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ABSTRACT

The second in a series of four reports on the Electronic Equipment Maintenance Training (EEMT) project, this document summarizes the system definition phase of the EEMT program. The purpose of this phase of the project was to define a comprehensive set of functions and training requirements that the EEMT must satisfy within the training mission of the electronics technician (ET) and electronics warfare technician (EW) schools, and define EEMT hardware requirements to support a prototype production effort. The procedures were to: (1) analyze a sample of ET and EW equipment to identify components and modules common to both ratings, (2) generate a list of tasks with terminal and enabling objectives and generalities derived for each task, (3) choose appropriate instructional objectives based on design boundaries, (4) develop five conceptual designs for the prototype EEMT, and (5) select one design for prototype development. Results were that inputs for the Device Test and Evaluation Master Plan (DTEMP) for two-dimensional and three-dimensional versions of the EEMT were developed to serve as the single management document for all test and evaluation efforts conducted during EEMT systems acquisition. (Author/MER)

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ELECTRONIC EQUIMENT MAINTENANCE TRAINING (EEMT) SYSTEM: SYSTEM DEFINITION PHASE

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FOREWORD

This research and development was conducted in support of Navy Decision Coordinating Paper Z0789-PN, Subproject .01 (Class "A" Electronic Equipment Maintenance Training (EEMT) System and was sponsored by the Chief of Naval Operations (OP-115 and OP-987H) and the Chief of Naval Material (NMAT-08E1).

This report is the second in a series concerning the EEMTS project, which has been divided into four phases: (1) concept formulation, (2) system definition, (3) prototype development, and (4) system test and evaluation (T&E). The first (NPRDC Tech. Note 79-3) identified design options for the EEMT, and formulated a "strawman" functional design based on those options. This report concerns the EEMT system definition phase. Subsequent reports will address the production, test and evaluation of prototype and production versions of the EEMT.

Two other reports have been published on a related research project. These reports described the field evaluation of and hardware/software development for the Generalized Maintenance Trainer Simulator (NPRDC TRs 80-30 and 81-9).

Appreciation is expressed to the following for their cooperation and assistance during the data collection for this research:

1. Mr. Ted Pearson, Dr. Lyle MacKeraghan, and Mr. Willard Stubbs of the Training Analysis and Evaluation Group.

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SUMMARY

Problem and Background

The use of operational equipment as a primary means for providing training and hands-on practice of electronics maintenance tasks in electronics-oriented class "A" schools can be costly, inefficient, inadequate, and occasionally dangerous. Therefore, the Navy has initiated an engineering development effort to develop and to test and evaluate a general-purpose electronic equipment maintenance training (EEMT) system that can significantly reduce reliance on operational equipment at the class "A" school level. The Electronics Technician (FT) and Electronics Warfare Technician (EW) Class "A" schools were designated as the target users of the prototype EEMT. The EEMT project is being conducted in four phases: (1) concept formu'ation, (2) system definition, (3) prototype development, and (4) system test and evaluation (T&E). In Phase I, concept feasibility was confirmed and a basic system design concept was formulated.

Objective

The work described herein was conducted under Phase II. The purpose of Phase II was to define (1) a comprehensive set of functions and trianing requirements that the EEMT must satisfy within the training mission of the ET and EW Class "A" schools and (2) EEMT hardware requirements to support a prototype production effort.

System Definition

1. A sample of ET and EW equipment was analyzed to identify components and modules that were common to both ratings. Six generic equipment components were identified: receivers, transmitters, antennas, power supplies, controls and monitors, and digital processors. A list of task actions was then developed based on the components and modules identified in the equipment commonality analysis.

2. Terminal objectives, enabling objectives, and generalities were derived for each task included in the generic task action list. Also, the training objectives were organized into a common-core EEMT curriculum configuration appropriate, with some modifications, for ET and EW "A" schools.

3. The instructional objectives and generalities and the EEMT curriculum defined in previous steps were used to select instructional media. A simulation media algorithm was used to determine whether two-dimensional (2D) or three-dimensional (3D) media, ranging from low to high fidelity, were required. A support media algorithm was used to choose among various types of support media.

4. Based on an established list of design boundaries and requirements, five alternate conceptual designs were developed for the prototype EEMT. Subsequently, one design was selected for prototype development. In this design, the 2D and 3D portions of the system were independent units, capable of either separate or combined operation. Functional system specifications for the 2D and 3D units were developed around this design.

5. Inputs for the Device Test and Evaluation Master Plan (DTEMP) for the 2D and 3D versions of the EEMT were developed. The DTEMP will serve as the single management document for all test and evaluation efforts conducted during EEMTS acquisition.

Conclusions

A common ET and EW curriculum for electronic maintenance training at the "A" school level exists that can be implemented by an EEMT. Furthermore, it appears that the EEMT can replace many of the functions of operational equipment in these "A" schools and deliver a better training program.

CONTENTS

INTRODUCTION

Problem and Background

At present, operational equipment is being used as a primary means for providing training and hands-on practice of electronics maintenance tasks in electronics-oriented class "A" schools. This practice can be costly, inefficient, inadequate, and occasionally dangerous. Therefore, the Navy has initiated an engineering development effort to develop, test, and evaluate a general-purpose electronic equipment maintenance training (EEMT) system that can significantly reduce reliance on operational equipment at the class "A" school level. The Electronics Technician (ET) and Electronics Warfare Technician (EW) Class "A" schools were designated as the target users of the prototype EEMT.

The EEMT project is being conducted in four phases: (1) concept formulation, (2) system definition, (3) prototype development, and (4) system test and evaluation (T&E). In Phase I, concept feasibility was confirmed and a basic system design concept was formulated (Wylie & Bailey, 1978).

The Generalized Maintenance Trainer/Simulator (GMTS), sometimes called the "Rigney System," has been developed and field tested by the Behavioral Technology Laboratories (BTL), University of Southern California, under a project closely related to the EEMT project (Rigney, Towne, Moran, & Mishler, 1980; Towne & Munro, 1981). The GMTS is a relatively low-cost, stand-alone system for providing intensive practice in troubleshooting. It can be applied to any target equipment or system by compiling the particular efforts of indicators in various configurations and modes and by preparing microfiche images of the equipment in a multitude of normal and abnormal states.

Objective

The work described herein was conducted under Phase II, of the EEMT project, System Definition. The purpose of Phase II was to define (1) a comprehensive set of functions and training requirements that the EEMT must satisfy within the training mission of the ET and EW Class "A" schools and (2) EEMT hardware requirements to support a prototype production effort.

SYSTEM DEFINITION

The steps included in EEMT system definition are listed below and described in the following paragraphs.

1. Electronic equipment and maintenance task commonality analyses.
2. Training requirements analysis.
3. Fidelity and media fidelity requirements analyses.
4. Conceptual design development.
5. Design review and system specification.
6. Device Test and Evaluation Master Plan (DTEMP) development.

Step 1--Electronic Equipment and Maintenance Task Commonality Analyses

Equipment Commonality Analysis

To determine commonality across ET and EW equipment, a representative sample, based on a fleet equipment sample approved by the Navy, was selected for analysis. A four-level equipment taxonomy--systems, equipment, subassemblies, and modules--was developed for use in the equipment commonality analysis. The specific types of electronic equipments were then examined to define the components that were common (i.e., could be expected to be encountered by personnel from both the ET and EW ratings).

Six generic equipment components were identified from the representative equipment listing: receivers, transmitters, antennas, power supplies, controls and monitors, and digital processors. According to selection criteria used, these components were contained in at least 20 percent of the equipment encountered by an ET or an EW. A more detailed analysis of each component was then conducted to determine modules that occurred across families of equipments. Modules were defined as "a collection of parts that performs a particular electronic function (e.g., oscillator, multivibrator, amplifier)," (Pine, Daniels, & Herringa, 1979).

Another interesting result of this analysis was the distribution of equipment technologies: 92 percent contained transistors; 79 percent, vacuum tubes, and 33 percent, integrated circuits (ICs). Although this distribution will certainly shift toward ICs in the next several years, the current representation of vacuum tube technology in fleet equipment implies the necessity of including at least some tube technology in the EEMT trainer.

In addition to being useful for determining equipment commonality, the hierarchical nature of electronic equipment also has implications for how best to train electronic organizational concepts. Whenever possible, the relationship between constructional organization and electronic function ought to be maintained. The correspondence between the functional and structural design in electronic equipment is known as functional packaging, and is the method of packaging predominately used in modern designs. Functional packaging should enhance skills acquisition since it allows students to clearly see the relationship between electronic functions and the physical structures in which they occur.

Task Commonality Analysis

A list of behaviors or task actions (e.g., "align," "operate," etc.) was developed based on the components and modules identified in the equipment commonality analysis. These behaviors were then coupled with the six generic components (i.e., receivers, transmitters, etc.) to provide a generic task such as "align power supply" or "operate receiver." Results were augmented by existing Navy task listings and subject matter expert (SME) judgments. The final task listing was reviewed by ET and EW school personnel.

The task commonality analysis resulted in the list of 42 tasks given in Table 1. As shown, 28 (67%) of these tasks are applicable to both ETs and EWs; 12, to ETs only; and 2, to EWs only.

Step 2--Analysis of Training Requirements

A variety of source documents (e.g., technical manuals and maintenance requirement cards) and SME judgments were used to derive terminal objectives (behavior, conditions, standards), enabling objectives (knowledge/skill components, task components), and generalities (rules, procedures, methods) for each task included in the generic task action list. During this process, it became evident that substantial commonality existed among maintenance, test, measurement, and adjustment procedures. Although the procedures for performing a certain task differed as a function of the specific electronic equipment

Table 1

Generic Task Listing

Task Number	Task Description	Rating Applicability ET	Rating Applicability EW
	Common Generic Preventive Maintenance Tasks:		
A002	Energize the equipment using set-up and turn-on procedures.	X	X
A007	Test/operate the equipment.	X	X
	Common Generic Corrective Maintenance Tasks:		
B014	Perform signal tracing of equipment/subassemblies/module.	X	X
B015	Perform waveform analysis.	X	X
B016	Measure voltage.	X	X
B019	Measure current using ammeter/multimeter.	X	X
B020	Measure resistance, opens, and shorts using VOM or electronic multimeter.	X	X
B023	Check and align synchros.	X	X
B025	Test transistors: ● Using octopus. ● Using ohmmeter.	X	X
B026	Isolate faults and troubleshoot equipment components, modules, and parts using 6-step logical troubleshooting procedure.	X	X
	Receiver Tasks (100-199):		
A107	Measure sensitivity of the receiver: ● SSB with USB, LSB. ● AM. ● FM.	X	X
A112	Measure MDS on the receiver.	X	X
A115	Measure receiver noise figure.	X	X
A119	Measure AGC characteristic on the receiver.	X	-
A121	Test receiver frequency calibration.	X	X
A122	Align: ● IF amplifier AM FM Pulse ● RF amplifier.	X	X
B123	Align beat frequency oscillator.	X	-
A125	Measure radar ring time.	X	-
A133	Measure selectivity and bandwidth on the AM, FM, and pulse-type wide band receiver.	X	X
B134	Measure and adjust receiver video/audio gain.	X	X
B136	Check receiver oscillator stability and accuracy.	X	X

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Table 1 (Continued)

Task Number	Task Description	Rating Applicability ET	EW
Transmitter Tasks (200-299):			
A202	Measure and adjust frequency of transmitter.	X	-
A203	Measure RF power.	X	X
B207	Check oscillator frequency.		-
B221	Align transmitter.	X	X
A226	Measure and observe transmitter waveforms.	X	X
B231	Measure percent of modulation of transmitter.	X	-
Antenna System Tasks (300-399):			
A300	Measure VSWR on antenna system: • Probe technique with waveguide. • Through-line wattmeter on transmission line method. • TDR method. • FDR method.	X	X
A319	Check coupler for signal attenuation using power meter.	X	X
A320	Measure insulation resistance at various points in RF transmission line system.	X	-
Power Supply Tasks (400-499):			
B403	Test and adjust power supply: • HV. • Regulated.	X	X
Control/Monitor Tasks (500-599):			
A520	Test range rings accuracy and adjust range rings oscillator.	X	-
A523	Test accuracy and adjust range strobe generator.	X	-
A524	Test and adjust discrimination balance on teletype.	X	-
A525	Measure and adjust converter bias on teletype.	X	-
A532	Test/verify diversity balance of a converter diversity group.	X	-
Digital Processor Tasks (600-699):			
A601	Run the System Operational Diagnostics Tests to test digital functions and modules.	-	X
B613	Run System Diagnostic Tests (SDT) to isolate faults in digital functions and modules.	-	X
B616	Test digital circuits for proper inputs and outputs: • Logic gates. • Storage elements. • Analog to digital converter.	X	X
B617	Check proper counting action in a series of flip/flops using binary or decimal counter.	X	X
B618	Check/measure timing functions on gating circuits.	X	X
B619	Check encoding/decoding schemes for digital displays.	X	X

used, such differences were not fundamental. Rather, they appeared in control settings, measurement specifications, parts numbers, and other features unique to a particular radar indicator, HF transmitter, etc. Training for such features can be accomplished only with the operational gear and would take place in "C" school or on the job.

To assure the successful development and use of a generic EEMT, it is imperative that one is aware of what can and cannot be learned on a generic system. The primary limiting factor in this consideration is that a generic system is unlikely to resemble, in its particulars, the system that the trainee will be required to maintain in actual practice. This implies that the specific equipment configuration, location and use of controls and switches, and values of operational parameters (e.g., frequencies, voltages, power) will differ between the "A" school and fleet environments.

Transfer of training is likely to be low for performance tasks that are highly dependent on equipment and operational particulars (e.g., specific troubleshooting tasks and tasks that involve a great deal of assembly and disassembly) and high for tasks that are independent of specific equipment configurations (e.g., conduct of tests and measurements, use of test equipment, and practice of standard procedures). Thus, these latter tasks should be emphasized on the EEMT.

The training objectives were organized into a common-core EEMT curriculum configuration appropriate, with some modifications, for ET and EW "A" schools. The curriculum unit topics were structured around the principal maintenance activities (tests, measurements, adjustments, and alignments) and generic components (receivers, transmitters, etc.) common to both ETs and EWs. A "top-down" training approach (from equipment to circuit and component), consistent with standard maintenance procedures, determined the structure of the lessons.

Master teachware algorithms were developed to support a "constructive" teachware authoring procedure in which subtasks (derived from the lesson content material) are structured into EEMT-teachware. The data base architecture in terms of information and process structure was defined in a linked list format and modularized for greater flexibility. Finally, functional requirements critical to administering and managing EEMT training in the "A" schools were generated.

Step 3--Fidelity and Media Requirements Analyses

The instructional objectives and generalities and the EEMT curriculum defined in steps 1 and 2 were used to select instructional media by applying two separate algorithms: one to determine the simulation media requirements and one to determine the support media requirements.

Fidelity Requirements Analysis

The simulation media algorithm, which posed questions concerning the manipulations required by the trainee and the stimulus environment in which such manipulations were to be performed, was used to determine whether 2D or 3D media, ranging from low to high fidelity, were required. Results indicated that the required 2D and 3D mix for prime equipment interfaces is 40 and 60 percent respectively. The 3D component of that mix largely involves simulation of the internal components of the prime equipment involved in adjustment, alignment, and measurement; the 2D component involves simulation of equipment front panels used throughout the curriculum and the prime equipment interfaces required for the common preventive and corrective maintenance portions of the curriculum.

The 2D and 3D mix[1] required for the test equipment interfaces is 10 and 90 percent respectively. This rather widespread requirement for high fidelity representation of test equipment is not surprising. In an earlier study, Pearson, MacKeraghan, Stubbs, and Moore (1974) concluded that a common core EW "A" school curriculum should emphasize the use of test equipment. Although the purpose of the Pearson study differed from that of the present analysis, the conclusions of both efforts probably derive from a common observation--the use of test equipment involves complex perceptual motor skills that must be thoroughly exercised and mastered in a realistic stimulus environment. These results imply that the EEMT design process must examine the concept of a hybrid system, in which high fidelity flat panel or 3D simulations of test equipment can be interfaced with both 3D and 2D prime equipment simulations.

Media Requirements Analysis

The support media algorithm, which posed questions about the information to be presented to the trainee, was applied to the nonmanipulative or study components of the objectives and generalities and was used to choose among various types of support media (e.g., video tape, printed text, figures, diagrams, pictures, photographs, and audio cassette tape). Results showed that the support media requirements for full-scale implementation of the EEMT would be substantial:

- Microfiche: 7000 images (USC Rigney System).
- Video tape: 195 minutes.
- Pictures and photos: 197 images.
- Figures and diagrams: 142 images.
- Printed text: 535 pages.
- Audio cassette tape: 835 minutes.[2]

The media requirements data also provided a means of estimating the amount of simulator time required by the EEMT curriculum. Assuming that (1) the 2D portion would be modified toward BTL's Rigney System, (2) presentation of each image takes 1 minute of training time, and (3) the average training week is 30 hours, it would take 3.8 weeks to administer the 2D portion of training. The 3D portion would take another 3.5 weeks, giving a total of about 7 weeks of 2D and 3D simulator time.

In the final stage of the media selection process, those training objectives assigned to simulation media were submitted to a more detailed algorithm to determine the required simulation fidelity of equipment features to be included in the EEMT training device. These data were used directly to develop the conceptual system designs.

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[1]It should be noted that the destinction between high fidelity flat panel test equipment simulations and 3D simulations is really an artifact of the algorithmic procedure used to select media. If a casing were added behind the simulated test equipment front panels, the panels would in fact be 3-dimensional. Thus, they were grouped with 3D media in mix estimates.

[2]The estimates for audio cassette assume that much of the printed text, and some of the instruction given on the simulator, would be duplicated in audio format and used to reduce the reading requirements for some students.

Step 4--Conceptual Design Development

A list of pertinent design variables and requirements was developed in close coordination with cognizant Navy organizations and was submitted to the Honeywell Systems and Research Center. Since these design variables required the use of a wide range of design options, Honeywell formed three design teams and instructed them to develop alternatives conforming to an established list of design boundaries and requirements. The list included the design boundaries developed in concert with cognizant Navy organizations and the fidelity and media requirements determined in Step 3.

Each design team independently developed a conceptual design for an EEMT simulator: Design "A" (Pine & Prietula, 1979), Design "B" (Koch & McAleese, 1979), and Design "C" (Heeringa & Pate, 1979). In addition, a design statement of common military characteristics was drafted (Daniels, 1979). Appendix A includes a copy of this statement and the three designs.

During the April 1979 EEMT review meeting held at NAVPERSRANDCEN, one additional design requirement was identified: a stand-alone capability for both the 2D and 3D units of the system. Moreover, it was noted that a design concept for an expanded Rigney System has capabilities similar to those specified for the 2D unit. Further, this concept incorporates adjunctive hardware and could support 3D requirements for the EEMT. Since the most efficient approach in concept would employ technology already developed, it was decided to use an expanded Rigney System as the 2D unit.

As a result of this meeting, two further conceptual designs were developed. BTL (1979) developed Design D, a stand-alone concept of the 2D unit, which was based on the Rigney System and which employed adjunctive hardware to support 3D operation. Honeywell, using the benefits of earlier designs, generated Design E (Daniels, Herringa, Koch, & Pine). In this design, the 2D and 3D portions of the system were independent units, capable of either separate or combined operation, and the 2D unit was an expanded verison of the Rigney System. Copies of these designs are also provided in Appendix A.

Step 5--Design Review and System Specification

An EEMT design review conference was held in Pensacola to review and evaluate concepts A through E. As a result of this meeting, Design E was selected as the basis for prototype development. Functional system specifications for the 2D and 3D units were developed around this design and written in accordance with MIL-STD-490. Appendix B provides copies of these specifications.

Step 6--Device Test and Evaluation Master Plan (DTEMP) Development

Inputs for the Device Test and Evaluation Master Plan (DTEMP) for the 2D and 3D versions of the EEMT were developed by Honeywell based on Design E (Pine & Daniels, 1979). The DTEMP will serve as the single management document for all test and evaluation (T&E) efforts conducted during the acquisition of the EEMT. It directs and controls the T&E, and identifies required contractor and government T&E resources, facilities, long range planning, programming, and budgeting.

CONCLUSIONS

A common ET and EW curriculum for electronic maintenance training at the "A" school level exists that can be implemented by an EEMT. Furthermore, it appears that the EEMT can replace many of the functions of operational equipment in these "A" schools and deliver a better training program.

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APPENDIX A

CONCEPTUAL DESIGNS FOR AN EEMT SIMULATOR

Page

1C

COMMON CHARACTERISTICS FOR DESIGNS A, B, AND C

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COMMON CHARACTERISTICS FOR DESIGNS
A, B, AND C

I. PREFACE

This document contains descriptions of three alternative conceptual designs for a simulator to support A school level electronics maintenance training. The training system for which these alternative designs have been developed is known officially within the Navy as the Class A Electronic Equipment Maintenance Training (EEMT) System. The simulator to be built in support of that system is known as the EEMT simulator.

Materials contained herein have been organized according to the format for detailed military characteristics (NAVTRAEQUIPCENINST 3910.4A), as ammended by the NPRDC Program Manager for the EEMT developmental effort. Ultimately, following Navy review and revision, certain of the materials contained herein will become the basis for developing a functional specification for the trainer and a section of the final Technical Report for for Contract N0123-78-C-0925 (between Honewyell and NPRDC). The exact materials to be included in that specification and report will be:

1. The common military characteristic
2. One of the three design military characteristics

Decision as to which alternative design will be included in that report will be made following a Navy design review meeting scheduled for CNET, Pensacola on 26 and 27 April 1979. The NPRDC program manager, Dr. J. S. McMichael will make that decision based on the alternative designs and inputs of the EEMT program Advisory Council.

This document, then, transmits in draft form statements of alternative design concepts to be considered for selection in April. The one alternative which is selected as a function of the April review meeting will become the basis for designing, building and evaluating prototype EEMT training device.

This document is organized into four major sections:

Section 1 - Common Military Characteristics
2 - Alternative A Military Characteristics
3 - Alternative B Military Characteristics
4 - Alternative C Military Characteristics

It is intended that the material contained in Section 1 be a part of each of the other (2,3 and 4) Sections.

II. SUMMARY

A. Purpose of the Device

The training purpose of a device to support the EEMT system concept is to provide the instructional delivery system needed to support the training and practice of electronic equipment preventive and corrective maintenance tasks. The EEMT device is to be designed for use in training Navy Class A School Electronic Technician and Electronic Warfare Technician trainees how to perform common tests and measurements required for maintenance of operational equipment. Test and measurements to be trained are those commonly required for radar, communications, ECM, and ESM equipment maintenance.

B. Operational Situation

The EEMT device will be part of a larger EEMT curriculum designed to bridge the gap between the fundamentals and equipment phases of ET and EW A School training. As such, the device will be used to support all of the training objectives of the EEMT curriculum. Together with the EEMT device, the remainder of the EEMT curriculum and supportive media are intended to be inserted either totally (stand alone) or in a segmented fashion into the ET and EW A School curricula. Operational insertion of EEMT into those curricula is scheduled for CY 1985.

The concept of a EEMT system is founded on two major factors. First, the inherent similarities which exist among electronic equipment maintenance tasks and procedures across equipment groups or families. Second, the availability of technology and simulation approaches to permit replacement with simulators of a large segment of operational equipment which are now or in the future may be otherwise required for such training.

C. Origin of Requirement

Development of an EEMT device is based on the requirement stated in OR-PN50 (26 July 1976) and as subsequently stated in NDCP-Z0789-PN (6 July 1977). As a result of that requirement the Navy Personnel Research and Development Center issued solicitation N00123-68-R-0925 (10 May 1978) to support Project Element 64703N, Training Devices Prototype Development. The resulting contract, entitled System Definition for Electronic Equipment Maintenance Training System, was awarded to Honeywell, Inc. on 15 August 1978. That contract was for the conduct of:

1. Equipment Commonality Analysis
2. Task Commonality Analysis
3. Training Requirements Analysis
4. Fidelity Requirements Analysis
5. Alternative Conceptual Design Concepts
6. System Specification Development, and
7. Test and Evaluation Plan Inputs Development

for the EEMT curriculum and device. Results of those activities are or will be covered in Honeywell reports.

- F2210-1 Equipment and Task Commonality Analysis - Jan. 1979
- F2210-2 Training Requirements Analysis - Mar. 1979
- F2210-3 Fidelity Requirements Analysis - May 1979
- F2210-4 Final Technical Report - July 1979
- F2210-5 Test and Evaluation Plan Inputs - July 1979
- F2210-6 Functional Specification for EEMT - July 1979

Behavioral objectives for the EEMT device are presented in Honeywell report F2210-2.

In addition to the data provided by the above reports, NPRDC has issued a list of design boundaries which contrain the EEMT Prototype conceptual design process. Those boundaries were transmitted to Honeywell with letter 306:JSM:ga dated 13 January 1979, from: Project Manager, Class A Electronic Equipment Maintenance Training system, NPRDC; To: Honeywell, Inc., Systems and Research Center, Minneapolis, Minnesota. The design boundaries placed on conceptual design of the EEMT device were:

DESIGN BOUNDARIES FOR EEMT PROTOTYPE

1. Conduct design effort in accordance with Contract N00123-78-C-0925.
2. Design to meet NDCP Z0789 - PN requirements.
3. Design-to-cost unit acquisition cost ≤ $50K (for simulation hardware) (unit = student station).
4. Reliability and Maintainability Requirements
   a. Reliability - MTBF ≥ 500 hrs
      Service life = ≥ 60,000 hrs
   b. Maintainability - MTTR = ≤ 30 mins
5. EEMT trainer maintenance concept
   a. Assume FOMM manuals for trainer maintenance
   b. Assume O level maintenance by Navy user (production version)
   c. Assume I level maintenance by Navy Evaluation and Training Support Center
   d. Assume Depot level maintenance by service contract (production version)
   e. Design system so that it can be placed in Navy Cog 20 system for production version

6. Trainer Hardware Requirements

   a. Equipment

      (1) Make maximum use of off-the-shelf, commercially available equipment and components

   b. Configuration

      (1) Use off-the-shelf card, module, circuit and functional designs where possible

7. Software Requirements

   a. Language - use standard language (e.g. PASCAL or FORTRAN) for operating system

   b. Modularize software

   c. User authoring capability

   d. Make maximum use of existing software modules and programs

   e. Do not require (or use) machine language for programming

   f. Do not make it manadatory that support media (e.g., video tape, sound on slide) are called or controlled by the simulation system

   g. Use existing standard computer operating system or special executive

   h. Structured programming approach to be used

8. Documentation Requirements

   a. Assume tailored MIL-SPEC requirements

   b. Assume requirements for delivery of enough documentation to build direct copies

   c. Software to be documented in accordance with SECNAVINST 3560.1

9. Trainer Programming/Modification Requirements

   a. Provide capability for USN instructor personnel to do lesson development and modification

   b. Capability for hardware expansion and 50% software expansion

10. Schedule

   a. Prototype design and build - 9/79-9/81 (24 mos) 3/80 CDR

   b. Prototype OT&E - 8/81-4/82 (9 mos)

   c. Approval for service use - May 82.

11. Training tasks to be accomplished by alternative prototype designs

   a. All those specified during System Definition contract phase

   b. Each alternative design must support training of all tasks

   c. Assume the following will be functionally defined and provided as requirements for the prototype program

      (1) Training requirements

      (2) Training objectives and generalities

      (3) Tasks to be trained

      (4) Media to be used

      (5) Fidelity required

      (6) Testing (trainee performance) requirements

      (7) Student/instructor/system functions

12. Trainee prerequisites

   All students will have:

   a. Successfully completed Basic E&E

   b. Completed some part of an IPD fundamentals curriculum (A School)

III. TRAINING ANALYSIS

Definition of the training requirement to be met using the EEMT system was obtained via a front-end analysis. That analysis identified the common training requirement to be met using the EEMT system, the behavioral training objectives and generalities involved, and the instructional media needed to train those objectives. The media selection process yielded two categories of training tasks--those which require simulation for support and those which do not. For the tasks to be simulated, the analysis was continued to identify a curriculum outline for the EEMT course segment, the simulator fidelity requirements, the administrative and management requirements of the EEMT system, and finally, alternative conceptual designs for the EEMT simulator.

The various analyses performed and results are completely documented in a series of interim reports. Specifically, the topics covered and reports are listed below:

Analysis Topic	Found in Honeywell Report No.
Equipment Commonality	F2210-1 (Jan 79)
Task Commonality	"
Training Objectives and Generalities	F2210-2 (Mar 79)
Lesson and Unit Outline	"
Curriculum Outline	"
Teachware Algorithms	"
CAI Data Base Requirements	"
Management and Administrative Requirements	"
Media Selection	F2210-3 (draft Mar 79)
Fidelity Requirememts	"

IV. SYSTEM CONSTRAINTS, UTILIZATION, SUPPORT, AND EVALUATION

A. Constraints

Of the three alternative design concepts developed, two (A&B) have been conceived to meet constraints required.

The third concept (C), by direction of NPRDC, was less constrained. Specifically, Design C was only constrained by boundaries statements 1 and 2.

B. Availability and Utilization

The EEMT device is to be installed into existing (1985) classroom/laboratory spaces at the ET A School, Great Lakes, and the EW A School, Pensacola, Florida. The device will be a multi-student design and may have a centralized, separate instructor console. Projected class sizes for those schools indicate the device must simultaneously accommodate between 20 and 25 trainees.

The device will be installed in each school on a semi-permanent basis. There is no requirement for frequent transportation of this device. The device design must permit ease of shipment, and installation at the school. Device may be designed in a modular fashion to accommodate ease of shipment and installation.

The device should operate from standard power sources available at each site. Air conditioning requirements should not exceed those available at each site. The device shall be designed for classroom/laboratory use and shall not require special protection from dust, vibration, humidity, heat/cold, or wind, unless such protection is designed into the device. The device shall be designed to operate in the normal ambient light provided at the installation site.

The device shall be designed to operate continuously 16 hours a day, five days a week, 52 weeks a year in the normal classroom/laboratory environment of the ET and EW A Schools. Medium life expectancy shall be seven years (hours per year ÷ 60,000).

Design shall permit continuation of training with between one and 19 (or 24) student stations in a shut-down-due-to-failure condition. This continuation shall involve the use of unfailed student stations to train students. No requirement exists to provide for the simultaneous training of more than one student at a single student station.

Training exercises shall be self paced. However, normal class scheduling indicates trainees will occupy the trainer for 50 minute class periods. Training exercise set up time shall not exceed five minutes.

C. Reliability

Design goal for MTBF shall be $\geq$ 500 hours.

D. Maintainability

Design goal for MTTR shall be $\leq$ 30 minutes.

Although the device shall be designed to minimize the need for contractor support, the prototype EEMT shall be totally supported by contractor personnel. The production version of the device shall be maintainable by available Navy personnel.

E. Evaluation Plan

The prototype EEMT simualtor is planned to undergo test and evaluation both in the factory and in the field (schools). Both engineering and formal training effectiveness evaluations are planned. Specific details of the evaluation will be found in evaluation pland and TEMP documents for this program.

V. RATIONALE FOR DESIGN

Design alternatives developed for this program reflect certain common conceptual features. As neitner the existance nor commonality of these features is obvious from the individual MCs which follow, those features will be described here.

The elements of commonality existing across the three alternative designs are:

- o Completeness
- o Modularity
- o Adaptability

The completeness element refers to the fact that all alternatives are designed to meet all OR, NDCP, and RFP requirements. Additionally, each design concept is consistent with all appropriate design boundaries. Further, each of the three concepts provides for the training, monitoring, measurement, testing, and reporting of all tasks identified for EEMT simulator training. Finally, all of the concepts are for complete training systems. That is, all functions required of the EEMT simulator have been accounted for.

The modularity element also applies across all concepts. This element refers to the design, the use, and the production of the device.

From the design perspective, each alternative concept is conceived of as being composed of a series of modular elements which may be literally plugged in/out as needed. Modularity applies to the simulation hardware, software, teachware, and to the EEMT course, itself. The hardware is conceptually designed so that simulated electronic cards/modules/components fit into drawers, etc., so that those drawers can plug into equipment racks, and so that equipment racks may be plugged into the controlling computer. Likewise, the software is modular by function (e.g., performance monitoring, training). Similarly, teachware, which corresponds to the training lessons, shall be written and used in a modular fashion to meet the specific training need.

Finally, due to the modular character of each of the trainer elements, acquisition and production of the trainer may, if desired, proceed modularly. That is, the basic 2D components of the simulator student station may be supplemented with some or all of the 3D elements. Thus, for the purposes of prototype evaluation, it may be desirable, and is certainly possible, to only construct part of the complete 3D compliment. Furthermore, for the centrally controlled multi station approaches, this feature means that only part of full compliment of student stations need be build. The trainer concept will function regardless of the numbers of stations implemented.

Adaptability refers to the conceptual characteristic which permits varied implementation and use schemes for each of the device concepts. Conceptually, and primarily via software characteristics, each design permits training of a variety of topics. Thus, as the need arises for expansion and/or a different use for the device, that use may be easily implemented. The adaptability element makes this concept appropriate for use in training such diverse topics as electronics, mechanics, hydraulics, etc. Clearly, when adapting to such a wide range of uses, attention must also be given to the character of 3D elements included with the trainer. However, the basic concept will easily permit such adaptation.

Based upon these three primary and common conceptual elements, three separate and complete design concepts have been developed. The specific design rationale for each concept is briefly outlined below. Detailed descriptions of each are presented in the concept specific MCs which follow.

Design concept Alternative A may be characterized as a highly refined version of the EEMT Strawman. As such, the concept rationale for A was to begin with that strawman, to apply requirements established by front end analysis data and to arrive at the concept. That process was followed and has yielded a design concept which possesses the features of:

- o Completely self contained student station
- o Combined instructor/student/materials generation capabilities
- o Generic 3D module simulations

The Alternative B concept maximizes design modularization. This rationale is used to achieve the highest levels of trainer expansion and versatility. Concept B is characterized by:

- o A centralized instructor function
- o 3-D simulations of actual equipment
- o Shared 3-D subassemblies

Alternative C, originally characterized as the unconstrained approach, represents the most capable concept. The rationale underlying concept C was to develop the most capable generic trainer that would reasonably be required. The potential for applications well beyond those required for the current electronics focus (e.g., mechanics, hydraulics, weapons) was a major feature of this rationale. Trainer functions likely to be required for such broader applications are embodied in the Alternative C concept which is characterized by:

- A centralized instructor function
- Generic 3-D modules and test equipment
- Computer control of all trainer features

DESIGN A

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I. INTRODUCTION

The rationale of Design "A" is to provide a completely self contained system with high student autonomy and maximum generalizability to the population of selected tasks and equipments. All materials, and computing power required for training is included in each unit. This should provide a system that is maximally, reliable, maintainable, supportable, transportable, and modular. These benefits accrue by eliminating inter-unit data transmissions, time sharing software, and the need for an instructor station.

The usual functions of an instructor station are incorporated in each unit by enriching the instructional format to provide the student with a greater "self" teaching capability. A mix of media including audio cassette and 16mm film are included as well as printed materials to provide a more complete knowledge base. The stand alone feature and highly modular design should also facilitate fitting a single trainer into the ET and EW pipelines.

The 2D/3D mix adopted in Design "A" was desired to maximize generalizability to the ET/EW representative equipment samples. This was done in several ways. Only those parts and modules requiring significant psychomotor skills, as determined by our fidelity analysis, was simulated in 3D. These 3D modules were designed to have commonality with the ET/EW representative samples at the part and module level. This will assure maximum generalizability. This generic concept is implemented by employing generic switches, controls, parts, and modules.

In addition, a part task approach is adopted which assures that only those parts of a task which involve significant manipulative skills will be taught on the 3D components. Finally, transfer of learning is maximized by providing high fidelity simulated test equipment in recognition of the fact that test equipment use is the one constant fact or in generic training.

II. SYSTEM CONCEPT

A. Concept Drawing

Figure A-1 is a concept drawing of Design "A." The trainer represented in this drawing is a stand alone system. It contains all the software, hardware, training materials, and computing power required to train the common ET/EW tasks in one unit. Conversion from a student station to an instructor's station is accomplished by simply adding a teletype/keyboard to the unit shown in the figure. This would allow an instructor to use any of the student stations to develop teachware. The stand alone aspect of this system is a unique feature among the Honeywell designs and provides a design alternative that highlights a fully self-contained approach. This should maximize transportability, maintainability, and supportability by eliminating central processing and intersystem data transmissions and communications.

The front panel of Design "A" (drawn parallel to the page) is divided into 2D and 3D components separated in the figure by a heavy line. Each of the 2D and 3D components will be described in more detail in subsequent sections.

The left side panel shown in Figure A-1 contains the trainer's computer hardware and floppy disk units. The right side panel would be used to store Instructional Manterial Packages (IMP) and 3D modules.

