

AD-A146 677

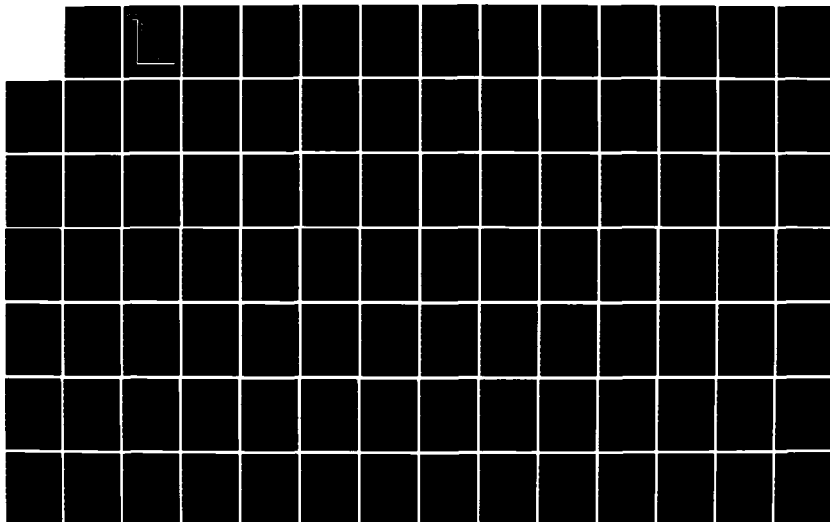
SITUATIONAL INTERACTIVE MICRO/GRAPHIC SIMULATOR SYSTEM
FOR IMPROVING MAINTENANCE PERFORMANCE(U) KINTON INC
ALEXANDRIA VA E L SHRIVER ET AL. SEP 84 AFHRL-TP-84-9
F33615-80-C-0012

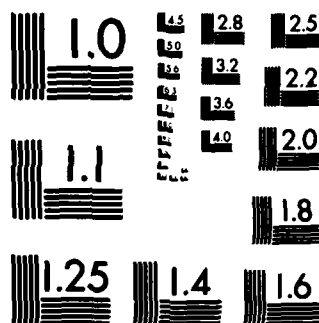
1/2

UNCLASSIFIED

F/G 5/9

NL





COPY RESOLUTION TEST CHART

6

AIR FORCE



AD-A146 677

HUMAN RESOURCES

**SITUATIONAL INTERACTIVE MICRO/GRAPHIC
SIMULATOR SYSTEM FOR IMPROVING
MAINTENANCE PERFORMANCE**

By

**Edgar L. Shriver
Robert C. Trexler**

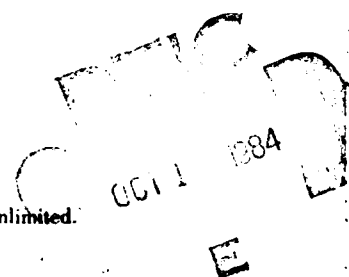
**Kinton, Incorporated
5707 Seminary Road
Bailey's Crossroads, Virginia 22041**

**TRAINING SYSTEMS DIVISION
Lowry Air Force Base, Colorado 80230**

September 1984

Final Technical Paper for Period January 1980 - January 1983

Approved for public release; distribution unlimited.



LABORATORY

DTIC FILE COPY

AIR FORCE SYSTEMS COMMAND

BROOKS AIR FORCE BASE, TEXAS 78235-5000

84 10 10 144

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely Government-related procurement, the United States Government incurs no responsibility or any obligation whatsoever. The fact that the Government may have formulated or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication, or otherwise in any manner construed, as licensing the holder, or any other person or corporation; or as conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

The Public Affairs Office has reviewed this paper, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This paper has been reviewed and is approved for publication.

THOMAS D. BAXTER, Major, USAF
Contract Monitor

JOSEPH Y. YASUTAKE, Technical Advisor
Training Systems Division

GRAHAM P. CROW, Colonel, USAF
Chief, Training Systems Division

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified		1b. RESTRICTIVE MARKINGS	
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE			
4. PERFORMING ORGANIZATION REPORT NUMBER(S)		5. MONITORING ORGANIZATION REPORT NUMBER(S) AFHRL-TP-84-9	
6a. NAME OF PERFORMING ORGANIZATION Kinton, Incorporated 5707 Seminary Road	6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION Training Systems Division Air Force Human Resources Laboratory	
6c. ADDRESS (City, State and ZIP Code) Bailey's Crossroads, Virginia 22041		7b. ADDRESS (City, State and ZIP Code) Lowry Air Force Base, Colorado 80230	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Air Force Human Resources Laboratory	8b. OFFICE SYMBOL (If applicable) HQ AFHRL	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F33615-80-C-0012	
8c. ADDRESS (City, State and ZIP Code) Brooks Air Force Base, Texas 78235		10. SOURCE OF FUNDING NOS.	
		PROGRAM ELEMENT NO. 63751F	TASK NO. 01
		PROJECT NO. 2361	WORK UNIT NO. 09
11. TITLE (Include Security Classification) Situational Interactive Micro/Graphic Simulator System for Improving Maintenance Performance			
12. PERSONAL AUTHOR(S) Shriver, Edgar L. Trexler, Robert C.			
13a. TYPE OF REPORT Final	13b. TIME COVERED FROM Jan 80 TO Jan 83	14. DATE OF REPORT (Yr., Mo., Day) September 1984	15. PAGE COUNT 154
16. SUPPLEMENTARY NOTATION			
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB. GR.	
		cognitive processes	
		courseware authoring	
		courseware development technology	
19. ABSTRACT (Continue on reverse if necessary and identify by block number) A generic hardware trainer tester was constructed using a microcomputer, two image storage/display devices, a magnetic card reader, a data entry keypad, and a printer. Problem-solving courseware was developed based on situational interaction techniques. Thirty problems simulated troubleshooting the major components of the FB-111A flight simulator. Students solved each problem by forming their hypotheses about the source of trouble, abstracting data from the displays/test instruments they chose to observe, and reformulating their hypotheses as needed. They completed the problem-solving process by replacing the malfunctioning part and verifying that this replacement cleared all symptoms. Some problems were multiple malfunctions. Fifteen newly assigned personnel had to find and correct malfunctions placed in the actual equipment, given only the AFTO Form 781 work order which stated a symptom of the problem. The six personnel with trainer tester experience solved all problems. The nine personnel without the simulator experience solved about half the problems. The simulator-experienced personnel solved the problems in half the time the others did. More than half the simulator-experienced personnel were consistent in taking steps that led directly to problem solution. None of the personnel who lacked simulator experience were consistent; all took irrelevant steps. Job supervisors look for consistent performance before trusting performers to avoid damage to themselves or the equipment. In effect, the simulator training reduces the time it takes new personnel to become consistent job performers. Because most maintenance personnel are in their first enlistment, this simulator offers the potential to increase the size of the productive work force in a maintenance unit.			
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐		21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL Nancy A. Perrigo Chief, STINFO Office		22b. TELEPHONE NUMBER (Including Area Code) (512) 536-3877	22c. OFFICE SYMBOL AFHRL/TSR

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

Item 18 (Continued):

electronic systems
generic simulators
image storage/retrieval
job performance measurement
maintenance training
maintenance unit productivity
microcomputer
on-the-job training
problem solving training
simulation
situational interaction
trainer/testers
troubleshooting

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

**SITUATIONAL INTERACTIVE MICRO/GRAPHIC SIMULATOR SYSTEM
FOR IMPROVING MAINTENANCE PERFORMANCE**

By

**Edgar L. Shriver
Robert C. Trexler**

**Kinton, Incorporated
5707 Seminary Road
Bailey's Crossroads, Virginia 22041**

**TRAINING SYSTEMS DIVISION
Lowry Air Force Base, Colorado 80230**

Accession For	
NTIS CM&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Avail. Codes	
Dist	Special

A-1



Reviewed and submitted for publication by

**Thomas D. Baxter, Major, USAF
Chief, Skills Development Branch**

**This publication is primarily a working paper.
It is published solely to document work performed.**

Research Site

The job site was chosen as the location for this effort. It was decided that on-site military personnel would perceive the device as fulfilling job performance objectives--rather than learning objectives associated with supporting instructors in presenting school topics.

Evaluation

A formative evaluation was part of the research design. Its purpose was to identify and correct hardware design deficiencies and to shape the content to directly support effective job performance, as defined by site supervisors.

The FSTT failed in minor ways several times during its first year of use. Only one of these failures required more than a day to identify. This was an intermittent failure which took about 2 months to identify and correct.

The personnel on the job site were able to use the trainer simulator after a briefing on what it was and how to turn it on. Trainee use did not require additional supervisor or instructor time. Personnel on site, especially newly assigned personnel, used the FSTT extensively on three shifts each day for a period of 15 months. They reported learning the troubleshooting skills on the FSTT that they needed to perform maintenance on operational equipment.

In the summative test, newly assigned personnel with 1 week of FSTT experience performed significantly better on the operational equipment than did newly assigned personnel without FSTT experience. The FSTT personnel correctly repaired the faults inserted in the operational equipment. The non-FSTT personnel correctly repaired less than half the same inserted faults. The FSTT personnel made the repairs in half the time that non-FSTT personnel required. Most FSTT personnel were consistently efficient in doing the maintenance work, but none of the non-FSTT personnel were consistent. Job supervisors cannot allow personnel who are inconsistent performers to work without supervision because they may damage themselves or the equipment. Thus, newcomers serve only as helpers, with few becoming productive members of the work force during their first enlistment. Since most members of the work force in the volunteer services are in their first term, the results of the present effort are especially significant in demonstrating a means of increasing the effective size of the productive work force.

The Formative and Summative Evaluations were straightforward and conclusive. The micro/graphic simulator system proved to be generally reliable and acceptable to job users and job supervisors, and it significantly improved job performance.

SUMMARY

Objective

The objective of the current effort was to improve performance in maintenance units through use of a micro/graphic simulation system. The simulation hardware/software was to be generic and low in cost. The technique for developing the content that made the generic device a simulation of specific operational equipment was to be simple and performable by personnel who were professional only in their maintenance skills on the operational equipment. The product of this effort was a Flight Simulator Troubleshooting Trainer (FSTT). It takes its name from the specific operational equipment (FB-111A Flight Simulator), the content of which was developed on the generic microprocessor/visual storage/display device. The cost of the generic hardware device was low (i.e., \$20,000) in comparison to other equipment of this type. The technique for generating content was simple and could be performed by amateur photography, artwork, and record-keeping, along with expert skills in troubleshooting.

Background

This effort is part of a broader research and development (R&D) program on maintenance training simulators conducted by the Air Force Human Resources Laboratory (AFHRL) at Lowry AFB, Colorado. The work reported here developed and evaluated the only generic device in this AFHRL program. It is a generic device in that the simulation content is independent of the hardware. It uses image storage/retrieval/display viewers rather than three-dimensional mock-ups or two-dimensional flat panel representations of the parent (real) system. Thus, it is the only simulator studied under this general program which uses a low cost generic microprocessor/video image device, with system specific graphic content, as a micro/graphic simulator system.

During the time the R&D was conducted, costs of microprocessors and image storage/display devices were so drastically reduced that other devices based on physical verisimilitude to the parent system are no longer in direct competition with micro/graphic simulator systems for procurement money. The micro/graphic devices cost only a few thousand dollars, whereas other two-dimensional and three-dimensional devices cost 10 to 100 times that amount. The principal questions about these low-cost micro/graphic devices is whether they can be used effectively in improving maintenance performance and how content can be developed for them to make them effective. In this effort, the content was developed using new Situational Interaction techniques. Situational Interaction creates a problem-solving environment for the learner, rather than a procedural solution for the learner to follow.

Recommendations

Users and supervisors approved of the situationally interactive FSTT content and recommended that such devices be placed at additional job sites and in the training school.

It is recommended that further studies of micro/graphic simulator systems be implemented, in which personnel trained with such systems are allowed to work on their own at selected job sites to determine the effects on unit productivity.

An additional recommendation is that the situationally interactive FSTT content be recorded on a more cost effective micro/graphic hardware system than was developed for delivering the content in this effort; i.e., a videodisc system to replace the microfiche system used. The cost of the microfiche-based system is three times the cost of a videodisc-based system and is inherently less reliable than a videodisc system with the same functional capability (effectiveness).

PREFACE

This Report is a research product of a program to improve performance of Air Force personnel in maintenance units through use of a micro/graphic simulator system.

The authors wish to express their appreciation for the cooperation of the following personnel: Captain Russell Seeman (380 BMW/D05) who was involved in the early stages of project definition; Chief David Marshall, NCOIC of the 380 AMS (MADD), who ensured access to facilities and personnel; and SMSGT Ronald Schmidt who served as the key interface between research staff and Air Force personnel.

In addition, the authors thank Mr. Dennis Bardelsic for his active interest as a civilian instructor in data collection through the formative and summative evaluation phases.

Dr. Edgar Smith, AFHRL Lowry AFB, was the initial COTR. Upon his retirement, he was replaced by Dr. Gerry Deignan, AFHRL.

Robert Trexler was the Program Director of the effort. Principal Investigator for the project was Dr. Edgar L. Shriver, President of Kinton, Incorporated.

TABLE OF CONTENTS

	<u>PAGE</u>
I. INTRODUCTION.	1
The Problem	1
Background.	1
II. APPROACH.	11
Simulation Approach	11
The Training Approach	13
III. DESCRIPTION OF THE TRAINING SYSTEM.	17
The Site.	17
The Trainer/Simulator	17
Specific Features	20
Microfiche Storage/Display Units.	20
Magnetic Card Reader.	20
Hexidecimal Keypads	21
In-Line Electro-Luminescent Display	21
Printer	21
Electronic Controller	21
Desk Enclosure.	21
The Courseware.	21
Authoring	22
Scoring	25
Job Aids.	26
Using the FSTT.	28
FSTT Cost Effectiveness Evaluation.	31
IV. FORMATIVE EVALUATION.	35
Evaluation Plan	35
Results	36
Hardware.	36
Courseware.	36
User Acceptance	37
User Performance.	42
Analysis of FSTT Printouts.	42
Interpretation.	46
Courseware Authoring.	46
Conclusions	46
V. SUMMATIVE EVALUATION (Experimental Design and Test)	49
Performance Measurement	49
Subject Population.	50
Selecting the Problem Set	51
Test Administration	51
Procedure	52
Data Analysis	52
Discussion.	58
Conclusions	59
Recommendations	59

TABLE OF CONTENTS (Continued)

	<u>PAGE</u>
REFERENCES.	61
APPENDIX A - AIDS TO SOLVING 30 FSTT TROUBLESHOOTING PROBLEMS . . .	63
APPENDIX B - AUTHORIZING TECHNIQUES FOR DEVELOPING FSTT SIMULATION PROBLEMS	95
APPENDIX C - SAMPLE PROBLEM	117
APPENDIX D - DESCRIPTION OF FSTT FAILURES AND CORRECTIVE ACTIONS TAKEN DURING FORMATIVE EVALUATION.	137

LIST OF FIGURES

Figure 1. Flight Simulator Troubleshooting Trainer (FSTT).	19
Figure 2. FSTT Courseware Authoring Process.	24
Figure 3. Linear Regression Equations, FSTT Score and Time as Function of Frame Requests	44

LIST OF TABLES

Table 1. Experimental Group Time to Perform Problems	53
Table 2. Control Group Time to Perform Problems.	54
Table 3. Experimental Group Percentage Correct Scores.	55
Table 4. Control Group Percentage Correct Scores	56

I. INTRODUCTION

The Problem

First-term Air Force personnel constitute most of the work force available in maintenance units. A major portion of their first enlistment has passed before electronic maintenance personnel become consistently competent to perform maintenance on the equipment without supervision. Some personnel never achieve sufficient competence to carry their fair share of the workload. A statement that 20 percent of the maintenance personnel do 80 percent of the work is met with affirmative nods in maintenance units. This situation is not new; it has been a problem to a greater or lesser degree for decades.

Job competence is not achieved in school. Schools do not have sufficient amounts of job-specific equipment to produce job-competent graduates, therefore, they concentrate on basics and fundamentals. The job sites, then, must develop the required job competence so that personnel can perform useful work rather than merely be "helpers." It is generally agreed by job site personnel that those newly assigned from school know almost nothing about doing their job (Chenzoff, et al., in press). At the job sites, however, equipment cannot be taken out of use for personnel to practice on. They must learn as helpers until they can be trusted not to cause damage.

If a low-cost trainer/simulator can provide synthetic job experience and make personnel consistently job competent early in their first enlistment, the effective size of the work force will be increased. Such a device would solve a problem of long standing. The present effort is concerned with exploiting the potential of low-cost microcomputers for a practical and effective solution to this problem.

Background

Research and development on maintenance of electronic systems has been conducted for more than 30 years. This R&D has dealt with methods of training, analysis, performance aiding, and performance measurement. The focus has been largely on troubleshooting, which is a primary job activity and one that constitutes a major problem. During this period there has been a shift from troubleshooting as problem solving to proceduralized troubleshooting. While both approaches are in practice today, neither is considered entirely satisfactory because troubleshooting skill takes a long time to develop, and many maintenance workers never develop enough proficiency to be more than marginally productive. Therefore, most of the troubleshooting work is done today by the small percentage of the work force who become proficient--with most personnel remaining relatively unproductive.

A justification for continuing poor maintenance performance that has been used for 30 years is that military equipment has become more complex. Therefore, the conclusions that follow indicate that automated test equipment must be used to proceduralize troubleshooting; Fully Proceduralized Job Performance Aids must be used to proceduralize troubleshooting; part-task trainers must be used; Technical Orders must be better organized; job performance must be measured to identify weaknesses; new learning technology is needed; and maintenance simulators are needed. There is substantial agreement that no satisfactory solution to the electronic maintenance training problem has been found. The solutions that involve proceduralizing troubleshooting have not been notably successful. A method enabling maintenance personnel to learn to solve problems without job experience remains to be developed.

The history of simulators--their physical fidelity, the transfer they mediate, their use as part-task trainers, etc.--has also been long and extensive. Simulators achieved their proven potential in training (in most people's minds) because flight simulators have been used with remarkable success for training pilots. Compared with actual aircraft, flight simulators are less expensive, safer, and better suited for controlling and measuring learning events. They are still very high in cost in comparison to what is practical to spend to prepare maintenance personnel for their job. The R&D question for the present effort was: Can training simulators of some type be produced at a low enough cost to support effective maintenance training?

Maintenance simulators have been used as part of R&D on training methods, although not a prominent part. Methods used in maintenance training R&D have tended toward devices that cost less than computer-based maintenance simulators; e.g., simulations of the troubleshooting process have often been based on paper media, from tab tests to symbolic substitute tests to cardboard mockups. It is only in the last few years that microcomputers have been inexpensive enough to be considered as having the same cost magnitude as paper.

The historical antecedents of the maintenance simulator developed in this effort are found in paper and graphics more than in the traditional flight simulator, because an electronic maintenance trainer simulator need not support development of the high degree of psychomotor skill that a pilot requires. This fact impacts maintenance simulator design. Piloting skills require coordinated psychomotor skills, and these skills are usually taught with three-dimensional (3D) simulators having high physical fidelity. Maintenance skills, on the other hand, do not have much of a psychophysical component. They require system concept understanding and problem-solving ability, skills that do not require a device with high physical fidelity for practice of maintenance actions.

The experienced electronic maintenance person uses logic or functional understanding of the system, along with knowledge that is system specific, to perform (non-proceduralized) troubleshooting. The troubleshooter needs

to know how to formulate hypotheses, make deductions from them, and check the deductions against facts obtained by measuring outputs of functional portions of the equipment; i.e., the hypothetico-deductive process. The troubleshooter also needs knowledge of location and appearance of parts to be able to "navigate" through the physical system in order to obtain the data from the system's outputs. The navigation requires specific knowledge of the physical appearance of objects and knowledge of the symbolic representations of objects in schematic diagrams and other "maps" of the physical system. The troubleshooter needs knowledge of failure probabilities, accessibility of components, and safety factors.

Some R&D projects and concepts are worth noting as historical antecedents for the way in which the present effort was approached.

The first known task analysis was made on a mimeograph machine in 1952 (Shriver, 1978). Operation of the machine is a procedure accomplished through a series of steps. Many tasks in the world of work are of this type. Problem solving is not similarly structured. Shriver, Fink, and Trexler (1959) developed the "Functional Analysis" technique to deal with the problem-solving job of electronic troubleshooting. They originally called it "Structured Cue-Response Analysis." When Shriver and Hart (1975) included this form of analysis in the "Front End Analysis" specification for the U.S. Army, they modified it slightly and renamed it "Functional Analysis."

The distinction between Task Analysis and Functional Analysis is a useful background concept. Task Analysis identifies a sequence of cues and responses or step-by-step procedures for performing a task. A troubleshooting task requires the identification and replacement of a bad component. Until the bad component is identified, the task is a problem to be solved. Functional Analysis categorizes the system into levels of assemblies, components, parts, and establishes their input-output dependencies to facilitate conceptualization of the problem. It provides a codification of the cues and responses, but it does not sequence them. When formatted as block diagrams, the results of the Functional Analysis provide a map. Like a road map, the diagrams do not give the instructions for how to get from one point to another. In troubleshooting, the user must decide where to go and what route to use to get there. The most efficient route will depend on conditions, such as ease of access, ease of obtaining measurements, and probability.

In the 1959 research by Shriver, Fink, and Trexler, several simulators were developed and used in a series of studies over a 6-year period. These training devices were described and compared in a report for a Naval Training Equipment Center (NTEC) Conference in 1975 (Shriver, 1975). The first devices in the series had substantial physical fidelity to the parent system. The later devices did not. They consisted of diagrams developed through Functional Analysis, placed on panels and "automated" with test points at all inputs/outputs. These devices were the historical "grand-fathers" of the "flat panel" devices, such as the Programmable Maintenance

Simulator (ECII). These devices and the instructional content based on Functional Analysis were shown to mediate high transfer in one study of the series. In this study, 30 students received 200 hours of training, including hands-on experience, on System A (an Acquisition Radar) and their troubleshooting performance was tested for 40 hours on 40 malfunction problems (on System A). A second group of 30 students received 200 hours of training on System B (a Tracking Radar) plus 24 hours of simulator training on System A. They were given the same performance test on System A. Though they had never been trained on System A nor had they even seen the system before, they performed as well as the students who had received 200 hours of training on System A.

The use of graphics in simulating the job also has a history in performance testing. In the AFHRL work on "symbolic substitutes" (Shriver & Foley, 1974a,b), performance tested on graphic representation of physical entities (symbolic substitutes) was compared to "hands-on" performance tested on the parent equipment. As troubleshooting tests, performance on the symbolic substitutes had a high correlation to performance on the system. However, the test administrators served as random access data storage and retrieval "devices," in that they selected and handed pages of data to test subjects when requested. Although the graphic technique was effective, the demands on administrators were too great for successful implementation. Shriver and Foley (1974a,b) at that time, called for research to develop a random access machine to present data graphically when requested by the troubleshooter. No low-cost random access machines were available at that time.

Edwards (1976) considered several instructional methods for teaching problem solving, including the case study or socratic method, the clinic or internship, as well as simulation. Of these three, she concluded that simulation was the most promising instructional method and, furthermore, that computer-based simulation could provide a flexible and individually responsive dimension while at the same time automatically scoring and maintaining records of student performance. Edwards felt that problem-solving skills are qualitatively different from other less complex kinds of intellectual processing. This same notion was considered by Condon, Ames, Hennessy, Shriver, and Seeman (1979), who discussed the need for training a wide variety of separate problems to increase general problem-solving ability.

McGuire (1976) discussed the use of written simulations, both as a training method and as a method for diagnostic testing. McGuire contrasted simulation training with conventional programmed instruction. She characterizes simulation training as follows: (a) focus is on the total problem, (b) the student assumes full control over the learning situation, (c) the student acts as a problem solver, (d) feedback is informative about events in the problem situation, and (e) branching is clearly a consequence of the student's own decisions. On the other hand, conventional programmed instruction is seen as follows: (a) concepts to be learned are broken into small segments, (b) focus is on bits and pieces until each segment of

understanding is error free, (c) carefully delineated questions are posed, (d) immediate feedback is provided to the student to correct misconceptions and to reinforce learning behavior, and (e) the learner has no genuine control over some learning sequences.

The performance assessment scheme developed by McGuire (1976) for evaluating the diagnostic ability of medical students was used as the basis for the extrinsic feedback system in the present study. Extrinsic feedback represents information about performance that would not come from performing on job equipment. In the present case, it comes from expert judgments about how efficient the choices of actions were in solving the problem. This extrinsic feedback system required experts to rate alternative actions in terms of their contribution to the solution of the problem. That is, some actions were rated extremely relevant, others less so, and some were unsafe and not permitted. These efficiency ratings were subjective, and because experts do not necessarily agree, the ratings do not represent an absolute standard or even a criterion for all aspects of performance. They may indeed promote inefficient learning by discouraging achievement of the objective, which is learning to map all paths to solution. Other paths will be more efficient for solving other problems, and all paths will be needed to learn the system.

Finally, a trainer device with physical characteristics that are very similar to those of the Flight Simulator Troubleshooting Trainer (FSTT) was noted in the literature. Rigney, Towne, Moran, and Mishler (1978) described the device, originally referred to as the Rigney Trainer. It used a microprocessor and microfiche storage system to present system data, and a cathode-ray tube (CRT) display to provide computer-assisted instruction (CAI) dialogue. The learning strategy for this trainer was instructional rather than experiential discovery learning. However, in terms of hardware, the FSTT and Rigney Trainer would interchangeably meet the same functional specifications. At a later date, this trainer was designated as the Electronic/Electric Maintenance Trainer (EEMT), and a videodisc storage device was substituted for the original microfiche device.

The history of training devices that mediate transfer by physical verisimilitude of components to a parent system is not treated in detail here, nor are procedural trainers or proceduralized jobs. The traditional use of physical fidelity and 2D versus 3D devices are not relevant issues in the present effort. The process of categorizing tasks as cognitive or psychomotor or procedural is not a relevant issue because the approach in the present effort was to avoid such categorizations. The focus is on the cognitive aspects of tasks, without denying that the same tasks have or could have psychophysical and specific knowledge aspects as well.

The present investigation treats specific knowledge as incidental learning content to be learned in the context of the larger objective which is learning to solve problems. This is contrary to abstracting specific knowledges and skills into categories or objectives for learning outside the simulated job content.

The research on the instructional approach of keeping the whole job content intact rather than abstracting it into parts for training is historically one of the oldest in psychology. It was called the "part-whole" issue in the early part of this century, and such studies abounded in the psychological literature. It split psychology into the Gestalt School (whole) and the Behaviorist School (part). The earliest military research application was by Jones and Odom (1954) when the Human Resources Research Organization (HumRRO) was first formed to conduct training research for the Army. The researchers found that soldiers consistently aimed their rifles high at night. The training that was developed on how to aim at night appeared to be completely ineffective. It was found that because soldiers did not believe they fired too high at night, they did not understand the instruction on how to fire lower. Therefore, a simulated nighttime job experience was created with silhouette targets to represent enemy soldiers. Unseen 12-foot panels were placed behind the simulated targets to collect the high bullet holes that resulted when the soldiers fired at the silhouettes. In the simulated situation, as in the actual job situation, soldiers believed they had hit the targets when they aimed at them. When they saw their hits in the panels from 4 to 12 feet above the heads of the silhouette targets, the instruction on how to correct their aiming procedure became meaningful. Each learned the procedures to correct the amount that they had aimed high. The following night, the soldiers applied what they had learned and hit the targets instead of the panels.

Shriver, Sivy, and Rosenquist (1955) used the same approach a year later to train infantry squads in night techniques of fire. Night techniques required coordination of individual fire to mass it at the enemy location using cues that were different under night conditions. These cues could not be recognized from a verbal explanation without a frame of reference. A standardized attack on a squad position was simulated as a criterion job situation. Squads of soldiers received experience in this whole job situation first, followed by successful instruction on procedures for using cues available at night to mass their fire to the right and left.

