MAINTENANCE READINESS THROUGH EFFECTIVE SIMULATION TRAINING

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INTRODUCTION

Prepare maintenance technicians to be job-ready. That is the goal of maintenance training. As it exists today, it works with varying degrees of proficiency. Much of it could work better if all the necessary training aids and devices were available to the training facility: Audiovisual devices, Maintenance Training Units (MTU's), Actual Equipment Trainers (AET's), Simulation Models, etc. How and what devices are selected for a particular application is an exercise in itself, and as such is often the reason why many training facilities don't have the necessary training aids. Effort is spent evaluating and determining which or what device best suits a particular need. In the meantime the training facility is making do with whatever it has.

This is the case with maintenance simulation. Simulation is fairly well accepted for operator training, especially in flight training. It has its obvious advantages--cost savings, safety, condensation of time, opportunity to practice procedures which occur only during rare and critical situations, etc. There is much debate over how many degrees of motion, how to provide the motion, and what fidelity should be provided. But whatever is required or desired is available - at a price. Simulation in other areas has been slow to be accepted, especially in maintenance training. One reason is that it is not always applicable to the training requirement, but in those instances where it is applicable, too often the reasons for not using it are not objective. It is often accepted conceptually, but it is something new, it is different, and not everyone who has the requirement is willing to make that step to simulation for maintenance training. Many people are studying the problem.

They ask how much fidelity; what is the transfer rate; what is the retention rate; how does it compare to existing processes; is it better than using maintenance training units or actual equipment trainers; how best to evaluate its applications? All valid questions, but the questions continue to outnumber the answers. Some of these people appear to be making the study of the problem an end in itself.

An attempt to justify simulation in maintenance training will not be made here; however, some studies which have been conducted with the particular device discussed in this paper are referenced: [1], [2], [3], [4], [7]. The main intent of this paper is to describe the use of a simulator in maintenance training at a facility that had a need and took the necessary steps to acquire it. That facility is the Marine Corps Air Station, Cherry Point, North Carolina, NAMTD 1006, where AV-8A Organizational and Intermediate Maintenance Activity training is conducted.

BACKGROUND

The AV-8A (Harrier) Aircraft is manufactured by Hawker-Siddley Aircraft, Ltd., in the United Kingdom. It is a high-performance attack jet aircraft with many complex internal operating systems. The aircraft is operational with the United States Marine Corps, Marine Air Group 32(MAG-32).

In early 1973, maintenance training for the AV-8A was being conducted at the Marine Corps Station, Beaufort, South Carolina. The programs of instruction for most of the courses were still in a developmental stage. Training was being conducted with only a very limited number of training aids. These were primarily static display panels and a few film transparencies. They allowed the instructor to provide the student with chalkboard talks and information about the various systems and their operation. The instructor was able to demonstrate limited systems operation and he could only discuss the theory of fault isolation procedures. If and when he had test equipment available, he was able to demonstrate calibration, checkout, and test maintenance.

The school was having the usual contest with squadron maintenance trying to acquire test equipment for training use. As is typical the school was usually on the short end. In those labs where they did have test equipment, they had the also typical problem of maintaining and calibrating it. When their test equipment was sent to the calibration lab, it received the lowest priority, and as a result there were long periods of time when the class would be without test equipment. When it was available in the classroom there was instructor reluctance to allow the student free use of it. The student had to be continually monitored. His inexperience with using the equipment generally resulted in its rapid deterioration. Acquisition of a maintenance training simulator would eliminate this problem.

A number of simulation models which could be used in the various courses were proposed by Educational Computer Corporation (ECC). The models were designed to satisfy training requirements imposed by the instructional staff and be able to be used within the existing courses and those that were yet to be developed. The use of the simulators would increase the overall effectiveness of the training by allowing the instructors to cover each system more thoroughly. The simulation models would be designed to include the necessary test equipment in each particular application and thus eliminate the requirement for the actual special support test and calibration equipment required. The student could be allowed free use of the models for practice without fear of damage.

In addition, the school was under pressure to begin its training. Expediency in delivery of equipment was critical. Subsequently, nine simulation models which would be designed to support the training requirements in selected courses of instruction, were proposed by Educational Computer Corporation. A contract was signed in May of 1973. In January 1974 the nine models were delivered and accepted. The mainframes had been delivered prior to that time. In approximately 28 weeks after contract the school had its simulations.

Originally, nine simulation models of the operating AV-8A Aircraft Electrical Systems were proposed. These would be used to support organizational level maintenance training at one site which was later transferred to MCAS Cherry Point, North Carolina. The simulation models would enable the instructor and/or the student to locate, operate, calibrate, test, and simulate the replacement of aircraft line replaceable assemblies. The nine models proposed were:

- Electrical Power Supply - AC-4KVA
- Power Supplies - DC - 4KVA
- Power Supplies - AC/DC 12KVA
- Gas Turbine Starter/Auxiliary Power Unit
- Power Plant Instrumentation
- Fuel System 1
- Fuel Panel 2
- Auto Stabilization
- Centralized Warning System

The use of these simulation models subsequently led to the ordering of eighteen additional simulation models, two of which, the "Air-Data Computer" and the "Engine Life Recorder" were designed for Intermediate Maintenance Activity (or "I" level) training.

