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ABSTRACT

An evaluation of the usability, effectiveness, and acceptance in a job environment was performed on a general purpose simulator using a simulation of a radar system. General purpose simulators permit sharing of a programable capacity among simulations, thus providing economical hands-on training and training not usually economically available by other means. Training and exercises in malfunction isolation were given Air National Guard personnel. Data obtained using questionnaires, a performance test, and interviews indicated that the simulation was usable, effective, and acceptable. Detailed information concerning: (1) the experience of the personnel receiving training, (2) learning and learning potential, (3) an evaluation of training potential by qualified personnel, and (4) attitudes and acceptance by field personnel was obtained and is reported. The goals of the training program were achieved to a satisfactory level. Actual performance scores also indicated training goal achievement. The pre- and posttest questionnaires are appended. (Author/BP)

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AIR FORCE

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TRYOUT OF A GENERAL PURPOSE SIMULATOR IN AN AIR NATIONAL GUARD TRAINING ENVIRONMENT

By

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This technical report has been reviewed and is approved.

MARTY R. ROCKWAY, Technical Director
Technical Training Division

Approved for publication.

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An evaluation of the usability, effectiveness, and acceptance in a job environment was performed on a general purpose simulator using a simulation of a radar system. General purpose simulators permit sharing of a programmable capability among simulations, thus providing economical hands-on training and training not usually economically available by other means. Training and exercises in malfunction isolation were given Air National Guard personnel. Data obtained using questionnaires, a performance test, and interviews indicated that the simulation was usable, effective and acceptable. However the requirement for articulating predictive principles for guiding simulation design was indicated.

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SUMMARY

Problem

Previous research under an Air Force contract has indicated that general purpose simulation in formal technical training may be feasible and cost-effective in many applications. The "general purpose" indicates the capability of using various interchangeable simulation modules on a shared mainframe console which provides programmable computer control of each of the simulation modules. Comparisons with an operational actual equipment trainer, indicated that the general purpose simulator provided equal effectiveness (to the criterion performance level) on normal procedures for much less money. In addition the general purpose simulator had the capability (not previously available) of providing training in malfunction isolation. The purpose of the present study was to evaluate general purpose simulation in the field using Air National Guard personnel to provide job-related training.

Approach

An evaluation of the usability, effectiveness, and acceptance in a job environment was performed on a general purpose simulator using a simulation of the APQ 126 Radar System. Training and exercises in malfunction isolation were given Air National Guard personnel. Data were obtained using questionnaires, a performance test and interviews. Operational and motivational similarity of the general purpose simulator to the job were explored.

Results

Data from the evaluation indicated that the simulation was usable, effective and acceptable. Detailed information concerning: (1) the experience of the personnel receiving training, (2) learning and learning potential, (3) an evaluation of training potential by qualified personnel, and (4) attitudes and acceptance by field personnel was obtained and is reported. Experience levels were generally over four years. Qualified personnel were able to troubleshoot the APQ 126 Radar System, while unqualified personnel were not able to work on the radar system prior to training. The goals of the training program were achieved to a satisfactory level. Actual performance scores also indicated training goal achievement. A survey of the potential of general purpose simulation indicated it as a generally preferred primary mode of training. Positive attitudes and general acceptance of general purpose simulation were recorded.

Conclusion

General purpose simulation can be an effective and economical tool for job training in work environments. Training in such areas as malfunction isolation can economically and rapidly be provided. However, factors which when manipulated can reduce cost and increase effectiveness have not been identified prior to a simulation design. Lack of engineering realism in this simulation did not negatively affect any measurable aspect of training. The requirement for articulating predictive principles for the psychotechnology of simulation design was identified as a task for future research.

