

LMA790-2-LMS

# LUNAR MODULE MISSION SIMULATOR

INSTRUCTORS HANDBOOK

VOLUME I

SIMULATOR DESCRIPTION



NAS 9-1100

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## INTRODUCTION

This handbook contains a detailed description of, and complete operating instructions for, the Lunar Module (LM) Mission Simulator. The handbook comprises two volumes: volume I, LM Mission Simulator Description, and volume II, Simulator Operation. Volume I is intended to completely familiarize the instructor with the LM Mission Simulator (LMS), the simulated subsystems, and the training activities to be performed. Volume II is intended for use by the instructor as a workbook; it contains the information required to set up and run training exercises.

Volume I contains three sections: Section 1, Simulator Description; Section 2, Subsystem Simulation; and Section 3, Training Activities. Section 1 describes the LMS configuration and function. All simulator peculiar controls and indicators are illustrated and described in detail. Section 2, familiarizes the instructor with the methods used in the LMS to accomplish LM subsystem simulation. Section 3 presents the information required by the instructor to set up a comprehensive series of LMS training exercises.

Volume II contains seven sections: Section 1, LMS Operation; Section 2, Malfunction Data; Section 3, Lunar Landing Mission Procedures; Section 4, Interface Operations; Section 5, Instructor Material; Section 6, Scripting Data Sheets; and Section 7, Simulator Output Tables. Section 1 contains step-by-step procedures required to bring the simulator up to a state of operational readiness. Section 2 presents a complete list of malfunctions available for insertion in the training exercises. Section 3 contains detailed sequences of nominal and non-nominal crew tasks performed during a lunar landing mission. Section 4 contains the setup procedures performed by the instructor for LMS-AMS, LMS-MCC, or LMS-AMS-MCC integrated operation. Section 5 contains instructor reference material to be used in setting up training exercises. Section 6 contains the primary materials used by the instructor to organize and conduct LMS training runs. Section 7 is a list of LMS program symbols and their definitions.

Frequent reference is made, in the handbook, to Apollo Operations Handbook, LMA790-3-LM2. These references direct the reader to detailed descriptions of the LM controls, indicators, and subsystems. LM Abbreviation List, LLI 790-1, supplied as a supplement to the instructor's handbook, defines the abbreviations used on the LM program, including those peculiar to the LMS.



## SECTION 1

## SIMULATOR DESCRIPTION

1.1 PURPOSE AND SCOPE.

This section describes the LM Mission Simulator (LMS) configuration and function. All controls and indicators, peculiar to the LMS, except those in the simulated LM cabin, are illustrated and described in detail. Controls and indicators in the simulated cabin are treated generally herein; for detailed information, refer to Apollo Operations Handbook, LMA790-3-LM 2.

1.2 GENERAL DESCRIPTION.

The LMS is a fixed-base training device that can simulate the characteristics of LM subsystems performance and flight dynamics. LM flights are simulated in a one-gravity environment by means of computer-controlled simulation of subsystem parameters, flight dynamics, and visual perspective. Observation and control by an instructor are accomplished at a station remote from the simulated LM cabin. The LMS provides training for LM flight crew astronauts in the operation of LM subsystems, in space navigation, and in crew procedures for space missions. Training includes basic manipulative skills in LM operation, basic LM subsystem operation procedures for all significant mission functions, crew response to mission contingencies, and integrated exercises directly involving Mission Control Center (MCC) facilities, the Apollo Mission Simulator (AMS), and the flight crew. In addition to normal operation, the LMS simulates malfunctioning subsystems and degraded subsystem performance. Specific training modes may be categorized as follows:

- Crew procedures - Training in crew procedures for accomplishing mission events and subsystem servicing
- Typical mission - Training in solving typical mission problems, and accelerated-time performance of a variety of complete training missions
- Typical integrated mission - Training in flight crew/flight controller closed-loop interface procedures for typical mission situations
- Specific mission - Training in flight crew practice of each specific LM manned flight and all projected normal and contingency variations
- Subsystem procedures - Training as defined in encompassing those LM subsystem procedures that are reiterated throughout the mission; that is, to use the subsystems, check subsystem status, and alter subsystem mode of operation.

A general-purpose digital computer is used for all computations. The programs written for the computer determine the completeness of simulation, dynamic response, and accuracy of results.

There are two complete LM simulators: one is at Manned Spacecraft Center (MSC), Houston, Texas; another one, at Kennedy Space Center (KSC), Cape Kennedy, Florida. The configuration of both simulators is essentially the same, the only significant difference is in facility layout.

Each LMS consists of a simulated LM cabin, instructor console, telemetry console, equipment cabinets, and external visual display equipment (EVDE). The arrangement of the LMS at the sites is shown in figures 1-1 and 1-2. The equipment shown in figures 1-1 and 1-2 is identified by unit number and listed in table 1-1. Because the installations at the training sites are similar, the MSC installation (figure 1-1) is described; differences in equipment layout at KSC are indicated.

The physical arrangement of the LMS provides direct lines of personnel communication, computer communication, and ease of maintenance. The total available area is used to provide a logical arrangement with adequate provisions for training mission personnel and observers. The main entrance aisle provides access to the instructor's console, which serves as the control center for the LMS. The instructors can monitor all activities from this location, observing personnel at the LMS cabin, the status of the peripheral computing equipment, and personnel entering the computer area.

The LMS cabin and EVDE are on a cement slab of the enclosure floor, which provides physical stability and support. The cabin and EVDE are the bulkiest portions of the LMS; They are located in the high-boy area



adjacent to the large access doors. The remaining equipment, located on computer-type flooring for ease of interconnection, is of modular construction and, therefore, can be rearranged over the life of the program.

A logical equipment communication scheme is inherent in the arrangement. The LMS cabin equipment and the EVDE connect to junction panels located in adjacent equipment cabinets. From there, the signals are routed to appropriate portions of the computing equipment, to the analog-to-digital converters, and, then, to the digital computers or other areas, such as the instructor or telemetry consoles. The signals from the digital computers are routed back to the junction panels, or to the AMS digital computer, when operating in the integrated mode. Such an arrangement minimizes the cabling requirements of the entire LMS.

### 1.3 POWER

The LMS operates on a 120/208-volt, 60-cycle, three-phase, four-wire, grounded system, with a separate 115-volt, single-phase service supply. The service supply provides power to convenience outlets and a 26-volt d-c utility power supply used to sequence power turn-on. Power is routed into a main power cabinet from the wall box installation. Total power consumption, under normal conditions with all equipment turned on, is approximately 255 kilovolt-amperes.

LMS power is divided into two categories: simulator power and utility power. Simulator power is routed through the main power circuit breaker. The 115-volt, 60-cycle utility power is independent of the main circuit breaker. Utility power feeds the convenience outlets and the d-c power supply. The 26-volt d-c power supply is used to sequence simulator power turn-on; to light status, cabin overhead, and emergency off lamps; and to energize relays.

The LMS has a sequential power turn-on system that reduces initial turn-on line surges and permits individual major subsystems to be turned on or off as required. The sequential power turn-on system can be operated in two modes: manual or sequential. In the manual mode, each subsystem is turned on independently; this mode is especially useful during maintenance. In the sequential mode, the life support buses are energized immediately; then, at 10-second intervals, the remaining subsystem buses are energized automatically. The LMS power system is described in detail in paragraph 1.8.1.

### 1.4 FUNCTIONAL EQUIPMENT GROUPS.

To facilitate presentation of the functional description of the LMS, a breakdown of the equipment according to functional groups and their relationship to each other is used. The breakdown separates discrete groups of equipment into logical task categories and permits a highly integrated equipment/function discussion. The primary equipment group breakdown is as follows:

- Control and monitor group
- Sensory group
- Data-processing group
- Ancillary group.

The functional equipment groups are described in detail in paragraphs 1.5 through 1.8.

#### 1.4.1 LMS FUNCTIONAL BLOCK DESCRIPTION.

All blocks shown in figure 1-3, except for the program control area, result from a basic functional hardware orientation (component/complex areas).

Within the program control area of figure 1-3, system programs and control programs that constitute LMS software requirements (simulated LM subsystems and environments) are reflected. The purpose and performance of each software block is discussed in its assigned paragraph, subordinate to the subsystems (software) descriptions. To reduce interface complexity, hardware/software relationships are coded with large open arrows to relate hardware signal/control interfaces; smaller flow lines show program interdependence.

Because figure 1-3 establishes the requirements for specific functional equipment categories and logically develops the hardware/software relationship, it defines the simulation task. Therefore, the block diagram not only provides an overall system concept, but permits correlation between simulation tasks and simulation objectives.



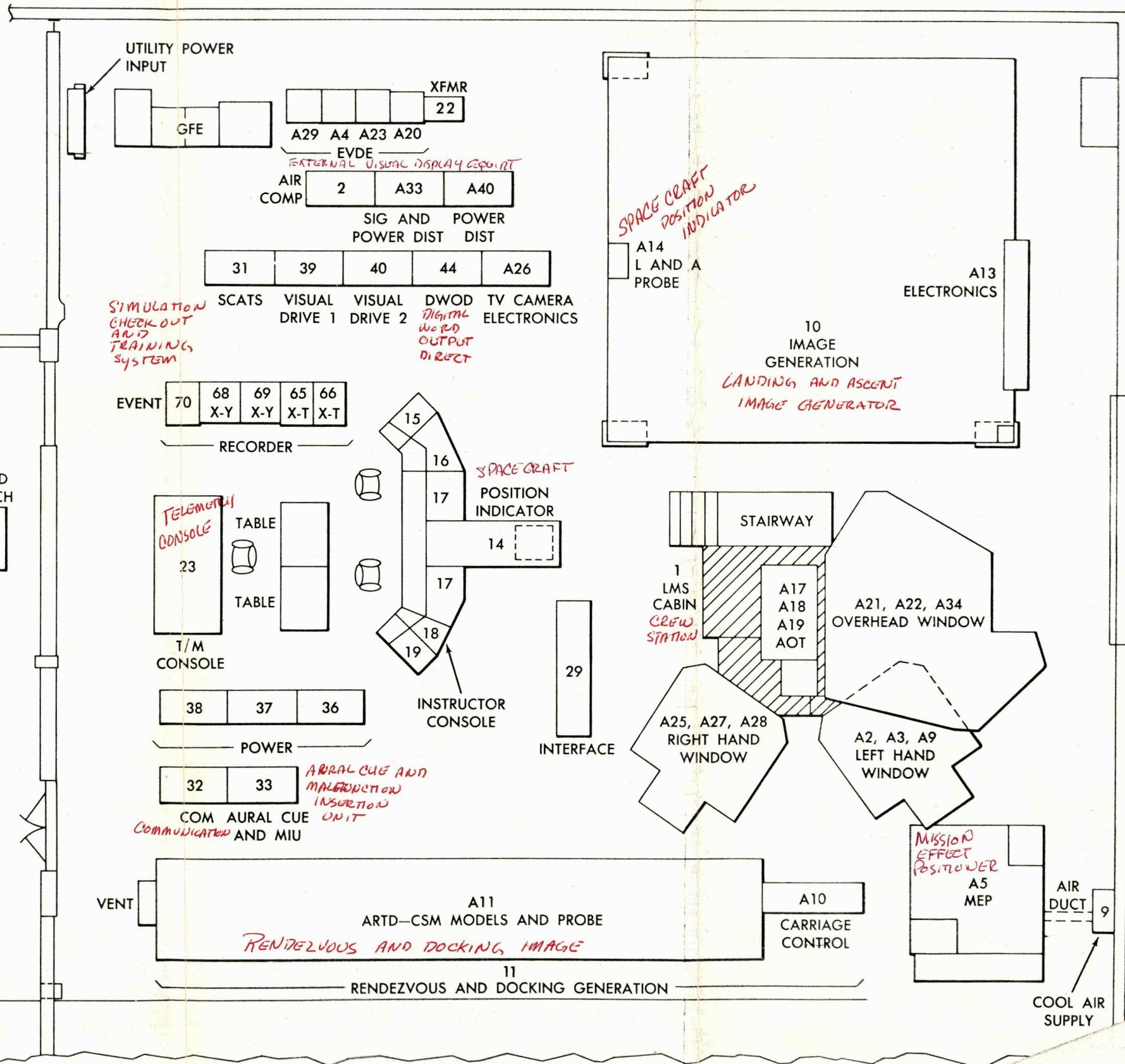
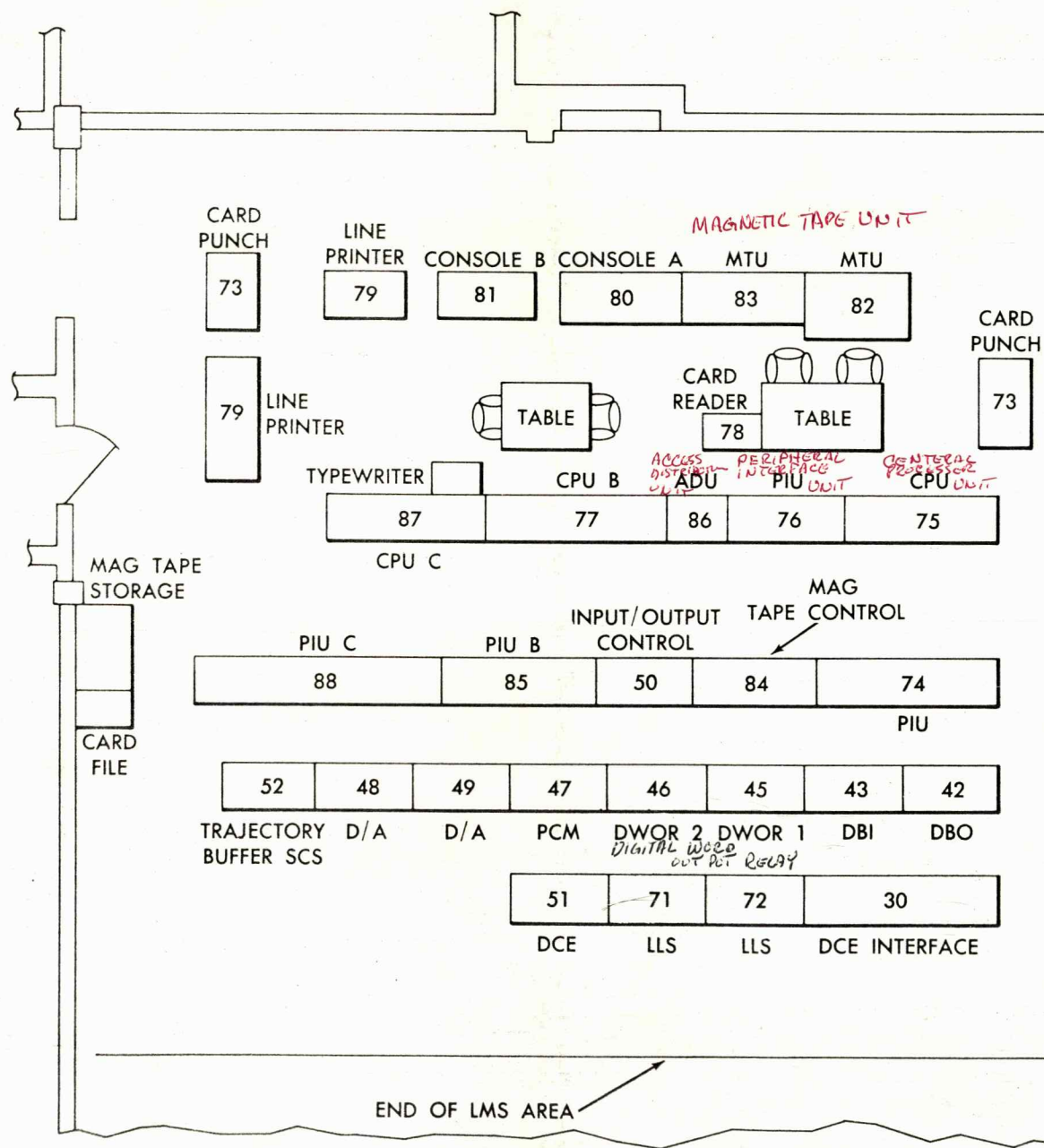
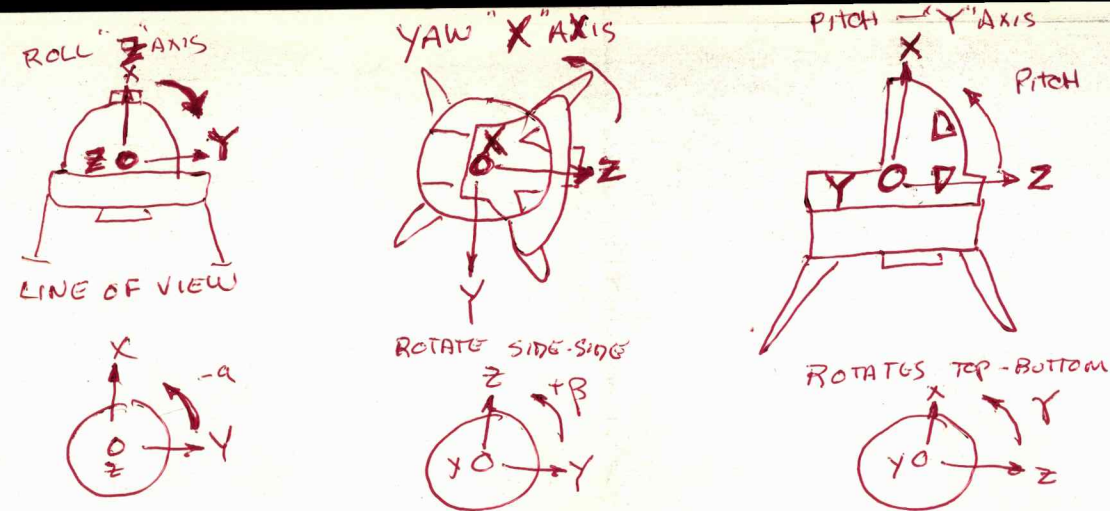
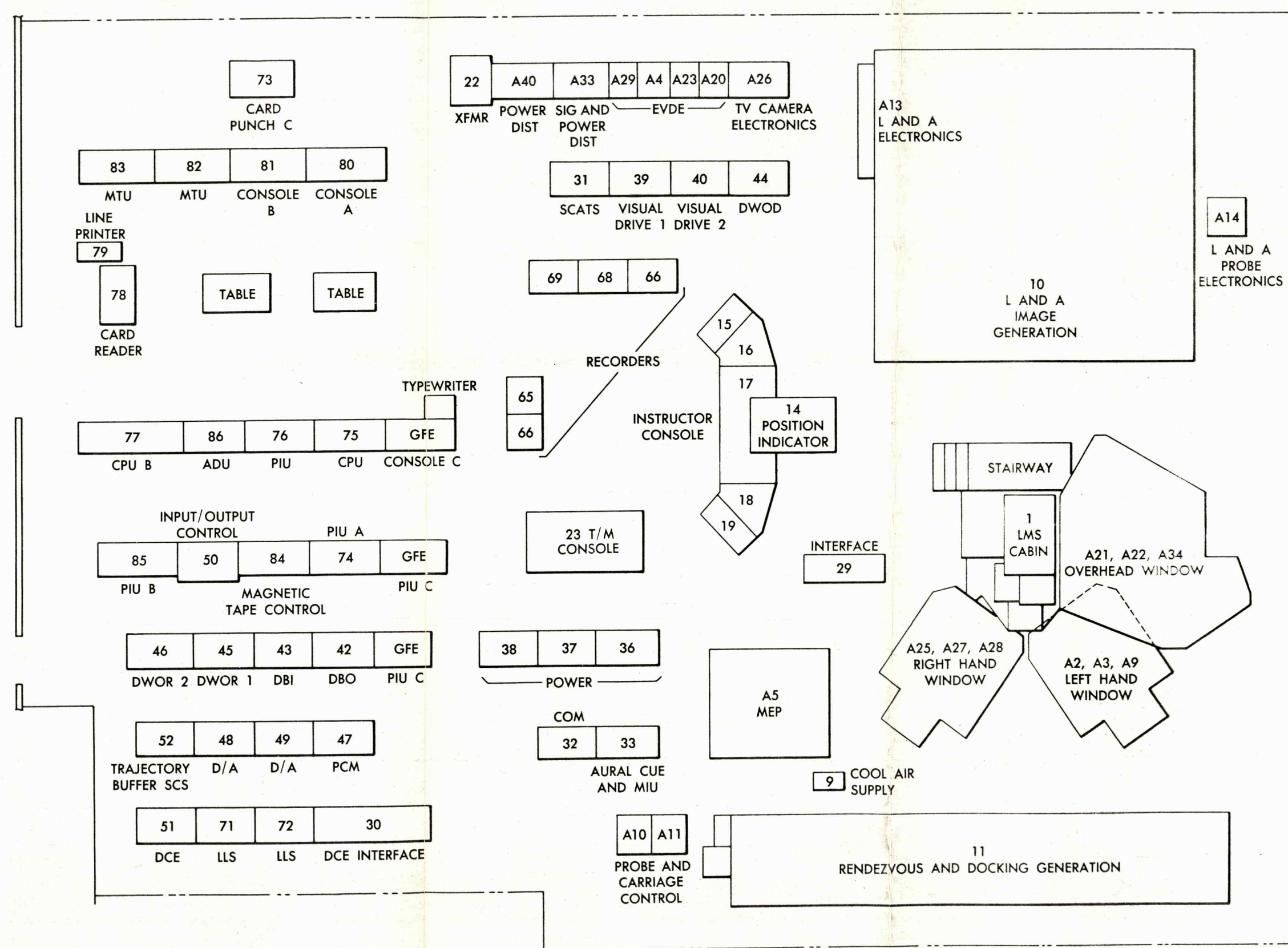


Figure 1-1. LMS Equipment Arrangement MSC, H





LMS-1-141

Figure 1-2. LMS Equipment Arrangement, KSC, Cape Kennedy, Florida



Table 1-1. LMS Equipment Arrangement

Unit No. (Figures 1-1 and 1-2)	Nomenclature	Description
1	Cabin crew station	LMS cabin simulates LM cabin area; controls and displays are mounted in same configuration as those in LM. In addition, structure includes closely related support equipment cabinet racks. Two suit pressurization control panels are mounted on structure, behind clear glass doors.
2	Compressor cabinet	Compressor cabinet houses four motor-driven air compressors and glass-lined, 30-gallon reserve supply tank to supply compressed air for pressure suits. (Building air may be used in place of compressed air.) Filters, regulators, and plumbing associated with compressed air supply are also in this cabinet.
10	Landing and ascent image generation unit	This structure houses lunar model and three-axis translational drive assemblies that provide visual effects in simulation of landing and ascent. Image generation unit consists of movable model of lunar surface and optical probe device that forms lunar image and distributes it to cabin windows.
11	Rendezvous and docking image generation unit	This structure provides darkened environment for two CSM models, which serve as rendezvous targets. Models are observed by mobile camera, which travels along track to simulate approach to docking. The two models are of different size, to accommodate range of focus field. Scale of CSM model used for docking is 1:20; for rendezvous, 1:80.
14	Spacecraft position indicator	This unit provides instructor with visual indication of simulated spacecraft orbital position. It traces simulated trajectory with moving spot of light over projected maplike display of earth or lunar surface. During rendezvous, two spots (CSM and LM) are traced.
15, 16, 17, 18, 19	Instructor console	This console has operating positions for Mission Coordinator, Commander Instructor, Systems Engineer Instructor, and Suit Technician. Console has repeaters of all LM cabin controls and readouts, and subsystem controls for entire simulator complex. Mounted on instructor console, but not part of it, are two closed-circuit EVDE TV monitors.
22	Autotransformer cabinet	This unit houses 125-kva autotransformer, which selects and stabilizes main input power supply to LMS complex.
23	Telemetry console	This console provides controls and displays for Telemetry Instructor to monitor any of approximately 500 analog telemetry data channels, and to malfunction as many as 8 bilevel and 8 analog channels simultaneously.
29, 30	Interface cabinets	These double-width cabinets contain cable termination taper pin jacks that are used for signal patching between digital conversion equipment and remainder of LMS complex.

Table 1-1. LMS Equipment Arrangement (cont)

Unit No. (Figures 1-1 and 1-2)	Nomenclature	Description
31	Simulation, checkout, and training system (SCATS) interface cabinet	This cabinet houses tie-in equipment for data linkage between LMS complex and MCC.
32	Communications unit cabinet	This cabinet houses audio and channel-switching equipment required to simulate various voice and signal transfers between LM, CSM, and earth tracking networks.
33	Aural cue and malfunction insertion unit (MIU) cabinet	This cabinet houses the logic circuitry required to interface with the malfunction insertion and display units at instructor console, and some printed circuit cards for aural cue system. Cards include white noise sources, voltage-controlled filters (VCF), and voltage-controlled attenuators (VCA) to provide realistic and synchronized acoustic environment within LMS cabin.
36	Power cabinet No. 1	This cabinet houses main input power feed and master breaker (1,000 amperes) for entire LMS complex, and circuit breakers for each major 115-volt a-c power bus (including life support, utility power, peripheral power, data conversion equipment (DCE), computer complex, EVDE, and 400- and 800-cycle generators).
37	Power cabinet No. 2	This cabinet houses only circuit breakers and the +14-, -14-, and 26-volt d-c power supplies. Largest circuit breaker is 300-ampere unit for EVDE 115-volt a-c supply. Small circuit breakers are for branches of main power bus (located in Unit No. 36).
38	Power cabinet No. 3	This cabinet is used for normal LMS startup. It houses switch lights that remotely control breakers for each major subsystem, running-time meters that monitor each power subsystem, and instrumentation to monitor voltage, current, frequency, and phase of input power for LMS. Autosequencer in cabinet is used to start up entire complex, automatically delaying each subsystem to avoid current surges and to ensure dependent power interlock. A 26-volt d-c power supply in addition to an instrumentation converter is also mounted in this bay.
39	Visual drive cabinet No. 1	This cabinet houses 6 data receiver (D/R) converters for EVDE driver, 22 isolation amplifiers that act as buffer between computer complex analog-to-digital (A/D) equipment and EVDE, and 42 electronic synchro driver printed circuit cards with associated power supply.
40	Visual drive cabinet No. 2	This cabinet houses 22 digital resolver converters that convert digital data from adjoining DWOD unit (No. 44) to a-c signals, appropriately scaled to drive synchro resolvers of EVDE.
42	Digital bit output (DBO) cabinet	This cabinet houses DBO equipment capable of handling 488 channels (387 functional and 101 spare).
43	Digital bit input (DBI) cabinet	This cabinet houses printed circuit cards and equipment to accommodate 576 channels (508 functional and 68 spare), with growth capability to accommodate as many as 720 channels. Sharing cabinet space are 9 DWI channels (8 functional and 1 spare), each accepting



Table 1-1. LMS Equipment Arrangement (cont)

Unit No. (Figures 1-1 and 1-2)	Nomenclature	Description
43 (cont)		24 discrete input lines; rack space is provided to add another 12 channels.
44	Digital word output direct (DWOD) cabinet No. 1	This cabinet houses 30 direct digital output channels with growth capacity to 64 lines. Discrete signals from the DWOD are converted as inputs to EVDE resolver drive circuits. Data registers to DWOD are buffered with isolation amplifiers before tie-in to EVDE.
45	Digital word output relay (DWOR) cabinet No. 1	This cabinet houses printed circuit cards and equipment to process bilevel outputs from computer as complete digital words, rather than on individual bit-by-bit basis. Common applications require relay buffering to assure continuity of signal during repetitive digital computations.
46	Digital word output relay (DWOR) cabinet No. 2	This cabinet is similar to cabinet No. 1 (unit No. 45). It houses DWOR printed circuit cards with maximum total capacity of 128 channels.
47	Pulse code modulation (PCM) and central timing equipment (CTE) cabinet	This cabinet houses highly stable, temperature-compensated oscillator that provides for necessary synchronization of all elements of LMS complex. External master sync signals are provided to LMS when used in integrated mode. These signals integrate all LMS elements to common chronological time base and synchronize two computer processors.
48	Digital-to-analog converter (D/A) cabinet	This cabinet houses 320 channels of D/A conversion printed circuit cards (with provision for maximum of 345 channels) that provide necessary conversion from digital calculations of computers to variable level analog signals required by LMS instrumentation.
49	Analog-to-digital converter (A/D) cabinet	There are 64 channels (27 functional and 37 spare) of conversion equipment housed in this cabinet (with additional card rack slots) for a maximum of 160 channels.
50	Input/output (I/O) control cabinet	This cabinet houses commutation sequencing equipment that controls loading of input and output data into channels of digital data conversion equipment. All conversion equipment devices are loaded under program control from I/O routines stored in computer complex.
51	Power unit	This cabinet houses two D/R converters for EVDE, and individual circuit breakers to protect elements of digital conversion equipment (DCE).
52	Trajectory buffer and stabilization and control section (SCS) input cabinet	This double-bay cabinet houses timing circuits and buffer registers to accept trajectory data from computer complex (in bit parallel, serial word form), and format it (serial bits) for transmission to MCC. The SCS portion includes timing pulse generator and counting registers to integrate short-duration signals from LMS cabin hand controllers.

Table 1-1. LMS Equipment Arrangement (cont)

Unit No. (Figures 1-1 and 1-2)	Nomenclature	Description
65, 66	X-T recorders	LMS complex includes two Brush recorders, which plot tracks of variable analog data (X) on fixed time base (T). Recording paper drive speed is selected to provide variable time base. X-plot is selected at different scale factors. Recorder operation and parameter selection are normally under program control through punched cards.
68, 69	X-Y plotters	Two dual-pen servo-driven plotting recorders permanently record trace of bifunctional relationships. Parameter pairs to be traced are selected by program control at computer input devices.
70	Event recorder and audio tape recorder	Event recorder is 20-channel bilevel recorder, which plots digital status on constant running time base. (Speeds can be selected.) Dual-head audio tape recorder automatically transfers between two tape heads to provide uninterrupted recording throughout training mission.
71	Lunar landmass simulator (LLS) computer cabinet	This cabinet houses solid-state electronic circuits for combining and processing video data derived from flying spot scanner outputs. Multiplexing of these signals and trigonometric transformation of elevation data is accomplished with LLS computer cabinet.
72	Lunar landmass simulator flying spot scanner unit	This cabinet houses optical equipment for simultaneously scanning dual factored transparencies. These photographic plates carry coded elevation data of segments of the lunar surface. Cabinet includes cathode-ray scanning equipment and associated high-voltage power supplies, and output devices that comprise optical lens system and photomultiplier tube for two transparency plates being scanned.
73	Card punch units	Both card punch units include their own power supply, power control circuits, and logic signal conditioning equipment.
74, 85	Peripheral interface units (PIU) A and B	Each cabinet houses identical equipment to provide for fanning out of computer interface connections. This is accomplished by diode gate cards terminating in computer sense lines. Each PIU cabinet contains interrupt line logic cards, direct memory access assembly and control unit, and its own power supply.
75	Central processor unit A	Part of LMS computer complex (DDP-224 central arithmetic processor). Central processor unit A has core memory capacity of 40,960 words. Each central processor executes its programmed instructions independently of the other.
76	Shared peripheral interface unit	This cabinet houses several common channel devices used by both computers. These include fully buffered channel; real time clock; interface expansion logic and its associated power supply; interface circuits for card reader, card punch, and line printer; and two time multiplexing units for card reader and card punch.



Table 1-1. LMS Equipment Arrangement (cont)

Unit No. (Figures 1-1 and 1-2)	Nomenclature	Description
77	Central processor unit B	This unit is similar to central processor unit A (No. 75), except for larger core memory of 49,152 words. Both share 8,192 words of common core memory, for total of 98,304.
78	Card reader unit	Card reader unit includes internal power supply, data handling logic, and switch panel to control its functions.
79	Line printer units	Two high-speed line printer units provide programmed printouts at 300 lines per minute. Paper supply magazine may be loaded with multiple carbon to print several copies at one pass.
80	Console unit A	This console unit houses basic controls for its associated DDP-224 computer. Console panel has indicators for arithmetic and control registers. Typewriter is mounted on writing surface.
81	Console unit B	This console unit is essentially identical with console unit A (No. 80).
82, 83	Magnetic tape units	These two dual-magnetic-tape transport cabinets house read-write control logic circuits and associated electronic signal processing. One time multiplex unit serves each half of dual units. Tape data may be used to initialize simulation problem or to record data during training mission.
84	Magnetic tape units control cabinet	This cabinet houses two tape control chassis; each operates one dual tape transport unit and two line multiplex units, permitting independent operation of each dual transport.
86	Shared access distribution unit	This cabinet houses flip-flop registers and decoding logic to establish joint core memory, shared by central processor units A and B and fully buffered channel equipment. Joint access of these devices to common core is regulated by priority logic circuit within this unit.
87	Central processor unit C	This DDP-224 computer is ISLGC. (Information will be supplied at later date.)
88	Peripheral interface unit (PIU) C	Provides for fanning out of central processor unit C (unit No. 87) interface connections.
A2, A3, A9	External visual display equipment (EVDE), left-hand window unit	This unit houses composite visual image-generating equipment, essentially identical with right-hand display unit (No. A25, A27, A28).
A4, A29	Left- and right-window EVDE star display electronics cabinet	This cabinet houses control chassis for individual image generators of left and right display windows. Controls for illuminators, celestial sphere, and occultation mask are included.
A5	Mission effects projector unit	This structure houses film-projecting equipment for projecting visual displays of lunar and earth scenes, which are picked up by closed-circuit TV for input to

Table 1-1. LMS Equipment Arrangement (cont)

Unit No. (Figures 1-1 and 1-2)	Nomenclature	Description
A5 (cont)		optical system of EVDE. Indexing of appropriate film slide to be viewed is under computer control.
A10, A11	Rendezvous and docking electronics unit	Twelve identical illuminator controllers are mounted in this unit. They provide high-current lamp intensity modulation when driven by control signal outputs from computer complex. Several illuminator power supplies are also housed in this unit.
A13	Landing and ascent control electronics and lunar model and drive electronics cabinet	This cabinet houses signal-processing circuitry and related camera and servo-controlled equipment.
A14	Landing and ascent probe electronics cabinet	This cabinet houses equipment to drive simulator and logic signals for landing/ascent probe.
A17, A18, A19	Alignment optical telescope (AOT) star display unit	This unit houses servo-driven starfield simulation equipment, including illumination sources for realistic celestial field and occultation equipment to duplicate eclipse effects.
A20, A23	Overhead and alignment optical telescope electronics cabinets	This cabinet houses equipment to provide control signals for displays that are visible through LMS cabin overhead window.
A21, A22 A34	External visual display equipment overhead window unit	This unit houses visual display generator system similar to left- and right-hand window units, except for lunar surface display.
A25, A27, A28	External visual display equipment, right-hand window unit	This equipment (like left-hand EVDE) generates composite visual display, which incorporates earth and lunar images, celestial field, and projected television view of CSM for rendezvous maneuvers. These images are combined in lens-mirror system that yields visual image display to crewmembers.
A26	TV camera control cabinet	One bay of this cabinet houses seven duplicate camera control units and four electronic special effects chassis. Adjoining bay includes TV power distribution controls, sync circuit chassis and monitor kinescope unit.
A33	Signal and power distribution cabinet	This dual-bay cabinet houses switching panel and several independent signal distribution units.
A40	External visual display equipment power cabinet	This dual-bay cabinet houses main switches and monitoring instruments for power distribution within EVDE and several individual power supply units.



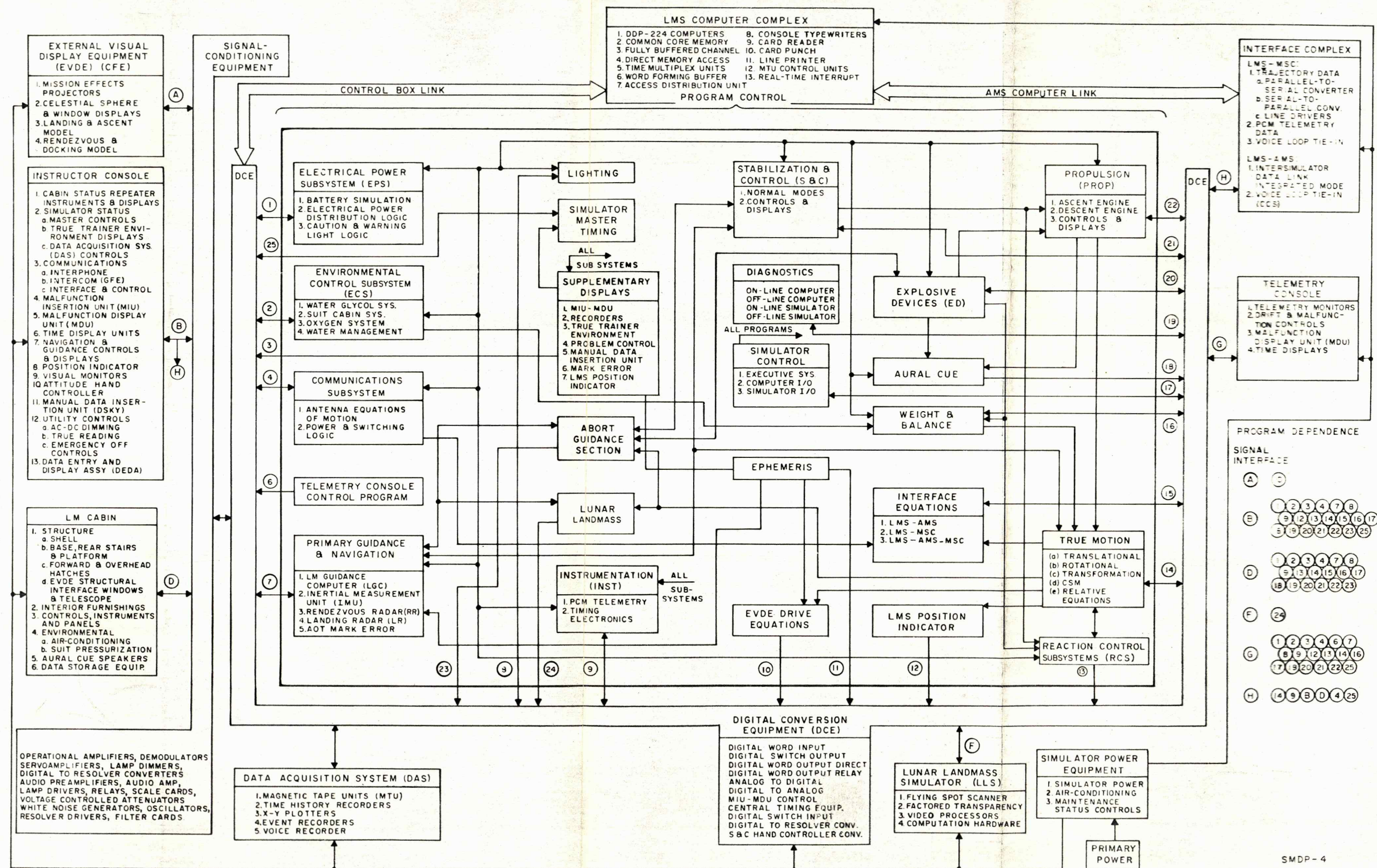


Figure 1-3. LMS Functional Block Diagram



#### 1.4.1.1 LMS Mission Phases.

The LMS is a complex of equipment that enables astronauts and ground personnel to undergo training that simulates manned earth-orbital, lunar-orbital, and lunar-landing missions. This training includes the following mission phases, as required for each type of mission:

- Translunar - LM subsystems checkout
- Circular lunar orbit - LM subsystem checkout and readiness
- Separation and descent orientation
- Coasting descent - transfer orbit
- Powered descent to hover
- Hover and landing
- Postlanding checkout
- Lunar-stay preparations
- Lunar-stay activities within LM
- Preascent checkout
- Powered ascent
- Coasting ascent - transfer orbit
- Rendezvous
- Docking
- Circular and elliptical earth orbits
- Synchronous orbit
- Parking orbit.

#### 1.4.1.2 LMS Modes of Operation.

Due to the commitment of LM, command module, and ground personnel training requirements (besides operating independently), the LMS can simulate LM earth-orbital, lunar-orbital, and lunar-landing missions; it operates in four modes, as follows:

- LMS independent
- LMS-MCC
- LMS-AMS
- LMS-AMS-MCC.

##### 1.4.1.2.1 LMS Independent Operation.

The primary purpose of LMS independent operation is to provide crew training in lunar-stay activities within the LM. During a LMS independent (nonintegrated) training session, the LMS instructors have complete control of LMS operation. With the MODE SELECTOR switch on the instructor console set to LMS ONLY, switches on the PROBLEM CONTROL panel control operation of the LMS during the various mission parameters. Equations of motion for the CSM are computed within the LMS complex, transmission of telemetry data between the LMS and MCC is halted, and simulated radio communication between LMS-AMS-MCC is terminated.

##### 1.4.1.2.2 LMS-MCC Operation.

In the LMS-MCC mode, the procedure for establishing CSM-to-ground communication status in the AMS is used for LM-to-ground communication status. The procedure consists of sending data from which that status can be computed, to MCC, and having MCC perform the subsequent calculations. This latter task falls logically to MCC because it controls sequencing of remote sites, and the LMS has no knowledge of which remote sites are operating. LM communication status is computed at MCC and sent to the LMS instructor console.

LMS computer status and time reference are transmitted together with trajectory data to permit MCC to evaluate and use the received trajectory data in real time. The LMS and MCC compute LM trajectory information in parallel; computations in the LMS are used to determine trajectory during astronaut-initiated maneuvers; computations at MCC are used to determine trajectory during ballistic flight. In the LMS, translation and rotation are computed at high iteration rates (10/second and 20/second), and realistic simulations of the Main Propulsion Subsystem; Guidance, Navigation, and Control Subsystem; and Reaction Control Subsystem are



included. Thus, during the thrusting period, the LMS computation of trajectory is quite accurate; it is used to update MCC equations. During ballistic flight, the LMS trajectory computations are updated to agree with MCC computations, and the LMS math model includes transformation of MCC trajectory data to the LMS coordinate system, logic that modifies LM position, and a discrete that defines the beginning of LM ballistic flight.

CSM trajectory and orientation are calculated in the LMS in any non-AMS mode. These data are sent to MCC, in the LMS-MCC mode, to provide a complete simulation of both vehicles at MCC during such important mission phases as lunar orbit and rendezvous.

#### 1.4.1.2.3 LMS-AMS Operation.

In the LMS-AMS mode, the LM-to-CSM communication status is computed in the LMS and sent to the AMS for the AMS instructor's information. Similarly, CSM-to-LM communication status is computed in the AMS and sent to the LMS for the LMS instructor's information. LM communication status with the ground stations is computed in the LMS and sent to the LMS instructor's console.

LMS computer status and time reference are transmitted together with trajectory data so that the AMS can use the data properly. Similarly, AMS computer status, time reference, and trajectory data are required by the LMS. In a simulated mission, when the CSM and LM are docked initially, both computers are started from the same initial condition, but the AMS computer trajectory is used as a "master" trajectory to update the LMS equations until separation. Because the time of LM separation cannot be predicted accurately, all data transfer between the AMS and LMS, required for LMS initialization, is transmitted continuously while the LM is attached to the CSM. CSM velocity, attitude, and position are sent to the LMS to initialize the LM equations of motion at separation and to provide CSM data for the LMS after separation. CSM body (B)-frame to inertial earth ( $I_E$ ) or inertial moon ( $I_M$ )-frame direction cosines are sent to the LMS so that CSM attitude with respect to LM body axes can be computed in the LMS after separation. The direction cosines are considered preferable to the Euler angles for this purpose. To meet the LMS position indicator/recorder and visual system requirements, CSM inertial longitude is also required by the LMS before separation.

When the LM is docked with the CSM, the AMS equations of motion compute combined vehicle position and attitude. Because, in general, LM mass, center of gravity, moments of inertia, and products of inertia may change considerably during separation (in a manner unknown to the AMS), these parameters are transferred to the AMS from the LMS when the vehicles are docked. This transfer is accomplished in the same manner as transfer of the Reaction Control Subsystem forces and moments. The available LM fixed body axes weight and balance data are transferred to the CSM fixed body axes, where the transfer equations to be used depend on the relative alignment of the LM body axis system. In the LMS-to-AMS trajectory data flow, LM velocity and position data are sent to the AMS on the assumption that the CSM is equipped with rendezvous radar. LM body (B)-frame to ( $I_M$ )-frame direction cosines are sent to the AMS so that LM attitude with respect to the CSM body axes can be computed in the AMS for use by the AMS visual equations.

#### 1.4.1.2.4 LMS-AMS-MCC Operation.

In the LMS-AMS-MCC mode, the CSM position and attitude data transmitted to MCC, in the LMS-MCC mode, can be sent directly from the AMS to MCC; the data are deleted from the LMS-MCC data flow. Because of differences between the LMS coordinate system used for LM translational motion computation and the coordinate system used in the AMS and at MCC, the following ground rule has been adopted for trajectory data flow during integrated operation: data from the LMS to the AMS and MCC, and from the AMS and MCC to the LMS, are transmitted in the common AMS and MCC coordinate system. Transformations required to transform the LMS trajectory data to this form or to transform the AMS and MCC trajectory data to the LMS coordinate system are performed in the LMS.

During the LMS-AMS and LMS-AMS-MCC integrated training exercises, the AMS generates the trajectory profile for all mission phases during which the LM is attached to the CSM. MCC furnishes trajectory data to the LMS to update the LM trajectory, if necessary. The LMS furnishes trajectory data in a format and at a sampling rate for conversion into ground tracking data for real-time input to the MCC computer complex. The LMS supplies position and attitude data to the AMS computer complex, from separation to docking, to drive the AMS visual cue, simulated communication, and simulated radar systems. Conversely, the LMS receives appropriate data from the AMS to drive (in synchronization) the LMS EVDE and simulated radar system. Signal conditioning is accomplished at the interface to accommodate an effective integration. In addition, the LMS provided MCC with on-off discrete control words to indicate spacecraft radar beacon operating status, to inform MCC that tracking is possible.

### 1.5 CONTROL AND MONITOR GROUP.

The control and monitor group consists of the instructor console, telemetry console, data acquisition subsystem, and interface complex discussed in paragraphs 1.5.1 through 1.5.4.



### 1.5.1 INSTRUCTOR CONSOLE.

The LMS instructor console (figure 1-4) is a U-shaped structure designed to accommodate two instructors and two support personnel. It occupies approximately 22 feet end-to-end in the wrap-around configuration. Each console section has independent fluorescent overhead lighting, and storage space under the desk area. The console contains repeater displays of the instruments within the simulated LM cabin and additional controls and displays to enable the instructors to effectively monitor and direct training situations.

The controls and displays on the instructor console panels enable the instructor to control the simulator, monitor the performance of the flight crew astronauts, provide aural and visual cues for system management, insert initial conditions and/or malfunctions, freeze the training mission, and record crew performance and flight parameters. Television monitors for observing the four window displays to be presented to the flight crew, and a spacecraft position indicator, are mounted on top of the console.

#### 1.5.1.1 Performance Monitoring.

The instructor console is monitored by a Mission Coordinator, a Commander Instructor, a Systems Engineer Instructor, and a Suit Technician. A Telemetry Instructor is at a separate console.

The Mission Coordinator monitors trainee power, selects the interface mode (LMS-AMS, LMS-MCC, etc), sets the initial condition, and controls the running of the problem. In addition to these specific responsibilities, he can monitor the overall problem (repeaters, malfunctions, communications, etc), as necessary, to enhance efficient and effective training.

The Commander and Systems Engineer Instructors monitor their respective flight crew astronauts. For this purpose, each has cabin repeater instruments and lights, switch position indicators, and the space flight position indicator. The instructors also have control responsibilities. Each can insert malfunctions, time events, and fail circuit breakers.

The Suit Technician monitors suit and cabin temperature, suit pressure, and suit airflow. He controls suit pressure and the pressurization rate.

The Telemetry Instructor can monitor problem malfunctions, insert malfunctions, and monitor transmission status, bilevel groups, digital words, and analog channel malfunctions.

In addition to the personal instruction given the flight crew, the instructors have access to records of the mission and performance. These records help in evaluation of each mission and add to the overall effectiveness of training. The following recording devices are available:

- A dual-head tape recorder provides a permanent record of Commander/Systems Engineer, and flight crew/instructor, conversation. The instructor can selectively record continuously or only during voice transmission.
- Two X-T recorders provide a record of variable quantities against a time base (chart speed). Each X-T recorder has eight channels and two time channels. The Systems Engineer Instructor can mark each X-T recorder by activating the appropriate switch on his RECORDERS panel. These marks facilitate referencing the recorded data, especially if the instructor uses a coding system for the marks. Typical variables programmed to be recorded are: total mass of the vehicle, axis position of a hand controller, propellant quantity, and attitude with respect to a specific reference system.
- Two X-Y plotters provides a record of one variable against another variable. There are two X-channels and two Y-channels. This fact, coupled with a large paper size (11 x 17 inches) results in an inherent recording accuracy much greater than that of the X-T recorders. The following are representative of the variables that can be recorded: range vs. range rate, altitude vs. distance to lunar landing site, altitude vs. altitude rate, and relative distance between the simulated CSM and the LM during rendezvous.
- A 20-channel event recorder provides a record of discrete events against a time base. The event recorder is particularly useful in recording specific procedures and sequences. For example, the switch sequence for jettison during ascent staging could be recorded. Another example would be the recording of crewmember reaction to a malfunction in a dual system (such as the Reaction Control Subsystem); the sequence of switching to the alternate system would be recorded along with the crewmember's reaction time.



1.5.1.1.1 CSM  $\Delta V$  Change Capability.

The instructor's  $\Delta V$  controls are primarily intended to give the instructor the added capability of positioning the CSM (within certain limits) out of plane with the LM position before start by the rendezvous and docking maneuvers. The controls are on the CSM CONTROL panel of the instructor console. Combined use of the  $\Delta V$  INSERT switches with the selectable TRANSLATION RATE X, Y, Z digiswitches on the CSM control panel provides the translation rates necessary to accomplish CSM positioning.

CSM attitude control is governed by the attitude mode selected and the CSM attitude hand controller located immediately in front of this panel. The three TRANSLATION RATE, X, Y, and Z switches on the CSM CONTROL panel are used to alter the inertial velocity of the CSM along the respective axis in positive or negative directions. The reference axis is parallel to the inertial nonrotating moon or earth frame, depending on the mission. These switches have a range of 0.00 to 9.99 feet per second in 0.01-foot-per-second increments. One  $\Delta V$  input, or all three simultaneously, may be inserted. Each time the INSERT button is pressed, an incremental velocity equivalent to the control setting is entered along the selected axis.

Attitude changes may be visually monitored at the TV monitors or at the FDAI on the flight control panel.

## 1.5.1.1.2 Spacecraft Position Indicator. (See figure 1-5.)

The spacecraft position indicator is not part of the instructor console, but is operated by the instructor in conjunction with the console. The instructor can display the current position and mission mode of the CSM and LM on the spacecraft position indicator screen. Manual controls enable power switching, automatic manual mode switching, background selection, and spot position control. The controls and displays of the spacecraft position indicator, and their function, are listed in table 1-2.

The spacecraft position indicator is a mechanical/optical projection system. Two spot projectors indicate current position of the LM and CSM. A background projector provides the necessary mission reference information.

The system consists of a display surface and projectors incorporated into a single unit mounted in its own cabinet. This cabinet and a cabinet of associated electronic equipment constitute the total equipment required for the spacecraft position indicator. It operates in automatic and manual modes. All input signals required for the indicator in its automatic mode are provided by the LMS computer in analog form.

The manual control panel permits manual operation of the indicator for power switching, automatic/manual mode switching, background selection, and spot position control. The panel is mounted below the projector display area, under a cover that conceals the controls. Equipment status indicators, also below the projector display area, are visible at all times.

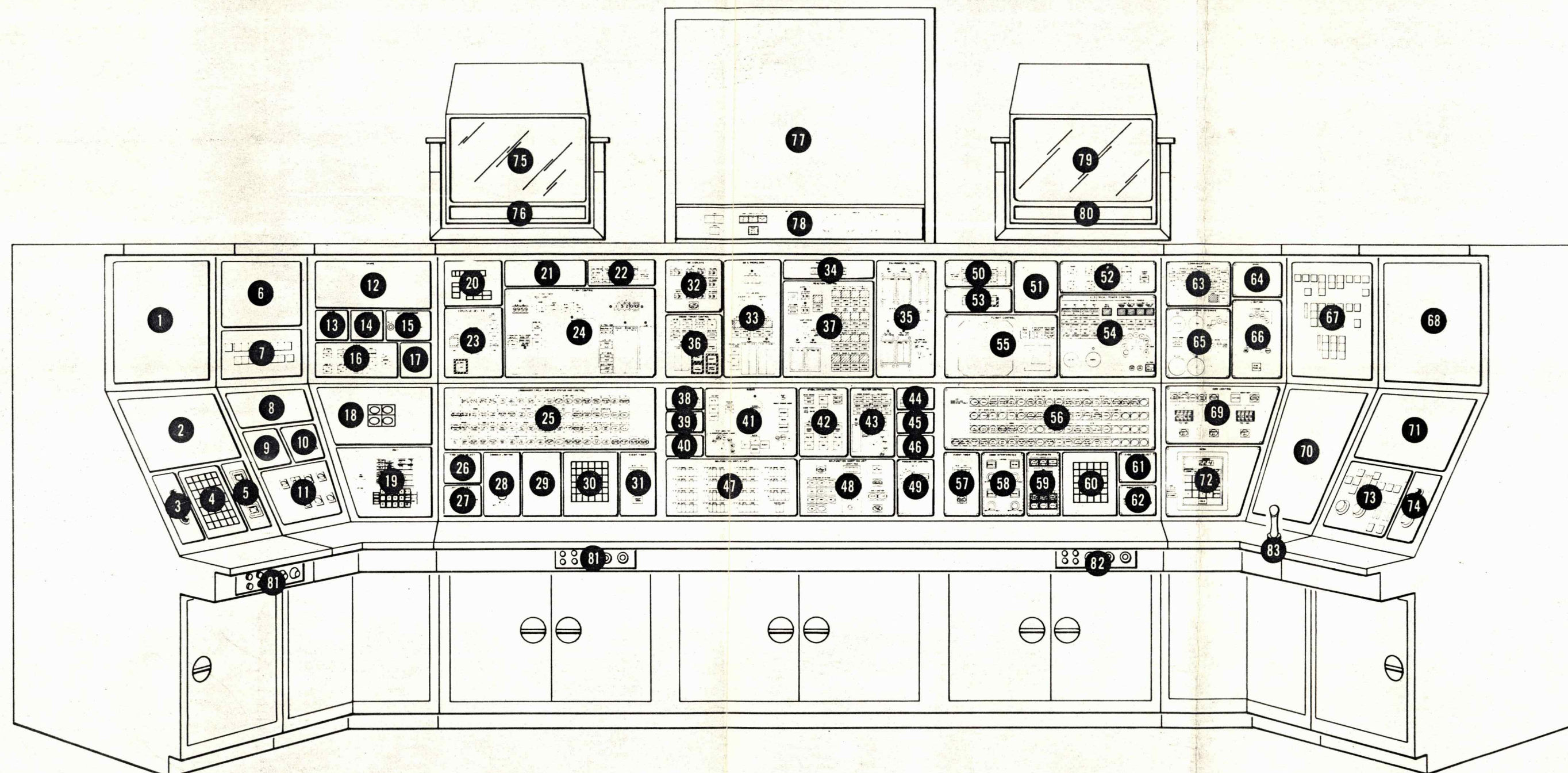
The projection system consists of the following:

- Two spot projectors (servo-driven in X-axis and Y-axis)
- A background projector and slide magazine with a maximum capacity of 48 slides. (Magazine is not loaded to capacity; currently, 21 slides are used.) Projector can select 29 slides automatically (by computer) or they can be selected manually.
- Electronics for control and switching of the projectors
- A manual control panel
- Background slides
- Equipment status indicators.

Each spot projection conforms to the following motion and tolerance requirements, as measured on the display surface for each axis of spot motion.

Maximum linear tracking speed	3 inches per second
Maximum slew speed	15 inches per second
Static accuracy	$\pm 0.1$ inch
Velocity constant	30/second





1. SPARE
2. SPARE
3. CONSOLE LIGHTING PANEL
4. CCS KEYSET PANEL
5. EMERGENCY PANEL
6. SPARE
7. SIMULATOR STATUS PANEL
8. SPARE
9. AURAL CUE PANEL
10. INTERFACE CONTROL PANEL
11. PROBLEM CONTROL PANEL
12. SPARE
13. SPARE
14. LIGHTING PANEL
15. AOT MARK ERROR PANEL

16. AUDIO PANEL
17. SPARE
18. COMMANDER CIRCUIT BREAKER STATUS AND CONTROL PANEL
19. DSKY PANEL
20. MISSION TIMER
21. SPARE
22. WARNING PANEL
23. EXPLOSIVE DEVICES PANEL
24. FLIGHT CONTROL PANEL
25. COMMANDER CIRCUIT BREAKER STATUS AND CONTROL PANEL
26. EVDE VIDEO SELECT PANEL
27. LEFT LAMP TEST PANEL
28. CONSOLE LIGHTING PANEL

29. SPARE
30. CCS KEYSET PANEL
31. EVENT TIMER PANEL
32. TIME DISPLAYS PANEL
33. MAIN PROPULSION PANEL
34. PARAMETER DISPLAY PANEL
35. ENVIRONMENTAL CONTROL PANEL
36. ENGINE THRUST CONTROL PANEL
37. REACTION CONTROL PANEL
38. CDR TRANSL CONTROLLER PANEL
39. TRUE INST READING PANEL
40. SPARE
41. RADAR PANEL
42. STABILIZATION CONTROL PANEL
43. HEATER CONTROL PANEL

44. SE TRANSL CONTROLLER PANEL
45. TRUE INST READING PANEL
46. SPARE
47. MALFUNCTION DISPLAY UNIT PANEL
48. MALFUNCTION INSERTION UNIT PANEL
49. PARAMETER CONTROL PANEL
50. CAUTION PANEL
51. SPARE
52. AUDIO PANEL
53. ENGINE THRUST PANEL
54. ELECTRICAL POWER CONTROL PANEL
55. FLIGHT CONTROL PANEL
56. SYSTEM ENGINEER CIRCUIT BREAKER STATUS CONTROL PANEL
57. EVENT TIMER PANEL

58. COMM INTERFERENCE PANEL
59. RECORDERS PANEL
60. CCS KEYSET PANEL
61. EVDE VIDEO SELECT PANEL
62. RIGHT LAMP TEST PANEL
63. COMMUNICATIONS PANEL
64. SPARE
65. COMMUNICATIONS ANTENNAS PANEL
66. LIGHTING PANEL
67. ECS VALVE POSITION INDICATORS
68. SPARE
69. CSM CONTROL PANEL
70. SPARE
71. SPARE
72. DEDA PANEL

73. TRUE TRAINEE ENVIRONMENT PANEL
74. CONSOLE LIGHTING PANEL
75. EVDE TV MONITOR
76. TV CONTROL PANEL
77. POSITION INDICATOR
78. POSITION INDICATOR CONTROL PANEL
79. EVDE TV MONITOR
80. TV CONTROL PANEL
81. COMMUNICATIONS CONTROL PANEL
82. COMMUNICATIONS CONTROL PANEL
83. HAND CONTROLLER

LMS-1-1

Figure 1-4. LMS Instructor Console



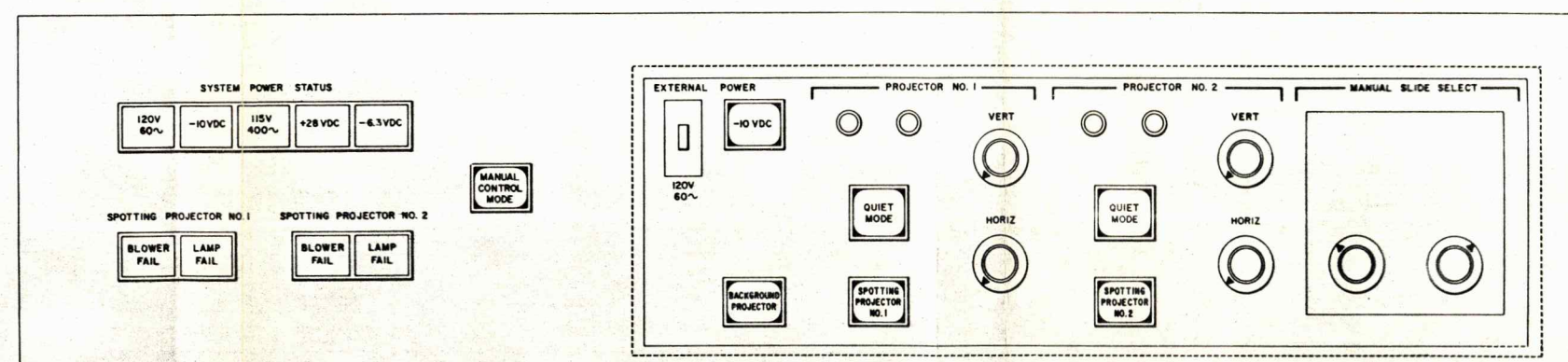
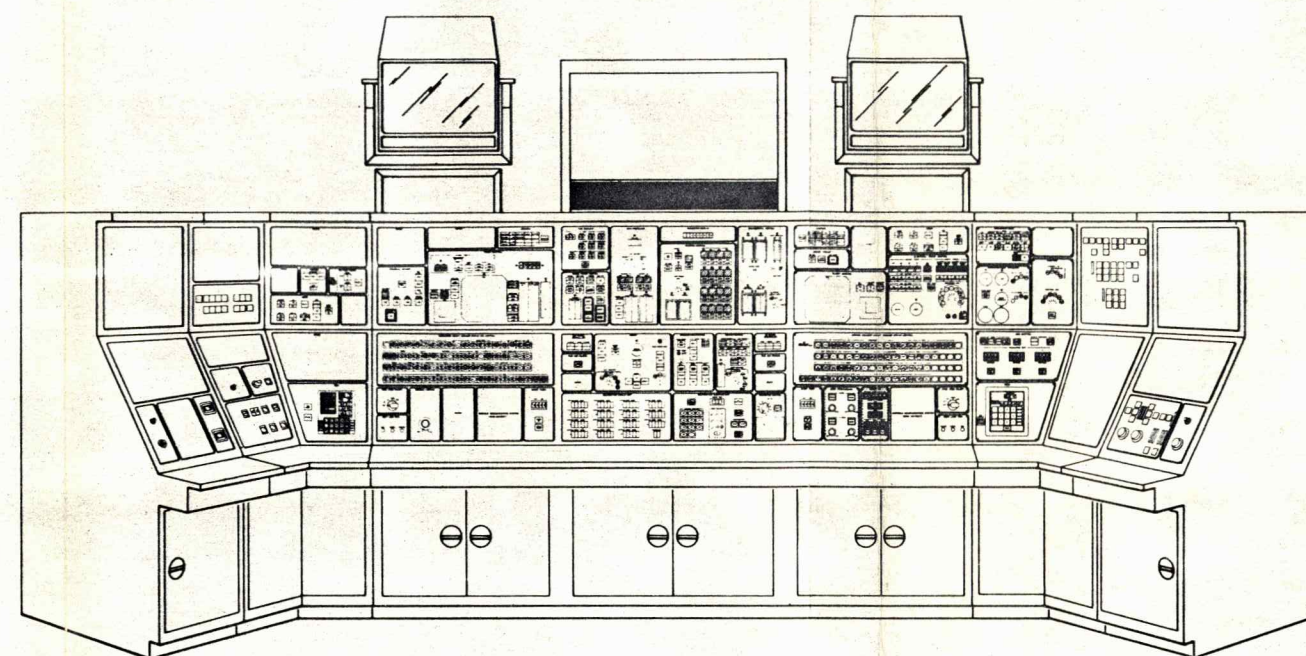


Figure 1-5. Spacecraft Position Indicator Control Panel



Table 1-2. Spacecraft Position Indicator, Controls and Displays

Control or Display	Function
SYSTEM POWER STATUS switches 120V 60 ~ -10 VDC 115V 400~ +28 VDC -6.3 VDC	When illuminated, indicates presence of various voltages
SPOTTING PROJECTOR NO. 1 BLOWER FAIL switch LAMP FAIL switch	Press-to-test switches; indicate blower or lamp failure
SPOTTING PROJECTOR NO. 2 BLOWER FAIL switch LAMP FAIL switch	Press-to-test switches; indicate blower or lamp failure
MANUAL CONTROL MODE switch	When illuminated equipment can be operated manually
EXTERNAL POWER circuit breaker 120V 6 ~ -10 VDC	Apply external power
BACKGROUND PROJECTOR switch	Turns on background projector
SPOTTING PROJECTOR NO. 1 switch	Turns on spotting projector No. 1
SPOTTING PROJECTOR NO. 2 switch	Turns on spotting projector No. 2
HORIZ knobs (two)	Horizontal drive control for spotting projector No. 1 or 2
VERT knobs (two)	Vertical drive control of spotting projector No. 1 or 2
QUIET MODE switches (two)	Turns on QUIET MODE lights in each projector
MANUAL SLIDE SELECT knobs (two)	Manual controls for changing slides

Precision background slides for the display system are provided in the background projector carousel. To assure repeatability and registration accuracy, it is recommended that these slides not be removed. If they must be removed, check that they are returned to their original carousel locations and are not switched from system to system. The slides are photographic reproductions on spectroscopic emulsion mounted on glass.

The spacecraft position indicator is in two cabinets. One cabinet contains all of the electronic equipment associated with the display unit, the other contains the display unit. The electronic cabinet houses the electronic equipment on standard 19-inch electronic equipment racks.

The front portion of the display cabinet is supported by the instructor console 61 inches high. The rear portion of the display cabinet is supported by the electronics cabinet.

The electronics cabinet has doors on both sides to provide full access to the equipment and cabling. The viewing screen is tilted forward at an angle to permit satisfactory viewing by an instructor seated at the console and an observer standing 15 feet from the display surface. For forced-air ventilation, the cabinet has inlet grills and exhaust blowers to circulate conditioned room air through the unit. The cabinet is dust tight. Heated exhaust air is externally expelled at the top. All intake and exhaust opening are filtered. The cabinet has casters and leveling jacks; a reinforced metal base permits lifting from underneath by means of a forklift. The cabinet is secured together and equipped with a grounding stud to prevent danger of electrical shock.



The interface between the LMS and the spacecraft position indicator has the following electrical characteristics:

Command signals (analog)	Variable between 0 and -10 volts dc; 0.025% accuracy; 1.5K-ohm source impedance. Load impedances are equal to, or greater than, 50K ohms. Inline scale adjustment is provided at load location.
Signal reference and grounds	
Servo reference voltages	-10 volts dc at 0.01% regulation
D-C signal return	Single-wire return for system ground
Chassis ground	Single wire for earth ground
Source power (primary a-c power)	120 volts ac, 60 cps, single phase, at approximately 4,450 volt-amperes

Requirements for other voltages are fulfilled from internal power supplies.

A utility electrical power circuit, included in the equipment, is independent of the master power switch. The circuit contains a trouble lamp and dual outlets that accept three-prong grounded plugs. The utility power circuit is connected directly to the simulator utility power circuit through a separate three-wire cable and connector.

The folded optics for the background projector consist of two factory-set first-surface mirrors that, in normal use, require no adjustment. Occasional cleaning (dust removal with a camel's-hair brush) is required during periodic maintenance.

Care should be taken to prevent dislocating the mirrors; if, however, the image on the viewing screen is displaced, adjustment of the bottom mirror is all that is necessary.

#### 1.5.1.1.3 TV Monitors.

The TV monitor controls are shown in figure 1-6; they are listed, with their functions, in table 1-3.

#### 1.5.1.2 Instructor Console Panels. (See figure 1-4.)

The panels of the instructor console, and their function, are listed in table 1-4. For detailed illustrations and descriptions, refer to paragraph 1.9.

#### 1.5.2 TELEMETRY CONSOLE.

The telemetry console acts as a ground support station (figure 1-7) in that telemetry signals from the LMS are continuously monitored by the telemetry console operator. The operator maintains contact with MCC during LMS training exercises. He can insert faults into the telemetry measurement data output from the various subsystems and can display the resultant malfunctioned data, the true data, or the data with malfunction removed, as desired.

The telemetry data are transmitted by hard line to MCC with the same accuracy as the actual LM telemetry system. The LMS can transmit 51,200 or 1,600 bits per second, in serial form, to MCC through line drivers. The telemetry output (eight-bit words) is capable of, but not limited to, a rate of 6,400 telemetry values per second, amounting to transmission of 51,200 bits per second. A flow diagram of the telemetry signals is shown in figure 1-8.

The telemetry console performs the following functions:

- Monitors all telemetry data before conversion to final PCM telemetry format
- Monitors LMS instrumentation control and switch positions that govern PCM rates and modes
- Inserts faults into the LMS telemetry system (except LGC)
- Displays the fault-modified data

(to be supplied)

Figure 1-6. TV Monitor, Control Panel

Table 1-3. TV Monitor, Controls

Control	Function
(Information to be supplied when available)	



Table 1-4. Instructor Console Panels

Figure 1-4 Index No.	Panel	Function
1	Spare	
2	Spare	
3	CONSOLE LIGHTING	Floodlighting and indicator lighting controls (left portion of console)
4	CCS keyset (position 520)	Provides simulator audio selections and call alert (visual and aural)
5	EMERGENCY	Emergency turn-off switches for EVDE and LMS complex
6	Spare	
7	SIMULATOR STATUS	Indicates subsystem power and computer status
8	Spare	
9	AURAL CUE	Controls audio level in cabin
10	INTERFACE CONTROL	Establishes degree of integration with AMS and MCC
11	PROBLEM CONTROL	Establishes operational phases in the running of mission programs and displays initial conditions
12	Spare	
13	Spare	
14	LIGHTING	Switch-position repeaters of Commander's LIGHTING control side panel
15	AOT MARK ERROR	Displays astronaut's sighting error of two stars
16	AUDIO	Switch-position repeaters of Commander's AUDIO selection side panel
17	Spare	
18	Spare	
19	DSKY	Fully operational repeater of Commander's DSKY panel; instructor may set in, or read out, guidance data just as astronauts do
20	MISSION TIMER	Repeater of cabin MISSION TIMER and controls
21	Spare	

Table 1-4. Instructor Console Panels (cont)

Figure 1-4 Index No.	Panel	Function
22	WARNING PANEL	Repeaters of WARNING annunciator panel and Commander's MASTER ALARM light
23	EXPLOSIVE DEVICES	Repeaters of switch positions and flags on Commander's EXPLOSIVE DEVICES panel
24	FLIGHT CONTROL	Repeaters of Commander's flight control instruments and related switch positions; includes repeaters of event timer controls and display
25	COMMANDER CIRCUIT BREAKER STATUS AND CONTROL	Switch-light fixtures for all of Commander's side panel circuit breakers. Illuminated switches fail any individual breaker and show status of all breakers.
26	EVDE VIDEO SELECT	Selects astronaut's visual display for viewing on left console TV monitor
27	LEFT LAMP TEST	All panel display lights go on in any of three zones on left half of instructor console.
28	CONSOLE LIGHTING	Controls dimming of console center section floodlight
29	Spare	
30	CCS keyset (position 518)	Provides simulator audio selections and call alert (visual and aural)
31	EVENT TIMER	Resettable electric timer for instructor's convenience
32	TIME DISPLAYS	Numerical readouts of various chronological mission parameters
33	MAIN PROPULSION	Repeaters of cabin MAIN PROPULSION panel switch position and system instrumentation displays
34	PARAMETER DISPLAY	Numerical readout of preselected parameters in computer core memory
35	ENVIRONMENTAL CONTROL	Repeaters of ECS instrumentation and control switch positions
36	ENGINE THRUST CONTROL	Repeaters of thrust control switches Commander's thrust indicators
37	REACTION CONTROL	Repeaters of RCS switch position and flags, as well as RCS instrumentation displays



Table 1-4. Instructor Console Panels (cont)

Figure 1-4 Index No.	Panel	Function
38	CDR TRANSL CON- TROLLER	Position display lights that indicate when Commander's hand controller has been displaced from neutral in any one of three axis
39	TRUE INST READING	Alternate-action switch that commands nonmalfunctioned (correct) readings at all instrument displays on left half of instructor console
40	Spare	
41	RADAR	Repeaters of radar control switch positions, displays of the radar component caution light, and signal strength meter
42	STABILIZATION CONTROL	Repeaters of switch positions on LM stabilization control panel
43	HEATER CONTROL	Repeaters of heater system control switches and related temperature indicator
44	SE TRANSL CON- TROLLER	Position display lights that indicate when Systems Engineer's hand controller has been displayed from neutral in any one of three axis
45	TRUE INST READING	Alternate-action switch that commands nonmalfunctioned (correct) readings at all instrument displays on right half of instructor console
46	Spare	
47	MALFUNCTION DISPLAY UNIT	Numerical readouts display as many as 15 malfunction codes. Overflow display indicates that more than 15 malfunctions are active or pending. (maximum overflow display is 11.)
48	MALFUNCTION INSERTION UNIT	Multiplexed control group that permits selection of manually initiated malfunction routines
49	PARAMETER CON- TROL	Selects display of as many as 12 preprogrammed parameter readouts
50	CAUTION	Repeaters of CAUTION annunciator panel and Systems Engineer's MASTER ALARM light
51	Spare	
52	AUDIO	Repeater indicators of switch positions selected at Systems Engineer's AUDIO panel



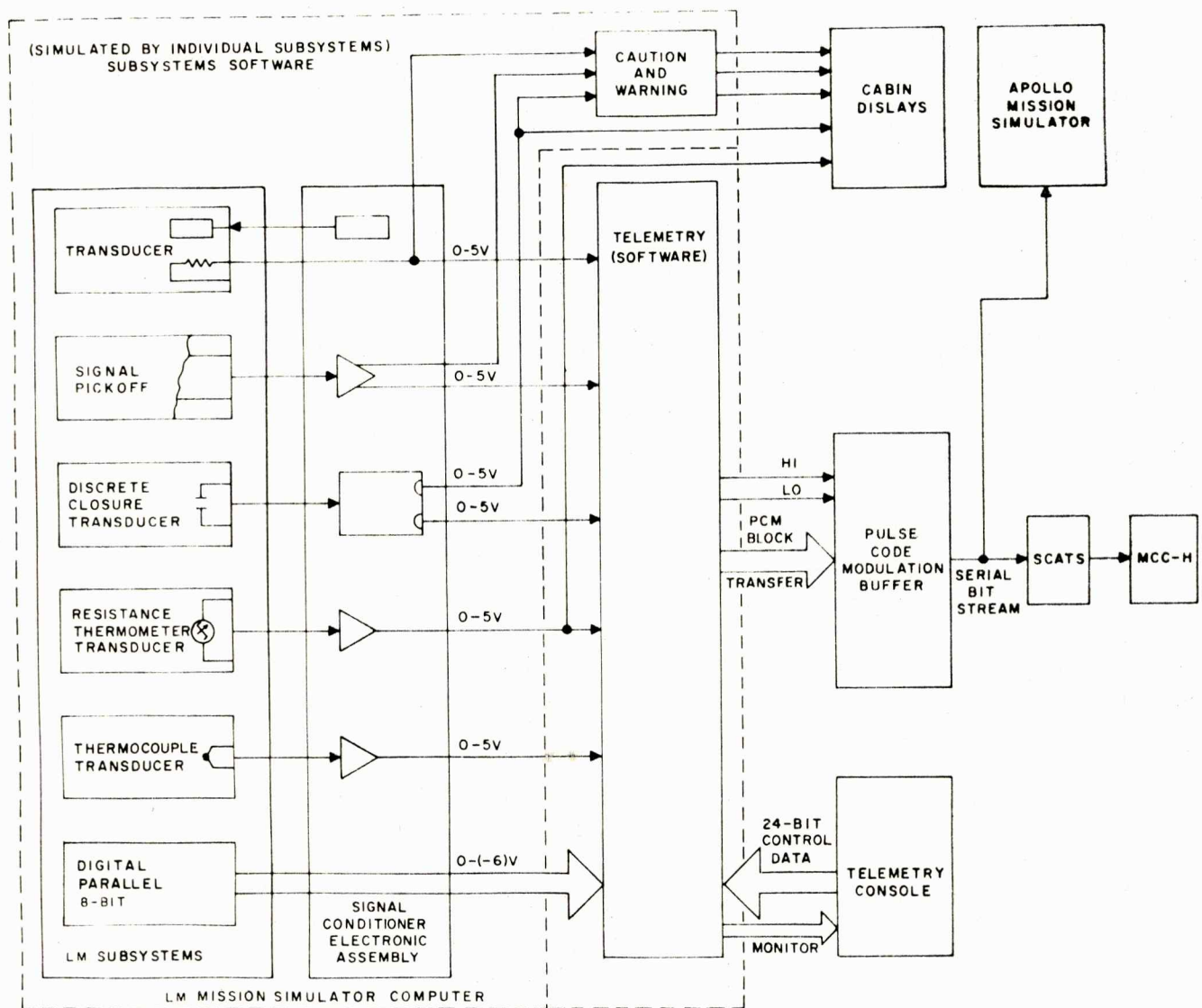
Table 1-4. Instructor Console Panels (cont)

Figure 1-4 Index No.	Panel	Function
53	ENGINE THRUST	Repeaters of Systems Engineer's thrust control switches and lunar contact annunciator
54	ELECTRICAL POWER CONTROL	Repeaters of ECS flags. Instrument readouts, switch settings, and component caution indicators
55	FLIGHT CONTROL	Repeaters of Systems Engineer's flight control instruments and related switch positions
56	SYSTEM ENGINEER CIRCUIT BREAKER STATUS CONTROL	Switch-light fixtures for all of Systems Engineer's side panel circuit breakers. Illuminated switches fail any individual breaker and show status of all breakers
57	EVENT TIMER	Resettable electric timer for instructor's convenience
58	COMM INTERFERENCE	Controls to introduce variable amounts of noise and voice distortion in voice communication channels
59	RECORDERS	Instructor's control switches for the two X-T recorders, one event recorder, two X-Y plotters, and voice recorder
60	CCS keyset (position 519)	Provides simulator audio selection and call alert (visual and aural)
61	EVDE VIDEO SELECT	Selects astronaut's visual displays for viewing on right console TV monitor
62	RIGHT LAMP TEST	Illuminates all panel display lights in any of three zones on right half of instructor console
63	COMMUNICATIONS	Repeaters of switch positions and of tape warning flag on Systems Engineer's COMMUNICATIONS side console panel.
64	Spare	
65	COMMUNICATIONS ANTENNAS	Repeaters of LM antenna panel indicators and of panel switch settings. Two meters also indicate the control positions for antenna directing knobs
66	LIGHTING	Repeaters of switch positions selected at Systems Engineer's LIGHTING panel
67	ECS VALVE POSITION INDICATORS	Lighted annunciators display manually controlled valve positions of ECS. Cabin and suit temperature control settings are displayed

Table 1-4. Instructor Console Panels (cont)

Figure 1-4 Index No.	Panel	Function
68	Spare	
69	CSM CONTROL	Digital and pushbutton switches to maneuver and control simulated CSM appearing in LMS training mission (when session does not require simulation integration with AMS)
70	Spare	
71	Spare	
72	DEDA	Fully operational repeater of LM DEDA panel; instructor may set in, or read out, guidance data just as astronauts do
73	TRUE TRAINEE ENVIRONMENT	Switches, regulators, and indicators with which Suit Technician monitors and controls astronaut's suit pressure and temperature, as well as cabin temperature
74	CONSOLE LIGHTING	Floodlighting and indicator lighting controls (right portion of console)
81 and 82	Communications control	Permits instructors to tie into console communication system
83	Hand controller	Permits instructor to control attitude of CSM model during rendezvous and docking



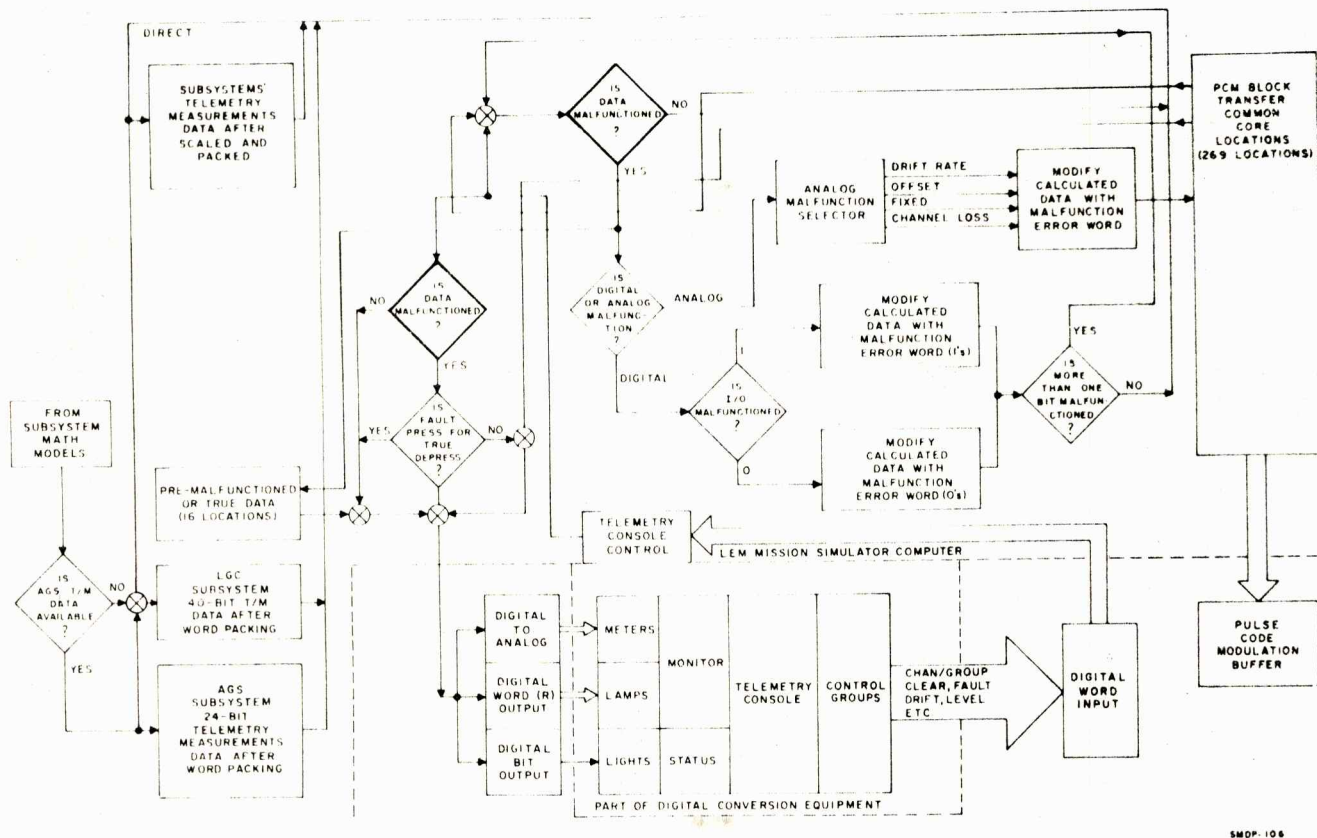


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Figure 1-7. Telemetry and Simulated Real-World Subsystem, Block Diagram

- Accepts fault insertions into control modes, such as level change, fixed level substitution, drift rate superposition, channel loss, and inhibit word
- Displays bilevel parameters on indicator lights
- Transmits data to MCC with frame and word rate identical with that of the LM
- Selects and displays digital and/or analog values
- Controls and displays all required normal and fault-inserted telemetry data (except LGC)
- Monitors MCC tie-in controls
- Indicates problem time.

The location of the telemetry console control and display panels is shown in figure 1-9. The panels are identified, and their functions given, in table 1-5. The individual controls and indicators are described in paragraph 1.10.



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Figure 1-8. Telemetry Signals and Measurements, Flow Diagram

Table 1-5. Telemetry Console Panels

Figure 1-9. Index No.	Panel	Function
1	Spare	
2	Spare	
3	Spare	
4	TIME DISPLAYS	Shows same time readouts as displayed on instructor console
5	TRANSMISSION STATUS	Selects type of biomedical data, and displays status of telemetry and biomedical transmission mode
6	Spare	
7	MALFUNCTION DISPLAY UNIT	Shows same numerical readouts of malfunction codes as displayed on instructor console
8	Spare	



Table 1-5. Telemetry Console Panels (cont)

Figure 1-9. Index No.	Panel	Function
9	BI-LEVEL GROUP & DIGITAL WORD MALFUNCTION	Has eight sets of controls to permit simultaneous simulation of onboard equipment malfunctions (64 bilevel groups or 8 digital words) to be transmitted to MCC
10	ANALOG CHANNEL MALFUNCTION	Has eight sets of controls to permit simultaneous simulation of onboard equipment malfunctions (eight analog data functions) to be transmitted to MCC
11	ANALOG CHANNEL MONITOR	Has eight display and control sets to permit simultaneous monitoring of status of eight analog data functions being transmitted to MCC
12	BI-LEVEL GROUP & DIGITAL WORD MONITOR	Has eight display and control sets to permit simultaneous monitoring of status of eight bilevel groups or digital word functions being transmitted to MCC
13	LAMP TEST	Tests all indicator lamps on telemetry console
14	Console communication system (CCS Keyset) (position 521)	Provides simulator audio selection and call alert (visual and aural)
15	Spare	
16	EMERGENCY	Turns off power to entire LMS, except 115-volt a-c utility power
17	Spare	
18	CONSOLE LIGHTING	Adjusts intensity of all indicator lamps and fluorescent flood lamps on telemetry console
19	Communications control	Permits telemetry personnel to tie into console communication system.

#### 1.5.2.1 Telemetry Digital Conversion Equipment.

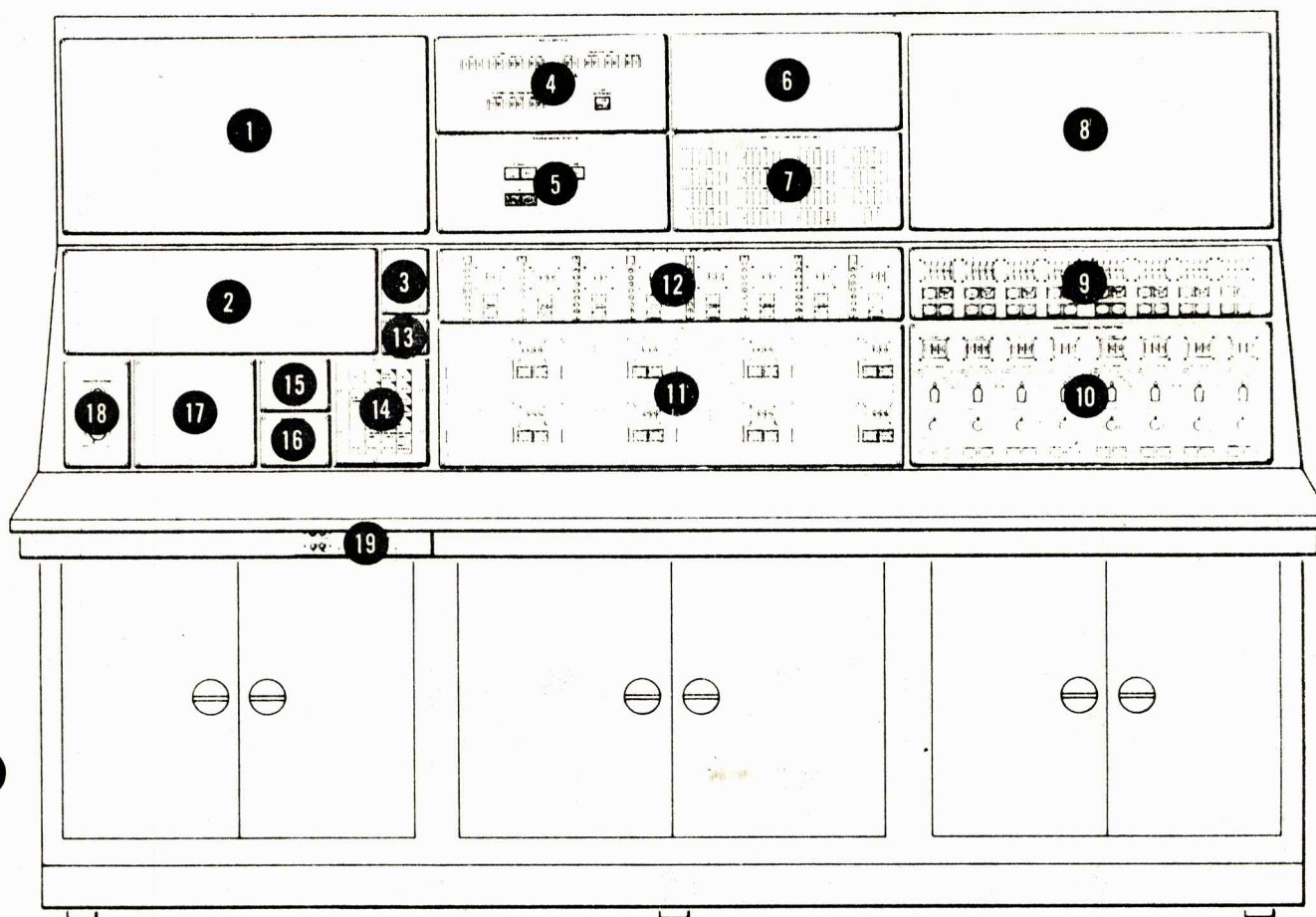
The telemetry console is tied to the computer complex to input malfunctions and output monitor data, through digital conversion equipment (DCE). The five input/output devices used for these functions are as follows:

- Input: Digital word input (DWI) equipment  
Analog-to-digital (A/D) converter
- Output: Digital bit output (DBO) equipment  
Digital word output relay (DWOR) equipment  
Digital-to-analog converter.

##### 1.5.2.1.1 Digital Word Input.

The 24-bit DWI connects to the telemetry console hardware, as follows:

- Bit 1 - This bit is not used.
- Bit 2 - This bit connects to the 16 CLEAR and 16 FAULT (PRESS FOR TRUE) switches in parallel on the bilevel group and digital word monitor and malfunction panels, and on the analog channel monitor and malfunction panels.



1. SPARE
2. SPARE
3. SPARE
4. TIME DISPLAYS PANEL
5. TRANSMISSION STATUS PANEL
6. SPARE
7. MALFUNCTION DISPLAY UNIT PANEL
8. SPARE
9. BI-LEVEL GROUP & DIGITAL WORD MALFUNCTION PANEL
10. ANALOG CHANNEL MALFUNCTION PANEL
11. ANALOG CHANNEL MONITOR PANEL
12. BI-LEVEL GROUP & DIGITAL WORD MONITOR PANEL
13. LAMP TEST PANEL
14. CONSOLE COMMUNICATION SYSTEM PANEL
15. SPARE
16. EMERGENCY PANEL
17. SPARE
18. CONSOLE LIGHTING PANEL
19. COMMUNICATIONS CONTROL PANEL

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Figure 1-9. Telemetry Console



- Bit 3 - This bit connects to three diodes, each of which connects to a different drift rate contact of the eight FAULT MODE switches on the ANALOG CHANNEL MALFUNCTION panel.
- Bit 4 - This bit connects to eight DRIFT RATE V/SEC X.001 contacts of the eight FAULT MODE switches in parallel on the ANALOG CHANNEL MALFUNCTION panel, and to the most significant bit (MSB) ( $2^2$ ) contact of the eight BIT digiswitches in parallel on the BI-LEVEL GROUP & DIGITAL WORD MALFUNCTION panel.
- Bit 5 - This bit connects to eight DRIFT RATE V/SEC X.01 contacts of the eight FAULT MODE switches in parallel on the ANALOG CHANNEL MALFUNCTION panel, and to the center ( $2^1$ ) contact of eight BIT digiswitches in parallel on the BI-LEVEL GROUP & DIGITAL WORD MALFUNCTION panel.
- Bit 6 - This bit connects to eight DRIFT RATE V/SEC X.1 contacts of the eight FAULT MODE switches in parallel on the ANALOG CHANNEL MALFUNCTION panel, and to the LSB ( $2^0$ ) contact of the eight BIT digiswitches in parallel on the BI-LEVEL GROUP & DIGITAL WORD MALFUNCTION panel.
- Bit 7 - This bit connects to eight OFFSET contacts of the eight FAULT MODE switches in parallel on the ANALOG CHANNEL MALFUNCTION panel, and to the eight GROUP/BIT switches in parallel on the BI-LEVEL GROUP & DIGITAL WORD MALFUNCTION panel.
- Bit 8 - This bit connects to eight FIXED contacts of the eight FAULT MODE switches in parallel on the ANALOG CHANNEL MALFUNCTION panel, and to the eight 1/0 switches in parallel on the BI-LEVEL GROUP & DIGITAL WORD MALFUNCTION panel.
- Bit 9 - This bit connects to eight CHAN LOSS contacts of the eight FAULT MODE switches in parallel on the ANALOG CHANNEL MALFUNCTION panel.
- Bit 10 through 18 - Each bit connects to 32 corresponding contacts on the 32 GROUP digiswitches in parallel on the bilevel group and digital word monitor and malfunction panels. Bit 10 connects to the most significant bit (MSB) contact of the leftmost module, bit 12 connects to the least significant bit (LSB) contact of the leftmost module, bit 13 connects to the MSB contact of the center module, etc, until bit 18 contacts to the LSB contact of the rightmost module of the 32 GROUP digiswitches.
- Bits 19 through 24 - These bits connect to a 32 x 6 event-to-binary diode matrix, with bit 19 connected to the MSB and bit 24 connected to the LSB of the binary output. The 32 event inputs are sequentially connected to the telemetry console control groups from left to right, starting with the BI-LEVEL GROUP & DIGITAL WORD MALFUNCTION MONITOR panel, followed by the BI-LEVEL GROUP & DIGITAL WORD MALFUNCTION panel, and, lastly, the ANALOG CHANNEL MALFUNCTION panel.

#### 1.5.2.1.2 Analog-to-Digital (A/D) Converter.

The eight A/D converters are connected to the eight RATE LEVEL potentiometers on the ANALOG CHANNEL MALFUNCTION panel; the digital portions of the A/D converters are associated with the 13 most significant bits of their respective computer words.

#### 1.5.2.1.3 Digital Bit Output (DBO).

The 48 DBO's are connected to 48 switches, as listed below; their relay contacts are associated with the LSB of the computer words.

- Sixteen DBO's are connected to 16 DISPLAY switches on the bilevel group and digital word and analog channel monitor panels.
- Sixteen DBO's are connected to 16 FAULT switches on the bilevel group and digital word and analog channel monitor panels.
- Sixteen DBO's are connected to 16 ENTER and 16 CLEAR switches on the bilevel group and digital word and analog channel malfunction panels.

#### 1.5.2.1.4 Digital Word Output Relay (DWOR).

Eight DWOR's consisting of eight relay contacts are connected to eight digital readout data strips consisting of eight lamps each. The eight DWOR relay contacts are associated with the eight most significant bits of their respective computer word.

#### 1.5.2.1.5 Digital-to-Analog (D/A) Converter.

The eight D/A converters are connected to the eight voltmeters on the ANALOG CHANNEL MONITOR panel; the digital portions of these D/A converters are associated with the 13 most significant bits of their respective computer words.

#### 1.5.2.2 General Program Requirements.

For the telemetry console to operate properly, a number of program requirements must be met. These are as follows:

- Checks are made for improper control group identification number; that is, 0 or greater than 32.
- Checks are made for improper channel number dialed up; that is, 0, greater than 317, or less than 187.
- Checks are made for improper group number dialed up; that is, 0 or greater than 186.
- A DWI insertion of a 24-bit word containing all zeros indicates no information is being inserted from the telemetry console.
- A DWI insertion of a 24-bit word with bits 10 through 18 (channel or group number) zero indicates that the previous malfunction or monitor control data is cleared and the CLEAR switch light is illuminated in the case of a BI-LEVEL GROUP & DIGITAL WORD MALFUNCTION panel or ANALOG CHANNEL MALFUNCTION panel insertion, or the DISPLAY switch light is extinguished in the case of a BI-LEVEL GROUP & DIGITAL WORD MONITOR panel or ANALOG CHANNEL MONITOR panel insertion.
- A DWI insertion of a 24-bit word with bits 19 through 24 (control group identification number) zero or greater than 32, or with bits 10 through 18 (channel or group number) greater than 317 or 186, respectively, suggests an error of some kind.
- A check is made indicating whether the malfunction previously entered on a certain control group was cleared before another malfunction is entered. This check prevents entering a new malfunction if it indicated that the control group has not been cleared.
- Although the BIT thumbwheel switch reads 1 through 8, it actually inserts an octal number 0 through 7, respectively, in binary form to the computer.
- Although BIT is stamped over the right thumbwheel switch only, the GROUP as well as the BIT thumbwheels must be dialed in order to malfunction a specific bit.
- FAULT MODE - CHAN LOSS means replacing data with all zeros.
- FAULT MODE - FIXED means replacing data scaled 5 volts equal to  $254 \times 2^{-8}$  by another word, scaled 5 volts equal to all 1's, whose value is determined by the RATE/LEVEL pot. The replacing word will not be negative or greater than +5 volts. This necessitates a check for negative.
- FAULT MODE - OFFSET means modifying data scaled 5 volts equal to  $254 \times 2^{-8}$  by another word, scaled 5 volts equal to all 1's, whose value is determined by the RATE/LEVEL pot. The modifying word will not be greater than +5 volts. Also, the result shall not be negative or greater than +5 volts.
- FAULT MODE - DRIFT RATE means modifying data scaled 5 volts equal to  $254 \times 2^{-8}$  by a rate (fixed change per iteration) scaled 5 volts equal to all 1's, whose value (or fixed change) is determined by the RATE/LEVEL pot. The modifying word will not be greater than +5 volts. Also, the result will not go negative or greater than +5 volts.
- The multiplication factor of 0.1, 0.01, or 0.001 of the FAULT MODE - DRIFT RATE positions is accomplished in the software before modification of the data.