SIMULATOR DESCRIPTION

At this point it would be well to describe what the simulation models are. The models mentioned are components of a system manufactured by Educational Computer Corporation. Detailed descriptions of the development and design of a simulation model are available in other papers: The Educational Computer Corporation Approach to Hands-On Maintenance Training, Siecko [5]; Effective Training Through Simulation--Now, Siecko and Breslin [6]. Figure 1 provides a description of an EC II-LP and its various subcomponents. Briefly, it is a main frame which houses a computer which is used to drive the display panel, the projector and the meter as required. The control console provides a means whereby the overall status of the simulation display panel can be changed; for example, from a normal configuration to a malfunctioning configuration, or requirement for various checkout procedures or a checkout of a system which contains a malfunctioning component. The display panel is the central focus of the simulation model in that it contains a facsimile rendering of the system or systems being simulated. This panel may also contain hardware as is required to facilitate the simulation. Figure 2 is a picture of the simulator with a simulation model inserted. Figures 3 and 4 depict the desk-size version of the EC II.

What is unique about these simulators is that they are programmable and the point of interaction with the operator (student or instructor) is the two-dimensional panel which contains a rendering of the prototype system or device being simulated. This panel may contain lifelike or actual hardware depending upon the training application. This, in turn, is supplemented with a random access slide projector to provide cues, symptoms, instruction, queries, and so forth, to the student or directions to the instructor. Operation of the simulation model is performed directly upon the panel. For example, the student or instructor would operate or perform a checkout procedure of a radar or navigational control system just as he would in real life. Control of the simulation is managed by an internal digital processor.

In addition to the panel I/O, there is a control panel which directs the status or condition of the simulation. This status can take many forms. One is that of a normal condition--where all operations reflect the system in a normal or operating state. Other conditions can be various malfunctioning states of the simulated system. Under these conditions, all indicators, components, and tests depicted or made on the panel behave as they would in the real world when the system has a specific malfunction. The device can accurately reflect selected equipment problems

