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THE MAINTENANCE TASK SIMULATOR-1 (MTS-1): A DEVICE FOR ELECTRONIC MAINTENANCE RESEARCH

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FOREWORD

This study was initiated by the Behavioral Sciences Laboratory of the Aerospace Medical Research Laboratories, Aerospace Medical Division, Wright-Patterson Air Force Base, Ohio. This report represents a portion of the applied research program conducted under Task 171004, "Techniques for Training, Aiding and Evaluating the Performance of Technical Tasks," of Project 1710, "Training, Personnel and Psychological Stress Aspects of Bioastronautics." Dr. Gordon A. Eckstrand, Chief, Training Research Division, was the Project Scientist. Dr. Ross L. Morgan, Chief, Technical Training Branch, was the Task Scientist.

The Maintenance Task Simulator-1 (MTS-1) described in this report was developed under Contract AF 33(657)10052 with Applied Science Associates, Inc. The Principal Investigator on this research contract was Dr. John D. Folley, Jr., who conceived the idea of such a simulator. The Research Technician was Mr. Thomas K. Elliott, who designed and fabricated the device. Dr. John A. Modrick of the Training Research Division initiated the contract for the Aerospace Medical Research Laboratories and Mr. John P. Foley, Jr. of the Technical Training Branch was the Contract Monitor. The research sponsored by this contract was initiated in October 1962 and completed in June 1964.

This technical report has been reviewed and is approved.

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ABSTRACT

The Maintenance Task Simulator (MTS-1) is a low priced task simulation device, specially constructed for research on performance aids used in conjunction with electronic maintenance. The device can present many complex electronic control-display panel configurations. The control-display panel is composed of a variety of modules which may contain a control or display or be blank. The device also contains sensing and recording circuitry, which provides a time-referenced record of control positions and sequence of manipulations by the subject. The device can support such research as determining the various skills and concepts required by the technician in performing various levels of electronic maintenance and developing effective techniques for evaluating the proficiency of electronic maintenance personnel. The logical next step would be to modify the MTS-1 for research on malfunction isolation tasks, ie, the portion of the troubleshooting task conducted behind the front panel, after localization has been done, up to but not including the point of replacing the defective component.

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INTRODUCTION

The Maintenance Task Simulator-1 (MTS-1) shown on Figure 1 provides equipment simulation for the study of such front-panel tasks as equipment checkout and malfunction localization. The MTS-1 was designed to overcome the difficulties inherent in the use of operational equipment for research on electronics maintenance tasks, either in the operational environment or in the laboratory, without sacrificing any of the significant aspects of task performance.

Effective research on electronics maintenance behavior requires that certain situational conditions be met, which cannot be met effectively through the use of operational equipment in the field or through fragmentation of the tasks into pencil-and-paper, part-task operations. In the operational environment, the researcher does not have control over the situation or the equipment. The relatively high complexity of equipment typically used for this kind of study results in a high failure rate, and the failures disrupt the study. Also, the collectors influence the behavior being observed.

Although paper-and-pencil fragments of tasks may effectively simulate portions of the cognitive parts of the task, they eliminate most of the situational factors and any of the relevant perceptual-motor factors that bear on performance. The relationship between performance on the pencil-and-paper tasks and performance on actual tasks is not usually known.

A compromise between these two extremes is to set up operational equipment in a laboratory and use this as the experimental vehicle. While this is a step in the right direction it also has serious drawbacks. First, it may be extremely expensive. A quarter of a million dollars is not an uncommon purchase price for this kind of equipment. Second, in addition to a high initial cost, it may be very expensive to maintain. Usually the services of a full-time technical representative are required. Third, even with a full-time technical representative, the equipment tends to fail relatively often, thereby disrupting the experimentation. Fourth, as in the operational situation, the data on performance must be collected by an observer, or else very complex changes in the equipment must be made in order to achieve automatic recording. Fifth, it is difficult to modify the equipment to vary the tasks being studied. The researcher is limited to using the particular equipment configuration he has available.

The MTS-1 represents an attempt to provide a reliable, low cost, high-fidelity simulator which incorporates automatic data recording and which avoids the above mentioned disadvantages associated with the use of operational equipment.

The following sections of the report deal, first, with the MTS-1 hardware and its operation, then with the rationale on which its design is based, and, finally, with its capabilities and limitations as a research tool.

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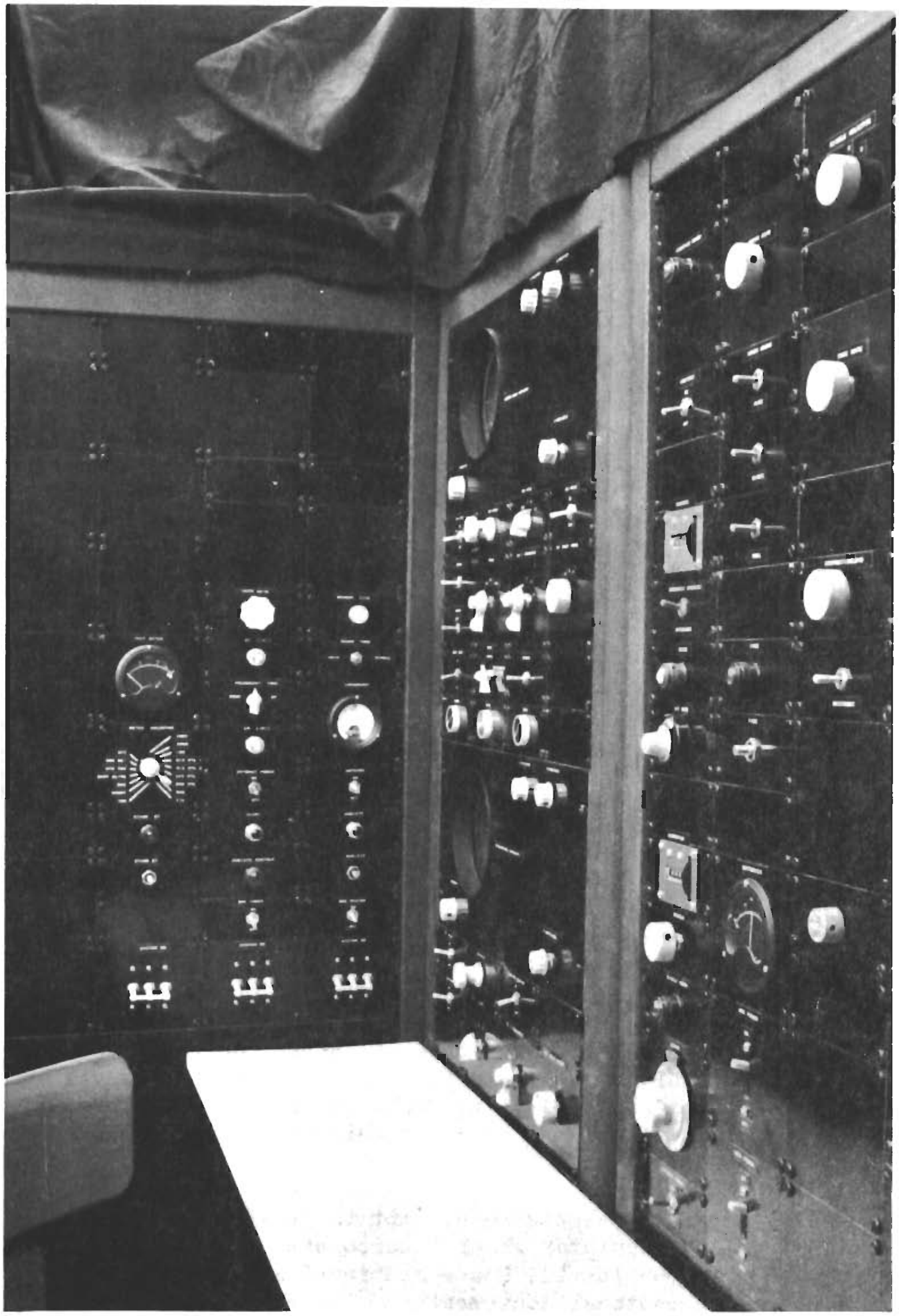

Figure 1. The MTS-1

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DESCRIPTION OF THE MTS-1

The major equipment divisions of the MTS-1, described below, are:

> The control-display panel, composed of a variety of modules which may contain a control or display, or be blank.
>
> The sensing and recording circuitry, which provides a time-referenced record of control positions and sequence of manipulations by the subject.
>
> The power supplies.
>
> The structural framework.

Control-Display Panel

The front-panel configuration presented by the MTS-1 varies with the equipment being simulated. Figures 2 and 3 show it set up to simulate a portion of the AN/ASB-4 bombing-navigation system.

The upper 33 inches of the open front-panel space (61-1/4 by 19-1/4 inches) is fitted with an aluminum framework on which the control-display modules are mounted from the front. Figure 4 shows examples of two of these modules. The lower part of the front-panel space is covered with a brushed-surface, black phenolic laminate panel.

A square, U-shaped bracket is attached to the rear of each module. This bracket contains several pin jacks used for interconnection of the modules. (See figure 5). The jacks are color coded as follows:

Red	-	Regulated power supply
Brown	-	Unregulated power supply
Black	-	System ground
Green	-	Digital voltmeter
Yellow	-	Another module
White	-	Sensing

Interconnection

Sensing circuitry and scopes are mounted on the inside of two of the racks (figure 6). Modules are connected into the system with standard patch cords that plug into the jacks on the backs of the modules. A patching panel (figure 7) is mounted in each cabinet to provide operating voltages, system ground, and multiple connections through which modules may be interconnected. Modules may also be connected directly to one another.