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TRYOUT OF A GENERAL PURPOSE SIMULATOR IN AN AIR NATIONAL GUARD TRAINING ENVIRONMENT

I. INTRODUCTION

The development of economical and effective simulation is necessary to provide student active practice of the task being learned. One possible technique for providing low cost hands-on training is general purpose simulation. Previous research under an Air Force contract has indicated that general purpose simulation in formal technical training may be feasible and cost-effective in many applications. This report evaluates the use of general purpose simulation in an on-the-job-training (OJT) environment.

General purpose simulation includes a family of simulators sharing certain features. Specific training requirements are met by modularized configurations which are seated upon a standard mainframe and control system. The mainframe console consists of a programmable digital computer, a random access rear-screen projection system, a computer controlled meter movement, and a control center (a digital keyboard with digital display indicators). The modularized configuring capability is derived from a task specific simulation display panel (a pictorial/schematic model of selected equipment with appropriate control circuitry), magnetic tape cassette computer program, a plastic embedded slide projection disc (for the customized projector), and interchangeable meterfaces and probes (when included). A specific simulator is activated by installing the appropriate slide projection disc, and the desired simulation display panel, on the mainframe and loading the matched magnetic tape cassette into the dedicated computer. The mainframe console holds the simulation display panel which, when locked in place, is controlled by the computer appropriately programmed. The control console keyboard then is used to select the conditions of simulator operation (normal or various preselected malfunction modes).

General purpose simulators (GPS) permit sharing of programmable control equipment in a variety of specific applications. A simulation representing a radar system can rapidly be reconfigured to represent a camera, a washing machine, a fire control system, or the ignition system of an engine. When a simulator configuration is installed normal system operation is simulated unless prespecified malfunctions are entered by means of the control panel. During malfunction operation, correct isolation of the malfunction automatically returns the operation to normal mode. The digital display indicators show elapsed time and the number of replacements. The number of systems tests can also be recorded when appropriate.

An evaluation of general purpose simulation, to increase hands-on capabilities in Air Force technical training in a resident environment, was conducted and results are documented in a technical report which is in press. A GPS marketed as the EC-II was procured from the Educational Computer Corporation. Following special factory training and an analysis of the course learning requirements, a faceplate (simulation display panel) and a sequence of slides were designed so as to simulate the APQ 126 Radar System which is associated with the A7D aircraft. The computer program, implementing the faceplate and selected slides, was developed by Educational Computer Corporation and procured from them. The finished product is pictured in Figure 1.

Evaluation of the resulting simulator was performed in several ways. Cost comparisons, effectiveness in learning, learner attitudes, and an analysis of design difficulty were performed in a selected Avionics course. Results showed that the initial cost for an operational GPS was less than ten percent that of the equivalent actual equipment trainer (AET). Moreover, training in techniques of malfunction isolation was not possible using the comparable AET. The GPS provided significant learning opportunities not previously available, nor readily feasible using other modes.

Training on both the GPS and the AET permitted student learning to the criterion performance level on normal operational procedures. No interference occurred when transferring either from the GPS to the AET or the AET to the GPS. As stated above, practice and feedback on the isolation of malfunctions was provided only on the GPS; a capability previously unavailable to the course of instruction.

A field evaluation using field personnel for instructors was requested by the Air National Guard to determine if general purpose simulation would assist in their OJT program. While the GPS was shown cost effective and feasible in a technical training resident school environment, its use in job training on the flight line had not been evaluated. The purpose of the present study was to evaluate the usability, effectiveness, and acceptability (by instructors and students) of general purpose simulation. The simulation

