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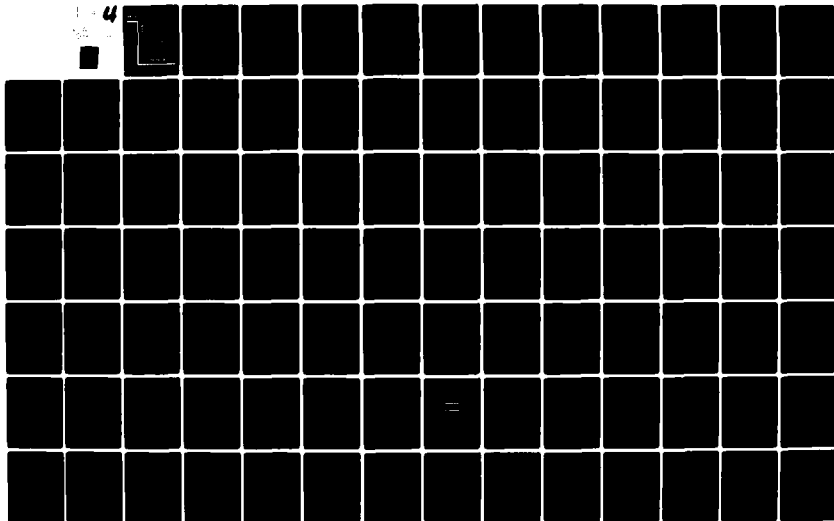
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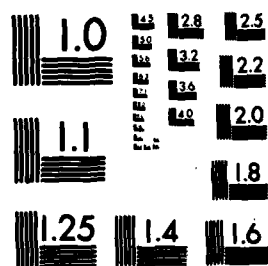
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6 RELATIVE COST AND TRAINING EFFECTIVENESS
OF THE 6883 THREE-DIMENSIONAL SIMULATOR
AND ACTUAL EQUIPMENT.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The cost and training effectiveness of the 6883 3-D simulator, as compared to that of operational 6883 test station equipment, for training intermediate level F-111 avionics maintenance personnel was evaluated. The objective of this study was to isolate classroom and field performance differences as a function of the training equipment used and to compare the costs of using the two systems in the existing ATC training course. Students entering the Converter/Flight Control Systems instruction block were randomly assigned to one of four basic experimental groups. A trouble-shooting performance test and a Projected Job Proficiency test were developed and administered to compare the training adequacy of the simulator and actual test station equipment. Student and		

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supervisor followup questionnaires were administered in the field to provide additional feedback about training experiences. It was found that the simulator and the actual test station equipment were equally capable of training students. It is hypothesized that a number of environmental factors, which were noted, may have reduced the likelihood of observing significant performance differences among experimental groups. These factors included shifting training objectives and classroom formats, equipment reliability, changing job requirements, and lack of a clearly defined role for the simulator in training.

The life cycle cost model used to compare actual and simulated equipment indicated that using actual equipment was approximately twice the cost of using the 6883 simulator for training. Since the 6883 test station was found to be one of the more reliable stations, it was hypothesized that, from a total course systems standpoint, the cost savings might be significantly higher. Although this investigation was hampered by the lack of systems-related cost data, the cost of alternative strategies for integrating simulators in the training environment was explored using a scenario format.

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SUMMARY

Problem

Actual equipment trainers are customarily employed in training to provide competent maintenance technicians to the field. As a training device, actual equipment does not readily permit the controlled presentation of malfunctions representative of the trouble-shooting problems which occur in operational settings. Furthermore, Air Force policy limits the type of faults which can be introduced into actual equipment even for training purposes. Hence, hands-on experience most often provided on actual equipment trainers is generally confined to routine procedural tasks rather than trouble-shooting training.

Less expensive real-time simulators do possess the capability for trouble-shooting training, incorporating "hands-on" practice to increase trouble-shooting skill on samples of field-related maintenance problems. In addition to improved skills training, the use of computer-based training simulators has the potential to release more expensive actual equipment for field operations. Simulators in comparison to actual equipment provide the opportunity to deliver instruction which permits greater:

- Actual Task Training
- Trouble-shooting Practice
- Task Specific Remediation
- Learner Diagnostics
- Learner Motivation
- Objective Evaluation
- Instructor Control (Task & Learner)
- Cost-Effective Training

Training simulators have been in use for years. Despite this fact, methodologically sound comparative studies of the training and cost-effectiveness of simulators and actual equipment used for training are conspicuously rare. Uncontrolled factors and inadequate evaluation methods have generally produced inconclusive results. Therefore, the usual finding of no skills and/or life cycle cost differences as a function of simulator vs actual equipment training is still widespread.

Objective

The major objective of the present evaluation was to determine the relative effectiveness of a 3-dimensional simulator and the 6883 actual equipment test station on dimensions of:

- Instructional Effectiveness/Efficiency
- Life Cycle Costs
- Attitudinal Acceptance
- Field Performance

The 6883 test station was chosen for the simulation project because it was considered representative of a class of test stations used in intermediate level training. The 6883 simulator was expected to provide more consistent training on procedural maintenance and trouble-shooting tasks in a safe training environment where the probability of personal injury and costly equipment damage are minimized.

Approach

The approach taken was to compare the simulator and actual equipment in three general areas: classroom performance, field performance, and cost. An experimental (simulator-trained) and control group (actual-equipment trained) comparison was provided within a limited practical exercise segment (3 days) of the F-111 Avionics Maintenance Course at Lowry AFB.

One hundred and fifteen F-111 Avionics Maintenance trainees were studied during the evaluation period. Eighty-five of these students were interviewed in field assignments subsequent to training. A trouble-shooting performance test was developed and administered on the training equipment to compare the training adequacy of the simulator to the actual test station equipment. Effects of training equipment on field performance were assessed by a "Projected Job Proficiency Test" which was administered upon completion of the instructional training block and follow-up student and supervisor questionnaires administered in the field.

A life cycle cost model was developed and implemented to compare the cost of using actual and simulated training equipment within 6883 instruction. In addition, cost scenarios were developed to initially describe alternative benefits and costs associated with three simulator training roles: (a) generic simulation employed solely throughout an entire course, (b) replacement of ten actual equipment test stations with up to ten test station specific simulators and (c) supplemental simulators to increase skills on those tasks which simulators

are shown to be as or more cost-effective than actual equipment. Additionally, course materials, STSs, and personnel files were reviewed to determine the constancy of training objectives and student competency. All equipment malfunctions were recorded and their impact on training and the cost model was assessed.

Results

The simulator and the actual test station equipment were found to be equally capable of training students. It is hypothesized that a number of environmental factors, which were noted, may have reduced the likelihood of observing significant performance differences among experimental groups. These factors included shifting training objectives and classroom formats, equipment reliability, changing job requirements, and lack of a clearly defined role for the simulator in training. Specifically, no significant differences in troubleshooting ability or field performance were found as a function of training or testing modes. Time to complete the troubleshooting performance test was not significantly different among groups and the minor differences noted were attributed to the slower response time of the simulator.

Personal interviews and subsequent field follow-up questionnaires indicated that students were equally comfortable operating either trainer. Field-related data did not indicate significant differences in field performance, based on training mode, regardless of field equipment assignment.

The cost comparison indicated that actual equipment costs were approximately twice those of the 6883 simulator. Since the 6883 test station was one of the most reliable stations, it was hypothesized that, from a total course systems standpoint, cost savings might be significantly higher. Though training systems-related cost data were not available at this time, the cost of alternative role strategies for integrating simulators within the training environment was explored.

Conclusions

Students trained on the 6883 3-D simulator performed as well as students trained on actual equipment; the actual training *benefits* of the simulator were probably not realized, however, because the simulator was designed in view of a "replacement" philosophy. Given this design philosophy, the outcome of the cost comparison between trainers becomes the major factor in future procurement decisions given approximately equivalent training capability. Given a "supplemental" objective, improved performance becomes the major factor considered and an analysis of cost benefit in light of different levels of performance skills (i.e., training effectiveness) is more appropriate.

While other training alternatives may be possible, the true potential of simulation in training can be determined only by a focused research effort. A new training strategy which maximizes the training potential of a simulator must be implemented when simulator hardware is incorporated into an existing training system.

PREFACE

This second Interim Report completes Phase II of the cost and training effectiveness evaluation of the 6883 simulator, as compared to the actual 6883 test station equipment, for training intermediate level F-111 avionics maintenance personnel at Lowry AFB. The plan for this evaluation was discussed in detail in the 1979 Phase I Interim Report (TR-79-13). The final report, to be distributed at the conclusion of Phase III, will include evaluation of the flat panel training simulator as compared to the 3-dimensional training simulator and the actual equipment trainer. It will also include a discussion of any revisions made in the evaluation plan or data collection instruments.

The project is being conducted for the Air Force Human Resources Laboratory, Air Force Systems Command, United States Air Force, Brooks Air Force Base, Texas. This evaluation is being conducted under the technical supervision of Dr. Gerard M. Deignan, Air Force Human Resources Laboratory, Project Scientist for Program 2361-02-01. Lt Col Downing is the Simulation Program Manager.

The evaluation outlined in this report was developed by the Social Systems Research and Evaluation Division of the Denver Research Institute, University of Denver, Denver, Colorado, under Contract Number F33615-78-C-0018. Dr. Louis F. Cicchinelli is the Principal Investigator and overall Project Director.

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CHAPTER 1

INTRODUCTION

Miller (1974) and Miller and Gardner (1975) provide an extensive analysis of the need for simulated training in general and, specifically, for the development of the 6883 three-dimensional (3-D) simulator employed in this study. Factors influencing the decision to proceed with the development and implementation of the 6883 simulator included the high cost of actual equipment trainers (AET), their low reliability, safety factors, high noise levels in the work area, and the limited scope of training that can be accomplished on AETs because appropriate malfunctions cannot be inserted without extensive and costly modifications. The decision to simulate the 6883 (Converter-Flight Control Systems) test station was based on its representativeness of a class of test stations, moderate complexity of displays, training use established, and opportunity for comparative evaluation.

Previous Research

The application of simulation techniques and equipment to maintenance training is not a new concept, since such research efforts date back to the early 1950s. Yet only during the past few years have extensive efforts been made to realize the potential of the approach. These efforts have established two important points: maintenance training simulators can be cost effective (Miller, 1978; Fink, Shriver, Downing, & Miller, 1978; Montemerlo, 1977) and can provide training comparable to the actual equipment (Miller, 1974; Hurlock & Slough, 1976; Crawford & Hurlock, 1976; Wright & Campbell, 1975; Daniels, Datta, Gardner, & Modrick, 1975). Furthermore, for tasks requiring problem solving skills and cognitive strategies, simulation may be the best instructional approach (Kearsley, 1977).

Despite this demonstrated effectiveness, there is a growing belief that simulator trainers are not being utilized to their full capacity and that much of the simulator training research is subject to methodological problems. Caro (1977) specifically identifies a number of factors which he found to affect Air Force simulator training effectiveness. Brock (1977), however, found that the introduction of simulation into maintenance training could reduce the amount of theory which had to be taught to obtain a particular level of learning. He noted that only a subset of required skills are being taught in existing maintenance training programs and that the addition of simulation methodology may only change the subset which is being trained. Miller (1978) agrees that simulation in maintenance training may result in performance capabilities for maintenance program graduates which are

not achievable with actual equipment trainers. He adds, however, that training instructors, or those who are responsible for acquisition of training systems, do not seem ready to acknowledge this potential. Thus, the key to simulation efficacy may be the manner in which it is utilized rather than the choice of hardware.

Defining the role of simulation in training entails a comprehensive review of the training environment--its objectives, methods, goals, and means of assessment. This process has been studied extensively by the Air Force under the designation, Instructional System Development (ISD). To date ISD has been utilized very little in the development of training and evaluation instruments for simulator programs.

Generally, attempts have been made to determine training objectives through the more limited task-analytic approach. In theory, such an analysis produces training which is more job-relevant and makes the use of simulation more practical. However, its success is dependent on an accurate determination of skill level requirements, and previous efforts in this area have been disappointing (Brock, 1977; Montemerlo, 1976). One reason for this lack of success may be the failure to include student trouble-shooting abilities as a task objective.

While only a few simulator maintenance training programs have been in operation long enough to assess implementation effects, additional problems become apparent when the ISD approach is taken. First, there is the need to assess the fidelity of the training device in order to establish the equivalency of training contexts. Otherwise, the evaluation design may incorporate different training and testing contexts and render the results inconclusive (Kearsley, 1977). Special attention must be given to psychological fidelity since the level of realism can have important impacts on training effectiveness (Miller, 1978). Second, there is the need for a criterion measure of training effectiveness. Previous researchers have had difficulty in establishing such a measure without incurring high costs (Miller, 1978). And finally, problems can arise as a result of instructor opposition. Instructors may see their teaching role threatened by the incorporation of simulation methods or may disagree with required changes in the academic structure.

Since 1975, the ISD process has been specifically prescribed for use in all new instructional systems (AF Manual 50-2, 1975). But, while several ISD schemes have been developed (Gagne, 1970; Merrill, 1971; Markle & Tieman, 1972), no consensus on their applicability to simulator-based maintenance training has been reached. Without this consensus investigators can only take Miller's (1978) advice to "concentrate on where and when simulation technology can best be applied and under what conditions."

The present study necessarily involved some of the issues discussed above. Concerning the use of simulation in maintenance training, specifically, it was important to consider the role of the simulated training device in training, its fidelity to AET, and user acceptance of the new equipment. Furthermore, the cost analysis of the simulator and AET station forced examination of concepts and assumptions that link training effectiveness with the respective system costs. Even though the 3-dimensional simulator represented only one of a family of simulators that might comprise a complete training equipment system, the cost comparison between subsystem components provided a unique opportunity to isolate unanticipated requirements (costs) and/or cost savings that might accrue at the system level. Thus, the overall objective of the cost analysis was to contribute to the evolution of Air Force policy regarding simulators and the use of simulation in intermediate-level maintenance training.

The Role of the 6883 3-Dimensional Simulator

A simulated trainer can be utilized in one of three ways: (a) to provide initial contact with the equipment for the purpose of identifying components; (b) to complement the AET, allowing more versatility of training while lacking the complexity of the AET; or (c) to replace the AET in a training program, delaying technician contact with the AET until the period of on-the-job training (OJT).

Fink and Shriver (1978) identified four stages of learning: (a) the novice stage, (b) the uncoordinated skills stage, (c) the coordinated skill in a training environment stage, and (d) the job proficiency on operational equipment stage. They suggest that the simulated training device should play a role during the third stage, the conclusion of which usually means the student has met the course requirements. Use of the AET would be reserved for OJT, or stage four. At stage three, the simulated trainer would replace the AET and would allow students to perform operational checks, remove and replace components, and locate malfunctions. In general, the simulator would teach the logical skills required to isolate malfunctions. The emphasis in this stage is on teaching the "conceptual aspects of troubleshooting" and preparing students to "train or work on real equipment." Fink and Shriver consider this to be the most cost-effective way to use simulated training devices. This approach to using simulators in training is consistent with the earlier observations of Shriver and Foley (1974). At that time, they viewed the maintenance activity as having a very strong "organizing factor." A "failure of the performer to correctly organize unrelated discriminations and actions will result in his being unable to perform the required maintenance activity."

This use of simulated equipment as a replacement for AET is further supported by Wheaton et al. (1976) and by Pieper (1968, 1969), who reported that "significant additional course cost reductions were

also achieved through the *substitution* of simulators for expensive and scarce tactically configured equipment." Miller and Gardner (1975) refer to the 6883 simulator as an *alternative* to the current use of AET.

Fidelity of the 3-Dimensional Simulator

Equipment (or physical) fidelity of simulated trainers is defined as the comprehensiveness and level of detail with which the real world (AET) is physically represented (Narva, 1978); psychological (or functional) fidelity is defined as the degree to which the trainee *perceives* the simulated device as a duplicate of the actual equipment (Miller & Gardner, 1975). Psychological fidelity is a very important consideration in evaluating simulated training devices. Wheaton et al. (1976) proposed that the importance of psychological fidelity was affirmed by observed performance differences. They hypothesized that these differences were due to the fact that physically identical controls, which operated differently on a simulated device than on the AET, had a detrimental impact on transfer of learning.

Fink and Shriver (1978) maintain that only task-specific components of training equipment should be simulated and they should have a high degree of psychological fidelity. Displays and operational controls beyond those required for selected maintenance tasks are "at least irrelevant and may even be distracting to the novice technician." It is Narva's (1978) assumption that "the potential for transfer of training will increase as a function of the degree to which the required activities, mental and physical, are represented in the device and the degree to which the training device follows 'good' practice in these activities." Matheny (1974) maintains that psychological equivalency, not physical equivalency, results in positive skills transfer and should be a primary factor in equipment design decisions. The design of the 3-dimensional simulator involved producing an instrument that "looked like the real equipment and exhibited psychologically similar outputs but did not require the complex internal circuitry of the real equipment" (Miller & Gardner, 1975).

User Acceptability and Training Needs

Fink and Shriver (1978) distributed questionnaires to maintenance instructors. Their findings most germane to a discussion of simulated training devices were

- Most instructors were willing to use low-cost/fidelity training devices as supplemental to AETs, but not as replacements.
- Most instructors reported a heavy reliance on AETs and preferred to keep it that way.

- Forty-three percent of all instructors considered the training equipment they were currently using to be reliable. This figure was lower for electronic maintenance instructors.
- Sixty-six percent of the instructors used the AET to teach nomenclature and 73 percent used it to teach parts location.
- Sixty-five percent believed that students need to handle actual equipment because graphic or photographic representations are not sufficient.
- Forty-two percent felt trouble-shooting should be taught on the AET, while 53 percent would use a trouble-shooting logic trainer, but only if that training was followed by training on the AET.
- Fourteen percent of those responding considered the low cost and easy maintenance of simulated training devices as primary issues in any decision to use simulated training devices.

In short, it was found that instructors prefer to use proven instructional devices with which they have some familiarity. They would accept new training devices, but only after considerable evidence had been collected regarding effectiveness of the devices. Since the trainee will eventually operate an actual test station in the field assignment, the instructors viewed the AET as a superior training device despite its drawbacks regarding flexibility, reliability, safety, and noise. In view of these instructor attitudes, Fink and Shriver (1978) expressed reservations about expanding the role of instructors and field personnel beyond that of identifying training problem areas.

Pieper (1968, 1969) discussed the problem of determining actual job requirements and criticized the two methods most often used. He suggested that one method, reviewing instructional materials, assumes that the Plan of Instruction (POI) contains all field-related tasks. This is not a valid assumption. He also pointed out that surveying field personnel, the second method, may be biased by senior NCO or commander preferences which are not necessarily the most effective methods of training. The task analysis necessary for the design of the 6883 3-dimensional simulator was based on a combination of these methods.

CHAPTER 2

EVALUATION DESIGN

This chapter provides a brief outline of the major components of the evaluation design and the research objectives. This information is necessary to place the discussion of the evaluation environment presented in Chapter 3 in a proper context.

Research Objectives

The objective of this study was to design and implement a comprehensive cost-training effectiveness evaluation of a 6883 3-dimensional simulator, as compared to the use of operational 6883 test station equipment for training intermediate level (I-level) F-111 avionics maintenance personnel.

The evaluation plan outlined in this section was developed in view of information collected by the Denver Research Institute (DRI) evaluation team over the initial six months of the project. A complete discussion of the overall design employed and its underlying rationale was presented in the first interim report for this project (Cicchinelli, 1979). While the general framework remained consistent with the proposed contract statement of work, some minor modifications were made in the manner of implementation based on an analysis of the training and field environments. The overall design was divided into three components to facilitate reference to the three major evaluation components originally outlined in the proposal. Specifically, the three major components of the evaluation were classroom performance, field performance, and cost analysis.

Classroom Performance

The basic research design used to assess classroom performance as a function of training mode (actual or simulated test station equipment) is shown in Figure 1. Four experimental groups were defined by the two training modes and two performance testing modes.

		TRAINING MODE	
		Simulator	Actual Equipment
TESTING MODE	Simulator	A	B
	Actual Equipment	C	D

Figure 1. Research Design for Comparing Classroom Performance

Clearly, performance differences in operating and maintaining *actual* test stations as a function of the training equipment was of primary interest. However, two testing modes, actual and simulator equipment, were used because it was expected that the simulator might provide training or testing capabilities which were not available on the actual equipment. Further, it was necessary to determine the extent to which any observed differences in performance were due to familiarity with the test equipment.

Job Performance

The design shown in Figure 2 was used to assess the impact of training mode on job performance in the field. The design includes eight experimental groups and is sensitive to the possibility that testing classroom performance itself constitutes additional training. Thus, the assessment of field performance must be conducted in view of the four levels of training resulting from the various combinations of classroom training and testing modes.