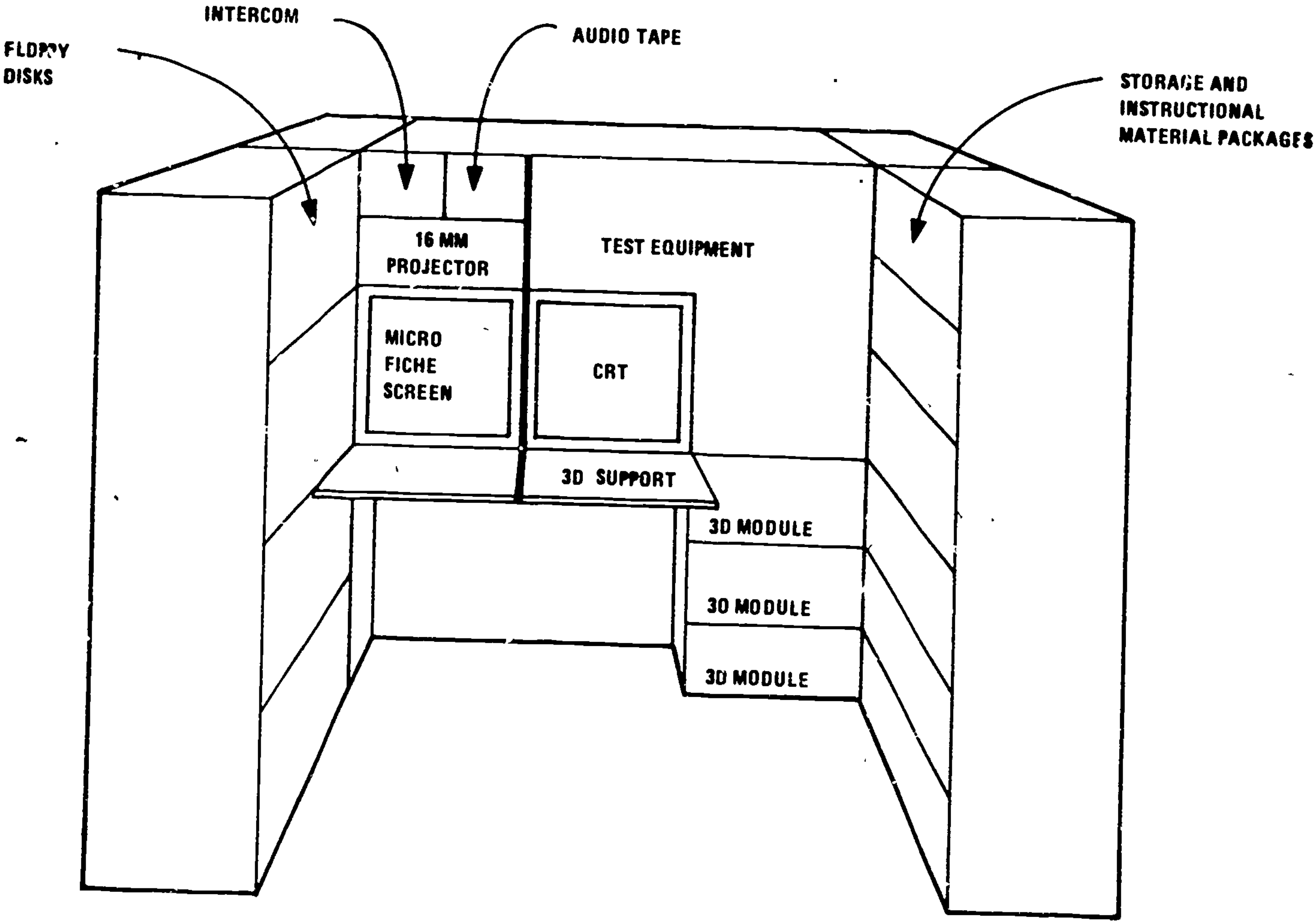


FIGURE A-1 DESIGN "A" CONCEPT DRAWING.

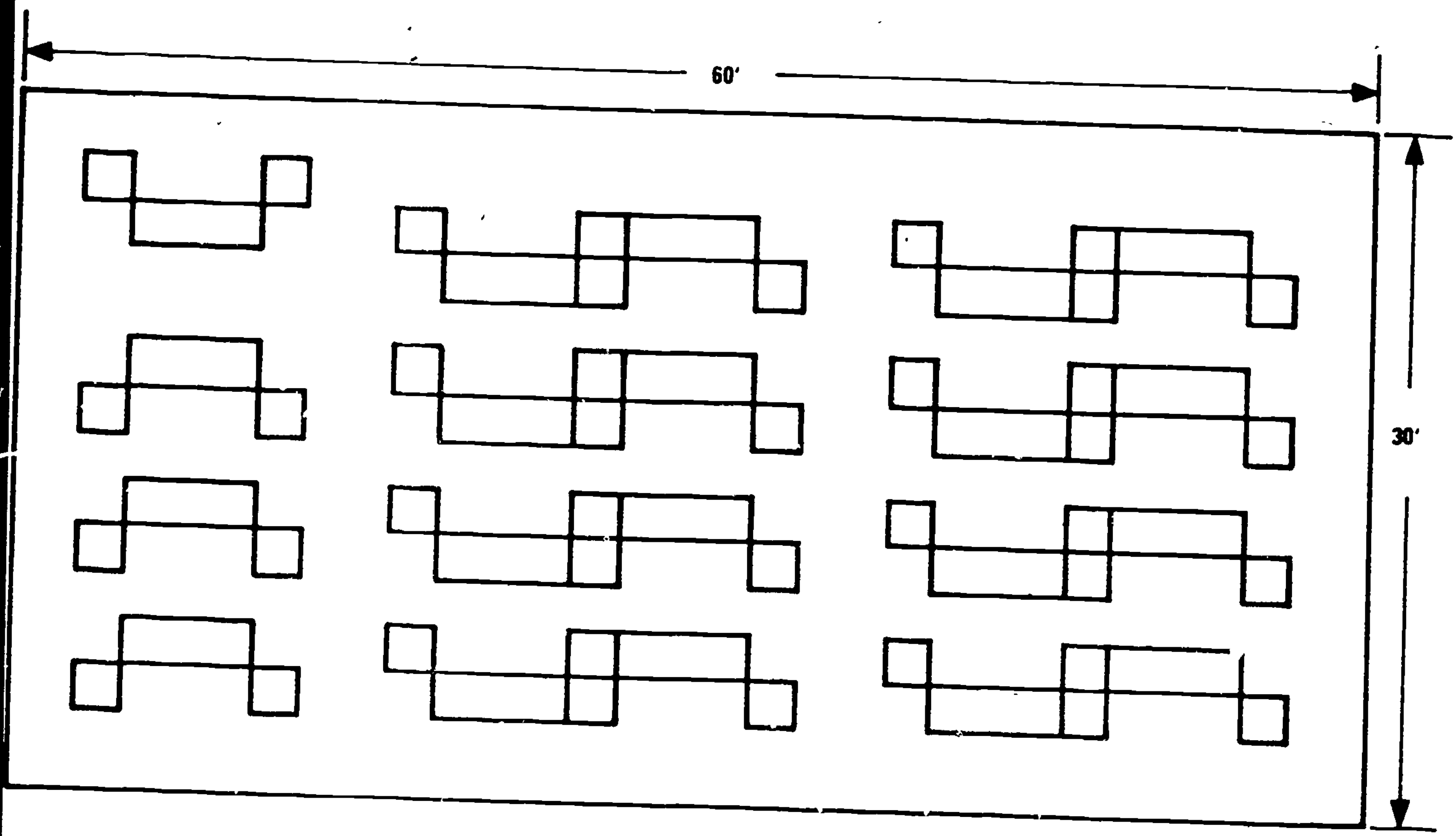
An additional feature, not clearly evident in Figure A-1, is its shape which has been designed to optimize space utilization. It is anticipated that the laboratory space in which these trainers will be housed will be limited.

Figure A-2 shows a top view of 2D Design "A" trainers arranged in a 60 x 30 foot room. The economy of the perpendicular side panel design is evident in this figure.

B. Functional Diagram

A functional diagram showing more of the engineering details of Design "A" is shown in Figure A-3. As this figure indicates, Design "A" is a microcomputer based system with floppy disk mass storage and distributed processing. The processing is distributed between the graphic CRT and the other components of the system. A separate microcomputer could also be added to handle the 3D modules if this appears necessary after a more detailed analysis of the processing load has been completed.

The graphic CRT, shown at the top of the figure has a dedicated processor supported by a dual floppy disk. This should assure the high fidelity waveform capability found to be required in our Fidelity Analysis. The remaining components, interactive microfiche, and 3D modules, are driven by a second microcomputer supported by two dual floppy disks. In addition, a teletype/keyboard unit can be tied into the second computer for developing teachware. The 16mm projector, intercoms, audio cassette, and of course, the storage area are not computer controlled.



POSSIBLE ROOM CONFIGURATION

FIGURE A- 2. TOP VIEW OF POSSIBLE ROOM CONFIGURATION USING DESIGN "A".

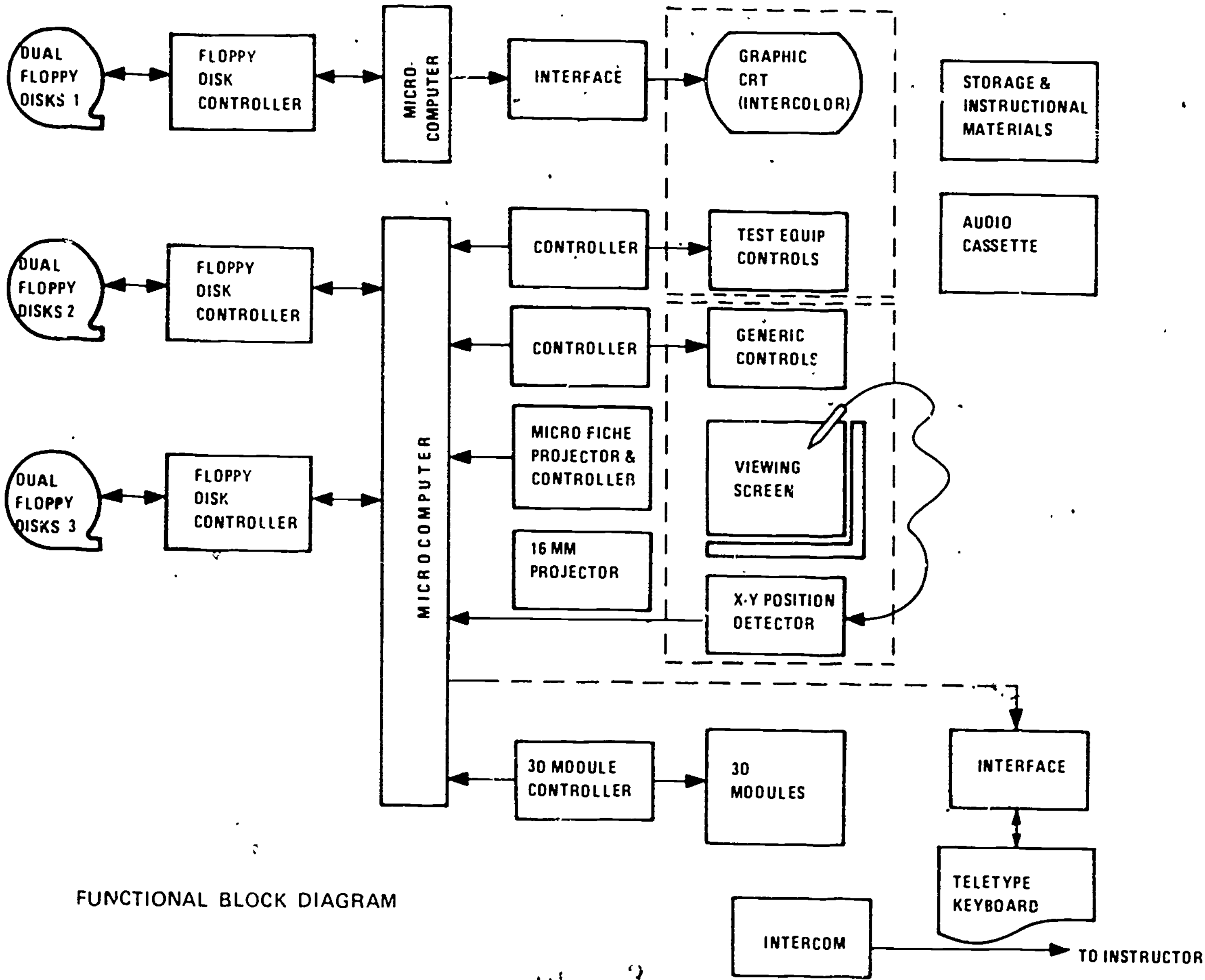


FIGURE A-3. DESIGN "A" FUNCTIONAL DIAGRAM.

III. STUDENT STATION

The Student Station for Design "A" is a completely self contained stand alone unit. It consists of 2D and 3D components.

A. 2D Components

The primary ensemble of 2D components comprising the trainer are shown in Figure A- 4 and include:

- o Call light and intercom
- o An audio cassette player
- o A sound-filmstrip projector, sharing a screen with
- o An interactive microfiche unit;
- o A large screen, intelligent graphics terminal; and
- o A removable package of instructional materials.

Call light and intercom. The role of the instructor in Design "A" is seen as being a mobile provider of special help and remedial instruction. A "call" light is provided on top of the unit to request help from the instructor. There will be times, however, when some means of remote communication between the students and the instructor is desirable, e.g., when the instructor is developing teachware. An intercom system, connected between units, is provided for this purpose.

Audio cassette. The role of the audio cassette player is the delivery of the basic instructions and directions for a given laboratory task. The laboratory exercise essentially describes a well-defined series of experiences; furthermore, learning in this laboratory type of environment has been successfully

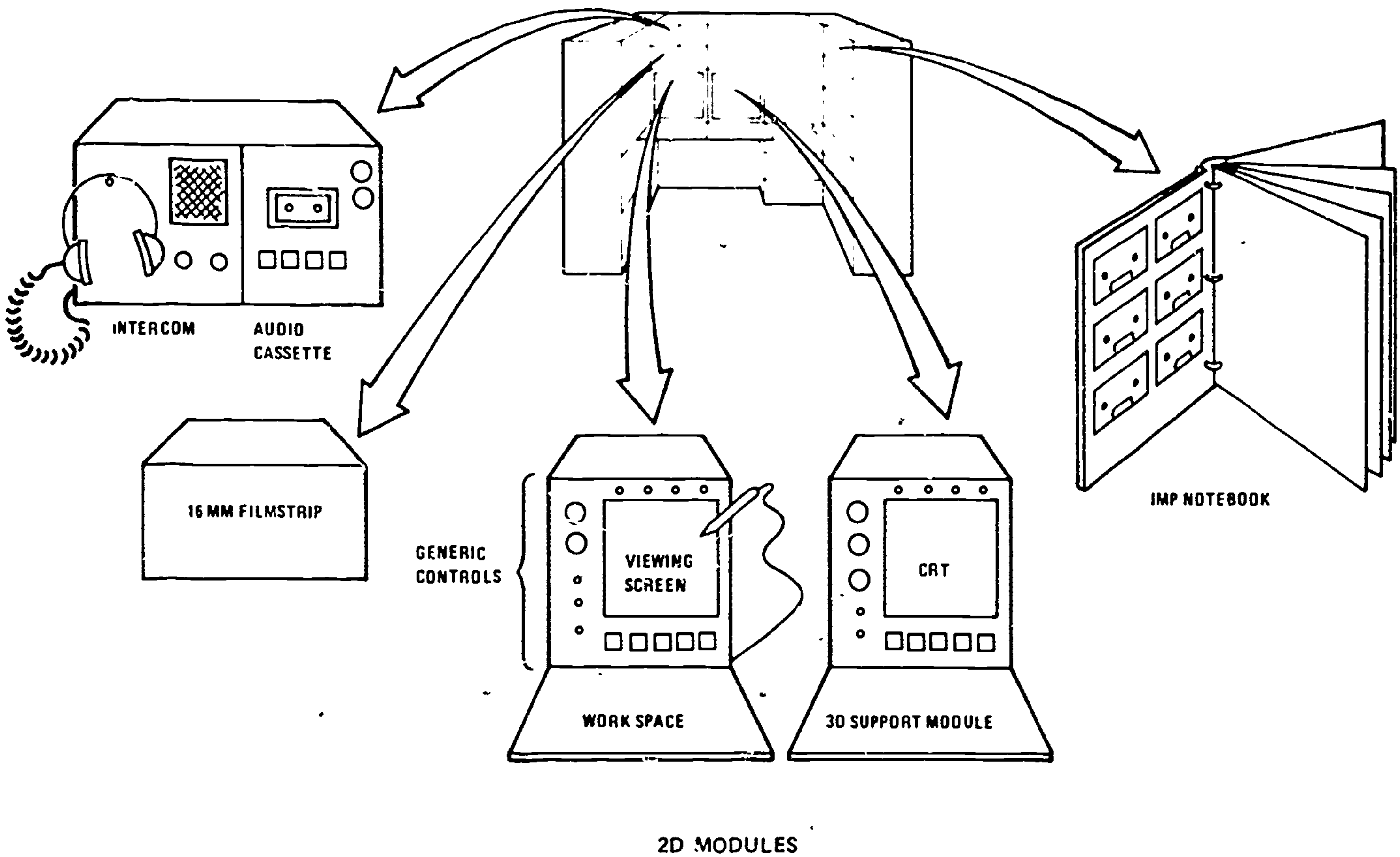


FIGURE A-4. DESIGN "A" 2D COMPONENTS

managed by the audio-driven, modular, multimedia approach (Russell 1974, Creager & Murray, 1971, Postlethwait, Novak, & Murray, 1972) especially with students having reading problems. An example of how this strategy is implemented is given in the section describing the scenario.

Sound-filmstrip. Sound with accompanying motion is necessary when depicting a motion sequence, micro or macroscopic images of real equipment and motion, sound-equipment associations, and abstract animation (Briggs, 1970). This media is particularly useful for demonstrating task procedures on operational gear and/or the training device.

The filmstrip is projected on the same screen used to show the interactive microfiche.

Interactive microfiche. Although sound-motion is both necessary and desirable for a variety of reasons in certain learning environments, most motion, especially continuous, is irrelevant (O'Connor, 1942; Dachling et al. 1970, Wells, 1970; Wells et al. 1973). Consequently, an interactive microfiche system would retain the important image fidelity demand yet offer the added attribute of interaction.

The interactive capability is realized with a stylus-select procedure (e.g., sonic pen) and a programmable processor which interprets the selection as programmed and accesses the correct slide (or slides) from several thousands available. By having this large number of addressable slides, many sequence procedures may be illustrated by microfiche rather than motion, retaining the pedogogic interaction.

A set of generic switches and controls representative of those found on ET/EW equipment front panels are located along the edge of the microfiche display screen. The generic controls can be related to actual controls shown on a microfiche slide of operation gear and used to provide manipulative responses while carrying out a task on the 2D components.

Graphics Terminal. This medium is seen to fulfill the need for simulating test equipment displays and functions. A processor would accept input from adjacent mock-up test panel controls (via A/D converters) and generate proper "readings" on the simulated display. Although the required fidelity of a given display is a function of the specific objective to be achieved, it is believed that this mock-up can provide the requisite environment for acquisition of the skills. Furthermore, this medium also allows other types of computer-based interaction, such as testing, instruction, mock-up of other front panels, circuit mock-up, and other simulations. Flexibility is achieved through an inexpensive, removable storage medium (e.g., floppy disks).

Instructional Materials Package. These packages contain the necessary (and hopefully sufficient) resources for the student to successfully manage his own learning for a signle, conceptual unit of subject matter, a module, within the confines of a student station. A typical material package for a module may contain:

- Audio cassettes - for instructions directing the laboratory exercises;
- Filmstrips - for viewing instructional segments;
- Tray of microfiche - for the interactive reader;
- Floppy Disks - for the intelligent graphic terminal; and
- Printed Material - to support other aspects of the exercise.

This reflects not only the importance of media providing stimuli in accordance with the demands of the capability to be learned (Gagne and Briggs, 1974), but the motivational implications of allowing a student control over his own attentional processes (Gagne, 1974).

B. 3D Components

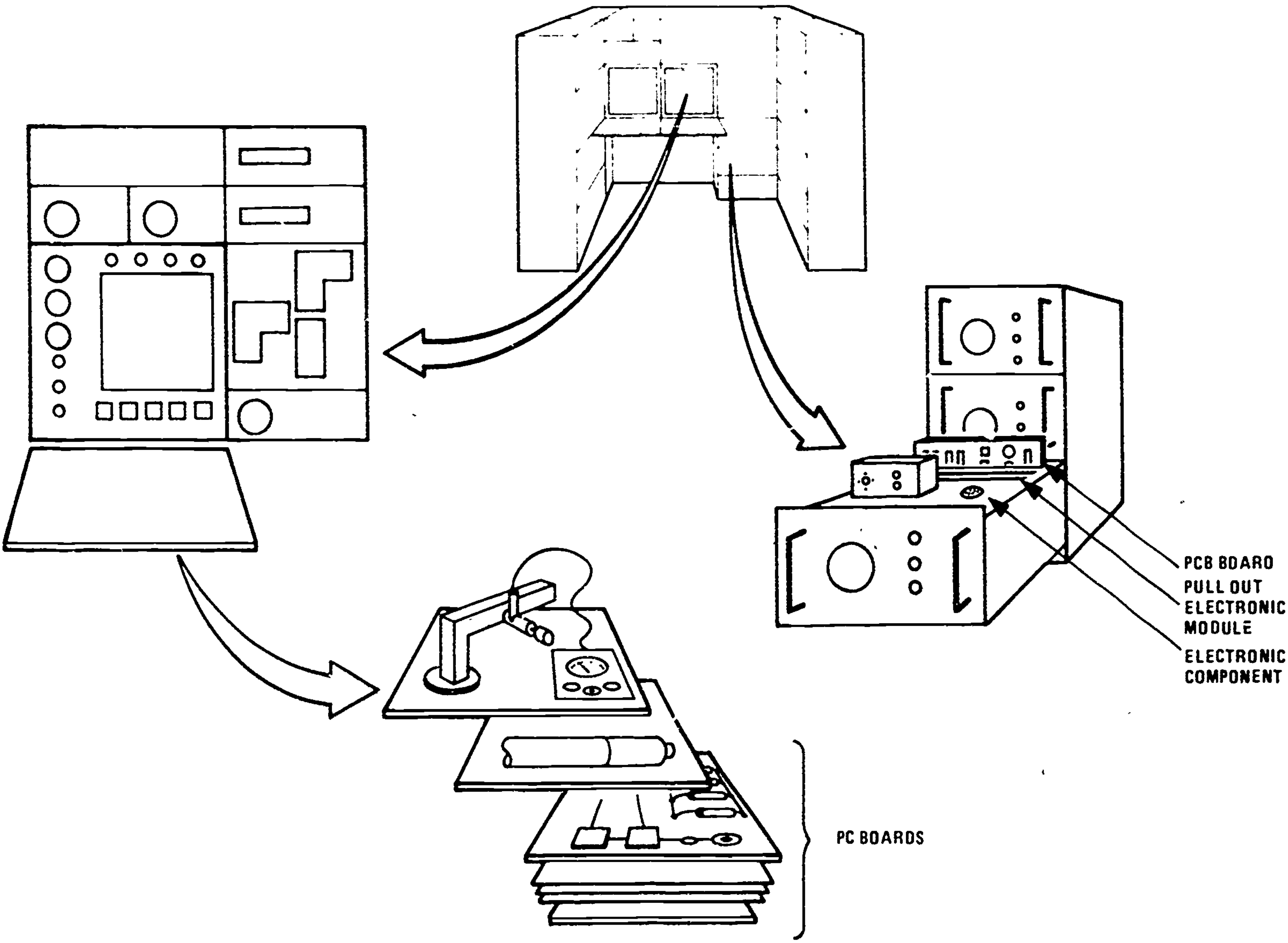
The 3D components are shown in Figure A-5 and include:

- o Functional test equipment mock-ups with waveforms displayed on the graphic CRT
- o 3D support unit and modules, consisting of:
  - module boards, and
  - pull-out drawers.

Functional test equipment mock-ups. The results of the Honeywell Analysis indicate that high fidelity functional test equipment mock-ups are required for training. These results are consistent with TAEG Report 9-2 which emphasized the importance of test equipment in teaching maintenance.

Test equipment is the one aspect of generic maintenance training which remains constant from one training environment to another. Because of these considerations Design "A" simulates test equipment with high fidelity functional mock-ups of test equipment front panels. This should assure that the student will acquire proficiency in using test equipment with maximum transfer to other training and operational environments.

Test equipment containing CRT displays will be grouped around the graphic CRT and use its display for representing all waveforms. CRT's on the test equipment will be non-functional.



DESIGN A – 3D MODULES

FIGURE A-5. DESIGN "A" 3D COMPONENTS.

This arrangement will serve two important purposes. First, it will greatly reduce system cost. Secondly, it will allow waveforms to be displayed in an enlarged format i.e., the graphic CRT display is larger than the CRT's on most test equipment, so that a higher level of waveform fidelity can be achieved.

The Honeywell Training Requirements and Fidelity Requirement Analyses indicated that the following kinds of parts and modules must be simulated in 3D:

- Amps: IF, RF, Power
- Frequency Multiplier (3 stages)
- Modulator
- Waveguide
- Coax cable
- Oscillator
- Power supply
- Teletype controller
- Assorted connectors, cables, & jacks
- Generic switches, controls, adjustment screws & sockets
- Cassette player
- Circuit boards:
  - Sweep generator
  - Resolver driver
  - Video cursor sweep switch
  - Range rings oscillator
  - Logic gates
  - Flip flop storage elements
  - A/D converter

The intent in choosing a format for simulating these parts and modules was to select a format which met the fidelity requirements with respect to three dimensional cues and manipulations capabilities while at the same time being highly modular, having appropriate contextual cues, and being compatible with the part task principle.

The approach adopted in Design "A" was to simulate these parts with two types of 3D modules:

o 3D training boards, and

o Pull-out drawer(s)

3D training boards. The 3D training boards will be self-contained instructional units that are connected to a support unit located just under the graphic CRT. Several such-boards are shown at the bottom of Figure A-5. Each board will consist of the electronic elements needed to train a particular task or task part. The components on the boards will be mocked up to the minimum level of fidelity required to train a task and will include a removable card containing information pertaining to the performance of that task.

For example, the top board depicted in Figure A-5, consists of a 3-dimensional model of a waveguide section with a functional VSWR meter and probe. This board would be used to train task A300--Measure VSWR on antenna systems. The accompanying information card would give the procedure for performing task A300. Since it is removable, it could be removed during testing.

Pull-out drawers. Pull-out drawers located as indicated in Figure A-5 are also provided for carrying out manipulative task parts. The initial trainer would contain one drawer with the capability to expand to three drawers. The drawer will have a generic front panel containing a functional meter and several functional generic controls.

The inside of the drawer will contain a selection of common electronic elements, e.g., adjustment screws, sockets, test points, required to perform the generic tasks described in the Honeywell Training Requirement Analysis Report. In addition, the architecture of the inside of the drawer will be designed to provide a sample of design techniques and technologies including:

- Technologies:
  - IC
  - Tube
  - Transistor
- Design techniques:
  - Strap down
  - Modular
  - PC Boards

New technologies or higher fidelity modules could be added with additional drawers.

IV. INSTRUCTOR STATION

No separate instructor station exists for Design "A." A student station can be used for generating teachware, scoring student performance, and obtaining performance reports by attaching a keyboard/printer terminal.

V. SYSTEM PERFORMANCE CAPABILITIES

There are three main modes in which the trainer can be used:

- o Preparation of instructional materials
- o Student use
- o Evaluation

This subsection describes preparation of instructional materials and the evaluation procedure.

The use of the system by the student is described with a scenario in the next section.

A. Preparation of Materials

The first step in using the trainer is carried out by the instructor prior to training and involves preparing all the instructional materials the student will need for a given unit. The instructor must begin by defining the lesson segments and selecting appropriate training materials to support each segment. Design "A" provides the instructor with a wide range of media from which to choose. The combination of media chosen for any given lesson will depend on the specific topic and the instructor's preference. A typical lesson might involve the following activities on the part of the instructor:

Decide on the best 2D/3D mix for tasks to be taught. For example, if a task is being introduced for the first time in the context of preventive maintenance, the instructor may wish to provide a high mix of 3D manipulation. In this case, all parts of the task which require significant manipulations might be assigned to 3D modules. If, however, the same task has been previously introduced and is now being taught in the context of corrective maintenance, a higher 2D mix might be called for.

Select from among available teachware modules or generate new teachware. A number of teachware modules incorporating various media mixes will be available for each curriculum lesson. An individual teachware module consists of a pair of floppy disks which contain the graphics and computer instructions necessary to control, present, and evaluate all aspects of a lesson segment. The instructor chooses the module from among those available which must closely match the media mix he desires. If none of the existing modules are adequate for his needs, the instructor can generate a new teachware module. He accomplishes this by connecting the keyboard/teletype terminal to any student station and using the teachware authoring language to generate a new module.

Prepare additional instructional materials. Instructions to the student as well as background and other information pertaining to a tasks will be delivered five basic ways, by:

- o audio tape
- o CRT
- o microfiche slides
- o 16mm film, or
- o printed material.

A variety of alternative media have been provided to minimize the amount of reading required of the student, to add interest, and to provide the most appropriate format for a particular application.

Once again, the instructor is given a great deal of freedom in choosing the mix of media he feels is best.

All messages and instructions to be delivered to the student via CRT and microfiche are controlled by computer and are specified as part of the teachware. These will, therefore, be taken care of during the selection or generation of teachware. In this step audio tapes, 16mm film, and printed materials must be selected or prepared. Again a variety of prepared materials will be available from which the instructor can choose, or he can generate new materials.

B. Evaluation

Several evaluation modes are available:

- o informal feedback
- o formal evaluation

Informal feedback. This mode of evaluation is provided to the student as a matter of course during normal use of the teachware. For example, a student who shorts out a circuit while making a measurement will be given a message to this effect.

Formal evaluation. Formal evaluation would generally be used either directly before or after a group of lesson segments, to determine student attainment of instructional objectives. In this mode, the feedback options could be turned off, if desired.

The output of the evaluation process would be a diagnostic report for informal evaluation, and for the formal evaluation:

- o an attainment score in terms of percentage of objectives met, for each student,

- o list of objectives failed, for each student
- o optional diagnostic report, consisting of all feedback messages received by the student during the evaluation session
- o Accumulative statistics across students.

Evaluation, i.e., scoring and generation of reports, could be carried out at any station and would consist of:

- o connecting the teletype terminal
- o loading the disk containing the evaluation programs
- o sequentially loading the disk containing the student response listing for each student to be evaluated. (student response histories could probably be recorded on 1-5 disks since not all students would be tested at once.)
- o running the evaluation program and obtaining output on the printer.

Based on the results of the formal evaluation the student can be directed to one of several courses of action:

- o repeat one or more lesson segments
- o take a new lesson segment (the topic and difficulty of which can be made contingent on the students performance)
- o demonstrate proficiency on operational gear
- o receive remedial training in one or more areas of deficiency.

VI. SCENARIO

The best way to demonstrate the use of Design "A" by the student is with a scenario.

The student begins by selecting the Instructional Materials Package for a particular unit lesson from the storage area at his station. Assume that this lesson is about monitoring waveforms on transmitters. The package includes:

- o An audio cassette
- o A 16mm film
- o Several floppy disks, and
- o An instructional workbook for this lesson.

All materials are contained in a single binder.

The student proceeds by loading the floppy disk and playing the audio cassette which introduces the lesson and provides further instructions and background. The student is next instructed to view a 16mm film on monitoring waveforms in transmitters. This film demonstrates the monitoring procedure on several operational gear and then on the trainer. While viewing the film, the student can refer to the procedural steps in his workbook.

At this point, the student has the option to either repeat the film or to practice the task. Practice on this task is gained by using the interactive microfiche, the simulated oscilloscope, and the pull-out drawer. Task parts are allocated to each depending on the fidelity required to facilitate learning. In this case, the student uses the interactive microfiche to gain access to the test points in a socket where the oscilloscope leads must be placed. Access is gained by sequencially pointing to the part of the equipment to be removed with the sonic pen. A new slide, with the desired modifications is shown immediately.

The 3D representation of the desired test points are located on a module in an equipment drawer. Once access to the socket, P1, are gained, the student performs the remainder of the task on the simulated oscilloscope and pull out drawer.

Figure A-6 shows the last slide the student might receive on the microfiche screen. This slide indicates where in the generic drawer socket, P1, is located.

The student next sets up the oscilloscope and monitors the required waveforms. Throughout this task the student is given feedback on the graphic CRT. Based on his performance on this task, the student is directed to:

- o repeat the lesson
- o call for instructor assistance
- o move on to another lesson.

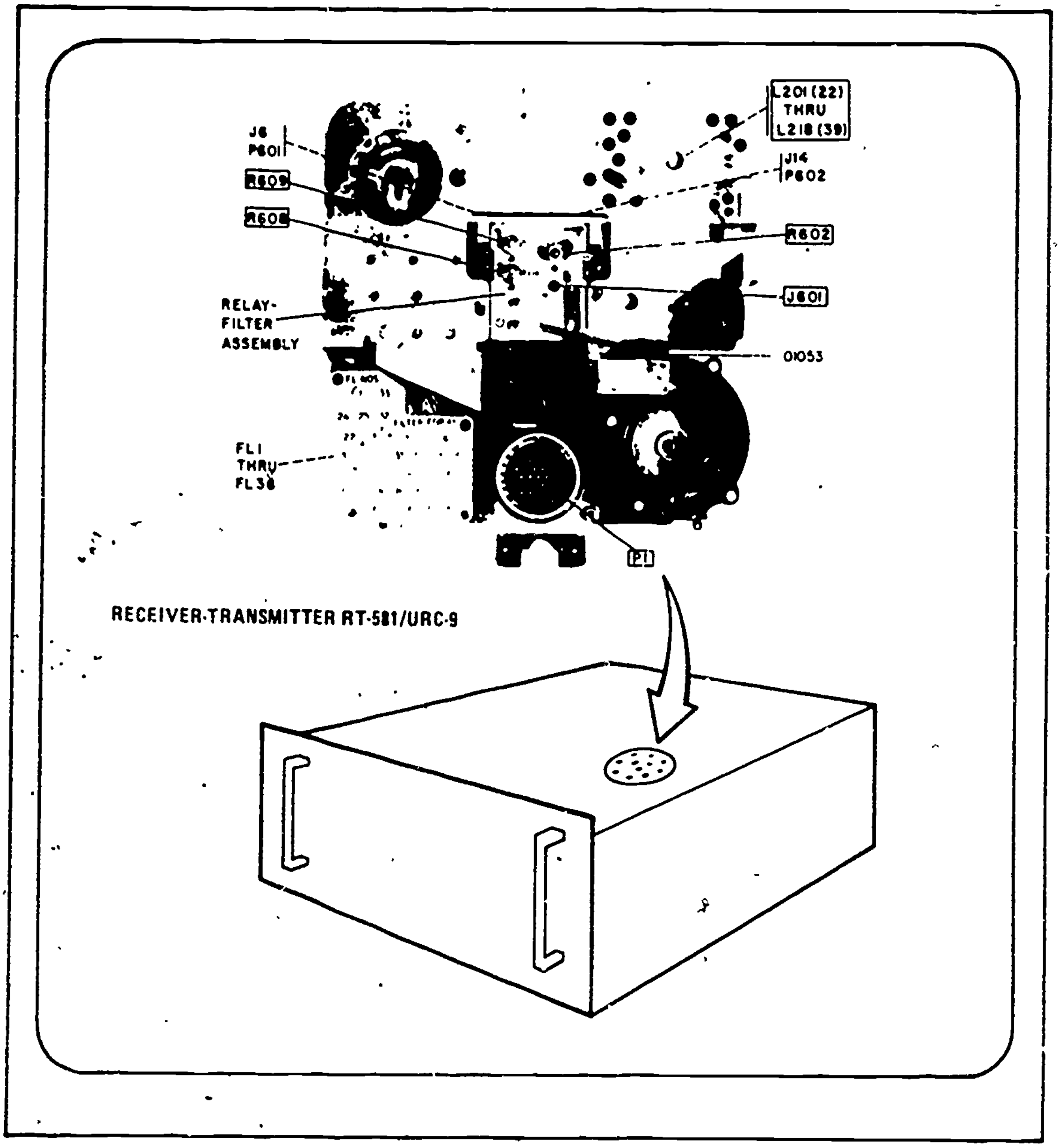


FIGURE A-6. LAST SLIDE RECEIVED ON MICROFICHE SCREEN IN LEARNING HOW TO MONITOR WAVEFORMS ON A TRANSMITTER.

VII. CONCLUSIONS

The features of Design "A" are summarized in Figure A-7. This design is a fully independent unit requiring no central processing or instructor station. Each unit contains all the materials, and computing power to train the generic tasks described in the Honeywell Training Requirement Analysis Report. Furthermore, any unit can be used to generate evaluation reports by connecting a keyboard/printer terminal to it.

The stand alone design should provide a highly reliable, transportable, maintainable, and supportable system. First, because it is completely self-contained it has no interunit data transmission, or time sharing problems to worry about. This not only means increased reliability and maintainability, but should provide faster response times as well. This is further facilitated by the distributed processing feature of the design.

The fact that Design "A" is self-contained obviously increases its transportability. Furthermore, because there is no instructor station, there is less hardware and software to maintain and support.

The stand alone nature of this trainer is closely related to its auto-instructional aspect. The student is given a high degree of antomony by providing him with various instructional aids to reduce the need for instructor involvement.

A wide range of media are used in this capacity. Audio tape is used to reduce a student's reading requirement. 16mm film provides an excellent means for demonstrating how task procedures are carried out on operational gear vis-a-vis the trainer. Interactive microfiche can be used in the manner

FEATURES:

- o STAND ALONE
- o MULTIMEDIA
- o HIGHLY MODULAR
- o PART TASK PHILOSOPHY
- o GENERIC 3D CONTROLS, MODULES, & PARTS
- o HIGH FIDELITY TEST EQUIPMENT

FIGURE A-7 SUMMARY OF DESIGN "A" FEATURES.

of the Rigney system, while high fidelity waveforms, and alphanumeric information is provided on the graphic CRT. In addition, hands-on manipulative skills can be practiced on the functinal test equipment mock-ups and 3D components designed to provide maximum transfer of learning to the operational environment.

Because of the student autonomy afforded by the range of auto-instructional materials available in this system and its highly modules design, instructors are given a great deal of time and freedom for planning and designing instruction. This flexibility is a necessity given the existing difference in ET and EW curriculums and the requirement to use a single trainer for both.