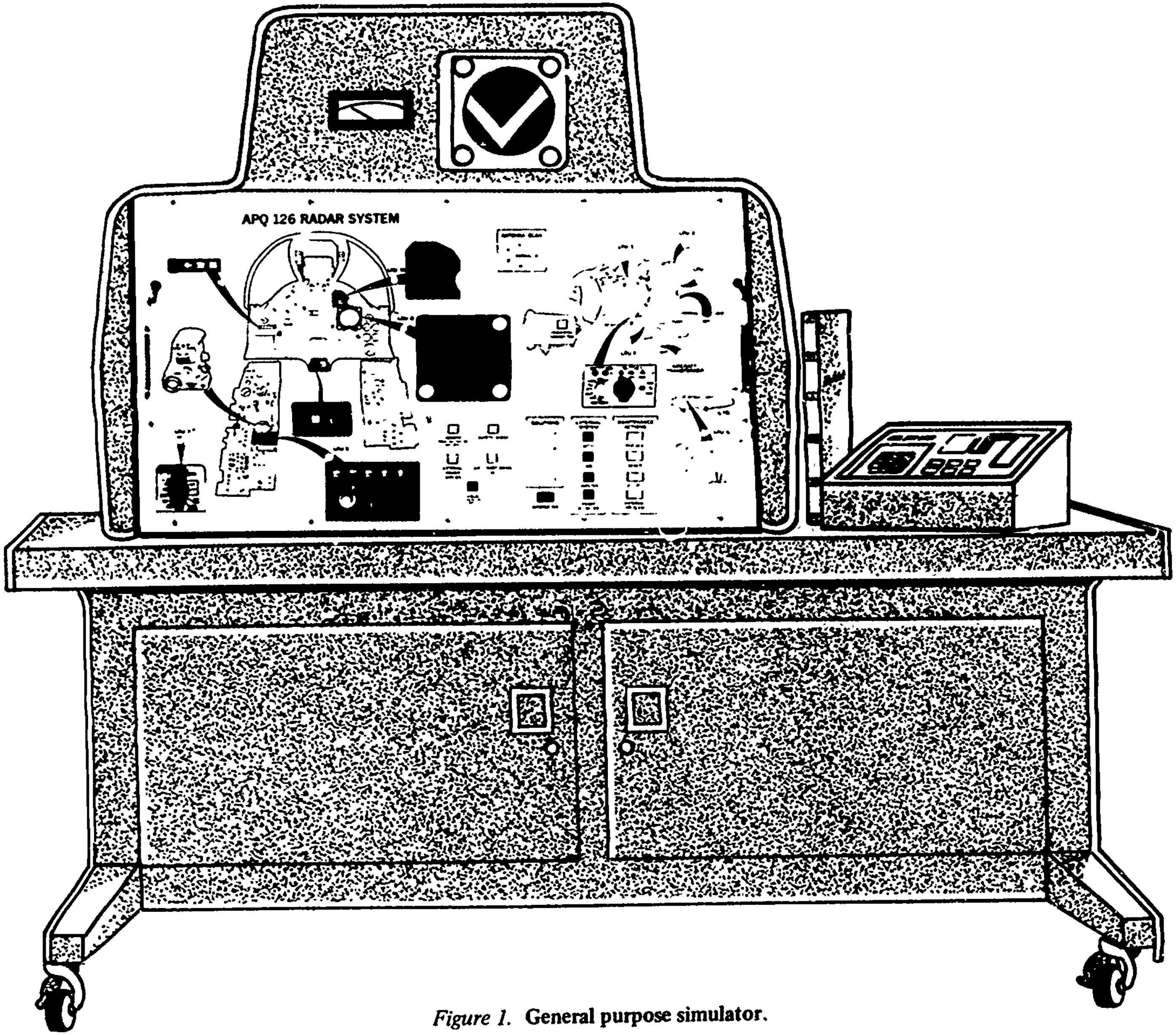

Figure 1. **General purpose simulator.**

of the APQ 126 Radar System previously developed for use in an avionics course in a formal technical training school was used. This simulation based on the school requirements enabled training in normal operational procedures and malfunction isolation to the -3 skill level on the APQ 126 Radar System.