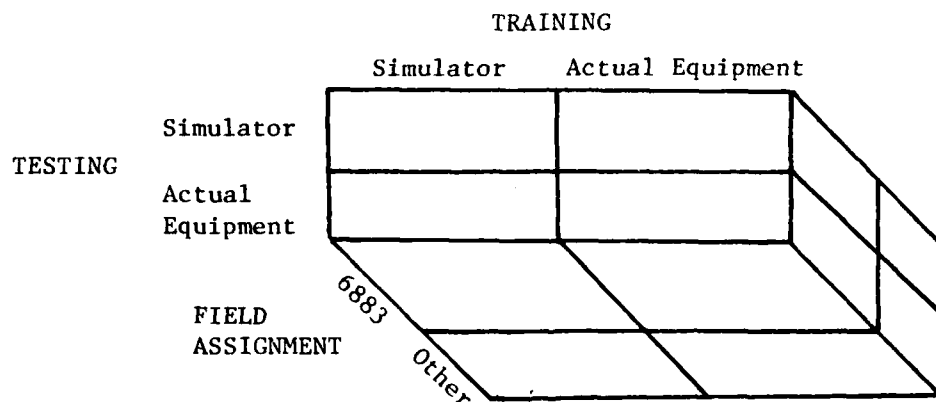


Figure 2. Research Design Used for Comparing Field Performance

Cost Analysis

The comparison of costs associated with using the 6883 actual test station and the 6883 3-dimensional simulator for training was based on the model shown in Figure 3. The basic model consists of a matrix of six major cost categories and two components of life cycle costs. The model is simply the "ingredients approach" discussed by Levin (1975) in which cost elements are identified and evaluated consistent with the ATC acquisition and training environment. The cost elements or ingredients associated with each cost category are evaluated either as one-time costs (primarily Investment Costs) or as Recurring Annual Costs, consistent with AFHRL's perspective on economic analysis (Williams, 1977).

Cost Categories ¹	Life Cycle	
	Investment Costs	Operating Years 1-15
Facilities		
Equipment		
Instructional Material/Training		
Personnel		
Students		
Miscellaneous		

Figure 3. Cost Comparison Model

The model used to establish the life cycle cost comparison also provides the framework for evaluating alternative simulator implementation strategies, particularly those involving proposed changes in such "ingredients" as student flow, course length, and time to complete specific instructional blocks. In this sense, the model is general. Moreover, it will also be used to establish comparative life cycle costs of the flat panel test station simulator scheduled for evaluation during 1980 (Phase III of this project).

To assess cost-effectiveness, it was assumed that both trainers have equal training effectiveness. Hence, the life cycle cost comparison between trainers will indicate which is the most cost-effective, i.e., the trainer exhibiting the least total cost of ownership. This is a useful approach since it establishes baseline cost data. It is also consistent with the original simulator design objective of developing a functional (training) replacement for the 6883 test station (Miller & Gardner, 1975). The discussion of the cost analysis findings will address the validity of the equal effectiveness assumption, however, in light of factors (e.g., equipment availability, STS standards) found to influence the training effectiveness of the respective trainers.

Additionally, three scenarios are presented as part of the discussion of the cost analysis. They outline fundamentally different

¹Line items associated with each major cost category are presented in the "Results and Discussion" section of the report.

simulator implementation strategies from that encountered in the actual training environment. The scenarios are: (a) the use of a generic test station simulator, (b) the use of combined test station/simulator complements, and (c) the replacement of actual equipment trainers with different simulators. These scenarios or training strategies were chosen because they are thought to engage the relevant Air Force simulator training policy options.

Hypotheses to be Tested

This evaluation plan was designed to address the following hypotheses:

- Practical training on the 6883 simulator and the 6883 test station results in identical performance on the standard Air Training Command block tests for subsequent training.
- Airmen trained on the 6883 simulator and the 6883 test station are equally accurate in solving trouble-shooting problems.
- Airmen trained on the 6883 simulator and the 6883 test station are equally efficient in solving trouble-shooting problems.
- Airmen trained on the 6883 simulator and the 6883 test station operate the actual test station with equal proficiency.
- Airmen trained on the 6883 simulator and the 6883 test station are equally familiar and comfortable in operating the actual test station without supervision.
- Airmen trained on the 6883 simulator and the 6883 test station will acquire equivalent job-related experience.
- Airmen trained on the 6883 simulator and the 6883 test station will be equally capable of operating the 6883 test station in the field.
- Airmen trained on the 6883 simulator and the 6883 test station are equally capable of operating assigned test stations, other than the 6883 station, in the field.

CHAPTER 3

THE EVALUATION ENVIRONMENT

During the first six months of the project, the DRI evaluation team conducted an analysis of the activities associated with the F-111 avionics maintenance course and subsequent field assignments for graduates of the course. This assessment included the collection and review of course-related documents, interviews with instructors and students, and direct observation of the theory and practical 6883 classroom proceedings, as well as other test station training blocks. The review of the classroom and field environments uncovered a number of factors which had a direct impact on the implementation of the planned evaluation. The most important of these factors are

- Training objectives
- Format of training program
- Availability of cost data
- Reliability of training equipment
- Status of the 6883 3-dimensional simulator
- Assignment and OJT in the field

The impact of each of these factors on the evaluation is discussed in the following pages.

Training Objectives

Training on the 6883 Converter-Flight Control Systems Test Station occurs as part of a 23-week intermediate level F-111 avionics maintenance course. The objectives of this course and the associated Specialty Training Standards (STS) have been in a continuous state of change over the past few years.

A number of factors have contributed to the need to modify course objectives and content. Perhaps the most important factor is the evolution of the F-111 aircraft itself. As more sophisticated F-111 models have been developed, course content has been modified to include instruction in the operation and maintenance of new test stations capable of testing the new aircraft systems. Prior to 1978, students were trained as test station *operators* (course ABR326X1B; nine days of 6883 theory and practical training) or as test station *maintenance personnel* (course ABR326X0B; five days of 6883 theory and practical training). In 1978, these career options were integrated into a single career path, and a new Specialty Training Standard (STS) was developed to reflect

course modifications. In this combined course (Interim Course ABR326X1D), theory and practical training on the 6883 test station was reduced to a total of eight days. More recently, still another plan of instruction was developed in accordance with STS ABR326X4A which became effective in April 1979. This course includes expanded required skill levels for 3-level training.

Given that the specifications for the 6883 3-dimensional simulator were developed when operation and maintenance training were alternative career choices, and given the recent merger of the two courses, we felt that it was important to review course materials used over at least the last two years rather than the proposed one-year period. The approach used to analyze course documentation and the use of the 6883 actual test station in training was to compare training objectives at three discrete points in time. Specifically, the comparison was among instructional objectives used when maintenance and operation of the 6883 test station were separate courses, instructional objectives of the 1978 combined interim course (ABR326X1F), and the training objectives used for course ABR326X4A, which was in place during this evaluation effort. Briefly stated, our analysis of training objectives revealed that while many objectives remained the same over time, some objectives (e.g., training on the Yaw Computer LRU) which were used to define the simulator capabilities were eliminated due to the significant reduction in training time available. Since these training exercises were no longer employed, it was not appropriate to include the associated simulator capabilities in any tests of student performance.

It is interesting to note that while course objectives did change over time, the relevant STS requirements did not substantially change. This finding led us to the observation that the specialty standards are general enough to allow for interpretation, depending on one's perspective. That is, training and field personnel could easily assume that somewhat different skills are associated with specific requirements, such as "trouble-shooting." Clearly, the lack of specific criteria for adequate performance poses potential problems for an evaluation that attempts to assess training effectiveness. The problem was circumvented in this study by considering only comparative training effectiveness, and ignoring the more basic consideration of training adequacy. In short, then, this study answered the question, "How do simulator trained students perform as compared to actual equipment trained students?" Although an assessment of the overall adequacy of that training was considered beyond the scope of this project, we do recommend that "adequacy of training" be a primary consideration in the development of Air Force training policy.

Format of Training Program

The comparative analysis of course content changes over the past two years indicated that most of the objectives of the former

maintenance and operations courses have been retained, although the time allocated to each has been greatly reduced. In fact, at the beginning of the current performance data collection phase, only two days of practical training on the 6883 test station were included in the F-111 avionics maintenance course. This very limited contact with the 6883 test station equipment clearly reduced the likelihood that performance differences as a function of training equipment would be observed. Due to the short training period, it became necessary to track numerous variables which might obscure actual performance differences. Much effort was expended in controlling for individual differences, minor training deviations, instructor and supervisor differences, etc., in an attempt to reduce confounding of the performance measures by changing contextual factors.

DRI originally proposed to rely heavily on existing test instruments to collect relevant data. Further, it was proposed to emphasize training on the 6883 3-dimensional simulator since previous test scores from students trained on the actual test station equipment would be made available to serve as baseline data. However, after completing the review of courses, it was found that the merger of 3ARB326X1D (operations) and 3ARB326X0B (maintenance) was not the only major change in instructional format over the past years. In fact, these two courses have undergone numerous modifications and the new combined course was continually altered even during the data collection period. Associated with these course changes were modifications in the test instruments used. In 1979, the 6883 and 6886 test station practical blocks were merged. These formal modifications, together with numerous training "deviations" applied to nearly every class, made it inappropriate to use test scores for previous classes as baseline data.

It should also be noted that for some instruction blocks, previous test scores did not exist. For example, while the maintenance course included an evaluation of student performance during the 6883 practical block based on a performance criterion checklist, no similar testing procedure was employed in the operations course. Student performance in this course was rated as "satisfactory" or "unsatisfactory" on the basis of instructor's observations throughout the four days of training. In short, there were no standard Air Force test instruments available which could be used to compare the performance of a baseline group of trainees with those trained on the 6883 3-dimensional simulator.

Prior to the data collection period, practical training on the 6883 test station was considered a single block of instruction. However, in an effort to reduce the overall length of the course, it was decided to merge practical training on the 6883 and 6886 test stations into the same block of instruction. To maintain the same amount of student-equipment contact in one-half the time, classes were divided into two groups. One group trained on the 6883 test station for two days while the other group trained on the 6886 test station.

By reversing the groups for the remaining two days of practical training, all students completed their practical training on both test stations in four days rather than in eight days. The use of smaller groups and less time was expected to result in the same level of training as formerly given. Since all of the performance testing took place on the day after the practical block of instruction was complete, it was important to control for the sequence of training received by each student. This procedure was necessary to determine if 6886 test station training between 6883 training and testing had a detrimental effect on observed performance.

Two additional changes on the F-111 avionics maintenance training course occurred during the data collection period. First, the blocks of instruction within course 326X4A were rearranged. Theory training on the Electronic System Test Station and the Converter Flight Control Systems Test Station, and the combined practical instruction on these two test stations, were positioned earlier in the sequence of instruction blocks. This modification in the course format was expected to result in less experienced students being trained in the 6883 block of instruction. However, the change did afford an opportunity to examine more carefully the relative impact of actual and simulator training on subsequent blocks of instruction. The data collection plan was modified to carefully note any deviations in the sequence of training blocks. Thus, it was possible to examine the performance of students in any instruction block in view of specific prior training experiences.

Second, the practical block of instruction on the Electronic System and Converter Flight Control Systems Test Stations was expanded from four to six days: three days of practical experience on each test station. The extended training period was beneficial in that it increased the likelihood that any existing performance differences resulting from actual versus simulator training would be observed. However, since testing occurred after the entire block of practical instruction was completed, all classes necessarily had a weekend intervening between training and testing. Since this delay could differentially impact observed performance, the data collection plan was modified to record the specific nature of such uncontrolled time lapses.

Availability of Cost Data

The essential question explored in the Cost Analysis effort concerns the costs of ownership of alternative training devices. As might be expected, some difficulty in establishing costs of ownership was related to data access and reliability. Disaggregated estimates of the development costs of the simulator hardware, software, and courseware available from the manufacturer are not releasable. Thus, for the purposes of this report, the acquisition costs of the simulator hardware, software, and courseware have been lumped together and

treated as "sunk" costs. These sunk costs have been included in the assessment of the life cycle costs of the respective systems as Investment Costs (rf. Tables 15 and 16).

The contracted cost for developing and manufacturing the 6883 simulator was \$548,000. The contract cost itself does not reflect the total expenditure for development and production of the simulator because corporate funds and IR&D were used in years prior to the contract award to develop certain aspects of the technology used. An estimate of the dollar value of these somewhat indirect costs is not available from the manufacturer. The manufacturer believes that the actual costs incurred in development and production of the first 6883 simulator are *not* useful as an estimate of the costs of producing another simulator. The 6883 simulator was considered to be a research device incorporating features inconsistent with preproduction models and current computer technology. Our interest in estimating the actual cost of the 6883 simulator stemmed from a concern about the extent to which the simulator and the test station were functionally equivalent. For example, the simulator control system was designed to be expandable so that a minimum of four other satellite test station simulators comparable to the 6883 could be operated simultaneously from the same instructor station. Thus, it was considered important to be able to estimate the incremental cost of hardware and software development associated with the additional computer that provides master control for simultaneous operation of the satellite simulators.

A similar difficulty was encountered in regard to estimating the actual test station costs. ATC maintains two Burroughs D84 computer processors and related peripherals to actually "run" automatic fault isolation tests on ten test stations (including the 6883) used in F-111 training. Developing life cycle cost information on these Cenpac computers for purposes of allocating costs to the operation of the 6883 test station was seen to be a project equal in scope to the cost analysis of the 6883 test station and the effort was not undertaken.

These two problems highlight difficulties associated with attempting a cost analysis of subsystem components in the absence of a total system analysis. Although the 6883 test station and simulator are discrete elements in the training system, it is not known how representative they are of other system components. To illustrate this point, consider that the cost of maintenance for the 6883 test station was based on maintenance records. For purposes of comparison with the simulator, we have no way of judging if these costs are representative of the other test stations. Similar problems of representativeness arise with respect to the costs of courseware development. To summarize, then, the cost analysis should be understood as an effort to document the respective cost experiences for alternative training devices and that it omits important considerations and detail needed for generalizations about the cost of simulation at the training system

level. Hence, a fixed effects analysis of two *specific* training devices is provided here.

Reliability of the Training Equipment

A fundamental issue involved in the evaluation of simulated training devices, and the 6883 3-dimensional simulator in particular, is training equipment reliability. Clearly, equipment malfunctions have potential impact on the assessment of both performance and cost. Fink and Shriver (1978) conducted a survey of maintenance instructors and ascertained that 43 percent of those interviewed considered the actual equipment trainer (AET) they were using to be unreliable. Un-scheduled maintenance downtime for a one-year period ranged from a low of four hours to a high of 6,654 hours.

While malfunctions of both the 6883 test station and simulator were observed, actual training time was lost due to the availability of the two training instruments. The frequency of equipment failures, however, was sufficient to cause disruption of routine training and data collection. The major impact of malfunctions on the evaluation design was on the random assignment of trainees to experimental groups. Flexibility in evaluation design was essential to allow for unexpected changes in the training schedule and to minimize the potential loss of performance data.

These periodic interruptions or alterations in training still had some minor effects on our testing schedule, although a more significant impact resulted when the 6886 test station, the "partner" test station in the Converter-Flight Control System's block of instruction was not operational and remained unavailable for training from late August to mid-October 1979. During this time, four classes (21 students) did not receive 6886 practical training. Since our research design included assigning students to groups by training sequence (whether they received 6883 training before or after 6886 training), it was not possible to place these 21 students in the established sequence categories. This third type of training format was eliminated as a confounding factor when the analysis of training sequence found it to be unrelated to performance (rf. p. 43). It should be noted that impacts on 6883 training and performance due to equipment failures in other training blocks prior to the Converter-Flight Control blocks were anticipated, but uncontrolled in this research design. For example, in some instances, the first experience students had with an *operational* test station came in the Converter-Flight Control block.

In large part, equipment reliability defined the format of the training approach used on the actual test station equipment. Unlike the approach with preprogrammed malfunctions on the simulator, the acquisition of practical experience was dependent on pre-existing or

unexpected equipment failures. This was particularly true of the trouble-shooting aspects of training. In its extreme forms (which were observed during the experimental period), this dependency resulted in very limited training. At those times when all test replaceable units (TRUs) and line replaceable units (LRUs) operated without malfunction, it was not possible to demonstrate trouble-shooting techniques. At other times when a specific TRU failure caused the test station to be inoperative, no training was possible.

Finally, equipment malfunctions during training sometimes resulted in different training sequences for various classes. To maintain student flow, ATC maintains a policy of moving on to another phase of training and returning to the block of instruction that was missed when the equipment becomes operational. In some instances, when specific AETs remain inoperable for long periods of time, a class may not receive any training in a particular block. A "training deviation" is filed for the class and graduation occurs as scheduled. With respect to the evaluation effort, these random variations in the training sequence made it impossible to assess the efforts of prior training on performance in the 6883 practical block of instruction.

Status of the 6883 3-Dimensional Simulator

The 6883 simulator was not completely operational upon arrival at Lowry in June 1978. Much time was devoted to "debugging" training exercises and modifying the hardware to improve the system (Schneider, 1978). While these activities did improve the performance of the system, the formative evaluation also delayed the start of this data collection effort and resulted in additional costs which would normally not be incurred in the acquisition of a production model of the simulator. These costs were monitored and particular attention was given to them when implementing the cost analysis (rf. p. 72). All modifications to the simulator were monitored carefully to ensure that both the capabilities and limitations of the equipment were considered in designing student performance measurement instruments.

Assignment and OJT in the Field

Once trainees are assigned to the field, they enter the training phase called on-the-job training (OJT). Field training is relatively informal and is designed to develop the skills needed to operate and maintain the assigned test station.

Field site visits conducted in the course of the project, revealed that the number of technicians available and their technical competency upon arrival determined the extent and type of OJT received. Due to the individualized approach to providing OJT in the field, it was not possible to use the extent and type of OJT required

as an indicator of training effectiveness. Another method of assessing field performance considered was to record the number and cost of replacement parts requested and used by new technicians to perform test station and LRU repairs. Utilizing this indirect measure of training effectiveness was not feasible either due to the complexities of obtaining such data in the field. In short, it was difficult to isolate clear measures of long-range impact of simulator training.

It was anticipated that the performance of simulator-trained personnel and actual equipment-trained personnel would be compared at specified intervals of time in the field. The effects of on-the-job training were expected to be present and constant in both groups and, therefore, any differences in performance could be attributed to the mode of training. Clearly, with variable amounts of OJT, this assumption was not valid. In fact, if the originally proposed time series sampling framework was used, differences in performance due to training would be reduced as time in the field increased. Therefore, in order to obtain some measure of the long-range impact of simulator training on performance, it was necessary to devise a method of estimating job proficiency prior to field assignment, and to collect subjective ratings of field performance from supervisors shortly after the field placement (within about two weeks).

From discussions with ATC staff and field personnel, it became apparent that field assignments are made in view of the momentary demand for specific automatic test station operators. Thus, at best, only a small, undetermined number of airmen trained to operate the 6883 test station were expected to be assigned to the 6883 or 6873 test stations in the field. Although the nature of the field assignments remained a design variable, it was clear from the outset that extremely unequal sample sizes for students assigned to 6883 and other test stations would be obtained.

CHAPTER 4

METHODOLOGY

This chapter provides a discussion of all data collection instruments developed to assess both classroom and field performance as well as costs. The data collection and management techniques employed are also outlined. In addition, this chapter includes a discussion of some preliminary analyses conducted to verify the research design and performance test administered. An analysis of all data collected is provided in Chapter 5 of this report.

Assignment to Treatment Groups

A total sample of 115 F-111 avionics maintenance trainees participated in this study. Students were assigned to the eight treatment groups defined by training sequence and the two levels of training mode and test mode. Each "training class" was partitioned into two approximately equal groups for assignment to levels of training sequence and mode, whereas the "student" was the unit of assignment to a level of test mode. It should be noted that although training sequence was initially considered in the assignment strategy, subsequent analysis indicated that performance did not vary as a function of training sequence (rf. p. 45). The distribution of students among the four remaining experimental groups is shown in Figure 4.

		TRAINING MODE	
		Simulator	Actual Equipment
TESTING MODE	Simulator	28	29
	Actual Equipment	28	30

Figure 4. Distribution of Students Among
Experimental Groups

The assignment of students to groups was essentially random. The schedule was adjusted monthly in an effort to maintain approximately equal group sizes throughout the data collection period. Since the adjustments made were necessary due to random fluctuations in class size, unscheduled deviations from the course timetable, and unpredicted equipment malfunctions, the overall attempt to randomly assign students to experimental groups was not compromised.

Despite this effort at random assignment, it was conceivable that observed performance would be a function of student aptitude.

To justify attributing any observed differences to training mode, it was necessary to consider pre-existing individual differences among students. To examine the possibility that a matched sample strategy should be included in the assignment plan, the relationship between aptitude scores and scores on prior instruction block exams, and performance in the 6883 theory and practical blocks of instruction was analyzed for a sample of 104 trainees over the previous two years. Table 1 shows that this analysis indicated that only modest correlations existed between aptitude, as measured by Air Force testing protocols, and the 6883 theory training block scores. No relationship between aptitude and practical block scores was found. This may be due to the "pass-fail" system used to rate practical performance. It is important to note that the analysis of prior performance was based on previous block examinations which have been continually revised to reflect changes in course content. Therefore, these findings are not *necessarily* generalizable to the test instruments used in this evaluation effort. Although no systematic bias due to aptitude was expected to confound the performance measures and a matched sample design was not used, group equivalence was again examined as part of the analysis (rf. p. 45). No significant relationship between aptitude scores and performance was found.

