in the PROG STOP Window of DATAC. GO is displayed in the Results window.

(1) What is the most probable cause of the failure?

(2) What else may cause the failure?

(3) What TO and figure # would you use to physically locate these SRUs?

(4) What are the names of these SRUs?

(5) Which SRU would you R & R first?

(6) What would you do to verify a bad card?

(7) What other SRUs are used in this test?

APPENDIX C:

Test Instruments

APPE DIX C-1:

Troubleshooting Test Booklet

This is a test of your ability to troubleshoot the Converter/Flight Control equipment. You will be presented with a number of troubleshooting situations and a series of problems dealing with each situation.

For each problem, select the single best answer by marking the appropriate slot with the red marker provided. Be sure to choose and mark each answer carefully because you may not change an answer once it has been marked. Also, you must mark an answer to each problem before going on to the next one.

Mark slot b below and then continue on to the next page.

a.

b.

c.

d.

e.

The test will be timed so work as quickly and accurately as possible. All necessary TOs have been provided. The blank spaces of this booklet may be used as workspaces.

Please enter your name and class number in the spaces provided below. When you have done so, mark any one of the slots below and wait until you are told to begin the test.

0.1
a.
b.
c.
d.
e.

Name _____ Class _____

a.

b.

c.

d.

e.

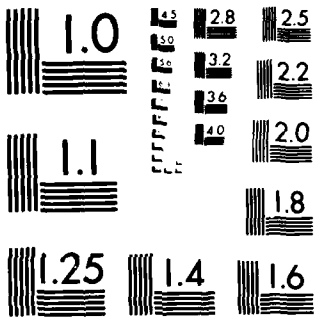
AD-A149 417 INTERACTIVE GRAPHICS SIMULATOR: DESIGN DEVELOPMENT AND EFFECTIVENESS/COST EVALUATION(U) DENVER RESEARCH INST CO W J PIEPER ET AL. DEC 84 AFHRL-TR-84-38 2/2

UNCLASSIFIED F33615-81-C-0006 F/G 5/9 NL

END

FILMED

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

* * * * * * * * * * * * * * * * * * * Situation #1 *

1.1 Test Station Maintenance Tape (request number 839902) fails at test number 202661. The DVM indicates +15.00 vdc. Repeating the test produces the same results. You first step in diagnosing the problem to the component level is to:

		0.2
a.	swap the DVM with a good one	a.
b.	turn the "Oscilloscope Input" switch to DVM to verify the signal	b.
c.	check the counter time	c.
d.	check input power into the A3A6	d.
e.	check input/output voltages of the FCS Adapter	e.

1.2 You have decided to check the input/output voltages of the FCS Adapter. With a PSM-6 you monitor A4A1 TP12 and TP13 on the front panel. The voltage you read is +15 vdc. This indicates:

1.1		
a.	a.	A4A1A1K13 or associated logic defective
b.	b.	A4A1A10 defective
c.	c.	A4A1PS1 defective
d.	d.	A4A1A1K17 or associated logic defective
e.	e.	insufficient information at this point

1.3 The previous problem indicated that A4A1A1K17 or associated logic is defective. The signal level of Control Line B3/14 found at A4A1J1 is 0.0 vdc. This indicates:

a. A4A1A1K17 defective

b. A4A1CR17 shorted

c. A3A6A20Q6 shorted

d. A3A6A20Q5 shorted

e. A3A6A12 defective

1.2
a.
b.
c.
d.
e.

1.4 Assume that the reading in the previous problem indicated that A3A6A12 is defective. To verify the faulty component on the A12 card, you should:

1.3
a.
b.
c.
d.
e.

a. check outputs

b. check programming inputs

c. swap the card with A11

d. swap the card with A13

e. none of the above

1.5 Checking the output at A12 pins AA and 22 you find 0.0 vdc. What does this indicate?

		1.4
a.	A12Q13 defective	a.
b.	A12Q14 defective	b.
c.	A12Z10A defective	c.
d.	need to troubleshoot A20	d.
e.	need to troubleshoot A12 relay driver circuit (Z10A, Q13, Q14)	e.

1.6 Assume you are troubleshooting the relay driver circuit. Checking A12Z10A pin 9 you find +5 vdc. At the base of A12Q14 you find -12 vdc. Identify the fault.

1.5		
a.	a.	R19 open
b.	b.	Q13 shorted between emitter and collector
c.	c.	Q14 shorted between base and collector
d.	d.	R20 open
e.	e.	R21 shorted

This completes Situation #1. Take your test booklet to the test administrator before going on.

Time (in min.): _ _ _

* * * * * * * * * * * * * * * * * * Situation #2 *

2.1 Feel and Trim test number 300602 fails. The DVM reads 9.9999 vdc. Repeating the test produced the same results. What does the DVM reading indicate:

		1.6
a.	insufficient information at this point	a.
b.	PSC input signal overrange	b.
c.	PSC output signal overrange	c.
d.	DVM defective	d.
e.	A2A2 defective	e.

2.2 A PSC output signal overrange was indicated in the previous problem. To isolate this fail to the system level, you should:

2.1		
a.	a.	check the inputs and outputs to the Feel and Trim
b.	b.	check the output of A2A9
c.	c.	check the input to the DVM
d.	d.	check test point switching
e.	e.	check stimulus switching

2.3 The output from the Feel and Trim at J203 pins R and T is 115 vac. What could be the problem?

		2.2
a.	Feel and Trim defective	a.
b.	A4A2 or associated logic	b.
c.	A4A2 "Mode" switch in the "QUADRATURE" position	c.
d.	A4A2 "Pre-set Data" switch was not depressed	d.
e.	adapter is defective	e.