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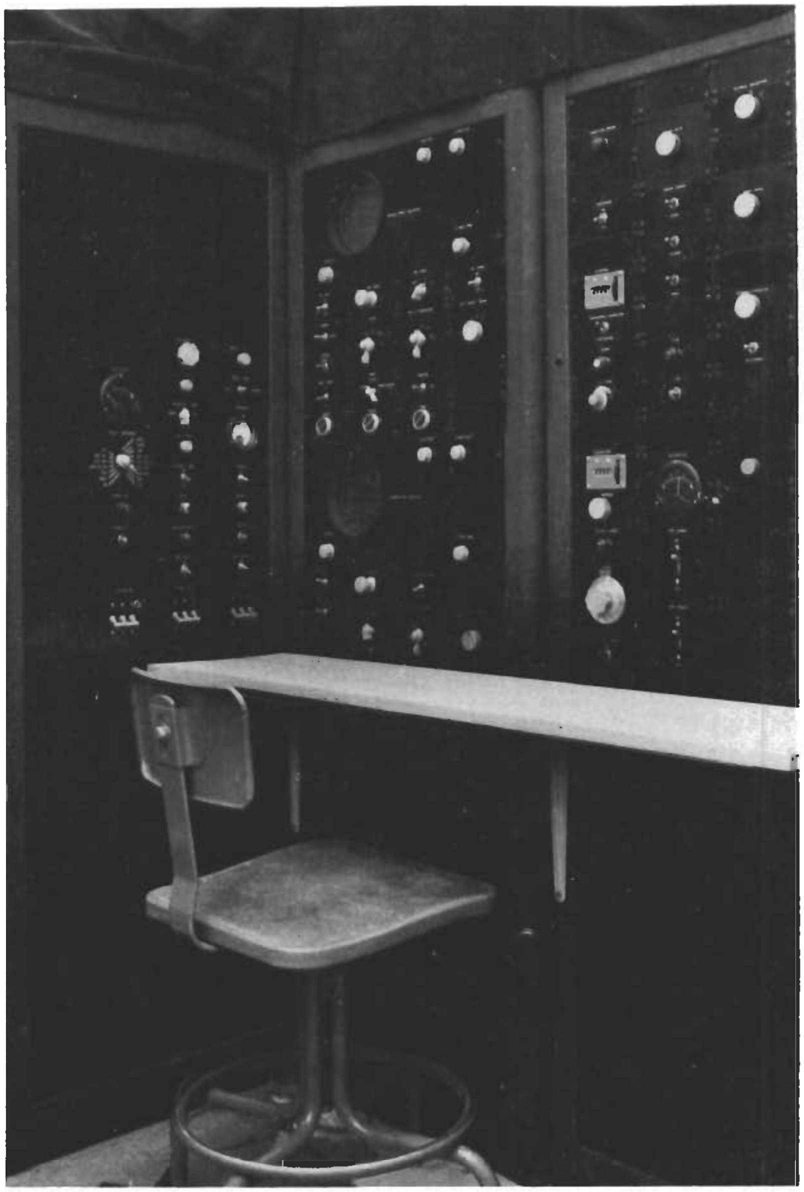

Figure 2. Simulation of the AN/ASB-4 High Speed Bombing Radar and Radar Data Presentation Set Sections

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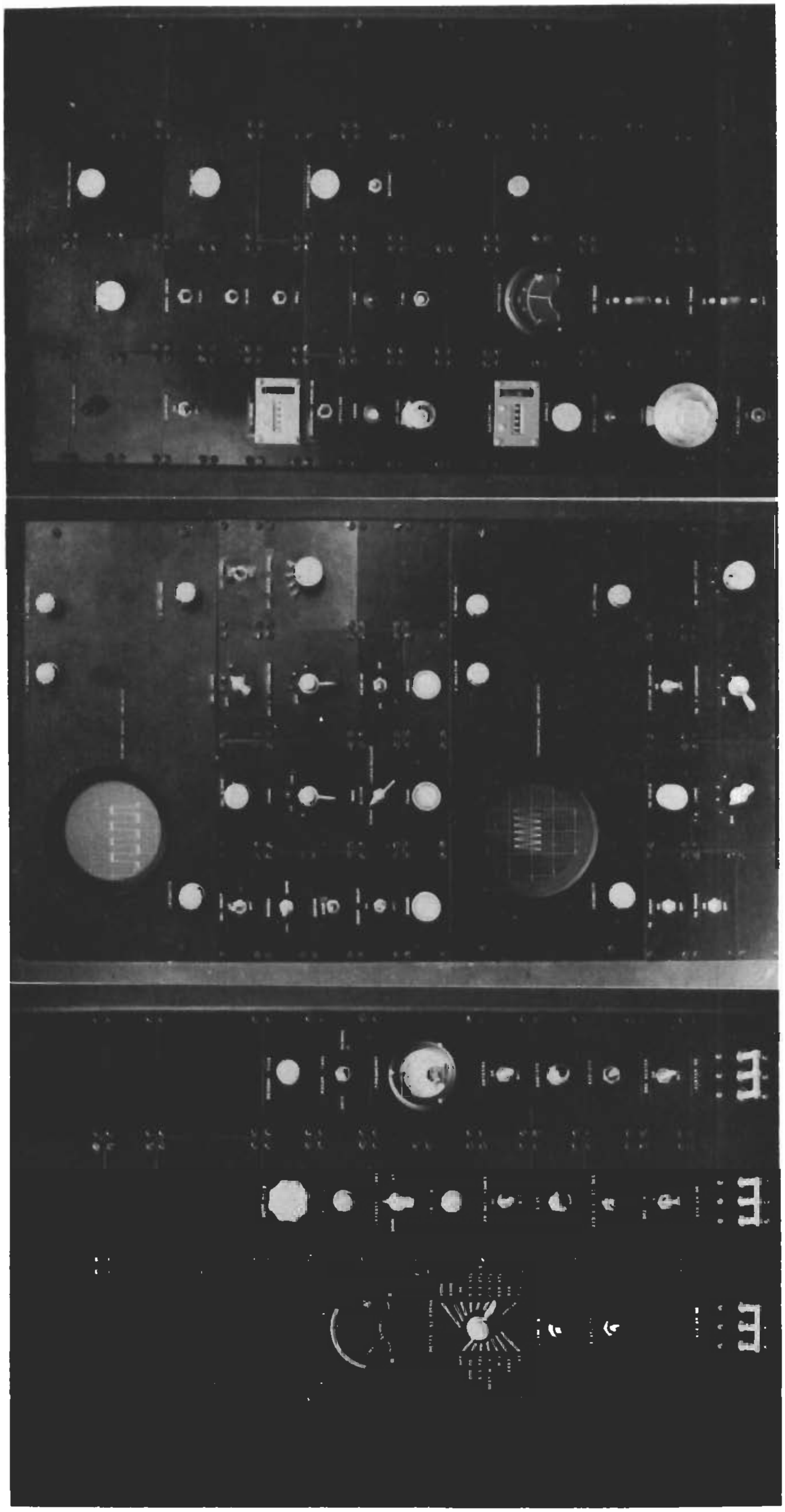

Figure 3. Detail of Three Front-Panel Sections

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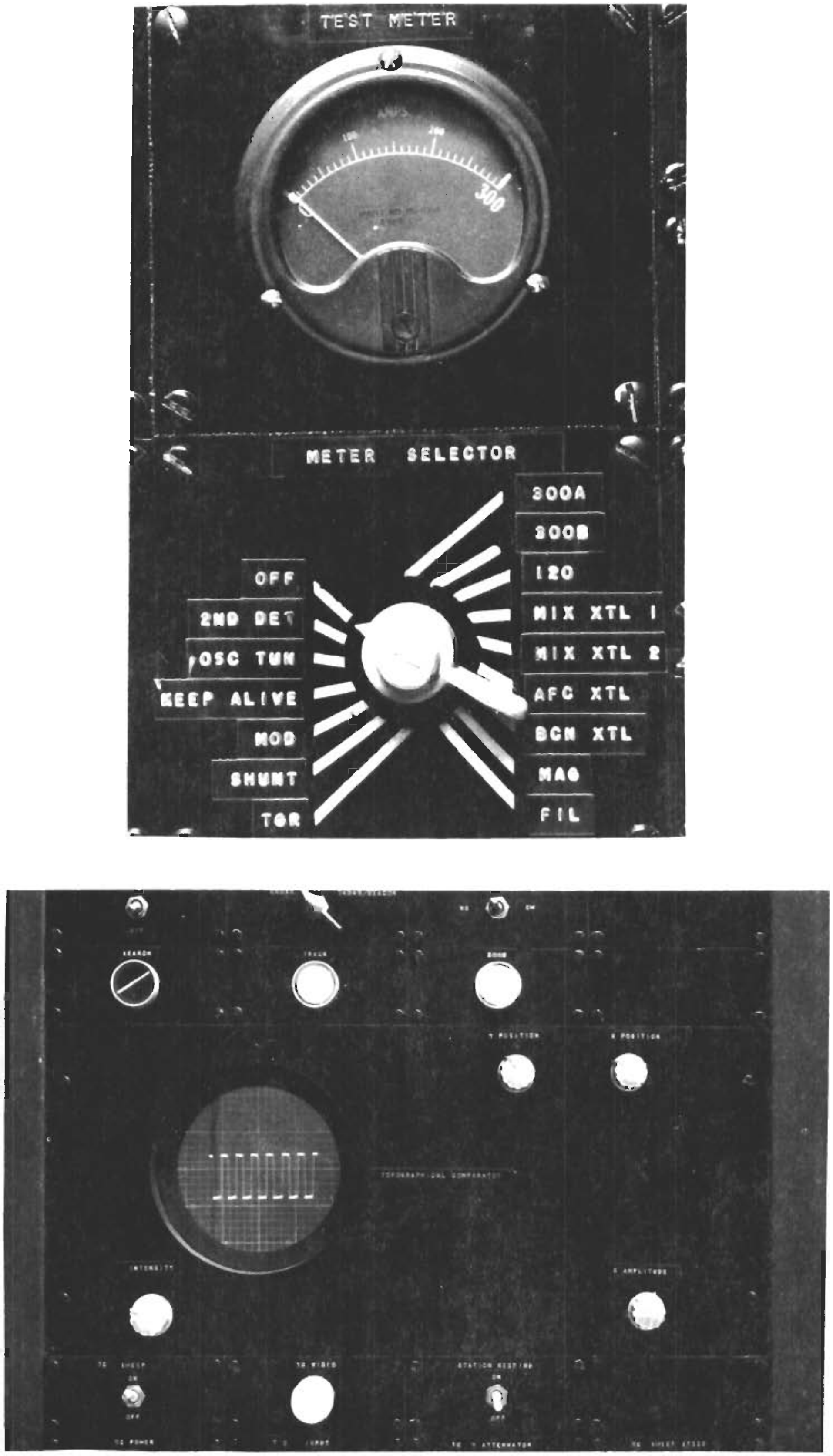