This instructional model was applied by other HumRRO researchers in the 1950s. It was applied to maintenance training by several researchers including Shriver, Brown, Shoemaker, McKnight, Gebhard, and their associates. Shoemaker (1960) coined the name "functional context" to mean that the context of the whole function is kept intact as the first training experience, followed by detailed instruction on the various aspects of the whole experience.

Research applications showed high student motivation and large increases in job performance capability. However, use of this instructional model more or less ceased after showing great promise in research. It required large amounts of operational equipment for each student to experience whole-job task situations, and schools did not have those quantities of equipment. Now that low-cost microcomputers and image storage

devices can simulate functioning operational equipment, the approach has finally become practical. The present effort is designed to keep the functional context of whole-job tasks intact in simulations.

In the present effort the instructional strategy is functional context or learn-by-doing or discovery learning. The model for the problem-solving situations is the hypothetico-deductive process, and the technique for creating the situations is Situational Interaction based on microprocessor control of random access to images of operational equipment and technical orders (TOs).

This historical summary has been an introduction to the concepts of importance in the present effort. In addition, several studies conducted over the past 6 years were direct antecedents to the present work. They were part of an overall AFHRL effort, which included a literature survey, needs analysis, market survey, job analysis of flight simulator maintenance, and development of functional and procurement specifications for flight simulator maintenance simulators.

The literature survey (Condon, et al., 1979; Fink & Shriver, 1978a) showed that physical fidelity was the primary means used for making simulators like the parent system. An exception was the flat-panel simulator, or 2D device, which gains its verisimilitude by a combination of graphic depictions on one or more flat panels upon which selected controls and displays from the parent system are mounted. In the literature, R&D issues focused on physical fidelity and transfer. Some discussion of psychological fidelity was found but without an operational definition or practical implementation of it, except in 2D flat panel simulators. Little consideration of practical factors, such as reliability of devices or affordability to enable every student to have one, was found in the literature.

The needs analysis (Fink & Shriver, 1978b) revealed that school maintenance instructors perceived no need for maintenance training devices or maintenance simulators with which they had no personal experience. Those who had no experience with anything but real equipment saw no use for anything but real equipment or a maintenance simulator with extremely high physical fidelity. The respondents in the needs analysis were told of research results that demonstrated training effectiveness of graphic simulations of real equipment, and the instructional concept of increasing physical fidelity of simulators with increasing skill levels was discussed. The instructors acknowledged that graphics and overhead projectors or simple plastic models were useful to support their lectures, but could not accept them as objects on which to practice.

A market survey revealed that there was an abundance of off-the-shelf components for low-cost, microprocessor-controlled video display devices. There were image storage devices based on videodisc (laser), magnetic disc, and microfiche technology. Videodisc mastering processes were not considered sufficiently reliable. Magnetic disc technology could not convert photographic images to images stored on magnetic disc. Microfiche

storage devices were available, simple to master from photographs, and to change or update.

The job analysis (Condon, et al., 1979) revealed that troubleshooting was the principal main-tenance job on FB-111A flight simulators. The troubleshooting technical orders on this parent system had not been proceduralized. Troubleshooting was still essentially a problem-solving job. Descriptions of about 60 troubleshooting problem situations, representative of failures in flight simulators and obtained through records and interviews with personnel who had performed the troubleshooting, were used to identify job performance requirements. Comparing the job performance requirements to course content in the school revealed little correspondence. The course contained extensive treatment of basics and fundamentals useful only with experience. The only practice available in the course was on an obsolete flight simulator, and very few course hours involved actual experience on the obsolete equipment.

Two procurement specifications were produced, one for a relatively expensive simulator based on physical fidelity, the other based on micro-computer random access to stored images of operational equipment. It was decided not to procure the high physical fidelity device (in spite of the opinions of school instructors) because the R&D requirement was to develop and test the effectiveness of a conceptual trainer/simulator. The conceptual trainer was believed to be particularly suitable to deliver on-the-job training. The lack of perceived need by school instructors contributed to the decision to introduce the Flight Simulator Troubleshooting Trainer (FSTT) at the job site. Another reason for field testing the FSTT at the job site was to increase the probability of obtaining actual job performance data in the summative evaluation. There was no other place to obtain performance data on the parent system.

The specification called for the use of graphics and words exclusively to create the verisimilitude with the parent system. All stimuli representing the parent system and its technical documentation were to be presented on viewing screens. All responses by users/students were to be input to the computer through a device such as the hexadecimal pad.

This concept was a distinct departure from the tradition of trainers/simulators that gain fidelity through hardware similarity or through spatial orientation of objects. In terms of physical fidelity, flat-panel and other types of 2D trainers are midway between the older tradition and the device developed in the present effort. Flat-panel devices have often been selected for maintenance training because of their suitability for training maintenance skills and because they are less costly than 3D trainers and they can support sophisticated instructional strategies and performance assessment schemes. They have also been used as procedural trainers (Pieper & Benson, 1975). But regardless of how they are used, the 2D flat-panel device is expensive in comparison to devices which use microprocessors to select graphic images for display on screens.

The availability of low-cost microcomputers now makes conceptual trainers for electronic troubleshooters practical. In the past few years several such trainers have been developed in research for the Navy and Army. In fact, any number of variations in such trainer simulators can be constructed by cabling together components available from any number of vendors. With all such combinations of hardware, it is the courseware used to provide the content of the training that makes the hardware a trainer/simulator. It is also the courseware and learning strategies that determine what kind of simulator it will be.

The present trainer/simulator is an extremely simple device built of high quality components. The software or application program is burned into a memory (EPROM) chip. It is designed to require no special computer programming/authoring skills on the part of the person who prepares the courseware troubleshooting problems. Lessons for entirely different parent systems can be prepared for the same hardware/software device. The device itself is not system specific--only the courseware content is system specific. The trainer/simulator gains its verisimilitude to the parent system from graphic content, not from hardware features.

The trainer/simulator is based on what has been learned in previous R&D efforts. The R&D has been quite extensive, it has shown good results, and it leads precisely to the approach made possible when the random access microprocessor became sufficiently low in cost to make the approach practical.

II. APPROACH

Simulation Approach

The FSTT is a low-cost, stand-alone interactive graphic simulator which permits simulation of the conceptual aspects of system troubleshooting and repair within the format of problem-solving exercises. The physical medium is visual images displayed upon independently addressed, dual random access micrographic projectors. User-simulator interaction is permitted by means of a 16-key keypad and microprocessor control. Magnetic cards are used to select problems and to control the in-line display feed-back. A printer provides records of student performance. Courseware consists of simulations of troubleshooting problems represented by photographs of actual equipment components, displays, and documentation.

As of this writing, the random access hardware developed to implement the situationally interactive courseware is obsolete. The random access capability is available now from other sources, most notably the videodisk microcomputer combination. The FSTT is described in detail in the following pages for its historical interest and to provide a record, as well as to give the functional specifications for programming other media such as videodisk/microcomputer hardware to accomplish the same functions.

In a previous study, school instructors were asked about their needs for simulators. They reported a need for small training devices to illustrate their lectures but did not perceive a need for a simulator such as the one developed in this effort.

The reason the instructors did not perceive this need provides the key to understanding the need that the present simulator is designed to fill. The traditional process for developing instructional content implicitly accepts the fact that the real job situation cannot be made available in the school. Therefore, techniques have been developed for abstracting job requirements from the actual job situation so they can be presented by instructors. Traditionally, the means used for abstracting is to deduce assumptions about skill and knowledge requirements of the job. The instructor then uses a verbal medium to deliver instructions on those skills and knowledge. Instructors can illustrate their lectures with the aid of graphic media, and they can use simple mockups and other devices in support of the instruction. Therefore, when school instructors are asked what simulators they need, their interpretation of need must be in terms of devices to support their lectures.

The well known instructional systems development (ISD) methodology provides a more formal process of deriving task requirements from the job. The requirements are stated in terms of terminal and enabling objectives that describe the job task actions. Alternative media to choose from when using ISD processes are substantially increased over those available to the classroom instructor. One of about a dozen media for presenting

instruction is a simulator. Within ISD the simulator is considered as an instructional medium to be used after the analytical abstraction of requirements from the job situation.

The simulator built and tested in the present effort was not designed as an instructional medium but as a performance criterion situation in which learning could take place. The simulator is designed to provide synthetic experience in repairing the prime equipment. That job involves a broad spectrum of job knowledge and skills. The job requirements include learning the location of the displays and controls, their normal and abnormal appearances, where to go to find test points, what components are accessible, what activities take more time than others to perform, which activities are dangerous to perform, which functions are dependent on which other functions, how to deduce what parts have an effect on other parts' outputs, etc. The simulator was designed to have these job requirements imbedded such that the learner discovers and masters them in the single context of the simulated job situation. This is possible because the simulation is a detailed representation of the job and requires no separate instruction. The simulation design is based on the assumptions of discovery learning or learning-by-doing--the way that people learn by experience on the actual job.

The intent of the present effort was to exploit the existing capabilities of low-cost microcomputers, rather than to design new hardware, to meet job/training requirements. The capability of low-cost microcomputers to access job task situations quickly in graphic displays was the principal capability that made the present simulator possible. The design objective was to make a simulation as much like the job as possible with available graphic image projectors and microprocessor random access capabilities.

The job features that can be simulated with the low-cost hardware combinations are sensory discriminations and cognitive aspects as opposed to psychomotor aspects. In this study, it was clearly recognized that there are some psychomotor aspects to the job being simulated. It was also recognized that there were job/training requirements for knowledge of locations of operational equipment components. The simulator hardware has the capability of providing views of these components in the context of their locations.

The troubleshooting problems provided by the courseware were designed to require users to look at overall views of the operational equipment, choose a location to examine next, from that view choose the next, etc. The visible cues that users would confront in the real situation were all represented graphically.

The simulator was designed with two screens so users could see simultaneously a view of where they had been and a view of what they might choose to inspect. The dual screen design was partially derived from the requirement for learning locations from two-dimensional views of operational equipment. Two screens also made it possible to simulate using TO documentation while looking at the physical equipment.

Specific job characteristics are simulated with the courseware problems rather than with hardware characteristics. Since the courseware problems were designed to keep as much as possible of the job situations intact in their job context, the learning situations were also the criterion tests of performance.

The Training Approach

The FSTT trainer/simulator system places students in a problem situation and allows them to work their way to a solution of the problem using the strategy of discovery learning. There are many elements of specific knowledge required to solve a problem and even more to solve it efficiently. The FSTT's training strategy meets the problem-solving objective and also provides practice in discovering and using specific knowledge.

The scientific hypothetico-deductive model is the basis for problem solving using the FSTT. In this model the student forms a hypothesis after being confronted with the situation (data, symptoms, conditions, etc.). The student then selects actions that produce situations from which the student will obtain collect data that support or negate the hypothesis. Based on this information, a more specific hypothesis is formed, and the process continues until a final solution is reached. The solution/conclusion is tested by replacing the part identified as faulty and confirming that the replacement corrected the malfunction.

Learning problem solving by the hypothetico-deductive process is accomplished in the present simulator through a technique called Situational Interaction. Utilization of the technique requires random access hardware capability, images of situations that provide information, choices of actions to be taken, and the means for the student to input choices to the random access computer.

The images that constitute the courseware designed for the present application enable students to practice the hypothetico-deductive process. The student learns while practicing, thus discovering how to solve the problem and also how to become more efficient in solving it. The courseware provides some aids to solution that are lists of reasonable actions to take in a situation, but no instructions are given on what choices should be made. In solving each problem, the student learns many specifics. Most are concerned with the parent system--what symptoms look like, where they are found, where test points are located, which test points require the least effort to gain access to, etc. Last but not least, the student learns something about the probability of failure for various components in the parent system. All of this specific learning is accomplished in the context of the general learning strategy.

The problems are taken from all the different functional areas of the parent system so the initial symptoms in each problem will be unique; e.g., pneumatic leaks, audio communications failures, visual display symptoms,

control malfunctions, etc. After the initial symptoms are diagnosed, the problems involve similar processes of making tests of successively smaller numbers of parts. The specific locations, test instruments and values at test points differ for different problems, but the same hypothetico-deductive process is used to narrow and isolate the problem in all areas of the equipment by working through the functional dependencies. Students learn the specifics of each area while applying the common hypothetico-deductive process. Thus, the learning strategy is that of discovering specifics in the functional context of a common process.

The student is challenged to apply the common process and to learn the specifics in the problem situation. In conventional training, as a rule specifics are first learned separately and then applied. This convention is contrary to the functional context and discovery learning research findings, findings which have largely been confined to the laboratory. There has been very little application because prior to the advent of the low-cost, random access machine, discovery learning experiments were conducted with real equipment or actual equipment trainers (ATEs). Research studies could garner a sufficient amount of real equipment to test the learning strategy, but schools could never collect enough real equipment to implement the strategy in practice.

The low-cost microcomputer makes the equipment simulation a viable alternative to the actual equipment as a learning medium; as such the present effort is designed to the microcomputer as an alternative. This means determining whether the job context can be simulated well enough for the learning to take place in the problem-solving situation as it does on the job; that is, without abstracting the job specifics.

The term Situational Interaction is being used in this paper to refer to the type of learning situation created by the present simulation. The interaction takes place as the learner's choice of response to one situation results in being required to confront a consequent situation. Such choices and consequent situations continue until the learner solves the problem imbedded in the situation(s). The choices made are not correct or incorrect, though some are more or less efficient than others in solving the problem. Repeated trials are used so what the person learned in the first trial can be applied in the second. In the second or subsequent trials, more is learned, and the learner becomes more efficient in solving the problem. A series of such Situational Interaction problems may be used, with each simulating some aspect of the real situation, to simulate complex jobs.

The technology for developing Situational Interaction courseware for low-cost simulations is not generally well developed. Techniques have not previously been developed to create a microcomputer simulation of the job situation with the performance requirements imbedded in the situation. The techniques are quite different from abstracting the requirements and then using a simulator as the medium for presenting instruction.

This paper focuses on the techniques of developing simulations with microcomputers and graphic displays that imbed the job requirements in the simulated situation.

III. DESCRIPTION OF THE TRAINING SYSTEM

The Site

The FB-111A Flight Simulator at Plattsburgh Air Force Base is in use 24 hours per day. It is used in pilot training for two shifts: the day shift and the night shift. Maintenance of the flight simulator takes place on the midnight or midshift.

While flight crews are using the Flight Simulator for training, maintenance personnel are on standby to make immediate repairs should the simulator break down. Generally, the most highly qualified (five level) personnel are assigned to this duty. Three-level (apprentice) personnel are present as part of their requirement to learn on the job by assisting the five-level personnel. Equipment failures are usually the result of normal and more or less random deterioration of circuit components.

If the maintenance personnel on hand cannot repair the trouble immediately, it is written up as a maintenance action on an AFTO Form 781 to be addressed on the night shift.

Access to the equipment by research personnel was generally limited to the night shift, always on a "no interference" basis. R&D activities that required Flight Simulator access were photographing for courseware development, verifying symptoms and solutions, and performance testing for the summative evaluation.

The repair and tuning of the simulator for use by the flight crews is the primary mission of the maintenance personnel. It takes precedence over other activities including training. The site supervisor is reluctant to have anything done to the flight simulator that might cause it not to be ready later in the day.

The Trainer/Simulator

The FSTT is a graphic display simulator, not an analogue simulator. Analogue training devices are models of the prime equipment, or parts of it, constructed to generate display information or an analogue to the parent equipment displays. Early electrical analogues modeled components of mechanical systems. This approach was reasonable because the equations of motion (harmonic) for mechanical systems are so similar to those for electrical systems that the conversion is simple. The flight simulator itself uses analogue systems to mimic the performance of the aircraft under specific but quite wide ranges of operating parameters.

With analogue training devices, one need not have a priori knowledge of the equipment's failure modes to develop troubleshooting problems. One merely needs to "fail" the simulated part in the trainer, and all the

resulting effects are analogous to those that would appear in the prime equipment--depending, of course, on the fidelity of the model.

In the FSTT the graphic content that represents the prime equipment's operations is produced by operating the prime equipment to generate the displays and taking pictures of the results. The content depicted on the frames of the fiche is taken from the system being simulated. For the present effort, the content was the hardware configuration of the FB-111A Flight Simulator at Plattsburgh Air Force Base. But it could have been any type of prime equipment. Of course, new courseware content--i.e., photographic images of the prime equipment and images of technical data--have to be developed for each prime system.

The FSTT hardware provides random access to selected images; and, thus, the hardware is generic to any prime equipment. Only the images (courseware) change when the prime equipment changes. The hardware for presenting the images does not change.

The FSTT is shown in Figure 1 (see the following page). The FSTT hardware consists of dual, random access microfiche storage/display units operated via hexadecimal keypads, a magnetic card reader, a controller, and a printer. The logical characteristics are defined in firmware (read-only memory), contained within a microcomputer. The courseware is stored in microfiche cartridges placed in slots in each display unit and in a magnetic card that holds binary data.

The controller (a microcomputer using an Intel 80/24 microprocessor) handles the keyboard input, the selection of microfiche frames, the presentation of messages on the in-line display, the recording of student activities, and the output to the line printer. The FSTT is a stand-alone, self-contained system and requires no external support during its regular operation, other than a 110-VAC outlet.

The FSTT was constructed and assembled in accordance with the best commercial practices. Its design and fabrication adhere to quality constructional methods, typical of laboratory test equipment. It functions reliably in an environment that does not require special treatment or preparation for use (60 to 100 degrees Fahrenheit, 20 to 100 percent relative humidity, non-condensing). When not in use, the trainer may be transported and stored in a harsher environment with respect to temperature, humidity, and atmospheric pressure.

Major components of the FSTT are standard, widely available commercial parts with low-cost maintenance and replacement. The enclosure (a heavy-duty metal desk with provisions for holding the internal electronics) is a rigid structure with hard surfaces, finished to provide for personnel safety, protection from deterioration, and an attractive appearance. The external finish is light blue, with a walnut-colored working surface.

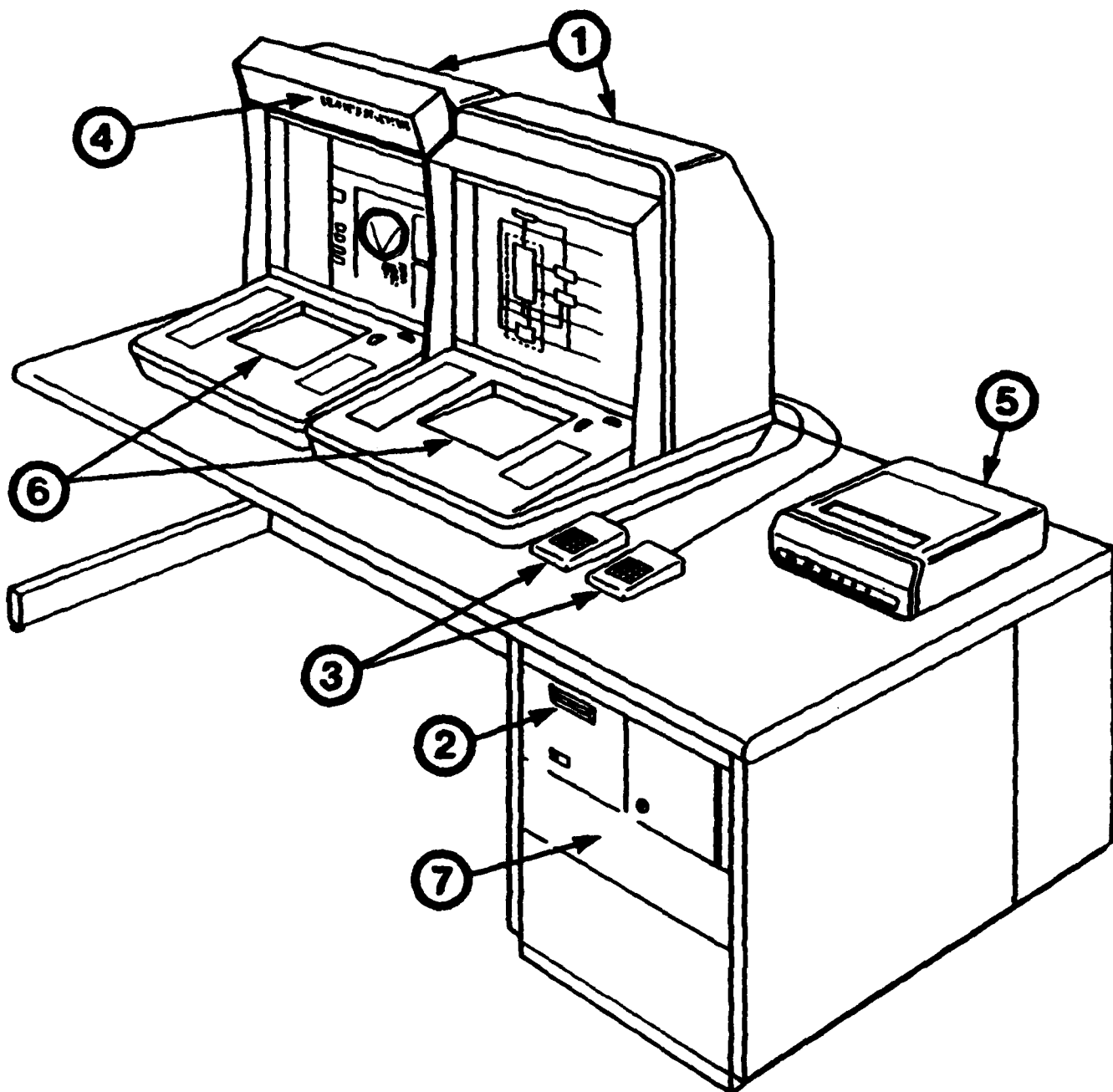


FIGURE 1. FLIGHT SIMULATOR TROUBLESHOOTING TRAINER (FSTT)

The displays (an in-line electro-luminescent display and two microfiche storage/display units) provide for a readable size, and are conveniently located for the user. The keypads are simple in appearance and use.

No unusual or specialized equipment is required to test or maintain the FSTT. Diagnostics leading to the replacement of defective major components (e.g., one of the two printed-circuit cards) can be performed by means of internally stored diagnostic procedures.

The principal hardware components shown in Figure 1 are these:

- Two Microfiche Storage/Display Units (1)
- Magnetic Card Reader (2)
- Two Hexidecimal Keypads (3)
- Electro-Luminescent Display (4)
- Quiet, Hardcopy Printer (5)
- Microfiche Cartridges Inserted in Slots (6)
- Electronic Controller (7), consisting of:
 - Microprocessor and Memory Card
 - I/O Interface Card
 - Card Case, Motherboard and Power Supply
- Desk-Style Enclosure

Specific Features

A description of the specific features of the FSTT follows. The commercial products selected for this application do not represent all possible options; they are the alternatives selected by the researchers in this instance. Their selection in no way constitutes an endorsement of the products by the United States Air Force.

Microfiche Storage/Display Units. The microfiche storage/display components are Model 95s, manufactured by Consolidated Micrographics (formerly Bruning Division of AM International, Inc.). These are automated retrieval/display systems, each with a cartridge holding up to 30 microfiche. The left-hand unit is Type 2498, handling fiche of 7 x 14 frame format; the right-hand unit is Type 2463 for fiche of 7 x 9 frame format. Both units are modified so that the FSTT controller and its interface replace the keyboards and directly drive the components in the selection of fiche and the row/column to be displayed. The left-hand unit is also modified to provide for mechanical support only of the in-line display (DEI Model DE/432).

Magnetic Card Reader. The magnetic card reader is the Model KB-31, manufactured by Vertel, Inc. This reader is interfaced to the FSTT controller via a parallel input/output (I/O) port on the microprocessor card.

Hexidecimal Keypads. Two 16-key (4 x 4) keypads are incorporated into the FSTT, one for the use of students during PRACTICE and EXAM modes of operation, the other for the use of courseware authors in the AUTHOR mode. The two keypads are identical mechanically and electrically, differing only in the inscriptions on the keys. These keypads are interfaced to the FSTT controller via a parallel I/O port on the microprocessor card.

In-Line Electro-Luminescent Display. The in-line display is the Model DE/432, manufactured by the Digital Electronics Division, Chemetrics, Inc. This display provides for one line of 32 characters, uses a 5 x 7 dot matrix for each character, and includes character encoders for the full 96-character ASCII set. The display technology used is vacuum fluorescent with a blue-green color, filterable to blue, green, or yellow.

Printer. The hardcopy printer for the FSTT is the Minitem Receive Only (RO) Terminal, Model 1201, manufactured by Computer Devices, Inc. This desk-top printer, is operated at 30 characters/second and supports the entire printable, 96-character ASCII set. It is interfaced in the FSTT to the serial RS-232C port of the microprocessor card, within the FSTT controller.

Electronic Controller. The FSTT controller consists of three principal units: the microprocessor card, the I/O interface card, and the supporting card cage, motherboard, and power supply. The microprocessor card with its associated memory and support circuitry is the iSBC 80/24, manufactured by Intel Corporation.

The FSTT I/O interface card is a customized, wire-wrapped card whose principal function is to condition the signals sent to the microfiche readers by the iSBC 80/24 in order to drive the fiche carriers. This card also provides for the interface to the in-line alphanumeric display.

The mechanical and electrical support for the controller components is provided by a four-slot, multibus card cage and motherboard (Intel iSBC Model 604); by a power supply (Power Onc, Inc., Type CP-291); and by an electronic chassis assembly (Vent Rack, Inc., Type CH-A-7-X-21 with Type TC-A-21 cover).

Desk Enclosure. The entire FSTT is contained in, and mechanically supported by an electronic desk enclosure, Type OD-266634-CL, manufactured by Optima, and finished in blue/walnut. This is a heavy-duty, metal desk of conventional office furniture styling. The FSTT controller and magnetic card reader are contained in the desk's pedestal. The two microfiche units and the keypads and printer are supported on the top surface of this desk.

The Courseware

FSTT courseware consists of individual troubleshooting problems which are identified in terms of an observable fault and which contain all the

information needed to identify the cause of malfunction, make the needed repair, and verify that normal operation has been restored. The physical media for each troubleshooting problem consisted of two microfiche and one magnetic card.

Authoring. The courseware in this effort contained 30 typical troubleshooting problems drawn from all areas of the prime equipment and covering virtually all major components. Each problem was to be solved by identifying a specific failed part and verifying that its replacement cleared the symptoms of malfunction. Part failures were selected from actual malfunctions that had occurred on the job in operation of the FB-111A flight simulator. The maintenance records of the squadron (380 AMS/MAAN) were examined, and a list of failures that were typical, representative, and challenging was developed. The records provided instances where failure symptoms were caused by a single failed part, by two failed parts, and by no failed parts but a misinterpretation by the operator. Troubleshooting problems reflecting all three types were constructed as follows:

- Problem 1 - Hourglass sweep on cockpit Attack Radar (AR) indicator
- Problem 2 - Windshield wiper symptom on cockpit AR indicator
- Problem 3 - Power lost (28 VDC)
- Problem 4 - No AR video
- Problem 5 - Incorrect AR video
- Problem 7 - No video on any scope--no time signal
- Problem 8 - Cross-hairs do not fall on target
- Problem 9 - Cannot complete fiducial alignment (oscillations)
- Problem 0 - Mirror image on AR video
- Problem 10 - Off-flag on Mach indicator
- Problem 11 - HSI bearing pointer does not rotate
- Problem 12 - Motion "on" lights (platform) remain lit after motion has been deselected
- Problem 13 - Number 1 UHF does not transmit
- Problem 14 - Instructor console light does not light when switchlight is depressed
- Problem 15 - Instructor console does not show AR range selected in cockpit
- Problem 16 - Sluggish response to radical stick inputs
- Problem 17 - Lagging response to control stick
- Problem 18 - Main DC load cannot be applied
- Problem 19 - No tanker beacon symbol on AR
- Problem 20 - Antenna tilt not within limits
- Problem 21 - Pilots cannot transmit or receive
- Problem 22 - No azimuth marker on either radar set
- Problem 23 - Instrument Landing System (ILS) identifier inoperative
- Problem 24 - Console microphones are weak and garbled
- Problem 25 - Terrain Following Radar (TFR) climb/dive bar inoperative
- Problem 26 - Radar Land Mass System (RLMS) power supply inoperative
- Problem 27 - Navigator cannot communicate with pilot
- Problem 28 - No low level reflectance
- Problem 29 - Right shoulder strap locks
- Problem 30 - Engine performance indicators do not correspond with throttle positions

A description of each of the problems is included at Appendix A, Aids to Problem Solution.