2.4 The reference to the PSC is correct and programming is correct into the PSC. What is the problem?

2.3		
a.	a.	Ratio Transformer defective
b.	b.	DVM defective
c.	c.	PSC defective
d.	d.	LRU cable defective
e.	e.	insufficient information at this point

This completes Situation #2. Take your test booklet to the test administrator before going on.

Time (in min.): _ _ _

* Situation #3 *

3.1 Feel and Trim checkout test number 300830 failed automatic testing. The DVM indicates 0.0 vdc. Repeating the test and replacing the Upper Relay Panel produces the same results. Your first step in diagnosing the problem to the system level is to:

		2.4
a.	swap the DVM with a good one	a.
b.	check the input voltage to A2A9	b.
c.	R/R stimulus relay 12/3	c.
d.	check inputs and outputs of the Feel and Trim	d.
e.	insufficient information at this point	e.

3.2 The best first step in diagnosing the test failure at number 300830 is to check inputs and outputs to the Feel and Trim. The input signal on J234 pins 27 and 28 is +28 vdc. This indicates:

3.1		
a.	a.	internal trouble with the Feel and Trim
b.	b.	stimulus relay 12/4 has welded contacts
c.	c.	A3A5 defective
d.	d.	A4A5 defective
e.	e.	insufficient information at this point

3.3 The Feel and Trim input signal on J234 pins 27 and 28 is +28 vdc. The signal at A3A2A15P14 pins 180 and 181 is 0.0 vdc. All cables are good. What can you determine from this?

		3.2
a.	test point relay 1/051 defective	a.
b.	Feel and Trim defective	b.
c.	A3A2A31 "LRU Power" switch in the "OFF" position	c.
d.	stimulus relay 12/4 defective	d.
e.	insufficient information at this point	e.

This completes Situation #3. Take your test booklet to the test administrator before going on. Time (in min.): _ _ _

* * * * * * * * * * * * * * * * * * * Situation #4 *

4.1 While running the Feel and Trim checkout automatic testing fails at test number 300846. The DVM reads 0.0 vdc. Repeating the test and replacing nonredundant board TB4 yields the same results. Your first step in troubleshooting the problem is to check the inputs and outputs of the Feel and Trim. The signal level at J202 pin ~~a~~ U is +28 vdc. The signal level at J202 pin L is +12 vdc. This indicates a problem in:

3.3		
a.	a.	the Feel and Trim
b.	b.	stimulus circuits
c.	c.	evaluation circuits
d.	d.	the DVM
e.	e.	insufficient information at this time

4.2 A problem in the evaluation circuits is indicated. Checking A3A2A31J6 pins C and A you find 0.0 vdc. What is your next step?

a. check test point switching

b. check stimulus switching

c. R/R test point relay 1/058

d. R/R stimulus relay 08/2

e. R/R stimulus relay 09/0

4.1
a.
b.
c.
d.
e.

4.3 Setting the DVM to "K-OHMS," "TRACK," and an appropriate range with a jumper installed between A3A2A15 pins UU26 and VV26 you enter the program 110F14*203548. The DVM reads 9999.9 Ohms. What is your next step in isolating the problem?

4.2
a.
b.
c.
d.
e.

a. R/R test point relay A3A2A14K11

b. R/R test point relay A3A2A14K23

c. check programming outputs of A4A5

d. check programming outputs of A3A5

e. swap DVM with a good one

4.4 Checking A3A5J143 and J116 you find the correct pulses. No other pulses are present. Cabling from A3A5 to A3A2 is good. Your next step is to:

a. R/R A3A5A22

b. R/R A3A5A37

c. R/R A3A2A14K11

d. R/R A3A2A14K23

e. R/R A3A5A72

4.3
a.
b.
c.
d.
e.

4.5 You have replaced relay A3A2A14K11 that you suspect was the problem. Now how can you verify that you have repaired the problem?

4.4
a.
b.
c.
d.
e.

a. check test point relay I/058 at the patch panel

b. reinstall necessary equipment and repeat test

c. run Test Station Maintenance Tape (test request number 839901)

d. resume testing at the next zero-ending test number

e. check the test point controller

4.6 Assume you check the relay at the patch panel as you did prior to replacing it. That is, setting the DVM to "K-OHMS," "TRACK," and an appropriate range with a jumper installed between A3A2A15 pins UU26 and VV26 you enter the program 110F14*203548. The DVM reads 9999.9 Ohms. You should next:

		4.5
a.	R/R A3A2A14K11	a.
b.	R/R A3A2A14K23	b.
c.	swap the DVM with a good one	c.
d.	check for continuity between A3A2A14J9 pins 195, 196 and J7 pins 12, 13	d.
e.	check for continuity between A3A2A14J9 pins 203, 204 and J7 pins 6, 7	e.

4.7 Using the PSM-6 you read an open circuit between A3A2A14J9 pin 203 and J7 pin 6, and a short between J9 pin 204 and J7 pin 7. Since A3A2A14K11 was just replaced, what should you do?

4.6		
a.	a.	check wiring between A3A2A15P14 and A3A2A15
b.	b.	check wiring between A3A2A15P19 and A3A2A15P20
c.	c.	R/R A3A2A14K11
d.	d.	check wiring between A3A2A14J7, J9 and relay A3A2A14K11
e.	e.	no problem is indicated

This completes Situation #4. Take your test booklet to the test administrator before going on.