Figure 4. Test Meter and Meter Selector Modules

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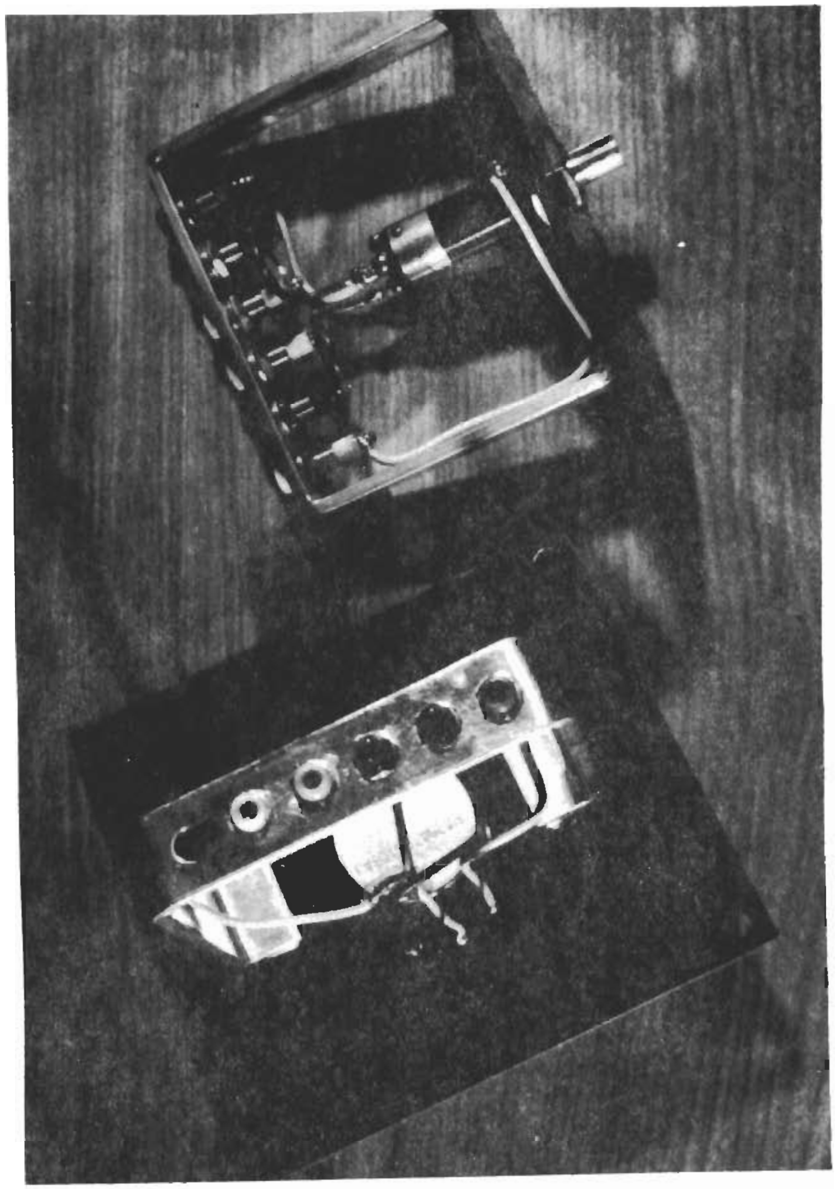

Figure 5. Detail of a Typical Module

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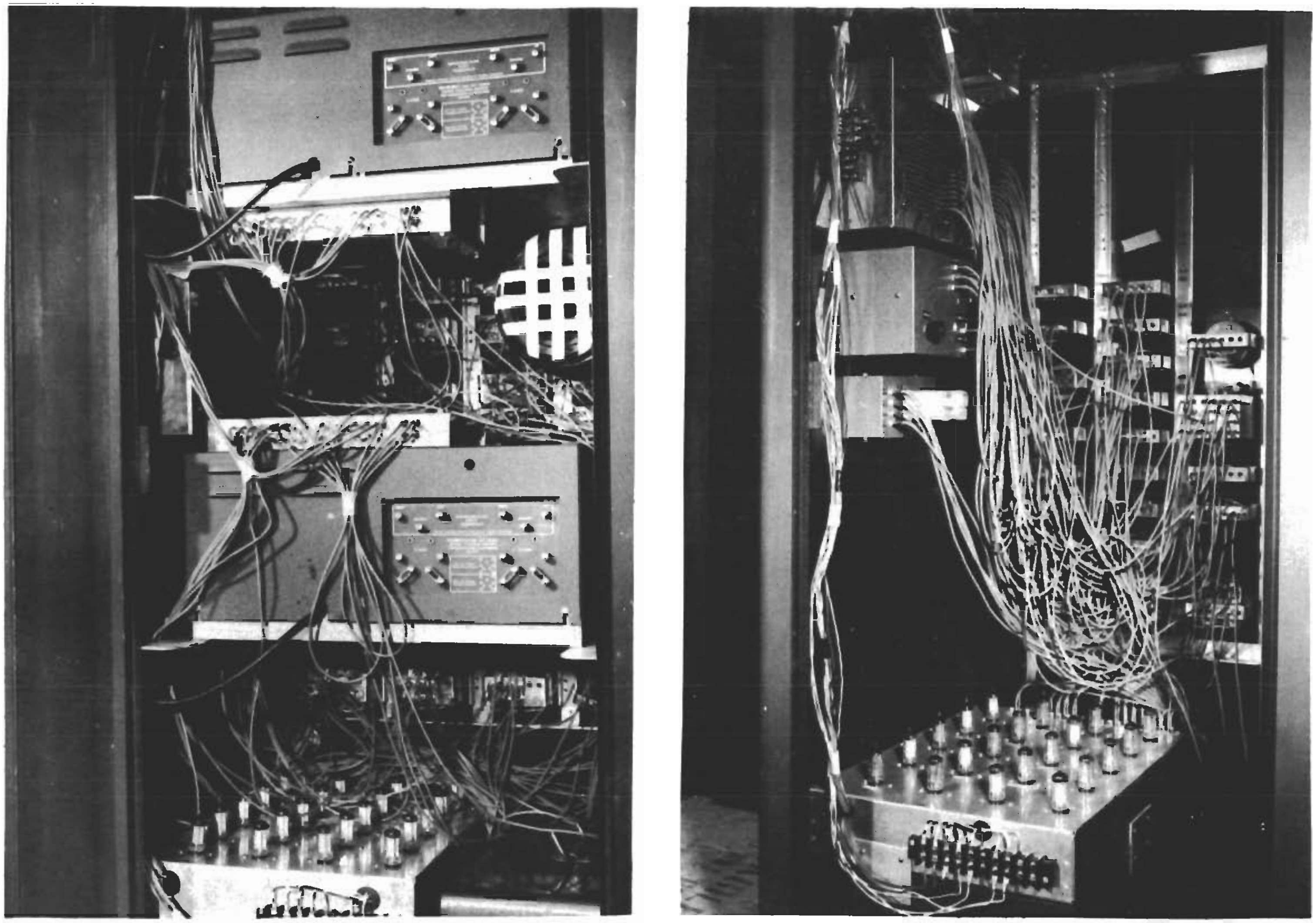

Figure 6. Interior of Two Racks Showing Sensing Circuitry (Bottom Both) Scopes (Top & Center Right) and Accessory Circuitry (Center Left)