Once the failures were selected, it was necessary to verify the visible symptoms and signal values associated with each failed part. These effects could be predicted to some degree by the troubleshooting expert through a knowledge of system hardware dependencies. In this effort the actual equipment was also used to establish the symptoms. Either the failed part was placed in the system by substituting a board known to be bad from the stock of such boards waiting repair, or its effects were induced through electronic "jiggering"; e.g. the throwing of a switch or complete removal of a board. Once a failure had been inserted or induced in the system, the displays, switches, and other locations that would be examined in the process of troubleshooting could be photographed to show the bad symptoms and test point readings.

Courseware was made up of four types of materials for each of the troubleshooting problems:

1. Photographic simulations of the physical components of the prime equipment from overall views of the cockpit, instructor console, and cabinets, down to individual test points. Where a physical component would provide a visible symptom, photographic simulations were made of the component's appearance both when the failure symptom was present and when the equipment was operating correctly. Where an indication of a good or bad part would be obtained by reading test equipment probing a test point, photographic simulations were made of the test equipment display both with the correct value (of a good part) and the incorrect value (of a bad part). Verification is inherent in the troubleshooting process of replacing the bad component and verifying that all the bad outputs are now good. The courseware author must take pictures of the good outputs to develop the verification frames.
2. Facsimiles of technical documentation including pages from technical orders, block diagrams, schematics.
3. Lists of parts that could be replaced.
4. Lists of possible actions to be taken next.

The photographic simulations comprised the bulk of the courseware. They were produced by photographing the actual equipment as troubleshooting steps were performed. Pictures were taken of the cockpit with all its controls and displays. Strategic places in the signal path between the failed part and the final output were identified and the signal measurements photographed. This was done by mounting a camera on the test instrument; e.g., an oscilloscope. Pictures were taken on several different routes that a troubleshooter might reasonably choose to isolate the fault.

Many photographic simulations could be used in several problems, such as pictures taken of locations of parts; e.g., cabinets before they were opened, when they were open, when a drawer was pulled out. Photographs of "normal" operating signals were reused from problem to problem because, aside from some very specific signals which depend on switching the setting of mode and range, the good signals are generally the same for all problems.

A Mamiya RB 67 Pro-S camera system and Tektronix Oscilloscope Camera were used to support the data collection effort. A variety of films and film-types may be used, including Polaroid prints, Polaroid positive/negative film, color negative film, color positive film, and black-and-white negative film. The research personnel did most of the picture-taking, however, it was demonstrated that no special skills were needed. Figure 2 depicts the FSTT courseware authoring process.

A full description of the courseware authoring techniques is included at Appendix B.

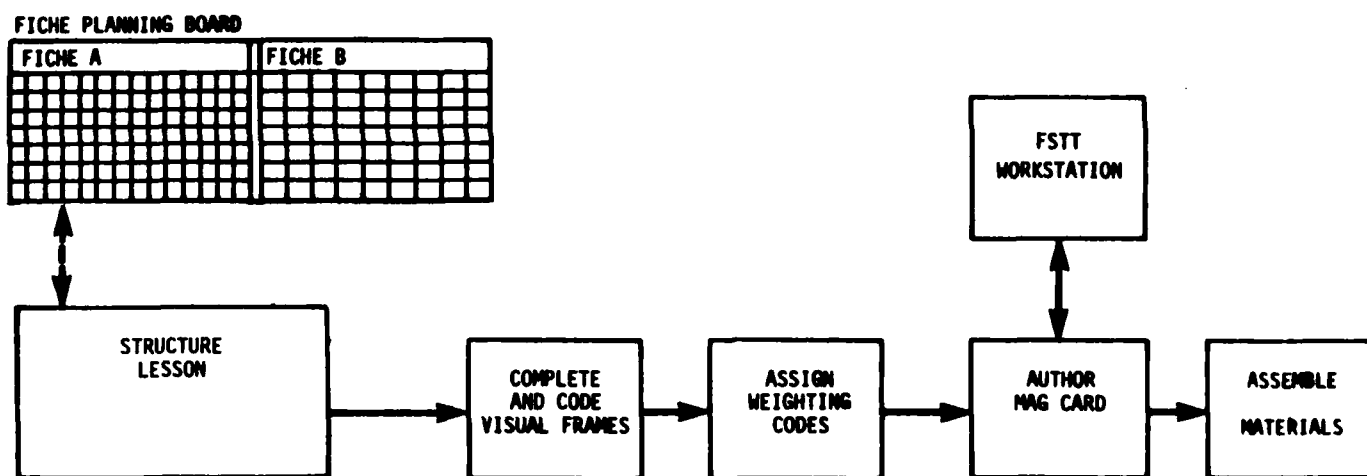


Figure 2. FSTT Courseware Authoring Process

The alternative routes to solving each problem were mapped. The routes were the alternative sets of steps that could be followed to perform the troubleshooting. This phase of problem authoring can be easily accomplished by individual subject matter experts using their troubleshooting competence and experience. The troubleshooting strategy for solving the problems was developed with the the technical supervisory personnel from the 380 AMS/MAAD.

After following several troubleshooting strategies to solution and taking pictures for each, the author chooses the set of steps that would isolate the failed part using the fewest number of checks. This is called the "optimum" solution. Other troubleshooting strategies were logical but not necessarily the most efficient for the specific failure. The optimum path is much easier to identify after completing the troubleshooting. Even expert troubleshooters seldom choose the optimum path when they start--and even after the fact--not all experts will agree on the best strategy. The optimum path is relatively efficient with respect to others.

The author must assign the selected images to specific locations on the two fiche. Each of these locations has a unique two-digit access code so that when this code is entered on the keypad, the corresponding image is displayed. The available images on the fiche are distributed according to preset format rules.

The locations that a user can "go to" from any one photograph are given their two-character access codes. These codes must appear over those locations on that photograph. The authoring was a matter of manually putting the codes on the pictures and putting the pictures in the appropriate frames of the two microfiche according to the pre-established format.

Pictures of technical order pages that are relevant to the steps described in the troubleshooting process are likewise given access codes. For instance, there are codes that enable users to go to detailed schematic diagrams selected from overall diagrams. As a check on the codes and pictures, the author goes through each troubleshooting path, checking to ensure that the records codes refer the user to the intended steps. The author then uses a layout that graphically displays the locations for each picture on the microfiche.

The coded pictures, identified as to which frame of each microfiche they are to be placed on, are sent to the microfiche printer. The troubleshooting problems developed in this effort had one color and one black-and-white microfiche. Pages from TOs are placed on the black-and-white fiche, as are test point readings. Pictures of the equipment are placed on the color fiche. The black-and-white fiche require 2 to 3 days for film processing; the color fiche require about 2 weeks. The cost was less than a dollar a copy for the black-and-white fiche a few dollars for color. The two fiche are loaded into cartridges, one for each viewer. Usually about 15 problems were loaded into the cartridges at one time.

Scoring. The scoring system provided extrinsic feedback to the student on how good the choices were. The system was developed from what the experts (on the average) said was the most efficient path to take.

With the fiche and location records in hand, the author entered the scoring codes on a plastic magnetic card. The plastic card was placed in the magcard reader slot and the author's keypad was used to enter the

efficiency scores for each choice. This required only a few hours to accomplish. The program entered on the plastic card was scoring for the paths used to solve the problem and also instruction to the printer for recording data on use (i.e., problem number, student ID number, time, data, and each access code entered on the hexadecimal pad).

The original system design provided for performance judgments to be displayed after each action taken by the student. Extrinsic feedback was displayed on the monitor in terms of the efficiency of the action in finding the most direct route to the faulty part. The most efficient action possible received three pluses; the least efficient action received three minuses. The plus and minus messages were reinforced verbally with "relevant" and "irrelevant" messages on the in-line display. In addition, the capability was built into the system to provide routine CAI-type feedback of "correct" and "incorrect" responses in the event a courseware author wanted to include CAI-type verbal questions in the sequences.

Situational Interaction does not employ CAI verbal strategies. The situation provides the feedback on the correctness of the solution; i.e., when the faulty part is replaced, the situations displayed to the student change from malfunction symptoms to evidence of correctly functioning equipment. The student must simulate job actions to determine that the malfunction has cleared. The student does this by performing the series of troubleshooting actions again and verifying that the bad test readings and other symptoms are gone.

The system was also capable of having the in-line display feedback appear intermittently according to various reinforcement schedules. Reinforcement is effective in making a single response resistant to extinction; however, this is antithetical to the objective of learning to solve problems. Therefore, it was illogical to include modes for reinforcement schedules in the FSTT hardware design. This fact was amusingly demonstrated when some users accidentally set the FSTT on a reinforcement mode; they perceived that the FSTT was malfunctioning because it did not display the efficient score each time the user made a choice.

Job Aids. When the FSTT was first delivered to Plattsburgh AFB, the job supervisors saw that it could be used on the job as an aid, as well as for training before the job is performed. The researchers explained that use as a job aid would require the development of a "map" having routes that went to each replaceable part. The routes in the map used for training go only to the replaceable parts that were selected as faults for the problems. The AFHRL deemed such a job-aiding tool worth investigation. One area of the flight simulator (Landmass) was selected for this development. The contract was modified to produce the job-aiding sample on the Landmass subsystem. When it was time to test this sample job-aiding material, the Air Force job supervisor had second thoughts about going ahead with the test. Because Air Force regulations specify that only approved technical documentation may be used for maintenance on

operational equipment, it was decided that use of such non-regulation materials to support actual job performance--as opposed to training--would be a violation of regulations.

The job aiding materials that were developed have the following characteristics:

1. The routes to each replaceable part (in the Landmass subsystem) are identified and "mapped" just as the routes to the selected malfunction are mapped with the standard problems.
2. The user is free to follow any route to solution.
3. The map of the routes is based on a Hierarchically Structured Functional Organization (HSFO).

The routes to each replaceable part are developed in the same manner as the routes to a specific part are developed. That is, each replaceable part is considered in turn. The initial symptom of its malfunction is identified and pictures are taken; other test points are identified on the route between the symptom and the part, and those pictures are taken. In this process, it should be recognized that there is substantial redundancy. That is, the initial portion of routes are common to several replaceable parts. The middle section of routes are common to fewer, but usually more than one part, and only the final tests are unique to one replaceable part.

The hierarchical structure of the functional components is this branching of routes from initial symptom to replaceable parts. The organization of this hierarchical structure may be learned, or it may be used as an aid on the job. Using this type of job aid represents practice. The entire hierarchical structure may be learned. It should be noted that this is not the case with Job Performance Aids (JPAs). The developers of JPAs construct the "trees" or hierarchical structure of the system, but the JPA (in all its forms) does not make this structure evident to the user. The user follows the steps given in the JPA and may memorize certain steps or sequences of steps, but typically does not perceive the hierarchical structure.

The job aiding materials produced in the present effort were intentionally designed to reveal the organization of the functional entities in the hierarchical structure. This represents new R&D not merely a new application of JPAs.

To use the job-aiding materials, the user first looks at the symptom of malfunction on the actual equipment. Then, via the FSTT, the user accesses the symptom, which is broken into optional choices in the job-aiding materials. The user chooses the feature of the symptom that is like the one seen on the actual equipment, enters the choice on the FSTT keypad, and receives a view of the situation resulting from that choice.

This situation also has choices. The user makes test measurements on the actual equipment and selects the choice where a bad test point reading was found. After entering this choice in the keypad, the user proceeds in a like manner until the (bad) replaceable part is identified. That part is then replaced and the result verified.

The user may "back-up" on the FSTT at any time or start over. As with the FSTT problems, the user learns the hierarchical structure while moving down (and back) the routes to the various sources of trouble.

It is recognized that the job-aiding materials can be used for training as well as in support of actual job performance. That is, users can move through the routes in the hierarchical structure in order to learn the structure. However it appears that making problems out of job-aiding material would provide a better learning situation. Once the job-aiding materials have been developed, most of the development work for making problems has been done. So conversion to problems would be an easy matter. This was not done in the present effort because it was anticipated that the job-aiding materials would be tested on the operational equipment.

Using the FSTT

When selecting a problem to work on, the user inserts the plastic card for that problem in the card reader. This causes one fiche to be drawn from each of two cartridges mounted below the two display screens. Most problems have about 100 pictures on each of two fiche.

To initiate the problem, the user enters "00" on the keypad. The user then sees a description of the symptom of the problem on one screen and a line-drawing overview of the parent system on the other screen. The symptom is described on Air Force Form 781 as it would be prepared by the person who first noted the problem on the operational equipment. This is the usual way a maintenance person receives notification of the problem in the job situation.

The user's first step is to look at the symptom. Overlaid on the overview of the equipment are a number of alphanumeric access codes at the locations of the major components of the system. These are the choices of where to look for the symptom. The user must choose one of the coded locations. Entering the code for this choice on the keypad causes a picture of the major component to appear on the screen where the Form 781 was previously shown. Coded locations on that picture allow the user to call up detailed views of the displays visible or available at that location. There are usually several displays from which to choose. The user must recognize the specific display that will show the symptom and enter its access code on the keypad. A detailed image of this display then appears on the other screen.

The frame from which the access code was selected always remains on its screen while the newly accessed frame appears on the screen of the

alternate display unit. These two related views remain until a new frame is selected from among the codes shown on the images. An access code on the second frame can be entered, and a new image will replace the original image on the first viewer. Or an alternative code can be selected off the first image, and a different frame will appear on the second screen.

The user studies the symptom display to formulate a first hypothesis as to the source of the problem. The user deduces from this hypothesis what other symptoms or test point readings will be bad and must then look at these symptoms/readings to confirm or deny the hypothesis.

The overview of the equipment will give the user the location codes for collecting the needed malfunction data. Several kinds of information are available. The alphanumeric codes on the images are shown inside circles, diamonds, squares, or triangles. These shapes identify the type of information the code will retrieve.

The circle  refers to an observation location. When a circled code is entered, the user will get a view of what could be observed at the location marked by the circle. The observation may be a more detailed view (e.g., one cabinet enlarged from many cabinets or one area of focus on a large panel) from which the user can recognize the symptom, or it may be a view of what would appear on the test instrument when a probe is applied to that location (e.g., the output read at a test point).

If the code is in a square , choosing it will provide a view of a block diagram, schematic diagram, or other information found on a page from a T0. The content of the T0 page will relate to what the user is physically observing on the other screen. The page from the T0 has codes on it for retrieving more detailed views of schematics.

Choosing a code in a triangle  provides a menu of optional replacement actions that can be taken.

If the code is in a diamond , the user will receive a strategy summary, such as a list of optional actions that are reasonable to try at this point. This form of help is available only in the training mode.

At any time, the user may go back to a previous display (up to five steps back) or start from the beginning. The user may choose an access code of a test point and obtain a picture of the test instrument showing the reading at that point. The user may also choose access codes that provide schematics or other information from T0s, and then choose access codes on schematics to obtain other schematics with more detail on the component of interest. When finished collecting information and ready to make a replacement, the user chooses an access code that provides a "menu" of possible replacement actions. Among the options are correct replacements which are safe as well as some replacement options that are unsafe. A user who decides to make a replacement that is both incorrect and dangerous gets an "abort" message on the in-line display and must start over.

Before choosing an action the user may want to review the replacement procedures in the T0. This is done by selecting the access code for the replacement action being considered. If the procedure in the T0 indicates that the action is appropriate, the user then enters the code for replacing that part and verifies that replacing the part has cleared the symptoms.

To confirm the correct repair has been made, the user must go back to reexamine the test point readings and symptoms that were bad. In fact, the entry of the correct replacement code changes all the frames to correct test point readings and good symptoms, but this is not confirmed until the student checks it. If the faulty part is replaced, all these readings and symptoms are now good. If the problem has more than one malfunctioning part, the symptoms for the part correctly replaced will be good, but bad symptoms will remain for the other faulty part.

After deciding the repair has been verified, the user presses a CC code on the hexadecimal pad and receives a performance score on the inline display. At this point, the display will tell whether or not the problem has been solved. It must be remembered that the scoring system for the FSTT is oriented to the problem at hand. The highest score is given to the performance with the fewest frame requests--those that are directly relevant to solving that particular problem. A complete record of all the user's actions is printed out on the hard copy printer.

In a few problems (called zero problems), a symptom will not be seen. The user's objective on zero problems is to recognize that the write-up on the Form 781 work order was incorrect.

Each problem provides options that allow the user to create alternative paths for collecting information about the pattern of symptoms and test point readings produced by the malfunction which caused the initial symptom of failure.

Some paths are more efficient than others. Some paths lead only to good readings and thus become dead ends. That is, a good signal means that components providing inputs to it are also good. If a path with only good readings is taken, the user is "off" the path leading to the bad component.

The readings and symptoms represent intrinsic feedback, the same kind of feedback the parent system provides when a technician makes the checks and takes the actions the student is doing on the simulated equipment. The user receives another kind of feedback in the training mode. An inline display above the left screen gives the student a judgment of the efficiency of each step taken (on a six-point scale) and a cumulative score on how efficient the selection of steps has been on the average. Efficiency does not equal correctness. The user can correctly identify and repair a failure with any degree of efficiency. In the test or pure simulation mode, the user is limited to intrinsic feedback only. Some supervisors preferred to keep the FSTT in the pure simulation mode at all times.

While looking for the bad indications, the user is collecting information. Even if the indication is good, that finding is useful information. Getting a good indication will require the user to modify the working hypothesis. From the modified hypothesis a new deduction about the location of a bad reading is made and checked. Several good indications in turn will suggest that the hypotheses are not very effective.

Sometimes choices are equally likely and sometimes not. The most efficient set of choices is where each one reveals a bad symptom or reading. Such a set usually requires a little luck in choosing between equally likely probabilities. Some problems require more choices than others to solve the problem. The user must modify a hypothesis until each specific deduction from it identifies a location that has a bad symptom or test point reading.

In this simulated experience, the user abstracts information from each situation depicted on a screen, then uses the information to restructure a hypothesis and choose the next situation. The next situation may or may not be what was expected. Regardless, the user must get out of that situation and into another. The user interacts with each situation. The

situation does not tell the user what to do next. The user's hypotheses and deductions structure the information that is abstracted and influences the choice of what to do. This is similar to the actual job experience and is called synthetic experience. When working on this problem the next time, the student will have in mind the structure derived from the hypotheses and experience from the first trial. This cognitive understanding is quite different from learning a pre-established sequence of steps to solve each problem.

One sample problem was made to acquaint users with the FSTT. This problem is included at Appendix C.

FSTT Cost Effectiveness Evaluation

FSTT hardware and software costs include construction and development costs. To exclude the development costs, the costs of the components and assembly have been broken out of the total costs. FSTT hardware components amounted to \$15,000. The two microfiche viewers accounted for \$7,000 of this total. The cost of assembling the components was approximately \$10,000. The cost of components and assembly would have been less for quantity production, depending on the kind of assembly line process which was established for the quantity ordered. For an order of hundreds of devices, the cost probably would have been on the order of \$15,000 for each copy.

The life cycle costs of the device are essentially maintenance costs and an amortization of the capital cost over the device's life. The maintenance costs for the year the system was at the job site included the cost of correcting design bugs as well as of routine maintenance. The life of

the system can be estimated from one year of wear and tear. We estimate the hardware will survive for three to five years on a job site. Routine maintenance costs for the hardware amounted to approximately \$1,300 during one year. This amount would increase in subsequent years, probably reaching \$3,000 in three years and \$5,000 in five years.

The life cycle for three years would be as follows:

Three-Year Life Cycle

COST = $\$15,000 \div 3 \text{ years} = \$5,000/\text{year}$

MAINTENANCE - 1st Year \$1,300
 2nd Year 2,000
 3rd Year 3,000

 \$6,300

$\$6,300 \div 3 \text{ years} = \$2,100/\text{year}$
 TOTAL/YEAR \$7,100/year

THREE-YEAR LIFE = $3 \times \$7,100 = \$21,300$
 (No Resale Value)

Five-Year Life Cycle

COST = $\$15,000 \div 5 \text{ years} = \$3,000/\text{year}$

MAINTENANCE - 1st Year \$1,300
 2nd Year 2,000
 3rd Year 3,000
 4th Year 4,000
 5th Year 5,000

 \$15,300

$\$15,300 \div 5 \text{ years} = \$3,060/\text{year}$

 TOTAL/YEAR \$6,060/year

FIVE-YEAR LIFE = $5 \times \$6,060 = \$30,300$
 (No Resale Value)

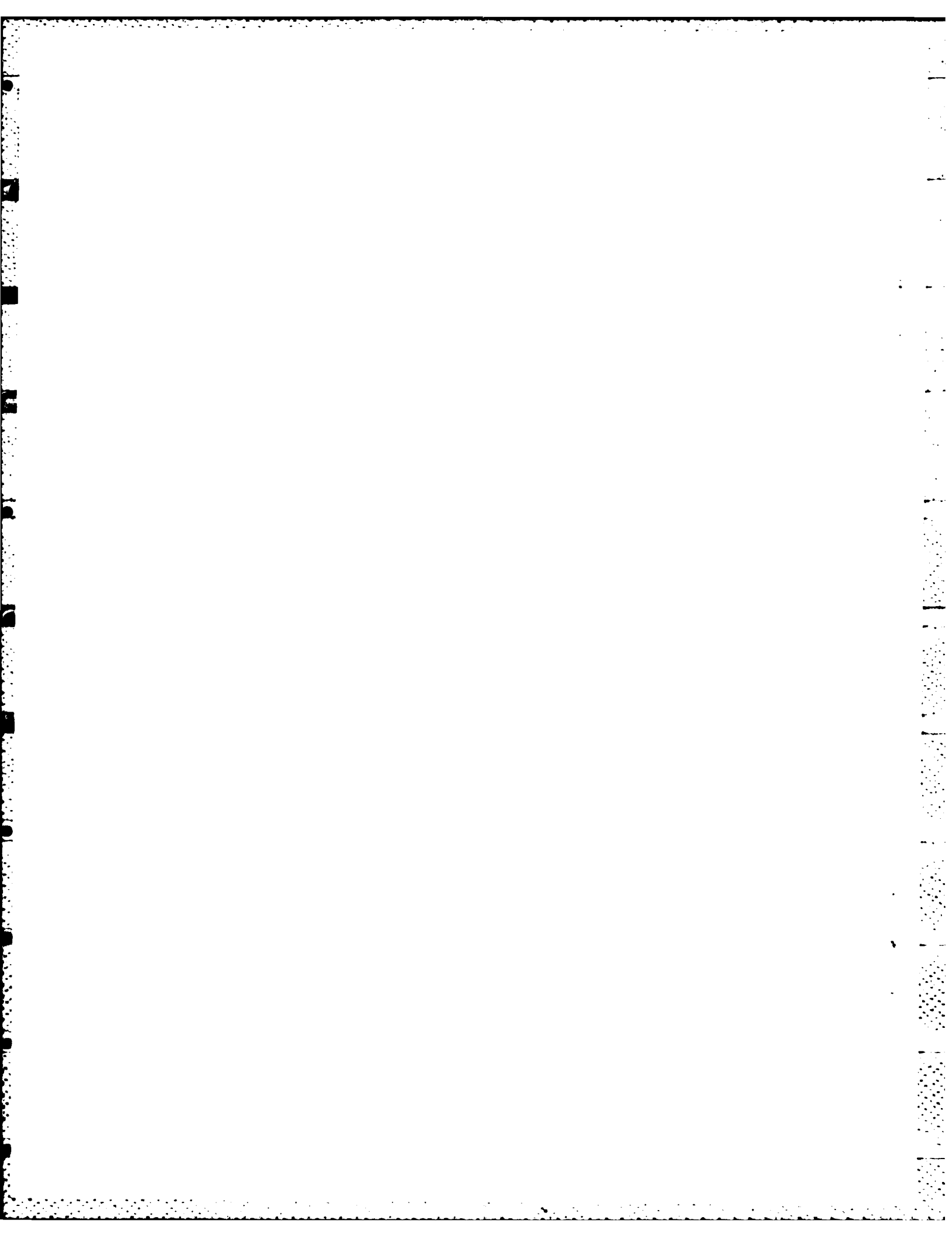
Depending upon the number of years of amortization, assumptions about the number of copies of the hardware ordered, and failure rates over a period of 3.5 years, the total life cycle system costs are on the order of six to seven thousand dollars per year or about \$21,300 for a three-year life and and \$30,300 for a five-year life.

The cost of alternative hardware, in the form of videodisc player and microprocessor, would be less than \$5,000 for the same hardware capability. At the time the FSTT hardware was designed, the videodisc mastering process was not reliable. However, it is reliable at the time of this report. A videodisc-based system has one inherent disadvantage a photographic system does not have. The schematic diagrams in the technical documentation have horizontal lines between parts that will not be shown through the roster lines on a standard cathode ray tube. Presumably this problem can be overcome by using the video camera to make close up views of schematic diagrams after showing a view of the whole schematic page. This close-up procedure was not tested in the current effort. Although there is no experimental evidence of the effectiveness of the procedure, it is reasonable to believe that this general capability of video cameras to "blow up" an image would be as effective for schematic diagrams as it is for other images.

A videodisc-based system has:

1. the same capability for selecting and presenting the images of the FSTT courseware, in color and equal visual quality with the same response time as the microfiche device, assuming the schematic diagram problem is readily solved by a close-up view.
2. a cost that is less than one third the cost of the microfiche-based system. The total cost of the videodisc-based system is less than the cost per year of the microfiche-based system.
3. reliability that is inherently greater because it has fewer moving parts than the microfiche system.

The FSTT courseware and software were the ingredients producing the result in the current effort. The content of the situationally interactive FSTT training problems can be converted to videodisc images merely by using a video camera on the image content. The software of the FSTT device can be programmed on a microprocessor to cause the images on videodisc to unfold in the same manner they unfolded to student action on the FSTT device. In short, a videodisc-based system can support the situationally interactive content that produced the results in this effort. Therefore, a videodisc system and a microprocessor added to the videodisc player can be programmed to duplicate the functions of the microprocessor in the microfiche-based system and would be more cost effective than the microfiche-based system used in the FSTT experiment.



IV. FORMATIVE EVALUATION

Evaluation Plan

In general, formative evaluation is the developmental stage of trying out an R&D product and revising it on the basis of observations made during its use. The Formative Evaluation Plan for the FSTT called for the research staff to deliver the system to the job site at Plattsburgh AFB (380 AMS/MAAD) and remain there for 2 weeks to help set it up, demonstrate its use, and show job supervisors how to develop courseware problems themselves. The FSTT was placed near the operational flight simulator and was available for use 24 hours each day. Personnel who were not on duty during a shift could use the FSTT; and if personnel on a work shift were not too busy, they could practice on it. One civilian instructor was very enthusiastic about the usefulness of the FSTT and was made the chief point of contact during formative evaluation. In that role, the instructor provided initial introduction of the FSTT to users and was often available to discuss problems with them. This instructor also collected and sent the hard copy printout data on trainee performance to Kinton for analysis.

The purposes of the evaluation were to ensure that the courseware was technically correct, the system was accepted by supervisors and trainee users, the hardware was reliable and free of design flaws, and competent troubleshooters could develop courseware with ease. Sources of evaluation data were observations made by research personnel, print-out records of the FSTT itself, and questionnaires answered by job site personnel. The products of the formative evaluation were to be: perfected and reliable hardware, verified and validated courseware, user acceptance measurements, and user performance data.

According to the evaluation plan all hardware failures were to be corrected promptly by Kinton. If the failure was due to a design fault, the design was to be revised. If it was caused by something that could be prevented, a preventive maintenance procedure was to be developed. If the fault was caused by normal wear, it was to be noted.

The courseware was to be evaluated in two increments: 20 problems delivered with the hardware and 10 developed at a later date. After the job supervisors had examined and recommended revisions to the first 20 problems, the second increment was to be developed consistent with the recommended revisions. As revisions to the first 20 problems were being made, the remaining problems were being used by on site personnel-- inexperienced and experienced alike. During the period of April through November 1982, the number of problems available for users increased from 5 to 30 as revisions were made and new problems developed.