The final issue considered which relates to the assignment of students to treatment groups is the procedure used to make field assignments. Evaluator control over this factor was not possible since assignments are made on the basis of demand in the field. Thus, data collected subsequent to field assignments were analyzed separately for trainees assigned to the 6883 or 6873 test station and trainees assigned to other automatic test stations. It was expected that the group sizes would be unequal on this factor. In fact, our field follow-up data for the first 63 students indicated only 12 were ever assigned to the 6883 or 6873 test stations, and only six of these were still assigned to the 6883 or 6873 stations at the time of our second follow-up.

Data Collection

Consistent with the three components of the evaluation design discussed earlier in this report, three general types of information were collected: classroom-related data, field-related data, and cost-related data. The strategy for collecting classroom and field data was carefully designed to minimize, as much as possible, the number of interruptions of normal Air Force procedures.

Classroom-Related Data

As a result of a cooperative agreement between ATC and HRL, one day at the end of the Converter-Flight Control Systems practical block of instruction was made available to DRI for data collection. This temporary departure from the normal training schedule, effective for the duration of this project, allowed data to be collected without

TABLE 1

Correlations between Student Characteristics and
Prior Performance and 6883 Test Station Performance

Factors	6883 Theory Block	6883 Practical Block
Age	.09	.19
Sex	.17	.15
ASVAB-General	.26*	.36
ASVAB-Mechanical	.11	.10
ASVAB-Administrative	.09	.22
ASVAB-Electronics	.29*	.28
AFQT	.29*	.37
Fundamentals of Electronics	.41**	.36
Avionics	.41**	.23
CENPAC	.10	.01
DATAAC	.06	.21
CATE	.51**	.37
Test Station 6863	.39**	.33
Test Station 6886	.41**	.22

*Significant at .05 level.

**Significant at .01 level.

altering the usual 6883 training protocol. Allocating one day for testing immediately following the 6883 training was extremely helpful to this evaluation effort for a number of reasons. First, the logistics of integrating the data collection into ongoing training were simplified. Second, the use of the actual or simulated 6883 test stations occurred as it normally would if there had been no evaluation effort. Third, the availability of testing time immediately following 6883 training eliminated the possibility that observed performance would be adversely affected by intervening training. Finally, collecting performance data from each student at the same point in the training sequence ensured that all students had similar levels of training at the time of testing. Clearly, the cooperation of ATC in this matter was essential to the evaluation effort and DRI is appreciative of their assistance.

In order to collect all information required from an entire class of students (usually six) in a single day, it was necessary to administer the performance tests and conduct the interviews in a different order for each student. Administration of the trouble-shooting performance test for the first student was followed by the personal interview. During the time that any one student was being administered the trouble-shooting performance test, the remaining students, who had either completed or were awaiting their turn to be tested, were given a Projected Job Proficiency Test. When all students in a class had completed the performance test, the Projected Job Proficiency Test, and had been interviewed, the evaluation day was complete.

Prior to the evaluation day, DRI staff reviewed ATC records for the current class to determine if any training deviations had occurred or if any unscheduled maintenance periods were recorded. The type of training received was also recorded and it was confirmed that the experimental group assignments were still valid.

Since the F-111 maintenance course was restructured (rf. p. 21), it was necessary for ATC to revise test instruments to reflect changes in course objectives. Thus, it was not appropriate to compare the performance of previous classes trained on the 6883 actual test station equipment to the performance of classes trained on the 6883 simulator. Our evaluation plan considered this factor and a design element which allowed us to collect 6883 performance data from students trained on the actual equipment as well as on the simulator was included. Additionally, all performance scores on instructional blocks before and after the 6883 blocks were recorded for students included in this study. The following sections provide a brief discussion of the major data collection instruments developed and other sources of classroom-related data.

Student trouble-shooting ability test. This test was designed so that it could be administered on either the actual test station equipment or the simulator. The primary focus of this test was on trouble-shooting skills; the problem selected included the identification

and correction of a malfunction in an LRU and a simultaneous malfunction in the test station. The test was designed to examine the ability of a student to perceive the test station and its associated LRUs as an integrated system. The two-step nature of the malfunction was chosen to test the logical process of trouble-shooting. The test was dissimilar to the lessons available on the 6883 3-dimensional simulator and to the majority of malfunctions encountered on the 6883 actual equipment. Thus, the task was new to all students.

The trouble-shooting test items, which were individually scored by trained Denver Research Institute personnel, are shown in Section A-1 of Appendix A. Each item constitutes a discrete step that a student had to complete in order to identify the malfunction. In addition to recording the completion (and noncompletion) of the required steps, the nature of all errors committed was noted on the scoring form. An analysis of these errors was conducted to isolate any differences between students trained on the 6883 3-dimensional simulator and actual test station equipment. In addition to the measures of performance, time to complete various portions of the test and degree of instructor assistance required during testing were also recorded. It should be noted that at specific points in the test protocol, instructor prompting was necessary; the amount of information provided was controlled as well as possible. As Shriver and Foley (1974) discussed, however, it is difficult to ensure that consistent information is provided because few technicians use the same logic tree to solve a problem. Information that is useful to one person might be unenlightening to others.

The emphasis on trouble-shooting performance testing was validated by field personnel at both Plattsburgh and Cannon AFBs. Twenty-four avionics personnel, having at least two years of field experience, were asked to rate the relevancy of the 6883-related STS standards to job performance. Trouble-shooting test station malfunctions was considered the most important job skill. Respondents also rated the ability to analyze a specific problem logically as a critical skill. Understanding the operation of the test station, its component TRUs, and associated signal flow were considered necessary to effectively trouble-shoot the station and LRUs. The mean ratings of all STS standards by field personnel are shown in Table 2.

Student and instructor interviews. Each student participating in the study was interviewed immediately after they completed the trouble-shooting test to obtain their opinions and attitudes concerning the use of simulators in training. The interview guide is shown in Section A-2 of Appendix A. In addition to the collection of student data, each trainee's personal file was reviewed. Demographic information, aptitude scores, and prior and subsequent block scores were recorded.

The ATC Instructor Questionnaire was administered in December 1979 to 20 instructors in the F-111 training program at Lowry AFB. They were asked to respond to questions regarding the general use of

TABLE 2
Summary of STS Ratings by Field Personnel

STS Item	Rating
<u>General</u>	(n=24)
Purpose and function of test station (27a)	3.7
Theory and signal flow of switching complex (27b1)	4.2
Theory and signal flow of switching control unit (27b2)	3.85
Theory and signal flow of ratio input filter (27b3)	3.15
Theory and signal flow of FCS adapter (27b4)	3.05
Theory and signal flow of CDU adapter (27b5)	3.1
Theory and signal flow of SCU controller (27b6)	3.45
Theory and signal flow of parallel digital adapter (27b7)	3.35
Theory and signal flow of serial digital adapter (27b8)	3.5
Theory and signal flow of digital interface unit (27b9)	3.6
Theory and signal flow of signal converter simulator (27b10)	3.55
Perform confidence test for test station (27c)	2.3
Perform diagnostic testing of the test station (27d1)	3.65
Trouble-shoot malfunctions of the test station (27d2)	4.35
Perform maintenance of the test station (27d3)	3.7
Verify/calibrate the test station (27d4)	3.0
<u>Feel and Trim</u>	(n=23)
General information and electrical characteristics (28a1)	3.4
Data flow and interface with test station (28b1)	4.0
Test and inspect (28c1)	2.85

Rating scale: 1 2 3 4 5
 irrelevant slightly relevant very critical
 relevant relevant

TABLE 2 (cont.)

STS Item	Rating
Isolate malfunctions (28d1)	4.05
Repair (28e1)	3.4
<u>Multiplexer Converter</u>	(n=23)
General information and electrical characteristics (28a3)	3.65
Data flow and interface with the test station (28b3)	4.0
Test and inspect (28c3)	2.85
Isolate malfunctions (28d3)	4.05
Repair (28e3)	3.35
<u>Flight Control Computers (FCC)</u>	(n=23)
General information and electrical characteristics (28a4)	3.1
Data flow and interface with the test station (28b4)	3.7
Test and inspect (28c4)	2.75
Isolate malfunctions (28d4)	3.2
Repair (28e4)	3.1
<u>Other LRUs</u> (please specify any other LRU or Astro Electronics)	(n=2)
General information and electrical characteristics (28a5)	3.5
Data flow and interface with the test station (28b5)	3.0
Test and inspect (28c5)	2.0
Isolate malfunctions (28d5)	2.5
Repair (28e5)	2.5

TABLE 2 (cont.)

STS Item	Rating
<u>General Capabilities</u>	(n=23)
Practice housekeeping consistent with safety of personnel and equipment (3b)	3.55
Apply safety precautions pertaining to using tools and equipment (3a)	3.7
Use of technical manuals as a source of information for performing maintenance and inspection (4b)	4.1
Selection, care, and use of hand tools (10a)	3.2
Apply safety precautions pertaining to high voltage (NA)	4.3
Use of maintenance data collection forms (7c)	2.65
<u>Additional Tasks Not Listed</u>	
Reading of test data charts with the aid of shop systems TO	5 (n=3)
Reading flight line malfunctions from 350 tags and associate with failure while on test station	4 (n=5)
Understanding of TRU and LRU circuitry relationships and approaching trouble-shooting tasks in a logical manner rather than using a shotgun method	4.5 (n=5)
Theory and signal flow of phase sensitive converter TRU	5 (n=2)
Theory and signal flow of ratio-transformer TRU	5 (n=1)
Theory and signal flow of station miscellaneous switching unit	4 (n=1)

simulators in training and about the 6883 3-dimensional simulator in particular. Due to schedule constraints, annual leave, and educational commitments, it was necessary to allow the instructors to complete the questionnaires when possible and return them to DRI staff. This questionnaire is provided in Section A-3 of Appendix A.

Course content and equipment malfunction. The effort to determine the nature of actual test station use in training included the collection and review of course-related documents, interviews with instructors and students, and direct observation of classroom proceedings.

Additionally, the specific training received by students on both the 6883 actual test station and simulator was recorded. The training received was categorized according to the TRUs of the AET or simulator addressed in the lesson, the LRUs which were included in the training period, and the complexity of the training. Training equipment malfunctions for both pieces of equipment were also recorded. This was accomplished by reviewing maintenance department records for the AET and reviewing the daily log, maintained by ATC and HRL personnel, for the simulator. In addition, appropriate instructors were interviewed to corroborate the written records for both trainers. An emphasis in compiling equipment malfunction data was on those malfunctions which in any way interrupted or interfered with the training of the avionics technicians. Therefore, the data presented does not include all equipment downtime, but only those instances or periods relevant to the study. This information served a dual purpose: to track any effects of malfunctions on training and to provide information for cost analysis.

Data was also collected regarding deviations in training for students during the period of their 6883 training. Deviations are given to students who, for any of several reasons including equipment malfunctions, have not received all of the required training time in a particular block. Reasons for deviations range from adverse weather conditions to Base Commander authorized events to equipment breakdowns.

Field-Related Data

It was originally planned to assess the possible impact of simulator training on actual job performance. As previously discussed (rf. p. 27), differences in job performance as a function of training equipment would be obscured by the variable nature of OJT. To circumvent this problem, we developed a paper-and-pencil test as a predictor of future job performance. This instrument was administered on the test day immediately following 6883 training.

Subsequent to permanent field assignment, all technicians who participated in this evaluation project and their field supervisors completed follow-up questionnaires. Since former students could be assigned to any one of three work shifts or were on temporary leave for medical or educational reasons locating them was itself a

difficult task. Field personnel were instrumental in this aspect of the data collection effort. They assumed the responsibility of distributing the questionnaires and forwarding all information to DRI. Generally, the technicians and their supervisors completed the questionnaires at their assigned station. Only about 15 minutes of each person's time was required.

Predicting job proficiency. In order to insure the validity of the Projected Job Proficiency Test, a criteria of job proficiency was established. Questions were solicited from supervisors which they felt would reflect what is expected of newly trained personnel. A total of 75 questions (and answers) were received. From these and questions obtained from Lowry AFB instructors, a 70-item pencil-and-paper test of job proficiency was developed (Section A-4 of Appendix A). Since time constraints did not permit pretesting the instrument on student populations prior to implementation, the following precautions were taken: (1) the test instrument was shown to ATC instructor personnel and the 6883 curriculum supervisor for comments regarding the applicability and validity of the questions utilized, and (2) an item analysis capability has been incorporated into the data collection instrument to permit an item analysis of the test instrument. Prior to implementation, the test instrument required only one modification, as suggested by ATC personnel.

Field technician survey. To generate field performance data, the originally proposed field performance task was replaced with an interview questionnaire. Technicians who had participated in the evaluation program and were subsequently assigned to the field were asked to rate the adequacy of their ATC F-111 training and its relationship to their field work. Those technicians who had contact with the simulator during training were asked specifically to rate the adequacy of simulator training. Section A-5 of Appendix A includes this questionnaire.

Field supervisor survey. Technicians in OJT are assigned a supervisor who assists them in becoming familiar with the responsibilities of field assignments and who rates their performance during the OJT period. The supervisor may work at the assigned test station with the technician or may only be available to answer questions on an as-needed basis. Personnel limitations require that one supervisor be responsible for more than one technician in most cases. These supervisors were asked to rate the performances of technicians in areas of housekeeping, use of testing equipment, knowledge of LRU and TRU circuit flow and operation, and trouble-shooting initiative. There were a total of 25 items on which each technician was rated.

As originally planned, former students were to be rated after three, six, and nine months of field experience. It was felt, however, that by six, certainly by nine months, any effects of training would have been diluted by formal OJT and practical experience obtained in the field. Thus, field follow-up data were collected in September and

October 1979 (after 2-20 weeks of field experience) during on-site interviews by DRI staff. In January 1980 (after 2-34 weeks of field experience), data was again collected on all students using a mail questionnaire. Treating time in the field as a continuous variable allowed us to examine performance differences as a function of time. The supervisor rating form is included as Section A-6 of Appendix A.

Cost-Related Data

A comparison of life cycle costs associated with the 6883 simulator and AET--under the assumption of equal training effectiveness--was conducted to determine which trainer was more cost-effective. Since the 6883 simulator is one of the first such devices introduced into the intermediate level maintenance training environment, this analysis will also serve as a point of reference for a discussion of simulation options available in Air Force maintenance training.

The question of which trainer is more cost-effective can be complicated when different training equipment utilization patterns for the simulator and AET also produce differences in training effectiveness. For example, the more costly equipment alternative might still be the most cost-effective because the equipment, together with its utilization strategy, produces proportionately greater training effectiveness.

These complications were not encountered in the evaluation because the total training environment was not disturbed by the introduction of the simulator. That is, with the introduction of the simulator, no new training strategy was imposed which could have been expected to result in differences in training effectiveness. Thus, the comparison of only the life cycle costs of the two equipment items is a realistic way to establish which of the trainers is more cost-effective.²

²It should be noted that the term, "cost-effectiveness," is used here in a limited sense: . . . "which of two or more equivalent training systems has the least total cost of ownership." The notion of cost-effectiveness of simulation in training is a broad concept that presumes (a) equal effectiveness of both simulators and actual equipment trainers and (b) that student performance can be gauged by objective performance criteria associated with student task performance on the actual equipment. In this context, cost-effectiveness analysis of simulation training would include a determination of the marginal utility of the simulator; that is, at what point does greater use of the simulator no longer reduce training costs for the simulator-AET combination. Orlansky and String (1977) develop this important topic in their review of Cost-Effectiveness of Flight Simulators for Military Training. This issue is not engaged in the present cost analysis because the amount of training could not be systematically varied (for institutional reasons), nor could student performance of trouble-shooting tasks be ascertained using existing Air Force performance criteria. This assessment is not intended to be a criticism, rather it is a comment on the maturity of simulation development for the maintenance training field.

Life cycle cost comparison. The approach taken to the development of the life cycle cost comparison considers that the simulator is a replacement alternative to AET. The respective cost streams for each of the trainers were calculated for a projected 15-year life. Since the comparison used 1978 as the reference year, AET costs incurred prior to 1978 were adjusted according to the annual inflation rate to establish investment costs in 1978 dollars. Operating costs were discounted at 10 percent annually to establish net present value in 1978 dollars.³ Figure 5 displays the framework for cost comparison and the major categories for which input data were acquired.

Cost Categories	Simulator	AET
Facilities		
Equipment		
Industrial Materials		
Personnel		
Students		
Miscellaneous		
TOTAL (construction \$)		
NPV (1978)		
Cost Effectiveness (\$ per student-hour)		

Figure 5. Life Cycle Cost Comparison Framework

Related cost models. Two studies concerned with the cost of training systems have been particularly useful in this work. The Naval Training Analysis and Evaluation Group (Braby, Henry, Parrish, & Swope, 1975) developed a cost model which included methods for evaluating the elements in each cost category shown above. A computer program for calculating total training cost was also provided. The TAEC model and its cost element estimation procedures would have been used in this work except for two drawbacks: (1) the model contains insufficient detail concerning the equipment acquisition life cycle phase that was considered important here, and (2) the emphasis given the TAEC model was one of predicting costs of alternative systems for the purpose of cost minimization and not for predicting total costs of system ownership.

³This discount rate is consistent with OMB Guidelines (Circular A94).

The Air Force Human Resources Laboratory, Wright Patterson AFB (Eggemeier et al., 1979) completed a life cycle cost estimation for F-16 simulated and AET equipment maintenance training systems in which they used the Braby model as a starting point. In addition, they incorporated a logistics support cost model to estimate elements in the equipment cost category. The latter model was originally developed by the Simulator System Program Office (SPO) to estimate costs for aircrew simulators. The principal value of the logistics support model is that it can be used to estimate certain cost elements based on functional relationships derived from historical acquisition data. This technique was helpful in the present study for estimating sustaining investment costs associated with the 6883 AET operation. In addition, the F-16 analysis also provided guidance in estimating elements in other cost categories. These cost elements were directly related to ongoing efforts since F-16 training will be conducted at Lowry AFB when these trainers become available.

Thus, the cost model presented in this study is perhaps best thought of as a method for organizing and tabulating cost elements ("ingredients") for which historical data are available. The sources of the historical data for the AET station used in this cost comparison included the 3450th TTG Avionics Branch and the Logistics Support Group (Lowry AFB). The sources of data for the simulator include AFHRL/TT (technical monitor for the simulator contract) and the manufacturer of the simulator.

Data Management

After students completed their F-111 training and performance data were collected, coding forms designed by DRI were completed and the data were entered into a computer tape file for subsequent analysis. At this point, all data except field follow-up data had been collected for each student.

The data collected regarding training deviations, training received, unscheduled maintenance, and personal interviews were also organized for analysis by DRI. When the evaluation period was concluded, the impact of these various factors on training and performance was assessed.

Field follow-up data were collected and checked against a list of the technicians, their base assignments, and length of time in the field. A search was initiated to find those technicians who were not at the base to which they were assigned at graduation.

CHAPTER 5

RESULTS AND DISCUSSION

The primary focus of this cost and training effectiveness evaluation was to examine classroom and field performance as a function of training mode (AET or simulator) and to assess the costs of using the alternative types of training equipment. This chapter provides a discussion of all evaluation findings together with the outcome of all supporting analyses undertaken.

Preliminary Analyses

In order to insure that any observed differences in student performance could be attributed to the training equipment used, it was necessary to consider two possible sources of confounding: training sequence and pre-existing student differences.

Impact of Training Sequence on Performance

Variations in the sequence of training on the 6883 and 6886 test stations were inherent in the ATC environment. Although testing followed both segments of training, for some students 6886 training preceded both 6883 training and subsequent DRI testing, for others, it occurred between 6883 training and the testing. To control for possible 6886 interference, this factor was therefore added to the basic experimental design, resulting in two levels each of training mode, testing mode, and training sequence.

Failure of the 6886 test station equipment late in the experiment made this scheme less tenable, for 21 of the 115-student sample did not receive any 6886 training. Two solutions to this problem were considered. One was to add a third level of the training sequence factor and call it "none." It was decided, however, that adding a third level to the training sequence variable would result in a loss of statistical power without contributing to the analysis of interference effects. The more viable approach taken was to examine the impact of training sequence independent of the 21 students who received no training on the 6886 test station. If there were no apparent differences in student performance as a function of training sequence and if all three types of sequence were equally distributed across training/testing modes, then it would be reasonable to collapse across the sequence factor for all remaining analyses.