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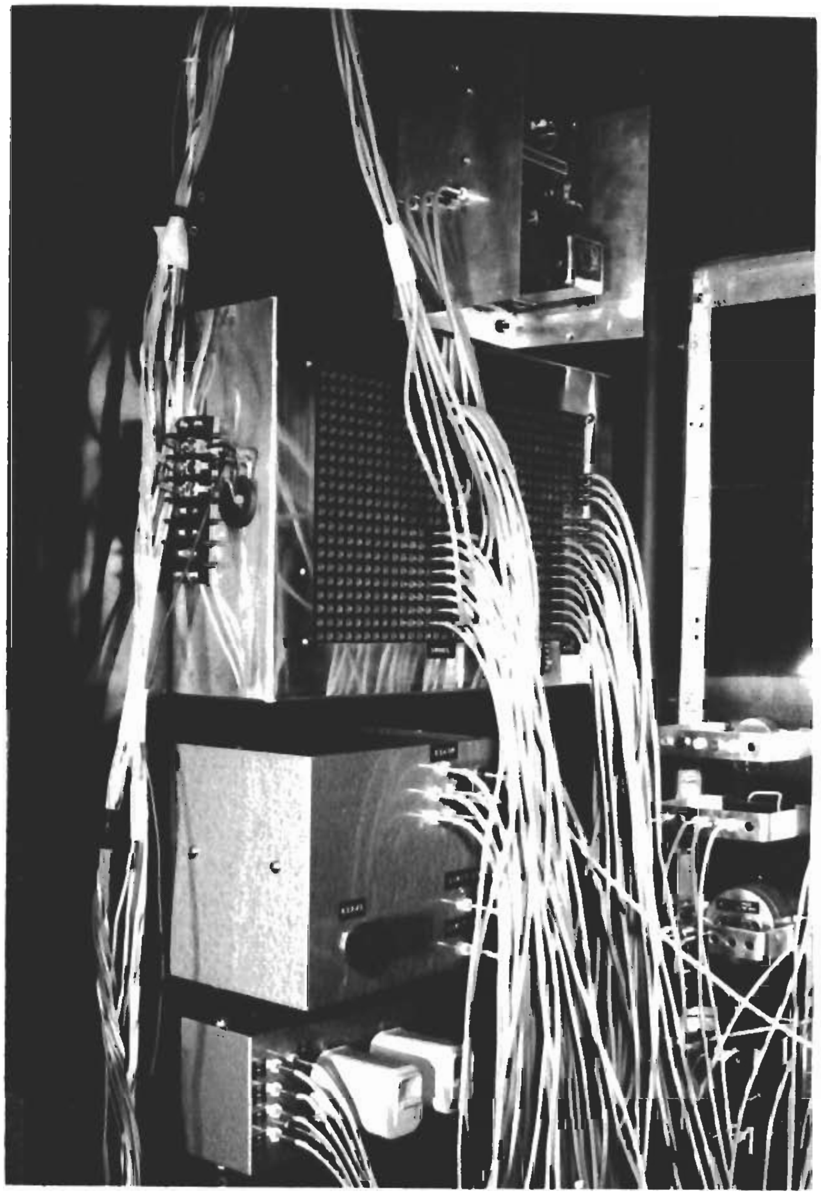

Figure 7. Patch Board and Accessory Circuitry

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Modules may be interconnected in a large number of ways, in addition to the obvious way in which a single control operates a single display. Controls may be connected in series, so that both must be operated to produce a desired output indication, or they may be connected in parallel to produce other kinds of interactions. Controls may be used to select which other controls will operate displays. Combinations of the above modes of operation may be employed as well. The particular operating relationships to patch together in a given instance are determined by analysis of the operation of the equipment to be simulated.

Unusual control-display relationships may be produced by inserting accessory circuits. Figure 7 shows three such accessory circuits. The box at the top of figure 7 contains a small, reversible, variable-speed motor which drives a potentiometer that may operate lights or meters, and the motor may be operated by a variety of controls. The box below the patch field in figure 7 contains a time-delay circuit, continuously variable from 0 to 5 minutes, which may be inserted between a switch and any other control(s) or display(s).

Sensing and Recording System (Figures 8 and 9)

A printed record is made of the response, each time the operator touches a control. When the operator touches a control, the recorder immediately prints the name of the control touched, the setting of the control when it was touched, and the time the control was touched. When the operator releases the control, whether or not he changed its setting, the recorder again prints the name of the control, the time, and the control setting when it was released. As long as the operator remains in contact with the control, no other operation can be recorded. It is impossible to operate a single control so fast that the operation will not be recorded. The rate of operation of a series of controls may not exceed three per second, however, if all operations are to be recorded.

The sensing and recording system consists of five parts:

Electrically conductive controls on the modules. Controls with nonmetallic handles or knobs are painted with a lacquer containing metallic silver to make them conductive.

One sensing circuit for each control. This circuit closes a relay when the subject touches a control.

A digital voltmeter, which indicates the position of the touched control in terms of a DC voltage which varies between 0 and 28 volts.

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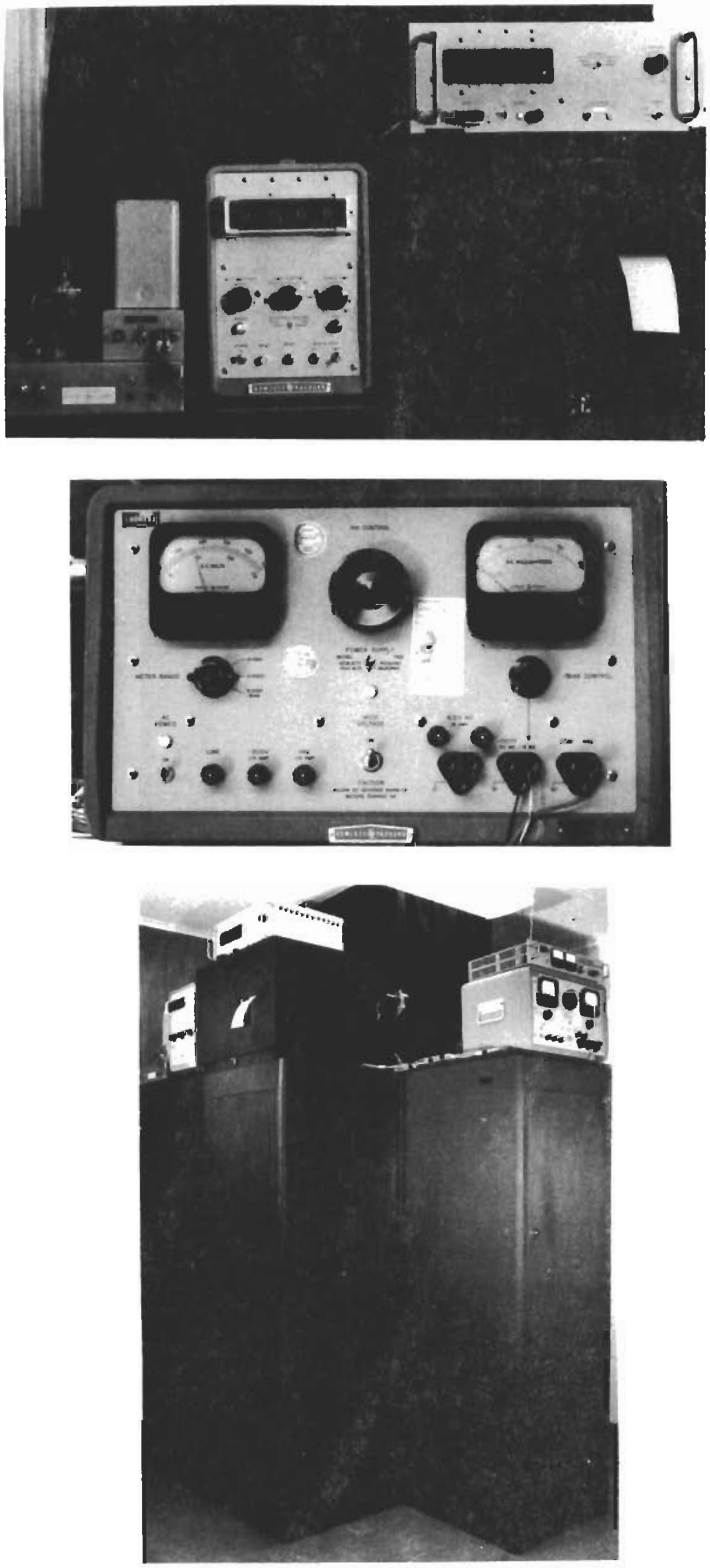

Figure 8. Recording Apparatus and Power Supplies

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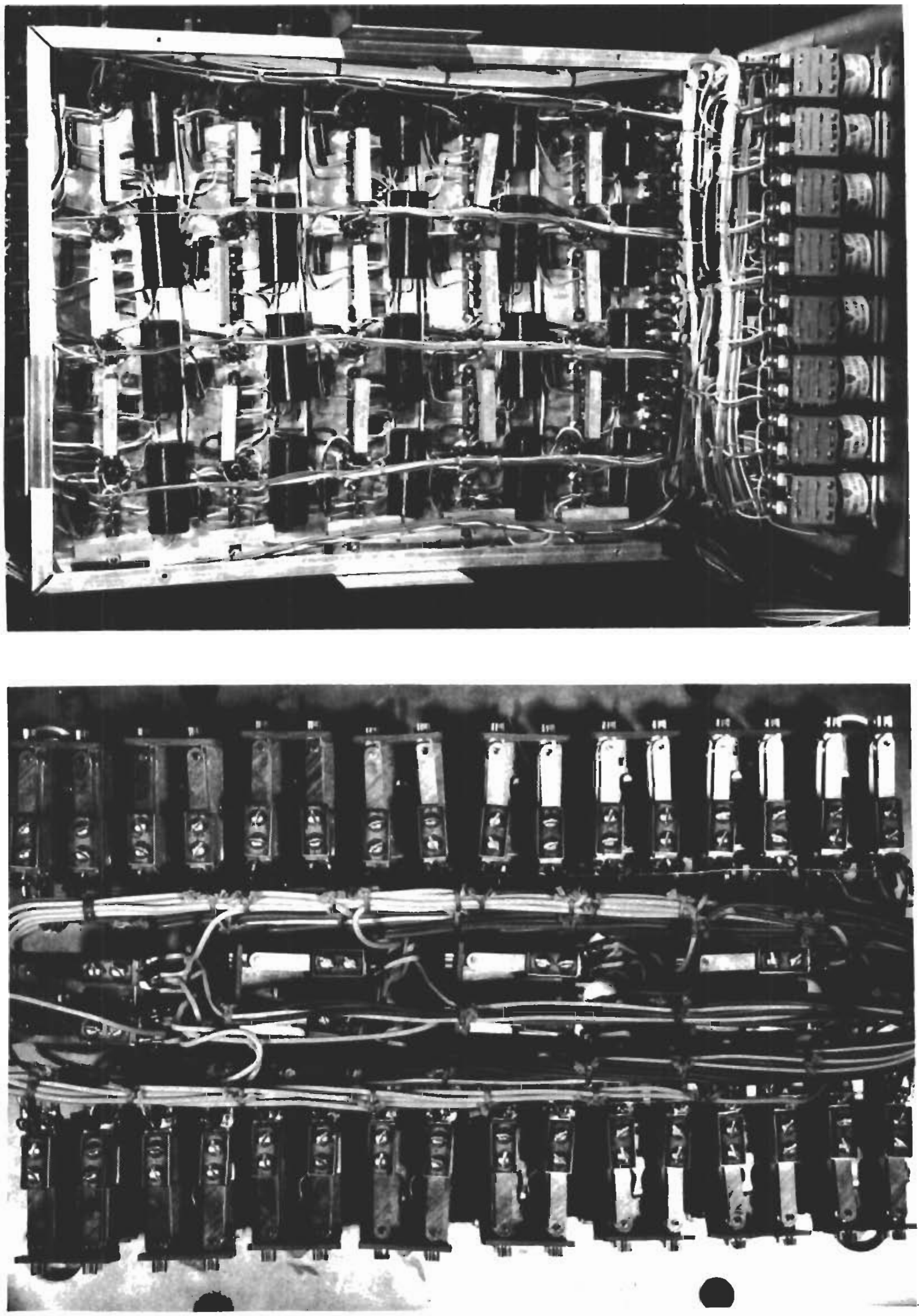