The nature of the 2D/3D mix in Design "A" was motivated by the desire to provide training with transfer to the largest possible percentage of the representative equipments and tasks. Over 50 equipments and 42 different tasks were selected for training. The approach chosen to assure generalization to this large combination of tasks and equipments was to:

- design simulated equipment with commonality at the part and module level, and to

- adopt a part task pholosophy for hands-on practice.

The part task philosophy was to provide hands-on manipulative components only for those "parts" of a task requiring significant psychomotor skills. Where hands-on manipulations are called for, they are performed on generic switches, controls, modules, and parts. This approach is motivated by the organizational nature of electronic equipment.

Electronic equipment are structured in a hierarchical arrangement. A taxonomy having five levels--was adopted in this program. At the highest level--system--all equipments are unique. Increased commonality between equipments is found, the lower the level we look at. At the parts level complete commonality exists, since all equipments are built from a common set of parts. Design "A" strives to assure transfer of training by designing simulated equipment to incorporate the modules and parts found to be most common in the performance of the ET and EW selected tasks. In the 2D components of the system this is accomplished by providing "generic" switches and controls. In the 3D components this is accomplished by maintaining fidelity to operational gear at the part and module levels.

Finally, Design "A" simulates test equipment with high fidelity functional mock-ups. This approach should maximize transfer of learning, since essentially the same set of test equipment is used to maintain all the prime equipment in the representative sample.

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DESIGN B

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I. INTRODUCTION

A. Basic Assumptions

The EEMT System will be an instructional delivery system to support training and practice of electronic equipment preventive and corrective maintenance tasks. Design B, defined in this report, is one alternative conceptual design that satisfies all the requirements of the EEMT System.

Conceptual Design B is based on several boundaries and assumptions common to all three conceptual designs (refer to Common Military Characteristics, Honeywell Report F2210-4.1). These include:

1. The EEMT system will be a hybrid 2-D/3-D system to support both ET and EW Class A training.

2. All maintenance tasks identified in the Training Requirements Analysis Report (Honeywell Report F2210-2) will be trained by the system.

3. Instruction will be self-paced.

Other assumptions are adopted for, and form the groundwork of, Design B:

4. The hardware specified for the training device will be minimally adequate for training the instructional objectives and generalities.

5. Student station space requirements will be minimized.

6. The expansion capability for maintenance training of new-technology equipment will be maximized.

7. Cost of student station hardware per copy at production will be limited.

8. The EEMT curriculum will be flexible.

9. Components of the student station hardware will be modularized for maximum flexibility.

B. Functional Characteristics

The design process for EEMT system Design B began with the identification of functional characteristics, requirements, and constraints. Functional characteristics critical to the system are listed below, together with ideas for potential implementations of those characteristics.

1. Establishment of initial conditions
   - o system set-up and energization
   - o reset switches and controls to intitial positions.

2. Trainee ID entry (log-on).

3. Text presentation
   - o static frames sufficient
   - o self-paced progression.

4. Functional presentation of photos, drawings
   - o interactive capability.

5. Audio capability
   - intercom and audio signals come through same system
   - audio speaker to present "change of slide" signal.

6. Student/instructor interaction
   - intercom
   - instructor station display of any current student station display.

7. Feedback presentation
   - text and audio, also possibly flashing light
   - standard set of messages
   - additional tutorial messages for remedial aid
   - audio/visual alarm capability for safety violations.

8. Malfunction insertion
   - symptom-only mode for purposes of symptom recognition and fault diagnosis may be desirable.

9. Objective testing
   - built-in performance testing
   - objective questions (e.g., multiple choice) in programmed text fashion.

10. Lecture/demo capability
    - cursor capability on instructor plasma display; joystick for pointing
    - repeater at instructor station.

11. Performance measures
    - menu at instructor station under his control.

12. Adaptive branching capability for aiding level

   - o different aiding methods for different students--adaptively select the aiding level, either automatically or under instructor control
   - o option for selecting slides for more detailed explanation.

13. Replay capability

   - o memory requirement (within student station microprocessor) for replay of procedure showing switch/control settings, meter readings, etc.

14. Hardcopy output

   - o capability for ordering performance data hard-copy output for individual or class, from instructor station.

15. Instructor set-up

   - o readiness checks and daily maintenance functions
   - o daily set-up and preparation
   - o selecting the lessons
   - o diagnostic software routines for readiness checks (e.g., input device for informing system to implement readiness checks and provide feedback to instructor).

16. Teachware generation and modification

   - o production and editing capability for microfiche
   - o computer output microfiche--draw graphically on microfiche slide--may be desirable.
   - o digitizer for entering graphics into the computer, transforming a picture to electronic pulses, <u>or</u>
   - o transforming a glossy picture to dots, then to 512/512 matrix for high resolution.

C. Overview of Design B

System Design B is a training system capable of addressing each of the functional characteristics. It involves a classroom configuration with instructor station and multiple student stations. Each student station contains a microfiche projection system, an interactive plasma display with touchpanel. simulated representative electronic equipment subassemblies, simulated operational test equipments, and generic test equipment.

In the following section (Section II), the Design B system is described in general terms--environmental variables and computer support. Subsequently, Sections III and IV present comprehensive descriptions of the student station and instructor station, respectively.

The training of maintenance procedures in this EEMT system would involve both group and individual instruction. The instructor would have available a demonstration capability via the student microfiche and plasma displays. To perform the training tasks, students would receive instructions, step through the task procedure, and answer test questions in a programmed computer assisted instruction (CAI) manner. For most tasks, the student would be directed to a particular 3-D simulated subassembly on which he would perform tests and measurements using appropriate test equipment. A summarization of the performance capabilities of the system is found in Section V. Then, Section VI presents a detailed description of one possible scenario for maintenance task training on the Design B system. The functional characteristics, hardware features, and system performance capabilities are all drawn together in Section VII in which conclusions and Design B advantages are outlined.

II. SYSTEM DESCRIPTION

A. Environmental Variables

Design B specifies an optimal instructor load of 20/1; i.e., 20 student stations for each instructor station. The classroom size necessary to support this configuration is approximately 30 x 60 ft. Figure B-1 shows a classroom/lab layout that accommodates 20 student stations and 1 instructor station in the 30 x 60 ft. room.

The supply area for generic equipment subassemblies on the right-hand edge provides storage for the simulated equipment used by the trainees in tests and measurements. Each subassembly resembles a pull-out equipment drawer that the trainee takes to his own test rack and connects. This and other details of the classroom configuration in Figure B-1 are explained below.

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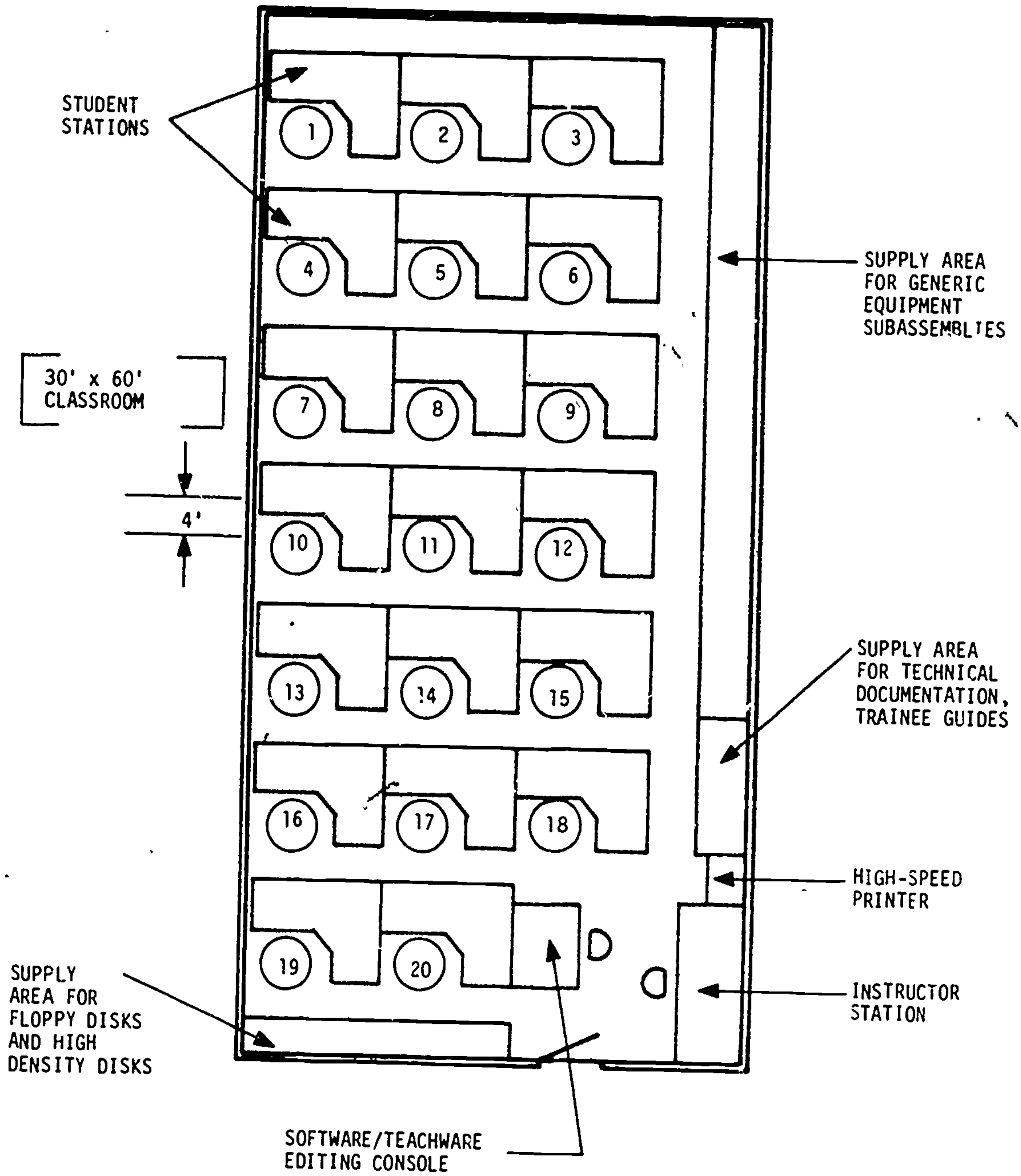

FIGURE B-1. EEMT SYSTEM CONCEPTUAL DESIGN B - POTENTIAL CLASSROOM CONFIGURATION

B. Computer System

Centralized Components. The computer system to support training in Design B is a distributed processing system. A central 16 bit microprocessor at the instructor station facility controls input/output, display, and instructor functions. Associated with this processor are two separate mass storage media in the form of dual high density floppy disks. In one disk resides the operating system, teachware, data base, and utility programs. It is accessed periodically by the student station processors as needed. The second disk stores performance data from the student station processors. These data are routed up-line at the instructor's request.

A second microprocessor (8 b t capacity) at the instructor station facility is dedicated to test equipment display data. An associated floppy disk stores these data, particularly waveforms, for presentation on the student station test equipment displays.

Remote Components. Each student station is an "intelligent" data processing unit with three microprocessors and limited core storage. The functions of these microprocessors are as follows:

1. Input/output and teachware. Two floppy disk mass storage media are attached; they store data compatible with those on the two centralized dual high density floppy disks:

   a. operating system, teachware, data base, utility programs,

   b. performance measures.

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2. Plasma display image generation.

3. Generic equipment subassemblies control.

Finally, one additional microprocessor is located off-line in a separate console. It controls software/teachware production and modification and contains associated mass storage media compatible with those at the instructor and student stations (dual high density floppy disk and floppy disk).

III. STUDENT STATION

A. Student Console

Microfiche/Plasma Display. The student's primary interface with the teachware and the instructor is the interactive microfiche plus plasma touchpanel display. The functions of this display system include:

1. Presentation of photos (e.g., equipment front panels) or line drawings from the microfiche system with a maximum random access time averaging three seconds,
2. Interaction with the microfiche images via the touchpanel (e.g., making switch and control settings, requesting a meter reading, calling for a closer and more detailed view),
3. Display of CAI messages and student responses,
4. Instructor demonstration of correct switch settings, test point locations, etc. by means of cursor.

Function Keyboard. A set of function keys below the display panel controls the permanent functions. These include:

1. ON/OFF switch for console power,
2. ON/OFF switch for microfiche projector,
3. ON/OFF switch for tone generator,
4. ON/OFF switch for generic equipment rack power,

5. ON/OFF switch for plasma unit,

6. FUNCTIONS switch to display menu of available functions,

7. START switch to initiate a lesson,

8. RETURN switch to return to initial configuration at beginning of lesson,

9. REPLAY switch to replay the entered procedure from the beginning of the lesson,

10. CALL switch for instructor aid,

11. TEST EQUIPMENT switch to display a menu of available test equipments to be represented through the generic test equipment front panel,

12. Several auxiliary switches for expansion of capabilities.

Intercom. An intercom system provides the primary auditory interaction with the instructor. When talking with the instructor, the trainee wears a headset with headphone and microphone. At other times, he removes the headset and turns it off. Audio outputs such as change-of-slide beep, safety violation alarm, receiver AF noise, etc. are then routed to a speaker in front of the trainee's seat. All audio jacks in the student station test equipments or generic equipment subassemblies are wired in parallel.

In summary, the components of the student intercom system are the following:

1. Headset with headphone and microphone,

2. Speaker,

3. Insertion jacks for headset,

4. Volume control and OFF switch,

5. Sonalert or audio alarm.

Other Components. Other features which support the student console are self-explanatory:

1. AF tone generator,

2. Microfiche projector,

3. Storage compartment for floppy disks and microfiche cassettes,

4. Floppy disk drive unit,

5. Power supply,

6. Storage compartment for instructional materials--workbooks, trainee guides, technical manuals,

7. Set of common hand tools,

8. Storage bins for test equipment support materials, and for hand tools.

Figure B-2 is a representation of the student station for Design B. The generic equipment subassemblies relay rack, test equipment rack, and generic test equipment will be discussed next.

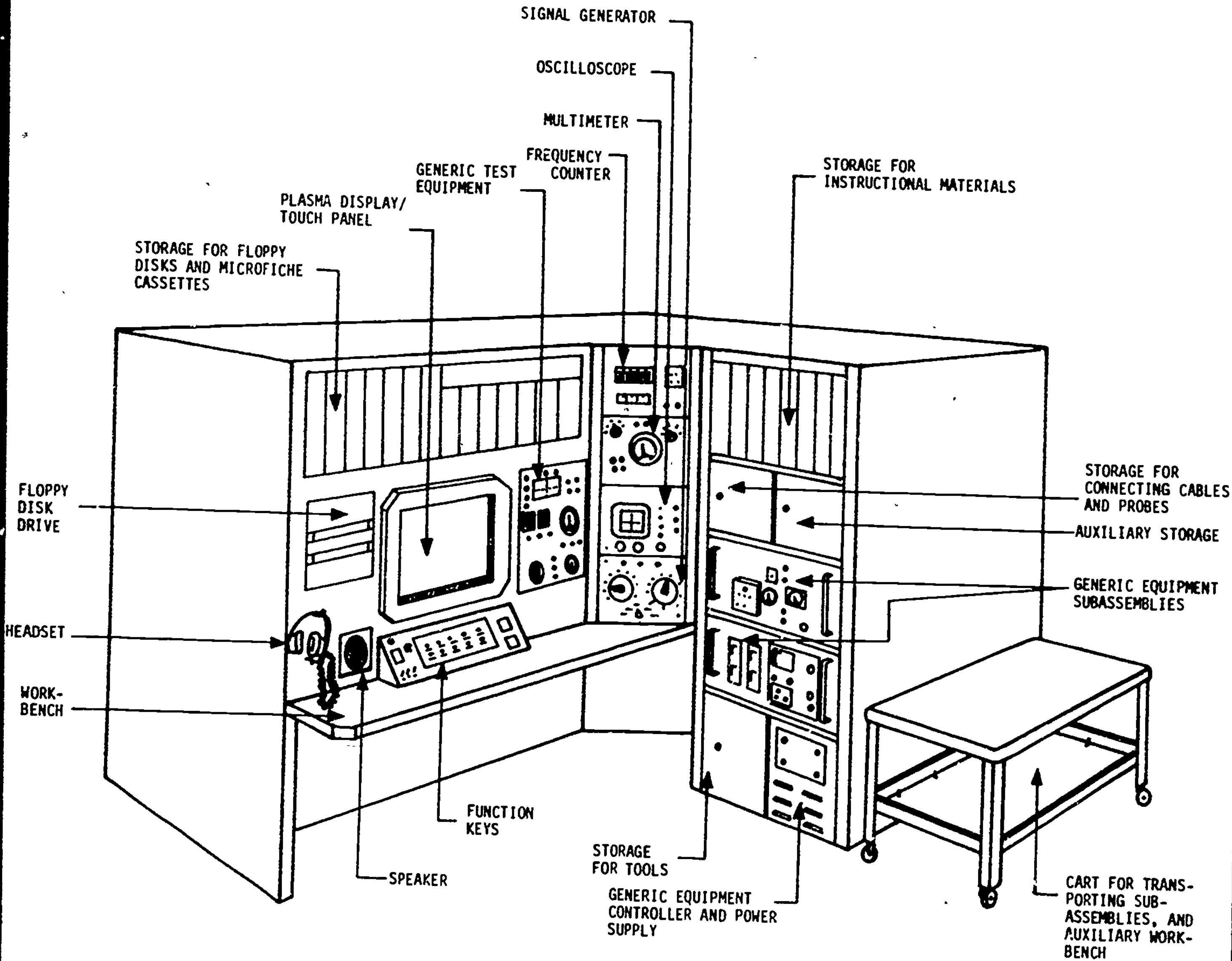

FIGURE B-2. EEMT SYSTEM CONCEPTUAL DESIGN B - STUDENT STATION

B. Generic Equipment Subassemblies

The generic equipment subassemblies are simulated, generic versions of representative electronic subassemblies which ET and EW personnel maintain. As stated above, they are pull-out, removable drawers that the trainee obtains from the supply area according to his needs for the upcoming lesson. The flexible and self-paced EEMT curriculum eliminates the need for a full complement of electronic subassemblies at each student station. Plans should call for between 10 and 12 identical subassemblies stored in the supply area, rather than the full 20. This equipment reduction realizes substantial cost savings.

The flat panel controls for the generic equipment subassemblies are functionally simulated in three dimensions. Controls important for the represented operational equipment are included; less critical controls may be deleted.

The interior of each drawer is accessible from above when the drawer is pulled out. Modules, parts, circuits, test points, and other common component parts (CCPs) representative of common ET/EW equipments are 3-D functionally simulated within the drawers. These components are representative of the three electronic ages--vacuum tubes, transistors, and integrated circuits--in proportions identified in the Equipment and Task Commonality Report, Honeywell Report F2210-1. The CCPs required for tests and measurements are wired with low voltage power. They are connected by flexible ribbon cabling to the generic equipment rack logic and subsequently to the dedicated microprocessor controlling the generic equipment subassemblies. Figure B-3 depicts a hypothetical example of a generic equipment subassembly complete with front panel and interior modules, parts, and circuit boards.

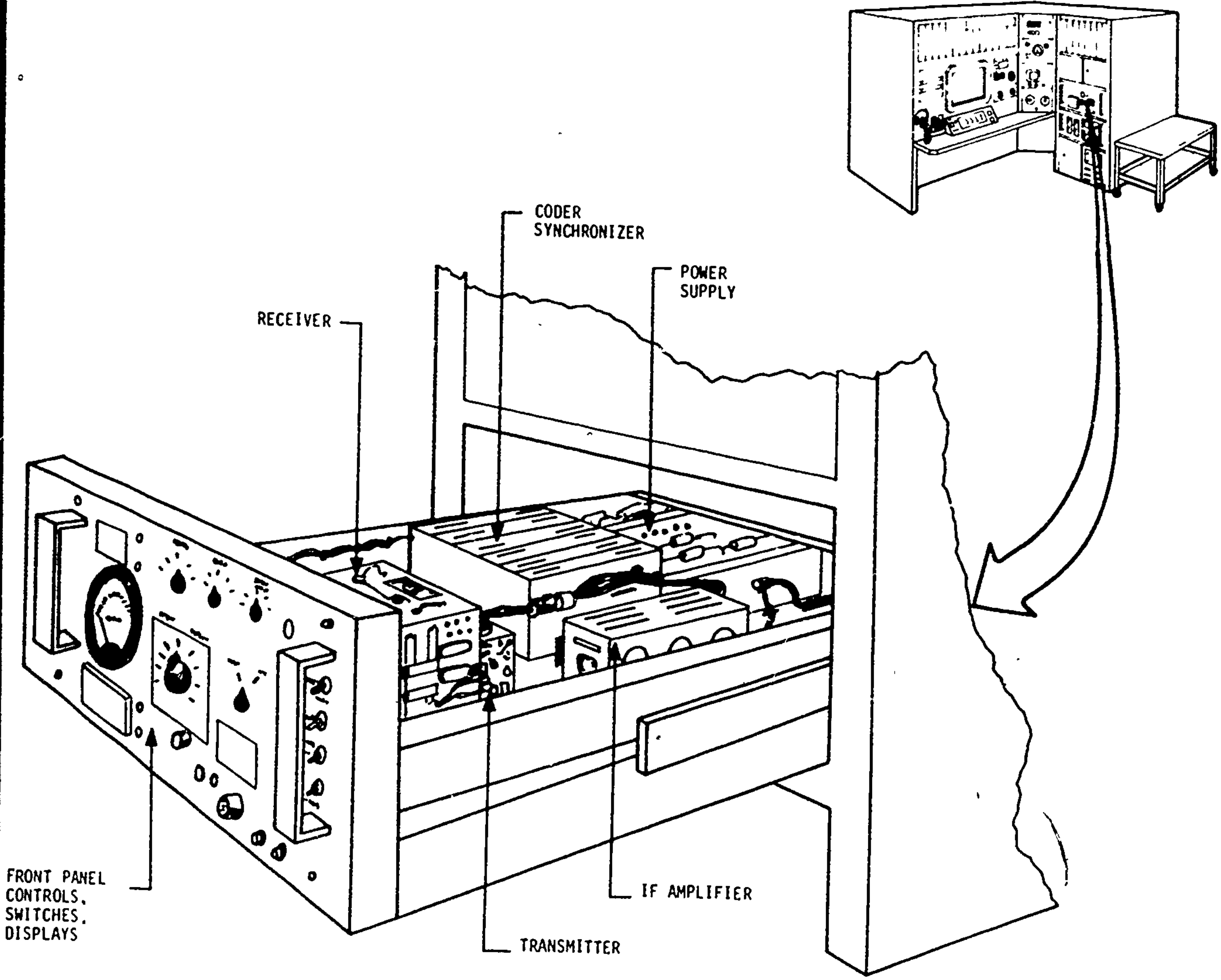

FIGURE B-3. EEMT SYSTEM CONCEPTUAL DESIGN B
- EXAMPLE OF REPRESENTATIVE MODULES AND CIRCUITS WITHIN GENERIC EQUIPMENT SUBASSEMBLY

Representative Equipments. Representative equipments most appropriate for 3-D simulation are listed in Table B-1. An emphasis on these equipments will ensure a good representation of new-technology chip circuitry as well as component circuit boards and common older technology circuitry.

Table B-1

Representative Equipments for Generic 3-D Simulation

Category	Designator
Countermeasures set	AN/WLR-11 AN/WLR-8
Automated EW system	AN/SLQ-32 AN/SLQ-17
Comm receiver	R-1051 AN/WSC-3
Antenna coupler	AN/SRA-56,57,58
Comm radio set	AN/SRC-20,21
Radar set	AN/SPS-67
Navaids - Omega receiving set	AN/SRN-12
MK 12 IFF	
transponder	AN/APX-72
interrogator	AN/UPX-23
decoder	AN/UPA-59

Subassemblies/Modules. A discrete and relatively small number of subassemblies/modules are necessary for 3-D hands-on maintenance training (*Fidelity Requirements Analysis Report*, Honeywell Report F2210-3). A preliminary list of subassemblies/modules for Design B, in addition to their means of representation and possible sources, is presented in Table B-2.

Table B-2

Subassemblies/Modules Required
for 3-D Simulation

Name	Representation	How Many Needed	Possible Sources
Power supply	1. drawer (EW-HV) 2. drawer (ET-LV) 3. removable module (regulated)	3	AN/SLQ-32 AN/UPX-23
RF transmission line	assembly that can be attached to side of cabinet	1	AN/SPS-67
Antenna coupler	drawer	1	AN/SRA-56, 57,58
RF antenna wave-guide	assemblies attached to side of cabinet	2	a. AN/SLQ-32 b. AN/SPS-67
Slotted line	assembly that can be connected to side of receiver/transmitter	1	AN/SPS-67
Modulator	module within receiver/transmitter drawer	1	AN/SLQ-32
Oscillator	module within receiver drawer	1	AN/SLQ-32
Receiver unit	drawer, switching capability or separate representation of AM,FM, and pulse	3	a. AN/SRN-12 b. R-1051 c. AN/WLR-11
RF amp	1. module within receiver drawer 2. drawer	2	a. AN/SLQ-32 R-1051 b. AN/SRC-20, 21

Table B-2

Subassemblies/Modules Required for 3-D Simulation

(concluded)

Name	Representation	How Many Needed	Possible Sources
IF amp	module within receiver drawer 1. AM 2. PM 3. pulse	3	AN/UPX-23 AN/SRC-20,21
Receiver/ transmitter unit	drawer	2	AN/SRC-20,21 AN/SPS-67 AN/WSC-3
Digital section	pull-out PCBs	2	a. RT-859/ APX-72 b. AN/SLQ-32
Beat frequency oscillator	module within receiver/trans-mitter drawer	1	AN/SRC-21,21
Radio set control	drawer	1	AN/SRC-20,21

C. Simulated Test Equipment

Simulated representative common test equipments are mounted in a diagonal rack at the trainee's right (see Figure B-2). The four basic test equipments represented are:

1. frequency counter,

2. multimeter,

3. dual-trace oscilloscope,

4. signal/pulse generator.

The front panels of these test equipments, including scopes, meters, controls, and switches, are functionally simulated and appear with high fidelity. Detachable probes, connecting cables, and jacks are provided for actual connection with appropriate jacks and test points on the generic equipment subassemblies.

The oscilloscope display consists of a raster-scan TV cathode ray tube (CRT) with 512 line resolution. It is controlled by the dedicated centralized microprocessor which accesses appropriate waveforms stored on its floppy disk, then routes the signals through a multiplexer and a TV controller.

Other required test equipments identified in the <u>Fidelity Requirements Analysis Report</u> include: megger, power meter, bolometer, microammeter, spectrum analyzer, and noise generator. These test equipments are less commonly used. Consequently, a generic representation of these and the remaining test equipments appear on one large front panel in front of the trainee.

The generic test equipment contains one raster-scan TV CRT, meters, digital readouts, and various multipurpose controls. The appropriate displays and controls for any particular piece of test gear are indexed on a microfiche pictorial view of that test equipment. Although the generic test equipment does not exactly resemble any actual test equipments, the displays, controls, switches, jacks, etc. are functionally simulated.

The student station functional block diagram in Figure B-4 shows all the features of the student station and how they are interconnected. Included are the three microprocessors and the three main functional divisions--1.) 2-D interactive display, 2.) generic simulated equipment, and 3.) simulated test equipment.

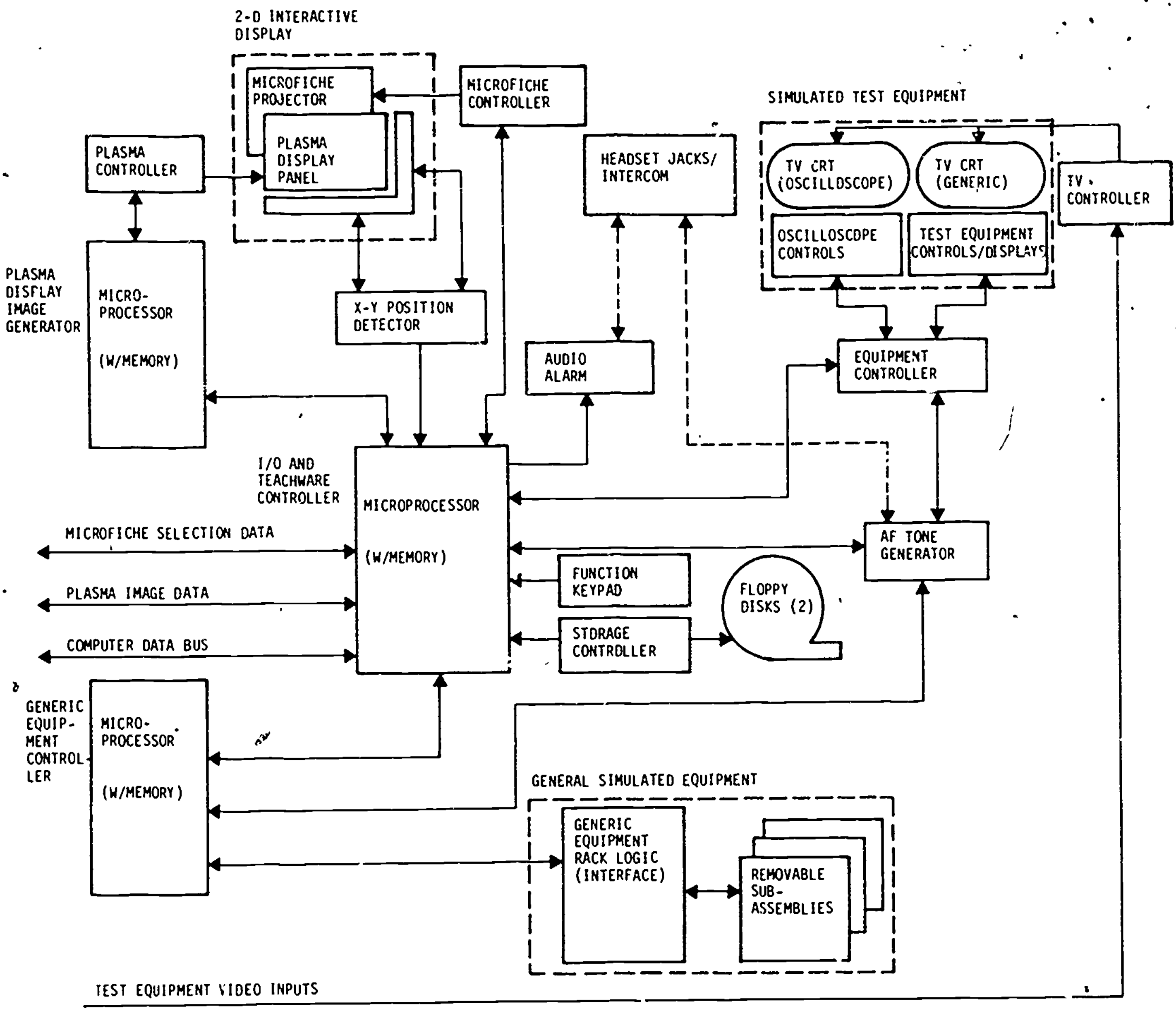

FIGURE B-4. EEMT SYSTEM CONCEPTUAL DESIGN B - FUNCTIONAL BLOCK DIAGRAM FOR STUDENT STATION

IV. INSTRUCTOR STATION

A. Instructor Console

Microfiche/Plasma Display. The instructor's primary interface with the teachware and the students is an interactive microfiche plus plasma touchpanel display identical to that at the student stations. Through this display system, the instructor has the capability for these various functions:

1. Monitoring averaged data on class performance,

2. Monitoring the microfiche and plasma images as they are presented at any one student station,

3. Remotely operating any or all student station microfiche projectors to show desired details, etc.,

4. Pointing with a joystick-controlled cursor to specific features on any or all student displays,

5. Insertion of single or multiple preprogrammed malfunctions into the teachware.

To control these functions, the following features are present at the instructor station.

Function Keyboard. A set of function keys below the display panel controls the permanent functions. These include:

1. ON/OFF power switch,

2. ON/OFF switch for microfiche projector,

3. ON/OFF switch for plasma unit,

4. FUNCTIONS switch to display menu of available functions,

5. VIDEO SELECT switch to call up display of video routing options for student stations,

6. MONITOR switch to display numeric keyboard for selection of one student console,

7. READINESS CHECK key to initiate equipment diagnostic checks,

8. HARD COPY switch to route the current display to the printer,

9. Several auxiliary switches for expansion of capabilities.

Intercom. An intercom system at the instructor station complements and controls the student station intercoms. A headset with headphone and microphone is available for audio interaction with student(s). Other components of the instructor intercom system are the following:

1. Speaker,

2. Insertion jack with automatic speaker cutoff,

3. Volume control and OFF switch,

4. Auxiliary jacks to permit connection of additional headphones,

5. Audio alert to signal student calls for help,

6. Communications control panel

   a. ON/OFF switches--1 per student station,

   b. ALL switch to route audio messages to all student stations,

   c. RESET switch to reset all switches to OFF position.

<u>Other Components</u>. Other features which support the instructor console are self-explanatory:

1. Power supplies,

2. Microfiche projector,

3. Joystick for controlling the cursor at instructor plasma display and at student plasma displays,

4. Storage compartments for microfiche cassettes, floppy disks, and high density disks,

5. Floppy disk drive unit,

6. High density disk drive unit,

7. AF tone generator,

8. High-speed printer under instructor control for hard copy of performance data, etc.

Figure B-5 is a representation of the instructor station for Design B. In addition, the instructor station functional block diagram in Figure B-6 shows all the features of the instructor station and how they are interconnected.

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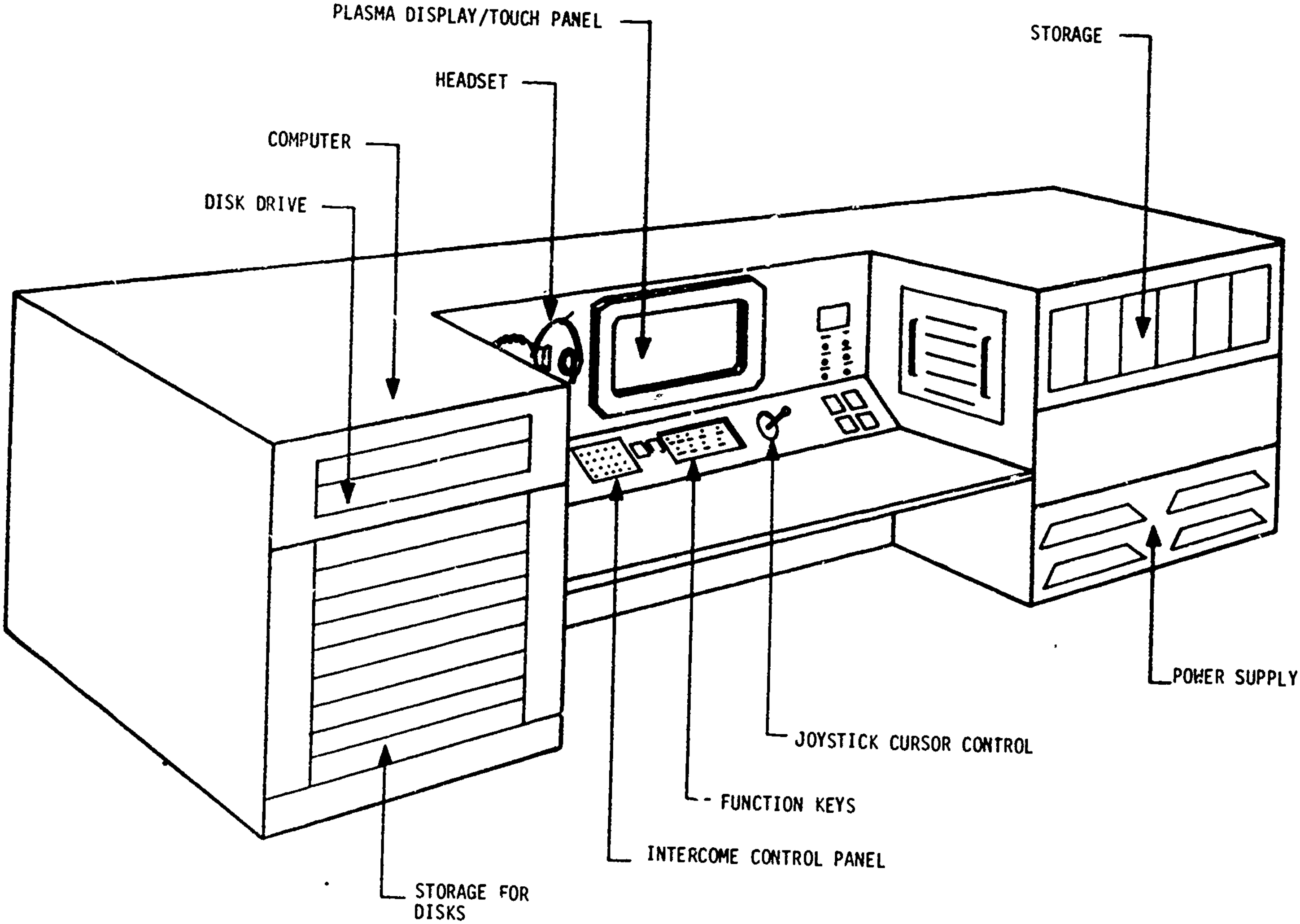

FIGURE B-5. EEMT SYSTEM CONCEPTUAL DESIGN B - INSTRUCTOR STATION

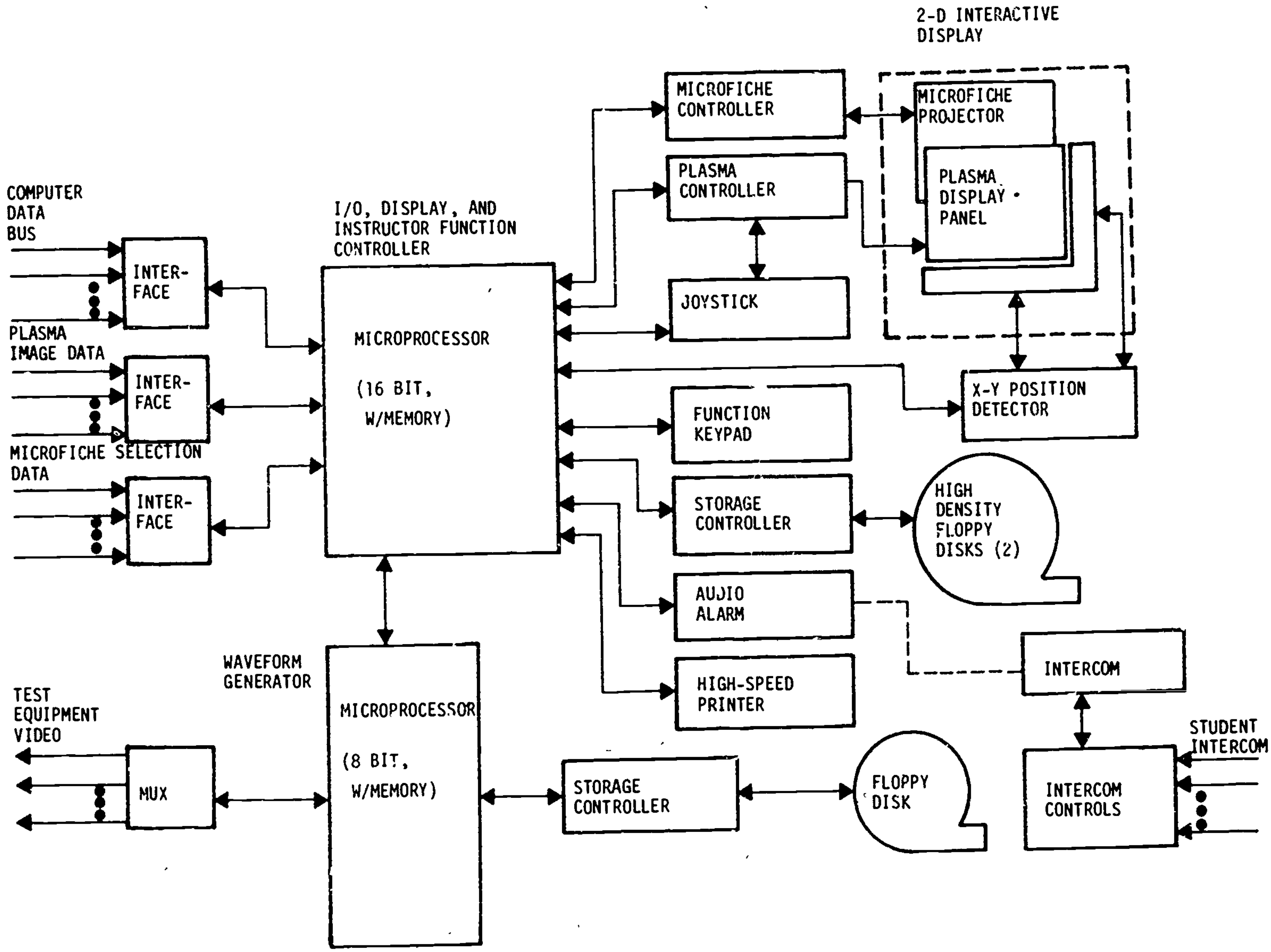

FIGURE B-6. EEMT SYSTEM CONCEPTUAL DESIGN B
- FUNCTIONAL BLOCK DIAGRAM FOR INSTRUCTOR STATION

B. Teachware/Software Editing Facility

A separate off-line facility is required for production and modification of the software and teachware. A raster-scan TV CRT provides the display medium. The instructor uses an alphanumeric keyboard to enter text and operating system changes and a sonic digitizer to create or modify waveform data. A dedicated microprocessor is used for editing, and changes are stored on high density disk or floppy disk, as appropriate. Storage and playback units compatible with both forms of mass storage media are needed. In addition, a high-speed printer is provided at this facility. Figure B-7 is a functional block diagram of the teachware/software editing facility.