Results

Hardware. After its delivery to Plattsburgh AFB, the FSTT was generally reliable but had some hardware failures. Most were corrected within days or weeks, but one intermittent failure, associated with the magcard reader, resulted in a several-month shutdown. The source of difficulty was that a longer data cable for connecting the card reader to the computer was substituted for the one supplied by the card reader manufacturer. The added length resulted in lower signal strength and intermittent inability of the computer to get the data needed for processing. The FSTT design was changed to provide for a cable of proper length between the card reader and the computer.

At one point the FSTT failed to accept the calibration data or the problem card data. A head cleaning card had been provided to remove accumulations of magnetic particles on the head; however, job site personnel had not performed this preventive maintenance, and the head-cleaning card provided for this purpose could not be found. When the head was cleaned, normal operation was resumed.

Originally, users reported they could not tell if the FSTT was working when first turned on. In order to provide some feedback to the user, a software change was written so that the in-line display showed an "R" when the data card was being read, a "W" when being written to, and a "D" when outputting to the printer. In addition, if the card reader was unable to accept valid data from the card, one of the set of error messages was displayed (e.g., "try another track").

Other hardware problems were of a minor nature. They are reported in Appendix D.

Courseware. The original courseware troubleshooting problems were examined in detail by job site personnel who had many years of experience maintaining the flight simulator. They worked through each problem. Some courseware content, usually a photograph, but sometimes a diagram, required correction. Of the 20 problems, 15 needed some revision.

Corrections to the problems entailed selecting substitute illustrations, coding them, rephotographing, and resubmitting the package to the micropublisher for reshooting into microfiche. The revised fiche were mailed to Plattsburgh AFB for inspection and insertion into the cartridges. No more than two revisions were ever needed for any problem. The revisions were simple and inexpensive to make on microfiche. For the second set of 10 problems the job supervisors suggested that the problems be "easier" because the first set had a sufficient number of difficult problems. In effect "easier" meant problems for which there were only a few possible causes of the bad symptoms and which the student could solve by using probability of failure to replace components, without obtaining data from additional test points. No requests were made for additional multiple malfunction problems--which are the most difficult of all.

Site experts believed that scoring of a few problems should be revised. This was done by recoding the magnetic card and did not require revision of the fiche. The magcards were revised the same way they were originally made; i.e., the card for a problem was put in the FSTT card reader slot, and the scoring codes were entered in Author mode and recorded on all four stripes of the magcard. Changing the scoring on a magcard took no more than 1 or 2 hours per problem.

User Acceptance. User acceptance was measured by questionnaire and by usage. The conditions for use were as follows. The formative evaluation was designed such that the operational maintenance unit could have the FSTT removed any time they felt it was not useful in helping them accomplish their maintenance mission. No personnel in the unit were required to use the FSTT. The FSTT was carried on the unit's inventory; therefore, it was subject to inspection during the unit's Operational Readiness Inspection. As such, it represented a risk to the unit that it would be inoperative at the time of inspection and thus reduce the unit's operational readiness. This was a risk they would take only if they felt the benefit was greater than the risk. Therefore, usage for 15 months was, in itself, an important measure of user acceptance by novices, experienced personnel, and supervisors. Data were recorded as to who used it and how much. These data are underestimates of actual usage as some records are known to have been lost.

The initial reaction of both instructors and trainees to the FSTT was very positive. Indeed, until the magcard reader failure totally interrupted usage, the FSTT was used extensively--even though there was no requirement to do so. The routine hardware failures that were corrected promptly did not affect attitudes of on-site personnel.

A single-page, open-ended interview data collection form was constructed to obtain data from users on what they learned and how they liked learning on the FSTT. These users included both skill-level-three persons and experienced personnel. Not everyone who had used the FSTT during the formative evaluation was available for the questionnaire interview. Many had been transferred or were on TDY or leave.

The following comments were extracted from the FSTT Evaluation Forms completed by users and supervisors after experience with the FSTT during the formative evaluation. The responses representing both motivation/attitude factors and specific things learned are typical of those obtained:

Question 1

How much is learned by novice maintenance technicians by interacting with the FSTT?

- o Logical troubleshooting procedures.

- o Shows where to start, step-by-step, how to complete the problem, but the problem does not account for preferences in troubleshooting style.
- o I learned to break the problem down into smaller parts for troubleshooting.
- o Location of switches, where to look to collect symptoms. Good maintenance practices and techniques; they cut out wasted time, learn efficient troubleshooting.
- o The novice learns to cut the problem up or to narrow it down to small areas.
- o Step by step troubleshooting.
- o Gives you the locations and names of cabinets.
- o Learn location data, procedures specific to problem and logical sequence to go by, required to validate the writings.
- o It teaches you exactly where to go to troubleshoot.
- o I learned about cabinet identification, saw typical problems.
- o I found it confusing and feel the 781 write-ups are vague.
- o Feel some prior knowledge of the (flight) simulator is desirable before using the FSTT.
- o Some are too deep without classroom.

Interpretation

Most things users said they learned are things it was expected that they would learn "incidentally" without making enabling objectives for them (e.g., names of cabinets, locations, logical sequence, etc.). They also said they learned to break a problem down into smaller parts for troubleshooting. We would not expect users to say they had learned the hypothetico-deductive process. But we interpret their statements to mean they used the hypothetico-deductive process to break the process down into steps. The FSTT did not provide step-by-step procedures or logical troubleshooting procedures. So if users say that is what they learned it must mean they learned the hypothetico-deductive process for doing it by themselves. That is, they achieved the end objective of learning how to solve problems (troubleshoot) on this system. The last three comments refer to vagueness and confusion. Looking at answers to other questions by the respondents who made these comments, the following was noted. One said simpler problems were not needed and the FSTT experience was useful in solving the problems on the job. Another reported getting a lot out of

it, having no complaints, and solved a problem on the job like on the FSTT. Thus the confusing/vague comments were regarded as a "first reaction" and not something that continued through their experience on the FSTT. The comment about "too deep without classroom" was made by a classroom instructor.

Question 2

Describe the extent of acceptance by novice personnel.

- o It was great; high acceptance.
- o Helpful for the novice.
- o Fun to use; helped a lot when I first arrived.
- o First confused, then fun.
- o Acceptance is OK, here.
- o Fun to use and a challenge.
- o I liked it, didn't have to worry about breaking the (flight) simulator.
- o I like it; you know you won't damage the real equipment.
- o Very interesting. Good.
- o They liked it. Good.

Interpretation

Clearly this is good acceptance. Fun is mentioned more than once, as is freedom from fear of damaging the real equipment. Challenging is mentioned. "Confusing first and then fun" could be construed as "challenging."

Question 3

Describe the extent of acceptance by experienced personnel.

- o They ate it up.
- o Definitely very helpful, good for cross-training.
- o Good when it works, useful; wish I had more time to use it.
- o I think I got more out of it than the junior personnel.
- o Like a video game.

Interpretation

Clearly acceptance was high by experienced personnel. The video game comment is interpreted to mean that video games don't instruct users as to how to get high scores. They challenge the user to find out how to perform better, just as the FSTT does.

Question 4

What troubles in the Flight Simulator did you repair subsequent to training on the FSTT in which that training was of help?

- o Hourglass on AR Scope.
- o Hourglass sweep and the off flag, motion on lamp, deflection in yoke servo.
- o No video.
- o I understood what I was looking for.
- o Harness release.
- o Pilot transmit/receive, instrument type.
- o Attack Radar in cockpit.
- o Attack Radar had no video.
- o Strobing on the Attack Radar Monitor.

Interpretation

The problems mentioned are similar but not all the same as those on FSTT problems. Users are able to solve similar problems not just the specific ones from FSTT, thus meeting the objective of solving problems not just learning procedures for solving specific problems.

Question 5

About how long should novice personnel use the FSTT as a troubleshooting trainer for practice before using it as a job aid?

- o Answers ranged from a couple weeks to a year.

Interpretation

The question was not specific enough to get a specific answer; and in fact, the FSTT was not used as a job aid. Also, users were allowed to use the FSTT any way they chose during the formative evaluation. Thus, they probably considered their use and their prior skill level in answering the question.

Question 6

Did the FSTT prepare you to recognize certain types of failures when they actually occurred?

- o Answers were generally "Yes," with specifics noted by some.

Interpretation

Answers were consistent with those for Question 4.

Question 7

Would additional simpler problems be useful?

- o Answers included "Yes" and "No," but more respondents answered "Yes."

Interpretation

Most users would like a few more simple problems, but an almost equal number said they would not. Making problems simpler could, of course, reduce the challenge.

Question 8

Were the problems supplied challenging?

- o Answers were all "Yes."

Interpretation

The authors believe it is better to keep the problems challenging rather than make them easier. The problems, as they stand, are based on malfunctions that have historically occurred and thus represent the current level of difficulty on the job.

Question 9

Were the "Aids to Problem Solution" useful in understanding the logic of the problems?

- o Some yes, some no, and several instances where they were not seen or not available.

Interpretation

The Aids, reprinted in Appendix A, represent a good description of what is involved in each problem. They are not an integral part of the learning process for the FSTT, as indicated by the answers to this question.

User Performance.

Analysis of FSTT Printouts

The records of user practice sessions with the FSTT obtained from the 380 AMS/MAAD were examined to determine what kind of learning experience the users had. The data from the printout included the problem number, the man-number, whether a correct repair was made, whether the repair was verified, total time per problem, number of frame requests, and what frames were requested.

Records on 40 individuals were returned from the job site during the formative evaluation. It is known that individuals kept some of their records and some were lost. Judging from the amount of paper used for the printer in comparison to the amount returned, about 20 percent of the records were returned for analysis. There is no reason to believe the records returned were not a representative sample. The 40 persons produced 167 records, or about 4 records (trials) per person.

For each trial on the FSTT the student entered an ID number. These numbers were assigned for data collection purposes, rather than Social Security Account Numbers (SSAs), because of Privacy Act restrictions.

The data showed there were 14 persons who attempted no more than a single exposure to the FSTT. Eight used ID numbers not assigned to the roster for the unit. Perhaps these might have been supervisors who merely wished to "try" the FSTT. Such use is of interest; therefore, the records were included in the general descriptive statistics of this section.

There were 69 cases, more than one-third of the attempts to solve problems, in which the correct repair and verification were made on the first try. Successive attempts to solve a problem were evident from the fact that the same ID number for the same problems bore consecutive start and stop times. Of interest was the relationship of the number of frames requested to the amount of time taken for a solution. The data extracted from the printed records were formatted in the following way:

Rec#	Pr#	C.R.	Ver	SCR	ST	FR	1st
------	-----	------	-----	-----	----	----	-----

These abbreviations have the following meanings:

Rec#: The record number which changes from one sort to another.

(A "sort" is a sequence of items based on either alpha or numeric characters. For example, a sort can change from alphabetical to numerical.)

Pr#: The problem number, from 1 to 30.

C.R.: The yes/no statement of whether a correct repair was made.

SCR: The printed "combined" score.

Ver: The yes/no statement of whether a verification run was made.

ST: System Time: minutes a person worked on the problem.

FR: The number of frames accessed by the person.

1st: A number (1, 2, or 3) identifying which attempt this was to solve the same problem.

The data were organized according to problem, and means were determined for SCR, ST, and FR.

Figure 3 shows a plot of the data for this group of records. The abscissa is calibrated in two scales: frame requests and system time in minutes. The ordinate is calibrated in total score. As can be seen from this figure, when either frame requests or system time increases, the efficiency score, on the average, tends to fall. Linear regression calculations on these data provide the following equations:

Score as a function of frame requests, "FR"

$$\text{eq 1: } S = -0.3fr + 94$$

Score as a function of system time, "ST"

$$\text{eq 2: } S = -0.2st + 88$$

In general, the longer the person spent trying to solve the problem, the lower the efficiency score. Also, the more frames requested, the lower the efficiency score.

It was of interest to remove the data for those persons who were known to be supervisors or who could not be identified as other noncommissioned officers or civilian instructors to see if the linear regression equations would change significantly. The results were as follows:

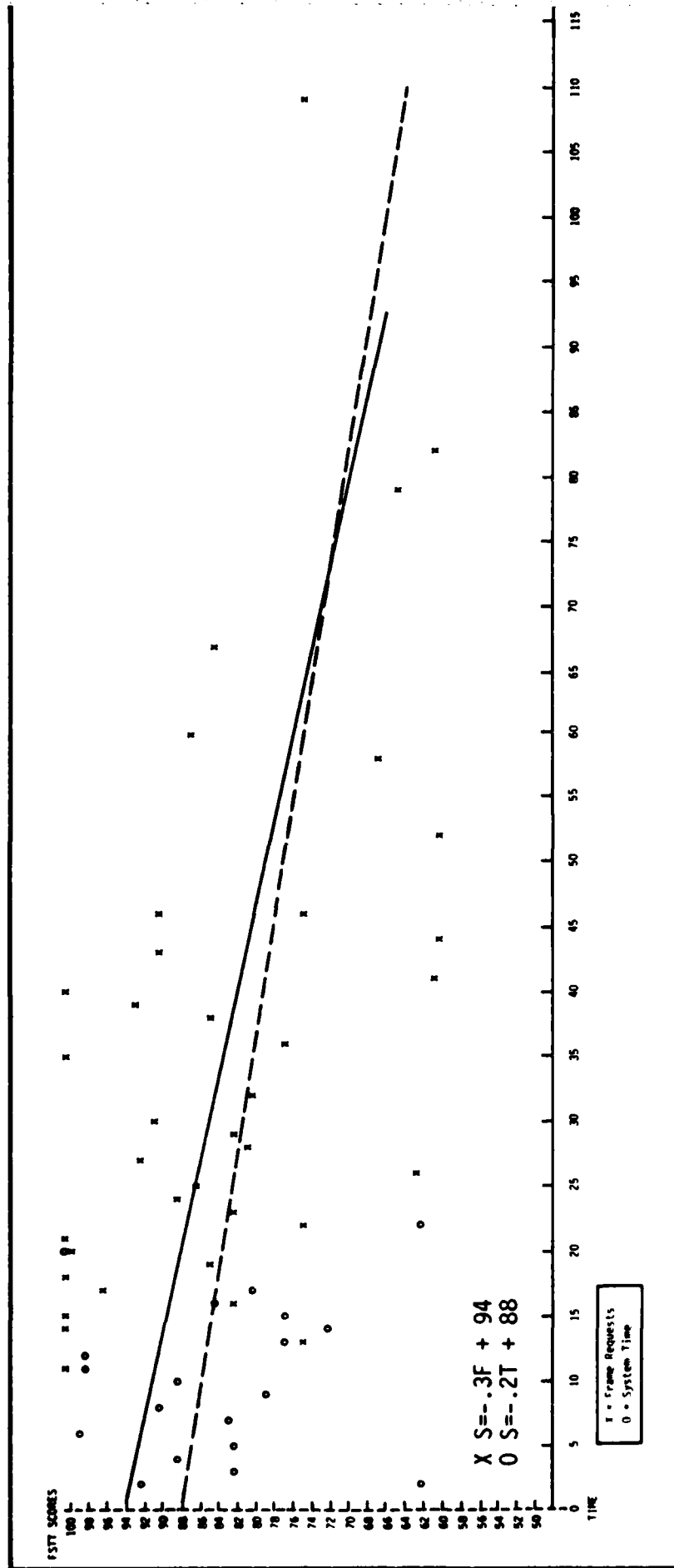
Score as a function of frame requests, reduced data base.

$$\text{eq 3: } S = -0.33fr + 97.04$$

Score as a function of system time, reduced data base.

$$\text{eq 4: } S = -0.75st + 92.17$$

Comparing equation 1 with 3, there seems to be little difference between the two on score as a function of frame requests among those people who solved the problems on their first trial and also verified the solutions. The group consisting of both "inexperienced" and "experienced" seemed to have used as many frames as did the "inexperienced" group alone.



Number of Frame Requests or System Time (minutes)

Figure 3. Linear Regression Equations
FSTT Score and Time as Function of Frame Requests

Comparing equations 2 and 4, there is a considerable difference in the slope of the equation. Novice efficiency scores tended to fall off more rapidly than did those of the whole group, as a function of time on the problem. This suggests that for the same amount of time on the system, novices tended to make more mistakes, thereby getting a lower score even when they solved the problem. In other words, experienced personnel tended to spend more time considering their actions, whereas inexperienced personnel tended to act. This fact has implications for maintenance of operational equipment. Equipment cannot be damaged when a troubleshooter is thinking; it can only be damaged when the troubleshooter is working on it. Although only some actions are potentially damaging, it is generally a good practice to think before acting.

There is no learning style that is particularly effective or ineffective, and a high efficiency score on the first attempt is not necessarily desirable. A person who examines the relationships of options in order to develop a general problem-solving skill may get low scores on solving the specific problem. The important point is that users continued to work on problems until they solved them--one way or another.

It was evident from the records of people who tried a problem several times that the number of frame requests was smaller, the efficiency was better, and the time was very short with successive trials. Typical performance patterns for those who did not solve the problem on the first recorded attempt showed initially a long session time (30 to 60 minutes) with a large number of frame requests, and neither repair nor verification. The second time through the problem usually showed better efficiency scores, shorter session times (5 to 10 minutes), and fewer frame requests with a correct repair; but often verification was not accomplished. Verifying the repair required more frame requests. Verification of repair was a source of some consternation to FSTT users. To their perception, they appeared to be deprived of a "solved" message when they knew from their efforts they had made the proper repair. Verification is a process that is required on the job--it is not an idiosyncrasy of the FSTT.

The users apparently learned verification was required on the job after they found it was required on the FSTT. It is obviously better to learn this from FSTT experience than from job experience, just as it is better to learn all other aspects of job performance in a situation where no harm can be done.

Data printouts showed some users were attempting several solutions in a row in order to get a better efficiency score as well as a verification checkoff. However, many users would use a second (or third) trial to "explore" the less efficient paths to solution. This lowered their efficiency scores from their earlier scores. It generally took users a half hour or so to solve the problem during the first trial and a few minutes in later trials--except when they were "exploring."

Interpretation

One interpretation of the results obtained from the hard copy printouts of performance on the FSTT is as follows. The machine's scores derived from a scoring system based on expert judgments of efficient and rapid troubleshooting. Printouts showed students responded to this value but also ignored it as an objective in order to meet their own objective of exploration.

There is an inherent choice of exploration versus efficiency in solving problems. The scoring system rewarded efficiency. Users responded to this reward but also did a significant amount of exploration. In effect, users had three goals: to solve the problem, to solve it efficiently, and to explore. Their behavior reflects the fact that they pursued the goals alternatively or concomitantly according to their own inclinations. Since there is no learning strategy that is known to be better than their own inclinations, it is said here that the behaviors exhibited are appropriate to the goals.

The data from the printer is interpreted to show that the efficiency scoring system should not be the only basis used to evaluate what people have learned in this discovery learning situation, nor should the learning situation be forced to conform to the scoring system for efficiency. To meet the exploration goal, the efficiency score will be lower, and this is appropriate. As users develop their own conception of what is efficient, the efficiency scoring system will probably be ignored entirely. At that point the FSTT users would join all the other experts in arguing about what is most efficient.

Courseware Authoring. Information was provided to job supervisors on how to structure the fiche, how to affix and remove mattes to photographic enlargements, how to apply arrows and codes for observation, and so forth. However, because personnel viewed the preparation of courseware as being outside their job descriptions, the capability of job site personnel to develop their own problems for the trainer could not be tested in the formative evaluation. However, it seemed clear that they had the capability to do so had they wished. This finding indicated that a duty position would have to be created or additional duties formally assigned to an existing job, if on-site courseware development were to become a reality.

Conclusions

The installation of the FSTT in the operational environment of the 380 AMS/MAAD showed that technicians would and did use it to solve troubleshooting problems. Level three personnel found it to be a way to gain troubleshooting experience on exact simulations of their equipment. They could not get this experience in the real world even though the equipment was present on site. Their role as helper did not provide them practice in troubleshooting because troubleshooting was done by the level-five (or higher) technicians. Level five persons could familiarize themselves with

troubles that appeared in the "flights" portion of the simulation if they were typically assigned to work on "bomb/nav" problems and vice versa. Instructors on site found that the FSTT could be used to prepare personnel for using data collection, troubleshooting strategies, and verifications required on the job. In addition, confidence in the trainer was amply demonstrated by the fact that the maintenance site supervisor permitted novice personnel to troubleshoot operational equipment in the summative evaluation.

It was apparent from the formative evaluation that, with a reasonable amount of preventive maintenance, the trainer was reliable and could find continued high acceptance in the 380 AMS/MAAD and, therefore, in any other similar organization for which appropriate problem sets were produced for their equipment.



V. SUMMATIVE EVALUATION

Experimental Design and Test

Performance Measurement

Very little job performance data have been collected anywhere for any purpose because job-site personnel are extremely reluctant to have such data collected. From the earliest time-and-motion studies, both job incumbents and supervisors have perceived job measurements as inimical to their personal interests. To get around this, organizations conducting research have used the technique of taking over responsibility for job equipment and creating a job-like situation where performance can be measured. But when a research organization takes over the responsibility for the equipment, the job site is no longer an operational and the data are not data from an operational site.

It is not, therefore, for lack of measurement techniques that data are almost never collected at job sites. In the 1950s more performance data were collected than in the 1960s, and more in the 1960s than in the 1970s (Shriver, Hart, 1975). Almost all performance data collected in the past 30 years were collected under research control of conditions in ways that are not possible on the actual operational job site.

The present effort was designed to maximize the opportunities for collecting actual job performance data. One of the reasons for selecting a job site for experimental treatment rather than a school was to increase the probability that job supervisors would not resist collecting performance data on the job. It was believed that if the job site personnel saw the trainer/simulator being used by site personnel and felt it was beneficial, they would allow performance data to be collected at the job site. This generally proved to be the case. In the present effort the number of subjects and the number of malfunctions they were allowed to troubleshoot were not large, but this is probably the maximum amount of performance data that could be obtained from an operational job site.

The job supervisors did cooperate more in this effort than in other situations reported in the literature. Thus, this represents an isolated case where data on job performance were collected on the job site. The only non-operational condition imposed by job-site supervisors was that subjects not take any major actions on the operational equipment before saying what they intended to do. As the test event actually unfolded, no subjects were denied the actions they wanted to take, so this condition had no practical effect.

The remainder of this section describes the design and conduct of an on-site job performance test to determine if persons who were trained in troubleshooting by means of the FSTT would be able to troubleshoot the actual equipment better than did those who were not so trained.

Subject Population

In the actual job situation there were 13 persons who were newly assigned and present for duty during the 2-month period of job performance tests. The research design called for separating these personnel into two groups matched on relevant factors.

These newly assigned personnel consisted of three-level personnel recently graduated from school. No five-level personnel were in the target population because they already had about 6 months of duty on station. Because their individual experiences varied in 6 months on the job, these personnel could not be matched accurately into two groups.

All personnel to be tested had to be on duty and available for testing during the night shift, and they had to have received orientation. The orientation consisted of one week of on-site instruction designed to familiarize newcomers with the FB-111A flight simulator. Orientation is conducted by experienced civilian personnel and is required by the site supervisor before any personnel are allowed to work on the actual equipment at this site. The experimental group then received FSTT training; the control group did not receive FSTT training.

In the first month of job performance testing, six persons were identified who were newly assigned to the site. Three of them were working on the night shift when testing began; the other three started working on the night shift when the normal shift rotation occurred. There was a good match for the personnel in these two groups of three, so the first three were assigned to the control group and tested immediately, while the second three were assigned to the experimental group, given FSTT training, and tested when they rotated to the night shift.

The second month of job performance testing was similar to the first. An additional seven newly assigned personnel were available. They were divided into two matched groups, with the odd person placed in the control group. While the testing was underway, one person from the experimental group became unavailable. Another person, who became available too late to complete FSTT training before being tested, was added to the control group. Thus, the total number actually tested in the 2 months was five in the experimental group and eight in the control group.

A note on the matching of the personnel is in order. The subject population that arrived on the job site in this short period was relatively homogeneous. The recruiting conditions that prevail over a short period like 2 months brings into the service a relatively homogeneous group. Recruitment quotas were being rather easily met at the time these personnel were recruited. They met the aptitude standards for entry to the AFSC training from which they all graduated. Thus, matching of individuals was easily accomplished.

One person assigned to the control group performed substantially less well than all the other members of the control group. This was not foreseeable from any background factors.

Selecting the Problem Set

The same job performance test was provided to subjects in both groups. A failed component or abnormal operating condition was inserted in the actual equipment of the otherwise normally operating system. The malfunctions selected for job performance testing purposes were those which would not result in damage to the operational flight simulator. No failed parts could be inserted into the FB-111 flight simulator that could conceivably disable the equipment or impose such additional maintenance demands as to cause downtime on the prime equipment and run the risk of the equipment not being available for use by flight crews when needed. The problem set was thus limited to a sample of 6 of the 30 problems which had been used as the training inventory on the FSTT. Maintenance personnel of the 380th AMS and researchers jointly selected the subset of 6 problems for use in the evaluation.

The problems were subsequently reduced to 5 because one problem which involved swapping a chassis known to be bad for one known to be good might possibly cause additional damage. Finally, during actual testing it was found that a portion of the prime equipment was out of order and would not support introduction of one of these five problems; thus, the performance test was reduced to four malfunction problems.

Test Administration

To determine what a reasonable length of time might be for making the diagnosis and repair for each malfunction problem, two five-level technicians (supervisors) solved the problems. It was believed that five-level technicians would have little difficulty with the malfunctions. In fact, the two technicians who participated in establishing the time standards did not differ from the three-level technicians in their approach to troubleshooting. After the first few trials, the five-level technicians found that their workload prevented further participation. What data had been collected were used to set a half hour time limit on correcting each malfunction (problem).

Performance testing of 30 minutes on each of 4 problems would require 2 hours of testing per subject. Responsible persons at the 380th AMS (MAAD) agreed that a 1 hour per person could be spared from maintenance during the night shift until performance testing was completed. This schedule would have resulted in 2 days of testing per subject. In actuality, some testing was allowed on the other shifts. This permitted the testing to be completed in less time.

Test security procedures ensured that no one being tested observed the test malfunction being inserted into the equipment. It was impossible, however, to keep the subjects from communicating about the problems to one another if they chose to do so. There was no certain way to determine whether this occurred; however, there were no indications from their performance to suggest that any subject had advance information.

Procedure

A form was devised for collecting data on the troubleshooting performance of the subjects during their shift on the job site. The form was used to collect two kinds of data: first, success of the subject in solving the problem and time to solutions, and second, a record of every step that was actually taken in the troubleshooting process. One member of the research staff making observations was a former FB-111A maintenance technician who evaluated the actions taken by the test subjects and assigned a numerical score to each attempt at problem solution. The numerical score was the percentage of steps taken which were relevant to the solution.

Before each problem administration, the malfunction was inserted into the flight simulator and checked to ensure that the stated symptom pattern actually occurred. Then, the subject was called into the bay and handed a card giving the statement of the malfunction. This is the way a person on the shift normally receives a task. The subject was told not to take any major actions without telling the job supervisor what action was planned. Otherwise nothing was added to the routine procedure; that is, it was a normal job task so far as the subject was concerned. No further words were spoken. The test was started. The test administrator and the shift supervisor, a five-level technician, observed the subject; the former, to record what the subject was doing and the latter, to prevent performance of any actions that could damage the equipment. The test administrator recorded the cabinets that the subject went to and each step the subject took. In all cases, the administrator noted the time when either the problem was solved or the problem time ran out. After completing the problem, the subject was sent from the bay to wait until the next malfunction was inserted. Typically, this took about 5 minutes. Then the subject was recalled to begin with the next problem. Some of the subjects solved the problems in very short times, on the order of 5 minutes, and completed more than the two problems originally scheduled for 1-hour testing period.

Data Analysis

Data collected on this group of newly assigned technicians were analyzed using a t-test on the means of their times on the problems, and also on their "scores" as given by the test administrator based on observations of their performance. Table 1 shows how long each individual in the

experimental group took on each problem, whether solved or not. If a subject solved the problem, the time to solution was the time used. If a subject used the entire time (30 minutes) but still did not solve the problem, 30 minutes was used as the time.