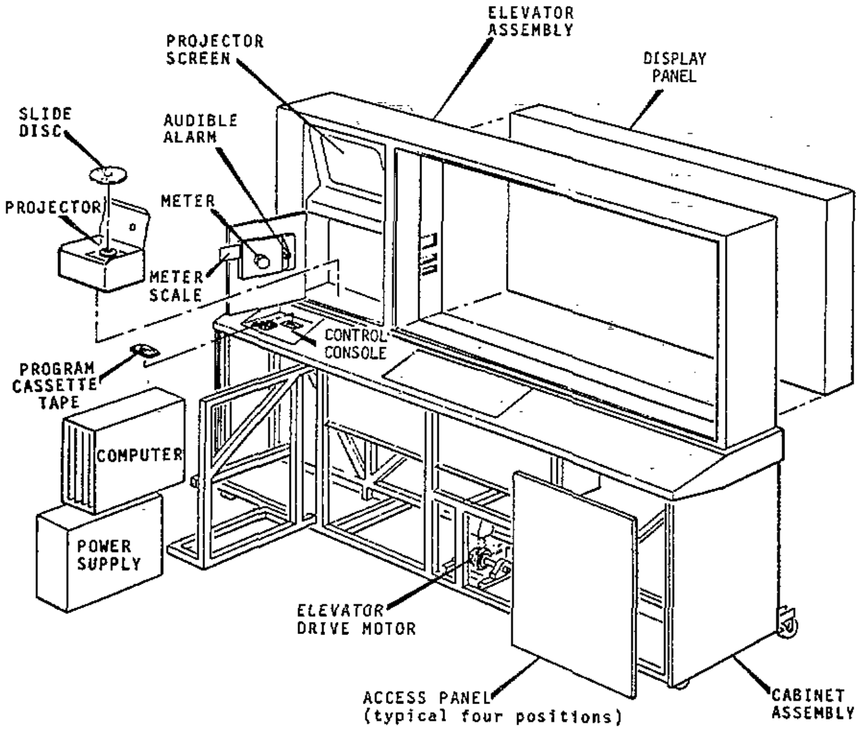

Figure 1. Exploded View of EC II-LP

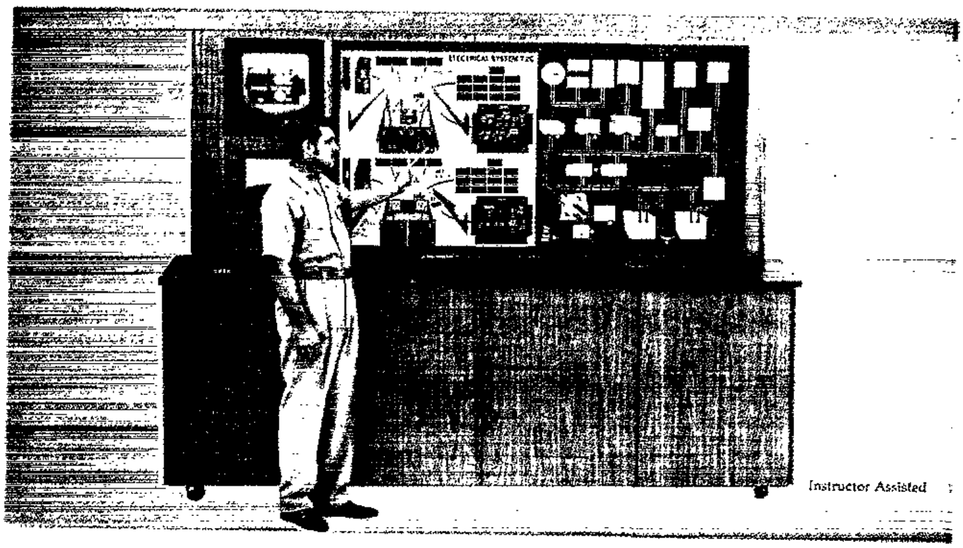

Figure 2. EC II-LP

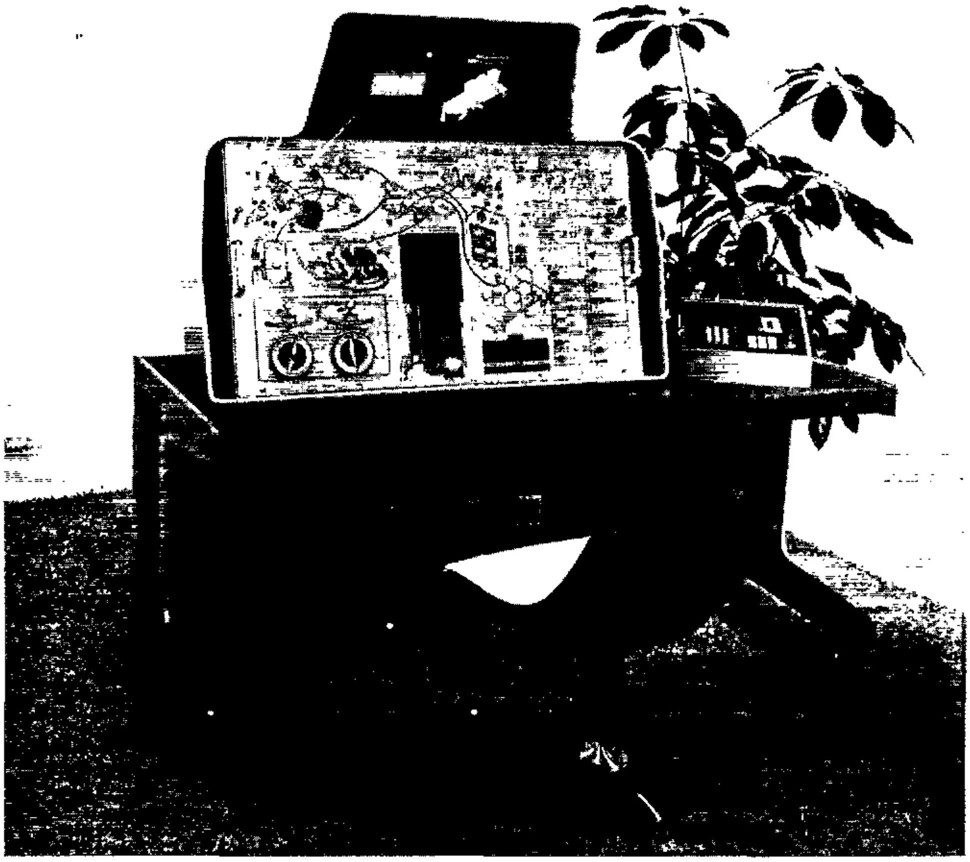

Figure 3. EC II

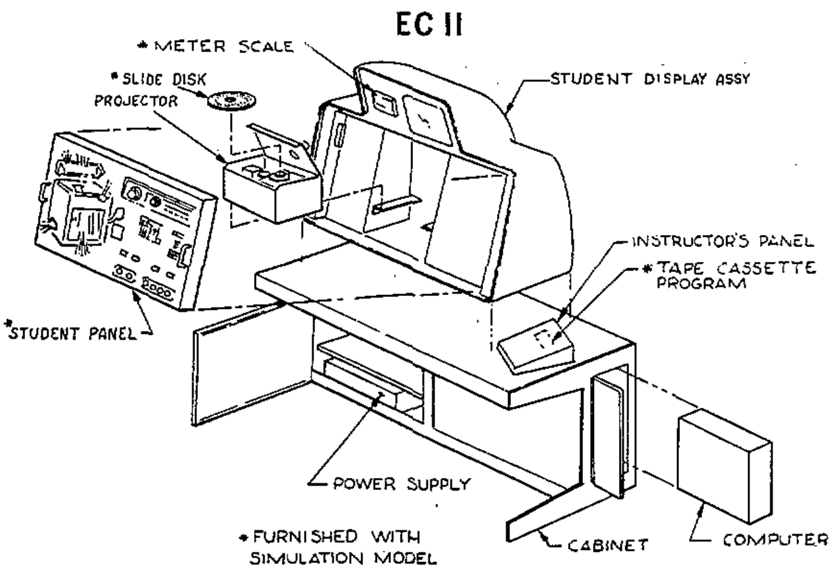

Figure 4. Exploded View of EC II

and a student can repeatedly practice his diagnostic skills until he reaches some required proficiency level.