One additional remote facility is called for with Design B--a microfiche production station. This includes a camera tripod unit and various photographic and editing supplies.

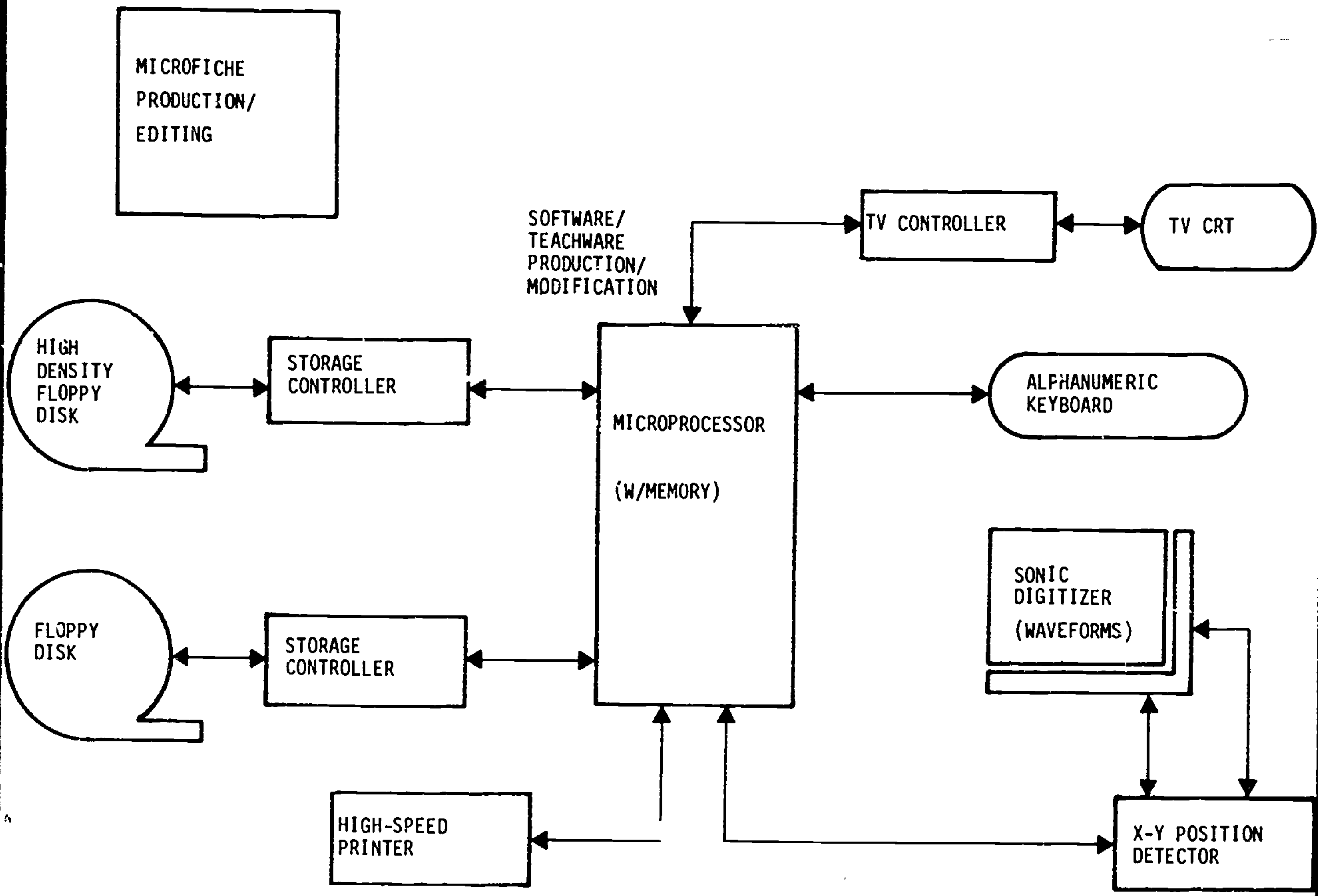

FIGURE B-7. EEMT SYSTEM CONCEPTUAL DESIGN B
- SOFTWARE/TEACHWARE/MICROFICHE PRODUCTION FACILITIES

V. SYSTEM PERFORMANCE CAPABILITIES

The first four sections of this report define functional characteristics of EEMT System Design B and the hardware capable of supporting these functions in terms of computer system, student station, and instructor station. Discussion of these system hardware features provides only indirect evidence for the wide scope of system capabilities contained in Design B. Consequently, this section focuses on modes of operation and system performance capabilities. In Section VI, many of the Design B system modes of operation and functions are illustrated in a sample scenario for training.

A. Modes of Operation

Most system operating functions are under instructor control and initialized by means of the function switches at his console. The basic modes of operation are:

1. READINESS CHECKS--To prepare the system for training, the readiness check implements diagnostic routines and reports any malfunctions.

2. PERFORMANCE MEASUREMENT--The operating system stored on floppy disk at the student station compares the results of his actions (e.g., probe connections, switch setting, meter reading) with the preprogrammed standards for correctness. The performance measurement data are collected on the floppy disk dedicated for that purpose. Periodically, under instructor control, they are routed up-line to the dual high density floppy disk at the instructor station.

3. EVALUATION--Simple evaluation at the level of task step correctness is associated with the performance measurement process above. At the instructor station, some simple statistical routines can be implemented to collapse the performance data across students and lessons; summary statistics are displayed for the instructor at his request.

4. LECTURE/DEMONSTRATION--Instructor remotely controls microfiche projectors (with random access) and intercom at any or all student stations. His cursor-control joystick moves a pointer at those student plasma displays.

5. MALFUNCTION INSERTION--Controlled through the software, malfunctions and concomitant symptoms can be entered by means of a malfunction menu of preprogrammed faults ranging from subassembly down to circuit level.

6. PRODUCTION/EDITING of software and teachware is accomplished off-line at a CRT with keyboard (see Figures B-1 and B-7). The authoring language does not demand prerequisite programming skills on the part of the instructor.

7. MICROFICHE PRODUCTION--Self-contained microfiche production and editing units are available commercially.

B. Performance Capabilities

Other system performance capabilities which are software features can be considered subsumed under one or more of the modes of operation above. They include the following.

Automatic Pacing. The instructional procedure is branched in a hierarchical manner to accommodate the slowest learners. Rapid learners, by answering the multiple choice questions correctly, bypass all or most of the branches which contain review material and remedial aid. Both types of learners will have satisfied all the performance standards and met the terminal objective of the lesson, although they progressed at different rates.

Feedback. The performance measurement process compares student actions with standards at each task step. These results are displayed on the student plasma panel at the completion of each step. Acknowledgement of "correct" can be accomplished with one or more standard messages. Error messages contain a specialized explanation followed by an automatic reset or branching for remedial aid, should the trainee request it. Signalling for instructor advice is always an option.

C. Instructor Role

Once he has energized the system and assigned lessons, the instructor need not maintain a controlling status to keep the system running. He can remain involved in the instructional process to any degree he chooses. Most instructors may prefer to introduce new lessons with demonstrations rather than rely solely on a workbook. The instructor can request class performance statistics periodically and monitor students who fall behind. In addition, he may circulate around the stations to look over students' shoulders if he feels better utilized in this manner.

VI. SCENARIO FOR TRAINING

The following is a detailed hypothetical description of a scenario for maintenance task training on the Design B EEMT system. Section A is devoted to a daily readiness check and system energization as performed by the instructor before training commences. Section B covers a training mode of operation in which a student learns maintenance Task g-A122, "Align IF amplifier (AM)." Section C describes the training scenario for Task g-A133, "Measure selectivity and bandwidth on FM wide band receiver."

Although the scenario is a hypothetical one, the details of the scenario description effectively illustrate many system performance capabilities of Design B. Where particulars would deal only with design implementation issues, they are omitted and marked "to be determined" (TBD).

A. System Readiness Procedures

Action	System Response
At 0730, 30 minutes before the first lab is scheduled, the instructor prepares to run the trainer daily readiness check. At the instructor console he:	
(1) Sets the ON/OFF power switch, ON/OFF microfiche projector switch, and ON/OFF plasma unit switch to ON	(a) Power is applied to all equipments at the instructor station. (b) The plasma displays: PLEASE LOAD OPERATING PROGRAM and draws a function key labeled LOAD PROGRAM.
(2) Inserts the DAILY READINESS floppy disk.	
(3) Presses the LOAD PROGRAM function key on the plasma display (touch-panel)	(a) The daily readiness software routines are read from the disk. (b) The plasma displays: DAILY READINESS CHECK LOADED AND EXECUTING . . . At this point the readiness software routines perform a predetermined, short (15 minute) checkout of trainer stations. The exact nature of these checks is TBD. If a malfunction is detected, an error message is displayed on the plasma. Based upon the error type, the instructor/operator will isolate the fault by loading and executing appropriate diagnostic software. The specific nature of this software is TBD. . . .

Action	System Response
	(c) At the completion of the readiness check, the status of the instructor console and 20 student stations is displayed on the instructor's plasma display. A function key labeled LOAD PROGRAM is drawn on the plasma display.
Since the status of all trainer systems is GO, the instructor is ready to load the instructional software (i.e., the instructional operating system). He:	
(4) Removes the DAILY READINESS disk and inserts the OPERATING SYSTEM disk	
(5) Inserts a RECORD-KEEPING disk (i.e., to store student performance measures, etc.) into the second slot	
(6) Presses LOAD PROGRAM on the plasma touch panel	(a) The operating system software is read from disk, and execution begins. (b) A "menu" of allowable instructor functions appears on the plasma display with function keys drawn next to each description.

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Action	System Response
The instructor needs to determine the specific instructional lessons each trainee will be presented. He:	
(1) Presses LESSONS BY STUDENT on the plasma touchpanel.	(a) The plasma displays a summary table of the lessons completed and those remaining for each student.
(2) Presses the HARD COPY function switch on the instructor console	(a) A hard copy of the display format appearing on the plasma display is printed on the line printer.
The instructor uses this hard copy during the 15 minutes before lab begins to assign specific lessons to each student. He posts lesson and carrel assignments or reads them when the trainees enter the lab.	

B. Training Procedure--Lesson Topic 3.3.1.1--Align IF Amplifer (AM)

Action	System Response
Seaman Jones has been assigned Lesson Topic 3.3--Receiver Alignments Procedures. He selects the proper workbook from the student station storage cabinet, turns to Lesson 3.3.1.1--IF Amplifier (AM). The workbook lists the simulated generic equipment subassembly (e.g., generic AM transceiver subassembly) and computer disk required. Jones checks out these items from the supply area, brings them back to his station, inserts the disk into the disk drive unit, slides the equipment drawer into the equipment relay rack, and connects the hook-up cable. Following directions in the workbook, the trainee begins the lab session. He:	
(1) Sets the various student station power switches to ON	
(2) Presses the START function switch on the function keyboard	(a) Since Jones has not logged into the system, the student plasma displays PLEASE LOG IN and draws a numeric function keypad and an ENTER key.
(3) Enters his student ID number onto the plasma display by touching with his finger the appropriate numbered blocks	(a) The plasma displays Jones' ID number as he enters it.

Action	System Response
(4) Presses the ENTER key on the plasma touchpanel.	(a) The plasma displays PLEASE ENTER THE LESSON NUMBER ASSIGNED TO YOU, the numeric function keypad, and an ENTER key.
	(b) The training system searches the record-keeping disk at the instructor station to locate Jones' file.
(5) Enters 3.3.1.1 on the numeric function keypad, and then presses the ENTER key.	(a) The system checks the validity of the number entered against the set of legal lesson numbers and against Jones' performance file. The response to this check is TBD.
	(b) The plasma displays: YOU MAY NOW BEGIN. READ THE INSTRUCTIONS IN YOUR STUDENT WORKBOOK CAREFULLY, THEN PRESS "START" BELOW TO BEGIN THE LESSON.
	(c) The system loads the Lesson 3.3.1.1 teachware from the instructor station disk, and loads the microfiche cassette associated with this lesson into the microfiche projector.
Jones reads the instructions in his workbook which define objectives of the lesson and summary of the alignment procedure. When finished, he:	
(6) Presses the START function switch on the console	(a) The system begins to monitor Jones' performance of the alignment task.

Action	System Response
To configure the system for alignment procedures on the IF amplifier, Jones:	
(1) Sets up the simulated transceiver front panel (i.e., front of drawer) controls and switches as directed by his workbook.	(a) The system evaluates each trainee action for correctness. Cueing and feedback are provided on the plasma display as appropriate. (The exact nature of this feedback is TBD.) If Jones makes a serious error, an audio tone is sounded.
(2) Physically inserts test equipment probes and cables into the appropriately labeled jacks on the test equipment front panels (e.g., MULTIMETER, FREQUENCY COUNTER)	
(3) Slides out the generic subassembly drawer to gain access to the 3-D simulated modules and circuits mounted inside	
(4) Connects the test equipment to appropriate test points or ground/connection points inside the drawer. (These are 3-D generic representations of typical operational hardware.)	(a) The system senses each connection and evaluates correctness. (b) The test equipment displays respond with realistic values according to the control settings.

With the system configured, Jones is ready to align the IF amplifier. With the multimeter probe at J305 test jack, he:

(1) Operates manual frequency units switch to "9" on the simulated transceiver front panel

Action		System Response	
(2)	Adjusts IF trimmer capacitor inside the transceiver drawer while watching the multimeter display	(a)	Multimeter display value varies realistically as the capacitor is adjusted.
(3)	Stops the capacitor adjustment when the multimeter value is maximized	(a)	The system will evaluate the final value to determine if it falls within a predefined tolerance band--i.e., whether or not Jones has maximized the value.
(4)	Operator manual frequency units switch to "O"		—
(5)	Adjusts IF tuning coil inside drawer while watching the multimeter	(a)	Multimeter display value varies realistically as the coil is adjusted.
(6)	Stops the coil adjustment when the multimeter value is maximized	(a)	The system will evaluate the final value to determine if it falls within a predefined tolerance band.
(7)	Repeats steps 1-6 until changes in coil and capacitor adjustment produce no further increase in multimeter display value		
	. . .		. . .
(25)	Keys transmitter	(a)	RF WATTMETER display on the generic test equipment front panel shows realistic rf signal power value.

Action	System Response
At this point, Jones makes an error. He should be adjusting a trimmer capacitor, but instead disconnects a multimeter probe and inserts it into a test point where high voltage is present. This is a critical error since it could damage the operational equipment and be hazardous to the technician.	(a) The system evaluates the criticality of the error. Since it is critical, an audible alarm is sounded at the instructor console as well as at the student console. The system "freezes" at the step where the error occurred, and the plasma displays: YOU HAVE MADE AN ERROR. DO NOT CONTINUE WITH THE LESSON. REVIEW THE LAST 3 STEPS IN THE PROCEDURE.
The instructor was viewing on his plasma screen a display summarizing the performance of all trainees when Jones makes his error. Hearing the audible alarm sound at his console, the instructor:	
(1) Presses the MONITOR function switch on his console	(a) The plasma displays a numeric keyboard and ENTER key.
(2) Presses the number of Jones' station and then ENTER	(a) The plasma displays a status report and summary for student Jones, including the current lesson number.
	(b) The microfiche cassette for the appropriate lesson is loaded into the microfiche projector.
	(c) Special function keys appear at the bottom of the plasma, including DISPLAY and TEST EQUIPMENT.

Action	System Response
(3) Presses the DISPLAY function key on the touchpanel	(a) The plasma displays both the microfiche slide and any overlaid plasma entries as they are currently displayed at Jones' console, plus a small set of function keys at the bottom of the display (e.g., RESUME).
(4) Puts on the headset; engages the ON switch on the intercom control panel for the number corresponding to Jones' station	(a) Voice communication between the instructor and Jones is established.
(5) Coaches Jones over the intercom on the correct action at that step in the procedure	

To restart Jones' lesson, the instructor:

(1) Presses the RESUME function key drawn on Jones' station report shown at the instructor plasma	(a) The plasma at the student console displays: RE-START YOUR LESSON AT STEP 26 BY PRESSING THE "RESTART" KEY BELOW, and draws a RESTART function key.

Jones presses the RESTART key and then proceeds with the module as before.

•
•
•

After completing the alignment procedure, Jones returns the generic equipment subassembly plus software disk to the central supply area before leaving the lab.

C. Training Procedure--Lesson Topic 3.1.1.7--Measure Selectivity and Bardwidth on FM Wide Band Receiver

Action	System Response
Seaman Doe has been assigned Lesson Topic 3.1--Receiver Tests and Measurement Procedures. In the appropriate workbook, he turns to Lesson 3.1.1.7--Selectivity and Bandwidth (FM). He obtains the proper generic equipment subassembly and disk.	
The instructor is preparing a lecture/demonstration on Lesson 3.1.1.7. To accomplish this, he:	
(1) Presses the FUNCTIONS function switch	(a) The instructor plasma displays a menu of functions and displays available to the instructor.
(2) Presses the LECTURE function on the touch-panel	(a) A display showing 20 student stations and associated keys for selection appears on the plasma.
(3) Selects the student stations he wants involved in the lecture and presses ENTER	(a) The system "links" each of the selected stations to the instructor station in software for the lecture.
	(b) The plasma displays ENTER LESSON NUMBER and draws a numeric keypad.
(4) Manually operates the INTERCOM CONTROL to establish voice communication with each selected student station	

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Action	System Response
(5) Enters the lesson number 3.1.1.7 on the touch-panel keypad	(a) The system loads the appropriate microfiche cassettes into each of the selected stations.
	(b) As each student involved in the lecture logs on, the plasma displays: PLEASE PUT ON YOUR HEADSET, TURN TO LESSON 3.1.1.7 IN WORKBOOK 3.1, AND WAIT FOR THE LECTURE TO BEGIN.
	(c) When all students are logged in, a PROCEED message is displayed at the instructor's plasma.
(6) Presses the PROCEED function key on the touchpanel	(a) The first preprogrammed microfiche slide appears simultaneously at the instructor station and at selected student stations.
	(b) Various function keys are displayed on the instructor's plasma.

To conduct the lecture/demonstration, the instructor now verbally lectures his students. To advance the microfiche slides he presses the FWD function key on his touchpanel. If he wants to highlight a specific feature on a slide he would address it verbally while he:

(1) Adjusts the joystick at the instructor console until a cursor on the plasma display overlays the feature	(a) A cursor appears on all student plasma displays, coinciding with the position of the instructor's cursor.

Action	System Response
After the lecture, each student is instructed by the instructor to proceed with his lesson.	
Seaman Doe completes his initial set-up and begins the lesson. Step 4 of the measurement procedure requires Doe to set up test equipment. The oscilloscope and RF signal generator are represented in the simulated test equipment rack and function in a realistic manner. Less common test equipments are represented on the generic test equipment and used in conjunction with information presented on the plasma/microfiche. For example, to set up the electronic voltmeter in Step 5a of the measurement task, Doe:	
(1) Presses the TEST EQUIPMENT function switch at his console	(a) The plasma displays a menu of available test equipment and draws function keys for selecting particular devices(s).
(2) Presses ELECTRONIC VOLTMETER on the touchpanel.	(a) A microfiche slide of the electronic multimeter is rear projected on the plasma display. All controls/displays are labeled with a code corresponding to the controls/displays on the generic test equipment front panel.

Action	System Response
(3) Connects cables from the simulated "electronic voltmeter" (the generic test equipment) across the input resistor of the limiter stage inside the generic equipment subassembly drawer.	(a) An appropriate reading on the voltmeter is displayed. (b) Settings on the generic controls are indicated as plasma overlays on the microfiche slide display.
(4) Increases signal generator input gradually	(a) Corresponding rise in the voltmeter reading is displayed.
. . .	. . .

At the end of the lab session, the instructor wishes to receive a hard copy printout of the performance of each student during the lab. To accomplish this he:

(1) Presses the FUNCTION function switch at his console	(a) The function menu is displayed.
(2) Presses PERFORMANCE REPORT BY STUDENT on the touchpanel	
(3) Presses the HARD COPY function switch at his console.	(a) A performance report for each trainee is printed on the line printer.

VII. CONCLUSIONS

This report describes one alternative conceptual design for the EEMT System which satisfies all the system requirements and boundaries as set forth in the Conceptual Design for an EEMT Simulator--Common Military Characteristics (Honeywell Report F2210-4.1). It is a hybrid 2-D/3-D instructional delivery system designed to support all the terminal objectives in the EEMT curriculum (Training Requirements Analysis Report, Honeywell Report F2210-2).

The primary assumptions on which Design B is based are extensive expansion capability and versatility. Characteristics of the design that attest to its capability for high-quality and cost-effective electronic maintenance training are outlined below:

1. Maximum fidelity and completeness of 3-D hands-on training by virture of modular, interchangeable, and representative generic equipment subassemblies,

2. Maximum expansion capability for 3-D training; new-technology simulated equipment subassemblies can be easily added to the system,

3. Maximum efficiency of 3-D training since no unused simulated equipment is tied up at the student stations,

4. Maximum flexibility, high resolution, and reliability inherent in the microfiche projection plus plasma touchpanel display,

5. Capability for easy expansion of software by virture of distributed processing capability with centralized mass storage,

6. Efficient mix among instructor control, automation, and flexibility due to extensive instructor capabilities at a centralized facility.

DESIGN C

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CONCEPTUAL DESIGN FOR AN EEMT SIMULATOR

I. INTRODUCTION

A. Purpose

This report describes Alternative Conceptual Design C, one of three Honeywell designs for a generic EEMT system. The alternative design meets all the necessary training requirements determined from the previous analyses. This report will describe the design by presenting information in the following categories:

- o Basic Assumptions
- o System Overview and Configuration
- o Student Station
- o Instructor Station
- o Scenario
- o Conclusions

B. Basic Assumptions

Certain basic assumptions were made prior to the formation of a concept for this design. These assumptions served to guide the design process and set an overall philosophy for the device. The basic assumptions for Design C are as follows:

- o Maximize the "hands-on" training requirement stated in NDCP and advocted by the ET and EW Schools.

- Design a hybrid 2-D/3-D trainer.

- Meet the fidelity requirements specified in the Fidelity Requirements Analysis Report.

- Provide simulation necessary to meet the objectives and generalities specified in the Training Requirements Analysis Report.

- Meet a deficiency of test equipment usage in performance of test, measurement, and trouble-shooting tasks.

- Attempt an application of SOA technology for '80-'81 prototype design and fabrication.

- Synthesize a design not constrained to 50K re-occurring production cost.

- Develop the most capable generic trainer that would reasonably be required.

- Consider trainer functions likely to be considered for applications beyond current electronics focus.

II. SYSTEM OVERVIEW

A. System Configuration

The system configuration for Design C provides for a multi-student single instructor arrangement as shown in Figure C-1. This arrangement allows for a 20:1 student-to-instructor ratio. A single instructor station is strategically centered among the 20 student stations. Four clusters are formed by arranging five student stations into a pentagon configuration. The pentagon configuration permits the optimum arrangement for each student station in terms of overall form factor and provides for adequate student isolation. Isolation partitions aid in the reduction of noise and visual distractions. The clustering also offers possibilities for consorted or centralized data and display processing.

Each pentagon cluster approaches 20 feet across. A dimension for four clusters and an instructor station, therefore, requires a room size of 2500 sq.ft. with dimensions of 50' x 50'.

B. Stations

Student Station. The 20 student stations in Design C are identical. A single student station has a wrap-around, flattened-U design providing three interfaces to the student. The three interfaces conveniently present simulated equipment, simulated test equipment, and an interactive display, all necessary for training a curriculum oriented toward training tests, measures, and troubleshooting tasks.

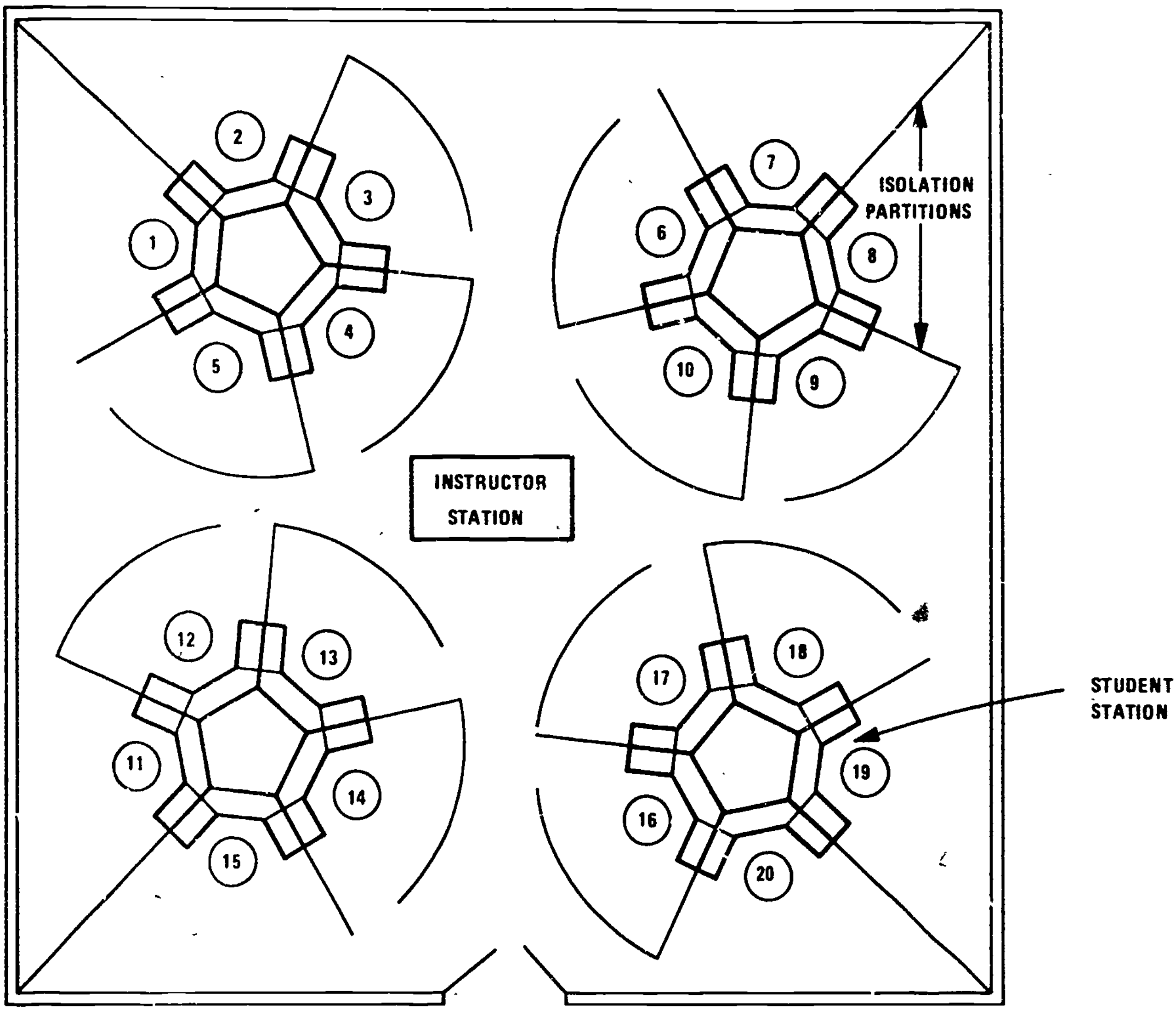

FIGURE C-1. EEMT SYSTEM CONCEPTUAL DESIGN C - POTENTIAL CLASSROOM CONFIGURATION

Instructor Station. A single instructor station and master computer controls and monitors the EEMT system of 20 student stations. The central location not only allows for a minimum access distant to each student station, but also keeps the data paths equal in length to minimize timing anomalies.

III. STUDENT STATION

The EEMT student station incorporates a hybrid 2-D/3-D simulation capability. High fidelity simulated test equipment front panels and simulated equipment in pull-out drawers provide "hands-on" training while an interactive 2-D display provides needed CAI messsages, graphic images, and a function keyboard and force stick allows student responses and inputs.

The wrap-around or flattened U arrangement as shown in Figure C-2 allows the student easy access to the interactive display and simulated equipment and test equipment. The desk-level shelf allows the student to read and follow his T.O. or other appropriate lesson guide placed before him. The drawers below the shelf provide for the storage of the appropriate lesson materials, tools, test equipment probes, leads, cables, and connectors, as well as any simulated equipment and test equipment not mounted in the flat panels or racks above.

A. Simulated Test Equipment

Simulated test equipment front panels are mounted in a flat panel directly facing the student, as shown in Figure C-2. The switches, controls, meters, and displays are functionally simulated. The test equipment allows the student to perform tests, measures and troubleshooting on the simulated equipment.

The appropriate simulated leads, probes, and cables may be selected by the student from the cabinet below the shelf and physically plugged into jacks provided in the front panels of the test equipment. The computer will monitor that the appropriate connections have been made and that the proper cables

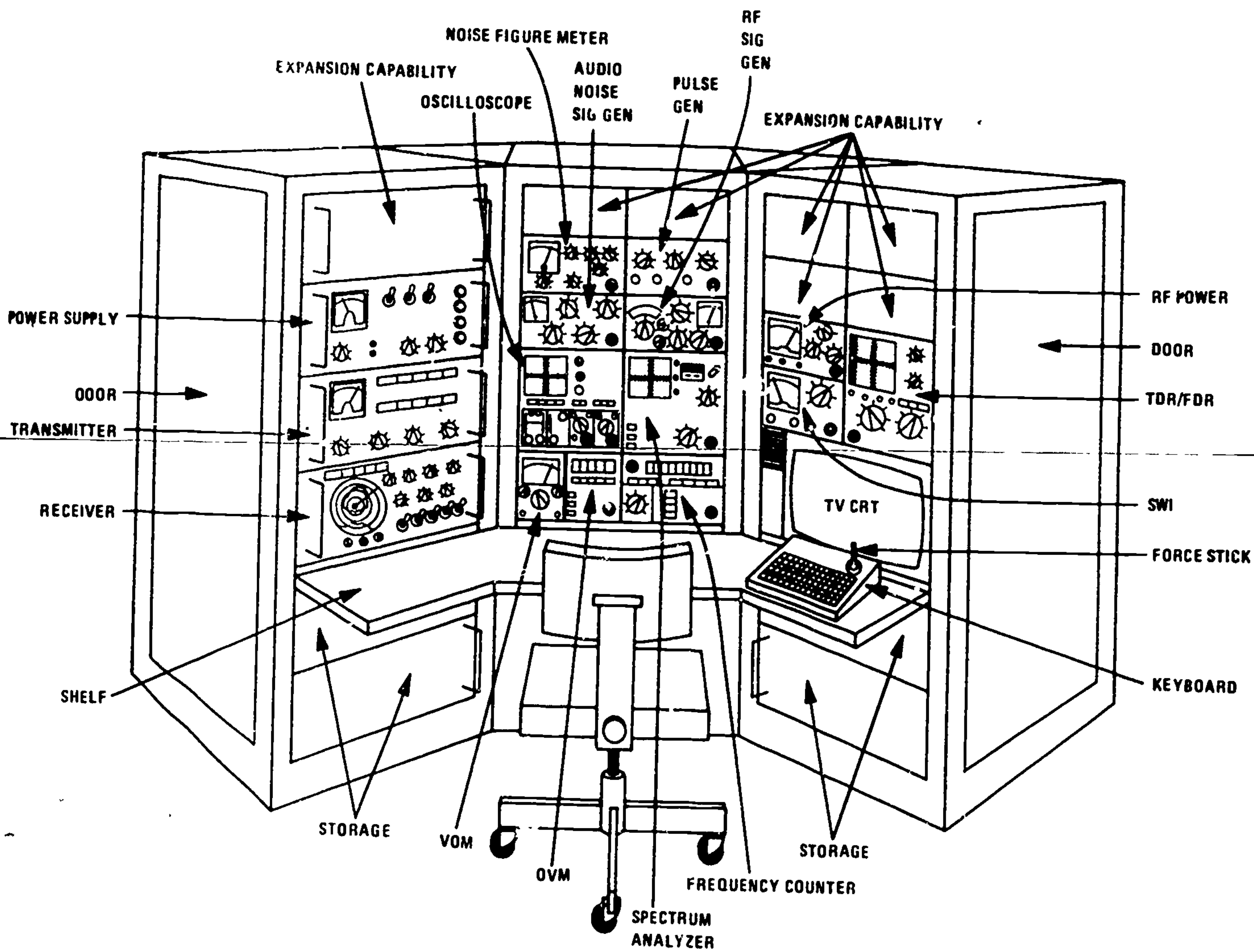

FIGURE C-2. EEMT SYSTEM CONCEPTUAL DESIGN C - STUDENT STATION have been selected. The test equipment will respond appropriately when the leads or probes are placed at designated test points in the equipment. A scenario later in this report describes how the test equipment connections might be made to accomplish a specific task within a lesson.

The 12 test equipments defined to perform the training tasks are listed in Table C-1. Some of the similar test equipments are combined in order to create a representative or generic test equipment. For example, a Multiple Function Signal Generator combines capabilities of AM, CW, FM, RF sweep and Pulsed RF Signal Generators over the frequency ranges required to perform the training tasks.

The simulated front panels of the test equipment most frequently used (e.g., VOM, oscilloscope) are mounted adjacent to the simulated equipment for more favorable accessability by the student. Expansion capability exists on the flat panel surface of the center and right racks for the addition of needed future test equipments.

The display of the oscilloscope, spectrum analyzer, and TDR/FDR will present the simulated waveforms by means of separate CRTs. The standard raster scan video monitor (512 lines) should provide adequate resolution for the presentation of waveforms. Figure C-3 shows an example of the front panel simulated oscilloscope.