The mean time for experimental subjects to correct the malfunctions was 7 minutes. The mean time to complete each task successfully ranged from about 3 minutes to 13 minutes. Among the five subjects there was one failure to solve one problem.

Table 1.

Experimental Group Time to Perform Problems

SUBJECT	PROBLEMS			
(FSTT)	PWR 3	VID 5	HDSET 21	ILS 23
E1	3	12	3	13
E2	2	1	23	7
E3	4	5	6	3
E4	7	1	30	14
E5	1	1	1	3
AMOUNT OF TIME	17	20	63	40
NUMBER OF ATTEMPTS	5	5	5	5
MEAN TIME	3.4	4	12.6	8
TOTAL AMOUNT OF TIME	140			
TOTAL NUMBER OF ATTEMPTS	20			
TOTAL MEAN TIME	7			

Table 2 provides the time each control group subject took to perform each of the four tasks. The mean time to perform the tasks was 14.3 minutes. The mean time to complete each of the four tasks ranged from about 11 minutes to 17 minutes. Among the eight subjects there were nine failures to solve a problem.

Table 2.
Control Group Time to Perform Problems

SUBJECT	PROBLEMS			
(FSTT)	PWR 3	VID 5	HDSET 21	ILS 23
C1	5	4	13	3
C2	30	30	30	30
C3	1	29	8	3
C4	5	10	8	30
C5	7	15	3	8
C6	30	11	17	8
C7	1	1	30	23
C8	7	1	27	30
SUM	86	101	136	135
NUMBER	8	8	8	8
MEAN	10.75	12.625	17	16.875
TOTAL TIME: 458				
COUNT: 32				
MEAN: 14.3125				

In comparing the times, it may be seen that the experimental group solved the problems in less than half the time required by the control group. The only overlap in mean performance was that the experimental group took slightly longer to solve the most difficult problem than the control group took to solve the easiest problem. The 't' value, using the formula:

$$t = \frac{(M1-M2)}{\frac{(\text{SUMX1}^2 + \text{SUMX2}^2)}{(N1 + N2 - 2)} \times \frac{(N1 + N2)}{(N1 \times N2)}}$$

is 2.496. This value is significant at the $P < .05$ level with 12 degrees of freedom (Lindgren, McElroth, 1959).

Tables 3 and 4 show the scores of experimental and control group subjects based on the test administrator's evaluation of irrelevant/incorrect actions taken while each subject performed each problem. Ten points were

subtracted from 100 (perfect score) for each of the actions taken that was determined to be irrelevant to a rational approach to the solution of the problem. The mean score for experimental group performance was 81; the mean for control group performance was 53. The "t" value, using the formula shown above, was calculated to be 2.674. Again, this value was significant at the $P < .05$ level for 12 degrees of freedom.

Table 3.

Experimental Group Percentage Correct Scores

SUBJECT (FSTT)	PROBLEMS			
	PWR 3	VID 5	DSET 21	ILS 23
F1	100	90	90	100
F2	100	70	60	80
F3	60	40	30	100
F4	100	100	0	80
F5	100	100	100	100
SUM	46	400	300	460
NUMBER	5	5	5	5
MEAN	92	80	60	92
STANDARD DEVIATION	17.8	25.5	35.4	11
TOTAL SCORE:	1620			
COUNT:	20			
XM1 MEAN:	81			
STANDARD DEVIATION:	25.9			

Table 4.
Control Group Percentage Correct Scores

SUBJECT (FSTT)	PROBLEMS			
	PWR 3	VID 5	DSET 2	ILS 23
N1	100	70	0	100
N2	0	0	0	0
N3	90	20	100	100
N4	100	60	100	0
N5	50	80	100	90
N6	0	0	40	40
N7	100	100	60	40
N8	40	100	20	0
SUM	480	430	420	370
NUMBER	8	8	8	8
MEAN	60	53.75	52.5	46.25
STANDARD DEVIATION	43.9	41.7	44	45
TOTAL SCORE:	1700			
COUNT:	32			
XM2 MEAN:	53.125			
STANDARD DEVIATION:	41.8			

It might be noted that significance is not reached with such small samples unless the differences between the mean performances of the two groups are substantial and the variance is small. In common terms it means that with a small sample, there must be little or no overlap between the two groups to achieve significance. Some researchers are reluctant to accept the results of small sample statistics. Others feel that whenever significance is reached with a small N, it shows that the effect of the experimental variable is very strong. In the present case there is no reason to believe that differences in test conditions would change the results. Since there is reasonable consistency in the performances of the experimental group, it is unlikely that the results were a function of some uncontrolled test conditions.

The scores prepared by the test administrator were based on technical judgments of the relevance of actions taken to solve each problem. A person receiving a score of 100 was performing as efficiently as any person could perform on the task. Even experienced personnel do not perform with

100 percent efficiency every time they troubleshoot a problem. These scores were not as objective as scores based on the time required to troubleshoot problems, but they were more objective than qualitative statements that the subject was "lost" or "didn't know what to do next." In fact, supervisors based their judgments of personnel on technical points such as those used to produce these scores; thus, these scores quantified the technical points that supervisors use to evaluate performance. Supervisors are interested in consistency of performance because inconsistent performance suggests that the person cannot be trusted to perform without injuring himself or damaging the equipment.

It may be noted that personnel who are "lost" or "stumbling" are using up time. There is, therefore, a high correlation between performance time and being "lost." In the current results that correlation is obvious.

One more thing should be noted in connection with these scores. Technical observations provide a good indication of whether or not personnel passed information to each other about the problems they were tested on. That is, if a person takes a particular action before another action that is logically prior to it, it may be an indication of prior knowledge about the problem. The technical observer reported that there were no such actions and, therefore, no indication information had been passed from subject to subject.

The usefulness of these scores is primarily in the insight they provide to consistency of performance. In the experimental group, there are ten 100 percent scores out of 20 scores. Half the performances were as good as they could be on those tasks. Looking at the subjects shows that two out of five personnel were consistent: F1 and F5 with two 90 scores and the rest 100s. Even very experienced personnel would not be expected to perform more consistently. One subject had scores of 100, 70, 60, and 80. That is good, but not consistent enough to satisfy some supervisors. The other experimental subject, F3, had scores too low to trust him on the job: 60, 40, 30, and 100.

From looking at the control group, it may be seen that there are ten 100 scores out of 32 scores. This shows that school graduates can perform some tasks on the job. On the other hand, this confirms supervisors' attitudes that newly assigned personnel cannot be trusted to work on their own, for fear they will injure themselves or damage the equipment. None of the control group subjects was consistent. Two of the control subjects who had two 100 scores also have a zero score and another relatively poor score on other tasks (N1-N4). One of the other subjects with two 100 scores has relatively poor scores on the other two tasks (N7). One of the other 100 scores was received by a subject who was a predominantly poor performer on the other tasks (N8). The worst performance by any subject in the control group is all zeros (N2). The next worst is two zeros and two 40s (N6). The problem with newly assigned personnel, as shown by the control group performance, is lack of consistency as much as lack of job competence. Consistency is what job supervisors look for to build their trust enough to allow newly assigned personnel to work on the job.

It was noted that one control group subject failed all problems (all zeros). In order to show that the overall results were not a function of this one aberrant case, the subject's score was raised from zero to the mean for the control group. The statistics indicated the same level of confidence in the significance of the difference between the control and experimental groups when this subject's scores were changed from zero to the average control group scores on each task.

Discussion

The experimental group clearly differed from the control group on all measures of job performance on the job tasks used in this experiment. The difference is statistically significant.

There was room for improvement in the consistency of one or two experimental group subjects; however, none of the control group subjects was consistent. Again, job supervisors are interested in consistency. They avoid giving responsibility to newly assigned personnel. The fact that there is no consistency in the control group subjects' performance confirms the job supervisor's traditional viewpoint that newly assigned personnel cannot be trusted to work on their own on the job. With most of the work force being first-term personnel, waiting for them to develop consistency, only to have them transferred or leave the service, is not cost-effective. Clearly there is a need to increase consistency of job performance early so that first-termers can perform useful work, rather than serve only in a helper role.

The demonstrated capability of the FSTT to improve the performance of newly assigned personnel and make more than half of them consistent performers is an outcome which is greatly needed in Air Force maintenance. It should be noted that this outcome was obtained in a relatively casual manner. There was no command emphasis on the FSTT experience. The FSTT was merely a device on trial, yet it demonstrated a substantial effect. This result was with a trivial investment in time and material on the part of the squadron, yet at least half the personnel receiving FSTT experience became consistent performers whereas none of those without FSTT experience did so. It is highly probable that some command emphasis and another 40 or 50 hours of FSTT experience would have an even greater effect--such as making all newly arrived personnel consistent performers. This represents the next step for future research. The FSTT has demonstrated what it can do on its own. The next step is to make it the basis for a program to see if job supervisors can change their attitude toward new personnel and give them job responsibilities wherein they can produce useful work rather than perform as helpers for 6 months to a year.

Conclusions

1. A nominal amount of training experience on the FSTT significantly improves the job performance capability of personnel newly assigned to maintenance jobs (on the FB-111 Flight Simulator).
2. At least half the personnel with (nominal) FSTT training experience demonstrated consistency in job performance, whereas none of the newly assigned personnel without FSTT experience demonstrated consistency.
3. It is highly likely that a courseware program like that used on the FSTT hardware, with the objective of giving newly assigned personnel work to do on their own (rather than serve as helpers for 6 months), would demonstrate greater work productivity in maintenance units.
4. The FSTT developed for this project provided the random access capability required to make the courseware effective. There are now cheaper and more reliable hardware devices that provide quick access to any frame of visual image in storage according to a software program.

Recommendations

1. Use the FSTT courseware as the basis for a program to obtain useful work from newly assigned maintenance personnel and, as a result, increase unit productivity.
2. Make videotape images of the FSTT courseware frames and produce a videodisk to replace the microfiche component of the FSTT hardware.
3. Direct the program toward flight simulator maintenance and expand it to operational aircraft maintenance if it proves effective for flight simulator maintenance.

REFERENCES

- Chenzoff, A.P., Beilstein, K.R., Shipton, D.L., Joyce, R.P., Campbell, W.B., & Weimer, R.E. Analysis to Improve the Maintenance Environment: A View from Active-Duty Aircraft Maintenance Personnel. (AFHRL-TR-83-14) Wright-Patterson AFB, OH: Logistics and Human Factors Division, Air Force Human Resources Laboratory (in press).
- Condon, C.F.M., Ames, L.L., Hennessy, J.R., Shriver, E.L., & Seeman, R.E. Flight Simulator Maintenance Training: Potential Use of State-of-the-Art Simulation Techniques. (AFHRL TR-79-19, AD-A072 478) Lowry AFB, CO: Technical Training Division, Air Force Human Resources Laboratory, June 1979.
- Edwards, J.B. Simulation to Teach or Evaluation Problem Solving in Professional Programs. In Second Symposium on Applied Learning Systems: Professional Development Program. Washington, DC: The Society for Applied Learning Technology, July 21-23, 1976, pp. 272-287.
- Fink, C.D. & Shriver, E.L. Maintenance Training Simulators at Air Force Technical Training Centers: Present and Potential Use. (AFHRL TR-78-77, AD-A064 692) Lowry AFB, CO: Technical Training Division, Air Force Human Resources Laboratory, December 1978.
- Fink, C.D. & Shriver, E.L. Simulators for Maintenance Training: Some Issues, Problems, and Areas for Future Research. (AFHRL TR-78-27, AD-A060 088) Lowry AFB, CO: Technical Training Division, Air Force Human Resources Laboratory, July 1978.
- Jones, F.E. & Odom, W.F. MOONLIGHT II: Training the Infantry Soldier to Fire the M1 Rifle at Night. (AD-57 972) HumRRO, December 1954.
- Lindgren, B.W. & McElrath, G.W. Introduction to Probability and Statistics. Macmillan, 1959. Table III Percentiles of the t Distribution.
- McGuire, C.H. Construction and Use of Written Simulations. The Psychological Corporation, 1976.
- Pieper, W.J. & Benson, P.H. Simulation Design Manual for the EC-II Simulator. (AFHRL-TR-75-14, AD-A014 798) Lowry AFB, CO: Technical Training Division, Air Force Human Resources Laboratory, May 1975.
- Rigney, J.W., Towne, D.M., Moran, P.J., & Mishler, R.A. Field Evaluation of the Generalized Maintenance-Trainer Simulator: II. AN/SPA-66 Radar Repeater. Technical Report No. 90. Los Angeles, CA: University of Southern California, Behavioral Technology Laboratories, November 1978.

- Shoemaker, Harry A. The Functional Context Method of Instruction. In IRE Transactions on Education, Volume E-3, No. 2. (AD-656-939) Alexandria, VA: Human Resources Research Office, June 1960.
- Shriver, E.L. History of ISD Concepts. Paper presented at the Conference on Application of ISD to Emerging Weapons Systems of the 80's, Society for Applied Learning Technology, October 26-27, 1978.
- Shriver, E.L. Maintenance Training Systems, From Technical Manuals to Automated Job Performance Aids and Training Devices. New Concepts in Maintenance Trainers and Performance Aids. Orlando, FL: Naval Training Equipment Center, October 1975.
- Shriver, E.L., Fink, C.D., & Trexler, R.C. Increasing Electronics Maintenance Proficiency Through Cue-Response Analysis. Research Memorandum. Alexandria, VA: HumRRO, October 1959.
- Shriver, E.L. & Foley, J.P., Jr. Evaluating Maintenance Performance: The Development of Graphic Symbolic Substitutes for Criterion Referenced Job Task Performance Tests for Electronic Maintenance. (AFHRL TR-74-57, (III)) November 1974.
- Shriver E.L. & Foley, J.P., Jr. Evaluating Maintenance Performance: The Development and Tryout of Criterion Referenced Job Performance Tests for Electronic Maintenance. (AFHRL TR-74-57, (II) Part I) September, 1974.
- Shriver, E.L. & Hart F.L. Study and Proposal for the Improvement of Military Technical Information Transfer Methods. Technical Memorandum 29-75. (AD-013 409) Aberdeen, MD: U.S. Army Human Engineering Laboratory, December 1975.
- Shriver, E.L., Sivy, J., & Rosenquist, H.S. MOONLIGHT II: Training the Rifle Squad in Night Technique of Fire. (AD-72-721) Alexandria, VA: HumRRO, May 1955.

APPENDIX A - AIDS TO SOLVING 30 FSTT TROUBLESHOOTING PROBLEMS

FSTT
AIDS TO PROBLEM SOLUTION

PROBLEM #1

IIISAF FORM 781 STATEMENT: "HOURGLASS SWEEP ON COCKPIT AR INDICATOR"

GENERAL: The Attack Radar Indicator in the simulator cockpit has been modified so that it contains somewhat different circuitry from the AR indicator in the aircraft. But it still has many similarities. The AR monitor on the console, on the other hand, is quite different. A significant difference lays in how many sweeps are generated and displayed. The cockpit indicator has two circuits relating to sweep that (1) produce a sectored PPI shaped display, and (2) run the sweep out in range. The Yoke Servo circuit is concerned with azimuth, while the sweep circuit, or gamma servo, is responsible for range. Troubles in either of these circuits will show up locally. That is, the symptom will show up in the indicator but not on the console. The hourglass sweep is called that because of its resemblance to an hourglass.

SPECIFIC: Start with a strategy page to see what options for troubleshooting are available.

Check switch settings to determine that normal operating settings are in effect, and that a false trouble is not present.

Check if the symptom is present and localized or generalized.

If local in nature, isolate to the removable part.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____



FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #2

USAF FORM 781 STATEMENT: "WINDSHIELD WIPER SYMPTOM ON AR COCKPIT INDICATOR"

GENERAL: The Attack Radar Indicator in the simulator cockpit differs from the monitor on the console. Generally, the console monitor repeats the display that appears on the cockpit display. When the pilot changes ranges, the monitor will show the changed ranges. But if the CRT in the indicator in the cockpit burned out, the console monitor would continue to display video since culture returns are generated by the Landmass system and are shared by both displays. In other words, there are some kinds of troubles that are specific to the hardware in each physical location. When such troubles occur, the effects are not necessarily seen on both displays.

The Gamma servo circuitry and the Yoke servo circuitry in the AR cockpit indicator will affect the shape of the display seen on that indicator. Troubles in either of these circuits will not necessarily be displayed on the console monitor.

The Yoke servo circuitry affects the shape of the "fan." The Gamma servo circuitry affects range sweep.

SPECIFIC: Start with a strategy page to see what options are available.

Check switch settings to ensure normal operation.

Check if symptom is present, and where located.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #3

USAF FORM 781 STATEMENT: "POWER LOST (28VDC)"

GENERAL: The simulator uses many different power levels of both AC and DC. In troubleshooting power failures, it is useful to divide the systems into AC systems and DC systems, as they both have their own methods of control. Simulator power is input to cabinet 4, MAIN SIMULATOR POWER. Cabinet 5, consisting of power supplies and circuit breakers, permits selective distribution of power to simulator systems and subsystems. If observation of power panels and of circuit breaker panels fails to localize the problem, go to the power distribution prints and try to trace the circuits.

SPECIFIC: Check the 781. What power was lost? What controls the power supplied to the element(s) or systems that lost power? If it is not a power supply that failed, it could be a circuit breaker. Power supplies are usually located near circuit breaker panels, or incorporate circuit breakers (though not always).

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #4

USAF FORM 781 STATEMENT: "NO VIDEO DISPLAYED"

GENERAL: Many write-ups are either misleading or ambiguous in practice. The reason for this is that the person doing the writing may not be able to describe the symptom meaningfully. Technicians must learn to live with this fact, and treat the write-up as an attempt to provide information, but not to put too much faith in it. For example, "NO VIDEO DISPLAYED" may mean totally blank screens to one person, missing culture returns to another, and so on. Generally, it is wise to examine all displays that would show video, both on the console and in the cockpit. Determine what kinds of images are in fact displayed, and on which scope. Since range marks are not generated in the Landmass, presence or absence of these marks helps to isolate the trouble. Even if the FSS and film plate are functioning properly, if the antenna is not sweeping, the culture returns will not be displayed.

SPECIFIC: Check the strategy page of troubleshooting strategy options.

Verify the presence of the reported symptom, and try to determine what the 781 means.

Check status of controls and configuration of the AR.

Verify presence of antenna motion.

Check AR video distribution.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #5

USAF FORM 781 STATEMENT: "INCORRECT AR VIDEO"

GENERAL: There are many ways in which the AR video can be incorrect. The write-up is not specific as to where the symptom was observed. Since the console AR monitor and the AR indicator in the cockpit can have different displays if one or the other is faulty, it is important to check both places. Also, it is important to see if the mode of operation is consistent with the display observed. Check switch position.

SPECIFIC: Check the strategy frames to see what troubleshooting paths are available to you.

Check both displays.

Check switch settings.

Verify the symptom.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #6

USAF FORM 781 STATEMENT: "NO VIDEO ON ANY SCOPE - NO TIME SIGNAL"

GENERAL: There are three scopes to consider: the ARS (attack radar set, cockpit), the ARM (attack radar monitor, console), and the TFR/TAR (terrain following radar-terrain avoidance radar, both cockpit and console). In this case there is nothing on any of the scopes. This symptom requires starting a system checkout at a broad and high level. Since all scopes are affected, the failure is common to all three systems. The fault is something that either controls the video to the scopes, or has to do with its production and delivery to the scopes. A clue is provided in the 781: "no time signal." While this is general and does not pinpoint a system, it does afford some help because the simulation is computer controlled and gating, controlling RLMS/Tactics operations, whichever mode is selected, is critical.

A second clue: Computer/linkage timing is good. (Do not consider the computer suspect.)

SPECIFIC: Verify loss of video. Find a system (or systems) common to all scopes.

Check for operation or loss of operation from a high level, narrowing down to a system (or systems). What was meant by saying "loss of time signal"?

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #7

USAF FORM 781 STATEMENT: "CROSS-HAIRS DO NOT FALL ON TARGET"

GENERAL: As the FB-111 flies over areas of the earth, its geographic coordinates depend on its speed and direction of flight. In the simulator, the transparency (filmpate or "map") in the optics cabinet of the RLMS duplicates the topographic features found in the real world so that realistic navigation and radar operations can take place. The coordinates are updated in a way that will correspond with the motion of the aircraft relative to the ground. This requires precise alignments between the RLMS optics and the aircraft display systems (navigation and radar/tactics display instrumentation). The simulator incorporates the means by which non-linearities can be corrected (ground map-transparency alignments) so that the crew can be presented accurate data. If, for instance, one were to attempt navigating to PAFB, the known latitude, longitude, and elevation could be entered to the the Navigation Display Unit, and if within radar range, one could position cursors on the ARS over PAFB; there would be no disagreement, the cross-hairs would be over the base, and the NDU would show PAFB's geographic coordinates.

SPECIFIC: Check the ARS and NDU and try to get the cross-hairs to target the latitude-longitude data in the NDU.

Go through RLMS and check optics.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #8

USAF FORM 781 STATEMENT: "CANNOT COMPLETE FIDUCIAL ALIGNMENT
(OSCILLATIONS)"

GENERAL: A fiducial alignment is a procedure whereby the optics cabinet filmplate is positioned to allow the FSS to scan each fiducial mark found on the four sides of the filmplate. When aligned, the filmplate data will accurately reflect the latitude and longitude position of the aircraft/ground returns etc.). The filmplate is positioned by servos. The filmplate motion computer is the subsystem that controls filmplate positioning. The write-up indicates there are "oscillations" occurring, and therefore it is impossible to keep the scan centered over the desired spot.

SPECIFIC: The RLMS uses a small general-purpose computer, the Raytheon 703. This computer is tied in to allow the RLMS to perform, among other things, computations involving latitude/longitude data. These coordinates are used to position the filmplate transparency according to aircraft flight attitude/conditions. It is not necessary to perform the "fiducial alignment" in this problem. The objective is to remove the oscillations from the system so that a fiducial alignment can be done.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #9

USAF FORM 781 STATEMENT: "MIRROR IMAGE ON AR VIDEO"

GENERAL: The simulator uses many systems to simulate radars. These include: optics (initial ground return data), DTG, VGE (air targets, video pulses, triggers etc.), servos (antenna motion simulation), and the necessary computers and handshaking systems (linkage, DTG, BCM.703 Raytheon, etc.). A failure in any one of these systems results in a faulty radar system simulation. This ranges from degraded performance to total failure. The ARS in this problem is operational, but a "mirror image" has appeared.

SPECIFIC: Since both indicators show the condition, the problem must be in circuits common to both. Is there anything in the radar computers that could cause this condition? The TFR is OK. (Is gross video data from optics, etc. good then?)

Check the ARS-ARM scopes.

Check sweep circuits.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #10

USAF FORM 781 STATEMENT: "OFF-FLAG ON MACH INDICATOR"

GENERAL: The Mach airspeed indicator is part of the cockpit flight instrumentation. The indicator on the console is a digital readout unit. The one in the cockpit is an actual aircraft indicator. Cockpit indicators are, for the most part, synchro-driven devices. Data driving them come from the ESRD system in cabinet 14. These indicators, however, also receive logic data and power from simulated flight director computer systems (simulated by the simulator main computer). The MAS (Mach airspeed indicator) uses a "black box," located beneath the pilot's area of the cockpit. The ESRD system inputs to this box, which in turn outputs to the indicator.

SPECIFIC: Determine if the write-up is valid. In some cases of fault determination, it is necessary to track more than one possible fault; keep this in mind.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #11

USAF FORM 781 STATEMENT: "HSI BEARING POINTER DOES NOT ROTATE"

GENERAL: The HSI (Horizontal Situation Indicator) in the cockpit is used in flight navigation. It contains a compass card, a "to-from" indicator, a distance readout, bearing pointer, a course deviation bar, course set window and a power on-off flag. The HSI unit is not simulated; it is an actual aircraft instrument. However, drive voltages and logic status supplying the HSI are simulated. Cockpit flight instrumentation uses synchros driven by 26-volt, 400 Hz power.

SPECIFIC: Verify the 781.

Find the cause of the write-up by checking HSI circuitry (simulator circuits, of course, not those internal to the HSI).

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #12

USAF FORM 781 STATEMENT: "MOTION 'ON' LIGHTS (PLATFORM) REMAIN LIT
AFTER MOTION HAS BEEN DESELECTED"

GENERAL: On the left and right side stairways providing cockpit platform access are two warning lights. "Flight in Progress" and "Motion On." One of these two warning lights remains lit.

SPECIFIC: How is the warning light deactivated? Has the system been turned off or is it still on?

Check the T0s.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #13

USAF FORM 781 STATEMENT: "NUMBER 1 UHF DOES NOT TRANSMIT"

GENERAL: The FB-111 uses various devices/equipment for communications as well as navigation aids. There are two UHF systems onboard the FB-111: numbers 1 and 2. The simulated transmission facilities in the cockpit are exact replicas of actual com-sets used in the aircraft. Those on the console, however, are comprised of the tactics and flight instructor's transmit and monitor circuits. The crew members in the cockpit transmit to the console. By observing console displays, console instructors can ensure that the range, frequencies, and ID data are such that communication could actually take place in the real world. Console personnel can then acknowledge reception of crew member messages.

SPECIFIC: The UHF system uses a system of selectable frequencies. Those on the console should match those in the cockpit. How is transmission effected (cockpit to console)?

Verify the write-up.

Check to see if all transmission is out, or if it is specific to one circuit.

Check the interface circuit prints and trace signals.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #14

USAF FORM 781 STATEMENT: "INSTRUCTOR CONSOLE LIGHT DOES NOT LIGHT WHEN SWITCHLIGHT IS DEPRESSED"

GENERAL: Console switchlights are switches with a lightbulb in them. When they are lit, they signify that the system/subsystem is active (or should be). In other words, by depressing a switchlight (which then illuminates), whatever that switchlight controls should become active (or inactive).

SPECIFIC: Is the lightbulb good? Which switchlight is the 781 referring to? Refer to the prints and check the lights/voltage input(s).

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #15

USAF FORM 781 STATEMENT: "INSTRUCTOR CONSOLE DOES NOT SHOW AR RANGE
SELECTED IN COCKPIT"

GENERAL: When a crew member, or technician, alters a switch position in the cockpit, the event is observable at the console. It may be as simple as a single light coming on or going off, or it could be a series of lights coming on or going off. It could be an involved intermix of status display changes, lights coming on or going off, and extensive reorientations of flight and tactics displays. The Attack Radar in the cockpit can be operated in a variety of modes and ranges and the actions of the individual manipulating and ARS controls can be observed at the Attack Radar Monitor panel, tactics console.

SPECIFIC: Verify the write-up.

Check the cockpit to ensure the range switch is configured properly to allow the console light to be checked.

Check the TO prints for the circuit path.

Verify whatever repair actions taken result in proper simulator operation.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #16

USAF FORM 781 STATEMENT: "MOTION SYSTEM DOES NOT ERECT PROPERLY"

GENERAL: The motion system is an electro-mechanical-hydraulic system that the simulator uses to move the cockpit in response to pilot control stick movement, and external conditions, like bumpiness in nap-of-the-earth flying. There are five hydraulic cylinders that control cockpit attitude. One of the three vertical cylinders could be responsible for incorrect motion system erection. Or, something that is common to all three systems could be at fault.

The first step would be to find out what troubleshooting strategies are available. The principal strategy page is located at trainer code 55.

The "mule" or hydraulic pumping unit must be operational if the motion system is to erect properly. PRESSURES required must be available.

SPECIFIC: Check the options or measurements available under "hydraulic strategies."

Under normal conditions, the pressure gauges at the mule do not show any pressure, but it is possible to momentarily turn these valves on to measure the pressure in the system.

If there is a leak, hydraulic fluid will be noticed.

If the pressure is too low, proper erection cannot be obtained, and repressurization will be required. Diagrams found at 02 and 03 will lead to measurements of the pressure and appropriate corrective action. Once proper pressure has been achieved, the gauges will read 3000 psi when the platform is fully erected.