Figure 9. Sensing Circuitry, Interior View

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An electronic timer, which provides time inputs to the recorder in tenths of seconds.

A high-speed printer, which records time and response data on a printed tape.

The recording process is accomplished in the following manner. The knob or handle on each control is connected to its own capacitance relay through the control shaft and patch cords. This relay closes on contact between the body capacitance of the subject and the control he touches. When one relay is energized, all others are blocked. The relay closure connects the control which was touched to the digital voltmeter which reads the voltage on the control, 0 to +28.0 VDC, and delivers the reading, along with a print command, to the printer. At the same time, the relay inputs the two-digit coded name of the control to the printer. When the printer prints, it also records the time, which it takes from the electronic counter. Time is recorded in tenths of seconds up to 9,999.

Once energized, the relay is prevented from de-energizing for a sufficient time to permit all necessary information to enter the printer. When the relay does de-energize, due to the release of the control by the operator, the digital voltmeter again samples the voltage on the control and causes the printer to print it, along with the time and the control identification.

The functional block diagram of the MTS-1 shown in figure 10 provides a graphic representation of the recording process. Figure 11 shows a performance record tape.

At present, the system can sense and record responses on sixty different controls. Although each cabinet of the MTS-1 has sensing circuits for 20 channels, unused circuits can be "borrowed" from the other cabinets by cross-patching, should one panel contain more than 20 controls.

Power Supplies

Electrical power for the controls and displays is supplied, by a closely-regulated, ripple-free, 28-volt-DC power supply, through the patch board (figure 7) in each cabinet. A 28-volt-AC supply is available for the operation of lights and other circuitry where regulation is not necessary. For reasons of safety, all controls and displays are operated by 28 volts. If a display (or control) requires higher voltages for its operation (scopes, for example), these voltages are isolated from the front panel by low-voltage relays.

The power supply for the sensing circuits provides + 150 volts DC and - 5 volts DC. A separate supply provides 6.3 volts AC for filaments. 117 volts AC is available from several receptacles on the top of each cabinet. The total power requirement for the MTS-1 is less than 2,500 watts.

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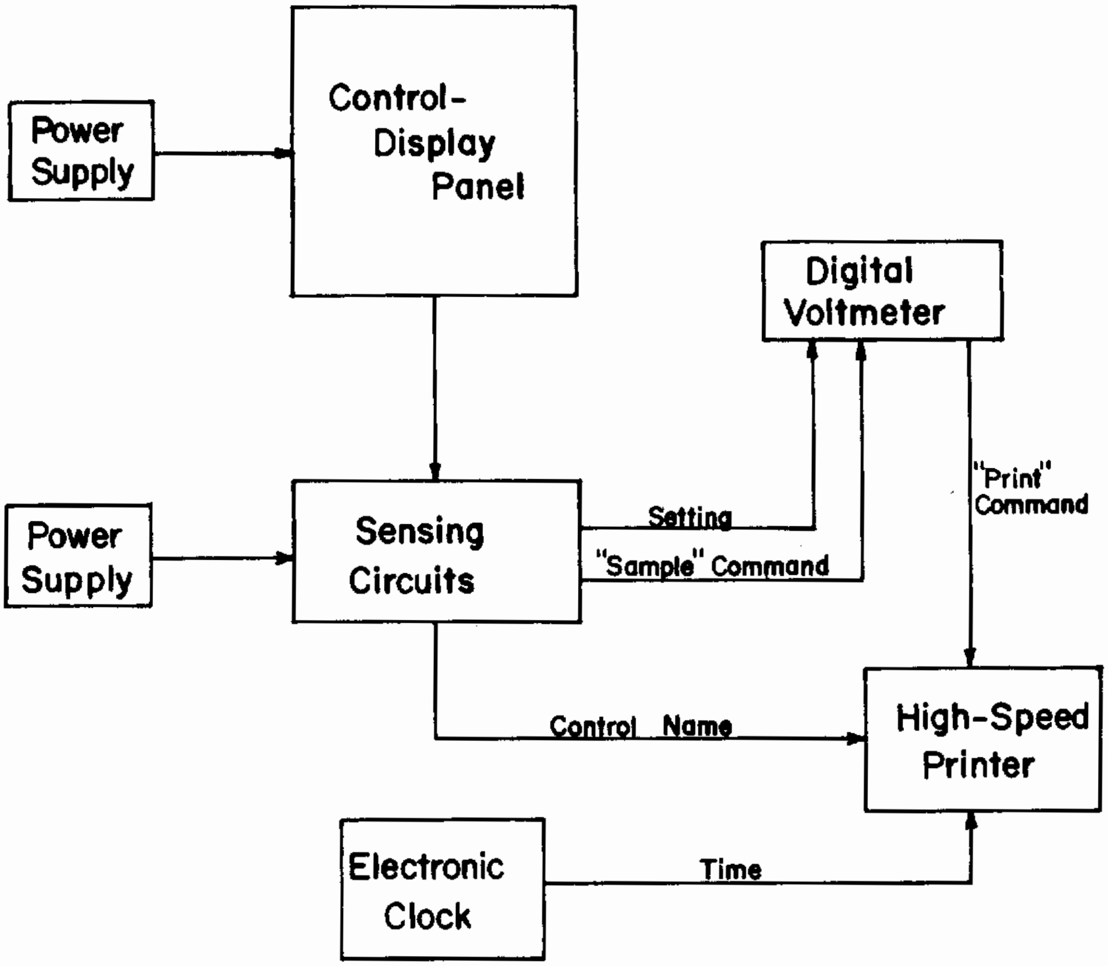

Figure 10 **MTS-1**

Functional Block Diagram

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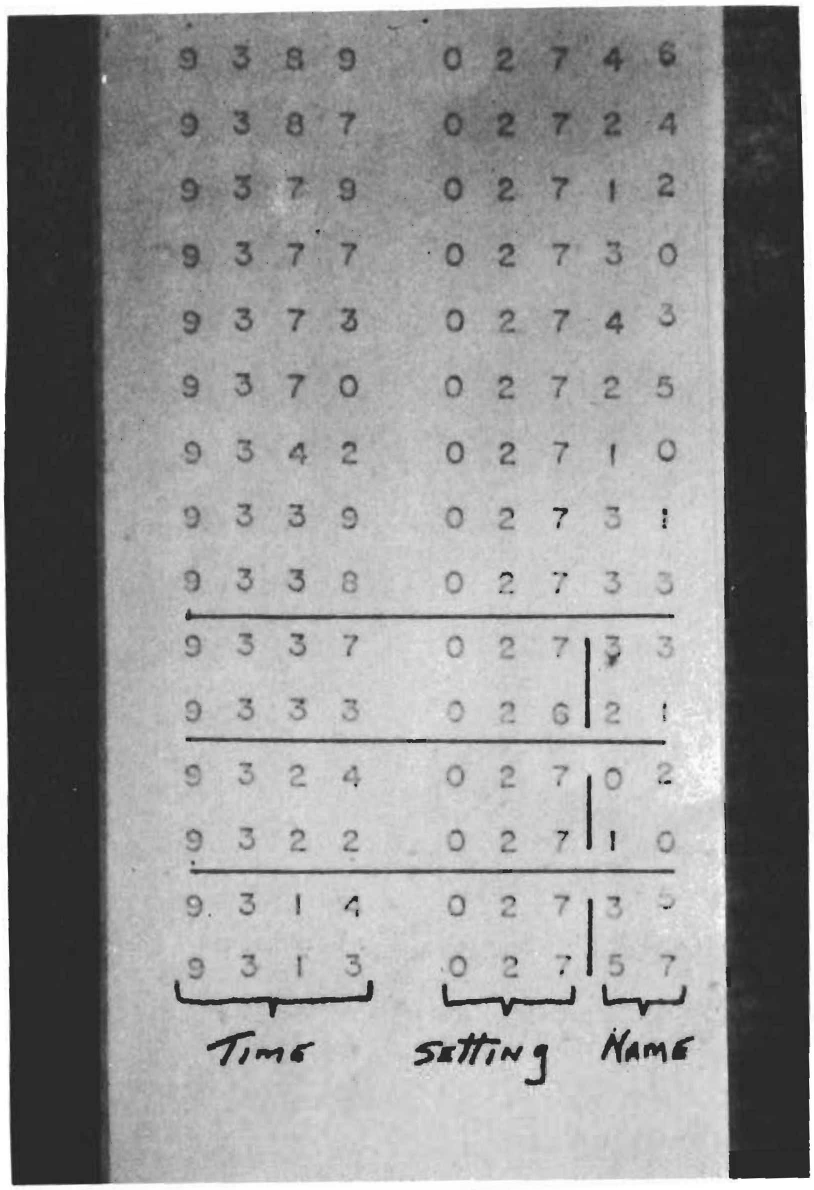

Figure 11

Performance Record Tape

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Structural Framework

The supporting structure of the MTS-1 is presently composed of three standard, steel relay-rack cabinets, 69-1/2 by 23-5/8 by 23-5/8 inches, which contain or support all of the equipment associated with the device. The bottom of each cabinet is fitted with a shelf which supports part of the recording equipment. Auxiliary apparatus may be placed on the shelf or affixed to the interior walls of the cabinets. The tops of the cabinets support power supplies, recording equipment, and external wiring, resting on wooden plates.