Time (in min.): _ _ _

* * * * * * * * * * * * * * * * * * * Situation #5 *

5.1 You are troubleshooting Test Station Maintenance Tape (test request number 839902) test number 202923, which failed during automatic testing. There was no signal present on the Oscilloscope. You determined test point relay 1/082 is operating properly. The signal generator is also functioning properly. The signal Control Line B/21 (ground) is present at A4A1J1 pin b. Suppose you checked the output of A4A1A9A and found the proper square wave. What should you do next?

4.7
a.
b.
c.
d.
e.

a. check the output of A4A1A8A

b. R/R A4A1K1

c. R/R A4A1K2

d. R/R A4A1CR2

e. none of the above

5.2 Assume you checked the input to A4A1A8A and found 0.0 vdc (ground). You should next:

5.1
a.
b.
c.
d.
e.

a. check A4A1A9A

b. check A4A1A8A

c. R/R A4A1K1

d. R/R A4A1K2

e. R/R A4A1CR2

5.3 Assume the input to A4A1A8A was the correct square wave and the output from A4A1A8A at J11 pin S was a constant -28 vdc. What should you do?

	5.2
a. R/R A4A1A9A	a.
b. R/R A4A1A8A	b.
c. R/R A4A1K2	c.
d. check A4A1K1	d.
e. check A4A1CR2	e.

This completes Situation #5. Take your test booklet to the test administrator before going on. Time (in min.): _ _ _

* * * * * * * * * * * * * * * * * * * Situation #6 *

6.1 When troubleshooting a circuit, you find that the input is present and the output is not present. What basic determination can you make at this point?

5.3
a.
b.
c.
d.
e.

a. the circuit is serviceable

b. the circuit is defective

c. the input is being applied at the wrong place

d. the circuit was improperly designed

e. insufficient information to make any determination

6.2 Feel and Trim test number 300620 fails. The DVM reads 0.0 vdc. Repeating the test produces the same indications. The first step in troubleshooting to the circuit level is to:

a. swap the Feel and Trim with a good one

b. check the inputs and outputs of the Feel and Trim

c. swap the DVM with a good one

d. swap A2A9 with a good one

e. check test point relay 1/046

6.1
a.
b.
c.
d.
e.

6.3 Still at test number 300620, you have decided to check the inputs and outputs of the Feel and Trim. The input at J202-d is 0.0 vdc; the output voltage at J234-39 and J234-22 is 0.0 vac. This indicates a problem in the:

6.2
a.
b.
c.
d.
e.

a. test station stimulus circuits

b. test station evaluation circuits

c. Feel and Trim

d. FCS Adapter A4A1

e. stimulus switching circuits

6.4 You continue by troubleshooting the test station stimulus circuits. Checking at A3A2A15 pin X34 you read 0.0 vdc. .cu find 28 vdc at A15P6 pin 62. What is your next step?

	6.3
a. R/R A3A2A6K3	a.
b. troubleshoot A3A2A6 and associated logic	b.
c. R/R A3A2A6K2	c.
d. Troubleshoot A3A2A5 and associated logic	d.
e. none of the above	e.

6.5 Assume that in the previous problem you have decided to troubleshoot A3A2A6 and associated logic. What should you do now to isolate the problem to the relay or associated logic?

6.4	
a.	a. R/R A3A2A6K3
b.	b. R/R A3A2A6K2
c.	c. troubleshoot A3A5
d.	d. troubleshoot A1A8
e.	e. troubleshoot A4A5

6.6 When troubleshooting a circuit which turns a device "on" or "off" in response to programming inputs, you find that the correct programming is present to turn the device "on." However, upon closer examination, you discover that the input which would turn the device "off" is also present. The device being in the "off" state is the reason you suspected this circuit to be faulty. What is the problem?

a. programming

b. the "on" circuitry

c. the "off" circuitry

d. the device

e. some other circuit

6.5
a.
b.
c.
d.
e.

6.7 You are troubleshooting A4A5. Checking test points for steering numbers 1, 2, 3, and 5 you find that the signals are correct. At test point J126 you find a constant logic high. What action should you take?

6.6
a.
b.
c.
d.
e.

a. R/R A3A2A6K3

b. R/R A4A5A57

c. check the input(s) to A4A5A56

d. check the input(s) to A4A5A57

e. R/R A4A5A56

6.8 The input at A4A5A56 pin A is a logic low. What should you do next?

a. R/R A3A2A6K3

b. R/R A4A5A57

c. check inputs to A4A5A57

d. R/R A4A5A56

e. R/R A4A5A35

6.7
a.
b.
c.
d.
e.

The test is now completed. Please return your test booklet to the test administrator.

6.8
a.
b.
c.
d.
e.

Time (in min.): _ _ _

APPENDIX C-2

PROCEDURAL TEST BOOKLET

1. Perform the following steps:

   a. On power distribution panel A1A1, position 400 CPS, 60 CPS MAIN, and 60 CPS OUTLETS circuit breakers to ON (up).

   b. On power distribution panel (A1A1), rotate SELECTOR switch to 400 CPS PHASE A while observing that MAIN VOLTAGE meter indicates 115 (± 11) volts.

   c. On variable power control (A1A5), rotate PHASE SELECTOR switch to C and adjust PHASE C ADJUST control to obtain an indication of 115 volts on voltmeter. Observe an indicatin of 400 (±20) Hz on frequency meter.

   d. On ratio input filter (A2A2), rotate FILTER MODE switch to INVERTED and observe that INVERTED indicator lamp lights and NON-INV indicator lamp goes out. Return FILTER MODE switch to PROGRAM.