In practice, this is a transitory thing taking perhaps up to 10 seconds to erect fully, during which time the gauge will show a lesser pressure.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #17

USAF FORM 781 STATEMENT: "LAGGING RESPONSE TO CONTROL STICK"

GENERAL: The control sticks (or control columns, as they are referred to in the T0s) are mechanically connected via a system of bell-cranks, arms and levers to hydraulic servos and transducers. These allow the simulator to follow-up stick movements with the right "feel" feedback from the control column as well as cockpit platform motion. Unless there is an obvious clue to possible fault, whether it be hydraulic, mechanical, or electrical, it is a good idea to check mechanical elements briefly. Then, check for electrical inputs.

SPECIFIC: The term "control loading" applies to the flight control system used in the simulator whereby flight control inputs initiated within the cockpit are sensed and output via the mechanical-hydraulic-electrical system to the linkage computer. Do not attempt performing a control loading alignment unless sure it is needed. Try to check the obvious, or if not obvious, then easily accessible items first. The simulator is provided with built-in test equipment; try to use the "digibox" for core checks.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #18

USAF FORM 781 STATEMENT: "MAIN DC LOAD CANNOT BE APPLIED"

GENERAL: The simulator uses a wide variety of power supplies. In addition to the power supplies, circuit breakers are used to control power routing and prevent damage due to voltage surges and overloads. The power supplies use internal controls as well as feedback to provide constant and linear outputs. Power distribution throughout the simulator fans out from cabinets 4 and 5. From the circuit breaker panels on cabinet 5, power to user systems can be selectively removed or applied as desired.

SPECIFIC: Check the 781 write-up. Where is power removed from?

By checking the power distribution prints found in the TOs, it is possible to trace the circuit paths of the various power systems from cabinet 4 to the final using element.

Check power supply panel indicators for normal or abnormal values.

If a circuit breaker trips immediately upon reset, there is a chance it is defective; also, the input to it is abnormally high.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #19

USAF FORM 781 STATEMENT: "NO TANKER BEACON SYMBOL ON AR"

GENERAL: In refueling operations, the Attack Radar Set is used as a means of locating the tanker and then tracking (homing) to the tanker for the refuel. The ARS has to be put into the air mode and the target (tanker) acquired via the tracking handle for a lock-on. (The aircraft can fly to the tanker automatically.) The tanker should appear on the ARS scope as a series of lines (strokes) patterned according to the code selected.

SPECIFIC: Determine if the ARS is configured for air mode. Determine what procedures provide the necessary video on the ARS and ARM scopes. (Since this is a tactical function, the DTG and VGE should concern you.)

Verify whatever repair actions you have taken by observing the ARS and ARM scopes to see that a tanker beacon becomes visible.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #20

USAF FORM 781 STATEMENT: "ANTENNA TILT NOT WITHIN LIMITS"

GENERAL: The actual antenna within the nosecone of the FB-111 is engineered to operate within certain tilt angle limitations. The simulator is designed to the same limitations on the simulated radar. Instead of using servos to position an antenna dish, the servos in the simulator are driven to the same angles/limits as in the actual aircraft and shaft encoders digitize the information to be processed in other circuits.

SPECIFIC: It is suggested that the areas you choose to check out be chosen with the T0 material referenced with it; i.e., if you are going to check the outputs of the radar receiver computer, go to the -1 (T0).

Check the AR interface system prints.

Verify the limits corresponding to the required values.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #21

USAF FORM 781 STATEMENT: "PILOTS CAN'T TRANSMIT OR RECEIVE"

GENERAL: Intercommunications circuits and systems allow the pilot and WSSO to communicate to each other. There are various circuit paths to consider, but if there is no communication at all (hot mike function allows the lines to stay open), then it could be necessary to check the systems/power supplies in common with one another.

SPECIFIC: Check items that receive a lot of use and are subjected to mechanical stress.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #22

USAF FORM 781 STATEMENT: "NO AZIMUTH MARKER ON EITHER RADAR SET"

GENERAL: The radar scope azimuth marker allows a radar set operator/observer to relate radar returns to a given aircraft heading. The azimuth marker is moved to run through the return. The angle between the marker on aircraft heading is used in target acquisition. The azimuth marker on the console is slaved to the one in the cockpit. (Since both ARS and ARM receive the same signal from interface, the displays should be the same.) There is an azimuth marker video intensity control pot on the ARS panel beneath the ARS CRT, however, this pot has no effect in this problem.

SPECIFIC: The azimuth marker pulse is a video pulse, produced by the video circuitry in cabinet 6, which receives commands and data from DTG, cabinet 19.

Check the ARS and ARM (scopes).

Check video output from cabinet 6.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #23

USAF FORM 781 STATEMENT: "ILS IDENTIFIER INOPERATIVE"

GENERAL: The Instrument Landing System (ILS) allows for blind let-downs using cockpit instrumentation that is receiving radio data from ground sources. The pilot flies down to the selected field by means of pitch and course deviations bars on the ADI as well as audio tone cues that are specific to the airfield being approached.

SPECIFIC: Verify the 781. Check to see if the identifier is present.

Check the ILS control panel in the cockpit for its set-up. The set-up of the ILS panel must be right for the field desired. The ILS, when working properly, presents deviations on the ADI, aural cues (identifier), as well as outer and middle marker cues.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #24

USAF FORM 781 STATEMENT: "CONSOLE MICROPHONES ARE WEAK AND GARBLED"

GENERAL: The console microphones are connected into whatever communication system is selected, and permits console-to-cockpit, console-to-console (tactics to flights), and hot mike intercom, at a volume level adjustable from the console. Cabinet 15 contains circuits, amplifiers, filters and oscillators used in simulating the intercom/communications systems. (Cabinet 15 contains circuits, amplifiers, filters, and oscillators used in simulating the intercom/communications systems. (Cabinet 15 does not have them all, however. Most of them are to be found in the audio and aural cue cabinet.)

SPECIFIC: Verify the 781.

Check the T0s to determine the circuit paths the various communications systems take.

Verify the repair by checking the system out.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #25

USAF FORM 781 STATEMENT: "TFR CLIMB/DIVE BAR INOPERATIVE"

GENERAL: The TFR (Terrain Following Radar) system allows for blind let-downs, and fast, low-level, terrain following flight. There are basically two ways of using it in flight. The first way is by selecting the auto TF function, presetting flight controls and allowing the TFR unit to "fly" the aircraft handsoff. The other way is to fly the aircraft manually, but to use the pitch steering bar, visible on the ADI, which becomes available if the manual mode is selected. There are several things to keep in mind concerning the TFR system. It is adjustable to fly the aircraft at several preset levels. If the TFR is not in auto TF and manual TF flight is selected, the pilot has to rely on aural and visual cues. If over flat terrain, the ADI pitch bar should be somewhere near the center of the ADI when the aircraft attitude is level flight and the ground clearance is set within the flight envelope.

SPECIFIC: Check the 781 write-up. Observe the TFR control panel; observe the ADI.

Check the prints.

Verify whatever repair action taken restores the use of the ADI pitch bar.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

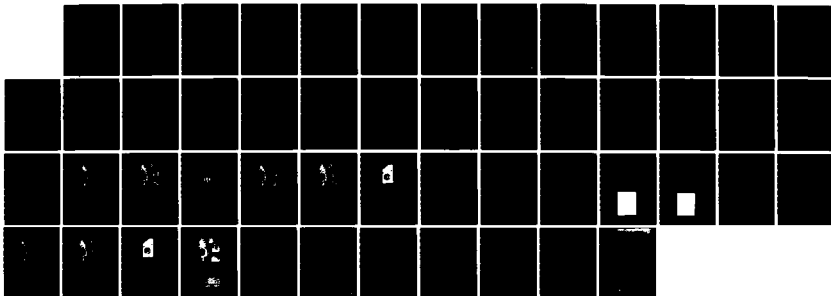
AD-A146 677

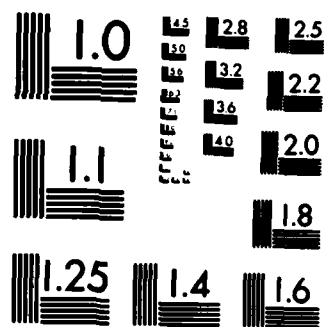
SITUATIONAL INTERACTIVE MICRO/GRAPHIC SIMULATOR SYSTEM
FOR IMPROVING MAINTENANCE PERFORMANCE(U) KINTON INC
ALEXANDRIA VA E L SHRIVER ET AL. SEP 84 AFHRL-TP-84-9
F33615-80-C-0012 F/G 5/9

2/2

UNCLASSIFIED

NL





COPY RESOLUTION TEST CHART

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #26

USAF FORM 781 STATEMENT: "NO LOW LEVEL REFLECTANCE"

GENERAL: The Attack Radar is capable of several modes of operation. The returns displayed on the AR monitor and cockpit indicator can include such topographic characteristics as returns from electric power transmission lines and poles. In the simulator, the circuitry that processes such returns is called the Low Level Reflectance circuits. Without returns of this type, the display may appear to be acceptable. In general, these returns may be difficult to see on the scopes even when present because of the presence of other returns that may be stronger, and mask them.

One generally useful strategy to adopt when verifying this symptom is to set the simulator to the location where it is known that low-level reflectance would be available if the circuitry was operational.

This strategy may or may not be available to you.

SPECIFIC: Check the strategy page to see what troubleshooting options are available to you.

Observe the AR scopes, both for signals and settings.

Find the RLMS circuitry dealing with low level reflectance, and check for proper signals.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #27

USAF FORM 781 STATEMENT: "NAVIGATOR CANNOT COMMUNICATE WITH PILOT"

GENERAL: There are several switches in the cockpit that pilot and navigator each can operate in order to activate different modes of communication. There is a switch on the throttles, used in air to ground communication, and there are other switches on the floorboards for use in the intercom system. In addition, the setting of switches on the UHF and HF radios have a bearing on the success of voice communication. The simulator does not actually use a radio, but does have switch circuitry that mimics the circuits in the aircraft.

SPECIFIC: Check the strategy page to see what troubleshooting options are available to you.

It may be necessary to make voltage measurements within the intercom circuitry.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #28

USAF FORM 781 STATEMENT: "NO LOW LEVEL REFLECTANCE"

GENERAL: The video displays on the AR scopes simulate cultural returns that are interpretable as reflectance data from specific objects on the ground. The filmplate is color coded to provide data for every portion of a ground return visible on the real radar. These levels of intensity/illumination are called steps, and each one is used to correspond to a given ground effect/intensity. The WSSO, or technician, observes the ARS scope hoping to see proper returns for the given area of radar scan. By noting a lack of "low-level reflectance," you can refer immediately to the RLMS subsystem that has to do with this problem.

SPECIFIC: Check the AR scopes. Go to the RLMS section and check to see how the filmplate video is being processed (or isn't being processed).

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #29

USAF FORM 781 STATEMENT: "RIGHT SHOULDER STRAP LOCKS"

GENERAL: The shoulder strap or inertial reel assembly is part of the crew's equipment for restraining them during rapid aircraft accelerations, and during emergency ejection. Controls for straps are located in the cockpit.

SPECIFIC: Check the strategy frame to determine an effective troubleshooting strategy.

Ensure that the reported symptom actually exists.

Check for broken cables, or misadjustments.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

FSTT

AIDS TO PROBLEM SOLUTION

PROBLEM #30

USAF FORM 781 STATEMENT: "ENGINE PERFORMANCE INDICATORS DO NOT
CORRESPOND WITH THROTTLE POSITIONS"

GENERAL: When the throttles in the cockpit are moved, there are many cues that show the resulting effect of throttle repositioning. If they are advanced, fuel flow increases, the RPM indicators (tachometers) spool upwards, and other engine performance indicators show the resulting effects of increased engine thrust. For the computer to know engine status, inputs are necessary so that the computer can acknowledge the action taken in the cockpit.

SPECIFIC: Verify the write-up.

Check the throttles. There is a way the motion of the throttles is being translated into electrical inputs to the computer. Find the location, and check the cores. Check the TOs.

EMPLOYEE NUMBER: _____

DATE PROBLEM WAS TRIED: _____

SCORE: _____

APPENDIX B - AUTHORIZING TECHNIQUES FOR DEVELOPING FSTT SIMULATION PROBLEMS

APPENDIX B - AUTHORIZING TECHNIQUES FOR DEVELOPING FSTT SIMULATION PROBLEMS

The content of courseware problems for the FSTT is produced by courseware authoring activities. This is a formal description of the authoring activities. In practice, the process is simpler than it sounds in a verbal specification. And, in practice, shortcuts in documenting the procedures may be taken. The following description presents specifics for the process of courseware development.

PROCEDURES

The first step in authoring a problem for the FSTT is to identify and select a fault upon which a troubleshooting problem can be based. The next step is to identify a set of troubleshooting steps that will efficiently isolate the fault. While each author will have a preferred method for isolating the fault, each method should be effective in achieving the solution and the repair of the fault. After the specific sets of observations and required tests have been determined, alternative sets or paths to solution should also be identified. Alternative troubleshooting paths are those which are not as efficient as the optimal path. An alternative path can be absolutely wrong, in the sense that taking an action on this path is dangerous to personnel or equipment, but to be effective, alternative paths should be reasonable and appear sensible to the user. The author may obtain information about the troubleshooting path from a functional analysis of the system and from the technical orders for the system. An author who is an experienced troubleshooter of the operational system already possesses sufficient knowledge of the system but still must explicitly identify all the steps and data.

The next step is to specify the observations and specific test points at which to make measurements. These data should be entered in the field data collection book as the guides for collecting data in the field. Data already in the resource file may satisfy certain requirements; however, until that is known, it is best to consider that all data will be obtained through on-site observations.

Next, the author should consult the resource file. The resource (described elsewhere) contains the selected photographs that were used in the construction of the previous problems. It is, obviously, possible that some of the photographs needed in the new problem can be found in the resource file. If so, there is no requirement to take new photographs unless there have been equipment changes.

If additional photographs are needed, with the field data collection workbook in hand and the camera equipment available, the author will go to the field and arrange to take the pictures. These photographs will show equipment locations. At some locations, symptoms of the fault will be

displayed. At others, test points will be available so that test equipment can be installed and pictures taken of the test instrument readings. The equipment must be set up for the operating conditions under which the trouble occurs including insertion of the fault selected. Any test equipment needed should also be taken to the field to provide needed pictures. The field data collection workbook can be used for recording data about the photographs being taken and what they show.

When photographs taken in the field are finished and are judged suitable for developing a problem, the author will identify those requiring enlargements. Otherwise, if transparencies are to be used directly, they will be part of the problem content.

Developing the Problem

When all the necessary materials are available, development of the problem should begin through use of fiche assignment sheets and the fiche planning board.

All FSTT problems begin with a statement of the problem, as it appears on a Form 781, on the left-hand viewer. On the right viewer, a diagram which shows the overall physical layout of equipment in the simulator bay is displayed. These frames are accessed with the 00 code to start each problem.

For each potential action available to the user, a corresponding code must be assigned. Codes are assigned to locations on the top level diagram and will allow access to detailed pictures of the system components relevant to the problem; e.g., the cabinet that a troubleshooter would go to collect information. The same procedure should be followed for each location which gives a choice on the top level diagram. This copy may be photographs, cropped pictures, cropped parts of the enlargements, or parts of photostats of the T0s. They must be identified and placed on the fiche assignment sheets, and a miniature copy placed on the fiche planning board.

When the codes have been assigned to the copy, they should be checked off against the fiche assignment sheets. Fiche assignment sheets are a convenient control on which fiche assignments have been made, which codes have been allocated, which codes call other codes, and what the content is for a particular code location. After the codes have been assigned, the content must then be assigned to the fiche locations corresponding to those codes. The author should mark up the fiche assignment sheet and place the images of that content on the fiche planning board. There should be some representation (either a miniature, or a note identifying the material) of the image to be assigned to a fiche location placed in each of the cells used in the fiche planning board.

Next, the author should assign the test point data codes. The photographs taken of test points in the field are a usual source of such information. It is possible to represent the normal condition by means of

the word "normal" rather than the actual value, but it is preferable to use a value. If the test point data is a voltage and there is no interest in having students practice reading voltage scales in the problem, then the voltage obtained at a test point may be printed on the copy (e.g., 128 VDC).

The optimal patch (strategy) through the problem should be plotted first. The author simply assigns the specific diagrams and figures to places within the problem on the fiche planning board such that it will be possible always to keep previous frames in place while accessing data on the other viewer. This is a preferred solution although it is not absolutely mandatory. When all of the required copy for the optimal path, including test point data, have been assigned to the fiche locations, the author then goes back to the strategy page and assigns the alternate paths. These may include some of the copy previously indicated on the optimal path.

Arranging the Abort Paths

In some problems, it may be desirable to include an action that would cause some danger. If such an action is provided as an option on a path, it should be specially coded by assigning an ADC to that particular frame. This code will cause the problem to "abort" if it is selected. After an abort, the user must start the problem over again.

Selecting Assistance Frames

The codes 07 through 18 are the frame codes at which it is possible to obtain assistance. The author may use theory of operation, relevant suggestions for action, or other assistance on these frames. Generally anything that reviews the situation the user is in provides help. The help should not just tell the user what to do next to get out of the situation.

Checking the Code Assignments

When all of the copy has been assigned, the author should then ensure that each frame selected brings up copy at the locations called for. That is, if the top level diagram calls for a picture at code 70, then it would be important to find that there has been content assigned to 70 and that that content is what is supposed to be there. This is a verification process that ensures all fiche codes have been appropriately designated. The fiche assignment sheets should also contain the listings of the "from" and "to" calls.

When the author is satisfied that this is the case, the codes should be placed on the copy. The coding activities essentially fall into three main areas. The first of these is the coding of the color enlargements.

Coding Enlargements

The color enlargements may be masked so as to exclude certain areas which are of no interest to the problem at hand. They may be masked in either the horizontal or vertical format. Photographs should be masked, and then tissue paper or vellum placed over the masks. The courseware author then indicates by pencil on the tissue paper where specific codes should be placed on the copy. These codes have previously been identified on the facsimile of the photograph used in the fiche planning board, so it is a matter of transcribing those data, as well as the frame location code, onto the cover sheets for the enlargements. (For example, 21A23. 21 refers to Problem 21, A refers to fiche A, and 23 refers to the 23rd frame on the fiche.)

After the author has designated the trainer codes, the copy can be coded using specially printed sticky-back tabs. White and black arrows are used to connect each code to the specific hardware item to which the trainer code refers. The white- and black-bordered arrows are used because they are visible under every circumstance of dark photograph or light photograph. When all the color enlargements have been so coded by the author, they are then turned over to the copy preparer (who may also be the author) and included in the enlargement. Subsequently, they are photographed by means of the copy stand in order to obtain color transparencies. (See Micropublishing for description of that process.)

Preparing Photostat

The second preparation activity is in connection with the stats. These are photostatic copies of pages that have been selected from the technical orders (TOs). The photostatic material itself is reasonably tough material that will withstand the attachment and removal of sticky-back code tabs. In assigning codes to the photostats, the author uses a xerox copy of the page and marks up that copy for subsequent use as a guide to coding the stat. Again, frame location codes are placed in the lower left-hand corner, and the copy is mounted on sheets of paper measuring 14 x 11 inches. This size of paper provides a constant size of image for the fiche maker and ensures that the full image frame is occupied even though the content of the frame may occupy less space.

Test Point Photographs

The waveforms used in connection with observations of an oscilloscope are placed on the black/white fiche. Here the negatives taken from the P/N-type polaroid oscilloscope camera film can serve as the basic source for the waveform. Each negative is subsequently xeroxed and the copy placed on 8-1/2-inch by 11-inch paper. The paper subsequently is coded with the frame location code so there is no ambiguity about where to place the image within the frame. There are no access codes placed on the copy of test point readings.

When the copy has been prepared for a fiche, a fiche layout sheet is prepared. A fiche layout sheet is a symbolic representation of the corresponding fiche planning board. All those locations on the fiche which are not used are so indicated by an X.

Fiche Layout

The fiche layout sheets are the principal means of communication between the courseware author and the fiche maker. Essentially, they tell the fiche maker which fiche location frames have been identified. In addition, of course, each frame of copy submitted is identified by a location number. The fiche layout sheet is also used as an inventory control document to ensure that every frame to be microfiched has been prepared and is ready to be sent to the micropublisher.

Header

The header is a title identifying the fiche. It will provide the problem number and any other codes that may be desired; for example, the revision number and the data for publication of that problem. The material to be microfiched should then be assembled into a package and sent to the micropublisher with header and instructions for publication.

Transparencies for Color Fiche

Transparencies for use in color micrographics should be retained in the paper holders which are supplied by the film processor doing the work. These paper holders should be labeled with the frame identification of the image. During the photographing of the enlargements, the photographer may have used several different aperture settings in order to achieve the proper exposure. The author should select the most appropriate photograph and indicate on the covers which one was selected. This can be done by using a check mark or an X, or some other symbol of that sort.

In construction of the color microfiche, not every frame contains a transparency or color image. In those cases where line art or text are used, the copy should be placed on blue paper (e.g., Hammermill Four Bond Blue #10164-2). The blue paper provides a means of making copies of the content and at the same time gives the microfiche maker less trouble in obtaining color balance for the color microfiche. The set of materials to be sent to the color microfiche maker, therefore, consists of a set of labeled color transparencies and the set of blue paper hard copy, plus the fiche layout sheets and the transmittal letter. Before any of the materials have been sent to the microfiche maker, archive copies of the materials are prepared. The archive copies consist of xeroxed (or other dry copier) reproductions of the materials. These archive copies are important because, in the event a revision needs to be made, the specific

coding for a given stat or enlargement can be reconstructed more easily. Hence, archive copies are prepared and stored with the materials that are in the resource file after they leave the lesson development file.

After the fiche are returned from the micropublisher, they should be loaded into the carriers and brought into the FSTT for examination. The points to look for are discussed in the section on micropublishing. Following examination of the fiche for copy quality, if satisfactory, then the magnetic card coding can be undertaken.

Magnetic Card Coding - Introduction

In using the FSTT, users receive feedback on their selection of frames in the form of messages that appear on the in-line display above the left microfiche viewer. The specific words used as the qualitative feedback repertoire are: correct, incorrect, relevant, irrelevant, and the + and - symbols. When the action taken by the user is judged to be very inefficient, three minus signs are used. Where a choice on the optimal path is entered, three plus signs appear.

In addition, other messages are provided under certain circumstances. For example, if the user chooses to make a repair that would result in damage either to the equipment or self, the message "EQUIPMENT DAMAGED-ABORT" could be given. (A listing of the messages is provided on the Mag Card Coding Guide at the end of this Appendix.) The FSTT has been hard-wired for this set of messages, but it is the author who must elect whether to use the messages.

In addition to the messages that appear as part of the normal solution to a problem, other messages that have been incorporated into the FSTT allow the author to interact with the device during the authoring phase. An example of a message that can appear is "BAD DATA READ ON MAG CARD." This message occurs if an attempt to load a blank mag card was made.

Each addressable fiche frame associated with a given problem is accessed by inputting the two digit hex code associated with that image. These access codes have been previously referred to as "trainer" codes or sometimes just "codes." When a code is entered by means of the trainee keypad, the associated fiche frame is displayed on the appropriate fiche viewer. When a code is entered on the trainee keypad, the electronic controller examines it and determines from the stored values associated with that code and the conditions existing at the time, what efficiency score to display as a result. The in-line display then shows the results of that calculation. However, in order for the FSTT to perform this calculation, the values associated with the trainer codes must be recorded on the magnetic card for the lesson.

The solution of a given troubleshooting problem can be performed by acquiring the needed data from available sources in a logical fashion.

The images selected for use in any given lesson were selected by the courseware author because they constitute a feasible set of images to represent places at which to obtain information about the condition of the equipment and, thereby, to solve the problem. The fiche would contain photographs of the places at which a troubleshooter would examine and collect additional data such as images of waveforms as seen on oscilloscopes or control settings on equipment. The fiche also contain pages from the T0s that would be relevant to the decisions to be made as to where to make tests. The fiche also contain photographs of panels or cabinets which do not display data; the user must observe a more detailed view in order to obtain the data needed.

If the problem contained only that subset of data or images which were relevant to the optimal solution of a given problem, it would not adequately represent the real world, in which both relevant and irrelevant pages of a T0 are available. Moreover, since in the real world a trainee could examine not only the relevant test points but also the test points that have correct values, the FSTT has been designed to provide for the examining of test points and collecting data, even though those test points might not be the most efficient ones for the solution of a given problem. Consequently, every frame that is accessible must be evaluated by the author as to its importance to the efficient (optimal) solution of the problem. In those cases where the abort messages are to be used, it is clear that the abort should result in a "no solution" of the problem.

A table showing the hex weighting codes and the corresponding messages is provided at the end of this section. Hex weighting codes from 1 through F are used. The hex code 0 is the default value and simply means that if 0 were inserted in a given mag card location, the entry would not result in score computation nor would there be any feedback provided for accessing that particular frame. Seven values are used in computing the score: 0 through 6. The maximum value (6) is given in the case of a highly relevant (highly efficient) or correct choice. On the other hand, the value 0 (as selected by hex code 1 or 9) may be used for the highly irrelevant (highly inefficient) case, or highly incorrect case.

The FSTT has been designed with the objective of ensuring that if the optimal path is taken through a problem, a score of 100 percent would be possible. The only way that such a score can occur is if every frame associated with the most efficient path is scored either as a hex code "7" (meaning relevant three pluses) or "F" (meaning correct three pluses). If the score is anything less than three pluses for the optimal path, then 100 percent cannot be achieved.

The courseware author has the options of performing the hex weighting operation with or without using the FSTT as an aid. It is recommended that the FSTT be used if at all possible. The reason is that the FSTT provides for immediate access to the frame requested, which has been selected from the image already being displayed.

<u>Weighting Code</u>	<u>Meaning</u>	<u>Computational Value</u>
0	Item not used for scoring.	---
1	Irrelevant (---)	0
2	Irrelevant (--)	1
3	Irrelevant (-)	2
4	Neutral (relevant)	3
5	Relevant (+)	4
6	Relevant (++)	5
7	Relevant (+++)	6
8	Unsafe	0
9	Incorrect (---)	0
A	Incorrect (--)	1
B	Incorrect (-)	2
C	Neutral (correct)	3
D	Correct (+)	4
E	Correct (++)	5
F	Correct (+++)	6

Coding the Mag Card

The author will load in the fiche for the problem and press 00 to start. At this point, the overall diagram of the equipment is displayed and the options for selecting troubleshooting strategies and/or making observations are presented. The author should then systematically request the frames that represent exercising the optimal path for solving the problem. (This, of course, has been done prior to obtaining the photographs in the first place, the data for which are in the field data collection workbooks.) The printer should be turned on because it will provide a convenient record of the path taken through the problem. Once the author has determined that an optimal path has been established, then the values 7 or F, depending on whether the choice is relevant or correct, should be assigned to each of the trainer codes in the path. This is best done by entering the data immediately onto the Mag Card Coding Guides, an example of which can be found on the final three pages of this Appendix.

The correct repair must be selected to solve the problem, followed by a verification that a repair has been made. Finally, the user must declare that a solution has occurred. Courseware authorship includes coding each frame for the condition that exists when there is a malfunction and for the condition that exists when the malfunction has been cleared. Thus,

for each frame there are two locations on the magnetic coding guide for inserting hex weighting codes. The space to the right is the one to use when the repair has not yet been made. The one on the left is the place for the hex weight under the condition that a repair has been made. Just because there are two locations in which to place hex weights, it does not mean that the hex weights need be different. That is, it may be efficient to make a measurement at a certain location when trying to correct the fault (before repair) and also when trying to verify that the fault has been corrected (after repair). In that case, the coding for the second time through (for verification) should be negative even though it was positive the first time through.

It is not necessary to enter 0s for those frames not used in the problem. If the code for that frame is entered accidentally the FSTT will display a frame which does not have a picture on it, but there will be no effect upon the score.