Table 3 presents descriptive statistics for the three overall trouble-shooting test measures--total test score, total time to test completion, and a rating of the degree of assistance required--as a function of training sequence and experimental conditions. Note that

TABLE 3

Overall Trouble-Shooting Test Proficiency as a
Function of 6883-6886 Training Sequence and
6883 Training/Testing Mode

			Mode of Training-Testing			
			Actual/ Actual	Actual/ Simulator	Simulator/ Actual	Simulator/ Simulator
Total Test Score	6886 then 6883	N $\bar{x}$ σ	12 24.08 1.56	12 22.25 1.48	9 23.33 1.50	12 22.75 1.66
	6883 then 6886	N $\bar{x}$ σ	10 23.00 2.26	10 23.40 1.65	11 23.27 0.90	13 22.92 1.66
Total Time	6886 then 6883	N $\bar{x}$ σ	12 52.67 11.11	12 61.50 8.04	9 48.22 4.97	12 58.08 8.89
	6883 then 6886	N $\bar{x}$ σ	10 47.50 6.64	10 56.80 8.31	11 57.64 7.86	13 55.31 11.09
Assistance Required	6886 then 6883	N $\bar{x}$ σ	12 2.21 0.80	12 2.25 0.62	9 1.67 0.71	12 2.33 0.78
	6883 then 6886	N $\bar{x}$ σ	10 2.20 0.63	10 2.10 0.74	11 2.64 0.67	13 2.31 0.75

*For the three dependent measures shown the main effect of training sequence was not significant.

there is a discrepancy between the reported sample size of 89 and the 94 students who actually participated in the study. This difference resulted from the fact that five students solved the experimental problem prematurely--they detected the blown fuse without proceeding through the required steps. In such cases, data were recorded for the particular items completed, but these students were not included in analyses of overall proficiency.

Subsequent two-way analyses of variance on these data revealed no significant main effects of sequence $F(1,81) < 1$ for both total score and time to completion. Nor were the ratings of degree of assistance required distributed unequally between 6886-first and 6883-first training sequences ($\chi^2(2) = 1.251$, $p = .535$). The lack of relationship between training sequence and overall performance was even more apparent when point-biserial correlations were computed. The coefficients relating sequence to total score, total time, and assistance were .015, -.059, and .116, respectively. It seems reasonable to conclude that intervening 6886 training had no appreciable effect on experimental testing.

The second important consideration was whether or not the final three sequence levels (6886-first, 6883-first, and none) were distributed equally across the four experimental conditions. If not, it might be argued that the presence or absence of 6886 training per se could influence the findings. A tabulation of the actual and expected frequencies of students across conditions is provided in Table 4. Using a chi square analysis, no evidence was found to suggest that levels of sequence were distributed unequally across the training/testing modes ($\chi^2(6) = 5.533$, $p = .477$).

In summary then, the potential interference of intervening 6886 training upon 6883 performance was not substantiated. The three levels of training sequence obtained appear unrelated to the four critical experimental conditions. Since some change in the evaluation design was necessitated by the 6886 training deviations and the expansion of the sequence factor to three levels would add little while reducing statistical power, training sequence was ignored as a factor in all subsequent analyses.

Tests for Bias in Group Assignments

Having eliminated training sequence from further analyses, it was necessary to determine if any meaningful pre-existing differences existed between students assigned to the four remaining experimental conditions. The biasing factors considered were sex, aptitude, and achievement in prior training blocks.

Bias due to sex. Although it is difficult to predict just how the training and testing modes might differentially affect men and women, sex was considered an important factor in any possible biasing.

TABLE 4

Distribution of Students Across Experimental Conditions
as a Function of Eventual 6886/6883 Training Sequence.

		Mode of Training-Testing				Total
		Actual/ Actual	Actual/ Simulator	Simulator/ Actual	Simulator/ Simulator	
Training Sequence	6886 then 6883	14(12)	12(12)	9(11)	12(11)	47
	6883 then 6886	12(12)	10(12)	11(11)	13(11)	47
	none	3(5)	7(5)	8(5)	3(5)	21
	Total	30	29	28	28	115

Note: Expected frequencies for each cell are in parentheses.

Table 5 presents the distribution of students across experimental groups by sex. Not surprisingly, a chi square analysis of these data failed to show any significant relationship between sex and group assignment ($\chi^2(3) = 2.637$, $p = .451$). Thus, there is no reason to believe that males and females were unequally distributed among experimental groups.

Bias due to inherent ability. Perhaps a more pertinent question is whether or not these groups of students differed in their basic abilities. Two sets of test scores were used to address somewhat different aspects of this question. The first set of scores included the results of five standard Air Force screening instruments used to measure student aptitudes. A one-way analysis of variance was completed for each type of score by assignment level and the resulting values are presented in Table 6.

A word of caution must be offered with regard to interpreting the exact probability levels reported. Despite the fact that these scores cannot be considered truly independent because the same students produced the scores for each measure, some adjustment must be made to avoid capitalizing on chance. Miller (1966) suggested that even when such multiple tests are not independent, a significance level of α/n (where α = some probability and n = the number of tests performed) on each test will guarantee, with a probability of at least $1 - \alpha$, that no true null hypothesis will be rejected (Fisher's method of adjustment). For the present situation, then, this method suggests that the meaningful significance level should be $.01(.05/5)$.

Admittedly, this approach is rather conservative, especially for the purposes of identifying possible biasing factors. If Fisher's adjustment is not used, however, less weight must be given to an occasional significant result if it occurs along with a number of results that are nonsignificant. Thus, the marginally significant difference ($p = .09$) between groups on AFQT scores is of dubious importance.

Rather than dismiss this finding out of hand, however, a correlational analysis was performed to determine to what extent, if any, these AFQT scores were related to the three primary experimental performance measures. The resulting correlation coefficients were .065 for total test score, $-.176$ for total time to completion, and $-.143$ for the degree of assistance required. These correlations are not significant even at $p = .1$ ($df = 80$). Thus, any difference in aptitude, as measured by the AFQT, is not related to subsequent trouble-shooting performance.

Bias due to prior achievement. Even more directly related to the issue of student ability and group assignment was the second set of measures which was comprised of the 11 prior block scores obtained during avionics training. Practical test scores for the Electronics System TS and Converter-Flight Control TS instructional blocks were

TABLE 5

Observed and Expected Frequencies of Males and Females
by Experimental Training/Testing Modes

Mode of Training/Testing	Male Students	Female Students	Total
Actual/Actual	27(26)	3(4)	30
Actual/Simulator	23(25)	6(4)	29
Simulator/Actual	26(27)	2(4)	28
Simulator/Simulator	24(24)	4(4)	28
Total	100	15	115

Note: Expected frequencies are in parentheses.

TABLE 6

Aptitude Scores as a Function of Experimental Group

Aptitude Test		Mode of Training/Testing				F-Ratio
		Actual/ Actual	Actual/ Simulator	Simulator/ Actual	Simulator/ Simulator	
General	N	29	28	27	28	1.13 (p= .34)
	$\bar{x}$	87.2	83.0	83.9	81.8	
	σ	9.0	11.6	11.7	13.6	
Mechanical	N	29	28	27	28	.1
	$\bar{x}$	79.0	74.1	75.7	74.3	
	σ	16.8	17.2	18.9	19.6	
Admin.	N	29	28	27	28	.1
	$\bar{x}$	76.7	73.6	73.0	73.9	
	σ	16.8	19.8	18.7	17.6	
Electronics	N	29	28	27	28	.1
	$\bar{x}$	88.1	86.2	87.4	88.6	
	σ	7.9	5.8	5.0	5.2	
AFQT	N	25	22	20	22	2.20 (p= .09)
	$\bar{x}$	81.7	75.3	80.4	74.3	
	σ	10.4	11.6	11.8	12.5	

omitted from further study since *all* students received a grade of "satisfactory." The remaining nine scores were included in an analysis of variance (Table 7).

The argument made above concerning significance levels must again be considered when interpreting these findings. Since nine tests were made, Fisher's method suggests that a functional alpha-level of .006(.05/9) be used. By this criterion, no significant differences in group assignment were found as a function of prior achievement. However, for purposes of identifying bias, those block scores with marginal differences warranted further investigation. Specifically, correlations were computed between the experimental dependent measures and the Data Logic and CATE block scores. For total test score, the correlations with Data Logic and CATE scores were .143 and .005, respectively; for total time to completion they were -.177 and -.176; and for the degree of assistance required they were -.017 and -.157. Since these correlations are not significant at $p = .1$ ($df = 80$), there is no evidence that these prior achievement measures are related to performance on the experimental task.

To summarize, three factors were considered as sources of possible bias in the assignment of students to the four training/testing conditions of this study: sex, aptitude, and prior ATC performance. The groups did not differ significantly on any of these measures. Further correlational analyses showed that even in those cases where it might be argued that a slight bias existed, variables were not meaningfully related to performance on the trouble-shooting test.

Analysis of Trouble-shooting Performance

A central issue to be addressed by this investigation was whether simulator and actual equipment training would result in equal levels of student performance on a practical trouble-shooting problem as might be encountered in the field. Because of stringent selection criteria used for entry into avionics technician training, it was not surprising to find that students were fairly homogeneous with respect to their prior performance in the program. Neither could marked differences in subsequent performance be expected after such a brief training manipulation. Thus, the test developed to isolate any training differences had to be particularly sensitive to differences in the training equipment (rf. pp. 26-27). To reiterate, the test consisted of a timed, serial, hands-on 29-item task which allowed three overall dependent measures of performance: a total score, the total time necessary for test completion, and a three-point rating of the degree of assistance required for test completion.

Trouble-shooting as a Function of Training/Testing Modes

Table 8 summarizes performance as a function of training and testing modes.

TABLE 7

Previous Block Scores as a Function of Assignment
to Experimental Training/Testing Conditions

Prior Block		Mode of Training/Testing				F-Ratio
		Actual/ Actual	Actual/ Simulator	Simulator/ Actual	Simulator/ Simulator	
Fundamentals of Electronics	N	30	29	28	28	< 1
	$\bar{X}$	89.6	88.6	90.1	89.8	
	σ	6.71	4.92	7.28	5.81	
Introduction to Avionics Age Principles	N	30	29	28	28	1.23 p = .30
	$\bar{X}$	90.3	89.9	90.6	87.5	
	σ	6.43	6.74	6.41	6.81	
CENPAC	N	30	29	28	28	< 1
	$\bar{X}$	84.9	82.2	85.6	84.5	
	σ	10.16	11.14	9.68	9.22	
DATAC	N	30	29	28	28	< 1
	$\bar{X}$	85.3	85.1	87.1	82.1	
	σ	12.01	10.12	10.38	11.64	
Data Logic Anal- ysis of Counter Timer & Power Supplies	N	30	29	28	28	2.88 p = .04
	$\bar{X}$	84.2	82.5	89.1	86.2	
	σ	9.50	9.38	8.70	7.49	
CATE	N	30	29	28	28	3.62 p = .02
	$\bar{X}$	89.7	84.5	89.4	84.1	
	σ	8.31	8.85	6.94	9.35	
Navigations & Weapons Deliv- ery TS	N	30	29	28	28	< 1
	$\bar{X}$	87.3	89.4	88.8	88.0	
	σ	10.38	9.05	9.73	8.25	
Electronic Systems TS	N	30	29	28	28	1.58 p = .20
	$\bar{X}$	92.0	87.2	89.6	87.6	
	σ	8.49	9.63	9.33	9.88	
Converter Flight Control TS	N	30	29	28	27	< 1
	$\bar{X}$	87.1	85.8	87.0	86.0	
	σ	9.37	10.68	11.13	11.75	

TABLE 8

Overall Trouble-Shooting Test Proficiency as a
Function of Training and Testing Modes

Test Mode			Training Mode	
			Actual TS	Simulator
Total Test Score	Actual	N $\bar{X}$ σ	24 23.56 1.86	28 22.82 1.47
	Simulator	N $\bar{X}$ σ	29 22.66 1.56	28 22.86 1.53
Total Time in Minutes	Actual	N $\bar{X}$ σ	24 50.21 9.14	18 53.75 7.72
	Simulator	N $\bar{X}$ σ	29 58.10 7.81	28 55.93 9.66
Instructor Assis- tance Required	Actual	N $\bar{X}$ σ	24 2.24 .66	28 2.29 .85
	Simulator	N $\bar{X}$ σ	29 2.24 .64	28 2.29 .71

While all 115 students may have completed any particular test item, only 109 overall test scores are shown. This is due to the method of scoring the test. For those students who were able, for whatever reasons, to isolate the cause of the malfunction (the blown fuse) without completing all of the intermediate steps, no overall measures were recorded. Instead, data for the items completed were included only insofar as they were in correct sequential order. It is interesting that all six students who prematurely detected the blown fuse were in the actual equipment test situation where the fuse holder was necessarily activated prior to the test. Also, all six had been trained on the actual 6883 test station and this finding may reflect their familiarity with actual test station operation, experience with blown fuses, or possibly the importance of fidelity between training and testing equipment in general.

Three hypotheses were of particular interest:

1. Students trained on the 6883 simulator and the 6883 test station are equally accurate in solving trouble-shooting problems.
2. Students trained on the 6883 simulator and the 6883 test station are equally efficient in solving trouble-shooting problems.
3. Students trained on the 6883 simulator and the 6883 test station operate the actual test station with equal proficiency.

To test the first hypothesis, a two-way analysis of variance was performed on the test score data with training and testing modes as the independent variables. The main effects of both variables were nonsignificant ($F(1,105) < 1$) for training and ($F(1,105) = 1.099$, $p = .15$) for testing) as was the interaction ($F(1,105) = 2.449$, $p = .12$). Thus, there was no evidence to suggest that training differentially affected accuracy of trouble-shooting.

The second hypothesis, regarding problem-solving efficiency, was tested by submitting the total completion time measure to an analysis of variance similar to that for total scores. No main effect of training was revealed ($F(1,105) < 1$) but a significant testing main effect ($F(1,105) = 9.312$, $p = .003$) and a marginally significant interaction ($F(1,105) = 2.999$, $p = .086$) were found. That is, regardless of training mode, students took longer if tested on the simulator than if tested on the actual 6883 test station; this effect was somewhat more pronounced for actual test station than for simulator trained students. It is interesting to note that this pattern of results was also obtained for total test scores as summarized above, although the effects were not statistically significant.

Based upon observation, there were two possible factors involved in this finding. First, the simulator was slower to respond to student input than the actual 6883 equipment, and thus, testing on the simulator resulted in slower overall completion times, even for those familiar with the equipment. Simulator-trained students who were tested on the actual test station did not immediately take advantage of the slightly faster test station as did actual equipment-trained students. Second, because of this difference, the actual equipment-trained students learned to respond quickly. Therefore, when transferred to the simulator for testing, more errors (increased time) were made until the student became familiar with the difference in machine responses. This impression was not always consistent with item error rates since mistakes that were corrected prior to step completion were not counted as errors. For instance, if a student entered a test number too quickly for the machine to record it properly, but corrected the error before pressing "test request," no error was noted. The pattern of partial test times lends some credence to this notion. There was a difference of 7.89 minutes in total test time between actual-trained students who were tested on the actual and simulated equipment, but 6.34 minutes of this time had already accrued by the 19th test item.

Hypothesis #3 required an examination of the simple main effect of training at the actual equipment level of testing. Completion times for this actual/actual versus simulator/actual comparison did not differ significantly ($F(1,105) = 2.193$, $p = .14$) while there was a marginal difference in total test scores ($F(1,105) = 2.903$, $p = .09$). That is, actual-trained students scored slightly higher on actual equipment testing than simulator-trained students. This effect is minor, though, and may be the result of machine-specific experience rather than qualitative differences in training. It seems entirely plausible, for example, that students would be more nervous being tested on the real test station if their only experience had been with a simulator where errors are not as serious.

A brief examination of the degree of assistance required was carried out despite this measure's lack of sensitivity. The group means reported in Table 8 are extremely similar and a chi square analysis showed no evidence that ratings were related to experimental conditions ($\chi^2(6) = 9.63$, $p = .14$).

In sum, then, simulator- and AET-trained students did not differ appreciably with respect to overall trouble-shooting ability as measured by the practical test. A very slight advantage in test accuracy was found for actual- as opposed to simulator-trained students tested on the actual 6883, but this finding was not mirrored using completion time as a measure. The simulator proved to be a somewhat slower testing device which caused some interference for actual-trained students.

Training, Testing, and Specific Trouble-Shooting Test Item Analysis

Table 9 includes the error rates for each of the 29 items on the experimental trouble-shooting test as a function of training and testing modes. A review of the data suggests the following observations:

- Of the five safety errors committed (item #1), four were made by simulator-trained students and the fifth was made during a simulator testing session. This finding suggests that students may have failed to perceive the simulator as an actual test station. Special efforts should be directed toward ensuring that safety is not compromised by this apparent difference in attitude.
- Seventeen of the 27 errors involving entering test numbers (items #2, #6, and #9) were committed during simulator testing. This was most likely the result of the simulator's somewhat slower response time noted previously or a lack of sensitivity in the simulator pushbuttons.
- No errors were made on item #5, since the completion of this step was entirely a matter of automatic sequencing. This item was excluded from determination of the total test score.
- Students had particular difficulty with item #18--rerunning the test by returning to the previous "0-ending" test number. The higher error rates for students tested on the simulator again suggest that the poor response of the equipment may be responsible. Both the AET and simulator had a test-repeat option button which did not require returning to the previous "0-ending" test number. Students trained on the actual equipment often selected this option, which works but is not preferred in this case. This was recorded as an error.
- Students trained on the actual equipment were more likely to suspect a test station fault and were better able to apply the appropriate procedure (items #22-#25). This difference may be the result of different amounts of experience with test station malfunctions or related to the notion that the simulator is not a real test station and, therefore, not prone to malfunctions. In general, decoding the fault isolation proved to be a difficult task for students.
- As items #28 and #29 indicated, students tested on the actual equipment did not offer alternative explanations for the test station failure. This was related to the

TABLE 9

Error Rates by Experimental Condition for Trouble-Shooting Test Items

Item #	Mode of Training/Testing			
	Actual/ Actual	Actual/ Simulator	Simulator/ Actual	Simulator/ Simulator
1.	.00	.03	.04	.11
2.	.03	.03	.11	.04
3.	.03	.14	.07	.11
4.	.07	.14	.00	.04
5.	.00	.00	.00	.00
6.	.10	.24	.00	.21
7.	.00	.00	.11	.04
8.	.00	.00	.00	.00
9.	.03	.03	.07	.04
10.	.03	.03	.04	.04
11.	.00	.00	.00	.00
12.	.00	.03	.00	.00
13.	.00	.00	.00	.00
14.	.00	.00	.00	.04
15.	.00	.00	.00	.04
16.	.07	.07	.03	.07
17.	.04	.03	.04	.07
18.	.24	.41	.21	.18
19.	.08	.00	.00	.00
20.	.12	.10	.18	.18
21.	.04	.10	.14	.04
22.	.29	.31	.39	.25
23.	.42	.69	.82	.71
24.	.38	.59	.57	.79
25.	.54	.69	.64	.82
26.	.08	.14	.07	.04
27.	.13	.17	.04	.00
28.	.83	.41	.82	.32
29.	.08	.24	.11	.14

fidelity issue since the lighted fuse holder, visible on the actual equipment, was not available on the simulator until very late in the testing schedule. Thus, actual tested students saw the problem more quickly and did not need to pose alternatives. Due to instructor involvement, the intent of this item was not realized. That is, regardless of a correct solution, students were required to be asked about alternatives by instructors, but were not.

Two general comments might be made with respect to the foregoing observations. First, a number of errors and differences in error rates appear attributable to differences in the testing equipment. Second, and more important, the pattern of errors suggested that students may treat the simulator as something less than a real test station. This has important implications for teaching safety and test station maintenance.

User Acceptance

Another element of this evaluation was to obtain an indication of the utility and adequacy of simulation training from two perspectives; students and instructors. The results of the survey of each group are discussed below.

Analysis of Student Interview Data

A two-person testing situation had originally been proposed to assess training effects on student attitudes and abilities in the absence of supervision. Specifically, the following hypothesis was proposed: personnel trained on the 6883 simulator and 6883 test station are equally familiar and comfortable in operating the actual test station without supervision. While this methodology was not implemented due to low student availability and logistical problems, an attempt was made to address this question indirectly via student interviews. Eighty-six percent of simulator-trained and 92 percent of actual-trained students reported "feeling comfortable" operating the equipment. This difference between groups was not significant ($\chi^2(1) = 1.395, p = .5$). In general, both groups of students felt that they understood the equipment's operation (80 percent vs. 88 percent) and that they were prepared to handle trouble-shooting tasks in the field (58 percent vs. 66 percent). Additionally, there were no differences in student attitudes concerning their perceived level of competence, opinions about the 6883 block, or machine-specific preferences as a function of training mode. Despite variability of training associated with AET and the simulator, students were just as likely to say that the simulator or actual equipment training was routine (30 percent and 32 percent, respectively). This latter point was particularly surprising in light of the dramatic difference in the number and variety of lessons offered in the two training modes.