2. Connect the Feel and Trim provided for check-out as follows:

   a. Connect Feel and Trim adapter (A44583) to patch panel (A3A2A15).

   b. Connect P4 of cable assembly W62 to J1 on adapter.

   c. Connect P4 of cable assembly W63 to J2 on adapter.

3. Assume that all test station preparation and turn-on is complete. Initiate UUT Feel and Trim (part no. 12C1154-869) testing as follows:

   a. On DATAC drawer (A1A3) rotate MODE switch to NORMAL.

   b. On DATAC, enter applicable test request number from figure below and depress TEST REQUEST pushbutton.

   c. Verify that TEST NUMBER display on DATAC agrees with test request number in figure.

   d. Depress START pushbutton and verify that date in MEASUREMENT display agrees with date in figure.

   e. Depress START pushbutton to begin testing.

Program Tape		Test Station	Unit Under Test	Test Request Number	Section
Number	Date And Display				
5A9-2-42-28-1CT-1	29 September 1976 (290976)	12A6883-1 and -2	12C1154-855 12C1154-867 12C1154-869	830401	II
81F-12C060-U033-OOA-001	9 December 1980 (091280)		12C1154-887 12C1154-889	830402	III

4. At this point, interrupt the automatic test sequence and jump to test #301740. Re-initiate automatic testing at that point.

5. Automatic testing stops at #301752. Perform the following steps:

   a. On test panel (A3A2A31) rotate OSCOP INPUT SIGNAL SEL sw to DIGITAL MULTR.

   b. Using the DIFFERENTIAL/DC OFFSET AMPLIFIER in the oscilloscope, set the oscilloscope controls as follows:

-DC or A coupling sw	Depress in or set switch to DC
+DC or B coupling sw	Depress in or set switch to DC
VERNIER	Fully cw
V/DIV	.5
SWEEP MODE	AUTO

   c. Interpret the oscilloscope signal and report your findings to the test administrator.

6. The lack of an oscilloscope signal in the previous step indicates a failure at test #301752. Reseat the patch panel adapter. Then repeat the test using one of the two acceptable methods for repeating tests. Appropriate TO information is located at the end of this test.

7. There is still no oscilloscope signal. Use an alternative method from the one used in step 6 to repeat test #301752.

8. Verify that the lack of a signal is not due to a problem with oscilloscope channel A by rerouting the input to channel A through channel B. Report your findings to the test administrator.

9. Verify whether or not the signal applied is getting to the Feel and Trim. Perform the necessary steps to check for continuity using a DVM probe and patch panel pins V20 and Z20 and report your findings to the test administrator.

   Caution: If you choose to disconnect cable A2A2, handle carefully; pins on the A2A2 cable are "hot."

10. Program Relay 04/0 using the following code:

    131024*4051

    Report whether or not the relay is operating to the test administrator.

11. Perform a visual inspection of the Signal Generator (A4A4). Report your results to the test administrator <u>before taking any action</u>.