The operation of the simulation can be either directed or random. This is an option of the simulation designer and is dependent upon the governing factors within the training system. These factors are uncovered during the design of the training system. Most often, when troubleshooting has been selected as one of the learning criteria, the student has been relegated to the study of flowcharts, OJT, and reliance on his ability to apply his theoretical understanding to the real world. This device provides simulated practice in troubleshooting and diagnostics in a controlled learning environment.

The programmability of this type of simulator provides it with unlimited potential. For example, while the panel remains unchanged, the control console or a separate program can request a condition which is fully instructional-introducing the student to the simulated system and diagnostic techniques. Another condition can be such that the student is left to his own capabilities-without instructional control. The program can be constructed to monitor the student as much as is desired. Modification of the simulation model is inherent within its design. The program can be modified inexpensively and at any time. A modification of the panel generally involves only a patch to change artwork and/or the addition or removal of some panel component.

The device is built by Educational Computer Corporation in various forms. One model is produced in a desk-size configuration (the ECII). A second is a larger version used for classroom demonstration (the EC II-LP).

APPLICATION OF SIMULATION MODELS

The NAMTD 1006 receives most of its students directly from the Naval Aviation "A" School, Memphis. An entering student is normally assigned to one course. After completion he then receives on-the-job training (OJT) at the squadron and only after his Work Center Supervisor deems he is capable of unsupervised activity does he receive his MOS rating. He may, however, be sent back to the school for other speciality training and thus have more than one MOS.

Courses at the NAMTD range from four weeks for the Aircraft Engine Mechanic Organizational Course to 13 weeks for the Electrician Organizational Course. The school is authorized to teach 26 courses, but only 13 courses utilize the simulation models, of which they have 27 (See figures 5, 6, 7, and 8 for pictures of the display panels for some of these models.):

- Nose Wheel Steering
- Head-Up Display System
- 4KVA DC Power Supply
- LAU-7/A Guided Missile Launcher
- Engine Fuel System
- CNI (Navigation)
- Landing Gear
- Wheel Brakes and Antiskid
- No. 1 Hydraulic Power Supply
- Wing Flaps
- Cabin Air Conditioning
- Armament Control System
- Gas Turbine Starter/Auxiliary Power Unit
- 4KVA AC Electrical System
- 12KVA AC/DC Electrical System
- No. 2 Hydraulic Power and Ram Air Emergency Supplies
- CNI (Communications)
- Air Brake
- No. 1 Fuel System
- No. 2 Fuel System
- Centralized Warning System
- AV-8A Autostabilization System
- Power Plant Instrumentation
- Baseline 800 Attitude and Heading Reference System
- Baseline 800 Weapon Aiming System
- Air Data Computer
- Engine Life Recorder

Because the EC II-LP simulator main frame is a standard item and all of the simulation models are interchangeable, the school requires only nine simulator main frames to support its 27 different simulation models. The main frames are portable and are moved to the classroom as they are needed, depending upon course scheduling and student flow. The appropriate model-display panel, program, and slide disk are then inserted and the simulators are ready.

All of the simulation models are programmed for normal operation status and contain malfunctions selected to intensify the training requirements. All courses which utilize the simulators reflect their use in their programs of instruction.

The following is a list of courses taught at the NAMTD 1006 that utilize the simulator and the simulation models used in each course.

__ Pilot's AV-8A FAM: A seven-day course which utilizes approximately 20 of the available models.

__ Enlisted AV-8A FAM: A four-day course which uses fourteen of the models.

"O" - Level Maintenance AV-8A

__ Electrician Organizational Course: A six-week course using nine models primarily designed for electrician training:

- Gas Turbine Starter/Auxiliary Power Unit
- 4KVA DC Power Supply
- 4KVA AC Electrical System
- 12KVA AC/DC Electrical System
- Centralized Warning System
- No. 1 Fuel System
- No. 2 Fuel System
- Power Plant Instrumentation
- AV-8A Autostabilization System

Five hydraulic/electrical models:

- Wing Flaps
- Landing Gear
- Wheel Brakes and Antiskid
- Air Brake
- Nose Wheel Steering

One Environmental/Electrical:

- Cabin Air Conditioning

One INAS/Electrical

- Baseline 800 Attitude and Heading Reference System

__ Armament Organizational Course - utilizes two panels:

- Armament Control System
- LAU-7/A Guided Missile Launcher

__ Environmental Organizational Course - utilizes one panel:

- Cabin Air Conditioning

__ INAS (Initial Navigation Attack System) Organizational Course utilizes 3 panels

- Baseline 800 Weapon Aiming System
- Baseline 800 Attitude and Heading Reference System
- Head-Up Display System

__ Hydraulics Organizational Course - utilizes seven panels:

- No. 2 Hydraulic Power and Ram Air Emergency Supplies
- Wing Flaps
- Landing Gear
- Wheel Brakes and Antiskid
- Air Brake
- Nose Wheel Steering
- No. 1 Hydraulic Power Supply

__ CNI (Communication, Navigation and Identification) Organizational Course - utilizes two panels:

- CNI (Navigation)
- CNI (Communications)

__ Aircraft Mechanic Organizational Course - utilizes one panel:

- Engine Fuel System

<u>Intermediate Maintenance Activity (IMA) AV-8A</u>

__ Air Data Computer IMA Course - utilizes one model:

- Air Data Computer

__ Engine Life Recorder IMA Course - utilizes one model:

- Engine Life Recorder
  (This course will be discussed at some length in the text of this paper.)