These observations suggest that student attitudes were not particularly relevant to the issue of simulator effectiveness. Because the experimental manipulation was introduced early in the course and for a short time (2-3 days), students simply did not have enough experience to evaluate the training methods used. This highlights the critical role of instructor attitudes about the use of simulators in training on their subsequent effectiveness. Since students had not yet developed the necessary frame of reference, they were most likely to rely upon the experiences and opinions of their instructors to form attitudes toward the simulator training equipment.

Analysis of Instructor Survey Data

Twenty F-111 instructors at Lowry ATC were surveyed regarding their teaching experience, field experience, attitudes about simulated training in general, and opinions about the 6883 3-dimensional simulator specifically. The results of the questionnaire are shown in Table 10.

Only three of the instructors surveyed had taught 6883 theory and only two had taught 6883 practical during 1979. The 3-dimensional simulator was used exclusively in the 6883 block of instruction; therefore, very few of the F-111 instructors had any contact with the simulated trainer as an instructional instrument. In fact, only six instructors had seen a demonstration of the simulator, and only one had used it as a regular part of his/her teaching. The average length of time as an instructor at Lowry ATC was 15.9 months, although the range of time was from one to 48 months.

Only limited data were available to assess the impact of the use of the simulator on training methods. The six instructors who had some contact with the equipment commented as follows: two reported becoming aware of weaknesses in the course materials and their own teaching methods; three claimed to have changed their emphasis on various aspects of the course material; and one respondent indicated that he requested that changes be made in the Plan of Instruction (POI) for other block(s) based on the lesson materials utilized on the simulator. Additionally, instructors commented that the simulator was too slow in response time, lacked well-designed software, and was accompanied by poorly organized technical manuals. Instructors did, however, expect that simulators would replace many AETs in the future.

Estimation of Field Preparedness

Two methods were used to assess the impact of training mode on student acquisition of field-relevant skills. One analysis dealt with the results of the Projected Job Proficiency Test (PJPT) which was administered to all students at the conclusion of the 6883 instructional block. As discussed previously in this report, the PJPT was

TABLE 10
Results of Lowry ATC F-111 Instructor Questionnaire

Questions	Scale Score*
Simulator training is a good idea.	2.5
Simulator training can be more effective than actual equipment training.	3.0
Simulator training can provide training equivalent with actual equipment training.	2.7
Simulated trainers must be highly similar to actual equipment to be effective.	2.0
Simulated trainers can provide adequate training at a cost savings.	2.9
Simulated training allows for more complexity of training.	2.9
Simulated trainers are more reliable than actual equipment.	2.2
Simulated trainers teach safety procedures better than actual equipment.	2.8
Simulated trainers provide more variety of training than actual equipment.	2.9
Simulated training is something I would use as an integral part of my teaching program.	2.5
Important aspects of simulated training equipment include:	
The complexity of the equipment.	2.5
The capability of the software to meet STS and Air Force objectives.	1.9
A lower cost of hardware and operating expenses compared to actual equipment.	1.8
A high degree of similarity of the simulated equipment to the actual equipment.	1.6
A savings in the time required for training.	2.5
The degree of Air Force personnel control over the design of the equipment.	1.9
The capability of Air Force personnel to modify existing or to create new lessons for the simulator.	1.8
The mobility of the equipment.	3.2
The reliability of the equipment.	1.4
The ease of maintenance of the equipment.	1.5
The ability to monitor student performance.	1.6
The ease of use for the instructional staff in presenting training materials.	1.8
Responses of those who had some experience with the 3-D simulator:	
The hardware is too simple for the simulator to be an effective training instrument.	3.3
The software is well designed for instructional purposes.	2.5
The lessons meet STS and course objectives.	2.3
Students appear to regard the simulator as performing as an actual test station.	3.0
The simulator is a better training instrument than the actual test station.	2.7
I have used/will use the 3-D simulator as an integral part of my teaching program.	2.9

*The scale used was a five-point scale where 1 = agree strongly and 5 = disagree strongly.

specifically developed for this purpose (rf. p. 38). Since subsequent instructional blocks included training components similar to those in OJT, student performance in those blocks also indicated field preparedness. Therefore, the second analysis examined the results of AF-administered achievement tests for these later blocks.

Projected Job Proficiency as a Function of Training Mode

The PJPT was a paper-and-pencil test that included two sections: 32 short-answer completion items (Part I) and 38 four-alternative choice items (Part II). Each completion item was worth one point toward the total score, although partial credit was awarded for some answers. Table 11 summarizes the PJPT results as a function of 6883 training and includes the results of two one-way analyses of variance. The small sample sizes reflect the fact that this test was developed subsequent to project start-up.

TABLE 11
Field Criterion Performance Test Results as a Function
of 6883 Instructional Training

		Training Mode		F-Ratio
		Actual	Simulator	
Short Answer (Part I)	N	45	34	<1
	$\bar{x}$	13.89	13.99	
	σ	5.46	5.57	
Multiple Choice (Part II)	N	45	34	<1
	$\bar{x}$	23.91	22.97	
	σ	3.65	4.68	

The primary hypothesis to be tested with this measure was that students trained on the 6883 simulator and the 6883 test station acquired equivalent job-related experience. This hypothesis was not rejected when PJPT scores were the dependent measure. However, a number of contributing factors may have made this measure less sensitive than desired.

In general, the test was long and difficult. This was particularly apparent from the Part I (administered after Part II) results, where the low scores typically reflected a failure to finish the test within the three hours allotted. Part II scores were also low, suggesting that the test's difficulty may have had a discouraging effect on student performance from the outset. Another problem was that guidelines were not made explicit with respect to guessing on the Part II items. Presumably, some students did select their best guess when

unsure of an answer, yet the fact that others left some items blank suggests that not all students were using that strategy.

Subsequent Classroom Performance as a Function of 6883 Training

Another facet of assessing possible training effects on job-related abilities was the analysis of subsequent instructional block scores. It was anticipated that practical blocks would be particularly sensitive to simulator versus actual training experiences in the 6883 block and also most similar to the eventual field training situation. Four of the nine subsequent training blocks were practical, but no training differences could be found since *all* students receive a grade of "satisfactory" in each. The failure of this data to detect any differences seems attributable to two methodological constraints. First, the method of practical block evaluation (satisfactory-unsatisfactory) was not sufficiently sensitive, especially for such a homogeneous sample of students. Second, seven students were deviated out of the final two practical blocks and all seven had been simulator-trained on the 6883.

Since practical blocks offered no useful data, performance in subsequent theory instruction blocks was examined as an alternate means of assessment. Table 12 presents the mean block scores for the five theoretical courses as a function of 6883 training mode. A series of one-way analyses of variance showed no training differences in these scores and these findings were reflected by the low training score correlations reported. In brief, then, students seem to perform equally well on subsequent instructional blocks whether trained on the 6883 3-dimensional simulator or the 6883 test station

Assessment of Field Performance

To determine whether simulator- and actual-trained technicians were equally capable of operating F-111 automatic test stations in the field, subjective ratings of each technicians's performance were collected from both the technicians themselves and their supervisors. The abilities of those students assigned to 6883 and 6873 equipment were of particular interest. Since the impact of 6883 training mode might be expected to change with experience, two field follow-up surveys were conducted, the first in September/October 1979 and the second in January 1980.

Student Follow-up Surveys

Table 13 presents mean technician ratings for each of the 12 survey questions as a function of 6883 ATC training mode and time spent in the field. Eighty-five technicians were included in at least one follow-up and 56 were included in both surveys. Although 115 students participated in the DRI evaluation, a number of them could not be

TABLE 12

Correlation Coefficients Relating Training to Subsequent
Instructional Block Performance

Instructional Block		Training	Mode	r
		Actual	Simulator	
Computer TS	N $\bar{x}$ s	39 90.69 7.68	36 91.28 10.33	-.032
Attitude & Rate TS	N $\bar{x}$ s	39 89.72 7.41	35 87.69 6.53	.143
Displays TS	N $\bar{x}$ s	20 90.40 8.56	20 91.05 5.58	-.045
Video TS	N $\bar{x}$ s	59 90.03 7.46	55 89.85 6.34	.013
Radar-Transmitter Modulator TS	N $\bar{x}$ s	57 92.46 6.29	54 90.37 8.19	.142

TABLE 13

Mean Technician Field Questionnaire Ratings by 6883 Training Mode
and Approximate Amount of Field Experience*

Technician Follow-up Questionnaire Item	6883 Training Mode	Weeks of Field Experience							
		0-4	5-8	9-12	13-16	17-20	21-24	25-28	29-32
Comfortable with current TS equipment	Simulator	(3.7)	3.7	4.1	4.8	4.3	4.6	4.0	4.1
	AET	(3.0)	4.4	4.6	4.3	4.1	4.2	4.0	(4.5)
Adequacy of TOs for TS and LRU trouble-shooting	Simulator	(3.0)	3.4	3.4	2.6	3.2	3.0	3.6	2.8
	AET	(3.3)	3.6	3.6	3.8	3.5	3.0	3.2	(4.0)
Extent to which OJT addresses current needs	Simulator	(3.7)	3.6	4.1	3.6	3.5	3.6	3.8	3.3
	AET	(3.3)	4.3	4.0	3.9	3.9	4.0	3.4	(4.0)
Relevancy of ATC training to current assignment	Simulator	(3.0)	3.0	3.1	2.6	2.9	2.6	2.6	3.0
	AET	(2.8)	2.4	3.4	3.6	2.8	4.2	3.1	(3.0)
Amount of ATC training utilized in current assignment	Simulator	(3.0)	2.9	2.9	3.0	3.1	2.6	2.8	2.6
	AET	(3.3)	3.5	3.2	3.4	3.0	3.0	2.8	(4.0)
Adequacy of ATC trouble- shooting training for current assignment	Simulator	(3.0)	2.1	2.3	2.4	2.5	1.7	3.0	2.3
	AET	(4.0)	2.1	3.0	2.9	2.3	2.9	3.0	(2.5)

*Responses based on a 5-point scale where 1 = Not at All and 5 = Very Much. Mean ratings based on less than 5 technician responses are in parentheses.

TABLE 13 (cont.)

Technician Follow-up Questionnaire Item	6883 Training Mode	Weeks of Field Experience									
		0-4	5-8	9-12	13-16	17-20	21-24	25-28	29-32		
Importance of ATC 6883 training for current assignment	Simulator	(1.7)	2.9	2.9	2.4	1.8	2.1	1.8	1.4		
	AET	(2.0)	2.3	2.1	2.5	1.9	3.0	1.9	(2.0)		
Impact of ATC training deviations on current assignment	Simulator	(2.7)	2.1	2.8	2.0	1.9	1.9	1.6	2.3		
	AET	(2.3)	2.5	1.7	1.6	2.2	2.0	1.8	(2.0)		
Enjoyed interacting with the 6883 training simulator	Simulator	(3.7)	4.4	3.7	2.6	2.8	2.7	3.6	2.1		
	AET**	(2.5)	3.0	3.3	2.8	3.2	(2.3)	(4.3)	(2.5)		
Ability of simulator to copy actual TS operation	Simulator	(3.7)	3.9	3.3	2.8	2.7	2.3	3.4	1.9		
	AET**	(4.0)	4.3	3.2	2.8	3.1	(2.3)	(3.7)	(3.0)		
Superiority of 6883 simu- lator over TS as train- ing instrument	Simulator	(2.7)	3.5	2.7	3.0	2.0	1.9	2.6	1.1		
	AET**	(2.5)	4.3	2.0	2.2	2.4	(1.3)	(3.3)	(2.5)		
Usefulness of simulators for ATC training	Simulator	(2.7)	4.2	3.1	2.4	2.2	2.3	3.4	1.1		
	AET**	(3.0)	4.3	2.8	2.4	3.0	(2.0)	(4.0)	(3.5)		

*Responses based on a 5-point scale with 1 = Not at All and 5 = Very Much. Mean ratings based on less than 5 technician responses are in parentheses.

**Includes only those technicians tested on the simulator following 6883 ATC training.

located for subsequent field assessment due to attrition, reassignment, or inaccurate personnel records. Also, because of the six to eight week time lag between ATC graduation and commencement of actual field duties, the last classes in the DRI sample had not yet had any field experience at the time of the second follow-up.

The data in Table 13 were based on the combined responses from both follow-ups so that a maximum of 141 ratings were obtained per item. When distributed across the 16 training by experience conditions, however, cell sample sizes varied from 1 to 23 observations. Because of this disparity and the fact that 56 technicians were surveyed twice, the data are presented primarily for descriptive purposes. Ratings were fairly consistent within items and appeared generally unrelated to training mode or amount of field experience. A separate consideration of responses provided by 6883 and 6873 technicians was not feasible because of the small number of respondents assigned to those test stations (only 14 in the first and 12 in the second follow-up).

In addition to the questions summarized in Table 13, the technicians were also asked to provide comments on the ATC course structure and the relevancy of ATC course content to their current field assignments. The following opinions were expressed:

- TO familiarity and trouble-shooting skills were cited as the most useful aspects of ATC training.
- Theory portions of ATC training were considered to be of limited use in current field assignments.
- Most respondents felt that ATC provided adequate preparation for OJT, although a variety of suggestions were made to improve the training program. These included increasing hands-on TS operation and trouble-shooting, paying more attention to paperwork and combining theory and practical portions of instruction in a single format.
- Concerning the 6883 simulator, recommendations were made to increase fidelity, decrease sensitivity, and increase keyboard response speed. Several technicians felt that the simulator should not be used as part of training.

Supervisor Follow-up Surveys

Table 14 presents the mean ratings of technician performance as determined by field supervisors for 6883 training modes and amount of field experience. As with the technician ratings discussed above, these data were based on the combined results of two follow-ups and sample sizes varied greatly between cells. Empty cells in Table 14

TABLE 14

Mean Supervisor Field Questionnaire Ratings by Technician Training Mode
and Approximate Amount of Field Experience*

Supervisor Follow-up Questionnaire Item	6883 Training Mode	Weeks of Field Experience									
		0-4	5-8	9-12	13-16	17-20	21-24	25-28	29-32		
Practices housekeeping consistent with safety	Simulator	(4.5)	4.3	4.1	4.0	4.2	4.4	4.6	4.5		
	AET	(4.8)	4.1	4.2	4.4	4.1	4.5	4.8	(4.5)		
Applies safety precautions while operating TS equip- ment	Simulator	(4.0)	4.1	4.6	4.4	4.5	4.6	4.4	4.8		
	AET	(5.0)	3.9	4.4	4.5	4.3	4.5	4.8	(4.5)		
Use of TOs for maintenance and trouble-shooting	Simulator	(3.5)	3.8	4.0	4.4	4.3	4.6	4.6	4.6		
	AET	(4.5)	4.0	4.3	4.3	4.3	4.2	4.0	(4.5)		
Use and care of tools and equipment	Simulator	(3.5)	3.8	4.1	4.0	4.1	4.6	4.6	4.6		
	AET	(4.3)	4.0	4.2	4.6	4.1	4.5	4.7	(4.5)		
General understanding of TS purpose and functions	Simulator	(3.5)	3.3	3.7	4.0	4.0	4.4	(3.5)	4.6		
	AET	(4.8)	3.5	3.3	4.0	3.8	4.0	4.0	(4.0)		
Understands GENPAC purpose and function	Simulator	(2.7)	3.2	3.5	3.6	(3.7)	3.9	(3.3)	3.8		
	AET	(3.5)	3.4	3.2	3.6	3.3	3.8	3.6	(3.0)		

*Responses based on a 5-point performance scale with 1 = Very Poor and 5 = Very Good. Mean ratings based on less than 5 supervisor responses are in parentheses.

TABLE 14 (cont.)

Supervisor Follow-up Questionnaire Item	6883 Training Mode	Weeks of Field Experience							
		0-4	5-8	9-12	13-16	17-20	21-24	25-28	29-32
Understands purpose and function of 6883 or 6873 TS	Simulator	-	3.5	3.8	-	-	-	(4.0)	-
	AET	-	-	3.3	(2.7)	3.2	(4.0)	3.4	(2.0)
Understands signal flow and theory of associated LRUs	Simulator	-	3.0	3.1	-	-	-	(3.5)	-
	AET	-	-	3.4	(3.3)	3.1	(4.0)	3.4	(2.0)
Diagnostic testing ability	Simulator	(3.0)	3.4	3.9	4.0	4.1	4.1	(4.5)	4.6
	AET	(4.0)	3.5	3.7	4.6	3.8	4.3	3.8	(4.0)
Trouble-shooting ability	Simulator	(3.0)	3.1	4.0	4.0	4.3	4.1	(4.0)	4.6
	AET	(4.0)	3.3	3.6	4.4	3.8	4.3	3.8	(4.0)
Routine maintenance ability	Simulator	(3.0)	3.1	3.9	4.0	4.1	4.1	(4.0)	4.6
	AET	(4.0)	3.3	3.7	4.4	3.8	4.5	3.5	(4.0)
Understands LRU/SRU data flow and interface with 6883/6873 TS	Simulator	-	3.0	3.0	(4.0)	-	-	(3.8)	(4.0)
	AET	-	-	3.4	(3.7)	3.0	(4.0)	3.4	(2.0)

*Responses based on a 5-point performance scale with 1 = Very Poor and 5 = Very Good. Mean ratings based on less than 5 supervisor responses are in parentheses.

TABLE 14 (cont.)

Supervisor Follow-up Questionnaire Item	6883 Training Mode	Weeks of Field Experience									
		0-4	5-8	9-12	13-16	17-20	21-24	25-28	29-32		
Coordinates work with other personnel	Simulator	(3.0)	3.8	3.5	(3.6)	4.1	(4.0)	(4.0)	4.3		
	AET	(5.0)	3.5	4.0	4.2	3.9	-	4.7	(4.0)		
Ability to resolve tech- nical problems	Simulator	(3.5)	3.2	3.7	4.0	4.1	4.4	3.2	4.4		
	AET	(4.3)	3.3	3.6	3.9	3.5	4.0	4.5	(3.5)		
Ability to work without supervision	Simulator	(3.5)	3.5	4.0	4.0	4.1	4.4	3.0	4.6		
	AET	(4.0)	3.8	4.1	4.3	3.7	4.5	4.3	(3.0)		
Initiative in trouble- shooting tasks	Simulator	(3.3)	3.7	4.0	4.4	4.4	4.3	3.8	4.6		
	AET	(4.5)	4.1	4.2	4.3	3.7	4.5	4.6	(3.0)		
Attitude toward assigned tasks	Simulator	(3.7)	3.9	4.4	4.8	4.3	4.4	3.8	4.5		
	AET	(4.5)	4.1	4.3	4.3	4.0	4.7	4.8	(3.5)		
Overall ability compared to others at the same level	Simulator	(3.5)	3.7	4.3	4.6	4.3	4.4	3.8	4.5		
	AET	(4.3)	2.6	4.1	4.3	4.1	4.5	4.3	(3.0)		

*Responses based on a 5-point performance scale with 1 = Very Poor and 5 = Very Good. Mean ratings based on less than 5 supervisor responses are in parentheses.

resulted since supervisors felt they were not qualified to rate certain aspects of technician performance or that some items were not applicable.

No noticeable differences in technician performance were found as a function of 6883 training mode. Not surprisingly, however, many items did suggest an increase in technician abilities with increased field experience.

Cost Analysis

Table 15 shows the major factors of the life cycle cost comparison. Recurring and nonrecurring costs have been combined to provide profiles of costs in constant 1978 dollars. The net present value of each cost stream projected for 15-year life cycles and discounted at 10 percent is also shown, along with the estimated training costs per student-hour of instruction.

TABLE 15

The Life Cycle Cost Comparison

Cost Categories	Simulator	AET
Facilities	\$ 110,650	\$ 110,650
Equipment	1,594,330	4,902,140
Industrial Materials	26,000	27,890
Personnel	89,270	72,530
Students	357,770	357,770
Miscellaneous	0	0
TOTAL	\$2,183,000	\$5,470,980
NPV (1978)	\$1,501,090	\$3,895,680
Cost Effectiveness-- \$s per student-hour	\$348/student-hour	\$902/student-hour

Table 16 and 17 show tabulations of the individual cost estimates for elements that comprise each category, together with explanatory information for the AET and simulator, respectively. The tables are structured so that the 1978 Investment Costs could be considered as sunk costs: from this perspective, the costs in constant dollars of operating the AET and the simulator for 15-year life cycles are \$3,366,150 and \$1,588,020. The life cycle cost comparison, which also clearly favors the simulator, shows that simulation is an important

TABLE 16
Life Cycle Costs (Thousands of Dollars) for 6883 AFT--Constant 1978 Dollars

Cost Category	Cost Element	Inv. Cost 1978	Operating Years (15)				Total	Comments*
			1978	1979	1980	'81-'93		
Facilities	Replacement cost of space Supplemental furnishings	0.50	7.34	7.34	7.34	7.34	110.15	450 sq. ft. @ \$16.32/ft. (A)
Equipment	6883 test station and LRUs Acquisition management Sustaining investment Maintenance (672 hrs./year) Operating costs (power)	1,954.33 150.00	0.0	195.4	195.4	195.4	2,736.02	Inflated 79.5% from 1972 Est. at 7.57 of AET cost (C) Est. at 10% of AET cost (D) 0.323 person-years (E-5) (E)
Instructional Materials	Tos and software Update laboratory exercises	0	1.86	1.86	1.86	1.86	27.89	Included in equip. costs (F) 0.16 person-years (E-5) (G)
Personnel	Laboratory Instructor (720 hrs./year) Overhead burden		3.73	3.73	3.73	3.73	56.01	0.33 person-years (E-5) (H)
Students	Wages (180 students/yr.--3 days) Permanent change in station Miscellaneous support cost		15.20	15.20	15.20	15.20	227.89	Equiv. to 2.077 yr. (E-2) \$23,300 apportioned over 23 weeks
Miscellaneous	Not estimated		0.0	0.0	0.0	0.0	0.0	2.077 yrs. at \$79.25/wk. (J) No supplies regularly used in 6883 laboratory training
TOTALS		2,104.83	42.0	237.4	237.4	237.4	3,366.15	

Total cost in constant dollars = \$5,470.98

Net present value (1978) = \$3,895.68

*Additional comments in Appendix B.