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RATIONALE FOR MTS-1 DESIGN

General

The MTS-1 was designed to achieve two objectives:

To provide a realistic equipment element for simulation of checkout and fault localization tasks without the disadvantages of complex operational equipment.

To provide a device specifically suited for use in research on performance of these types of tasks.

Simulation

Achievement of the first objective required a careful analysis of the tasks to determine what aspects of equipment, both physical and functional, were important in performance of the tasks. Only those equipment attributes thought to be essential for effective simulation of the tasks were to be included in the MTS-1.

Characterizations of the kinds of tasks for which the MTS-1 is intended, and the conclusions reached regarding the equipment attributes to be simulated are as follows:

Checkout Procedures

These are usually performed either as a part of equipment turn-on or on a scheduled basis to give assurance that equipment is operating properly. The checkout task may be described as one of operating controls in a predetermined sequence and manner, and observing displays to see that outputs fall within prescribed tolerance limits.

The behavioral requirements of this type of task are of two kinds:

Knowledge of the sequence in which the controls are to be operated and the displays observed.

Ability to operate the controls and read the displays correctly.

Although it may appear that these two requirements are quite independent and could validly be studied separately, this is not necessarily the case. The cueing effects or the disrupting effects of actually performing the individual steps in the procedure are not known. From one point of view, the performance of the individual steps can be considered a disruptive activity intervening between items in a serial memory list (the procedural sequence). On

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the other hand, the presence of the visual and other cues provided by the controls and displays may facilitate learning and recall of the procedural sequence. Because of this uncertainty, it is concluded that the configuration of controls and displays should be preserved in the simulator if the sequential aspect of the task is to be studied with confidence.

The difficulty of various control operations and display readings varies with the abilities of the subjects. Many operations and readings could be within the normal repertoire of one group of subjects, but may not be within the repertoire of another group. It seems probable that this kind of variation would have significant effect on the learning and performance of checkout procedures. Since these effects are not known, it was concluded that operable controls and readable displays should be used in the MTS-1 if performance of individual procedural steps were to be studied with confidence.

Since the entire task is performed using only the controls and displays on the front panel, it was concluded that interconnections internal to the equipment being simulated could be ignored. All that was required was enough internal connection to make the appropriate displays respond to the various controls. The electrical signals that would do this could be of any convenient kind. Displays, other than oscilloscopes, could be made to appear authentic by choice of appropriate scales. Thus, for example, a meter labeled "Frequency" and calibrated in megacycles could be operated by a control on a potentiometer that did nothing but vary a low DC voltage connected across the meter. The subject would not be aware of the subterfuge as he adjusted the "Frequency" in accordance with the specified procedure.

Localization

This activity takes place when an out-of-tolerance indication is observed. It is the first stage in the process of identifying and clearning a malfunction.

Localization likewise imposes two behavioral requirements:

Identifying out-of-tolerance display indications to produce a pattern of symptoms.

Deducing from the symptom pattern and the system data flow, the components which can or cannot contain the malfunction that produces that pattern of symptoms.

As with checkout procedures, these two types of behavior may seem quite independent of one another. Identifying individual out-of-tolerance indications is the same as performing some of the individual steps in a checkout procedure. Once the pattern of symptoms is identified, the reasoning is predominantly a cognitive

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process, and should no longer involve the physical equipment. Experimental subjects and technicians do not reason perfectly, however, any more than they identify malfunction symptoms perfectly. Consequently, they may wish to refer back to the equipment, or recheck some display after they have started to reason out the problem. In order to study a realistic representation of the task of localization, therefore, active controls and displays must be provided.

Localization, like checkout, is performed only on the front panel of the equipment. The data flow which is used in the reasoning comes to the subject not from the equipment, but from data flow diagrams included in the equipment technical manuals. As a consequence, the flow of data in the actual equipment need not be duplicated in the MTS-1. Controls and displays can be connected directly to one another. The complex circuits controlled by the controls and monitored by the displays in the operational equipment can be omitted from the simulator without degrading the fidelity of simulation of the localization task. The only requirements are that the controls and displays on the front panel match those given on the data flow diagrams, and that combinations of out-of-tolerance conditions that contradict the data flow not be presented to the subject.

It was concluded, in summary, that the MTS-1 should have the following characteristics to permit simulation of checkout and fault localization:

Actual controls and displays should be used. The characteristics of the controls and displays present on a panel, are thought to affect the performance of tasks performed on that panel. Since the precise nature of this effect is not known, the consequences of omitting actual hardware is likewise unknown.

The operating relationships between controls and displays (ie, which controls affect which displays, and the nature of the effect) should be maintained in the simulation. It will be more difficult to learn to operate, for example, a control which has, in its relationship with a display, a large amount of backlash or lag, than one which does not.

The physical proximity of controls and displays and their locations on the equipment front-panel should be preserved in the simulation.

Internal data flow could be omitted from the device without degrading the quality of the simulation.

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Nonsimulation Features for Research Use

In addition to providing for task simulation, the MTS-1 is designed as a research tool. The following design objectives were considered in arriving at some of the features already described in the section entitled General Description of the MTS-1.

It should be possible to vary independently any characteristic of the front panel eg, the distance between controls and displays, the nature and number of controls and displays, etc., in order to discover how equipment variables affect learning and performance.

It should be possible to simulate a large number of different equipment front panels, in order to generalize research results. It would be extremely convenient if objectives 1 and 2 could both be achieved with essentially the same hardware.

Since the "equipment" is to be operated, at least in part, by novices it should be virtually impossible to damage it through manipulation of the controls.

Great care should be exercised in the design of the hardware, to minimize the possibility of malfunctions. One of the main objections to the use of actual equipment in research of this kind is the introduction of error due to equipment breakdown during experiments.

Shock hazard to subjects should be eliminated.

The equipment itself should automatically sense and record the time, magnitude, and sequence of control manipulations. This would permit analysis of errors of omission, commission, and setting; total performance time; control manipulation time; and time between manipulations, as well as finer analyses. Automatic sensing and recording prevents contamination of the experimental results by observers and eliminates errors which enter when human data recorders are used.

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CAPABILITIES AND LIMITATIONS OF THE MTS-1

General

The MTS-1 was designed primarily as a research tool. It resulted from an attempt to combine fidelity of simulation with simplicity, reliability, and ease of response identification and recording for the purpose of studying the performance of maintenance tasks. In its present form, the MTS-1 makes possible the study of the maintenance tasks of equipment checkout and fault localization with minimum performance disruption from data collection and minimum interruption from equipment malfunction. It will be well suited for use in studies in which accurately timed, uncontaminated records of the sequence and nature of operations performed by a subject on a simulated front panel are needed. Its five outstanding features are:

Fidelity of simulation: Actual controls and displays can be operated and read by the subjects.

Versatility: It can easily simulate a wide variety of front panels, control-display relationships, and internal data flow.

Reliability: The MTS-1 has now run for two hundred hours without malfunction.

Automatic response recording: A tape is printed giving the time, sequence, and nature of the responses made by the subject.

Low cost: The MTS-1 can be built at a small fraction of the cost of the Bomb-Nav System it is currently set up to simulate.

Response identification and recording are automatic, permitting performance measures to be made, free from contamination by a human observer. Error in recording is eliminated. Recording is accomplished with sensing circuits wired to all controls and to a high-speed printer which produces a time-based sequential record of all control operations.

To the subject, the front panel of the MTS-1 looks like a bonafide piece of military equipment. It is built up from a selection of controls, displays, and blank panels mounted on modules.

The controls can be operated, and the displays, which respond to the controls, can be read. The subject can thus perform specified front-panel checkout procedures just as he would on operational equipment. Out-of-tolerance indications can be simulated merely by specifying as the "correct" indication any value other than the one that will appear on a display.

The controls and displays can be easily arranged in many different configurations, permitting simulation of a large variety of

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equipment front panels. Rearrangement is accomplished by moving the modules on which the controls and displays are mounted. With a few exceptions, any module can occupy any location on the panel; and any control can be wired, with patch cords, to operate almost any display.

Simulating Front Panel Tasks

Simulation of an equipment front panel with the MTS-1 is accomplished in the following manner. The panel to be simulated is analyzed to determine;

The number and kinds of controls and displays present

Which controls affect which displays

The nature of control-display relationships, eg, lag, backlash, control-display ratio, etc

The spatial relationships among front panel components

Then the tasks on which performance is to be studied, eg, equipment checkout and malfunction localization, are analyzed to determine;

The controls and displays attended to by the operator

The out-of-tolerance indications produced by the actual equipment

With the information obtained from the above analyses, the researcher is able to place appropriate controls and displays, from the selection at his disposal, on the front panel, simulating their actual arrangement and spatial relationships. Controls and displays may then be connected electrically to produce the operating relationships indicated by the analysis of the actual panel. Controls and displays present on the panel being simulated, but not used in the tasks under study, are present on the panel but need not be connected electrically.