II. METHOD

Training was conducted for the field evaluation by Air National Guard personnel. An experienced five-level weapons systems mechanic on the A7D aircraft was trained in the use of the APQ 126 simulation program on the GPS by an experienced instructor from the Avionics Department at Lowry AFB, Colorado. Later a three-level mechanic with previous experience in teaching high school was trained so as to perform as an instructor.

The five-level technician oriented the nine remaining weapons control shop mechanics to the GPS at Buckley Field, Colorado. Orientation consisted of showing each man how to operate the simulator and giving him practice on isolating some predetermined malfunctions. Then each of the mechanics was tested in malfunction isolation. A questionnaire (Appendix A) was administered before and after working with the simulator. This questionnaire was used to determine previous experience, learning, a comparative evaluation of training potential, attitudes, and acceptance. The time and number of replacements for malfunction isolation also were recorded by each technician. Since all technicians were skilled, this exercise provided an indication of acceptability and perceived usefulness of the simulator. The capabilities of a generalized simulation approach to training were shown to each mechanic by direct experience.

On a different day, all three reserve Air National Guard personnel were trained by the three-level technician. For the first hour, the three were trained together in normal system operation. An additional hour and one-half instruction was provided to each individually. Following training each student was tested in malfunction isolation. Questionnaires were administered before and after training to determine previous experience, learning, attitudes and acceptance.

On the following day, three five-level technicians from the Avionics Aerospace Ground Equipment Repair Shop were cross-trained using the GPS. The three-level technician conducted the training in the same manner as previously described for the reserve personnel training.

Data were thus acquired from eleven qualified personnel and six unqualified personnel. All assigned personnel in the appropriate specialty area were used to collect this data.

III. RESULTS

Information acquired from the field evaluation questionnaires included: (1) the experience and background of the participating personnel, (2) learning, (3) an evaluation of training potential by experienced personnel, and (4) attitudinal and acceptance indicators.

Experience. Nine of the eleven full time Air National Guard personnel in the weapons control shop had between four and eight years experience. Median level experience for the eleven qualified personnel was 4½ years. All were familiar with the APQ 126 Radar System and reported themselves qualified to troubleshoot this system.

With respect to skill level, three participants were at the -7 level, five at the -5 level and one man at the -3 level. Six personnel had worked on other radar systems, while five had no experience on any other radar system. It was reported to the experimenter that other radar experience would provide only minimal transfer to the operation of this system. The primary mode of initial training received on the APQ 126 Radar System was reported as: Actual equipment trainer–6 persons, Equipment as installed on aircraft–4 persons, Lecture and technical order–1 person.

The three reserve personnel had between 2½ and 5½ years experience. One had worked on the A7D aircraft under supervision, and two had begun informal training on the APQ 126 Radar System. All had limited experience on another radar system. None were qualified to troubleshoot this radar system.

The three Avionics Aerospace Ground Equipment Repair Shop personnel each carried a five-level skill AFSC and ranged from 3½ to 5 years experience. One reported some familiarity (and no training) with the

APQ 126 Radar System and two had experience on other radar systems. None were qualified to troubleshoot the APQ 126 Radar System.

Learning. The three level-training program, which the GPS implemented, was intended to teach: (1) the purpose of the controls, (2) the interpretation of normal versus malfunction operation, (3) the performance of system self-checks, and (4) the exercise of malfunction isolation.

Each person was asked whether the GPS effectively met the four training goals. They stated that they could perform the objectives as a result of the instruction. Table 1 presents the questionnaire results and also the performance test scores on malfunction isolation. It should be noted that the isolation of malfunctions is not possible without achieving the three enabling goals. Scores on the performance test substantiate the self reported learning. Two five-level personnel felt that appropriate system self checks were not adequately covered by the program and one felt that malfunction isolation training was not adequate.