12. Perform the necessary steps to remove and replace board A25 in the Switching Control Unit (A3A6). This board is accessible from the underside of the drawer and all screws have been loosened to save time.

```
|------|-------------------------------------------------------------|-------------------------------------------------------------|
|3017361|                                                            |                                                             |
|      | F10000*E61000*                                              |                                                             |
|      | E71031*512340 711627*300000 626300*120F14*203443            |MEASURE 5--1 VINPH AT PINS J3K,J3W                           |
|      | 616300*626162*E61014*E74100*E61000*E61300*                  |                                                             |
|      |                                                             |                                                             |
|      |        UL= F06000       LL= F04000                          |                                                             |
|      |                                                             |                                                             |
|      |DW WD CD.ADVERSE YAW BOARD TB1 IS DEFECTIVE                  |                                                             |
|------|-------------------------------------------------------------|-------------------------------------------------------------|
|3017401|YAW RATE - TAKE OFF AND LAND CONFIGURATION                  |                                                             |
|      |                                                             |                                                             |
|      | F10000*626300*140000*                                       |                                                             |
|      | 613F00*131023*335100 622000*613E00*623000*613C00*           |APPLY 14 VDC TO PIN 34J9                                     |
|      | 623800*613400*623938*373635 343332 31303F                   |                                                             |
|      | 613F00*622000*613E00*623000*613C00*623800*613400*           |APPLY 14 VDC TO PIN J15J                                     |
|      | 623938*373635 343332 31303F                                 |                                                             |
|      | 613F00*622000*613E00*623000*613C00*623800*613400*           |APPLY 14 VDC TO PIN J25A                                     |
|      | 623938*373635 343332 31303F                                 |                                                             |
|      | 131120*315100                                               |APPLY 28 VDCF TO PIN J25B                                    |
|      | 131129*305100                                               |APPLY 28 VDCF TO PIN 34J34                                   |
|      | 626300*110F13*203440 616312*621400*                         |ROUTE RELAY 1A040 TO PSC REF                                 |
|      | E11120*340000 E61600*F25200*                                |WAIT 10 SECS                                                 |
|      | E71031*512340 711327*300000 626300*120F14*203448            |MEASURE 0 -- 0.3  VINPH AT PINS J05B,J05C                    |
|      | 616300*626162*E61014*E74100*E61000*E61300*                  |                                                             |
|      |                                                             |                                                             |
|      |        UL= F03000       LL= E03000                          |                                                             |
|      |                                                             |                                                             |
|      |IF TEST IS WD CD. ADVERSE YAW BOARD TB3 IS                   |                                                             |
|      |DEFECTIVE                                                    |                                                             |
|------|-------------------------------------------------------------|-------------------------------------------------------------|
|3017441|                                                            |                                                             |
|      | F10000*E61000*                                              |                                                             |
|      | E71031*512340 711327*300000 626300*120F14*203443            |MEASURE 0 -- 0.3  VINPH AT PINS J1K,J1D                      |
|      | 616300*626162*E61014*E74100*E61000*E61300*                  |                                                             |
|      |                                                             |                                                             |
|      |        UL= F03000       LL= E03000                          |                                                             |
|      |                                                             |                                                             |
|      |IF TEST IS WD CD. ADVERSE YAW BOARD TB2 IS                   |                                                             |
|      |DEFECTIVE                                                    |                                                             |
|------|-------------------------------------------------------------|-------------------------------------------------------------|
|3017481|                                                            |                                                             |
|      | F10000*E61000*                                              |                                                             |
|      | E71031*512340 711327*300000 626300*120F14*203445            |MEASURE  0  -- 0.3   VINPH AT PINS J3K,J3W                   |
|      | 616300*626162*E61014*E74100*E61000*E61300*                  |                                                             |
|      |                                                             |                                                             |
|      |        UL= F03000       LL= E03000                          |                                                             |
|      |                                                             |                                                             |
|      |IF TEST IS WD CD. ADVERSE YAW BOARD TB1 IS                   |                                                             |
|      |DEFECTIVE                                                    |                                                             |
|------|-------------------------------------------------------------|-------------------------------------------------------------|
|3017491|                                                            |                                                             |
|      | F10000*E61000*                                              |                                                             |
|      | E71031*512340 626300*110F14*203244 E61014*E74100*           |MEASURE 14 -- 0.5  VDC AT PINS 4J15,4J31                     |
|      | E61000*E61300*                                              |                                                             |
|      |                                                             |                                                             |
|      |        UL= F14500       LL= F13500                          |                                                             |
|      |                                                             |                                                             |
|------|-------------------------------------------------------------|-------------------------------------------------------------|
|3017521|                                                            |                                                             |
|      | F10000*E61000*                                              |                                                             |
|      | 414052*612035 140000 131024*303651                          |APPLY  0.08 HZ   2.1 V MOD SIN WAVE TO PINS J08B,J06         |
|      | 626300*110F13*203440 616312*621400*                         |ROUTE RELAY 1A040 TO PSC REF                                 |
|      | E71032*512042 711627*300000 626300*120F14*203448            |READ WITH PSC  5  VINPH AT PINS J05B,J05C                    |
|      | 616300*626162*F25400*                                       |                                                             |
|      |                                                             |                                                             |
|      |                                                             |                                                             |
|      |                        NOTE                                 |                                                             |
|      |                                                             |                                                             |
|      |THIS TEST IS A FREQUENCY RESPONSE TEST OF THE RATE           |                                                             |
|      |GYRO CHANNEL AND THE FREQUENCY IS NOT CRITICAL               |                                                             |
|      |                                                             |                                                             |
|      |A. ON TEST PANEL, ROTATE 'OSCP INPUT' 'SIG SEL'              |                                                             |
|      |   SW TO 'DIGITAL MULTR'                                     |                                                             |
|      |B. USING THE DIFFERENTIAL/DC OFFSET AMPLIFIER ON             |                                                             |
|      |   THE OSCILLOSCOPE, SET THE OSCILLOSCOPE CONTROLS           |                                                             |
|      |   AS FOLLOWS ---                                            |                                                             |
|      |                                                             |                                                             |
|      |        -'DC' COUPLING SWITCH   DEPRESS IN                   |                                                             |
|      |        -'DC' COUPLING SWITCH   DEPRESS IN                   |                                                             |
|      |              'VERNIER'         FULLY CW                     |                                                             |
|      |               'V/DIV'          .5                           |                                                             |
|      |            'SWEEP MODE'        'AUTO'                       |                                                             |
|------|-------------------------------------------------------------|-------------------------------------------------------------|
```

PROCEDURAL TEST: SET-UP AND MATERIALS LIST

1. Student Test Booklet

2. Administration/Scoring Guides

3. Stop Watch

4. TOs:

   a. 33D7-17-15-2
   b. 5A9-2-42-28-1
   c. 33D7-42-1-132

5. 6883 test station set for normal LRU testing except as follows:

   a. Blown fuse in signal generator
   b. Power off
   c. O-scope: +and - AC power in, SWEEP MODE not AUTO, V/DVI at .05, VERNIER fully CCW, channel A & B cables at normal
   d. SIGNAL SELECT SW at AUTO TEST POINT
   e. DVM to allow reset via page 9
   f. FILTER MODE on A2A2 to NON-INV
   g. A1A1 PHASE SELECTOR to C
   h. A1A5 PHASE SELECTOR to A

6. Additional equipment:

   a. Feel and trim (12C1154-869) with cover removed and cables attached
   b. Feel and trim adapter (A44583-001) in drawer but not secured
   c. Patch board
   d. DVM cable in tool kit
   e. Spare fuse for signal generator in place
   f. Spare -28V relay driver (A33613-001) for replacement in A3A6 TRU

		Column
PROCEDURAL TEST ADMINISTRATION/SCORING GUIDE	Name _ _ _ _ _ _	1-6
	Class _ _ _ _ _ _	7-12
	Training Code _ _	13-14

Read to the student:

"This is a test of how well you can perform the procedures normally involved in the operation and maintenance of the 6883 test station. While the actions you will be asked to complete are typical of those encountered in the field, they are not meant to represent any specific set of operation or maintenance procedures. You are asked to simply complete the steps specified in the testing booklet as quickly and accurately as possible. Complete only those steps specified. TOs are available for reference if necessary, and all appropriate equipment has been provided. Are these any questions?"