The sequence of operations performed by a man in checking actual equipment is determined by the internal data flow of the equipment being checked. Before given observations can be made, the equipment must be placed in a state which will permit those observations. Actual equipment provides little latitude for the researcher who wishes to reorder the sequence of operations in a checkout procedure.

The relative electrical independence of MTS-1 front-panel components permits checkout tasks to be structured in such a way as to be similar to the tasks performed on actual equipment or in some other order which is thought to be superior to the existing procedure. The only restriction on reordering the steps in a procedure for the MTS-1 is that controls must be operated before the displays to which they are connected are to be observed. Thus, reordering would be accomplished by control-display pairs.

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The MTS-1 has wide flexibility in the simulation of data flow for fault localization problems, since it contains no data flow of its own, in the usual sense of the term. The apparent data flow in the simulated "system" can thus be changed merely by changing the data flow diagram presented to the subject. The only restriction placed on these variations is that the controls and displays on the MTS-1 front panel must match those shown on the data flow diagram.

Out-of-tolerance indications may be simulated by the presentation of "wrong" readings and/or tolerances in the performance aids used by subjects. Thus, patterns of out-of-tolerance indications known to be produced by specific malfunctions in the actual equipment may be presented without altering the MTS-1 in any way. Completely arbitrary out-of-tolerance indications may be presented as well, so long as they are consistent with data-flow information given to the subjects.

Data Analysis

The performance record tape produced by the MTS-1 (See figure 11) permits the researcher to obtain the following kinds of information about performance:

Directly:

The sequence in which controls are touched

The positions of the controls, when touched and when released

The time required to perform the task under study, wholly or by parts

Indirectly, by computation:

The magnitude and direction of change in control position for each operation of a control

The time required for each control manipulation and the mean control manipulation time

The total time between control manipulations and the mean time between control manipulations

Although the scheme for scoring errors has not been completely worked out at this writing, it is expected that the method to be employed will be to compare a subject's performance record tape to a standard tape having the correct sequence and setting information. Errors of control setting, addition and deletion of steps will be noted and recorded manually.

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MTS-1 Reliability

All malfunctions in the MTS-1 during the conduct of the pilot study, described below, were due to errors in construction or damage to components during construction. After these causes were eliminated there were over 200 consecutive hours of malfunction-free operation.

Usually a malfunction in one of the sensing and recording channels does not necessitate stopping a subject in the course of an experimental trial (though some data may be lost). The inputs to the recording system from the control involved may be moved to a spare channel in a matter of seconds after the malfunction is noted.

If the fault is in a control or display on the front panel, the affected component usually can be changed easily between trials if a spare module is available. A malfunction in the front-panel power supply is the only occurrence which should necessitate stopping during training trials. During testing trials, those in which a record of what the subject is doing is important, a malfunction in the printer, digital voltmeter, electronic counter, or main power supply would necessitate stopping. None of these units has malfunctioned to date.

Though the values of supply voltages and components in the response sensing circuitry are critical, no breakdown due to component aging has yet been observed. It is too early to tell what the effects of this criticality may be.

Operational Test of the MTS-1

During the development of the MTS-1, a pilot study was conducted for the purpose of perfecting the device and the research techniques and materials associated with it. Twelve subjects were given 2 hours per week per individual to perform procedures simulating the High Speed Bombing Radar and Radar Data Presentation Set checkout procedures of the AN/ASB-4 Bombing Navigation System. This part of the study yielded 192 subject hours of data and at least 50 additional operating hours, employed in exhaustive checks on the operation of the MTS-1 itself.

The data are, for the most part, unanalyzed, but two significant facts have emerged relative to procedure completion time:

High-and low-aptitude groups (selected on bases of AF electronic aptitude scores) maintained a time differential throughout the course of the study, the high groups performing more rapidly.

After 7 weeks of practice (2 hours per subject per week), performance times for groups and for individuals had not reached an asymptotic level, and were still quite variable. This suggests that future studies of this kind should anticipate protracted running times.

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Limitations of the MTS-1

Simulation

The physical size and structure of the MTS-1 front panel imposes certain limitations on the fidelity with which some systems may be simulated. Irregularly shaped or extremely large panels cannot be well simulated, nor can those wherein a front-panel component density of about 15 components per square foot is exceeded. A very large number of equipment front panels, however, remain within these limits. With some additions and modifications (more racks and/or modules), the number could be enlarged. The presently available selection of modules is also limited, but all of the common types of controls and displays are represented. New modules can usually be integrated into the front panel and the recording system without necessitating any changes in the existing apparatus.

Performance Record Scoring

An additional consideration, which may be thought to constitute a limitation on the capability of the MTS-1 as a research tool, is the difficulty of scoring performance record tapes. As presently conceived, the process of scoring tapes is a laborious clerical task. In one experimental hour, a subject can easily produce a tape having over 400 lines of printing. Since each pair of prints (touch and release) must be examined to discover its sequence and must be examined for time and setting, approximately 1000 items of data must be handled for each experimental hour before any computations can be performed. It is thought, however, that the present cost of scoring the data tapes is offset by the gains in information about performance which the sensing and recording system makes possible.

Expanding the Capability of the MTS-1

The MTS-1 now has the capability of simulating the equipment aspect of front panel checkout and malfunction localization tasks. The logical next step would be to consider the possibility of modifying this device for research on malfunction isolation tasks. (Isolation is the portion of the troubleshooting task which is conducted behind the front panel, after localization has been done, up to but not including the point of replacing the defective component.) The design of the MTS-1 provides for the addition of an isolation task simulator (ITS). Briefly, the ITS would provide for insertion behind the front-panel of variable amounts of black-boxed circuitry, test points, cabling, etc., between the components on the MTS-1 control-display panel. Provision would be made for simulating a large number of data-flow configurations. Complete troubleshooting tasks from a variety of systems could then be studied.

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APPENDIX I

MODULES PRESENTLY AVAILABLE FOR MTS-1 FRONT PANEL

Item	Quantity
Voltmeter	3
Light	10
Potentiometer	9
Micropot	2
Circuit Breaker	3
Circuit Breaker (Instrumented Dummy)	5
Toggle Switch	16
Toggle Switch (Momentary)	4
Multiple Contract Rotary Switch	9
Rotary Switch (Momentary)	2
Counter, 6 Digit	2
Push Button Switch	5
Push Button Switch (Lighted)	3
Oscilloscope (4 pots on scope)	2
Total controls & displays	81
Blanks	188

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APPENDIX II

SENSING & RECORDING CIRCUIT OPERATION

The operator is connected at J_1 (fig. 12 page 29) producing a voltage spike on the grid of thyratron V_1 causing it to go into conduction. This energizes K_1 and K_p. S_3 of K_p opens, stopping conduction through V_1 by opening its cathode circuit and the cathode circuit of all channel relays (K_2 - K_{60}). Thus no other relay may be energized. However, K_1 is held in through the action of C_1 discharging through its coil. Through the contacts of K_1S_4, V_1 obtains its own unique ground and returns to conduction.

When K_p energized, movement of K_pS_1 produced a voltage step which was applied to the sample command circuitry of the DVM. K_1S_1 and K_1S_2 each applied bias to one digit on the units and tens print wheel respectively in the printer. The combination of digits is unique to the channel.

Approximately 150ms after K_p is energized, the digital voltmeter has read the voltage on the control to which K_1S_4 is connected and delivers a print command to the printer which then prints the appropriate information.

When the operator disconnects at J_1, V_1 goes out of conduction and K_p drops out immediately -- providing sufficient time has elapsed to permit C_d to charge to a level which will hold V_1 off. K_1, however, is held in for about 200ms by the action of C_1 to permit the sampling of the DVM and operation of the printer resulting from the switching of K_pS_1. The full cycle is now complete and any channel may be activated.