TABLE 17
Life Cycle Costs (Thousands of Dollars) for 6883 Simulator--Constant 1978 Dollars

Cost Category	Cost Element	Inv. Cost 1978	Operating Years (15)				Total	Comments*
Facilities	Replacement cost of space Supplemental furnishings	0.5	7.34	7.34	7.34	7.34	110.15	450 sq. ft. @ \$16.32/ft. (A)
Equipment	6883 simulator, software and courseware Specification and acquisition management Support and installation Sustaining investment	548.00 45.68	19.86 34.5	31.18 57.5	0 65.33	0 65.33	51.02 941.33	Contract value Est. based on project rds. (K) Est. based on project rds. (L) Eng. change, maint., records space (M)
	Air conditioning and inst. Operating costs (power)	0.8	0.5	0.5	0.5	0.5	7.5	
Instructional Materials	Software revision (lessons) Overhead burden		7.86 0.6	15.71 1.63	0.0 0.0	0.0 0.0	23.57 2.43	Full-time E-7 for 18 mos.
Personnel	Laboratory instructor Overhead burden		5.60 2.10	11.20 3.10	11.20 3.10	3.73 1.10	72.75 21.50	Full-time E-5 until 1981
Students	Kaplan (180 students/yr.--3 days) Permanent change in station		15.20 0.1	15.20 0.1	15.20 0.1	15.20 0.1	227.89 1.5	Equiv. to 2.077 yrs. (E-3) \$23,300 apportioned over 23 weeks
	Miscellaneous support costs		8.55	8.55	8.55	8.55	128.38	2.077 yrs. at \$79.25/wk.
Miscellaneous	Not estimated		0.0	0.0	0.0	0.0	0.0	No supplies regularly used in 6883 simulation training
TOTALS		594.98	102.39	152.01	111.32	101.85	1,588.02	

Total cost in constant dollars = \$2,183.00
Net present value (1978) = \$1,501.09

*Additional comments in Appendix B.

training option for maintenance training. The following examination of some of the cost assumptions inherent in this comparison only supports this finding.

Cost Assumptions

A major issue involved in planning this analysis was that the simulator system cost was actually known to be higher than is represented by the contract cost of \$548,000. Only now can this be put in perspective. First, the question can be asked, "What is the impact on the cost-effectiveness ratio if the actual cost of the simulator is perhaps double the contract price?" In a net present value (NPV) calculation, the acquisition costs are *not* discounted, thus the effect of doubling the contract price is not obscured by the discounting process. If the actual cost of the simulator were doubled, increasing the NPV of the simulator to \$2,731,000, the ratio of cost per student-hour of instruction would increase only 25 percent (\$474/hour), just about one-half of the ratio found for the AET.

Second, the analysis also produced some evidence that the actual cost of the simulator was approximately double the contract price. The Logistics Support Cost model developed by the Simulator SPO (1979) provided insight into the relationship between system cost and the Sustaining Investment cost component, which involves test station spares and spare components and inventory management. This model, used to assess costs of the F-16 simulator, indicated that the initial system acquisition and support costs were approximately equal to the 15-year life cycle costs projected for "Sustaining Investment" (\$4,919,000 and \$4,965,000 respectively⁴). This relationship is important because it reflects the lower cost of spares associated with simulators based on actual cost experience with one-of-a-kind systems. Table 17 presents an estimate for sustaining investment over the life cycle of the 6883 simulator. The \$941,000 projected is consistent with an estimate of \$1,000,000 for the actual system and support costs of the simulator.

In considering the policy implications of a 2 to 1 ratio in the cost effectiveness of the 6883 simulator, it is important to understand that the estimate for the AET is extremely conservative. It was noted earlier that the costs of the CENPAC computers were not allocated to the 6883 test station and examination of Table 16 shows that no cost element was included in the equipment category that reflects the cost of installation and start-up of the AET. Installation and start-up costs for the simulator were fully allocated and it can be seen in Table 17 that these costs were perhaps unexpectedly high due to problems encountered in bringing the simulator on-line during 1978 and 1979.

⁴See Table 1, LSC Model Estimate of the Cost of the Hardware-Based Simulated F-16 Avionics Intermediate Shop for Maintenance Training (Eggemeier et al., 1979).

The particular value of the cost comparison, then, lies in the notion that with cost experience derived from actual trainer alternatives, there is an obvious preference for the simulator.

Alternative Simulation Scenarios

A 2 to 1 cost effectiveness advantage has been determined for the 6883 simulator under the assumption of equal training effectiveness and identical patterns of trainer use. This determination has particular significance if, in fact, the simulator does provide student training to the same level as achieved on the AET. As already discussed, while no major performance differences were observed, it is not true that the content of training and use patterns were identical for all groups studied. The following discussion presents a particular perspective on this issue, a perspective suggested by the strong cost advantages of the 6883 simulator.

The concern about training effectiveness of the simulator can be seen in Figure 6. The diagram indicates that the simulator effectively trains procedures and trouble-shooting through the automatic testing features of the device to a level consistent with the STS for 3-level personnel. The broken line associated with the AET indicates that the AET trains to the 3-level less well because of the unpredictable nature of equipment performance during each training session (the uniformity of training issue). The simulator can train consistently to the 3-level. The AET can do something that cannot be done on the simulator, however, and that is to provide hands-on trouble-shooting experience when the fault cannot be corrected through automatic testing procedures. It should be clear from the diagram that if the technical school is to provide experience in the manual trouble-shooting domain (regardless of how well such requirements are reflected in the STS), then AETs are essential to the training. This conclusion ignores the potential for another type of simulator which is designed to provide manual trouble-shooting training. With this hierarchy of training objectives in mind, we invoke the cost model and analysis for guidance in examining alternatives for simulation as demonstrated by the 6883 4-dimensional simulator.

The generic test station simulator. This first scenario examined considers the potential for utilizing a generic test station simulator as a means for providing structured training in trouble-shooting procedures. The assumption is made that these procedures employ only automatic testing for fault isolation. The presumption is also made that training on the generic simulator would eliminate the need for AET training on some of the ten trainers now used in the course. It will be seen that this scenario, as well as the others that follow, is hampered by our lack of information about the life cycle cost of the entire training system, but certain conclusions can be drawn based on the cost analysis of the 6883 3-dimensional simulator and AET.

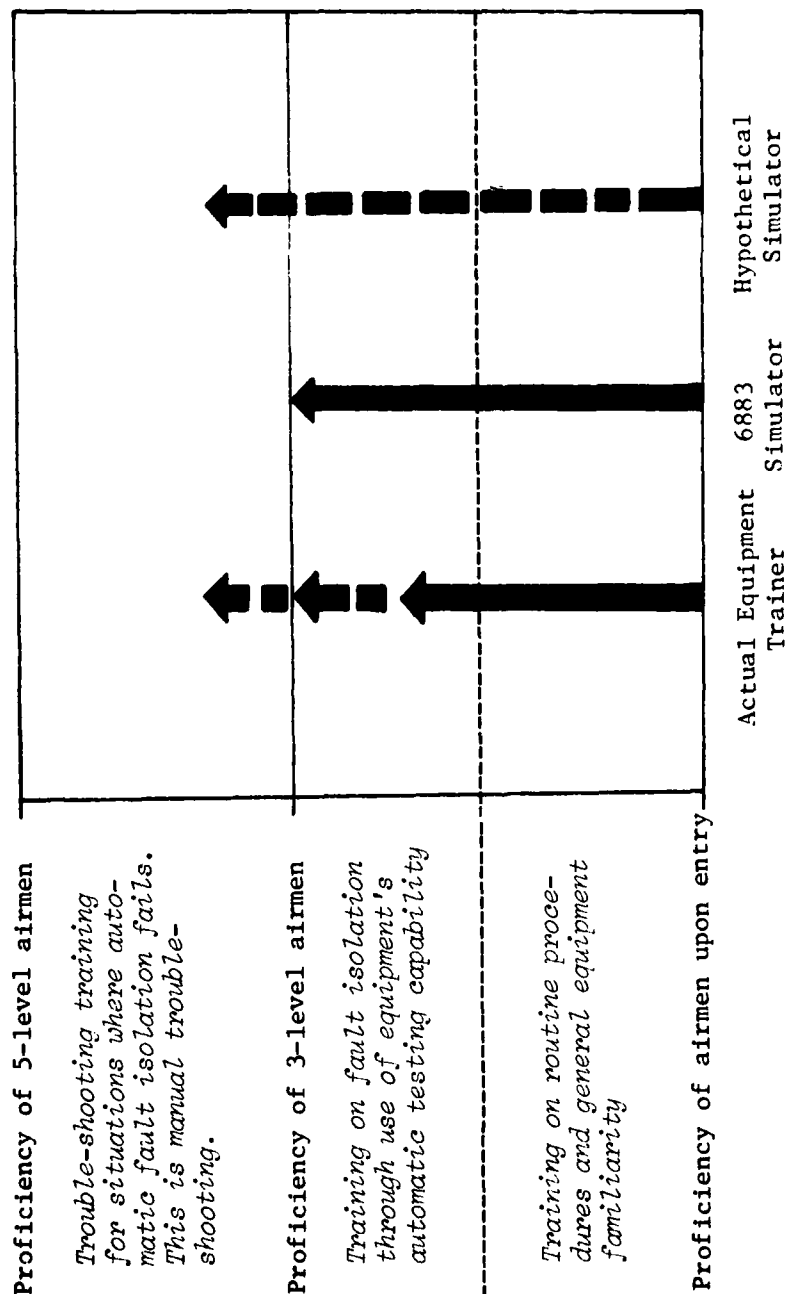


Figure 6. Training Capability of Equipment in Relation to the Implicit Hierarchy of Training Objectives

Table 18 reviews the operating status of the ten test stations as of August 31, 1979. The table suggests (1) that manual trouble-shooting experience *cannot* be a feature of all practical exercise sessions due to variations in test station availability, and (2) that 3-dimensional simulators patterned after the 6883 could be useful to deliver training related to procedure and automatic fault isolation, given the variability of test station status. From this assessment, it could be argued that test stations with the best records of operational status are in a real sense now being used as generic test stations--to the extent that experience with procedures and fault isolation must be transferable to other (nonoperating) test stations.

The pattern of use for the generic simulator proposed in this scenario is one in which training is tailored in response to current AET status. By designing a library of lessons to reflect different classes of faults and related procedures (reflecting individual test station characteristics), the lessons selected for particular student trials could serve to help link the experience gained on the simulator with that normally obtained on the nonfunctional AET.

The question of the cost effectiveness of the generic simulation in this scenario can be examined in a straightforward way. Clearly, the scenario does not promise cost savings because the simulator represents additional cost. In fact, increased training costs will be incurred because the pattern of simulator use proposed does not disturb the life cycle cost picture for the AETs. In a life cycle cost analysis of the AET training system, however, if the costs associated with student and instructor time are aggregated for all procedural and fault isolation training time lost due to AET status, then it is conceivable that the benefits of the generic simulator will exceed costs. If, for example, as few as 120 hours per student are lost out of approximately 930 hours required for the course (13 percent), then a simulator would be justified on the basis of its cost/benefit ratio over the 15-year life cycle since increased training effectiveness would offset the higher training costs.

Combined test station/simulator complements. This second scenario examines the situation in which a full complement of simulators, one for each of the AETs, is postulated. The pattern of use considered is one in which the simulator is used to train procedures and automatic fault isolation and the AET is used to provide for equipment familiarity and "manual" trouble-shooting experience. The scenario cannot be evaluated without more information on current training system life cycle and some estimate of how the 6883 AET actually compares with other test stations in order to gauge simulation costs. It is difficult to see the circumstances, however, in which the combination of reduced training time and reduced AET maintenance costs, along with increased manual trouble-shooting skills, would produce a cost/benefit ratio less than one. The only other major source of cost saving that has the potential of offsetting the simulator investment

TABLE 18
ATC F-111 LRUs and Operating Status as of 8/31/79

Test Station Number	Description	Operating Status
6802	Radar-Transmitter-Modulator (RTM): Models A & E; total LRUs possible is 4; LRUs available at ATC are MRT, Transmitter Synchronizer	Parts and maintenance problems; limited use
6803	Computer; total LRUs possible is 6, LRUs available at ATC are Navigations Computer, Feel & Trim	None at all; has been down 2 months
6805	Attitude and Rate	Limited use
6815	Video: Models A & E; total LRUs possible is 6; LRUs available at ATC are Antenna Receiver, Interference Blanker	Limited use
6863	Digital; total LRUs possible is 5-6; LRUs available at ATC are Computer, IRU	Limited use; was completely down for 2 years, being worked on
6882	Radar-Transmitter-Modulator (RTM): Model D	None at all
6883	Converter Flight Controls; total LRUs possible is 4; LRUs available at ATC are Feel & Trim (869), Feel & Trim (855), Multiplex Converter, only Yaw Computer unavailable	Best running TS; closest to realizing full training potential
6885	Video: Model D	Limited use
6886	Electronic Systems; total LRUs possible is over 80, can be used (with adaptation) for more than 100 LRUs in the field; LRUs available at ATC are HSI, ECA and Antenna Receiver being repaired	Usually operating, but down for 1 week recently
6887	Displays; total LRUs possible is 3-4; LRUs available at ATC are 2 (didn't get names)	Working well
CENPAC	Composed of 3 separate computers	One hit by lightning in 1978 is still down; other two are working, but with intermittent problems

is to return some of the AETs (and LRUs) to inventory to serve as spares for the flight line. Based on the cost effectiveness ratio found for the 6883 simulator, it would be necessary to return perhaps five AETs to F-111 weapon system inventory: training for those blocks of instruction affected would then be accomplished on 3-dimensional simulators. Without attempting to generalize further, this option may be worthy of consideration by ATC given the existing AET operational status.

Replace AETs with simulators. This final scenario is potentially the most revolutionary one because it suggests new patterns in simulator use and simulator development. It proposes that all of the AETs are returned to inventory and that no attempt be made to train manual trouble-shooting skills on actual equipment within the residence phase of F-111 maintenance training. Manual trouble-shooting principles could, of course, be taught using advanced simulators. There are many difficulties inherent in this scenario, principally because implementation would require changes both in the residential and OJT environment, as well as changes in training policy. For example, the residence training environment would need to be modified to optimize the effectiveness of simulators in training procedures and trouble-shooting, while the OJT environment would need to be organized to insure that the transfer of training occurs to the actual equipment.

The scenario postulates that the course duration could be reduced--possibly to 16 weeks instead of 23 weeks--in view of the increased training potential associated with the simulators. The scenario recognizes that students' manual trouble-shooting skills are not well developed in the training environment and that simulation technology could lead to a redefinition of the training process.

Evaluation of this scenario is not possible here because of the broad implications for OJT, Logistics Command, and ATC. It has been included here only to show the range of options that might be considered in an attempt to establish cost effective training programs that maximize the potential of instructional technology.

CHAPTER 6

GENERAL DISCUSSION

The findings of this study suggest a number of critical factors which should be considered in future efforts to investigate the role of simulators in maintenance training.

Identification of Training Objectives

Any comparative analysis of simulators and AET must be based on a clear understanding of training objectives. The present study was conducted at a time when classroom objectives were rapidly changing to meet the changing requirements of the field assignment. Given the lead time necessary to develop the specifications of a simulator and to construct the trainer, it should be expected that the capabilities of the simulator were somewhat limited with respect to current training needs. Since it is unlikely and perhaps undesirable that the objectives of a training course can be stabilized for long periods of time, the useful lifespan of major simulators may be significantly increased by emphasizing training related to the general skills required to operate and maintain all test stations. The specialized functions of each test station could be simulated with less costly module simulators, which are either disposable or reprogrammable to meet changing needs. Such an approach is not unlike the "Test Station Replaceable Unit" (TRU) design of equipment already in use. While the main purpose of the TRUs is to improve the capability of repairing test stations quickly, thereby reducing "downtime," the component system also makes it easier to update (within limits) test stations to provide testing capability for new or modified aircraft systems. There is no reason to expect that a simulator designed to replace a test station will not be subject to the same limitations on utility due to improvement in aircraft design.

In view of changing course objectives and needs in the field, it seems that an explicit statement of minimal trouble-shooting standards should be made. These standards could then form the basis of a variety of training strategies and trainers.

Define the Anticipated Role of Simulation

From the outset of any investigation, the intent of introducing simulators into training should be clearly stated. That is, it should be determined if the simulator designed is expected to *replace* or *supplement* actual training equipment. Both are valid approaches to the use of simulation, of course, but require somewhat different equipment and research designs.

If the primary objective of incorporating a simulator into training is to replace more costly, less reliable, and more dangerous actual equipment, then it is clear that both psychological and physical fidelity must be considered. In this case, it is more likely that the simulator will include the capability of demonstrating basic operations procedures while duplicating, to a large extent, the physical appearance of the actual equipment. Physical fidelity is important since trainees will be assigned to actual equipment in the field. A lack of sufficient physical fidelity in the simulator and no exposure to actual equipment in training would almost certainly result in reduced initial performance on actual equipment in the field. However, research may determine which tasks require full fidelity trainers.

If, on the other hand, the objective of incorporating a simulator into training is to supplement the use of actual test station equipment, then psychological fidelity should be emphasized. In either case, psychological fidelity of sensitivity to operator actions must be established. Interviews with students who had contact with the 6883 simulator, conducted directly after the 6883/6886 practical block, and responses from technicians on the field follow-up questionnaires, indicated disappointment with the simulator on this aspect of design. That is, while the two trainers looked similar, the simulator reacted differently (slower) to operator input. This flaw was also referred to by Becar (1978) in his evaluation of the 6883 Maintenance Trainer System. Supplemental simulators can more easily focus on more complex tasks, including training on equipment malfunctions which cannot be introduced or experienced on actual test station equipment. The next phase of this project, the evaluation of the flat panel simulator is expected to provide data on this issue, since the simulator includes a troubleshooting trainer.

The use of simulators for training maintenance skills offers an opportunity to provide consistent training since they are less subject to random malfunctions. Further, simulators designed to augment AET can be more easily used to train personnel in the operation and maintenance of test stations in general. More general skills (e.g., systems and problem solving) not unique to any specific test station can be provided as an introduction to training on specific test stations. In the present study, it was found that students trained on the 6883 3-dimensional simulator performed as well as students trained on actual equipment; the true training benefits of the simulator were probably not realized, however, because the simulator was designed to replace the AET. Improved student performance was expected because the simulator would provide more consistent training experiences. Given the underlying assumption that the 6883 simulator might replace AET, the outcome of the cost comparison between trainers becomes the major factor in future procurement decisions, given approximately equivalent training capability. Given a "supplemental" objective, improved performance becomes the major factor considered and an analysis of cost-benefit is most appropriate.

Approach to Teaching

It is unlikely that a simulator of any quality will be accepted into existing training curriculum if it is not somewhat consistent with existing student-teacher interaction policies. It seems that only a self-instruction mode in which the simulator guides the student through a series of problems might result in alteration of these policies. To encourage teacher acceptance, the simulator should be effective as both a visual aid and demonstration tool. This would allow the simulator to be effectively incorporated into training segments (e.g., theory familiarization) which do not include extensive practical trouble-shooting experience. Such a dual purpose simulator would be almost essential if replacement of existing equipment is planned. Also, the thorough introduction of the training simulator to the training staff, highlighting uses, real and potential, of the equipment in the overall training program, will improve instructor acceptance.

The environmental constraints on this study suggest that many instructional practices have evolved which are deemed necessary to maximize the effectiveness of actual equipment as trainers. Given this situation, it is not surprising that performance differences as a function of training equipment were not observed. The potential impact of simulator training on student performance may be realized only if a utilization strategy accompanies the placement of a simulator into an existing training environment. This plan for using the simulator would insure that its unique training capabilities were tapped, and benefits in terms of improved performance, consistent training, reduced training time, and cost savings might then be measurable.