__ Head-Up Display (HUD) IMA Course - utilizes part of the "O" level "Head Up Display System" model in a FAM fashion for teaching symbology, modes of operation, and a system overview.

INTERMEDIATE MAINTENANCE ACTIVITY

The system maintenance plan describes the overall maintenance structure for each system in the AV-8A and states which Line Replaceable Units (LRU) exist in that system. At the Organizational Level (O-Level) maintenance the technician is required to perform a systems checkout to the line replaceable level and isolates and replaces faulty LRU's. For each LRU an individual maintenance plan exists and the Intermediate Maintenance Activity (IMA) or I-Level maintenance technician is responsible for this activity. Intermediate maintenance activity requires that the LRU be checked, repaired, and tested to the Sub-Replaceable Assembly (SRA) level and then the technician repairs the SRA, or he identifies the faulty component and the SRA is sent to the mini-lab for component replacement. Two of the simulation models listed above, the "Air Data Computer" and the "Engine Life Recorder" are IMA models.

These two simulation models were just recently received by the NAMTD 1006: the "Engine Life Recorder" (ELR) and the "Air Data Computer" (ADC), and will be used for I-level training. At the time of this writing the course had not yet been completed for the Air Data Computer; however, five classes have used the simulation model for the ELR, and the sixth was in progress. Classes usually contain four students each. Before the school had the simulation model, students received lectures in operation, test and checkout procedures for ELR Intermediate Maintenance Activity. However, no practical exercises were available. Any practical knowledge gained had to await OJT at the squadron level.

The Engine Life Recorder (ELR) "provides a visible means of indicating the used life of a gas turbine engine. The recorder is connected to the thermocouples in the jet pipe and the voltage produced by the thermocouples is used to drive a numerical display in the recorder, the rate of count being related to engine temperature." (A.P.112G-0132-1)

The simulation model of the Engine Life Recorder is designed primarily to provide a student with an individualized hands-on medium for operating and troubleshooting the ELR as depicted on the display panel. Figure 9 is a picture of the Engine Life Recorder display panel. It also allows the instructor to demonstrate the unit to a group of students. Through inclusion of applicable supporting test equipment, both normal and malfunction operations in an Intermediate Maintenance Activity can be simulated. The display panel allows the student or the instructor to make operational checks, troubleshoot, fault isolate, and make simulated equipment adjustments and calibration checks. The panel provides views and test points to allow these activities. Simulated on the panel is an ELR Test set, a power supply, a VOM, a stop watch, and a DANA digital voltmeter. Using the simulated ELR components he can perform the checkout, test, calibration and troubleshooting procedures specified in the technical manual (A.P. 112G-0132-1).

Especially important to the learning situation is the fact that the student can practice making adjustments to the trim pots which regulate the counters. For example; the test procedures require that certain standard conditions be established for the thermocouple inputs and the technician must regulate particular trim pots to bring the count within specification. He does this using the stopwatch and observing the ELR digital counter readout. This procedure is done on the simulator just as it would be in actual practice.

Another advantage of the simulator is that it is programmed to inform the student when he errs. It tells him where he can go for additional information. He is made aware of unsafe practices such as are warned against in the manual. Because it is simulated and under program control the test equipment never needs calibration. For example; if he uses the ohmmeter with power applied to the unit, he doesn't destroy a VOM or DVM.

In addition to providing practice in test and checkout procedures for the ELR IMA student technician this model also can depict the following malfunctions:

- Diode D24 open
- V T 9 open
- Relay C on board 3 inoperative
- Zener diode Z20 on board 3 open
- Amplifier A1 on board 1 fails
- Trim pot RV4 on LAW unit open

These malfunctions are entered through the control console keyboard by simply pressing their identifier code and hitting the enter key. When that is done all observable indications on the display panel (voltage checks, counts, etc.) react as they would on the actual equipment. The malfunctions programmed for this simulation model were selected on the basis of their commonality and frequency of occurrence determined at the overhaul facility.

Thus, when the student completes his training using the simulation model, he has already had practice in going through a full checkout procedure with equipment replicated as being in the normal state and checkout procedures where various malfunctions occur during the checkout. He gets real, life-like practice in "tweaking" the ELR to bring it into specification and he also simulates replacement of various representative components. He could not get this with actual equipment in the lab. Thus, when he leaves the school for an assigned squadron, he already has a basic useable maintenance skill.

CONCLUSION

In its Organizational and some Intermediate Maintenance Activity training the school relies almost entirely on use of its simulation models. When one tours the NAMTD 1006 Training Facility, there is no test or calibration equipment in the classes using the simulators.

The NAMTD 1006 had a critical training problem: To prepare maintenance trainees for the squadron, but they were without the necessary facilities. In order to meet their objective they took a pragmatic look at what was available to solve their problem. They made their decision to select simulation equipment and followed through with it.