Table 1. Learning on the GPS

Learning Indicator	Type Personnel		
	Qualified	Unqualified	Combined (Qualified and Unqualified)
Did you learn purpose of controls (Yes/Total)	11/11	6/6	17/17
Can you interpret normal/malfunction operation (Yes/Total)	11/11	6/6	17/17
Can you perform system self checks (Yes/Total)	9/11	6/6	15/17
Can you isolate malfunctions (Yes/Total)	10/11	5/6	15/17
Mean number replacements (Units)	1.43	1.71	
Median of average malfunction isolation time (Minutes)	1.76	2.82	

Evaluation of Training Potential. In inquiring into training potential, only the opinions of the qualified personnel are summarized since their duties could call for them to provide training. They also have enough job experience to realize what aspects of the job require training. These experienced technicians felt that if they were a training person that the fastest primary mode of instruction would be:

General Purpose Simulator -- 5 persons

Installed equipment – 4 persons

Actual equipment trainer – 2 persons

Experienced technicians felt that the most effective mode of learning would be:

Installed equipment – 8 persons

Actual equipment trainer 3 persons

Mode of instruction making learning the easiest was felt by experienced technicians to be:

General Purpose Simulator – 6 persons

Installed equipment – 3 persons

Actual equipment trainer – 1 person

Attitudes and Acceptance. All personnel rated the learning on the GPS as easy, while fourteen of seventeen liked the GPS application to learning. All but one of the experienced technicians recommended the use of a simulator such as the one evaluated for use in training the APQ 126 Radar System and other systems to be trained. Most frequently mentioned as suitable for generalized simulation were the A7 computer and head-up display (HUD) systems. Several also suggested the appropriateness for this approach in any or all avionics systems.

IV. DISCUSSION

The evaluation of the APQ 126 Radar System simulation on the GPS conducted at Buckley Field was designed to determine effectiveness, usability, and acceptance in a job environment.

The goals which the simulator was designed to achieve were accomplished by all personnel. Not only were the students asked whether they had learned specific tasks or operations, a performance test also showed a high level of achievement using the GPS. Of particular note is the programmed capability provided by the simulator enabling training in the isolation of selected malfunctions. Experienced mechanics given the write-up averaged less than two minutes to identify and correct each malfunction in the simulation. Time to clear a malfunction on the flight line would average over an hour per malfunction because of the need to actually remove the faulty component, and probably slightly longer when training is also being accomplished. Thus, the time compression provided by the simulation enables more practice in developing the concepts involved in the isolation of malfunctions. The big picture is made clearer.

All personnel exposed to the GPS indicated that it provided an effective and efficient approach to learning. Learning was reported as easy on the GPS by everyone responding. Most recommended its use in Air National Guard training.

Speed and ease of training made the GPS a preferred primary mode of instruction by experienced mechanics. The effectiveness when used in conjunction with actual equipment also was seen as indicating the usability of the GPS in training. With only minimal exposure to the GPS, many experienced mechanics selected it as a preferred primary training mode. The recommendations of these experienced mechanics indicate that the GPS is usable for field training. Further, the training program on the APQ 126 using the GPS was conducted by the least experienced of the weapons control shop mechanics – a three-level person. He was able in only 2½ hours apiece to provide satisfactory training in both normal and malfunction isolation mode for all students. The GPS is shown as usable in field training by the present data.

Student and instructor acceptance of the GPS was indicated by the questionnaire data. Experienced mechanics generally indicated that training could be performed faster and easier on the GPS. This would indicate acceptance. The GPS was recommended for training by most of the personnel. This also indicates acceptance. When directly queried most personnel liked using the APQ 126 Radar System simulation on the GPS.

This report indicates the efficiency and effectiveness of the simulation of an APQ 126 Radar System in a field training environment. The results are not unexpected. Simulation as a method of instruction can be effective for teaching many tasks and skills in technical training. A wide variety of procedural sequences, perceptual-motor skills, identifications, conceptual tasks and team functions have been effectively learned through the use of simulation. The approach of systematically abstracting and partially duplicating tasks, activities, or operations can provide transfer of training from a synthetic environment to a real environment. Simulation allows student involvement in learning, paced to the needs of the individual. Learning by doing is emphasized. Both practice opportunities and forms of feedback usually not available when using the actual equipment or when operating in the real world may also be provided.