Certain additional items are needed by the student to accomplish the maintenance tasks. These items, shown in Table C-2, include simulated modular test equipment and other devices, simulated probes, cables, adapters, and tools. These items, stored in the drawers below the shelf, can be retrieved

Table C-1

SIMULATED TEST EQUIPMENT

Similated Test Equipment	Capabilities Represented	Task Frequency[1]
VOM	Voltmeter Ammeter Microammeter	8
Oscilloscope	Oscilloscope	18
DVM	Digital Voltmeter Electronic Multimeter	9
Multiple Function Signal Generator	AM, FM, CW, RF Sweep and Pulsed RF Signal Generators over all frequency ranges	15
Pulse Generator	Pulse Generator	2
Noise/Audio Generator	Noise Generator Audio Generator	2
Frequency Counter	Frequency Counter	8
RF Power Meter	Through-Line Wattmeter Bolometer Wattmeter Power Meter RF Power Meter	7
Spectrum Analyzer	Spectrum Analyzer	1
TDR/FDR	TDR/FDR	1
SWI	SWI	1
Logic Analyzer	Future	?

[1]The task frequency does not include the use of the test equipment for fault analysis.

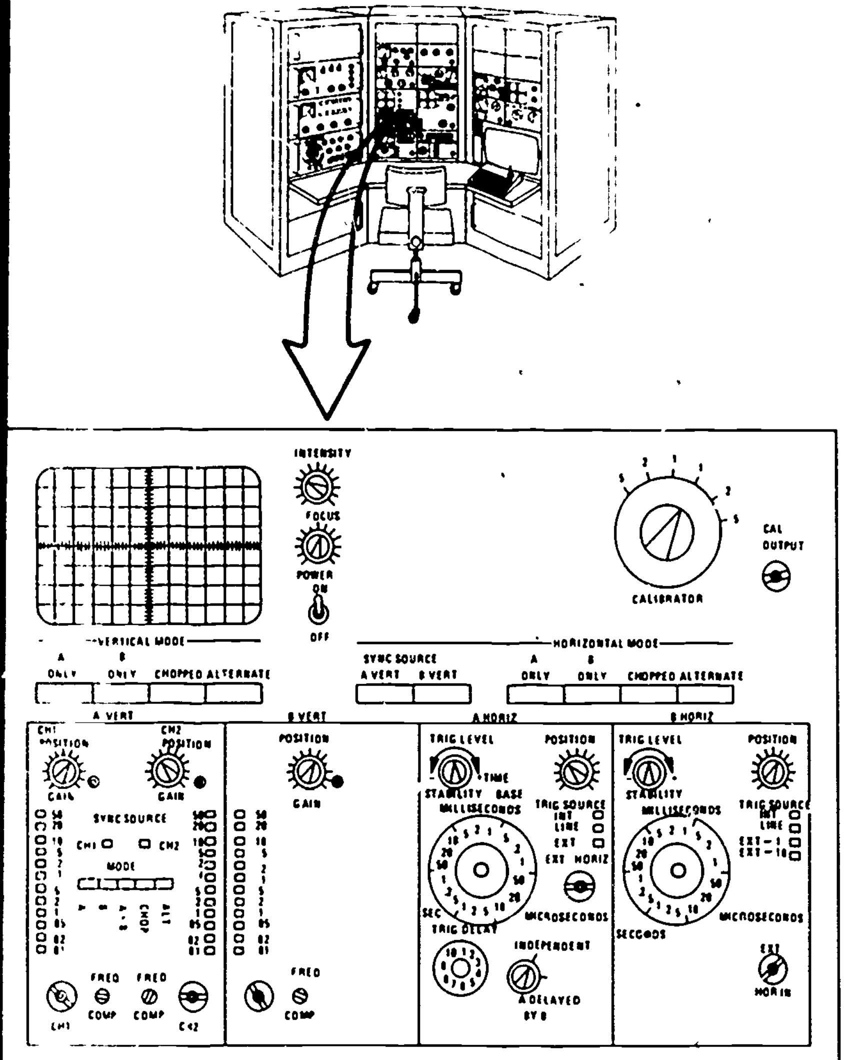

FIGURE C-3. EEMT SYSTEM CONCEPTUAL DESIGN C
- SIMULATED OSCILLOSCOPE

Table C-2

ADDITIONAL STORED ITEMS

Simulated Modular Test Equipment and Other Devices	Simulated Probes, Cables and Adapters	Tools
Octopus	Oscilloscope Probes	Common Hand Tools
Synchro Test Set	Logic Probes	Tuning Tool
Fixed Attenuator	Adapters	Alignment Tool
Attenuator	Test Adapters	Tuning Wand
Loading Resistor	Test Cables	Steel Ruler
Impedence Matching Device (Dummy Antenna)	Test Leads	Grounding Stake
	Detector (Mount)	
	Demodulator Probes	
	Detector Probe	
	Bolometer Probe	
	Cables	
	Shorting Probe	
	Loop Coupler	

by the student when needed. A simulated wall socket of the student station provides for plug-in of the octopus and synchro test set.

B. Simulated Generic Electronic Equipment

Simulated generic electronic equipment front panels and pull-out drawers are mounted in the rack adjacent to the simulated test equipment to the left of the student as previouly illustrated in Figure C-2. The 3-D equipment provides "hands-on" training and allows the student to perform tests, measures, alignments, adjustments, and troubleshooting on simulated equipment.

The front panels of a generic receiver transmitter, and power supply will be contained on the front of three respective pull-out drawers of the rack. The switches, controls, meters, and indicators are functionally simulated to allow the student to set-up, turn-on, and vary the switches and controls in performance of a maintenance task. The appropriate cable connectors and jacks are present to allow physical cabling of the equipment and test equipment.

The pull-out drawers expose visually simulated 3-D subassemblies, circuits, and cards in order to allow the student access to internal components. A select number of functionally simulated test points are provided. Figure C-4 shows an example of the contents of the transmitter drawer. The transmitter shown contains three ages of technology--vacuum tubes, solid state (diode/transistor logic) and integrated circuits--in order to provide those three necessary areas of maintenance training. Cards containing integrated circuits are most frequent within the drawer in order to allow the greatest emphasis of maintenance training on newer digital equipment. The drawer also presents electronic packaging in three common ways--strap-down, module and circuit cards--in order to give the student exposure to maintenance on each type.

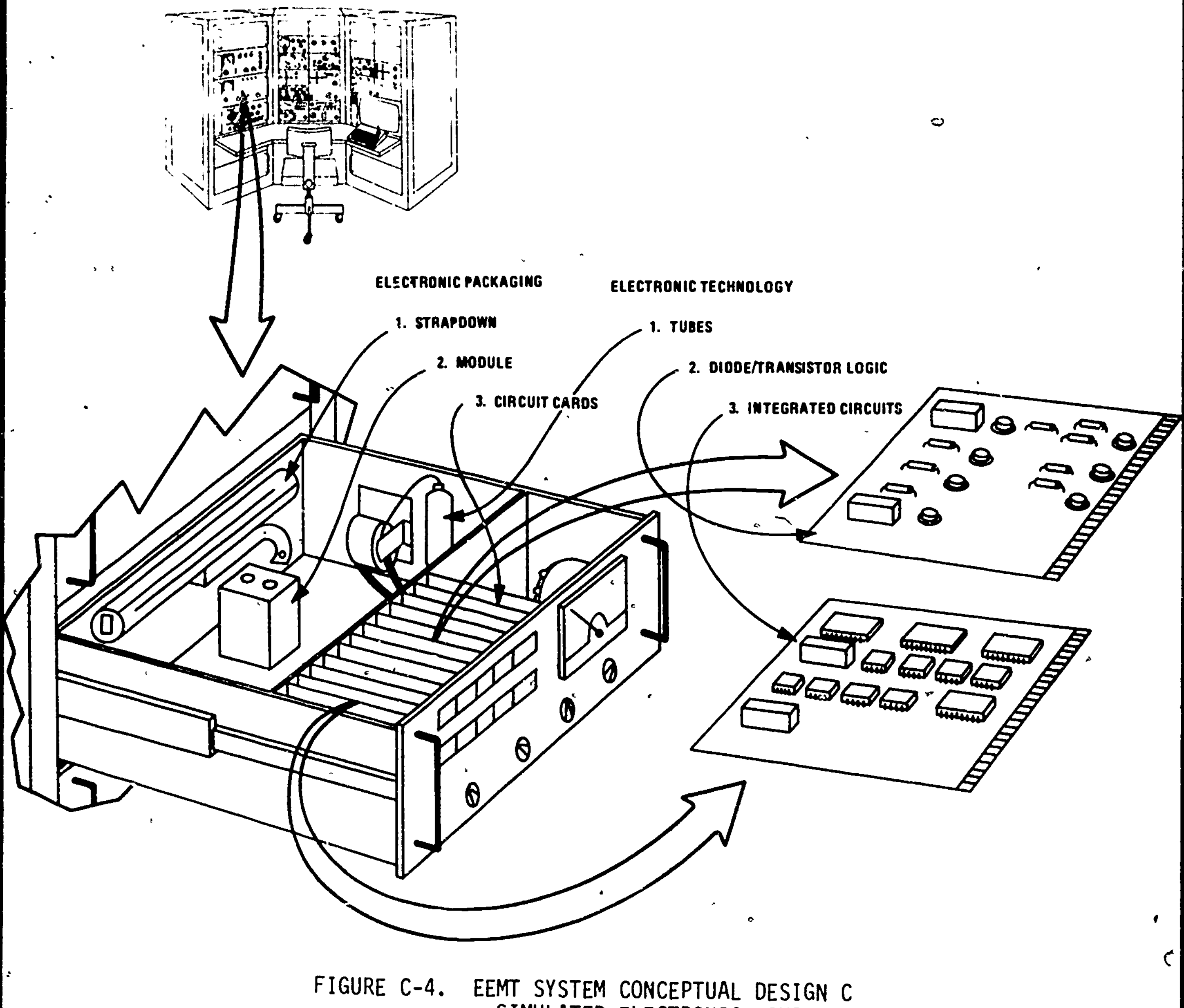

FIGURE C-4. EEMT SYSTEM CONCEPTUAL DESIGN C
- SIMULATED ELECTRONIC EQUIPMENT

The 3-D mockup receiver, transmitter, and power supply, along with the previously described test equipment, allow the student to accomplish respectively the receiver, transmitter, and power supply tasks defined in the training requirements analysis. Antenna tasks are accomplished by including a simulated waveguide and RF transmission line in the back of the transmitter drawer. Digital maintenance tasks are accomplished by the inclusion of digital circuitry within each of the three equipment drawers. Expansion capability exists in the upper pull-out drawer for the addition of future generic simulated electronic equipment.

The probable contents of the three equipment drawers are listed in Table C-3. These contents, either visually or functionally simulated as defined by the Fidelity Requirements Analysis, allow the student to perform most of the common (ET and EW) tasks in a "hands-on" manner.

Table C-3

Probable Contents of Simulated Equipment Drawers

Receiver Drawer
RF Amplifier • HF Trimmer Capacitor • Oscillator Coil
IF Amplifier • IF Trimmer Capacitor • IF Tuning Coil • IF Tuning Slugs
Limiter • Input Resistor
BFO • Inductor
Card for Range Strobe Generator and Range Rings Oscillator • Potentiometer for Adjustment
Digital Processor • Random Logic • ROM
Test Points Necessary to Support Designated Tasks

Table C-3

Probable Contents of Simulated Equipment Drawers (continued)

Transmitter Drawer
RF Amplifier ● Tuning Slugs Master Oscillator ● Adjustable Reactor Frequency Multiplier ● BITE Meter ● Electronic Meter Waveguide ● Slotted Line RF Transmission Line ● Cable Adapters Antenna Synchro Assembly ● Synchro Null Adjustment Modulator ● Terminal Board Output Tank Circuit ● Adjustable Reactor Digital Processor ● Random Logic ● ROM Test Points Necessary to Support Designated Tasks

Table C-3

Probable Contents of Simulated Equipment Drawers (concluded)

Power Supply Drawer
Printed Circuit Cards
Strapdown Regulator Module
Transformer
Inductor
Digital Processor • Random Logic • ROM
Test Points Necessary to Support Designated Tasks

C. Interactive 2-D Display

The interactive 2-D display presents all CAI messages and graphic drawings. A force stick and function keyboard allow for a variety of student inputs. While the majority of the student's actions will occur "hands-on" with the simulated equipment and test equipment, a means to guide the student's action demands CAI messages and other types of information. Any portions of lessons which cannot be accomplished with the 3-D simulated equipment and the simulated test equipment will be accomplished via the interactive 2-D display.

TV CRT. The 2-D display is provided by a raster scan CRT. Single frame or video information is displayed via mass storage from the master computer which accesses the information from mass memory. Information to be displayed on the 2-D display includes the following:

- Block diagrams
- Schematics
- Equipment/test equipment graphic images
- Alphanumerics
- CAI messages
- Graphics
- BITE information (for task performance)
- PPI scope
- Student keyboard entries

The CAI messages always appear in the upper left hand corner of the display. A tone generator provides a tone to alert the student that a new message (CAI) and/or new alpha-numeric information has been flashed onto the display. A repeating tone also sounds in instances where the student has made a critical error. The student keyboard entries appear in the bottom left hand corner of the display.

Force Stick. The force stick provides a reliable means for the student to indicate points on schematics, block diagrams, and other graphic images on the 2-D display.

A crosshair cursor slues with force stick movement as an indication to the student of the force stick position. A button on the top of the force stick allows for coordinate entry. The 2-D display is interactive in the sense that the computer system responds appropriately with force stick entry.

Keyboard. A keyboard located beneath the display handles a variety of student entry functions with an ease and versatility needed for accomplishing a lesson. The keyboard provides for:

- Student sign-on
- Test question response
- Identification of faulty unit
- Entering determined measurement values of voltage, current, power, and resistance
  - polarity
  - magnitude
  - units

- o Entering other values
- o Student indication of "READY" signal to system

Intercom. The intercom at the student station is a means for student-instructor dialogue. A headset with microphone is provided along with a volume control/off switch. An intercom speaker is provided at the student station. The intercom may also be used independent of the headset and microphone.

Help Call. A help call switch is provided at the student station in order to allow the student to call the instructor when help is needed.

Figure C-5 presents the functional block diagram of the student station. Two processors are required at the student station. A display processor controls the TV CRTs of the interative displays and three test equipment displays with data flow from mass memory of a master computer at the instructor station. Another processor is the focus for the simulated electronic equipment and various test equipment also with a data bus from the master computer at the instructor station.

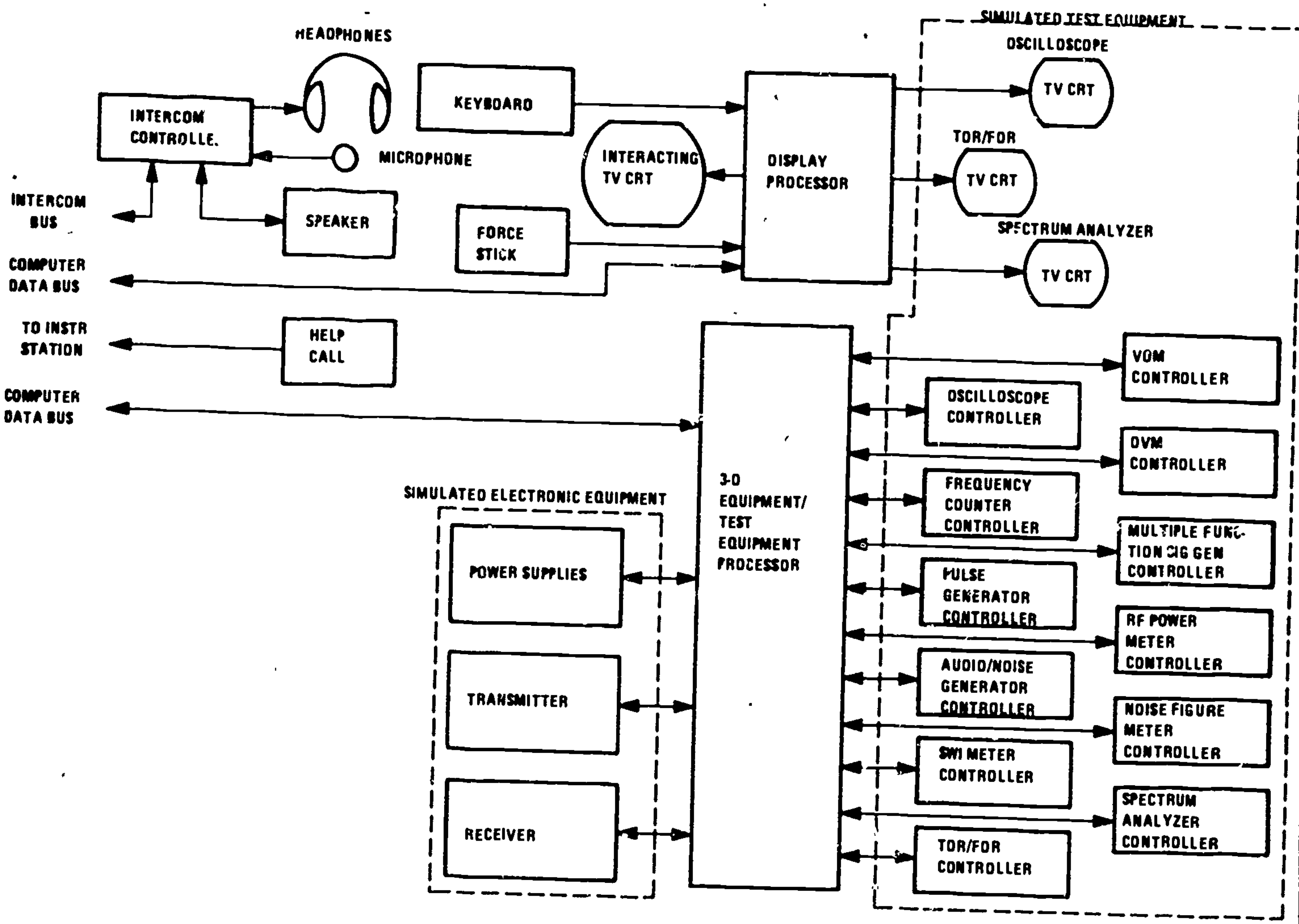

FIGURE C-5. EEMT SYSTEM CONCEPTUAL DESIGN C - STUDENT STATION FUNCTIONAL BLOCK DESIGN

IV. INSTRUCTOR STATION

The instructor station is designed as a distinct, stand-alone configuration strategically centered among the twenty student stations. The station, shown in Figure C-6, both houses the master computer, mass storage media, mass storage media controller, power distribution unit, and display processor and also provides automated controlling, monitoring and instructing capabilities through the keyboard, two CRT displays, force stick, hardcopy output and intercom. Locking cabinets below the shelf provide storage for system operation, diagnostic and instructional material as well as for the library of mass storage media devices.

A. Display System

The display system provides the instructor with a flexible means to monitor student performance and provide any needed instruction. The display system consists of two raster scan CRTs, a 96 character alphanumeric keyboard, a force stick and a hardcopy output. The display capabilities of the two CRTs are interchangable in case of a single CRT malfunction. The display system provides the means to perform the following functions:

1. Perform morning readiness tests
2. Author required lessons
3. Edit, combine, or string required lessons
4. Add to or edit data base
5. Display either student or class performance
6. Provide the means to initialize either the class or a single or group of students

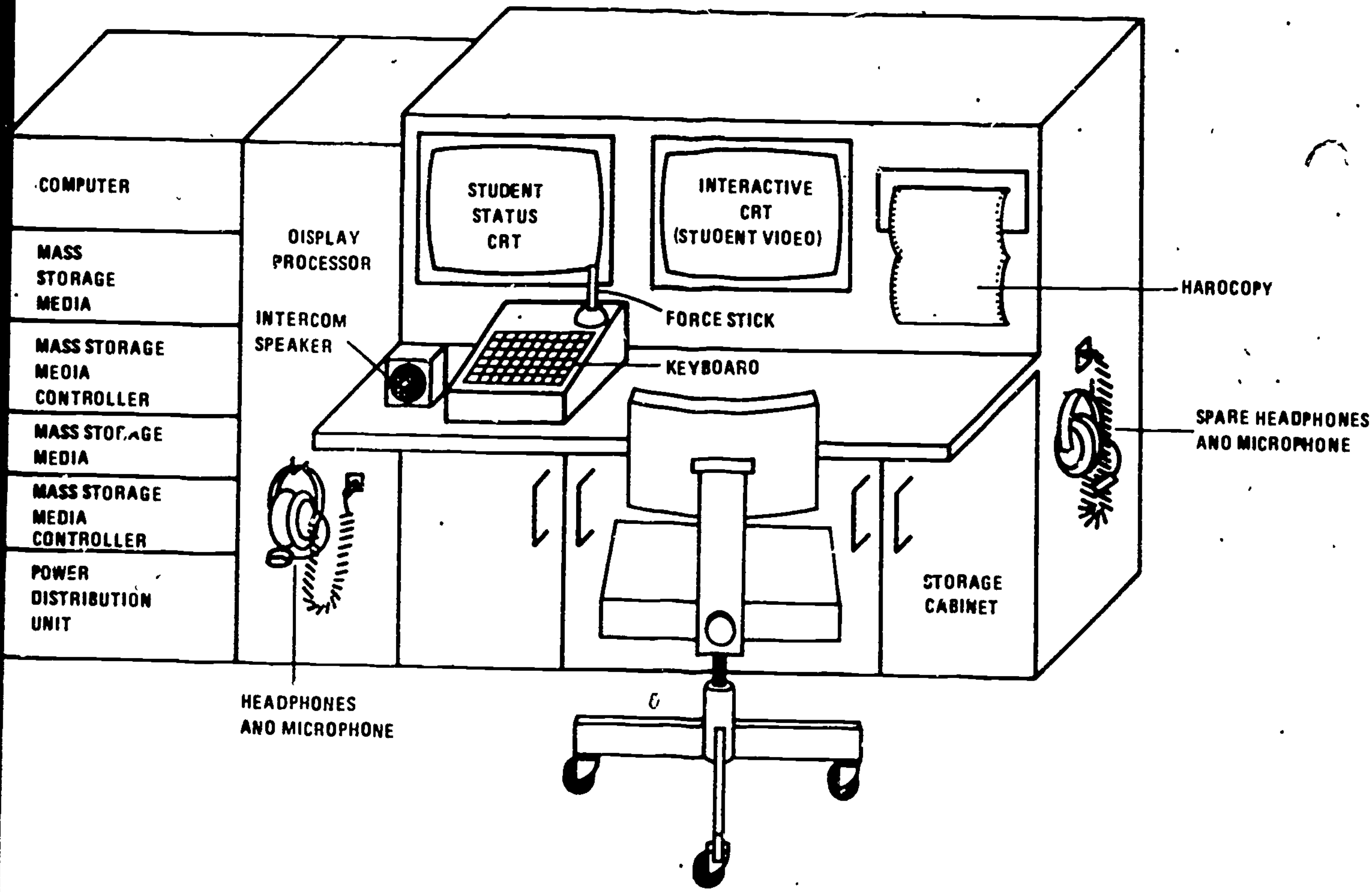

FIGURE C-6. EEMT SYSTEM CONCEPTUAL DESIGN C - INSTRUCTOR STATION

7. Enable any required intercom channels

Student Status CRT. The student status CRT displays both student status information and other more general information necessary for interactions with the EEMT system. The student status information allows the instructor to track classroom performance during a classroom training session. Summarized status data of either the class or individual students are readily available. This information includes:

- Student action summaries
- Student error summaries
- Student aiding level
- Student branching status
- Student safety violations and critical errors

In addition, other system information is displayed on this CRT in order to allow interaction with and operation of the EEMT system. This information includes:

- System initialization information
- Interactive computer messages
- Keyboard entry display field
- System diagnostic information
- BITE display
- Lesson selection menus
- Malfunction selection menus

Interactive CRT. The interactive CRT allows the instructor to monitor the video display of any single student station. The instructor cursor appears on this display and is controlled by the force stick. The instructor cursor is repeated at the designated student station(s) and may be used for pointing out areas on the designated student display(s) either as an aid to a single student or in a classroom demonstration mode.

B. Intercom System

The intercom system consists of a headset, microphone, speaker, intercom controller and the required intercom audio circuits for duplex operation between the instructor and the class, student group or individual student. The intercom system may be used with or without the headset and microphone for communication to any or all of the student stations. Selection of the audio channel is made via the keyboard. The tone generator at the instructor station gives an auditory signal when a student requests help. The instructor can identify the student through a flashing student number on the display.

C. Hardcopy

A hardcopy located to the right of the displays gives the instructor a portable record of necessary events upon request. Hardcopy printout information includes:

- Class performance data
- Single student performance data
- Past schedule information
- Assessment and Test Score Data
- Trainer Diagnostic and BITE information

D. Master Computer System

The master computer system provides capability for controlling the entire EEMT system as shown by Figure C-7. The student monitoring function is performed by means of the requisite program modules and a magnetic media storage device. The training system program (TSP) is loaded from mass storage magnetic media into the master computer real memory for control and manipulation. This loading is performed by means of a boot routine within the master computer controller. Each TSP contains the operating system program (OSP), morning readiness program (MRP), task type training program (TTTP), task type data base (TTD), student monitor program (SMP), and various utility programs.

The real memory section of the master computer system contains sufficient expansion capacity to permit a 50% growth based upon a plug-in concept. The total TTD is not resident within real memory but only that module or modules presently in use. This technique of virtual memory keeps core size manageable while permitting the greatest flexibility in data base manipulation.

The TTD provides all the routines, simulation programs, data point images, student monitors, and teachware algorithms peculiar to a task media selected for instruction. These task media selections are:

- o receiver systems
- o transmitter systems
- o antenna systems
- o power supply systems

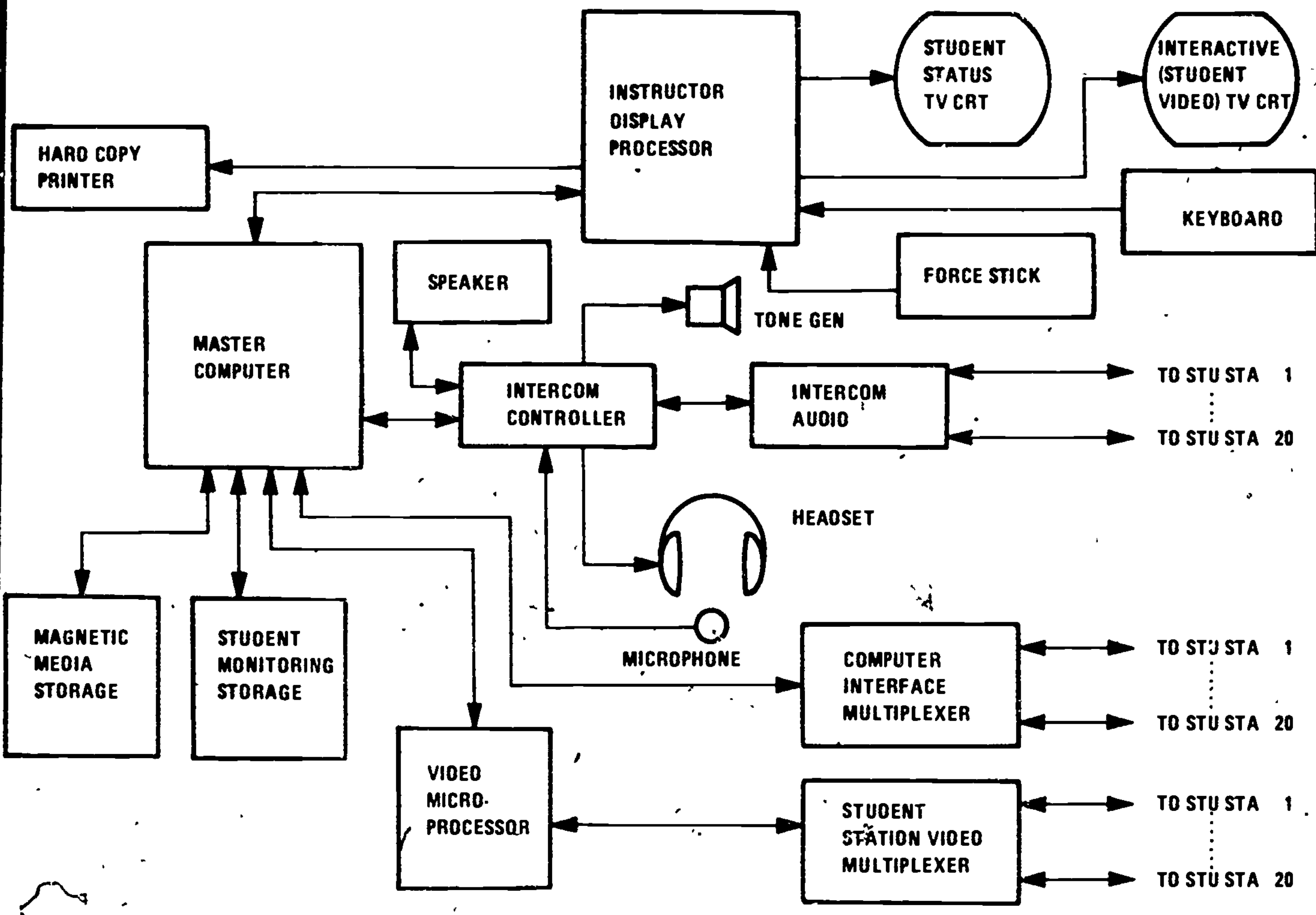

FIGURE C-7. EEMT SYSTEM CONCEPTUAL DESIGN C - INSTRUCTOR STATION FUNCTIONAL BLOCK DIAGRAM

- control/monitor systems
- digital processor systems

The TTD is made available to each of 20 student stations through a duplex data handling system implemented by means of the master computer controller, master computer memory, and computer interface multiplexer. This TTD transfer is controlled by means of an interrupt protocol and is of sufficient speed to keep all required data transfers in quasi real-time. The return data for duplex operation consists of student summary data which is logged in magnetic media for student monitoring.

E. System Diagnostics and BITE

The design of system provides the requisite hierarchy for selectable on-line testing, morning readiness tests and diagnostic tests. The degree of test intensity is directly related to the test mission and anticipated system faults.

On-line Tests. The on-line testing for BITE provides a means to scan all major system functions within some interval of time. This test is cyclical in nature on a not-to-interfere basis with the training mission or activity. A summary display status can be presented to the instructor for risk assessment. Only fatal faults are considered sufficient to stop training--those involved with functions necessary for that specific lesson. These faults are logged with the student performance monitoring information for later identification and permanent record.

Morning Readiness Test. The morning readiness test can be enabled automatically during start up or it can be initiated upon an instructor request. This morning readiness test is a test which forces the display system to exercise all display generation functions, perform display processor to master computer memory readback tests, verify reset states on all simulated test equipment and 3-D equipment, perform 3D and test equipment processor memory readback tests and other abbreviated visual and manual tests requiring interaction at each individual student station.

Diagnostic Tests. The ability to perform diagnostic tests are enabled whenever corrective maintenance requires intense stimulation of specific system functions. These tests consist of the same basic modules of the morning readiness test and online tests but are more ambitious and intense in nature.

V. SCENARIO

The following scenario describes how training for the EEMT simulator might commence, beginning with an instructor initialization of the system leading up to the lesson and malfunction selection. The scenario continues at the student station with the student performing the selected lesson of Receiver MDS. Finally, the scenario once again focuses on the instructor station where the instructor is monitoring the students' performance and aiding a student who is having difficulty in performing the lesson.

A. Instructor Initialization of System and Lesson Set-Up.

- Instructor enters training room to initial the system for the day's training session on Receiver MDS
- Instructor turns on system power
- Instructor selects appropriate training system operational program
- Instructor loads the operational program
- Instructor logs class data
- The instructor selects from his modes of DEMO, TEST, INSTRUCT, and REPEAT
- Instructor selects INSTRUCT mode through keyboard entry
- Instructor receives a student status CRT a menu of EEMT lessons
- Instructor selects lesson on Receiver MDS and makes keyboard entry
- Instructor receives on student status CRT a menu of possible malfunctions

- Instructor selects symptom -- MDS too low
- Instructor selects faulty component -- IF Amplifier
- Instructor selects CAI parameters
  - Aiding level
  - Action limits
  - Time allotted
- Students arrive. Instructor assigns them to student station and directs them to begin lesson

B. Training Lesson at Student Station

- Student ID (Log-in) via keyboard
- CRT message given for unit and T.O./Lesson Guide selection. "TODAY'S LESSON IS RECEIVER MDS. BEGIN BY ..."
- Student obtains T.O./Lesson Guide from storage drawer
- CRT message given for lesson introduction
- Student directed to set-up 3-D receiver front panel and test equipment front panel controls
- Student sets simulated receiver controls
- Student sets simulated test equipment controls
- Student enters READY on keyboard
- Student directed to select appropriate cables from storage drawer

- Student selects appropriate cables and physically cables equipment and test equipment by inserting simulated cables into simulated test jacks
- Student receives feedback and aiding as appropriate
- Student adjusts controls for MDS determination
- Student calculates MDS and enters MDS calculation value on keyboard
- Student compares value he obtained to the acceptable value in his T.O./Lesson Guide.
- Student dicovers that MDS value he determined is low in comparison to acceptable value
- Student presses function key FI to indicate he wishes to fault isolate the receiver
- Student given block diagram of receiver to allow him to consider troubleshooting measures he might take
- Student decides to check waveforms at various points in the receiver using an oscilloscope
- Student uses oscilloscope to make waveform measurements by inserting probes at various test points in the simulated equipment
- Student makes waveform measurement at IF Amplifier
- Student finds too much noise and MDS signal which is too low in amplitude

- Student identifies through keyboard the faulty unit he wants to replace- IF Amplifier
- Student rechecks system by again performing test of Receiver MDS
- Student determines MDS value, finds his value agrees with accepted value
- Student has completed Receiver MDS lesson
- Feedback on student's performance given on CRT
- Student returns simulated equipment and test equipment at student station to proper condition, disassembles the set-up and stores all cables and documents

C. Instructor Monitoring and Aiding

- Instructor is at the student station monitoring students actions on student status CRT
- Instructor hears tone of student call for help
- Instructor views on student status CRT flashing student number of student requesting help
- Instructor talks to student on intercom to determine area of difficulty
- Instructor talks student through problem or uses repeated instructor cursor to point out areas of difficulty on student's graphic display

- Instructor traces back through the steps leading to the problem and sets a REPEAT mode for student
- Instructor goes into DEMO mode in order to present subroutine of remedial loop

VI. CONCLUSIONS

Design C, through its unique configuration and design features, offers many distinct advantages. These advantages may be discussed in terms of the overall classroom configuration, the student and instructor station designs, and the decision for a centralized master computer.

A. Overall Classroom Configuration

Design C presents a classroom configuration with twenty student stations grouped into four clusters around the instructor station. Five student stations comprise a cluster creating a pentagon configuration. The layout of this arrangement offers these advantages:

- The central location for the master computer allows for a minimum access distance to each student station and provides data paths equal in length to minimize timing anomalies.
- The student clustering arrangement offers potentials for consorted or centralized data and display processing.
- The pentagon configuration permits optimum arrangement for each student station in terms of overall form factor and provides for adequate student isolation.
- Isolation partitions between student stations reduce noise and visual distraction.

B. Student Station Design

The student station design meets the needed student interaction with simulated test equipment, simulated generic equipment and an interactive display The design handles all defined training requirements with a self-contained station. The student station design provides these advantages:

- o Identical, fully-contained student stations meet the "worst-case" requirement, i.e., a lock step curriculum with all students working on the same lesson at the same time.
- o The wrap-around, flattened-U design of the student station allows for easy access to the simulated equipment, test equipment, and interactive display.
- o The design provides "hands-on" training in a highly realistic manner.
- o Primary student focus is placed on use of the high fidelity test equipment to perform tests, measures and trouble shooting or the simulated drawers of generic equipment.
- o The self-contained, permanent simulated equipment drawers eliminate reliability problems associated with large number of plug-in unprotected modules.
- o Flat panel presentation of front panels of test equipment simplifies hardware design.
- o Below the shelf drawers provide storage for additionally needed items, e.g., T.O.s, lesson guides, simulated probes and cables, tools, etc.
- o Expansion capability is available for additional or future equipments and test equipments.

- The force stick provides a reliable means for interaction with the 2-D display.
- The computer-controlled video display provides a high flexibility means for accessing and displaying graphic and waveform information.
- The computer-controlled video display provides the means for repeatable image registration.

C. Instructor Station and Centralized Master Computer Design

The instructor station design meets a primary requirement for instructional control and student monitoring. The instructor is aided in his task by two displays, an alphanumeric keyboard for communication to the system, an instructor force stick-controlled cursor and intercom for communication to the student and a hardcopy printout of certain necessary information. The centralized master computer coordinates the activity of the twenty student stations. The instructor station design offers these advantages:

- The instructor display system allows the instructor to achieve student monitoring and aiding for all twenty student stations from a single location.
- Dual purpose displays permit for the simultaneous occurence of single student aiding activity and an ongoing updated student status display.
- Interchangeable displays provide increased training reliability.
- Courseware and software authoring and editing as well as waveform modification can be achieved at the single instructor station.

- The instructor cursor repeated at designated student station(s) can be used for pointing out areas on student display(s).

In addition, the centralized master computer

- Provides inherent centralized training control
- Provides cost saving through time sharing to student stations
- Provides a more simplified software and computer architecture
- Allows for continuous accumulation of student performance monitoring data base
- Provides a high degree of automation for system diagnostics
- Enhances BITE features

DESIGN D

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1.0 INTRODUCTION

1.1 Objective

To present one possible design concept for the Electronic Equipment Maintenance Trainer (EEMT) at a level of detail sufficient to convey completely the training context and objectives, intended applications, equipment features and capabilities, support requirements, and cost targets.

1.2 General Requirement

The general requirement is for a training device that will provide self-paced, adaptive instruction in all tasks required to maintain Naval electronic systems and equipment, to bridge the gap between electronic theory and practice of electronics maintenance.

1.3 General Approach

The approach taken is to combine an expanded Rigney System with generalized adjunctive simulation hardware that is equipment family specific, i.e., radar.

1.4 Initial Development

The initial implementation of EEMT will be in the domain of ET-EW enlisted rate training to validate the design concept.