- Although the output of the RATE/LEVEL pot is inserted into the computer by means of an A/D converter (which uses  $\pm 10$  volts), a data word input of all 1's will be designated 5 volts, substantiating the panel markings. No rescaling is necessary.
- Because the RATE/LEVEL pot output is inserted into the computer directly by means of an A/D converter, it is not affected by the ENTER or CLEAR switch light. This provides the capability of changing manually the DRIFT RATE V/SEC or the LEVEL VOLTS in discrete jumps or smoothly (slew) without pressing the ENTER switch light. Pressing the CLEAR switch light will not clear this input.
- The DISPLAY switch light, when pressed, will go off by the computer and will not go on until the control data has been accepted and verification has been made (assuring that the monitor data requested is the data received).
- Although the voltmeter is connected to the computer by means of a D/A converter (which converts to  $\pm 10$  volts), other equipment used in conjunction with the voltmeter makes the D/A converter appear as if it converts to  $\pm 5$  volts. Therefore, the computer data, already scaled 5 volts equal to all 1's, is rescaled.
- The FAULT (PRESS FOR TRUE) switch light (when lit), will be extinguished by the computer, and will stay extinguished for the period during which the switch light is pressed. It will go on when it is no longer pressed. Nothing will occur if the FAULT (PRESS FOR TRUE) switch light is pressed when the monitored data was not malfunctioned and the FAULT (PRESS FOR TRUE) switch light was not lit.
- Regardless of units or scaling, all subsystem analog values, except three, shall be rescaled so that the telemetry upper range equals  $254 \times 2^{-8}$  and the lower range equals  $1 \times 2^{-8}$  whether it is zero or not. It is important that the programmer take into account the scaling of the variable from the subsystems' math model (M/M) and symbol dictionary.
- All subsystem Booleans whose information is in bit 24 are packed in bit locations 2 through 9.
- All subsystem calculated values after rescaling, or Booleans after packing, are stored into the common core in a prescribed order.
- A number of subsystem analog and digital words, which turn out to be constants, are stored by premission loading into the common core in a prescribed position.
- A number of subsystem digital words are stored directly by the subsystem into the common core in a prescribed position.
- The data associated with the 24-bit AGS and 40-bit LGC digital word are packed in the telemetry program before they are stored into the common core in a prescribed position.
- The 24-bit AGS digital word is broken down into three 24-bit digital words with data in bit locations 2 through 9.
- The 40-bit LGC digital word is broken down into five 24-bit digital words with data in bit locations 2 through 9.
- All LGC data (discretes and variables) are packed in bit locations 2 through 9.
- A check is made to determine whether a channel, an entire group, or only a single bit is malfunctioned on a different control group, when malfunctioning a particular control group. When this occurs, the latter will prevail. The malfunction and control data of the former control group is cleared and its accompanying ENTER and CLEAR switch lights go off and go on, respectively.
- The data information in bit locations 2 through 9 of the DWI are discretized, stating conditions of the telemetry console insertions to the computer. They are to be checked accordingly, depending on which mode of operation the Telemetry Instructor has chosen.
- All AGS data (discretes and variables) are packed in bit locations 2 through 9.

### 1.5.2.3 Computer Program Requirements.

There are two methods of inputting to the computer and three methods of outputting from the computer in relation to the telemetry console. They are, respectively, DWI and A/D; and DBO, DWOR, and D/A.

#### 1.5.2.3.1 Digital Word Input.

The DWI inserts a 24-bit word that contains the following information into the computer:

Bit No.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
									Channel or group identification number									Switch identification number					
Clear/fault																							
Drift rate																							
Drift rate x 0.001																							
Drift rate x 0.01																							
Drift rate x 0.1																							
Offset/group																							
Fixed/1																							
Channel loss																							

The switch identification number in bit locations 19 through 24 may be any number from 0 to 32, inclusive, expressed in binary notation, depending upon which control group has been selected. Zero will be the condition when no information is being entered, and any number greater than 32 will indicate a computer, DCE, or telemetry console hardware malfunction. The channel/group identification number in bit locations 10 through 18 may be any number from 0 to 279, inclusive, expressed in binary notation, depending upon which channel or group number has been dialed. Zero will be the condition when no information is being entered, and any number greater than 279 will indicate a computer, DCE, telemetry console, or telemetry instructor error.

All the information in bits 2 through 9 is not there simultaneously, but depends upon the mode of telemetry console operation (malfunction insertion or monitor; analog or digital). This concept is expressed more clearly within the following descriptions.

#### 1.5.2.3.2 Digital Word Input (Digital Malfunction).

The DWI inserts into the computer for the bilevel group and digital word malfunction mode, as follows:

Bit No.	2	4, 5, 6	7	8
	Enter/Clear	Bit No.	Group/Bit	1/0
State 1	Clear	Bit number in binary notation	Group/Bit	1
State 0	Enter		Group/Bit	0

**NOTE**

Bit locations 10 through 18 identify channel or group number; bit locations 19 through 24 identify switch number. The bit identification number in bit locations 4 through 6 may be any number between 0 and 7, inclusive, expressed in binary notation, indicating bit 1 through 8 dialed up, respectively.



## 1.5.2.3.3 Digital Word Input (Analog Malfunction).

The DWI inserts into the computer for the analog channel malfunction mode, as follows:

Bit No.	2	3	4	5	6	7	8	9
	Enter/ Clear	Drift rate	Drift rate x 0.001	Drift rate x 0.01	Drift rate x 0.1	Offset	Fixed	Channel loss
<u>State 1</u>	Clear	Drift rate	Drift rate x 0.001	Drift rate x 0.01	Drift rate x 0.1	Offset	Fixed	Channel loss
<u>State 0</u>	Enter	Drift rate	Drift rate x 0.001	Drift rate x 0.01	Drift rate x 0.1	Offset	Fixed	Channel loss

**NOTE**

Bit locations 10 through 18 identify channel or group number; bit locations 19 through 24 identify switch number. The information in bits 4 through 9 is not all contained simultaneously but only one bit at a time, depending upon the FAULT MODE switch position selected. If one of the drift rates, bits 4 through 6, is selected, bit 3 will be in the 0 state. This is done to reduce the number of checks required in the programming.

## 1.5.2.3.4 Digital Word Input (Bilevel Group and Digital Word Monitor).

The DWI inserts into the computer for the bilevel group and digital word monitor mode, as follows:

Bit No.	2	10 through 18	19 through 24
	Display/Fault	Channel or group identification number	Switch identification number
<u>State 1</u>	Fault		
<u>State 0</u>	Display		

## 1.5.2.3.5 Digital Word Input (Analog Monitor).

The DWI inserts into the computer for analog channel monitor, as follows:

Bit No.	2	10 through 18	19 through 24
	Display/Fault	Channel or group identification number	Switch identification number
<u>State 1</u>	Fault		
<u>State 0</u>	Display		

## 1.5.2.3.6 Analog-to-Digital (A/D) Converter.

The A/D converter inserts a 13-bit word into the computer. The data information is inserted into bits 1 through 13; bit 1 is the sign bit. The 13-bit word will equal  $\pm 5$  volts where all 1's equal 5 volts and all 0's equal zero volts. Mathematically, this may be expressed as  $2^{-9} \times 5 \times 2^{-3} \times 4,096/5$ .

#### 1.5.2.3.7 Digital Bit Output (DBO).

The DBO looks at the least significant bit (bit 24) of the 24-bit computer word for a 1 or a 0 and, then, converts it to one of two relay contact positions.

#### 1.5.2.3.8 Digital Word Output Relay (DWOR).

The DWOR looks at the 8 most significant bits (bits 2 through 9) of the 24-bit computer word (for the state of each) and, then, converts each of them to one of two relay contact positions.

#### 1.5.2.3.9 Digital-to-Analog (D/A) Converter.

The D/A converter looks at the 13 most significant bits (bits 1 through 13) of the 24-bit computer word; bit 1 is the sign bit. The 13-bit word will equal  $\pm 5$  volts where all 1's equal 5 volts and all 0's equal zero volts. The 13-bit word from the computer will never be negative. Mathematically, this may be expressed as  $2^{-9} \times 5 \times 2^{-3} \times 4,096/5$ .

### 1.5.3 DATA ACQUISITION SUBSYSTEM.

The data acquisition subsystem (DAS) consists of magnetic tape units, X-Y plotters, X-T recorders, an event recorder, and a dual-head audio tape recorder. These devices accurately record data related to the performance of the LMS, for evaluation of training missions. The devices can operate continuously for the duration of any training session.

#### 1.5.3.1 Magnetic Tape Units. (See figure 1-10.)

The LMS computer complex contains two dual magnetic tape units (MTU's) with integrated word transfer capability and computer interface electronics. The MTU's are 75-inch-per-second units; each can be controlled by either computer via its direct memory access unit, through the magnetic tape time multiplex unit. The MTU's are controlled with an "output control pulse" (OCP) instruction and monitored by a "skip if sense line not set" (SKS) instruction. Either computer can use either MTU; both computers can access separate MTU's at the same time. The magnetic tape is a high-speed storage medium for recording and retaining data. Information is read (detected) or written (stored) by passing the oxide side of the tape over read/write heads. Information may be written on any one of seven independent tracks on the tape. During a write operation, seven recording heads are placed vertically across the tape; seven bits may be recorded simultaneously, one bit on each track. A seven-track nonreturn-to-zero recording scheme is used. In this system, magnetic particles on the tape are aligned in the positive or negative direction. A binary 1 is recorded by reversing the polarity; no polarity reversal results in a 0. Thus, each track of the tape is fully magnetized and the polarity is reversed as each bit is recorded. A line (or frame) of tape data consists of a six-bit character and a parity (check) bit. Tracks No. 0 through 5 specify the character; track No. 6 holds the parity bit.

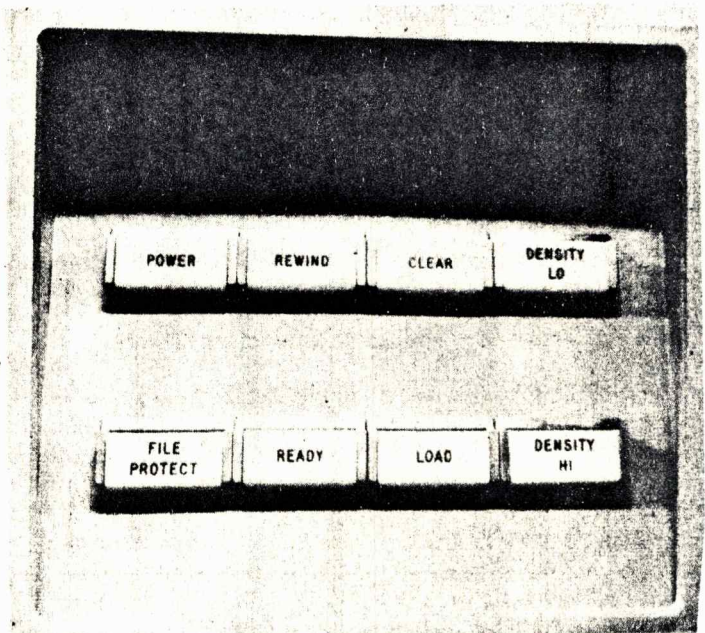
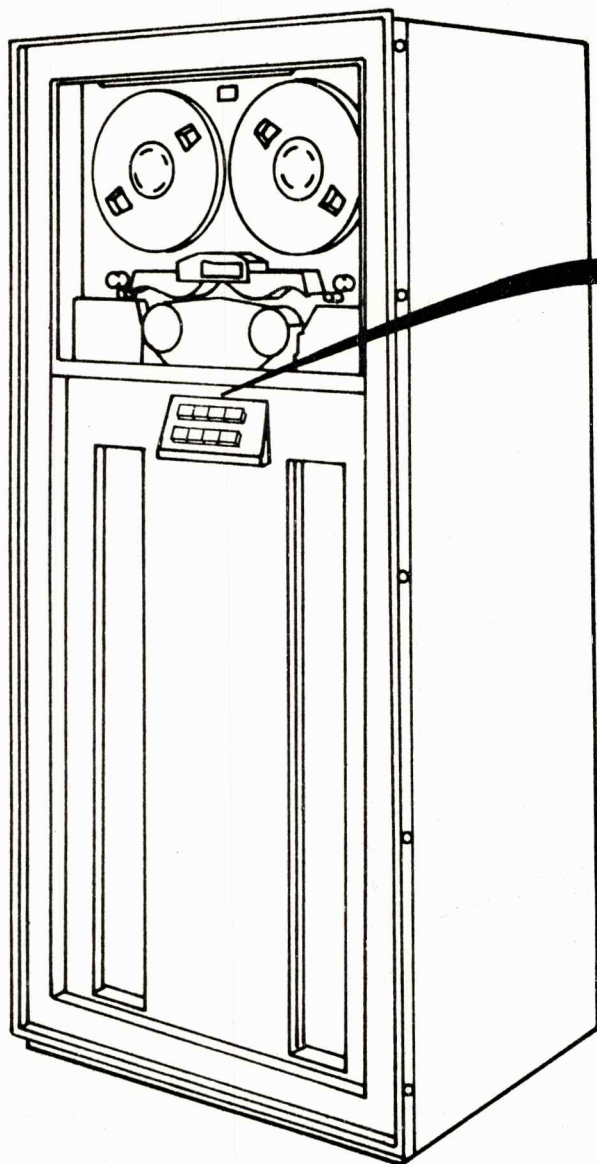
Data are recorded in one of two formats: binary or binary-coded decimal (BCD). Tape is binary if data are recorded just as they are represented in core storage. In BCD format, digits, characters, and special symbols are represented in core storage by six-bit binary numbers. The formats also differ in the selection of parity bits. The parity bit in binary format is chosen so that the total number of bits in any line must be odd. In BCD format, the total number of bits must be even. The format is selected by the control unit, which also designates the correct parity bit that accompanies each character.

Data recorded on the tape are arranged in groups called records and files. A minimum of one line of information constitutes a record. Adjacent records are separated by a 3/4-inch unrecorded area (record gap). A longitudinal parity bit is recorded in coded format, at the end of each record; the number of 1's in each record track is made even. A file consists of groups of records. Adjacent files are separated by recording an end-of-file mark after the last record in the file. The end-of-file mark consists of an octal 17 (BCD) and its check character (also an octal 17).

During a read or write operation, tape is moved from the supply reel, past the read/write heads, to the takeup reel. Tape motion is provided by two fluted capstans that rotate continuously in opposite directions. Tape is drawn against the drive capstan by vacuum and floated over the nondriving capstan by air pressure. If the tape is moving from the supply reel to the takeup reel (forward motion), the left capstan drives the tape. If tape motion is in the opposite (reverse) direction, the right capstan provides the drive. Tape motion is quickly and smoothly stopped by means of a pneumatic brake port, using vacuum. Because pressure is applied to both capstans during this period, neither capstan contacts (drives) the tape.

The head assembly consists of individual read and write heads, an erase head, tape cleaners, and a pneumatic pad. Each of the seven read/write heads used in the tape transport has two magnet gaps. One gap is used for writing; the other, for reading. The gaps are arranged so that, during a write operation, the tape first passes under the write gap to record the data; then under the read gap to check the writing. This allows each





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Figure 1-10. Magnetic Tape Unit, Control Panel

line of information to be examined and verified immediately after it is written on the tape. Thus, if any discrepancy occurs during the write operation, it is immediately detected at the read head. The broadband erase head, energized during write operations only, removes all information previously recorded on the tape. New information is, therefore, recorded on electronically "clean" tape at all times during a write operation.

The two tape cleaners, one on either side of heads, pneumatically remove foreign particles from the tape surface during a read or write operation. A pneumatic pad maintains precise contact pressure between the tape and head gaps. The contact pressure is provided by air pressure, which minimizes head and tape wear by blowing the tape against the heads.

The transport can accelerate tape to high speed within  $2.75 \pm 0.5$  milliseconds. Tape motion is completely stopped within  $2.25 \pm 0.50$  milliseconds. The transport uses a vacuum loops to minimize the tape mass that must be accelerated during the 2.75-millisecond period. These loops separate the heavy tape reels from the

portion of the tape under the heads. The two tape loops form tape reservoirs for the capstan drive system. During the first few milliseconds of acceleration, the actuated capstan pulls tape from one loop and places it in the second loop. As tape is drawn from one column, it is replaced from the reel above it. As tape is fed into the opposite column, the associated reel takes up the slack. The heavy tape reels are, therefore, given more time to accelerate and act to increase or decrease the amount of tape in the vacuum column. Tape loops buffer the heavy reels out of the high-acceleration capstan drive system. This minimizes the inertia in the high-acceleration systems, because the capstans need only accelerate the mass of a few feet of tape. The vacuum columns also maintain tension throughout the system. Each loop fits snugly into a chamber and divides it into two parts. The lower part of the column is under reduced pressure. The upper part is at atmospheric pressure and pushes the loop down, providing slight tension on the loop.

The reel drive controls the position of the tape loops in the vacuum columns. A servo system, between each loop and tape drive, positions the tape reels by responding to signals from the vacuum column photosense indicators. If the tape loop in a column is too long, the photosense indicators signal the reel drive to take up tape. If the loop is too short, the indicators signal the reel drive to deliver tape.

The MTU controls and displays (figure 1-10) are listed, with their function, in table 1-6.

Table 1-6. Magnetic Tape Unit, Controls and Displays

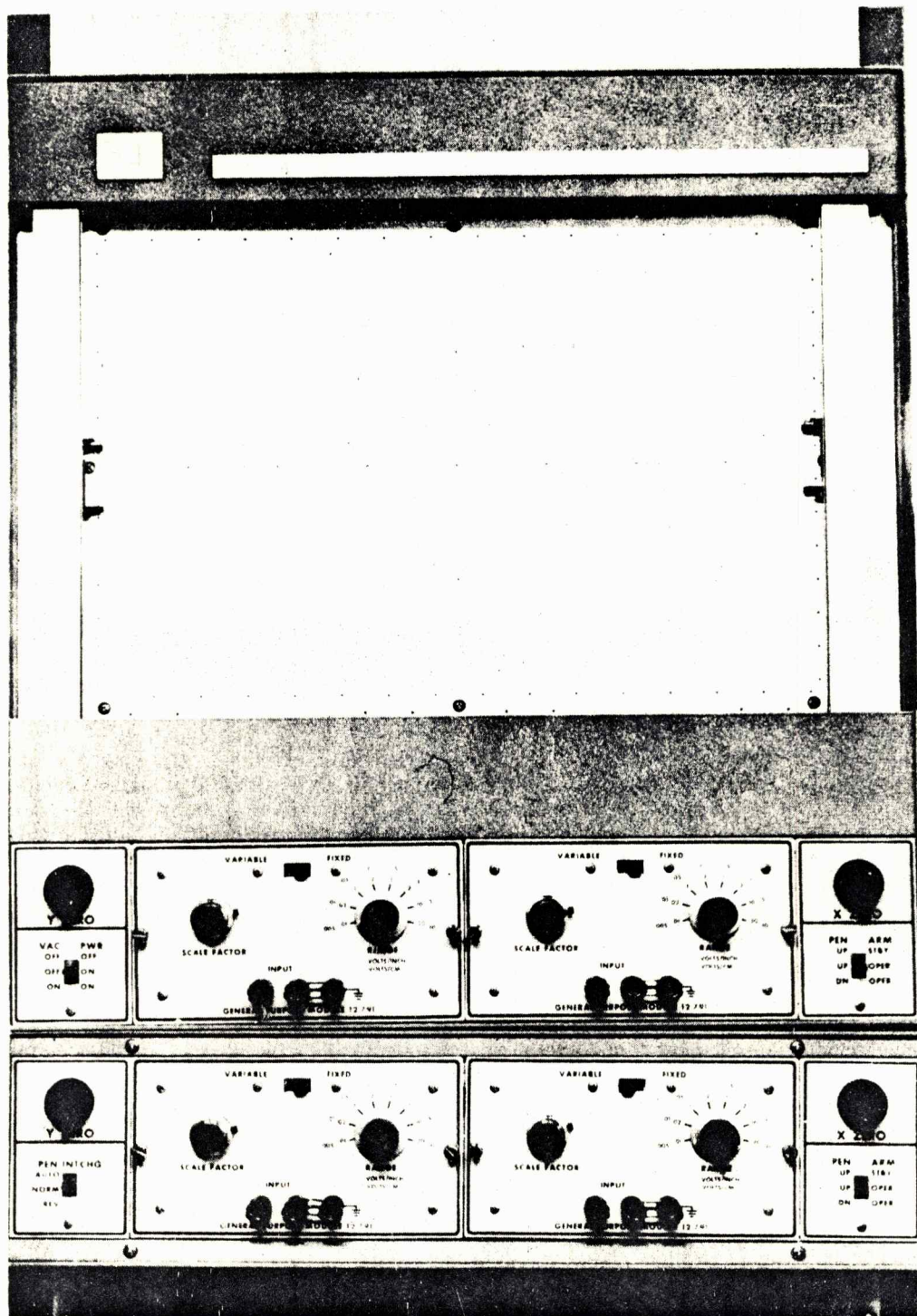
Control or Display	Function	Remarks
POWER switch	Applies and removes operating voltages	Switch must be pressed and held for approximately 2 seconds.
REWIND switch	Causes tape to be moved onto supply reel at high speed	Motion stops when load point is detected.
CLEAR switch	Removes all external command conditions from transport logic	
DENSITY LO switch	Selects information transfer rate of 200 bits per inch	
FILE PROTECT indicator	Indicated file protect ring is present in supply reel	
READY switch	Places unit under external control	No panel command, except CLEAR, is valid.
LOAD switch	Initiates operation that pulls tape into loop boxes, then moves tape forward to load point	
DENSITY HI switch	Selects information transfer rate of 556 bits per inch	

#### 1.5.3.2 X-Y Plotters. (See figure 1-11.)

The X-Y plotters are dual-arm, dual-pen, 11- by 17-inch recorders. They are near the instructor console, where they are readily accessible for adjustment and observation. The plotters are mounted in standard vertical racks, with vertical plotting surfaces and dual pens for versatility. The plotting surface is 11 by 17 inches.

The plotters use a null-balance technique to record one variable voltage as a function of a second variable voltage. This is accomplished by applying one voltage (designated X) to a servo system that controls the position of the arm in the horizontal direction (abscissa). The second voltage (designated Y) is applied to another servo system that controls the motion of the recording pen along the arm (ordinate). The combined action of these two positioning systems provides a plot of X versus Y.





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Figure 1-11. X-Y Plotter



The data may be plotted as a continuous inked line, or as points along the contour of the curve (point plotting). The type of plot (continuous or point) depends upon the accessory equipment used with the plotter. Curves are plotted on standard paper held on the plotting surface by a vacuum blower system. A standby circuit, which moves the pen and arm clear of the plotting surface, provides access to the surface to change paper, compare curves, or to apply overlays.

#### 1.5.3.2.1 Servo Systems.

The pen and arm servo systems are of the closed-loop type. Because the systems are basically identical, the pen servo system is described.

An input signal E1 (the Y-coordinate of the desired plot) is applied as the input order voltage. This order voltage is the pen-positioning signal; that is, this voltage indicates the required position of the pen with respect to the Y=0 point. A feedback or position voltage E2 is obtained via a wiper on the pen carriage, which contacts the pen mandrel. The E2 voltage indicates the exact physical position of the pen with respect to the Y=0 point.

The E1 input signal is scaled by a plug-in module and applied to a chopper circuit. The E2 position voltage is applied directly to the center-tapped primary of the chopper input transformer. The difference in potential between the two voltages produces an error signal E3. This error signal essentially indicates the direction and distance the pen carriage must move from its present location to the ordered position. The polarity of E3 (the polarity of the chopper output with respect to the center tap of the input transformer) is dependent on the magnitude and polarity relationship between E1 and E2. This polarity determines the phase of the chopper-generated a-c error signal (E4); the magnitude of this a-c signal is dependent upon the magnitude of E3.

The a-c error signal is amplified by a servoamplifier and applied to the control winding of a two-phase induction servomotor. The magnitude of the a-c error signal determines the rate of motor rotation; the phase of this error signal determines the direction of motor rotation. As the pen servomotor rotates, it drives a pulley via a gear train. This pulley, in turn, drives the pen carriage cable that moves the pen carriage along the arm to position the wiper on the pen mandrel. This changes the magnitude of E2 so that it approaches that of E1 (after scaling). As E2 approaches E1, the error signal becomes smaller until E1 and E2 are equal and E3 becomes zero. At this point the servo reaches a null condition and stops.

#### 1.5.3.2.2 Pen Lift System.

The pen of the plotter is raised and lowered via an electromechanical system. A spring-loaded pen lift solenoid, when energized, raises a pen lift bar and permits the pen to descend to the plotting surface; a spring assures positive contact of the pen with the plotting surface, regardless of the plane in which the plotter is mounted. When the pen lift solenoid is deenergized, the pen lift bar is pulled toward the plotting surface. (The solenoid is spring loaded to assure positive action.) The bar catches the pen and causes the pen to pivot in the carriage pivot, thus lifting the writing point from the plotting surface.

#### 1.5.3.2.3 Mode Selection Circuits.

The operating mode of the plotter is controlled by the dual-purpose, three-position PEN-ARM switch. When the PEN-ARM switch is set to UP/STBY, the external input signal is removed from the servoamplifier and the amplifier input is connected to the junction of the standby resistors. In the case of the arm servo, these resistors are of unequal value so that the arm moves to the extreme right side of the board. The pen servo standby resistors are of equal value; therefore, the pen moves to the center of the arm.

When the PEN-ARM switch is set to UP/OPER or DN/OPER, the standby voltages are removed from the servo and the external input signals are connected. In either of these two positions, the pen and arm follow the input signal variations.

#### 1.5.3.2.4 Arm Lock System.

The plotter features an arm lock system that prevents the arm from moving when primary power is removed from the instrument. With the arm locked in position, the plotter is less susceptible to damage during transit and some maintenance. The lock mechanism is not a positive-action lock; it only prevents rotation of the arm tape drive pulley. This feature permits the tape to slip if a large force is inadvertently applied to the arm and thus tends to prevent loss of arm squareness, or damage due to accidentally hitting the arm. The drive arm tape should not be purposely forced to slip; this will damage the drive pulley system.

#### 1.5.3.2.5 Controls.

The X-Y plotters controls (figure 1-11) are listed, with their function, in table 1-7.



Table 1-7. X-Y Plotter Controls

Control	Function
ZERO potentiometers	Permit setting location of $X=0$ , $Y=0$ (O, O point) anywhere within 30- by 45-inch area centered about plotting surface
SCALE FACTOR control	Enables attenuation of variable scale for plotted parameter
VARIABLE-FIXED switch	Provides selection of scale factor control to either manually variable or fixed
External INPUT plugs	Provide input connection and either chassis or floating ground
RANGE control	Enabled setting of plot range in either volts/cm or volts/inch. Plug-in module must be removed for access to switch for scale change.
PEN ARM switch	
UP-STBY	Lifts pen from plotting surface and positions it to center of arm. Arm is positioned to extreme side of travel.
UP-OPER	Lifts pen from plotting surface and moves carriage in response to input signals. Arm moves in response to input signals.
PEN INTCHG switch	
AUTO	Enables automatic interchange of pen and arm functions in event of an arm interception
NORMAL	Disables pen-arm interchange function
REV	Interchanges data inputs and parallax networks regardless of position of arms
VAC PWR switch	
OFF-OFF	Removes primary power from all plotter and vacuum systems
OFF-ON	Energizes plotter circuitry, but vacuum systems remain off
ON-ON	Applies primary power to both vacuum and plotter systems

#### 1.5.3.3 X-T Recorders. (See figure 1-12.)

Each X-T recorder is an eight-channel recorder that has an oscillograph installed horizontally in a drawer in the unit pedestal. Attenuator and recorder functions (including remote-operate) are initiated by pushbutton controls. Rectilinear pen motion produces records on rectangular coordinate charts graduated in 50 divisions. The recorder pens use pressurized fluid. The oscillograph has 12 selectable chart speeds. The X-T recorder is housed in a 54-inch-high console with a sloped front control panel.

##### 1.5.3.3.1 Attenuation and Control Panel Assembly.

The attenuation and control panel assembly is an input-signal-conditioning device; it is in the top front of the console. The EXTERNAL FUNCTIONS switches are convenience controls, used when the recorder is operated with the computers or a remote system. Four pushbuttons (RESET, HOLD, RUN, and MARK) provide

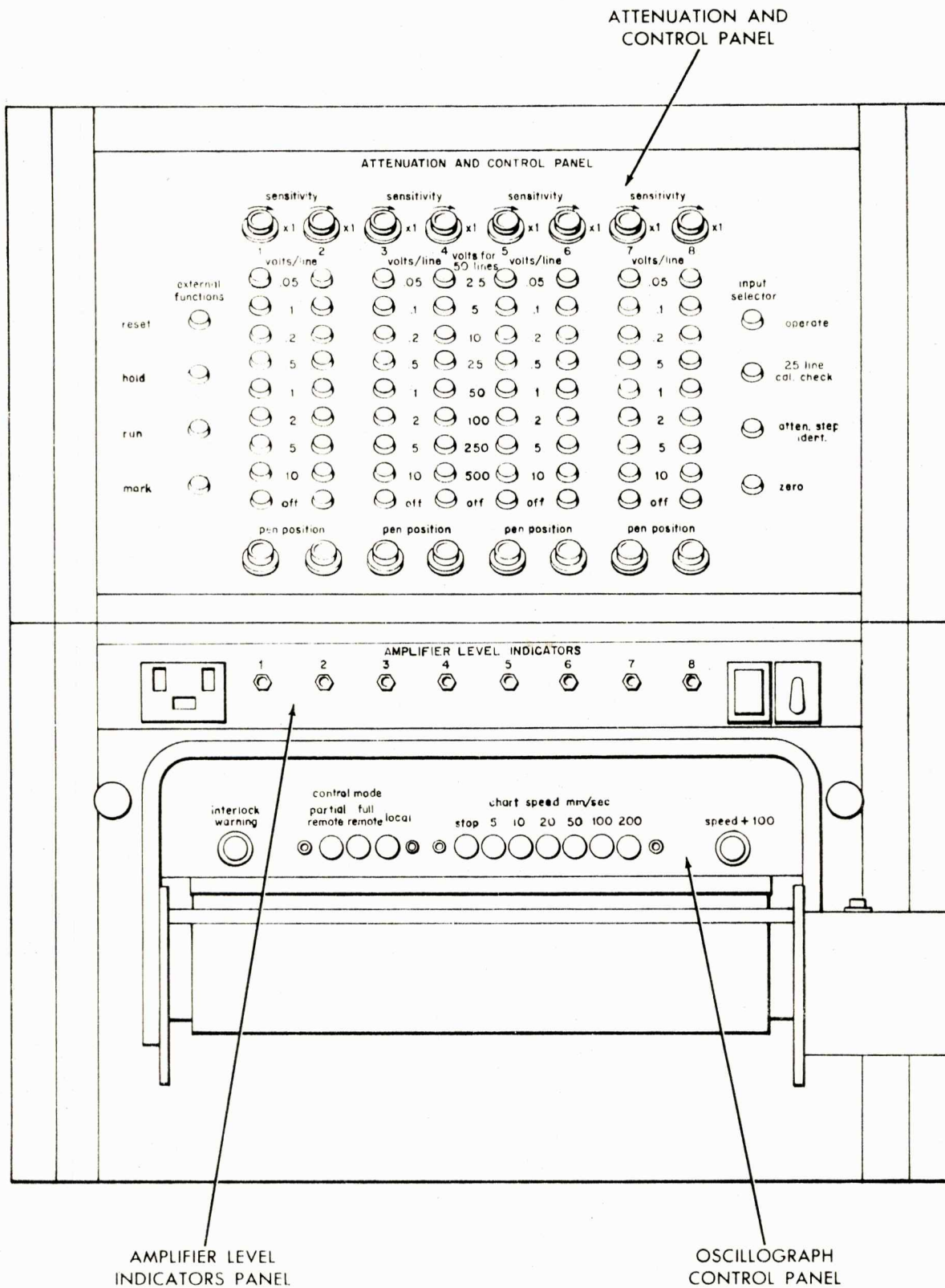


Figure 1-12. X-T Recorder

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contact closures that enable the operator to control computer reset (initial conditions), hold, or run modes of operation from the recorder. They are momentary switches; though labeled for analog computer use, they may be used for any remote control operations in which such switch closures are needed. The attenuator buttons are in the center of the panel, with nine attenuator positions for each channel expressed in volts per chart line. Eight pen position controls are at the bottom of the panel. These controls permit each pen to be positioned anywhere within the channel, and permit either edge of the channel, or any point between, to be used as a baseline (zero signal position). The remainder of the controls perform zeroing, coding, calibration, and operating functions.

#### 1.5.3.3.2 Oscillograph.

The oscillograph, in the center front of the console, is the heart of the system. It contains pens, a pen-motor, chart paper, and a writing table.

#### 1.5.3.3.3 Amplifier Level Indicators Panel.

The amplifier level indicators panel is directly above the oscillograph. The panel consists of a convenience outlet, level light indicators (one for each channel), a main power indicator light, and the main power switch.

#### 1.5.3.3.4 Drive Amplifier Frame.

The drive amplifier frame contains receptacles that supply signal input and output, as well as output connectors of the drive amplifiers. It also contains output connections to the oscillograph to connect penmotors in the oscillograph. Air-circulating fans and motors are attached to the frame.

#### 1.5.3.3.5 Filament Regulator.

The filament regulator supplies regulated d-c voltage to the heaters of the vacuum tubes of the input circuits of the drive amplifier. It derives its power from an 18.9-volt a-c source in the 150-volt power supply.

#### 1.5.3.3.6 20-KC Power Supply.

The 20-kc power supply operates from +24- and -24 volt d-c inputs. It supplies a precisely regulated 20-kc signal that is adjustable from 7.5 to 8.5 volts rms. This signal is used to provide the position information from the feedback penmotor.

#### 1.5.3.3.7 24-Volt D-C Power Supply.

This power supply furnishes the 20-kc power supply with +24 and -24 volts dc. It also supplies the drive amplifier frame with +24 and -24 volts dc for transistor output stages 30 seconds after main power is turned on (only if chart is moving).

#### 1.5.3.3.8 150-Volt D-C Power Supply.

This power supply furnishes 6.3 volts rms to third-stage filaments of the drive amplifier, regulated +85 and -85 volts for calibration of the attenuator panel, and +150 and -150 volts to the vacuum tubes of the pen drive amplifiers.

#### 1.5.3.3.9 Main Connector Panel and Harness Assembly.

This panel is used to interconnect the oscillograph 20-kc power supply, filament regulator, drive amplifier frame, and d-c supplies to the main power source through the master power switch. It also brings out to more convenient terminals the internal connections from the oscillograph.

#### 1.5.3.3.10 Amplifiers.

Four specially designed dual-channel amplifiers are in the drive amplifier frame; they are accessible from the front and rear of the console. The amplifiers are completely interchangeable, although slight adjustment of the controls may be desirable for optimum performance.

#### 1.5.3.3.11 Controls and Displays.

The X-T recorder controls and displays (figure 1-12) are listed, with their function, in table 1-8.

Table 1-8. X-T Recorder Panels, Controls and Displays

Control or Display	Function
Attenuation and Control Panel	
EXTERNAL FUNCTIONS pushbuttons	
RESET	Resets pens to initial conditions
HOLD	Enables computer hold of operation from recorder
RUN	Enables control of computer run mode of recorder operation
MARK	Operates left event marker and deflects its pen toward center of chart
Attenuator pushbuttons (64)	Enables selection of volts per chart line for each channel
PEN POSITION controls (8)	Permits each pen to be positioned anywhere within channel and use of this position as zero base
PEN POSITION locking knob	Locks pen in selected position to prevent inadvertent movement
INPUT SELECTOR pushbutton	Causes pens of all channels to return to selected zero positions
ATTEN STEP IDENT pushbutton	Causes all active pens to deflect and record attenuator settings and pen polarity switch settings
25 LINE CAL CHECK pushbutton	Used to check or calibrate drive amplifier system; supplies standard calibration input to all channels
OPERATE pushbutton	Enables normal operation of system
SENSITIVITY control	Allows intermediate sensitivities to be selected between fixed pushbutton values. Controls must be fully clockwise to obtain pushbutton attenuation value.
Locking knob	Prevents inadvertent movement of sensitivity control
Oscillograph Control Panel	
INTERLOCK WARNING lamp	Indicates one or both interlock switches are open
CONTROL MODE push-buttons	
PARTIAL REMOTE	Transfers chart drive on-off control to remote location; does not transfer speed control
FULL REMOTE	Chart speed and on-off control is transferred to a remote location.
LOCAL	Full control of unit is enabled at control panel.



Table 1-8. X-T Recorder Panels, Controls and Displays (cont)

Control or Display	Function
Oscillograph Control Panel (cont)	
CHART SPEED MM/SEC	
STOP pushbutton	Stops chart drive and disables power to pass
CHART SPEED pushbuttons	Enables chart drive speed relative to pushbutton pressed; releases STOP pushbutton
SPEED +100 switch	Divides selected chart drive speeds by 100 when enabled
PAPER TAKE UP pushbutton	When pressed, takes up slack in paper and actuates paper take up reel drive
TAKE UP SPEED control	Provides three speed control of paper drive
Amplifier Level Indicators Panel	
Amplifier level lamp	Indicates magnitude of lamp intensity output of related amplifier
Main power lamp	Light goes on when power to unit is on.
Main power switch	Applies power to entire unit

#### 1.5.3.4 Audio Tape Recorder. (See figure 1-13.)

The dual-head audio tape recorder provides the LMS with the following capabilities:

- Dual tape deck recorder system permits unlimited recording of sound presented to the LMS cabin.
- Portable playback system permits playback of recordings obtained from the recorder.
- Continuous loop delay system provides a 1.2-second time delay of all simulated S-band voice communications at lunar distance between the LMS and MCC.

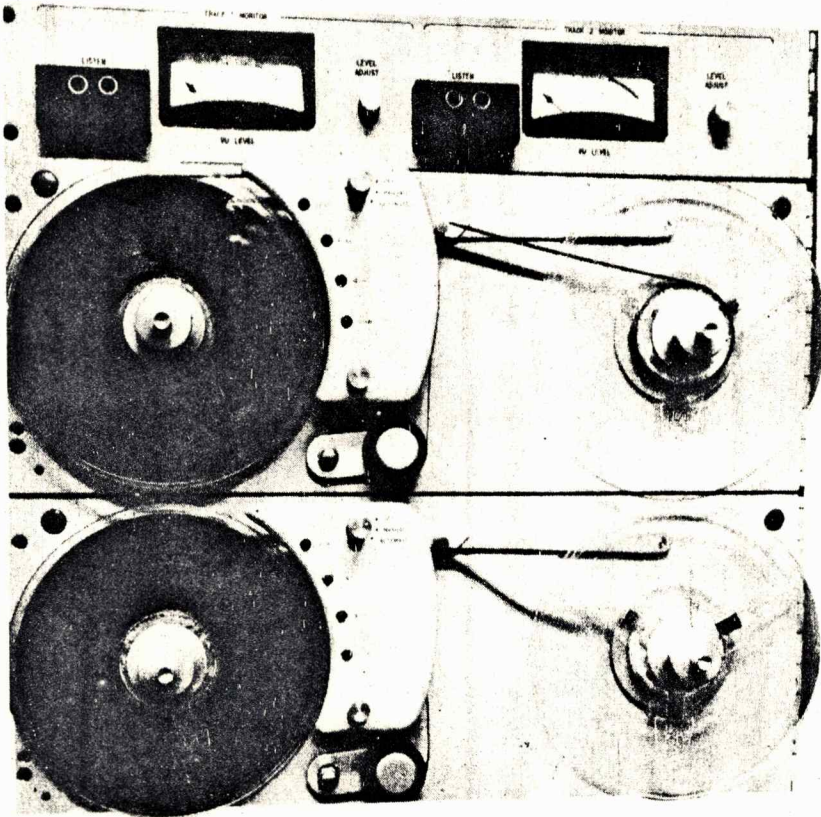
The LMS audio tape recorder is designed primarily for heavy duty application, requiring up to 24 hours of continuous operation. The recorder is mounted in the recorder cabinet adjacent to the instructor console.

The setting of the OFF-MANUAL-AUTOMATIC selector switch on each tape deck controls the operational mode of the recorder system. In the OFF position, no power is applied to the tape deck; in the MANUAL position, power is applied and the STOP, PLAY, fast forward, and rewind pushbuttons on the front panel of each tape deck control operation of that tape deck. When both tape deck selector switches are set to AUTOMATIC, the recorder system operates only in response to an external start command, which originates from the instructor console RECORDERS panel. The instructor has the option of selecting CONT RECORD (which supplies a continuous start command to the recorder system) or VOX RECORD (which supplies a start command only when astronaut audio is being presented to the recorder system input).

A VU LEVEL indicator, on each track monitor panel, is driven via the reproduce heads of the active tape deck. Deflection of the indicators and running of the tape deck give the instructor visual indication that audio to the Commander or to the Systems Engineer has been recorded. The record levels are adjustable with the LEVEL ADJUST controls, one for each track input. Earphone LISTEN jacks are provided for insertion of the instructor's headset.

Both tape deck selector switches are set to MANUAL to load tape reels. When the reels are loaded and threaded, the selector switches are set to AUTOMATIC to permit the instructor to control operation. Upon





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Figure 1-13. Audio Tape Recorder

receipt of a start command, one of the tape decks starts normal forward-speed operation and continues for the duration of the command. Cessation of the command causes the tape deck forward motion to stop until receipt of another start command. Approximately 3 seconds before the tape is completely full, the recorder automatically starts the other tape deck in normal forward-speed operation to effect an approximate 3-second overlap in the audio being recorded. At the end of this overlap period (when the tape on the first tape deck is completely full), the recorder stops audio input to the first tape deck, places it into a fast reverse mode of operation, and automatically stops it when it is fully rewound. At this time, the REPLACE REEL light on the instructor console panel RECORDERS goes on to inform the instructor that a reel must be replaced. The instructor then sets the OFF-MANUAL-AUTOMATIC selector switch to MANUAL, replaces the rewound reel of tape with a new one, threads the tape onto the takeup reel, and sets the selector switch to AUTOMATIC. The recorder system then causes the REPLACE REEL light to go off. Operation of the second tape deck is identical with that of the first. Continued replacement of a full rewind reel before the other one is filled provides unlimited recording capability.

#### 1.5.3.4.1 Portable Playback System.

The voice playback unit is stowed at the instructor console; it is used by the instructor for postmission playback. The playback unit may be used at any location where 115-volt, 60-cycle power is available.

The setting of the OFF-MANUAL-AUTOMATIC selector switch on the tape deck front panel controls the operational mode of the playback system. In the OFF position, no power is applied to the system; in the MANUAL position, power is applied and the STOP, PLAY, fast forward, and rewind pushbuttons control operation of the playback system; in the AUTOMATIC position, power is also applied, but only the PLAY push-button is operational. The difference between the manual and automatic modes of operation is in the operational sequence at the end of normal forward-speed operation; that is, when end-of-tape occurs. In the manual mode, the tape stops; in the automatic mode, the system is automatically placed into rewind and stopped when the tape has been fully rewound.



The position (1, 2, or BOTH) of the track select switch on the playback unit selects audio from track No. 1, track No. 2, or both tracks mixed, for presentation to the speaker and to the headset jacks. Volume is controlled with the VOLUME control, adjacent to the track select switch. The tape deck selector switch is set to MANUAL, the tape to be played is mounted and threaded, and the STOP, fast forward, and rewind pushbuttons are used to position the tape to the desired starting point. At this point, tape playback is initiated by pressing the play pushbutton. If automatic operation is desired, the tape deck selector switch is set to AUTOMATIC. If AUTOMATIC has been selected, the selector switch must be set to MANUAL before threading a new reel onto the takeup reel.

#### 1.5.3.4.2 Continuous Loop Delay System.

The delay recorder system is mounted in the LMS peripheral cabinet that contains the voice communications equipment. It is the means by which S-band voice is delayed by 1.2 seconds when the simulated LM is at lunar distance. The delay is provided by the delay system when an externally generated LM-in-lunar-orbit command is provided. An ON OFF switch applies 115-volt, 60-cycle power to the system. No other panel controls are provided. With the ON OFF switch set to ON, the audio inputs (S-band up voice and S-band down voice) are delayed 1.2 seconds when the LM-in-lunar-orbit command is present.

#### 1.5.3.4.3 Controls and Displays.

The controls and displays of the audio tape recorder (figure 1-13) are listed, with their function, in table 1-9.

Table 1-9. Audio Tape Recorder, Controls and Displays

Control or Display	Function
TRACK 1 MONITOR	
LISTEN jack	Permits monitoring of signal being recorded, using earphones or auxiliary amplifier
TRACK 1 MONITOR VU LEVEL indicator	Indicates VU level of signal being recorded on track No. 1
LEVEL ADJUST control	Permits adjustment of VU level recorded signal on track No. 1
OFF/MANUAL/AUTOMATIC selector switch	Enables operator to select manual or automatic recording and turn off
STOP pushbutton	Stops takeup and supply reels when pressed
PLAY pushbutton	Places recorder in playback mode
Fast forward pushbutton (arrow pointing to right)	Places recorder reel mechanism in fast forward mode
Rewind pushbutton (arrow pointing to left)	Places recorder reel mechanism in rewind mode
<div style="text-align: center; border: 1px solid black; padding: 2px; margin: 10px auto; width: 100px;">NOTE</div> <p>Controls and displays for track No. 2 are similar to those for track No. 1.</p>	

#### 1.5.3.5 Event Recorder.

A 20-channel event recorder is used in the LMS. It is a compact, precision measuring instrument that uses inkless writing elements to produce graphs of simulator parameters. Events are recorded by opening or closing external circuitry connected to the recorder. The contact-making devices may be operated from mechanical rotation of thrust, from changing of position, or from changes in pressure, temperature, or light intensity.

The chart drive mechanism is an electromechanical device that converts electrical energy into linear motion through the use of a motor and various gear assemblies.

The motor drive assembly consists of a synchronous motor and a reduction gear head. The motor is operated from a frequency-regulated source of a-c power. The gear head provides a 60-to-1 speed change. The output shaft of the gear head powers the chart drive transmission. Because the chart transport assembly is on the front of the chassis, a special drive coupling is used. The driving mechanism is coupled to the chart transport by a chain and sprocket arrangement that maintains constant speed and accurate timing throughout the system. A precision gear train in the transport assembly unwinds the chart paper from a supply roll, propels it over a drive roller, and rewinds it on a reroll arbor. The drive roller has a number of formed pins at each end, which engage marginal perforations in the paper and feed the chart under the writing element smoothly and at a constant rate. A time-set knob for manually advancing the chart paper is provided on the right end of the drive roller. An overrun clutch in the reroll assembly maintains proper tension on the chart paper. The transport assembly on the chart driver has a chart supply indicator that indicate the amount of chart paper remaining on the supply roll. Reloading is accomplished by a tilt-down transport.

The controls for the event recorder consist of the STYLUS POWER switch that controls power to the stylus heaters, and the STYLUS HEAT control (screwdriver adjustment) that is used to adjust stylus heat for desired line contrast.

#### 1.5.4 INTERFACE COMPLEX.

The LMS interface complex consists of the following sections:

- Trajectory link
- Telemetry link
- Communication links
- Timing links
- Biomedical link.

##### 1.5.4.1 Trajectory Link.

The LMS interface complex provides a standard block of 60 data words 20 times each second to MCC. The data words describe the trajectory of the simulated LM mission. The central unit of this data transfer is the trajectory buffer. The buffer includes 256 words of core memory (5-microsecond cycle time) to facilitate synchronization of the data interchange. The 24-bit word length of the LMS data is converted from parallel to serial format before transmission to MCC. The signal lines that link the LMS with MCC carry this data at the rate of 40,800 bits per second.

##### 1.5.4.2 Telemetry Link.

To provide mission training for range support personnel, the LMS is equipped to supply telemetry data in the same quantity and quality that would be transmitted during a normal flight. These data are relayed to MCC for distribution among the various support groups. A pulse-code-modulation (PCM) buffer is required to handle the data transfer. This assembly includes core memory, logic and timing circuits, and parallel-to-serial data conversion equipment. These telemetry ties carry 255 parametric channels from the LMS to MCC. Each data word is expressed as eight binary bits. The data synchronization and format controls, within the buffer assembly, provide for two rates of transfer: 1,600 or 51,200 bits per second. These are the normal S-band and backup VHF data transfer rates used in the LM subsystems.

##### 1.5.4.3 Communication Links.

Sixteen independent audio loops are available with the LMS interface. They provide simulated radio communication channels, as well as several modes of intercommunication necessary for the functioning of the ground training missions. In this latter category are intercom loops among the instructors, as well as those



with the maintenance personnel and support staff. Particularly important among these audio connections are the interface ties between the LMS, the AMS, and MCC. These integrate the two simulator complexes and provide essential voice communications training for MCC and downrange personnel. The subordinate utility loops (for example, the faculty intercom) make possible the most effective coordination of the mission exercise.

Three console communication system (CCS) keyboards, mounted at the LMS instructor console, provide manual selection of all audio interface connections. The cabling and electronic assemblies necessary to furnish power to these audio selection keyboards are provided for the LMS as contractor-furnished equipment (CFE). The audio loops internal to the LMS are transformer coupled to the interface connections to assure complete signal level isolation.

#### 1.5.4.4 Timing Links.

Timing and data synchronization are essential when the LMS is operated independently, as well as when the complex is operated in one of the integrated modes. For independent operation, the central timing equipment (CTE) of the LMS provides the functions performed by the LM pulse-code-modulation and timing equipment (PCMTE). In integrated operation, synchronization is essential for the transfer of data, much of which is in serial form.

The basic timing standard to which all signals of the CTE are synchronized is timing signals transmitted from the National Bureau of Standards, Washington, D.C. (station WWV). The timing equipment provides four basic output signals in the form of -6-volt pulses, as follows:

- A 40-millisecond (minimum) pulse at the rate of one per minute, as a synchronizing input signal to the computer complex
- A 100-millisecond pulse at the rate of five per minute, to drive the two utility event timers at the instructor console
- A 1-kc square-wave pulse train that serves as a timing signal input to the computer complex
- A 51.2-kc signal that provides gating pulses to the PCM for the high rate telemetry transfers.

When the LMS is operated independently (nonintegrated), the CTE provides an internally generated time standard. The clock pulse generator has a stability of two parts per million.

#### 1.5.4.5 Biomedical Link.

An analog signal generated by the electrocardiograph (EKG) sensors in the astronauts' pressure suits is supplied from the LMS to the MCC interface. The LMS can substitute a prerecorded synthetic data signal in the EKG telemetry channel. Switches at the LMS telemetry console enable transfer of this biomedical data over the simulated S-band. They also control the channel inputs, selecting either of the two astronauts' pressure suits or the synthetic recorded data.

### 1.6 SENSORY GROUP.

The sensory group consists of the lunar landmass simulator, the external visual display equipment, the LMS cabin, and the aural cue equipment, discussed in paragraphs 1.6.1 through 1.6.4.

#### 1.6.1 LUNAR LANDMASS SIMULATOR.

The lunar landmass simulator (LLS) simulates lunar terrain characteristics beneath the LM; it is used to familiarize, train, and increase the proficiency of, the flight crew in performing the lunar landing phase of the LM mission. Basically, the LLS operates in conjunction with the simulated landing radar in the LMS computers to generate a drive signal for the altitude range indicator located in the LMS cabin. The LLS is a special-purpose hybrid computer that operates on-line in a real-time mode. It accepts data and control signals from the LMS computers and feeds back internally generated analog and logic signals to the LMS computers. The LLS determines the elevation of the lunar terrain with respect to a lunar datum plane. Elevation is measured from a terrain coordinate position at the intersection point of the lunar terrain with the centroid of the landing radar ranging beam transmitted from the simulated LM. (See figure 1-14.) The geometric symbols and their definitions are given in table 1-10.

The LLS continuously solves equations involving motion, geometric relationships, and lunar landmass characteristics. Simulation is accomplished by the end computation that produces the drive signal for the altitude range indicator. Equations of motion for the LM require extreme accuracy and are solved digitally by the LMS computer; the frequency response of the signal is restricted to a few cycles per second to permit

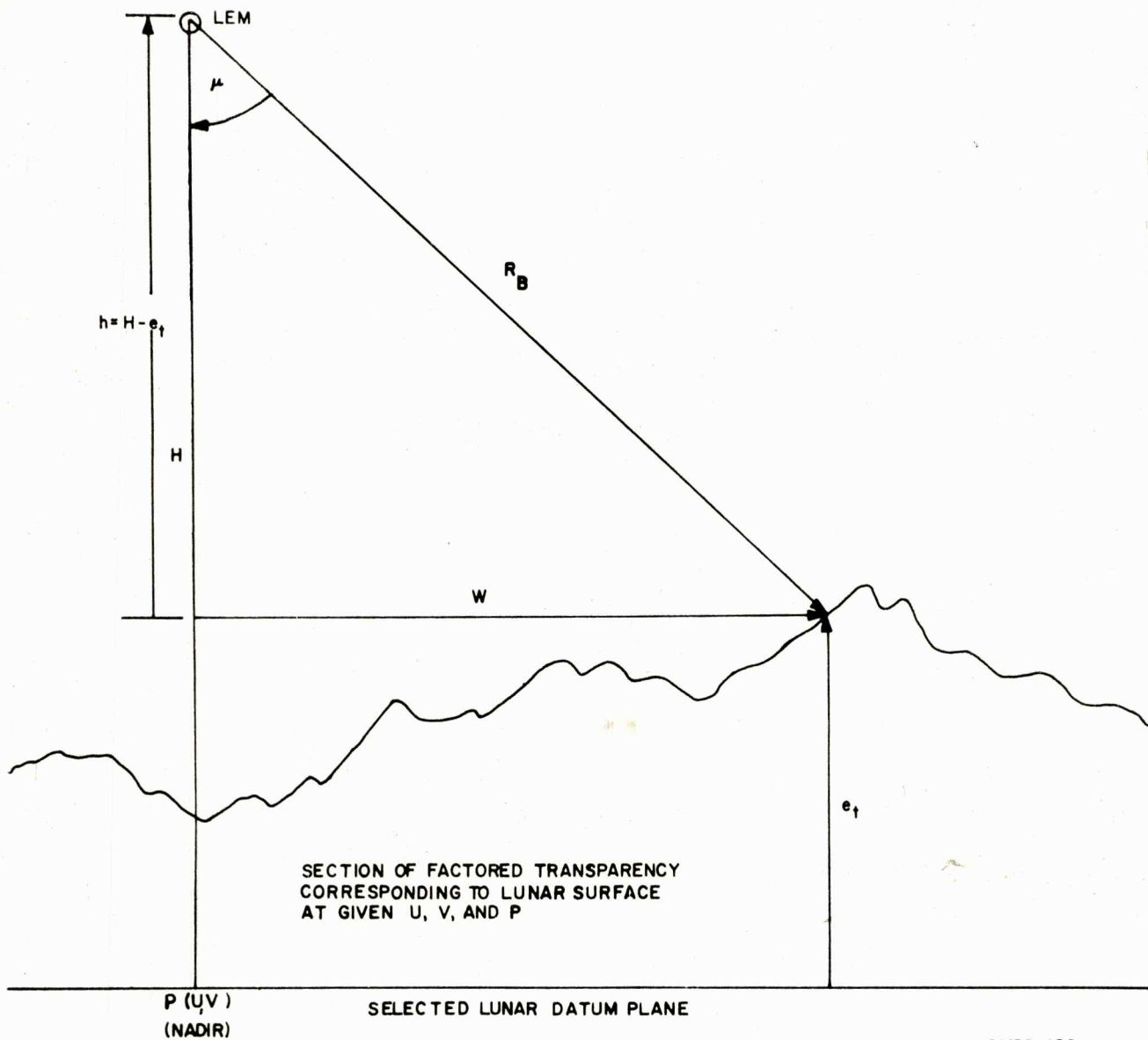


Figure 1-14. Basic Lunar Landmass Simulator Elevation Signal Geometry

digital computation. The lunar terrain elevation signal is computed within the LLS to provide for adequate random access to data storage and for a high rate of solution by use of the LLS high-speed analog computer. See figure 1-15 for a block diagram of the LLS.

The radar return signal is simulated by scanning factored transparencies that represent lunar landmass, with a moving beam of light, and converting the light (after it passes through the transparencies) to electrical signals. The transmittivity (ability to pass light) of a particular area of the transparency may be measured by light to produce electrical signals that represent the coarse and fine elevation levels of the corresponding area of the lunar surface. The moving beam of light (flying spot) is presented on a cathode-ray tube (CRT) that is a flying spot scanner (FSS). From the CRT, the flying spot is transmitted into an optical assembly, where it is split into three beams: two beams are transmitted through the two transparencies and detected by coarse and fine photomultiplier tubes to provide an altitude range indication; the third beam is applied to the monitor read-out channel photomultiplier tube for use as a scan monitor light stabilization signal. (See figure 1-16.)



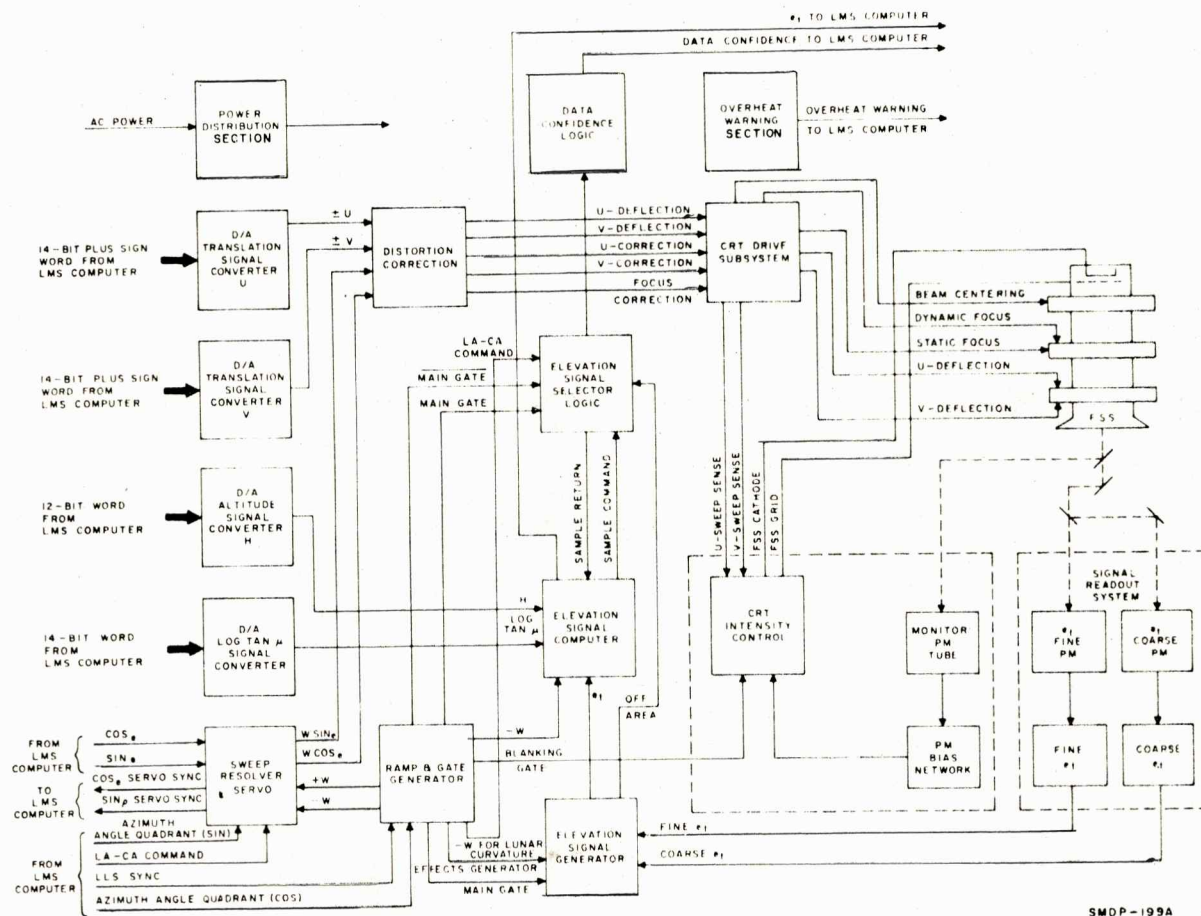


Figure 1-15. Lunar Landmass Simulator, Block Diagram

The LLS contains the following functional components and assemblies:

- Photographic image transparencies (factored transparencies) that contain lunar elevation/landmass (terrain contour levels) in the form of grey-level image densities
- A CRT that originates a light source
- Optical equipment required to project the light beam onto the photographic image transparencies
- Computation equipment and CRT beam-splitting/deflection optics that permit the light beam to be positioned upon, and swept over, the image transparencies (The command signals from the LMS computer complex that position, orient, and initiate the light beam sweep are proportional to the attitude and translation of the LM-transmitted radar ranging beam.)
- Photoelectric and video-processing equipment (elevation signal selector computer) that extracts and processes the information stored on the image transparencies and provides an output signal proportional to lunar terrain elevation at a point intercepted by the centroid of the radar ranging beam.

The LLS generates video signals that represent coarse and fine elevation radar returns in synchronism with positioning and firing of the simulated LMS radar antenna. The LLS computer outputs represent terrain elevation at the first radar intersection point. A constant-diameter spot on the CRT represents the radar beam at all simulated altitudes.

Table 1-10. LLS Geometry, Symbols and Definitions

Symbol	Definition
$\theta$	Angle between lunar radii
$e_t$	Lunar terrain elevation above lunar datum-specifically, along a lunar radius vector containing the LM radar intercept point
$h$	Absolute altitude of LM
$W$	Radius vector from $\rho(U, V)$ to lunar terrain intercept point
$\mu$	Angle between local vertical and effective radar boresight vector
$\rho$	Angle of azimuth of radar boresight relative to LM reference azimuth
$H$	Height of LM above lunar datum surface
$R_B$	Radar slant range from LM to lunar terrain intercept ground range from LM nadir point to lunar terrain intercept; $W = R_B \sin$
$U, V$	Coordinates of LM nadir position on lunar surface
$R_m$	Lunar radius

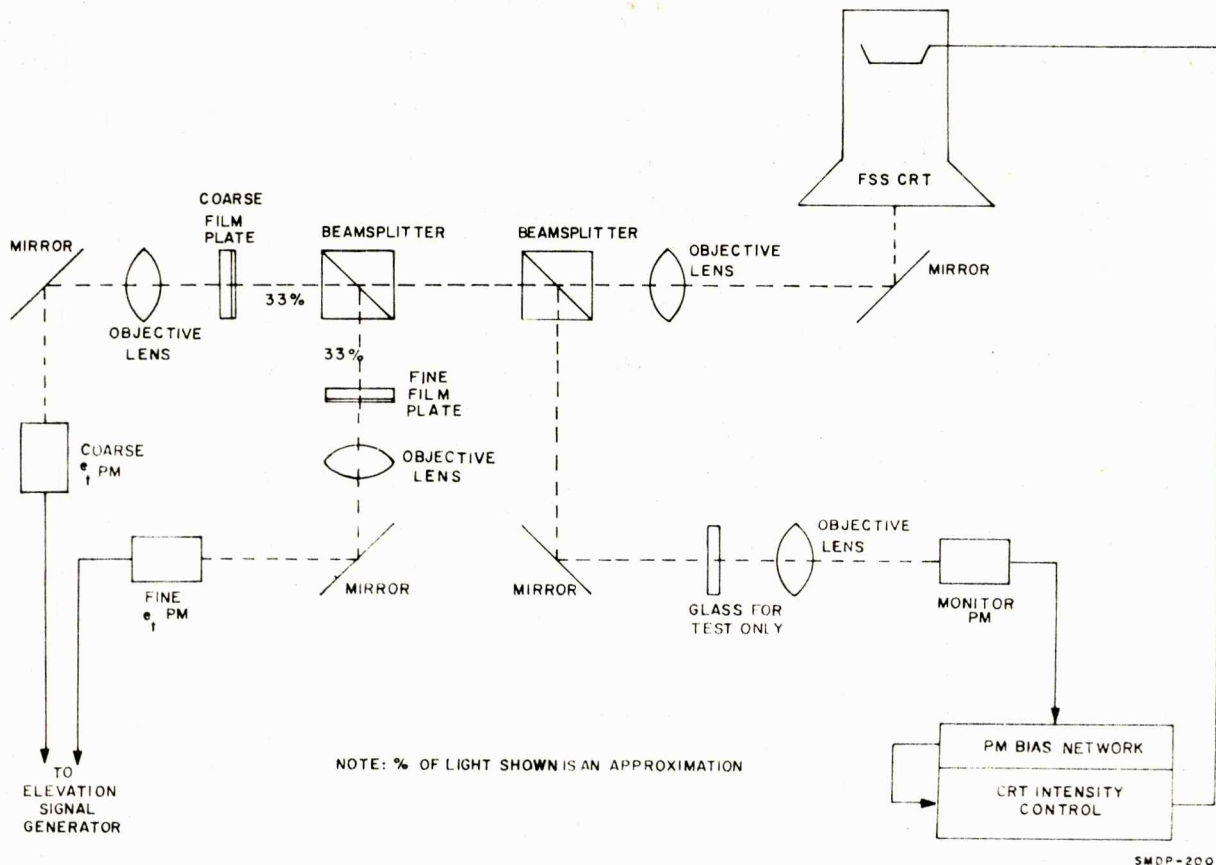


Figure 1-16. Flying Spot Scanner, Simplified Schematic Diagram



The LLS simulates landing radar operation from 50,000 feet above the lunar surface to touchdown, with definitive information below 20,000 feet. Data that enables interpolation of altitude in 5-foot intervals is acquired from 1,000 feet downward. The computational data provided by the LLS takes into account the effects of lunar curvature upon all signal information.

Two landmass areas, at different scale factors, are simulated for each LM mission: a 16-nautical-mile square corridor area, and a 16,000-foot-diameter circular landing area. The scale factor for the corridor image is 1,200,000 to 1; for the landing area, 60,000 to 1. Surface-contour intervals are 100 feet for the corridor area; 5 feet, for the landing area. For each area, terrain elevation is resolved into a maximum of 49 different levels. The landing area encompasses maximum terrain variations of 248 feet.

Ten landing corridors are simulated in the LLS. The landing footprint, located at the terminal point of the corridor, is defined as the area that can be reached from the hover point with a maximum velocity. This area is 16,000 feet in diameter. The landing site will be the 50-million-square-foot area, located at the terminal point of the ten corridors. Its orientation varies, however, from one corridor to another to permit different approaches under varying conditions, and to agree with the view presented through the LMS windows by the external visual display equipment (EVDE).

The FSS generates a spot of approximately 1-mil diameter on the CRT phosphor, which creates light emission at the spectral frequency of the phosphor. This spot of light is imaged by beam-splitting optics and focused on a factored transparency that represents landmass. The LLS can resolve 0.001-inch contour intervals at 1.6- and 3.0-inch displacement from the central optical axis, with a positional accuracy of  $\pm 0.001$  inch in the landing and corridor area images, respectively. Mechanical factors that effect spot resolution include lens uniformity, positional accuracy of FSS face and factored transparency, flatness of FSS face and surface of transparency, and stability of adjustment. Factors that affect positional accuracy of the spot include lens linearity, positional accuracy of topographical features on the transparency, and stability of adjustment.

Positional accuracy of the spot, relative to topographical elements on the factored transparency, is dependent upon electrical circuitry. Mechanical controls that contribute to overall alignment accuracy consist of close dimensional control of features of the transparency, triaxial adjustment of the transparency relative to the optical path centerline, and control of the temperature of the optical system to minimize thermal distortion. The temperature control system uses cooling air available to the cabinet from the underfloor area.

#### 1.6.1.1 Controls and Displays.

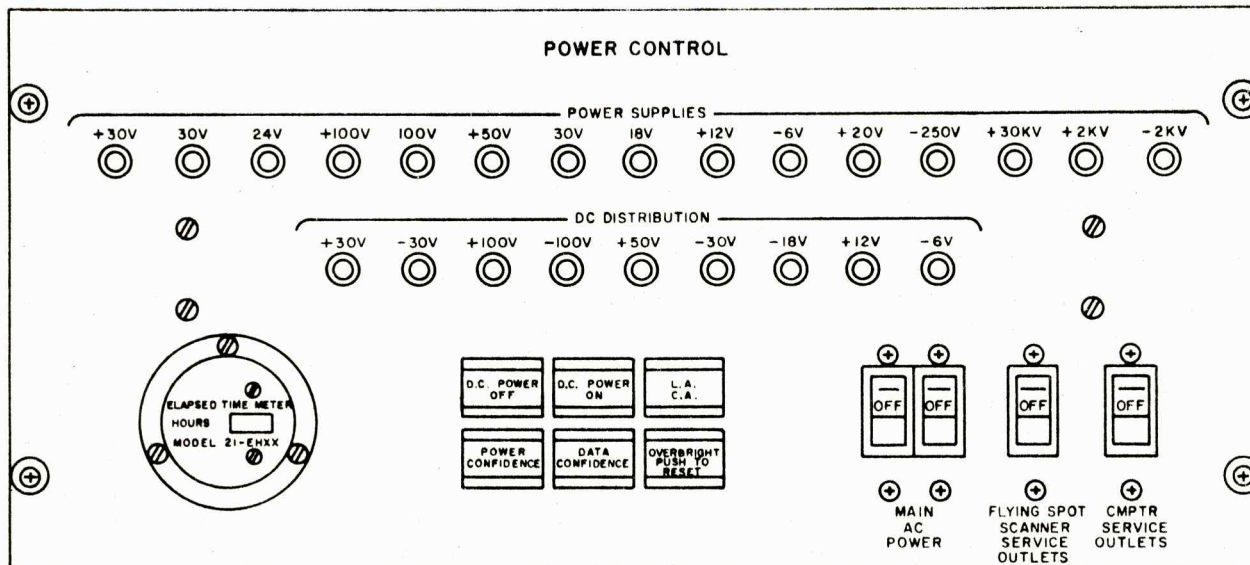
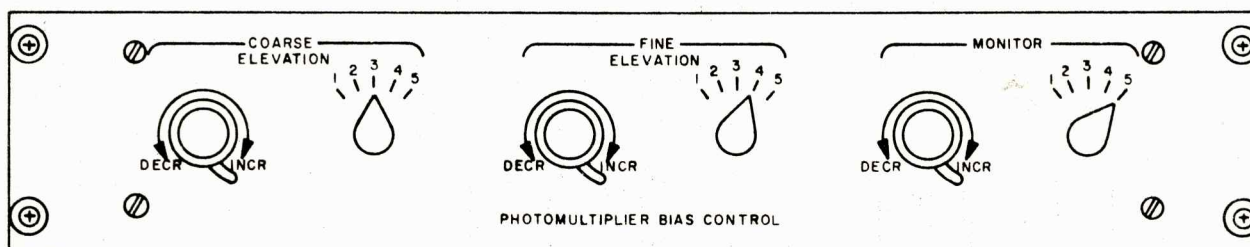
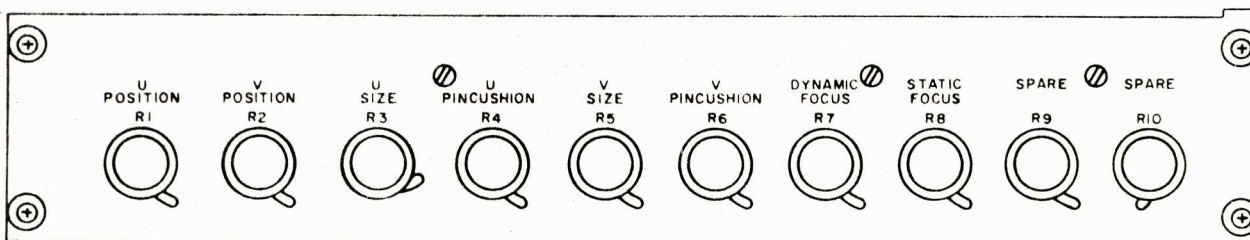
The LLS controls and displays (figure 1-17) are listed, with their function, in table 1-11.

#### 1.6.1.2 Data Conversion.

Because the LLS portions of the LMS computer operate digitally and the LLS computations are based on analog techniques, the information passing across the LMS-LLS-LMS interfaces must be converted accordingly, as follows:

- U (longitude portion of LM nadir point): Input from the LMS computer as 14 bits (DWOD) plus sign (DBO). This is converted to analog data in LLS digital-to-analog (D/A) converter.
- V (latitude portion of LM nadir point): Input from the LMS computer as 14 bits (DWOD) plus sign (DBO). This is converted to analog data in the LLS D/A converter.
- H (LM height above datum): Input from the LMS computer as 12 bits, always positive. This is converted to analog data in LLS D/A converter.
- $\mu$  (angle between local vertical and effective radar boresight): Input from the LMS computer as 14 bits in the form  $\log \tan \mu$ . This is converted to analog data in the LLS D/A converter.
- $\rho$  (azimuth angle of radar boresight): Input from the LMS computer in the form of two sets of four-wire analog resolver data, representing the sine and cosine of  $\rho$ . Each set also inputs sign and reference data for quadrant resolution and phase comparison, respectively. Conversion to pot shaft angle in the LLS is accomplished by the resolver shaft-positioning servo.
- Sync signal (one-bit output from LMS computer): Direct use, no conversion in the LLS
- Landing/corridor area commands (one-bit output from LMS computer): Direct use, no conversion in the LLS

## LLS COMPUTER CABINET POWER CONTROL PANEL

FLYING SPOT SCANNER CABINET  
PHOTOMULTIPLIER BIAS CONTROL PANELFLYING SPOT SCANNER CABINET  
CRT ALIGNMENT CONTROL PANEL

LMS-1-133

Figure 1-17. Lunar Landmass Simulator, Controls and Displays



Table 1-11. Lunar Landmass Simulator, Controls and Displays

Control or Display	Function
<b>POWER CONTROL Panel</b>	
<p><b>POWER SUPPLIES</b> indicators +30V, -30V, -24V, +100V, -100V, +50V, -30V, -18V, +12V, -6V, -20V, -250V, +30KV, +2KV, -2KV</p> <p><b>DC DISTRIBUTION</b> indicators +30V, -30V, +100V, -100V, +50V, -30V, -18V, +2V, -6V</p> <p><b>OPERATING TIME</b> meter</p> <p><b>DC POWER OFF</b> switch</p> <p><b>DC POWER ON</b> switch</p> <p><b>LA/CA</b> indicator</p> <p><b>POWER CONFIDENCE</b> indicator</p> <p><b>DATA CONFIDENCE</b> indicator</p> <p><b>FSS OVERBRIGHT PUSH TO RESET</b> switch light</p> <p><b>MAIN AC POWER, FLYING SPOT SCANNER SERVICE OUTLETS and CMPTR SERVICE OUTLETS</b> circuit breakers</p>	<p>Indicate operational status of LLS power supplies</p> <p>Indicate operational status of d-c voltages applied to LLS distribution buses</p> <p>Indicates total number of hours LLS is in operation</p> <p>Provides d-c power turnoff without disturbing primary a-c power distribution</p> <p>Applies primary d-c power for LLS distribution</p> <p>Indicates mode of operation (landing area or corridor area)</p> <p>Green light indicates that 30KV, +2KV, and -2KV power supplies are operating properly. Red light indicates that one or more power supplies (30KV, +2KV, and -2KV) are inoperative.</p> <p>Green light indicates that LLS is solving problems correctly and is providing solutions to LMS computer complex. Red light indicates that LLS computer is receiving erroneous information from LMS computer complex, and cannot perform its problem-solving function.</p> <p>Green light indicates that scan of FSS CRT is at normal brightness levels. Red light indicates that automatic blanking has occurred because of unsafe brightness condition. Switch must be pressed to remove blanked condition.</p> <p>Control primary a-c power to indicated circuit and service outlets</p>
<b>PHOTOMULTIPLIER BIAS CONTROL PANEL</b>	
<p><b>COARSE ELEVATION, FINE ELEVATION, and MONITOR</b> vernier controls</p> <p>Step-type, selector switches</p>	<p>Provide vernier control of gain of photomultiplier tubes; used in conjunction with step-type selector switches during alignment procedures</p> <p>Provide stepped levels (1, 2, 3, 4, and 5) of photomultiplier gain; used in conjunction with COARSE and FINE ELEVATION vernier controls during alignment procedures</p>

Table 1-11. Lunar Landmass Simulator, Controls and Displays (cont)

Control or Display	Function
CRT Alignment Control Panel	
U POSITION R1 V POSITION R2 U SIZE R3 U PINCUSHION R4 V SIZE R5 V PINCUSHION R6 DYNAMIC FOCUS R7 STATIC FOCUS R8 SPARE R9 SPARE R10	CRT Alignment Control panel The controls are adjusted during initial alignment. The nomenclature of the controls is self-explanatory as it applies to the FSS CRT.

- $e_t$  (lunar terrain elevation above lunar datum): LLS elevation data. Analog output directly to LMS computer: one-bit outputs (DBO) on status and/or confidence of  $e_t$  output
- Two A/D inputs to the LMS computer to permit synchronization of each multiturn azimuth servo,  $\cos \rho$  and  $\sin \rho$
- DBI to the LMS computer, indicating that the LLS has not determined a value for  $e_t$  within two sweeps (approximately 84 to 100 milliseconds).

#### 1.6.1.2.1 Computer Drive Signals.

Twelve drive signals (figure 1-18) are supplied to the LLS by the LMS computer complex and its associated signal-conversion equipment, as follows:

- U (longitude portion of LM nadir point): A 14-bit digital word, plus sign, proportional to the longitude coordinate of the point of intersection of a lunar radius extended to the LM center of gravity. This selenographic coordinate position is translated into the coordinate system required by the landing site and each landing corridor orientation; it is used within the LLS to establish the origin of the light beam sweep on the factored transparency.
- V (latitude portion of LM nadir point): A 14-bit digital word, plus sign, proportional to the latitude coordinate of the point of intersection of a lunar radius extended to the LM center of gravity. This selenographic coordinate position is translated into the coordinate system required by the landing site and each landing corridor orientation; it is used within the LLS to establish the origin of the light beam sweep on the factored transparency.
- H (LM height above datum): A 12-bit digital word, proportional to the distance between the lunar datum and the LM center of gravity, measured along a lunar radius. This signal reflects the unique lunar datum for each landing site and landing corridor. The scaling is as follows:

Digital word 00-----0 (12 bits)

Altitude, H = 0 feet (corridors and landing sites)

Digital word 11-----1 (12 bits)

Altitude, H = 2,048 feet (landing site)

Altitude, H = 65,536 feet (corridor).

- Log  $\tan \mu$  (log tangent of effective radar boresight angle): A 14-bit digital word, proportional to the log tangent of the angle between the centroid vector of the radar ranging signal and a lunar radius passing through the center of the radar beam source. The scaling is as follows:

Digital word 00-----0 (14 bits)

Log  $\tan \mu = -4$



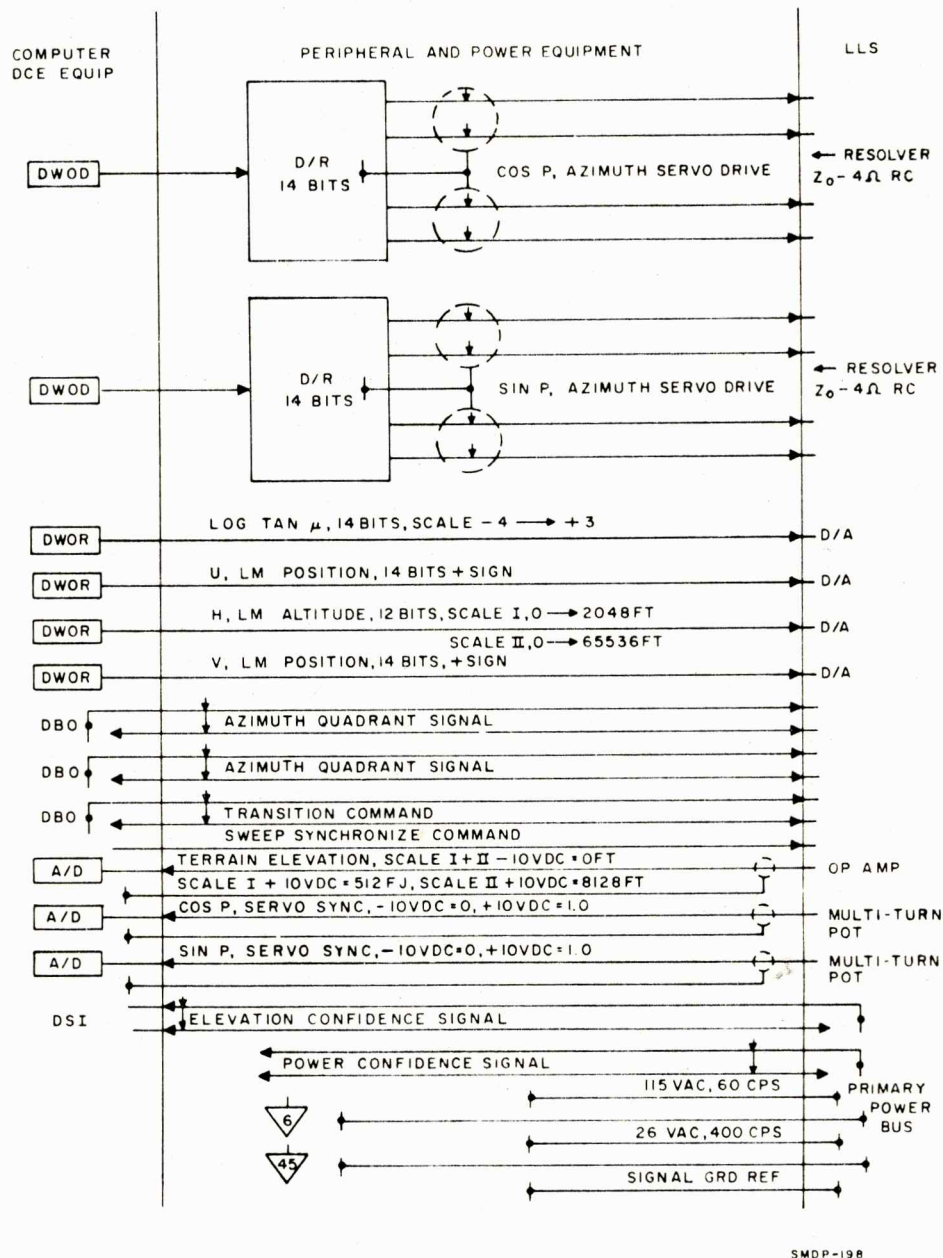


Figure 1-18. LLS-LMS Interface, Signal Diagram

Digital word 11-----1 (14 bits)

Log tan  $\mu = +3$ .

- Sin ( $\sin \rho$ ), cos ( $\sin \rho$ ): Two 400-cycle resolver source signals (14-bit conversion), proportional to the sine of the radar boresight azimuth angle. This azimuth angle is transformed into the coordinates that define each corridor and landing site, depending on their orientation on the factored transparency. A number of turns of the simulated source resolver represent the load range of  $\sin \rho$  between 0 and 1.
- Sin ( $\cos \rho$ ), cos ( $\cos \rho$ ): Two 400-cycle resolver source signals (14-bit conversion) proportional to the cosine of the radar boresight azimuth angle. This azimuth angle is transformed into the coordinates that define each corridor and landing site, depending on their orientation on the factored transparency. A number of turns of the simulated source resolver represent the load range of  $\cos \rho$  between 0 and 1.

- Digital bit outputs (DBO's): Two Boolean signals (contact closures) that define the quadrant of the radar boresight azimuth angle ( $\rho$ ). The relationship between binary code and quadrant is dependent upon the orientation of the factored transparency.
- Digital bit output (DBO): A Boolean signal that informs the LLS that a scale change is necessary during transition from a landing corridor to a landing site
- Sweep synchronizing signal: A signal that initiates the flying spot sweep from the nadir position, subsequent to a computer update of the required position and orientation command signals.

#### 1.6.1.2.2 Translational and Rotational Velocity.

The translational velocity of the simulated LM is as follows:

- 600 feet/second at the landing site scale
- 6,000 feet/second at the landing corridor scale.

The rotational velocity of the simulated LM is 60°/second at the smallest simulated landing site scale.

#### 1.6.1.2.3 Output Signals.

LLS output signals are as follows:

- A d-c analog voltage ( $\pm 10$  volts maximum), proportional to the elevation of the lunar terrain above the lunar datum at the point of radar beam intercept. Two elevation scales are applicable to this output: one scale represents the maximum differential elevation of a landing corridor; the other, the maximum differential elevation of a landing site. The scaling is as follows:
  - 10 volts dc is equal to 0 feet above the lunar datum
  - +10 volts dc is equal to 512 feet above the lunar datum landing site
  - +10 volts dc is equal to 8,128 feet above the lunar datum landing corridor.
- An A/D input signal, proportional to the cosine of the radar boresight angle ( $\rho$ ). This signal permits synchronization of a multiturn servomechanism in the LLS. The servomechanism, upon receiving the analog signal, produces a computer output command signal that is proportional to  $\cos \rho$ .
- An A/D input signal, proportional to the sine of the radar boresight angle ( $\rho$ ). This signal permits synchronization of a multiturn servomechanism in the LLS. The servomechanism, upon receiving the analog signal, produces a computer output command signal that is proportional to  $\sin \rho$ .
- A confidence signal, using a set of contact closures, to indicate that all lunar landmass simulation power is available and operating
- An elevation confidence signal, using a contact closure, to indicate that no value of terrain elevation has been determined within two CRT sweeps (approximately 105 milliseconds).

#### NOTE

This signal does not affect the operational continuity of the LLS. Upon determination of an elevation value, the contact closure is negated.

#### 1.6.1.3 Power Distribution.

Actuation of the main a-c power switch feeds 110-volt, 60-cycle power to the LLS. The a-c voltage is distributed to modular power supplies that energize control relays. The +20-, -24-, and +6-volt supplies are routed directly to distribution. The -24-volt supply is the relay logic supply; a relay opens the -24-volt line if a power supply fails or if its output drops. This relay action terminates distribution of power to the computer cards and deenergizes the high-voltage power supply network. After the relays are energized and the -24-volt



line is complete, an additional relay is activated manually so that -18 volts is applied to the computer cards via the distribution panel. The -2- and +2-kilovolt supplies each have an internal 30-second time delay. When these supplies attain their respective voltages and all relays are energized, the LLS is ready for operation.

#### 1.6.1.4 Flying Spot Scanner.

The flying spot scanner (FSS) provides a means of addressing and reading data on the factored transparencies, by performing the following major functions:

- Accepts input command data in the form of parallel digital words and four-wire synchro signals
- Synchronizes system operation to the 50-millisecond data update rate of the LMS computer
- Accepts, and operates on, logical input signals to control the scaling and polarity of data inputs and functional computations
- Generates sawtooth ramp and gate signals for use in analog computation and CRT sweep
- Provides for geometric aspect distortion
- Provides for dynamic focus correction
- Stabilizes CRT spot intensity
- Protects the CRT from overbrightness and loss of sweep deflection voltage
- Presents coarse and fine nonstandardized elevation signals to the elevation signal generator for further processing
- Provides the elevation signal generator with positive and negative sweeps
- Transmits a confidence signal to the LMS computer to denote proper operation of the FSS.

The FSS generates and positions a CRT spot on the factored transparency and reads the light level that results after the spot has been modulated by the specific density of the factored transparency. The FSS optical system comprises the lenses, mirrors, and alignment devices necessary to focus the spot on the factored transparencies and, then, to direct the modulated spot into photomultiplier tubes for readout. The FSS assembly has integral high-voltage power supplies, distribution networks, and control-monitor electronics. A simplified schematic diagram of the FSS is shown in figure 1-16.

The luminous spot on the face of the CRT is focused through a 1-to-1 imaging system onto two factored-transparency plate areas. A condensing lens behind each plate area floods a corresponding photomultiplier tube with light from the focused spot; the intensity of the light is modulated by the density of the emulsion on the transparency. Approximately 12% of the spot energy is diverted by a condensing lens before reaching the transparency plates. This portion of the spot, projected into a third photomultiplier tube is used for maintaining constant spot brightness through suitable circuitry.

##### 1.6.1.4.1 CRT Deflection Drive.

Deflection drive signals are generated in two different ways. First, to simulate the LM position directly above the lunar surface, the digital inputs (U and V) are received and converted into scaled analog voltages in the 14-bit D/A converter. A logic signal for sign accompanies each digital signal to invert the output of the D/A converter, if required. After modification in the geometric aspect distortion corrector, the signals (U and V) are directly applied to the deflection drivers in rectilinear coordinates. The second type of drive signal is derived from translation of the ramp (W) through angle  $\rho$ , into rectilinear-coordinate drive signals U and V. The sweep resolver servo is used to resolve the ramp through multiplication of the ramp by  $\sin \rho$  and  $\cos \rho$  values. The deflection signals (U and V), after modification by the geometric aspect distortion corrector, are summed with the other deflection drive signals (U and V) in the deflection drive circuits.

#### 1.6.1.5 Lunar Landmass Simulator Computer.

The LLS computer contains the solid-state electronics used to generate control and logic signals for the LLS and to process the FSS terrain elevation signals stored in two images on the factored transparency. The LLS signal processing multiplexes and standardizes the coarse and fine terrain elevation information; it also performs trigonometric computations to generate the proper composite lunar terrain elevation signal at the point of intercept of the landing radar beam with the lunar surface. The computer is subdivided into two major functional assemblies: the elevation-signal generator and the elevation signal selector computer.



#### 1.6.1.5.1 Elevation Signal Generator.

The elevation signal generator (ESG) consists of voltage discriminators and logic circuits that multiplex, standardize, and generate a composite terrain elevation signal. The ESG performs the following functions:

- Provides unambiguous discrimination of one of nine coarse levels and one of the nine fine levels presented as the output of the FSS
- Provides the complement of the detected even fine levels before adding the proper value of fine data to coarse data
- Standardizes coarse and fine signal levels before multiplexing
- Sums coarse and fine terrain elevation signals to form a composite linear terrain elevation signal.

#### 1.6.1.5.2 Elevation Signal Selector Computer.

The elevation signal selector computer translates and processes the FSS data for use as signal inputs to the altitude range indicator in the LMS cabin. Basically, the elevation signal selector computer performs the following functions:

- Generates standardized elevation data from the FSS and corrects for lunar curvature effects
- Computes the proper elevation signal, based upon elevation angle comparison techniques
- Samples and filters elevation data for continuous presentation to the LMS altitude range indicator
- Processes the required LMS computer input data for internal use and computation.

Analog signals that correspond to variations in lunar terrain elevation are received from the FSS photo-multiplier tubes and processed by the ESG, where a standardized terrain elevation signal is generated. The value of the terrain elevation signal is further processed and corrected in the lunar curvature effects generator because the spherical lunar datum surface cannot be directly simulated on the factored transparency. The corrected value of the terrain elevation signal is then sent to the angle comparison computer and the sample and hold circuit. The sample and hold circuit holds the value of the terrain elevation signal, as determined by the angle comparison computer, until the next sync or updating command pulse is received from the LMS computer. Thus, a steady sequence of lunar terrain elevation output signals is supplied.

The angle comparison computer receives values of height of the LM above the lunar datum surface and log tan from the LMS computer (updated at the 42-millisecond sync rate) and all values of the terrain elevation signal generated by the FSS. When the internally generated angle equals the angle received from the LMS computer, the value of the terrain elevation signal being swept at that time is sampled and held as output data.

#### 1.6.1.5.3 Lunar Curvature Effects Generator.

As the ground range increases from the local vertical, the effects of the spherical lunar datum must be taken into account. Figure 1-19 depicts the geometry of lunar curvature effects. The lunar curvature effects generator receives swept elevation data from the elevation signal generator and a ramp (W), corresponding to ground range from the FSS ramp generator. Increments proportional to the ground range are subtracted from the swept elevation data to compensate for the spherical lunar datum surface.

#### 1.6.1.5.4 Ramp and Gate Generation.

Basic to the operation of the FSS and the elevation signal selector computer are synchronization of circuit functions and generation of a sweep ramp (W) for use throughout the LLS. Operation of the LLS is performed at 42 milliseconds/scan. Generation of the  $\pm$  ramp ( $\pm W$ ) and a flyback gate in the synchronizer and gate generator is synchronized to the LMS computer sample-data rate of 50 milliseconds. This synchronization is accomplished through use of the sync signal, received from the LMS computer, which starts generation of the ramp.



### 1.6.1.6 Factored Transparency.

The requirements for landmass simulation are imposed on the LLS from a knowledge of the LM mission profile and the LM landing radar operating characteristics. Two landmass areas, at different scale factors, must be simulated for each LM mission: the 16-nautical-mile square corridor area and the 16,000-foot-diameter circular landing area. Surface contour intervals are 100 feet for the corridor area; 5 feet, for the landing area. For each area, terrain elevation must be resolved into a maximum of 81 different levels.

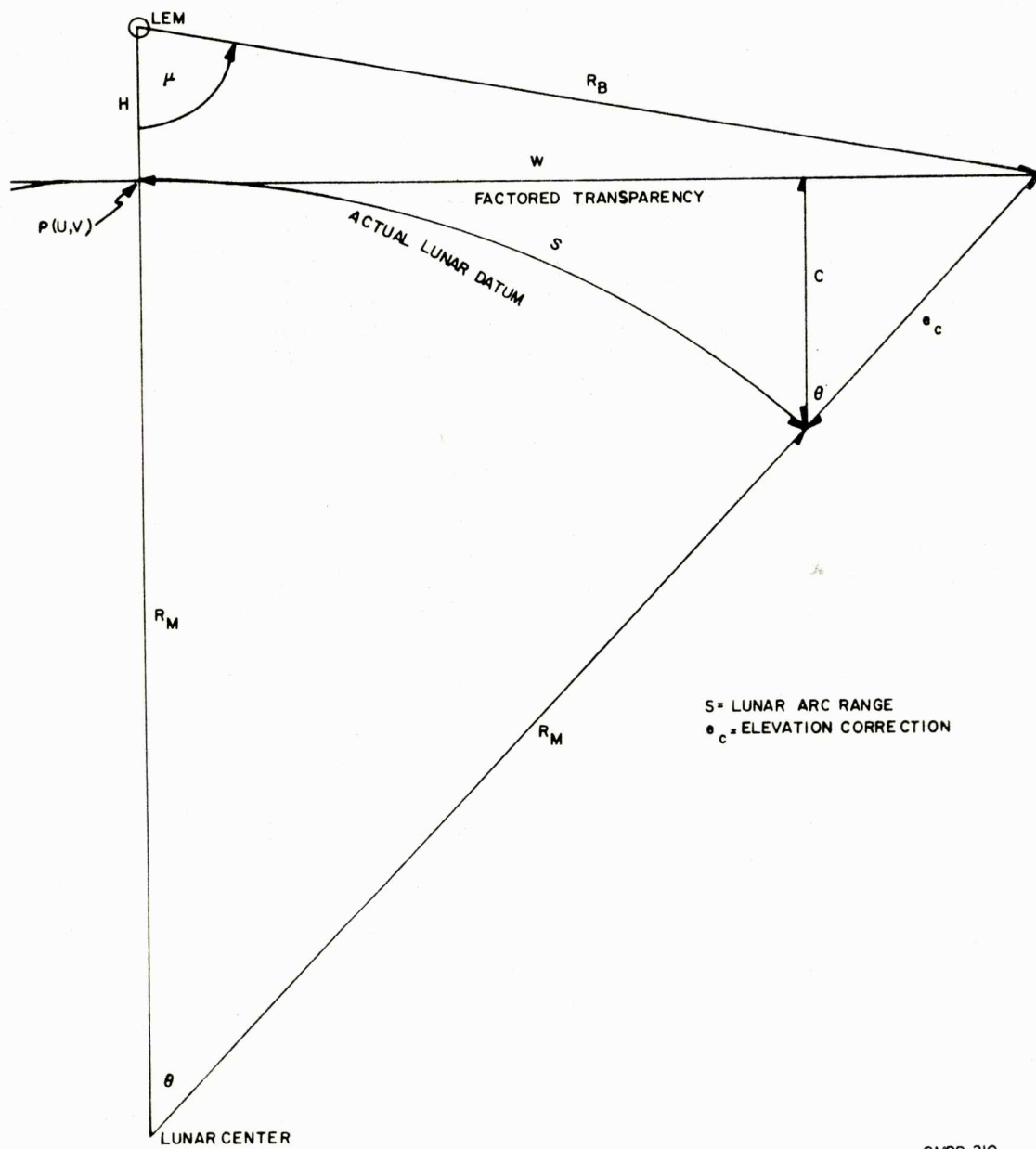


Figure 1-19. Lunar Curvature Effects Geometry

Analog data storage in the form of a factored transparency provides the necessary landmass storage. This type of factored transparency system is necessitated by real-time computing requirements and the need for random access to any part of the landmass data. Lunar terrain is simulated by storing the features of the terrain on two separate film-like transparencies. The ability of the terrain to reflect transmitted radar pulses is simulated through the transmittivity (ability to pass light) of the transparencies. One transparency is used to produce coarse elevation data; the other, to provide fine elevation data. Each transparency depicts a corridor area and a landing area at different scale factors. The transparencies represent a map-like view of a lunar area; the transmittivity at any point of the transparency represents the elevation of the corresponding point on the terrain. With this stored information available, synthetic radar returns can be produced.