Answer questions then "begin."

Start clock.

pg. 1

Note errors/comments			
	1. Remove all jewelry	_	15
	2. Power switches "on" in proper sequence (L to R)	_	16
	3. Rotate SELECTOR switch to 400 CPS PHASE A; observe 115v	_	17
	4. Rotate to PHASE C	_	18
	5. Adjust PHASE C control to show 115v and 400 Hz	_	19
	6. Rotate FILTER MODE to INVERTED; observe lamps	_	20
	7. Return FILTER MODE to PROGRAM	_	21
	Note Time: _ _ / _ _ Reset clock		22-25

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pg. 2	Note errors/comments		
	8. Power switch on test panel (400 CPS, A3A3) to OFF	__	26
	9. Select and install adapter (Caution: Be sure that power is off)	__	27
	10. Connect cables to adapter, turn power back on	__	28
	Note time: Reset clock	__ __/__ __	29-32
pg. 3	11 Set MODE switch to NORMAL	__	33
	12. Enter and request test #830401	__	34
	13. Verify test number, press START (allow 1 minute)	__	35
	14. Verify test date, press START (allow 1 minute)	__	36
	Note time: Reset clock	__ __/__ __	37-40
pg. 4	15. Turn MODE switch CW through STOP, back to NORMAL (or) turn MODE switch CCW to SINGLE TEST back to NORMAL	__	41
	16. Enter test #301740, TEST REQUEST	__	42
	17. Press START (allow 1 minute)	__	43
	Note time: Reset clock	__ __/__ __	44-47

pg. 5	Note errors/comments	18. Rotate OSCOP INPUT SIGNAL SEL switch to DIGITAL MULTR	__	48
		19. Press NEG DC coupling switch Press POS DC coupling switch (or slide coupling switches)	__	49
		20. Set VERNIER to fully CW	__	50
		21. Set V/DIV at .5	__	51
		22. Set SWEEP mode on AUTO Allow 5 minutes for O-scope setup.	__	52
		23. Student says "no signal"	__	53
		Note time: Tell student to continue Reset clock	__ __/__ __	54-57
pg. 6		24. Reseat adapter (remove right hand cable if necessary)	__	58
		25. Rotate MODE switch to REPEAT, press START	__	59
		Note time: Reset clock	__ __/__ __	60-63
pg. 7		26. Rotate MODE switch to NORMAL	__	64
		27. Using TO page in booklet, locate last zero-ending test #	_	65
		28. Enter Test #301740, TEST REQUEST and START. Allow 3 minutes.	__	66
		Note time: Reset clock	__ __/__ __	67-70

pg. 8

Note errors/comments

29. Disconnect A & B ___ 1

30. Reconnect A to B input ___ 2

31. Select channel B on DISPLAY switch (or depress appropriate pushbuttons) ___ 3

Student reports "still nothing"

Note time: __ __/__ __ 4-7
Tell student to continue
Reset clock

pg. 9

32. Power switch on test panel to OFF (Caution: Power must be off before continuing) ___ 8

33. Remove adapter, install patch board (optional: turn power back on) ___ 9

Set up DVM as follows:

34. POWER to FILTER OUT or any setting other than REMOTE ___ 10

35. PRINT CONTROL to TRACK ___ 11

36. FUNCTION to K ohms ___ 12

37. RANGE to K ohms ___ 13

38. Remove A2A2 input cable; Connect DVM cable ___ 14

39. Student has following options. Check appropriate lines. No other options are acceptable.

39.a. Check Pin #s V20-Z20, reading should be 0 (or)
39.b. Set MODE switch to KEYBOARD (or) reading should be all 9s.
39.c. Set MODE switch to KEYBOARD Enter #131024, then ADDRESS Enter 4051 then INFO ___ 15

Note time: __ __/__ __ 16-19
Tell student to continue
Reset clock

p. 10	Note errors/comments			
		40. Set MODE switch to KEYBOARD (already set if student used options 39.b., 39.c., above)	__	20
		41. Enter #131024 then ADDRESS (optional if student used option 39.c., above)	__	21
		42. Enter 4051 then INFO (or) Enter 3051, then INFO (if option 39.c. used above)	_	22
		43. Student reports that relay <u>is</u> operating	__	23
		Note time: Tell student to continue Reset clock	__ __/__ __	24-27
pg. 11		44. Locate Signal Generator (A4A4)	__	28
		45. Detect blown fuse	__	29
		Note time: Tell student to "remove power from the signal generator then replace the fuse" Reset clock	__ __/__ __	30-33
		46. A4A4 power to OFF (<u>Caution</u>: Does not remove power to fuse. Tell student "before continuing be aware that the fuse is wired before the switch and is therefore still hot.")	__	34
		47. Replace fuse via fuse cap using signal generator spare (mark as incorrect if student turns off power to test station <u>unless</u> fuse does not come out with fuse cap; if latter case, power off is correct)	__	35
		48. Power to ON; fuse light is now off	__	36
		Note time: Tell student to continue Reset clock	__ __/__ __	37-40

p. 12

Note errors/comments		
49. Enter 14, ADDRESS	__	41
50. Enter 15, ADDRESS (Caution: Do not allow student to proceed unles steps 49 and 50 performed.)	__	42
51. Locate SCU	__	43
52. Turn power OFF (Caution: Do not allow student to extend drawer unless power is off.)	__	44
53. Extend unit (lower cover removed)	__	45
54. Locate and remove component (A25)	__	46
55. Replace unit	__	47
Note time:	__ __/__ __	48-51
Debrief student, answer questions. Reset test station.		
Instructor rating of student ability (1 = very poor, 7 = excellent)	__	52

APPENDIX C-3:

Projected Job Proficiency Test

INSTRUCTIONS:

For each of the 35 questions in this test, select your best answer by circling the appropriate letter on the answer sheet. Do not write in the test booklet.