Verification Frames

Because it is important to ensure that work has resulted in an effective repair, the FSTT provides for four verification frames. The author chooses how many of these will be used for a particular problem, and then inserts the codes associated with these frames in Line 1, Rows 16 through 23 of the mag card. The purpose of the verification frames is to require the user to access those frames prior to declaring the problem to be solved (CC). The FSTT will present a message "solved, so many minutes, such and such a score" if the user accesses those verification frames. If the user fails to access one or more of the verification frames, a correct solution to the problem will not be given. That is, even though a correct repair is made, no credit for a solution is given. If the author elects not to use verification, then no frames need be accessed during the verification check.

Once the coding for the optimal path has been determined and entered on the magnetic coding guide, the remainder of the frames available in the problem should be coded.

The next section describes the forms required and the procedures to use in actually performing the coding operation.

Mag Card Authoring

1. Data source

Work from Trainer Code Assignment Sheet (original problem workbook or problem architecture document).

- a. Each frame used in a fiche must be coded.

- b. Enter data onto Mag Card Coding Guide in pencil.
2. Code in this sequence
- a. Header
 - b. Malfunction present
 - (1) Optimal path
 - (a) Code optimal path to solution as Fs or 7s to ensure a possible 100 score.
 - (b) Identify verification codes (up to four OK; code as 7 or F).
 - (2) Code suboptimal path with mix of weights (author judgment).
 - (3) Wrong path
 - (a) Code false trails.
 - (b) Code incorrect or hazardous actions.
 - c. Malfunction absent (repair made)
 - (1) Optimal path
 - (a) Select subset of frames as minimum for verification.
 - (b) Code these verification frames as 7 or F on second run through. Students must select these verification frames; hence, full weight for these is needed.
 - (2) Suboptimal path
 - (a) Select frames that are not absolutely essential for verification but are not irrelevant/incorrect.
 - (b) Code as less than optimal.
 - (3) Wrong paths
 - (a) Select frames that are irrelevant or incorrect for verification.
 - (b) Code a lower Mag Card Code for all wrong path choices on second run through since these codes should not be selected at all.

2. When ready to code, take Mag Card Coding Guide (MCCG) to FSTT

a. Prepare to code mag card.

(1) Get blank mag card. (If no blank card is available, "zero" a card by recording over the one that is data-filled. "Zero" a card by entering the AUTHOR mode and entering "0" for every column on every row. When all rows contain "zeros," press "record." This will record "0" onto the mag card in the reader. Do this for all four stripes.) This card will be the zero card. It should be used in PRACTICE mode to turn-on the FSTT, prior to entry to AUTHOR mode. Start with a blank card so that no extraneous data can misrepresent the problem being simulated.

b. With the mag card in place, turn to AUTHOR mode. The line display will show the cursor at Row 0, Column 0. The LD should read 0000000000000000. Move the cursor to the position of the first data to enter, probably Column 3. It is best to use the FWD key to do this, although the 0 key may be used. There is no need to enter zero. When "Record" is pressed, the mag card is written with the data that appear on the LD. If zeros are present, they are recorded as zeros. The TAB key moves the cursor to the right five spaces at a time. The SCROLL key moves one line at a time, with the cursor in the same column. The LINE number key moves the cursor to a specific line number, but scrolling does too and may be easier. Mistakes are corrected by backing over the error and keying correctly.

c. Enter all data, row by row. (It is a one-person job, but can be speeded up if one person reads the data and another enters it. NOTE: All keys require a firm force to activate them. At times, it seems as though an entry was made but only the second keystroke appears on the LD. When in the AUTHOR mode, simply backspace over the incorrect code and enter the correct one. When in the PRACTICE mode, simply depress the cancel key. The result is an X immediately beside the digit displayed. Both digits may then be reentered.)

d. When finished, press "Print" to get a hard copy of the keystrokes entered.

(1) Verify keystrokes by comparing the MCCG to the printout.

(2) Make corrections as needed.

e. Press "Record." This records the data on a card. Now may be a good time to copy all stripes.

f. Verify data are recorded.

(1) Press "Load."

The mag card can be re-recorded as follows:

1. Insert mag card in AUTHOR mode.
 - a. Enter "BKSPACD" to get into normal edit.
 - b. Line display will then show the contents of Line "00."
2. On line "00" enter data of this revision, if desired. (This space was intended for noting changed fiche frames, but could also be used to record other revisions.) Similarly, space for Lesson SN is also available for this record. Get Line #01 (use SCROLL key).
3. Use FWD key to move cursor to Column 1.
4. Enter code (cursor moves to next column).
5. Enter remainder of reinforcement code.
6. Replace mag card with spare (to retain original.)
7.
 - a. Press "RECORD" key and watch in-line display.
 - b. Press "LOAD" key and watch in-line display.
8. When display shows Line 00, the newly recorded stripe has been reloaded. Recording is finished.
9. To ensure backup of this code, remove and reinsert card with another stripe into reader.
10. Press RECORD. (Do this for the remainder of the stripes.)

PROCEDURE - FORMS REQUIRED

Mag Card Coding Guide

The FSTT has been designed to handle three different kinds of problems. The first and most common type is the "single malfunction" type of problem. The second is called the "compound malfunction" and the third is the "no-malfunction" problem.

Magnetic Card Coding Guides were developed for each problem type and fiche layout. For the single malfunction (for many trainer codes), two

adjacent locations on the fiche are accessed by a given trainer code. One location is for the system with the malfunction present; the condition is for the system free of trouble. Depending on the nature of the malfunction, the image to be located in the related locations may be the same or may be different. In the case of a no-malfunction problem, there is but one image to show under all circumstances for a given trainer code.

In the case of the compound malfunction, four physically adjacent locations are available for display of images associated with a specific trainer code. These locations are filled as follows:

1. A location at which the image to be displayed is that of the measurement test point when both troubles A and B are present simultaneously in the system.
2. When one of the troubles has been repaired.
3. When the other one of the troubles has been repaired.
4. When no troubles exist in the system at all.

Data Entry

All data relating to the identification of a given problem, and the weighting codes associated with the user's choice of fiche frame to view must be entered onto the magnetic stripe associated with the problem. This is done during the authoring phase.

Data Source

The workbook, prepared as both a field data collection and authoring workbook, contains the pages organized to record the needed data.

Fiche Assignment Procedures

When the author has specified a set of measurements and/or observations, to make for a given problem, the related photographs must be assigned to specific frame locations in each fiche. While there is considerable freedom to assign such locations, certain constraints do exist. For example, certain locations (the second and third rows of Fiche A and B, and the fourth and fifth rows of B) are tied together by the design of the system. If the user selects frames within this "system drawings" area, both viewers slew such that related images are displayed. Asking for assistance (AA), brings up the related frame (from the fourth or fifth row of B) on the right-hand viewer. It is important that the courseware author use these dedicated fiche frame locations correctly. Nothing prevents misuse, of course. The problem is that if the frames are misused, they

might not be available when needed. Likewise, test and measurement (TM) frames (located predominantly in Fiche C) have the characteristic that when a repair action changes the condition of the problem (makes bad signal good because a repair has been made), the FSTT then causes a different frame to be displayed in place of the frame containing a photograph of a TM display illustrating the malfunction condition. Clearly, selecting one of the T&M frames to contain system level data would not be useful.

Entering Codes

Once the weights have been allocated to the frames, they must then be entered into the magnetic stripe.

The first column identifies the line number. (When the mag card is inserted into the card reader and the author mode has been selected, the line display should light up, showing the cursor underline in the first, leftmost position. This is position at nibble "0". At the extreme left the display will show "L00 C00" meaning L=line # "00" and C=Column #). The heading of the second column is "nibble." This column specifies which nibbles are associated with the data element shown in the third column, "content." In this example, the data entries for line 00, nibbles 00 through 15 are shown. As indicated, the simulator ID is given in nibbles 00-03. (The digits that appear in the line display each occupy one display position. The display is capable of displaying 32 alphanumeric digits. Although the display has been designed to show any ASCII character, each character position has only a half-byte associated with it; i.e., four bits when authoring. Thus, the codes that may be interpreted by the microprocessor can be any of the 16 hexadecimal digits, 0-F. Although the display will provide for the showing of messages in clear text, such as "UNSAFE," when the display is used during the authoring phase, it will merely display the values of the hex codes inserted, i.e., 0-F.)

The example identifies the simulator as Number 1. (This number could be some part of the specific simulator identification number at Plattsburgh.) However, since the problems are developed in support of a particular configuration of equipment, it is important to specify the simulator to which the problem refers.

Line 00

Nibbles 04-09 Nibbles 04 through 07 are to be used in identifying the lesson. In the example, the lesson Serial Number is "4," shown in position 7. Nibbles 08 and 09 identify the suffix code to be used. This code specifies which fiche will be pulled from the cartridge for the problem.

Nibbles 10-15 These nibbles provide for entering the month, day, and year of the revision (or edition) of the problem. (It is assumed some coding changes will occur because of improvements in the design of the problem--or hardware changes in the equipment being simulated--flight simulator.)

Line 01

Nibble 00 Specifies number of malfunctions in the problem (0, 1, or 2). In the example, the number "1" is inserted, identifying this problem as being a "single malfunction problem."

Nibble 01 The first digit in the reinforcement condition set. It is the "message code."

Nibble 02 The second digit in the reinforcement condition set. It is the "schedule code."

Nibble 03 The "score code" specifies conditions for displaying the score.

Nibbles 04, 05 Specifies the fault identification code for malfunction A. In the example, F9 is the ID. (When F9 is keyed by the user, the repair Menu #1 on the leftmost viewer is displayed, and the FSTT is conditioned to receive the keystrokes associated with nibbles 08 and 09, provided that the frame named in nibbles 06 and 07 has been accessed first.

Nibbles 06, 07 Fault frame - malfunction A. The trainer code entered here is the one which will cause display of the frame containing the malfunctioning part. It is required that the trainee key this trainer code prior to keying in the fault code. Although the fault code can be keyed at any time, the correctness of the problem's solution--i.e., credit for using sound troubleshooting methods--will be given only on the condition that the fault frame be screened first. This prevents a trainee from solving problems by simply entering all the fault codes and the available repair options.

Nibbles 08, 09 Correct repair code - malfunction A. The code entered here is the switch that turns otherwise bad signals to good ones. If an author definable code (ADC) is used, then no physical change appears to follow when this code is entered. However, if the code is a trainer code, a viewer could easily slew to an image not seen previously. Therefore, the software is designed to make the switch prior to slewing to the new view.

Nibbles 10-15 Unused.

Nibbles 16-23 Verification Frames. The code entered here is the trainer code of frames (up to four) that must be seen following "00" after a repair has been made. A 100 percent solution will not be awarded unless the trainee accesses these frames (if used).

Line 02

Nibbles 00-15 Lesson Stop Codes. These 16 positions are locked to the eight messages that can abort a lesson. There are 16 nibbles available because each pair of nibbles, while related to a specific message, may contain either "00", in which case no message would be provided, or they may contain an "author definable hex code." In the latter case, the input of this code from the keypad would result in display of the selected message. The ADC would be accessed by the trainee from some photograph that would provide it as a part of the display, or it could be the result of a menu page which provided options for repair actions. In the example, lesson stop codes for nibbles 08 and 09 were inserted. This is for "possible injury" and "A4" was selected. When A4 is keyed, the problem aborts.

MAGNETIC CARD CODING GUIDE

LINE	NIBL	CONTENTS	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24									
00	00 03	ID Data																																		
	04 09	Lesson Serial #+ Suf.	Simulator ID.				Lesson S.N.			Suffix Code	Month	Day Date	Year																							
	10 15	Date Last Revision																																		
01	00 09		00 Number of Malfunctions Rein- forcement Condi- tions			01 Message Code		02 Schedule Code		03 Score Code		04 Fault ID for Malfunction A		05		06 Fault Frame Malfunction A		07		08 Correct Repair Code Malfunction A		09		Verification Trainer codes												

continued next page

LINE /	NTBL	CONTENTS	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	20	22	23	24
			Incorrect 12. Procedure	Abort	You Cannot 13. Continue	Abort	Test Equipment 14. Damaged	Abort	Equipment 15. Damaged	Abort	Possible 16. Injury	Abort	Possible 17. Fatality	Abort	Safety 18. Violation	Abort	Possible 19. Shock	Abort	20. No Assistance Available Here		21. No Prior Entries Available						
02	00 15	Lesson Stop Codes																									
		(Stop Code is ADC A4 to get MSG 16)									ADC																
03	00 07	Hex Weighting Codes: Author Definable	A3	A4	A5	A6	A7	A8	A9	AB																	
04	00 07	-	AC	AC	AE	AF	BD	B1	B2	B3																	
05	00 07	-	B4	B5	B6	B7	BB	B9	BA	BC																	
06	00 07		BD	BE	BF	C0	C1	C2	C3	C4																	
07	00 07	-	C5	C6	C7	C8	C9	CA	CB	CD																	
08	00 07	Author Defin- able Codes Hex Code	CE	CF	DD	D1	D2	D3	D4	D5																	
09	00 23	Trainer Code Fiche A, Row A Hex Mt. Code	4A	4A	4B	4B	4C	4C	4D	4D	4E	4E	4F	4F	50	50	51	51	52	52	53	53	54	54	55	55	
10	00 13	Trainer Code Fiche A, Row D Hex Mt. Code	62	66	63	63	64	64	65	65	66	66	67	67	68	68											

continued next page

LINE	NIBL	CONTENTS	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
11	00 13	Row A-E	69	69	6A	6A	6B	6B	6C	6C	6D	6D	6E	6E	6F	6F											
12	00 13	Row A-F	70	70	71	71	72	72	73	73	74	74	75	75	76	76											
13	00 08	Row A-G	77	77	78	78	79	79	7A	7A																	
14	00 11	Row B-A	01	01	02	02	03	03	04	04	05	05	06	06													
15	00 17	Row B-B	07	07	08	08	09	09	0A	0A	0B	0B	0C	0C	0D	0D	0E	0E	0F	0F							
16	00 17	Row B-C	10	10	11	11	12	12	13	13	14	14	15	15	16	16	17	17	18	18							
17	00 17	Row B-F	19	19	1A	1A	1B	1B	1C	1C	1D	1D	1E	1E	1F	1F	20	20	21	21							
18	00 17	Row B-G	22	22	23	23	24	24	25	25	26	26	27	27	28	28	29	29	2A	2A							
19	00 27	Row C-B	56	56	57	57	58	58	59	59	5A	5A	5B	5B	5C	5C	5D	5D	5E	5E	5F	5F	60	60	61	61	
20	00 13	Row C-B	7B	7B	7C	7C	7D	7D	7E	7E	7F	7F	80	80	81	81											
21	00 13	Row C-C	82	82	83	83	84	84	85	85	86	86	87	87	88	88											
22	00 13	Row C-D	89	89	8A	8A	8B	8B	8C	8C	8D	8D	8E	8E	8F	8F											
23	00 13	Row C-E	90	90	91	91	92	92	93	93	94	94	95	95	96	96											
24	00 13	Fiche C, Row F	97	97	98	98	99	99	9A	9A	9B	9B	9C	9C	9D	9D											
25	00 09	Fiche C, Row G	9E	9E	9F	9F	A0	A0	A1	A1	A2	A2															
26	00 07	Fiche D, Row A	2B	2B	2C	2C	2D	2D	2E	2E																	
27	00 08	Fiche D, Row B	2F	2F	30	30	31	31	32	32	33																
28	00 08	Fiche D, Row C	33	34	34	35	35	36	36	37	37																
29	00 08	Fiche D, Row D	38	38	39	39	3A	3A	3B	3B	3C																
30	00 08	Fiche D, Row E	3C	3D	3D	3E	3E	3F	3F	40	40																
31	00 08	Fiche D, Row F	41	41	42	42	43	43	44	44	45																
32	00 09	Fiche D, Row G	45	46	46	47	47	48	48	49	49																

APPENDIX C - SAMPLE PROBLEM

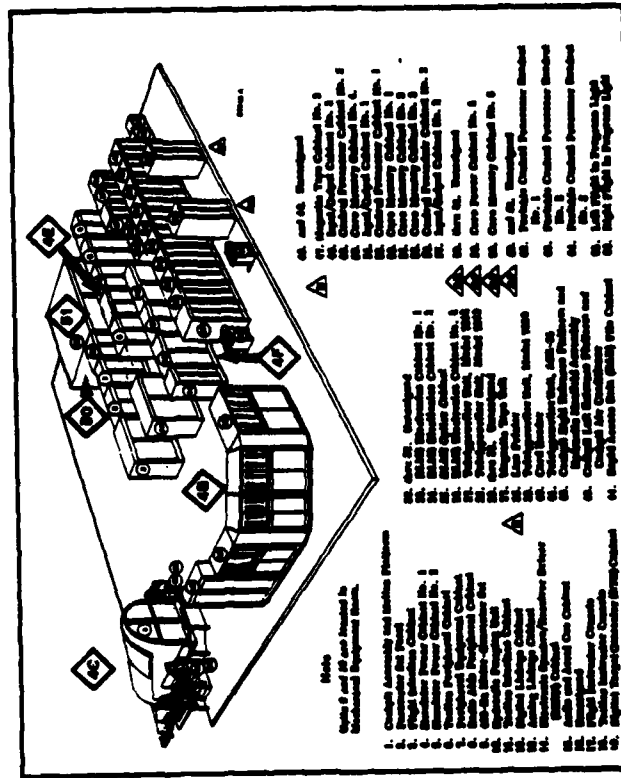
APPENDIX C - SAMPLE PROBLEM

Students use this Sample Problem as a guide for how to use the FSTT in solving other FSTT troubleshooting problems. The guidance is designed to tell the user what codes to enter and why. The user is guided through an efficient path to solution. Of course, the user may choose to stray from the guidance, may use it more than once, or may ignore the guidance. The words of guidance below the frames in the printed version do not appear on the FSTT screens. They appear only on this copy. The frames shown on the printed Sample Problem are frames that do come up on the FSTT as the user works his way through the sample. No other FSTT problems appear in a guided version.

4B

Console

- 07 - Attack Radar Monitor
- 08 - Navigation Display Unit
- 0E - Communications-Navigation
- 14 - Terrain-Following Radar
- 18 - Computer Control Unit

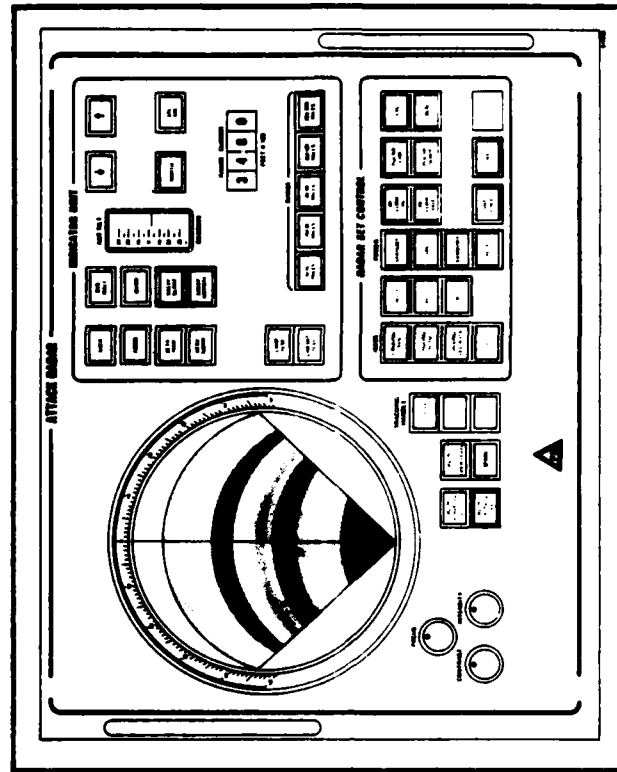


If you select Trainer Code 4B, console, this changes the image on the left viewer as shown. You can then choose among the systems listed here. In this case the choice is the Attack Radar Monitor, Trainer Code 07.

07

Console

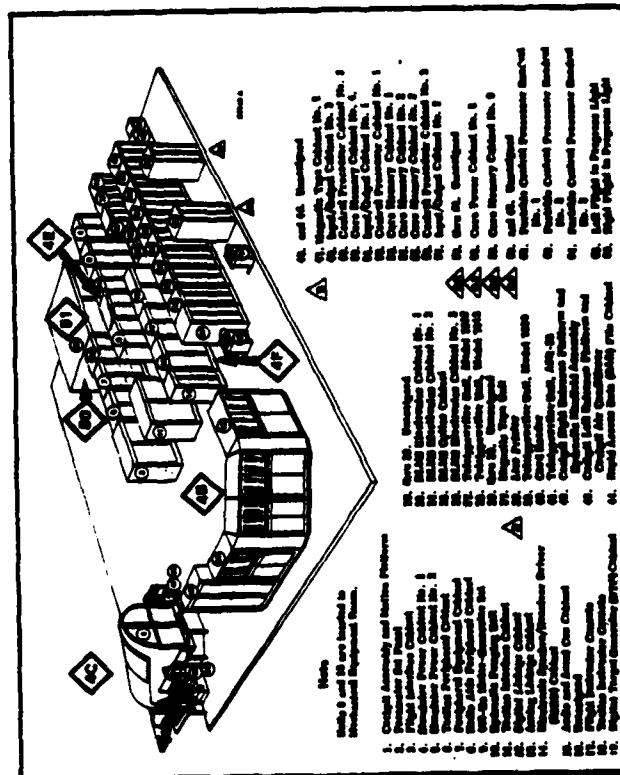
- 07 - Attack Radar Monitor
- 08 - Navigation Display Unit
- 0E - Communications-Navigation
- 14 - Terrain-Following Radar
- 18 - Computer Control Unit



A picture of the Attack Radar Monitor appears on the right-hand viewer with the fault symptom visible. The trainagle at the bottom of the picture means you can bring up a menu of repairs if you key the fault code shown there. In this case you go back to the starting frame to get to other locations at which to collect data by keying-in Trainer Code "00."

00

DATE	TIME	LOCATION	NAME	STATUS	REMARKS
17/12/01	0				
WINDSHIELD WIPER SCAN ON					
COCKPIT ATTACK RADAR INDICATOR					
REPAIRS BY <i>John Valley</i> A/C 00000					
DATE	TIME	LOCATION	NAME	STATUS	REMARKS
MAINTENANCE DISCREPANCY AND WORK DOCUMENT					
AFSTO 27-71A					



Now back at the beginning, the operator wants to go to the cockpit, and keys-in Trainer Code 4C.

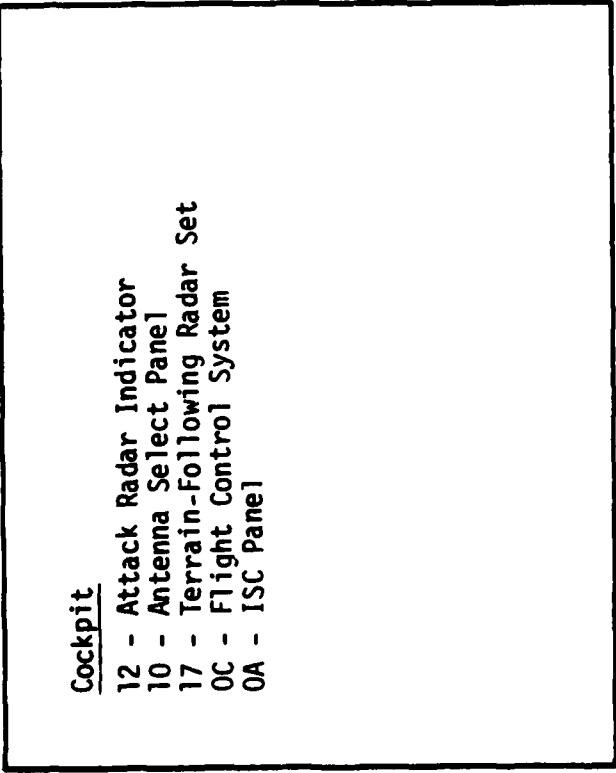
4C

Cockpit

- 12 - Attack Radar Indicator
- 10 - Antenna Select Panel
- 17 - Terrain-Following Radar Set
- 0C - Flight Control System
- 0A - ISC Panel

Cockpit

- 12 - Attack Radar Indicator
- 10 - Antenna Select Panel
- 17 - Terrain-Following Radar Set
- 0C - Flight Control System
- 0A - ISC Panel



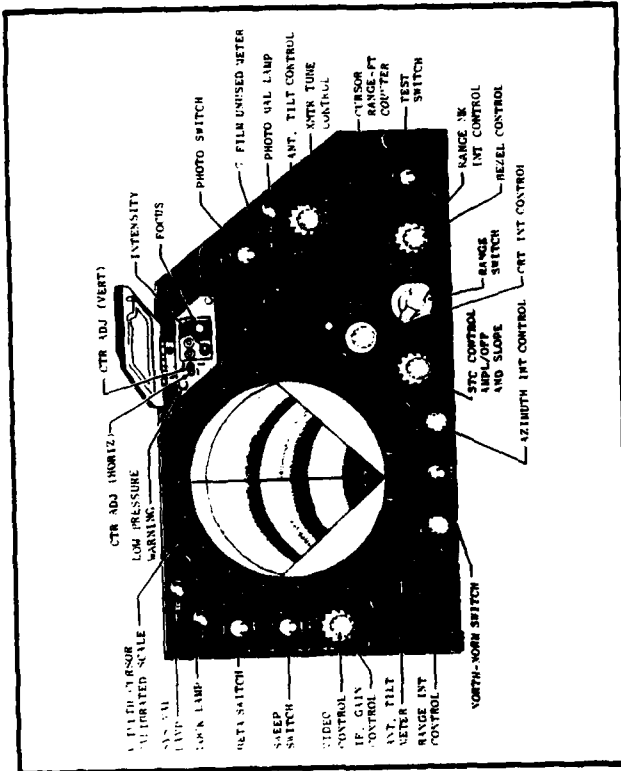
Deciding upon the Attack Radar Indicator, the operator keys-in its Trainer Code "12."

12

Attack Radar Indicator

54	-	Gamma Servo
15	-	I-Deflection
0D	-	Q-Deflection
09	-	Power Supply
08	-	Yoke Servo

54 - Gamma Servo
15 - I-Deflection
0D - Q-Deflection
09 - Power Supply
08 - Yoke Servo

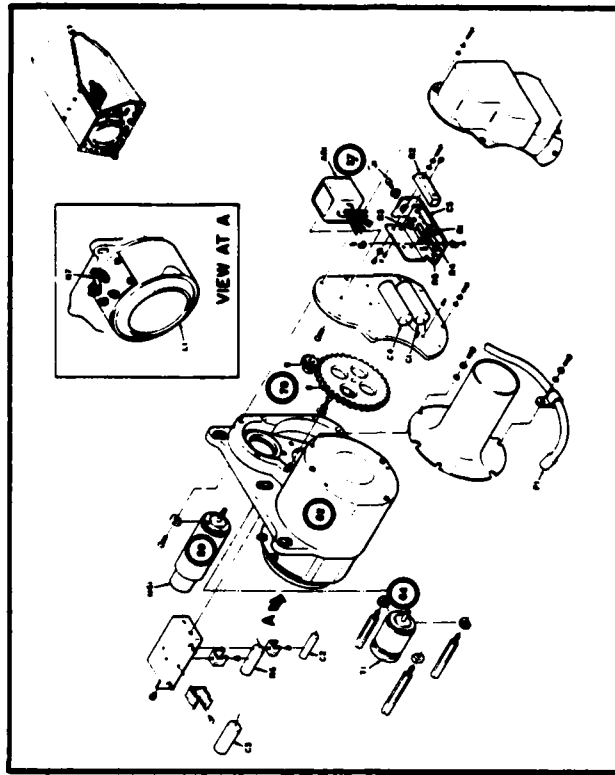


The picture of the Indicator appears on the right screen and five Attack Radar Indicator subsystems are available on the left. You get the Yoke Servo by keying-in Trainer Code "08."

08

Yoke Servo

- 11 - Spur Gear Lubrication
- 16 - Motor Generator
- 13 - Synchro Control Transformer
- OF - Electronic Control Amplifier



On the right is the exploded view of components of the Yoke Servo, and the opportunity to get more data on certain components. At this stage, the operator is faced with various Yoke Servo unit components. If you want some help here, you can request assistance by keying-in "AA."