Generalization of Findings

As evidenced by the fact that an entire chapter of this report was devoted to the impact of the environment on the evaluation effort, the generalizability of findings can only, by necessity, be limited. While every effort was made to adapt experimental design principles for use in this natural experiment, it was not possible to rely on many of the premises of basic learning theory. Until parameters such as content, method, and duration of training, all known to affect learning, are subject to more careful control, a true cost-effectiveness analysis of simulation training is not possible. The point at which simulators provide the best training for a specified cost or the least cost for specific training can be determined only if control over relevant learning factors is possible. To answer the question, "Do simulators provide more cost-effective training than AET?" we must be able to maximize the use of simulator capabilities beyond those available on actual test stations. Simply stated, AETs are not designed for training purposes; simulators can be designed solely for that purpose.

Experimentation in the natural training environment is necessarily limited by the fact that simulators must provide training at least equivalent to that provided by existing AETs. The adequacy of training on AETs in relation to the STS is assumed here; however, the issue could also be investigated empirically. Obviously, it is not feasible to risk the possibility of providing inferior training in the interest of research, which is focused on defining the conditions of maximum cost-effective simulator training. There are two viable solutions to avoiding the limitations imposed by the natural environment. First, the student could be deviated from normal training to participate in a well controlled research study and then subsequently re-enter the training sequence at the point of departure. The additional cost of deviating students (i.e., cost of additional day in ATC) would be part of the research costs. The disruption of student flow from the field's perspective would occur only at the start of such a project and should not cause any significant shortages of field personnel since student flow is normally somewhat erratic. The second alternative is to carefully structure a significant block of training time to allow the research project to be integrated into the existing training sequence. Students would complete training in the same time frame as usual (or sooner), and any adverse impacts of the research on performance could be corrected by OJT. The additional training required (if any) would become itself a measure of training effectiveness. While other alternatives may be possible, the main point is that true potential of simulation in training can be determined only by a focused research effort. Clearly, some additional costs will be incurred by such a research effort--a small price, however, given the potential utility of the information in defining the future role of simulation in maintenance training. Such research would insure that future investments in simulators would be based on factual information rather than assumptions. The information obtained should highlight the conditions under which the use of simulators in maintenance training is most effective. The overall cost savings to the Air Force would be extensive regardless of the findings. Many future research dollars could be more wisely invested if simulation in training was not demonstrated to be cost-effective even under ideal conditions, or many training dollars might be saved by appropriate utilization of simulation in training as defined by experimentally determined guidelines.

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APPENDIX A

DATA COLLECTION INSTRUMENTS

Section A-1	Trouble-Shooting Test
Section A-2	Student Interview
Section A-3	Instructor Interview
Section A-4	Projected Job Proficiency Test
Section A-5	Field Technician Survey
Section A-6	Field Supervisor Survey

Section A-1

TROUBLE-SHOOTING TEST AND DATA RECORDING SHEET

Student Name _____ Training Mode _____
Observer _____ Testing Mode _____

Note Time	Steps Completed	ERROR NOTED (indicate step # and your comment)	
		Yes	No
0			
	1. Remove all jewelry.	---	---
	2. Enter and request test #330401.	---	---
	3. Verify test number, press START.	---	---
	4. Verify test date, press START.	---	---
			
	5. Does LRU pass test #300150.	---	---
	6. Testing halts at #300610; enter #300650, TEST REQUEST, START.	---	---
	7. Testing halts at #300755; when "go" press START, observe increasing + voltage, press START.	---	---
	8. Testing halts at #300764; when "go" press START, observe increasing - voltage, press START.	---	---
	9. Testing halts at #300824; enter #300830, TEST REQUEST, START.	---	---
	10. Testing halts at #301752; rotate OSCP, INPUT SIGNAL SEL switch to "digital multir."	---	---
			
	11. Press NEG DC COUPLING switch.	---	---
	12. Press POS DC COUPLING switch.	---	---
	13. Set VERNIER to "fully cw."	---	---

<u>Note Time</u>	<u>Steps Completed</u>	<u>Yes</u>	<u>No</u>	<u>Error Noted</u>
	14. Set V/DIV at .5.	—	—	
	15. Set SWEEP MODE on "auto".	—	—	
	Note. Simul. only: Reset system to allow rerun of test tape. On student console, press FAULT DETECT/RETURN.			
	16. Adjust to obtain display, observe sine wave (should <u>not</u> be there).	—	—	
—	...			
	17. Determine that the Yaw Board TB3 is defective.	—	—	
	18. Rerun test tape from #301740.	—	—	
	19. Advise board replacement.	—	—	
—	...			
	Note: Simul. only: Indicate TB3 is replaced. On student console, press START.			
	20. Rerun test tape from #301740.	—	—	
	21. Student should offer alternative explanations of malfunction. (Instructor should only state that "Yaw Board TB3 was apparently not the cause.")	—	—	
—	...			
	22. After 5 minutes: Instructor suggests that "test station caused the malfunction."	—	—	
	23. After another 5 minutes: Instructor suggests that "the test program should be decoded."	—	—	
	24. Student decodes program in total.	—	—	
	25. Student decodes program in part.	—	—	
	26. Student identifies missing power input.	—	—	
	27. Student notes that power light is off.	—	—	
—	...			

<u>Note Time</u>	<u>Steps Completed</u>	<u>Yes</u>	<u>No</u>	<u>Error Noted</u>
	28. Student suggests alternative explanations for lack of power.	—	—	
	29. Students suggests that a fuse has blown.	—	—	
	30. Degree of instructor assistance required:			
	very little	—		
	moderate	—		
	a lot	—		

.....

Section A-2

INTERVIEW QUESTIONS FOR AIR FORCE AVIONICS TECHNICIAN STUDENTS

1. Did you feel that you had sufficient training time on the equipment in the 6883 block?
2. Did you feel your time on the training equipment in the 6883 block was well utilized?
3. What segments of your time on the equipment would you increase? Decrease?
4. Did you receive sufficient individual attention on the equipment during your training?
5. Was there variety in the training on the 6883 equipment or was it mostly routine?
6. Do you feel comfortable operating the equipment?
7. Do you feel you understand how to operate the equipment? Did you have any problems?
8. Was the equipment more sophisticated than you expected? Less?
9. Was the equipment more sophisticated than you think was necessary to complete your training?
10. Were there equipment malfunctions during your training which hindered your training? Benefited your training?
11. Did you receive trouble-shooting experience on the 6883 training equipment?
12. Would you like to have more trouble-shooting experience in your training?
13. Do you feel adequately prepared in your trouble-shooting experience for your field assignment?
14. Has your training given you sufficient experience in using the DDC to solve test station and LRU problems in the field?
15. What would you change in the TOs to make them more useful?
16. Did you find the TOs adequate for solving test station and LRU problems and operating the equipment?
17. Was your training instructor helpful in explaining the equipment and its use?
18. Did the instructor provide sufficient guidance while you were training on the 6883 equipment? Too little? Too much?
19. Was the instructor's guidance necessary to successful completion of your training on the 6883 equipment?
20. Did the instructor's attitude toward the training equipment have any effect on your training on the equipment?

21. Did the testing procedure test your capabilities on the 6883 training equipment?
22. Were the testing procedures difficult? Why?
23. What would you include in a test of your capabilities on the 6883 training equipment? Leave out?
24. What capabilities should a 3-level avionics technician have with respect to operating test station equipment in the field?
25. Do you feel you have those 3-level capabilities as a result of your training?
26. What factors would you add to your training, or increase the amount of attention to, to better prepare you for your field assignment?
27. Do you understand the overall purpose of the training program? What is that purpose to your knowledge?
28. Did your training on the 6883 equipment help your overall understanding of the purpose of the training program?
29. Do you have any additional comments, questions, or suggestions?

Section A-3

6883 3-DIMENSIONAL SIMULATOR EVALUATION PROJECT INSTRUCTOR QUESTIONNAIRE

About how long in months have you been an instructor at Lowry AFB? _____

Approximately how many times in the past year have you taught each of the following blocks?

6883 Theory _____ 6886 Theory _____

6883 Practical _____ 6886 Practical _____

Other blocks _____

If you have had field experience with Test Stations, please indicate the length of such experience and whether your experience involved TS operation, TS maintenance, or both _____

In the next section, we would like you to rate how much you would agree with each of the following statements on a five(5)-point scale, where 1=agree strongly and 5=disagree strongly.

From your general knowledge of and experience with simulated training, do you feel that simulated training:

	agree strongly			disagree strongly	
	1	2	3	4	5
a) is a good idea	1	2	3	4	5
b) can be more effective than actual equipment	1	2	3	4	5
c) can provide equivalent training with actual equipment	1	2	3	4	5
d) must be highly similar to actual equipment to be useful	1	2	3	4	5
e) can provide adequate training at a cost savings	1	2	3	4	5
f) allows for more complexity of training	1	2	3	4	5
g) is more reliable than actual equipment	1	2	3	4	5
h) teaches safety training better than actual equipment	1	2	3	4	5
i) provides more variety of training than actual equipment	1	2	3	4	5
j) is something you would use as an integral part of your teaching program	1	2	3	4	5

Please rate how important you feel each of the following factors is in evaluating a simulated training device:

	very important			unim- portant	
	1	2	3	4	5
a) complexity of the equipment	1	2	3	4	5
b) capability of the software to meet STS and Air Force objectives	1	2	3	4	5
c) a lower cost of hardware and operating expenditures compared to actual equipment	1	2	3	4	5
d) a high degree of similarity of the simulated equipment to the actual equipment	1	2	3	4	5
e) a savings in the amount of time required for training	1	2	3	4	5
f) the degree of control of AF personnel over the design of the equipment	1	2	3	4	5
g) the capability of AF personnel to modify existing or create new lessons for the simulated trainer	1	2	3	4	5
h) mobility of the equipment, for versatility of use in the classroom	1	2	3	4	5
i) reliability of performance of the equipment	1	2	3	4	5
j) ease of maintenance of the equipment	1	2	3	4	5
k) ability to more closely monitor student performance on the equipment	1	2	3	4	5
l) variety of material covered in lessons compared to actual equipment	1	2	3	4	5
m) ease of use for training staff in presenting training materials	1	2	3	4	5

Please indicate the amount of experience you have had with the 6983 3-dimensional Training Simulator by checking the appropriate statements below:

- a) _____ have heard about it, but never actually used it
- b) _____ have seen a demonstration of it
- c) _____ have had limited use of it, as a reference for teaching
- d) _____ have used it as a regular part of my teaching
- e) _____ have been involved with writing lessons for use on it
- f) _____ have been involved with the design and development of the unit
- g) _____ no contact or experience with the unit (if yes, please skip the next section)

From your experience with the 6883 3-D Training Simulator, to what extent would you agree with the following statements:

	agree strongly			disagree strongly	
a) the hardware is too simple for it to be an effective training instrument	1	2	3	4	5
b) the software (lessons) is well-designed instruction purposes	1	2	3	4	5
c) the lessons meet STS and course objectives	1	2	3	4	5
d) students appear to regard the simulator as an actual Test Station	1	2	3	4	5
e) the simulator is a better training instrument than the test station	1	2	3	4	5
f) I have used/will use the 3-D simulated trainer as an integral part of my teaching program	1	2	3	4	5

What involvement have you had with the Denver Research Institute's evaluation of the 3-dimensional simulator? Please check any applicable statements.

- a) ☐ proctored the three-hour written test
- b) ☐ proctored the practical performance test
- c) ☐ assisted with the design of the two tests
- d) ☐ was interviewed regarding my teaching methods and course material
- e) ☐ had no involvement with the DRI evaluation program or development of materials (If no involvement, skip next section)

To what extent would you say your involvement with the DRI evaluation has influenced your approach to teaching? Check any appropriate statements.

- a) ☐ I have become aware of weaknesses in my methods of presenting block material
- b) ☐ I have become aware of weaknesses in the course material
- c) ☐ I have put more emphasis on certain areas of the course material
- d) ☐ I have made changes in the Plan of Instruction (POI) for the block(s) I teach
- e) ☐ I have requested changes in the course material for the block(s) I teach
- f) ☐ I have not been influenced in my methods of teaching by the DRI evaluation
- g) ☐ I have not seen any reason to alter course materials due to the DRI evaluation

Do you have any additional comments to make regarding the 6883 3-D
Training Simulator, its design and use, or the DRI evaluation program?

AD-A091 808

DENVER RESEARCH INST CO SOCIAL SYSTEMS RESEARCH AND --ETC F/G 5/9
RELATIVE COST AND TRAINING EFFECTIVENESS OF THE 6883 THREE-DIME--ETC(U)
SEP 80 L F CICHINELLI, K R HARMON F33615-78-C-0018

UNCLASSIFIED

AFHRL-TR-80-24

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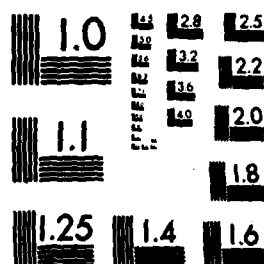
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551F121

OF 4

AD A

091308



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Section A-4

DO NOT WRITE IN THIS BOOKLET

FIELD PERSONNEL TEST QUESTIONS
for
THREE-LEVEL AVIONICS TECHNICIANS

Compiled by
The Denver Research Institute
for
AF Contract No. F33615-78-C-0018
Project No. 2361

DO NOT WRITE IN THIS BOOKLET

FIELD TEST QUESTIONS

PART I

- 1) Which TO would be used to operate the Converter-Flight Control Systems Test Station?
- 2) Which TO is used to perform Confidence Testing?
- 3) Which TO contains Maintenance Test Instructions?
- 4) Which TO would be used when ordering parts for the Signal Converter Unit Controller A2A1?
- 5) Which TO would be used when ordering parts for the Signal Data Converter A2A8?
- 6) List the TO, Section, and Paragraph of the procedure used to calibrate the Variable Power Control A1A5.
- 7) List the six TOs that would be used to operate, verify, calibrate, trouble-shoot, repair, and order parts for the A1 Converter in the Signal Data Converter A2A8.

Answer the following questions and write the TO reference where the answers may be found.

- 8) What happens when Address E613 is programmed?
- 9) What is produced when the DATAC Mode Switch is rotated through STOP?
- 10) When connecting power to the test station, what is connected to the red lead?
- 11) Test Point 11 on the DIU, A2A5 is used to monitor _____
- 12) What is the part number of an NG36?
- 13) At what temperature should the overtemp lamp in rack 1 flash?
- 14) What is the purpose of Signal Select Switch, A3A2A31S2 when in AUTO TEST POINT?

- 15) DATAC displays DMM BAL. This indicates?
- 16) When using the Oscilloscope to check a signal of 35KHz, which position of the Main Trigger Coupling Switch should be used?
- 17) List the sequence and control settings to light the Manual Mode lamp on the Power Supply Controller, A1A2.
- 18) What Address/subaddress is used to reset the Power Supply Controller, A1A2?
- 19) What Address/subaddress is used to reset the power stimulus relays?
- 20) List the sequence and control settings and all the indicated results when the DATAC Logic Verify is performed.
- 21) List three conditions that will light the Switch Fail indication on the DATAC Prog Stop indicator.

Decode Test Number 202574 of Test Tape Request Number 839902 and answer the following questions.

- 22) Describe the function of each part of a program.
- 23) What is the part number of the Self-Test Adapter?
- 24) What is the value of the measured stimulus?
- 25) List the relays by reference designation.
 - (a) Test Point Selection
 - (b) Test Point Distribution
 - (c) Stimulus
- 26) Identify the Patch Panel pin numbers used to route the signal through the Self-Test Adapter.

27) For Test Number 202574, DATAC Measurement and Result displays F00003 and NO-GO Low:

- (a) Why is Test Number 211307 displayed?
- (b) What is the most probable fault?
- (c) What is the second most probable fault?
- (d) What is the third most probable fault?

Decode Test Number 203310 of Test Tape Request Number 839902 and answer the following questions.

- 28) Describe the function of each part of the program.
- 29) What is the part number of the Self-Test Adapter?
- 30) List the following relays by reference designation:
- (a) Test Point Selection
 - (b) Test Point Distribution
 - (c) Miscellaneous Relay/s
- 31) What is the number of events (pulses) during the time period?
- 32) What is the frequency (PRF) of the measured signal?

PART II.

- 33) How does the converter store information into the computers?
- | | |
|---------------------|---------------------|
| A. Digital-Parallel | C. Parallel-Digital |
| B. Serial | D. Digital-Analog |
- 34) The converter processes what type of data from the computers to provide analog outputs?
- | | |
|-------------------|--------------------------|
| A. Analog-Digital | C. Serial Digital Data |
| B. Discrete Data | D. Parallel Digital Data |
- 35) What type of inputs/outputs function as status and control signals?
- | | |
|------------|-------------|
| A. Synchro | C. Discrete |
| B. DC | D. Serial |

- 36) The data processed by the converter is in the form of synchro, AC, DC, and resolver signals. They are of what type?
- | | |
|----------------|------------------|
| A. Analog Data | C. Digital Data |
| B. Serial Data | D. Discrete Data |
- 37) What is the advantage of parallel digital over serial digital data?
- | | |
|--------------------|-------------------|
| A. More components | C. Time |
| B. More wire | D. Amount of data |
- 38) The amount of times we do a given signal is known as the:
- | | |
|------------------|-----------------|
| A. Command Pulse | C. Data Request |
| B. Rate Group | D. Acknowledge |
- 39) Which area of the converter controls the WDC?
- | | |
|-------------------|-------------|
| A. Area I | C. Area III |
| B. Area I and III | D. Area II |
- 40) What starts the rate group?
- | | |
|------------------|----------------|
| A. Command Pulse | C. Acknowledge |
| B. Data Request | D. Parity |
- 41) The arithmetic section of a computer is:
- | | |
|----------------------------|----------------------|
| A. Central Processing Unit | C. Input/Output |
| B. Core | D. None of the above |
- 42) The purpose of the 05 tape is to check:
- | | |
|-----------|----------------------------|
| A. Inputs | C. Outputs |
| B. Bite | D. Converter Set Overloads |
- 43) How many outer limit checks are you allowed to fail on any test?
- | | |
|----------|---------|
| A. Two | C. One |
| B. Three | D. None |
- 44) A1A2 (Power Supply Controller) controls the power out of which drawer?
- | | |
|----------------------------------|-----------------------------------|
| A. Variable Power Control (A1A5) | C. Micrologic Power Supply (A1A9) |
| B. Power Supply (A2A9) | D. Power Supply (A3PS1) |
- 45) The logic Power Supply (A1A8) will cause which display on DATAC when the $\pm 12\text{VDC}$ PWR SUP and the $\pm 28\text{VDC}$ PWR SUP is tripped off?
- | | |
|---|----------------------------------|
| A. No go low | C. No go high and Cenpac control |
| B. Combination of TRU inhibit and Switch Fail | D. Switch Fail |

- 46) Switching Control Unit (A3A6) controls the setting of routing relays inside the following drawers:
- A. FCS Adapter (A4A1)
 - B. Transformer Converter (A4A2)
 - C. Ratio Transformer (A4A6)
 - D. All the above
- 47) If an adapter's schematic cannot be found in the station T.O., then it can be found in which T.O.?
- A. T.O. 35-1-181 F-111 Miscellaneous Aerospace Ground Equipment, WRALC Multiple Part Numbers
 - B. T.O. 35-1-181-2 F-111 Miscellaneous Aerospace Ground Equipment SMALC Multiple Part Numbers
 - C. T.O. 33D7-38-1-112 F-111F Shop System
 - D. A or B
- 48) The VD_4 in Stimulus Relay Can controls the:
- A. Setting of a relay supplying +28 vdc to the can
 - B. Setting of relay supplying ± 12 vdc to the can
 - C. Information Input lines
 - D. Steering Input lines
- 49) A VD_4 , which is continuously shutting off, can be fixed by:
- A. It cannot be fixed
 - B. By adjusting the Variable Resistor counterclockwise
 - C. Adjusting the Variable Resistor clockwise
 - D. Removing it from the Relay can and allowing it to cool down
- 50) A Flip Flop needs what signals to set:
- A. A low on 1, high on 0, and a clock pulse
 - B. A high on 1, high on 0, and no clock pulse
 - C. A high on 1, low on 0, and a clock pulse
 - D. None of the above
- 51) Power Supply Sense Lines:
- A. Regulate the Power Supply at a point outside the Power Supply
 - B. Check for a current overload at the LRU
 - C. Regulate the Power Supply at some point inside the Power Supply
 - D. None of the above
- 52) The Emergency Off button is located:
- A. On Cenpac
 - B. On DATAC
 - C. On the Stimulus Controller
 - D. On the Test Point Controller