1.5 General Cost Target

The target of 50K per student station in quantity production is not exceeded by the design concept described herein. Initial estimates fall in the 35-40K region (Reference NDCP 20789-PN).

2.0 TRAINING OBJECTIVES

2.1 To provide individualized instruction and guided practice in the functional organization of individual families of Naval electronic equipment and systems.

2.2 Instruction in the purpose and operation of functional units, sections, sub-sections or other functional elements, as appropriate to each equipment family.

2.3 Instruction/practice in logical troubleshooting including the following specific task areas:

- Observation/isolation of symptom set
- Formulation of hypotheses
    - Interpret functional block diagrams
    - Interpret schematic diagrams
    - Use A-priori fault information

- Performance of diagnostic tests
  - Establish system states
  - Locate test points
  - Perform tests and measurements
  - Use test equipment
  - Use BITE, ATE or SATE
  - Use maintenance aids
- Verification of hypotheses or formulation of new hypotheses
- Repair/replacement of defective components/modules
- Performance of in-place adaptive corrections
- Verification of proper equipment operation
- Completion of maintenance documentation.

2.4 Instruction/practice in performing operational checks and adjustments, including alignment and calibration actions appropriate to the equipment family at issue.

2.5 Instruction/practice in the use of maintenance manuals and diagrams.

2.6 Instruction/practice in preventive maintenance procedures.

3.0 GROUND RULES AND ASSUMPTIONS

3.1 The feasibility and capability of the Rigney system technology has been established firmly. It is prudent to capitalize on proven technologies rather than develop new ones. It is highly desirable to incorporate the Rigney technology into EEMT but also to preserve a stand-alone capability for specific-equipment training, part-task maintenance training, and presentation of maintenance documentation.

3.2 Although the initial configuration of EEMT is for ET and EW enlisted rate training, it is essential to design EEMT for use with other rates, schools, and equipment families.

3.3 It is highly desirable to use the stand-alone portions of the system for training control, performance monitoring, fault insertion and other CAI/CMI features to lower costs and avoid redundancy, since these features are not equipment-family dependent.

3.4 Maintenance tasks will change significantly during the next ten years. EEMT must reflect both present and future technologies.

3.5 A minimum of four adjunctive equipments are required for ET/EW enlisted rate training serving the technologies of radar, communications and ECM/ESM. A possible fifth equipment is required for NAVAIDS.

3.6 Functional packaging is essential to mediate transfer of training and performance.

3.7 Actual test equipment rather than simulated test equipment should be used since it is available at the schools, since established calibration facilities are required in any event, since trainees must become familiar with test equipment calibration requirements, set-ups and error sources, and since it is not cost-effective or practical to simulate any but the most common (and simple) items of test equipment.

3.8 The key mechanism for transfer of performance is the accomplishment of a discrete maintenance action/activity within a specific equipment context.

3.9 Vacuum-tube, discrete component technology must be represented as must modular-discrete, modular integrated and modular monolithic technology. SEM technology also is required.

3.10 PM/FL technologies are desirable with both integral and transportable diagnostic programs in cartridge/ROM form. Testability and redundant switching are also desirable.

3.11 Fault localization practice is considered to be the single most important skill for ET/EWs. EEMT must provide both training and practice in fault localization or it will not likely be cost-effective.

3.12 Critical tasks must be represented as well as common tasks.

3.13 EEMT must provide for gradual building of skills at several levels. An example follows: The skill is AC voltage measurement.

- AC voltage measurement at component (capacitor)
- AC voltage measurement at circuit (oscillator)
- AC voltage measurement at group (I.F. strip)
- AC voltage measurement at section (rcvr. sensitivity)

3.14 Adjunctive simulation equipment must detach from program control display elements so each can be used as a stand-alone element. Power sources must be independent.

3.15 Hazardous voltages may be present physically but must be caged to prevent accidents.

3.16 The expanded Rigney system and the adjunctive simulation hardware are used in the same location.

4.0 APPLICATIONS

4.1 Immediate

4.1.1 The anticipated application is for Naval enlisted rate training of ET and EW personnel at Great Lakes NTC and Correy Station. The EEMT can be used within the constraints of the existing curricula at those schools but curriculum modifications will be required to take full advantage of the device's capability. Existing applications are in the special circuits, test equipment, receiver-transmitter, troubleshooting and generic equipment organization portions of the curricula. Distributed applications are required with time intervening between sessions on the trainer.

4.1.2 Other immediate applications involve Class C training for specific radar, communications, ECM/ESM and NAVAID equipment. These applications require the development of transportable programs to support training.

4.2 Long-term Applications

Eventual uses of EEMT are expected to include several families of Naval electronic systems — data systems, missile direction systems, point defense systems, underwater fire-control systems, sonar systems, torpedos, and training devices.

4.3 The number of student stations required for effective training will vary with the application. For the initial ET-EW device, twenty stations appear optimum at this time.

5.0 EQUIPMENT DESCRIPTION

5.1 General Description

The two major system components are the expanded Rigney system (one per device) and the adjunctive simulation equipment (four per device). Figure 1 shows the general design concept. The four items of adjunctive hardware are as follows: radar system, communications system, indicator/processor equipment, and ECM/ESM equipment.

5.2 Present Rigney System

At present, the Rigney system consists of the following parts: optical display and storage, sonic pen, interactive CRT display, disc storage, computer and compiled program. Figure 2 shows the present Rigney system.

5.3 The expanded system will consist of the following major parts: video picture element (optical display or video disc), interactive CRT display, Rockwell touch panel, adjunctive disc storage and processor, internal disc storage, computer and resident program. The changes are intended to increase storage and processing capacity to provide for enhanced CAI-CMI capability, to provide a more accurate and reliable indicator of X-Y position (Rockwell touch panel) and to permit video motion not now possible, but only if that capability proves to be cost effective. Figure 3 shows the expanded Rigney system.

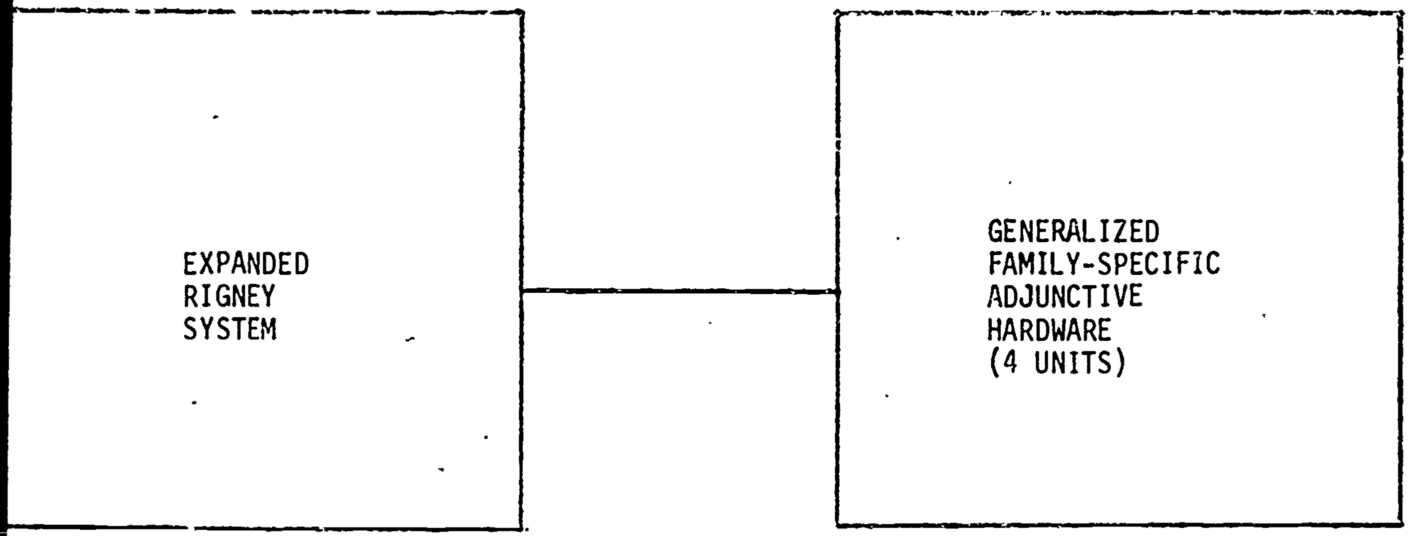
5.4 Trainee Interfaces

The trainee interfaces are as follows: optical projection display (or CRT), interactive CRT display, Rockwell touch panel, and adjunctive simulation hardware.

5.4.1 The optical projection display retrieves and portrays any one of many previously-created images. A minimum of 1000 images in storage is required, more are considered desirable. Speed of accessing any image shall be 2 seconds within grouped sets (average) and 4 seconds across sets (average). The display must be at least 6"x10". The images shall be easily viewed in normal light with approximately equal brightness across the screen.

Figure 1

GENERAL SYSTEM CONCEPT



UNIT 1. COMMUNICATIONS TRANSCEIVER

UNIT 2. RADAR TRANSMITTER AND RECEIVER

UNIT 3. INDICATOR/PROCESSOR

UNIT 4. ACTIVE/PASSIVE COUNTERMEASURES

Figure 2

PRESENT RIGNEY SYSTEM

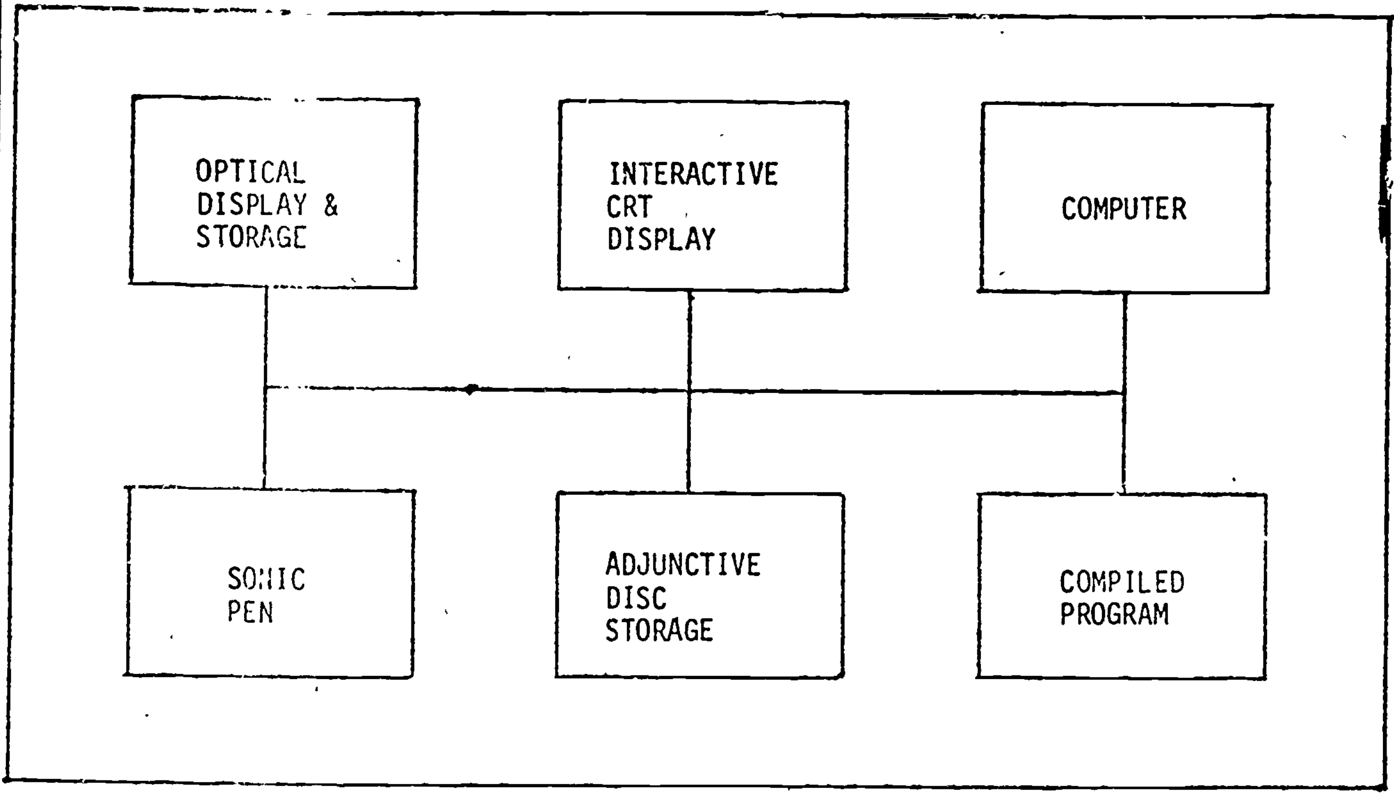
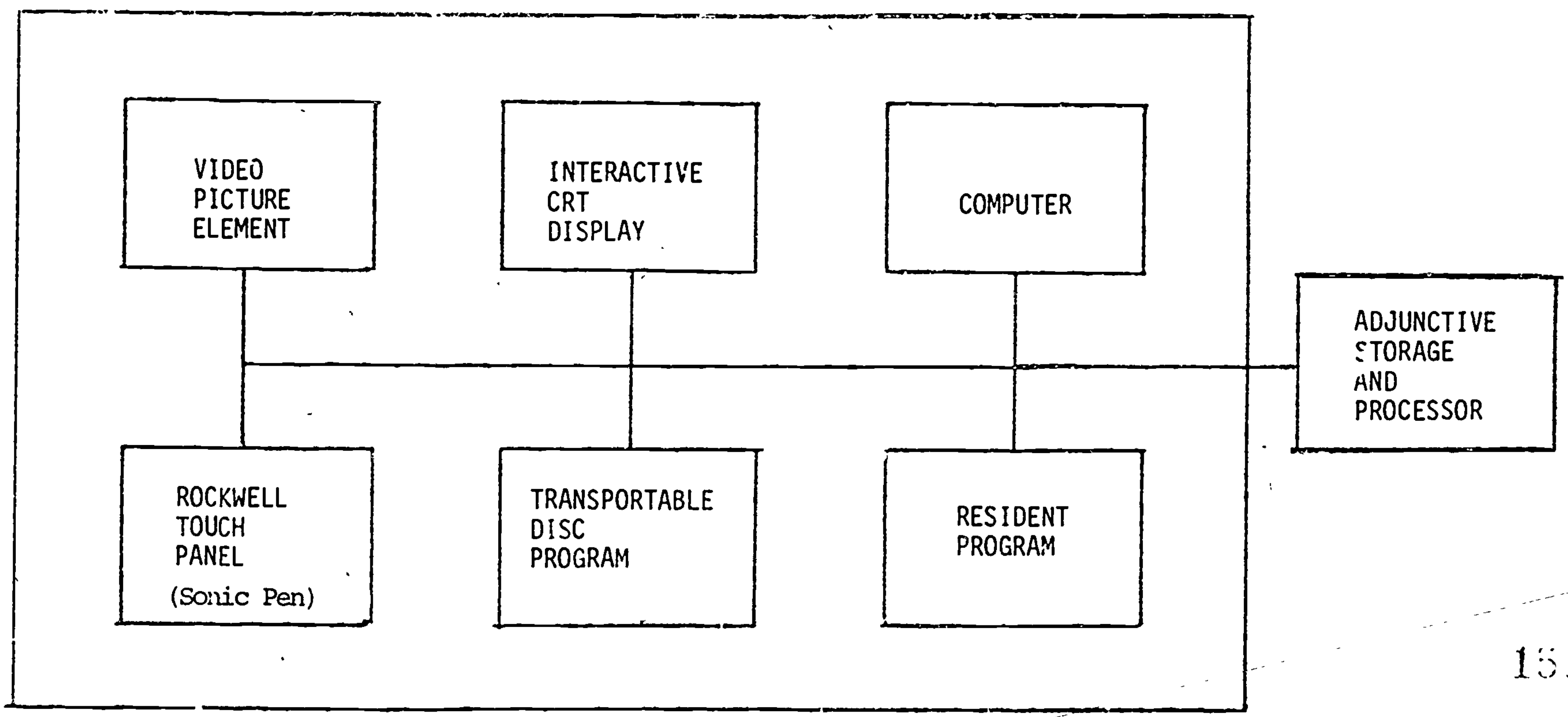


Figure 3
EXPANDED RIGNEY SYSTEM



5.4.2 The interactive CRT display is provided for program-generated text and graphics. It will display at least 100 characters per line and 30 lines of text per page. It will be at least 6"x10" and no larger than 10"x10".

5.4.3 Means will be provided to sense any position on either display, in relation to some base, to an accuracy of .1" or better. Response time is .5 sec. or faster.

5.4.4 Storage must be provided to read-write to external media. Storage capacity shall be determined by conducting a "sizing and timing analysis" part of the engineering design tradeoff requirement. The storage requirements could run to 10^6 bits per student station.

5.4.5 The CPU will be required to process DOD-1 standard code. Capacity shall be determined during the required "sizing and timing" analyses.

5.4.6 The resident program will be written in DOD-1 standard code. It will direct and mediate all CAI-CMI features as described below.

5.5 CAI-CMI Features

5.5.1 Physical Structure Exploration

Discrete zoom steps using stored images.

5.5.2 Functional Structure Exploration

Discrete zoom steps using functional hierarcy: system, equipment, section, group, circuit, component

5.5.3 Computer-generated Dialog

Fault localization

Align, adjust, calibrate

In-situ tests and measurements

5.5.4 Performace data recording (each trainee)

Latency and accuracy for each problem

Derived score for each problem set

Progress measures for entire course

Knowledge of results

Guided practice

History of individual student performance

5.6 Adjunctive Simulation Hardware

Four items of equipment are indicated for ET/EW enlisted rate training:

- Generalized communication transceiver
- Representative surface search radar
- Indicator/processor/PMFL/A-D, D-A
- Simplified ECM/ESM set.

5.6.1 Functional Packaging

All adjunctive simulation equipment will be functionally packaged; that is, there shall be an obvious correspondence between the functional and constructional designs. Figure 4 illustrates functional-constructional correspondence.

5.6.2 Generalized Communication Transceiver - Figure 5

Major sections are as follows (groups in parentheses):

Input-output (headsets, handsets, digital encoders)
Signal coding (scrambler mod./demod.)
Multiplexer-baseband (mux. mod./demod.)
Modulator (audio, drivers, modulators)
Power amplifier (H.F. amp.)
T-R Switching (cavity, keep-alive, rotating joint)
Antenna (antenna & multicoupler)
Receiver (audio, demod, I.F. amps-double conversion)
R.F. signal amplifier (R.F. strip, noise suppression)

5.6.3 Surface Search Radar - Figure 6

Antenna (antenna, T-R switch, pedestal)
Transmitter (driver, modulator, RF oscillator, mag.)
Power Supply (rectifier, filter, regulator)
Receiver (IF strip, detector, freq. conversion)
Timer (trigger, indicator, marker)

5.6.4 Indicator/Controller/PMFL/A-D, D-A/Processor - Figure 7

CRT (PPI scope, drive, sync, sweep gen)
Processor (digital post processing)
PMFL (ROM, cartridge load, T-R, MUX/sample)
A to D converter (counting, binary/number)
D to A converter (number/binary, binary/voltage)

Figure 4

FUNCTIONAL PACKAGING AND TERMINOLOGY

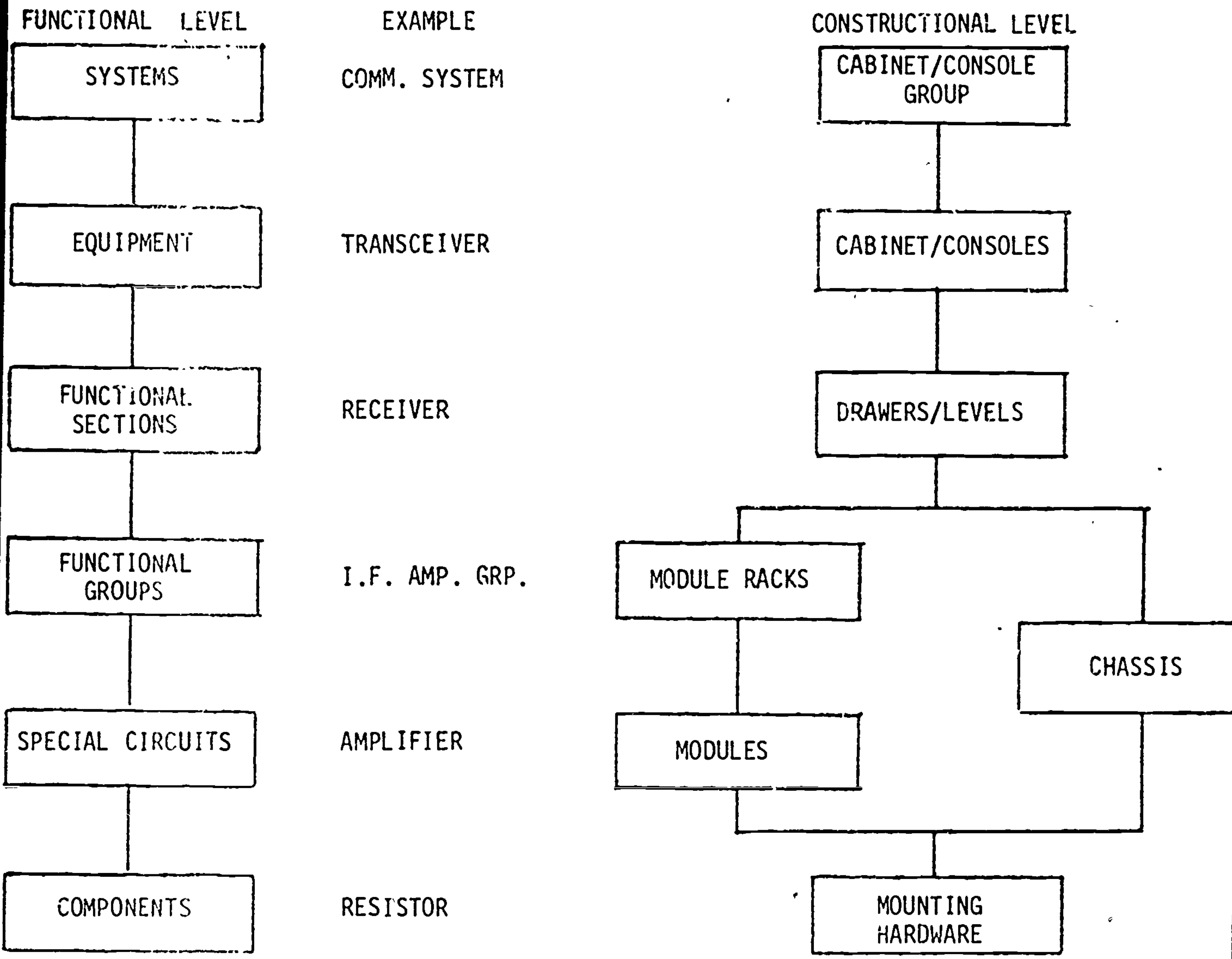


Figure 5

COMMUNICATIONS TRANSCEIVER EQUIPMENT

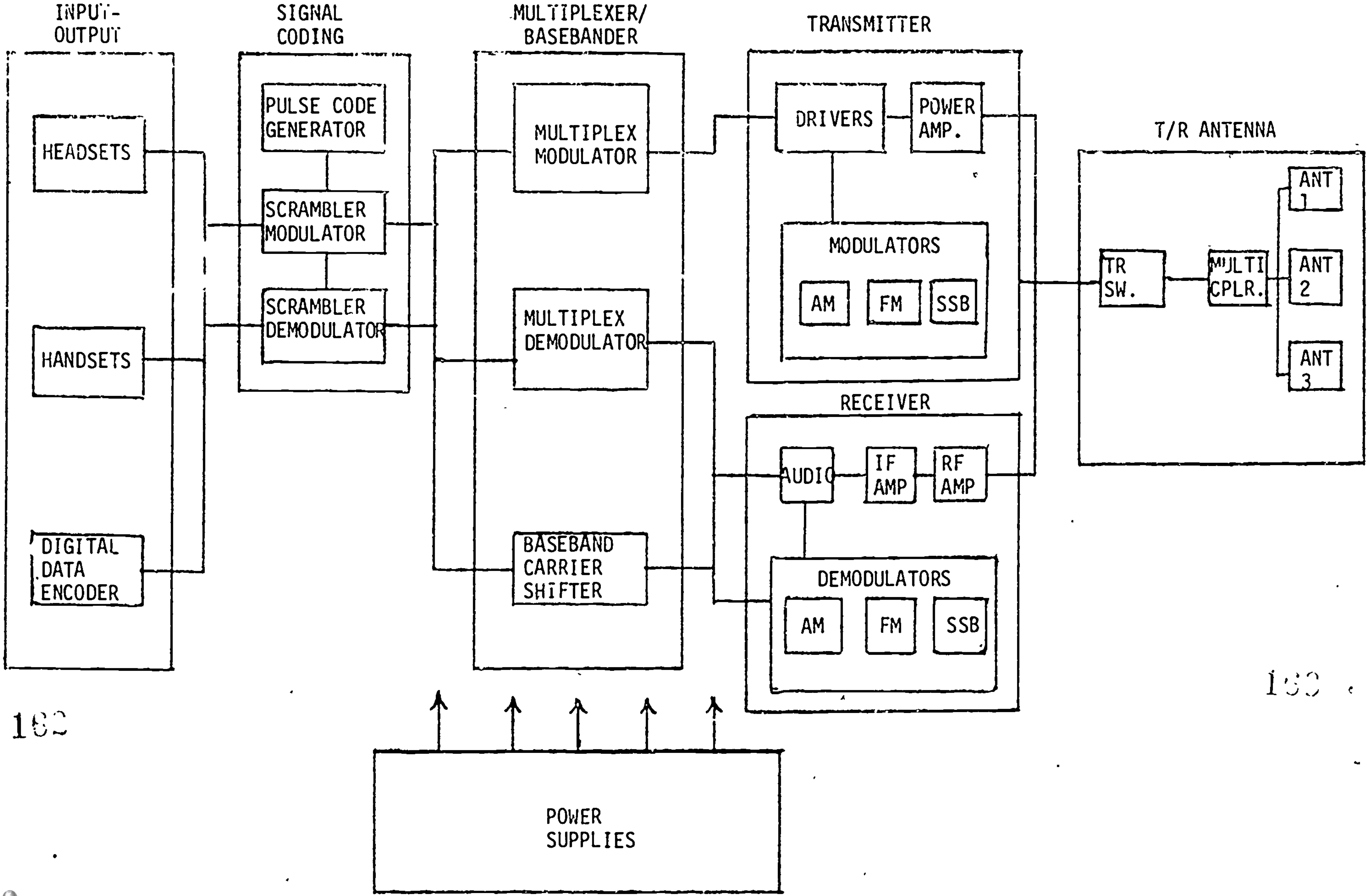


Figure 6

RADAR TRANSMITTER AND RECEIVER EQUIPMENT

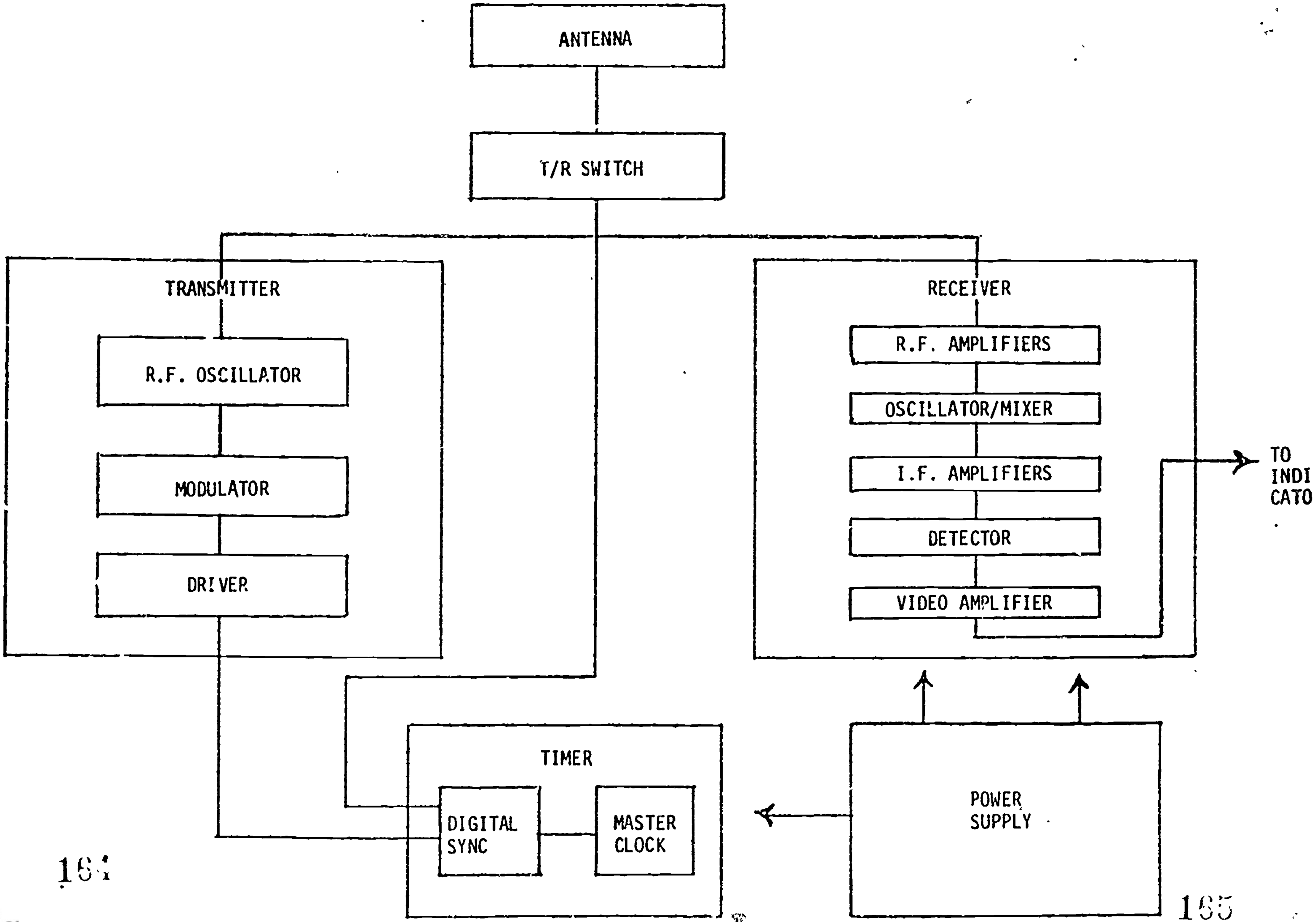
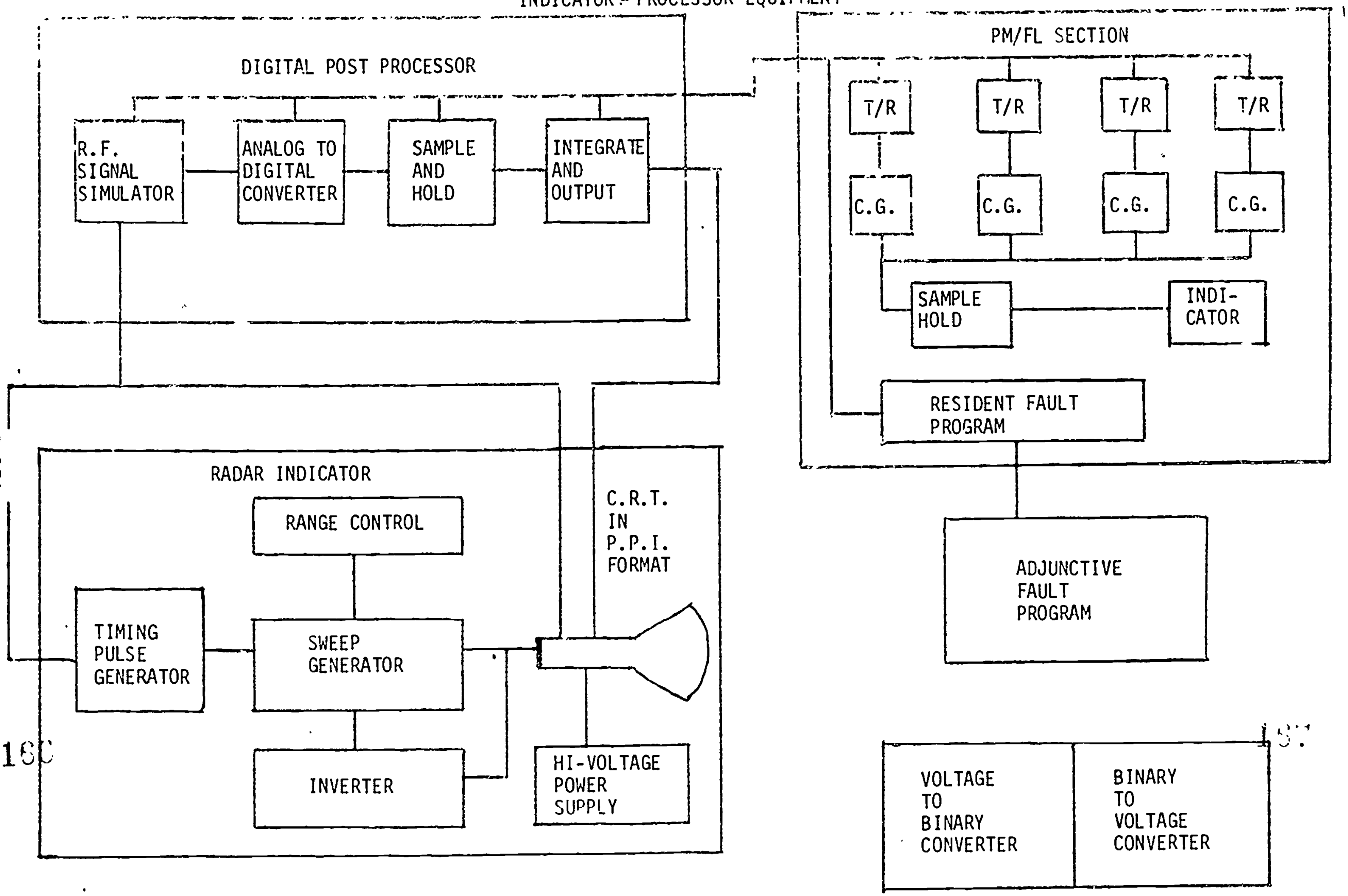


Figure 7

INDICATOR - PROCESSOR EQUIPMENT



5.6.5 ECM/ESM - Figure 8

See classified supplement. [Not included herein]

5.6.6 Technologies

Generalized communications transceiver -

- Vacuum-tube, discrete components.

Surface search radar -

- Standard Hardware, SEM (except CRT and magnetron).

Indicator/processor -

- Monolithic, modular.

ECM/ESM -

- Solid-state, modular.

5.6.7 Engineering Development Trade Studies

Use of video disc to replace optical projection

Use of Rockwell touch panel to replace sonic pen

Adjunctive vs. integral storage/processing

Development of NAVAIDS adjunctive equipment

Cost-effectiveness of automatic fault introduction

Cost of adding I.F.F. capability to radar unit.

Cost effectiveness of monitoring test equipment settings

6.0 SUPPORT REQUIREMENTS

6.1 Initial Support Items for EEMT Equipment

Technical manuals (FOMM manuals)

Software preparation

Reliability/maintainability analyses

Factory training course

Initial spares inventory

Safety analysis

Transportation/set-up

Curriculum development

Instructors guide

6.2 Life-cycle Support Items

Long-term spares inventory

Software changes/training effectiveness

Curriculum changes/training effectiveness

7.0 SOFTWARE REQUIREMENTS

7.1 Executive Program - Resident

7.1.1 Housekeeping routines

Zoom, inverse zoom

Functional, constructional, schematic, pictorial

7.1.2 Administer problem sets

Explore 20 sets, 2 forms

Fault localize 20 sets, 2 forms

Align, adjust, calibrate 20 sets, 2 forms

Test/measurement 20 sets, 2 forms

7.1.3 Data recording — accuracy and latency for

Problem

Set

Cumulative

Knowledge of results

History of individual student performance

7.2 Data Bases - transportable

Communications transceiver

Radar receiver/transmitter

Indicator/processor/PMFL/A-D, D-A

ECM/ESM

8.0 NDCP EXCEPTIONS

No instructor's console

No authoring capability

No instructor lesson modifications

DESIGN E

R. W. Daniels
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Page

I. INTRODUCTION

A. Purpose

This draft document contains the description of a conceptual design for a simulator to support A school level electronics maintenance training. The training system for which this concept has been developed is known officially within the Navy as Class A Electronics Maintenance Training (EEMT) system. The simulator to be built to support that system is known as the EEMT simulator.

The EEMT simulator will be an instructional delivery system to initially support training and practice of electronic equipment preventive and corrective maintenance tasks. The Honeywell design concept, defined in this report, is one alternative conceptual design that satisfies all of the requirements for the EEMT simulator.

B. Basic Assumptions

This concept is based on several assumptions common to the three previous Honeywell concepts (refer to Honeywell Reports F2210-4.1, 4.2, 4.3, and 4.4). These include:

1. The EEMT system will be a hybrid 2-D/3-D system to support both ET and EW Class A training.

2. All maintenance tasks identified in the Training Requirements Analysis Report (Honeywell Report F2210-2) will be trained by the system.

3. The fidelity requirements specified in the Fidelity Requirements Analysis (Honeywell Report F2210-3) will be met.

Additionally, information obtained at NPRDC review of Honeywell designs A, B, and C (16-18 April) indicate the following further assumptions to be warranted:

4. The 2-D portion of the EEMT simulator must be a Rigney system.

5. Design of the EEMT simulator must permit:

   a. Combined 2-D/3-D use

   b. Stand alone 2-D use

   c. Stand alone 3-D use.

Consequently, Honeywell now proposes an additional concept which meets the Navy's needs. It is based upon all of the data developed during the system definition program phase together with the two assumptions (listed above) added during the April 16 and 17 review meeting. For the purposes of this report the concept will be referred to as Concept E.