AA

Yoke Servo

- 11 - Spur Gear Lubrication
- 16 - Motor Generator
- 13 - Synchro Control Transformer
- 0F - Electronic Control Amplifier

Deflection Circuits

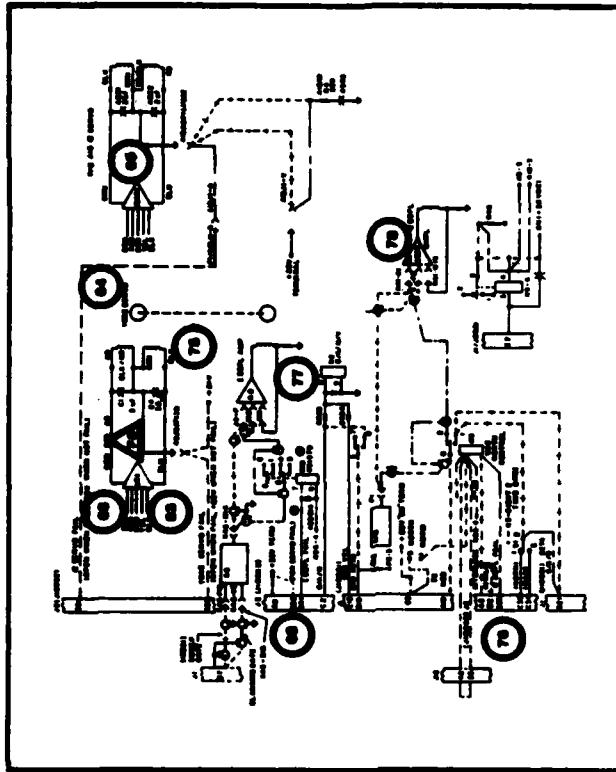
The deflection circuits consist of the yoke servo assembly, I deflection amplifier, Q deflection amplifier, and the horizontal and vertical centering circuits. All deflection voltages are applied to coils mounted on the radarscope yoke. The yoke servo drives (turns) the deflection coils around the radarscope at an angle corresponding to azimuth (θ_A), azimuth drift ($\theta_A - \delta$), or $\theta_A + \theta_H$ (for the north-oriented modes). Inline deflection (I) from the summing amplifier is amplified further in the I deflection amplifier to obtain the necessary drive before application to the I deflection coils. The Q deflection drive is obtained from the A deflection amplifier. Horizontal and vertical centering is accomplished (and adjustable) by dc centering voltages obtained from the horizontal and vertical dc amplifiers.

On the right is a paragraph briefly outlining the role played by the Indicator Sweep and Deflection circuits. Upon reading the assistance frame, you can pick any one of the four listed options to pursue.

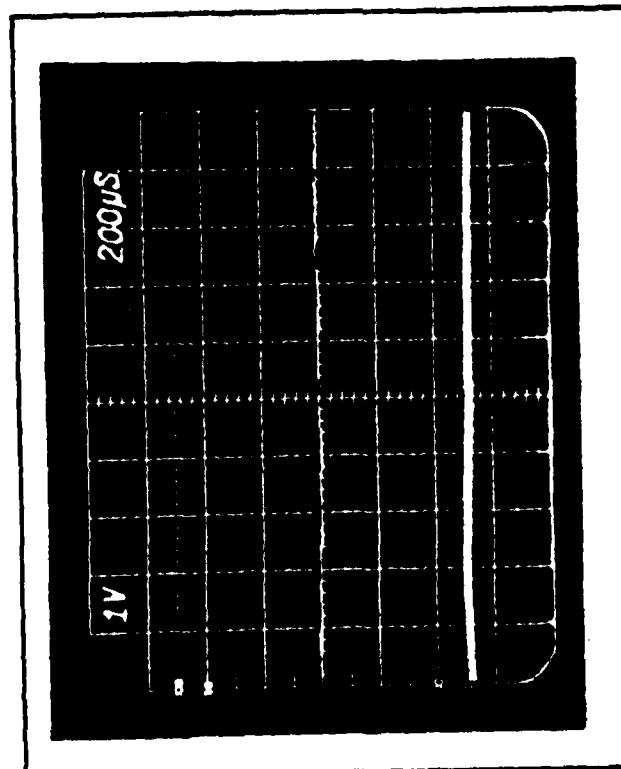
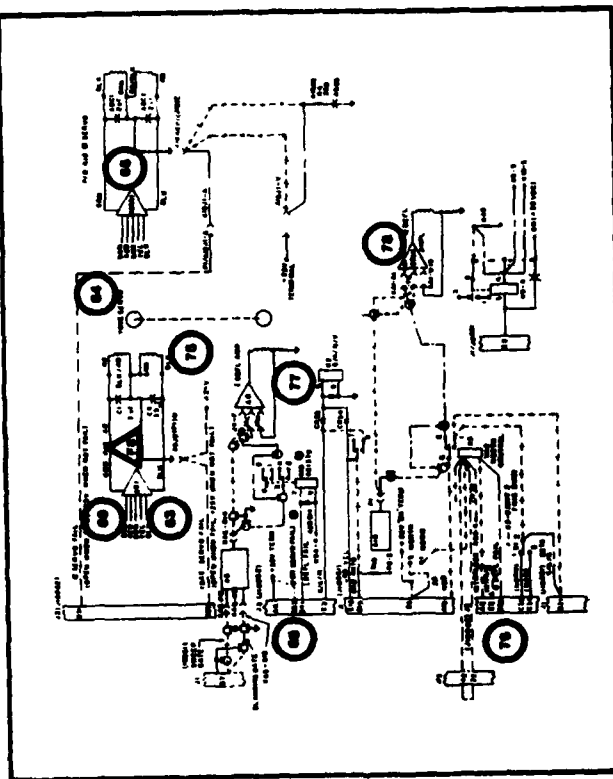
0F ++

Electronic Control Amplifier

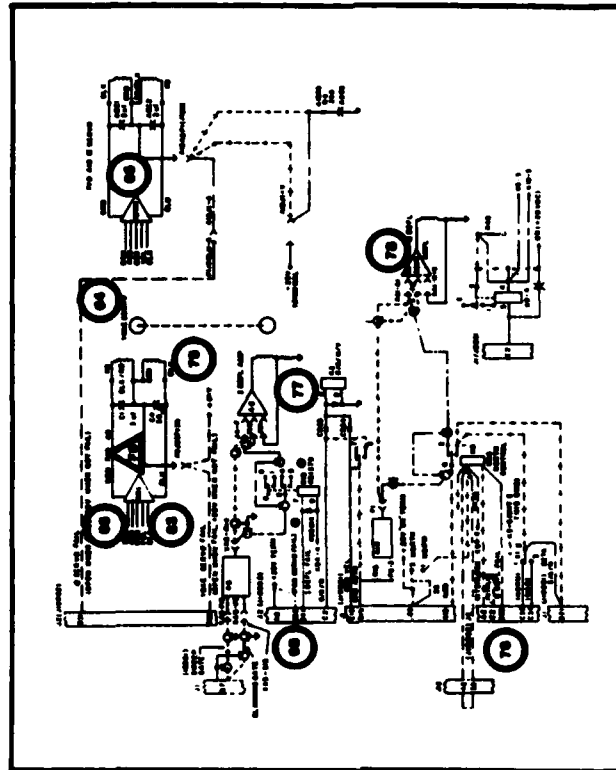
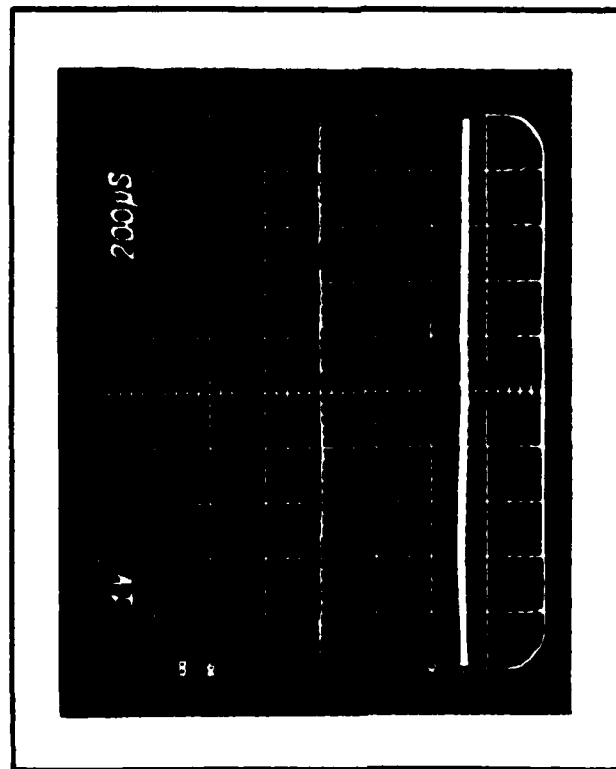
11 - 35VDC Bias
16 - Deflection Output
13 - Deflection Return
0F - Amplifier Input



If you select Control Amplifier, Trainer Code "0F," the right-hand viewer shows the amplifier schematic diagram. To measure at a test point, key in the circled code, like 66.



Left view now shows the selected Oscilloscope display. Select another test point: Trainer Code 63.



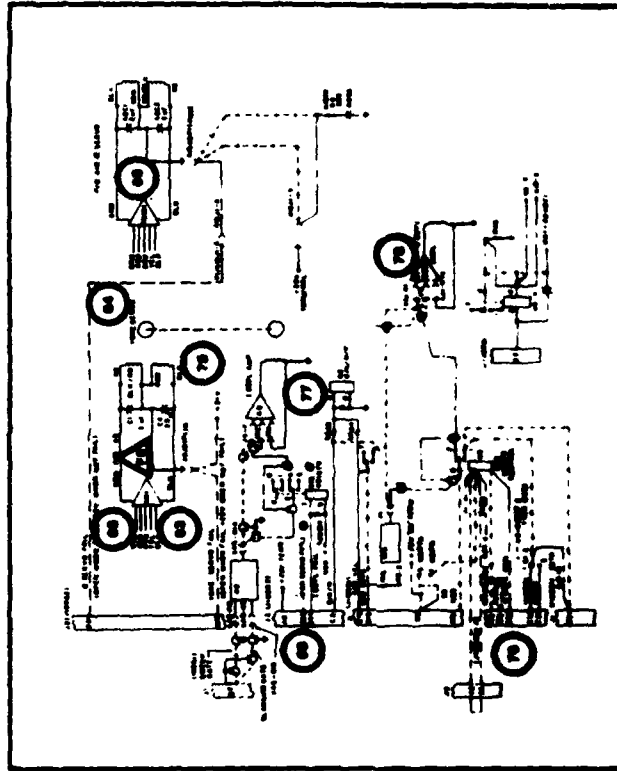
Now, knowing that these signals are not correct, you can select a repair code (F8) in preparation for making a repair.

F8

Repair Menu

- A5 - Replace Motor Generator
- A3 - Lubricate Spur Gears
- A4 - Remove and Replace Yoke Servo
- A6 - Remove and Replace Amplifier

- A5 - Replace Motor Generator
- A3 - Lubricate Spur Gears
- A4 - Remove and Replace Yoke Servo
- A6 - Remove and Replace Amplifier

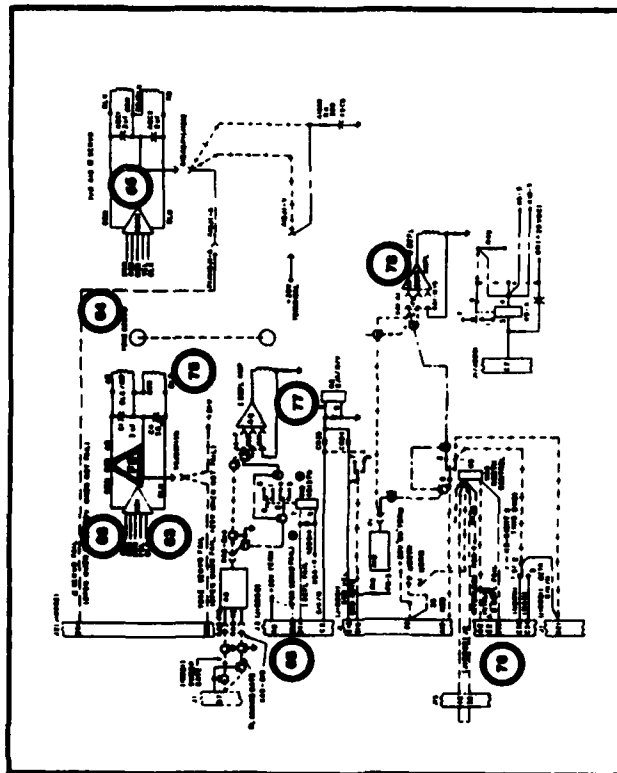


The operator chooses A6, removal and replacement of the servo amplifier. No frame change occurs. If this was the correct repair, the FSTT would be ready for you to verify that your repair was effective.

A6

Repair Menu

- A5 - Replace Motor Generator
- A3 - Lubricate Spur Gears
- A4 - Remove and Replace Yoke Servo
- A6 - Remove and Replace Amplifier



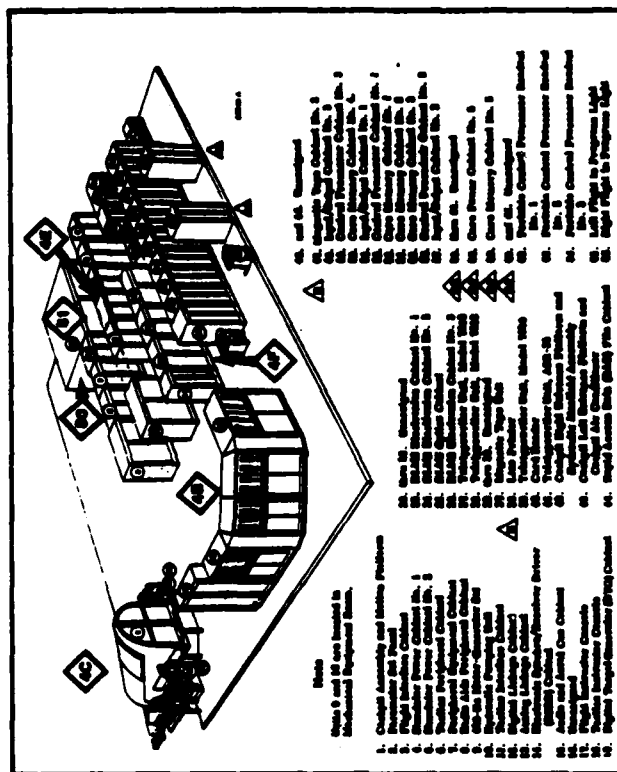
To do this you can return to the starting point and check the operation of the cockpit AR Indicator which was not operating properly. "00" is keyed-in.

4C

Cockpit

- 12 - Attack Radar Indicator
- 10 - Antenna Select Panel
- 17 - Terrain-Following Radar Set
- 0C - Flight Control System
- 0A - ISC Panel

Attack Radar Indicator is requested.



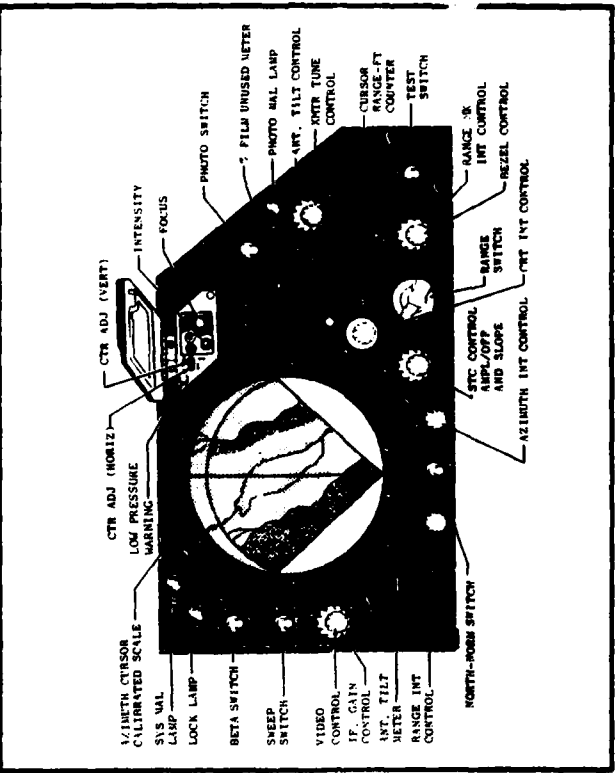
12

Attack Radar Indicator

R1-Replace Gamma Servo
15-I-Deflection
0D-Q-Deflection
09-Power Supply
08-Yoke Servo

Attack Radar Indicator

R1-Replace Gamma Servo
15-I-Deflection
0D-Q-Deflection
09-Power Supply
08-Yoke Servo



Note that the symptom has disappeared. Since the problem is solved, key-in "CC."

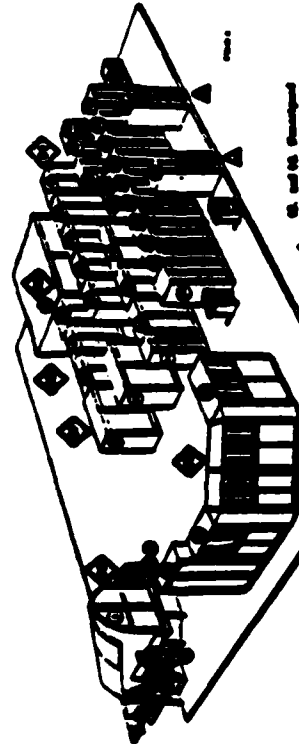
SOLVED: MINUTES 027 . . . SCORE: 085

Compare your score with the list below:

NAME	SCORE	TIME
1. J. J. J.	100	025
2. J. J. J.	95	030
3. J. J. J.	90	035
4. J. J. J.	85	040
5. J. J. J.	80	045

The following list contains all problems in the FSTT library:

- Problem 1: A car is moving at 60 mph. How far will it travel in 1 hour?
- Problem 2: A car is moving at 60 mph. How far will it travel in 2 hours?
- Problem 3: A car is moving at 60 mph. How far will it travel in 3 hours?
- Problem 4: A car is moving at 60 mph. How far will it travel in 4 hours?
- Problem 5: A car is moving at 60 mph. How far will it travel in 5 hours?
- Problem 6: A car is moving at 60 mph. How far will it travel in 6 hours?
- Problem 7: A car is moving at 60 mph. How far will it travel in 7 hours?
- Problem 8: A car is moving at 60 mph. How far will it travel in 8 hours?
- Problem 9: A car is moving at 60 mph. How far will it travel in 9 hours?
- Problem 10: A car is moving at 60 mph. How far will it travel in 10 hours?



Below the drawing is a list of problems and their solutions:

Problem 1: A car is moving at 60 mph. How far will it travel in 1 hour?

Solution: 60 miles.

Problem 2: A car is moving at 60 mph. How far will it travel in 2 hours?

Solution: 120 miles.

Problem 3: A car is moving at 60 mph. How far will it travel in 3 hours?

Solution: 180 miles.

Problem 4: A car is moving at 60 mph. How far will it travel in 4 hours?

Solution: 240 miles.

Problem 5: A car is moving at 60 mph. How far will it travel in 5 hours?

Solution: 300 miles.

Problem 6: A car is moving at 60 mph. How far will it travel in 6 hours?

Solution: 360 miles.

Problem 7: A car is moving at 60 mph. How far will it travel in 7 hours?

Solution: 420 miles.

Problem 8: A car is moving at 60 mph. How far will it travel in 8 hours?

Solution: 480 miles.

Problem 9: A car is moving at 60 mph. How far will it travel in 9 hours?

Solution: 540 miles.

Problem 10: A car is moving at 60 mph. How far will it travel in 10 hours?

Solution: 600 miles.

In-line display shows time to solution and score. The final presentation provides a "Terminal" frame which lists other problems available in the FSTT library. You can compare your score against a scale available from your instructor (supervisor). This varies from problem to problem. You may wish to redo the problem to get a higher score. It wouldn't hurt. The Printer will show you the path you took to solve the problem.

APPENDIX D - DESCRIPTION OF FSTT FAILURES AND CORRECTIVE
ACTIONS TAKEN DURING FORMATIVE EVALUATION

APPENDIX D - DESCRIPTION OF FSTT FAILURES AND CORRECTIVE ACTIONS TAKEN DURING FORMATIVE EVALUATION

HARDWARE PROBLEMS CORRECTED DURING FORMATIVE EVALUATION

Microfiche Viewers

The microfiche viewers had three kinds of problems. First, one of the two printed circuit boards in each of the viewers suffered a burned out power transistor. The problem was routinely solved and a repair made. This board is in the circuitry which extracts fiche from the cartridges. Unless the fiche can be pulled into the viewer, it cannot be seen. Another problem was that the fiche and their jackets were being mangled by the mechanical innards of the viewers. While this did not happen very often, it justified obtaining both multiple copies of fiche (10 per problem) and extra carriers.

All fiche in the cartridges are contained within transparent mylar carriers. When a fiche is selected, a nylon "prod" moves to the correct position for that fiche and strikes a tab that is part of the carrier. This causes the carrier to move about 1/8 inch into the viewer to contact a set of rollers which withdraws the carrier into the viewer. These rollers are a source of dirt distribution in the system. If any carrier should have an oily smudge on it, some part of the dirt will be transferred to the rollers. Thereafter, the roller will transfer a part of the dirt to other carriers and so on. This means that carriers should be kept free of dirt, and as dust free as possible before use, and should be cleaned periodically. Replacement of the rollers and carriers would be a

Repeated strikes on the tabs of the carriers tends to wear them out. If the carriers are not replaced soon enough, a time will come when the carrier will not be drawn into the viewer because the tab is bent and does not transmit the force needed to move the carriers. Periodic (monthly) inspection of these tabs will effectively identify those which are wearing out and which can then be replaced.

The carriers (Consolidated Micrographics, successor to Bruning) were purchased in sets of 30 carriers. The cartridge has this capacity; however, in the FSTT application, the cartridges are loaded with only 15 carriers. There are 15 spares available. By removing the carriers for even numbers, and turning them over, an additional set of odd numbered carriers is obtained. Hence, because of how the fiche carriers are used (15 per cartridge), a set of 30 spare carriers actually provides two sets of spares.

As mentioned previously, carriers can be mangled by the mechanical handling system. A possible cause of this is poor positioning of the fiche internal to the carrier. If part of the fiche extends beyond the edge of the carrier, it can be caught askew to the rollers, causing

entrance to the platen at an angle. This will cause either the fiche or the carrier to be mangled. If that occurs, the FSTT must be shut down and the materials removed from the viewer interior. A replacement fiche and carrier then need to be installed. Since five copies of each fiche were produced and spare carriers were provided, no serious problem resulted from this cause.

Users of the FSTT were not really concerned about dirt in the visual path, but it does not make a good impression on casual observers of the device. There are several places where dirt can enter and possibly cause a problem. Dust can settle into the optical path mirrors and lenses. Dust is easy to remove from these surfaces, using a dry air jet or lens tissues. Dust and dirt can also be deposited on the fiche themselves. Even though each fiche is in its own paper jacket prior to loading in a carrier, some dust matter can land on them and particles of dust sometimes show up in the projected image. As a result, it was found that use of nylon gloves (lint-free gloves) was helpful in handling the fiche and carriers. Powder or oils must not be used to increase sliding of one carrier over the other. There is some sticking of carriers which results in two or more carriers being withdrawn at once; it is caused by a buildup of static electricity. While this buildup is difficult to prevent, it is easy to overcome. The user should merely press on the tabs when the cartridge is out of the viewer and gently move the carriers against themselves and manually touch the plastic edges of the carriers. Using a photographer's brush (with radioactive element) will discharge the carrier during loading to minimize electrostatic attractions of dust during this phase of use.

Alignment

During hardware development, tests on the repeatability of viewer presentations were made. It is desirable for the image displayed to fall on the same physical place on the screen for each frame. These tests showed that the viewer was able to position the image within $\pm 1/4$ inch. Accordingly, a mask was designed to hide this amount of error from view. Implications for copy preparation are that codes need to be placed well within the edges of a frame, lest they be cut off partially or wholly by the mask. Variability in image presentation, however, was not due entirely to electromechanical viewer fiche positions. The fiche themselves need to be positioned within the carriers at fixed locations.

Two fiche producers were used in making the fiche. Each produced fiche with slight variations, both from fiche to fiche and from manufacturer to manufacturer. Reducing this variability was done through cutting the fiche material to standard dimensions. Ultimately, it was evident that the manual positioning controls on the viewers themselves were needed and in fact, were used.

As previously stated, the purpose of the calibration card was to load a table of values that would instruct the viewer as to where to position its fiche transport to display a frame. Although calibrations can be quite exact for a given "MASTER" fiche, there are enough other variables of non-standard type which effectively offset the fine-tuning of the calibration. With care, standardized fiche can be produced and loaded. But the friction factors in the mechanical system will always impose the need for minor adjustments in positioning.

Obviously, a feedback servo-positioning system could be designed to overcome this registration problem. It would not, however, be off-the-shelf.

The preceding discussion notwithstanding, users--both the instructors and the three-level airmen--were not at all concerned with "dirt" in the visual path, or the need to manually position a frame.

Readability of Access Codes

The original access code design consisted of black or white inked hex digits on transparent plastic peel-off, self adhesive labels. These were used in the first few problems produced. These codes were found to have insufficient contrast and were discontinued in favor of opaque hex codes of the same size.

Another change was made to use codes of almost twice the original size to enhance the readability. Black print on white backgrounds was used when the image was darkly hued. This requirement was imposed by the color microfiche maker who tended to wash away the black print on white backgrounds if used on dark hues as a result of the longer time exposures required to copy the dark-hued materials. (Some of the photographs of simulator cabinets resulted in high contrast pictures which were predominantly dark. Long exposures were needed to capture the detail that was needed.)

Aids to Problem Solution

A special set of aids was developed for each problem consisting of one printed page per problem. These are included in Appendix A. They serve to provide the reader with a description of each problem. No revisions were made to them during formative evaluation as they did not appear to be used much by FSTT users, and no comments were made about them.

Miscellaneous Observations

The photographs shown as FSTT images provide a self-revealing record of flight simulator status for the abnormal and normal conditions. It was not necessary to state the conditions of switches and meters and scopes--

the states are revealed by their own positions when the user calls up the picture with the switch settings shown on it. Each problem used an initial frame that showed a Form 781 write-up. It was expected that on the job a repairman would:

1. Discover what the write-up meant.
2. Verify its accuracy.
3. Search for the cause.
4. Repair.
5. Verify the repair.

Users routinely performed all these functions, except the last. They did not recognize that they had to verify that their repair had cleared all symptoms of malfunction. This verification is an essential step on the job. It may be that users did not initially realize that the FSTT required this function just as the job did. However, the scoring display reads "not finished" if the user does not verify after making the replacement of the bad part (even though the bad part has been replaced). Some users complained that this "robbed" them of credit for a solution. However, users of the FSTT learned that verification was part of the job function and that the FSTT required the function to be performed.

On problems with multiple malfunctions, the symptoms of the second malfunction would remain after the first malfunction was verified.

With the FSTT, the users are permitted to move about the system and to make measurements according to their own desires. Some users tended to be reluctant to make a selection at first. There are general reasons for this:

1. Fear of making a mistake and the ensuing embarrassment.
2. Awkwardness in a new environment.
3. Inability to select a measurement which they desire but which is not available in the image being viewed.

As for fear of making an error, it was found that most users get over this quickly on the FSTT. Curiously it was observed that in multiple trainee situations, the presence of a peer encourages a certain banter, which in turn, tends to make the user more willing to take a chance.

Awkwardness in the new environment is a common phenomenon. In the case of the FSTT, the user sees access codes with square, circular, diamond-shaped, and triangular surrounds. Now, practically, these distinctions in shape do not make any difference since keying a unique

hex code will display whatever is on the related frame. There is no difference in scoring based on these shapes. The shape merely aids the user in choosing the type of action to be taken. This awkwardness was readily overcome.

There is a limit to the number of access codes that can be placed on one image. In the real world the number of actions that can be taken is much larger. However, only a few are reasonable. The FSTT has a reasonable number of choices.

END

FILMED

1-84

DTIC