#### 1.6.2 EXTERNAL VISUAL DISPLAY EQUIPMENT. (See figure 1-20.)

The external visual display equipment (EVDE) consists of four viewing subsystems: left window, right window, overhead window, and telescope. Each viewing subsystem comprises a visual display section with inputs from television and celestial sphere image generators controlled by commands from the LMS computer via the interface junction section. The image-generating sections generate lunar or earth mission images and transmit them to the visual display section. There are seven image-generating sections (figure 1-21) as follows:

- Three window star displays
- Telescope star display
- Rendezvous and docking
- Landing and ascent
- Mission effects projector.

The EVDE major components are listed in table 1-12. The visual display sections present the generated views to the flight crew astronauts by combining TV and star displays. The interface junction section provides the electrical interface between the LMS computer and EVDE.

The EVDE presents a realistic simulation of views expected to be seen by the flight crew astronauts through the three LM cabin windows and the telescope during the lunar or earth mission. Simulated views of the Command and Service modules (CSM) during rendezvous, docking, and flyby maneuvers are presented.

The window and telescope displays provide the following:

- Realistic visual presentation of external environment during all flight phases
- Simulation of attitude orientation of Reaction Control Subsystem
- CSM acquisition for tracking, rendezvous, docking, and flyby
- Lunar landing, including abort
- Lunar launch.

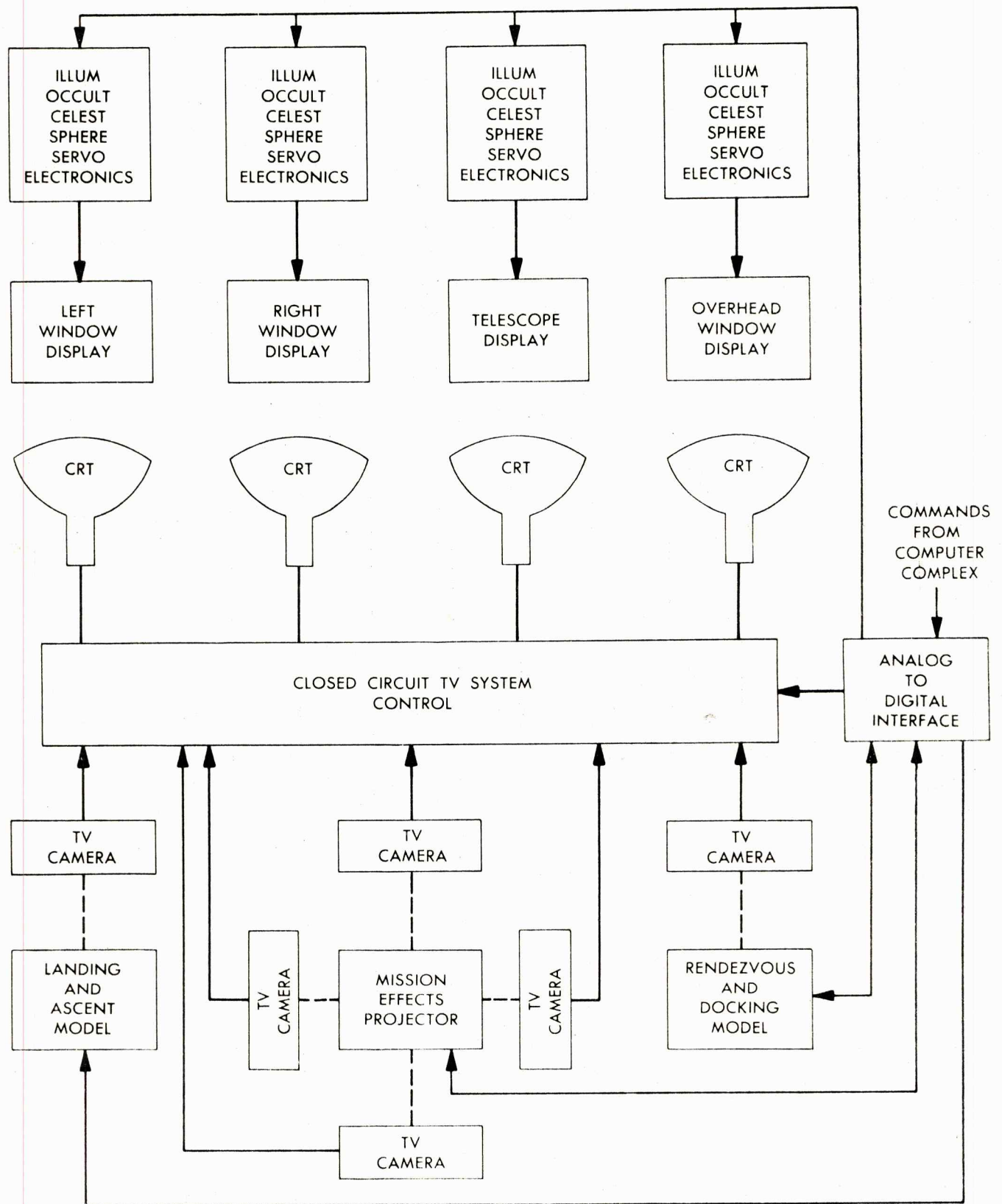
The external views through the LM windows and telescope are simulated by display of virtual images of the stars, earth, moon, and the CSM. The image pattern, shape proportionate size, outline, and detail depend on viewing range, orientation of object with respect to LM angular displacement, and visual perspective as commanded by the computer complex. Scenes are superimposed over a star background without noticeable blurring, distortion, or bleed-through. Scenes are shifted without noticeable jitter. Shifts in scale are minimized; they do not detract from training value.

The following exterior portions of the LM that are within the field of view are visible as masks:

- Reaction Control Subsystem jets
- Portion of the forward hatch
- Front landing gear leg and pad.

These items are displayed as they would be seen from the viewing position. During the ascent phase, the front landing gear leg mask is removed upon receipt of a signal from the computer. Relative velocity, acceleration, and positioning of the objects being viewed by the flight crew are obtained by the response of the image





LMS 1 60

Figure 1-20. External Visual Display Equipment, Block Diagram

generators to reciprocal computer commands. Views of the lunar surface, generated by the mission effects projector (MEP), are presented through all windows and the telescope when the simulated LM is at an altitude above 1,200 feet and in the proper attitude. At a simulated altitude of 1,200 feet or less, above the lunar surface, images of stars, earth, lunar views (depending on vehicle attitude), and the CSM (as a blinking light) are available through the overhead window and telescope; the right or left window presents a lunar-surface view as generated by the landing and ascent model. The remaining window presents an appropriate MEP-generated scene that will not drop below 300 feet, even after touchdown. Displays of the CSM are presented independently, simultaneously, and in the correct angular relationship (perspective) through both front windows, or through the overhead window alone, or in the telescope alone.

The following occultations are provided upon command from the LMS computer:

- Of the stars behind the moon (by occulter)
- Of the earth behind the moon (by occulter)
- Of the CSM behind the moon (computer control)
- Of the moon behind the CSM (by video insertion)
- Of the lunar surface by the LM shadow (by video insertion of CSM docking end view).

Table 1-12. EVDE Major Components

Designation	Nomenclature
A1	Left window display
A4	Left window display, electronics rack
A5	Mission effects projector (MEP)
A5A1	MEP controls assembly
A5A2	MEP probe
A10	Rendezvous and docking image generator
A10A5	Rendezvous and docking model controls assembly
A10A6	Rendezvous and docking model and probe electronics rack
A13	Landing and ascent image generator
A16	Telescope display
A20	Telescope display, electronics rack
A23	Overhead window display, electronics rack
A26	Closed-circuit TV, control rack
A29	Right window display, electronics rack
A32	Right window display
A33	Signal distribution, IJS
A38	Overhead window display
A40	Power distribution rack, IJS



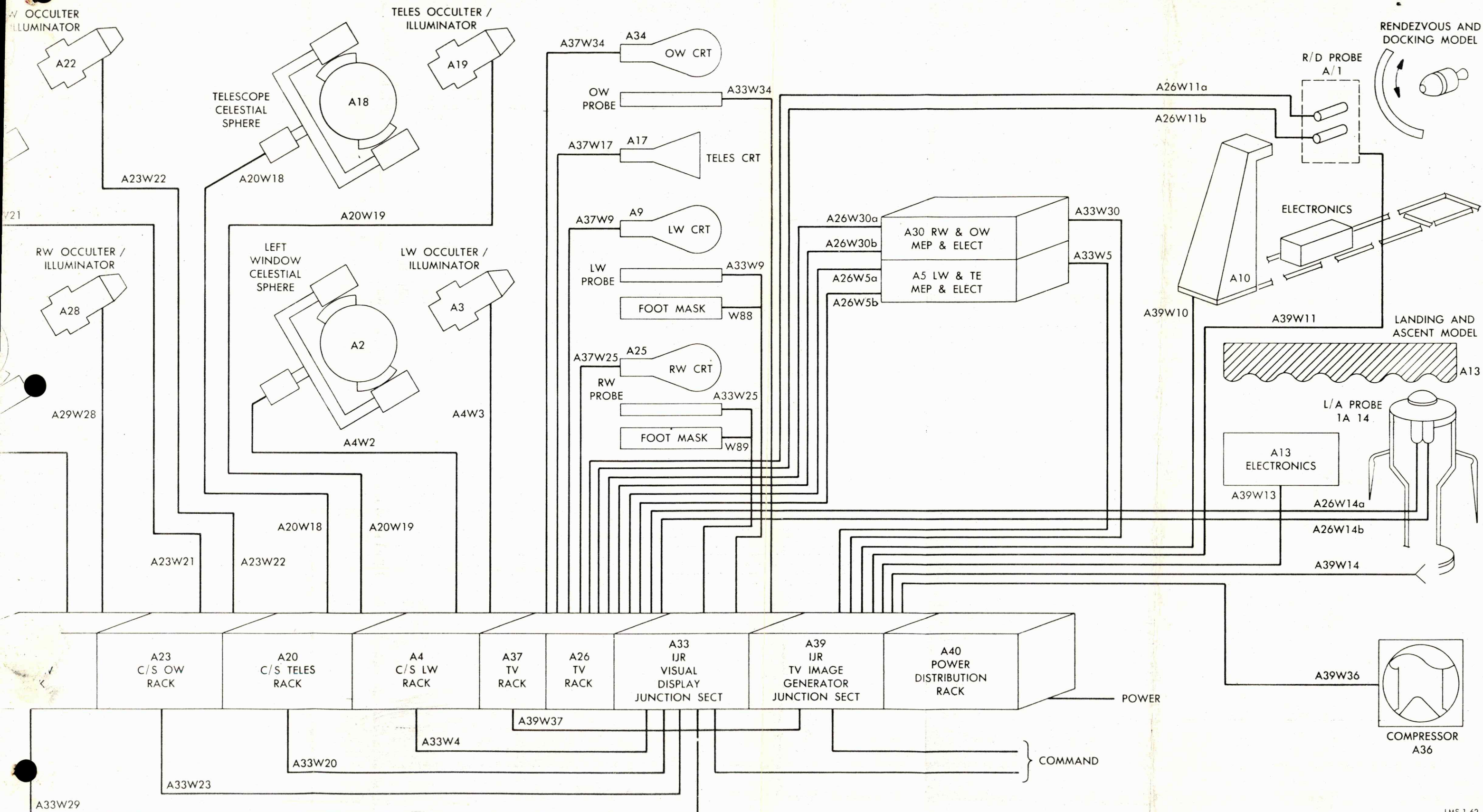


Figure 1-21. External Visual Display Equipment, Functional Schematic



The EVDE generates, integrates, and presents views of the lunar surface, CSM, starfield, and earth in apparent six degrees of freedom (with respect to two viewers) during the following operational phases:

- Lunar orbit
- Descent
  - Coasting descent transfer orbit
  - Powered descent
    - Initial powered descent
    - Final powered descent
    - Hover to landing
- Ascent
  - Powered ascent
  - Coasting ascent transfer orbit
  - Rendezvous
  - Docking
- Abort.

Due to the absence of a lunar atmosphere, scene brightness falls off rapidly as the viewing angle increases from the nadir. The EVDE provides scene brightness consistent with changes in viewing angle. Contrast range (approximately 6 to 1) due to the different albedos of the various substances that make up the lunar surface is simulated. Brightness of each star is to the nearest magnitude. (A brightness change of 2.51 is equal to a one-magnitude change.) Brightness is rounded to the nearest magnitude integer.

Upon command from the computer, the display scene may be positioned to any position previously attained during a problem, and includes adequate control of transient effects of the return to protect the equipment from damage. Repositioning to any part of the problem does not take more than 5 minutes; it usually takes less than 2 minutes. The image generation sections provide the following rotational and translational accuracy. Rotational static accuracy is better than  $0.5^\circ$ , except that the celestial sphere image generator of the telescope display has an accuracy of 1.0 minute of arc. The navigational stars of the telescope celestial sphere are presented to the optics of the telescope with an accuracy of  $\pm 1.0$  minute of arc with respect to their true interspatial position. The remainder of the star background is sufficiently accurate to enable recognition of constellations so that navigational stars can be identified.

The nadir position is accurate within  $1.0''$  of maximum scale altitude for each MEP altitude range. Rendezvous and docking range are within  $1.0''$  of range from 30,000 to 10 feet, and within  $10.0''$  of range from 10 to 4 feet. Landing altitude is accurate within  $1.0''$  of altitude from 1,000 to 20 feet.

#### 1.6.2.1 Overhead Window Display.

The overhead window projects a composite of separately generated images through the simulated LM cabin window. One image is of an occulted celestial starfield. Superimposed upon this image, is an image composed of inserted images generated by the MEP, and A or R and D TV inputs. The overhead window display subsystem includes the following assemblies:

- Eyepiece beamsplitter
- Eyepiece mirror
- Aspheric corrector lens and beamsplitter
- Celestial sphere beamsplitter
- Celestial sphere mirror

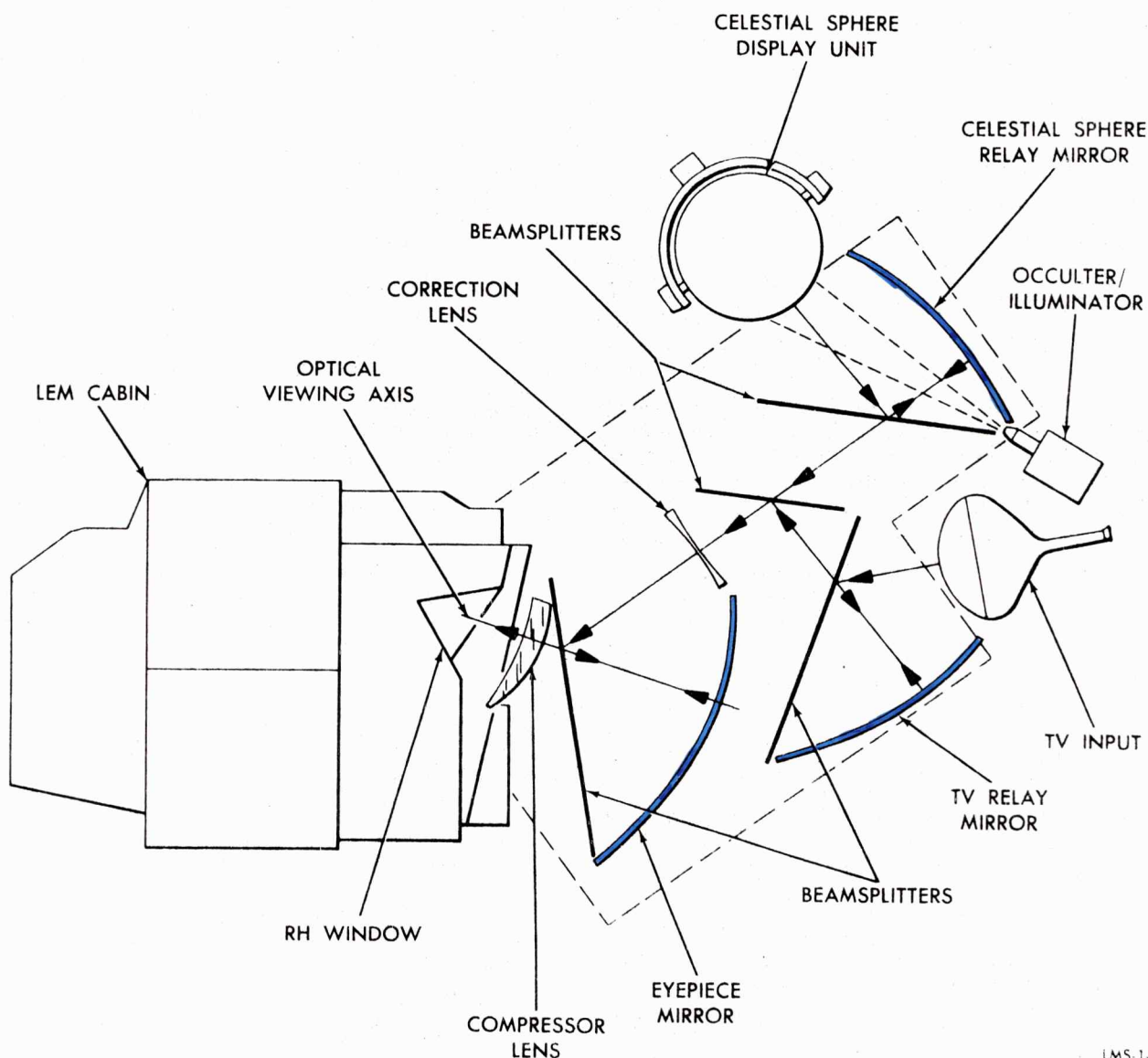


- TV beamsplitter
- TV mirror.

The optical elements are mechanically mounted; they provide an 8-inch circular pupil and a  $45^\circ \times 65^\circ$  field of view. The overhead window display is stationary; it has no moving parts.

#### 1.6.2.2 Left and Right Window Displays.

The left and right windows display the starfield image seen by the astronauts. Figure 1-22 depicts the right window display, which is typical of the optical arrangement in the other windows. It consists of a celestial sphere, celestial sphere electronics assembly, and an illuminator and occulter assembly. One assembly is required for each window display (left, right, and overhead windows of the simulated LM cabin). A window display consists of a 500-watt mercury arc lamp that illuminates a 27-inch-diameter celestial sphere through the image-forming, condensing, and transformation optics. The starfield is simulated by steel balls of various diameters, accurately placed on the outer surface of the celestial sphere. A single occulting mechanism, in the collimated portion of the light path, provides lunar occultation. This occultation system comprises a variable-diameter disk effectively subject to two-dimensional placement in two orthogonal directions. The disk diameter is a function of the solid angle subtended by the object to be occulted, as seen from the LMS cabin.



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Figure 1-22. Right Window Display, Functional Diagram

During actual space flight, the view of the celestial sphere shows changes that correspond to the position and attitude of the LM and to its roll, pitch, and yaw motions. This changing view of the celestial sphere is simulated by mounting the celestial sphere in a gimbal system that provides rotation of the celestial sphere about three orthogonal axes which are related by transformations to roll, pitch, and yaw. The celestial sphere is rotated by three motors in response to commands generated by the computer.

#### 1.6.2.3 Telescope Star Display.

The telescope star display provides the LMS telescope with a simulated starfield display and means for occultation of this field. The telescope star display, in conjunction with the telescope display subsection, presents an infinite image starfield that is displayed at the entrance pupil of the LMS telescope. The illumination system for this display provides the means for lighting and controlling the image size of the simulated stars. The illumination source is collimated by the condensing lens of the projector lamp assembly, projected through the occulter assembly, and refocused by the projection lens assembly onto the subminiature relay mirror that is cemented to the celestial sphere beamsplitter mirror. This secondary image serves as the source for illuminating the celestial sphere. The balls, illuminated by this light source, form an image of the light source at their focal surface. This image is minified by the ratio of the distance from the ball to the source and the focal distance of the ball. The resultant image, viewed by the telescope, is subliminal (less than 1 minute of arc).

Motion of the LM relative to the moon and stars is simulated in the telescope star display by motion of the celestial sphere and lunar occulter in response to computer-derived commands. For this purpose, the gimbaled celestial sphere (containing the starfield) has three degrees of freedom.

The illumination-occultation assemblies are A18, A19, and A20, figure 1-22. A high-pressure mercury arc lamp and a collimating lens are housed in the projection lamp assembly. The collimated beam of light is projected through the lunar occulter assembly, and a servo-driven occulting disk is focused on the surface of the celestial sphere by the projection lens assembly. The optical axis of this system is coincident with the telescope line of sight; the X-axis of the occulter is contained in the X, Z plane; its Y-axis is aligned parallel to the Y-axis of the simulated LM cabin. The diameter of the occulting disk is varied by signals from the computer, to correspond with the distance of the LM from the moon.

#### 1.6.2.4 Rendezvous and Docking Section.

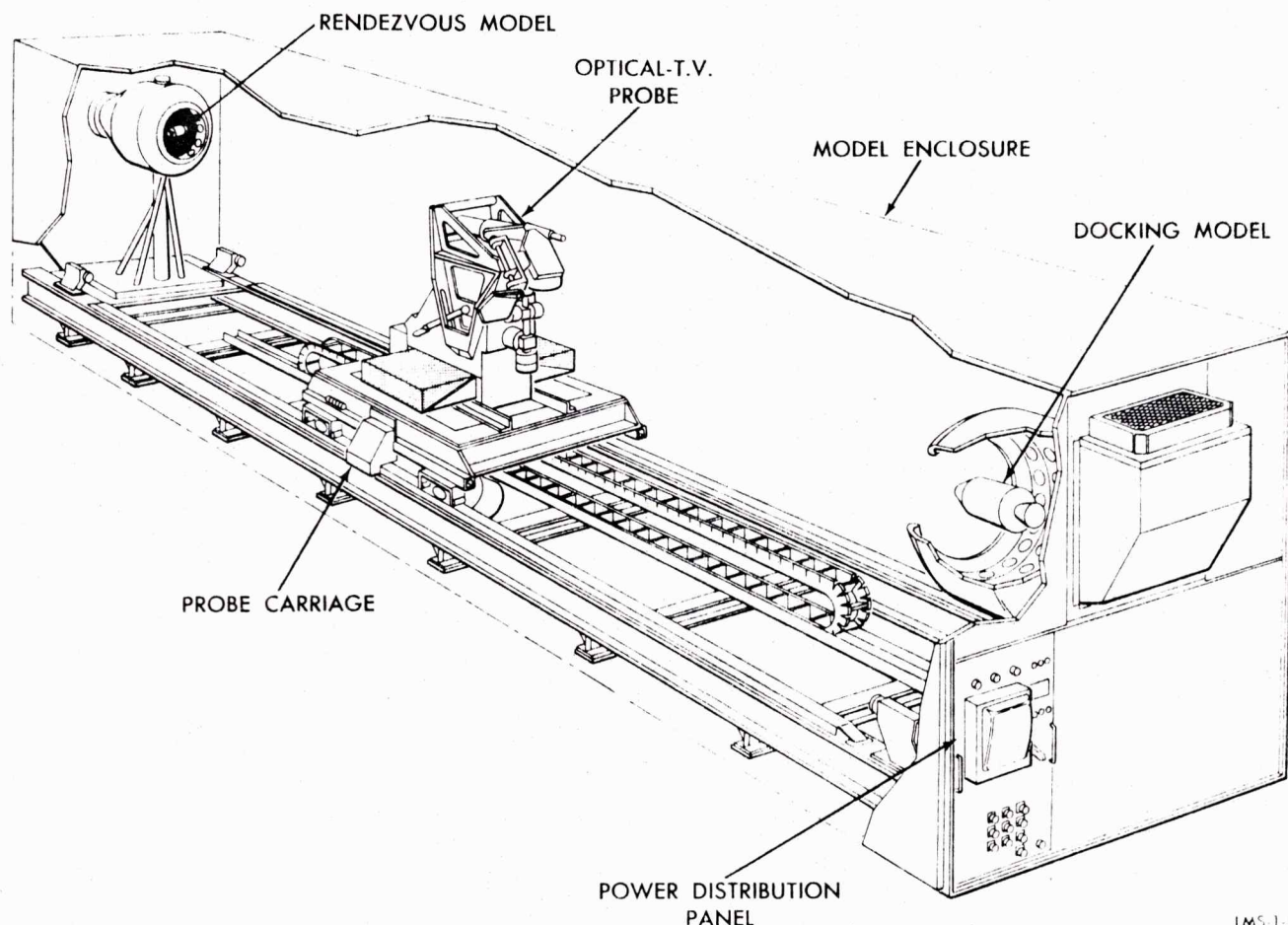
The rendezvous and docking section (figure 1-23) visually simulates the rendezvous and docking maneuver, with models of the CSM and TV probes, in a space of approximately 30 feet. The rendezvous and docking section consists of the following subsystems:

- CSM models and probe carriage
- Rendezvous and docking probe
- Closed-circuit TV
- Right window focusing CRT
- Left window focusing CRT
- Overhead window focusing CRT.

##### 1.6.2.4.1 CSM Models and Probe Carriage.

This subsystem simulates the view of the CSM and the range between the CSM and the LM. The initial phase of rendezvous, from 20 nautical miles to 14,000 feet, is represented by a blinking beacon light located in the nose of the rendezvous model. During the second phase of rendezvous, between 14,000 and 8,000 feet, the CSM is represented as an object by the illuminated model. During these two phases, the probe carriage is 25 feet from the rendezvous model. The intensity of the blinking beacon light and the illumination of the model is video attenuated to approximate the change of range. The third phase of rendezvous, from 8,000 feet to 530 feet, is simulated by motion of the carriage toward the rendezvous model, from 25 feet to 18.8 inches. At the 530-foot range, the view from the probe is reversed, by removal of the dissolve mirror, placing the carriage 26.5 feet from the docking model. Closing the range from 530 feet to the docking point is simulated by travel of the carriage toward the docking model. The illumination subassembly of both models consists of fixed banks of lights arranged in rings surrounding the models. Lighting of the models simulates solar illumination by selective switching of the proper quadrant of light banks. The electronics section receives command signals and transmits power to effect all previously described drives and switching.





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Figure 1-23. Rendezvous and Docking Image Generator

#### 1.6.2.4.2 Rendezvous and Docking Probe.

The docking probe assembly simulates the views from the LM in its various attitudes with respect to the CSM. The prime component of the assembly is the articulated twin probe, whose optical systems transfer the images of the CSM onto the faces of two stationary TV camera tubes. Servo-controlled lenses focus the images as a function of range. The optical system is capable of unlimited rotation of the lines of sight in azimuth and elevation. The third rotational degree of freedom, roll of the LM about the image axis between the LM and CSM is taken care of by differential model roll.

Azimuth and elevation motions are transmitted to an optical scanning head assembly, which contains a differential drive to sort out pure azimuth and elevation motor and data-element rotations. A shaft that combines azimuth and elevation rotations drives the derotation prisms in the optical derotation and focus subassembly. The focusing lens drive requires a nonlinear command signal as a function of model range to move the lens over a total distance of 0.060 inch.

The basic optical probe design places the entrance pupils at a separation and displacement (from the center of rotation) at  $1/20$  scale of the left and right window viewpoints of the two astronauts, corresponding to the  $1/20$  scale of the docking model, thus assuring proper perspective and angular orientation during the docking phase. The 25-foot model distance, corresponding to the 8,000-foot range at the start of the final rendezvous phase, requires a  $1/320$  scale reduction of probe and model. By interposition of a 4X power telescope between the  $1/20$  scale probe and the  $1/80$  scale rendezvous model, size and perspective are properly scaled by optical methods. A smooth transition from rendezvous and docking model view is performed by withdrawal of a dissolve mirror at the 530-foot transition range. After dissolve mirror withdrawal, the entire telescope assembly is moved behind the articulated probe to avoid interference with the illumination subassembly during the terminal docking phase. In addition to the left and right window view presentation, the probe is used to present exclusive views through the overhead window or through the telescope in its three discrete directional settings. To assure

proper image orientation and line-of-sight direction, corresponding coordinate transformations must be fed into the computer.

#### 1.6.2.4.3 Closed-Circuit TV.

The closed-circuit TV electronics section controls the cameras, produces the sync signals, and contains a video switching unit for selection of the proper CRT display for left or right window, overhead window, or telescope view. It also contains the beacon light attenuator to approximate the change of range, and video insertion units to insert the image of the CSM (whose shadow is illuminated sufficiently to effect switching) into the image received from the MEP.

#### 1.6.2.4.4 Window Focusing CRT.

The CRT focusing assembly makes the presentation of the docking maneuver as realistic as possible. As the CSM approaches the LM, the virtual image of the CRT face (which appears normally at infinity) is placed at the proper range by a forward focusing motion of the CRT with respect to the window optical systems. By placing the image at the actual CSM range, the realism of the display is enhanced by both parallax and eye accommodation of the observer. Computer signals, based on a nonlinear function of CSM range, position the CRT carriage through a servo-driven ball-screw and nut arrangement.

#### 1.6.2.5 Landing and Ascent Section.

The landing and ascent section (figure 1-24) produces realistic images of the landing and ascent maneuver of the LM. The landing and ascent section comprises the following subsections:

- Lunar model and three-axis translational drive
- Horizon rings
- Illumination
- Optical probe
- Main frame.

##### 1.6.2.5.1 Lunar Model and Three-axis Translational Drive Subsection.

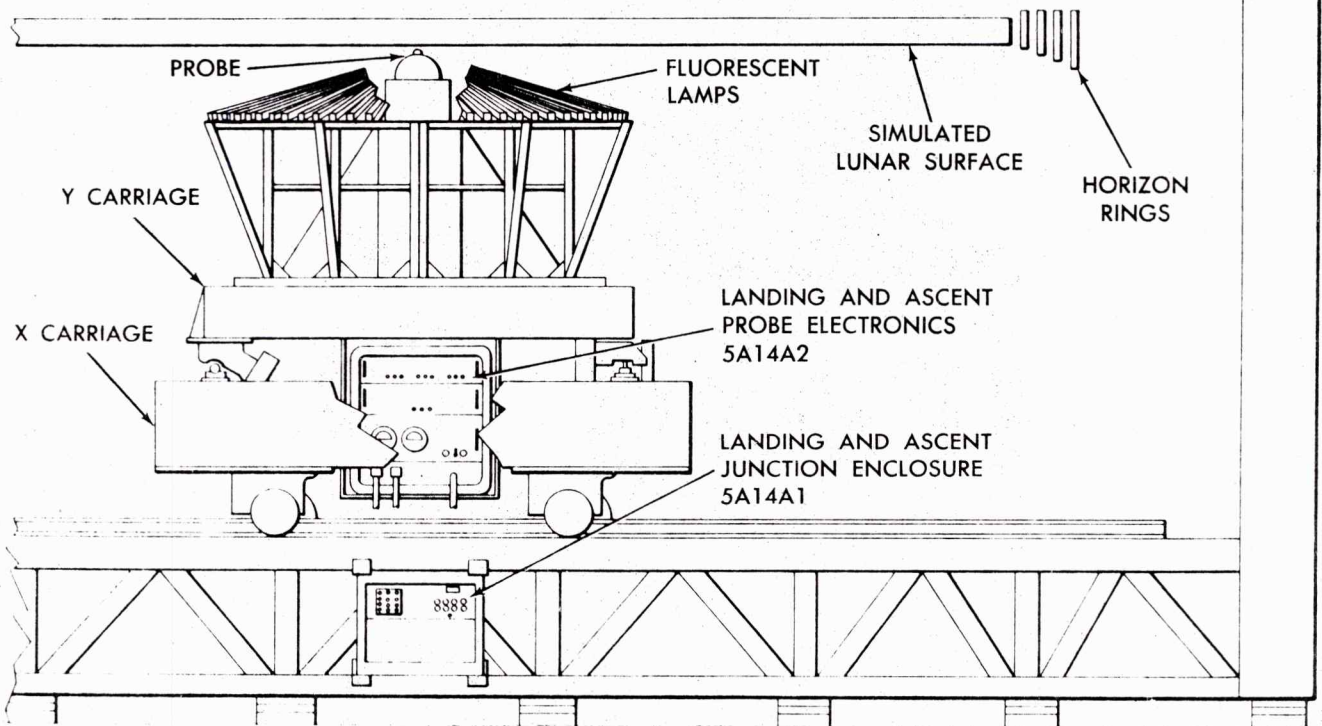
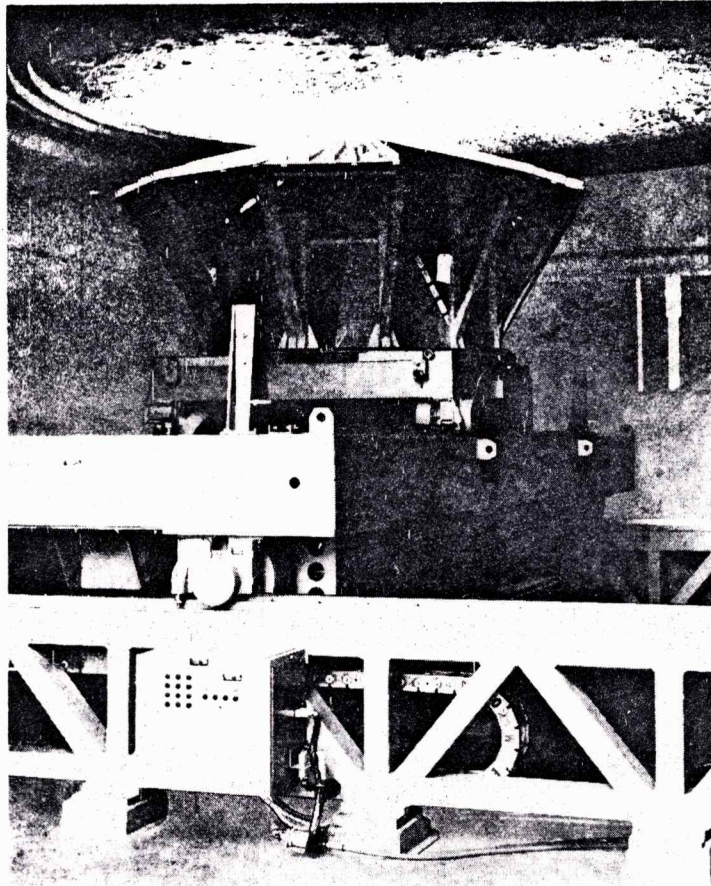
The lunar model and three-axis translational drive subsection comprises a movable carriage in the X-plane and Y-plane, a movable model of the lunar surface in the Z-plane, an optical probe, a control console, an illumination system, and mechanical supporting components.

The lunar surface is represented by a three-dimensional scale model; approximately 35% of its surface is suitable for simulation of landing. The optical probe is movable in three rotational axes (roll, pitch, and yaw). When combined with the three translational axes (X, Y, and Z) of the simulator, the visual display realistically portrays the lunar surface to the astronauts. The lunar surface is divided into three types of terrain to permit landing practice to be accomplished on boulder-strewn, crater-filled, and low-hilled or hummock-filled terrain. The computer positions the optical probe in the X-axis and Y-axis to simulate translational motion and positions the lunar surface closer or farther from the optical probe to simulate ascent or descent.

Shadows caused by the sun are painted on the model for a nominal elevation angle of 45°. The shadows are rendered as black, with approximately 0.10 reflectivity. Specular reflectivity is minimized by use of a textured surface. The overall surface of the model is white, providing good light diffusion. The ratio of total reflected light to total incident light is greater than 0.5. Specular light reflections are minimized to prevent mirror effects.

The 16-foot-diameter lunar surface contains three 120° segments that simulate the different detailed lunar features. One segment contains hummocks (rough conical shapes) that range from 0.02 inch high with 15° sloping sides to 0.4 inch high with 30° sloping sides. It also contains small fissures and fault scarps that range from 0.004 to 0.055 inch high. Another segment contains boulders (rough spherical shapes) that range from 0.02 to 0.04 inch high. This surface also contains large fissures and fault scarps that range from 0.02 to 0.20 inch wide. The third segment includes craters that range from 3 to 300 feet (0.003 to 0.3 foot, model dimensions) in diameter, with depths from 1 to 100 feet (0.001 to 0.1 foot, model dimensions), respectively. The craters have rounded corners.





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Figure 1-24. Landing and Ascent Section

#### 1.6.2.5.2 Horizon Rings Subsection.

The horizon rings subsection comprises three equal 120° segments; each segment provides a continuous view of its associated lunar-surface area. In addition, terrain features on the horizon rings are used to show distant landscapes in relation to simulated altitude, from 22 to 1.5 simulated miles. The horizon that would be visible is also presented on a ring to enable complete simulation of environment even when the optical probe is tilted. The image on the ring is artistically rendered; the simulated horizon line is placed to provide the required horizon-line effect. The light reflectivity values of the lunar-surface model serve as a guide for the relectivity values used on the horizon ring subsection.

#### 1.6.2.5.3 Illumination Subsection.

The lunar model is illuminated by a fluorescent lighting system that provides a level of brightness, over the entire surface, that is representative of the falloff of light as a result of viewing angle. A total of 145 lamps are used. Twelve 30° sections face the model; they tilt away from the outer edge of model at 18° to form a cone-shaped lighting dish. Each section contains twelve 23-inch-long, 20-watts lamps. A high-intensity fluorescent lamp, wound in a spiral, surrounds the optical probe; its light is cast straight down over the nadir point. This lamp receives 2,500 volts ac from a step-up transformer mounted on the Y-axis carriage.

#### 1.6.2.5.4 Optical Probe.

The optical probe scans a 3-dimensional lunar model scaled 1,000 to 1. The scanning angle is the angle (with respect to the nadir) observed by the astronaut during actual lunar landing or ascent. The entrance pupil of the system is within the elevation prism, with an instantaneous field of view of 110°. The pupil can be positioned 0.25 to 18.00 inches away from the lunar model, which, at 1,000 to 1 scale, is equivalent to 21 to 1,500 feet.

The objective prism, which is statically mounted to the objective assembly, deviates the line of sight from the elevation prism to permit an arrangement whereby the lower conjugate distance can be varied to compensate for changes of the object distance. The lower focusing assembly contains the two Porro mirrors, which, by trombone action, dynamically vary the conjugate distance by a factor of two. As the object distance changes, the two field lenses are positioned with respect to each other and the objective lens to compensate for change in focus.

For the lower section of the optical system, the movable optics compensate for variations of the object distance and focus. Additional corrections and dynamic motions of the remaining portion of the optical system are required. Due to the inherent characteristics of the scanning system, rotation of the elevation prism produces a one-speed rotation of the image, which requires a derotating device and rotation of the relay lens in the system. Additionally, the relay lens is tilted to return the slanted image normal to the optical axis.

Dynamic variations of the upper conjugate are similar to those of the lower conjugate, except that a pentaprism is incorporated in the system to provide an unequal number of reflecting surfaces; by the unique arrangement of a mirror, Porro prism, and pentaprism, a derotator is incorporated into the system. By trombone action of the Porro prism, dynamic variations of the upper conjugate are obtained.

The camera, mounted directly above the pentaprism, contains the vidicon upon which the image is focused and then transmitted to the TV receiver in the window display.

#### 1.6.2.5.5 Main Frame Subsection.

X-Carriage. The X-carriage is composed of four steel box beams, welded together to form a 22- by 7-1 1/2-foot rectangular frame. The X-carriage is positioned in relation to the lunar model by the X-drive wheel assemblies, it is driven by torquer amplifiers that respond to command error signals. The Y-carriage is mounted on the two long beams of the X-carriage. A liquid spring and a limit switch, which stops the carriage at the extreme limits of travel, extend from each corner of the X-carriage.

Y-Carriage. The Y-carriage is a welded aluminum channel structure, which supports the optical probe and the illumination section. It is composed of a 62-inch-diameter inner rolled channel (to provide attachment to the optical probe), and four straight sections, which form an outer box. The Y-carriage is positioned in relation to the lunar model by torquer amplifiers, which respond to command error signals. Liquid springs and limit switches to bring the Y-carriage to a halt when the extreme limits of travel are reached.

X-Y Track System. Two types of tracks are used in transporting the X-carriage and Y-carriage. Each carriage has one track of each type to provide maximum accuracy in carriage positioning. The first type is a flat piece of hardened steel that is fastened to a machined surface on the track support. The second type is a cylindrical piece of hardened steel that rests in a V-grooved bar bolted to a machined area on the track surface.



Terrain and Horizon Rings. To simulate the distant lunar terrain and the horizon to an astronaut, a series of terrain and horizon rings are used. Each of these five rings consists of eight circular sections of two pieces of aluminum bonded together and filled with expanded foam. They are suspended from the Z-drive by a series of eight supports 45° apart. The terrain rings are painted to resemble distant lunar features and are cut along the bottom surfaces according to the terrain portrayed. Each successive ring, from the center, is representative of further terrain. The fixed horizon ring includes some black sky, as well as distant terrain.

Drive System. The X-carriage and Y-carriage are driven by torque-powered friction drive wheels at each end of the carriage. By locating a drive assembly at each corner of the carriage, extremely linear servo operation and response is possible. In addition, driving each end of the carriage eliminates the rotational effects of the carriage while positioning.

#### 1.6.2.6 Mission Effects Projector. (See figure 1-25.)

Lunar views from 200 nautical miles down to 300 feet are generated for the LMS by the mission effects projector (MEP). The MEP uses two 50-foot film strips to project lunar scenes onto four circular screens which are viewed by four TV cameras (one each for the right, left, and overhead window, and one for the telescope.) Spacecraft attitude motion is simulated by an articulated optical probe in front of the TV camera. Spacecraft translational motion (along orbit or across orbit) is simulated by either moving the film lengthwise (from one film spool to the other) or sideways (by moving the entire cassette). A film set consists of two cassettes (A and B) each containing 50 feet of film. Film A contains film scales 1, 3 and 5; film B contains film scales 2, 4, and 6. The specific film scales cover the following altitudes:

<u>Film</u>	<u>Scale</u>	<u>Maximum Altitude</u>	<u>Minimum Altitude</u>
A	1	192 nm	14.5 nm
B	2	14.5 nm	5.4 nm
A	3	34, 776 feet	9,107 feet
B	4	9,107 feet	2,380 feet
A	5	2,380 feet	1,240 feet
B	6	1,240 feet	314 feet

Altitude changes on any given film scales are accomplished by varying varifocal settings, which are similar to zoom lenses used in commercial TV.

Scales 1 and 2 cover full lunar orbits. For example, to simulate an 80-nautical-mile circular lunar orbit, scale 1 would be used at all times and would be slewed back to its beginning when orbiting over the dark portion of the lunar surface is simulated. A similar method is used for film scale 2 when the simulated orbit altitude is in scale 2 range. Scale 3 covers one-quarter of the lunar orbit, specifically, it covers the area where the ten landing sites are located. Scales 4 and 5 cover the landing site with its corridor. All ten landing sites contained on one film set. To allow for three different sun angles, the film set is divided into three sections, each containing a different mission. For mission A (first section), scales 4 and 5 depict landing sites I, II, III and IV. For mission B (second section), scales 4 and 5 depict landing sites V, VI, VII. The third section contains mission C on which scales 4 and 5 depict landing sites VIII, IX and X. Before starting a training session, the instructor has to determine which mission is to be flown depending on landing site and/or sun angle selection.

Film scale 6 depicts an area of approximately 8 by 6 nautical miles which represents the landing site below 1,240 feet. This view is fed to the right window while the Commander receives the landing and ascent image in the left window. The view presented by film scale 6 does not go all the way to touchdown; however the instructor can transpose the left and right window views by means of the L/A IMAGE switch (on the PROBLEM CONTROL panel) at the instructor console. On scales 4, 5 and 6 the center of each film strip represents the particular landing site.

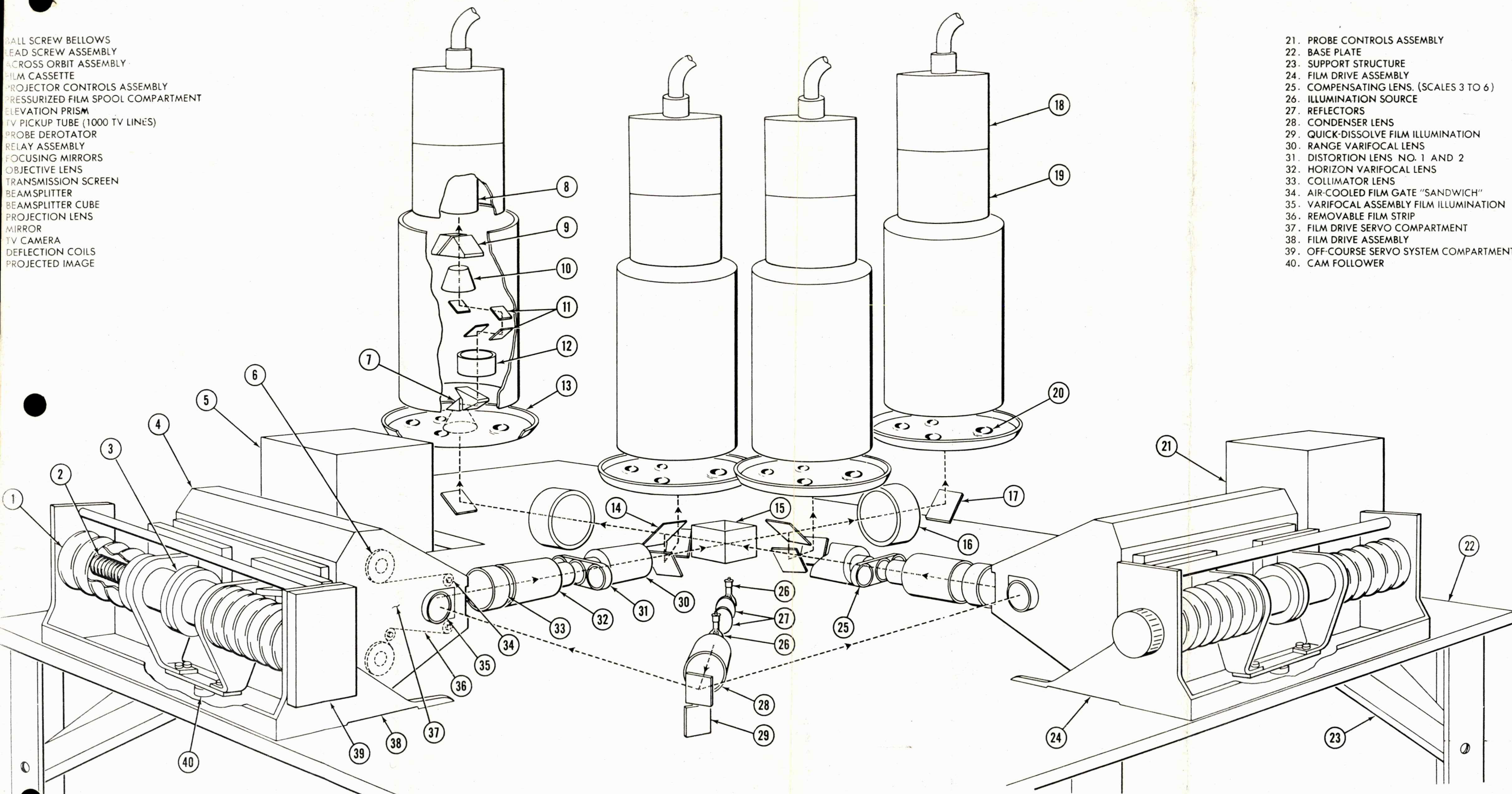
To achieve proper perspective, the MEP contains distortion lenses that automatically gives the proper curvature to the lunar (on earth) scene.

During descent to the lunar surface, the spacecraft goes through the various film scales in the MEP. At each crossover point in film scales, the MEP will be driven so that the film in the cassette not being viewed will be made ready for a dissolve. This Dissolve is accomplished by a dissolve mirror so that very little discontinuity is observed in the final image.



1. BALL SCREW BELLOWS  
 2. HEAD SCREW ASSEMBLY  
 3. CROSS ORBIT ASSEMBLY  
 4. FILM CASSETTE  
 5. PROJECTOR CONTROLS ASSEMBLY  
 6. PRESSURIZED FILM SPOOL COMPARTMENT  
 7. ELEVATION PRISM  
 8. TV PICKUP TUBE (1000 TV LINES)  
 9. PROBE DEROTATOR  
 10. RELAY ASSEMBLY  
 11. FOCUSING MIRRORS  
 12. OBJECTIVE LENS  
 13. TRANSMISSION SCREEN  
 14. BEAMSPLITTER  
 15. BEAMSPLITTER CUBE  
 16. PROJECTION LENS  
 17. MIRROR  
 18. TV CAMERA  
 19. DEFLECTION COILS  
 20. PROJECTED IMAGE

21. PROBE CONTROLS ASSEMBLY  
 22. BASE PLATE  
 23. SUPPORT STRUCTURE  
 24. FILM DRIVE ASSEMBLY  
 25. COMPENSATING LENS. (SCALES 3 TO 6)  
 26. ILLUMINATION SOURCE  
 27. REFLECTORS  
 28. CONDENSER LENS  
 29. QUICK-DISSOLVE FILM ILLUMINATION  
 30. RANGE VARIFOCA LENS  
 31. DISTORTION LENS NO. 1 AND 2  
 32. HORIZON VARIFOCA LENS  
 33. COLLIMATOR LENS  
 34. AIR-COOLED FILM GATE "SANDWICH"  
 35. VARIFOCA ASSEMBLY FILM ILLUMINATION  
 36. REMOVABLE FILM STRIP  
 37. FILM DRIVE SERVO COMPARTMENT  
 38. FILM DRIVE ASSEMBLY  
 39. OFF-COURSE SERVO SYSTEM COMPARTMENT  
 40. CAM FOLLOWER



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Figure 1-25. Mission Effects Projector, Functional Diagram



Earth views are generated in a similar manner as lunar views except for the following differences. There is only one altitude scale required (100 NM to 300 NM) for earth views, and variation of varifocal settings can easily cover this range. Each film strip contains eight full earth orbits. These orbits range from 60° N latitude to 60° S latitude which adequately covers the range used for manned earth orbits. Each orbit depicts sunlit and moonlit areas, separated by a diffuse terminator. As the mission proceeds to the next orbit the terminator is displaced in a westerly direction by 22.5°. The film strip in cassette A is the same as in cassette B except for a 180° shift in the longitude start and end points. A dissolve to cassette B is not required until eight orbits are completed, so that 16 orbits are available to move the terminator through a full 360°.

The instructor sets up the mission so that the terminator crossings are simulated at the proper time. If the correct mission start time is set in, the proper terminators will be set automatically at reset by the non-real time (NRT) program.

#### 1.6.2.7 Interface Junction Section. (See figure 1-22.)

The interface junction section consists of the following:

- Closed-circuit TV system, including control rack A26
- Power distribution rack A40 and signal distribution rack A33
- Interconnecting cables.

##### 1.6.2.7.1 Closed-circuit TV system.

The closed-circuit TV (CCTV) system provides control and flexibility of presentation to a greater degree than would be possible with an optical-mechanical system.

The CCTV system consists of the following equipment:

- Seven precision TV camera chains
- One dual rack assembly
- Three large spherical remote TV units
- One small flat-faced remote TV unit
- Two 17-inch instructor monitors.

By use of computer controlled articulated optical probes the various cameras receive images from the MEP film, the CSM, and the lunar surface of the landing and ascent section. These images are then electronically acted upon and fed to the three window displays and telescope via special CRT's.

##### 1.6.2.7.2 Power Distribution Rack A40.

The power distribution rack contains the main a-c power distribution units; switching; fuses; and overload safety, phase failure safety, and pilot light indicators. In addition, the rack contains two d-c power supplies: ±12 and 28 volts.

##### 1.6.2.7.3 Signal Distribution Rack A33.

The signal distribution rack functions as the prime distribution center for all signals (command information) between the LMS computer and the subsections of the EVDE. In addition, the rack contains a 500-watt, 400-cycle power amplifier; a 1,500-watt, 400-cycle power amplifier; and a +10-volt d-c dual power amplifier.

##### 1.6.2.7.4 Interconnecting Cables.

The interconnecting cables connect the various parts of the EVDE electrically. These cables are functionally divided into two main categories: CCTV, and power and signal distribution.

The interconnecting cables transmit power from, and signals to and from, the LMS computer via the interface junction section to the various parts of the EVDE. The cables provide adequate flexibility and mechanical strength, minimize voltage drop, provide shielding against radiation, and accommodate changes in operational requirements by use of spare conductors and connector terminals.

### 1.6.3 SIMULATED LM CABIN

The LMS cabin meets the functional needs of the simulator while retaining the characteristics of the LM. The interior of the LMS cabin is an authentic replica of the LM interior; the external configuration is coordinated with the visual equipment to provide an integrated training device. The base unit contains components for simulation of LM air-conditioning, water, and oxygen for the pressure suit equipment. It also contains electrical test and patch panels. The components within the base structure are readily accessible for maintenance, via removable panels on the exterior of the structure.

The crew area contains instruments, displays, controls, a telescope and navigational aid, and food storage and preparation facilities, as found in the LM. The instruments, controls, and displays (figure 1-26) are mounted in the same configuration as those in the LM. Refer to Apollo Operations Handbook, LMA790-3-LM 2, for detailed descriptions of cabin controls and displays. Units not required for simulation are present in physical appearance only; attempted activation of these units has no effect on the simulator. All controls in the LMS cabin operate in a manner identical with that in the LM. Control functions approximate the LM performance curves; the controls are instrumented to provide the necessary output signals to the computer. Instrumentation does not mar the appearance of the controls nor is it obvious to the astronauts. Some equipment in the interior can be maintained in-flight. Therefore, to maintain the authenticity of the cabin, the areas behind the affected panels, doors, and/or modules are also authentic replicas of the actual area containing such equipment.

#### 1.6.3.1 Structure

The cabin shell is constructed of lightweight sheet-metal sections suitably reinforced to hold the required contours. It is lined on the interior with fiberglass blanket material of sufficient thickness to provide thermal and acoustical insulation. All sections are attached to the structure on neoprene-insulated surfaces with quick-opening (quarter-turn) fasteners and are hinged to provide maximum accessibility to the back of the simulated LM equipment, as well as to the support equipment. All cabin units are accessible through the shell

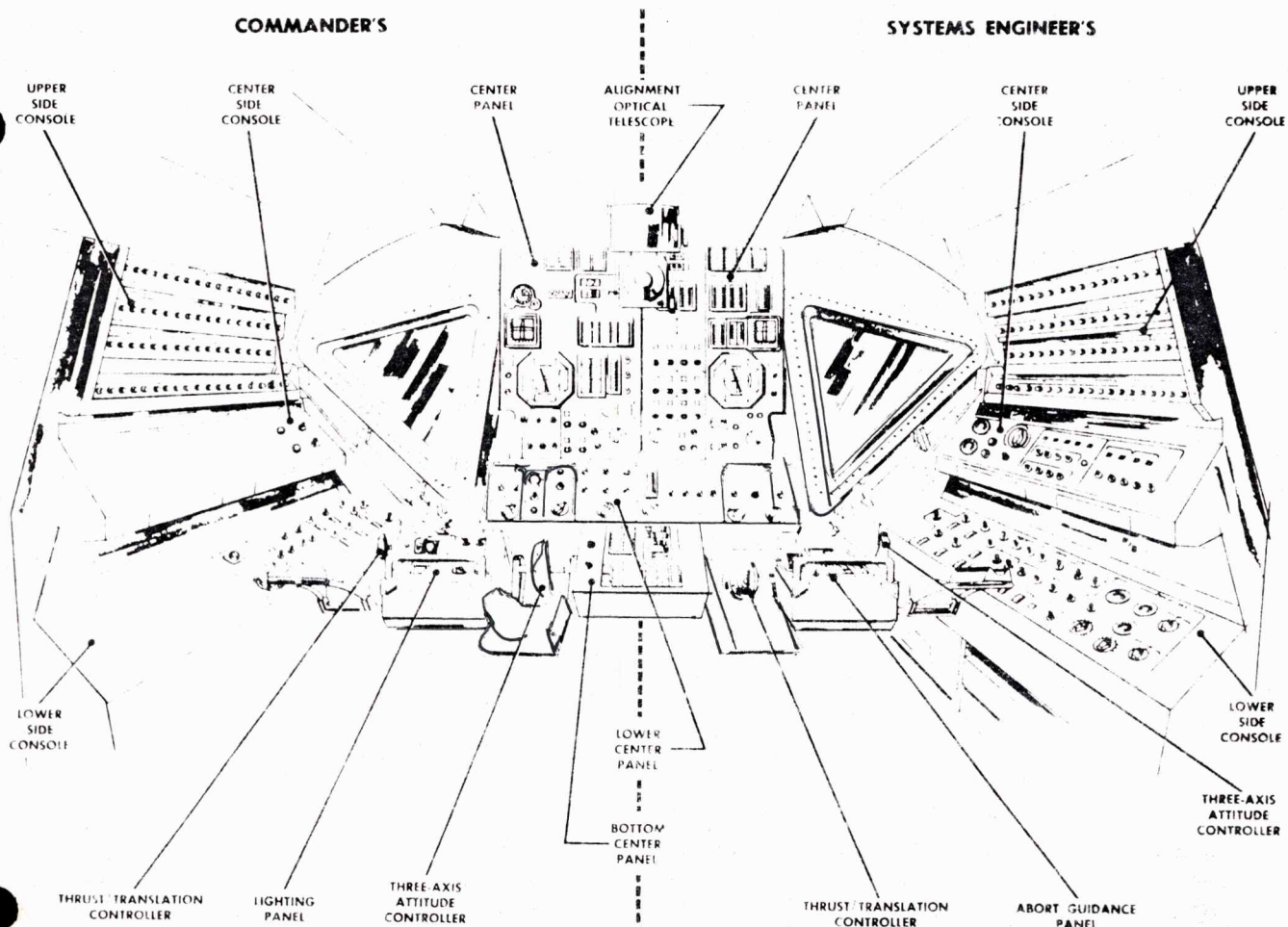


Figure 1-26. LMS Cabin

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panels, for inspection, testing, alignment, replacement, or modification, without interference with other units. This complete accessibility, the ability to separate the cabin into fore and aft sections, and the modular mounting of cabin components facilitates updating the cabin to conform with subsequent LM configurations.

#### 1.6.3.2 Visual Presentations.

The LMS cabin contains three windows, as in the LM; each window is equipped with an "out-the-window, infinite-distance" type of visual display. The displays consist of presentations of lunar and starfield areas, rendezvous and docking with the CSM, lunar surface in LM descent configuration, and rendezvous and docking with the CSM in LM ascent configuration. The window displays are synchronized to provide the proper scene at each window; the astronaut views a realistic presentation from any position within the exit pupil. Below 1,300-foot elevation, two-dimensional views of the lunar surface are presented at the left or right window as selected on the instructor console. Views in the remaining windows are two-dimensional; they are satisfactory for altitude and velocity cues only. The visual equipment provides presentations that appear to vary in distance from zero feet (the docking presentations) to infinity (the starfield presentations).

The telescope has visual equipment for the required views of the lunar surface or the 57 navigation stars. The telescope, capable of X 1 magnification, is used for general surface scanning or star locating. The navigational aid position, slaved to the telescope, is used to provide navigational measurements of lunar landmarks or limbs and of navigational stars. The scenes presented in the telescope are synchronized with the other visual displays.

#### 1.6.3.3 Cabin Environment.

Cabin illumination and temperature are controlled by the astronaut to the same extent as in the LM. The cabin is air-conditioned; the system controls temperature and humidity. Conditioned air is ducted into the cabin through grilles and auxiliary points to provide uniform, draft-free distribution. The temperature and quantity of air supplied to the astronauts' pressure suits are also variable through astronaut controls. The simulated pressure suit system is designed so that no danger exists to the astronauts either because of complete loss of ventilating air or overpressurization. The pressure suit system uses room air suitably compressed in an oil-free breathing air compressor and filtered for water condensate, microparticles, and odors; or building air.

#### 1.6.3.4 Ingress and Egress.

The cabin is aligned with the Z-axis horizontal. Normal access to the cabin is provided by a door in the rear bulkhead. This door opens outward to an exterior platform and stairs. The bulkhead equipment in this region (tape recorder, simulated guidance computer, and simulated power servo assembly) is attached to the door. The door is essentially indiscernible from the inside; it has an inconspicuous handle. Both hatches (top and forward), on the interior, are authentic replicas of the LM hatches; they require an identical release procedure to unlatch and open them.

#### 1.6.3.5 Cabling.

The right side area adjacent to the cabin houses the interconnection junction panel. All units, modules, and panels in the cabin are wired with single-headed cables directly to the interconnection junction panel. In a similar manner, all cables from the instructor console, computers, and EVDE that connect to the cabin are wired with single-headed connectors from the equipment cabinets to the interconnection junction panel. The cables are arranged on the panel so that each may be removed and replaced without difficulty. In addition to serving as the major interconnection point, the interconnect junction panel serves as the main checking point for all signals in the cabin. Updating is easily accomplished through interconnection repatching and without cable revision.

#### 1.6.3.6 Suit Maintenance Panels.

The LMS cabin structure includes two suit maintenance panels, one for each pressure suit system. The panels are identical, except that SUIT MAINTENANCE PANEL NO. 1 has additional control switch lights for the life support power and a master switch for the suit supply air compressors. The air compressors are actuated when pressurized air is selected instead of ambient building air.

Each suit maintenance panel contains a manual primary pressure regulator and a primary pressure gage. Downstream of each regulator, a flowmeter is included for each suit. (It is mounted on the respective suit maintenance panel.) Gages on each maintenance panel monitor the actual suit inlet pressure, the suit outlet pressure, and the pressure differential across the suit.

The LMS scheme of suit pressurization, functioning in an unpressurized cabin, is based on the ratio of theoretical cabin pressure versus theoretical suit pressure. In normal operation, the Suit Technician adjusts the pressure of the two suits to be proportional to the theoretical relative pressure difference between suit and



cabin pressures. This differential is calculated within the computer complex and displayed on the SIM Δ P indicator on the TRUE TRAINEE ENVIRONMENT panel on the instructor console. If desired, the suit pressure may be controlled from the maintenance panels. Pressing the SUIT TECH CONTROL switch light extinguishes this lamp and transfers control to the two suit maintenance panels. Simultaneously, the MAINT PANEL CONT lamp on the TRUE TRAINEE ENVIRONMENT panel goes on to warn that suit pressure regulation is controlled from the maintenance panels. Each maintenance panel has three similar INCREASE, DECREASE, and HOLD switch lights. These switches are electrically parallel with the switches on the TRUE TRAINEE ENVIRONMENT panel and function (light up and pull in under solenoid control) simultaneously with them. The maintenance panel switches, however, command fixed pilot servo rates: 90 seconds for maximum suit inflation; 30 seconds for full deflation. The MAINT IN PROGRESS warning loop may also be controlled by a switch light on SUIT MAINTENANCE PANEL NO. 1.

A manual mode is also provided to control the suit air supply temperature during maintenance periods, when the computer complex may not be available for on-line operation. The manual mode is selected with the SUIT TEMP MANUAL switch light on SUIT MAINTENANCE PANEL NO. 1. Adjoining the switch light are two temperature indicators that display the suit inlet temperature for the Commander's and Systems Engineer's PGA's. An adjacent manual control knob permits selecting the desired air supply temperature.

The cabin temperature may also be manually controlled, with a potentiometer on SUIT MAINTENANCE PANEL NO. 1. Pressing the CABIN TEMP MANUAL switch interrupts the normal computer control input, and lights an indicator on the TRUE TRAINEE ENVIRONMENT panel to warn that cabin temperature is being regulated at the suit maintenance panel.

The suit maintenance panels are shown in figures 1-27 and 1-28; their controls and displays, and their functions, are listed in table 1-13.

#### 1.6.4 AURAL CUE EQUIPMENT.

Audible cues are presented whenever applicable, during the training exercise. These cues are sounds produced by the firing of reaction jets, by the descent and ascent engines; by landing, or a mechanical noise that is considered an aural cue for flight crew control of the LMS. In addition, noise levels in the communications channel, sound experienced in the LM, and ambient sound levels are simulated. The simulated sounds are transmitted to the flight crew through headsets and loudspeakers in the LMS cabin. The instructor console is included in this loop to control the amplitude of sound on all channels of communication. Soundproofing confines aural cues to the LMS cabin. The aural cue system (figure 1-29) can reproduce the following sounds:

- Ascent and descent engine operation
- RCS jet firing
- Cabin decompression
- Background
- Explosive devices
- LM-CSM docking
- Landing gear extension
- Ambient noise (400 cps)
- Lunar landing.

The aural cues (except the lunar landing cue) are generated independently at a given instant and are summed in a summing amplifier. The signal output (simulated aural cue) of the summing amplifier is fed to a voltage-controlled attenuator (VCA) that is controlled by a manually adjusted decibel control potentiometer (up to 60 db) on the instructor console. The VCA output is fed to a second VCA that routes the aural cue signal through a power amplifier to a single speaker in the LMS cabin. The second VCA, controlled by a signal originating in the cabin decompression circuitry, enables the volume of the summed aural cues to be a function of a simulated reduced air density caused by cabin decompression.

##### 1.6.4.1 Lunar Landing Aural Cue Generation.

The lunar landing aural cue is produced by a solenoid-operated striker arm that strikes a metal plate in the LMS cabin. Generation of the lunar landing sounds differs from generation of the other aural cues in that



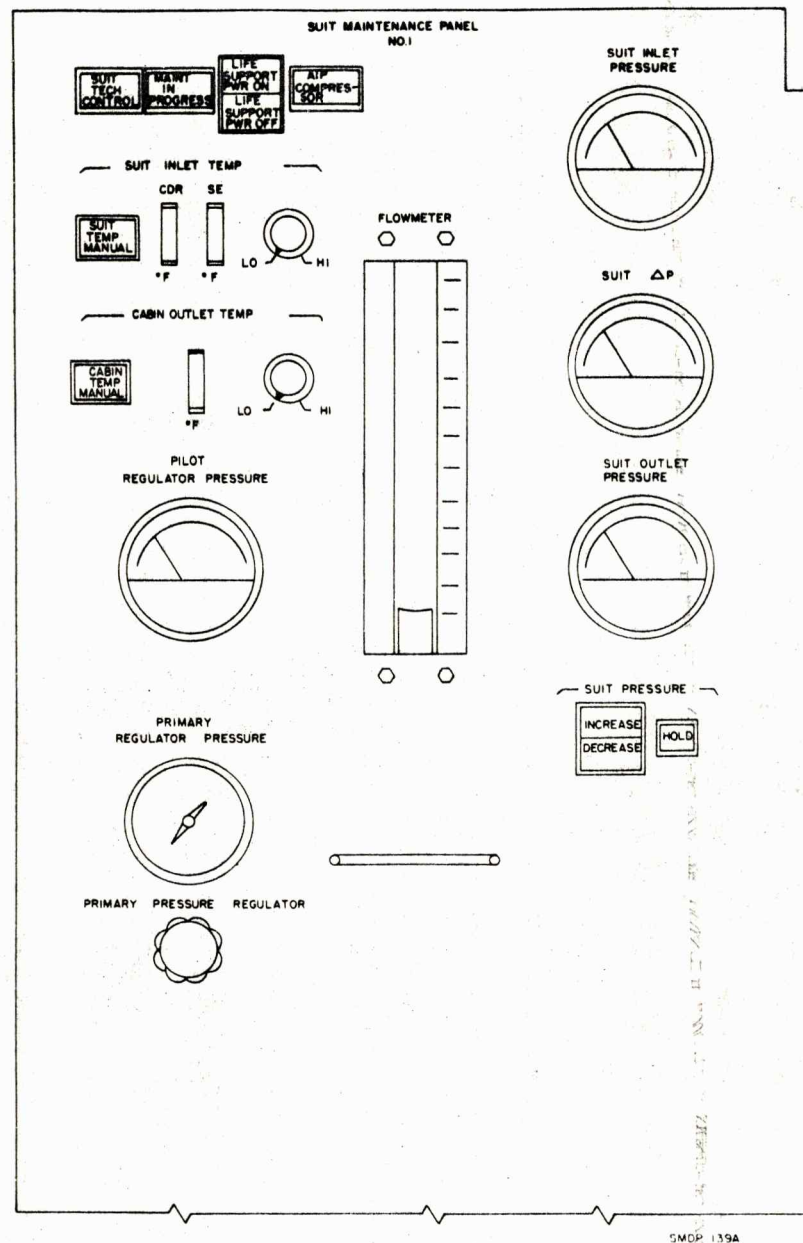


Figure 1-27. SUIT MAINTENANCE PANEL NO. 1

the cabin speaker and summing amplifier are not used. Operation of the solenoid is controlled by a digital output (DBO) signal determined by the aural cue simulation program.

#### 1.6.4.2 Ascent and Descent Engine Aural Cue Generation.

White noise is fed into a voice-controlled filter (VCF) that has its cutoff frequency controlled by a D/A signal determined by the aural cue simulation program. The output of the VCF is fed into a VCA, where it is attenuated as a function of a D/A signal also determined by the aural cue simulation program. The VCA output is summed with other aural cues in the summing amplifier.

Table 1-13. Suit Maintenance Panels, Controls and Displays

Control or Display	Function
LIFE SUPPORT PWR ON switch light	In sequence mode, displays life support power status; in manual mode, enables control of life support power and display of life support power status.
LIFE SUPPORT PWR OFF switch light	Turns off life support power
AIR COMPRESSOR switch light	Turns four air compressors on and off. Light goes on when switch is pressed. Compressors operate as function of power (life support) being available.
<div style="border: 1px solid black; padding: 5px; text-align: center;">NOTE</div> <p>In sequence mode, life support power failure results in compressor No. 1 switching automatically to utility power. Manual mode is for maintenance and does not require automatic switchover.</p>	
SUIT INLET TEMP	Enable monitoring and control of suit temperature. Temperature control is active only in manual mode. Normal mode for training is computer control mode. This mode is selected by deactivating SUIT TEMP MANUAL switch light.
SUIT TEMP MANUAL switch light	In manual mode, a time lag exists between setting LO-HI control and achieving desired temperature.
CDR °F temperature gage	
SE °F temperature gage	
LO-HI temperature control	
CABIN OUTLET TEMP	Enables monitoring and control of cabin temperature. Temperature control is active only in manual mode. Normal mode for training is computer control mode.
CABIN TEMP MANUAL switch light	
°F temperature gage meter	
LO-HI temperature control	
SUIT PRESSURE	Transfer control of pressurization and depressurization to Suit Technician at instructor console (TRUE TRAINEE ENVIRONMENT panel). Pressure is transferred in HOLD status to whichever panel has control. HOLD light will go on.
INCREASE switch light	
DECREASE switch light	
HOLD switch light	
MAINT IN PROGRESS switch light	Turns off life support power. When sequence mode is selected at main power panel, second activation of MAINT IN PROGRESS switch turns life support power back on. When manual mode is selected at main power panel, second activation of MAINT IN PROGRESS switch permits manual control of life support power.
SUIT TECH CONTROL switch light	Transfers control of suit pressure regulation to appropriate maintenance panel
PILOT REGULATOR PRESSURE indicator	Indicates pressure after adjustment by SUIT PRESSURE control on TRUE TRAINEE ENVIRONMENT panel



Table 1-13. Suit Maintenance Panels, Controls and Displays (cont)

Control or Display	Function
PRIMARY PRESSURE REGULATOR control	Controls inlet pressure into appropriate pressure suit
PRIMARY REGULATOR PRESSURE indicator	Indicates pressure after adjustment by PRIMARY PRESSURE REGULATOR
FLOWMETER	Indicates flow rate into appropriate pressure suit
SUIT INLET PRESSURE indicator	Indicates inlet pressure into appropriate pressure suit
SUIT OUTLET PRESSURE indicator	Indicates outlet pressure from appropriate pressure suit
SUIT $\Delta$ P indicator	Indicates difference between suit inlet and outlet pressures
<div style="text-align: center; border: 1px solid black; padding: 5px; margin: 10px auto; width: 200px;">NOTE</div> <p>The MAINT IN PROGRESS, LIFE SUPPORT PWR ON, and LIFE SUPPORT PWR OFF switch lights are on the main power panel and on SUIT MAINTENANCE PANEL NO. 1. Functions are identical at both panels.</p>	

#### 1.6.4.3 RCS Jet Aural Cue Generation.

White voice is fed into a VCF that has its cutoff frequency controlled by a potentiometer mounted on the VCF. The VCF output is fed into a VCA, where it is attenuated as a function of a D/A signal determined by the aural cue simulation program. The VCA output is summed with other aural cues in the summing amplifier.

#### 1.6.4.4 Cabin Decompression Aural Cue Generation.

Cabin decompression sound simulation is initiated by a DBO signal determined by the aural cue simulation program. Approximately 2 seconds after the DBO is received, a capacitor discharges into a VCA that is connected between the VCA controlled by the decibel control potentiometer on the instructor console and the power amplifier. The capacitor discharge causes all aural cues to attenuate as a function of simulated cabin decompression. The DBO also actuates a relay that enables white noise to be fed into a VCF that has its cutoff frequency controlled by a potentiometer mounted on the VCF. The VCF output is fed to the summing amplifier.

#### 1.6.4.5 Background Aural Cue Generation.

White noise is fed into the summing amplifier via a potentiometer that varies the signal amplitude. Background noise is not controlled separately; it is varied, with the other aural cues, by the decibel control attenuation potentiometer on the instructor console.

#### 1.6.4.6 Explosive Devices Aural Cue Generation.

A low-frequency reverberator generates the explosive devices aural cues. A DBO signal, determined by the aural cue simulation program, actuates a relay and, in turn, the reverberator. The output of the reverberator is fed into the summing amplifier.

#### 1.6.4.7 LM-CSM Docking Aural Cue Generation.

A low-frequency reverberator generates the LM-CSM docking aural cue. A DBO signal, determined by the aural cue simulation program, actuates a relay and, in turn, the reverberator. The output of the reverberator is fed into the summing amplifier.

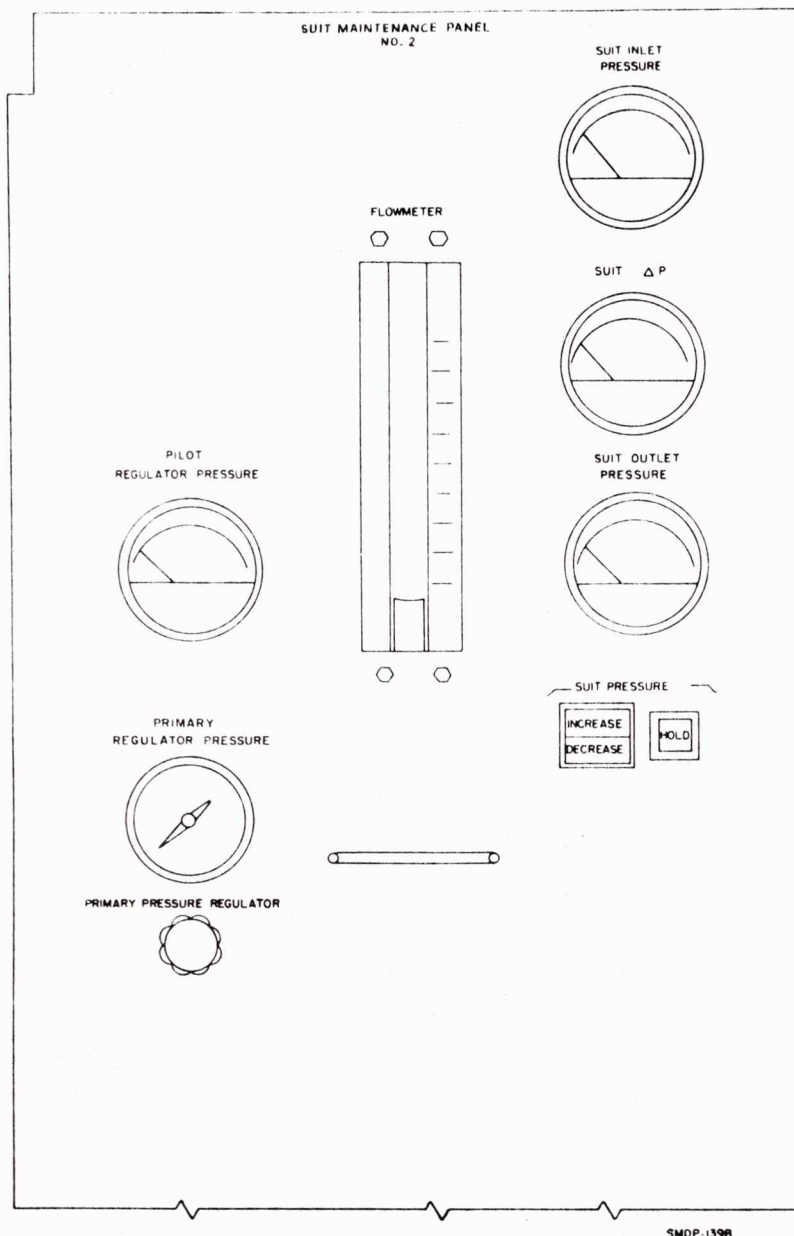


Figure 1-28. SUIT MAINTENANCE PANEL NO. 2

#### 1.6.4.8 Landing Gear Extension Aural Cue Generation.

A low-frequency reverberator generates the landing gear extension aural cue. A DBO signal, determined by the explosive devices program, actuates a relay and, in turn, the reverberator. The output of the reverberator is fed into the summing amplifier.

#### 1.6.4.9 Ambient Noise Aural Cue Generation.

Ambient noise, produced in the LM by the 400-cycle inverters, is simulated by a 400-cps generator. A DBO signal, determined by the aural cue simulation program, actuates a relay that connects the output of the 400-cps generator to a potentiometer that adjusts signal level. The potentiometer output is fed into a summing amplifier via a transformer.



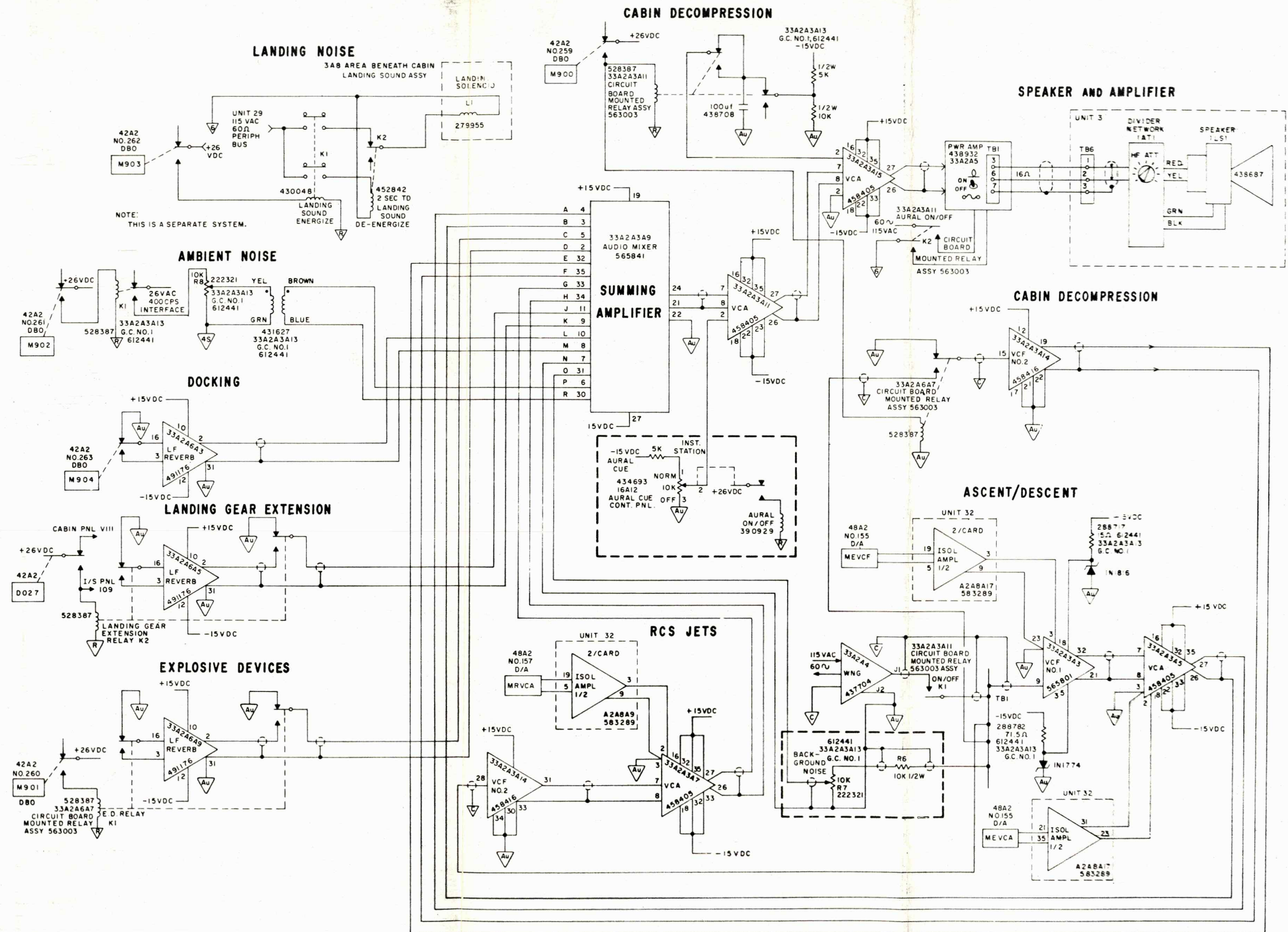


Figure 1-29. Aural Cue System Diagram



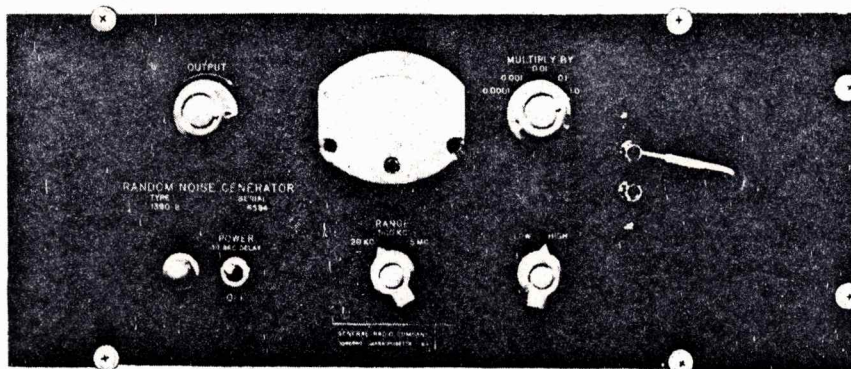


Figure 1-30. Random Noise Generator, Control Panel

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#### 1.6.4.10 Random Noise Generator.

The random noise generator provides a high level of electrical noise; it is used to introduce squelch and simulated atmospheric noise into the intercom system. The generator uses a gas-discharge tube as its noise source. A transverse magnetic field is applied to the tube to eliminate oscillations and to increase the noise level at high frequencies. The noise output from the gas tube is amplified in a two-stage amplifier. Between the two stages, the noise spectrum is shaped in one of three different ways, depending on the setting of the generator RANGE switch. In the 20 KC position, a low-pass filter is inserted; it has a gradual roll-off above 30 kc, with the audio range to 20 kc uniform in spectrum level. In the 500 KC position, a low-pass filter which has a roll-off above 500 kc, is inserted. In the 5 MC position, a peaking network compensates for the drop in noise output from the gas tube at high frequencies, so that a spectrum is obtainable to 5 mc. The random noise generator controls and displays (figure 1-30) are listed, with their functions, in table 1-14.

#### 1.6.4.11 Intercom Power Amplifier.

The intercom power amplifier provides audio power amplification for the aural cue system and for voice communications throughout the simulator complex. It is a high-powered, solid-state device, capable of providing 50 watts of audio power output (40 watts rms) with minimal distortion and phase shift.

Table 1-14. Random Noise Generator, Controls and Displays

Control or Display	Function
OUTPUT control	Varies output voltage
POWER switch	Energizes generator
RANGE selector switch	Selects network used for shaping noise spectrum
MULTIPLY BY selector switch	Attenuates output voltage
OUTPUT VOLTS indicator	Indicates rms value of noise at generator output terminals
LOW/HIGH switch	In LOW position, introduces a 10:1 resistance pad after gas-tube noise source to reduce effect of amplitude limitations of amplifier and to reduce noise field



## 1.7 DATA-PROCESSING GROUP.

The data-processing group is subdivided into two major sections for discussion purposes: computer complex and data conversion equipment. The data-processing group controls the training missions in accordance with the programs it is instructed to use. Faithful simulation of LM dynamics over the entire flight regime is provided; motion with six degrees of freedom takes into account LM moments of inertia, location of the center of gravity, propulsion subsystems used, RCS jets selected, etc. During integrated training, generation of a mission profile is a joint function of the LMS and AMA data-processing groups; the LMS is required to interchange trajectory data with IMCC and/or the AMS.

### 1.7.1 COMPUTER COMPLEX.

The LMS computer complex consists of three basic general-purpose digital computers with optional equipment and associated peripheral equipment.

#### NOTE

The following discussion refers to the two basic LMS computers (A and B). The third computer (computer C) is the interpretatively simulated LM guidance computer (ISLGC). This computer accepts the MIT/IL tape for the LM and interprets the tape into computer language compatible with the LMS. Information pertaining to the ISLGC will be supplied at a later date.

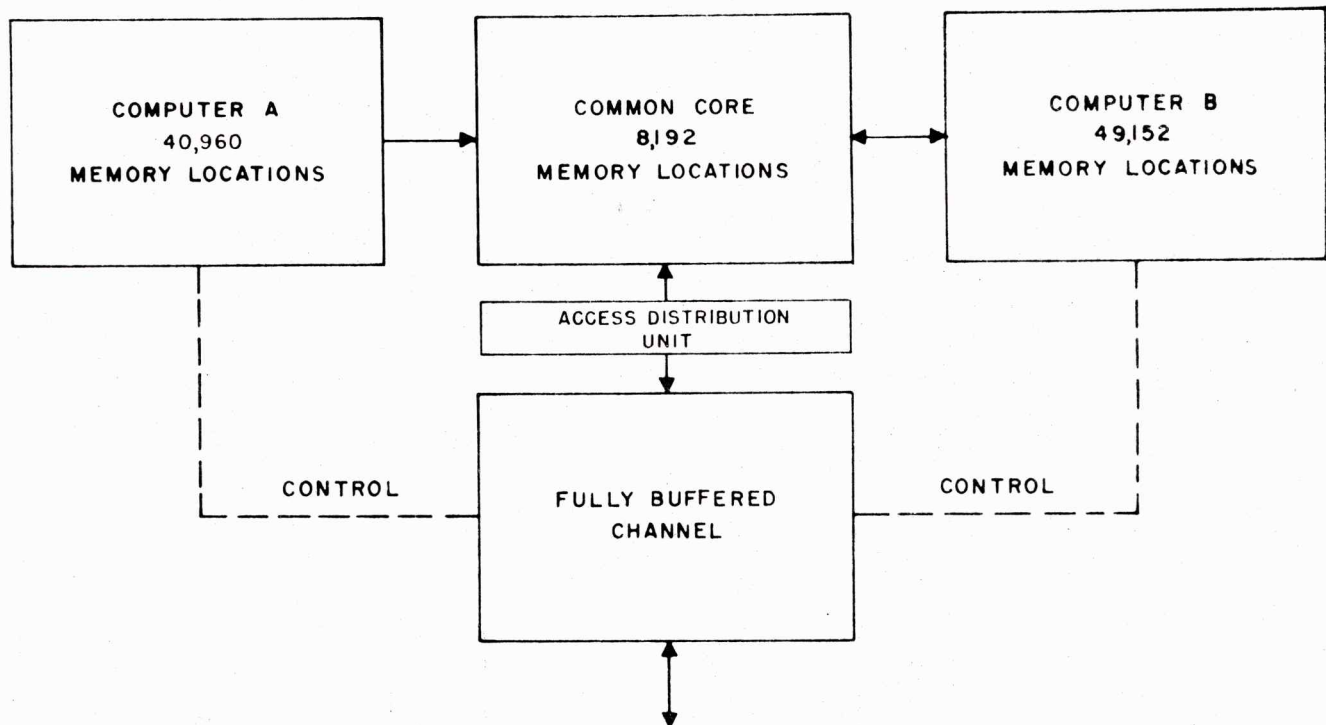
Elements of the computer complex have been integrated into a system that accommodates the various requirements imposed by intricate space mission simulation; it provides the capacity, speed, and expansion capability required for the computing needs of the LMS. The complex is used to simulate subsystems; compute and display LM dynamics; control visual displays and recorders; and to receive, and respond to, signals transmitted from the LMS cabin, instructor console, and other units. The complex also executes a predetermined sequence of events; drives displays and indicators through data conversion units; and inserts, and responds to, simulated subsystem malfunctions. These functions are executed under control of computer programs stored in the computer memory. The computers may also be used to aid in maintenance procedures, by using the appropriate "off-line" diagnostic routines.

The major elements of the computing system are digital computers, an access distribution unit (ADU), a common memory, and a fully buffered channel (FBC). Data flow between these units is shown in figure 1-31.

Two computers are used: one contains 40,960 memory words; the other, 49,152 memory words. In addition, the two computers share a common dual block of memory cores that contain 4,096 words each. Total storage capacity of the system is 98,304 memory locations.

A block diagram of the computer complex is shown in figure 1-32. The logic of each computer treats the common block of memory as if it were its own. All intercomputer communication, during normal operation, is through the common memory. No instructions are stored in the common memory. This design feature minimizes the total number of memory accesses to the common memory and, hence, the probability that two or more devices will simultaneously request access. Computation time lost for reasons of intercomputer communication may be attributed only to the time lost while waiting to gain access to the common memory; this lost time is less than 10 memory cycles (19 microseconds) per 50-millisecond computing period (worst case) in each computer.

A major feature of the basic system is that high-speed repetitive data transfers between either or both of the LMS computers and external points such as the AMS, input/output (I/O) conversion equipment, and the data acquisition system (DAS). Data is transferred in blocks from the common memory through a fully buffered channel, or from the private memory of each computer through its respective direct memory access channel. In this manner, for transfer of data to the I/O conversion equipment and AMS interface, data blocks being transferred out of the computer complex can be filled up directly by both computers. Due to the electronic characteristics of the FBC, a computer sacrifices time to this external communication problem only if the other computer or the FBC has previously requested access to the common memory. The lost-time figure (19 microseconds/50-millisecond period) accounts for time lost to internal (intercomputer), as well as external (I/O, AMS, DAS), communications.



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Figure 1-31. Dual Computer Interface, Simplified Block Diagram

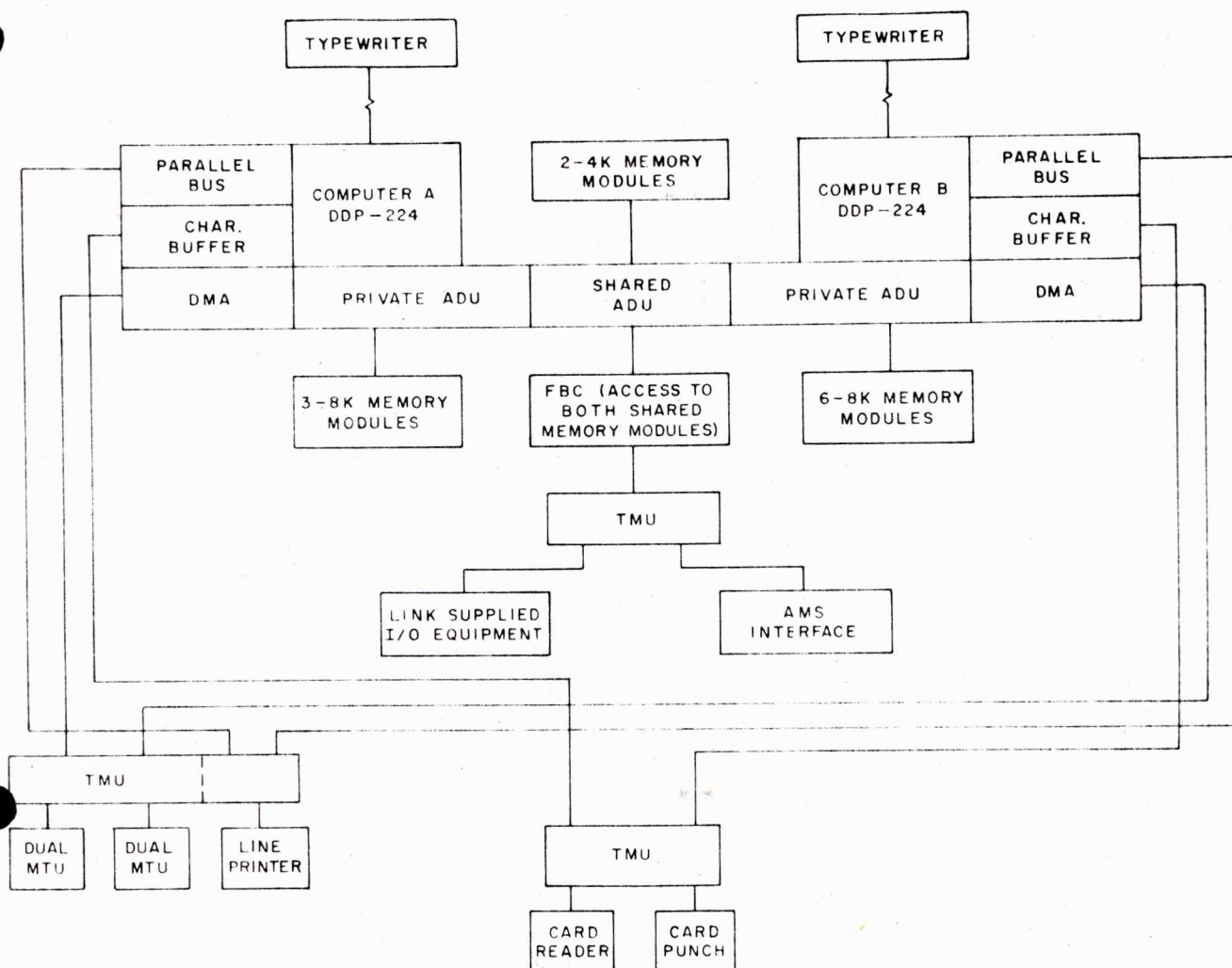
For transfer of data to the DAS magnetic tape unit, block transfer of data from each computer is in parallel with the FBC. Separate paths from the private memory of each computer are provided, using direct memory access channels and switching units so that each computer, in turn, can record its DAS data on a single magnetic tape. The direct memory access channels (DMA's) differ from the FBC in that they are cycle-stealing and interrupt the computer program only if both require memory access at the same instant. For a "worst case" of DAS output of 500 words every 50 milliseconds (about the limit of magnetic tape units, running at 75 ips), an access would be required every 100 microseconds. Because this access requires only 1.9 microseconds, this amounts to approximately 2.0% of the time. However, if the computer program does not require an access at this time, no time will be lost, because the DMA is simply filling in a "hole" in the program.

A highly significant feature of the system is that the DMA and the FBC may be communicating with the computers and shared memory simultaneously. Thus, the I/O control, magnetic tape unit No. 1 or 2, magnetic tape unit No. 3 or 4, the card punch, and the card reader may be operating simultaneously. The virtue of this arrangement is that multipath communication possibilities are available without computer intervention, so that input/output capability is flexible. Also, future system requirements may be met without hardware modification. During normal operation, the FBC handles all communication with the AMS link and the I/O conversion control unit; the two DMA's communicate only with the DAS magnetic tape units and line printer to read in changes to the computer program from the second magnetic tape unit (MTU) (on an "on-line" basis).