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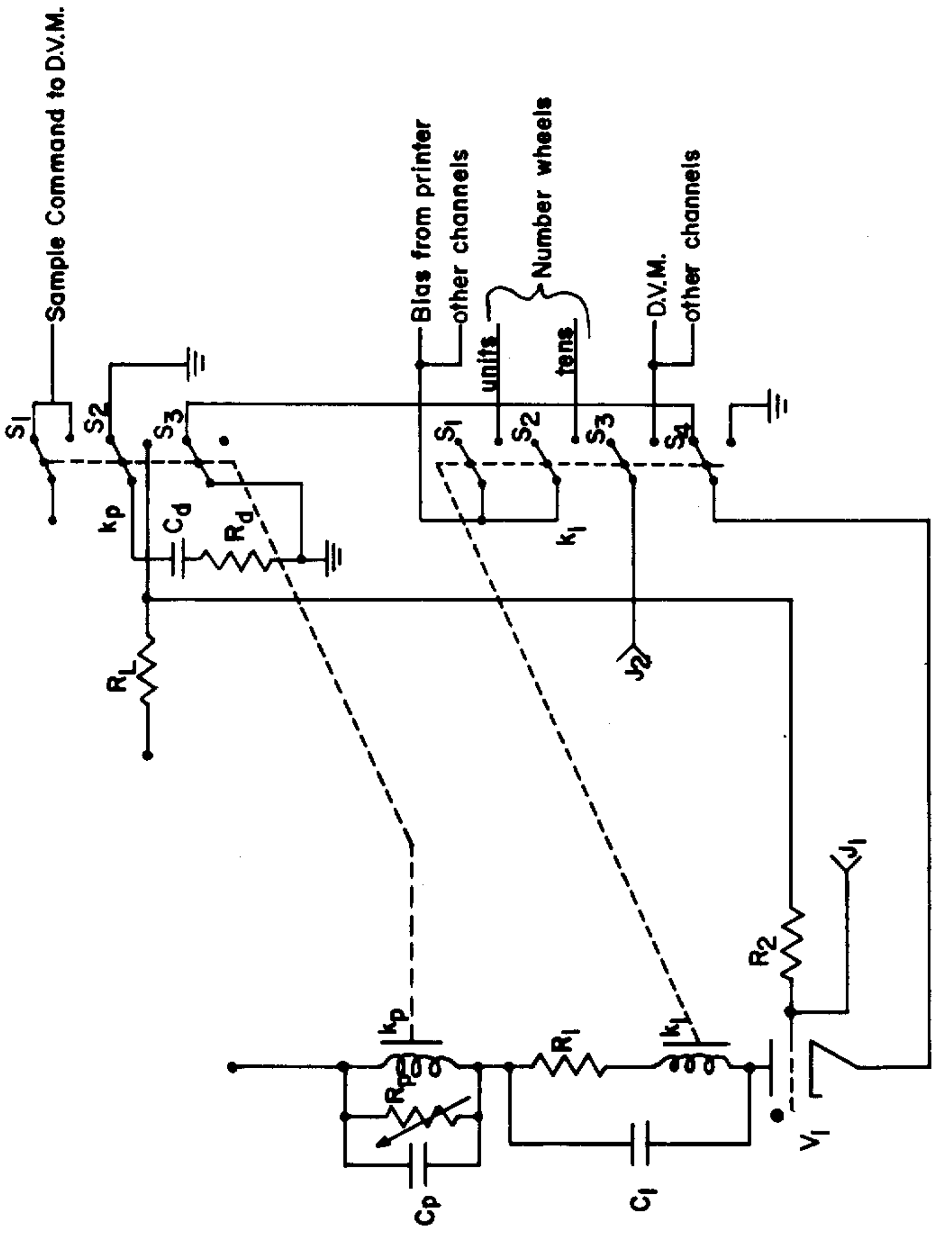

Figure 12. Sensing Circuit

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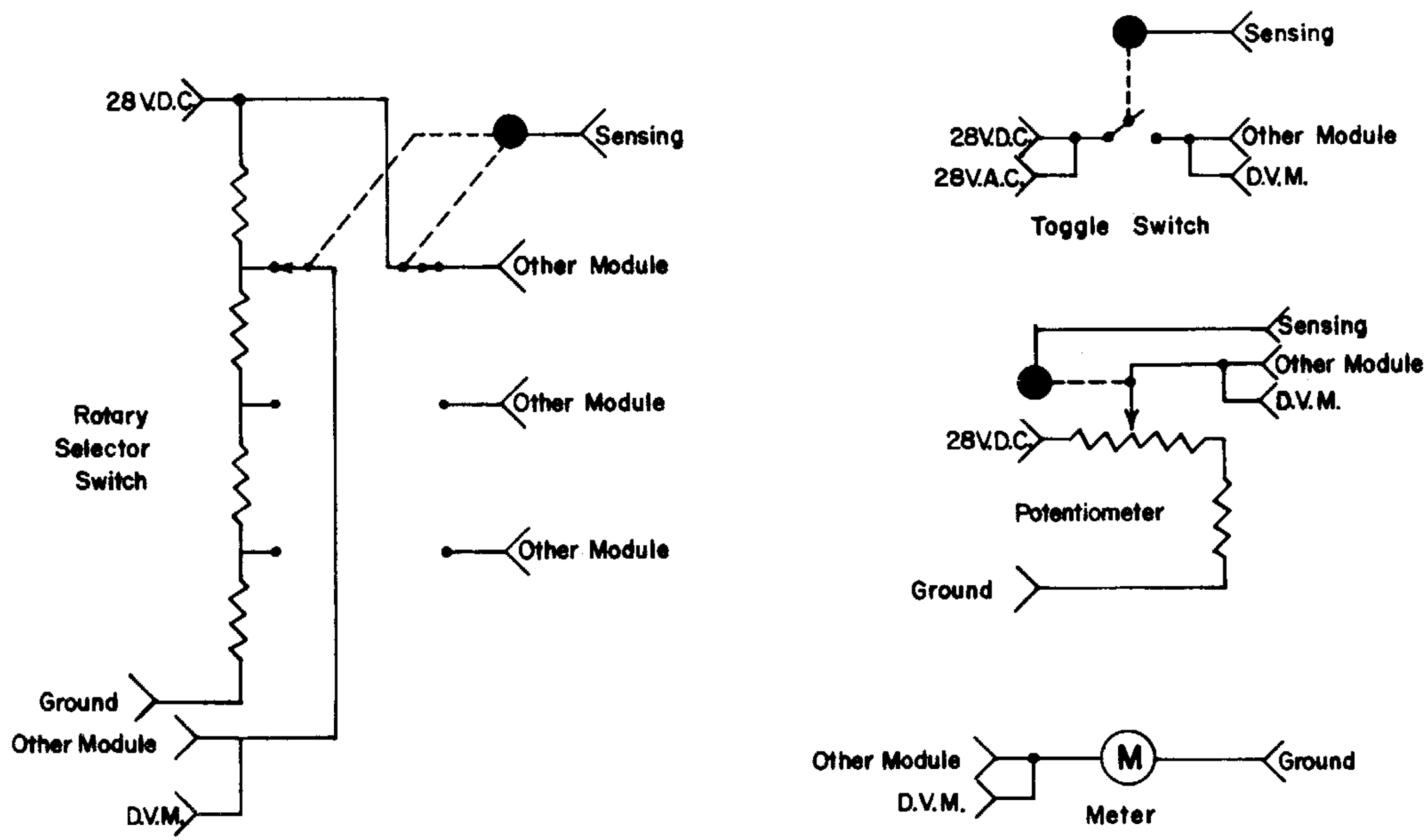

Figure 13. Diagrams of Example Modules

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APPENDIX III

MTS-1 OPERATION

1. Experimental session procedure
2. Normal turn-on procedure
3. Recording Apparatus normal control positions
4. System check
5. Component check

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MTS-1 OPERATION

1. EXPERIMENTAL SESSION PROCEDURE

1. Perform system check (see below).
2. Clear the tape. Write subject's name, the date, and the name of the task subject will perform.
3. Seat subject at the front panel and give any necessary instructions.
4. Place grounding plate in subject's sock (this connects him to the recording apparatus).
5. Tell subject to begin.

2. NORMAL TURN ON PROCEDURE

1. Filaments, on
2. Counter Power, on
3. DVM Power, on
4. Printer Power, on
5. Printer Cabinet Blower, on
6. 28VDC Power, on
7. High-Voltage Power Supply AC Power, on
8. (After about 15 Sec.) High Voltage, on
9. Record Switch, on

3. RECORDING APPARATUS NORMAL CONTROL POSITIONS

Counter

1. Power, on
2. Manual Gate, count
3. Gate Selector, manual
4. Input Sensitivity Control, mid-position

Digital Voltmeter

1. Power, on
2. Sampling Control, ext. (switch at extreme clockwise limit of rotation)
3. Range Switch, hold (Range set at + ___. by alternately operating Range Switch to Step position then releasing it until proper range is set.)

Printer

1. Power, on
2. Spacing Control 2
3. Record Switch, on

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4. SYSTEM CHECK

1. Set normal control positions on recording apparatus.
2. Turn on filaments.
3. Turn on 28VDC supply & set to 27.0 volts.
4. Turn on high-voltage AC power - after about 30 sec., set Meter Range Switch to 0-500 and adjust high-voltage control until DC volts meter reads 150.0. Then set Meter Range Switch to 0-150V Bias and adjust Bias Control until DC Volt Meter reads -5.0 volts. Turn High Voltage on.
5. Place grounding plate in sock.
6. Operate controls on left-hand panel in known sequence.
7. Check printer tape against Naming Code.
8. If there is no printing, re-perform System Check.

5. COMPONENT CHECK

To Check Counter:

1. Set controls to normal settings - indicators should show counting 1 count/0.1 sec.
2. Depress Record Switch on printer - Gate lamp should blink off, then on as printer prints.
3. Depress Count Switch - count stops. Press reset button - indicators reset to 0000.
4. Rotate Display time Control fully CCW. Set Gate Selector Switch to 0 sec. Input Sensitivity Control to Check position (Switch at CCW Extreme) - Counter should read 60.
5. Reset Controls to normal positions.

To Check Digital Volt Meter:

1. Set controls to normal positions.
2. Set Range Switch to Auto Set Sampling Control out of EXT, but fully CW. Depress Calibrate Button. Meter should read +7.43V + 0.05V.
3. Reset controls to normal positions.

To Check Printer

1. Set controls to normal positions.
2. Depress Record Switch completely - printer should print rapidly.
3. Reset controls to normal positions.

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13. ABSTRACT

The Maintenance Task Simulator (MTS-1) is a low priced task simulation device, specially constructed for research on performance aids used in conjunction with electronic maintenance. The device can present many complex electronic control-display panel configurations. The control-display panel is composed of a variety of modules which may contain a control or display or be blank. The device also contains sensing and recording circuitry, which provides a time-referenced record of control positions and sequence of manipulations by the subject. The device can support such research as determining the various skills and concepts required by the technician in performing various levels of electronic maintenance and developing effective techniques for evaluating the proficiency of electronic maintenance personnel. The logical next step would be to modify the MTS-1 for research on malfunction isolation tasks, ie, the portion of the troubleshooting task conducted behind the front panel, after localization has been done, up to but not including the point of replacing the defective component.

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	ROLE	WT	ROLE	WT	ROLE	WT
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Test Equipment (Electronics)						
Maintenance						
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