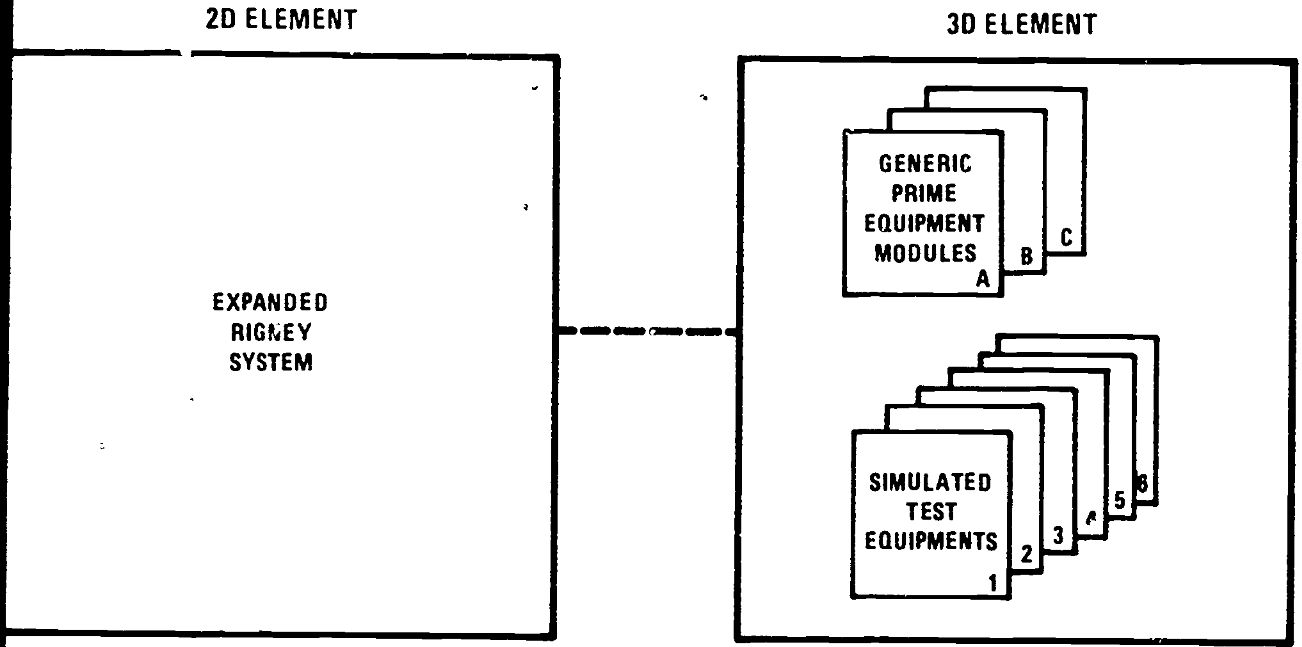
II. SYSTEM OVERVIEW

Simulator Conceptual Design E is composed of two major elements (see Figure E-1). The 2-D portion of this concept is an expanded version of the USCD Rigney system. That element is described elsewhere and will not be defined in detail in this document.

The 3-D element of the EEMT simulator for Honeywell Concept E is composed of a mainframe structure and a series of plug-in 3-D modules. This 3-D element is designed for training and practice of these maintenance tasks requiring hands-on performance for learning. As such, the contents and organization of the 3-D plug in modules have been designed to maximize the learning and transfer of these skills.

Although Concept E does not include a dedicated instructor console, the functions to be performed by instructor personnel are provided for. Specifically, Concept E involves a portable, plug-in keyboard (provided as part of the 2-D Rigney element of this concept) which can be attached to any 3-D mainframe. This will permit instructor personnel to perform the following functions on the 3-D element of the system without that element being connected to the 2-D element:

- o Generate/modify 3-D teachware problems
- o Insert/remove simulated malfunctions for the 3-D modules
- o Run performance evaluation programs.



17:

Figure E-1. EEMT System Conceptual Design E - Block Diagram

III. SIMULATOR ELEMENTS

The EEMT system conceptual Design E is composed of two independent units--an expanded 2-D Rigney System and a 3-D hands-on training simulator. Figure E-2 represents the 2-D and 3-D elements as they might appear in the connected mode.

A. 2-D Element

The 2-D component of the EEMT system Design E is an expanded Rigney system, the major parts of which are: video picture element, interactive CRT display and detachable keyboard, touchpanel, internal disk storage, and computer and resident program. This 2-D element of the EEMT system is compatible with and operates the software comprising the Rigney system. It is capable of stand alone, independent operation without being connected to a 3-D element.

The 2-D element can be connected to a 3-D training unit by means of a data transmission line. In the connected mode the computer and compiled program of the Rigney system are capable of monitoring, but not necessarily driving, functions of the 3-D element. Performance monitoring data on 3-D hands-on tasks to be written directly on a disk at the 3-D element or routed to the 2-D processor for purposes of performance evaluation and feedback.

B. 3-D Element

The 3-D element of Design E is capable of operating independently of the 2-D element, or in a connected mode. The permanently installed components of the 3-D element mainframe are:

1. Microprocessor dedicated to control of generic equipment modules,

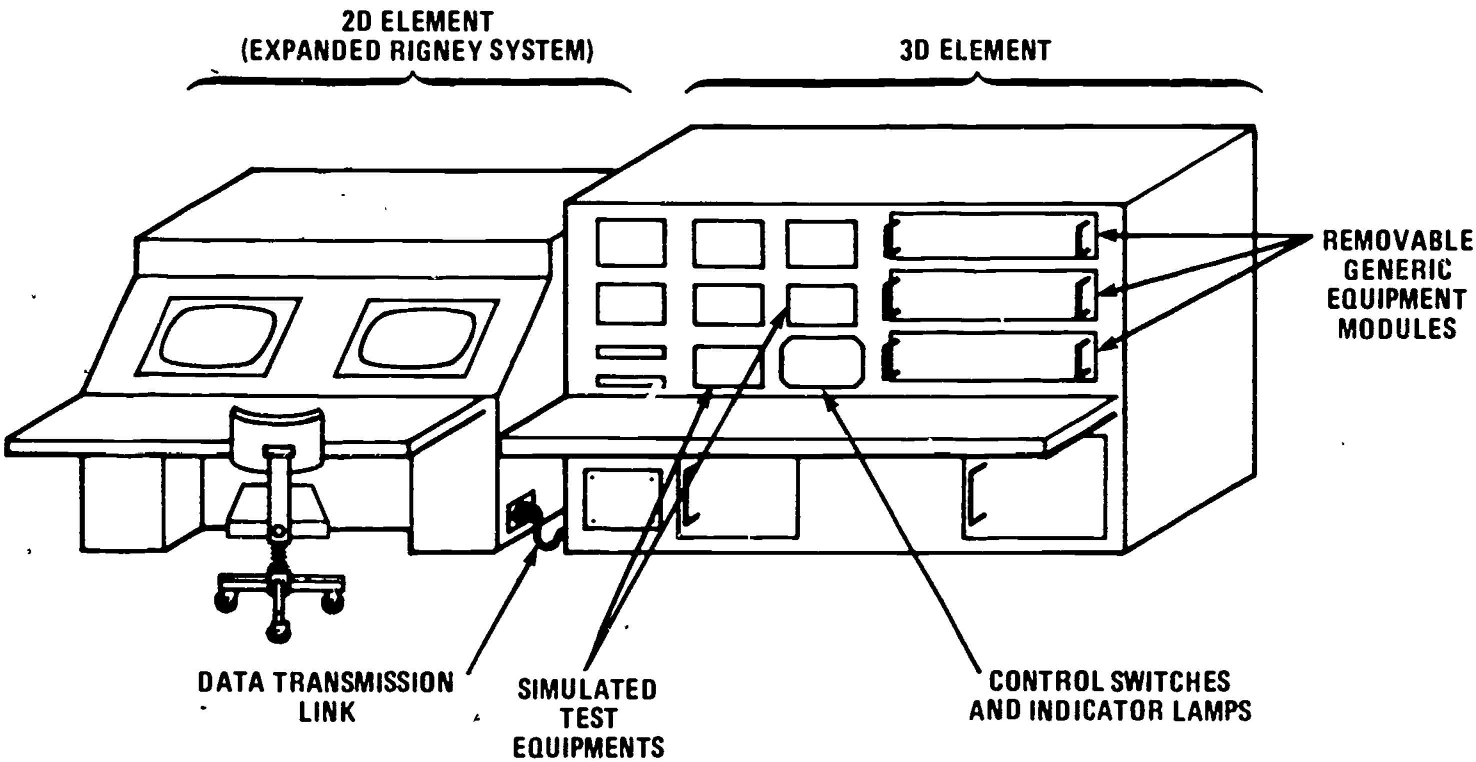


Figure E-2. EEMT System Conceptual Design
- Student Station with 2-D and 3-D Elements

2. Microprocessor dedicated to control of simulated test equipments,

3. Floppy disk mass storage associated with both microprocessors; permits storage of performance monitoring data, and automatic pacing data to accommodate slow, moderate, or fast learners when the 3-D simulator is being used in the detached configuration,

4. Test equipment multiplexer for translating waveforms,

5. Five pieces of simulated common test equipments plus an associated controller for each,

6. Generic, multipurpose test equipment device for functionally representing other, less common test equipments,

7. Power supply,

8. Set of function switches for ON/OFF POWER, PROGRAM LOAD, RUN, CALL FOR AID, etc.,

9. Set of indicator lamps for providing extrinsic feedback,

10. Various detachable probes and connecting cables,

11. Audio alarm to signal critical errors and safety violations,

12. Cabinet storage space for common hand tools, probes and cables, and instructional materials.

The functional block diagram in Figure E-3 shows the features of the student station 3-D element and how they are interconnected.

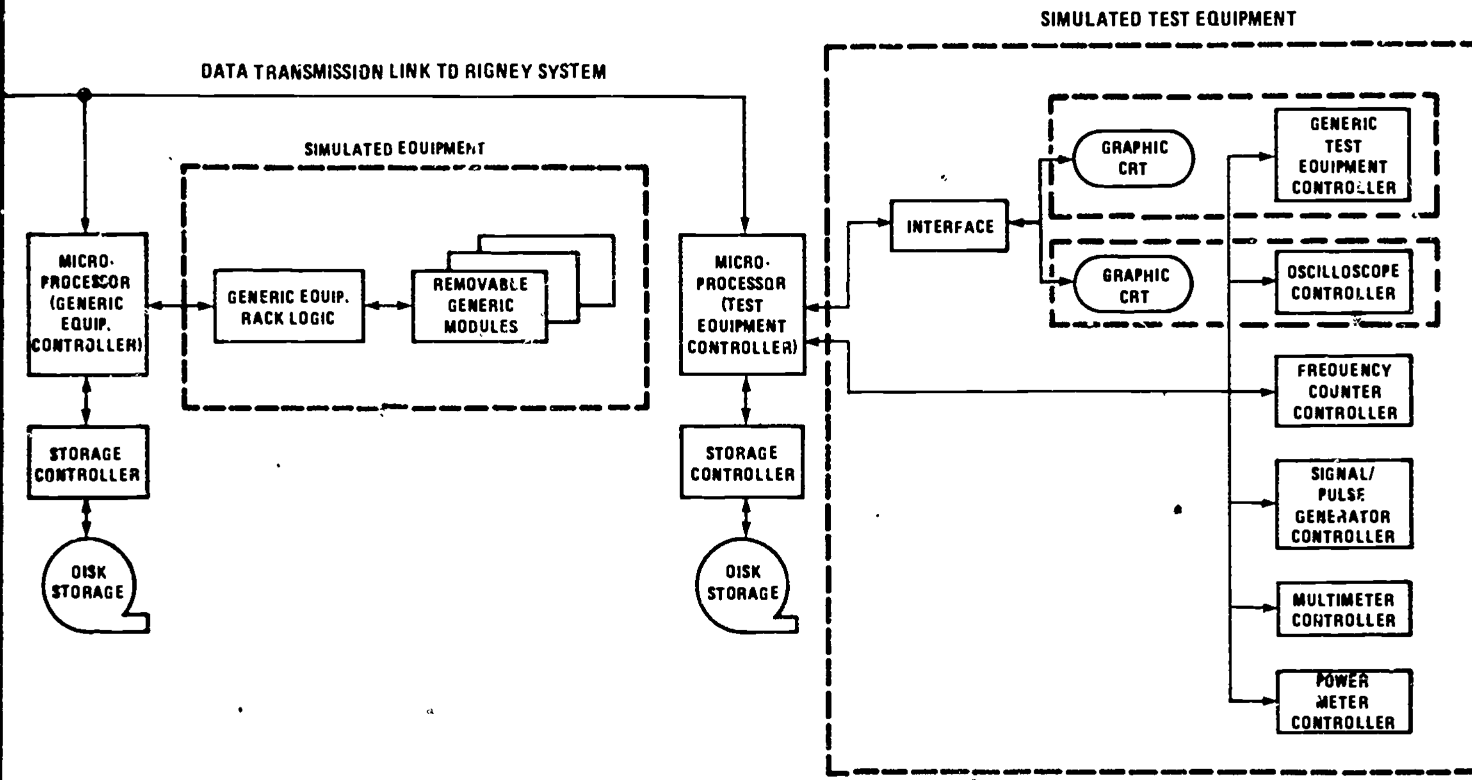


Figure E-3. EEMT System Conceptual Design E - Functional Block Diagram for 3-D Simulator

Generic Equipment Modules. The generic equipment modules are simulated, generic versions of representative electronic equipments, functional groups, or subassemblies which ET/EW technicians maintain. They are pull-out, removable drawers that the trainee obtains from a supply area according to his needs for the upcoming lesson. The flexible and self-paced EEMT curriculum eliminates the need for a full complement of electronic equipment modules at each student station.

The 3-D simulator console provides space for three plug-in drawers. The generic equipment modules are connected by flexible ribbon cabling to the generic equipment rack logic and subsequently to the dedicated microprocessor controlling the generic equipment modules.

A discrete number of generic equipment modules are necessary to support the 3-D hands-on maintenance training objectives (Fidelity Requirements Analysis Report, Honeywell Report F2210.3). These modules are derived from four equipment families: radar, communications, ECM/ESM, and indicator/controller/processor. When appropriate modules are loaded into the 3-D simulator relay rack, they can achieve a configuration typical of an equipment or system; e.g., a receiver-transmitter unit, radio frequency amplifier, and radio set control interconnected to form a communications radio set. Examples of generic equipment modules to support 3-D hands-on training are tabulated in Conceptual Design for an EEMT Simulator--Design Alternative B, Honeywell Report F2210-4.3. Both the front panel and internal components of the equipment modules will be simulated.

The interior of each drawer is accessible from above when the drawer is pulled out. Modules, parts, circuits, test points, and other common component parts (CCPs) representative of common

ET/EW equipments are 3-D functionally simulated within the drawers. These components are representative of the three electronic ages--vacuum tube, transistor, and integrated circuit--in proportions identified in the Equipment and Task Commonality Report, Honeywell Report F2210.1. The modules also present electronic packaging in three common ways--strap-down, module and circuit cards--in order to give the student exposure to maintenance on each type. Figure E-4 depicts a hypothetical example of a generic equipment module complete with front panel controls/displays and interior components, parts, and circuit boards.

The design of 3-D generic equipment modules capitalizes on existing equipment designs in terms of the construction of circuit cards and circuit boards, the layout of drawers, etc. This strategy reduces development costs of new designs.

Simulated Test Equipment. Simulated common test equipments are mounted in the mainframe of the 3-D EEMT simulator. The most frequently used test equipments are represented:

1. Multimeter
2. Frequency Counter
3. Signal/Pulse Generator
4. Oscilloscope
5. Power Meter

The front panels of these test equipments--including switches, controls, meters, and displays--are functionally simulated with high fidelity. Detachable probes, connecting cables, and jacks are provided for actual connection with appropriate jacks and test points on the generic equipment modules.

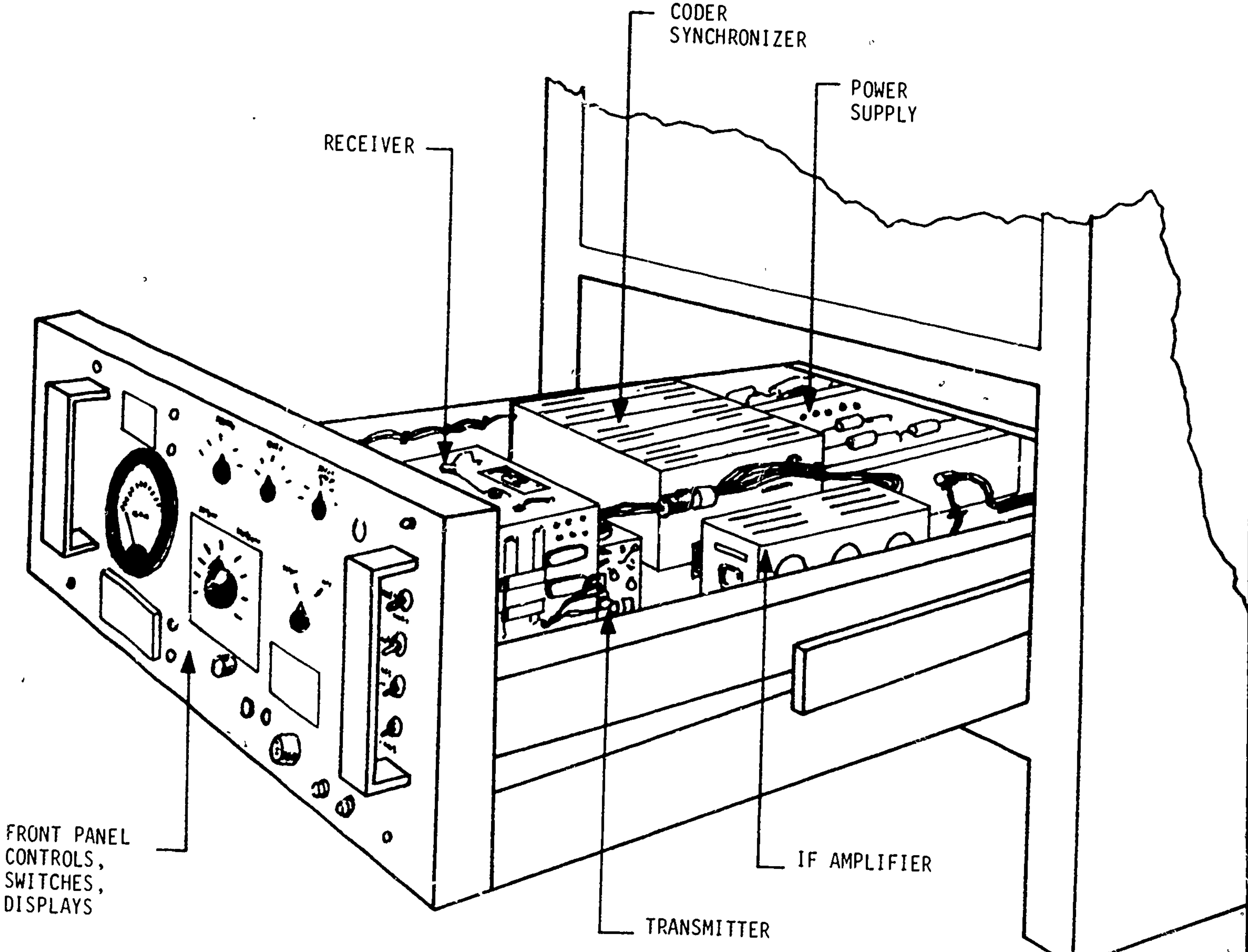


Figure E-4. EEMT System Conceptual Design E - Example of Representative Equipment Module

The computer will monitor that the appropriate connections had been made and that the proper cables have been selected. The test equipment will respond appropriately when the leads or probes are placed at designated test points in the equipment.

The display of the oscilloscope presents waveforms by means of a CRT. The standard raster-scan video monitor (512 lines) provides adequate resolution for the presentation of waveforms. The oscilloscope is controlled by the dedicated centralized microprocessor which accesses the appropriate waveforms stored on its floppy disk then routes the signal through a multiplexer and a TV controller interface. Figure E-5 shows the front panel of the simulated oscilloscope.

Other required test equipments needed in the performance of the training generalities include: megger, through-line wattmeter, bolometer, wattmeter, microammeter, spectrum analyzer, TDR, FDR, SWI, and noise generator. These test equipments are less frequently used. Consequently, a generic representation of these and the remaining test equipments appear on one large front panel in front of the trainee. The generic test equipment contains one raster-scan TV CRT, meters, digital readouts, and various multipurpose controls.

The raster-scan monitor included on the generic test equipment can be used as a vehicle for displaying CAI alphanumeric messages during training and for teachware modification. A trade-off study should take place to specifically address this issue.

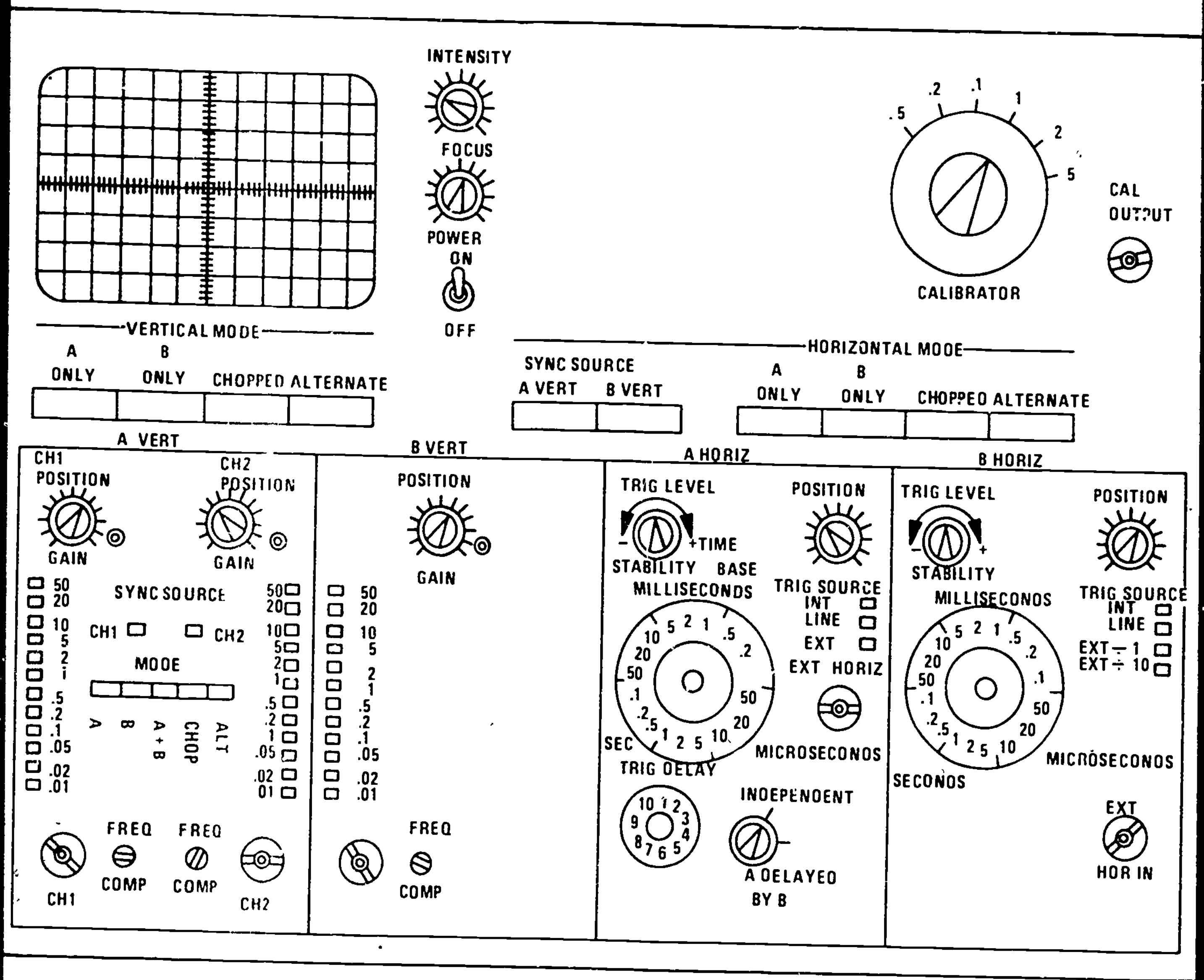


Figure E-5. EEMT System Conceptual Design E - Simulated Oscilloscope

IV. SYSTEM PERFORMANCE CAPABILITIES

A. Computer Architecture for Teachware/Software

The 3-D component of Design E can be operated either connected to, or disconnected from, the 2-D component. It contains all the computer hardware and software necessary to allow it to perform in both of these modes. As shown in Figure E-3, the computer architecture for the 3-D element is a distributed microprocessor based system. It contains dual floppy disk mass storage and the capability to "talk" between processors and with the 2-D element through an intercomputer data link.

Two microprocessors, each with associated dual floppy disk mass storage, are contained in the 3-D simulator. One processor is dedicated to the simulated test equipment and graphic CRT; the other controls the simulated prime equipment and handles intercomputer communication chores. A separate microprocessor, located in either the 2-D or 3-D component, could be added specifically to handle intercomputer communications if deemed necessary after a more detailed analysis of the processing load.

The intercomputer data link allows data to be transmitted between the two processors in the 3-D simulator and between the 2-D and 3-D elements. Major data transmissions take place among the processors and associated subcomponents of the 3-D element. Data transmissions between the 2-D and 3-D elements are intended to be lighter, primarily consisting of:

- performance data, and
- I/O channel status data

Each I/O channel indicates the status of specific 3-D functions or states, including indication of:

- o a safety violation
- o other critical errors
- o completion of a task
- o need for assistance

B. Performance Monitoring

The 3-D component of Design E possesses an independent performance monitoring and evaluation capability. Two primary modes of evaluation are provided:

- o informal evaluation
- o formal evaluation

Informal evaluation. This mode of evaluation refers to the feedback and diagnostic information given to the student while he performs tasks (or parts of tasks) on the 3-D portion of the trainer. These messages are part of the teachware system and are created during teachware generation. During the operation of the trainer, the teachware compares student actions with standards at each task step. Based on the results of this comparison, the student is given one or more of the following kinds of feedback:

- o Positive feedback -- message, e.g., "correct"
- o Negative feedback in one of two forms
  - brief message on CRT
  - auditory alarm (primarily to indicate a safety hazard)

- diagnostic message on CRT to explain an action which led to negative feedback

Formal evaluation. Formal evaluation would generally be used either directly before or after a group of lesson segments to determine student attainment of instructional objectives. In this mode, the feedback options could be turned off if desired.

The output of the evaluation process would be a diagnostic report for informal evaluation and for the formal evaluation:

- an attainment score in terms of percentage of objectives met, for each student,
- list of objectives failed, for each student,
- optional diagnostic report, consisting of all feedback messages received by the student during the evaluation session,
- accumulative statistics across students.

Evaluation, i.e., scoring and generation of reports, could be carried out at either the 2-D or 3-D components, and would consist of:

- connecting the teletype terminal to enter commands and obtain hardcopy of reports,
- loading the disk containing the evaluation programs,
- sequentially loading the disk containing the student response history for each student to be evaluated, and
- running the evaluation program and obtaining output on the printer.

Based on the results of the formal evaluation, the student can be directed to one of several courses of action:

- o repeat one or more lesson segments,
- o take a new lesson segment (the topic and difficulty of which can be made contingent on the student's performance),
- o demonstrate proficiency on operational gear,
- o receive remedial training in one or more areas of deficiency.

C. Teachware/Software Modification

The capability is provided to generate/modify both teachware and software. For the 2-D element, this function is performed with the keyboard in the fashion normally used with the expanded Rigney concept. In the case of the 3-D element, this function is also performed using the keyboard, as explained below.

Simulator parameters to be controlled by the 3-D teachware and software are:

- o functioning of simulated 3-D modules
- o functioning of simulated test equipment
- o student monitoring for 3-D
- o performance data recording for 3-D
- o lesson branching to accommodate various levels of learner progress for 3-D
- o student feedback via 3-D.
- o simulator status monitoring for 3-D

- o interfacing with 2-D element
- o automatic simulated fault insertion in 3-D.

To accommodate the inevitable changes which will be required to each of those parameters, Concept E provides for modification by instructor level personnel. That modification (or generation) will be accomplished using the portable keyboard, the mass storage medium and the capability of the 3-D processor. Specifically, with the keyboard attached to the 3-D system element, unique, non-training, preprogrammed mass storage media will be used to provide the capability to perform the following generation or modification actions to the 3-D teachware/software:

1. Generate/modify teachware material
   - o Simulated equipment performance values - normal and faulted
   - o Test values - normal and failed
   - o Sequence of required trainee inputs - e.g., procedures
   - o Timing requirements for trainee inputs
   - o Trainee error criteria - pass/fail and exact value or sequence
   - o Critical error alarm use
   - o Trainee feedback
   - o Branching strategy - slow, moderate, and fast learners.
2. Generate/modify software material
   - o Basic software architecture
   - o Basic teachware software architecture.

To most conveniently provide the above capabilities, the 3-D teachware and software architecture shall be developed to permit teachware materials to be entered into the system as computer data. This capability will involve use of an architecture which will permit the instructor to "fill-in-the-blanks" to achieve the desired generation or modification action. Use of this fill in the blanks capability will be supported with a teachware generation/modification guidebook.

Software generation/modification will be accomplished in a similar fashion using the keyboard, dual interactive mass storage media, and 3-D element processor. In this case, however, generation and modification actions will be accomplished in computer language and with the language protocals.

D. Instructor Role

Using the Concept E simulator the instructor will function primarily as a training manager and tutor. The training manager role will involve such functions as:

- Assignment of lessons
- Determing problem exercises
- Selecting malfunctions
- Assessing trainee progress.

Because Concept E automates the function of trainee monitoring, the instructor is more available to provide individual tutorial assistance to trainees. In this role, the instructor will be able to respond to individual trainees whose performance indicates a problem and to trainees who request individual assistance.

E. Supporting Media

Design E is intended for "hands-on" training of maintenance procedures. It is assumed that technical data, background skills and knowledges, and other study components are taught primarily in a lecture format in the classroom. This design does, however, provide for conveying these data as well as written and oral instructions and video demonstrations through the use of adjunct supporting media. These media are modular and can be used at the trainer or carried off and used somewhere else, allowing the trainer to be used by another student.

The supporting media for Design E include:

- Audio cassette player
- Video cassette player
- Workbook.

Audio cassette player. The role of the audio cassette player is the delivery of the basic instructions and directions for a given laboratory task. The laboratory exercise essentially describes a well-defined series of experiences; furthermore, learning in this laboratory type of environment has been successfully managed by the audio-driven, modular, multimedia approach (Russell 1974, Creager & Murray, 1971, Postelthwait, Novak, & Murray, 1972) especially with students having reading problems.

Video cassette player. Sound with accompanying motion is necessary when depicting a motion sequence, micro or macroscopic images of real equipment and motion, sound-equipment associations, and abstract animation (Briggs, 1970). These media are particularly useful for demonstrating task procedures on operational gear and/or the training device.

Workbook. The workbook serves as the student's primary instructional guide when he is not using the computer driven components of the trainer. It also serves to integrage and guide the instruction given to the student through the various media of the trainer. The workbook will include:

- Instructions for operating the trainer,
- Instructions for each lesson,

- Technical data required for a lesson including:
  - Written material and diagrams from TMs
  - Maintenance requirement cards
  - Troubleshooting charts
  - Other operational data,
- Background skills and knowledges, and
- Exercises covering task procedures and background skills and knowledges.

F. Engineering Development Trade-Off Studies

The following are possible trade-off studies warranted during the engineering design phase in order to assess the feasibility of some Design E options:

1. Size and characteristics of the processors in the 3-D simulator as a function of the required amount of intercommunication between the 2-D and 3-D elements.

2. Feasibility of including a CRT or other alphanumeric data medium in the 3-D simulator to provide CAI messages and objective testing.

3. Feasibility of providing hardcopy output at each 3-D simulator student station.

4. Feasibility of connecting all student station 3-D elements in a classroom (20) to a single alphanumeric display medium. This modified "instructor station" would store and analyze performance data transmitted from the student stations.

V. CONCLUSIONS

This report describes one of four Honeywell conceptual designs for the EEMT system. All four designs, A, B, C, and E, satisfy all the system requirements and boundaries set forth in the Conceptual Design for an EEMT Simulator--Common Military Characteristics (Honeywell Report F2210-4.1). Design E meets two assumptions added during the April 16 and 17 NPRDC Review Meeting:

- The 2-D portion of the EEMT simulator must be a Rigney system.

- Design of the EEMT simulator must permit both combined and independent use of the 2-D and 3-D elements.

Honeywell Design E meets all of the requirements referred to above with a concept composed of a 2-D and a 3-D element capable of being operated together or independently. The 2-D portion of this concept is an expanded version of the USCD Rigney system. The 3-D portion consists of a series of plug-in modules for functionally simulating prime gear and test equipment.

The 3-D component contains all the computer hardware and software necessary to allow it to be used either in conjunction with, or independently from, the 2-D element. The computer architecture for the 3-D element is a distributed microprocessor based system with dual floppy disk mass storage and the capability to "talk" between processors and with the 2-D element.

A keyboard/teletype can be added to the 3-D portion to allow an instructor to insert malfunctions, develop teachware, and run performance evaluation programs.

The primary characteristics of Design E can be summarized as follows:

- Stand alone 2-D and 3-D elements that can be used either together or apart
- Functionally simulated generic equipment with high fidelity pull out drawers
- High fidelity functionally simulated test equipment
- Compliant with all requirements and constraints
- Distributed processing
- Formal and informal performance evaluation capability
- Modifiable and modular teachware
- Supporting media, including:
  - audio cassette
  - video cassette player
  - workbook.

This design should provide a system that is maximally reliable, maintainable, supportable, transportable, and modular. These benefits accrue by minimizing inter-unit data transmissions, time sharing software, and the need for an instructor station by using a stand alone concept.

The usual functions of an instructor station are incorporated in each unit by enriching the instructional format to provide the student with a greater "self" teaching capability.

A mix of media including audio cassette and video cassette are included as well as printed materials to provide a more complete knowledge base. The stand alone feature and highly modular design should also facilitate fitting a single trainer into the ET and EW pipelines.

The 2-D/3-D mix adopted in Design E was desired to maximize generalizability to the ET/EW representative equipment samples and to make maximum use of developments in parallel Navy advanced development programs. This was done in several ways. Only those parts and modules requiring significant psychomotor skills, as determined by our fidelity analysis, was simul-ted in 3-D. These 3-D modules were designed to have commonality with the ET/EW representative samples at the equipment, subassembly, and module levels. This will assure maximum generalizability. Maximum use of existing concepts was achieved by defining the 2-D portion of the system to be an expanded version of the Rigney system.

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APPENDIX B

EEMT SPECIFICATIONS, TWO-DIMENSIONAL (EEMT 2D) AND THREE-DIMENSIONAL (EEMT 3D) VERSIONS

SPECIFICATION FOR ELECTRONIC EQUIPMENT MAINTENANCE TRAINING SYSTEM, TWO-DIMENSIONAL VERSION (EEMTS 2D)

1.0 INTRODUCTION

1.1 Background of Unit 1 (2D)

For several years, the Behavioral Technology Laboratory of the University of Southern California (BTL/USC) has been under contract to the Navy to develop a computer-based training system for teaching electronic maintenance techniques to naval enlisted technicians. The BTL system simulates actual maintenance activities, and consists, essentially, of display hardware (that constitutes the trainee interface), computer and peripheral components, and a compiled software program supporting the presentation. The system controls the sequential presentation of training problems to the student for familiarization training on operational equipment appropriate to the student's Navy rate (i.e., electronic warfare technician (EW) or electronic technician (ET)) and for training and practice in logical troubleshooting. It also provides guidance to the student during the learning process and feedback on the excellence of his performance. It compiles student performance statistics for individual problems and problem sets. It provides adaptive, self-paced, individualized instruction in both simple and complex troubleshooting problems. It is capable of simulating a wide variety of specific maintenance actions; however, this simulation is "two dimensional," lacking some of the "hands-on" characteristics of traditional maintenance training conducted with operational equipment or electronic training devices.

To date, the BTL training system has undergone two phases of development. The first phase involved the design and test of an experimental model known as the Rigney system, named after its developer, the late Dr. Joseph Rigney of BTL/USC. This model was evaluated using Navy enlisted technicians as subjects. The results of the evaluation were highly encouraging, leading immediately to subsequent development work.

The second phase of development presently being conducted has involved the design, development, and construction of a new model incorporating the following changes: (1) a change in the software language from IMLAC assembly language to UCSD Pascal, (2) the incorporation of new off-the-shelf hardware, and (3) the addition of several new training "protocols" to enhance the overall capability of the device. At the present time, this model is nearly completed; it will be available for evaluation in the very near future.

Unit 1 of the present procurement will be an engineering-development model of the BTL training system.

1.2 Background of Unit 2 (3D)

In a separate development, Honeywell Systems and Research Center, Minneapolis, Minnesota, was awarded a contract in September 1978 to define the characteristics of a computer-based maintenance training system incorporating digitally-controlled simulation of "hands-on" maintenance actions. This design involved the use of simulated electronic hardware and simulated test equipment to teach electronic tests and measurement to enlisted trainees. The ET and EW rates were selected as representative technician groups to demonstrate the feasibility of the training concept.

Honeywell first identified a group of typical electronic equipment and systems maintained by ET and EW personnel. They then conducted a commonality analysis to identify common equipment, common modules and common circuits among the sample of equipment selected. Next, they systematically identified the maintenance activities required by the common equipment group. These maintenance activities included tests, measurements, calibrations, and other required maintenance actions.