The LMS computer complex, operating in conjunction with the instructor console, can:

- Start with known initial conditions to permit initiation of a training mission from a minimum of 24 points without programming
- Stop and restart at any point in a mission
- Reset to any one of the 24 sets of initial conditions from stored parameters in less than 2 minutes
- Run in accelerated time (32 times real time) during coasting phases of a mission, without loss of accuracy in the computation of trajectory and/or quantities of expendables





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Figure 1-32. LMS Computer Complex, Block Diagram

- Be manually reset to initial conditions during reset or hold periods
- Operate either as master or slaved to the AMS for control of the LMS operating modes (operate, stop, reset freeze, and accelerate).

#### 1.7.1.1 Digital Computers. (See figure 1-33.)

The LMS computer complex uses three digital computers. (Refer to note in paragraph 1.7.1.) These are 24-bit word, parallel-binary, single-address, stored-program computers, with indexing and indirect addressing features. They are of modular design, which provides a high degree of flexibility and permits expansion of the computing system in speed, memory, and input/output capabilities. Solid-state circuits with a coincident-current magnetic core memory, which stores program instructions and data, are used throughout the computers. The computer is an integral unit that consists of a three-bay cabinet and a control and maintenance console. The console contains the switches, indicators, and controls required to start, stop, and manually control computer operation. The computer controls and indicators (figure 1-33) are listed, with their function, in table 1-15. The maintenance section of the console, located under a panel cover, provides indicators that can be used as an aid in localizing computer malfunctions, and controls to facilitate computer maintenance.

The logical units of each computer may be combined into four primary functional subdivisions: arithmetic, control, memory, and input/output. Control and data flow within the primary functional subdivisions is shown in figure 1-34. Figure 1-35 is a block diagram of the computer.

#### 1.7.1.1.1 Memory Unit.

For a digital computer to perform computations, all the data pertinent to the problem and the method of solution (instructions) must be stored in the computer before it attempts the actual solution. Similarly, for spacecraft simulation, all the information relative to the spacecraft and the sequence of events must be stored in the computer before starting a training mission. This information is in two types of digital words: a data word and an instruction word. A series of instruction words makes up the computer program. The memory unit is the device in which these words are stored.

A magnetic core unit is the basic memory of each computer. In the LMS, each computer has a different number of internal memory locations (40,960 for computer A, and 49,152 for computer B), as well as access to a common core unit of 8,192 locations. The expanded memory of each computer is built with standard core units that can store 4,096 24-bit words. A memory address register (MAR) and memory information register (MIR) are considered part of each memory. The MAR locates the word that is to be put into, or taken out of, the memory; the MIR furnishes temporary storage while the words are being transferred into, or out of, the memory. Each memory module contains its own power supplies, and controls for testing the modules with

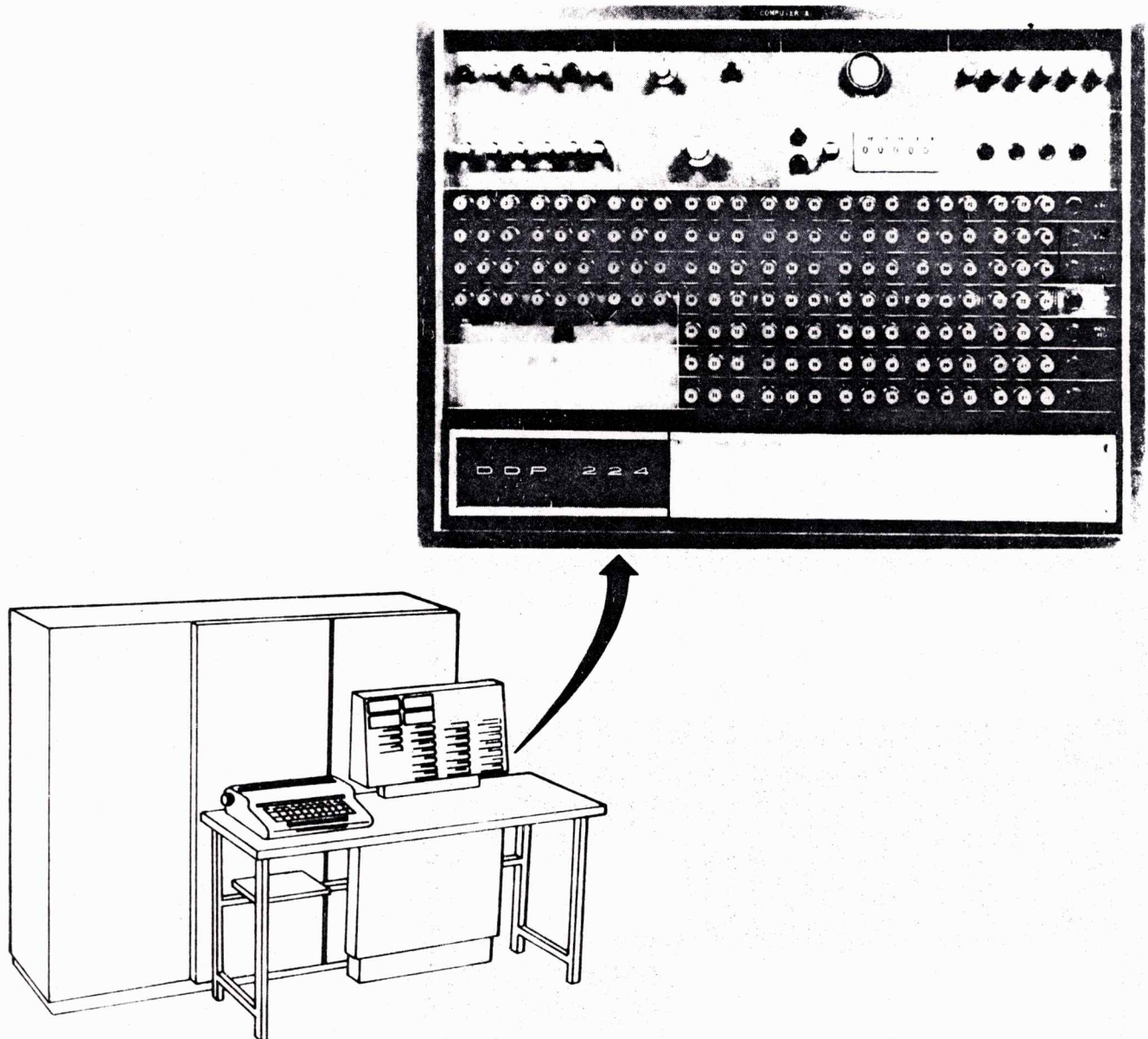


Figure 1-33. Computer Panel

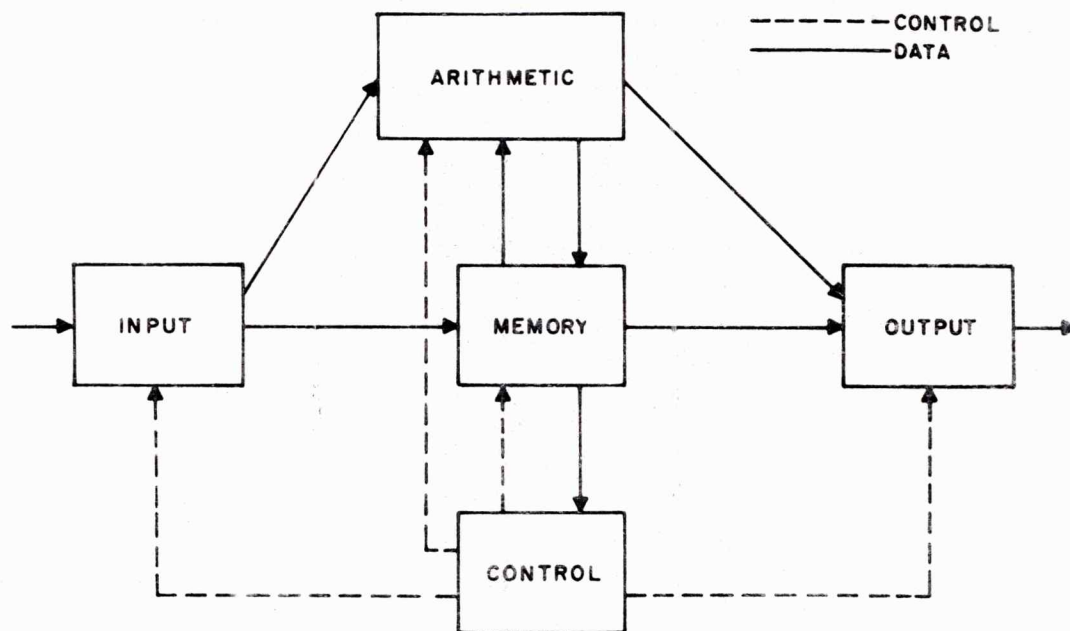


Table 1-15. Computer Control Panel, Controls and Displays

Control or Display	Function
START/OFF-LINE switch	Starts operation enabled by input/output function selector switch
CONT/PULSED switch	Not used
STOP CODE switch	Not used
PUNCH POWER switch	Not used
TAPE FEED switch	Not used
TAPE LOW indicator	Not used
FILL selector switch	Selects type of data to be loaded into computer
PAPER TAPE	Not used
CARD RDR HOL	Enables card reader to load Hollerith data from punched cards into computer memory
CARD RDR BINARY	Enables card reader to load binary data from punched cards into computer memory
FILL switch	Loads computer memory from device selected by FILL selector switch
Input/output function selector switch	Not used
START switch	Starts computer operation
STOP switch	Stops computer operation
POWER switch	Turns computer and auxiliary equipment power on and off
RUN MODE - PROG HALT switch	RUN MODE position inhibits program halt address register. PROG HALT position controls effect of program halt address register.
Program halt address register thumbwheels	Select address at which program will halt
INPUT PARITY indicator	Detects errors while reading character information
I/O HOLD indicator	Indicates that computer is holding input/output until device is ready
INTERRUPT indicator	Indicates execution of interrupt subroutine
OVERFLOW indicator	Indicates that overflow fault has occurred in computation
IMP DIVIDE indicator	Indicates that improper divide has occurred or that improper binary-to-DCD conversion has been attempted
HALT indicator	Indicates that halt flip-flop is set and that no operations, except interrupts, can take place

Table 1-15. Computer Control Panel, Controls and Displays (cont)

Control or Display	Function
MASTER CLEAR switch	Halts computer; resets all registers, control clock unit, ready and enable flip-flops of input/output channels, interrupt enable, input parity, overflow, and improper divide flip-flops; stops all peripheral devices
SING OP switch	Causes computer to execute command stored in memory location indicated by program register
FETCH STOP switch	Causes computer to execute fetch cycle only
EXECUTE switch	Causes computer to execute command set in OP-code register
A, B, Z, PROG, INDEX REG switch lights	Indicates contents of A, B, Z, program and index registers and allow bit-by-bit entry
Reset switches	Enable each register to be cleared to zero
OP-CODE register switch lights	Indicate contents of OP-code register and allows bit-by-bit entry
Reset switch	Clears OP-code register, index bits, and indirect addressing bit to zero



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Figure 1-34. Digital Computer, Primary Functional Subdivisions



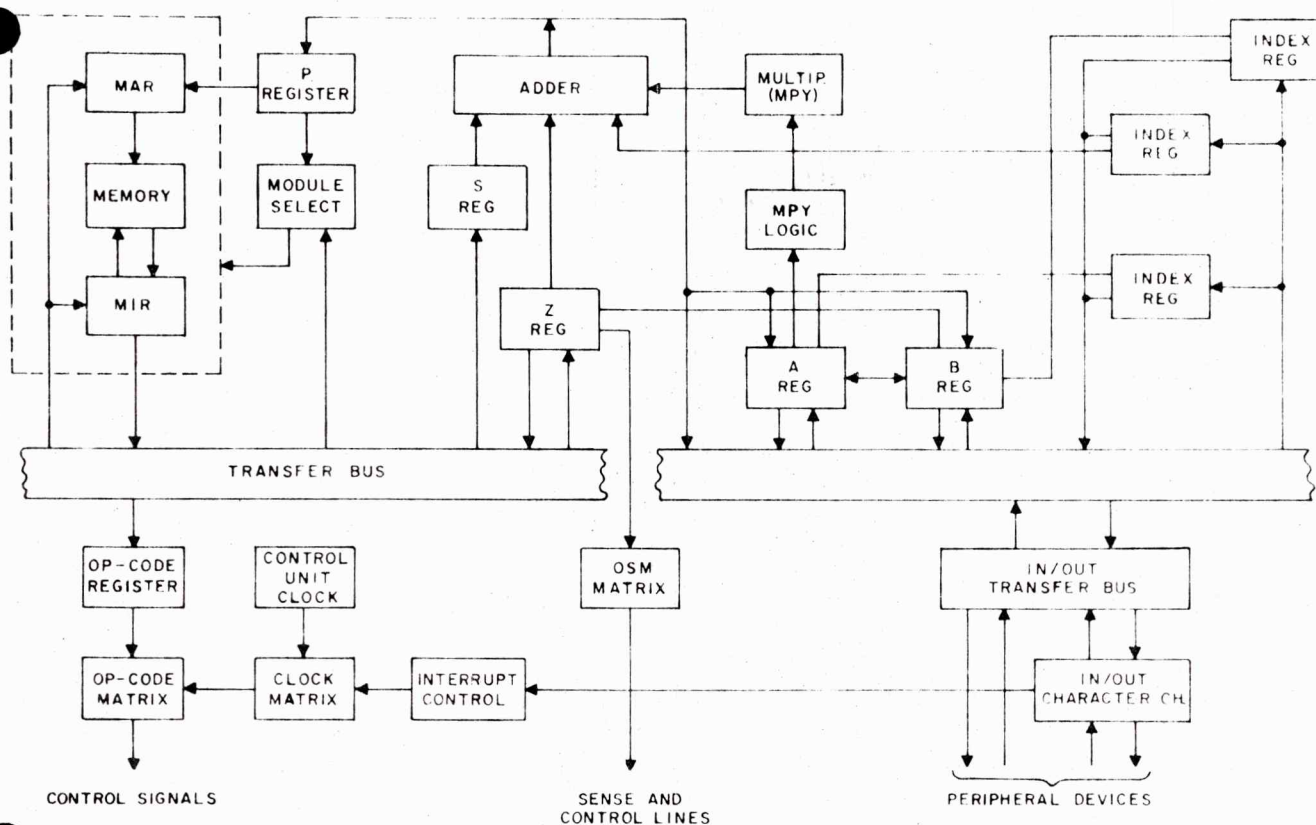


Figure 1-35. Digital Computer, Block Diagram

voltages and current set at margins. Information read from each module is transferred to the control and arithmetic sections of the computer as amplified logic levels (in volts), rather than as low-level pulses, either directly from magnetic cores (in millivolts) or from sense amplifiers. All transfer operations are implemented in parallel. Although the memory is designed to operate at 1.75 microseconds, it is conservatively run at a 1.9-microsecond cycle time. Access time is 0.8 microsecond. Thus, instructions that do not access memory for an operand, such as TAX (transfer A to index), take one cycle, or 1.9 microseconds; instructions that require an access for an operand, such as LDA (load A), take two cycles, or 3.8 microseconds.

#### 1.7.1.1.2 Input Output Unit.

The input section provides the means of inserting the program into the memory from peripheral devices (typewriter, magnetic tape units, etc). The output section is used to connect data-recording devices, such as the card or tape punches and magnetic tape units, to the computer. The input/output (I/O) unit also enables transfer of information between the data conversion units and the computers. The I/O unit of each computer includes parallel input/output channels, input/output character channels, and sense lines and interrupt control, and generates command signals as follows:

- The parallel input/output channels are gating devices that are used in conjunction with the FBC's and DMA's to transfer data between the memory and the peripheral equipment and data conversion equipment
- The input/output character channels are gating devices that are used to connect the computers with the typewriter
- The sense lines and interrupt control are used to detect conditions within, or external to, the computers, which require alterations to the computer programs
- The generated command signals are used to control external equipment such as the typewriter. Signals generated in the I/O unit are also used to establish ADU priorities and to select upper or lower sections of the memory bank.

## 1.7.1.1.4 Direct Memory Access Channels

The direct memory access channels (DMA's) are similar to the FBC in design and operation. They are used to transfer data between the peripheral equipment (magnetic tape units, card reader and punch, line printer, and typewriter) and the computers.

## 1.7.1.1.4 Control Unit.

A computer program consists of a series of instruction words, which are stored in the memory unit. The control unit "fetches" each instruction word, in sequence, from memory, translates the word, and issues commands to other parts of the computer that will execute the task defined by the instruction word. Execution of the instruction word depends on timing pulses and control signals that are generated in the control unit. The control unit of each computer contains an operation code register, an operation code matrix, a program register, index registers, shift counters (S-registers), a control unit clock, and a clock matrix.

OP-Code Register. The OP-code register contains the six-bit operation code for the instruction being performed, two index bits, and the indirect address bit. It is displayed and manually controlled on the computer control panel.

OP-Code Matrix. This is a gating structure that decodes the six-bit operation code into control signals.

Program Register. The program register (P-register) is also a counter; it contains the memory location of the next instruction to be performed. Normally, its contents are incremented by a 1 each time a new command is "fetched" from the memory. In case of a jump, the program counter is loaded with the memory location to which the program is to jump. The P-register contains 15 bits, is displayed, and can be manually controlled on the computer control panel.

Index Registers. Three index registers are contained on each LMS computer. When the 15-bit index register is specified by an instruction, its contents are added to the address of the instruction; the result becomes a new address. A few instructions, such as scale and normalize, use the index register for control and counting. Display and manual control is provided on the control panel.

Shift Counter. The low-order six bits of shift counters (S-registers) are used with instructions that require shifting. The shift counter is also used for temporary storage of exponents during floating-point operations. It contains 15 bits that are displayed on the maintenance panel. The shift counter cannot be manually controlled directly, although the SINGLE STEP pushbutton on the maintenance panel will cause stepping of the shift counter during execution of shift functions.

Control Unit Clock. The control unit clock generates the timing pulses needed for the various operation sequences of command executions. Contents are displayed on the maintenance panel. When the CLOCK switch is set to OFF, the clock pulses can be manually controlled with the SINGLE STEP pushbutton switch. Both switches are on the maintenance panel.

Clock Matrix. In the clock matrix, the control unit clock signals are gated with the outputs from the OP-code matrix, to provide the correct sequence of pulses for each command to be executed.

## 1.7.1.1.5 Arithmetic Unit.

The arithmetic unit performs computations when commanded by the instruction word. The arithmetic unit contains all the arithmetic registers in the computer. The contents of the arithmetic registers are displayed on the control panel; each bit content may be set to a 1 by pressing the pushbutton at the associated bit position on the control panel. Each register may be completely reset by pressing the RESET pushbutton adjacent to the register display. When the program HALT light is on, all arithmetic registers may be manually loaded.

A-Register. This is a 24-bit register that is the primary arithmetic and logic register of the computer.

B-Register. This is a 24-bit register that is an extension of the A-register for certain operations, including multiplication, division, and certain shifting operations.

Z-Register. This is a 24-bit register that receives its information from the memory. After a "fetch" command, its 15 least significant bits contain the operand address before modification or, in some cases, the operand. The nine most significant bits contain one indirect address bit, two index bits, and six operation-code bits. After an operand "fetch," the Z-register may contain the operand; it then operates as part of the arithmetic unit (AU).



AU and Transfer Bus. The AU and transfer bus are gating structures to which the computer registers are connected, both as to source and destination. In this way, information can be transferred from one register to another by simultaneous gating of the proper paths from one register to the bus and from the bus to the other register.

Adder and Multiply (MPY) Adder. These are logical structures that are used in executing arithmetic instructions. The MPY adder serves as a special "carry-save adder" to execute multiplication instructions.

#### 1.7.1.1.6 Word Format.

Two types of digital words are used in the computer program: instruction words and data words. Both are binary words that contain 24 bits. The format of the instruction and data words is shown in figure 1-36.

The instruction word consists of an operation code, an address, index bits, and the indirect addressing bit. The operation code consists of six bits that specify what command is to be executed. The address is a binary number that specifies the memory address of the data that is to be used in the operation. The index bits specify that an index register will be used with the operation. The indirect addressing bit indicates that an indirect address will be used.

The data word is represented by a 23-bit binary number, plus a sign bit. The sign bit indicates the polarity of the number; a 1 indicates a negative number; a 0, a positive number. The 23 bits indicate the magnitude of the number.

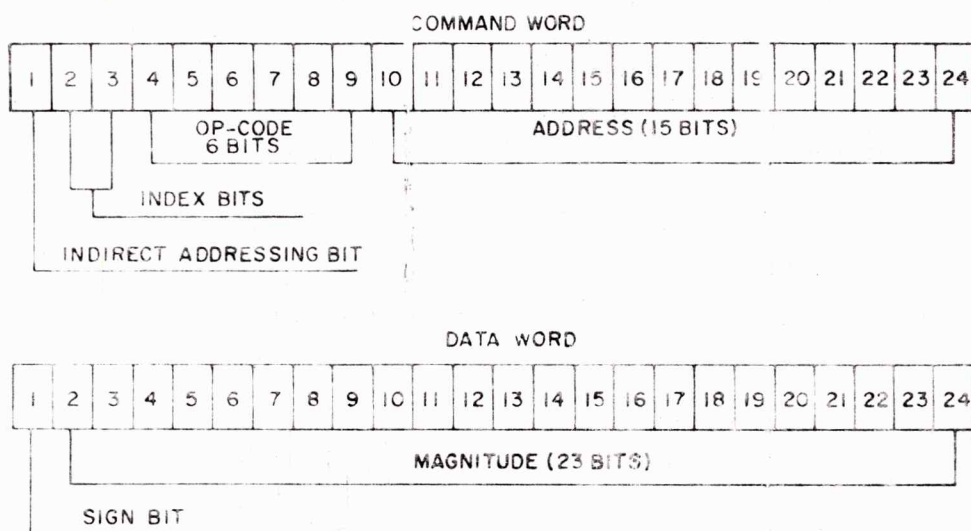
#### 1.7.1.2 Fully Buffered Channel.

A fully buffered channel (FBC) contains a data register and a control section. Once set up from an external source, the FBC can transfer data directly from, or to, memory, independent of the computer main frame. The FBC is used to transfer data between the data conversion units and the computers, without interfering with the computer program. If the FBC and the computer program address the same memory location simultaneously, the FBC takes priority.

#### 1.7.1.3 Access Distribution Unit.

The access distribution unit (ADU) provides priority control for the shared core memory block (8,192 words) of the computer complex. The central processor of either computer, as well as the FBC, may gain access to this group of core addresses.

The ADU can handle data inputs from as many as three computers and can connect them with as many as eight magnetic core memory modules. In the LMS, three input devices are used: the two computers and the FBC. The shared memory of the LMS is a dual ferrite coincident-current core assembly that consists of two modules, each having a storage capacity of 4,096 words.



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Figure 1-36. Computer Word Format

#### 1.7.1.4 Common Magnetic Core Memory.

The common magnetic core memory is a high-speed digital storage device capable of storing 24 bits of information in any one of 8,192 randomly accessible locations. Data, stored in arrays of 30- x 18-mil ferrite cores, are selected with conventional four-wire coincident-current techniques. The switching time of the cores and the frequency characteristics of the logic and driving circuitry permit a full-cycle repetition rate of 1.80 microseconds and an access time of 0.70 microsecond.

Figure 1-37 is a block diagram of the memory organization. Data supplied to the memory are inserted in the information register and, then, transferred to the core stack at a location determined by the address register. Regenerative information is retrieved by driving all cores at a selected address and setting information register stages corresponding to amplified outputs of switched cores. The data are then available at memory output terminals during simultaneous reinsertion (via inhibit drivers) into the core stack. Addressed cores are selected through successive decoding levels, the first of which occurs at selection switch and synchronized inputs. Selection switch and synchronized outputs intersect within the X and Y diode matrix (mounted in the stack assembly). This leads to final address selection at the intersection of X-lines and Y-lines within the core stack. Timing and control logic coordinates memory functions, decodes input commands, and provides signal outputs.

#### 1.7.1.5 Peripheral Equipment.

The following peripheral equipment is used with the computers as input-output devices for inserting, or reading out, computer data:

- Line printer
- Card punch
- Card reader
- Typewriters (2).

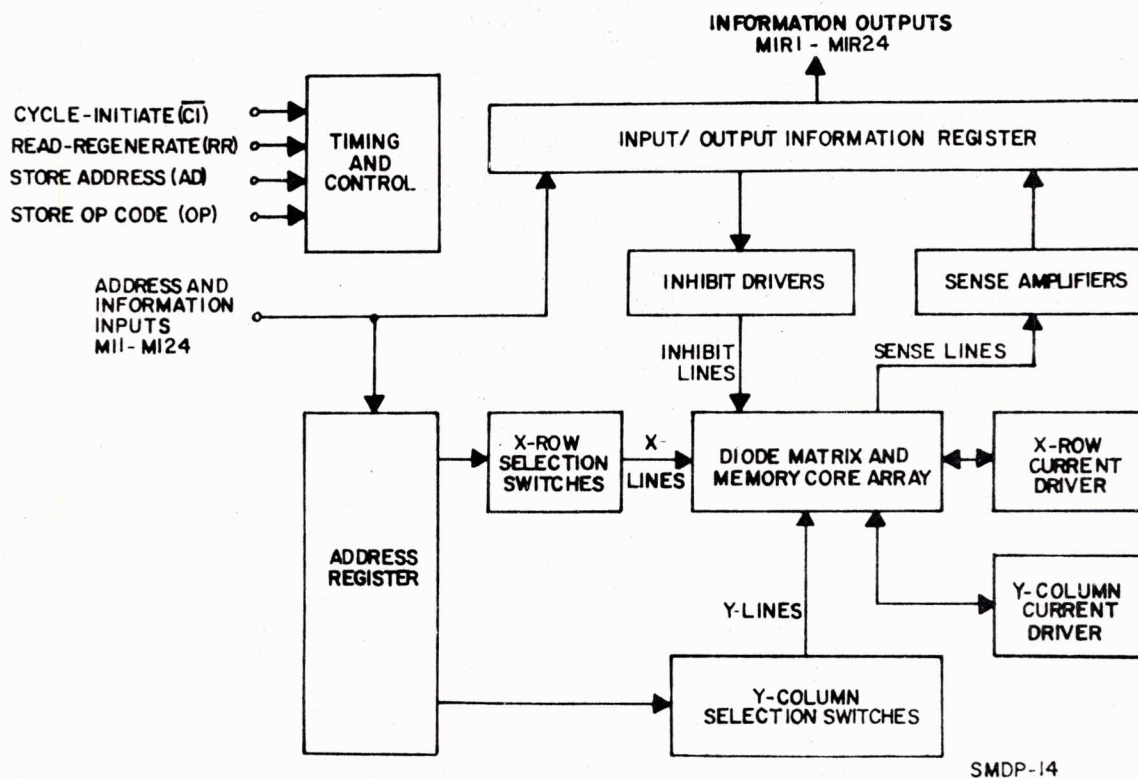


Figure 1-37. Common Core Memory, Block Diagram



## 1.7.1.5.1 Line Printer. (See figure 1-38.)

The buffered line printer accepts coded signals from the computer and produces printed copy at a rate of 300 lines per minute on all standard media. The printer is capable of a speed of 360 lines per minute, printing numeric characters only; it is shared between the computers through the line printer time multiplex unit. Each computer transfers data from its memory to the line printer via its input/output bus.

Printing is accomplished with a rotating character drum and a bank of linear motion print hammers. The character drum contains 62 characters, including capital letters and standard symbols commonly used for business and mathematical formulas. Each symbol is repeated 120 times (lengthwise) across the character drum to accommodate the line printer capacity of 210 characters per line.

The character drum rotates at 360 rpm, moving the 62 different characters past each of the 120 line print positions. For each character on the drum there is an associated print hammer. At the proper times during each line-printing cycle, the selected hammers impact the paper against a printing ribbon and onto the appropriate character on the drum, thus printing one complete line of the page.

The line printer supplies the interface with control, timing, and character code signals that identify the character approaching the print position. The interface scans the printer buffer that contains the characters to be printed, and compares each character with the approaching character code supplied by the printer. Each time a match occurs, a signal is sent to the corresponding hammer address and the selected hammers are pulsed, causing the approaching drum character to be printed at the selected positions. This sequence is repeated for each character until the 120 column locations are printed.

The line printer is connected to the computers through a parallel output channel via a time multiplex unit. Data transfer occurs with either OTM, OTA, or DMB instructions. The line printer controls and displays (figure 1-38) are listed, with their functions, in table 1-16.

## 1.7.1.5.2 Card Punch. (See figure 1-39.)

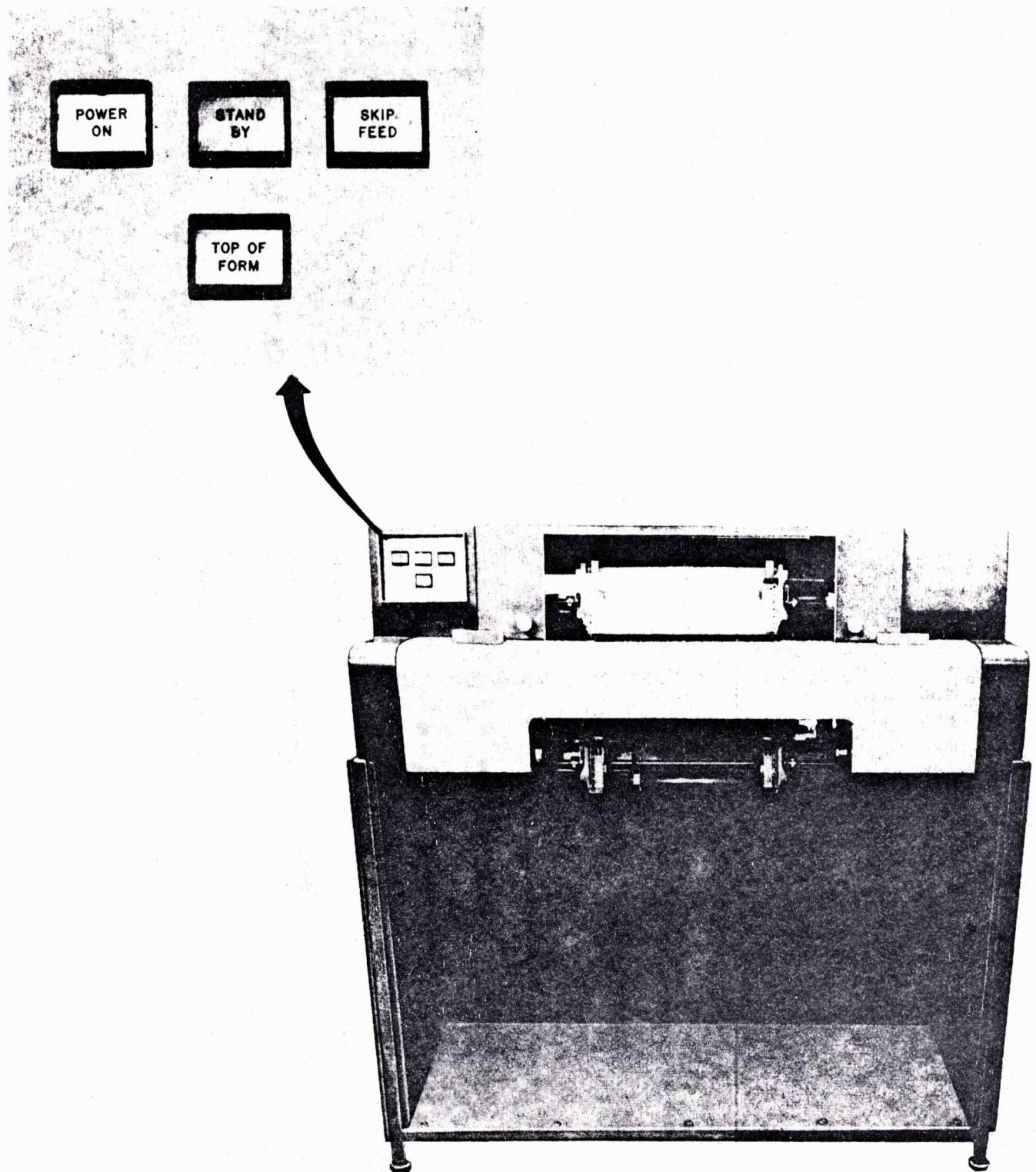
The card punch is connected to the character buffered I/O channels of the computers through a time multiplex unit. The card punch can process up to 100 cards per minute, or one card every 600 milliseconds. It is shared between the computers by means of the card punch time multiplex unit and is connected to each computer via that computer's character buffer and channel.

The punching operation is divided into four cycles, as follows:

- Feeding. After the POWER ON and START switches are pressed, a card is fed into the ready station and is held there by the die card lever.
- Punching. Upon receipt of a feed and punch command, a card movement mechanism passes the card (12th row first, face down) under the line of 80 punches, stopping the card momentarily under each of the 12 rows. At the proper column positions, as determined by the punch code received from the computer, the card is punched. When a card in the ready station starts its movement for punching, a second card is fed into the ready station.
- Checking. During the third cycle, the card is fed through the postpunch check brushes and checked for errors.

Table 1-16. Line Printer Control Panel, Controls and Displays

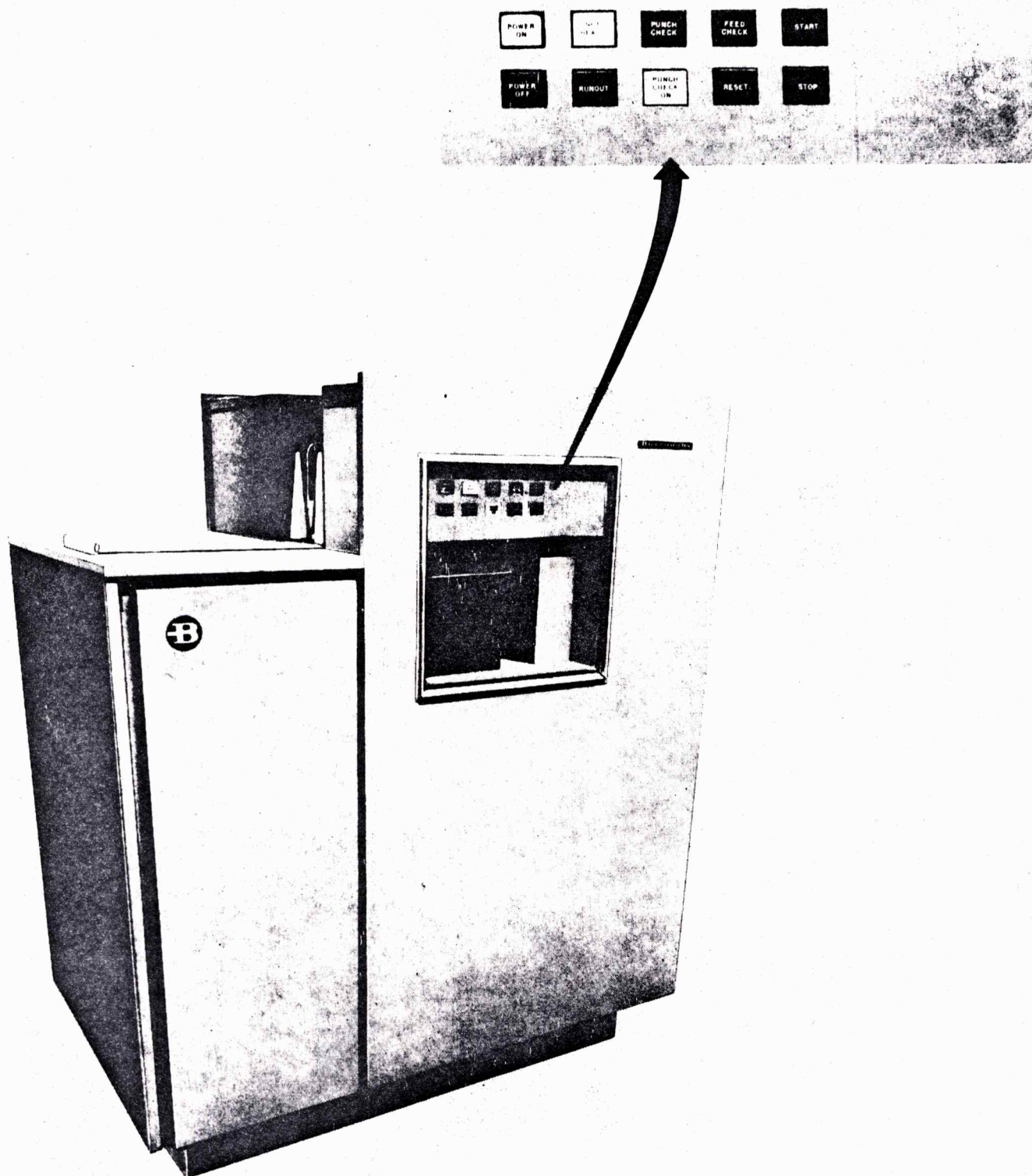
Control or Display	Function
POWER pushbutton switch	Controls main power to printer unit
STAND BY pushbutton switch	Places printer in print inhibit mode
SKIP FEED pushbutton switch	Advances paper position at fast rate
TOP OF FORM pushbutton switch	Positions paper to top of form



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Figure 1-38. Line Printer





SMDP-17

Figure 1-39. Card Punch

- Stacking. The card is placed on the output stack. After the START button is pressed, the punch is under control of the computer program; then an OCP "card punch select" signal can enable the card punch. Computer punch character code transfer is accomplished serially, one row at a time. For example, the 80 digits in row No. 12 are coded by shifting the code in, column by column, until the last column contains a "punch" or "no punch" signal. This requires 80 shifts before the punch strobe for that row. This process is repeated each time a new row is positioned under the punches, until all 12 rows have been punched. The computer uses three sense lines from the punch to monitor its operation, as follows:

SKS 22500 (punch busy) - Present from the time a card is clutched, until approximately 4.0 milliseconds after the last row has been punched

SKS 22501 (ready to punch next row) - Present while punching each row (approximately 820 microseconds)

SKS 22502 (invalid punch) - Present after every punching error.

The card punch controls and displays (figure 1-39) are listed, with their function, in table 1-17.

Table 1-17. Card Punch Control Panel, Controls and Displays

Control or Display	Function
POWER ON pushbutton switch	Applies line power to internal supplies; lights NOT READY indicator lamp
NOT READY indicator	Indicates unit is not ready for operation; lights when any of following conditions exist: <ul style="list-style-type: none"> <li>• Power-on sequence incomplete</li> <li>• No cards in hopper</li> <li>• START switch not pressed</li> <li>• Stacker full</li> <li>• STOP switch pressed</li> </ul>
PUNCH CHECK indicator	Indicates card has not been punched
FEED CHECK indicator	Indicates failure in card feed, or empty hopper
START pushbutton switch	Causes card to be fed into ready station
STOP pushbutton switch	Stops operation of unit; lights NOT READY indicator lamp
RESET pushbutton switch	Resets punch and feed-check circuitry; lights NOT READY indicator lamp
PUNCH CHECK ON indicator	Indicates that punch-check circuitry is operating
RUNOUT pushbutton switch	Causes last punched card to be fed to stacker; clears cards from feed
POWER OFF pushbutton switch	Removes line power from unit



## 1.7.1.5.3 Card Reader. (See figure 1-40.)

The card reader is a photoelectric card-reading device with a maximum reading speed of 200 cards per minute and a hopper and stacker capacity of 500 cards. The reader is completely buffered; the read circuitry is monitored automatically between card cycles. Invalid characters are detected during card reading under operator control. The reader is connected to the I/O character buffer channels of the computers through a time multiplex unit.

Two reading modes are possible: alphanumeric or Hollerith, and binary. In the alphanumeric mode, each column contains the code for one character. When reading Hollerith-coded cards, the unit reads the 12-bit character and feeds the code through an alphanumeric decoder. The decoder produces a six-bit coded character, which is encoded by the interface to a computer-compatible six-bit code. The alphanumeric system permits a maximum of 80 characters on a card; each card uses 80 computer memory locations. In the binary mode, each of the 80 card columns contains two 6-bit characters. The reader strobes each column twice: first it extracts the lowermost six bits of the column (rows No. 9, 8, 7, 6, 5, 4) and sends them to the interface; then the uppermost six bits are read and transmitted to the interface. This action is repeated for each column. Decoding is neither required nor performed. A maximum of forty 24-bit computer words can be accommodated on one card.

Two timing modes are also available: continuous and pulsed. In the continuous mode, an OCP signal causes the cards to be read until any one of three conditions exists: (1) the end of the file is reached (card hopper is empty), (2) a fault occurs in the card reader, or (3) a stop code on a card is read. In the pulsed mode, an OCP "read one card" signal must be received each time a read operation is to take place. The card reader controls and displays (figure 1-40) are listed, with their function, in table 1-18.

Table 1-18. Card Reader Control Panel, Controls and Displays

Control or Display	Function
POWER ON pushbutton switch	Initiates power-on sequence and lights NOT READY indicator lamp
NOT READY indicator	Goes on when one of following conditions exists: <ul style="list-style-type: none"> <li>• Power-on sequence incomplete</li> <li>• No cards in hopper</li> <li>• Stacker full</li> <li>• Read or validity check in progress</li> <li>• Feed-check in progress</li> <li>• STOP switch enabled</li> </ul>
FEED CHECK indicator	Goes on if card is not fed
VALIDITY CHECK indicator	Indicates invalid character is sensed
END OF FILE pushbutton switch	Enables processing of cards after last card is fed from hopper
START pushbutton switch	Puts card reader in ready condition and extinguishes NOT READY indicator lamp
STOP pushbutton switch	Places card reader in not ready condition
RESET pushbutton switch	Extinguishes VALIDITY CHECK, READ CHECK and FEED CHECK light
VALIDITY ON pushbutton switch	Causes validity check of each card character
READ CHECK indicator	Indicates failure of exciter lamp or circuitry
POWER OFF pushbutton switch	Removes power from power supply and extinguishes POWER ON indicator

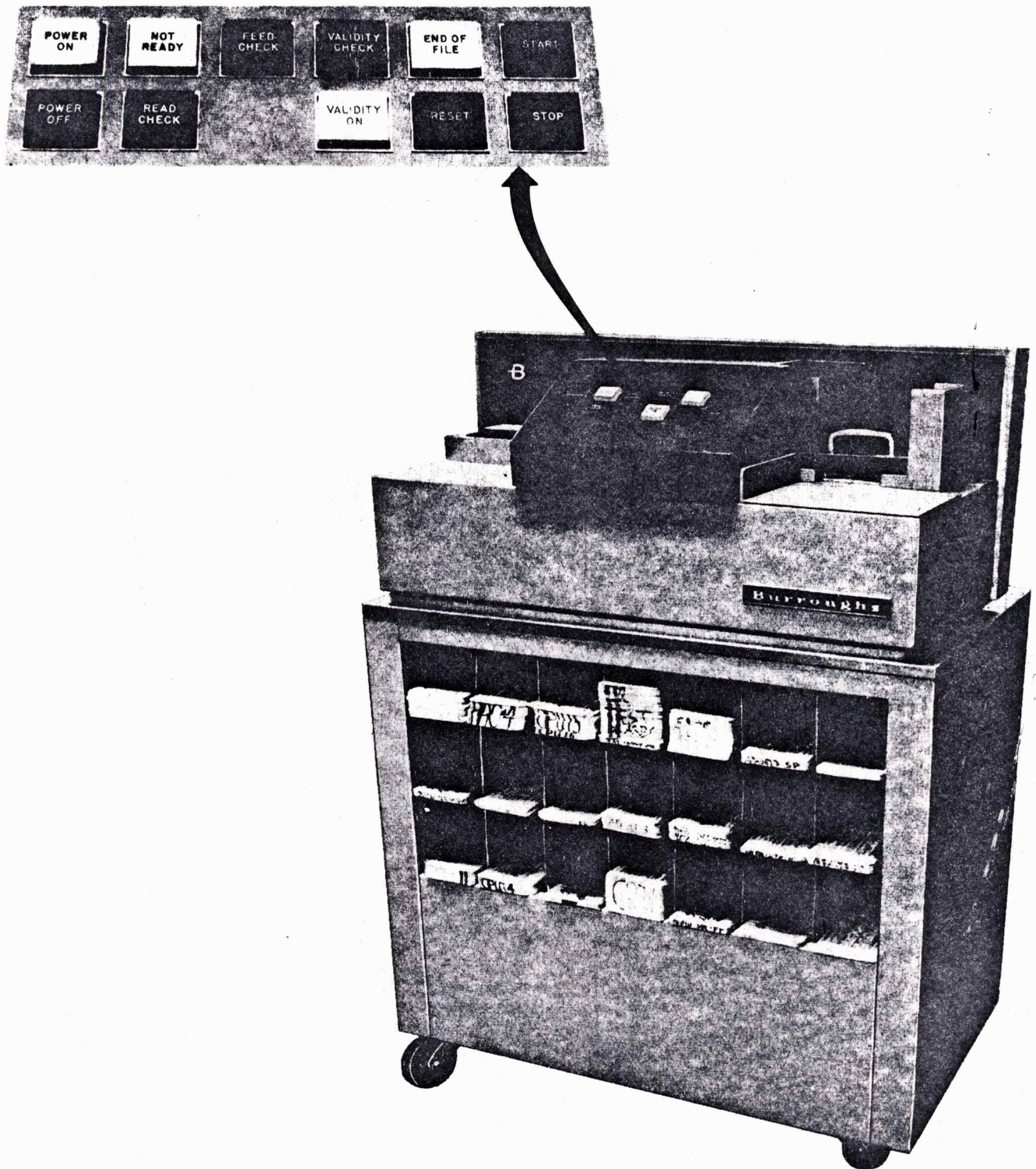


Figure 1-40. Card Reader



A typewriter is supplied with each computer. The typewriter is a 15-character-per-second revolving-ball machine that uses a type head and keyboard arrangement intended for use with each computer. The typewriter has a 15-inch carriage, with a 13-inch writing line. The typewriter ribbon and spool are in a snap-in cartridge to facilitate replacement.

The typewriter contains machine functions (top, space, uppercase, backspace, etc.), and coded characters similar to a standard typewriter. Communication with the computer uses the binary-coded-decimal format. The typewriter is connected to the computer via the typewriter interface logic and input/output character channel. The typewriter interface logic converts the characters into a form suitable for use by the computer and functions in reverse for data transmitted to the typewriter. Operation of the typewriter is controlled and monitored by OCP commands and sense lines. Interlock controls inhibit typewriter use, except when selected. To assist the instructor, the typewriter can:

- Change the variable being recorded on the X-Y plotters or X-T recorders during the freeze mode
- Interrogate and print out contents of any memory location during the freeze mode
- Notify that an error has been found
- Insert the date and time of day into the computer to enable identification of all recorded outputs
- Print out special messages; e.g., notify the instructor that the magnetic tape unit requires a new reel of tape.

The typewriter controls are listed, with their function, in table 1-19.

#### 1.7.2 DATA CONVERSION EQUIPMENT.

The data conversion equipment (DCE) accepts signals transferred between the computer complex and other LMS devices and converts them into a form suitable for use in each area. Input signals from the other LMS devices are in one of three forms: analog, digital bits, or digital words. Outputs from the computers are in word-serial, 24-bit parallel words.

Flow of information from the digital computers via the control unit, and to and from individual conversion devices, is shown in figure 1-42. Data are transferred between the computers and the control unit via the FBC. Transfer of data is under control of the real-time input/output program, which is initiated 20 times per second.

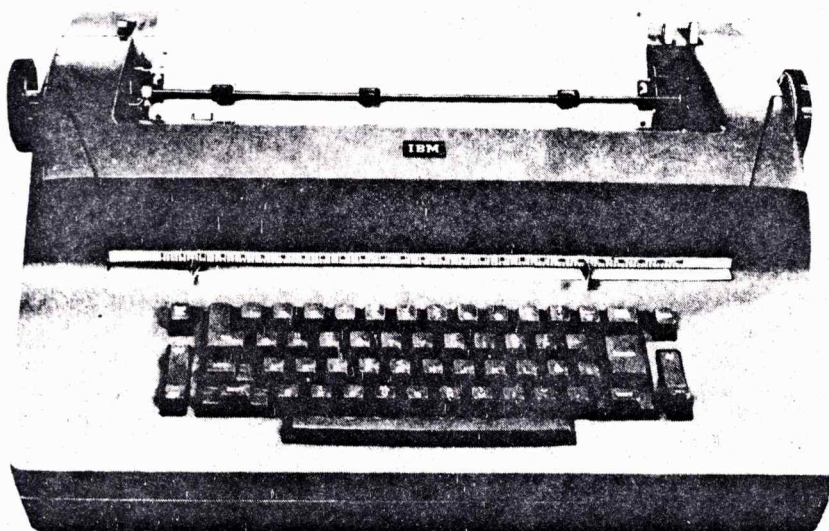


Figure 1-41. Selectric Typewriter

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Table 1-19. Typewriter Controls

Control	Function
Platen control	Rotates platen freely in either direction
Line space lever	Selects single or double spacing
Paper release lever	Enables positioning or removal of paper
Tab control pushbutton	Enables clearing or setting of tabs
MARGIN RELEASE pushbutton	Releases right and left margins
Tab pushbutton	Moves carriage to tab setting
Keyboard pushbuttons	Enable typing of standard and special characters
BACKSPACE pushbutton	Moves carriage toward left margin
INDEX pushbutton	Permits vertical spacing
CARRIER RETURN pushbutton	Returns carriage to left margin
Motor control	Activates typewriter
Space bar	Advances carriage toward right margin
SHIFT key	Shifts type to uppercase lettering
SHIFT LOCK	Locks shift key in position

The DCE consists of the following:

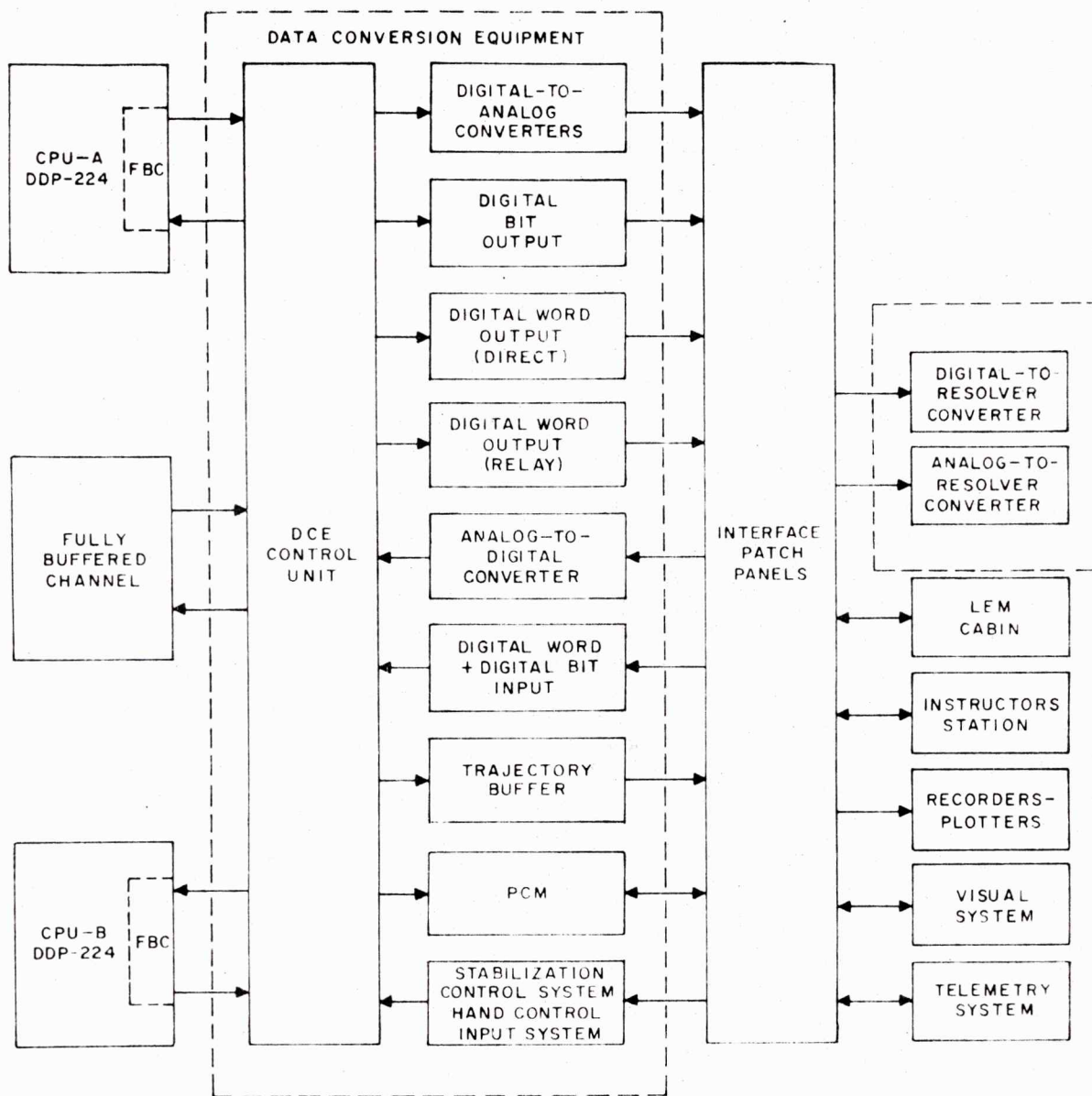
- Input/output control unit
- Digital bit output equipment
- Digital word output (direct) equipment
- Digital word output (relay) equipment
- Digital bit and digital word input equipment
- Stabilization and control subsystem converter
- Digital-to-analog converter
- Analog-to-digital converter
- Digital-to-resolver converter.

#### 1.7.2.1 Input/Output Control Unit.

The input/output (I/O) control unit controls the flow of all data between the (DCE) and the computer central processors. This unit accepts inputs via the 17 lines from each computer octal sense matrix, on which any of 30 combinations of device codes may be transmitted. An OSM register decodes this input by reading the last five bits of the OSM. A discrete device command is then put on the common DCE control lines.

The decoding and register circuitry of the I/O control unit is initialized at the start of each problem. All gating logic timing pulses required for I/O data transfers are generated within the I/O control unit. A 1-mc





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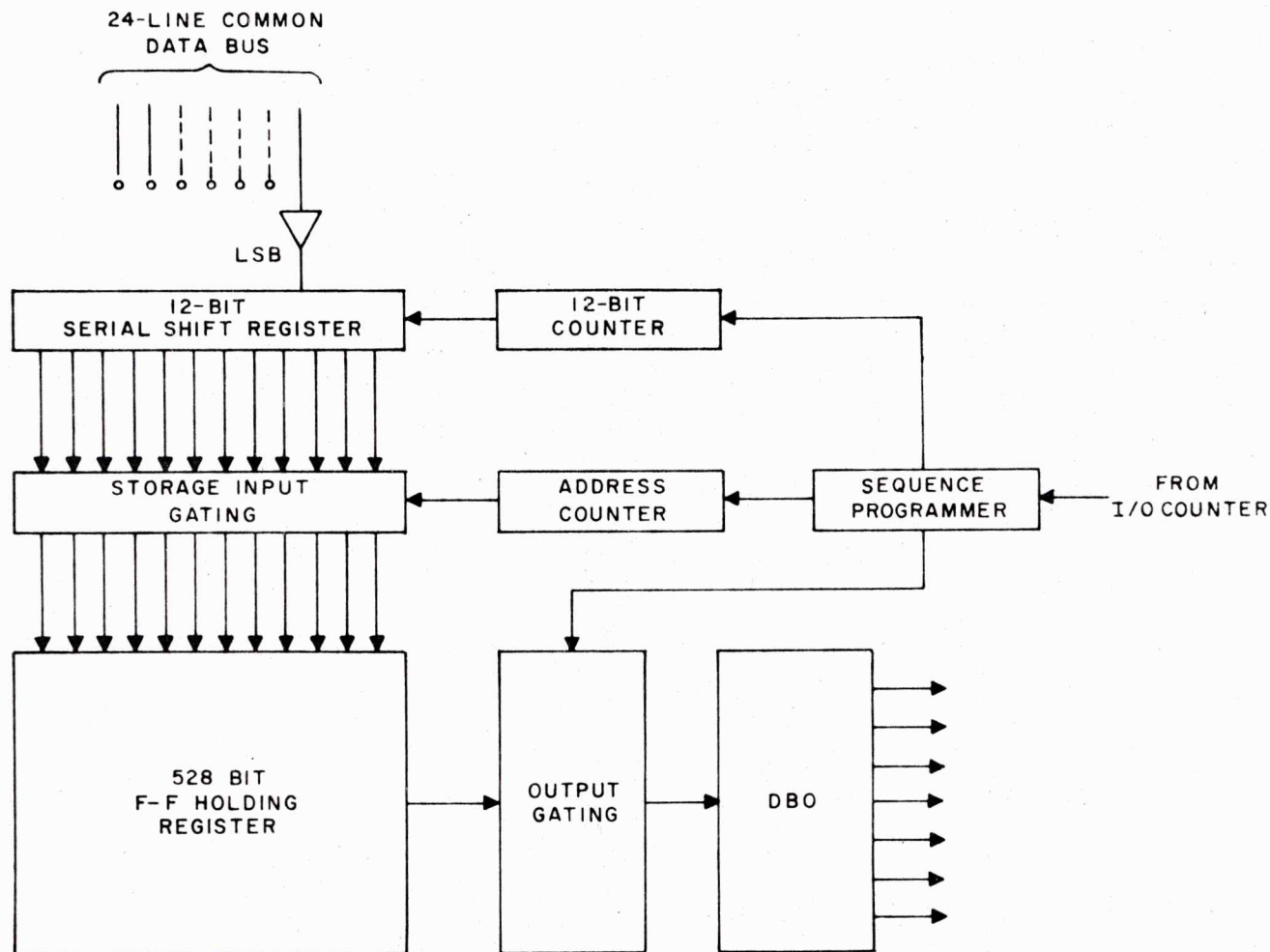
Figure 1-42. Data Conversion Equipment, Block Diagram

crystal oscillator provides the basic timing pulses to a data sequencer. Control logic circuitry gates the signals to the I/O interface and holding registers. Input and output registers hold the data being exchanged, until the device receiving the data is free to accept it. Output gates are then enabled to pass the data.

When a device is interrogated, a relay counter in the I/O control unit begins to increment a time span integrator. If a "device ready" reply is not received within 100 microseconds, the pending data transfer is skipped and an SKS pulse is returned to the computer that originally requested use of the input or output device. The I/O control unit supplies interrupt signals to the computers when the DCE has successfully completed a data transfer, indicating to the computers that the next request for data transfer can be honored.

#### 1.7.2.2 Digital Bit Output Equipment.

The digital bit output (DBO) equipment provides 388 functional and 101 spare discrete output channels between the computer complex and the other elements of the LMS. Data flow (figure 1-43) is made available through contact closures of mercury-wetted relays.



SMDP-24

Figure 1-43. Digital Bit Output Equipment, Flow Diagram

The digital data output from the computer is packed as the least significant bit (LSB) in a given data word stored in the computer core memory. These data words are transferred from the shared memory, through the FBC, to the I/O control cabinet. Though only the LSB is used, the entire word is transmitted over the 24-line data loop that ties together each of the DCE devices.

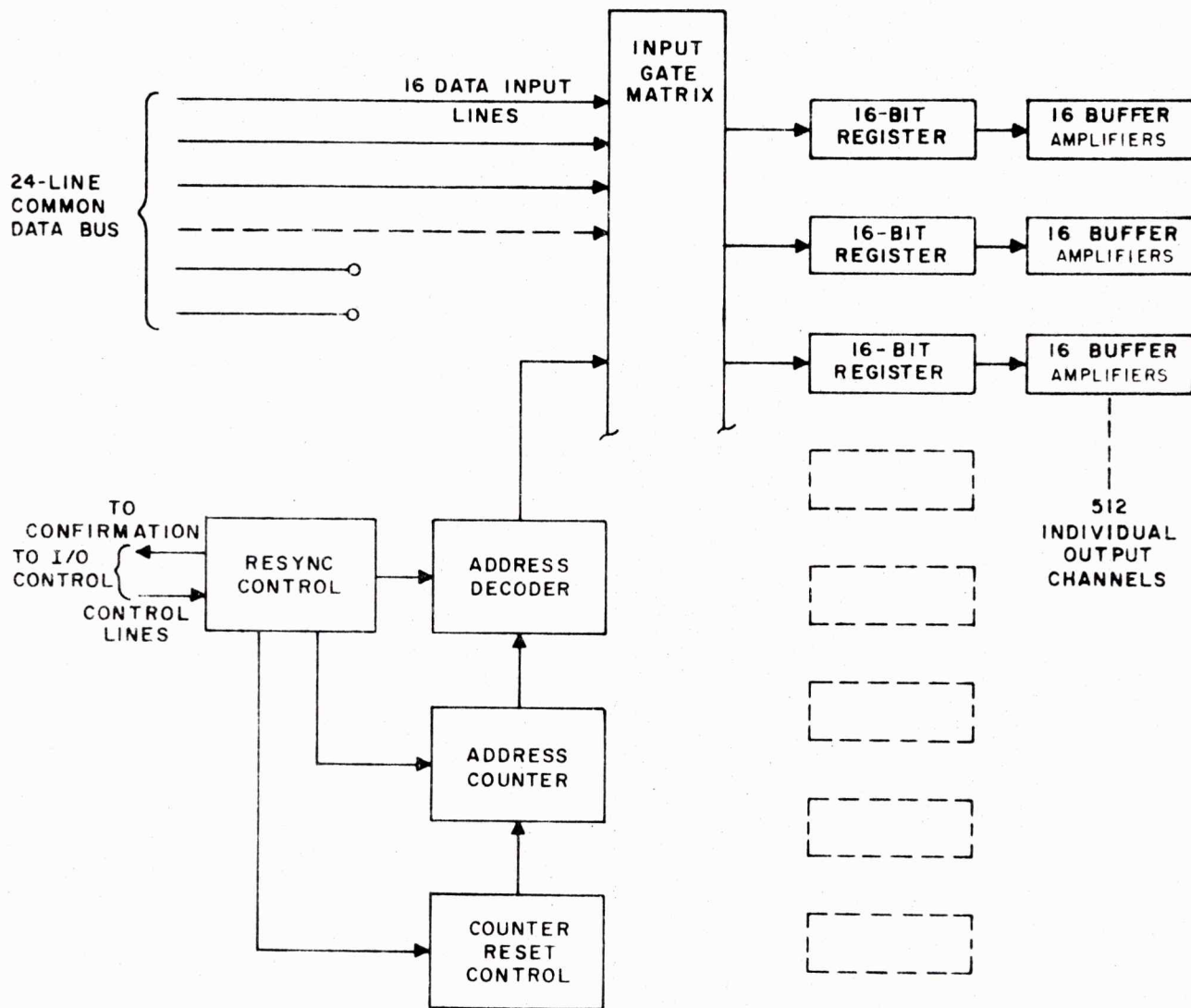
The sequence of the DBO equipment (repeated with each subsequent updating) is initiated by a function control pulse from the I/O control unit of cabinet No. 50. Receiving a "device ready" pulse in return, the computer output data is fed to the DBO equipment. The LSB is unpacked as each word is received, and serially loaded into a shift register. When an internal shift counter reaches 12, the 12 data bits are loaded into a flip-flop storage register. The data output from the computer is loaded into these serial buffer memories until all discrete signals have been stored. An address counter then triggers transfer pulses to each of the buffer data stores, transmitting all bits to the individual output relays. This serial loading, storing, and outputting of the digital data is controlled by a programmed logic device integral with the DBO equipment.

#### 1.7.2.3 Digital Word Output (Direct) Equipment.

The LMS digital word output (direct) (DWOD) equipment provides a data interface between the computer complex and the visual display drive circuitry. There are 32 groups of data, each comprising 16 individual bits. The digital information is stored in thirty-two 16-bit flip-flop registers. The state of each is sensed by an inverting amplifier that serves as a buffer with the adjoining visual equipment cabinet. Figure 1-44 is a flow diagram of the DWOD equipment.

The data control pulse initiates the update sequence by resetting an address counter to channel the incoming data to the first of 32 registers. The DWOD equipment then sends a "device ready" pulse back to the I/O control





SMDP-25

Figure 1-44. Digital Word Output (Direct) Equipment, Flow Diagram

unit. The data are strobed to the DWOD equipment in 16-bit parallel bursts, each of which results in a confirmation pulse being sent back to the I/O control unit to initiate the next data flow. As each 16-bit register is filled, the address counter is incremented by one, to strobe the next data burst into the subsequent register. The input data are received by the DWOD equipment via the 24-bit common data loop that connects all elements of the DCE. Logic control circuitry included in the DWOD equipment assures correct sequencing of the data flow within this output device.

#### 1.7.2.4 Digital Word Output (Relay) Equipment.

The digital word output (relay) (DWOR) equipment is similar to the DBO equipment. The DWOR equipment differs principally in that the data output from the computer is densely packed, providing 24 signal lines from each word read out of the core memory. A total of 1,344 channels are available for outputting digital data through the DWOR equipment.

After requesting access to the DWOR equipment (via the I/O control unit) and receiving a "device ready" confirmation pulse, the computer outputs a series of 56 data words, each 24 bits long, to the DWOR equipment. To buffer the high data output of the computer with the much slower (5 milliseconds) latching time for each of the DWOR equipment output relays, a core memory device is used to temporarily hold the digital data. Figure 1-45 is a flow diagram of the DWOR equipment.

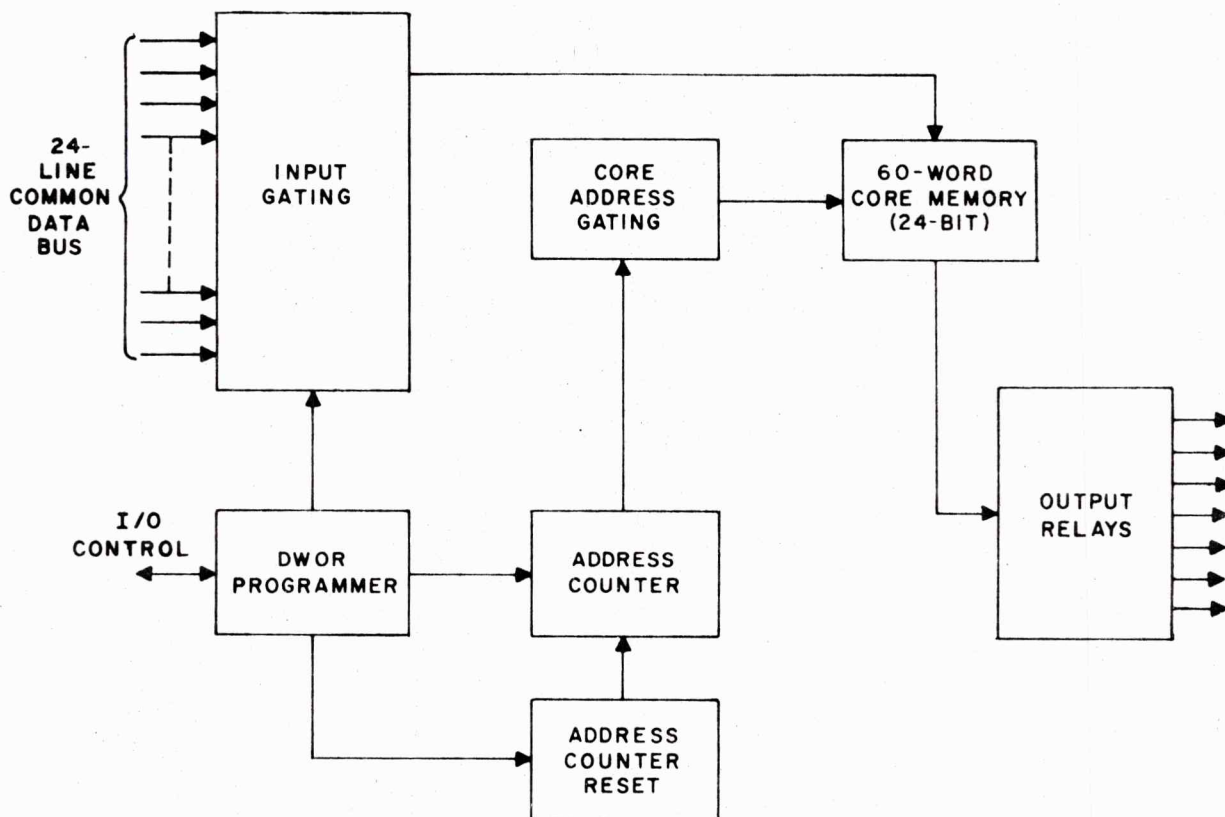
A programmer circuit is signaled by the I/O control unit to reset the address counters and begin acceptance of 24-bit data words from the common data bus. These incoming data are gated into the 56 sequential word addresses (each 24 bits long) of the ferrite core memory in the DWOR device. When the high-speed data transfer from the computer to the DWOR core memory is completed, the address counter is reset and the stored data are sequentially read out to the mercury relays, which are latched up from that point until the next updating sequence.

#### 1.7.2.5 Digital Bit and Digital Word Input Equipment.

This equipment provides an interface between the discrete switch closures of the simulator complex and the computed simulation programs. Figure 1-46 is a flow diagram of the digital bit and digital word input equipment. Data are handled in single bit processing (digital bit input), and in data packing of 24 bits handled in common as a single digital word input (DWI). A total of 576 (508 functional and 68 spare) channels of digital bit input (DBI) equipment and 8 (7 functional and 1 spare) DWI units are provided. A common control unit regulates both types of inputs.

A selection register sequences through the input AND gates when the input interrogation command is received from the I/O control unit. Each input bit is serially sensed, and loaded onto the common data loop, being gated into the least significant bit line. This sequential processing makes it possible to tie the output of all input gates together through an OR gate delta matrix that terminates in a single signal line (the LSB line).

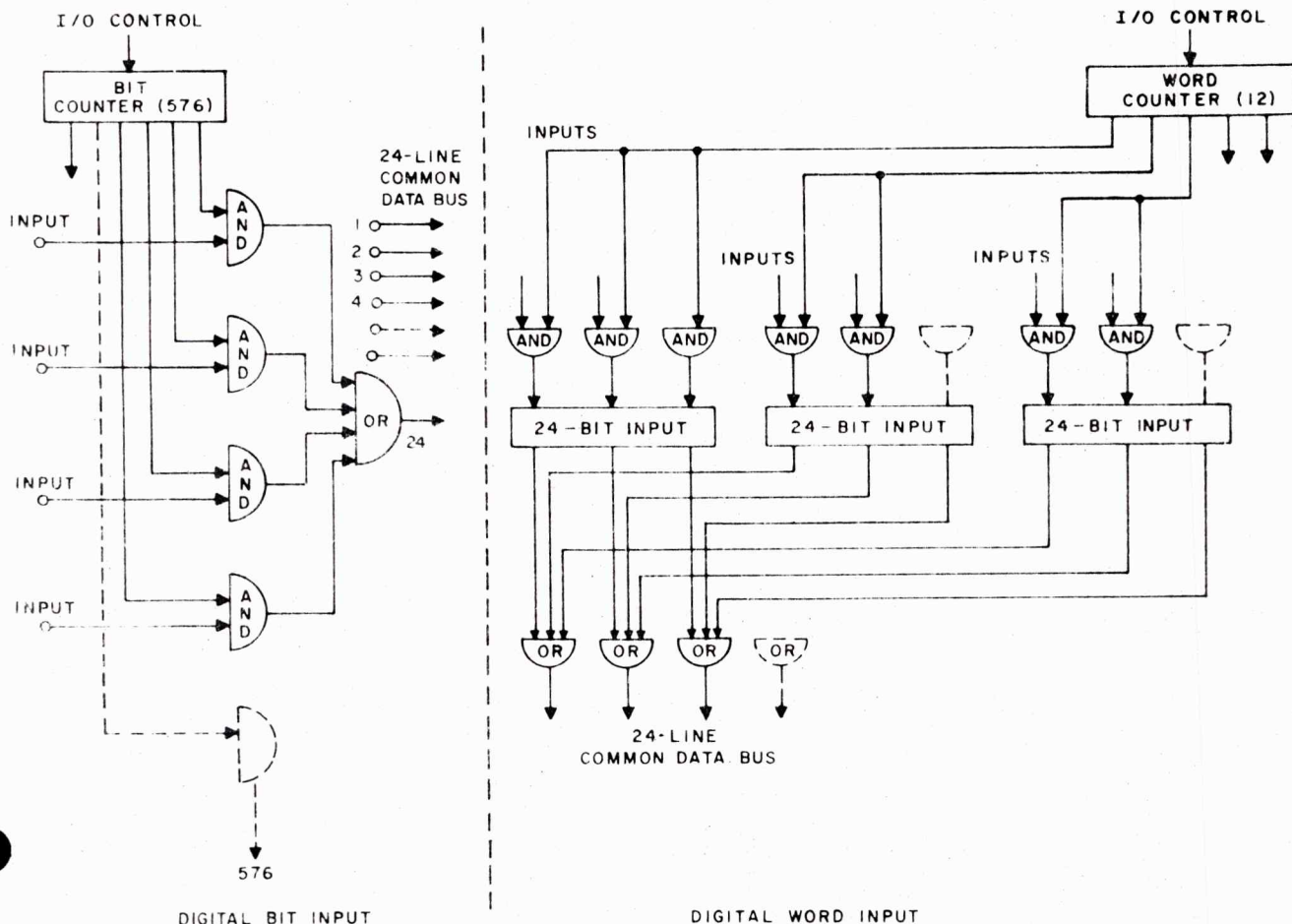
The DWI equipment is also sequenced; however, in this equipment, strobe pulses enable 24 AND gates simultaneously, transferring 24 bits to the common data loop as a single word. In processing this section, the



SMOP-26

Figure 1-45. Digital Word Output (Relay) Equipment, Flow Diagram





SMDP-27

Figure 1-46. Digital Bit and Digital Word Input Equipment, Flow Diagram

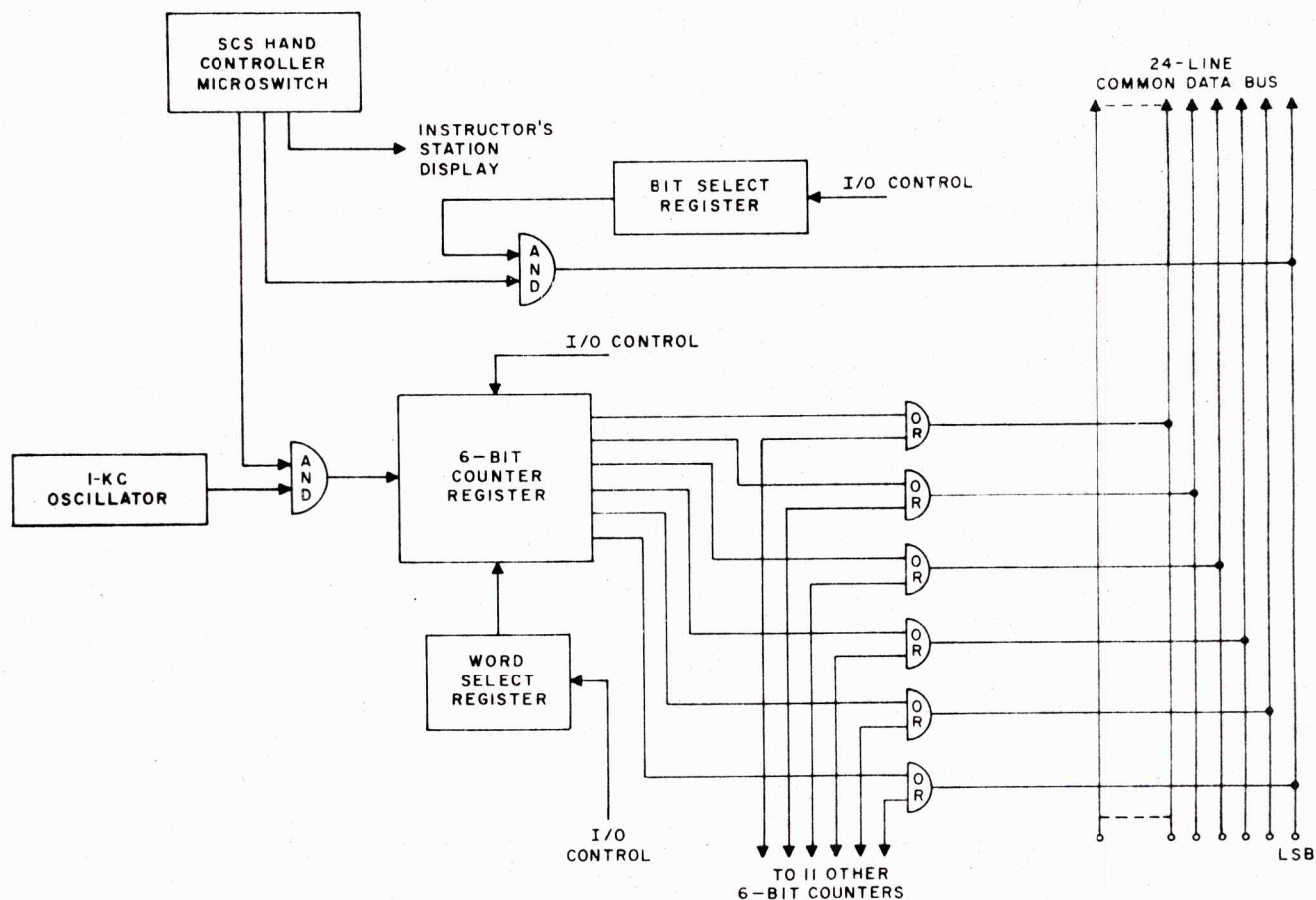
bits of similar magnitude in each of the groups are tied together by OR gates, terminating at 1 of the 24 common data loop lines.

#### 1.7.2.6 Stabilization and Control Subsystem Converter.

A special digital processing converter handles the momentary switching status data of the SCS hand controllers. Figure 1-47 is a flow diagram of this converter. Manual translation inputs from the crew are sensed by a set of 12 microswitches. Negative and positive displacement groups are provided for the  $2.5^\circ$  and  $10^\circ$  positions in each of three axes (pitch, roll, and yaw). For realistic simulation, the hand controller outputs are sampled at a higher rate than the normal 50-millisecond cycle time common to the LMS computer complex.

A series of 12 counters, each of six-bit capacity, is tied directly to the 12 hand controller microswitches. The counters are pulsed by a 1-kc signal generator when a controller switch is closed. In this way, the state of the counter is analogous to the time integral of the controller inputs. Use of a 1-kc oscillator results in a control input resolution of 1 millisecond.

The hand controller status is made available to the computer complex as discrete switch closures and as the integrating counter outputs. The discrete switch contacts are also tied to controller position displays at the instructor console. When the discrete switch status is interrogated by the computer, the I/O control unit sends a function pulse followed by a series of data strobes that sequentially gate each of the 12 switch lines into the 24th bit of the common data loop bus.



SMDP-28

Figure 1-47. Stabilization and Control Subsystem Converter, Flow Diagram

When the status of the 12 integrating counters is to be accessed, the I/O control unit outputs gating pulses that dump the six bits of each counter onto lines No. 19 through 24 of the common data loop. The channel counter then advances to the next six-bit register and dumps its contents onto two data loop lines. In this way, all 12 counters are read out during the normal 50-millisecond machine computation cycle.

#### 1.7.2.7 Digital-to-Analog Converter.

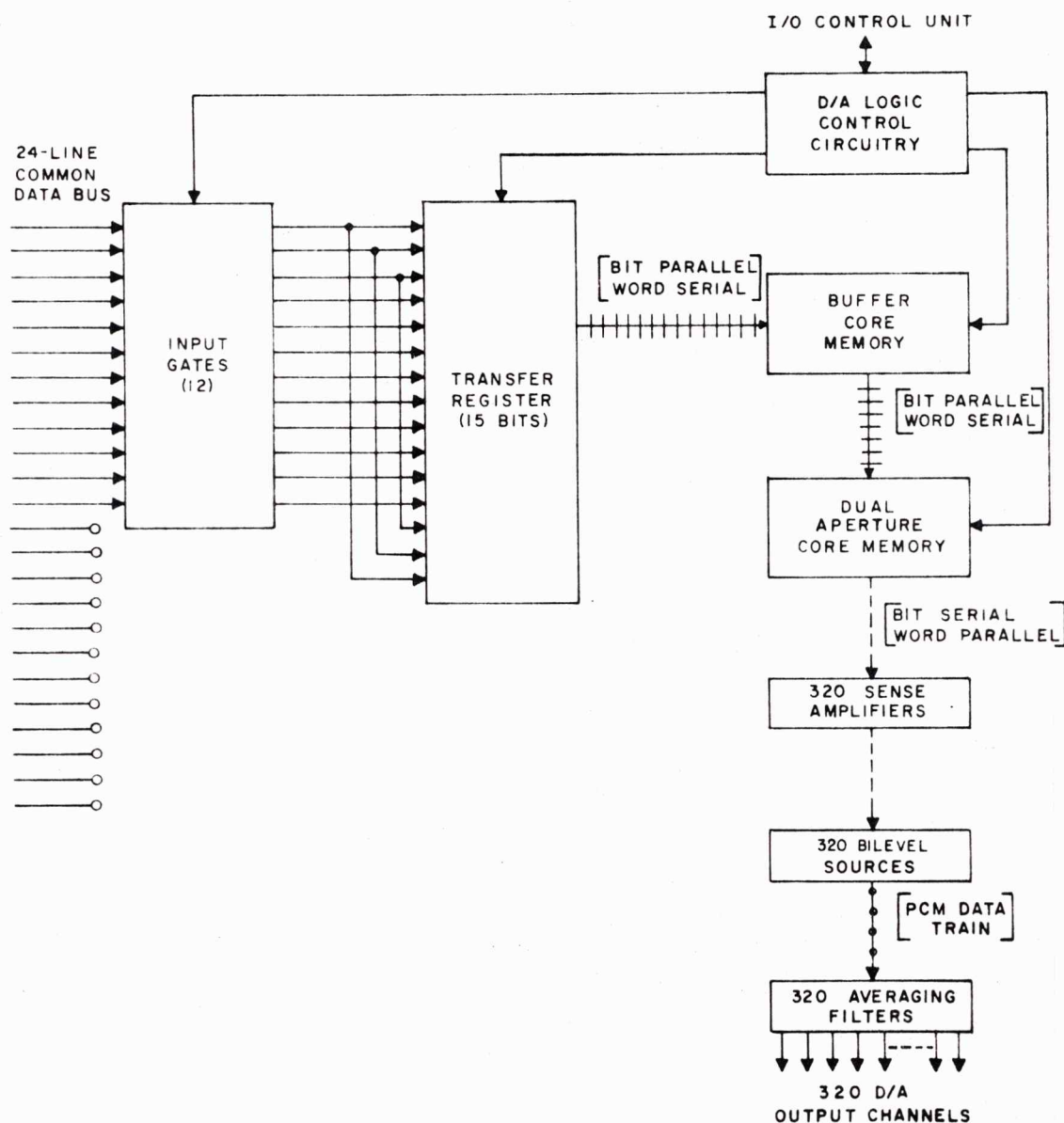
The basic concept of D/A conversion in the LMS computer complex is a scheme of averaging pulse-width-modulated signals. The digital data drives a flip-flop power switch back and forth between +10 and -10 volts. The gating is done on a time-weighted basis, the most significant bits holding the output voltage in one or the other state longer than the less significant bits. The algebraic sum of these plus and minus voltage excursions results in a time-integrated total voltage output that remains as the final output signal. Figure 1-48 is a flow diagram of the digital-to-analog converter.

The digital data is fed to the DCE on the 24-line common data bus. On command from the I/O control unit, 320 data words are sequentially gated onto the D/A conversion bus; they latch up a transfer register. Only 11 bits, plus the sign bit, are transferred from the common data bus. A core memory storage device holds the 320 data words while they are processed through the conversion equipment, because the computer output data must be transferred at a very high rate to clear the DCE data buses for other I/O operations.

Before loading into the buffer core memory of the D/A converter, the input data is examined and the transfer register outputs are set up to accomplish the following data transformations

- The sign bit is inverted.
- If the sign bit is negative, the complement of each data bit is gated from the transfer register into the buffer core.





SWDP-20

Figure 1-48. Digital-to-Analog Converter, Flow Diagram

- Three of the transfer register flip-flops (sign bit and two MSB) are each gated into pairs of cores in the buffer memory.

The logical control circuitry then gates the transformed 12 bits of digital data into the buffer core. This core memory is an off-the-shelf unit with a capacity of 512 words, each 15 bits long. Three of the 12 data bits are repeated. The updating data from the I/O control unit consists of 320 words transmitted in a rapid serial sequence. When the buffer has accepted all 320 words in the output data burst, a readout cycle is begun, at a much slower rate, to transfer the digital data into a special-purpose, dual-aperture, ferrite-core storage device that includes a nondestructive memory feature.

The buffer core data are loaded into the dual-aperture core in a sequence of 320 words; the 15 bits of each word are gated in parallel. The dual-aperture core consists of dual 256 word units (15 bits per word) of which only 320 words are used. The dual-aperture design of each ferrite-core makes it possible to pulse the core and read out the data without completely destroying its magnetic state. A half-current repriming pulse brings

each readout bit previously set to a 1 back to its saturated state; previously 0 cores do not react to this half normal drive current.

The sequence in which the data are read out from the dual-aperture core is given in table 1-20. The control logic unloads the core data in a bit-sequential, word-parallel mode. The sign bit of all 320 words is gated out simultaneously. The initial enable pulse for this bit lasts for 1,024 microseconds. Thereafter, each of the less significant bits are read out, being gated for descendingly shorter spans; each bit is enabled for only one half as much time as the preceding bit. In this process, the 15 bits of all 320 data words are read out in parallel over a span of approximately 4 milliseconds. The logic control circuitry then begins, immediately, to sequence through the 15 bits of each word again.

The digital output of the dual-aperture core is carried on parallel signal lines to 320 sense amplifiers that drive an equal number of bilevel, flip-flop voltage sources. This level-switching circuitry swings between +10 and -10 volts. The output of the bilevel voltage source is conducted through an averaging filter network. The signals fed to the D/A output networks are in the form of a continuous pulse-width-modulated data train. The most significant bits in each digital word converted appear as long pulses (+10 or -10 volts dc) followed by descendingly shorter pulse widths for each less significant bit. As each digital word read sequence is completed (4 milliseconds), the cycle is repeated; a continuous data stream is fed to the averaging filters. The time constant of these filters yields a smooth output signal on each of the 320 (241 functional and 79 spares) D/A channels, free of iterative fluctuations.

Table 1-20. Digital-to-Analog Serial Data Bit Read Sequence

Bit Position	Pulse Width ( $\mu$ sec)	Cycle Time ( $\mu$ sec)
$*2^0$	1,024	1,024
$2^{-1}$	512	1,536
$2^{-2}$	256	1,792
$2^R$	2	1,794
$2^{-10}$	2	1,796
$2^{-9}$	4	1,800
$2^{-8}$	8	1,808
$2^{-7}$	16	1,824
$2^{-6}$	32	1,856
$2^{-5}$	64	1,920
$2^{-4}$	128	2,048
$2^{-3}$	256	2,304
$2^{-2}$	256	2,560
$2^{-1}$	512	3,082
$*2^0$	1,024	4,096
* = Sign bit		
R = Roundoff bit.		



### 1.7.2.8 Analog-to-Digital Converter.

There are 64 channels of analog-to-digital (A/D) conversion equipment in the LMS, with a growth potential to 160 channels. The conversion scheme is based on a comparative process in which an internally generated voltage is compared with the incoming analog signal. The internal signal is adjusted, digitally, until the two voltages are alike, at which time the digital word required to generate the matching internal voltage is gated to the computer complex. Figure 1-49 is a flow diagram of the A/D converter.

After an input command signal is sent from the I/O control unit and a confirmation pulse is returned from the A/D converter, an address counter is reset to initiate input signal gating to a multiplexer. This unit sequentially selects each of the 64 input lines and connects it to a holding amplifier. The signal level of the input line is captured by the amplifier. The amplifier output provides a stable voltage source for the comparator circuit during the conversion process.

The comparison circuit includes an internal ladder network voltage source, excited by a very stable power supply. This ladder is latched up sequentially by an 11-bit register circuit that, starting at the maximum output voltage, begins to reduce the ladder connections until a match is reached between the ladder network output and the input analog signal captured by the holding amplifier. As each ladder "rung" is switched, the output of a comparator (differential amplifier) is sensed and the switch is reset or left latched, depending upon the relative magnitude of the two signals.

When the last bit (LSB) of the ladder network has been sampled by the comparator, a gating pulse dumps the contents of the ladder network latching register on the 11 most significant lines of the common data bus. The sign bit as sensed in the converter, is also gated out the 24-line data bus at this time. A pulse is then sent to advance the multiplexer address counter and thus initiate another conversion cycle by sampling another input analog signal line.

### 1.7.2.9 Digital-to-Resolver Converter.

The digital-to-resolver (D/R) converter is a self-contained, solid-state, modular, rack-mounted device. It accepts binary angle data from the computers and converts it to resolver form. The converter can drive a

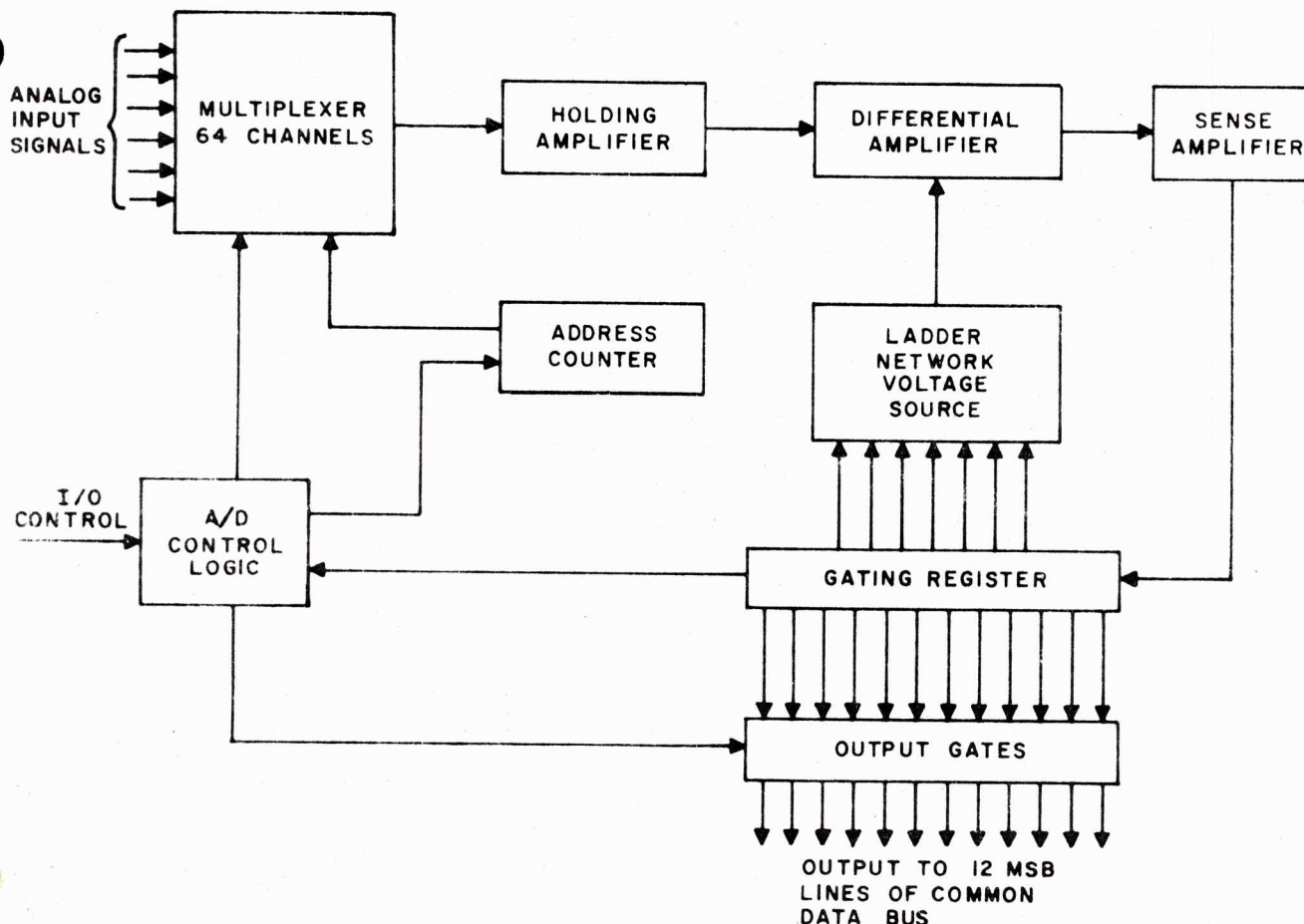


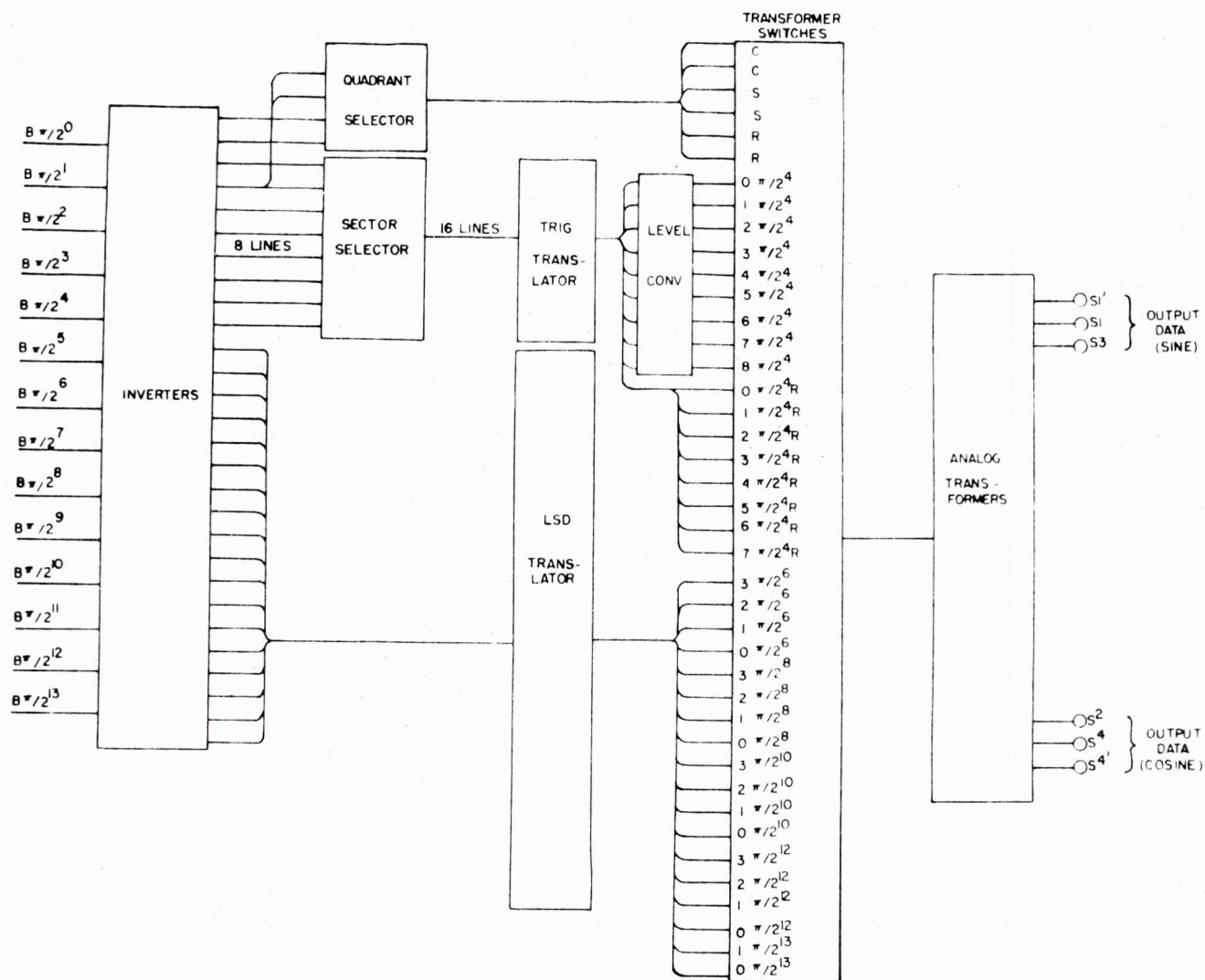
Figure 1-49. Analog-to-Digital Converter, Flow Diagram

resolver at 11.8 or 22.4 volts, line-to-line, with a static accuracy of 1.32 minutes of arc. Figure 1-50 is a block diagram of the D/R converter.