Be sure to mark only one answer per question. If you are unsure about an answer, circle your best guess. Try to answer all of the questions.

You will have 45 minutes to complete this test.

Do not turn the page until you are told to begin.

1. The converter set processes what type of data from the computers to provide analog outputs?

   A. Analog-Digital
   B. Discrete Data
   C. Serial Digital Data
   D. Parallel Digital Data

2. The amount of times we do a given signal is know as the:

   A. Command Pulse
   B. Rate Group
   C. Data Request
   D. Acknowledge

3. Which area of the converter controls the WDC?

   A. Area I
   B. Area I and III
   C. Area III
   D. Area II

4. The arithmatic section of a computer is:

   A. Central Processing Unit
   B. Core
   C. Input/Output
   D. None of the above

5. The purpose of the 05 tape is to check:

   A. Inputs
   B. Bite
   C. Outputs
   D. Converter Set Overloads

6. How many outer limit checks are you allowed to fail on any test?

   A. None
   B. One
   C. Two
   D. Three

7. A1A2 (Power Supply Controller) controls the power out of which drawer?

   A. Variable Power Control (A1A5)
   B. Power Supply (A2A9)
   C. Power Supply (A3PS1)
   D. Micrologic Power Supply (A1A9)

8. Switching Control Unit (A3A6) controls the setting of routing relays inside the following drawers:

   A. FCS Adapter (A4A1)
   B. Transformer Converter (A4A2)
   C. Ratio Transformer (A4A6)
   D. All the above

9. The VD_4 in Stimulus Relay Can controls the:

   A. Setting of a relay supplying +28 vdc to the can
   B. Setting of relay supplying ±12 vdc to the can.
   C. Information Input lines
   D. Steering Input lines

10. A Flip Flop needs what signals to set:

A. A low on 1, high on 0, and a clock pulse
B. A high on 1, high on 0, and no clock pulse
C. A high on 1, low on 0, and a clock pulse
D. None of the above

11. The Emergency Off button is located:

A. On Cenpac
B. On DATAC
C. On the Stimulus Controller
D. On the Test Point Controller

12. The Programming 131023* 34353651Info. refers to:

A. Resetting of Stimulus Relay 034, 035, 036
B. Setting of Relays 034
C. Setting of Relays 034, 035, 036
D. Setting of Relays 102, 343, 536

13. A4A6 provides Inputs (during maintenance testing) to:

A. DATAC
B. A4A7
C. A4A2
D. Cenpac

14. A F02A250V4A fuse is:

A. A slow Blow 250 Volt 4 Amp
B. A fast Blow 250 Volt 4 Amp
C. Both of the above
D. None of the above

15. Is it permissible to replace a fast Blow fuse with a slow Blow?

A. Yes
B. No
C. Sometimes
D. Depends on the amperage

16. Is it permissible to replace a fuse of a given amperage with one of a higher amperage?

A. Sometimes
B. Yes
C. No
D. Depends on the voltage

17. The 400 CPS on-off switch on A3A2A31 is used to control:

A. Signals applied to the LRU
B. Signals applied within the station
C. Neither
D. Power (as the STA, power off switch)

18. The DC volts meter on A1A2 measures the output of which power supply?

A. A2A5 Digital Interface Unit
B. Parallel Digital Adapter A2A4
C. A2A3 Serial Digital Adapter
D. None of the above

19. Power Stimulus Relays can be tested at the patch panel:

A. By jump 2 sets of contacts together
B. They cannot
C. In the usual manner
D. By programming a Test Point Relay

20. Stimulus Relays can be tested at the patch panel by:

A. Programming the Relay and ohms checking between the normally open contacts and the wiper
B. They cannot be checked
C. Programming the Relay and ohms checking between the normally closed contacts and the wiper
D. A or C

21. A coil will usually ohms check:

A. As an open
B. As one or two ohms
C. A very high number of ohms
D. It cannot be ohms checked

22. A rectifier is used to:

A. Change AC to DC
B. Change DC to AC
C. Balance the line
D. None of the above

23. A circuit breaker that will not reset usually indicates:

A. A short in the circuit
B. A broken circuit breaker
C. A shorted filter capacitor
D. All or any of the above

24. If you are not sure about a problem, you should:

A. Look at the T.O. and fake it
B. Ask someone
C. Push start on DATAC and proceed carefully
D. Go for a coffee break

25. A pulse period is measured by:

A. An o-scope
B. Counter Timer
C. DATAC
D. A or B

26. The front panel knobs of the TRUs can be enabled by the DATAC Mode Switch in which position?

A. Normal
B. Stop
C. Manual
D. Keyboard

27. The clock input for A2A1, A2A3, A2A4 comes from:

A. DATAC
B. Counter Timer
C. Signal generator
D. None of the above

28. An absence of a polarity sign on the DVM indicates:

A. No 115 AC
B. No drive from DATAC
C. Counter Time Circuit Breaker on Micrologic Power Supply tripped
D. Cenpac off line

29. The Test Station Interconnection Diagram is used to:

A. Get between cards inside a drawer
B. Get between drawers
C. Locate pins on unlisted cables
D. It is not used

30. A 3 Input OR gate requires what Inputs for a high output?

A. All highs
B. All lows
C. 2 highs and 1 low
D. A and C

31. 26VAC REF voltage on A3A2A32 is used in:

A. CSS (A2A8)
B. Ratio-Transformers A4A6 and A4A7
C. Programmable Transformer/ Converter A4A21
D. All of the above

32. To forward bias a PNP, you need to have:

A. A more negative on the base than the emitter
B. A more positive on the base than the emitter
C. A more negative on the base than the collector
D. A or C

33. What area of the converter controls the outputs?

A. Area I
B. Area II
C. Area III
D. Both A anc C

34. The purpose of the 03 tape is to check:

A. Inputs
B. Bite
C. Outputs
D. Converter Set Overloads

35. If you are in Redundant Ladder of the converter, you can check to be sure by using a probe and checking J609 Pin 64. It will be at:

A. 5 volts
B. 10 volts
C. Zero volts
D. 28 volts

APPENDIX C-4:

Student Interview Questionaire

STUDENT INTERVIEW

CLASS # _____ DATE _____

For each of the questions below, please circle the number that best expresses your opinion on a scale from 1 to 5, where 1 = Not at all, and 5 = Very much.

	Not at All				Very Much
1. Did you have sufficient time on the equipment in the 6883 block?	1	2	3	4	5
2. Was your time on the equipment well utilized?	1	2	3	4	5
3. Was there variety in the training on the equipment?	1	2	3	4	5
4. Do you have a good understanding of how to operate the equipment?	1	2	3	4	5
5. Do you feel comfortable operating the equipment?	1	2	3	4	5
6. To what extent did equipment malfunctions <u>hinder</u> your training?	1	2	3	4	5
7. To what extent did equipment malfunctions <u>benefit</u> your training?	1	2	3	4	5
8. How much of your training time on the equipment was spent on trouble-shooting?	1	2	3	4	5
9. Would you like to have had more trouble-shooting experience?	1	2	3	4	5
10. Do you feel that you have had adequate trouble-shooting experience for your field assignment?	1	2	3	4	5
11. Was your training instructor helpful in explaining the equipment and its use?	1	2	3	4	5

12. What were your impressions of the GS simulator as a training device? Positive? Negative?

13. Do you feel that the GS is sophisticated enough for 6883 training? Is it too sophisticated?

14. What do you see as the simulator's good points? What things are especially helpful in terms of training?

15. What do you see as the simulator's bad points? Are there any things about the equipment that you feel hindered training?

16. Are there any things about the simulator or the way it was used in training that you think should be changed?

Any other comments?

APPENDIX D:

Pre-6883 and Post-6883 Performance Results

Table D-1

Aptitude Test Scores

Test		Training Mode AET	Training Mode IGS	t-Value
ASVAB Composite				
General	N	22	21	0.98
	X	67.05	70.95	NS
	s	14.69	11.14	
Mechanical	N	22	21	0.65
	X	62.27	65.71	NS
	s	17.58	17.27	
Administrative	N	22	21	-0.54
	X	67.05	64.29	NS
	s	12.88	19.83	
Electronics	N	22	21	0.82
	X	72.73	74.76	NS
	s	7.52	8.73	
AFQT	N	22	21	1.64
	X	65.59	72.81	NS
	s	15.87	12.81	

Table D-2

End-of-Block Test Scores Summary

Block of Instruction		Training Mode AET	Training Mode IGS	t-Value
1. Electronic Principles	N	22	21	0.76
	X	88.09	89.48	NS
	s	4.87	6.90	
2. Introduction to Avionics	N	22	21	0.91
	X	91.5	93.2	NS
	s	5.93	6.27	
3. Central Processor and Controls	N	22	21	1.57
	X	88.36	92.00	NS
	s	8.36	6.69	
4. Binary Data Register Router	N	22	21	0.59
	X	87.64	89.00	NS
	s	7.08	7.96	
5. Common Automatic Test Equipment I	N	22	21	0.25
	X	86.14	87.14	NS
	s	14.22	12.20	
6. Common Automatic Test Equipment II	N	22	21	0.11
	X	86.86	87.14	NS
	s	7.56	9.20	
7. 6863 Test Station	N	22	21	1.40
	X	86.18	89.90	NS
	s	9.46	7.86	
8. 6886 Test Station	N	22	21	1.10
	X	85.64	88.29	NS
	s	7.58	8.25	

Table D-3

Block Test Scores After Block 9

Track I	Track II	Block of Instruction		Training Mode AET	Training Mode IGS	t-Value
--	10	Computer Test Station	N	16	16	0.93
			X	93.44	95.63	NS
			s	7.47	5.74	
--	11	Attitude and Rate Test Station	N	16	16	0.33
			X	88.75	89.69	NS
			s	8.27	7.63	
10	--	Displays Test Station	N	6	5	0.84
			X	89.00	92.00	NS
			s	7.48	2.83	
11	12	Video Test Station	N	18	18	0.99
			X	81.39	83.78	NS
			s	6.78	7.62	
12	13	Receiver Transmitter & Modulator Test Station	N	18	18	0.42
			X	81.44	82.89	NS
			s	9.74	10.95	

Note: Sample size differences are due to the fact that two training tracks (I and II) are available after block 9, with everyone being required to take Video Test Station and Receiver Transmitter & Modulator Test Station.

Table D-4

Projected Job Proficiency Test

Test		Training Mode AET	Training Mode IGS	t-Value
Projected Job Proficiency Test	N	21	21	0.14
	X	18.95	18.76	NS
	s	3.28	5.39	

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