Evaluation of the simulators was not their intent - preparing their students to be as job ready as possible was, and that is what they did. Their graduates can actually perform when they arrive at their assigned squadrons.

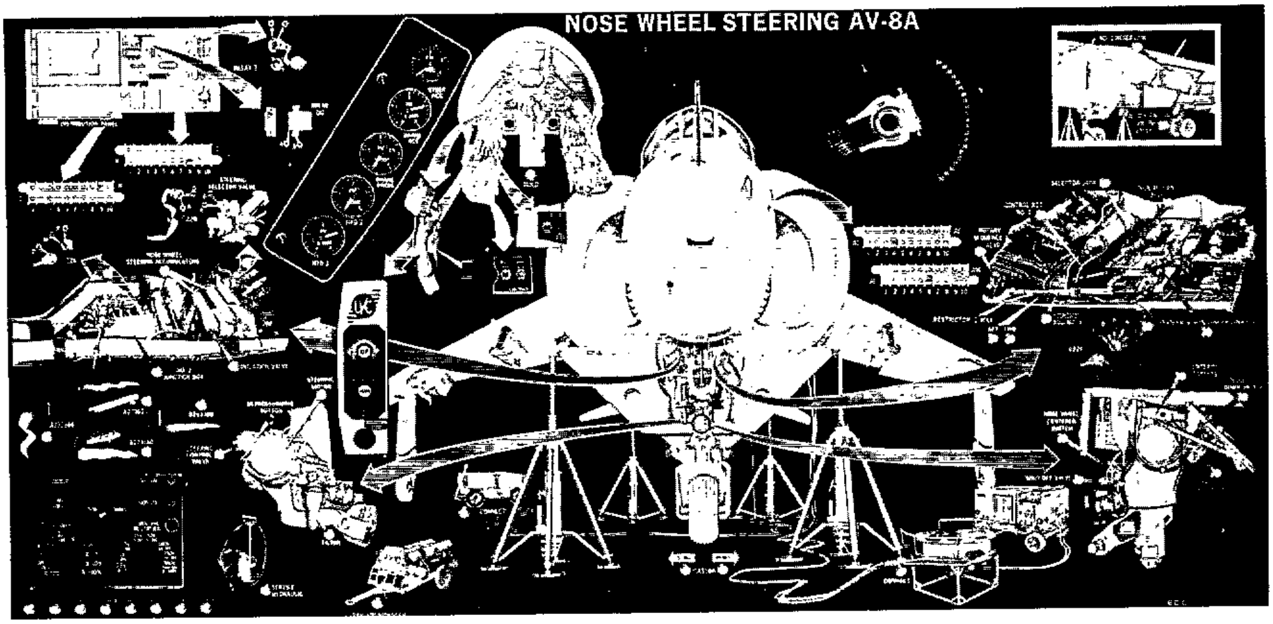

Figure 5. AV-8A Nose Wheel Steering Display Panel

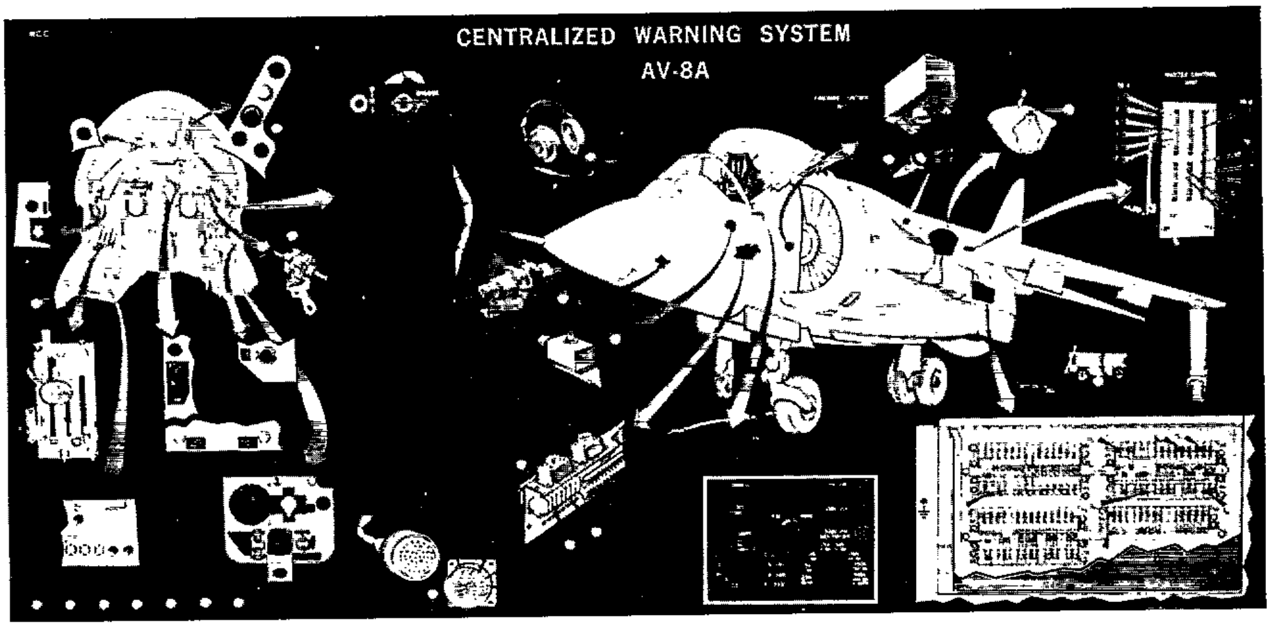

Figure 6. AV-8A Centralized Warning System Display Panel

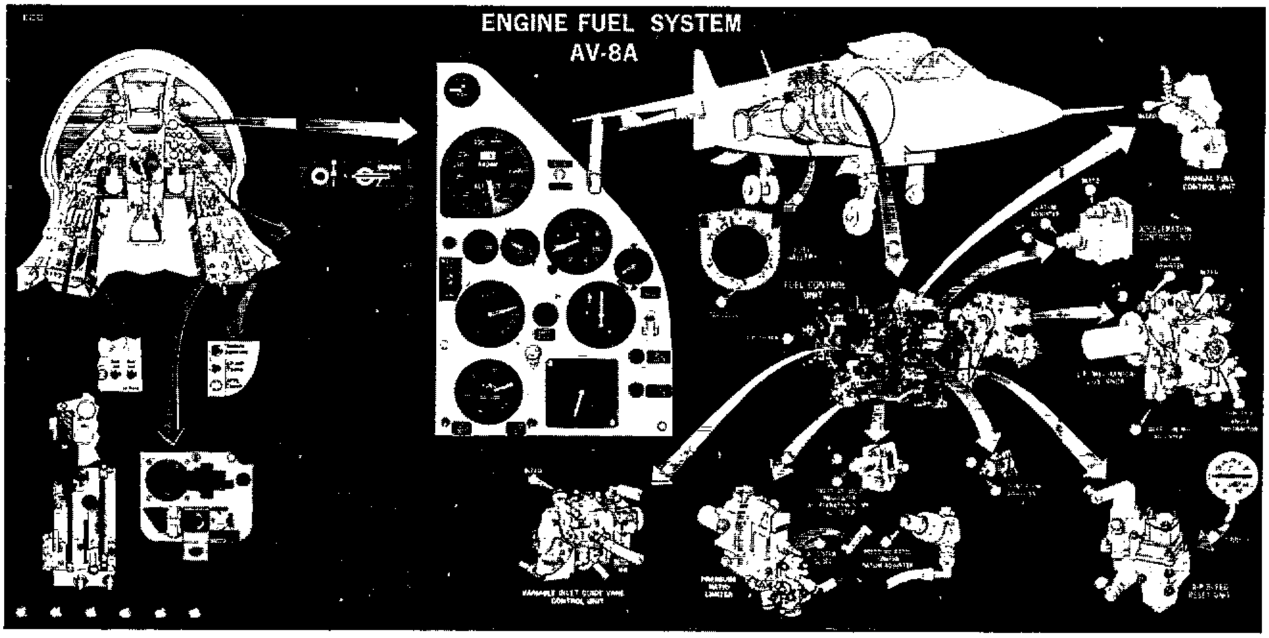

Figure 7. AV-8A Engine Fuel System Display Panel

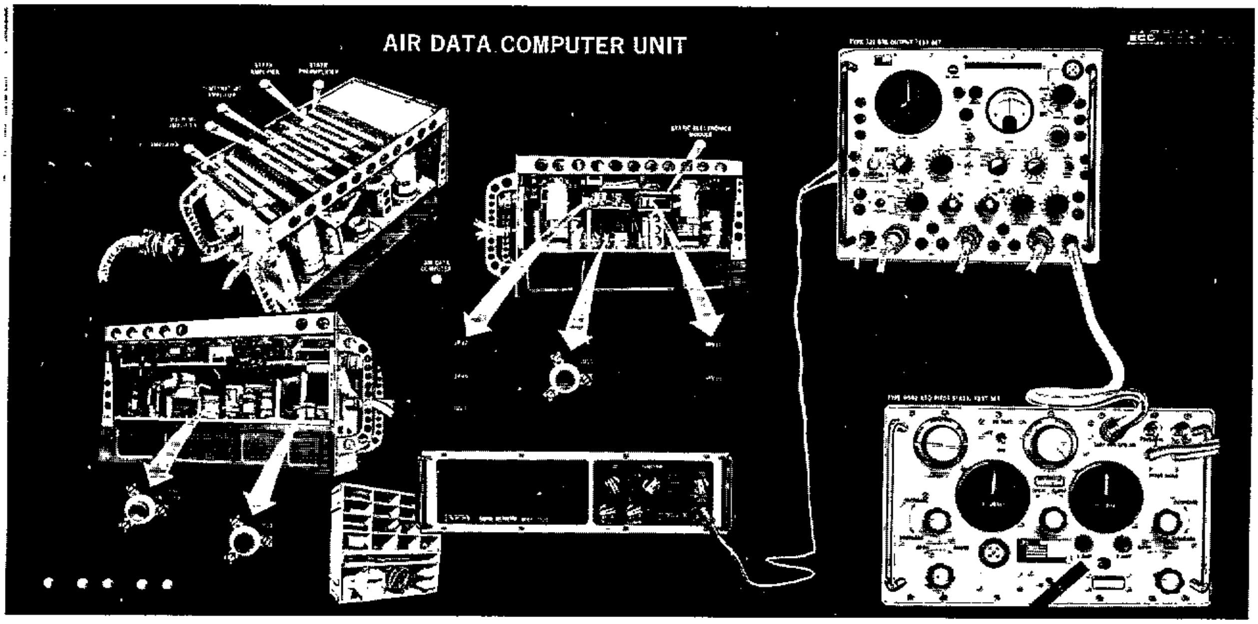

Figure 8. Air Data Computer Unit Display Panel

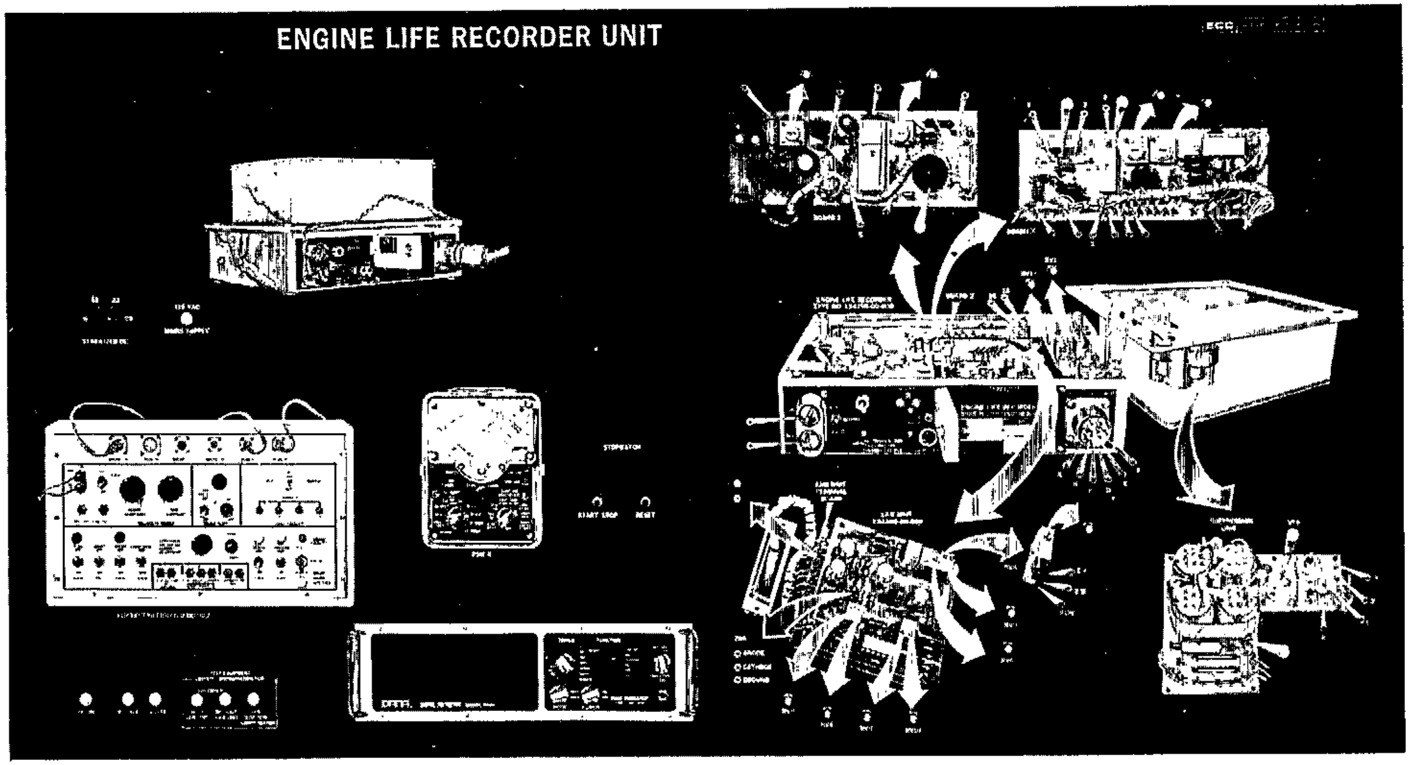

Figure 9. Engine Life Recorder Unit Display Panel

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MR. NICHOLAS A. SIECKO is Vice President of the Educational Research and Development of the Educational Computer Corporation, Orlando, Florida, and directs all of the educational projects for the company. He directed the federally sponsored experimental and demonstration manpower training center (Northeastern Pennsylvania Technical Center). Mr. Siecko is a co-holder of the patent for the design of the company's EC II general-purpose simulator and was responsible for establishing the training concepts which are now being implemented. He established the approach used in the design and development of simulation models used with the EC II, and the instructional programs for the SMART simulator. While with the Systems Operations Support, Inc., he developed, prepared, instructed, and evaluated vocational high school technical courses in one of the earlier attempts to apply a systems approach in a public school district vocational technical high school. He was employed by Burroughs Corporation as a Programmer and later as a Systems Analyst on the Atlas Missile Project. Mr. Siecko is a member of the American Society of Training and Development, National Security Industrial Association, and a charter member of the Society for Applied Learning Technology. He has a B.A. degree in Mathematics and has done graduate study in Psychology at the Villanova University.