Simulation often has training advantages over real world operation. Baker and Warnick (1970) list six techniques to enhance transfer of training. Application of these techniques makes the training situation physically dissimilar to the actual situations. These six conditions are:

1. Provide augmented feedback, i.e., extra knowledge of results during instruction.

2. Increase the number and frequency of crises, conflicts, equipment breakdowns, and emergencies.

3. Reduce the operational time for certain events, so as to increase the amount of practice.

4. In the total performance behavior, vary the part-task sequence, because small amounts of practice on several similar tasks promote more learning than large blocks of practice on a single task.

5. Provide guidance and stimulus support in the early or initial stages of learning.

6. During training, vary the progression of difficulty levels: a progressively easy-to-difficult procedure facilitates transfer of training.

Simulators represent a real situation in which tasks are performed or operations are carried out. They omit, however, selected parts of the real operation which are psychologically unimportant to the task of operation, which are dangerous, which are expensive, and hopefully they also omit some of the unpredictabilities of the real world. Simulators provide the learner with predetermined levels of control over the task or operation, thus allowing controlled practice on representative or critical aspects of the selected tasks or operations.

For training effectiveness the simulator must provide psychological realism (Miller, 1954). Job inputs or inputs identifiably representative of job inputs must be provided. The student must exercise some level of control over the system, typically based on the inputs. Some consequences as a result of the students interaction with the system also must be represented. Baker and Warnick (1970) state that operational similarity and motivational similarity must be incorporated into the simulation.

While simulation has been shown as an effective way of training for a wide variety of specific operations or tasks, the principles upon which the successes have been based remain unclear. In fact, our knowledge of the psychological principle of transfer of training is still incomplete. No predictive body of knowledge is available which will ensure the adequate design of a simulator for effective training. The specific goals of the training program, when used to direct the design of a simulator, generally result in a usable simulator, that is, a simulator which provides the required training. However, general factors which when manipulated, can reduce cost and increase training effectiveness have not been clearly identified.

One major difficulty, widely recognized by training technologists concerning simulation is the issue of realism. Psychological realism does not imply reproducing all aspects of the physical environment. Engineering fidelity and physical realism are not necessarily incorporated into a GPS. A fixed size face plate and a series of selected images and meter readings limit the possible visual inputs to the learner. Typically, other related units are not attached to the GPS although it has been done when deemed necessary. Denenberg (1954) first showed that physical realism in a tank hull trainer may not be necessary in providing necessary and adequate transfer to the job. While no generalizable simulation studies have been reported, results similar to Denenberg's study have been reported for a wide variety of simulators. In fact, AF Pamphlet 50-58 (Vol IV, Section 5–10f) provides specific guidance in selecting appropriate levels of representation. This section states that only those properties relevant to the learning task should be represented. An example is provided showing that either too much physical realism or too little realism are inappropriate in selecting the appropriate representation levels. The visual materials used and selected must provide the necessary inputs to enable the cuing of appropriate task performances. Physical realism provides no assurance that useful information will be seen, learned, or remembered. For example physical reality may be too complex for a beginning learner to make the appropriate discriminations, associations, and generalizations so as to meet the training requirements. Representations of reality frequently must be simplified and stylized in the early stages when learning efficiency is desired (Travers, 1964).

It has been customary in procuring new simulators to require engineering fidelity; that is, the simulator is required to function as nearly as possible in the way in which the real equipment functions. This usually means that an AET will be preferred. The implicit assumption is that better transfer can be directly associated to more realistic representations. Not only may this assumption be expensive, it may

also be detrimental to training. An operational item of equipment may not be designed for operating in ways which would provide the most effective training. For example, a landing gear hydraulic activator may be quite well designed for normal flight operations but might not hold up too well if operated 50 time an hour for 16 hours a day (if this were necessary in training).