The 14 (12 functional and 2 spares) lines of input data from the computer are delivered to inverters that create complements and act as buffers that drive the following circuitry. Inverter outputs for the first two bits of information and their complements are fed to the quadrant selector. The quadrant selector computes the quadrant in which the angle is located, by determining the polarity of the sine, cosine, and interpolation reference potentials. The output of the quadrant selector is fed to the transformer switches, which switch the inverting section of the analog transformers.

The inverter output for the second through fifth bits, and their complements, are fed to the sector selector. The sector selector changes the data from binary form to a 16-count form (0 to 15). The output of the sector selector is fed to the trigonometric translator. This section converts the data received from the sector selector to a form compatible with the transformer taps being switched. These data are fed to the level converter, which distributes them to the transformer switches. These switches select the trigonometric analog transformer tap required for the analog programmed.

The inverter outputs for the last nine bits of information, and their complements, are fed to the least significant digit (LSD) translator section. This section changes the binary data to a four-count form (0, 1, 2, and 3) by using successive pairs of binary bits. The outputs of the LSD translator are then fed directly to the solid-state transformer switches, which program the interpolation section of the analog transformers to the desired setting.



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Figure 1-50. Digital-to-Resolver Converter, Block Diagram



THE ANCILLARY GROUP

The ancillary functional group consists of the LMS power equipment, air-conditioning, and cabling, discussed in the paragraphs 1.8.1 through 1.8.3.

**1.8.1 LMS POWER.**

The LMS is designed for connection to a 120/208-volt, 60-cycle, three-phase, four-wire, grounded system, with a separate 115-volt, single-phase service supply. The service supply provides power to the 26-volt d-c utility supply used to sequence power turn-on and to 115-volt convenience outlets.

Three dual-bay cabinets and two single cabinets house the LMS main power supplies and associated equipment. In addition, many of the LMS racks contain their own power supply. Power cabinet No. 1 (36, table 1-1) houses the main input power feed system, the 1,000-ampere master circuit breaker, the circuit breakers for each major 115-volt a-c power bus, and the 400-cycle motor-generator set. Power cabinet No. 2 (37) houses only circuit breakers, among them the 300-ampere circuit breaker unit (100 amperes per phase) for the 115-volt a-c visual system supply and circuit breakers for branch lines off the main power buses. Power unit (51) contains two digital resolver converters for the visual system, and circuit breakers to protect individual components of the digital conversion equipment (DCE). EVDE power cabinet (A40) contains power supplies, main switches, and monitoring instruments for power distribution within the EVDE subsystem. Power cabinet No. 3 (38) is used to apply and monitor power to the LMS. It contains the switch lights for the major subsystem circuit breakers, running-time meters to monitor the operating time of each subsystem, and instrumentation to monitor voltage, current, frequency, and phase of the power inputs to the LMS. This cabinet also houses an instrumentation converter that provides 800-cycle power, and an autosequencer that delays startup of each subsystem to avoid current surge and to ensure dependable power interlock. The power cabinets are centrally located within the LMS complex to minimize voltage drop, reduce electromagnetic pickup and radiation, and maintain good d-c voltage regulation. Figure 1-51 is a block diagram of the LMS power system.

LMS power requirements for individual major subsystems are listed in table 1-21. The total power consumption, with the LMS operating under normal spaceflight conditions and with all equipment turned on, is 254.7 kva; the current per leg is given in table 1-22.

Table 1-21. LMS Power Requirements

External visual display equipment	100 kva
Computer complex	43 kva
Digital conversion equipment	25 kva
400-cycle motor-generator	30 kva
Life support equipment	25 kva
Utility	15 kva
Peripheral equipment	16.7 kva
Data recorders	3,500 va
Tape Recorder	100 va
Floodlight	600 va
Synchro resolver/driver	2,000 va
Landmass simulator	3,000 va
D-C power supplies	7,500 va

Table 1-22. Estimated Loads Per Phase

Equipment	Phase 1 (amperes)	Phase 2 (amperes)	Phase 3 (amperes)
Peripheral	40	40	40
Life support	26.5	28.2	26.4
Digital conversion equipment	43	43	43
400-cps motor-generator set	38	38	38
Computer complex	95	95	95
Total	242.5	244.2	242.4
<div style="text-align: center; border: 1px solid black; padding: 5px; margin: 10px auto; width: 100px;">NOTE</div> <ul style="list-style-type: none"> <li>• The EVDE will have a balanced load of 100 kva.</li> <li>• Two compressors will maintain pressure to life support equipment.</li> <li>• The 400-cps motor-generator set is considered 50% efficient.</li> </ul>			

When properly connected, LMS performance is satisfactory over a nominal  $\pm 8\%$  range at 120 and 208 volts ac without changing transformer taps. Performance is satisfactory with a steady frequency of  $60 \pm 1.8$  cps with a voltage and cycle recovery rate of 3 seconds. With the simulator in normal operation, the load on each phase is balanced as closely as possible, with an unbalanced current on any one leg not greater than 15% of the average of the three-leg currents.

The power factor is not less than 85% and has the same value in each leg. The maximum power required does not exceed the design capacity of the power supply rating. All power sources, except the 400-cycle supply and certain self-contained integral assembly supplies, are solid state. All supplies are continuously monitored automatically for overvoltage and overcurrent; all circuits are adequately protected by circuit breakers to avoid line or subsystem failures.

#### 1.8.1.1 Controls and Displays.

The LMS main power panel controls and displays (figure 1-52) are listed, with their function, in table 1-23. The controls are used to apply or remove power or to increase or decrease power to the LMS subsystems.

#### 1.8.1.2 Power Distribution.

The LMS power is divided into two independent distribution systems: simulator power and utility power.

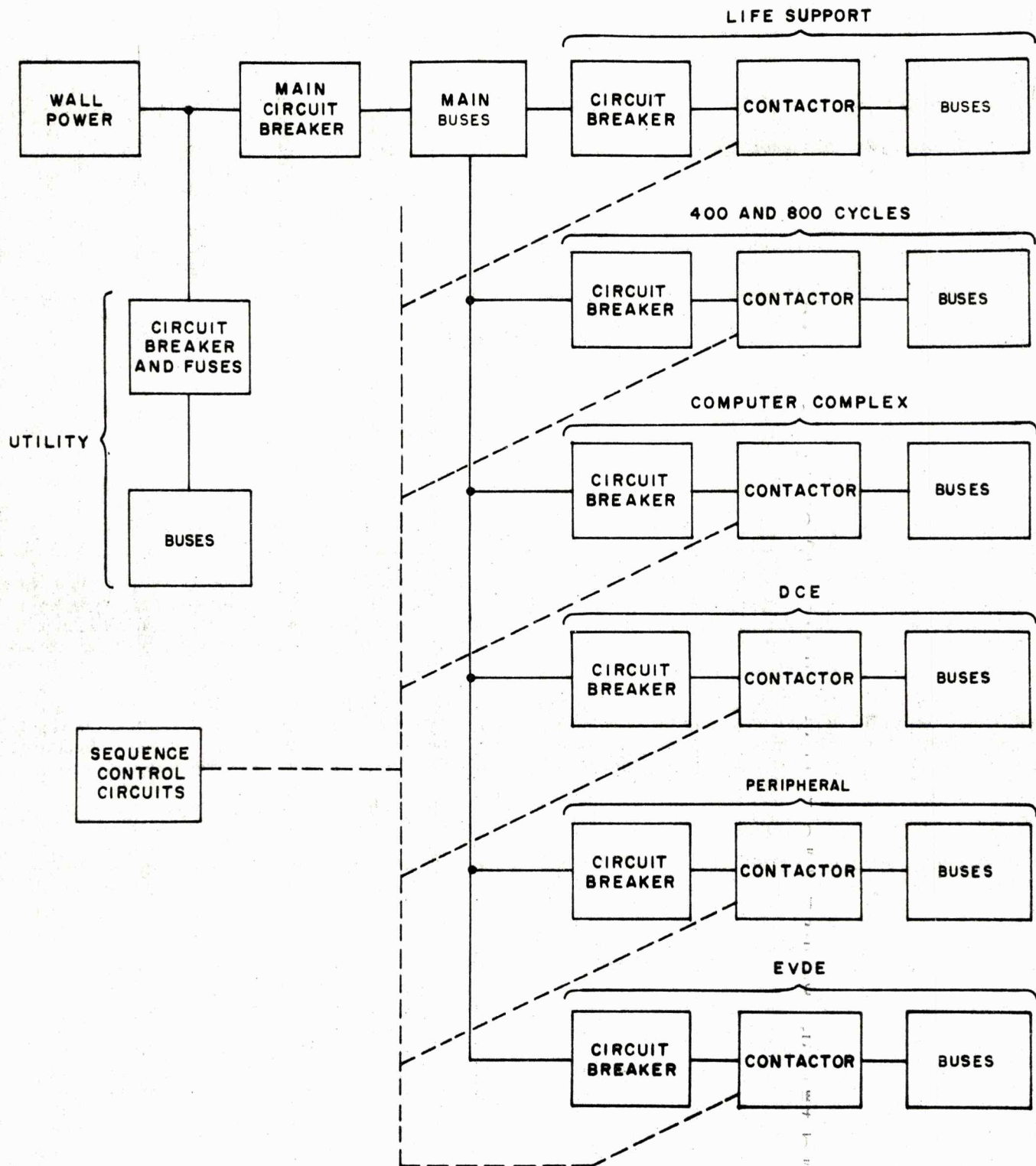
##### 1.8.1.2.1 Simulator Power.

Simulator power, supplied via the main circuit breaker, can be turned on or off with the breaker. The secondary side of the breaker supplies the main power buses. From the main power buses, power is distributed to six groups of bus bars; each group supplies power to a subsystem within the LMS. These subsystems provide a logical distribution of simulator power. A circuit breaker between the main buses and each subsystem bus provides system protection; a contactor enables individual subsystem turn-on via the sequencing control circuits.

##### 1.8.1.2.2 Utility Power.

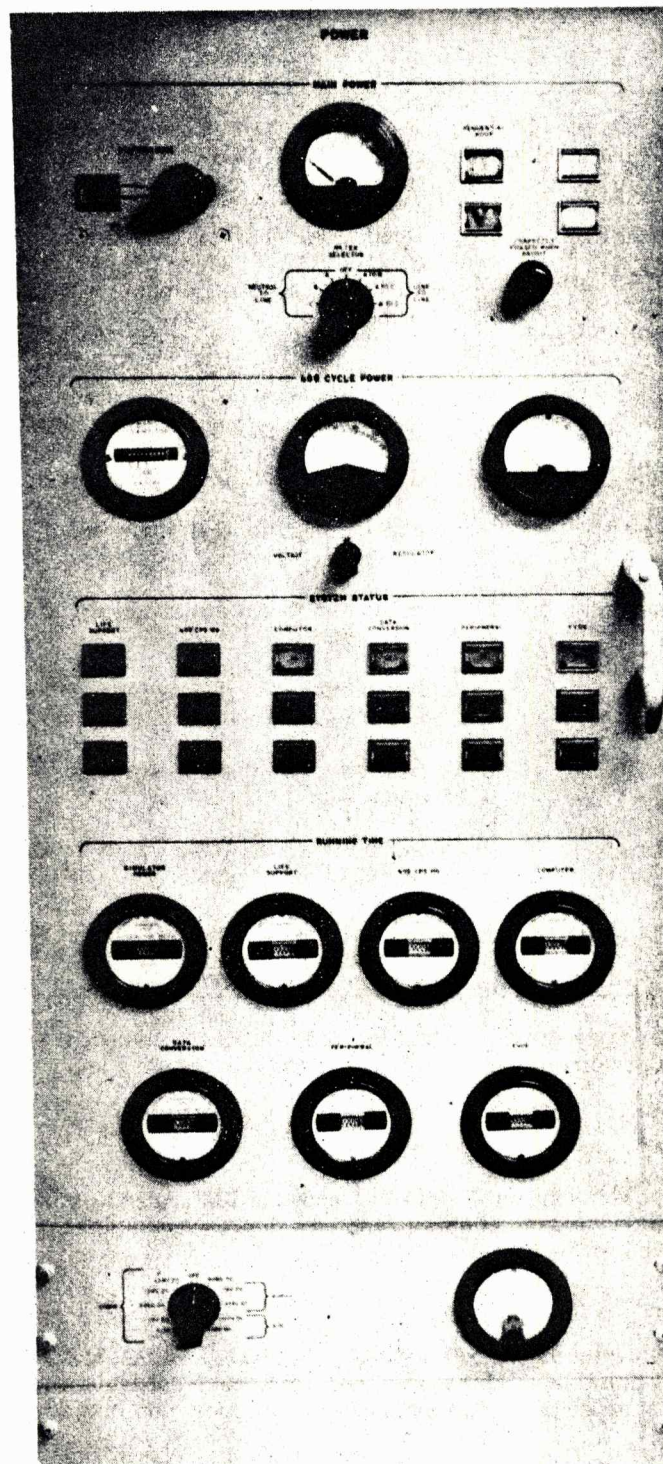
The utility power system is independent of the main circuit breaker used to supply simulator power. The utility buses have a separate circuit breaker, making them totally independent of the rest of the system. Power





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Figure 1-51. LMS Power System, Block Diagram



SMDP-161

Figure 1-52. LMS Main Power Panel



Table 1-23. Main Power Panel, Controls and Displays

Control or Display	Function
STARTING MODE switch	In SEQUENTIAL position, permits automatic system turn-on; in MANUAL position, permits manual system turn-on
SEQUENTIAL MODE ON/OFF switch lights	Used when STARTING MODE switch is set to SEQUENTIAL. When ON switch light is pressed, automatic sequential power turn-on of LMS subsystems occurs.
AC voltmeter	Indicates voltage between any two phases of input lines (phase A to B, phase A to C, phase B to C) or from any one phase to ground
METER SELECTOR switch	Selects voltage to be displayed on AC voltmeter
CORRECTLY PHASED WHEN BRIGHT indicator	Lights brightly when main power is correctly phased
400 CYCLE POWER frequency meter	Indicates operating frequency of 400-cycle generator
400 CYCLE POWER AC voltmeter	Indicates voltage being supplied by 400-cycle generating system
400 CYCLE POWER AC ammeter	Indicates line current supplied by 400-cycle generator
SYSTEM STATUS indicators	Indicates status (ON, OFF, or MAINT IN PROGRESS) of six LMS subsystems
RUNNING TIME meters	Indicate total time power has been applied to six LMS subsystems

from the utility buses is used for convenience outlets located in all LMS cabinets; for the +26-volt d-c utility power supply, which sequences power turn-on; to illuminate the status lights and EMERGENCY OFF lights, and to energize relays.

#### 1.8.1.3 Power Sequencing.

The LMS has a sequential power turn-on system that reduces line surge at initial turn-on and allows the individual main subsystems to be turned on or off as desired. This sequencing may be accomplished in either of two modes of operation: manual or sequential.

##### 1.8.1.3.1 Manual Mode.

When the STARTING MODE switch is set to MANUAL, the SEQUENTIAL MODE ON/OFF switch lights have no effect on the power system. In the manual mode of operation, each subsystem is turned on or off individually and is independent of the other subsystems. The manual mode of operation is mainly used for maintenance or overhaul procedures.

##### 1.8.1.3.2 Sequential Mode.

With the STARTING MODE switch set to SEQUENTIAL, power turn-on is accomplished by pressing the SEQUENTIAL MODE ON switch light. The life support subsystem buses are energized immediately. Then, at 10-second intervals, subsystems buses are energized in the following order: 400-cycle motor-generator, computer complex, digital conversion equipment, peripheral power equipment, and external visual display equipment. As each subsystem is energized, the appropriate status light on the instructor console main power panel goes on. The 400-cycle load contactor (generator) is energized automatically when the last subsystem bus is energized. Power turn-off is accomplished by pressing the SEQUENTIAL MODE OFF switch light, thereby disconnecting all simulator power circuits.



#### 1.8.1.4 EMERGENCY OFF and MAINTENANCE IN PROGRESS Switches.

EMERGENCY OFF switches are on the instructor console and on all peripheral equipment cabinets. Pressing an EMERGENCY OFF switch breaks a latching circuit to disconnect simulator power. The main power panel has MAINTENANCE IN PROGRESS switch lights for each LMS subsystem. Pressing a MAINTENANCE IN PROGRESS switch disables the related subsystem to permit maintenance personnel to perform repair procedures. Simultaneously, the appropriate MAINTENANCE IN PROGRESS light goes on to indicate which system is being repaired. The MAINTENANCE IN PROGRESS switch lights can be operated during the sequential or manual modes of operation.

#### 1.8.1.5 Subsystem Power.

##### 1.8.1.5.1 Life Support Subsystem.

The life support subsystem buses distribute power to equipment associated with true trainee environment. Such equipment includes heaters, air compressors, and air-conditioners. In the event of loss of any phase of life support power, the compressor that maintains suit pressure is automatically switched to the utility power bus.

##### 1.8.1.5.2 400-Cycle Motor-Generator.

The 60-cycle power is fed from the power buses in the power cabinet to a reduced voltage starter through a circuit breaker. From the starter it is fed to the motor of the motor-generator set, located remote from the peripheral equipment. The resultant 400-cycle power is routed back to the power cabinet where its voltage, current, and frequency are monitored. The 400-cycle power is then fed to a load contactor and distribution buses, and routed to the visual drive and instrument cabinets and to a 26-volt stepdown transformer. This transformer supplies power to the flight director attitude indicators (FDAI's) and a 400-cycle reference signal to the EVDE. The voltage output of the motor-generator is remotely controlled from the main power panel. In the manual mode of operation, the load contactor is energized by a load switch located on the main power panel; in the sequential mode, the load contactor is energized automatically, providing the motor-generator is at operating speed and the peripheral equipment power is on.

##### 1.8.1.5.3 Computer Complex.

The computer buses are energized through a circuit breaker and contactor. Power is routed to the computer complex area to be distributed to the computer and its supporting equipment.

##### 1.8.1.5.4 Digital Conversion Equipment.

The main circuit breaker and the contactor for the digital conversion equipment are in the main power cabinet. Distribution buses in a power bay within the digital conversion equipment area route this power through secondary circuit breakers to each cabinet.

##### 1.8.1.5.5 Peripheral Equipment.

The peripheral equipment power buses are protected by a circuit breaker; they are energized by a contactor. Power from these buses is distributed to the peripheral power supplies and converters.

##### 1.8.1.5.6 External Visual Display Equipment.

Power is supplied to the EVDE through a circuit breaker and contactor located in the main power cabinet. The instructor has an emergency switch that enables him to shut down power to the subsystem.

#### 1.8.1.6 LMS Power Components.

##### 1.8.1.6.1 D-C Power.

The d-c power supplies for the communication equipments obtain primary a-c power from the peripheral equipment power buses. A 20-ampere circuit breaker protects the circuit that feeds the power supplies, as well as the power supplies. This slow-blow circuit breaker withstands high transient currents without premature opening, thus preventing nuisance tripping during turn-on. The a-c feed wires to the peripheral power supplies are twisted pairs to reduce electromagnetic effects and a-c coupling in the system.

The +26-volt d-c supply is a 0- to 40-volt supply, capable of delivering 10 amperes. This supply provides floating power for the carbon microphones used in the Communications Subsystem. The +13-volt d-c supplies are 0- to 20-volt supplies capable of delivering 15 amperes. They provide power to the peripheral equipment



cards. The +24-volt d-c supplies, capable of delivering 10 amperes, are also used to provide power to peripheral equipment cards. Power from the various d-c power supplies is routed to their respective 1/2-inch silver-plated bus bars via No. 4 AWG wire. The large wire ensures good regulation at the buses. From the bus bars, power is routed to card bins, as needed.

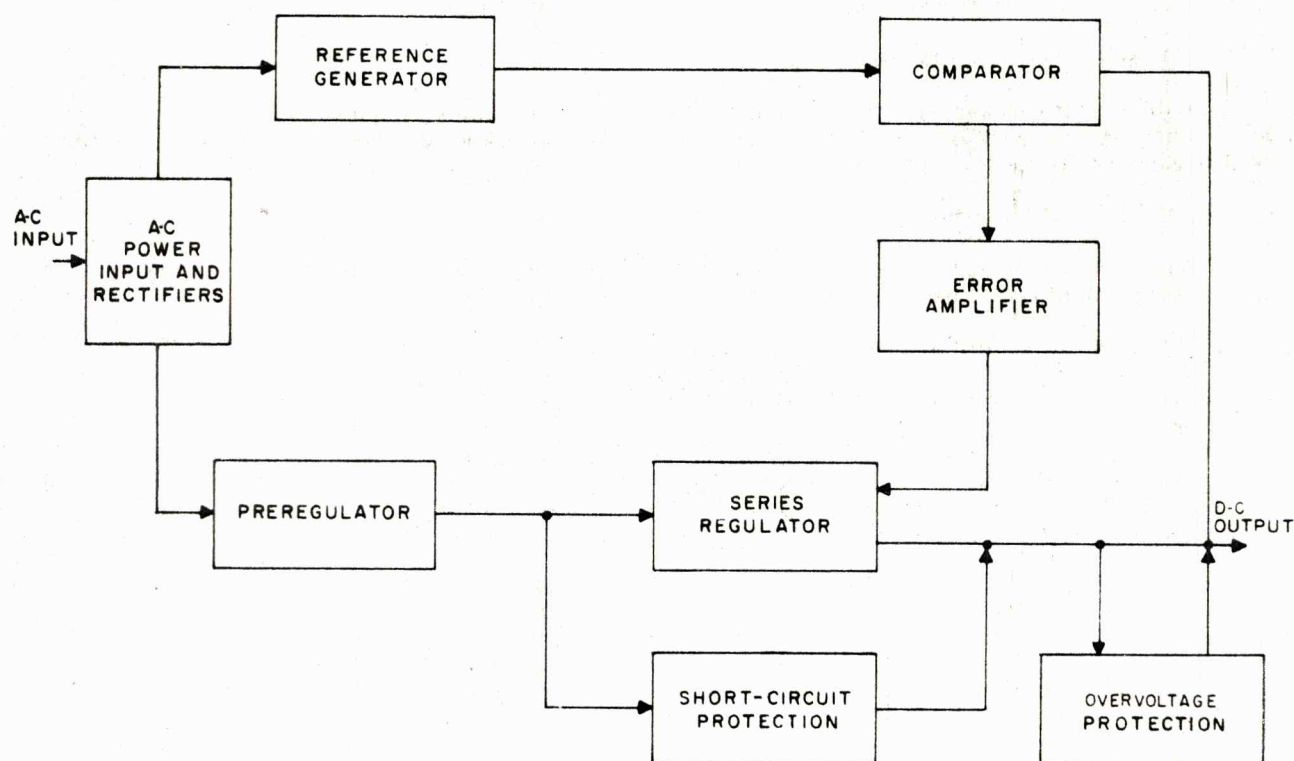
#### 1.8.1.6.2 Transistorized Power Supplies. (See figure 1-53.)

The transistorized power supplies provide adjustable-voltage, high-current sources for LMS functions requiring d-c power. The power supplies are basically identical; they are self-contained modular units, which are rack mounted within the peripheral equipment cabinets. The typical low-voltage supply transforms and rectifies the a-c input into a well-regulated, stable, and adjustable d-c output. The circuitry of the unit may be broken down as follows:

- Primary input
- Reference supply
- Preregulator
- Series regulator
- Comparator and error amplifier
- Overvoltage protection.

Input power is obtained through transformers, enabling the supply to operate with 120- or 208-volt a-c power sources, depending on jumper connections. The input circuit provides stepped-down ac for rectification.

The reference supply provides a stable, fixed voltage for the comparator, the error-sensing amplifier, and the constant-current generator. The output voltage of the reference supply is used to drive one side of the comparator. The other side of the comparator uses a Zener diode as a voltage reference. If there is a difference between the two sources, the difference amplifier will sense and amplify the difference, and adjust the voltage output accordingly.



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Figure 1-53. Typical Transistorized Power Supply, Block Diagram

The preregulator maintains the unregulated input voltage on the input filter capacitors at a suitable value compared to the output voltage, to lower the power dissipation across the series pass section. To accomplish this, silicon controlled rectifiers are fired at controlled points along the input sine wave to increase or decrease the potential to which the input capacitors may charge.

The preregulated d-c voltage from the silicon controlled rectifiers is directed through series pass transistors. The transistors are controlled by circuitry that causes them to act as variable resistors. Their overall resistance varies with the need of the power supply to increase or decrease its output voltage and current. A large current-handling throw-off resistor in parallel with the series pass transistors dissipates power within the series pass circuit under no-load conditions.

Voltage sensing and comparison are accomplished by the differential amplifier that compares a sample of the output voltage to the stable reference voltage. An unbalance, caused by a change in voltage at either sensing terminal, appears as a voltage change at the collector of the comparator amplifier transistors, where the amplified error voltage is used to adjust the series pass to correct the unbalance.

If the input voltage to the comparator amplifier becomes too high, the output voltage reference silicon controlled rectifier (SCR) is fired, placing an effective short circuit across the output terminals. This condition occurs if there is a failure in the series pass and the output voltage rises, or if there is a line transient or voltage feedback in the output line. Also, if there is a malfunction in the reference supply, the SCR gate control causes the overvoltage system to operate.

### 1.8.2 AIR-CONDITIONING.

A self-contained air-conditioning unit in the LMS heats and cools the LMS cabin, and the two pressure suits. An external source of compressed air and electric power are the only utilities required to operate this motor-driven, air-cooled, automatic air-conditioning unit.

### 1.8.3 CABLING.

Primary power is brought through nine 350 MCM cables (three per phase) into unit No. 36 (table 1-1), where it is fed to the top of circuit breaker CB2. From this point, the utility power is fed to fuses and circuit breaker CB1; then, to the utility buses in unit No. 37. Power is then distributed to convenience outlets and to the utility power supply. In addition, the primary power is fed through CB2 to three tubular bus bars: TB1, TB2, and TB3. The 400 CPS circuit breaker is located adjacent to these buses to allow a short run to the input side of the circuit breaker, through the breaker, and then out the bottom of the cabinet to the starter of the motor-generator set. Bus TB4 is the central ground. A circuit breaker and a contactor for four primary systems are located in unit No. 36.

Routing of the cables is described for one system only; routing is identical for the remaining three. A cable fed from each bus (TB1, TB2, and TB3 in unit No. 36) is routed across the bay to the top of circuit breaker CB1. These cables are then routed from the bottom of CB1 to contactor K1. From K1, the cables, along with a neutral cable, are routed along the side of the cabinet down through the bottom of the bay and over the bottom of unit No. 37. The cables are then attached to peripheral buses TB1, TB2, TB3, and TB4. From there, cables are routed to peripheral equipment.

## 1.9 INSTRUCTOR CONSOLE - CONTROLS AND DISPLAYS. (See figure 1-4.)

The general layout of the controls and displays maximizes instructor capability to control and monitor.

The repeater controls and displays are in the center console, directly in front of the instructors. The guidance computer keyboard display is in the same relative position as in the LM. The time displays are in the upper corners of the center console, within each instructor's line of sight. The corner segments of the console house the malfunction controls and displays. A malfunction insertion unit (MIU) is provided; separate circuit breaker failure panels are located to simulate the location of the actual circuit breaker panels in the LM. Controls that are used infrequently are on the left and right outboard consoles. The position indicator-recorder unit and the EVDE monitors are mounted on top of the center console; they are tilted forward to provide a viewing area perpendicular to the instructor's line of sight.

An instrument malfunction indicator light adjacent to each repeater instrument goes on when the related instrument fails. A TRUE READING switch in each functional group of instruments enables the instructor to read the true value of a failed parameter. The repeater indicators and displays are identical with those in the



simulated LM. To the extent practicable, repeater instrument panels duplicate instrument panels in the LM and are in the same relative position. Simulator controls and displays are divided into four categories as follows:

- Master controls
- Data acquisition system controls
- True trainee environment controls
- Visual controls and displays.

Master controls are on the PROBLEM CONTROL panel, in front of the mission coordinator. Simulator subsystem power and computer status are indicated on the SIMULATOR STATUS panel. Data acquisition system controls for the instructor console are on the RECORDERS panel on the right side of the center console. This panel contains the control switches for the two X-T recorders, one event recorder, two X-Y plotters, and the audio tape recorder. Flight crew environment controls and displays are on the TRUE TRAINEE ENVIRONMENT panel. This panel contains the switches, regulators, and indicators that control astronaut suit pressure and temperature and cabin pressure. The visual display controls on the EVDE VIDEO SELECT panels permit selection of the astronaut's EVDE-generated visual displays, for viewing on the left and right console TV monitors.

TIME DISPLAY units are at the top of the center console. Individual digital readouts are provided for GMT, problem time, elapsed time from separation, problem time from separation, and time from lunar touchdown. Individual event timers are also provided at each instructor position. The COMMANDER CIRCUIT BREAKER STATUS AND CONTROL panel and the SYSTEM ENGINEER CIRCUIT BREAKER STATUS CONTROL panel are on the left and right sides of the center console, respectively. A split-screen indicator with an alternate-action switch, on the instructor console, corresponds to each circuit breaker in the simulated LM cabin. The MALFUNCTION INSERTION UNIT and MALFUNCTION DISPLAY UNIT are on the lower part of the center console. These units enable the instructor to manually call up as many as 2,000 prestored malfunctions and to monitor as many as 15 computer- or instructor-generated malfunctions. A MALFUNCTION DISPLAY UNIT repeater is also provided at the telemetry console to keep the Telemetry Instructor informed as to malfunction status.

The spacecraft position indicator provides a means of determining the position of the simulated LM relative to celestial bodies, the Command and Service module (CSM) while separated from it, and the landing site during a simulated LM mission, as well as determining certain mission-oriented information. Annunciators that indicate the mission phase are included to define the mission mode. During the LMS independent mode of operation, the spacecraft position indicator aids the instructor in selecting a ground station for communication with the LM, and in determining when communication with the CSM is possible.

The hand controller, used in conjunction with a TV monitor, permits the instructor to change the attitude of the CSM. The instructor has the same TV monitor view that is provided in the flight crew's docking window. A left yaw movement of the CSM appears as a rightward movement across the screen when the simulated LM and CSM models face each other during docking maneuvers and the EVDE VIDEO SELECT switch is set to OVHD.

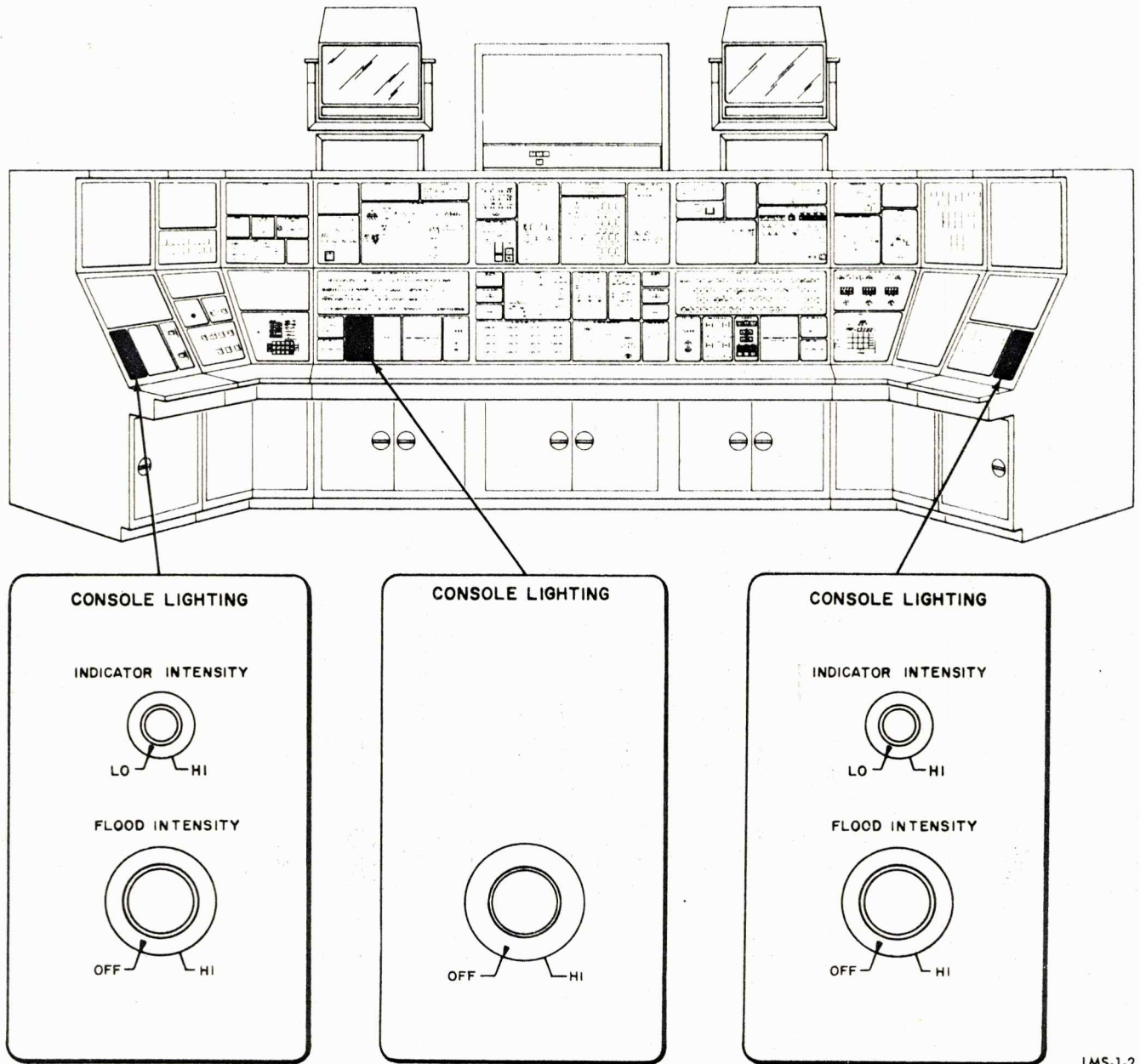
#### 1.9.1 CONSOLE LIGHTING PANELS. (See figure 1-54.)

Three CONSOLE LIGHTING panels (left, right, and center) control the intensity of the console floodlights and indicator lights. The left and right panels control floodlight and indicator light intensity; the center panel, only floodlight intensity. The controls of the CONSOLE LIGHTING panels are listed, with their function, in table 1-24.

#### 1.9.2 CONSOLE COMMUNICATION SYSTEM (CCS KEYSET) PANELS. (See figure 1-55.)

The console communication system provides voice communication for the simulator complex, as follows:

- Conference capability among operational positions of the simulator complex
- Communication between flight crew station and instructors
- Communication between the simulator complex, Mission Control Center (MCC), and other locations via interface with existing communications systems
- Communication between the LMS and the AMS
- Communications between instructors and support personnel



LMS-1-2

Figure 1-54. CONSOLE LIGHTING Panels



The console communication system consists of four keyset panels. Three are located at the instructor console; one, at the telemetry console. Keys with amber corners are only for monitoring the selected loop; any number of monitoring keys may be operated at one time. Pressing a key provides access to the associated loop and causes the key light to go on. The white keys are the talk/listen keys. Pressing a talk/listen key provides access to the associated loop and causes all other talk/listen keys in that loop to flash, and the station buzzers to sound. Pressing a second talk/listen key in the same loop changes the flashing signal to a steady light on all keys associated with the loop and silences the buzzers. Each talk/listen key is electrically interlocked with all other talk/listen keys so that only one key can be operated at one time. Pressing a second talk/listen key or the common RELEASE key causes the first talk/listen key to be released. Pressing a monitor key permits monitoring of the associated loop and causes the key light to go on. The monitor keys are not interlocked with other keys; any combination of monitor keys may be operated at one time. Pressing the RELEASE key disengages the established talk connection. Pressing the M.A. (multi access) key causes the talk interlock circuitry to be routed through a three-stage counter to permit actuation of as many as three talk/listen keys at one time; pressing a fourth talk/listen key or the common RELEASE key causes the three previously actuated talk/listen keys to be released and returns the interlock circuitry to normal. The RING key provides outgoing signaling within LMS complex and on intersite conference loops after the talk/listen key on the desired loop is pressed. The BUZZER CUT-OFF key is used to stop buzzer operation. The local conference keys (CONF-1, CONF-2, and CONF-3) are yellow and will have a steady light when pressed. These keys are not interlocked so that any combination of local conference keys may be operated at one time. All keys light when they are pressed.

The controls on the console communication system panels are listed, with their function in table 1-25 and 1-26.

### 1.9.3 COMMUNICATIONS CONTROL PANELS. (See figure 1-56.)

Three communications control panels provide conferencing and monitoring capability for personnel at the instructor and telemetry consoles. The controls of the communications control panels are listed, with their function, in table 1-27.

Table 1-24. CONSOLE LIGHTING Panels, Controls

Control	Function
INDICATOR INTENSITY control	Commander Instructor's control varies d-c voltage on all indicator lights on left side of instructor console. Systems Engineer Instructor's control affects right side of console.
FLOOD INTENSITY control	Commander Instructor's control varies intensity of fluorescent lamps located in left hood of console. Systems Engineer Instructor's control affects lamps located in right hood of console.
Flood intensity control (center panel)	Control mounted on center panel varies intensity of center panel hood lamps.

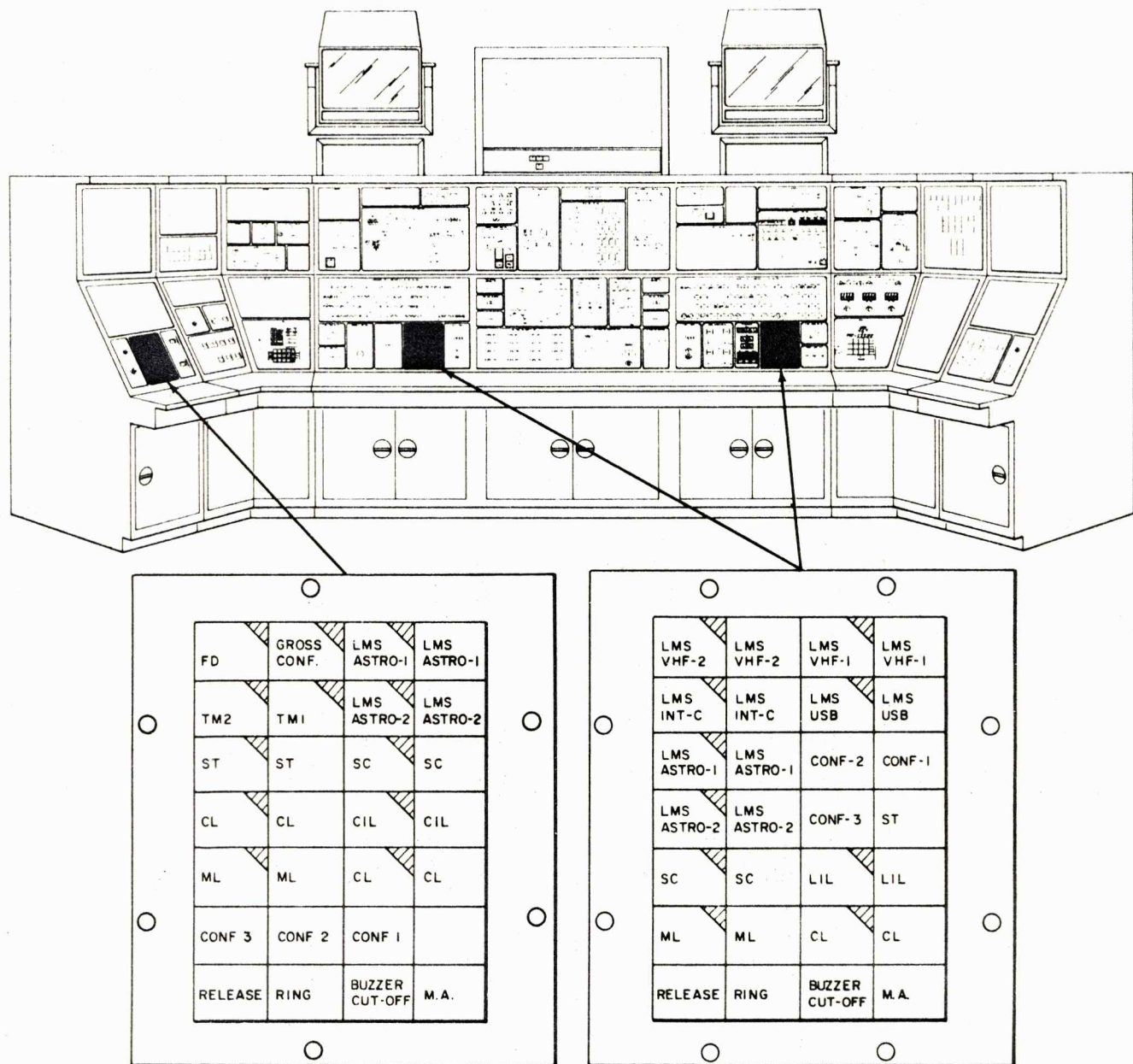
Table 1-25. Console Communications System (CCS Keyset) Commander's Instructor and Systems Engineer's Instructor Panels, Controls

Control	Function
LMS VHF-2 talk/listen and monitor keys	Provide conference capability via simulated LM VHF-B communications loop, and monitoring of loop
LMS VHF-1 talk/listen and monitor keys	Provide conference capability via simulated LM VHF-A communications loop, and monitoring of loop

Table 1-25. Console Communications System (CCS Keyset) Commander's Instructor and Systems Engineer's Instructor Panels, Controls (cont)

Control	Function
LMS INT-C talk/listen and monitor keys	Provide conference capability via simulated LM intercommunications loop between LMS personnel, and monitoring of loop
LMS USB talk/listen and monitor keys	Provide conference capability via simulated LM unified S-band communications loop, and monitoring of loop
LMS ASTRO-1 talk/listen and monitor keys	Provide conference capability between Commander, LMS Mission Coordinator, and LMS instructors, and monitoring of conference loop
LMS ASTRO-2 talk/listen and monitor keys	Provide conference capability between Systems Engineer, LMS Mission Coordinator, and LMS instructors, and monitoring of conference loop
CONF-1 talk/listen key	Provides conference capability via transfer loop 1 between LMS instructors, LMS Mission Coordinator, and AMS instructors
CONF-2 talk/listen key	Provides conference capability via transfer loop 2 between LMS instructors, LMS Mission Coordinator, and AMS instructors
CONF-3 talk/listen key	Provides conference capability via transfer loop 3 between LMS instructors, LMS Mission Coordinator, and AMS instructors
ST talk/listen key	Provides conference capability via simulator telemetry communications loop between telemetry instructor and simulator control area (SCA) personnel
SC talk/listen and monitor keys	Provide conference capability via simulator coordinator communications loop between LMS instructors and SCA personnel, and monitoring of loop
LIL talk/listen and monitor keys	Provide conference capability via LM instructors communications loop between LMS instructors, and monitoring of loop
ML talk/listen and monitor keys	Provide conference capability (for purpose of maintaining LMS) via maintenance loop between LMS instructors, LMS Mission Coordinator, and computer complex personnel, and monitoring of loop
CL talk/listen and monitor keys	Provide conference capability via computer loop between LMS instructors, LMS Mission Coordinator, and computer complex personnel, and monitoring of loop
M. A. key	Provides for simultaneous access to two or three selected talk/listen loops
BUZZER CUT-OFF key	Stops buzzer operation
RING key	Establishes buzzer signal on LMS complex and selected intersite loops after appropriate talk/listen key is pressed
RELEASE key	Releases established talk/listen key





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Figure 1-55. Console Communication System (CCS Keyset) Panels

Table 1-26. Console Communications System (CCS Keyset) Mission Coordinator's Panel, Controls

Control	Function
FD monitor key	Provides LMS Mission Coordinator with monitor capability of flight director's loop during simulated mission
GOSS CONF key	Provides conference capability with Goddard Space Flight Center, Greenbelt, Maryland, hereby tying LMS communications into the Manned Space Flight Network (MSFN)
LMS ASTRO-1 talk/listen and monitor key	Provide conference capability between Commander, LMS instructors, and LMS Mission Coordinator, and monitoring of conference loop
LMS ASTRO-2 talk/listen and monitor keys	Provide conference capability between Systems Engineer, LMS instructors, and LMS Mission Coordinator, and monitoring of conference loop
TM 1 monitor key	Enables LMS Mission Coordinator to monitor communications between LMS Telemetry Instructor and MCC telemetry personnel (communications loop 1)
TM 2 monitor key	Enables LMS Mission Coordinator to monitor communications between LMS Telemetry Instructor and MCC telemetry personnel (communications loop 2)
ST talk/listen and monitor keys	Provides conference capability via simulator telemetry communications loop between Telemetry Instructor and simulator control area (SCA) personnel, and monitoring of loop
SC talk/listen and monitor keys	Provide conference capability via simulator coordinator communications loop between LMS instructors and SCA personnel, and monitoring of loop
ML talk/listen and monitor keys	Provide conference capability (for purpose of maintaining LMS) via maintenance loop between LMS instructors, LMS Mission Coordinator, and computer complex personnel, and monitoring of loop
CL talk/listen and monitor keys	Provide conference capability via computer loop between LMS instructor console personnel and computer complex personnel, and monitoring of loop
CIL talk/listen and monitor keys	Provide conference capability via computer and instructor's loop between LMS instructor console personnel and computer complex personnel, and monitoring of loop
CONF-1 talk/listen key	Provides conference capability via transfer loop 1 between LMS instructors, LMS Mission Coordinator, and AMS instructors
CONF-2 talk/listen key	Provides conference capability via transfer loop 2 between LMS instructors, LMS Mission Coordinator, and AMS instructors



Table 1-26. Console Communications System (CCS Keyset) Mission Coordinator's Panel, Controls (cont)

Control	Function
CONF-3 talk/listen key	Provides conference capability via transfer loop 3 between LMS instructors, LMS Mission Coordinator, and AMS instructors
M. A. key	Provides for simultaneous access to two or three selected talk/listen loops
BUZZER CUT-OFF key	Stops buzzer operation
RING key	Establishes buzzer signal on LMS complex and selected intersite loops after appropriate talk/listen key is pressed
RELEASE key	Releases established talk/listen key

Table 1-27, Communications Control Panels, Controls

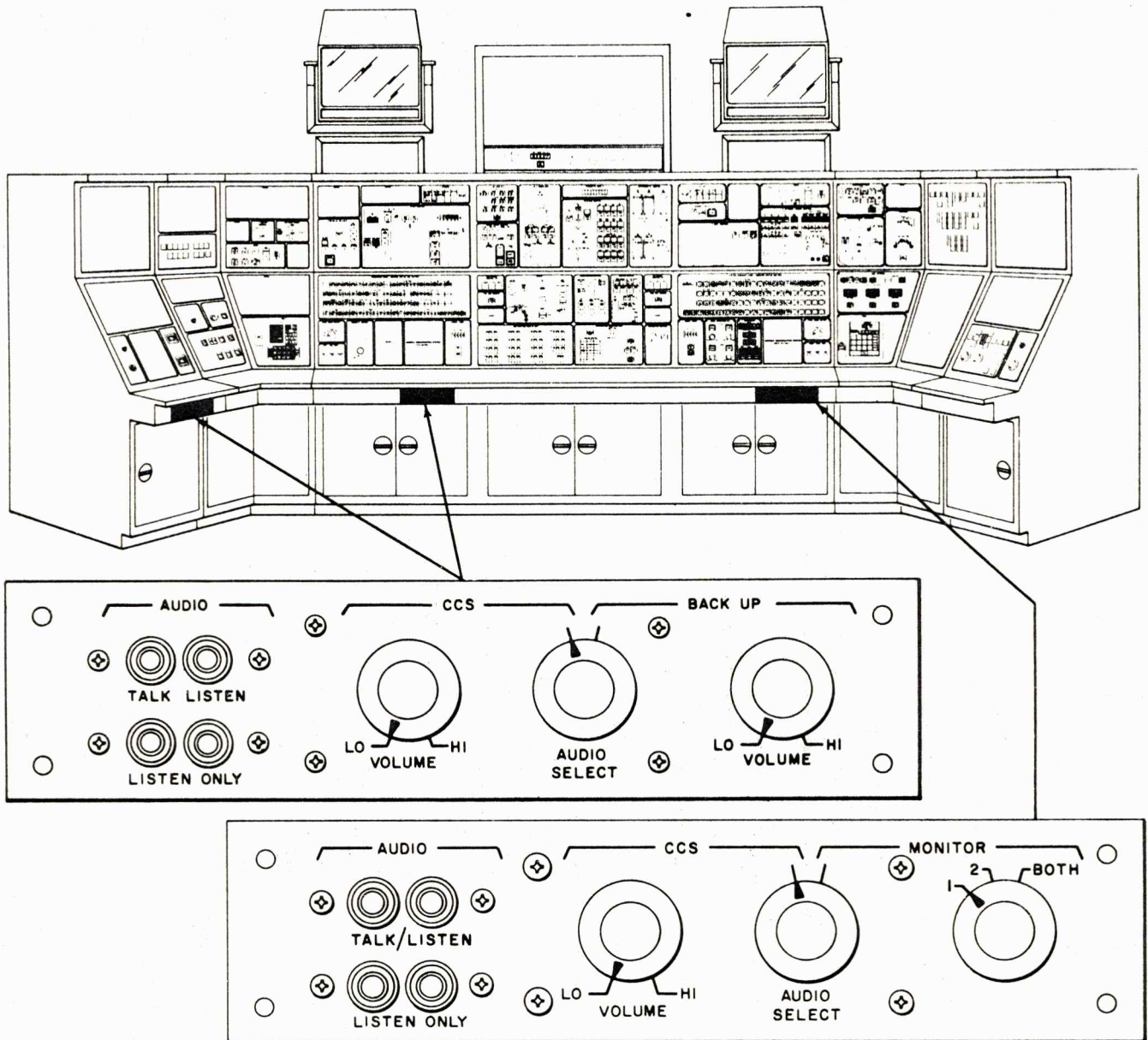
Control	Function
TALK/LISTEN jack	Accepts plug-in headset/microphone combination
LISTEN ONLY jack	Accepts plug-in monitor headset
VOLUME control	Adjusts volume of sound in headset
AUDIO SELECT switch (right side panel)	Selects CCS or monitor loop
MONITOR selector switch (right side panel)	Selects astronaut No. 1 loop, astronaut No. 2 loop, or both astronaut-monitoring loops
AUDIO SELECT switch (left side panels)	Selects CCS or backup loop
Backup VOLUME control (left side panels)	Adjusts volume in backup loop

## 1.9.4 EMERGENCY PANEL. (See figure 1-57.)

The EMERGENCY panel enables removal of primary power from the EVDE and LMS complex. The controls of the EMERGENCY panel are listed, with their function, in table 1-28.

Table 1-28. EMERGENCY Panel, Controls

Control	Function
EMER STOP switch	Pressing switch removes primary power, except 115-volt, 60-cps utility power, from trainer.
EVDE STOP switch	Pressing switch removes primary power from EVDE.



LMS-1-55

Figure 1-56. Communications Control Panels

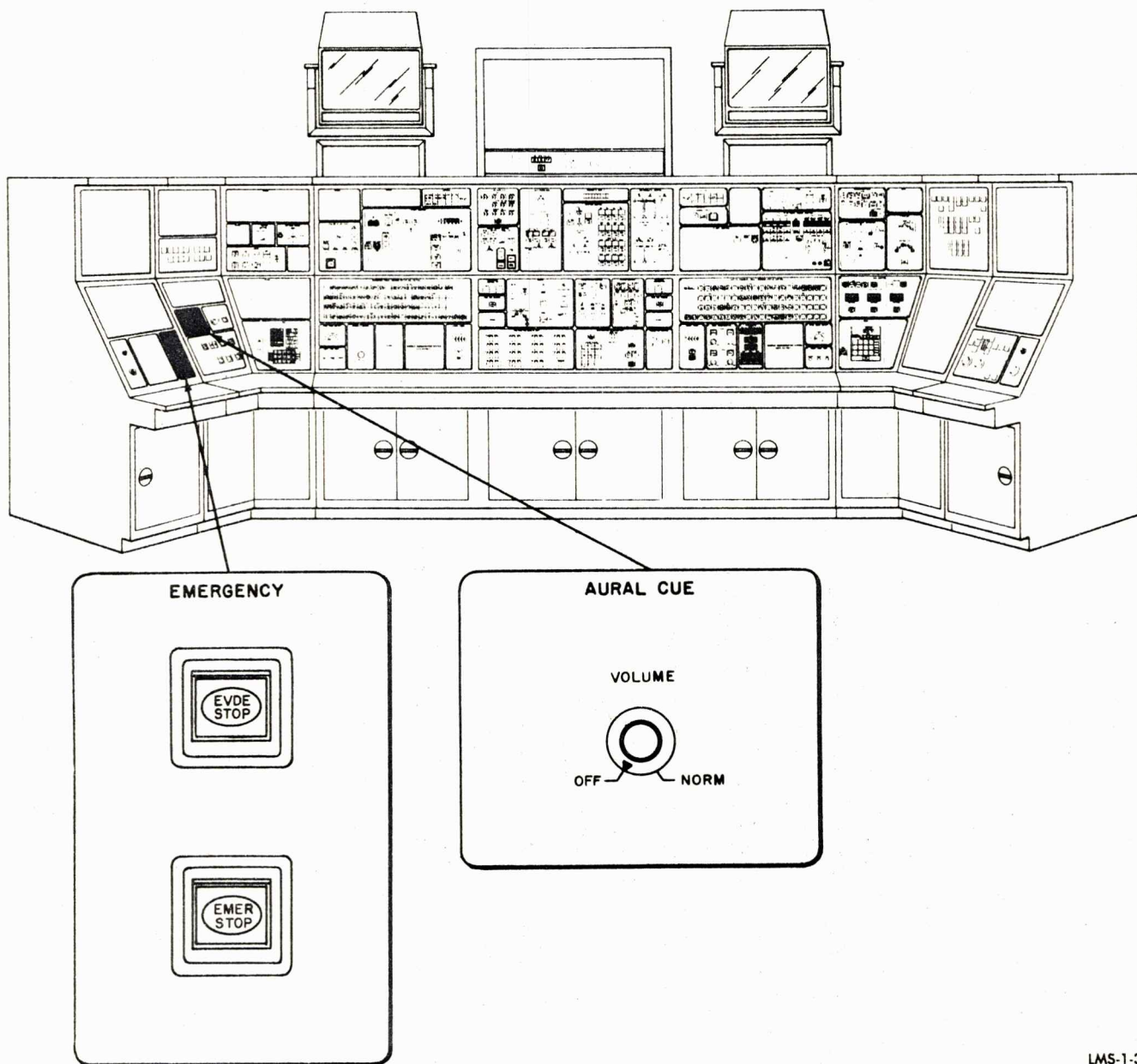
## 1.9.5 AURAL CUE PANEL. (See figure 1-57.)

The AURAL CUE panel controls the audio level in the simulated LM cabin, from zero to full volume. The control of the AURAL CUE panel is listed, with its function, in table 1-29.

Table 1-29. AURAL CUE Panel, Control

Control	Function
VOLUME control	Control varies level of aural cue signals to cabin loudspeakers, from zero to full volume.



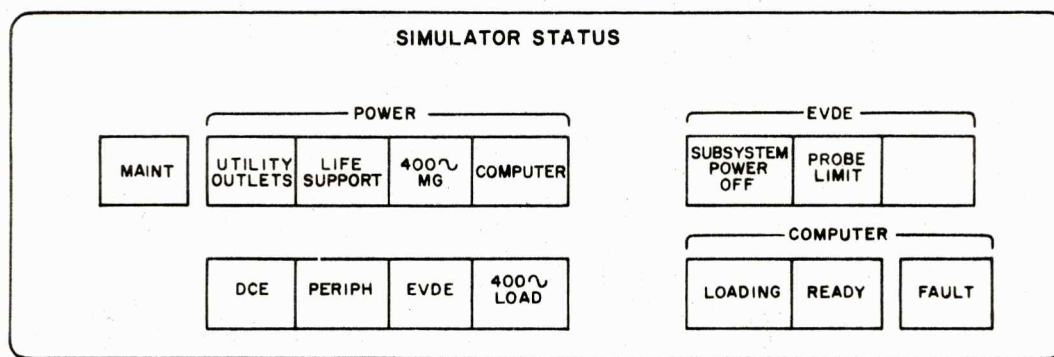
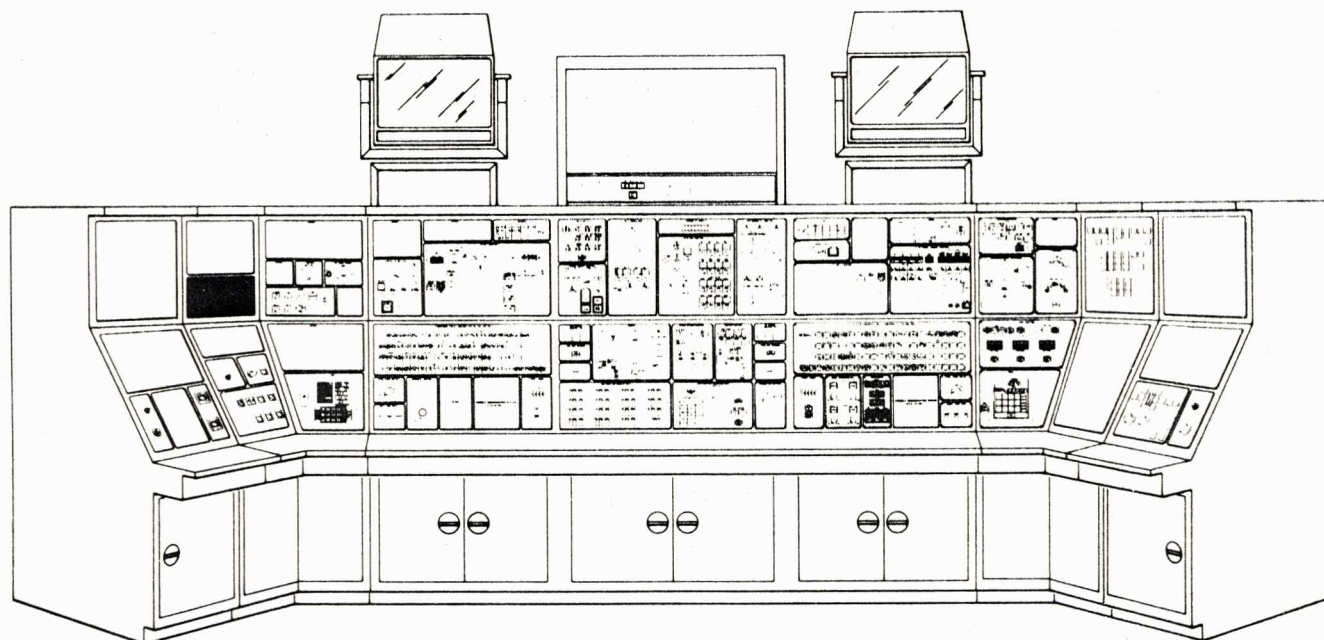


LMS-1-3

Figure 1-57. EMERGENCY and AURAL CUE Panels

#### 1.9.6 SIMULATOR STATUS PANEL. (See figure 1-58.)

The SIMULATOR STATUS panel displays major subsystem power status, EVDE power and probe limits, and computer status. The displays of the SIMULATOR STATUS panel are listed, with their function, in table 1-30.



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Figure 1-58. SIMULATOR STATUS Panel

Table 1-30. SIMULATOR STATUS Panel, Displays

Display	Function
MAINT indicator	When illuminated, indicates primary power is off and maintenance is in progress
POWER indicators	
UTILITY OUTLETS	When illuminated, indicate primary (60-cps) power available to major subsystems of LMS
LIFE SUPPORT	
400 ~ MG	
COMPUTER	
DCE	
PERIPH	
EVDE	
400 ~ LOAD	



Table 1-30. SIMULATOR STATUS Panel, Displays (cont)

Display	Function
EVDE indicators	
SUBSYSTEM POWER OFF	When illuminated, indicates that power is not available to one or more of seven EVDE subsystems (left window, right window, overhead window, telescope, landing/ascent image, and rendezvous/docking image)
PROBE LIMIT	Illuminated when R/D or L/A optical probes actuate any of their limit switches
COMPUTER indicators	
LOADING	When illuminated, indicates that computer peripheral equipment (magnetic tape units, card reader, etc) is being used to load computers; goes out when loading is complete
READY	Illuminated when computer is not being loaded (LOADING indicator light is off) and DCE is connected to computer
FAULT	When illuminated, indicates that off-line diagnostics have uncovered fault; goes out when fault is corrected

## 1.9.7 INTERFACE CONTROL PANEL. (See figure 1-59.)

The INTERFACE CONTROL panel provides the capability of interface operation for various combinations of the AMS and MCC with the LMS. The control of the INTERFACE CONTROL panel is listed, with its function, in table 1-31.

Table 1-31. INTERFACE CONTROL Panel, Control

Control	Function
MODE SELECTOR switch	Switch permits instructor to select mode of operation for problem. LMS ONLY position is for LMS independent operation. Other positions permit operation for various combinations of AMS and MCC with LMS

## 1.9.8 PROBLEM CONTROL PANEL. (See figure 1-59.)

The PROBLEM CONTROL panel is used to establish operational phases in the running of a mission program and to select and display initial conditions. The controls and displays of the PROBLEM CONTROL panel are listed, with their function, in table 1-32.

Table 1-32. PROBLEM CONTROL Panel, Controls and Displays

Control or Display	Function
READY/RUN light switch	Pressing pushbutton causes computer to go into run mode. READY light goes on when switch is actuated. RUN light goes on when next minute pulse is received. Problem begins at value of existing condition. For example, after pressing FREEZE pushbutton, instructor can use READY/RUN switch to "thaw" problem.

Table 1-32. PROBLEM CONTROL Panel, Controls and Displays (cont)

Control or Display	Function
<p>FREEZE light switch</p> <p>FAST TIME light switch (step ahead)</p> <p>CMPTR STORE light switch</p> <p>L/A IMAGE LEFT/RIGHT light switch</p> <p>INITIAL CONDITIONS light switch</p> <p>RESET light switch</p>	<p>Problem then continues from conditions that exist at time of freeze. However, if instructor wishes to resume value of INITIAL COND thumbwheel setting, he can do so by pressing RESET switch before READY/RUN switch.</p> <p>Causes computer to enter freeze mode. In freeze mode, integration and time-varying functions are held constant.</p> <p>Causes computer to go into speed 32 times real time. Switch permits instructor to hasten routine parts of mission.</p> <p>Causes computer to store initial-condition type of data that exist when switch is actuated. Initial conditions are stored in computer core.</p> <p>Permits switching landing and ascent image from left window to right window. (MEP is switched at same time, providing image for opposite window.)</p> <p>Establishes one of several available initial conditions to be loaded from magnetic tape into main frame computer, when set to appropriate number. Selected initial condition is constantly displayed. Simulator "resets" to initial condition selected.</p> <p>Enters initial condition requirement into computer. When actuated, RESET light and FREEZE light go on simultaneously. After initial conditions are transferred from magnetic tape to computer, RESET light goes out. READY/RUN switch can then be pressed. Controls in LMS cabin must be set to appropriate initial-condition settings. Instructor resets recorder modes, initial conditions, malfunctions, etc, as appropriate. Expendable items such as tape cartridges are replenished, as necessary.</p>

## 1.9.9 LIGHTING PANELS. (See figure 1-60.)

Two LIGHTING panels (one for the Commander; the other, for the Systems Engineer) contain repeater lights of LMS cabin lighting control panel switch positions. The displays of the LIGHTING panels are listed, with their function, in table 1-33.

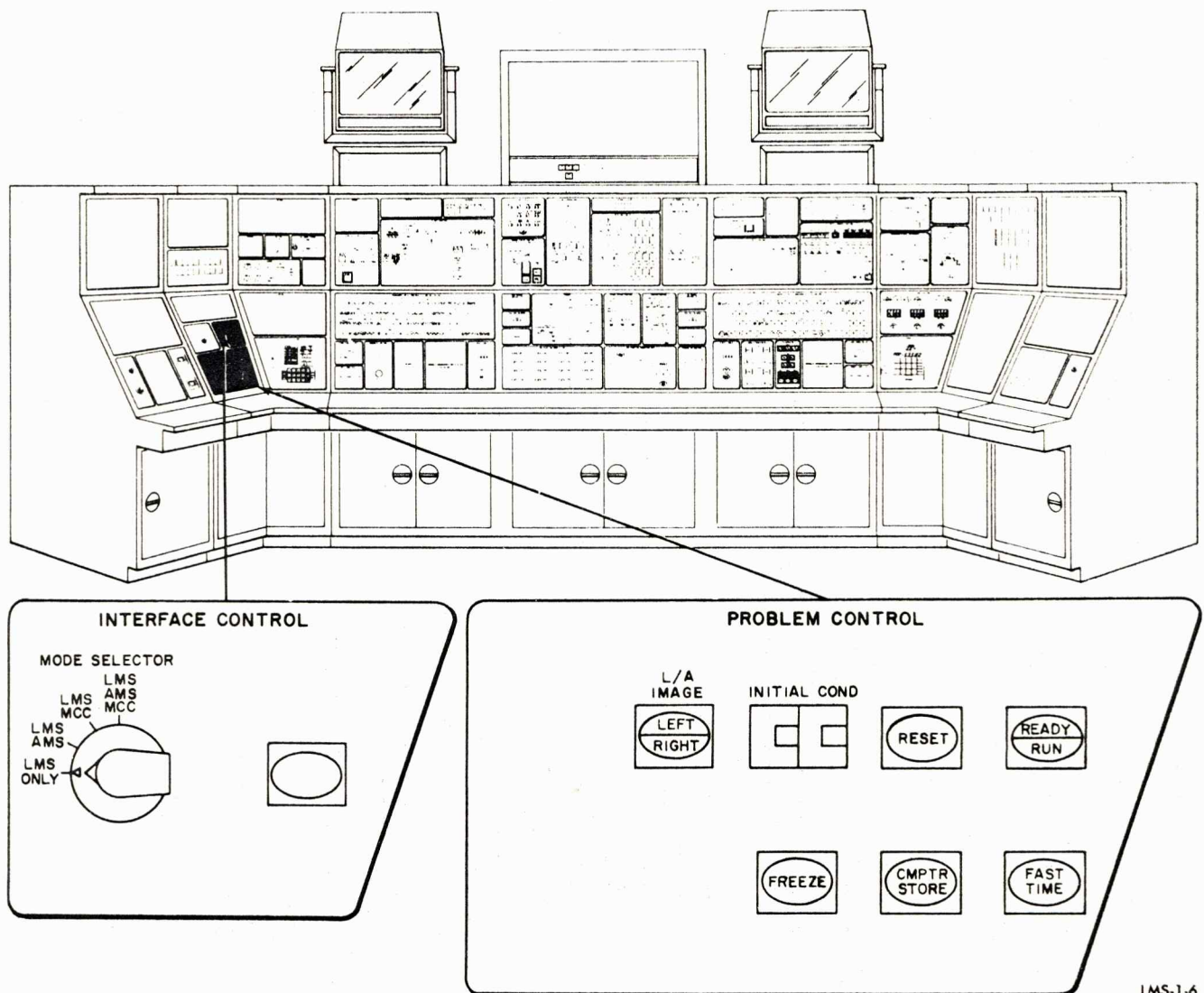
Table 1-33. Commander's and Systems Engineer's LIGHTING Panels, Displays

Display	Function
<p>OVERRIDE control repeater lights (CDR)</p> <p>ANUN</p> <p>NUM</p> <p>INTEG</p> <p>SIDE PANELS switch repeater light (CDR)</p>	<p>Indicates brightness of annunciators in caution and warning array, of component caution lights, and of electroluminescent (EL) numeric readouts</p> <p>Indicates brightness of low-level EL integrally illuminated markings and display</p> <p>Indicates control of lighting of Commander's side panel, independently of lighting of forward panel</p>



Table 1-33. Commander's and Systems Engineer's LIGHTING  
Panels, Displays (cont)

Display	Function
EXTERIOR LTG tracking repeater lights (SE)	
DOCK	Indicates docking lights are energized
DIM	Indicates tracking light is energized to 1% of full brightness
BRT	Indicates tracking light is energized to full (100%) brightness
LAMP/TONE TEST switch repeater lights (SE)	
ALM TONE	Indicates test of lamps in MASTER ALARM switch- light on Commander's and Systems Engineer's panels, and audible warning tone
C/W 1	Indicates test of lamps in first bank of caution and warning annunciators
EPB C/W 2	Indicates test of lamps in engine START and STOP button and in second bank of caution and warning annunciators
C/W 3	Indicates test of lamps in third bank of caution and warning annunciators
C/W 4	Indicates test of lamps in fourth bank of caution and warning annunciators
COMP	Indicates test of lamps in component caution indicators
SIDE PANELS switch repeater light (SE)	Indicates control of lighting on Systems Engineer's side panel
FLOOD switch repeater light	
ON	Indicates regulation of Systems Engineer's side panel floodlights with FLOOD control, INTEGRAL control, and INTEGRAL OVERRIDE switch
PARTIAL	Indicates partial regulation of side panel floodlights



LMS-1-6

Figure 1-59. INTERFACE CONTROL and PROBLEM CONTROL Panels

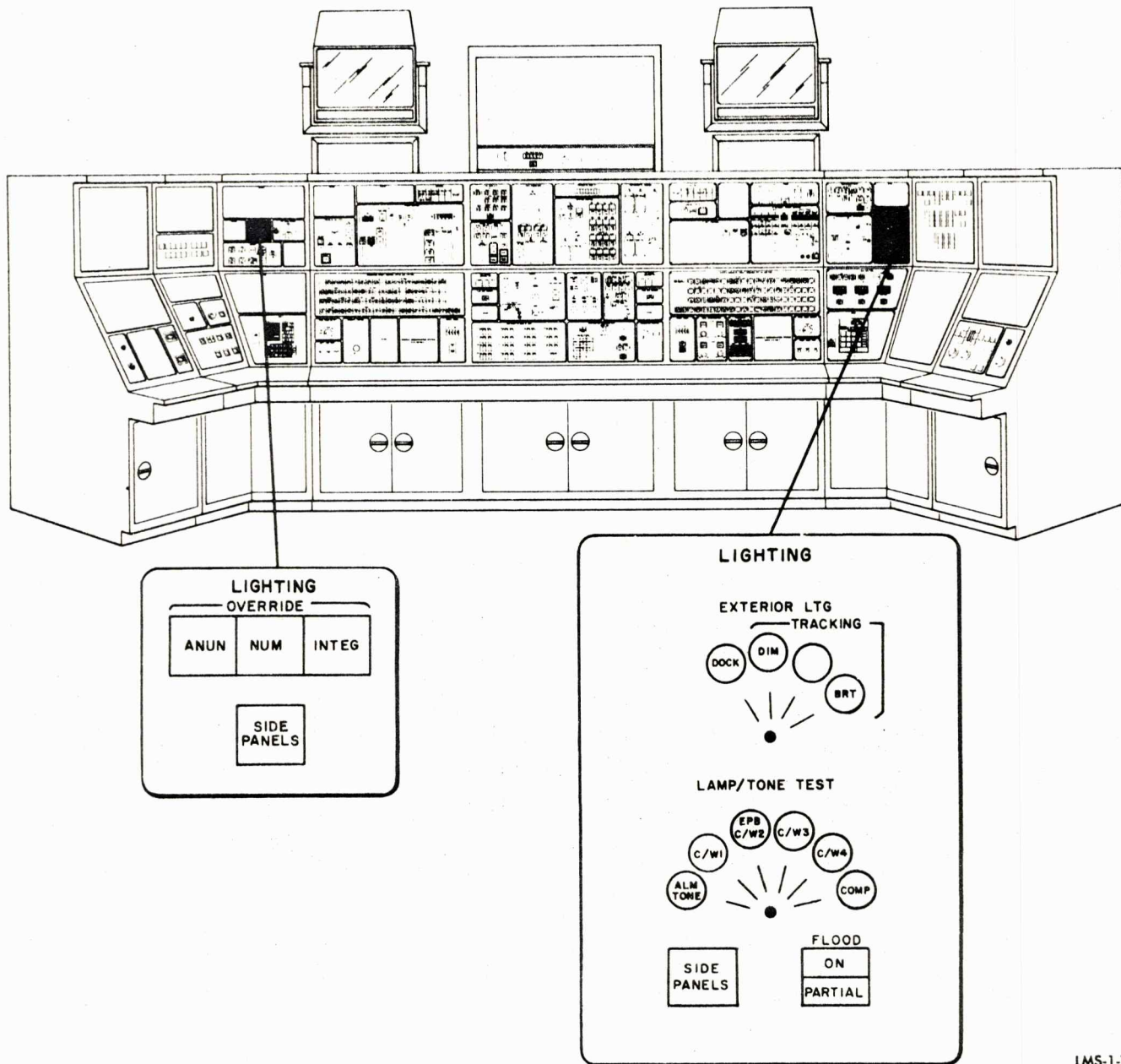
## 1.9.10 AOT MARK ERROR PANEL. (See figure 1-61.)

The AOT MARK ERROR panel displays the astronauts' sighting error of two stars. The controls and displays of the AOT MARK ERROR panel are listed, with their function, in table 1-34.

Table 1-34. AOT MARK ERROR Panel, Controls and Displays

Control or Display	Function
MRAD STAR 1 and MRAD STAR 2 displays	Indicate error difference between sighted value obtained by astronauts and true value obtained from LMS computer for two stars. Displays indicate from 0 to 99 milliradian.
RESET pushbutton	Clears digit error displays
REJECT control repeater light	Goes on when astronaut presses REJECT pushbutton in LMS cabin



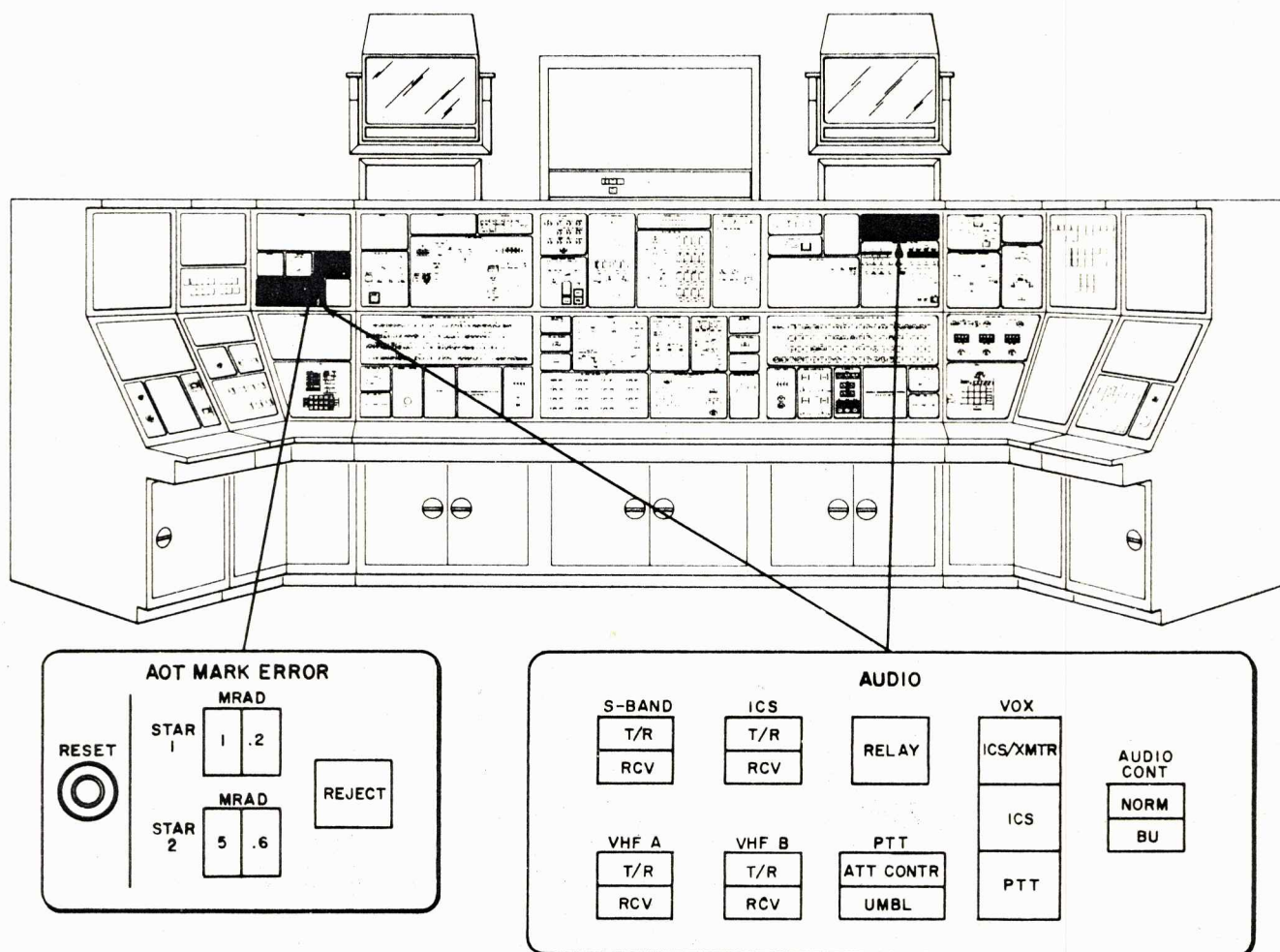


LMS-1-7

Figure 1-60. Commander's and Systems Engineer's LIGHTING Panels

## 1.9.11 AUDIO PANELS. (See figure 1-61.)

The AUDIO panels contains repeater lights of the switch positions in the LMS cabin, at the Commander and Systems Engineer AUDIO panels. The displays of the AUDIO panels are listed, with their function, in table 1-35.



LMS-1-8

Figure 1-61. AOT MARK ERROR and AUDIO Panels



Table 1-35. AUDIO Panels, Displays

Display	Function
S-BAND switch repeater lights	
T/R	Indicates routing of received S-band audio to head-set amplifier and routing of mike amplifier outputs to PMP for transmission via S-band equipment
RCV	Indicates routing of received S-band audio to headset amplifier
VHF A switch repeater lights	
T/R	Indicates routing of received VHF A audio to head-set amplifier and routing of mike amplifier outputs to PMP for transmission via VHF equipment. VOX keying voltage is routed to VHF A transmitter
RCV	Indicates routing of received VHF A audio to head-set amplifier
ICS switch repeater lights	
T/R	Indicates routing of mike amplifier outputs to ICS bus and, then, to headset
RCV	Indicates routing of audio signals on ICS bus to headsets
RELAY switch repeater light	Indicates voice conference capability between earth, LM, and EVA is established; indicates received EVA biomed data is relayed to earth. Also indicates, in event of failure of CSM-to-earth S-band link, the VHF received from CSM is relayed to earth via LM S-band transmitter
AUDIO CONT switch repeater light	
NORM	Indicates selection of normally operating audio center
BU	Indicates selection of alternate audio center
VOX switch repeater lights	
ICS/XMTR	Indicates VOX control circuit in audio center is enabled to key intercom and selected transmitter(s)
ICS	Indicates VOX control circuitry in audio center is enabled to key intercom only; selected transmitter(s) is keyed only by PTT switches
PTT	Indicates VOX control circuitry is disabled and intercom and selected transmitter(s) are keyed only by PTT switches

Table 1-35. AUDIO Panels, Displays (cont)

Display	Function
VHF B switch repeater lights	
T/R	Indicates routing of received VHF B audio to headset amplifier and routing of mike amplifier outputs to PMP for transmission via VHF equipment. Indicates VOX keying voltage is routed to VHF B transmitter
RCV	Indicates received VHF B voice routed to headset amplifier
PTT switch repeater lights	Indicate keying of intercom and/or selected transmitter(s), depending on setting of VOX switch
UMBL	Indicates activation of momentary pushbutton on each astronaut's communication umbilical.
ATT CONTR	Indicates actuation of push-to-talk pushbuttons on each astronaut's attitude controller

## 1.9.12 DSKY PANEL. (See figure 1-62.)

The DSKY panel is identical with the Commander's DSKY panel. The instructor may set in, or read out, guidance data in a manner identical with that of the flight crew. The controls and displays of the DSKY panel are listed, with their function, in table 1-36.

Table 1-36. DSKY Panel, Controls and Displays

Control or Display	Function
IMU CAGE switch	Used to avoid gimbal lock condition
ON	Enables IMU cage mode of operation
OFF	Stops IMU cage mode of operation
UPLINK ACTY indicator	Not used for manned flights
TEMP indicator	When lit, indicates that stable member temperature has exceeded its limit by $\pm 4^{\circ}$ F
	Operates when LGC is in standby mode
GIMBAL LOCK indicator	When lit, indicates that middle gimbal has driven through angle greater than $\pm 70$ from its zero position (When middle gimbal angle exceeds $\pm 85^{\circ}$ from its zero position, LGC automatically commands course align mode in ISS to prevent gimbal oscillation. Indicator lamp is then energized.)
PROG indicator	When lit, indicates that program check has failed (Indicator is controlled by computer program.)
RESTART indicator	When lit, indicates:  that word has been incorrectly transferred from memory - parity fail



Table 1-36. DSKY Panel, Controls and Displays (cont)

Control or Display	Function
RESTART indicator (cont)	<p>that computer is in endless control loop - TC trap</p> <p>that computer has been interrupted for 30 msec - RUPT lock</p> <p>that computer has not accomplished new job within 1.28 seconds</p> <p>that alarm has been generated by program control</p>
OPR ERR indicator	When lit, indicates that keyboard and display program has encountered improper operating conditions
TRACKER indicator	When lit, indicates rendezvous radar CDU failure or that improper data is received from rendezvous radar
KEY REL indicator	When lit, indicates that internal program has attempted to use DSKY and found it busy (Indicator is modulated by flash signal LGC is asking to be released)
STBY indicator	When lit, indicates that computer is in standby condition (Indicator lamp is deenergized if LGC is in operate mode.)
NO ATT indicator	When lit, indicates that ISS is not suitable for use as attitude reference (Indicator lamp is energize when LGC is in operate mode and there is no inertial reference.)
COMP ACTY indicator	When lit, indicates that LGC is in program other than dummy job and that LGC is not in standby mode
PROG display indicator	When lit, indicates program is being processed by LGC
VERB display indicator	When lit, indicates verb code entered at keyboard or commanded by LGC
NOUN display indicator	Indicates noun code entered at keyboard or commanded by LGC
Data display indicators	Indicate numerical data entered at keyboard or commanded by LGC (Sign is associated with data displayed if they are decimal form.)
VERB pushbutton	Conditions LGC to interpret next two numerical characters as verb code and extinguishes verb numerical display
NOUN pushbutton	Conditions LGC to interpret next two numerical characters as noun code and extinguishes noun numerical display
CLR pushbutton	Clears data contained in data displays (Pressing pushbutton clears data display being used. Successive pressing of pushbutton clears other two displays.)
STBY pushbutton	When pressed for first time, commands LGC to standby mode. (Pressing pushbutton again commands LGC to resume regular operation.)

Table 1-36. DSKY Panel, Controls and Displays (cont)

Control or Display	Function
KEY REL pushbutton	Releases DSKY displays initiated by keyboard action, so that information supplied by LGC program may be displayed
ENTR pushbutton	Informs LGC that assembled data are complete and that requested function is to be executed
RSET pushbutton	Turns off alarm conditions on DSKY if condition has been corrected
0 through 10 pushbutton	Enter numerical data, noun codes, and verb codes into LGC
+ and - pushbutton	Inform LGC that following numerical data are decimal, and indicate sign of data

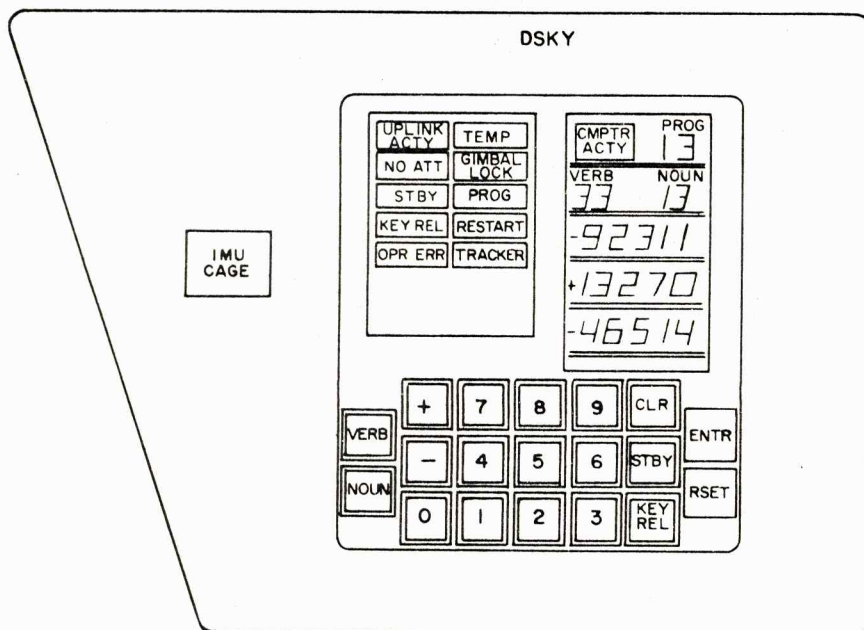
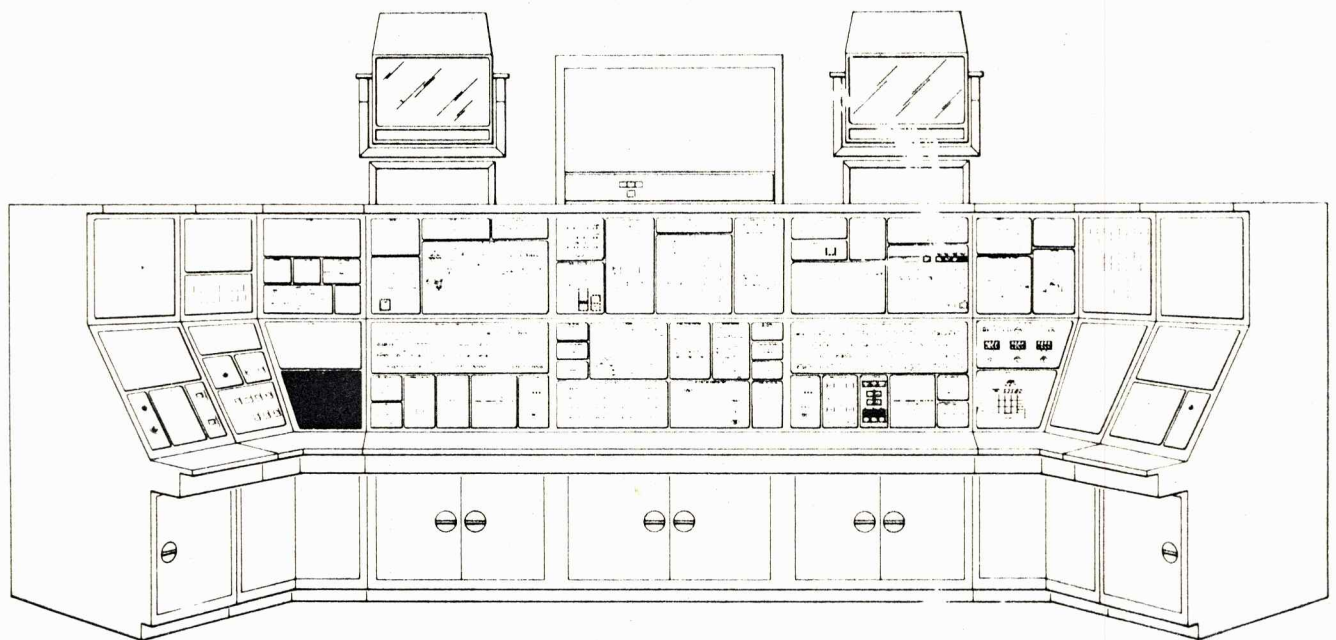


Figure 1-62. DSKY Panel



### 1.9.13 WARNING PANEL. (See figure 1-63.)

The WARNING panel contains repeater lights of the Commander's warning annunciator panel and MASTER ALARM light. The displays of the WARNING panel are listed, with their function, in table 1-37.

### 1.9.14 CAUTION PANEL. (See figure 1-63.)

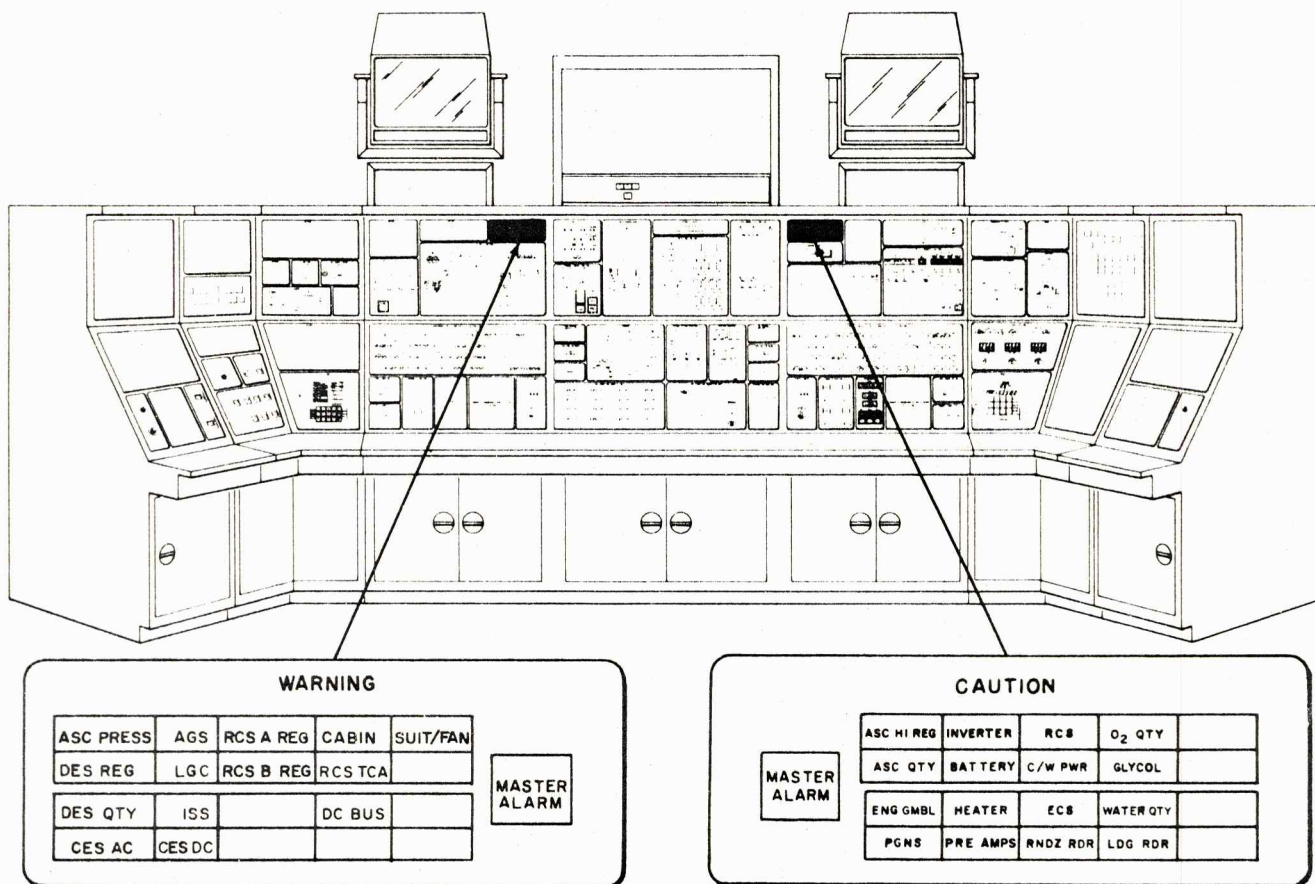
The CAUTION panel contains repeater lights of the Systems Engineer's caution annunciator panel and MASTER ALARM light. The displays of the CAUTION panel are listed, with their function, in table 1-38.

### 1.9.15 EXPLOSIVE DEVICES PANEL. (See figure 1-64.)

The EXPLOSIVE DEVICES panel contains repeater lights of the switch positions and flag indications on the Commander's EXPLOSIVE DEVICES panel. The displays of the EXPLOSIVE DEVICES panel are listed, with their functions, in table 1-39.

### 1.9.16 ENGINE THRUST CONTROL AND ENGINE THRUST PANELS. (See figure 1-64.)

The ENGINE THRUST CONTROL and ENGINE THRUST panel contains repeater lights and a repeater indicator of the Commander's thrust control switches and indicator. The displays of the ENGINE THRUST CONTROL and ENGINE THRUST panels are listed, with their functions, in table 1-40.