- 53) The Programming 131023* 34353651Info. refers to:
- | | |
|---|------------------------------------|
| A. Resetting of Stimulus Relays 034, 035, 036 | C. Setting of Relays 034, 035, 036 |
| B. Setting of Relays 034 | D. Setting of Relays 102, 343, 536 |
- 54) A4A6 provides Inputs (during maintenance testing) to:
- | | |
|----------|-----------|
| A. DATAC | C. A4A2 |
| B. A4A7 | D. Cenpac |
- 55) A F02A250V4A fuse is:
- | | |
|-------------------------------|----------------------|
| A. A slow Blow 250 Volt 4 Amp | C. Both of the above |
| B. A fast Blow 250 Volt 4 Amp | D. None of the above |
- 56) Is it permissible to replace a fast Blow fuse with a slow Blow?
- | | |
|--------|----------------------------|
| A. Yes | C. Sometimes |
| B. No | D. Depends on the amperage |
- 57) Is it permissible to replace a fuse of a given amperage with one of a higher amperage?
- | | |
|--------------|---------------------------|
| A. Sometimes | C. No |
| B. Yes | D. Depends on the voltage |
- 58) The 400 CPS on-off switch on A3A31 is used to control:
- | | |
|---------------------------------------|--------------------------------|
| A. Signals applied to the LRU | C. Neither |
| B. Signals applied within the station | D. Power as the STA. power off |
- 59) The DC volts meter on A1A2 measures the output of which power supply?
- | | |
|----------------------------------|--------------------------------|
| A. A2A5 Digital Interface Unit | C. A2A3 Serial Digital Adapter |
| B. Parallel Digital Adapter A2A4 | D. None of the above |
- 60) Power Stimulus Relays can be tested at the patch panel:
- | | |
|--------------------------------------|--|
| A. In the usual manner | C. They cannot |
| B. By programming a Test Point Relay | D. By jump 2 sets of contacts together |
- 61) Stimulus Relays can be tested at the patch panel by:
- | |
|---|
| A. Programming the Relay and ohms checking between the normally open contacts and the wiper |
| B. They cannot be checked |
| C. Programming the Relay and ohms checking between the normally closed contacts and the wiper |
| D. A or C |

- 62) Test Point Relays can be checked at the patch panel by:
- A. Programming the Relay and ohms checking between the contacts and A and C of the DVM Input Plug
 - B. Programming the Relay and ohms checking between the two patch panel pins
 - C. Programming the Relay and ohms checking between either pin and chassis ground
 - D. None of the above
- 63) A coil will usually ohms check:
- A. As an open
 - B. As one or two ohms
 - C. A very high number of ohms
 - D. It cannot be ohms checked
- 64) A Rectifier is used to:
- A. Change AC to DC
 - B. Change DC to AC
 - C. Balance the line
 - D. None of the above
- 65) A circuit breaker that will not reset usually indicates:
- A. A short in the circuit
 - B. A broken circuit breaker
 - C. A shorted filter capacitor
 - D. All or any of the above
- 66) If you are not sure about a problem, you should:
- A. Look at the T.O. and fake it
 - B. Ask someone
 - C. Push start on DATAC
 - D. Go for a coffee break
- 67) A pulse period is measured by:
- A. An o-scope
 - B. Counter Timer
 - C. DATAC
 - D. A or B
- 68) The Input cable on A2A2 should be removed when trying to manually measure a voltage with the DVM because:
- A. It is connected to the back of the DVM
 - B. It doesn't need to be disconnected
 - C. It will induce noise on the line
 - D. All of the above
- 69) The front panel knobs of the TRU's can be enabled by the DATAC Mode Switch in which position?
- A. Normal
 - B. Stop
 - C. Keyboard
 - D. Manual
- 70) The clock input for A2A1, A2A3, A2A4 comes from:
- A. DATAC
 - B. Counter Timer
 - C. Signal generator
 - D. None of the above

Section A-5

DRI F-111 TRAINING SIMULATOR EVALUATION PROJECT

AVIONICS TECHNICIAN SELF-RATING FORM

This form is to be used to assess the field performance of the technician named in the box on the right. The information contained on this form will in no way be used to affect the technician's personal or work records, or enhance or impede his/her career. This form becomes the sole property of the Denver Research Institute and HRL under the terms of Contract No. F33615-78-C-0018. This information is being collected to monitor the field performance of those technicians whose training performance was monitored at Lowry AFB during their ATC training assignment.

TO BE COMPLETED BY DRI

Technician Last Name: _____

Personal Security Number: _____

Current AFB Assignment: _____

Technician Time in Field: _____

3 mos. 6 mos. 9 mos.

BACKGROUND DATA

1. What is your current Test Station (TS) assignment? _____
Approximately how many weeks have you been assigned to that TS? _____
2. What previous TS assignments have you had since you have been in the field? _____
Approximately how many weeks were you at each of those assignments? _____
3. What is your current rank, and how long, in weeks, have you held that rank? _____
4. What other Air Force bases were you assigned to as an Avionics Technician, prior to this assignment, and how many weeks were you at each previous assignment (post-ATC training only)? _____
5. During the 6883 Test Station (Converter Flight Control) block of your ATC training at Lowry AFB, were you trained or tested on the Training Simulator? (Circle the correct answer):

a) Yes, trained on Simulator	c) Yes, trained and tested on Simulator
b) Yes, tested on Simulator	d) No, no contact with Simulator
e) Don't know	

On the following pages, we would appreciate your help in this evaluation project. Please answer the questions, to the best of your ability, using the standardized graduated scale. The questions relate to your current working situation and your ATC training at Lowry AFB. Circle the "x" on the scale which most accurately reflects your situation or opinion.

CURRENT FIELD ASSIGNMENT

6. How many hours of your eight-hour shift do you spend operating the TS, not including observation time? 0-1 2-3 4-5 6-7 8 or more
x x x x x
7. In operating the TS, how many others work at the TS with you? none 1 2 3 4 or more
x x x x x
8. How much individual attention do you receive on the TS during OJT? none some a lot
x x x x x
9. How comfortable do you feel operating the TS to which you are currently assigned? not at all somewhat very much
x x x x x
10. How much attention do you feel should be paid to troubleshooting during OJT? none some a lot
x x x x x
11. How much attention do you feel should be paid to theory during OJT? none some a lot
x x x x x
12. How much attention do you feel should be paid to maintenance during OJT? none some a lot
x x x x x
13. How adequate are the TOs for troubleshooting the TS and LRUs? not at all somewhat very adequate
x x x x x
14. To what extent does OJT address your training needs usually? not at all somewhat very much
x x x x x
15. To what extent does your current field assignment meet your personal/career objectives? not at all somewhat very much
x x x x x

PREVIOUS TRAINING

16. How relevant was your ATC training to your current field assignment? not at all somewhat very much
x x x x x
17. How much of your ATC training do you utilize in your current field assignment? none some a lot
x x x x x
18. How adequate was your ATC troubleshooting training for preparing you for your current assignment? not at all somewhat very much
x x x x x
19. How important was the Converter Flight Control (6383) block of your ATC training to your current assignment? not at all somewhat very important
x x x x x
20. To what extent does the training you missed at ATC (training for which you received deviations) affect your ability to operate the TS in your current assignment? not at all somewhat very much
x x x x x

PREVIOUS TRAINING

21. What aspects of your ATC training do you specifically use in your current field assignment? _____
22. What aspects of your ATC training do you use very little in your current field assignment? _____
23. What capabilities do you feel a three-level avionics technician should have when he/she begins his/her field assignment? _____
24. Do you feel that you had those capabilities as a result of your ATC training when you began your field assignment? YES _____ NO _____
If not, what do you feel you were inadequately prepared for? _____
25. What would you add to the overall ATC training program at Lowry AFB to better prepare avionics technicians for their field assignments? _____

The remaining questions on this questionnaire are directed to those technicians who received some training or testing on the Training Simulator at Lowry AFB. If you circled responses a, b, or c on question 5 of this questionnaire, please complete the questions to follow. If you circled responses d or e, you have completed the questionnaire and should return this form to your supervisor.

SIMULATOR SPECIFIC

26. To what extent did you enjoy interacting with the Training Simulator during ATC training at Lowry AFB? not at all some very much
x x x x
27. To what extent did the Training Simulator simulate actual TS operating conditions? not at all some very much
x x x x
28. Do you feel the Training Simulator was probably a better training instrument than the actual TS for ATC training? not at all some very much
x x x x
29. Do you think simulated training instruments should be used more frequently during ATC training? not at all some very much
x x x x

SIMULATOR SPECIFIC

30. What aspects of your Training Simulator experience did you find particularly enjoyable or beneficial? _____

31. What aspects of your Training Simulator experience did you find particularly bothersome or non-beneficial? _____

32. What would you change about the Training Simulator to make it a better training instrument? _____

You have completed the questionnaire. Please return this form to your field supervisor. Thank you for your assistance.

Section A-6

DRI F-111 AVIONICS TECHNICIAN EVALUATION PROJECT

Supervisor Rating Form

This form is to be used to assess the field performance of the technician named in the box on the right. The information contained on this form will in no way be used to affect the technician's personal or work records, or enhance or impede his/her career status. This form becomes the sole property of DRI and HRL under the terms of Air Force contract No. F33615-76-C-0018. This information is being collected to monitor the field performance of those technicians whose training performance was monitored at Lowry AFB during their ATC assignment.

TO BE COMPLETED BY DRI

Technician Last Name: _____

Personal Security Number: _____

Current AFB Assignment: _____

Technician Time in Field:
3 mos. 6 mos. 9 mos.

BACKGROUND DATA

1. Name of person rating technician: (include position, e.g. Br. Chief, Shop Chief, etc.)

2. Has technician left the Air Force? Yes _____ No _____ When? _____
3. Test station technician is currently operating (e.g., 6883, 6886, 6863, etc.):

4. Test station technician has operated for most of field duty: _____
5. Other test station's technician has operated during field duty: _____
6. Has technician been reassigned to duty other than TS operation?
Yes _____ No _____ If yes, what other duty and when?

7. Has technician received a promotion during current period of rating:
Yes _____ No _____ If yes, from what level to what level:

In the following section, please rate the technician's task performance on a scale of 1 to 5, where 1 signifies very poor or unsatisfactory performance, 2 signifies poor performance, 3 signifies satisfactory or fair performance, 4 signifies good performance, and 5 signifies very good or excellent performance. NA indicates this task is not applicable in rating the technician at this time.

		Very Poor		Fair		Very Good	
BASIC TRAINING COMPETENCY	8. Practices housekeeping consistent with the safety of personnel and equipment:	1	2	3	4	5	NA
	9. Applies safety precautions when maintaining/operating test station equipment (for example, removes all items of metal such as jewelry, watches, glasses, etc.):	1	2	3	4	5	NA
	10. Uses technical manuals as a source of information for performing maintenance and inspections:	1	2	3	4	5	NA
	11. Uses and cares for common test equipment and special tools for electronic maintenance applicable to tasks:	1	2	3	4	5	NA
	12. Performs soldering of electronic components:	1	2	3	4	5	NA
TEST STATION COMPETENCY	13. Understands purpose and function/operational concepts of test stations in general:	1	2	3	4	5	NA
	14. Understands purpose and function/operational concepts of Cenpac:	1	2	3	4	5	NA
	15. Understands purpose and function of Computer/Navigation and Flight Controls/Converter and Flight Controls test stations in particular:	1	2	3	4	5	NA
	16. Understands theory/signal flow of particular LRUs associated with test stations listed above:	1	2	3	4	5	NA
	17. Performs confidence test:	1	2	3	4	5	NA
	18. Operates test station and shop standards to perform diagnostic testing:	1	2	3	4	5	NA
	19. Operates test station and shop standards to troubleshoot malfunctions:	1	2	3	4	5	NA
	20. Operates test station and shop standards to perform maintenance:	1	2	3	4	5	NA

		Very					NA
		Poor		Fair		Good	
TSC (cont.)	21. Understands general LRU/SRU information and electrical characteristics for LRUs/SRUs assigned to Computer/Navigation and Flight Controls/Converter Flight Controls test stations:	1	2	3	4	5	NA
	22. Understands LRU/SRU data flow and interface with test stations listed above:	1	2	3	4	5	NA
ATTITUDE, INITIATIVE AND SUPERVISION	23. Prepares special requisitions, issue and turn-in slips:	1	2	3	4	5	NA
	24. Coordinates work with other personnel:	1	2	3	4	5	NA
	25. Assigns maintenance and repair work:	1	2	3	4	5	NA
	26. Reviews and prepares maintenance and inspection reports and charts:	1	2	3	4	5	NA
	27. Resolves technical problems assigned to him/her:	1	2	3	4	5	NA
	28. Works well without significant supervision:	1	2	3	4	5	NA
	29. Shows initiative in troubleshooting tasks:	1	2	3	4	5	NA
	30. Shows good work attitude toward assigned tasks:	1	2	3	4	5	NA
	31. How would you rate this technician compared to other technicians at the same (3,5,7 or 9) level of status?	1	2	3	4	5	NA

APPENDIX B
NOTES ON COST ANALYSIS
(rf pp. 61-62)

NOTES ON COST ANALYSIS

- A) Replacement cost of space estimate was taken from the F-16 cost study (Table 8). The estimate of \$16.27/square foot represents the amount the building inventory at Lowry AFB would be reduced at the end of 1977 if a training facility were scrapped.*
- B) The supplemental furnishings estimate for laboratory space was based on the approximate cost of items used in the laboratories.
- C) The acquisition cost estimates for the AET were guided by the estimates made for the F-16 trainer. The acquisition management cost for the 36th unit of production was 8.2 percent of the unit cost (Table 5). Our estimate of 7.5 percent was more conservative because the technology of the F-111 is not as sophisticated as that of the F-16, even though the F-111 station represents the eleventh unit produced.
- D) Sustaining Investment estimate was guided by the estimates made for the F-16 trainer which, in turn, were derived from Air Force Logistic Command experience. The Sustaining Investment required was found to be approximately 12.5 percent of the unit cost each year (Table 5). Our estimate of \$194,500 per year was 10 percent of the unit cost of the test station. The unit cost was inflated 79.5 percent to reflect wholesale commodity price changes from 1972 to 1978 (source: Economic Indicators, U.S. Government Printing Office, Washington, D.C., 1979). No estimate was made for logistics costs associated with the spares inventory.

*The F-16 study refers to a draft technical report, "Life Cycle Cost Estimation of Simulated vs. Actual Equipment Maintenance Training for the F-16 Avionics Intermediate Shop." This report was prepared by the AFHRL Advanced Systems Division, Wright-Patterson AFB, Ohio (T. Eggemeier et al., March 1979). The report (unpaged) was a substantial resource for cost data appropriate to training at Lowry AFB, and the equipment cost model employed provided substantial insight for estimates related to acquisition management costs and the logistical costs including Sustaining Investment for weapons subsystems.

- E) The personnel cost of maintenance on the 6883 AET was based on records of actual hours spent on repair from 1/1/79 to 7/30/79. (BLIS Report, Logistics Branch, Lowry AFB). The time spent during this period was assumed to be proportional to the yearly maintenance requirement. The grade level for costing purposes was estimated to be E-5.
- F) Since no student materials are required for 6883 laboratory work, this cost was assumed to be zero.
- G) Updating laboratory exercises was assumed to require one-sixth of an instructor year. Updating represents such activities as installing "faults" in the AET to facilitate "manual" troubleshooting exercises.
- H) Instructor contact time for laboratory training was estimated at 540 hours per year (180 students for three days, eight hours). The estimate was increased to 720 hours per year to better account for the fact that one full-time instructor would be assigned to teach 6883 theory and practice.
- I) The overhead or burden associated with maintaining one instructor one-third time was estimated by apportioning the salary of the course manager (GS-12), the course supervisor (E-7), and the instructor's supervisor (E-6) to management and administration of 24 instructors for one-third year. (Salary schedule source: AFR-173-10, 1978.)
- J) Miscellaneous student support costs for students in residence at Lowry AFB were estimated at \$79.25 per student per week; 540 student days represent 2.017 years, assuming 260 working days per year ($2.077 \times 52 \times \$79.25 = \$8,550$).
- K) Estimate based on AFHRL project records: 1056.5 hours (military) and 2357.5 hours (civilian) prior to installation of the simulator; cost factors for military and civilian personnel for AFHRL were assumed to be \$12/hour and \$14/hour over the 18-month period.
- L) Estimate based on AFHRL project records: 1482 hours (military) and 2374 hours (civilian) for support and installation. Same cost factors as used for (K), above.
- M) Sustaining Investment for the 6883 simulator was based on the cost of maintenance contracts in force from June 1978 until November 1979, and a contract being negotiated for 1980-1981.

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AD-A091 808

DENVER RESEARCH INST CO SOCIAL SYSTEMS RESEARCH AND --ETC F/G 4/9
RELATIVE COST AND TRAINING EFFECTIVENESS OF THE 4803 THREE-DIME--ETC
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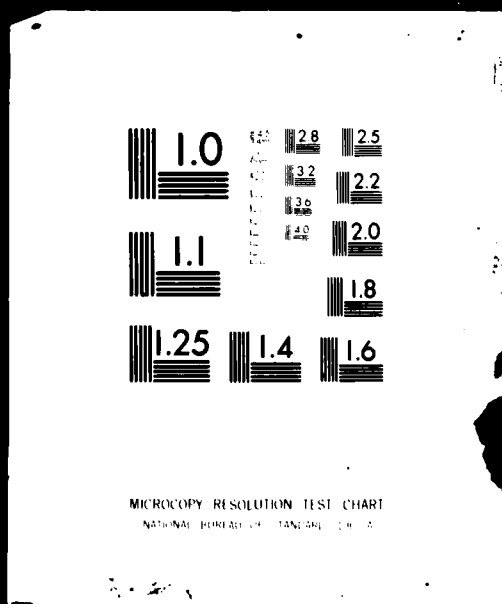
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UPPLEMENTARY

INFORMATION

DEPARTMENT OF THE AIR FORCE
AIR FORCE HUMAN RESOURCES LABORATORY (AFSC)
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REPLY TO
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16 JAN 1981

SUBJECT: Removal of Export Control Statement

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1. Please remove the Export Control Statement which erroneously appears on the Notice Page of the reports listed ~~██████████~~. This statement is intended for application to Statement B reports only.
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FOR THE COMMANDER

Wendell L Anderson

WENDELL L. ANDERSON, Lt Col, USAF
Chief, Technical Services Division

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AD-A091808



ON

AD-A091 808

DENVER RESEARCH INST CO SOCIAL SYSTEMS RESEARCH AND --ETC F/8 5/9
RELATIVE COST AND TRAINING EFFECTIVENESS OF THE 6883 THREE-DIME--ETC(U)
SEP 80 L F CICHINELLI, K R HARMON F33615-76-C-0018

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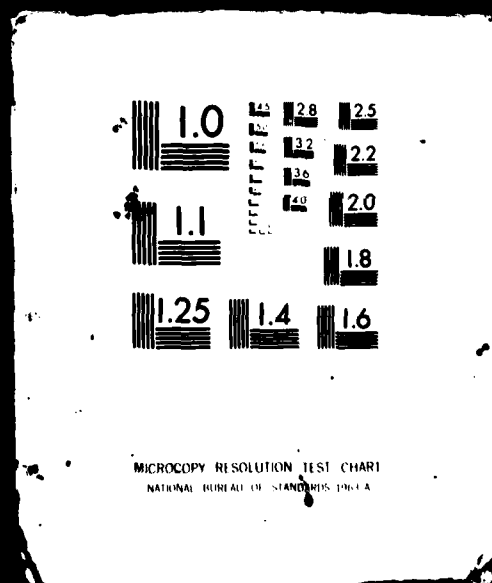
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ERRATA

AD-A091808
AFHRL-TR-80-24

RELATIVE COST AND TRAINING EFFECTIVENESS OF
THE 6883 THREE-DIMENSIONAL SIMULATOR AND ACTUAL EQUIPMENT

1. Page 67. Table 15 should be changed (asterisks (*) denote changes) as follows:

TABLE 15

The Life Cycle Cost Comparison

Cost Categories	Simulator	AET
Facilities	\$110,650	\$110,650
Equipment	1,594,330	4,902,140
Instructional Materials*	26,000	27,890
Personnel	91,250*	72,530
Students	357,770	357,770
Miscellaneous	0	0
Total	\$2,183,000	\$5,470,980
NPV (1978)	\$1,501,090	\$3,895,680
S/student-hour	$\frac{\$348}{15 \text{ yrs.}} = \$23/\text{student-hr.}^*$	$\frac{\$902}{15 \text{ yrs.}} = \$60/\text{student-hr.}^*$

2. Page 70. In paragraph 1. (\$474/hour) should be changed to (\$29/hour).

3. Page 110. Footnote H should be replaced with the following:

Instructor contact time for practical training on the 6883 test station was estimated at 540 hours per year (based on approximately 6 hours a day of actual student-instructor classroom interaction; 3 days of instruction per class; 30 classes per year). The estimate was increased to 720 hours per year to more accurately account for the fact that a full-time instructor (8 hours per day) would actually be assigned to teach the 6883 block of instruction.

4. Page 110. In line 3 of footnote J. 2.017 years should be changed to 2.077 years.

E. L. ELLIOTT
Chief, Technical Editing Office