1.3 The Present EEMTS Concept (2D/3D)

About midway through Honeywell's system-definition program, it was established that some maintenance tasks could be better taught using two-dimensional simulation techniques and that others could be better taught using three-dimensional simulation techniques. As a result, a decision was made to procure a new maintenance training system that incorporated both two-dimensional and three-dimensional components by merging the two development concepts.

2.0 SCOPE

2.1 Training Situation

The new EEMTS will support common-core initial skill maintenance training. For the initial application, the ET and EW rates have been selected.

2.2 Present Training Practices

At the present time, electronics maintenance in a variety of technical schools is taught using operational equipment. When used as a training vehicle, operational equipment tends to be costly, inflexible, subject to obsolescence, and frequently invalid. In today's cost-conscious environment, it is unrealistic to expect the various schools to have a complete range of operational equipment in sufficient quantities to rely exclusively upon that medium for the required hands-on training. The EEMTS, when fully developed, should significantly lessen the need for costly operational equipment in a variety of applications.

2.3 Generic Training

The EEMTS concept centralizes the subject matter of electronics maintenance training to its common components, emphasizing the similarity of signal processing functions that are found within families of equipment. The training objectives for the EEMTS focus on functional tests and measurements and on the generic logic of troubleshooting. The EEMTS, in its final form, will bridge the gap between the fundamental theory-oriented parts of the curricula and the equipment-specific training that follows.

2.4 General Trainer Characteristics

This functional specification (Section 4) describes all performance requirements that the equipment must meet but does not require any specific implementation of those requirements in hardware. An exception is that the software for Unit 1 is well along in development and must be retained. Therefore, the software requirement for Unit 1 is UCSD Pascal.

In the event that the Navy is able to standardize the characteristics of the new DOD-1 language (Ada) prior to or in the early stages of equipment development, the government may direct the use of that language to replace UCSD Pascal since Ada is a very similar language.

2.5 Use of Characteristics

Unit 1 can be used as a "stand-alone" training device, for both Class "A" and Class "C" training applications. In addition, it is the "system controller" in that it can direct Unit 2 through the administration of a series of training exercises. Units 1 and 2 can be connected together by cable to implement a sequence of exercises using both 2D and 3D components within the same problem series. Unit 1 "owns" the interface. The characteristics of this interface are described in Section 4.

2.6 Form of the Equipment

Unit 1 will be a "brassboard" model, to be subjected to operational evaluation and factory acceptance testing prior to procurement in production quantities.

2.7 Software Development

The task of developing software for Unit 1 has been given to BTL/USC. The winning contractor for Unit 1 shall interface with BTL as required. It is not expected that a prime contractor/subcontractor relationship will have to be established between the winning hardware contractor and BTL since the software will largely be in place by the time the hardware implementation is begun. Software changes will be possible at any time to accommodate changing hardware requirements; however, such changes can be made only with the express permission of BTL who will have the software "lead" on the program.

2.8 Training Objectives

A series of training objectives has been identified that must be met by the EEMTS. A general summary of these objectives follows:

1. Individualized instruction and guided practice in the functional organization of individual families of naval electronic equipment and systems.

2. Instruction in the purpose and operation of functional units, sections, groups, circuits or other functional elements, as appropriate to each equipment family.

3. Instruction and practice in logical troubleshooting including the following specific task areas:

a. Observations/isolation of symptom set.

b. Formulation of hypotheses including interpretation of functional block diagrams, interpretation of schematic diagrams, and use of a priori fault information.

c. Performance of diagnostic tests including initiation of system states, location of test points, performance of test and measurements, use of test equipment, use of BITE, ATE, or SATE.

d. Verification of hypotheses or formulation of new hypotheses.

e. Repair/replacement techniques for defective components and modules.

f. Performance of in-place adaptive corrections.

g. Verification of proper equipment operation.

h. Completion of maintenance documentation.

4. Instruction and practice in performing operational checks and adjustments, including alignment and calibration actions appropriate to the equipment family at issue.

5. Instruction and practice in the use of maintenance manuals and diagrams.

6. Instruction and practice in preventive maintenance procedures.

2.9 Physical Characteristics

An artist's conception of the appearance of the advanced development model of Unit 1 is shown in Figure A-1. The unit consists of a trainee's desk with associated displays, touch pen, and internal electronics. The trainee interfaces are an optical projection display, an interactive CRT display, and a command touch panel. The optical projection display portrays any one of a large number of previously created images. The interactive CRT display is provided for program-generated text and graphics. Means are provided to sense any position on either display, in relation to some base, using the touch pen provided.

Unit 1 is designed for normal classroom or laboratory use with normal power and lighting conditions and with no unusual facility or plant requirements. Unit 1 will be caster-mounted to allow easy movement from room to room.

2.10 Use Pattern

The EEMTS will be designed for use 16 hours per day (2 shifts), 50 weeks per year. Scheduled maintenance will be performed at night. Life expectancy is a minimum of 10 years.

2.11 Maintenance Philosophy

The EEMTS shall be designed to be maintained by trained Navy technicians. Maintenance will be simplified by the use of diagnostic programs/routines to isolate failed assemblies. Readily available and clearly marked test points shall be provided to further isolate the failed module, which can then be removed and replaced to ensure optimum availability during student training hours. The removed modules will be tested and repaired on a test bench away from the training area. Optimum interchangeability and use of standardized equipment shall be a firm design requirement to keep range and depth of spares to a minimum.

Organizational maintenance will be the responsibility of the user agency. Intermediate maintenance will be performed by trained personnel on-site at a location physically removed from the training area. Depot maintenance will be performed on material requiring major overhaul, complete rebuild, or specialized skills (i.e., computer memory).

2.12 Instructor's Module

An instructor's module will be designed and developed that will plug into Unit 1 to enable instructor personnel to make changes to or otherwise update the instructional

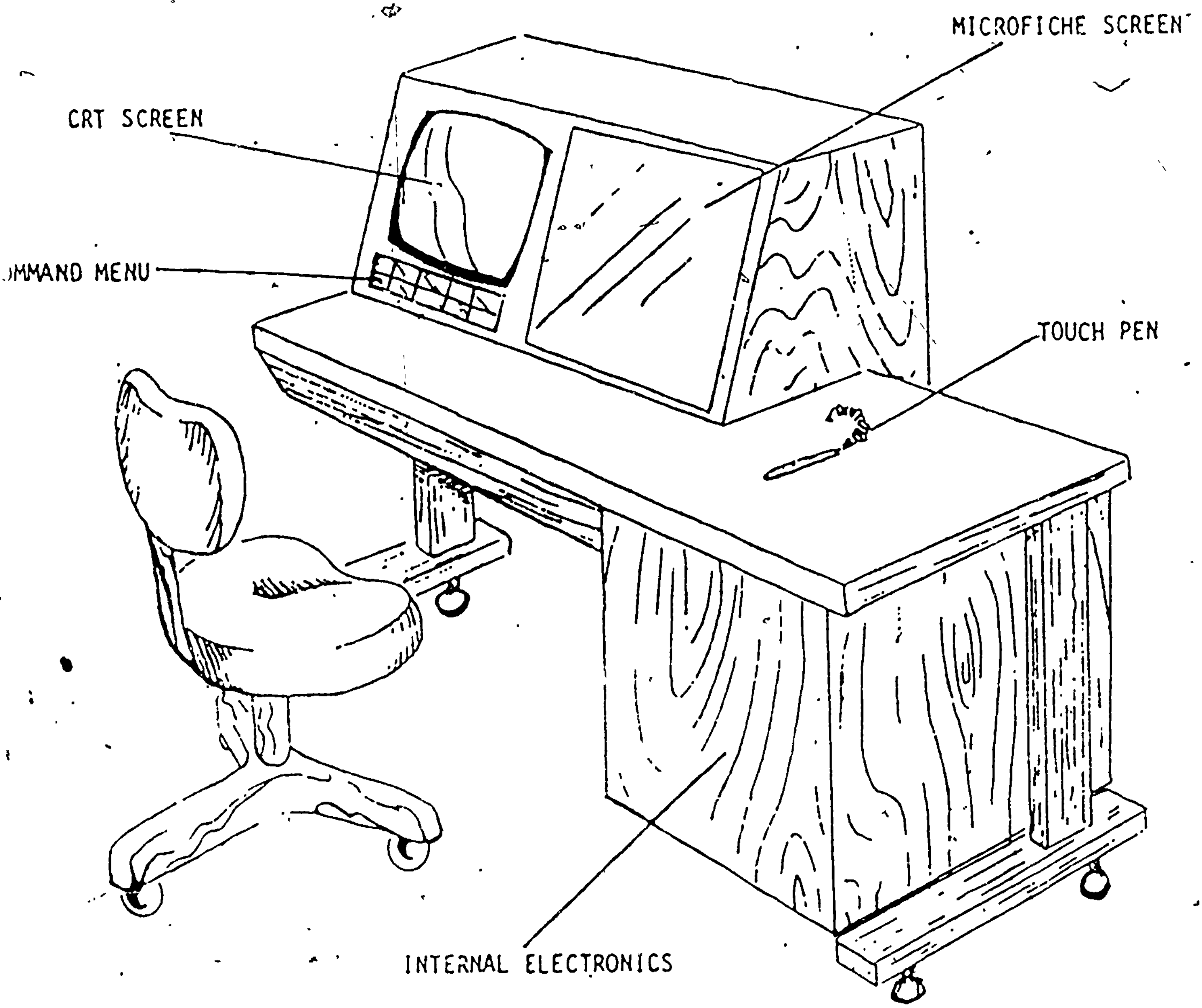

Figure A-1. Unit 1 (2-D) advanced development model.

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software. The design of this instructor's module will constitute an integral part of the design of Unit 1.

2.13 Mandatory Design Features

Certain features of Unit 1 are considered mandatory and others optional. The use of UCSD Pascal for Unit 1 and for the interface is a firm requirement of the program (except in the event that the Navy can standardize the Ada language in early development stages). The unit must run the compiled program being prepared by BTL/USC.

Unit 1 must incorporate a CRT display as a vehicle for trainee interaction with the system. This CRT will be used to present to the student the results of his actions (actions taken on either Unit 1 or Unit 2), provided those results require feedback on a completed problem.

Unit 1 must incorporate means of displaying high-resolution images to the trainee. In the existing configuration, a microfiche optical projection system is employed that can display any single image from among a very large number of stored images, on command from the software. This system has been found to be satisfactory from the standpoint of image quality; however, this approach has led to certain reliability problems.

2.14 Designer's Options

The incorporation of a video disk system into Unit 1 is a possibility. If a video disk system were selected, a second CRT likely would be required to replace microfiche graphics and display the information contained on the disk.

A potential major advantage of the video disk approach is the ability to portray motion. For example, it may prove advantageous for the trainee to view a skilled technician performing a certain maintenance action as part of the training process. If a video disk were selected, a single CRT could be used for the display of both images and alphanumerics rather than two separate display media, as is presently used. The fact that the images and text could not be viewed simultaneously, however, is viewed as a fairly sizeable disadvantage.

The BTL/USC approach requires that the student interact with the training device by indicating any selected position on the present optical or CRT display surfaces. This requirement was met in earlier models using a sonic pen system, a "sparking" stylus and two acoustic sensors that determine the position of the stylus with respect to some arbitrary coordinate system. Possible alternatives are a light pen or a plasma touch panel used in combination with a LED matrix. In this implementation, LEDs are installed along the left and bottom edges of a picture-frame-type molding. The top and right edges of the molding contain light-sensitive receptor elements. Interruption of the resulting light-beam matrix locates the position of the interrupting element with respect to an X-Y coordinate system.

Contractor personnel are free to pursue any of the optional implementations described above or to propose any other design that meets the requirements of this specification; however, data must be provided on the cost impact of the alternative so that the government can assess the cost effectiveness of the approach.

2.15 Feasible Designs

Some combinations of media that may be feasible are shown in Table A-1.

Table B-1

Some Design Possibilities

Design	Graphic (Pictorial) Display	Adaptive Display	Dynamic Display (Optional)	Advantages	Disadvantages
1	High-resolution CRT graphics	High-resolution CRT graphics	Video disc or Video tape	High reliability High response speed "All" electronic Easiest update Portability	High hardware cost Color would be costly Lower fidelity than Micrographics
2	Microfiche or Film strip	Graphics CRT	Video disc or Video tape	High resolution for troubleshooting simulation Color Separation of screens 2 and 3 Easy to update High fidelity	Medium reliability Requires many images Medium response speed
3	Computer graphics (plasma panel) over microfiche or film strip background	Graphics CRT or Plasma panel	Video disc or Video tape	Small number of images Easy to update High resolution	Medium reliability Medium response speed Medium fidelity Higher hardware cost
4	Video disc (if resolution is sufficient)	Graphics CRT	Video disc or Video tape	High response speed Low hardware cost High fidelity	Immature technology Doubtful resolution for troubleshooting simulation
5	Computer graphics over video disc background	Graphics CRT	Video disc or Video tape	High response speed	Difficult to update video disc background Medium fidelity

A development system has been assembled that generally meets the specifications given herein (no dynamic display device, #8, is included). This system, developed to experiment with the interactive requirements, consists of the following elements:

• Computer	Terak Model 8510/a with 56K bytes MOS RAM and two RS-232-C interfaces.
• Graphic Display	Bruning Model 95 microfiche projector with RS-232-C interface. Capacity 1,800 images.
• Adaptive Display	Computer text and graphics on 12" CRT.
• Mass-Storage	Terak 8512 flexible disc (two drives).
• User Input	Science Accessories Corporation, Graf-Pen sonic digitizer Model NT-301; 36" x 48" active area, 1mm resolution.
• Instructor's Module	Texas Instruments Silent 700.

Thus, it is seen that the development system is of design type two, Table A-1.

3.0 APPLICABLE DOCUMENTS

3.1 Software

UCSD Pascal, Version 1.5, September 1978.

3.2 Data Item Descriptions

All Data Item Descriptions from the Authorized Data List, NAVTRAEQUIPCEN Bulletin, are attached to the RFP.

3.3 Military Specifications and Standards

3.3.1 Military, MIL-T-23991, "Training Devices, Military, General Specification for" (Interfaces Only)

3.3.2 Maintainability, MIL-STD-470, "Maintainability Program Requirements for Systems and Equipment"

3.3.3 Maintainability Demonstration, MIL-STD-471, "Maintainability Demonstration"

3.3.4 Reliability, MIL-STD-785, "Reliability Program for Systems and Equipment Development and Production"

3.3.5 Reliability Test, MIL-STD-781C, "Reliability Tests; Experimental Distribution"

3.3.6 Human Engineering, MIL-H-46855A, "Human Engineering Requirements for Military Systems, Equipment, and Facilities"

3.3.7 Human Engineering, MIL-STD-1422, "Human Engineering Design Criteria for Military Systems, Equipment, and Facilities"

3.3.8 Quality Assurance, MIL-Q-9858A, "Quality Program Requirements"

3.3.9 Configuration Management, MIL-STD-480, "Configuration Control, Engineering Changes, Deviations, and Waivers"

3.3.10 Safety, MIL-STD-882A, "System Safety Program Requirements"

3.3.11 Provisioning Standards, MIL-STD-1561

3.3.12. MIL-STD 847
DOD 4100.38M
MIL-M-82376
MIL-P-29005
MIL-M-38748
MIL-I-45208
MIL-M-7298
MIL-M-3874
MIL-P-23189

4.0 REQUIRED FUNCTIONAL SPECIFICATIONS

4.1 General

The portion of a total training system termed 2D EEMTS will present two-dimensional displays of simulated equipments on flat screens, under computer control, in response to various actions and decisions by a user technician trainee.

The 2D EEMT is to be interactive (i.e., each action by the technician will cause the unit to respond in a way similar to the way the real equipment would respond). Responses by the unit will include: presenting an updated image of a simulated equipment following some action that affected its appearance, presenting text on a screen directing the technician in some aspect of his performance, and possibly, demonstrating tasks for a technician in response to a request for computed requirement.

An input device wi. allow the technician to communicate with the unit regarding his choice of action, and as nearly as possible, allow a reasonably realistic simulation of that action. Inputs will specify selected positions relative to a display (a photographic or computer-generated image of an equipment, a list of choices, etc.). Types of inputs to be handled include the following:

Related to the Simulation

- Setting a display switch
- Placing a simulated probe
- Shifting attention to a different section
- Selecting a manual action (adjust position, etc.)
- Swapping a suspected faulty element with a known good element
- Choosing test equipment to be employed
- Judging normality of displayed indicators

Related to Problem Control

- Command to terminate the problem
- Request for help

- Choose operational mode to practice

Storage of information shall be of two types, as follows:

- Random-access computer memory (RAM) for run-time storage of programs, storage of problem data for a problem in progress, and intraproblem performance data used for computer-student dialogue.

- Transportable, read-write mass storage of computer programs and data bases as well as storage of student progress information.

Appropriate interfaces shall be provided such that all input-output devices and memory are controlled by the CPU.

All hardware in the 2D EEMTS will be nonspecific to any particular equipment or family of equipments to be implemented via simulation; the specific behaviors and appearances of devices will be contained in digital data banks and audio-visual media, such as slides, microfiche, film-loop, etc.

4.2 Instructional Requirements

The system will be used to provide simulation/training in three general areas:

- Problem solving (troubleshooting)
- Serial-action (P/M, calibration, repair, etc.)
- Functional/physical organization

4.2.1 Troubleshooting. Troubleshooting simulation involves the selection, by a program, of an appropriate, preanalyzed malfunction and the simulation of the behavior of the operational equipment and the test equipment as the equipments are placed in various modes. It includes a step in which the technician identifies the element he believes is faulty and would replace if he were in an operational situation. The simulation continues until the technician terminates the problem, either by claiming the equipment is restored or by aborting the problem. If the technician incorrectly claims the equipment is restored, he is advised to continue troubleshooting, unless he is in a test mode. Inputs by the technician during this process are as follows:

- Changing the displayed setting of a discrete switch or continuous control, the latter by selecting from artificially defined discrete ranges (such as fully-clockwise, centered, until meter reads 10, etc.).

- Selecting a test equipment from a displayed list.

- Selecting the jack or pin to which the test equipment probe (or signal) will be attached.

- Shifting attention to a different section of the equipment (causing a new view to be displayed).

- Problem control commands, such as
  - calling for the current problem to end.
  - requesting assistance from the program
  - controlling presentation of fixed instructional sequences

Outputs consist of images displayed showing the equipment in its current state. This continually reflects actions taken by the technician, such as changing a switch setting, and responses of the simulated operational and test equipment, such as indicator and meter states.

4.2.2 Serial-Action Tasks. Serial-action tasks are those consisting of a (not necessarily fixed) sequence of discrete actions, as opposed to continuous, or tracking types of tasks. Examples of typical tasks involved are:

- Preventive maintenance (cleaning, checking, etc.)
- Alignment, calibration, and adjustment
- Repair
  - assembly/disassembly
  - replacement (discrete, monolithic, modular)
  - micro-repair
  - wiring or hardware
- Set-ups

The 2D EEMT shall provide instruction and exercise in performing such tasks by:

- Introducing, "demonstrating," and explaining the task--this will be a sequence of either static images or motion, with accompanying explanations either via text or audio, or both.

- Exercising the technician--via some relatively structured repetoire of possible interaction.

- Testing the technician--to provide a performance test pertaining to the technician's ability to generate the proper action sequence.

4.2.3 Equipment Understanding. The 2D EEMTS will be capable of administering instructions, exercises, and tests related to functional and physical organization of equipment, and to the purpose and theory of operation. This will generally follow a hierarchical structure in which detail is successively increased as the technician progresses down to sublevels in a system. Examples of technician inputs include:

- Identifying the subelements of a system, equipment, unit, module, etc.
- Identifying purposes of various elements.
- Locating functions in functional diagrams.
- Locating physical elements.
- Mapping functions into physical elements.
- Tracing flows of signals through diagrams.

The 2D EEMTS will present the visual images necessary to perform these exercises and respond to individual actions to reinforce correct responses, diagnose errors, and record progress.

4.3 Hardware Elements

The 2D EEMTS will consist of at least the following:

4.3.1 Digital Computer System. The digital compuer system shall meet all functional, operational, control, processing, and design requirements of this specification.

It will include the central processor, memory, mass storage devices, input-output devices, interface equipment, display processors and all integral power supplies and all software programs

4.3.1.1 Central Processor Requirements

4.3.1.1.1 Computer Language Capabilities. The Central Processor Unit (CPU) will be capable of executing compiled code for programs written in standard UCSD Pascal source language.

4.3.1.1.2 Computer Spare Processing Capacity. The total processing time used in the worst case path that is logically possible during any program iteration shall not exceed 50 percent of the total time available for that iteration or solution cycle.

4.3.1.2 Computer Random Access Memory (RAM) Requirements. No more than 50 percent of the main memory of the computer will be used to meet the processing and data storage requirements of this specification. The minimum acceptable size of RAM shall be 56k bytes. A timing and sizing analysis shall be performed to determine memory requirements.

4.3.1.3 Disc (Mass) Storage Requirements. Mass storage will be accomplished with magnetic disc. All process control, demonstration readiness, maintenance, test and diagnostics, utility data and initial condition files, and display page data will be contained on the disc. Not more than 50 percent of the total available storage capacity of each disc unit will be used to meet the total program and data storage requirements of this specification. The minimum acceptable capacity of mass storage to be provided will be no less than 3.5×10^6 bits. Access speed will be no greater than 200 ms/random access. The disc unit provided shall have a read error rate of no greater than 1 in 10^9 bits.

4.3.1.4 Instructor Terminal Requirements. An instructor terminal will be provided to include a keyboard with hard copy printer. The terminal will interface to any separate 2D EEMTS via a RS-232C interface. The terminal will provide the ability to initiate the various operating modes of the trainer under control of the software system. The terminal will give the instructor a means of developing or modifying trainer instructional software; loading and executing demonstration/readiness, utility, or maintenance programs; and obtaining student response history and evaluation data. The terminal provided shall be medium to low speed. The minimum acceptable speed is 300 baud.

4.3.1.5 Interface Requirements. The CPU shall have access to no less than two built-in RS-232C interfaces through which ASCII characters can pass from or to a 3D EEMTS (to be developed under separate contract) and an instructor's terminal.

4.3.2 Programming Requirements

4.3.2.1 Government Furnished Software. The main trainer programs consisting of all process control, I/O, and executive routines will be developed under a separate existing contract and will be furnished to the contractor within 3 months after contractor award. Development of instructional software will be accomplished via a proposed future contract and will not be required to fulfill the requirements of this specification.

4.3.2.2 Contracted Furnished Software

4.3.2.2.1 Commercial Computer Support Software. Commercial computer maintenance and utility programs (e.g., diagnostics, trace, debug, assembler, compiler, loader, etc.)

supplied by the manufacturer of the computer selected to implement the functional requirements of this specification shall be provided.

The maximum access time to produce a new image, in response to a sensed action by the technician, shall be 5 seconds. At any time, at least 50 images will be accessible within 2 seconds. That is, images may be grouped into sets of 50 or more, so that access to any image in the set is within 2 seconds.

Images will be displayed consistently on the viewing surface. The displayed location of a point on any image shall not deviate by more than 1 percent of the maximum image dimension. For example, if the image surface is 6 inches wide and 10 inches high, a point on any image shall be displayed consistently with a 0.1-inch radius circle.

4.3.4 Adaptive Display Device. This display device will provide the capability of producing computer-generated guidance to a student technician, in the form of alphanumerics and/or graphics, in response to his actions. It may be the same media as required for the graphic display device, although it is preferred to separate the display of simulation (content) material from pedagogical text. A split-screen or reverse (white on black background) character scheme may suffice to differentiate these two sources if the media of the graphic display and the adaptive display device are merged.

4.3.5 User Input Device. This will provide the capability of easily selecting any point on the graphics and adaptive displays to within 1/8-inch precision (i.e., 2 points 1/4-inch apart can be repeatedly selected correctly). The device will make the location available to the CPU, and in some manner produce an audio indication to confirm the entry.

The input media will allow any point on either the graphics or adaptive displays to be selected within 2 seconds, worst case. Candidate devices would include sonic digitizer, light-pen, controllable cursor (joystick, trackball), and light-beam matrix. It may be preferable that the motions used to select points be similar to those actually used on the operational equipment (i.e., touching a point is preferable to positioning a cursor with a joystick).

SPECIFICATION FOR ELECTRONIC EQUIPMENT MAINTENANCE TRAINING SYSTEM (EEMTS), THREE-DIMENSIONAL VERSION (EEMTS 3D)

1.0 INTRODUCTION

1.1 Background of Unit 1 (2D)

For several years, the Behavioral Technology Laboratories of the University of Southern California (BTL/USC) has been under contract to the Navy to develop a computer-based training system for teaching electronic maintenance techniques to naval enlisted technicians. The system simulates actual maintenance activities. The BTL system consists, essentially, of display hardware (that constitutes the trainee interface), computer and peripheral components, and compiled software program supporting the presentation. The training system controls the sequential presentation of training problems to the student naval rate (i.e., Electronic Technician (ET)), and for training and practice in logical troubleshooting. It also provides guidance to the student during the learning process and feedback on the excellence of his performance. It compiles student performance statistics for individual problems. It is capable of simulating a wide variety of specific maintenance actions; however, this simulation is "two dimensional," lacking some of the "hands-on" characteristics of traditional maintenance training conducted with operational equipment or electronic training devices.

To date, the BTL training system has undergone two phases of development. The first phase involved the design and test of an experimental model known as the Rigney system, named after its developer, the late Dr. Joseph Rigney of BTL/USC. This model was evaluated using naval enlisted technicians as subjects. The results of the evaluation were highly encouraging, leading immediately to subsequent development work.

The second phase of development has involved the design, development, and construction of a new model incorporating the following changes: (a) a change in the software language from IMLAC assembly language to UCSD Pascal, (b) the incorporation of new off-the-shelf hardware, and (c) the addition of several new training "protocols" to enhance the overall capability of the device. At the present time, this model is nearly completed. It will be available for evaluation in the very near future.

Unit 1 will be an engineering-development model of the BTL training system.

1.2 Background of Unit 2 (3D)

In a separate development, Honeywell Systems and Research Center, Minneapolis, MN was awarded a contract in September 1978 to define the characteristics of a computer-based maintenance training system incorporating digitally-controlled simulation of "hands-on" maintenance actions. This design involved the use of simulated electronic hardware and simulated test equipment to teach electronic tests and measurement to enlisted trainees. The Electronic Technician (ET) and Electronic Warfare Technician (EW) rates were selected as representative technician groups to demonstrate the feasibility of the training concept.

Honeywell first identified a group of typical electronic equipment and systems maintained by ET and EW personnel. They then conducted a commonality analysis to identify common equipment, common modules, and common circuits among the sample of equipment selected. Next, they identified, systematically, the maintenance activities required by the common equipment group. These maintenance activities included tests, measurements, calibrations, and other required maintenance actions.

Unit 2 of the prototype EEMT will be a three-dimensional, "hands-on" training system based in general on digital computer-controlled simulation technology but not necessarily on Honeywell's design. It is Unit 2 that will be developed under the present procurement.

1.3 The Present EEMT Concept (2D/3D)

About midway through Honeywell's system-definition program, it was established that some maintenance tasks could be better taught using 2D simulation techniques and that others could be better taught using 3D simulation techniques. As a result, a decision was made to procure a new maintenance training system that incorporated both 2D and 3D components by merging the two development concepts.

2.0 SCOPE

2.1 Training Situation

The new EEMT will support common-core initial skills maintenance training.

For the initial application, the ET and EW rates have been selected.

The design concept for Unit 2 is founded on the inherent simularities that exist among maintenance tasks and procedures common to operational equipment families. For the initial procurement, the families addressed are as follows: radar, communication, navigation, electronic countermeasures, and electronic surveillance.

2.2 Present Training Practices

At the present time, electronics maintenance in a variety of technical schools is taught using operational equipment. When used as a training vehicle, operational equipment tends to be costly, inflexible, subject to obsolescence, and frequently invalid. In today's cost-conscious environment, it is unrealistic to expect the various schools to have a complete range of operational equipment in sufficient quantities to rely exclusively upon that medium for the required hands-on training. The EEMTS device, when fully developed, should lessen significantly the need for costly operational equipment in a variety of applications.

2.3 Generic Training

The EEMT concept centralizes the subject matter of electronics maintenance training to its common components, emphasizing the similarity of generic signal processing functions that are found within families of equipment. The training objectives focus on functional tests and measurements and on the generic logic of troubleshooting. The trainer in its final form will bridge the gap between the fundamental, theory-oriented parts of the curricula and the equipment-specific training that follows.

2.4 General Trainer Characteristics

The general characteristics of Unit 2 are described in two documents.[1] Attachment 5, "Detail Characteristics for the Electronic Equipment Maintenance Training

[1] Attachments 5 and 6 are not included in this document but were available to contractors.

System," describes the EEMT requirement in general terms. The contractor is not required to adopt the design described therein except to the extent specified in the RFP. In the event of a conflict, the RFP takes precedence over Attachment 5. Attachment 6, "System Specification for the Three-Dimensional Unit (Unit 2) of the Electronic Equipment Maintenance Training System (EEMT)," describes one possible design concept for Unit 2 that the Navy believes will meet the requirement. The contractor is not required to comply with the provisions of that specification, nor with the design described therein, except to the extent specified in the RFP. In the event of a conflict, the RFP takes precedence.

The software for Unit 1 is well along in development and must be retained. Therefore, the software requirement for Unit 1 is UCSD Pascal. There is no specified software language requirement for Unit 2. However, Unit 2 will be required to "talk" to Unit 1 via an RS-232 interface.

2.5 Use Characteristics

Unit 1 can be used as a "stand-alone" training device, for both Class "A" and Class "C" applications. In addition, it is the "system controller" in that it can direct Unit 2 through the administration of a series of training exercises. Unit 1 and Unit 2 can be connected together by cable to implement a sequence of exercises using both 2D and 3D components within the same problem series. Unit 1 "owns" the interface. The characteristics of this interface are described in the functional specification of Unit 1.

Unit 2, at the offeror's option, can be proposed as a "stand-alone" unit, capable of operating in the absence of Unit 1, or as a "passive" unit, receiving direction from Unit 1 as to which of a number of problems to administer. In either case, a computer within Unit 2 initiates and controls all actions and elements that are required to simulate a specific 3D maintenance problem. Unit 1 incorporates the capability to compile statistics on accuracy and speed of performance for each problem and for problem sets. It also incorporates statistical programs to compile a record of student performance over time. Advantage may be taken of these capabilities, if desired.

At the contractor's option, feedback to the trainee concerning activities performed on Unit 2 can be passed to Unit 1 for display to the trainee, saving a display on Unit 2. Or, Unit 2 could initiate and display its own feedback information. The Unit 2 contractor is not excluded for the duplication of Unit 1 features that may be required to accomplish the program direction, trainee feedback, and performance statistics functions if, in his judgment, it will enable Unit 2 to "stand alone." However, the cost impact of this redundancy should be weighed carefully.

2.6 Form of the Equipment

The contractor shall design and develop two identical items of a "breadboard" for Unit 2. This breadboard must successfully complete operational evaluation and factory acceptance testing as a condition of further development and/or subsequent procurement in production quantities.

The government shall have an option to extend the size of the original "buy" up to two additional items of Unit 2 at any time during the contract.

2.7 Equipment Simulated

Unit 2 must incorporate 3D elements of typical equipment within the five families identified earlier: radar, communications, navigation, electronic countermeasures, and electronic surveillance. The simulation must incorporate "functional packaging"; that is, a correspondence must be maintained between the functional and the constructional characteristics of the simulated equipment. If, for example, the communications unit were designed to contain a (generic) receiver, a transmitter, a T/R switch, and an antenna, each of those functional sections should be identifiable physically by the trainee. Simulated electrical functions cannot be distributed through more than a single, identifiable, section or subsection of the Unit 2 equipment.

2.8 Simulation Technology

Unit 2 must be based in general on digital simulation technology. Some existing maintenance training technologies are known to employ a combination of digital and analog simulation. A hybrid approach is acceptable provided that the major emphasis of the simulation is of the digital synthetic type.

The task of developing software for Unit 1 has been given to BTL/USC. The sofware for Unit 2 will be developed by the winning contractor. The winning contractors for Unit 1 and Unit 2 shall develop the hardware and shall interface with BTL as required. It is not expected that a prime contractor/subcontractor relationship will have to be established between the winning hardware contractor(s) and BTL since the software will largely be in place by the time the hardware implementation is begun.

2.9 Training Objectives and Tasks

A series of training objectives has been identified that must be met by EEMT. A general summary of these objectives follows:

1. Individualized instruction and guided practice in the functional organization of individual families of naval electronic equipment and systems.

2. Instruction in the purpose and operation of functional units, sections, groups, circuits, or other functional elements as appropriate to each equipment family.

3. Instruction and practice in logical troubleshooting including the following specific task areas:

a. Observations/isolation of symptom set.

b. Formulation of hypotheses including interpretation of functional block diagrams, interpretation of schematic diagrams, and use of a priori fault information.

c. Performance of diagnostic tests including initiation of system states, location of test points, performance of test and measurements, use of test equipment, use of BITE, ATE, or SATE.

d. Verification of hypotheses or formulation of new hypotheses.

e. Repair/replacement techniques for defective components and modules.

f. Performance of in-place adaptive corrections.

g. Verification of proper equipment operation.

h. Completion of maintenance documentation.

4. Instruction and practice in performing operational checks and adjustments, including alignment and calibration actions appropriate to the equipment family at issue.

5. Instruction and practice in the use of maintenance manual and diagrams.

6. Instruction and practice in preventive maintenance procedures.

A group of support documents (Attachment 7, Appendix)[2] is provided with this RFP to prospective offerors. These documents have been prepared by Honeywell personnel as part of the previous system-definition contract. One such document, "Training Requirements Analysis Report," identifies and describes tasks that ET and EW personnel must perform. The list is lengthy but much overlap exists among tasks. The Unit 2 prospective offeror is encouraged to examine this list because it is believed that software development costs may depend importantly on the number of tasks to be simulated and perhaps on their complexity. The contractor is not required to incorporate all training tasks (although that is a desirable goal), if that approach proves non-cost-effective. The contractor may wish to select a group for incorporation that is a subset of the entire group, provided that the subset is representative of the group in terms of diversity, eliminating redundancy.

2.10 Trainee Interfaces

The trainee interfaces for Unit 2 are, at minimum, the simulated electronic equipment within five families, the test equipment, and, as an option, a CRT display for trainee interaction.

2.11 Use Pattern

The EEMT will be designed for use 16 hours per day (2 shifts), 50 weeks per year. Scheduled maintenance will be performed at night. Life expectancy is a minimum of 10 years.

Unit 2 is intended for normal classroom or laboratory use with normal power and lighting conditions and with no unusual facility of plant requirements. The unit will be caster-mounted to allow easy movement from room to room.

2.12 Technologies to be Simulated

Unit 2 must simulate several technologies that are common to equipments maintained by ET and EW technicians: (1) vacuum-tube, discrete-component technology, (2) modularized, discrete-component technology, (3) modularized, integrated-circuit technology, and (4) modularized, monolithic technology (MSI, LSI).

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[2]Attachment 7 is not included in this document but was available to contractors.

2.13 Maintenance Philosophy

The EEMTS shall be designed to be maintained by trained Navy technicians. Maintenance will be simplified by the use of diagnostic programs/routines to isolate failed assemblies. Readily available and clearly marked test points shall be provided to further isolate the failed module that can then be removed and replaced to ensure optimum availability during student training hours. The removed modules will be tested and repaired on a test bench away from the training area. Optimum interchangeability and use of standardized equipment shall be a firm design requirement to keep range and depth of spares to a minimum.

Organizational maintenance will be the responsibility of the user agency. Intermediate maintenance will be performed by trained personnel on-site at a location physically removed from the training area. Depot maintenance will be performed on material requiring major overhaul, complete rebuild, or specialized skills (i.e., computer memory).

3.0 APPLICABLE DOCUMENTS

3.1 Mil Specs and Standards

3.1.1 Military, MIL-T-23991, "Training Devices, Military, General Specification for" (interfaces only).

3.1.2 Maintainability, MIL-STD-470, "Maintainability Program Requirements for Systems and Equipment"

3.1.3 Maintainability Demonstration, MIL-STD-471, "Maintainability Demonstration"

3.1.4 Reliability, MIL-STD-785, "Reliability Program for Systems and Equipment Development and Production"

3.1.5 Reliability Test, MIL-STD-781C, "Reliability Tests; Exponential Distribution"

3.1.6 Human Engineering, MIL-H-46855A, "Human Engineering Requirements for Military Systems, Equipment, and Facilities"

3.1.7 Human Engineering, MIL-STD-1472, "Human Engineering Design criteria for Military Systems, Equipment, and Facilities"

3.1.8 Quality Assurance, MIL-Q-9858A, "Quality Program Requirements"

3.1.9 MIL-P-23189

3.1.10 MIL-I-45208

3.1.11 MIL-M-82376

3.1.12 MIL-Q-9858

4.0 REQUIRED CONTRACTOR TASKS

The contractor shall furnish the required material ' abor to design, develop, test, and support Unit 2 in accordance with his contract award, and within the constraints of the governing documents.

4.1 Hardware Requirements

The contractor shall be responsible for the development or purchase of all hardware. His designs shall meet all performance requirements and mandatory design features identified in this RFP; however, the specific implementation of the remaining requirements will be left to the contractor, in accordance with his baseline design. The selection of a computer for Unit 2 also shall be left to the contractor. The proposal must identify the contractor's selection and contain adequate rationale. The use of off-the-shelf components for Unit 2 is desired whenever possible.

4.2 Maintainability Requirements

Maintainability requirements will be in accordance with MIL-STD-470. The contractor must meet the requirement of 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, and 5.11 of MIL-STD-470 to be presented at design reviews. No written maintainability program plan is required.

4.3 Safety

The provisin of Requirement 1 of MIL-STD-454 shall be used as a design guide.

4.4 Human Engineering

The provisions of MIL-STD-1472 shall be used as a design guide.