LMS-1-11

Figure 1-63. WARNING and CAUTION Panels

Table 1-37. WARNING Panel, Displays

Display	Function
ASC PRESS warning repeater 1 light	Lights if pressure in either ascent helium tank drops below 3,000 psia before ascent pressurization or if blanket pressure in fuel or oxidizer lines at bi-propellant valves drops below 120 psia
DES REG warning repeater light	Lights if, after pressurization, pressure in descent helium lines downstream of regulators exceeds 260 psia or drops below 220 psia
LGC warning repeater light	Lights if failure occurs in LM guidance computer power supplies, counter, or scaler
ISS warning repeater light	Lights if IMU, PIPA, or CDU fails
DES QTY warning repeater light	Lights if, before staging, descent tanks contain fuel for approximately 10 seconds of burning time
CES AC warning repeater light	Lights if a-c voltage in control electronics section of GN&CS is out of tolerance
CES DC warning repeater light	Lights if d-c voltage of any d-c power supply in control electronics section of GN&CS is out of tolerance
AGS warning repeater light	Lights if failure occurs in any AGS power supply or if fail signal is generated by AEA test assembly
RCS TCA warning repeater light	Lights if there is a primary coil command to fire specific thruster, but no chamber pressure is experienced at that thruster; also lights if opposing colinear jets are on simultaneously
RCS A REG warning repeater light	Lights when pressure sensed by pressure transducer downstream of system A pressure regulators exceeds 195 psia or drops below 175 psia
RCS B REG warning repeater light	Lights when pressure sensed by pressure transducer downstream of system B pressure regulators exceeds 195 psia or drops below 175 psia
DC BUS warning repeater light	Lights if d-c voltage drops below 26.5 volts on either Commander's or Systems Engineer's d-c bus
CABIN warning repeater light	Lights if cabin pressure drops below 4.6 psia
SUIT/FAN warning repeater light	Lights if pressure within suit drops below 3.2 psia or if suit circulating fan No. 2 fails
MASTER ALARM repeater light (all subsystems - CDR and SE)	Lights by sensor signal with caution/warning light(s)
<div style="border: 1px solid black; padding: 5px; text-align: center;">NOTE</div> <p>An audible tone is initiated in conjunction with MASTER ALARM repeater light and caution/warning light(s)</p>	



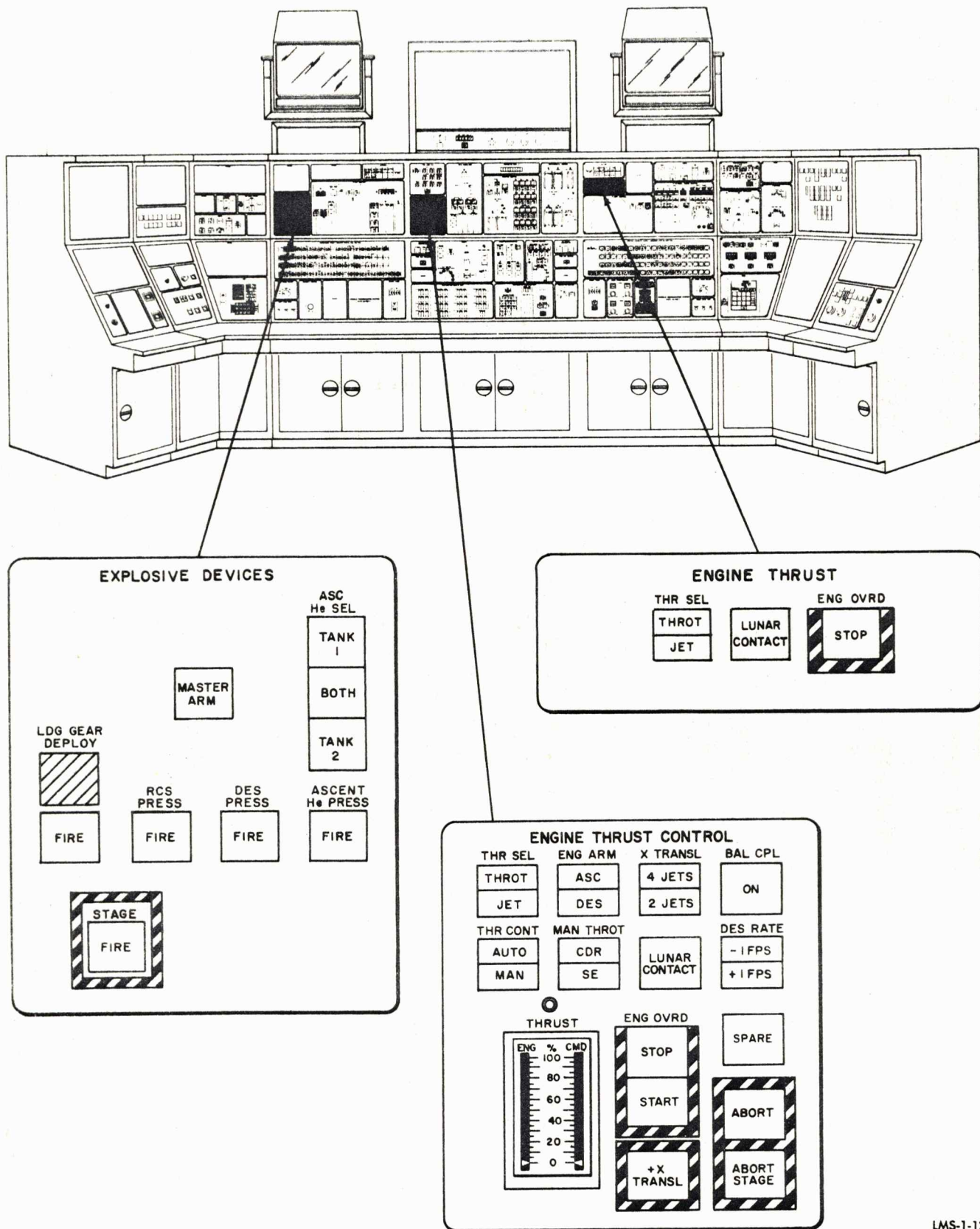
Table 1-38. CAUTION Panel, Displays

Displays	Function
ASC HI REG caution repeater light	Lights if helium pressure downstream of regulators in ascent helium lines exceeds 220 psia
ASC QTY caution repeater light	Lights if fuel or oxidizer in ascent tank is only sufficient for 10-second burn
ENG GIMBAL caution repeater light	Lights if difference between gimbal drive signal and gimbal response from Y - or Z-axis trim function is sensed
PGNS caution repeater light	Lights if any of following conditions is sensed: middle roll gimbal angle exceeds +60° or -60°, IMU temperature deviates $\pm 5^\circ$ from normal, AND of rendezvous radar operate and radar CDU fail, AND of rendezvous radar track enable and data good, AND of landing radar data not good and landing radar antenna in descent or hover position, data good signal with an ambiguous antenna position signal, program check failure, restart, and PIPA failure during nonthrusting periods
INVERTER caution repeater light	Lights if a-c bus voltage is less than 105 volts or greater than 125 volts, or if a-c bus frequency is less than 390 cps or greater than 410 cps
BATTERY CAUTION repeater light	Lights if overcurrent, reverse current, or over-temperature occurs in any descent or ascent battery
RNDZ RDR caution repeater light	Lights if rendezvous radar data-not-good condition occurs
LDG RDR caution repeater light	Lights if landing radar range data are not good or if velocity data are not good
PRE AMPS caution repeater light	Lights if either of two parallel redundant -4.7-volt d-c regulated power supplies that provide power to RCS preamplifiers fails
RCS caution repeater light	Lights if out-of-tolerance ratio of fuel to oxidizer remains in either system A or B tanks or if pressure of helium tank in either system A or B drops below 1,700 psia
HEATER caution repeater light	Lights if out-of-tolerance temperature exists in any of four RCS thruster quads, rendezvous radar assembly, landing radar antenna assembly, or S-band steerable antenna
C/W PWR caution repeater light	Lights if any regulated power supply fails
ECS caution repeater light	Lights if glycol pump fails, CO <sub>2</sub> partial pressure exceeds 7.6 mm Hg, water separator fails, or suit fan No. 1 fails

Table 1-38. CAUTION Panel, Displays (cont)

Display	Function
O <sub>2</sub> QTY caution repeater light	Lights if pressure in descent oxygen tank drops below 135 psia, if less-than-full pressure below 684 psia occurs in either ascent oxygen tank, or if less than 95 psia occurs in ascent tank No. 1
GLYCOL caution repeater light	Lights if glycol quantity in the primary coolant loop is low or if glycol temperature in primary loop, sensed at glycol water evaporator outlet, is high
WATER QTY caution repeater light	Lights if quantity in descent water tank falls below 10%, if less-than-full condition occurs in either ascent water tank, or if unequal levels occur in either of these ascent tanks
MASTER ALARM repeater light (all subsystems - CDR and SE)	Lights by sensor signal along with caution/warning light (s)
	<div style="border: 1px solid black; padding: 2px; text-align: center;">NOTE</div> <p>An audible tone is initiated in conjunction with the MASTER ALARM light and the caution/warning light (s)</p>





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Figure 1-64. Explosive Devices, Engine Thrust Control, and Engine Thrust Panels

Table 1-39. EXPLOSIVE DEVICES Panel, Displays

Display	Function
LDG GEAR DEPLOY status flag repeater	
Gray display	Indicates deployed status of LM landing gear
Barber-pole display	Indicates stowed status of LM landing gear
FIRE repeater light	Indicates explosive device that release landing gear are actuated
DES PRESS	
FIRE repeater light	Indicates squib valves that permit helium to flow from descent helium tanks to pressurize descent propulsion section are actuated
RCS PRESS	
FIRE repeater light	Indicates squib valves that permit helium to flow from RCS helium tanks to pressurize RCS are actuated
STAGE FIRE repeater light	Indicates explosive devices that separate descent and ascent stages are actuated
MASTER ARM repeater light	When lit, indicates actuation of all LM explosive devices
ASC He SEL switch	
TANK 1 repeater light	Indicates selection of squib valve for firing of ascent helium tank No. 1
BOTH repeater light	Indicates selection of squib valve for firing both ascent helium tanks
TANK 2 repeater light	Indicates selection of squib valve for firing ascent helium tank No. 2
ASCENT He PRESS	
FIRE repeater light	Indicates squib valve of ascent section helium tank or tanks selected by ASC He SEL switch are actuated



Table 1-40. ENGINE THRUST CONTROL and ENGINE THRUST Panels, Displays

Display	Function
ENG OVRD START switch repeater light	Indicates immediate firing of descent or ascent engine, depending upon setting of ENG ARM switch
ENG OVRD STOP switch (CDR & SE) repeater light	Indicates discrete stop signals to descent and ascent engines, independent of setting of ENG ARM switch is actuated
X-TRANSL switch repeater light	Indicates selection of number of jets for X-axis translation maneuvers
4 JETS	Indicates four jets for X-axis translation maneuvers are activated
2 JETS	Indicates two jets for X-axis translation maneuvers are activated
BAL CPL switch repeater light	Indicates selection of either balanced pairs of RCS jets in a couple or unbalanced X-axis RCS jets to maintain pitch and roll attitude during ascent engine thrust phase when AGS is in guidance control loop
ON repeater light	Indicates that, during initial phases of lunar ascent, maximum stabilization and control over any center-of-gravity thrust vector misalignment is effective
MAN THROT switch repeater light	Indicates selection of thrust/translation controller for manual adjustment of descent engine thrust level, when corresponding throttle/jets control select lever is set to THROTTLE
CDR repeater light	Indicates Commander's thrust/translation controller is adjusting descent engine thrust level
SE repeater light	Indicates Systems Engineer's thrust/translation controller is adjusting descent engine thrust level
THR CONT switch repeater light	Permits monitoring of switching from automatic throttle control (LGC) to manual throttle control
AUTO repeater light	Indicates LGC command signals are summed with manual command signals of throttles selected by MAN THROT switch for descent engine throttle control
MAN repeater light	Indicates interruption of LGC throttle command signals to descent engine
X-TRANSL switch repeater light	When switch is actuated, indicates four-jet translation in +X-direction
ABORT switch repeater light	Indicates abort initiated, using descent engine
ABORT STAGE switch repeater light	Indicates abort initiated, using only ascent engine
THRUST indicator repeater	Left needle displays descent engine chamber pressure; right needle displays manual thrust commands (SE's or CDR's thrust/translation controller) or LGC thrust commands, as selected with THR CONT switch. Display range is 0% to 100% thrust.

## 1.9.17 COMMANDER'S AND SYSTEMS ENGINEER'S FLIGHT CONTROL PANELS.

(See figures 1-65 and 1-66.)

The FLIGHT CONTROL panels contain repeater lights and indicators of the Commander's and Systems Engineer's flight control instruments and related switch positions. They also contain repeaters of event timer controls and displays. The displays of the Commander's and Systems Engineer's FLIGHT CONTROL panels are listed, with their function, in table 1-41.

Table 1-41. Commander's and Systems Engineer's  
FLIGHT CONTROL Panels, Displays

Display	Function
Flight director attitude indicator (FDAI) repeater (CDR and SE)	Displays total vehicle attitude, attitude rates and attitude errors, or vehicle attitude, attitude rates and rendezvous radar shaft and trunnion angles, depending upon setting of RATE/ERR MON switch
ROLL RATE indicator repeater	Displays roll rate of vehicle
PITCH RATE indicator repeater	Displays pitch rate of vehicle
YAW RATE indicator repeater	Displays yaw rate of vehicle
X-Pointer indicator repeater (CDR and SE)	Displays forward and lateral velocities, lateral velocities only, or rendezvous radar LOS elevation and azimuth angular rates, depending upon setting of RATE/ERR MON switch and MODE SEL switch
T/W indicator repeater (CDR)	Displays instantaneous X-axis acceleration in lunar g units ( $1\text{ g} = 5.32\text{ ft/sec}^2$ )
Altitude/range indicator repeater (CDR)	Displays range/range-rate information or altitude/altitude-rate information, as selected with ALT/RNG MON switch
EVENT TIMER indicator repeater (CDR)	Displays digital readout of time (0 minutes 0 seconds to 59 minutes 59 seconds, or 59 minutes 59 seconds to 0 minutes 0 seconds) as controlled with PRESET/COUNT switch, TIMER CONT switch, SLEW CONT MIN switch, and SLEW CONT SEC switch
RATE/ERR MON switch repeater light (CDR and SE)	Selects input to FDAI and X-pointer indicator
RNDZ RADAR	Shaft and trunnion angles of rendezvous radar are displayed by pitch and yaw error needles of FDAI, LOS azimuth and elevation rates are displayed on X-pointer indicator.
LDG RDR/CMPTR	Vehicle attitude errors are displayed by FDAI error needles; forward ( $V_z$ ) and lateral ( $V_y$ ) velocities are displayed on X-pointer indicator.



Table 1-41. Commander's and Systems Engineer's  
FLIGHT CONTROL Panels, Displays (cont)

Display	Function
ATTITUDE MON switch repeater lights (CDR and SE)	
PGNS	LM total attitude signals, after conditioning by gimbal angle sequencing transformation assembly (GASTA), are sent to FDAI ball; LGC attitude error signals are sent to FDAI pitch, roll, and yaw error needles. In AGS position, AGS total vehicle attitude signals are sent to FDAI ball; LGC attitude error signals are sent to FDAI pitch, roll, and yaw error needles.
AGS	AGS total LM attitude signals are sent to FDAI ball; AGS attitude error signals are sent to FDAI pitch, yaw, and roll error needles.
GUID CONT PGNS and AGS switch repeater lights (CDR)	Indicate selection of either PGNS or AGS for guidance control of LM
SHFT/TRUN switch repeater lights (CDR)	Indicate selection of range of rendezvous radar shaft and trunnion angles to be displayed by FDAI pitch and yaw error needles when either RATE/ERR MON switch is set to RNDZ RADAR
+50°	Full deflection of the FDAI pitch and yaw error needles indicates shaft and trunnion angles of +50° or -50° or greater.
+5°	Full deflection of the FDAI pitch and yaw error needles indicates shaft and trunnion angles of +5° or -5° or greater.
MODE SEL switch repeater lights (CDR)	Indicate selection of radar or computer data for display on X-pointer and altitude/range indicators
LDG RADAR	Indicates radar altitude, altitude rate, and forward and lateral velocity data are displayed
PGNS	Indicates LGC-computed altitude, altitude rate, and forward and lateral velocity are displayed
AGS	Indicates AGS-computed altitude, altitude rate, and lateral velocity are displayed
EVENT TIMER RESET/COUNT switch repeater lights (CDR)	
RESET	Indicates resetting of EVENT TIMER to zero
UP	Indicates EVENT TIMER is counting in increasing direction to 59 minutes and 59 seconds, returns to zero, and begins counting in increasing direction
DOWN	Indicates EVENT TIMER is counting in decreasing direction from preset value to zero minutes and zero seconds and then counts in increasing direction

Table 1-41. Commander's and Systems Engineer's  
FLIGHT CONTROL Panels, Displays (cont)

Display	Function
TIMER CONT START switch repeater light (CDR)	Indicates EVENT TIMER is beginning to count in direction selected with RESET/COUNT switch
EVENT TIMER SLEW MIN switch repeater light (CDR)	
TENS	Indicates slewing of tens-column digit of minutes pair at rate of two digits per second as long as switch is held in this position
UNIT	Indicates slewing of unit-column digit of minutes pair at rate of two digits per second as long as switch is held in this position
EVENT TIMER SLEW SEC switch repeater light (CDR)	
TENS	Indicates slewing of tens-column digit of seconds pair at rate of two digits per second as long as switch is held in this position
UNIT	Indicates slewing of unit-column digit of seconds pair at rate of two digits per second as long as switch is held in this position



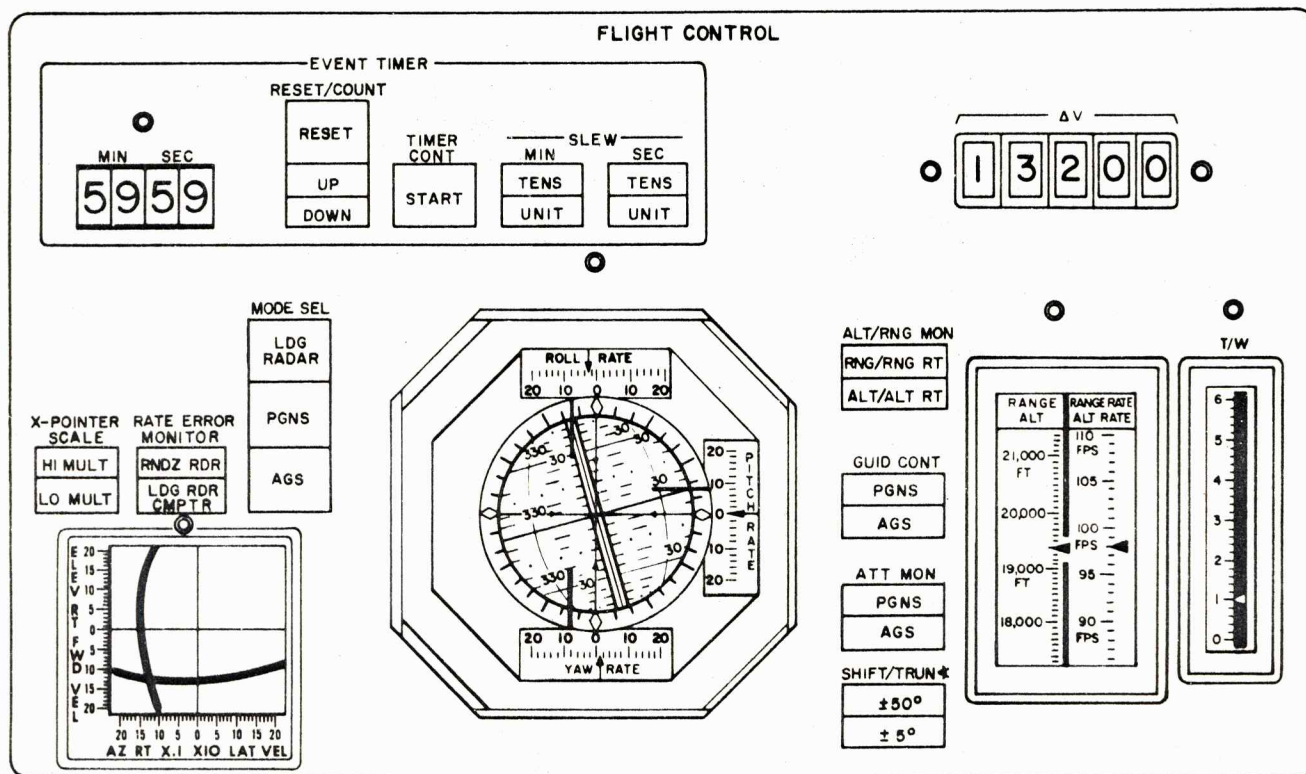
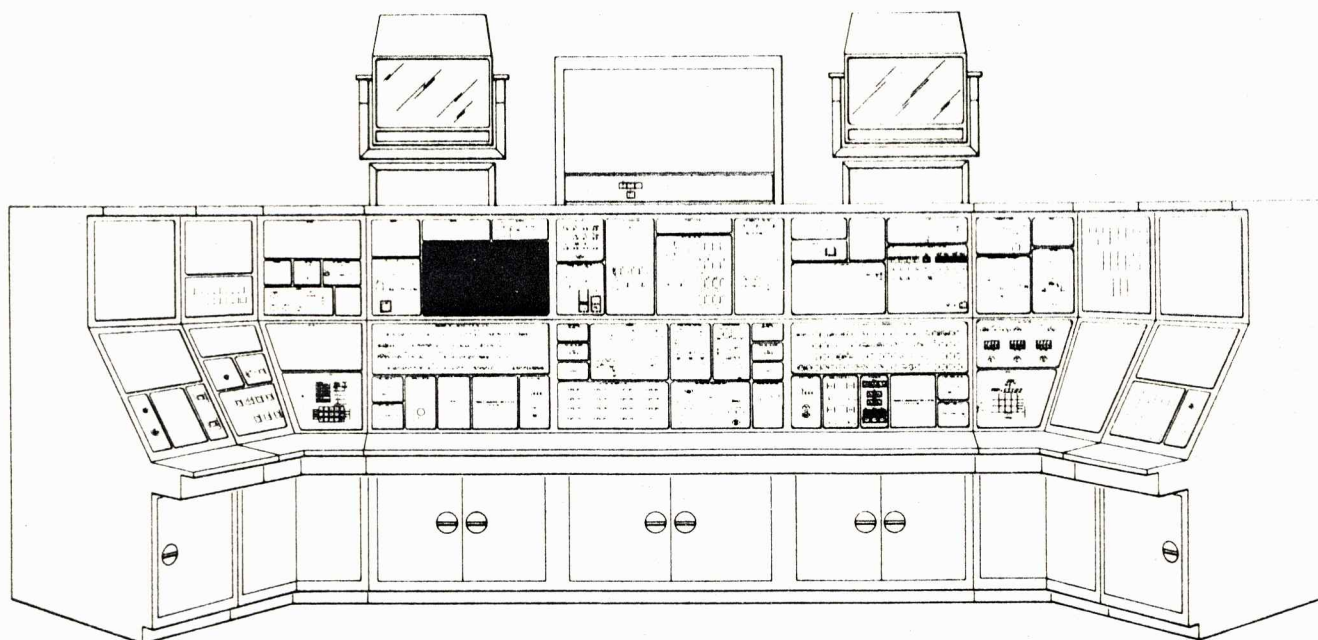
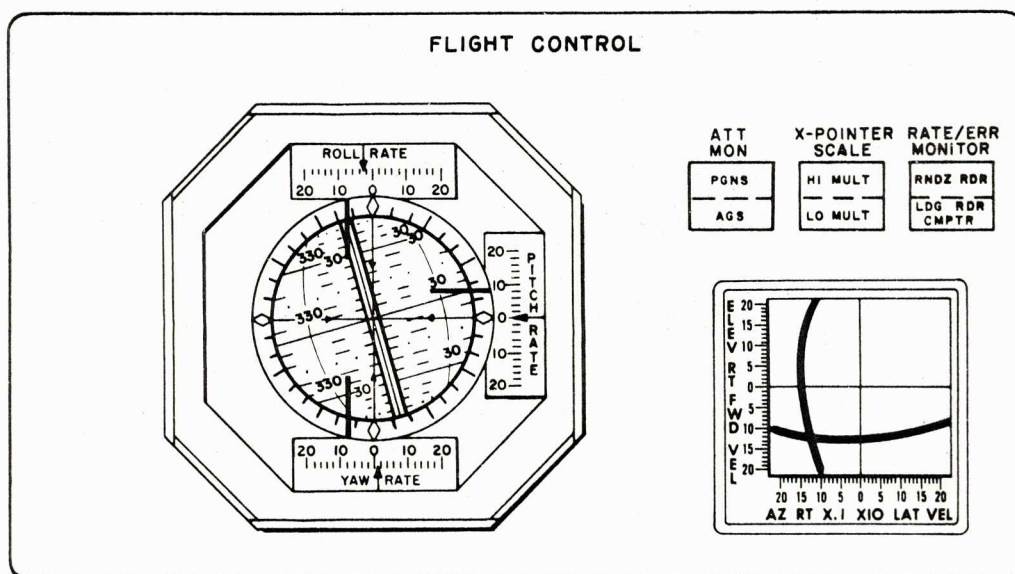
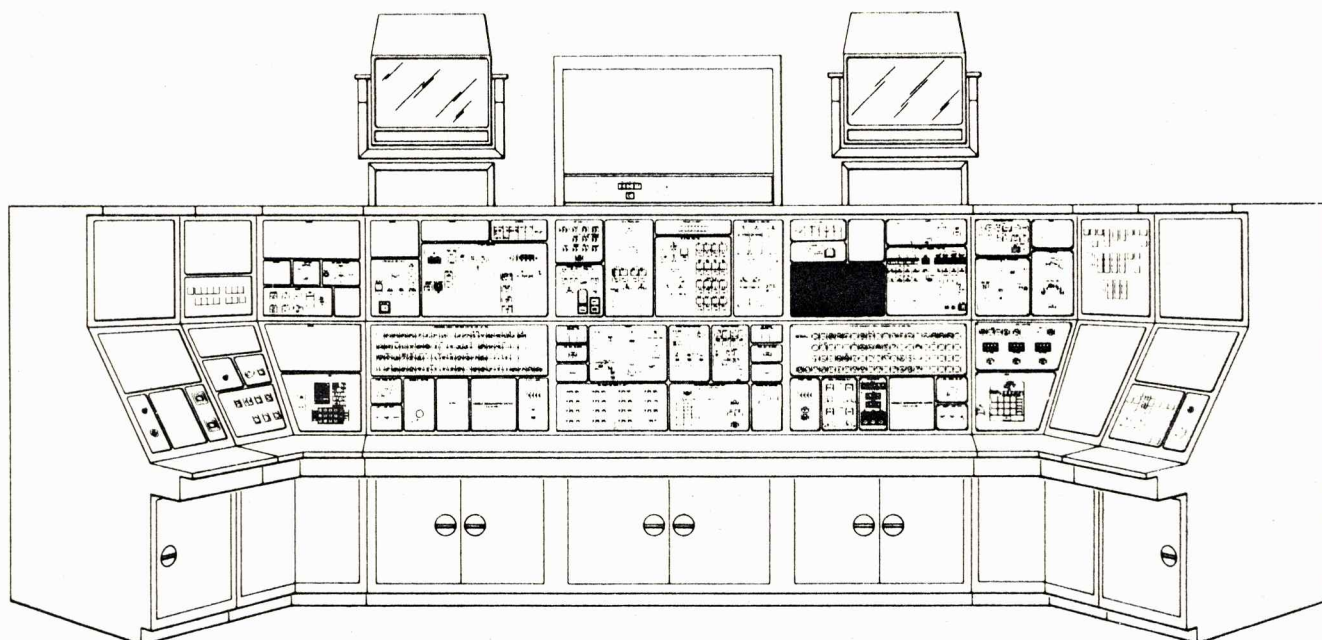


Figure 1-65. Commander's Flight Control Panel



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Figure 1-66. Systems Engineer's FLIGHT CONTROL Panel

1.9.18 COMMANDER CIRCUIT BREAKER STATUS AND CONTROL PANEL AND SYSTEM ENGINEER CIRCUIT BREAKER STATUS CONTROL PANEL. (See figures 1-67 and 1-68.)

The COMMANDER CIRCUIT BREAKER STATUS AND CONTROL panel and the SYSTEM ENGINEER CIRCUIT BREAKER STATUS CONTROL panel contain switch lights for all the Commander's and Systems Engineer's circuit breakers, respectively. The switch lights can fail any individual circuit breaker and show the status of all circuit breakers. The controls of the panels are listed, with their function, in table 1-42.

1.9.19 EVDE VIDEO SELECT PANELS. (See figure 1-69.)

The EVDE VIDEO SELECT panels select astronaut's visual displays, to be displayed at either the left or right console TV monitors. The control of the EVDE VIDEO SELECT panels is listed, with its function, in table 1-43.



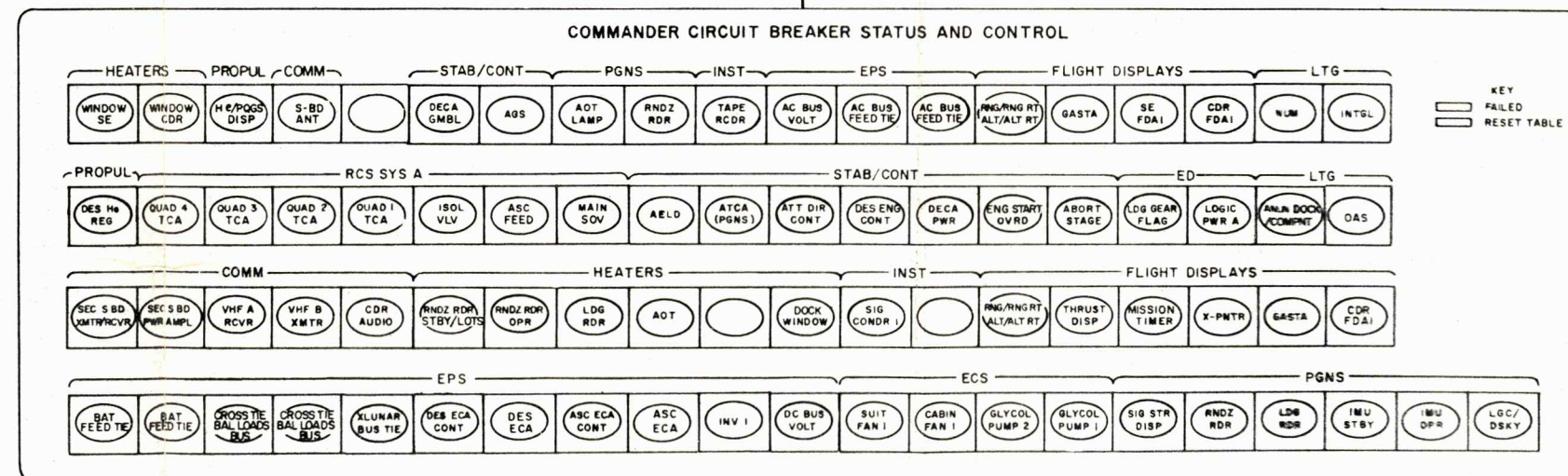
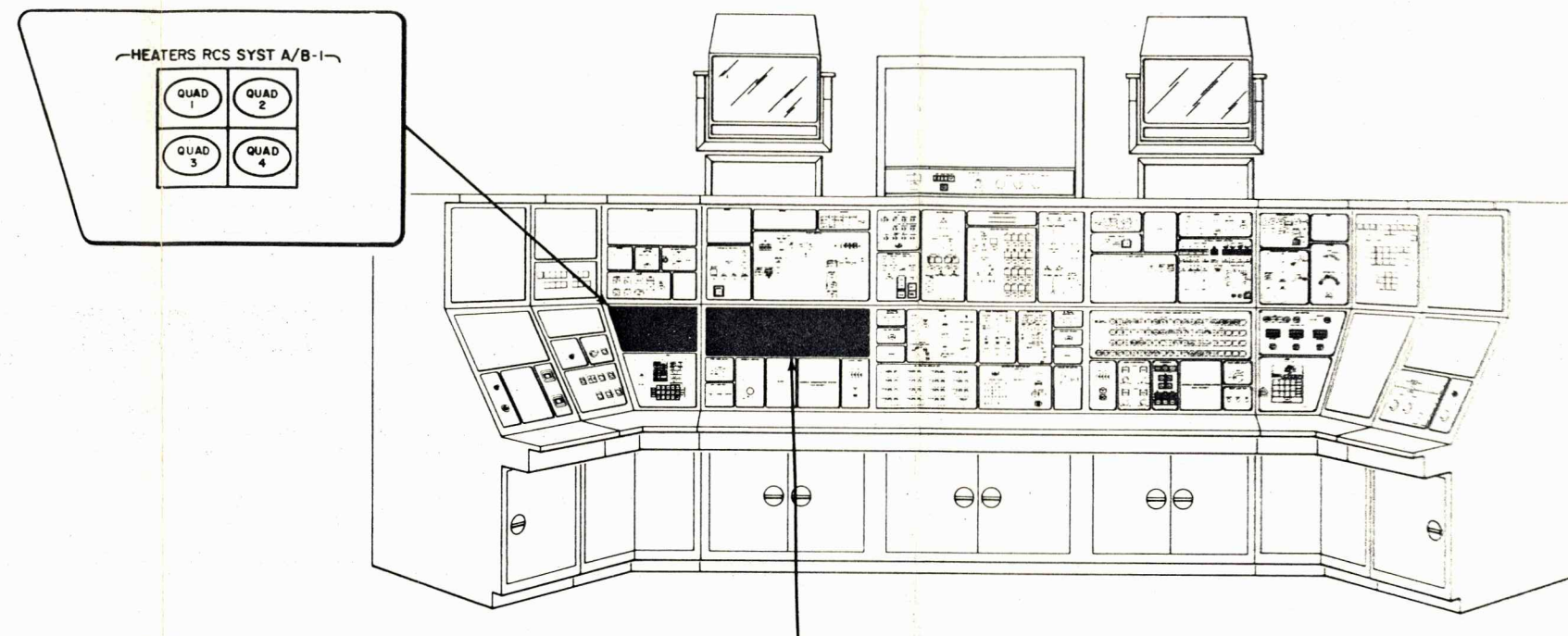


Figure 1-67. COMMANDER CIRCUIT BREAKER STATUS AND CONTROL Panel



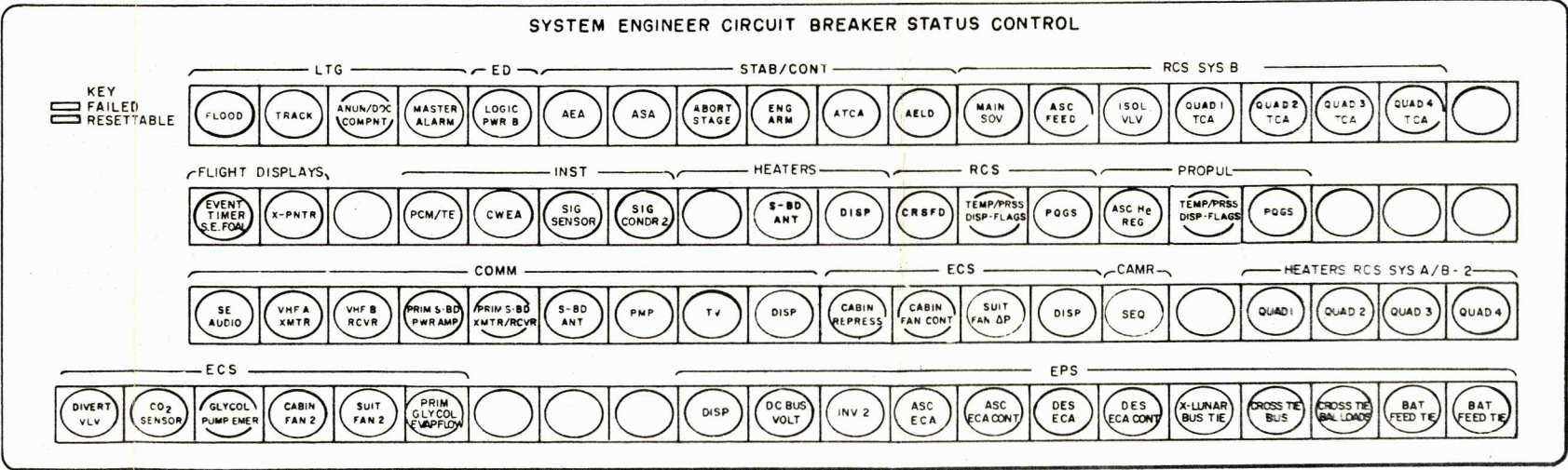
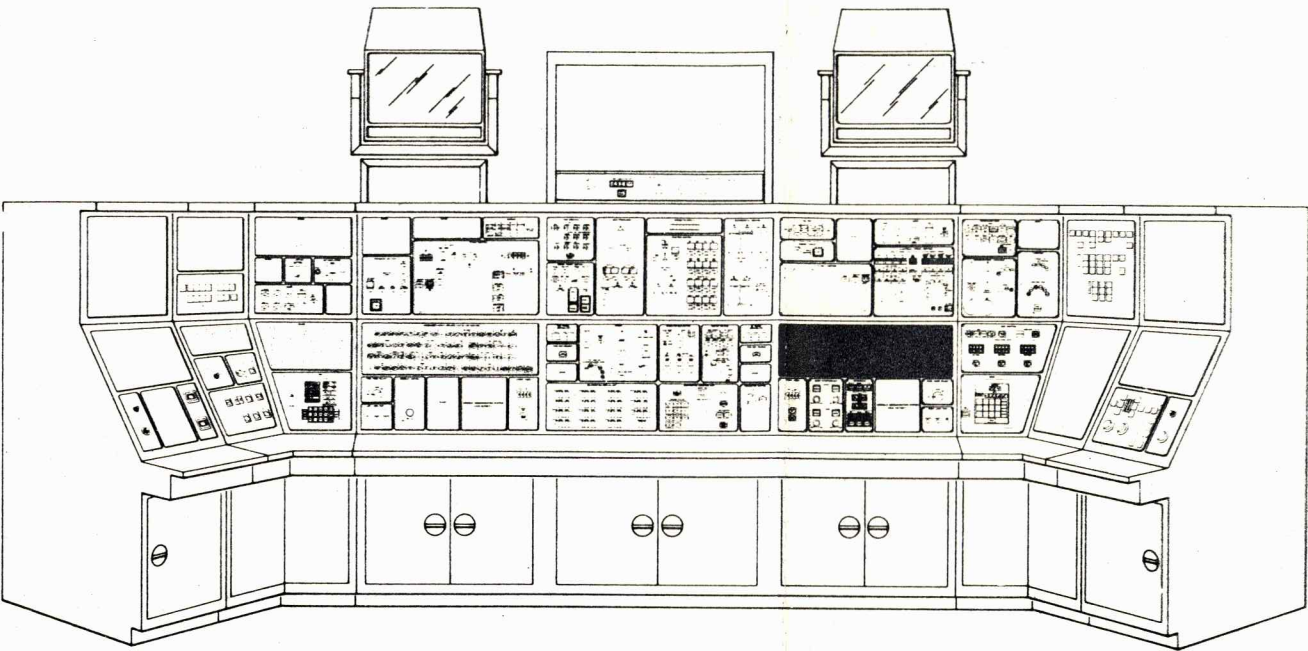


Figure 1-68. System Engineer Circuit Breaker Status Control Panel



Table 1-42. COMMANDER CIRCUIT BREAKER STATUS and CONTROL Panel and SYSTEM ENGINEER CIRCUIT BREAKER STATUS CONTROL Panel, Controls

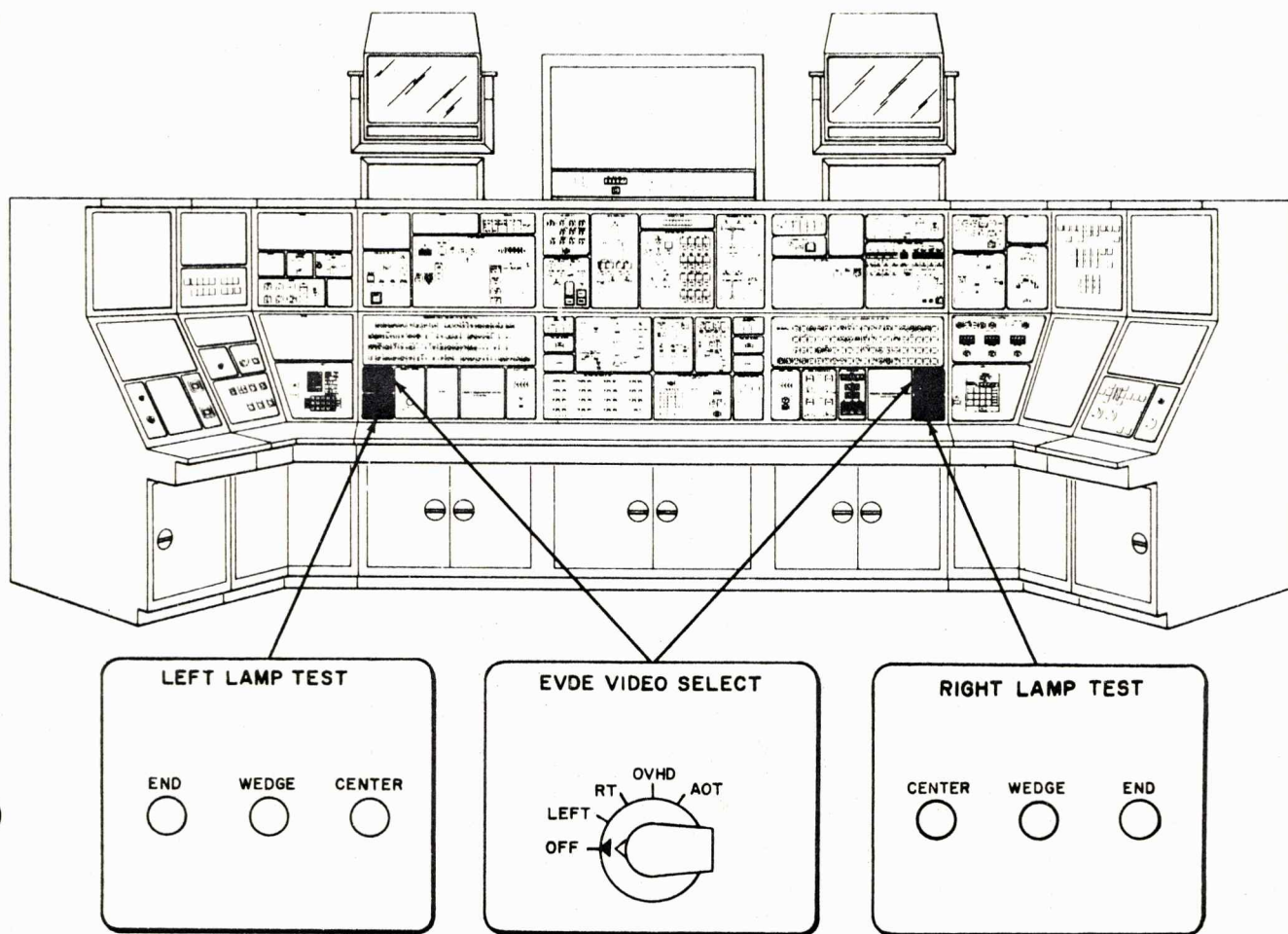
Controls	Function
Commander's and Systems Engineers circuit breaker switch lights (Refer to panel layout for switch light nomenclature.)	<p>Each instructor monitors and controls circuit breakers for which his crewmember is responsible. The placards and arrangement of the circuit breaker switch lights correspond to their cabin counterparts. Switch lights function as follows:</p> <p>Instructors can trip a circuit breaker in simulated LM cabin by pressing appropriate switch light. Switch light is illuminated amber, indicating that circuit breaker is tripped.</p> <p>While this condition exists, circuit breaker cannot be reset by crewmember. It remains in this condition until switch is actuated a second time. Failure is then removed.</p> <p>When flight crew circuit breaker is open and not tripped, it is resettable. When this condition exists, instructors' switch lights are illuminated white. (A circuit cannot be tripped and resettable at the same time.)</p> <p>In general, circuit breakers are tripped directly by instructor. However, a few of them can be tripped, using MIU. These switch lights on instructor's circuit breaker status and control panel go on in a manner identical with that described for direct "failures," (amber). Removal of malfunction, however, must be accomplished via MIU.</p>
<p style="text-align: center;"><b>NOTE</b></p> <p>Most nomenclature is on the indicator screen, rather than on the panel. This facilitates monitoring and eliminates unnecessary redundancy of nomenclature and color code. A function and color code key is supplied on the panels.</p>	

Table 1-43. EVDE VIDEO SELECT Panel, Control

Control	Function
EVDE VIDEO SELECT Switch	Permits each instructor to select window and telescope presentation for monitoring

## 1.9.20 LEFT LAMP TEST AND RIGHT LAMP TEST PANELS. (See figure 1-71.)

The LEFT LAMP TEST and RIGHT LAMP TEST panels enable each instructor to test all the display lights on his section of the instructor console. The controls of these panels are listed, with their function, in table 1-44.



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Figure 1-69. EVDE VIDEO SELECT, LEFT LAMP TEST, and RIGHT LAMP TEST Panels

Table 1-44. LEFT LAMP TEST and RIGHT LAMP TEST Panels, Controls

Control	Function	
LEFT LAMP TEST and RIGHT LAMP TEST switches  CENTER WEDGE  END	When activated, all lamps on appropriate sections of instructor console go on. Each instructor can test lamps on his half of console. Console dividing line is between following panels:	
	MAIN PROPULSION	REACTION CONTROL
	RADAR	STABILIZATION/CONTROL
	MDU	MIU



## 1.9.21 EVENT TIMER PANELS. (See figure 1-70.)

The event timers are resettable electric timers provided for the instructor's convenience in timing flight crew responses. Both instructors have identical timers. The EVENT TIMER panels controls and displays are listed with their functions in table 1-45.

## 1.9.22 TIME DISPLAYS PANEL. (See figure 1-70.)

The TIME DISPLAYS panel displays the numerical readouts of various mission problem times. The control and displays of the TIME DISPLAYS panel are listed, with their functions, in table 1-46.

## 1.9.23 MISSION TIMER PANEL. (See figure 1-70.)

The MISSION TIMER panel contains repeater lights and displays of the mission timer controls and displays in the LM cabin. The displays of the MISSION TIMER panel are listed, with their function, table 1-47.

Table 1-45. EVENT TIMER Panels, Controls and Displays

Control or Display	Function
EVENT TIMER MIN/SEC readout	The event timer is a manually settable four-digit display that is operated under control of a COUNT UP or COUNT DOWN switch light and is read in minutes and seconds.
COUNT UP/COUNT DOWN switch lights	Pressing either switch light will actuate counter in appropriate up or down direction. Pressing it a second time stops timer.

Table 1-46. TIME DISPLAYS Panel, Control and Displays

Control or Display	Function
GMT readout	Displays days, hours, minutes, and seconds
ELAPSED TIME FROM SEPARATION readout	Displays elapsed time from separation of SCM from LM
PROBLEM TIME readout	Displays problem time in days, hours, minutes, and seconds
LEM/APOLLO switch light	Selects either LM or Apollo problem time mode. When LEM is lit, problem time refers to time elapsed from start of LM mission, based on initial-condition setting. When APOLLO is lit, problem time is that of AMS.

**NOTE**

Problem time readouts are reset to initial-condition values when the problem is reset (that is, the RESET switch light on the PROBLEM CONTROL panel is actuated).

Table 1-47. MISSION TIMER Panel, Displays

Display	Function
TIMER CONT switch repeater lights	
START	Indicates MISSION TIMER counting upward from preset number

Table 1-47. MISSION TIMER Panel, Displays (cont)

Display	Function
STOP	Indicates MISSION TIMER count held and stopped until START or RESET is selected
RESET	Indicates MISSION TIMER numbers reset to zero
SLEW CONT HR switch repeater lights	
TENS	Indicates tens-column digit of MISSION TIMER HR columns is slewed at rate of two digits per second as long as switch is held in this position
UNITS	Indicates units-column digit of MISSION TIMER HR columns is slewed at rate of two digits per second as long as switch is held in this position
SLEW CONT MIN switch repeater lights	
TENS	Indicates tens-columns digit of MISSION TIMER MIN columns at rate of two digits per second as long as switch is held in this position
UNITS	Indicates units-column digit of MISSION TIMER MIN columns at rate of two digits per second as long as switch is held in this position
SLEW CONT SEC switch repeater lights	
TENS	Indicates tens-column digit of MISSION TIMER SEC columns slewed at rate of two digits per second as long as switch is held in this position
UNITS	Indicates units-column digit of MISSION TIMER SEC columns slewed at rate of two digits per second as long as switch is held in this position

## 1.9.24 MAIN PROPULSION PANEL. (See figure 1-71.)

The MAIN PROPULSION panel contains repeater lights and indicators of the main propulsion switch positions and instrumentation displays. The displays of the MAIN PROPULSION panel are listed, with their function, in table 1-48.

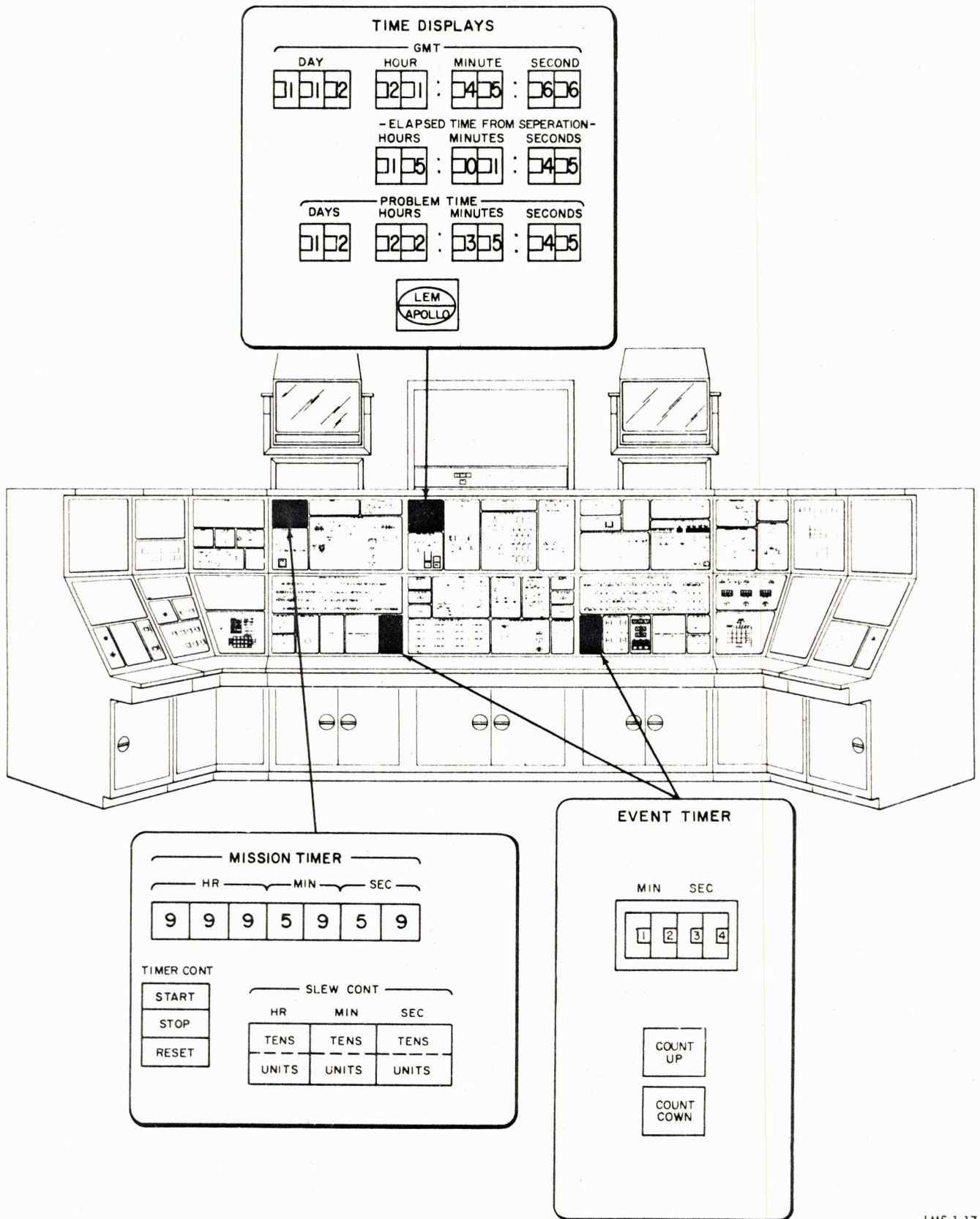
## 1.9.25 PARAMETER DISPLAY PANEL. (See figure 1-72.)

The PARAMETER DISPLAY panel displays up to 12 preprogrammed readouts. The display of the PARAMETER DISPLAY panel is listed with its function in table 1-49.

## 1.9.26 CDR TRANSL CONTROLLER AND SE TRANSL CONTROLLER PANELS. (See figure 1-72.)

The CDR TRANSL CONTROLLER and SE TRANSL CONTROLLER panels contain displays that indicate when the Commander's and Systems Engineer's hand controllers are displaced from neutral in any one of three axes. The displays of the CDR TRANSL CONTROLLER and SE TRANSL CONTROLLER panels are listed, with their function, in table 1-50.





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Figure 1-70. Event Timer, Time Displays, and Mission Timer Panels

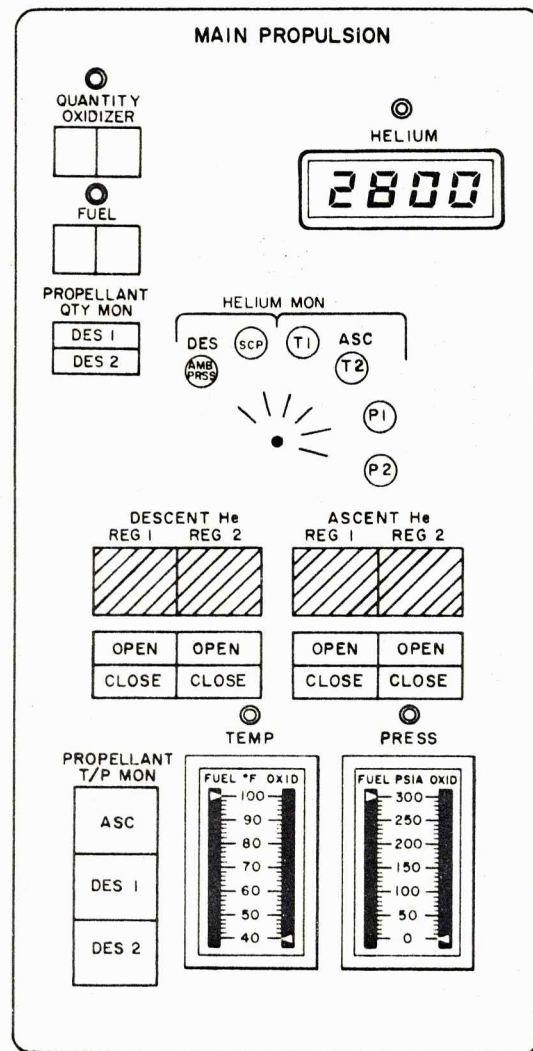
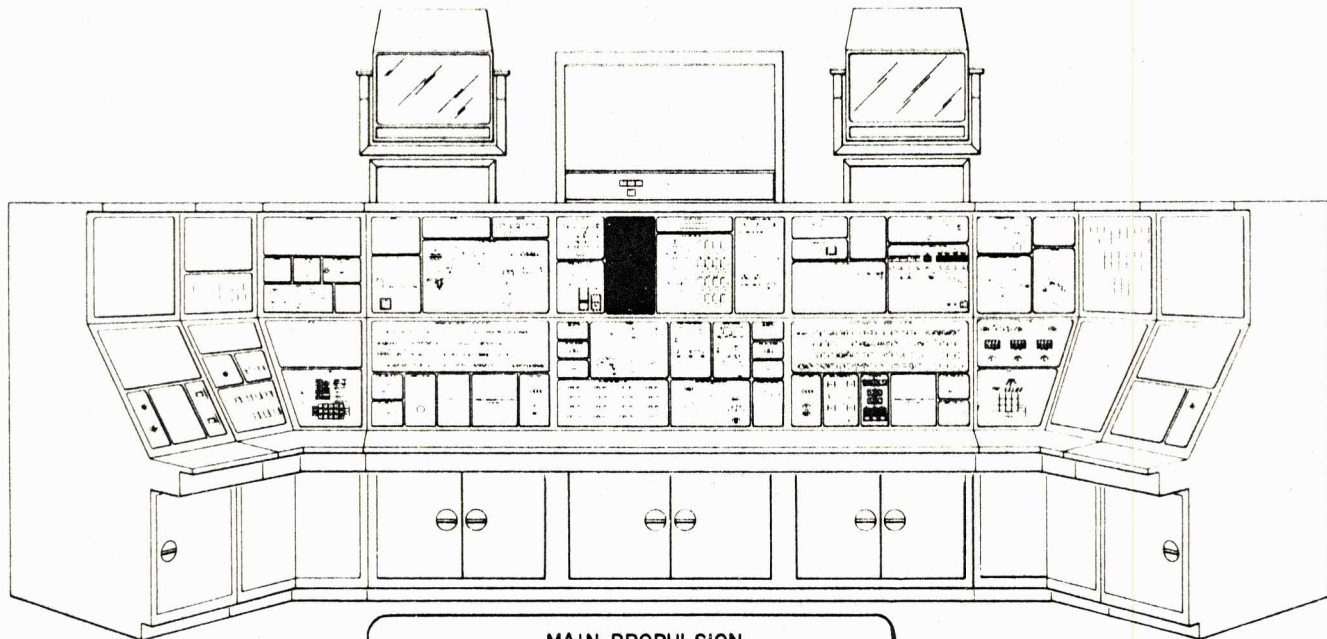


Figure 1-71. MAIN PROPULSION Panel



Table 1-48. MAIN PROPULSION Panel, Displays

Display	Function
ASCENT He REG 1 status flag repeater	
Gray display	Indicates open condition of helium valve controlled by ASCENT He REG 1 switch
Barber-pole display	Indicates closed condition of helium valve controlled by ASCENT He REG 1 switch
ASCENT He REG 2 status flag repeater	
Gray display	Indicates open condition of helium valve controlled by ASCENT He REG 2 switch
Barber-pole display	Indicates closed condition of helium valve controlled by ASCENT He REG 2 switch
DESCENT He REG 1 status flag repeater	
Gray display	Indicates open condition of helium valve controlled by DESCENT He REG 1 switch
Barber-pole display	Indicates closed condition of helium valve controlled by DESCENT He REG 1 switch
DESCENT He REG 2 status flag repeaters	
Gray display	Indicates open condition of helium valve controlled by DESCENT He REG 2 switch
Barber-pole display	Indicates closed condition of helium valve controlled by DESCENT He REG 2 switch
HELIUM indicator repeater	Indicates supercritical helium pressure (0 to 1,750 psia) of descent cryogenic storage vessel or ambient temperature (-120° to +100° F) or pressure (0 to 3,500 psia) of ascent helium tanks, as selected with HELIUM MON switch
PRESS indicator repeater	Indicates fuel and oxidizer pressure (0 to 300 psia) for ascent or descent propellant sections, as selected with PRPLNT TEMP/PRESS MON switch
TEMP indicator repeater	Indicates fuel and oxidizer temperature (+40° to +100° F) for ascent or descent propellant sections, as selected with PRPLNT TEMP/PRESS MON switch
QUANTITY indicator repeaters	Indicate propellant quantity for MPS
OXIDIZER (top window)	Displays digital readout of percentage (0% to 99%) of usable oxidizer remaining in descent tanks, as selected with PRPLNT QTY MON switch
FUEL (bottom window)	Displays digital readout of percentage (0% to 99%) of usable fuel remaining in descent tanks, as selected with PRPLNT QTY MON switch

Table 1-48. MAIN PROPULSION Panel, Displays (cont)

Display	Function
PRPLNT TEMP/PRESS MON switch repeater lights	Indicate input selected to propellant temperature- and pressure-indicating devices in ascent and descent propellant tanks
ASC	Indicates connection of signal output from pressure sensors of ascent propellant tanks to TEMP-PRESS indicators.
DES 1	Indicates connection signal output from temperature and pressure sensors of descent propellant tank No. 1 to TEMP-PRESS indicators.
DES 2	Indicates connection of signal output from temperature and pressure sensors of descent propellant tank No. 2 to TEMP-PRESS indicators.
ASCENT He REG 1 switch repeater lights	Indicate selection of inputs to normally open, latch-type, solenoid-operated helium valve upstream of helium pressure regulator No. 1
OPEN	Indicates helium solenoid that drives valve to open position is energized
CLOSE	Indicates helium solenoid that drives valve to closed position is energized
ASCENT He REG 2 switch repeater lights	Indicate selection of inputs to normally open latch- type, solenoid-operated helium valve upstream of helium pressure regulator No. 2
OPEN	Indicates helium solenoid that drives valve to open position is energized
CLOSE	Indicates helium solenoid that drives valve to closed position is energized
DESCENT He REG 1 switch repeater lights	Indicates selection of inputs to normally open, latch-type, solenoid-operated helium valve upstream of helium pressure regulator No. 1
OPEN	Indicates helium solenoid that drives valve to open position is energized
CLOSE	Indicates helium solenoid that drives valve to closed position is energized
DESCENT He REG 2 switch repeater lights	Indicate selection of inputs to normally open, latch- type, solenoid-operated helium valve upstream of helium pressure regulator No. 2
OPEN	Indicates helium solenoid that drives valve to open position is energized
CLOSE	Indicates helium solenoid that drives valve to closed position is energized



Table 1-48. MAIN PROPULSION Panel, Displays (cont)

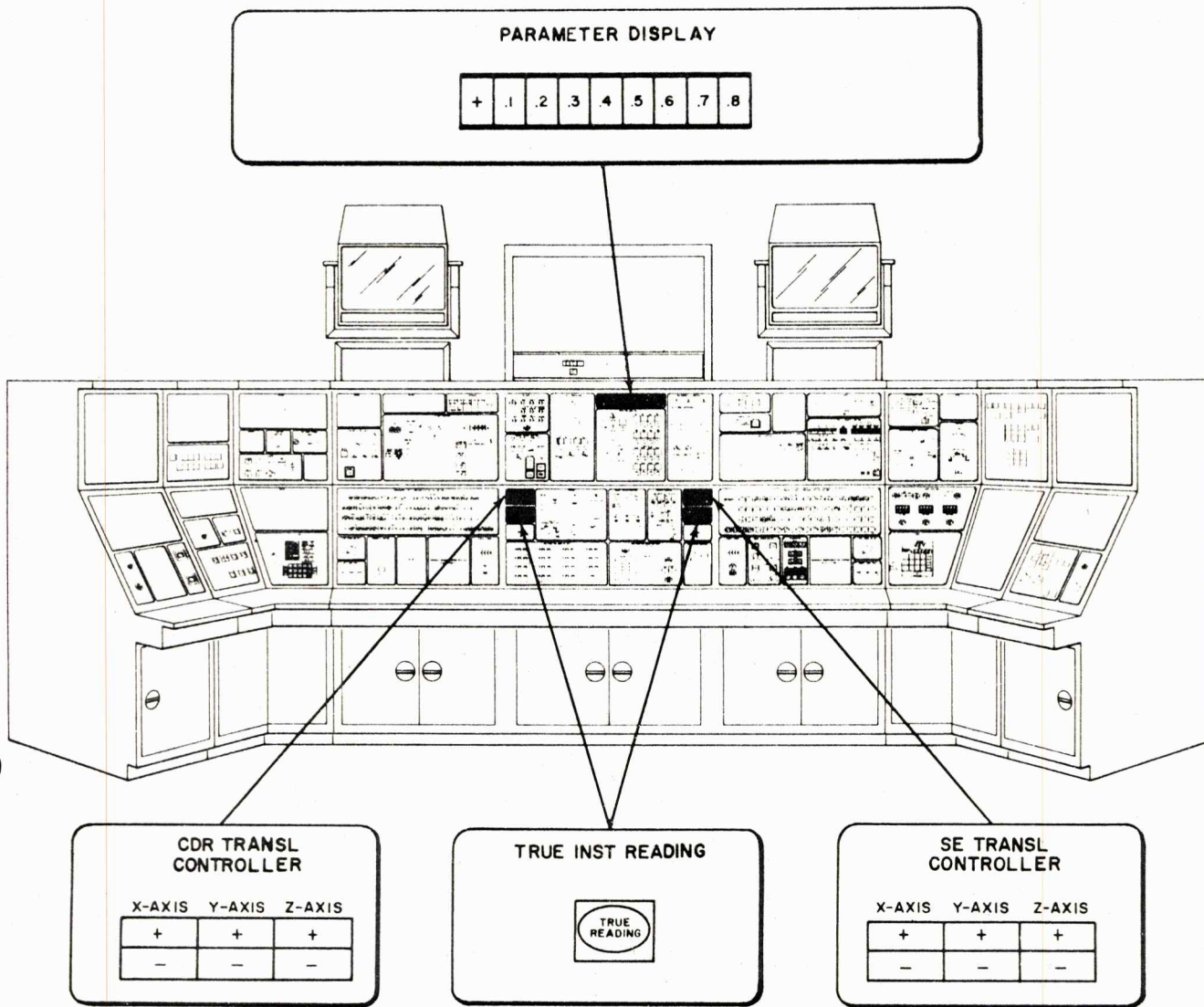
Display	Function
HELIUM MON switch repeater lights	Selects inputs to helium pressure-indicating device in descent cryogenic storage vessel and temperature- and pressure- indicating devices in ascent helium tanks
DESCENT SCP	Indicates connection of signal output from pressure sensor in descent cryogenic storage vessel to HELIUM indicator
DESCENT PRESS	Indicates connection of signal output from pressure sensor in descent helium bottle to HELIUM indicator
ASCENT T1	Indicates connection of signal output from temperature sensor of ascent tank No. 1 to HELIUM indicator
ASCENT T2	Indicates connection of signal output from temperature sensor of ascent tank No. 2 to HELIUM indicator
ASCENT P1	Indicates connection of signal output from pressure sensor in manifold downstream of ascent tank No. 2 and upstream of squib valves to HELIUM indicator
ASCENT P2	Indicates connection of signal output from pressure sensor in manifold downstream of ascent tank No. 2 and upstream of squib valves to HELIUM indicator
PRPLNT QTY MON switch repeater lights	Indicates selection of inputs to oxidizer and fuel quantity indicating devices in descent propellant tanks
DES 1	Monitors the discrete outputs from the quantity gaging sensor probe of oxidizer tank No. 1 and fuel tank No. 2 to QUANTITY indicators
DES 2	Monitors the discrete outputs from the quantity gaging sensor probe of oxidizer tank No. 1 and fuel tank No. 2 to QUANTITY indicators

Table 1-49. PARAMETER DISPLAY Panel, Display

Display	Function
PARAMETER DISPLAY projection lights	Permit instructor to display parameter plus and minus quantities to eight significant figures. Parameters are selected on parameter control panel.

Table 1-50. CDR TRANSL CONTROLLER and SE TRANSL CONTROLLER Panels, Displays

Display	Function
X-AXIS, Y-AXIS, Z-AXIS + and - indicator lights	Appropriate lamp lights to indicate that Commander's or Systems Engineer's thrust/translational hand controller has been displaced from neutral position.



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Figure 1-72. PARAMETER DISPLAY, CDR TRANSL CONTROLLER, SE TRANSL CONTROLLER, and TRUE INST READING Panels

#### 1.9.27 TRUE INST READING PANELS. (See figure 1-72.)

The TRUE INST READING panels enable the instructors to read true instrument values at all instruments on the left and right halves of the instructor console. The control of the TRUE INSTL READING panels is listed, with its function, in table 1-51.

#### 1.9.28 ENVIRONMENTAL CONTROL PANEL. (See figure 1-73.)

The ENVIRONMENTAL CONTROL panel contains repeater lights and indicators of the ENVIRONMENTAL CONTROL SUBSYSTEM instrumentation and control switch positions. The displays of the ENVIRONMENTAL CONTROL panel are listed, with their functions, in table 1-52.

#### 1.9.29 REACTION CONTROL PANEL. (See figure 1-74.)

The REACTION CONTROL panel contains repeater lights and indicators of the Reaction Control Subsystem (RCS) switch positions, flags, and instrumentation. The displays of the REACTION CONTROL panel are listed, with their functions, in table 1-53.



Table 1-51. TRUE INST READING Panels, Control

Control	Function
TRUE READING switch light	Causes specified malfunctioned repeater instruments (those whose malfunction indicator lights, adjacent to the instruments, are lit) to read true values. Flight crew astronaut's instrument reflects failed condition. Failed light adjacent to indicator remains lighted as long as failure exists in flight crew instruments. Time lag from switch actuation to instrument setting to true reading is insignificant (approximately one-quarter second or less). When TRUE READING switch is actuated a second time, instruments return to failed reading. Each instructor's TRUE READING switch affects only instruments on his half of console.

#### 1.9.30 RADAR PANEL. (See figure 1-75.)

The RADAR panel contains repeater lights and indicators that indicate the radar control switch positions, and the status of the radar component caution light and the signal strength meter. The displays of the RADAR panel are listed, with their function, in table 1-54.

#### 1.9.31 STABILIZATION/CONTROL PANEL. (See figure 1-76.)

The STABILIZATION/CONTROL panel contains repeater lights that indicate the stabilization control switch positions. The displays of the STABILIZATION/CONTROL panel are listed, with their function, in table 1-55.

#### 1.9.32 HEATER CONTROL PANEL. (See figure 1-76.)

The HEATER CONTROL panel contains repeater lights and an indicator that indicates the switch positions and temperature indication on the corresponding LMS cabin control panel. The displays of the HEATER CONTROL panel are listed, with their function, in table 1-56.

#### 1.9.33 MALFUNCTION DISPLAY UNIT PANEL. (See figure 1-77.)

The MALFUNCTION DISPLAY UNIT panel enables the instructor to read out as many as 15 malfunction codes on the display. An overflow display indicates that more than 15 malfunctions up to a maximum of 11) are active or pending. The displays of the MALFUNCTION DISPLAY UNIT panel are listed, with their function, in table 1-57.

#### 1.9.34 MALFUNCTION INSERTION UNIT PANEL. (See figure 1-78.)

The MALFUNCTION INSERTION UNIT enables selection of manually initiated malfunction routines. The controls and displays of the MALFUNCTION INSERTION UNIT panel are listed, with their function, in table 1-58.

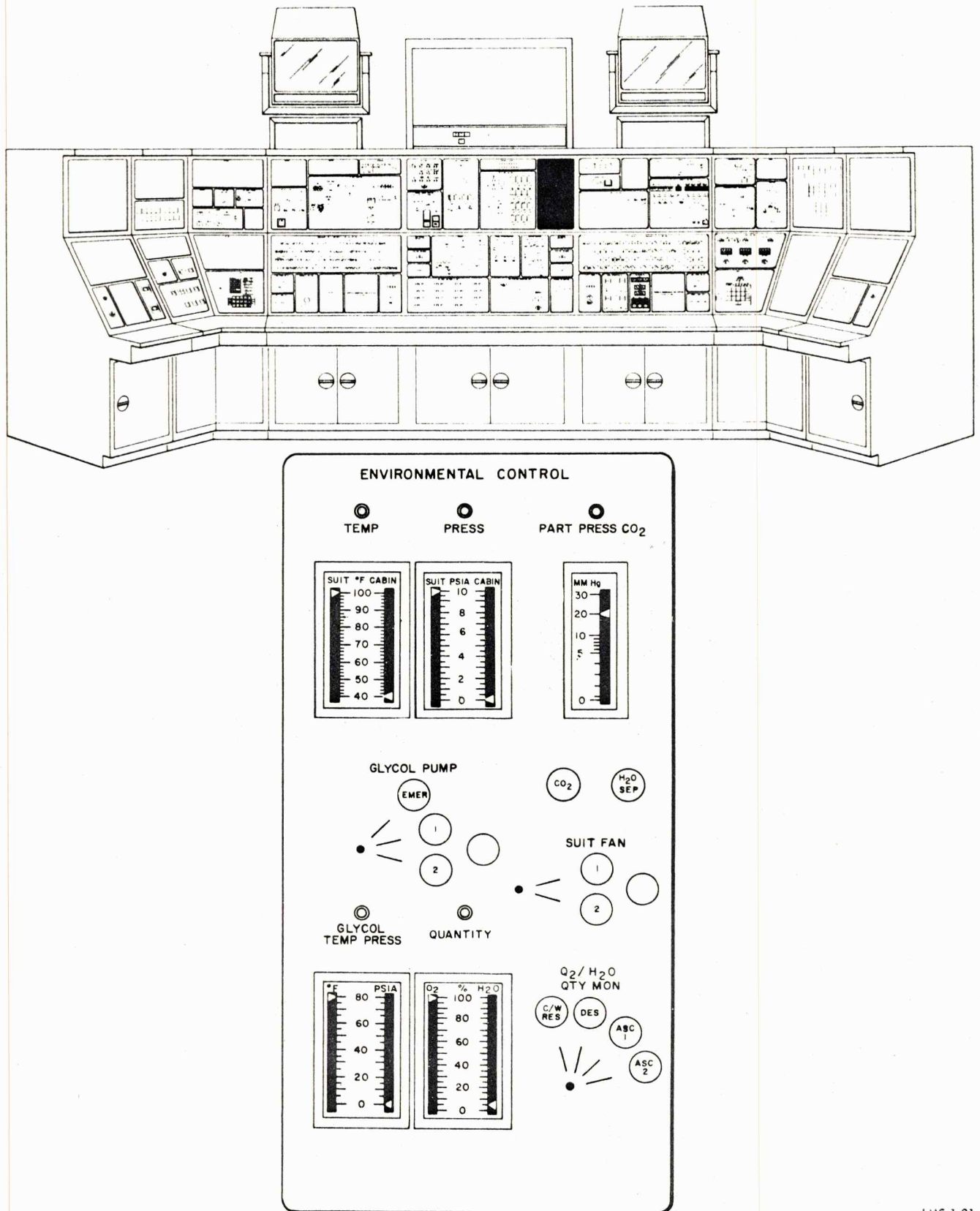
#### 1.9.35 PARAMETER CONTROL PANEL. (See figure 1-79.)

The PARAMETER CONTROL panel permits the instructor to select any one of 12 preprogrammed parameters for display. The controls of the PARAMETER CONTROL panel are listed, with their function, in table 1-59.

Table 1-52. ENVIRONMENTAL CONTROL Panel, Displays

Display	Function
SUIT PRESS indicator repeater	Displays suit circuit pressure (psia), sensed downstream of suit gas supply connectors
CABIN TEMP indicator repeater	Displays temperature (degrees Fahrenheit) of cabin interior sensed at cabin heat exchanger
SUIT TEMP indicator repeater	Displays temperature in suit circuit, sensed at suit circuit regenerative heat exchanger
O <sub>2</sub> QUANTITY indicator repeater	Displays quantity of oxygen remaining in descent oxygen tank or in either ascent oxygen tank, as selected with O <sub>2</sub> /H <sub>2</sub> O QTY MON switch
GLYCOL PRESS indicator repeater	Displays glycol pump discharge pressure in primary coolant loop. Following failure of primary loop and selection of emergency coolant pump with GLYCOL PUMP switch, indicator repeater light displays emergency glycol pump discharge pressure.
GLYCOL TEMP indicator repeater.	Displays glycol temperature in primary coolant loop. Following failure of primary loop and selection of emergency coolant pump with GLYCOL PUMP switch, indicator repeater displays emergency temperature.
SUIT FAN switch repeater lights	Indicate selection of either of two suit fans to circulate breathing oxygen in suit circuit
1	Indicates selection of fan No. 1
2	Indicates selection of fan No. 2
O <sub>2</sub> /H <sub>2</sub> O QTY MON switch repeater lights	Indicate switch positions that select O <sub>2</sub> QTY and H <sub>2</sub> O QTY indicators to display quantities remaining in descent or ascent oxygen and water storage tanks.
C/W RES	Indicates that signal is routed to caution and warning electronics assembly (CWEA) to extinguish O <sub>2</sub> QTY caution light or WATER QTY caution light if lit
DES	Indicates that descent oxygen tank quantity is displayed on O <sub>2</sub> QTY indicator and quantity remaining in descent water tank is displayed on H <sub>2</sub> O QTY indicator.
ASC 1	Indicates that quantity of ascent oxygen tank No. 1 is displayed on O <sub>2</sub> QTY indicator and quantity remaining in ascent water tank No. 1 is displayed on H <sub>2</sub> O QTY indicator.
ASC2	Indicates that quantity of ascent oxygen tank No. 2 is displayed on O <sub>2</sub> QTY indicator and quantity remaining in ascent water tank No. 2 is displayed on H <sub>2</sub> O QTY indicator.
GLYCOL PUMP switch repeater lights	Indicate selection of either of two circulating pumps in primary coolant loop, or circulating pump in emergency coolant loop.
1	Indicates activation of glycol pump No. 1 and by-passing automatic changeover feature
2	Indicates activation of glycol pump No. 2 and by-passing of automatic changeover feature
EMER	Indicates activation of glycol pump in emergency coolant pump





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Figure 1-73. Environmental Control Panel

Table 1-53. REACTION CONTROL Panel, Displays

Display	Function
SYSTEM A MAIN SOV status flag repeater	
Gray display	Indicates open condition of propellant main shutoff valves controlled by MAIN SOV switch
Barber-pole display	Indicates closed condition of main shutoff valves
SYSTEM A ASC FEED status flag repeater	
Gray display	Indicates open condition of ascent propellant interconnect valves controlled by ASC FEED switch
Barber-pole display	Indicates closed condition of interconnect valves
SYSTEM B MAIN SOV status flag repeater	
Gray display	Indicates open condition of propellant main shutoff valves controlled by MAIN SOV switch
Barber-pole display	Indicates closed condition of main shutoff valves
SYSTEM B ASC FEED status flag repeater	
Gray display	Indicates open condition of ascent propellant interconnect valves controlled by ASC FEED switch
Barber-pole display	Indicates closed condition of interconnect valves
SYSTEM A THRUSTER PAIR QUAD 1 status flag repeater	Indicates open, closed, and failed-closed condition of two isolation valves in propellant lines downstream of TCA's No. Iu and If
Gray display	Indicates open condition of two isolation valves controlled by QUAD 1 switch
Barber-pole display	Indicates closed condition of valves
Red display	Indicates TCA failure
SYSTEM A THRUSTER PAIR QUAD 2 status flag repeater	Indicates open, closed, and failed-closed condition of two isolation valves in propellant lines downstream of TCA No. IId and IIs
Gray display	Indicates open condition of two isolation valves controlled by QUAD 2 switch
Barber-pole display	Indicates closed condition of valves
Red display	Indicates TCA failure
SYSTEM B THRUSTER PAIR QUAD 1 status flag repeater	Indicates open, closed, and failed-closed condition of two isolation valves in propellant lines downstream of TCA No. Id and Is
Gray display	Indicates open condition of two isolation valves controlled by QUAD 1 switch
Barber-pole display	Indicates closed condition of valves
Red display	Indicates TCA failure



Table 1-53. REACTION CONTROL Panel, Displays (cont)

Display	Function
<b>SYSTEM B THRUSTER PAIR QUAD 2 status flag repeater</b>	Indicates open, closed, and failed-closed condition of two isolation valves in propellant lines downstream of TCA No. IIu and IIs
Gray display	Indicates open condition of two isolation valves controlled by QUAD 2 switch
Barber-pole display	Indicates closed condition of valves
Red display	Indicates TCA failure
<b>SYSTEM A THRUSTER PAIR QUAD 3 status flag repeater</b>	Indicates open, closed, and failed-closed condition of two isolation valves in propellant lines downstream of TCA No. IIIu and IIIs
Gray display	Indicates open condition of two isolation valves controlled by QUAD 3 switch
Barber-pole display	Indicates closed condition of valves
Red display	Indicates TCA failure
<b>SYSTEM A THRUSTER PAIR QUAD 4 status flag repeater</b>	Indicates open, closed, and failed-closed condition of two isolation valves in propellant lines downstream of TCA No. IVd and IVs
Gray display	Indicates open condition of two isolation valves controlled by QUAD 4 switch
Barber-pole display	Indicates closed condition of valves
Red display	Indicates TCA failure
<b>SYSTEM B THRUSTER PAIR QUAD 3 status flag repeater</b>	Indicates open, closed, and failed-closed condition of two isolation valves in propellant lines downstream of TCA No. IIIu and IIIs
Gray display	Indicates open condition of two isolation valves controlled by QUAD 3 switch
Barber-pole display	Indicates closed condition of valves
Red display	Indicates TCA failure
<b>SYSTEM B THRUSTER PAIR QUAD 4 status flag repeater</b>	Indicates open, closed, and failed-closed condition of two isolation valves in propellant lines downstream of TCA No. IVu and IVs
Gray display	Indicates open condition of two isolation valves controlled by QUAD 4 switch
Barber-pole display	Indicates closed condition of valves
Red display	Indicates TCA failure
<b>CSRFD status flag repeater</b>	Indicates open or closed condition of two latch-type, solenoid-operated fuel and oxidizer crossfeed valves in crossfeed piping arrangement between systems A and B
Gray display	Indicates open condition of fuel and oxidizer crossfeed valves controlled by CRSFD switch
Barber-pole display	Indicates closed condition valves

Table 1-53. REACTION CONTROL Panel, Displays (cont)

Display	Function
PRESS indicator repeater	Indicates pressure (0 to 3,500 psia) of helium, fuel, and oxidizer tanks and of fuel or oxidizer manifolds of systems A and B
TEMP indicator repeater light	Indicates temperature (+20° to +120° F) of helium, fuel, and oxidizer tanks of systems A and B
QUANTITY indicator repeater	Indicates quantity of propellant (0% to 99%) remaining in RCS propellant tanks
SYSTEM A MAIN SOV switch	Indicate selection of inputs to two latch-type, solenoid-operated, main shutoff valves in propellant lines downstream of propellant tanks
OPEN	Indicates propellant main shutoff solenoids that drive main shutoff valves to open position are energized
CLOSE	Indicates propellant main shutoff solenoids that drive main shutoff valves to closed position are energized
SYSTEM A ASC FEED switch repeater lights	Indicate selection of inputs to two latch-type, solenoid-operated, manifold control valves in ascent propellant line, which control flow of propellant from ascent propellant tanks
OPEN	Indicates ascent propellant interconnect solenoids that drive interconnect valves to open position are energized
CLOSE	Indicates ascent propellant interconnect solenoids that drive interconnect valves to closed position are energized
SYSTEM B MAIN SOV switch repeater lights	Indicate selection of inputs to two latch-type, solenoid-operated, main shutoff valves in propellant lines downstream of propellant tanks
OPEN	Indicates propellant main shutoff solenoids that drive main shutoff valves to open position are energized.
CLOSE	Indicates propellant main shutoff solenoids that drive main shutoff valves to closed position are energized
SYSTEM B ASC FEED switch repeater lights	Indicate selection of inputs to two latch-type, solenoid-operated, interconnect valves in ascent propellant line, which control flow of propellant from ascent propellant tanks
OPEN	Indicates ascent propellant interconnect solenoids that drive interconnect valves to open position are energized
CLOSE	Indicates ascent propellant interconnect solenoids that drive interconnect valves to closed position are energized
SYSTEM A THRUSTER PAIR QUAD 1 switch repeater lights	Indicate selection of inputs to two normally open, latch-type, solenoid-operated, shutoff, isolation valves in propellant lines downstream of TCA's, to control propellant flow to TCA No. 1u and 1f
OPEN	Indicates two isolation solenoids that drive isolation valves to open position are energized
CLOSE	Indicates two isolation solenoids that drive isolation valves to the closed position are energized



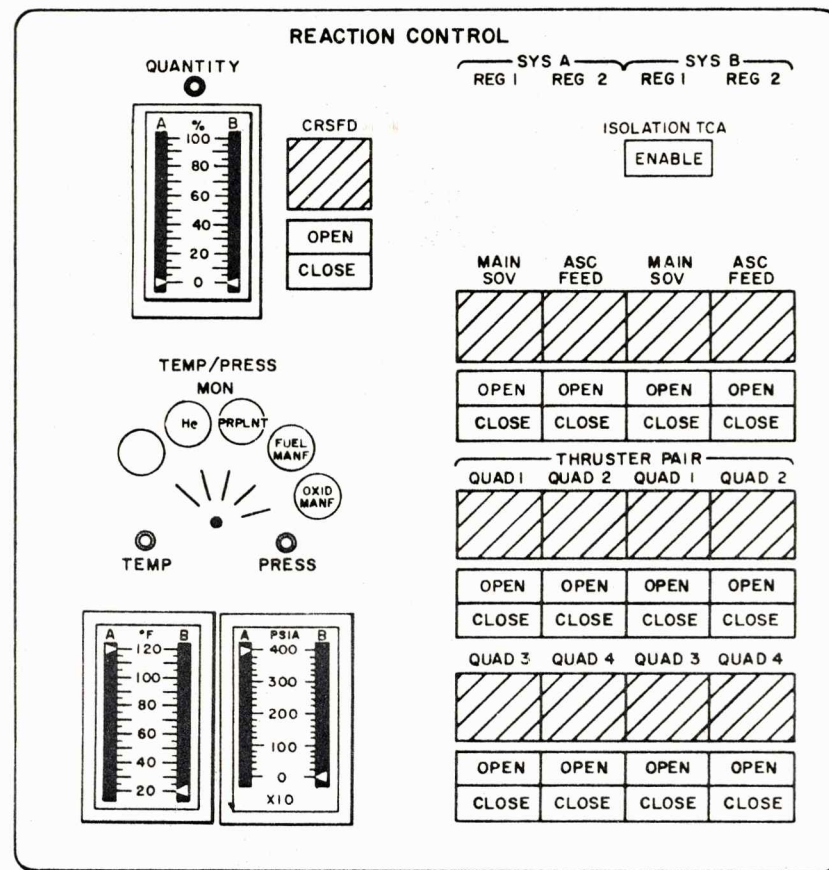
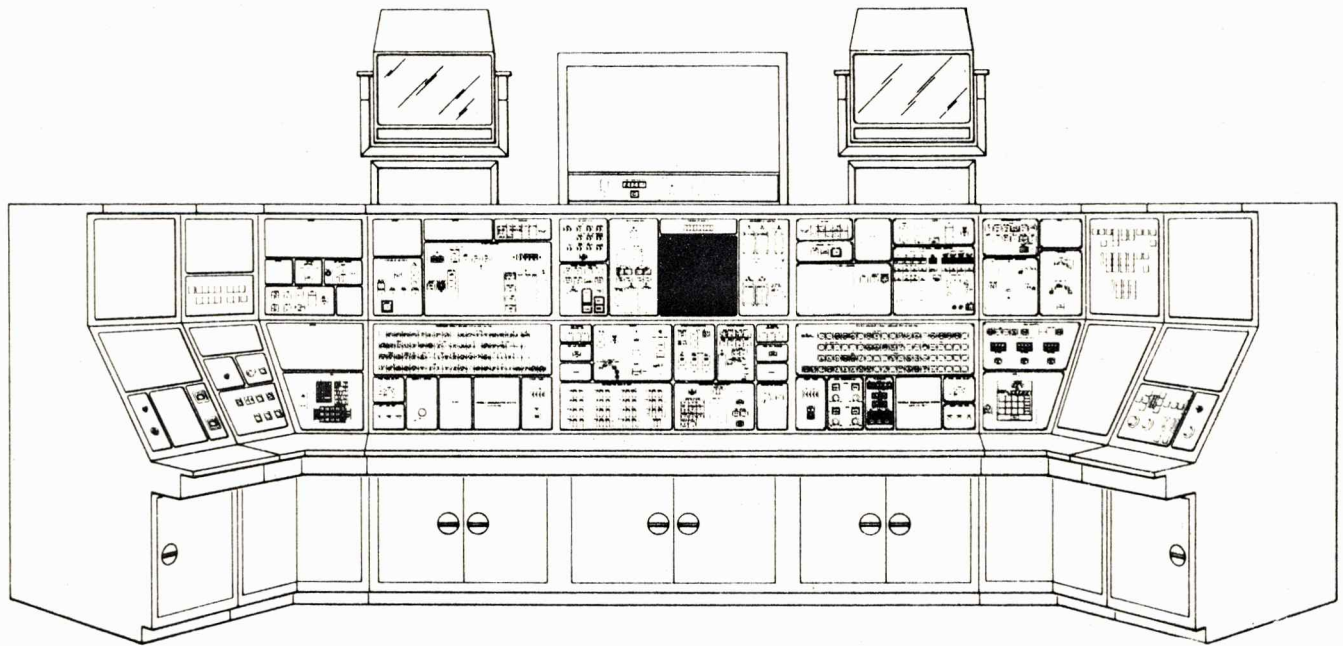
Table 1-53. REACTION CONTROL Panel, Displays (cont)

Display	Function
SYSTEM A THRUSTER PAIR QUAD 2 switch repeater lights	Indicate selection of inputs to two normally open, latch-type, solenoid-operated, shutoff, isolation valves in propellant lines downstream of TCA's, to control propellant flow to TCA No. IID and IIf
OPEN	Indicates that two isolation solenoids that drive isolation valves to open position are energized
CLOSE	Indicates that two isolation solenoids that drive isolation valves to closed position are energized
SYSTEM B THRUSTER PAIR QUAD 1 switch repeater lights	Indicate selection of inputs to two normally open, latch-type, solenoid-operated, shutoff, isolation valves in propellant lines downstream of TCA's, to control propellant flow to TCA No. Id and Is
OPEN	Indicates two isolation solenoids that drive isolation valves to open position are energized
CLOSE	Indicates two isolation solenoids that drive isolation valves to closed position are energized
SYSTEM B THRUSTER PAIR QUAD 2 switch repeater lights	Indicate selection of inputs to two normally open, latch-type, solenoid-operated, shutoff, isolation valves in propellant lines downstream of TCA's, to control propellant flow to TCA No. IIu and IIs
OPEN	Indicates two isolation solenoids that drive isolation valves to open position are energized
CLOSE	Indicates two isolation solenoids that drive isolation valves to closed position are energized
SYSTEM A THRUSTER PAIR QUAD 3 switch repeater lights	Indicate selection of inputs to two normally open, latch-type, solenoid-operated, shutoff, isolation valves to propellant lines downstream of TCA's, to control propellant flow to TCA No. IIIu and IIIs
OPEN	Indicates two isolation solenoids that drive isolation valves to open position are energized
CLOSE	Indicates two isolation solenoids that drive isolation valves to closed position are energized
SYSTEM A THRUSTER PAIR QUAD 4 switch repeater lights	Indicate selection of inputs to two normally open, latch-type, solenoid-operated, shutoff, isolation valves in propellant lines downstream of TCA's, to control propellant flow to TCA No. IVd and IVs
OPEN	Indicates two isolation solenoids that drive isolation valves to open position are energized
CLOSE	Indicates two isolation solenoids that drive isolation valves to closed position are energized.
SYSTEM B THRUSTER PAIR QUAD 3 switch repeater lights	Indicate selection of inputs to two normally open, latch-type, solenoid-operated, shutoff, isolation valves in propellant lines downstream of TCA's, to control propellant flow to TCA No. IIIId and IIIIf

Table 1-53. REACTION CONTROL Panel, Displays (cont)

Display	Function
OPEN	Indicates two isolation solenoids that drive isolation valves to open position are energized
CLOSE	Indicates two isolation solenoids that drive isolation valves to closed position are energized
SYSTEM B THRUSTER PAIR QUAD 4 switch repeater lights	Indicate selection of inputs to two normally open, latch-type, solenoid-operated, shutoff, isolation valves in propellant lines downstream of TCA's, to control propellant flow to TCA No. IVu and IVf
OPEN	Indicates two isolation solenoids that drive isolation valves to open position are energized
CLOSE	Indicates two isolation solenoids that drive isolation valves to closed position are energized
TEMP/PRESS MON switch repeater lights	Indicate selection of inputs to propellant temperature- and pressure-indicating devices for systems A and B
He	Indicates signal outputs from systems A and B helium tank temperature sensor and pressure transducer are connected to TEMP and PRESS indicators
PRPLNT	Indicates signal outputs from systems A and B fuel tank and oxidizer tank temperature sensors and pressure transducer are connected to TEMP and PRESS indicators
FUEL MANF	Indicates signal outputs from systems A and B fuel manifold pressure transducer are connected to PRESS indicator
OXID MANF	Indicates signal outputs from systems A and B oxidizer manifold pressure transducer are connected to PRESS indicator
CRSFD switch repeater lights	Indicate selection of inputs to two latch-type, solenoid-operated, fuel and oxidizer crossfeed valves located in crossfeed piping arrangement between systems A and B.
OPEN	Indicates signal outputs from fuel and oxidizer crossfeed valves are not connected to CRSFD status flag
CLOSE	Indicates signal outputs from fuel and oxidizer crossfeed valves are connected to CRSFD status flag
ISOLATION TCA switch repeater light	Provides automatic isolation of TCA's by LM Mission Programmer (LMP)
<div style="text-align: center;">NOTE</div> <p style="text-align: center;">This switch is not used.</p>	
ENABLE	Indicates automatic isolation of malfunctioning thruster pairs. Signals to all THRUSTER PAIR status flags are inhibited





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Figure 1-74. REACTION CONTROL Panel

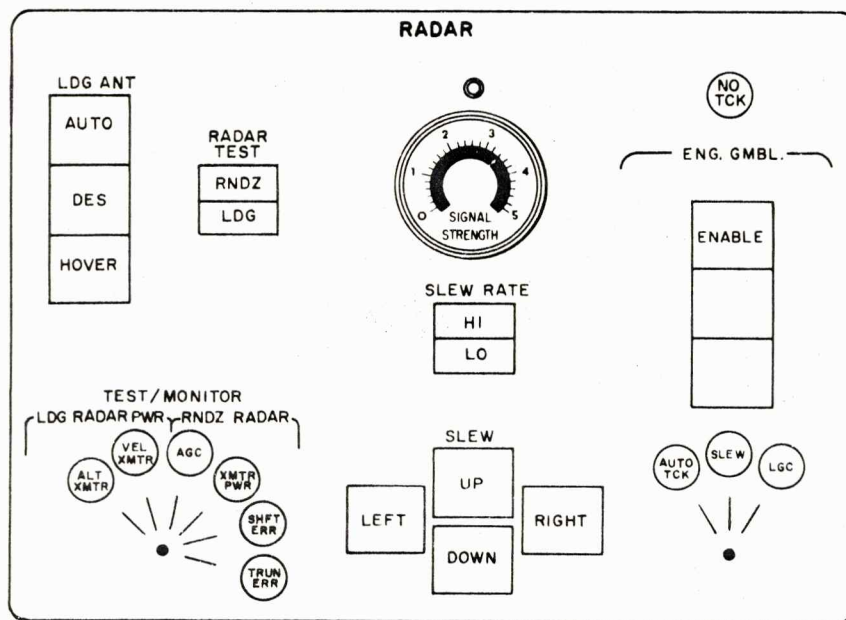
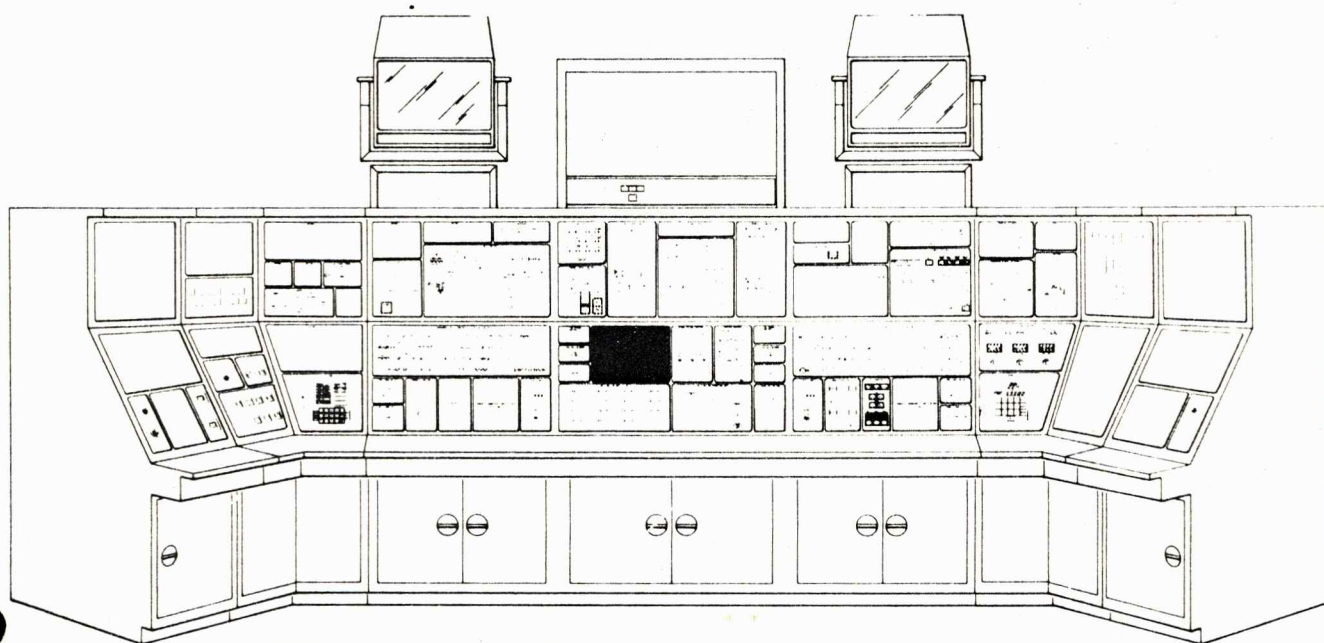
Table 1-54. RADAR Panel, Displays

Display	Function
NO TCK repeater light	Light goes on to indicate that rendezvous radar has broken track (data not good) in any one of three tracking modes
Signal strength meter repeater	Displays landing radar and rendezvous radar data for test and flight operations as selected with TEST/MONITOR switch
Manual SLEW switch repeaters lights	Indicate slewing of trunnion or shaft servos, or both, to position rendezvous radar antenna for manual acquisition of target and subsequent automatic tracking
UP	Indicates slewing of trunnion or shaft servos, or both, upward to position rendezvous radar antenna for manual acquisition of target and subsequent automatic tracking
RIGHT	Same indication as for UP light, except that slewing is to right
DOWN	Same indication as for UP light, except that slewing is downward
LEFT	Same indication as for UP light, except that slewing is to left
SLEW RATE switch repeater lights	Indicate two rates for manually slewing, rendezvous radar antenna with SLEW switch
HI	Indicates selection of high slew rate for quick coarse adjustments to guide antenna in direction of target
LO	Indicates selection of low slew rate for accurately peaking signal strength meter, enabling subsequent initiation of automatic tracking with RNDZ RADAR mode switch with assurance that main lobe lock will be achieved
AUTO TCK switch position repeater light	Indicates track is maintained by comparing received radar signals from three channels; errors are used to drive radar servos, thus maintaining track
SLEW switch position repeater light	Indicates rendezvous radar antenna drive is controlled manually with SLEW switch
LGC switch position repeater light	Indicates computer is automatically driving antenna toward target
LDG ANT switch repeater lights	
AUTO	Indicates LGC is positioning landing radar antenna as function of mission phase
DES	Indicates antenna is driving to first position used before hover point
HOVER	Indicates antenna is driving to its second position for final landing phase



Table 1-54. RADAR Panel, Displays (cont)

Display	Function
RADAR TEST switch repeater lights	
RNDZ	Indicates test circuitry is initiated and rendezvous radar performance is monitored on signal strength meter after appropriate setting of TEST/MONITOR switch
LDG	Indicates test circuitry is initiated and landing radar performance is monitored on signal strength meter after appropriate setting of TEST/MONITOR switch
TEST/MONITOR switch repeater lights	Indicates selection of landing radar rendezvous radar test data or flight performance data for monitoring on signal strength meter
ALT XMTR	Indicates selection of altitude range transmitter power output for display on signal strength meter during testing and flight operations
VEL XMTR	Indicates selection of velocity transmitter's power output for display on signal strength meter during testing and flight operations
AGC	Indicates selection of AGC during rendezvous radar testing. (Specific value of receiver signal strength should be displayed on signal strength meter; however, during flight operations signal will vary.)
XMTR PWR	Indicates selection of specific value of transmitter output power, which is displayed on signal strength meter during flight operations
SHAFT ERR	Indicates selection of shaft angle error signals (During testing, angle errors are displayed as needle fluctuations with equal amplitude on signal strength meter. During flight operations these error signals are displayed as needle fluctuations that represent the smoothness of servo tracking.)
TRUN ERR	Indicates selection of trunnion angle errors. (See comment for SHAFT ERR position.)