In actual practice, while actual equipment trainers or simulators are frequently used for demonstrations, they are not widely available for the student in technical training to actually manipulate. This results in a lack of hands-on practice for the students on job related skills. Unavailability of this training resource may result in a lower level of training which uses more classroom instruction time. It may take more time to accomplish less. When not provided job related skill training in school, the technical training graduate requires more OJT, thus reducing the job time available to the field unit from both the student and the person training him.

In summary, data collected from field use of a GPS indicated that psychological realism was economically captured in a simulation of the APQ 126 Radar System.

The goals which the simulator was designed to achieve were accomplished by all personnel. Operational similarity was achieved by providing job-like information inputs and enabling symbolic performance of appropriate actions in response to the preselected inputs. Motivational similarity—a feeling or attitude on the part of the student of functional similarity between the real equipment and the simulator was also achieved. This was indicated by its general acceptance by experienced mechanics as a useful training device following minimal exposure. This simulation specifically intended for training provided many advantages not obtainable when using the real equipment, at far less cost than either the real equipment or an AET.

The use of appropriate and well designed simulation is essential to cost-effective technical training in the Air Force. Design of the simulation, however, must be integrated with the design of the course and must implement the course goals. When selective practice of crucial job operations and appropriate feedback are required in training a simulator must be considered. Use of a GPS provides a reasonably economical simulation capability when a variety of simulations are required in a training program or when low student flow permits sharing of GPS capability among different programs.

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APPENDIX A: PRETESTING AND POSTTESTING QUESTIONNAIRE

PLEASE ANSWER THESE QUESTIONS BEFORE TRAINING

SSN____________________ RANK/GRADE____________ YEARS OF SERVICE______

Primary AFSC

Secondary AFSC

Have you had any experience with the A-7 aircraft? Yes No

I have experience working on equipment on the following aircraft

series:____

____

Are you familiar with the APQ 126 Radar System? Yes No

Have you received training on the APQ 126 Radar System? Yes No

If yes, did you learn from:

(a) Actual equipment trainer Yes No P

(b) Equipment as installed on the A-7 aircraft Yes No P

(c) TO and lecture Yes No P

(d) EC II Simulator Yes No P

(Please circle P for primary mode of training)

Have you worked on the APQ 126 Radar System? Yes No

Are you qualified to troubleshoot the APQ 126 Radar System? Yes No

Have you worked on other radar systems? Yes No

If yes, which____

PLEASE ANSWER THESE QUESTIONS FOLLOWING TRAINING

SSN ____________________

1. Did you like using this approach to learning? Yes No

2. Was the learning (a) easy or (b) difficult when using the ECII Simulator?

   (circle one) (a) (b)

3. Did you learn the purpose of the controls? Yes No

4. Can you interpret normal versus abnormal (malfunction) operation? Yes No

5. Can you perform the appropriate system self checks? Yes No

6. Can you isolate malfunctions? Yes No

7. Will this training enable you to work more effectively on the actual equipment? Yes No

8. As a training person using as a primary mode of instruction each of the following modes

   (a) Actual equipment trainer
   (b) Equipment as installed on A/C
   (c) TO and lecture
   (d) EC II Simulation

   Which mode would be the fastest? (a) (b) (c) (d) (Rank order with top choice #1)

   Which mode would provide most effective learning? (a) (b) (c) (d)

   Which mode would make learning the easiest? (a) (b) (c) (d)

9. Would you recommend the use of a simulator such as the EC II simulation of the APQ 126 for your training program?

   (a) For the APQ 126 Yes No
   (b) For other systems to be trained Yes No

MALFUNCTION MODES

MALF #	NUMBER OF REPLACEMENTS	TOTAL TIME
02		
06		
07		
08		
10		
11		
12		