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Figure 1-75. RADAR Panel



Table 1-55. STABILIZATION/CONTROL Panel, Displays

Display	Function
GYRO TEST control switch repeater lights	Indicate test signal is applied to rate gyro selected with GYRO TEST select switch
POS RT	Indicates that selected rate gyro output displaces FDAI rate needles at + 5°/second vehicle attitude rate
NEG RT	Same as POS RT, except that FDAI rate needles are displaced at -5°/second
DEADBAND switch repeater lights	Indicate selection of wide or narrow deadband
MAX	Indicates selection of large-amplitude limit cycle ( $\pm 5.0^\circ$ ) for attitude control system to conserve RCS fuel during coasting flight
MIN	Indicates selection of narrow deadband ( $\pm 0.3^\circ$ ) for periods when accurate manual control is required
ATTITUDE CONTROL PITCH, ROLL, and YAW switch repeater lights	Indicates AGS attitude control in pitch, roll, and yaw established in conjunction with MODE CONTROL switch
MODE CONT	Indicates vehicle attitude control about appropriate axis is determined by MODE CONTROL switch setting
PULSE	If AGS has been selected with GUID CONT switch, and ATTITUDE CONTROL switch is set to PULSE or DIR, this repeater indicates attitude about axis can only be controlled manually. Astronaut has openloop type of acceleration control when attitude controller is displaced more than one-fourth of its full throw in appropriate direction.
DIR	Indicates displaced attitude controller is activating pairs or reaction jets. Since attitude authority is still automatic via LGC, such jet firing interferes with automatic steering commands. Selection of DIR and attitude controller, causes jets to activate continuously instead of being pulsed.
MODE CONTROL switch repeater lights	Indicates outputs of attitude controllers, thrust/translation controllers, and selected guidance computer are affected
ATT HOLD	Indicates astronauts can command an angular rate proportional to displacement of attitude controllers in either PGNS or AGS. When attitude controller is out of neutral detent, ATTITUDE CONTROL switches in MODE CONT, AGS in control loop, attitude loops are opened and axis transducers are compared to rate gyro outputs to provide proportional commands.
AUTO	Indicates that with GUID CONT switch in AGS position, attitude error signals are sent to CES from AGS.
GYRO TEST select switch repeater lights	Indicates selection of FDAI rate gyro to be tested

Table 1-55. STABILIZATION/CONTROL Panel, Displays (cont)

Display	Function
GYRO TEST select switch repeater lights (cont)	
ROLL	Indicates selection of FDAI rate gyro to be tested in ROLL
PITCH	Indicates selection of FDAI rate gyro to be tested in PITCH
YAW	Indicates selection of FDAI rate gyro to be tested in YAW

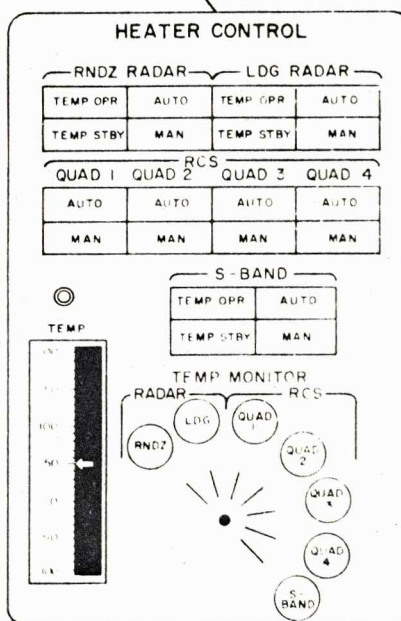
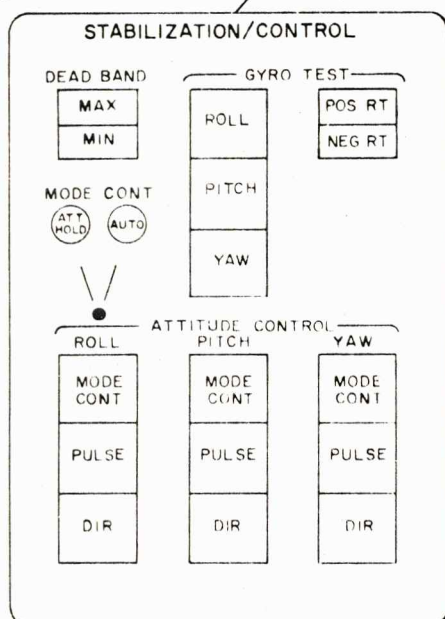
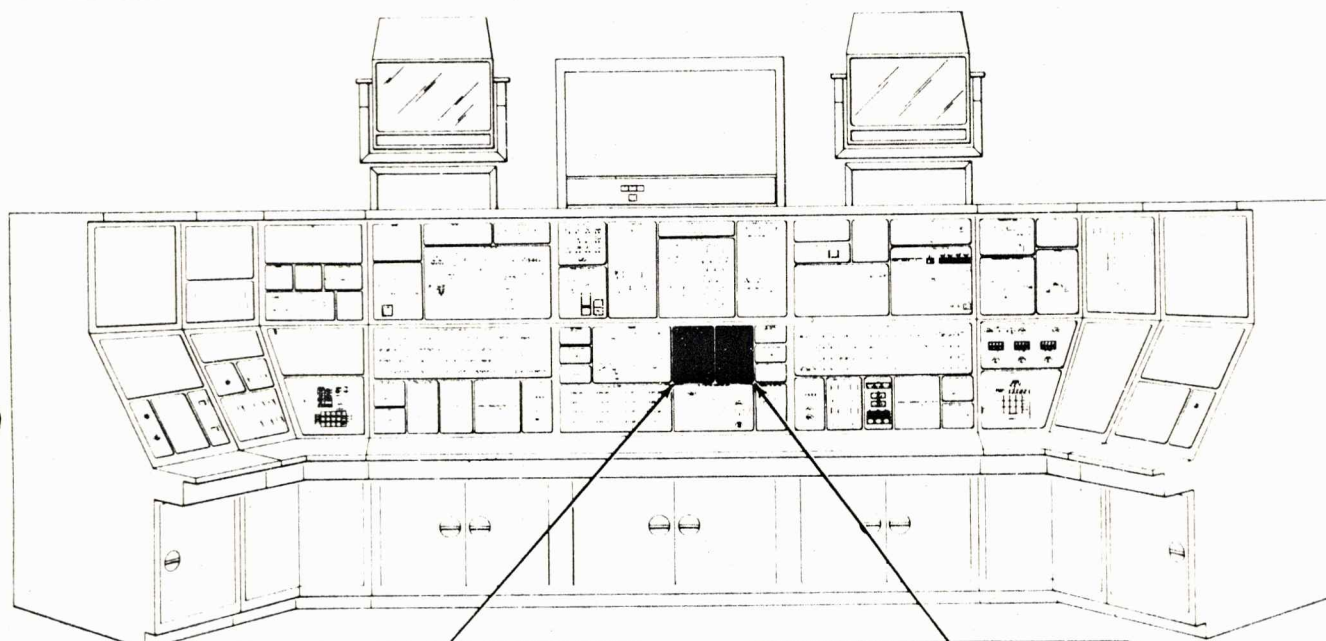


Figure 1-76. STABILIZATION CONTROL and HEATER CONTROL Panels

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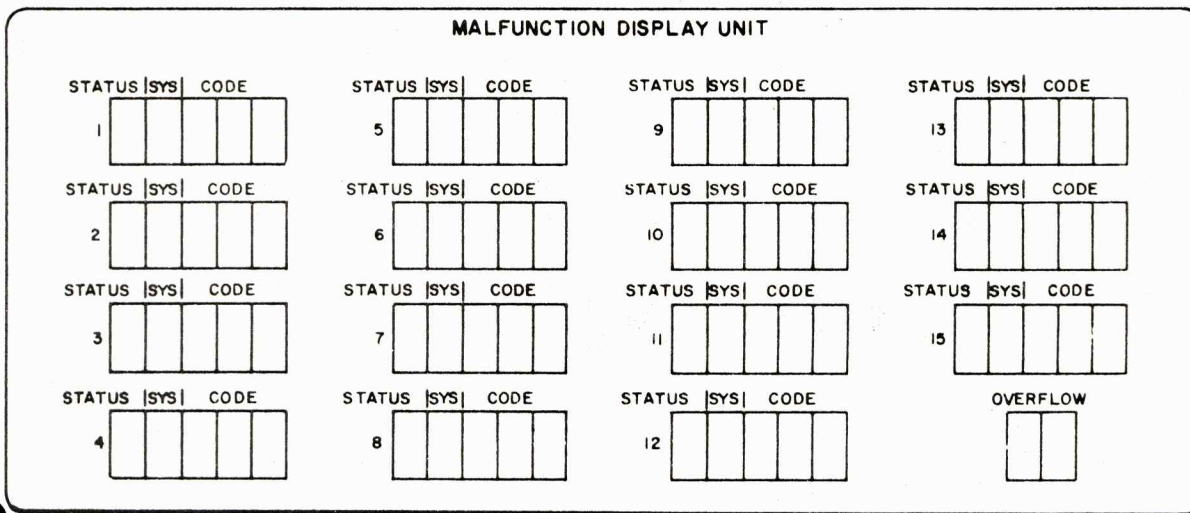
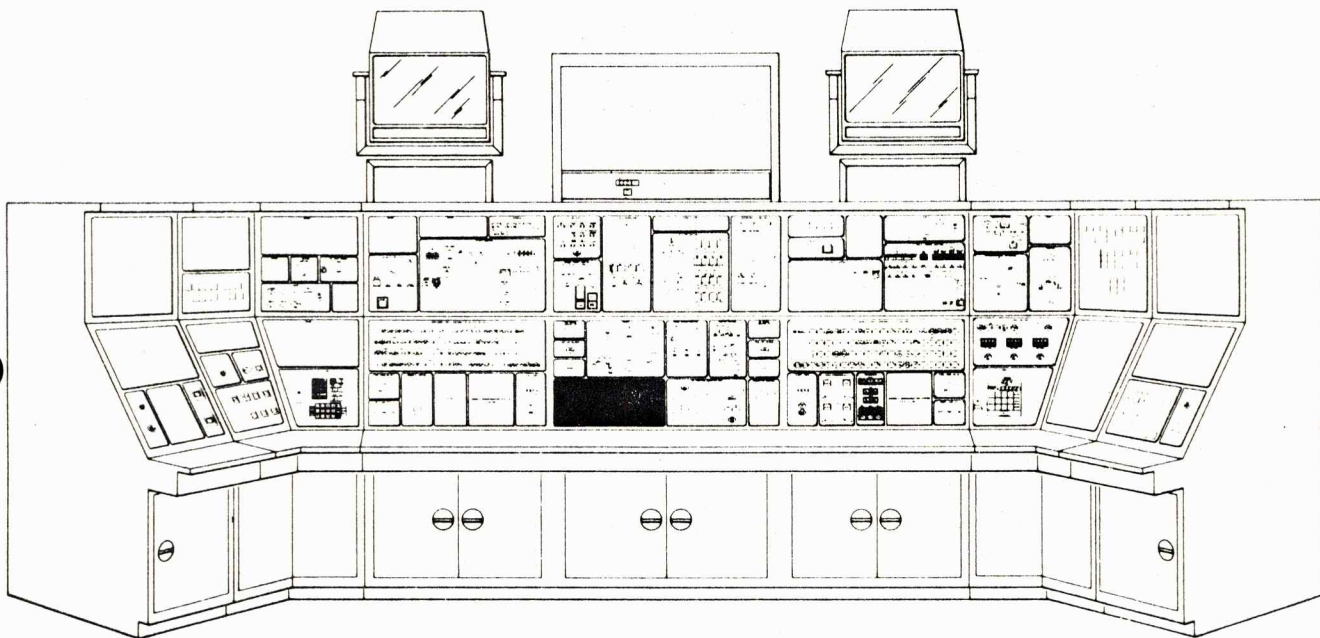


Table 1-56. HEATER CONTROL Panel, Displays

Display	Function
RNDZ RADAR switch repeater lights  TEMP OPR TEMP STBY AUTO MAN	Indicate selection of heater switch position for rendezvous radar antenna
LDG RADAR repeater lights  TEMP OPR TEMP STBY AUTO MAN	Indicate selection of heater switch positions for landing radar antenna
RCS repeater lights  QUAD 1  AUTO MAN	Indicate selection of heater switch positions for RCS thruster QUAD 1
QUAD 2  AUTO MAN	Indicate selection of heater switch positions for RCS thruster QUAD 2
QUAD 3  AUTO MAN	Indicate selection of heater switch positions for RCS thruster QUAD 3
QUAD 4  AUTO MAN	Indicate selection of heater switch positions for RCS thruster QUAD 4
S-BAND repeater lights  TEMP OPR TEMP STBY AUTO MAN	Indicates selection of heater switch positions for S-band antenna assembly
TEMP MONITOR repeater lights  RADAR  RNDZ  LDG  RCS  QUAD 1	Indicates selection of rendezvous radar for temperature monitoring on TEMP indicator  Indicates selection of landing radar for temperature monitoring on TEMP indicator  Indicates selection of QUAD 1 for temperature monitoring on TEMP indicator

Table 1-56. HEATER CONTROL Panel, Displays (cont)

Display	Function
RCS (cont)	
QUAD 2	Indicates selection of QUAD 2 for temperature monitoring on TEMP indicator
QUAD 3	Indicates selection of QUAD 3 for temperature monitoring on TEMP indicator
QUAD 4	Indicates selection of QUAD 4 for temperature monitoring on TEMP indicator
S-BAND	Indicates selection of S-band antenna for temperature monitoring on TEMP indicator
TEMP indicator repeater	Indicates temperature of assembly selected by TEMP MONITOR switch



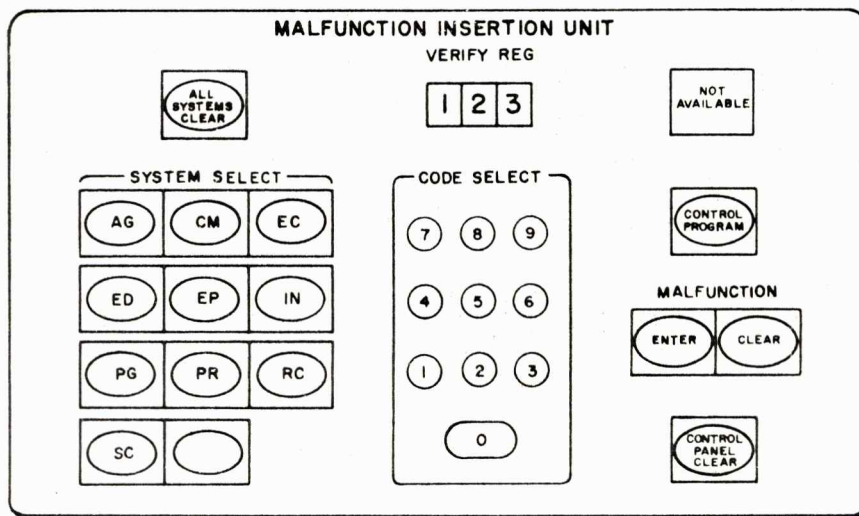
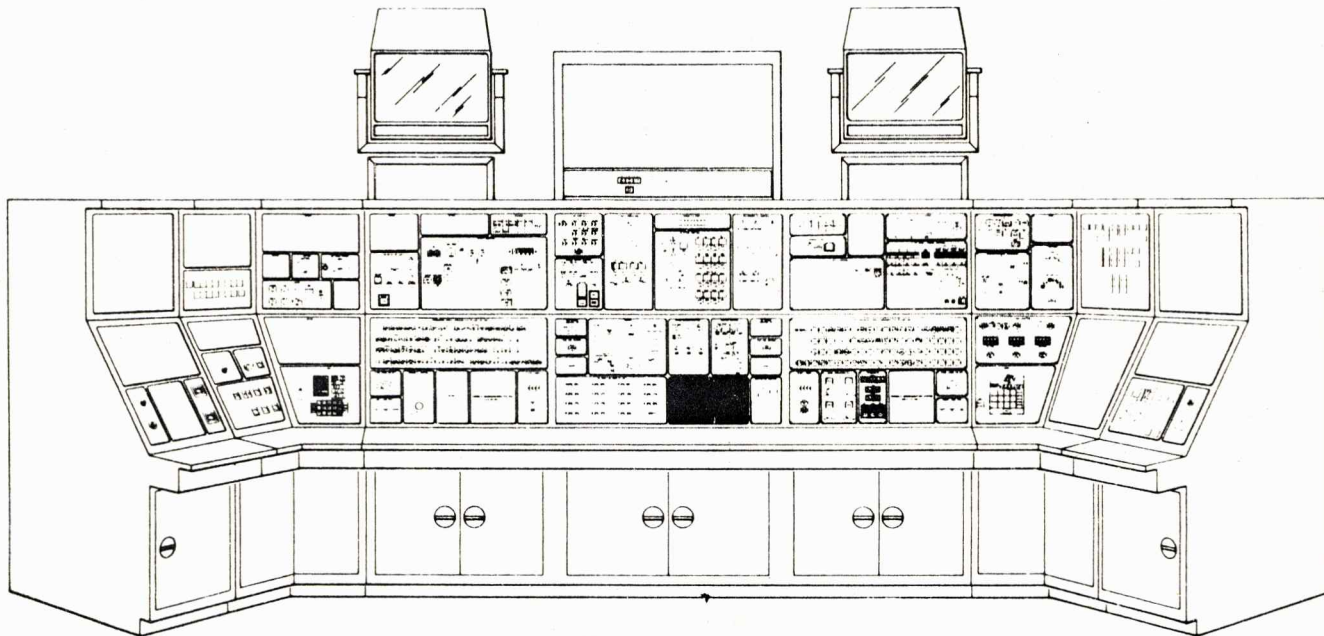
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Figure 1-77. MALFUNCTION DISPLAY UNIT Panel



Table 1-57. MALFUNCTION DISPLAY UNIT Panel, Displays

Display	Function
STATUS indicator lights	Indicate status of control program and direct malfunctions
T (white)	Projected when time-dependent control program is enabled
E (white)	Projected when event-dependent control program is enabled
IMP (blue)	Projected 1 minute before activation of malfunction by displayed time-dependent control program
ACT (amber)	Projected when either control program or direct malfunction is activated
SYS (one unit) indicator lights	Display designation of subsystem or section being malfunctioned
	AG (Abort guidance) CM (Communications) EC (Environmental control) ED (Explosive devices) EP (Electrical power) IN (Instrumentation) PG (Primary guidance and navigation) PR (Propulsion) RC (Reaction control) SC (Stabilization and control)
CODE (three units) indicator lights (0 through 9, each unit)	Displays three-digit code number of inserted malfunction
OVERFLOW indicator lights (two units) (01 through 11)	Display number of malfunctions in excess of 15, but not exceeding 26, that have been inserted simultaneously
<div style="text-align: center; border: 1px solid black; padding: 2px; width: fit-content; margin: 0 auto;"><b>NOTE</b></div> <p>The MDU display is automatic on a "next available" basis upon actuation of the MIU MALFUNCTION ENTER or CLEAR switches. When a display line is emptied, one of the overflowed malfunctions is displayed and the overflow indication is decreased by one.</p>	



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Figure 1-78, MALFUNCTION INSERTION UNIT Panel



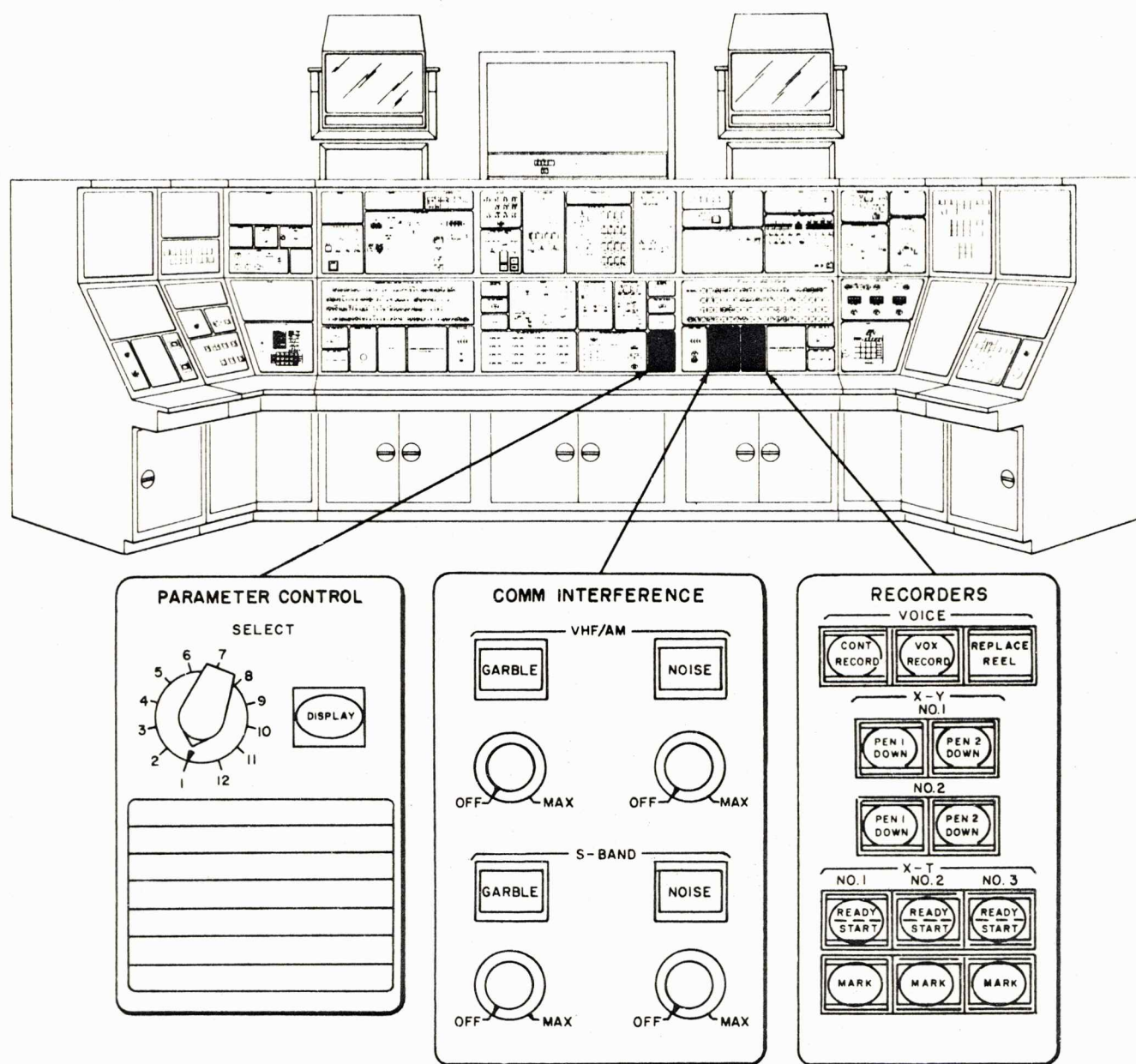
Table 1-58. MALFUNCTION INSERTION UNIT Panel, Controls and Displays

Control or Display	Function
ALL SYSTEMS CLEAR switch light	Permits instructor to deactivate all malfunction control programs and malfunctions. Clearing is "on line." This switch will clear control panel.
VERIFY REG readout	Displays malfunction code selected with keyboard. Display remains until CONTROL PANEL CLEAR switch or MALFUNCTION ENTER or CLEAR switches are actuated and negation of "not available" is established.
NOT AVAILABLE indicator Light	<p>After actuation of MALFUNCTION ENTER or CLEAR switches, NOT AVAILABLE light goes on if one of following conditions exists:</p> <ul style="list-style-type: none"> <li>● Control program was selected that is not in core</li> <li>● No malfunction is assigned to three-digit code selected.</li> </ul> <p><b>NOTE</b></p> <p>If NOT AVAILABLE light goes on, the MIU must be cleared manually with CONTROL PANEL CLEAR switch.</p>
SYSTEM SELECT switch lights	Permit instructor to select subsystem for subsequent deletion of all malfunctions associated with that subsystem, when used in conjunction with MALFUNCTION CLEAR switch. In addition, when used in conjunction with CODE SELECT keyboard, switches permit addressing individual malfunction for subsequent entering or deletion. Switch light goes on when pressed and remains lit until CONTROL PANEL CLEAR or MALFUNCTION ENTER or CLEAR switches are actuated and negation of "not available" is established. Legends are allocated alphabetically.
AG (Abort guidance)	
CM (Communications)	
EC (Environmental control)	
ED (Explosive devices)	
EP (Electrical power)	
IN (Instrumentation)	
PG (Primary navigation and guidance)	
PR (Propulsion)	
RC (Reaction control)	
SC (Stabilization and control)	
Spare	

Table 1-58. MALFUNCTION INSERTION UNIT, Panel Controls and Displays (cont)

Control or Display	Function
CODE SELECT keyboard	Permits selection of three-digit malfunction code, which, when used with SYSTEM SELECT, switch lights, enables instructor to address individual malfunction for subsequent entering or deletion. Code selected is displayed in displayed in VERIFY REG readout (filled from left to right sequentially). Code remains selected until CONTROL PANEL CLEAR switch or MALFUNCTION ENTER or CLEAR switches are actuated and negation of "not available" is established.
CONTROL PROGRAM switch light	Permits instructor to enter or delete control program malfunction (that is event - or time-dependent activation, rather than activation directly upon entering). Same malfunction can be inserted either directly or as control program. When pressed, switch light goes on and remains on until CONTROL PANEL CLEAR switch or MALFUNCTION ENTER or CLEAR switches are actuated and negation of "not available" is established.
MALFUNCTION ENTER and CLEAR switch lights	Permit instructor to enter and delete individual malfunctions, identified by the SYSTEM SELECT and CODE SELECT keyboards. When pressed, switch light goes on and remains on until CONTROL PANEL CLEAR switch is actuated or negation of "not available" is established.
CONTROL PANEL CLEAR switch light	<p>Actuation results in the following:</p> <ul style="list-style-type: none"> <li>• SYSTEM SELECT switch is deenergized</li> <li>• ALL SYSTEMS CLEAR switch is deenergized</li> <li>• VERIFY REGISTER becomes blank</li> <li>• NOT AVAILABLE/INVALID INSTRUCTION light goes off</li> <li>• ENTER and CLEAR MALFUNCTION switches are deenergized and go off</li> <li>• CONTROL PROGRAM switch is deenergized</li> </ul>





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Figure 1-79. PARAMETER CONTROL, COMM INTERFERENCE, and RECORDERS Panels

Table 1-59. PARAMETER CONTROL Panel, Controls

Control	Function
PARAMETER CONTROL SELECT switch	Permits instructor to select any 1 of 12 preprogrammed parameters for display. Instructor must decide, in advance of training mission, which 12 parameters he would like to have available and program selector accordingly.
DISPLAY switch light  (Placard)	Permits instructor to activate display of parameter selected. Light remains on until switch is actuated second time. Display then goes blank. When display is actuated, any 1 of 12 parameters can be displayed by selecting parameter with SELECT switch.  This placard is for abbreviated notes to aid instructor in identifying 12 predetermined parameters and their switch positions. Notes are to be written on placard, with grease pencil.

## 1.9.36 COMM INTERFERENCE PANEL. (See figure 1-79.)

The COMM INTERFERENCE panel enables control and insertion of variable amounts of noise distortion into the voice communications channels. The controls of the COMM INTERFERENCE panel are listed, with their function, in table 1-60.

## 1.9.37 RECORDERS PANEL. (See figure 1-79.)

The RECORDERS panel contains the instructor's control switches for the two X-T recorders, the two X-Y plotters, and the voice recorder. The controls and displays of the RECORDERS panel are listed, with their function, in table 1-61.

Table 1-60. COMM INTERFERENCE Panel, Controls

Control	Function
VHF/AM switch lights GARBLE OFF-MAX control NOISE OFF-MAX control	Permit instructor to vary intensity of garble and noise and to introduce selected amount of garble and noise into VHF/AM communications channel. Garble consists of distorting and clipping audio that is being routed to astronauts' headsets. For noise, white noise is mixed with audio, which is then routed to headsets. Switch light goes on when potentiometers are not in detented OFF position.
S-BAND switch lights GARBLE OFF-MAX control NOISE OFF-MAX control	Function in manner described for VHF/AM GARBLE and NOISE controls, except that they introduce interference into S-band communications



Table 1-61. RECORDERS Panel, Controls and Displays

Control or Display	Funtion
VOICE	
VOX RECORD switch light	When pressed, recorder records all audio that exists at each astronaut's headset and astronaut's voice during voice transmission only.
CONT RECORD switch light	When pressed, recorder records all audio that exists at each astronaut's headset and astronaut's voice on continuous record basis.
REPLACE REEL light	Indicates that one of the two tape reels in audio tape recorder must be replaced with fresh tape
X-Y Plotters	X-Y plotters are dual-arm, dual-pen X-Y position plotters.
NO. 1	
PEN 1 DOWN switch light	When pressed, these switch lights cause the pens to fall to plotting surface. When pressed a second time, pens lift from plotting surface. Light goes on when pens are down.
PEN 2 DOWN switch light	
NO. 2	
PEN 1 DOWN switch light	
PEN 2 DOWN switch light	
X-T Recorders	
NO. 1	X-T recorders are time history plotters. Twelve chart speeds are available. Writing method is pressurized fluid. Each unit has two event channels and eight analog channels. Analog channels are under computer control. Event channels, designated here as left and right, can be set up for remote instructor control. The functions of the following switch lights refer to the event channels in the remote mode.
NO. 2	
NO. 3	
READY START switch lights	READY indicates that power is on at recorder and that recorder is set up for remote operation. Switch starts and stops time drive of plotter when in READY condition. START light goes on when switch is pressed to start plotter and remains on until pressed a second time.
MARK switch lights	Used by instructor to mark event to facilitate later reference. Left and right sides of time history plot are marked simultaneously. Time marks occur automatically.

## 1.9.38 ELECTRICAL POWER CONTROL PANEL. (See figure 1-80.)

The ELECTRICAL POWER CONTROL panel contains repeater lights and indicators of the corresponding LM switch positions, ECS flags, instrument readouts, and component caution indicators. The displays of the ELECTRICAL POWER CONTROL panel are listed, with their function, in table 1-62.

## 1.9.39 COMMUNICATIONS PANEL. (See figure 1-81.)

The COMMUNICATIONS panel contains repeaters lights of the switch positions and warning flag on the corresponding System Engineer's COMMUNICATIONS side console panel in the LM. The displays of the COMMUNICATIONS panel are listed, with their function, in table 1-63.

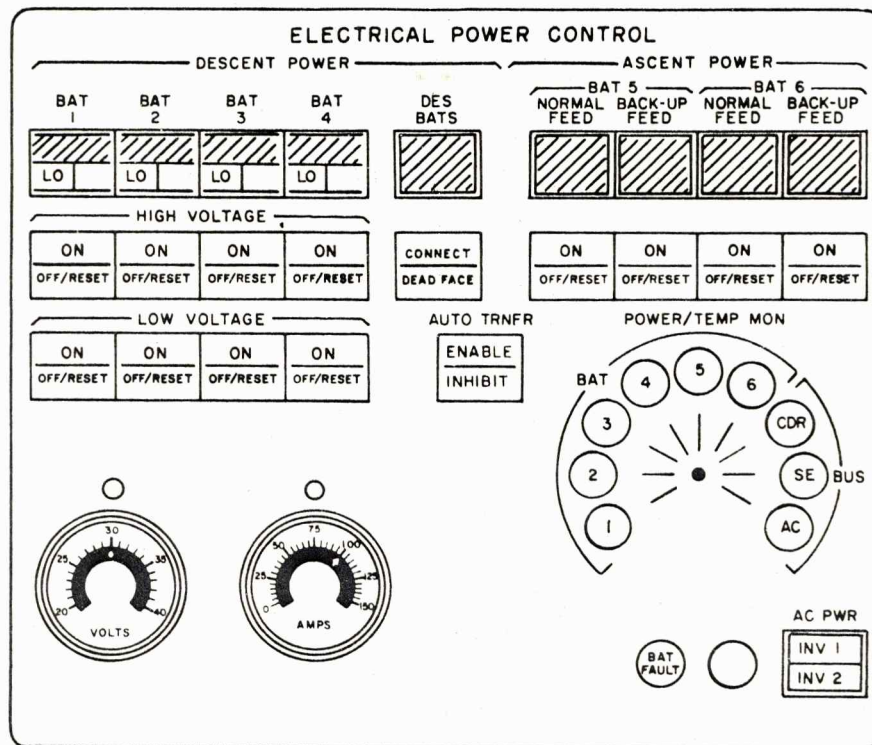
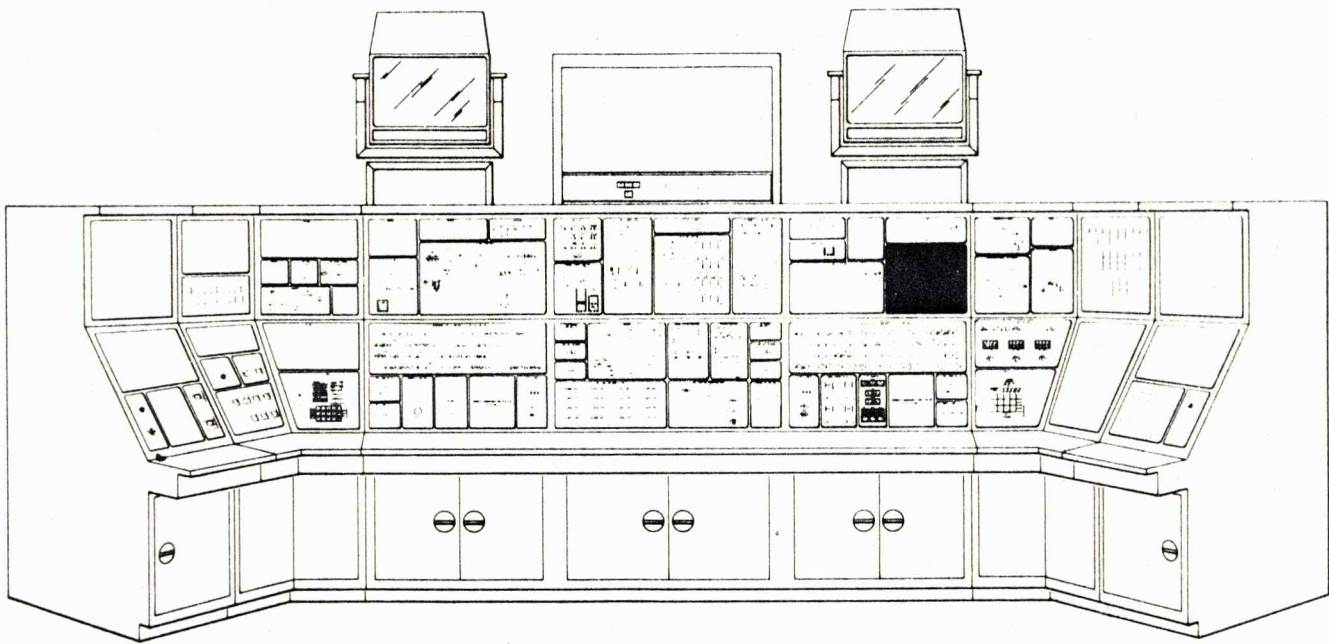


Figure 1-80. Electrical Power Control Panel



Table 1-62. ELECTRICAL POWER CONTROL Panel, Displays

Display	Function
DESCENT POWER BAT 1 status flag repeaters	
Gray display	Indicates descent battery No. 1 is on line
Barber-pole display	Indicates descent battery No. 1 is off line
BAT 2 status flag repeaters	
Gray display	Indicates descent battery No. 2 is on line
Barber-pole display	Indicates descent battery No. 2 is off line
BAT 3 status flag repeaters	
Gray display	Indicates descent battery No. 3 is on line
Barber-pole display	Indicates descent battery No. 3 is off line
BAT 4 status flag repeaters	
Gray display	Indicates descent battery No. 4 is on line
Barber-pole	Indicates descent battery No. 4 is off line
ASCENT POWER BAT 5 NORMAL FEED status flag repeaters	
Gray display	Indicates ascent battery No. 5 is connected to Systems Engineer's bus
Barber-pole display	Indicates ascent battery No. 5 is disconnected from Systems Engineer's bus
BAT 6 NORMAL FEED status flag repeaters	
Gray display	Indicates ascent battery No. 6 is connected to Commander's bus
Barber-pole display	Indicates ascent battery No. 6 is disconnected from Commander's bus
BAT 5 BACK UP FEED status flag repeaters	
Gray display	Indicates ascent battery No. 5 is connected to Commander's bus
Barber-pole display	Indicates ascent battery No. 5 is disconnected from Commander's bus
BAT 6 BACK UP FEED status flag repeaters	
Gray display	Indicates ascent battery No. 6 is connected to Systems Engineer's bus
Barber-pole display	Indicates ascent battery No. 6 is disconnected from Systems Engineer's bus

Table 1-62. ELECTRICAL POWER CONTROL Panel, Displays (cont)

Display	Function
DESCENT POWER DES BATS deadface status flag repeaters	Indicate whether descent stage deadface has been accomplished
Gray display	Indicates descent batteries are connected to ascent stage
Barber-pole display	Indicates descent batteries are disconnected and deadfaced
Voltmeter repeater	Indicates voltage of each of six batteries in EPS, and Commander's and Systems Engineer's d-c bus and a-c bus voltages, as selected by POWER/TEMP MON switch
Ammeter repeater	Indicates current flowing through each of six batteries in EPS, as selected by POWER/TEMP MON switch
DESCENT POWER BAT 1 HIGH VOLTAGE switch repeater lights	Indicate control of high-voltage output from descent battery No. 1
ON	Indicates high-voltage battery tap is on line
OFF/RESET	Indicates high-voltage battery tap is disconnected from line
BAT 2 HIGH VOLTAGE switch repeater lights	
ON	Indicates high-voltage battery tap is on line
OFF/RESET	Indicates high-voltage battery tap is disconnected from line
BAT 3 HIGH VOLTAGE switch repeater lights	Indicate control of high-voltage output from descent battery No. 3
ON	Indicates high-voltage battery tap is on line
OFF/RESET	Indicates high-voltage battery tap is disconnected from line
BAT 4 HIGH VOLTAGE switch repeater lights	Indicate control of high-voltage output from descent battery No. 4
ON	Indicates high-voltage battery tap is on line
OFF/RESET	Indicates high-voltage battery tap is disconnected from line
BAT 1 LOW VOLTAGE switch repeater lights	Indicate control of low-voltage output from descent battery No. 1
ON	Indicates low-voltage battery tap is on line
OFF/RESET	Indicates low-voltage battery tap is disconnected from line
BAT 2 LOW VOLTAGE switch repeater lights	Indicate control of low-voltage output from descent battery No. 2
ON	Indicates low-voltage battery tap is on line
OFF/RESET	Indicates low-voltage battery tap is disconnected from line



Table 1-62. ELECTRICAL POWER CONTROL Panel, Displays (cont)

Display	Function
DESCENT POWER (cont)	
BAT 3 LOW VOLTAGE switch repeater lights	Indicate control of low-voltage output from descent battery No. 3
ON	Indicates low-voltage battery tap is on line
OFF/RESET	Indicates low-voltage battery tap is disconnected from line
BAT 4 LOW VOLTAGE switch repeater lights	Indicate control of low-voltage output from descent battery No. 4
ON	Indicates low-voltage battery tap is on line
OFF/RESET	Indicates low-voltage battery tap is disconnected from line
DES BATS deadface switch repeater lights	Indicate interruption of power from descent batteries to ascent stage
CONNECT	Indicates power is delivered from descent batteries to ascent stage
DEADFACE	Indicates deadfacing relays are energized, isolating descent batteries on ascent stage side of staging guillotine
ASCENT POWER	
BAT 5 NORMAL FEED switch repeater lights	Indicate control of connection of ascent battery No. 5 to distribution bus
ON	Indicates ascent battery is connected to bus
OFF/RESET	Indicates ascent battery is disconnected from bus; ECA contactors made ready for overcurrent protection
BAT 6 NORMAL FEED switch repeater lights	Indicate control of connection of ascent battery No. 6 to distribution bus
ON	Indicates ascent battery is connected to bus
OFF/RESET	Indicates ascent battery is disconnected from bus; ECA contactors made ready for overcurrent protection
BAT 5 BACK UP FEED switch repeater lights	Indicate control of connection of ascent battery No. 5 to alternate feed bus
ON	Indicates ascent battery is connected to bus
OFF/RESET	Indicates ascent battery is disconnected from line; ECA contactors made ready for overcurrent protection
BAT 6 BACK UP FEED switch repeater lights	Indicate connection of ascent battery No. 6 to alternate feed bus
ON	Indicates ascent battery is connected to bus
OFF/RESET	Indicates ascent battery is disconnected from line; ECA contactors made ready for overcurrent protection

Table 1-62. ELECTRICAL POWER CONTROL Panel, Displays (cont)

Display	Function
AC PWR switch repeater lights	Indicate control of a-c power to a-c bus
INV 1	Indicates inverter No. 1 is supplying power to a-c bus
INV 2	Indicates inverter No. 2 is supplying power to a-c bus
POWER/TEMP MON switch repeater lights	Enable monitoring of voltage, current, and temperature of EPS power sources and distribution buses, using voltmeter, ammeter, and BAT FAULT component caution light
1	Indicates voltage, current, and temperature of descent battery No. 1 are monitored on voltmeter, ammeter, and BAT FAULT component caution light respectively
2	Same as for 1, for descent battery No. 2
3	Same as for 1, for descent battery No. 3
4	Same as for 1, for descent battery No. 4
5	Same as for 1, for ascent battery No. 5
6	Same as for 1, for ascent battery No. 6
CDR	Indicates voltage of Commander's d-c bus is displayed on voltmeter.
AC	Indicates voltage of a-c bus is displayed on voltmeter.
SE	Indicates voltage of Systems Engineer's d-c bus is displayed on voltmeter.
ASCENT POWER AUTO TRNFR switch repeater lights	Indicate automatic switchover whereby both ascent batteries energize buses if two or more descent batteries fail
ENABLE	Indicates ascent batteries energize buses
INHIBIT	Indicates connection of remaining good descent batteries and powering LM from CSM
BAT FAULT component caution light repeater	Lights when malfunctioning battery is selected with POWER/ TEMP MON switch

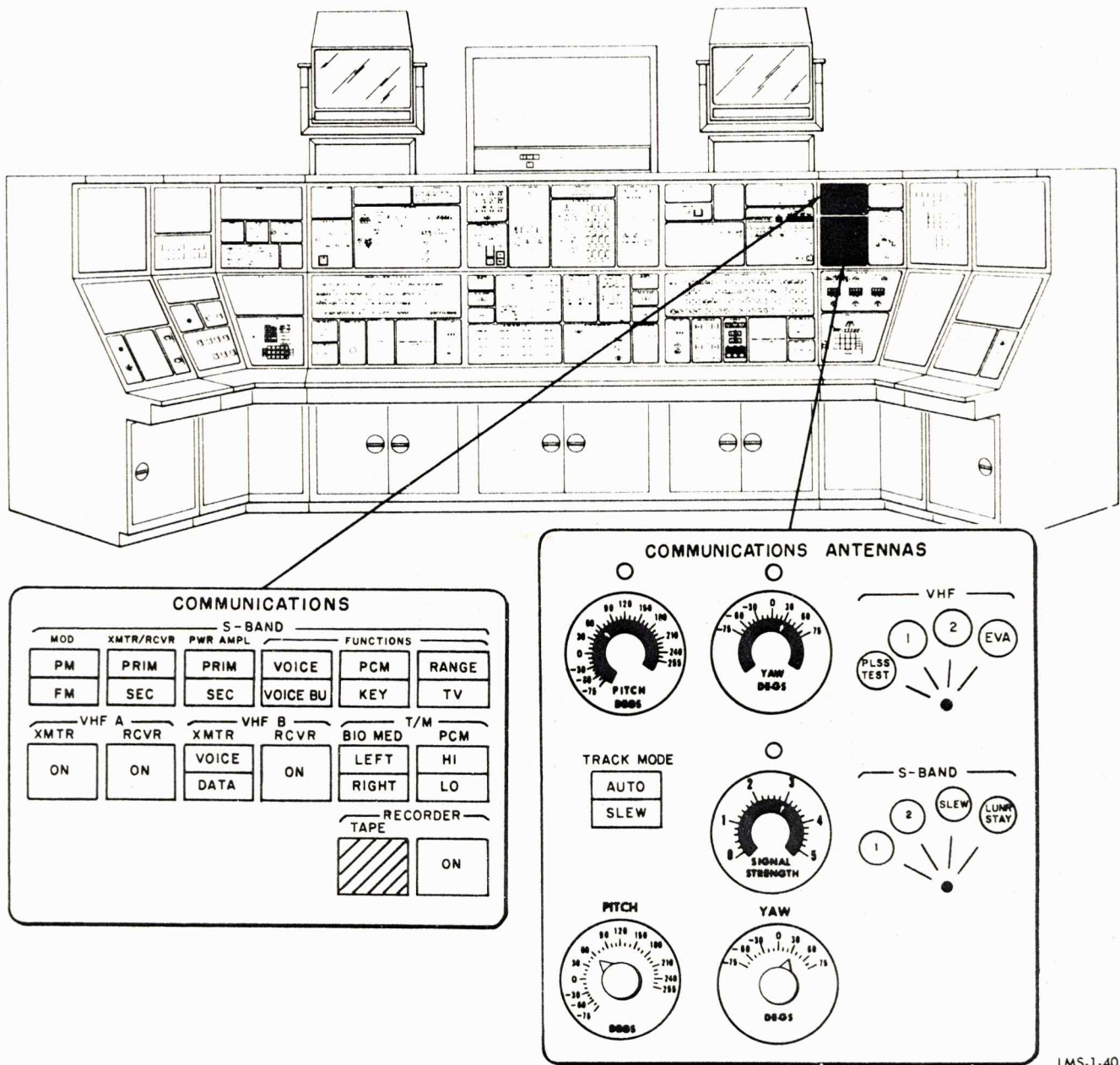
## 1.9.40 COMMUNICATIONS ANTENNAS PANEL. (See figure 1-81.)

The COMMUNICATIONS ANTENNAS panel contains repeater indicators and lights of the LM antenna pattern indicators and panel switch positions. Two meter movements also indicate the control positions for antenna-directing knobs. The displays of the COMMUNICATIONS ANTENNAS panel are listed, with their functions in table 1-64.

## 1.9.41 ECS VALVE POSITION INDICATORS PANEL. (See figure 1-82.)

The ECS VALVE POSITION INDICATORS panel displays the positions of the ECS manually controlled valves. Cabin and suit temperature control settings are also displayed on the panel. The displays of the ECS VALVE POSITION INDICATORS panel are listed, with their function, in table 1-65.





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Figure 1-81. COMMUNICATIONS and COMMUNICATIONS ANTENNAS Panels

Table 1-63. COMMUNICATIONS Panel, Displays

Display	Function
RECORDER TAPE status flag repeater	Indicates status of audio tape recorder in data storage electronics assembly (DSEA)
Gray display	Indicates that tape in DSEA is moving and voice is being recorded
Barber-pole display	Indicates that tape in DSEA is not moving and voice is not being recorded
S-BAND FUNCTIONS RANGE/TV switch repeater lights	Indicates selection of tracking and ranging or TV function for transmission via S-band equipment
RANGE	Indicates PM transmitter is transmitting received coded pseudorandom noise signals back to earth
TV	Indicates FM transmitter is transmitting video data back to earth
S-BAND PWR AMPL switch repeater lights	Indicate selection of either of two redundant amplifiers used with S-band equipment
PRIM	Indicates approximately 18.6 watts of RF power through primary stage
SEC	Indicates approximately 14.8 watts of RF power through secondary stage
T/M BIO MED switch repeater lights	Indicate crew station hardline biomedical data to be sent to earth via S-band
LEFT	Indicates hardline biomed data are fed from Commander's station
RIGHT	Indicates hardline biomed data are fed from Systems Engineer's station
S-BAND FUNCTIONS PCM/KEY switch repeater lights	
PCM	Indicates routing of telemetry data to PMP for transmission via S-band equipment
KEY	Indicates PM section of selected S-band transmitter is enabled, d-c power is applied to PMP emergency key gating circuitry, and PTT switches on ECS umbilicals and attitude controllers are enabled to serve as Morse code keyers for emergency transmissions
S-BAND MOD switch repeater lights	
PM	Indicates selection of phase-modulated transmission mode of S-band transmitter
FM	Indicates selection of frequency-modulated transmission mode of S-band transmitter



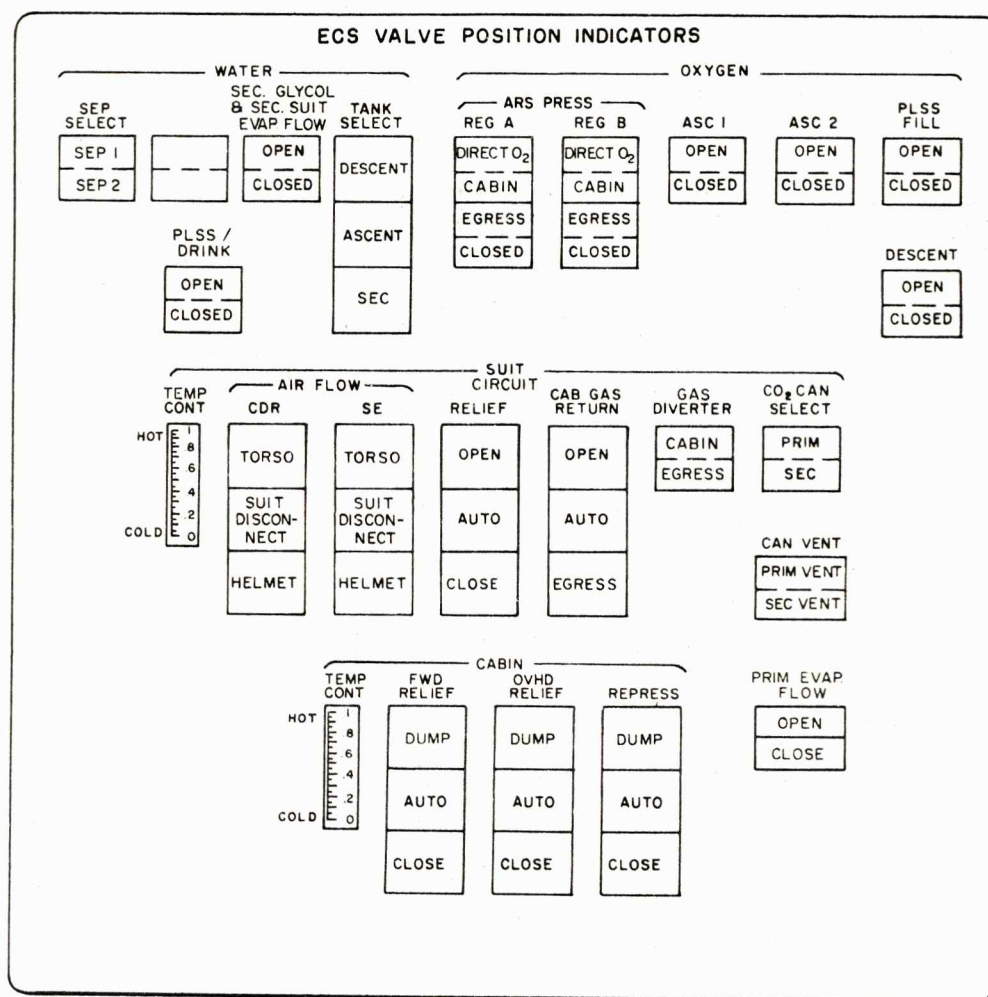
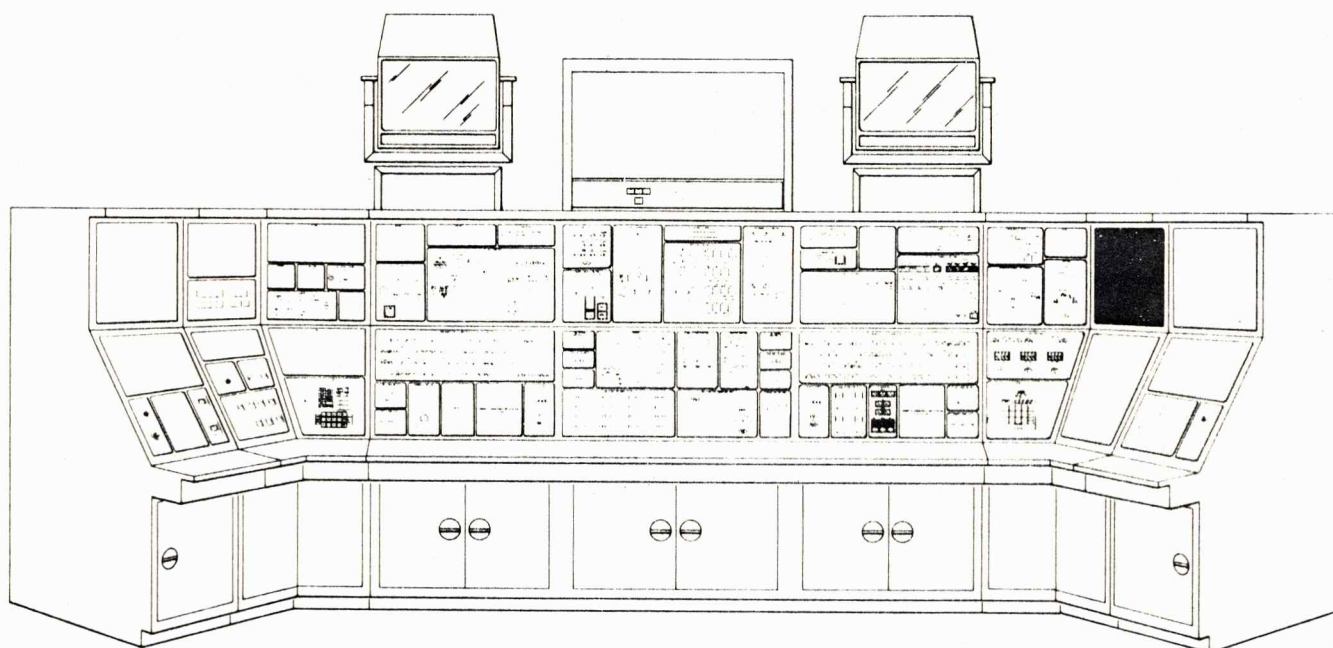
Table 1-63. COMMUNICATIONS Panel, Displays (cont)

Display	Function
S-BAND FUNCTIONS VOICE/ VOICE BU switch repeater lights	
VOICE	Indicates selection of normal voice function for transmission via S-band equipment
VOICE BU	Indicates automatic selection of PM section of S-band trans- mitter (regardless of setting of S-BAND MOD switch) to transmit voice directly on carrier, bypassing PMP
VHF A XMTR switch repeater light	
ON	Indicates application of 28 volts dc to transmitter
S-BAND XMTR/RCVR switch repeater lights	
PRIM	Indicates application of 28 volts dc to primary redundant XMTR/RCVR combination
SEC	Indicates application of 28 volts dc to secondary redundant XMTR/RCVR combination
VHF A RCVR switch repeater light	
ON	Indicates application of 28 volts dc to receiver
RECORDER switch repeater light	
ON	Indicates application of 28 volts dc to DSEA
VHF B XMTR switch repeater lights	
VOICE	Indicates application of 28 volts dc to transmitter and activates data mute circuit
DATA	Indicates application of 28 volts dc to transmitter and activates voice mute circuit
T/M PCM switch repeater lights	
HI	Indicates selection of high-bit-rate (51,200 bits per second) mode of operation in PCMTEA
LO	Indicates selection of low-bit-rate (1,600 bits per second) mode of operation in PCMTEA
VHF B RCVR switch repeater light	
ON	Indicates application of 28 volts dc to receiver

Table 1-64. COMMUNICATIONS ANTENNAS Panel, Displays

Display	Function
PITCH slew control repeater indicator	Indicates positioning of S-band steerable antenna, through synchro transmitter, in pitch axis
YAW slew control repeater indicator	Indicates positioning of S-band steerable antenna, through synchro transmitter, in yaw axis
SIGNAL STRENGTH indi- cator repeater	Displays intensity of S-band signals received from earth. When peaked, it indicates that S-band steerable antenna is pointing at earth.
PITCH indicator repeater	Displays pitch angles of S-band steerable antenna
YAW indicator repeater	Displays yaw angles of S-band steerable antenna
TRACK MODE switch repeater lights	Indicate selection of control mode by which S-band steerable antenna is positioned
AUTO	Indicates application of 28-volt dc and 115-volt, 400-cps ac to S-band steerable antenna
SLEW	Indicates application of 28-volt dc and 115-volt, 400-cps ac to S-band steerable antenna
S-BAND antenna switch repeater lights	Indicate selection of S-band antenna for communica- tion with earth
1	Indicates selection of omnidirectional antenna No. 1
2	Indicates selection of omnidirectional antenna No. 2
SLEW	Indicates selection of S-band steerable antenna
LUNAR STAY	Indicates selection of S-band erectable antenna for use during lunar stay
VHF antenna switch repeater lights	Indicate selection of VHF antenna or EVA equipment pregress checkout
PLSS TEST	Not used for LM 2 ( In LM 2, PLSS TEST and 1 switch positions are combined.)
1	Indicates selection of VHF antenna No. 1
2	Indicates selection of VHF antenna No. 2
EVA	Indicates selection of EVA antenna for VHF communica- tion between EVA and LM





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Figure 1-82. ECS VALVE POSITION INDICATORS Panel

Table 1-65. ECS VALVE POSITION INDICATORS Panel, Displays

Display	Function
OXYGEN DESCENT valve repeater lights	Indicate condition of DES O <sub>2</sub> valve in oxygen control module (OCM)
OPEN	Indicates DES O <sub>2</sub> valve is open to permit flow of oxygen from descent oxygen tank to OCM
CLOSED	Indicates DES O <sub>2</sub> valve is closed
OXYGEN ASC1 and ASC2 valves repeater lights	Indicate condition of related #1 ASC O <sub>2</sub> and #2 ASC O <sub>2</sub> valves in OCM
OPEN	Indicates related ASC O <sub>2</sub> valve is open to permit oxygen flow from ascent oxygen tank to OCM
CLOSED	Indicates related ASC O <sub>2</sub> valve is closed
OXYGEN PLSS FILL valve repeater lights	Indicates condition of PLSS FILL valve in OCM
OPEN	Indicates PLSS FILL valve is open to permit flow of oxygen to primary oxygen storage tank in PLSS
CLOSED	Indicates PLSS FILL valve is closed
OXYGEN ARS PRESS REG A and REG B valves repeater lights	Indicate condition of related PRESS REG A and PRESS REG B valve in OCM
DIRECT O <sub>2</sub>	Indicates related PRESS REG valve is in OPEN position to permit unregulated flow of oxygen into suit circuit (used when suit fans fail)
CABIN	Indicates related PRESS REG valve is in NORM position to permit regulated oxygen flow ( $5.0 \pm 0.2$ psia) to suit circuit (normal pressurized-cabin operation)
EGRESS	Indicates related PRESS REG valve is in EGRESS position to permit regulated oxygen flow ( $3.7 \pm 0.2$ psia) to suit circuit (used when cabin is not pressurized)
CLOSED	Indicates related PRESS REG valve is closed
WATER TANK SELECT valve repeater lights	Indicate condition of WATER TANK SELECT valve in water management section
DESCENT	Indicates WATER TANK SELECT valve is in DES position to permit descent water tank to provide water for primary boilers and for drinking
ASCENT	Indicates WATER TANK SELECT valve is in ASC position to permit both ascent water tanks to provide water for primary boilers and for drinking
SEC	Indicates WATER TANK SELECT valve is in EMER position to prevent water flow to primary boilers and to divert flow from water separators to emergency water boilers
SEC GLYCOL & SEC SUIT EVAP FLOW valve repeater lights	Indicate condition of SEC GLYCOL/SEC SUIT EVAP FLOW valve in water management section



Table 1-65. ECS VALVE POSITION INDICATORS Panel, Displays (cont)

Display	Function
OPEN	Indicates SEC GLYCOL/SEC SUIT EVAP FLOW valve is open to permit full water flow to secondary boiler and to emergency suit water boiler
CLOSED	Indicates SEC GLYCOL/SEC SUIT EVAP FLOW valve is closed to block flow to secondary boiler and to permit flow to suit water boiler (normal operation)
PLSS/DRINK valve repeater lights	Indicate condition of PLSS/DRINK valve in water management section
OPEN	Indicates PLSS/DRINK valve is open to supply water to water hose assembly
CLOSED	Indicates PLSS/DRINK valve is closed
SEP SELECT valve repeater lights	Indicate selection of one of two separators, which condense moisture in gas by centrifugal action and vent this water to primary water boiler
SEP 1	Indicates that WATER SEP SEL valve is in SEP 1 position to select water separator No. 1
SEP 2	Indicates that WATER SEP SEL valve is in SEP 2 position to select water separator No. 2
SUIT CIRCUIT CO <sub>2</sub> CAN SELECT valve repeater lights	Indicate selection of one of two LiOH canisters that remove CO <sub>2</sub> and noxious gases from suit circuit gas
PRIM	Indicates that CO <sub>2</sub> CANISTER SEL valve is in PRIM position to permit gas to be filtered through primary LiOH canister
SEC	Indicates that CO <sub>2</sub> CANISTER SEL valve is in SEC position to permit gas to filtered through secondary LiOH canister (permits replacement of primary canister)
SUIT CIRCUIT CAN VENT pushbutton repeater lights	Indicate momentary venting of related LiOH canister to reduce pressure and to facilitate removal
PRIM VENT	Indicates that primary LiOH canister VENT pushbutton is being pressed
SEC VENT	Indicates that secondary LiOH canister VENT pushbutton is being pressed
SUIT CURCUIT AIR FLOW CDR and SE valves repeater lights	Indicate condition of related SUIT FLOW control valve
TORSO	Indicates that related SUIT FLOW control valve is in TORSO position to permit half of oxygen flow to enter space suit at waist and half at helmet
SUIT DISCON	Indicates that related SUIT FLOW control valve is in SUIT DISCONNECT position to shut off oxygen flow at suit connector, by-passing pressure suit
HELMET	Indicates that related SUIT FLOW control valve is in HELMET position to permit oxygen to enter spacesuit through four extremity ducts and leave through faceplate

Table 1-65. ECS VALVE POSITION INDICATORS Panel, Displays (cont)

Display	Function
SUIT CIRCUIT TEMP CONT valve setting indicator	Indicates setting of suit temperature control valve that regulates suit circuit temperature
SUIT CURCUIT RELIEF valve repeater lights	Indicate condition of SUIT CURCUIT RELIEF valve that prevents overpressurization of pressure suits
OPEN	Indicates SUIT CIRCUIT RELIEF valve is in OPEN position (manual override of automatic control)
AUTO	Indicates SUIT CURCUIT RELIEF valve is in AUTO position, to be controlled by aneroid sensor
CLOSE	Indicates SUIT CIRCUIT RELIEF valve is in CLOSE position (manual override of automatic control)
SUIT CIRCUIT CAB GAS RETURN valve repeater lights	Indicate condition of CABIN GAS RETURN valve that returns cabin gas to suit circuit under normal operation or provides suit circuit integrity under rapid cabin decompression.
OPEN	Indicates that cabin gas is fed back to suit circuit for revitalization
AUTO	Indicates that gas flows into, but not out of, suit circuit with use of one-way check valve
EGRESS	Indicates override of one-way check valve, ensuring suit circuit integrity during unpressurized cabin operations
SUIT CIRCUIT GAS DI- VERTER valve repeater lights	Indicates condition of SUIT GAS DIVERTER valve (Valve has provisions for automatic closure by signal from cabin pressure sensor when cabin pressure drops below 4.6 psia. Valve also closes automatically when PRESS REG A and B controls are set to EGRESS.)
CABIN	Indicates that gas in suit circuit downstream of flow control valves flows into cabin (CABIN position is selected during open-faceplate operation, so that suit circuit will provide sufficient airflow to maintain oxygen level of cabin within limits.)
EGRESS	Indicates that gas in suit circuit is prevented from passing into cabin
CABIN FWD RELIEF and OVHD RELIEF valves repeater lights	Indicate condition of related relief and dump valve on each LM hatch (Valves provide means for cabin depressurization and cabin pressure relief.)
DUMP	Indicates override of AUTO position to permit astronaut to dump cabin pressure
AUTO	Indicates that valve acts automatically as pressure-relief device (Aneroid sensor valve causes valve to open at pressure of 5.8 psia or greater, thus bleeding excess cabin pressure)
CLOSE	Indicates override of AUTO position to close and lock relief valve so that no gas can escape in event of failure of AUTO mode
CABIN REPRESS valve repeater lights	Indicate condition of CABIN REPRESS valve
MANUAL	Indicates unregulated flow of oxygen into cabin from oxygen manifold



Table 1-65. ECS VALVE POSITION INDICATORS Panel, Displays (cont)

Display	Function
AUTO	Indicates CABIN REPRESS valve responds to inputs from cabin pressure sensor. (AUTO mode is disabled if PRESS REG A and B valve controls are set to EGRESS or if one valve is set to EGRESS and the other valve is set to CLOSE.)
CLOSE	Indicates oxygen flow to cabin from oxygen manifold is prevented
PRIM EVAP FLOW switch repeater lights	Indicates condition of PRIM EVAP FLOW valve that controls flow of water from water manifold to primary water boiler
OPEN	Indicates flow of water to primary water boiler
CLOSE	Indicates flow of water to primary water boiler is shut off
CABIN TEMP CONT valve setting indicator	Indicate setting of cabin temperature control valve that regulates cabin temperature

## 1.9.42 CSM CONTROL PANEL. (See figure 1-83.)

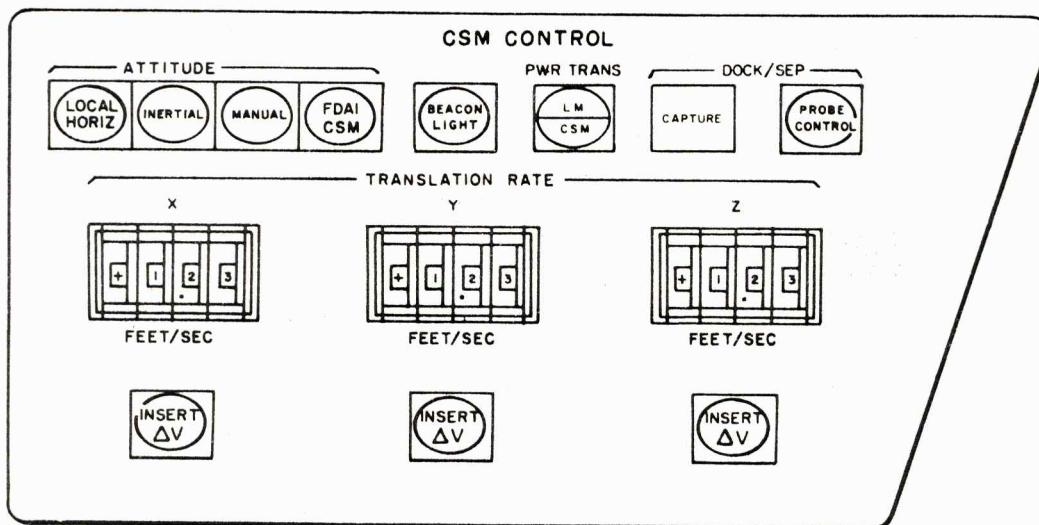
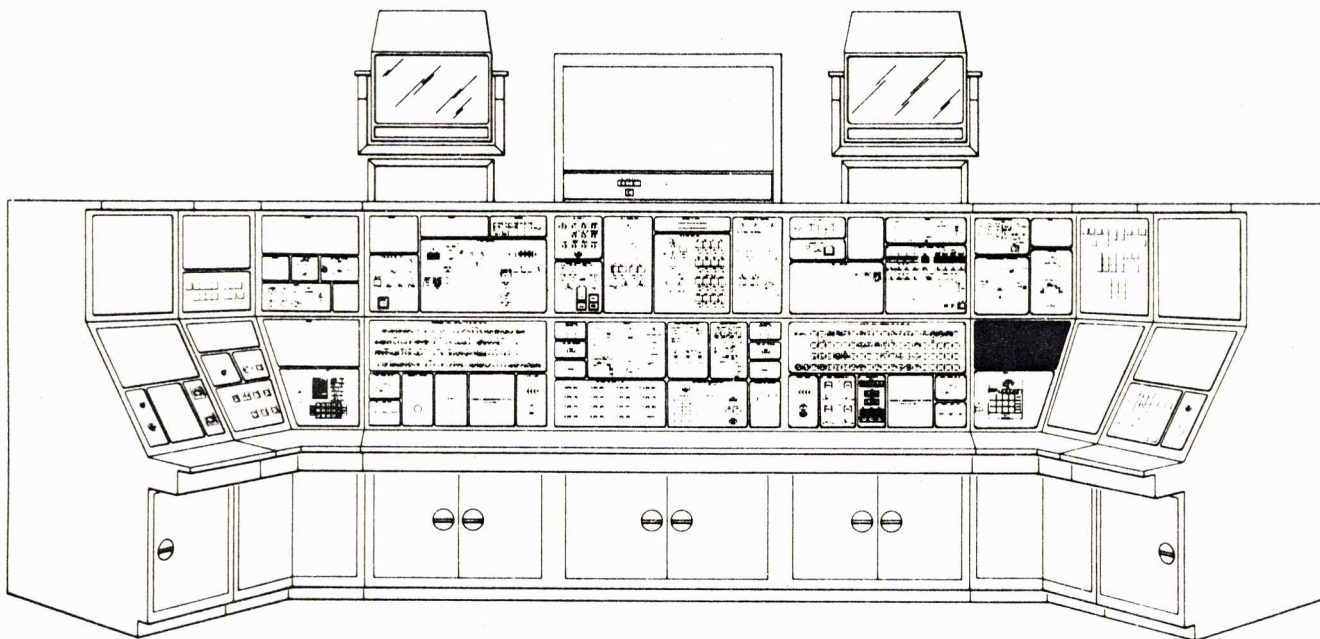
The CSM CONTROL panel contains digital displays and pushbuttons to maneuver and control the simulated CSM (when AMS simulation integration is not required). The controls and displays of the CSM CONTROL panel are listed, with their function, in table 1-66.

Table 1-66. CSM CONTROL Panel, Controls and Displays

Control or Display	Function
ATTITUDE switch lights	
LOCAL HORIZ	Holds attitude of CSM constant with respect to local horizon. Hand controller is inoperative in this mode. Computer program maintains vehicle in local horizontal of near celestial body.
INERTIAL	This mode uses fixed angles in space as its reference. Hand controller is inoperative in this mode. Computer program maintains CSM in inertial mode.
MANUAL	Places CSM in manual mode and enables hand controller so that instructor can maneuver CSM. In absence of command, CSM maintains its present inertial reference.
FDAI CSM	Systems Engineer Instructor's FDAI indicates CSM attitude.
BEACON LIGHT switch light	Turns on flashing docking light on CSM (in rendezvous and docking image generator) in EVDE
PWR TRNFR split-screen switch lights	Simulates power transfer from CSM to LM. Indicates that LM or CSM supply power
DOC/SEP	
CAPTURE indicator	Indicates that distance from LM to CSM is such that probe capture is possible
PROBE CONTROL switch light	When pressed, CSM probe is retracted

Table 1-66. CSM CONTROL Panel, Controls and Displays (cont)

Control or Display	Function
TRANSLATION RATE digital switches  X (FEET/SEC)  Y (FEET/SEC)  Z (FEET/SEC)  INSERT $\Delta V$ switch lights	Permit instructor to select CSM position change rates along indicated coordinates        Permit instructor to input selected X, Y, and Z rate changes to computer



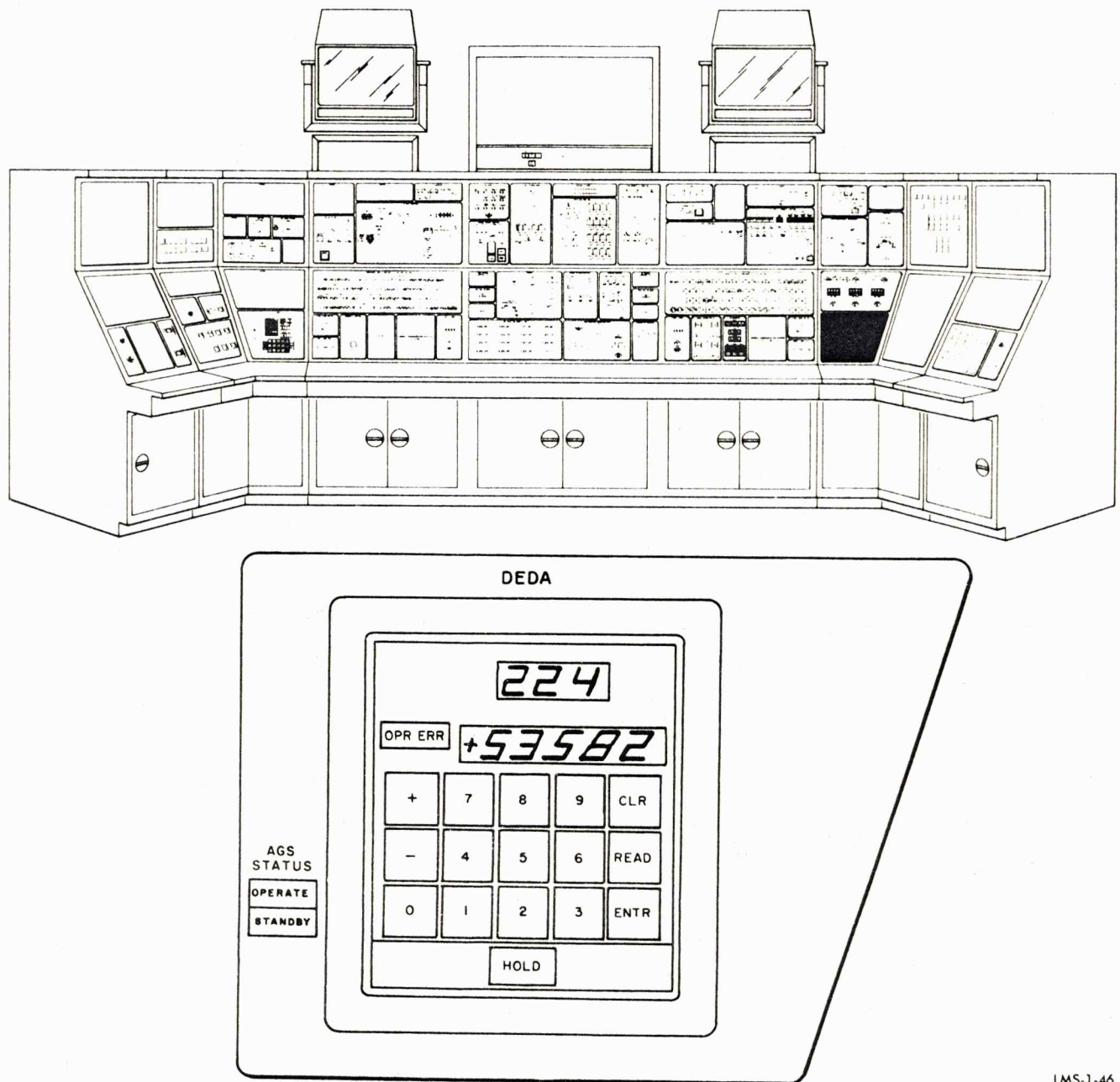
LMS-1-44

Figure 1-83. CSM CONTROL Panel



## 1.9.43 DEDA PANEL. (See figure 1-84.)

The DEDA panel is a fully operational repeater of the LM DEDA panel. It enables the instructor to input, or read out, guidance data. The controls and displays of the DEDA panel are listed, with their function, in table 1-67.



LMS-1-46

Figure 1-84. DEDA Panel

Table 1-67. DEDA Panel, Controls and Displays

Control or Display	Function
OPR ERR indicator repeater	OPR ERR legend is illuminated if incorrect number of pushbuttons are pressed for operation being performed, if + or - keys are not pressed first in entering data, and if "8" or "9" is used in entering address (which is limited to octal digits)
Three-digit indicator repeater	Displays digits that identify abort electronics assembly (AEA) computer address selected by astronaut via keyboard
Five-digit indicator repeater	Displays data to be entered into AEA computer address displayed on three-digit indicator. Displays data selected for readout from AEA computer location identified on three-digit indicator, if READ switch is pressed
Keyboard switch lights	Enables instructor to enter necessary values (0 through 9) and signs (+ and -) on three- and five-digit indicators
CLR switch light	Erases all numerals displayed on three- and five-digit indicators and cancels effect of HOLD switch
ENTR switch light	Enables instructor to enter data (set up on five-digit indicator) into AEA computer at address set up on three-digit indicator
READ switch light	Enables callup of AEA computer data from address set up on three-digit indicator, for display on five-digit indicator
HOLD switch light	Enables interruption of updating of any continuously changing data displayed on five-digit indicator
AGS STATUS switch lights	Enables placement of AGS in any one of three states
STANDBY	Indicates application of full power to entire ASA and then places AEA in its warmup mode
OPERATE	Indicates application of full power to ASA and AEA

#### 1.9.44 TRUE TRAINEE ENVIRONMENT PANEL. (See figure 1-85.)

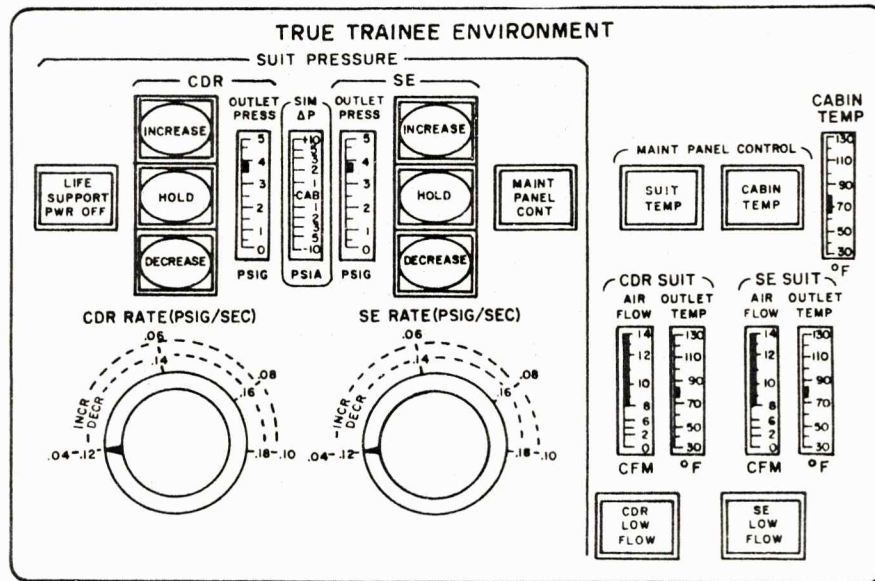
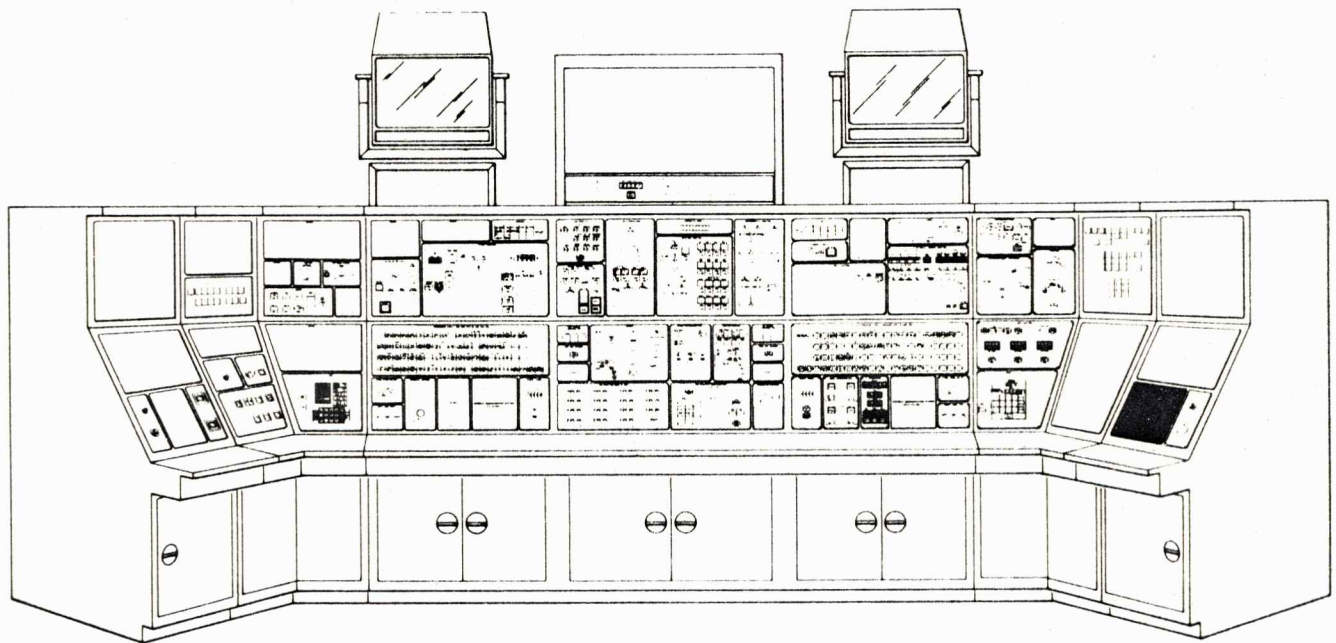
The TRUE TRAINEE ENVIRONMENT panel enables the Suit Technician to monitor the switches, regulators, and indicators that control the flight crew astronaut's suit pressure and temperature, and the cabin temperature. The controls and displays of the TRUE TRAINEE ENVIRONMENT panel are listed, with their function, in table 1-68.

#### 1.10 TELEMETRY CONSOLE - CONTROLS AND DISPLAYS.

The telemetry console monitors and controls the LMS telemetry subsystem. The Telemetry Instructor can impose malfunctions on the PCM bit stream data from the LMS subsystems and can monitor the resultant malfunctioned data or the true data (with malfunction removed). Ammeters and binary indicator lamps monitor the status of the analog data and the bilevel data outputs, respectively. Either type of data output can be monitored before or after malfunction insertion. After a malfunction is inserted, the true data can be monitored by pressing a FAULT (PRESS FOR TRUE) switch. Telemetry malfunctions may be imposed upon the analog data in the following forms: level change, fixed level substitution, drift rate superposition, and channel loss. Telemetry malfunctions may also be imposed upon a bilevel group or digital word in the form of logic substitution; that is, a 1 or a 0 may be substituted for any one or all of the eight bits in a bilevel group or digital word.

The 19 panels of the telemetry console (figure 1-9) are listed, with their functions, in table 1-5. A functional description of the telemetry console panel controls and displays is given in paragraphs 1.10.1 through 1.10.9.





LMS-1-45

Figure 1-85. TRUE TRAINEE ENVIRONMENT Panel

## 1.10.1 CONSOLE LIGHTING, EMERGENCY, AND LAMP TEST PANELS. (See figure 1-86.)

The controls and displays of the console lighting, EMERGENCY, and LAMP TEST panels are listed, with their function, in tables 1-69 through 1-71.

Table 1-68. TRUE TRAINEE ENVIRONMENT Panel, Controls and Displays

Control or Display	Function									
LIFE SUPPORT PWR OFF indicator	Indicates to Suit Technician that life support power is not available and, if life support power has failed (in sequence mode), that compressor No. 1 has automatically switched to utility power (if compressed air is used instead of building air). In this mode, air is not heated; this is a temporary backup mode to extend time available for corrective action (suit removal).									
CDR and SE switch lights  INCREASE  HOLD  DECREASE	Permit Suit Technician to control pressurization and depressurization of flight crew astronauts' suits. INCREASE and DECREASE switches energize motor that drives valve in appropriate direction. HOLD switch deenergizes motor and indicates that pressure is not changing. Instructor can increase or decrease pressure and hold pressure at any value. Pressure will not go below its minimum limit (0.1 psig) or above its maximum limit (3.9 psig). INCREASE and DECREASE remain pressed and lighted until pressure is driven to its limits or is "held" by Suit Technician. Switch lights are electrically interlocked. When control is at SUIT MAINTENANCE panel, switch lights at TRUE TRAINEE ENVIRONMENT panel repeat indications from that panel and vice versa.									
CDR and SE OUTLET PRESS indicators	Displays true suit outlet pressure from Commander's suit to Suit Technicians									
SIM Δ P indicator	Displays theoretical relative pressure difference between flight crew suit pressure and cabin pressure									
MAINT PANEL CONT indicator	Indicates that SUIT TECH CONTROL switch on SUIT MAINTENANCE PANEL NO. 1, which transfers suit pressurization control to TRUE TRAINEE ENVIRONMENT panel, has not been actuated. Light goes on when maintenance panel has control.									
CDR RATE (PSIG/SEC) and SE RATE (PSIG/SEC) controls	Permit Suit Technician to vary suit pressurization and depressurization rates from slow to fast as follows: <table><tr><td></td><td>Slow</td><td>Fast</td></tr><tr><td>Pressurization</td><td>90 seconds</td><td>45 seconds</td></tr><tr><td>Depressurization</td><td>30 seconds</td><td>19 seconds</td></tr></table>		Slow	Fast	Pressurization	90 seconds	45 seconds	Depressurization	30 seconds	19 seconds
	Slow	Fast								
Pressurization	90 seconds	45 seconds								
Depressurization	30 seconds	19 seconds								
	<div>NOTE</div> <p>Proper rate scale switching occurs (throughout the range of the control) as a function of the INCREASE and DECREASE switches (directly above) being activated.</p>									
MAINT PANEL CONTROL switch repeater lights	Indicate that suit and cabin temperature is not under computer control. Lights are repeaters of switches on SUIT MAINTENANCE PANEL NO. 1									
SUIT TEMP	Indicates that suit temperature is controlled manually									
CABIN TEMP	Indicates that cabin temperature is controlled manually									
CABIN TEMP indicator	Displays true cabin temperature									



Table 1-68. TRUE TRAINEE ENVIRONMENT Panel, Controls and Displays (cont)

Control or Display	Function
CDR and SE SUIT AIR FLOW CFM indicators	<p>Display true suit airflow</p> <p><b>NOTE</b></p> <p>Temperatures, pressures, and flow rates are automatically limited to specific ranges. Meter dials may indicate greater ranges for convenience of dial marking, calibration, and standardization.</p>
CDR and SE SUIT OUTLET TEMP indicators	<p>Display true suit outlet temperatures</p>
CDR LOW FLOW and SE LOW FLOW indicator lights	<p>Indicate that suit airflow (to respective suit) has dropped below 8 cfm</p> <p><b>NOTE</b></p> <p>Meters, indicator lights, and the indicator-light portion of switch lights operate at the maintenance panels (Suit Technician locations) at all times when the system is energized.</p>

#### 1.10.2 CONSOLE COMMUNICATION SYSTEM (CCS KEYSET) PANEL. (See figure 1-87.)

The console communication system panel has a keyset that enables the Telemetry Instructor to tie into the overall console communication system (CCS). The panel controls are listed, with their function, in table 1-72. The console communication system is described in paragraph 1.9.2.

#### 1.10.3 COMMUNICATIONS CONTROL PANEL. (See figure 1-87.)

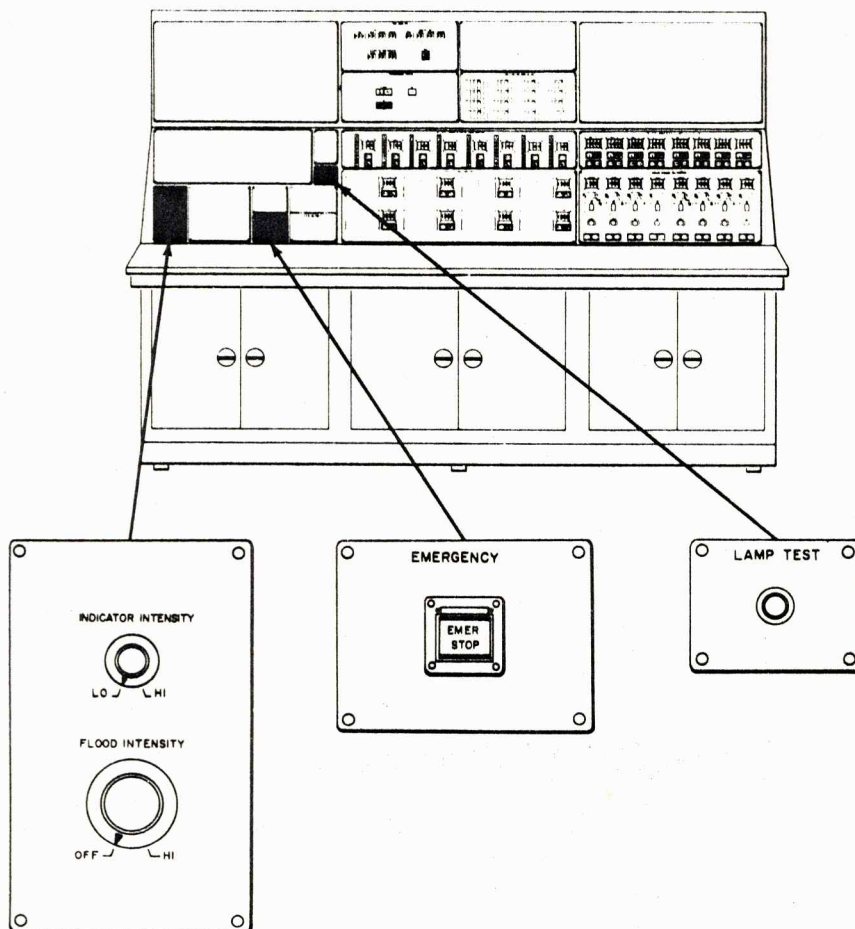
The communications control panel provides conference and monitoring capability between personnel at the telemetry and instructor consoles. The controls of the communications control panel are listed, with their function, in table 1-73.

#### 1.10.4 TIME DISPLAYS PANEL. (See figure 1-88.)

The data (Greenwich mean time, problem time, and elapsed time from separation) displayed on this panel are repeat indications of those displayed at the instructor console. The basis for the problem time (Apollo or LM) is selected at the instructor console and is shown to the Telemetry Instructor on the TIME REFERENCE indicator. The problem time readout is returned to the initial condition when the problem is reset at the instructor console PROBLEM CONTROL panel. The TIME DISPLAYS panel displays are listed, with their function, in table 1-74.

#### 1.10.5 TRANSMISSION STATUS PANEL. (See figure 1-88.)

This panel permits the Telemetry Instructor to select the type of biomedical data desired for transmission, and to monitor indicator lamps that display the status of telemetry and biomedical transmission modes. The TRANSMISSION STATUS panel controls and displays are listed, with their function, in table 1-75.



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Figure 1-86. Console Lighting, EMERGENCY and LAMP TEST Panels

Table 1-69. Console Lighting Panel, Controls

Control	Function
INDICATOR INTENSITY control	Permits simultaneous adjustment of illumination intensity of all telemetry console indicator lights by varying d-c voltage to lamps
FLOOD INTENSITY control	Permits simultaneous adjustment of illumination intensity of all fluorescent lights in telemetry cabinet hood by varying a-c voltage to lamps via autotransformer

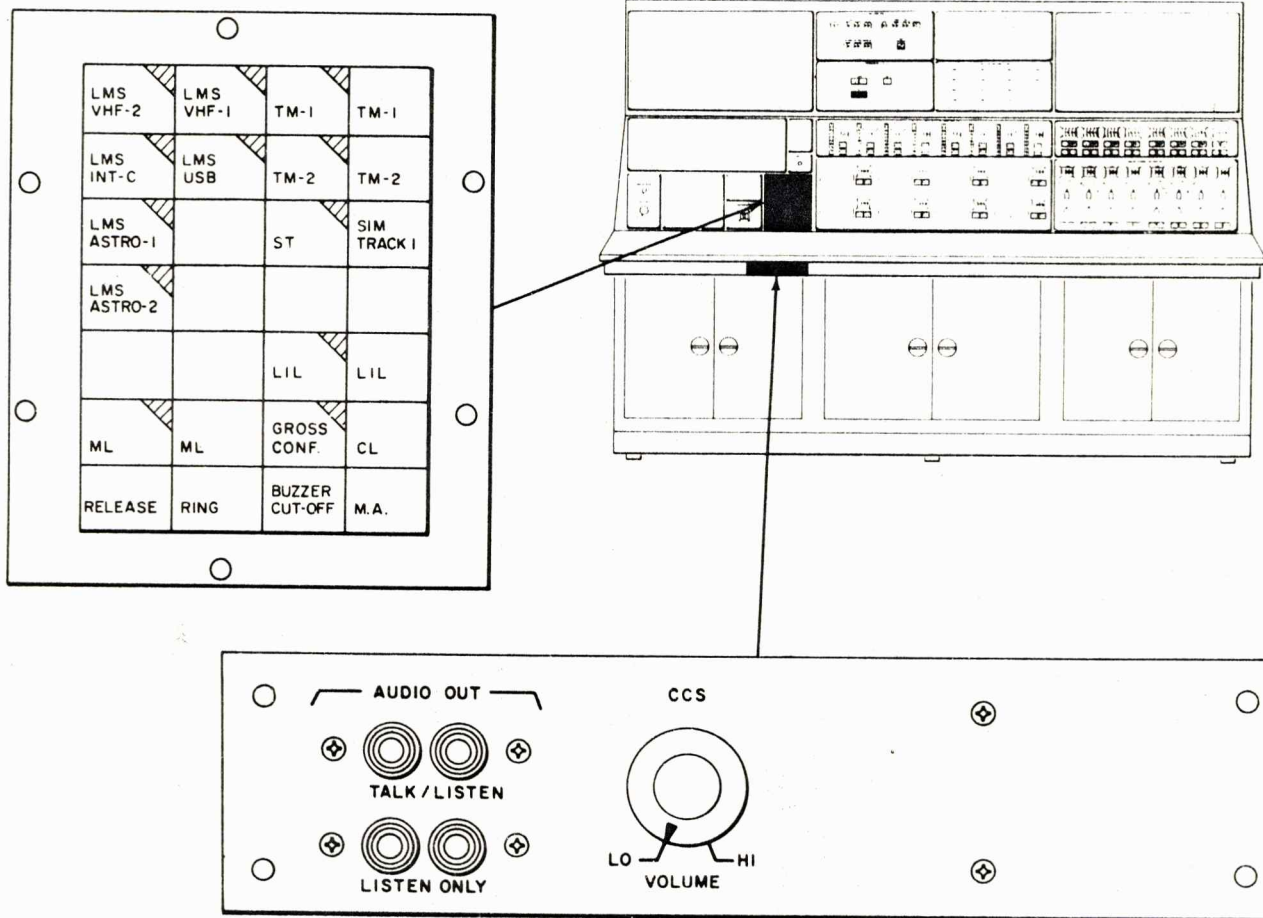
Table 1-70. EMERGENCY Panel, Control and Display

Control and Display	Function
EMER STOP alternate-action switch light	Permits emergency removal of all power, except 115-volt, 60-cps utility power, in LMS. Light goes on when switch is actuated.



Table 1-71. LAMP TEST Panel, Control

Control	Function
LAMP TEST momentary-action pushbutton	Permits simultaneous test of all indicator lights on telemetry console



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Figure 1-87. Console Communications System (CCS Keyset) and Communications Control Panels

Table 1-72. Console Communications System (CCS Keyset) Panel, Controls

Control	Function
LMS VHF-2 monitor key	Enables Telemetry Instructor to monitor simulated LM VHF-B communications loop
LMS VHF-1 monitor key	Enables Telemetry Instructor to monitor simulated LM VHF-A communications loop
TM-1 talk/listen and monitor keys	Provide conference capability between LMS Telemetry Instructor and MCC telemetry personnel, and monitoring of loop (T/M communications loop 1)
TM-2 talk/listen and monitor keys	Provide conference capability via T/M communications loop 2 between LMS Telemetry Instructor and MCC telemetry personnel, and monitoring of loop
SIM TRACK 1 talk/listen key	Provides conference capability via simulator tracking loop between LMS instructors and simulator control area (SCA) personnel
ST key	Provides conference capability via simulator telemetry communications loop between Telemetry Instructor and SCA personnel
LMS ASTRO-1 monitor key	Enables Telemetry Instructor to monitor communications between Commander and LMS instructor console personnel
LMS ASTRO-2 monitor key	Enables Telemetry Instructor to monitor communications between Systems Engineer and LMS instructor console personnel
LIL talk/listen and monitor keys	Provide conference capability via LMS instructors communications loop between LMS instructors, and monitoring of loop
ML talk/listen and monitor keys	Provide conference capability (for purpose of maintaining LMS) via maintenance loop between LMS instructors, LMS Mission Coordinator, and computer complex personnel, and monitoring of loop
CL talk/listen key	Provide conference capability via computer loop between LMS instructors, LMS Mission Coordinator, and computer complex personnel
GOSS CONF monitor key	Enables Telemetry Instructor to monitor communications with Goddard Space Flight Center, Greenbelt, Maryland, thereby tying LMS communications into the Manned Space Flight Network (MSFN)
M. A. key	Provides for simultaneous access to two or three selected talk/listen loops
BUZZER CUT-OFF key	Stops buzzer operation
RING key	Establishes buzzer signal on LMS complex and selected intersite loops after appropriate talk/listen key is pressed
RELEASE key	Releases established talk/listen key



Table 1-73. Communications Control Panel, Controls

Control	Function
TALK/LISTEN jack	Accepts plug-in headset/microphone combination
LISTEN ONLY jack	Accepts plug-in monitor headset
CCS VOLUME control	Adjusts volume of sound in headset

Table 1-74. TIME DISPLAYS Panel, Displays

Display	Function
GMT readout	Displays days, hours, minutes, and seconds based on Greenwich mean time
ELAPSED TIME FROM SEPARATION readout	Displays elapsed time from separation of Command module from LM, in hours, minutes, and seconds
PROBLEM TIME readout	Displays elapsed time from start of problem time in days, hours, minutes, and seconds
LEM/APOLLO indicator	Indicates LM or Apollo problem time mode. When LEM is lit, problem time refers to time elapsed from start of LM mission, based on initial condition setting. When APOLLO is lit, problem time is that of AMS.

Table 1-75. TRANSMISSION STATUS Panel, Controls and Displays

Control or Display	Function
S-BAND indicators	
HI/LO split-screen indicator	Indicates that telemetry is being transmitted via S-band at high bit rate of 51.2 kbs or low bit rate of 1.6 kbs
BIO light	Indicates that biomedical data is being transmitted by S-band equipment
BIO switch lights	
REAL/PRE-REC	Permits selection of real or prerecorded biomedical data for transmission to MCC
LEFT/RIGHT	Permits selection of one of two prerecorded tracks of biomedical data when prerecorded data is being transmitted; indicates which flight crew-member is data source when real biomedical data is being transmitted
VHF	
LO light	Indicates that telemetry is being transmitted to MCC via VHF at low bit rate of 1.6 kbs

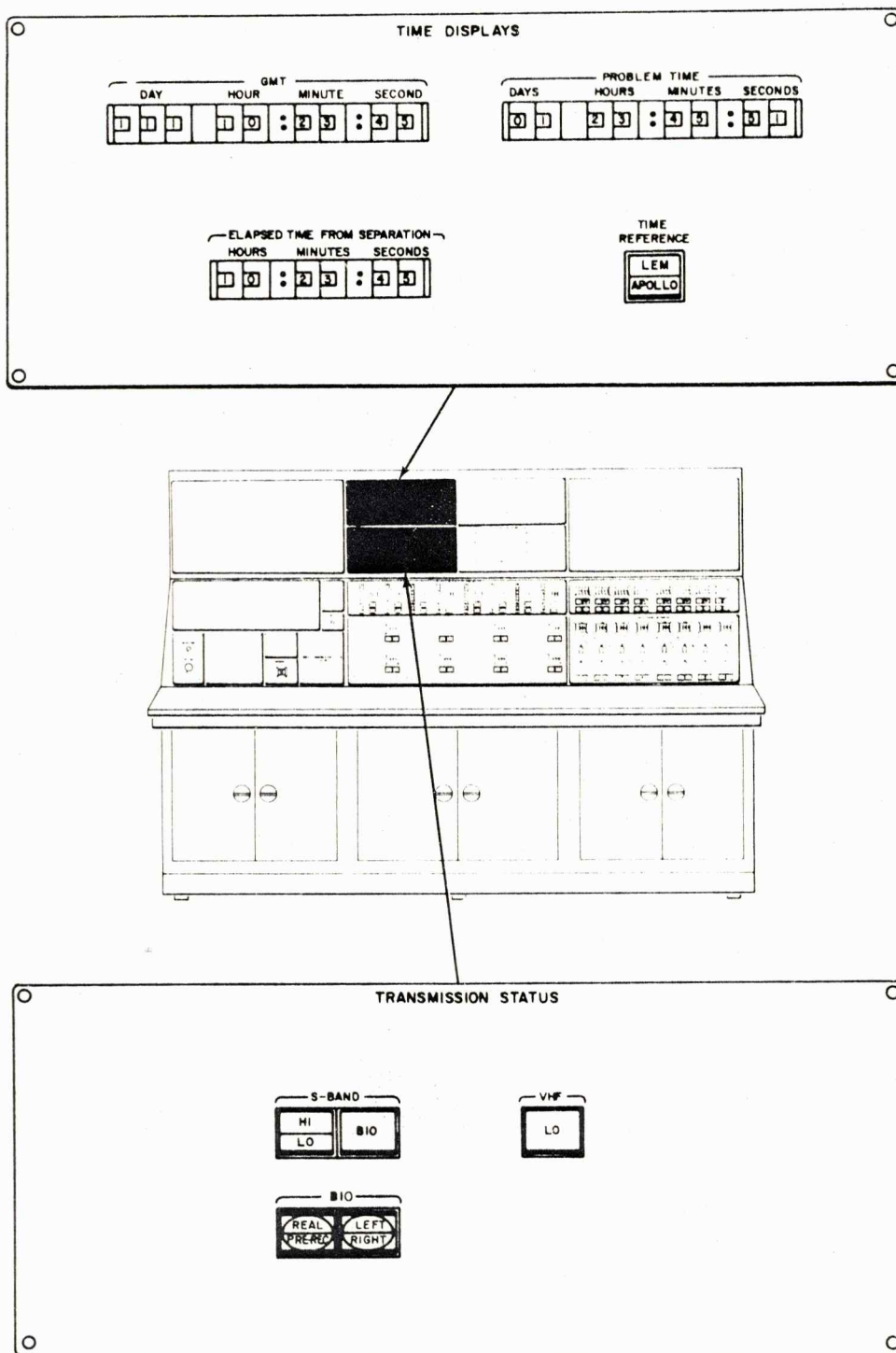
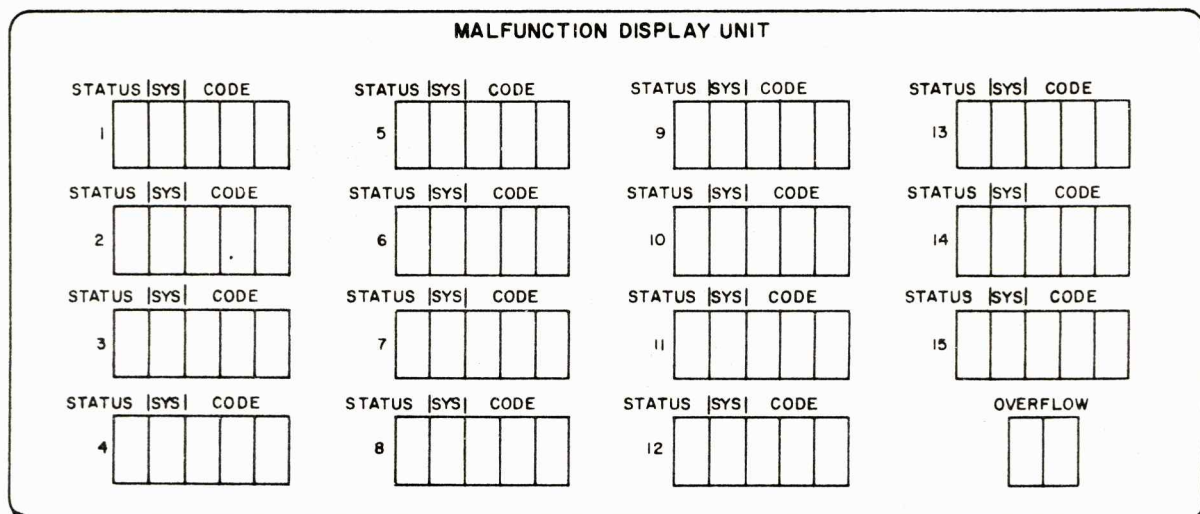
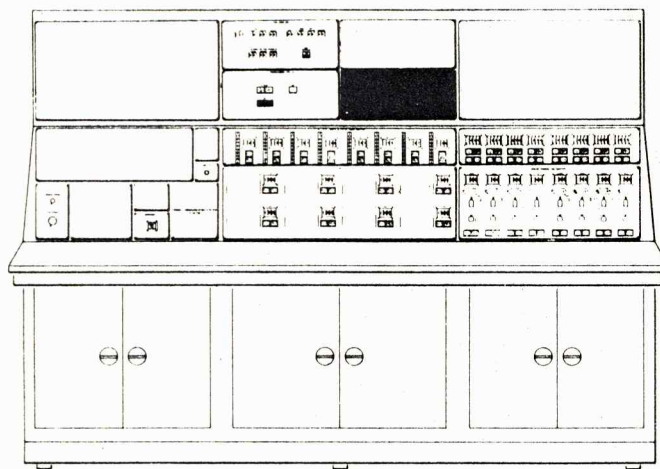


Figure 1-88. TIME DISPLAYS and TRANSMISSION STATUS Panels



## 1.10.6 MALFUNCTION DISPLAY UNIT PANEL. (See figure 1-89.)

Fifteen groups of status displays on the MALFUNCTION DISPLAY UNIT panel inform the Telemetry Instructor of the status of the malfunctions inserted at the instructor console. Each group of status displays consists of five indicators. One of the indicators shows the status of the malfunction; another indicates the subsystem in which the malfunction has been inserted. The remaining three indicators display (by three decimal digits) the code number of the particular malfunction. An OVERFLOW display indicates malfunction insertion overflow. Because the malfunction display unit can only display the status of 15 malfunctions and the computer can accept an unlimited number, the number of inserted malfunctions in excess of 15 (1 to 11) appears in the OVERFLOW display. Malfunctions in excess of 26 are not indicated. When 1 of the 15 displayed malfunctions is cleared, the status of the malfunction shown as 16 on the OVERFLOW display is displayed in place of the cleared malfunction. All overflow malfunctions advance in status on the OVERFLOW display, reducing the overflow count by 1, unless the total number of malfunctions still exceeds 25. The MALFUNCTION DISPLAY UNIT panel displays are listed, with their function, in table 1-76.



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Figure 1-89. MALFUNCTION DISPLAY UNIT Panel

Table 1-76. MALFUNCTION DISPLAY UNIT Panel, Displays

Display	Function
STATUS indicator	Indicates status of control program and direct malfunction as follows: <ul style="list-style-type: none"> <li>• T (white) is projected when time-dependent control program is enabled</li> <li>• E (white) is projected when event-dependent control is enabled</li> <li>• IMP (blue) is projected 1 minute before activation of malfunction by time-dependent control program</li> <li>• ACT (amber) is projected when control program or direct malfunction is activated</li> </ul>
SYS indicator	Displays designation of subsystem or section being malfunctioned, as follows: <ul style="list-style-type: none"> <li>AG (Abort guidance)</li> <li>CM (Communications)</li> <li>EC (Environmental control)</li> <li>ED (Explosive devices)</li> <li>EP (Electrical power)</li> <li>IN (Instrumentation)</li> <li>PG (Primary guidance and navigation)</li> <li>PR (Propulsion)</li> <li>RC (Reaction control)</li> <li>SC (Stabilization and control)</li> </ul>
CODE indicator (three digits)	Displays code number of inserted malfunctions
OVERFLOW indicator (two digits)	Displays number of malfunctions in excess of 15, but not exceeding 26, that have been inserted simultaneously

## 1.10.7 BI-LEVEL GROUP &amp; DIGITAL WORD MONITOR PANEL. (See figure 1-90.)

The eight display and control groups associated with this panel enable the Telemetry Instructor to monitor, simultaneously, the status of any 8 approximately 100 bilevel groups and digital word functions being transmitted to MCC. The BI-LEVEL GROUP & DIGITAL WORD MONITOR panel controls and displays are listed, with their function, in table 1-77. Blank placards on this panel may be used by the instructor to temporarily record pertinent information. (Use a grease pencil to write on placards.)

For the digital readout to display the data associated with the selected group and bit number, the instructor must press the DISPLAY switch associated with the appropriate display and control group combination. The DISPLAY switch is not illuminated automatically when pressed; it is illuminated by an output from the computer if the control information has been accepted. The digital readout displays this data until a new number is dialed up and the DISPLAY switch is pressed again. The FAULT (PRESS FOR TRUE) switch is used in conjunction with its associated digital readout to inform the instructor whether the displayed digital readout is true or malfunctioned. The FAULT (PRESS FOR TRUE) switch light goes on only when any of the bilevel bits, groups, or digital words displayed have been malfunctioned by means of the bilevel group and digital word malfunction controls, and the same bilevel bits, group, or digital word has been dialed up on the bilevel group and digital word monitor panel. The FAULT (PRESS FOR TRUE) switch light goes on as a result of a computer output. The pre-malfunctioned value (true readout) is displayed when the FAULT (PRESS FOR TRUE) switch is pressed, and its



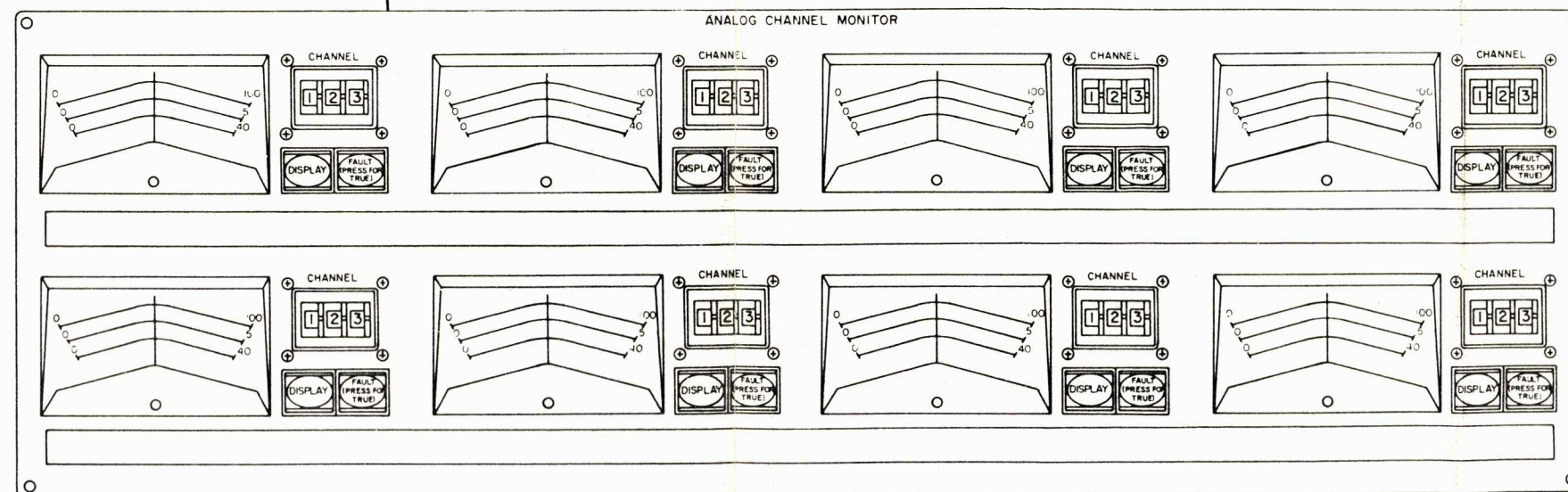
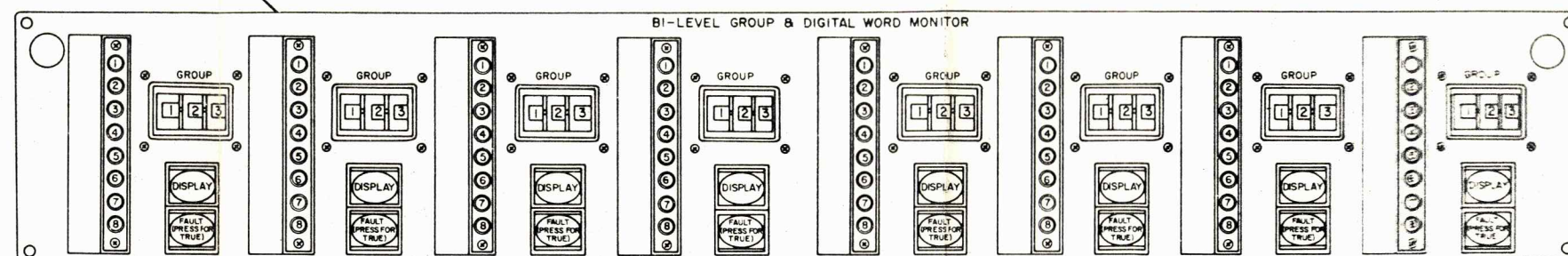
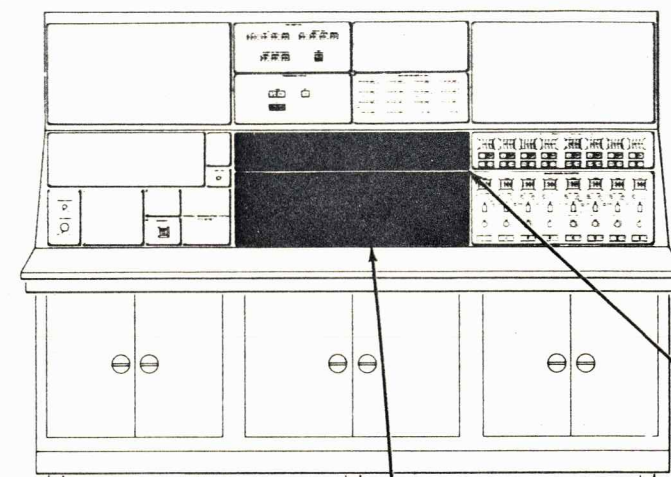


Figure 1-90. Bi-Level Group & Digital Word Monitor and Analog Channel Monitor Panels



Table 1-77. BI-LEVEL GROUP & DIGITAL WORD MONITOR  
Panel, Controls and Displays

Control or Display	Function
GROUP three-digit digiswitch	Permits dial-up of bilevel group selected for display (Number of selected bilevel group is displayed on wheels of digiswitches.)
DISPLAY switch light	Permits activation of associated eight-lamp binary indicator for group number selected by GROUP switch
FAULT (PRESS FOR TRUE) switch light	Lights when bilevel group has fault insertion. True reading (premalfunctioned group) is displayed on binary indicator when FAULT switch is pressed.
Binary indicator (eight-lamp data strip)	Simultaneously displays status of eight selected bilevel groups being transmitted to MCC. Bilevel condition (on or off) is indicated for each of the eight bits, each representing status of discrete event. (In some cases, all eight bits represent status of a digital word.)
<p style="text-align: center;"><b>NOTE</b></p> <p>Bilevel refers to the binary state of the indicator, whereby an on indication equals logic 1 (light goes on) and an off indication equals logic 0 (light goes off).</p>	

light goes off. Values malfunctioned by MIU action at the instructor console are indicated at the telemetry console, on the MALFUNCTION DISPLAY UNIT panel. Values malfunctioned by MIU action do not cause the FAULT (PRESS FOR TRUE) switch light to go on. The group numbers of the bilevel bits or digital words being monitored appear on the GROUP digiswitch. Data to correlate the group numbers with the specifics of the bilevel data or digital work displayed (that is, subsystem, type, state, etc.) are in a table to permit evaluating current status and localizing abnormal event indications. An abnormal readout can be the result of a malfunction introduced by the Telemetry Instructor, an MIU-introduced malfunction, or an improper flight crew response.

#### 1.10.8 ANALOG CHANNEL MONITOR PANEL. (See figure 1-90.)

The eight display and control groups associated with this panel enable the Telemetry Instructor to monitor, simultaneously, the status of any 8 of approximately 500 analog data functions (maximum) being transmitted to MCC. The ANALOG CHANNEL MONITOR panel controls and displays are listed, with their function, in table 1-78. Blank placards on this panel may be used by the instructor to temporarily record pertinent information. (Use a grease pencil to write on placards.)

For the voltmeter to display data associated with the selected channel number, the instructor must press the DISPLAY switch associated with the appropriate display and control group combination. The DISPLAY switch is not illuminated automatically when pressed; it is illuminated by an output from the computer, if the control information has been accepted. The voltmeter displays this data until a new number is dialed up and the DISPLAY switch is pressed again. The FAULT (PRESS FOR TRUE) switch is used in conjunction with its associated voltmeter to inform the instructor whether the displayed analog function is true or malfunctioned. The FAULT (PRESS FOR TRUE) switch light goes on only when the analog function has been malfunctioned by means of the analog channel malfunction controls, and the same channel has been dialed up on the analog channel monitor panel. The FAULT (PRESS FOR TRUE) switch light goes on by an output from the computer. The premalfunctioned value (true readout) is displayed when the FAULT (PRESS FOR TRUE) switch is pressed and its light goes off. Values malfunctioned by MIU action at the instructor console are indicated at the telemetry console, on the MALFUNCTION DISPLAY UNIT panel. Values malfunctioned with the MIU do not cause the



Table 1-78. ANALOG CHANNEL MONITOR Panel, Controls and Displays

Control or Display	Function
CHANNEL three-digit digiswitch	Permits dial-up of analog channel selected for display (Number of selected channel is displayed on wheels of digiswitches.)
FAULT (PRESS FOR TRUE) switch light	Lights when analog data has fault insertion. True reading (premalfunctioned data) is displayed on voltmeter when FAULT switch is pressed.
DISPLAY switch light	Activates associated voltmeter for analog channel selected by CHANNEL digiswitch
Voltmeter	Displays quantitative data (that is, fuel quantity, suit pressure) of eight selected analog functions being transmitted to MCC. Percent scale applies to both voltage scales (0 to 40 millivolts and 0 to 5 volts); it eliminates need to calculate voltages as percentage of full voltage.

FAULT (PRESS FOR TRUE) switch light to go on. The channel numbers of the analog lines being monitored appear on the CHANNEL digitswitches. Data to correlate the channel numbers with the specifics of an analog function displayed (that is, subsystem, type, range, quantity, etc) are in a table to permit evaluating current status and localizing abnormal event indications. An abnormal readout can be the result of a malfunction introduced by the Telemetry Instructor, an MIU-introduced malfunction, or an improper crew response.

#### 1.10.9 BI-LEVEL GROUP & DIGITAL WORD MALFUNCTION PANEL. (See figure 1-91.)

The eight control groups associated with this panel enable the Telemetry Instructor to simulate malfunctions of onboard equipment to the extent of imposing as many as 64 bilevel groups or 8 digital word malfunctions (of approximately 100 bilevel groups or digital words being transmitted to MCC).

The three methods of imposing malfunctions are as follows:

- Malfunction the entire group of eight bits on any, or all, of the control groups - In this case, the bit number specified by the single-digit BIT digiswitch is disregarded.
- Malfunction any one of the bits within a bilevel group or digital word on any, or all, of the control groups - In this case, the group number, within which the desired bit falls, is dialed up together with the bit number.
- Malfunction as many as eight bits within a bilevel group or digital word - This necessitates using as many control groups as there are different bits within the group to be malfunctioned.

To malfunction six different bits within a bilevel group or digital word, for example, requires the use of six control groups. For each control group, the group number within which the desired bit falls is dialed up together with the bit number.

To malfunction the selected group, bit, or bits, the Telemetry Instructor presses the ENTER switch associated with the appropriate control group combinations. The ENTER switch is lit as a result of a computer output if the control information has been accepted. Once it is entered, the malfunction associated with the group number cannot be changed until the CLEAR switch is actuated, after which new malfunction associated with the group number may be dialed up, and the ENTER switch is pressed again. The same procedure is necessary when a malfunction associated with a new channel number is desired. Should the same group (or the same bit within the same group) be entered on a second control group digitswitch, the latest entry prevails and the earlier selection clears automatically. The appropriate CLEAR light goes on when automatic clearing occurs. A malfunction is removed by pressing the appropriate CLEAR switch. The computer then causes the CLEAR switch light to go on, the ENTER switch light to go off, and the previously entered malfunction to be removed. Bilevel data, associated with a group and bit number, or digital word data associated with a group number dialed up on the malfunction panel, are transmitted to MCC unfaulted when the ENTER switch light is



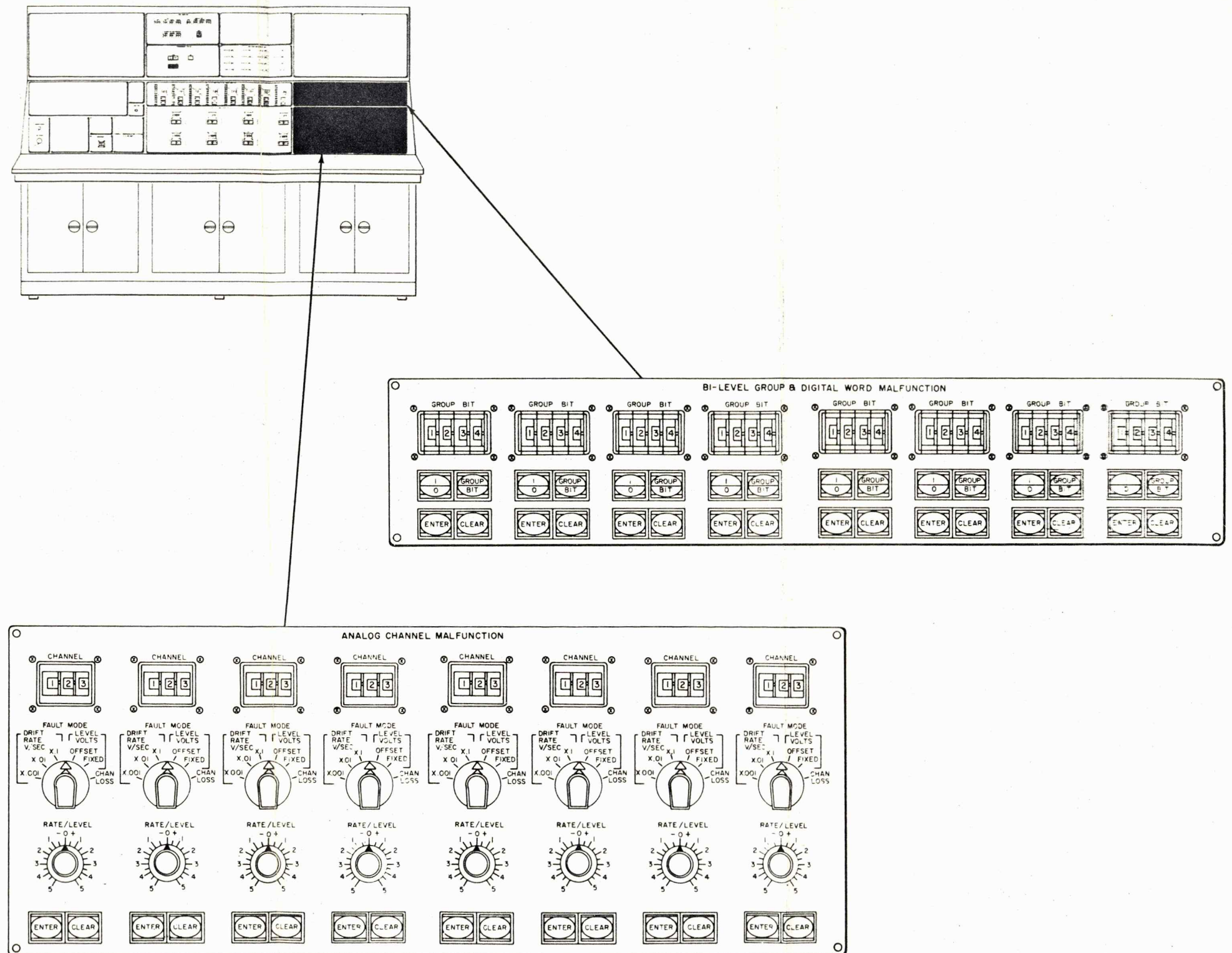


Figure 1-91. Bi-Level Group & Digital Word Malfunction and Analog Channel Malfunctional Panels



off and the CLEAR switch light is lit. The same data, malfunctioned, are transmitted to MCC when the ENTER switch light is on and the CLEAR switch light is off. Data to correlate the group and bit numbers with the specifics of a digital function (that is, subsystem, type, state, etc) are in a reference table. This table permits choice of the correct group and bit number (and type) to insert the desired malfunction and enables malfunctioning a digital word, consisting of one to five groups (8 to 40 bits), by approximately selecting and malfunctioning any of its composite groups.

The BI-LEVEL GROUP & DIGITAL WORD MALFUNCTION panel controls and displays are listed, with their function, in table 1-79.

#### 1.10.10 ANALOG CHANNEL MALFUNCTION PANEL. (See figure 1-91.)

The eight control groups associated with this panel enable the Telemetry Instructor to simulate malfunctions of onboard equipment to the extent of imposing as many as eight malfunctions (of approximately 400 analog data functions being transmitted to MCC).

To malfunction the selected channel, the Telemetry Instructor presses the ENTER switch associated with the appropriate control group combinations. The ENTER switch is lit as a result of a computer output if the control information has been accepted. Once it is entered, the malfunction associated with the channel number cannot be changed until the CLEAR switch is actuated, after which a new malfunction associated with the channel number may be dialed up, and the ENTER switch is again pressed. The same procedure is necessary when a malfunction associated with a new channel number is desired, except that, with the fault mode selected, the RATE/LEVEL potentiometer may be rotated as desired to give the added capability of a step or rate (in case

Table 1-79. BI-LEVEL GROUP & DIGITAL WORD MALFUNCTION Panel,  
Controls and Displays

Control or Display	Function
GROUP three-digit digiswitch	Permits dial-up of selected bilevel groups or digital words (Selected numbers are displayed on wheels of digiswitches.)
BIT single-digit digiswitch	Permits dial-up of one bit within selected group for subsequent malfunctioning
GROUP/BIT split-screen, alternate-action switch light	Permits malfunction to affect single bit within selected group or entire group. When GROUP lamp is lit, malfunction is directed to all eight bits, when BIT lamp is lit, malfunction is directed to only one selected bit.
CLEAR momentary-action switch light	Permits removal of previously entered malfunction and indicates cleared condition
ENTER momentary-action switch light	Permits faulting of group (or bit) selected for malfunction and indicates when malfunction data has been accepted by computer
1/0 split-screen, alternate-action switch light	Permits selection of either logic 1 level or logic 0 level substitution as type of bilevel malfunction to be entered
<div style="text-align: right; border: 1px solid black; padding: 2px; width: fit-content; margin: 10px auto;">NOTE</div> <p>Logic 1 causes an on indication on the bilevel group and digital word monitor panel (binary indicator light goes on); logic 0 causes an off indication (binary indicator light goes off).</p>	

of OFFSET or FIXED) or a change in rate (in case of DRIFT RATE). Should the same channel be entered on a second control group digit switch, the latest entry prevails and the earlier selection clears automatically. The appropriate CLEAR light goes on when automatic clearing occurs. A malfunction is removed by pressing the appropriate CLEAR switch. The computer then causes the CLEAR switch light to go on, the ENTER switch light to go off, and the previously entered malfunction to be removed. Analog data associated with a channel number dialed up on the malfunction panel are transmitted to MCC unfaulted when the ENTER switch light is off and the CLEAR switch light is lit. The same data, malfunctioned, are transmitted to MCC when the ENTER switch light is on and the CLEAR switch light is off. Data to correlate the channel numbers with the specifics of an analog function (that is, subsystem, type, range, quantity, etc) are in reference tables. These tables permit choice of the correct channel number and fault mode to insert the malfunction desired.

The ANALOG CHANNEL MALFUNCTION panel controls and displays are listed, with their function, in table 1-80.

Table 1-80. ANALOG CHANNEL MALFUNCTION Panel, Controls and Displays

Control or Display	Function
CHANNEL three-digit digiswitch	Permits dial-up of analog channel to be malfunctioned (Selected numbers are displayed on wheels of digiswitches.)
FAULT MODE selector switch	Permits selection of following malfunction modes to be imposed on analog data outputs: <ul style="list-style-type: none"> <li>• DRIFT RATE V/SEC: Drift rate superposition; causes analog data output to drift at specific rate (between zero and +0.5 volt per second), depending on scale factor selected (x0.1, x0.01, or x 0.001) and setting of RATE/LEVEL control.</li> <li>• LEVEL VOLTS OFFSET: Voltage level substitution; causes analog data output to be offset within range of + or -5.0 volts, depending on setting of RATE/LEVEL control. Result of offset does not cause analog output to exceed +5.0 volts or drop below zero volts.</li> <li>• LEVEL VOLTS FIXED: Substitution; causes analog data output to be replaced by fixed d-c level within range of 0 to +5 volts, depending on setting of RATE/LEVEL control</li> <li>• CHAN LOSS: Open-circuit simulation; causes all zeros to be transmitted for selected channel</li> </ul>
RATE/LEVEL control	Permits assignment of quantitative values (0 to +5 or -5.0) to fault mode DRIFT RATE V/SEC and LEVEL VOLTS selection
CLEAR momentary-action switch light	Permits removal of previously entered malfunction and indicates cleared condition
ENTER momentary-action switch light	Permits faulting of channel selected for malfunction and indicates when malfunction data has been accepted by computer



## SECTION 2

## SUBSYSTEM SIMULATION

2.1. PURPOSE AND SCOPE.

This section contains information to familiarize the instructor with the methods used in the LMS to accomplish LM subsystem simulation. A brief description and flow or block diagram of each LM subsystem is presented. Specific reference is made, in each subsystem description, to Apollo Operations Handbook, LMA790-3-LM 2. This reference directs the reader to a detailed description of the LM subsystem. The brief LM subsystem description is followed by a description of the subsystem as simulated in the LMS. Each simulated-subsystem description is supported by a diagram that indicates data flow between the related LMS elements.

2.2 SUBSYSTEMS CONFIGURATION.

All LMS subsystems realistically simulate the LM-2 subsystems.

2.3 ENVIRONMENTAL CONTROL SUBSYSTEM.

The LM Environmental Control Subsystem (ECS) provides two astronauts a completely controlled environment, with supplies of oxygen and water, for a maximum duration of 48 hours while the LM is separated from the CSM. (See figure 2-1.) The 48-hour period includes flight, lunar stay, and a 9-hour orbital contingency. Oxygen and water for the portable life support system (PLSS) are provided by the ECS for lunar excursions of the extravehicular astronaut (EVA).

The ECS controls the oxygen, pressurization, ventilation, and temperature of the LM cabin and the space suits worn by the astronauts. The ECS provides oxygen for the space suits, cabin, and PLSS; limits the level of carbon dioxide; removes odors, moisture, and particulate matter from the oxygen breathed by the astronauts; and automatically controls the temperature of the electronics equipment. In addition, the ECS stores water for drinking, heating, cooling, food preparation, and the PLSS.

Extensive sensing, warning, and protective devices, controls and displays, and automatically functioning components throughout the subsystem aid the astronauts in accurate and efficient operation of the ECS. Normal operation of the ECS requires monitoring the subsystem indicators and gages. Electrical and manual overrides, and backup or redundant capabilities provide alternate operation of the ECS, in the event of component failure.

The major portion of ECS equipment is in the pressurized compartment of the ascent stage. A glycol loop, two water tanks, and two gaseous oxygen (GOX) tanks are in the aft equipment bay of the ascent stage; a third (larger) GOX tank and a third (larger) water tank are in the descent stage. Electrical protection of critical ECS components is provided by circuit breakers on the Commander's and Systems Engineer's upper side consoles.

The ECS comprises an atmosphere revitalization section, oxygen cabin pressure section, a water management section, a heat transport section, and a cold plate section.

The atmosphere revitalization section (ARS) consists of a suit circuit that conditions oxygen for cooling and ventilating the pressure garment assemblies (PGA's) worn by the astronauts, and a cabin recirculation assembly that provides circulation and temperature control of cabin oxygen. The suit circuit controls the carbon dioxide level of the atmosphere breathed by the astronauts, removes odors and noxious gases from the atmosphere, removes excess moisture from the atmosphere, and provides control of the gas temperature and the gas flow through the PGA's.

The oxygen cabin pressure section (OCPS) maintains cabin pressure by supplying oxygen at a rate equal to cabin leakage and astronaut consumption. The OCPS also allows for cabin depressurization and subsequent pressurization by the astronauts, maintains space suit pressure during unpressurized-cabin operation, supplies oxygen to replenish the PLSS after lunar excursions, protects against loss of cabin pressure in the event of a puncture of the pressurized shell, and protects against overpressurization of the cabin.

The water management section (WMS) stores water for the metabolic needs of the astronauts, cabin emergency cooling, and for refilling the PLSS water tanks. The WMS consists of one water tank in the descent stage and two smaller water tanks in the ascent stage, water pressure regulators, check valves, shutoff valves, and interconnecting tubing.



The heat transport section (HTS) consists of a primary and secondary closed-loop system. Each system circulates an ethylene glycol-water coolant to provide temperature control of the electronic equipment. The primary system also provides temperature control of the oxygen circulated through the cabin and the PGA's.

The cold plate section (CPS) provides heat sinks for each piece of electronic equipment that requires active heat control and cooling.

Redundant circuits and components are provided to increase reliability. Power for the ECS is supplied from the LM Electrical Power Subsystem (EPS). The major portion of the ECS is integrated within a structural framework behind the crew stations in the cabin. A detailed description of the ECS is given in paragraph 2.6 of Apollo Operations Handbook, LMA790-3-LM 2.

### 2.3.1 ENVIRONMENTAL CONTROL SUBSYSTEM CONFIGURATION REFERENCE.

The Environmental Control Subsystem of the LMS accurately simulates the LM-2 ECS. Major differences include a normal 1-g cabin environment for the LMS as opposed to weightlessness prevalent on an actual mission, and low air pressure applied to the astronaut PGA's within the LMS, to merely simulate suit inflation. Although the true training environment within the LMS does not extend to cabin pressurization or the full temperature range found in space, the suit pressurization and the dual temperature control loops (cabin and space suit) do provide a realistic mission environment.

### 2.3.2 SIMULATED ENVIRONMENTAL CONTROL SUBSYSTEM. (See figure 2-2.)

#### 2.3.2.1 General.

The heating, cooling, and ventilation requirements of the LMS cabin are generated externally of the crew compartment and ducted into the cabin and astronaut suit circuit connections. The temperature of the incoming air is controlled within a range of  $+72^{\circ} \pm 15^{\circ}\text{F}$  by the crewmembers, by operating the simulated LM controls. The cabin pressure remains at normal room ambient throughout the entire training exercise. The suits can be inflated for periods of closed-faceplate operation. Inflation pressure does not exceed 3.7 psig, the inflation time interval being approximately 1 minute; deflation usually takes less than half a minute.

The following details are significant in the simulation of the ECS:

- The LMS cabin area remains at normal room ambient pressure at all times.
- The space suits are inflatable, but are kept at a nominal pressure during closed-faceplate operations.
- Crew heat outputs, carbon dioxide production, and oxygen consumption are considered constants in program computations.
- All electrical power requirements are considered constant, except for the cabin fan and coolant pumps.
- All space suit and cabin atmosphere requirements are supplied by conditioned air.
- The oxygen inflow valves and flow limiters are represented by equations. These equations can be modified by instructor-inserted malfunctions or crew settings.
- PLSS refill quantity is computed as a function of time and pressure.
- The cabin and suit temperature control valves are represented in the computation of temperature commands to the external air-conditioning and pressurization system.
- Water tank depletion is computed, using water boiloff quantities derived from simulated heat inputs.

#### 2.3.2.2 Simulation Methods. (See figure 2-2.)

To provide the realistic instrumentation and control responses for the ECS, each of the major subsystem parameters is calculated from a mathematical expression programmed into the LMS computer. Comprehensive mathematical analogs are included for each of the simulated oxygen and water tanks, as well as their complex manifolding. The simulated coolant systems are also programmed to reflect the system loads, as well as vehicle mission environment. All of these expressions include digital terms for the Electrical Power Subsystem logic needed to drive the various ECS hardware. Though the true training environment does not extend to cabin pressurization or the full temperature excursions found in space, the suit pressurization and the dual temperature control loops do provide a realistic training environment.



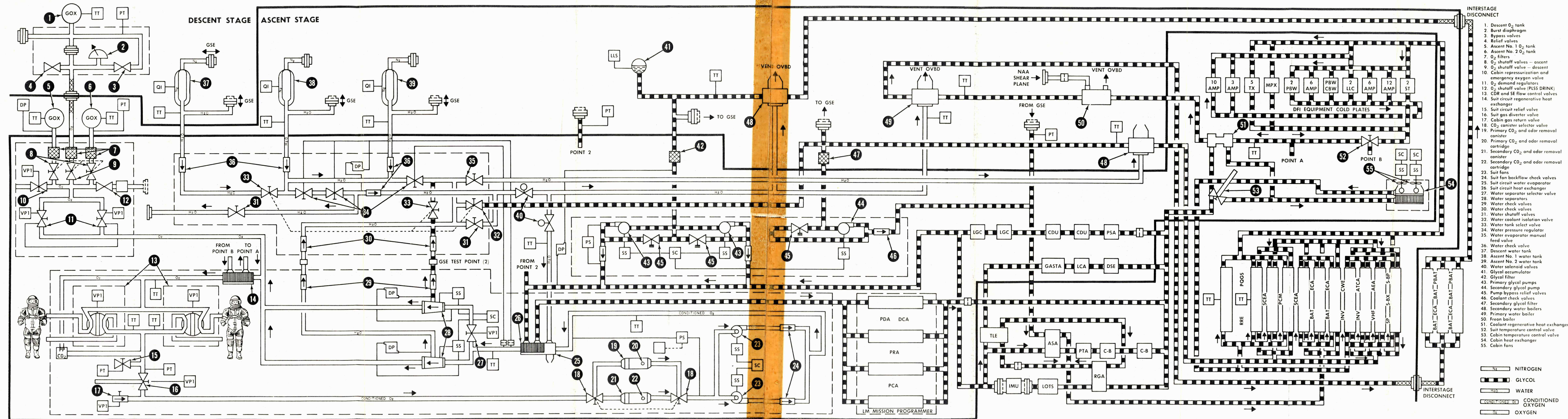


Figure 2-1. LM Environmental Control Subsystem, Simplified Flow Diagram



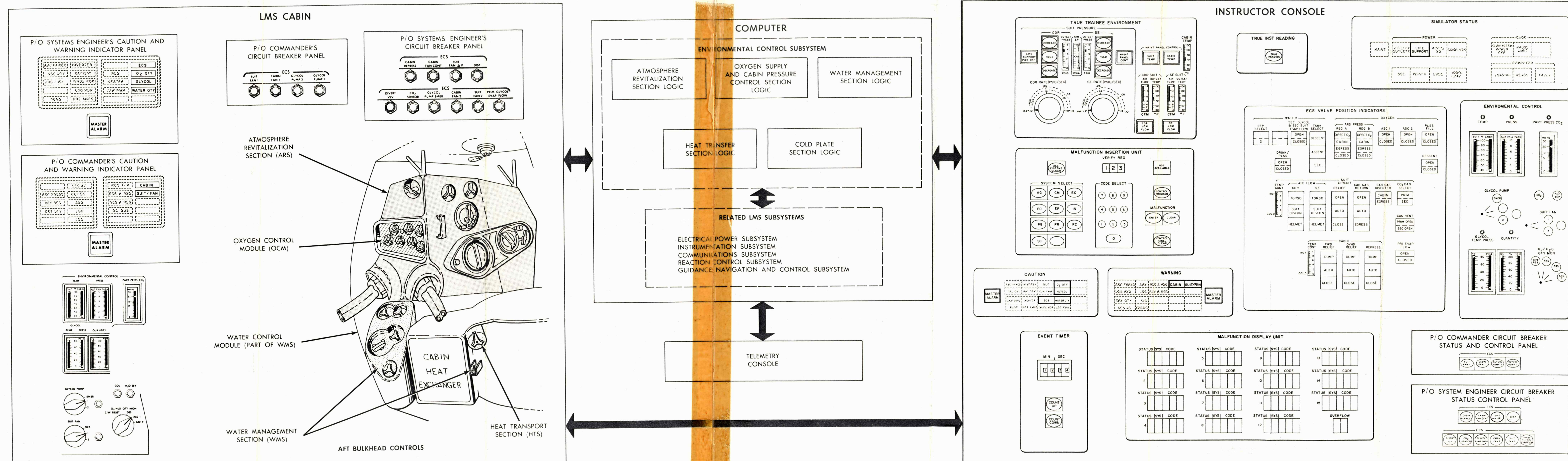


Figure 2-2. LMS Environmental Control Subsystem, Flow Diagram



All simulated LMS cabin gages indicate the simulated LM response to system controls rather than actual environmental conditions in the LMS cabin. The true cabin environmental conditions are displayed externally of the LMS cabin for safety monitoring by the instructors. PLSS use and recharging are simulated only to the extent of cabin system effects. Live lines (oxygen, water, electrical, etc) are not provided in the simulated ECS.

LMS crew station controls and indicators, gross data flow, and instructor console controls and indicators (peculiar to the ECS) are shown in figure 2-2. All LMS cabin controls and indicators are located in the exact configuration of those in LM 2. Crew control inputs and subsystem output displays are continually monitored at the instructor console. Responses to the control inputs are displayed on the telemetry console, as well as in the LMS cabin and on the instructor console. The telemetry data for the simulated ECS are given in table 2-1. The Manned Space Flight Network (MSFN) symbols used in table 2-1 are identified in volume II.

#### 2.3.2.2.1 Space Suit Simulated Environment.

The astronauts wear actual space suits in the LMS, providing realistic physical restrictions inherent in the pressure garment assembly (PGA), thereby affording essential practice in controlling the suit pressurization. The pressure supplied for the suits is low-pressure air, which provides normal suit inflation, without incurring any health or safety hazards. Space suit pressurization is controlled by a Suit Technician at the TRUE TRAINEE ENVIRONMENT panel on the instructor console. The LMS conditioned-air source is a bank of four 1.5-hp air compressors (of special oil-free design), which feed into a 30-gallon glass-lined reservoir. Special metal tubing is used extensively in the air supply plumbing to assure cleanliness and prevent buildup of foreign matter within the air system. Each compressor delivers approximately 13 cubic feet of air per minute at a maximum pressure of 35 psi. The compressor pressure regulators are set at staggered values to compensate for line pressure drops under increasing load demands. A mechanical relief valve is also included to vent inadvertent pressure buildup.

The LMS electrical power used in maintaining the true trainee environment is supplied by a common life support power bus, which is continually monitored by an indicator light on the TRUE TRAINEE ENVIRONMENT panel. The four air compressors which may be used for suit pressurization are powered directly from this bus, although compressor No. 1 has an emergency changeover relay. If the life support power bus fails, compressor No. 1 is automatically switched to a utility bus to assure a continued supply of air, thereby avoiding any discomfort due to rapid suit depressurization. (The utility power bus remains energized if the LMS emergency shutdown sequence is triggered.) The LMS cabin structure includes a maintenance panel for each PGA system. Illuminated control switches for the life support power are mounted on SUIT MAINTENANCE PANEL No. 1. The panel also has a master switch for the suit-pressurization air compressors. (In addition, the compressor cabinet bay includes individual shutoff switches for the four compressor motors.) Each compressor includes a thermal overload breaker in addition to external hydraulic/magnetic circuit breakers. A common 5-ampere magnetic circuit breaker in the LMS main power cabinet supplies the initial operating current for all ECS control circuitry.

Compressed air leaving the air reservoir passes through a heat exchanger in the LMS cabin air conditioner, where the air is chilled and dehumidified. Removal of carbon dioxide, odors, and noxious gas is controlled in the actual LM by lithium hydroxide canisters. These functions are simulated in the LMS by programmed equations in which saturation percentage is a function of time and computed carbon dioxide input. Changing simulated cartridges in the LMS cabin or switching to a fresh standby cartridge resets the saturation percentage to zero. The water separators, which condense and remove the water vapor in the LM, are simulated by programmed equations to provide water-quantity-removed logic and water-separator-fail logic. The conditioned air then passes through a 500-watt electrical heating unit, which constitutes the final temperature control (+50° to +90°F) before admission to the space suits. The heater unit is normally under LMS computer control to accommodate the simulated ECS crew inputs, as well as to reflect the operational status of the simulated spacecraft system. The LMS suit loop exhausts to the ambient atmosphere so that the air is continuously renewed. The ECS controls in the LMS cabin are fully operational; the pressure suit temperature and pressure displayed in the cabin are those calculated for a true space environment. However, the actual true pressure-suit pressure and temperature are restricted to safe limits (0.5 to 5 psi, and +50° to +90°F), and continually monitored at the instructor console. Two pressure indicators display the space suit outlet pressure for the Commander's and Systems Engineer's PGA. The TRUE TRAINEE ENVIRONMENT panel also includes dual readouts of the PGA outlet temperatures, covering the range of +30° to +130°F. In addition, a backup +90°F hi-limit thermostat is provided within the system as an additional safety device.

Once the desired air temperature is obtained, the PGA air supply passes through a final filter before reaching the pressure-regulation system. Each space suit maintenance panel contains a manual pressure regulator, a pressure gage, and a flowmeter. The flowmeter indicates the regulated flow rate of the air supply at the space suit inlets. The airflow through each pressure suit is also sensed at the pressure suit outlets. Two flowmeters on the TRUE TRAINEE ENVIRONMENT panel indicate airflow up to 14 cubic feet per minute (cfm). When airflow through either crewman's suit drops below 8 cfm, one of two red warning lamps glows on the TRUE TRAINEE ENVIRONMENT panel. Simulated space suit pressurization (in an unpressurized cabin) is



Table 2-1. LMS Environmental Control Subsystem Telemetry Data

MSFN No.	Description	Range			Unit or Type*
		Low	Nominal	High	
GF1082	Secondary suit fan select				CC
GF1083	Prime suit fan fail				CC
GF1084	Secondary suit fan fail				CC
GF1201	Suit inlet valve No. 1 closed				CC
GF1202	Suit inlet valve No. 2 closed				CC
GF1211	Suit pressure relief valve closed				CC
GF1212	Suit pressure relief valve open				CC
GF1221	Suit divider closed				CC
GF1231	Cabin gas return valve closed				CC
GF1232	Cabin gas return valve open				CC
GF1241	CO <sub>2</sub> cartridge in secondary position				CC
GF1281	Suit in temperature	+20		+120	° F
GF1291	Suit No. 1 out temperature	+20		+120	° F
GF1292	Suit No. 2 out temperature	+20		+120	° F
GF1301	Suit out pressure	0		10	psia
GF1521	CO <sub>2</sub> partial pressure	0		30	mm Hg
GF1651	Cabin temperature	+20		+120	° F
GF2021	Prime pump $\Delta P$	0		50	psia
GF2041	Accumulator glycol low				CC
GF3071	OX regulator A valve closed				CC
GF3072	OX regulator A valve open				CC
GF3073	OX regulator B valve closed				CC
GF3074	OX regulator B valve open				CC
GF3081	Emergency OX man open				CC
GF3571	Cabin pressure	0		10	psia
GF3572	Emergency OX valve open				CC
GF3582	Ascent OX No. 1 pressure	0		1,000	psia
*CC = Contact closure.					



Table 2-1. LMS Environmental Control Subsystem Telemetry Data (cont)

MSFN No.	Description	Range			Unit or Type*
		Low	Nominal	High	
GF3583	Ascent OX No. 2 pressure	0		1,000	psia
GF3584	Descent OX pressure	0		3,000	psia
GF3585	Ascent OX tank No. 1 temperature	0		+200	° F
GF3586	Ascent OX tank No. 2 temperature	0		+200	° F
GF3587	Descent OX temperature	0		+200	° F
GF3591	Safety valve No. 1 servo pressure	0		25	psia
GF3592	Safety valve No. 2 servo pressure	0		25	psia
GF4101	Main H <sub>2</sub> O regulator $\Delta^2$ P	0		2	psia
GF4511	Main W/B in temperature	+20		+160	° F
GF4541	Suit W/B in temperature	0		100	%
GF4581	Descent H <sub>2</sub> O quantity	0		100	%
GF4582	Ascent H <sub>2</sub> O No. 1 quantity	0		100	%
GF4583	Ascent H <sub>2</sub> O No. 2 quantity	0		100	%
GF9997	Select pump discharge pressure	0		60	psia
GF9998	Select W/B glycol temperature	+20		+120	° F
GF9999	Select H <sub>2</sub> O separator rate	500		3,600	rpm
*CC = Contact closure.					

based on the difference between theoretical cabin pressure and theoretical suit pressure. Normally, the instructor manually adjusts the pressure of the two suits to be proportional to the theoretical relative pressure differential. This differential is calculated within the LMS computer complex and displayed on the  $\Delta$  P meter of the TRUE TRAINEE ENVIRONMENT panel. It is also possible to regulate the space suit air pressures from the suit maintenance panels mounted on the LMS cabin bulkhead. The space suit umbilicals include inlet and outlet hose lines. Suit pressure control is maintained in the LMS by paired pressure regulators: one, on the suit inlet line; the other, on the suit outlet line. A servomotor-driven pilot valve biases the upstream regulator, thereby controlling its output pressure. The pilot valve outputs are displayed on each maintenance panel. Gages also monitor the actual suit inlet pressure (at the inlet regulator) and the suit outlet pressure (at the outlet regulator), as well as the pressure differential across the suit.

During the training mission, the space suit pressure is adjusted from the TRUE TRAINEE ENVIRONMENT panel. Switches are provided for each suit to increase, hold, or decrease the air pressure controlling the servomotor-driven pilot valves. These pilot valves assure that the suit pressure does not vary at a rate that would prove uncomfortable or injurious to the astronauts. Maximum suit pressurization requires an inflation time of not less than 45 seconds; the pilot valves will not depressurize the suits in less than 19 seconds. Commanding an increase in suit pressure causes the servomotor-driven pilot valve to drive, increasing the suit pressure at a variable rate. The servomotor stops when the pilot valve reaches its mechanical limit or when a hold command is manually initiated, or by electrical stops. Similarly, commanding a reduction in suit pressure drives the servomotor-driven pilot valve to reduce the suit pressure until the pilot valve mechanical limit is



reached or a hold command is initiated. The pilot valve reduces space suit pressures at three times the rate at which it increases the pressure. The rate of air pressure change is controlled by calibrated knobs on the TRUE TRAINEE ENVIRONMENT panel. The instructor normally selects the pressurization rate, then increases or reduces the suit pressure until the desired pressure level is reached. The servomotor-driven pilot valve is stopped by initiating a hold command. The instructor monitors the outlet pressure of both pressure suits on matching gages on the TRUE TRAINEE ENVIRONMENT panel. The indicator that displays theoretical suit-to-cabin pressure differential ( $\pm 10$  psi) is located between the two true suit pressure gages, to assist the instructor in controlling the true suit pressures. TRUE TRAINEE ENVIRONMENT panel control of suit pressure servomotor-driven pilot valves may also be transferred to the suit maintenance panels mounted on the LMS cabin bulkhead. In this condition, an indicator lamp on the TRUE TRAINEE ENVIRONMENT panel lights to alert the instructor that suit pressure regulation has been transferred. The maintenance panel controls fixed servomotor-driven pilot valve rates: 90 seconds for maximum suit inflation, and 30 seconds for full deflation.

#### 2.3.2.2.2 LMS Cabin Simulated Environment.

Cabin temperature control is another major function of the simulated ECS, providing the true training environment of the LMS. Though the LMS cabin is not pressurized, the air temperature is computer controlled to vary with the simulated spacecraft pressure readings over a range restricted to comfortable levels ( $+62^{\circ}$  to  $+89^{\circ}$ F). Air is supplied to the LMS cabin at a minimum rate of 185 cfm from a continuously running air conditioner. The cabin air supply is chilled and dehumidified in a Freon heat exchanger; it then flows over a 1,575-watt electric heating unit. The cabin temperature is regulated by switching this heating unit on and off. A  $+90^{\circ}$ F hi-limit thermostat provides a safety backup for the cabin temperature control system. Cabin temperature gages are located on the TRUE TRAINEE ENVIRONMENT panel at the instructor console and the suit maintenance panels mounted on the LMS cabin bulkhead. Under automatic computer control, the cabin temperature corresponds (within the  $+62^{\circ}$  to  $+89^{\circ}$ F safety limits) to the calculated theoretical values displayed in the LMS cabin. The cabin temperature may also be manually controlled by a variable control on the SUIT MAINTENANCE PANELS when command has been transferred by the Suit Technician.

The LMS cabin includes a supply of drinking water for crew comfort and to enhance the simulation. A 1-gallon thermos flask gravity-feeds the cabin water pistol. A computer-controlled solenoid valve may interrupt the flow, if the water-managing logic concerning the computed tank quantities dictate that drinking water would not be available to the crew at that time.

All ECS instruments and indicator lights of the LMS function as they would under actual flight conditions. The simulated subsystem responds to each control switch, circuit breaker, and valve in the LMS cabin. (The simulated mechanical valves do not control flow of gas or fluid, but are connected with electrical switches and potentiometers to transfer control settings to the computer complex, assuring that the simulated system calculations respond accordingly.) The instructor console contains repeater instrumentation for all ECS displays within the LMS cabin to permit monitoring meter readings and warning lights. In addition, the position of all ECS switches and circuit breakers, as well as most of the ECS manual valve settings within the LMS cabin, are indicated by annunciator displays on the instructor console.

#### 2.3.2.3 Malfunction Control.

ECS training in the LMS is primarily based on simulated malfunctions initiated by the instructor. These malfunctions may be programmed into the training mission or they may be manually inserted at the instructor's malfunction insertion unit. When the selected malfunction results in an erroneous ECS instrument readout, a light above the corresponding repeater instrument on the instructor console lights. The instructor's repeater indicators normally display the erroneous value just as it appears to the astronauts in the LMS cabin, though the correct values can be displayed at the instructor console when the instructor presses a true reading pushbutton. ECS circuit breakers are also controlled from the instructor console. The status of each circuit breaker on the Commander's and Systems Engineer's side panels is displayed by respective switch-lights, which are individually placarded. A step-ahead mode may be initiated during the training exercise, to advance the simulated mission to a desired time at an accelerated rate. All programmed maneuvers and malfunctions will be initiated during this advance interval. A complete list of malfunctions available for insertion into the ECS simulation is in section 2 of volume II.

### 2.4 GUIDANCE, NAVIGATION, AND CONTROL SUBSYSTEM.

The LM Guidance, Navigation, and Control Subsystem (GN&CS) provides the attitude control, guidance, and navigation necessary to accomplish lunar landing and ascent, and rendezvous and docking with the CSM. The GN&CS is an aided inertial guidance system whose principal sensors are the alignment optical telescope



(AOT), the inertial measurement unit (IMU), and the rendezvous and landing radars. The LM GN&CS consists of the following operational sections:

- Primary guidance, navigation, and control section (PGNCS)
- Control electronics section (CES)
- Abort guidance section (AGS)
- Rendezvous radar (RR) section
- Landing radar (LR) section.

The five sections of the GN&CS each contain similar equipment or perform related functions. The assemblies of the sections are listed in table 2-2.

Table 2-2. Assemblies of Guidance, Navigation, and Control Subsystem Sections

GN&CS Section	Assembly
Primary guidance, navigation, and control section (PGNCS)	Inertial measurement unit (IMU) Alignment optical telescope (AOT) LM guidance computer (LGC) Display and keyboard (DSKY) Coupling data unit (CDU) Signal-conditioning module (SCM) Pulse torque assembly (PTA) Power and servo assembly (PSA)
Control electronics section (CES)	Attitude and translation control assembly (ATCA) Rate gyro assembly (RGA) Descent engine control assembly (DECA) Gimbal drive actuator (GDA) Attitude controller assembly (ACA) Thrust/translation controller assembly (TTCA) Ascent engine latching device/sequencer (AELDS)
Abort guidance section (AGS)	Abort sensor assembly (ASA) Abort electronics assembly (AEA) Data entry and display assembly (DEDA)
Rendezvous radar section (RR)	Antenna assembly Microwave section Control panel
Landing radar section (LR)	Antenna assembly Electronics assembly Control panel

Two separate guidance paths are provided in the GN&CS: a primary guidance path and a secondary guidance path. (See figure 2-3.) The primary guidance path controls LM attitude and translation, using the sensing and computing assemblies of the PGNCS with the CES, RR section, and the LR section. The secondary (abort guidance) path is used to control LM attitude and translation if the PGNCS malfunctions; it uses the sensing and computing assemblies of the AGS with the CES, RR section, and LR section. The term "abort guidance path" is somewhat misleading in that any abort situation is normally under control of the PGNCS; the AGS is used only if the PGNCS malfunctions, to perform all operations necessary for a safe rendezvous with the orbiting CSM.

The PGNCS performs the following functions:

- Navigation - Performs navigation computations (usually during coasting flight), which maintain current position and velocity (state vector) of the LM during the mission
- Guidance - During powered flight, determines trajectory for arrival at predetermined target points
- Control - Issues guidance signals, which alter the thrust directions to effect the determined trajectory.

The PGNCS is basically an aided inertial guidance and navigation section. The main functions of the PGNCS are provided by the LGC with inputs from the IMU and the AOT. The LGC is a general-purpose digital computer with fixed and erasable memory banks: the fixed memory permanently stores navigation tables, trajectory parameters, programs, and constants; the erasable memory stores intermediate information, which can be changed at the discretion of the LM astronauts.

The IMU provides the inertial reference for the LM. Changes in LM attitude or velocity are sensed by the IMU and are relayed to the LGC and cabin instrumentation. The IMU inner gimbal platform is aligned to an inertial space reference site through the sighting of two or more predetermined navigational stars, using the AOT. The LGC receives inputs from the IMU, AOT, and LM astronaut, processes the information, and furnishes an output in the form of command signals and/or a data display on the LGC control panel (DSKY).

Angle inputs are provided to the LGC from the IMU and radars through the CDU's. Optics angles are entered into the LGC by the astronaut, using the DSKY keyboard. The LGC counters receive direct inputs from the IMU accelerometers and the radar range and velocity tracking networks. Discrete input and output signals enable the LGC to control the various modes of PGNCS operation. The astronauts enter all inputs and commands via the DSKY keyboard. Generally, the LGC performs four major functions:

- Calculates steering signals and generates engine discretes necessary to keep the LM on a required trajectory
- Aligns the stable member (innermost gimbal) of the IMU to a coordinate system defined by precise optical measurements
- Conducts limited malfunction isolation for the GN&CS
- Displays pertinent navigation information to the astronauts.

Using information from navigation fixes, the LGC determines the amount of deviation from the required trajectory and calculates the necessary corrective attitude and thrust commands. Velocity corrections are measured by the IMU and controlled by the LGC. During coasting phases, velocity corrections are not made continuously; they are initiated at predetermined checkpoints. The major LGC outputs are direct engine commands and thrust angle commands to the RCS and MPS. Radar antenna angles are commanded through the respective CDU's.

The CES provides control of the RCS and MPS to effect attitude and translation maneuvers about and along the LM X, Y, and Z axes during landing, rendezvous, and docking. The CES provides signals that fire any combination of the 16 thrust chamber assemblies (TCA's) of the RCS to control attitude and translation. The CES also provides on and off commands to the ascent and descent engine, descent engine throttle, and gimbal drive (to position the descent engine), and shutdown sequencing circuitry. The control of the engines and/or RCS thrusters originates from the LGC or AEA during automatic operation; from the ACA's and T/TCA's, during manual operations. In the event of a PGNCS malfunction, the AGS is substituted to operate with the CES.

The AGS is a simplified backup version of the PGNCS; it takes complete command of LM attitude and translation maneuvers only if the PGNCS malfunctions. The AGS and PGNCS operate simultaneously in a similar fashion, although only one of these GN&CS sections may actually control the LM at any given time.



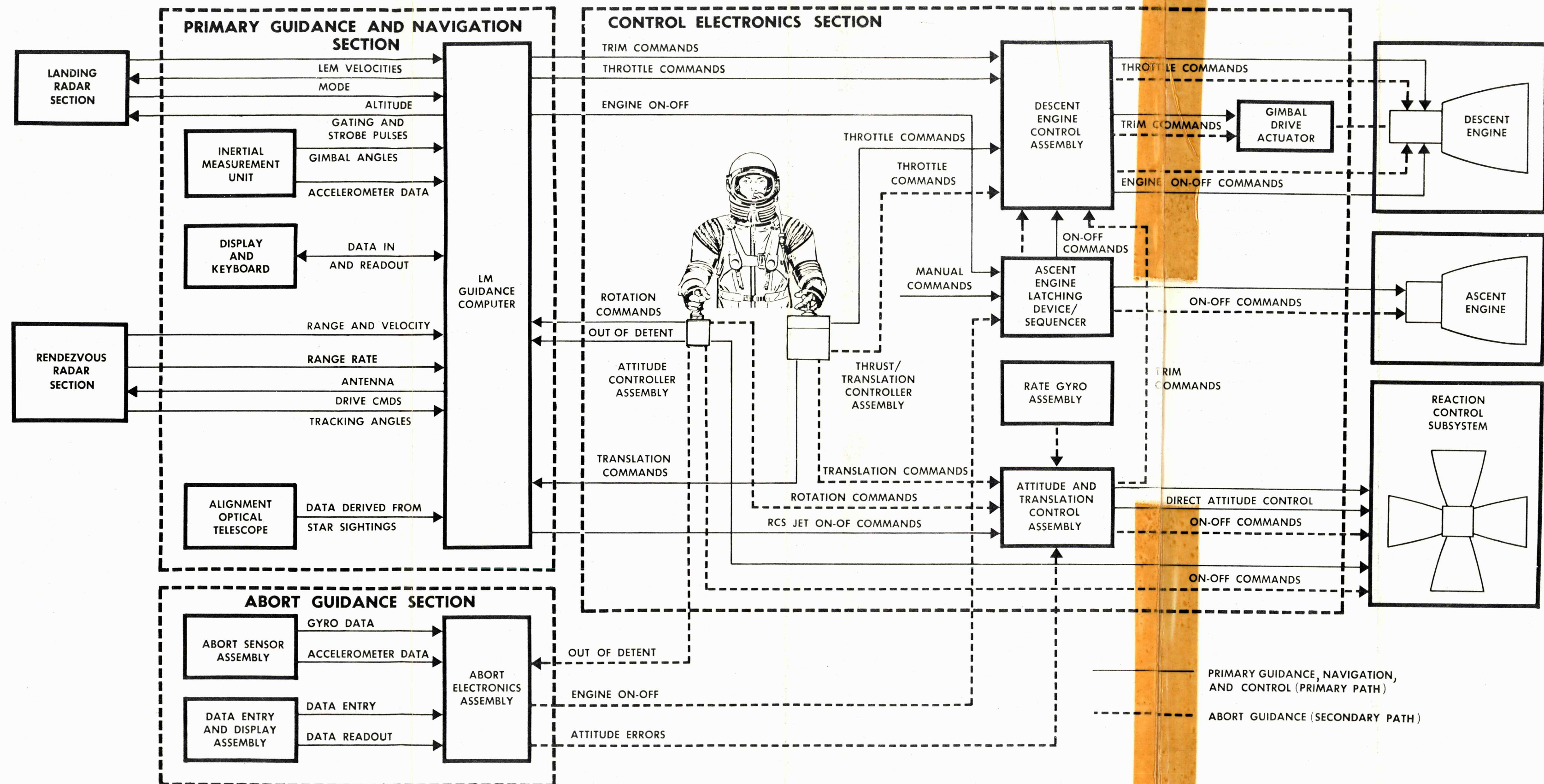


Figure 2-3. LM Guidance, Navigation, and Control Subsystem, Block Diagram



(The AGS contains its own inertial guidance and related AEA computer assemblies.) Each astronaut may observe the calculated parameters of the AGS or PGNCs on his flight director attitude indicator (FDAI). The AGS provides LM with a guidance and navigation capability from any point in the mission, for rendezvous and docking with the CSM; the AGS cannot provide attitude and translation commands for lunar descent or landing.

The RR section establishes a control link between the LM and CSM. The RR tracks a CSM transponder to provide range, range-rate, and line-of-sight (LOS) angles (relative to the CSM) for LGC computation of guidance and navigation data, during rendezvous maneuvers. The RR supplies this data to the LGC during coasting descent, lunar stay, and coast-to-terminal-rendezvous phases of the lunar mission. During the descent phase, the RR is used as a passive receiving device to monitor the landing trajectory, and to acquire and track the orbiting CSM should an abort maneuver be required. The RR is used as an active device during the ascent phase, to update inertially derived guidance and navigation data.

The LR section senses the velocity and altitude of the LM with respect to the lunar surface, during powered descent. These data are fed directly to the LGC to update inertially derived data. The LR functions as a three-beam doppler velocity sensor and an FM/CW radar altimeter. The LR contains self-test devices that permit operational checks without radar returns from external objects or the lunar surface. The LR antenna assembly can be rotated about the LM Y-axis and can assume either of two positions to maintain the radar altimeter beam approximately perpendicular to the lunar surface during the powered descent phase of the lunar mission.

Electrical power for the GN&CS is supplied by the Electrical Power Subsystem (EPS). Circuit breaker panels located on the Commander's and Systems Engineer's upper side console protect equipment against electrical malfunction.

A detailed description of the GN&CS is given in paragraph 2.2 of Apollo Operations Handbook, LMA790-3-LM2.

#### 2.4.1 GUIDANCE, NAVIGATION, AND CONTROL SUBSYSTEM CONFIGURATION REFERENCE.

The Guidance, Navigation, and Control Subsystem of the LMS accurately simulates the LM-2 GN&CS. The GN&CS controls and displays that are essential to astronaut training are identical with those in LM-2. Hardware assemblies that are not essential to astronaut training are represented by math models in the LMS computer software.

#### 2.4.2 SIMULATED GUIDANCE, NAVIGATION, AND CONTROL SUBSYSTEM.

##### 2.4.2.1 General.

Simulation of the two guidance paths (PGNCs and AGS) of the GN&CS is based on continuous calculations of equations of motion for the LM and the CSM, performed within the LMS computer complex. These true position and velocity values (computed on 24 digital bit word-length units) are modified or deliberately distorted to simulate the outputs of the LM onboard computer (LGC), which is a 16-bit word-length device. In addition to simulation of the more limited capacity onboard computer, the LMS computer programs incorporate all the sensor input logic and electrical power dependencies found in the LM.

The guidance simulation also includes operation of the LM cabin DSKY and DEDA panels. The LMS incorporates modified LM components for these panels, providing full functional capability for each. Normal in-flight data may be manually entered by the crew, and typical data are displayed on the panel readouts. The LMS computers are programmed to accept data readouts from the same parameter core addresses used in the LM computers. The onboard computer self-test routines, controlled and monitored at the DSKY and DEDA panels, are functionally simulated.

Throughout the simulated LM mission, GN&CS simulation is closely integrated with the EVDE. This includes simulation of the celestial star field, the sun, the earth view (mission effects projector), and the rendezvous target (CSM) and the lunar surface as viewed from the three cabin windows or through the AOT.

Simulation of the LM guidance system is based on simultaneous calculation of five basic groups of the equations of motion. The true values of attitude, position, and velocity are continuously computed for the CSM and the LM. In addition, four sets of the same parameters are stored as values that simulate the computations of the primary (PGNCs) and secondary (AGS) guidance sections of the LM and CSM. In this manner, the primary navigation data for each simulated section may be individually deviated to simulate subsystem



malfunctions. The following parameters are indicative of the calculations performed in the LMS computer complex to support the simulation of the GN&CS:

- LM attitude angles (3)
- LM position - geocentric (latitude, longitude, and altitude from the center of earth)
- LM position - lunarcentric
- LM velocity - geocentric ( in three orthogonal coordinates)
- LM velocity - lunarcentric
- CSM position - geocentric
- CSM position - lunarcentric
- CSM velocity - geocentric
- CSM-to-LM relative position - polar coordinates (true value computed, as well as simulated values for LGC, AEA, and RR)
- CSM-to-LM relative attitudes (for EVDE)
- CSM-to-LM relative velocity vector (true value, as well as simulated values for LGC, AEA, and RR)
- CSM orbital trajectory (true value, and deviated calculations to simulate operation of LGC and AEA)
- LM orbital trajectory (true value and calculations derived for LGC and AEA simulation)
- LM descent profile (for landing guidance)
- LM ascent profile (for primary and secondary guidance paths)
- LM RR antenna angles (2)
- LM radar signal strength (rendezvous and lunar-surface returns)
- LM IMU platform angles and orientation
- CSM IMU platform angles and orientation
- Logic expressions for electrical power, maneuvering and propulsion thrusting, sensor selections, radar LOS capabilities, and down-link telemetry capabilities.

#### 2.4.2.2 Simulation Methods.

LMS crew station controls and indicators, gross data flow, and instructor console controls and indicators (peculiar to the GN&CS, less radars) are shown in figure 2-4. All LMS cabin controls and indicators are located in the exact configuration of those in LM2. Crew control inputs and subsystem output displays are continuously monitored at the instructor console. Responses to the control inputs are displayed on the telemetry console, as well as in the LMS cabin and on the instructor console. The telemetry data for the simulated GN&CS are given in table 2-3. The Manned Space Flight Network (MSFN) symbols used in table 2-3 are identified in volume II.

##### 2.4.2.2.1 Primary Guidance, Navigation, and Control Section.

The functions of the LM PGNCS are simulated in the LMS by minimal use of modified LM hardware and maximum use of software programming techniques. The AOT and DSKY panel are necessarily operable, and included to enhance the AMS cabin panel configuration. The functions of the IMU, CDU's, SCM, PTA, PSA and LGC are duplicated by the LMS computer complex software.





Figure 2-4. LMS GN&CS Less Radars, Flow Diagram



Table 2-3. LMS Guidance, Navigation and Control Subsystem Telemetry Data

MSFN No.	Description	Low	Range Nominal	High	Unit or Type*
GG0001	PGNS down-link data (to T/M)				
GG1040	Volt, 120-vdc pulse torque reference	85	120	135	vdc
GG1110	Volt, 2.5-vdc T/M bias, PCM	0	2.5	5	vdc
GG1201	Volt, IMU 28v, 800-cycle IP-OP supply	0	28	31.1	vrms
GG1331	Volt, 3.2-kc, 28v supply	0	28	31.1	vrms
GG1513	IMU standby/off	Off		On	
GG1523	LGC operate	Off		On	
GG2001	Volt, X PIPA signal generator output, in phase	-2.5		+2.5	vrms
GG2021	Volt, Y PIPA signal generator output, in phase	-2.5		+2.5	vrms
GG2041	Volt, Z PIPA signal generator output, in phase	-2.5		+2.5	vrms
GG2107	Volt, IG servo error, in phase	-3	0	+3	vrms
GG2112	Volt, IG 1X resolver output, sin	-20.25		+20.25	vrms
GG2113	Volt, IG 1X resolver output, cos	-20.25		+20.25	vrms
GG2137	Volt, MG servo error, in phase	-3	0	+3	vrms
GG2142	Volt, MG 1X resolver output, sin	-20.25		+20.25	vrms
GG2143	Volt, MG 1X resolver output, cos	-20.25		+20.25	vrms
GG2167	Volt, OG servo error, in phase	-20.25		+20.25	vrms
GG2172	Volt, OG 1X resolver output, sin	-20.25		+20.25	vrms
GG2173	Volt, OG 1X resolver output, cos	-20.25		+20.25	vrms
GG2219	Volt, pitch CDU DAC out	-5	0	+5	vrms
GG2249	Volt, yaw CDU DAC out	-5	0	+5	vrms
GG2279	Volt, roll CDU DAC out	-5	0	+5	vrms
GG2300	Temperature, PIPA	+120	+130	+140	° F
GG2301	Temperature, IRIG	+123	+133	+143	° F
GG3304	Volt, radar shaft 1X resolver output, sin	-21.5		+21.5	vrms
GG3305	Volt, radar shaft 1X resolver output, cos	-21.5		+21.5	vrms
GG3324	Volt, radar trunnion 1X resolver output, sin	-21.5		+21.5	vrms
GG3325	Volt, radar trunnion 1X resolver output, cos	-21.5		+21.5	vrms
GG6020	PIPA calibrated temperature	+32		+122	° F
GG9001	LGC (warning)				CC
GG9002	ISS (warning)				CC

\*CC = Contact closure.

TABLE 2-3. LMS Guidance, Navigation and Control Subsystem Telemetry Data (cont)

MSFN No.	Description	Low	Range Nominal	High	Unit or Type*
GG9003	PGNS (caution)				CC
GH1204	ACA out of detent				CC
GH1214	Auto engine on command				CC
GH1217	Auto engine off command				CC
GH1230	Ascent engine arm (from panel)			28	vdc
GH1240	Volt, X-translation command	-10		+10	vdc
GH1241	Volt, Y-translation command	-10		+10	vdc
GH1242	Volt, Z-translation command	-10		+10	vdc
GH1247	Volt, yaw logic input error	-13	+.5	+13	vdc
GH1248	Volt, pitch logic input error	-13	+.5	+13	vdc
GH1249	Volt, roll logic input error	-13	+.5	+13	vdc
GH1260	Ascent engine on-off to propulsion				CC
GH1286	Engine fire override				CC
GH1301	DPS on				CC
GH1311	Volt, manual thrust command	2.6		15	vdc
GH1313	Volt, pitch GDA position (0.4 kc)	-15	+.05	+15	vrms
GH1314	Volt, roll GDA position (0.4 kc)	-15	+.05	+15	vrms
GH1323	Pitch trim fail				CC
GH1330	Roll trim fail				CC
GH1331	Volt, auto thrust command	0	.015	12	vdc
GH1348	Descent engine arm (DECA out)				CC
GH1418	Volt, jet No. 4u driver output, 28v	6 pps	max	10-400	ms
GH1419	Volt, jet No. 4d driver output, 28v	6 pps	max	10-400	ms
GH1420	Volt, jet No. 4f driver output, 28v	6 pps	max	10-400	ms
GH1421	Volt, jet No. 4s driver output, 28v	6 pps	max	10-400	ms
GH1422	Volt, jet No. 3u driver output, 28v	6 pps	max	10-400	ms
GH1423	Volt, jet No. 3d driver output, 28v	6 pps	max	10-400	ms
GH1424	Volt, jet No. 3f driver output, 28v	6 pps	max	10-400	ms
GH1425	Volt, jet No. 3s driver output, 28v	6 pps	max	10-400	ms
GH1426	Volt, jet No. 2u driver output, 28v	6 pps	max	10-400	ms
GH1427	Volt, jet No. 2d driver output, 28v	6 pps	max	10-400	ms
GH1428	Volt, jet No. 2f driver output, 28v	6 pps	max	10-400	ms
GH1429	Volt, jet No. 2s driver output, 28v	6 pps	max	10-400	ms
GH1430	Volt, jet No. 1u driver output, 28v	6 pps	max	10-400	ms
GH1431	Volt, jet No. 1d driver output, 28v	6 pps	max	10-400	ms
GH1432	Volt, jet No. 1f driver output, 28v	6 pps	max	10-400	ms
GH1433	Volt, jet No. 1s driver output, 28v	6 pps	max	10-400	ms

\*CC = Contact closure.



Table 2-3. LMS Guidance, Navigation and Control Subsystem Telemetry Data (cont)

MSFN No.	Description	Low	Range Nominal	High	Unit or Type*
GH1455	Volt, yaw attitude error (0.8 kc)	-5		+5	vrms
GH1456	Volt, pitch attitude error (0.8 kc)	-5		+5	vrms
GH1457	Volt, roll attitude error (0.8 kc)	-5		+5	vrms
GH1461	Volt, yaw rate gyroscope signal (0.8 kc)	-3.5		+3.5	vrms
GH1462	Volt, pitch rate gyroscope signal (0.8 kc)	-3.5		+3.5	
GH1463	Volt, roll rate gyroscope signal (0.8 kc)	-3.5		+3.5	
GH1609	SCS mode select				CC
GH1621	Guidance select switch (AGS)				CC
GH1283	Abort stage recommended				CC
GH1608	SCS mode select (auto)				CC
GH1628	Roll attitude control select (pulsed/direct)				CC
GH1629	Pitch attitude control select (pulsed/direct)				CC
GH1630	Yaw attitude control select (pulsed/direct)				CC
GH1893	X-translation override	0		28	vdc
GI0001	AGS down-link data (to T/M)	0		64	pps
GI3301	ASA temperature	0	+120	+250	° F
GI3305	AGS condition (warmup)				CC
GI3306	AGS condition (standby)				CC

\*CC = Contact closure.

The LMS PGNCS computes and regulates the primary mission path by performing three basic functions. Simulated navigation techniques are used to formulate the exact simulated LM location at any given time in the training mission. This is accomplished by using general navigation programs, service programs, and associated subroutines of the LMS computer complex. Simulated guidance techniques are used to compute the degree of error between predetermined and current locations of the simulated LM at any particular time. This is accomplished by using mission phase guidance programs, service programs, and associated subroutines of the LMS computer complex. Simulated control techniques are used to formulate the command signals that ultimately alter simulated LM translation and attitude to attain the predetermined mission trajectory determined by the guidance subsection. This control is primarily achieved by the digital auto pilot (DAP) function of the LMS computer C software.

The LMS simulates the characteristics of LM subsystem performance and flight dynamics. Three general-purpose digital computers comprise the LMS computer complex and perform the real-time computations maintaining simulated LM subsystem performance, flight dynamics, and visual effects. The LGC, which is the major assembly of the PGNCS, is entirely simulated in one computer, designated computer C. All other LM subsystem functions are simulated in two other computers, designated computers A and B. Computer C effects an interpretive simulation of the LM LGC by computing navigation and guidance equations from a magnetic tape originated at MIT/Instrumentation Laboratories. Computer C interpretively evaluates and transforms all tape

data into DP-224 computer language. This is achieved by using an individual subroutine for each individual LGC operation. Computer C is referred to as the interpretively simulated LM guidance computer (ISLGC), due to the nature of its operations. Pertinent operating features of the ISLGC are as follows:

- Computers A and B interface with ISLGC through a fixed block of 512 common core locations.
- The counters and input/output channels of the LM LGC are simulated by 24-bit memory locations in the ISLGC.
- There are two types of counters and channels: input and output. The functions of the input counters and channels are simulated by transferring data from common core locations to ISLGC locations. The functions of the output counters and channels are simulated by transferring data from ISLGC locations to common core locations.
- Data transfer to, and from, counters is of two types: incremental value and whole value. Whole-value data transfer takes precedence over previously stored data. Incremental value data transfer adds to or subtracts from, previously stored data. Data are transferred to, and from, the channels as packed or coded digital words.
- All data outputs from the ISLGC are available in common core, for sampling by the LMS programs, for at least 50 milliseconds. All data outputs from LMS programs are available in common core, for sampling by the ISLGC, for at least 50 milliseconds.
- Non-time-dependent priority interrupts in the LM LGC are simulated by transmission of output control pulses (OCP's) from computers A and B to the interrupt hardware of the ISLGC. Time-dependent priority interrupts in the LM LGC are simulated by hardware in the central timing equipment (CTE) and ISLGC.
- All data, except down-link data, appear in octal form.
- The ephemeris for 54 navigational stars can be stored.
- The ISLGC operates in the following modes: premission, freeze, run, store, reset, reset from tape, reset from core, write reset, and fast time (step ahead).
- The ISLGC maintains a telemetry output table in 250 locations in common core. These 250 locations are divided into 50 groups of five 8-bit telemetry words each.

The digital autopilot (DAP), part of the ISLGC, issues appropriate reaction jet firing commands, to control the simulated LM in attitude and translation. Basically, the reaction jet control loop functions as a pulse-duration sample data control system in which the ISLGC determines simulated LM steering errors and issues reaction jet pulse-duration thrust commands to reduce the errors.

The DAP has two basic modes of operation: automatic and attitude hold. In the automatic mode, all control commands originate automatically from guidance law computation in the ISLGC. In the attitude-hold mode, the crew can command attitude rates proportional to attitude controller displacement, and linear translation motion by means of on-off signals from the translation controller. When the attitude controller handle is returned to zero (detent) position, the attitude of the simulated LM is maintained at the value existing when the controller was returned to detent. When the translation controller is in detent, the simulated LM maintains its previous angular velocity.

In the automatic mode, the ISLGC compares simulated IMU gimbal angle information with gimbal angle command signals, which are generated from the guidance laws, to form the gimbal angle errors. The gimbal angle error signals are then transformed to body angle steering errors; the gimbal angle rate is also derived. These parameters are both used to compute reaction jet pulse-duration commands in accordance with the programmed ISLGC attitude control law. The pulse-duration commands plus the translation commands generated via the guidance law computations are included in the ISLGC reaction jet logic computations to derive specific reaction jet pulse-duration firing commands. The firing commands are sent from the ISLGC to the reaction jet drivers in the ATCA, which cause the appropriate simulated jets to fire.

In the attitude-hold mode, the ISLGC control function depends on whether the attitude controller is in, or out of, detent. With the attitude controller out of detent, attitude rate is commanded by the crew about all three axes. Therefore, incoming gimbal angle information must be used to derive gimbal angle rates which must be transformed to body angle rates. These body angle rates are compared with the command rates from the attitude controller to form attitude rate errors. These errors are used to compute reaction jet pulse-duration commands in accordance with the programmed ISLGC angular rate control law. The control law commands,



combined with the manual translation commands from the hand controller, are processed in the same manner as during the automatic mode. While in this rate command condition, the ISLGC must store simulated gimbal angle information for future use as a command signal when the attitude controller is returned to detent. When the simulated LM reaches the crew-commanded attitude, the controller handle is returned to detent. The ISLGC maintains the simulated LM at this new attitude, using the gimbal angle information stored while the controller was out of detent. This stored command signal is summed with the actual incoming gimbal angle information from the simulated CDU to form an error signal. This error signal is processed through the ISLGC in the same manner as during the automatic mode, to maintain simulated LM attitude. Translation commands from the hand controllers are digital. When the hand controller is out of detent, full simulated thrust is applied to the simulated LM; when the controller is in detent, there is no reaction jet thrust.

The digital hand controller used during simulated powered descent also turns the main engine. Limited control of the vehicle is possible, using this mode of operation. A switching criterion is included in this mode, such that a large error will be reduced, using simulated RCS jets.

#### 2.4.2.2.2 Control Electronics Section.

Signals from switches and controls in the LMS cabin pass through an interface, where they are converted from analog to digital form before entering the LMS computer complex. Signals from the computer complex are converted from digital to analog form to simulate indicators and to drive meters. The LMS computer complex contains all the necessary data enabling all pertinent components for transfer function evaluation, associated signal flow, telemetry points, and malfunction insertion locations.

Relays, power switches, and latching devices, which are open/close type units, perform logic functions. Resulting signals are used by the CES computer program circuitry to sense other subsystem parameters (deadband, mode, etc), for comparison. The resulting error signals are mixed with the results of the rate gyro program data to formulate rotational data. These data are processed to insert the correct deadband and gain characteristics. Telemetry points are the points at which signal levels are monitored and transmitted via telemetry to the MSCC. All simulated crew inputs and rate gyro and driver amplifier outputs are telemetered. A malfunction can be inserted in the simulated CES at all points in the section where simulated LM dynamics are affected and a crew action or decision is required.

#### 2.4.2.2.3 Abort Guidance Section.

The major approximations and assumptions of the simulated AGS computer program are in the abort sensor assembly (ASA). Gyros and accelerometers are used in the LM ASA. The gyros and accelerometers are assumed to be perfect in the LMS program; the ASA computer equations are only slight modifications of the equations of motion. These modifications are intended to account for possible malfunctioning of the temperature control, one of three power supplies, or the synchronizing signal from the abort electronics assembly (AEA). Initial conditions (references, etc.) are supplied to the AGS by the PGNCS, by the astronaut via the DEDA panel, or they may be constants such as the initial ASA temperature. Constants fall into three categories: hardwired, softwired octal, and softwired decimal constants entered into the computer via the DEDA decimal-to-binary conversion routine.

Hardwired constants are wired permanently into the computer memory. Softwired constants may be changed in the computer memory; they can be entered directly by punched tape or DEDA input. DEDA decimal constants provide the astronaut flexibility in specifying mission-dependent parameters. Software constants are actually variables, in the sense that they can be changed from the loaded values when specifically directed by the guidance equations.

The duration of the major computation cycle is 2 seconds. In this time, the equations update navigation, align the inertial frame of reference if requested, and solve the two-impulse rendezvous guidance problem three times; the best of the three solutions is selected. Within the 2-second cycle are subcycles of 20- and 40-milliseconds. Every 20-milliseconds, simulated gyro and accelerometer sensor data are processed, incrementing LM attitude direction cosines and thrust velocity. Every 40-milliseconds, attitude error signals and main engine on-off commands are issued. The lunar-surface align function, when requested, is also computed every 40 milliseconds. Therefore, the computer program must advance through the 2-second guidance computation cycle in segments of 20- and 40-millisecond subcycles.

The 20-millisecond subcycle consists of the following:

- Gyro data processing and compensation (corrections)
- Accelerometer data processing
- Attitude direction cosine updating

- Thrust velocity vector incrementing
- Decrementing velocity-to-be-gained to engine shutdown
- PGNCS Euler angle processing.

The 40-millisecond subcycle consists of the following:

- Output AGS attitude error signals
- Output AGS main engine commands (The engine off command has a 40-millisecond timing resolution.)
- FDAI computations (outputs to the attitude indicator)
- Lunar alignment submode (a digital servo loop nulling attitude error signals).

The 2-second cycle consists of the following:

- LM navigation update
- Initializing the LM and CSM computations
- CSM equations of motion
- Elliptical Kepler routine
- Radar filter
- Flight mode selection
- Coelliptic orbit planning equations
- Direct transfer flight planning
- Pitch-yaw guidance
- Lunar alignment and calibration equations
- AEA outputs to displays.

#### 2.4.2.2.4 Rendezvous Radar Section. (See figure 2-5.)

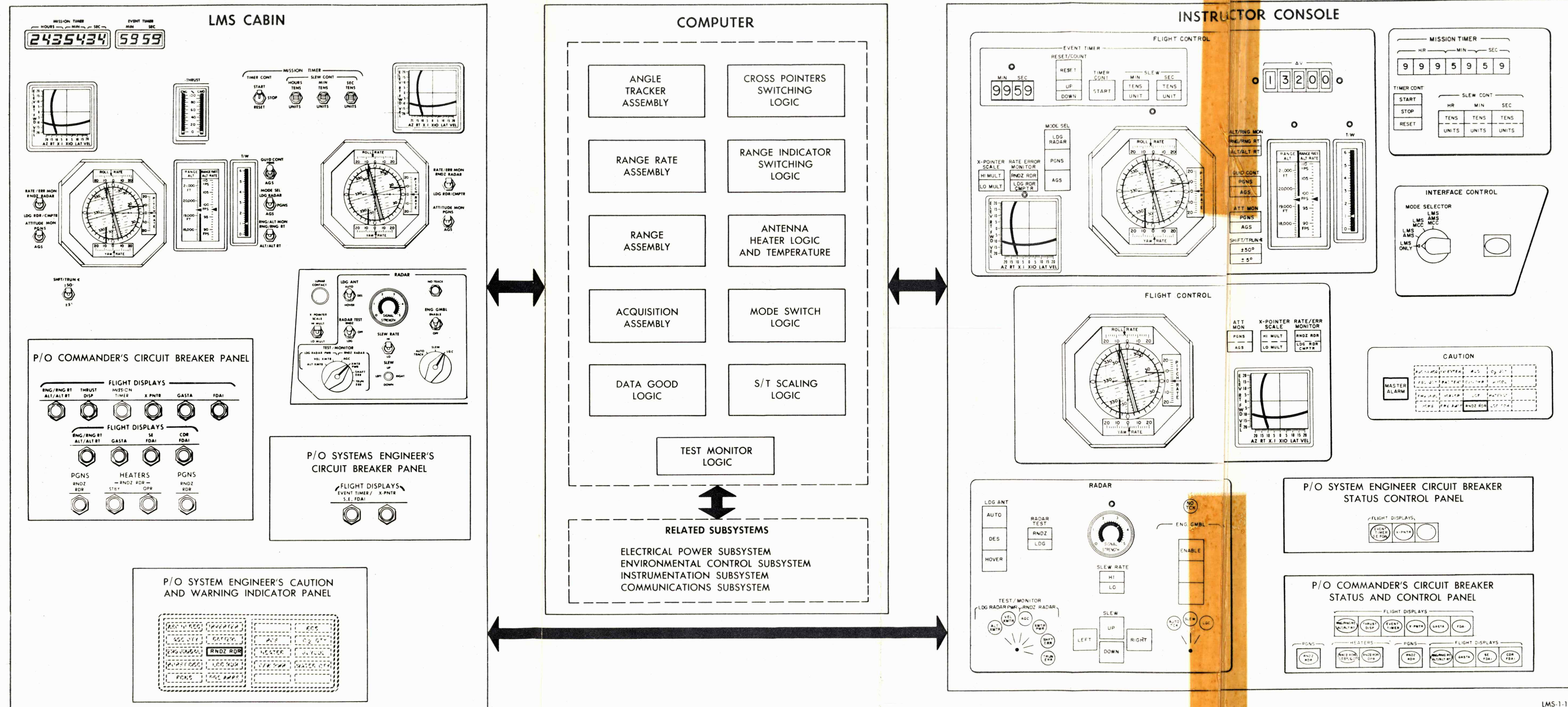
RR simulation demands a close integration between the equations of motion within the LMS computer complex and the EVDE. During rendezvous and docking operations, the astronauts in the LMS cabin observe the video image of a CSM model through the forward cabin windows and the overhead docking window. RR simulation accurately synchronizes the guidance maneuvers of the LMS (and the AMS for integrated missions), with the RR controls and displays and the visual docking simulator hardware.

The LM RR derives its significant measurement information from the following sources:

- The differences in signal strength on the monopulse antenna beams provide line-of-sight (LOS) angle and angular rate information.
- The phase delay between the transmitted and received modulation signals provides range information.
- The difference between transmitted and received RF (doppler effect) provides range-rate information.

In all instances, the significant information is derived directly from geometrical considerations; it is independent of radar-associated parameters (transmitter frequency, signal strength, etc.). The significant RR measurements represented in the LMS computer complex are those associated with generation of functions and signals required for cabin display, and simulated intersubsystem purposes. Related simulated assemblies of the RR include the antenna angle tracker, acquisition assembly, range-rate tracker, and range tracker. The remainder of the RR simulation involves the heater and temperature groups, power supply, display logic, self-test, monitoring, and mode control.







The simulated RR antenna angle tracker is operated in three distinct modes: auto tracking, LGC antenna designate, and manual slew. The simulation of the angle tracker assembly makes use of the fact that the true LOS (azimuth and elevation) angle information is available from the equations of motion. Ideally, the RR tracking-line azimuth and elevation angles and LOS to the CSM are equal. Therefore, in the auto tracking mode, the difference between the two azimuth and two elevation angles can be used to establish the antenna correction rate for each axis. The antenna servo slew rate is therefore the correction angle (difference angle) multiplied by a constant slew rate. The maximum rate required to maintain acquisition is determined by the aspect angle of the simulated antenna beam configuration. In the LGC antenna designate mode, the simulated RR antenna is pointed to the expected "look" angles of the CSM. In this instance, the LOS angles are replaced by the designated azimuth and elevation angles to establish the antenna correction rates. In the manual slew mode, the RR antenna is positioned about each axis at either of two slew rates. The direction of slew is determined by the positive or negative sign of the slew rate mathematical term so that integration results in an increase or decrease from the initial angle, for each repetition.

The acquisition assembly determines when the tracking-line azimuth and elevation angles are within a given cone of acquisition to establish the "data good" signal. The magnitude of the AGC display voltage, for simulation purposes, is approximated by the product of a function of the correction angle, the Gaussian distribution curve for range, and a constant transmitter RF power output level.

The range-rate tracker output is represented by adding the prominent errors and the true range rate from the equations of motion. These errors are predictable or random. The prominent predictable errors are dynamic lags with a given time constant; they are due to the output counter, which converts the data from a frequency form to a digital form. The random errors are simulated statistically. Range-rate information is not available until after the "data good" signal is established by the acquisition assembly.

The range tracker is simulated in a manner similar to that of the range-rate tracker. The output is derived by adding the prominent errors to the true range from the equations of motion. Noise inputs are not considered, because the high noise frequencies involved are not simulated directly and the effect over the slower simulation cycle is negligible. The time constant of the dynamic lag function is dependent upon range. The range changes slowly over increments of time approximately equal to the time constant value. A 15-foot static error is included to balance an equivalent dynamic error, which occurs when a typical mission range variation is programmed into the RR computer program. Range information becomes available only after the "data good" signal is established by the acquisition assembly.

The known sources of error in RR measurements have been included in the LMS computer program. In addition to the sources indicated, any of the gains or time constants in the RR section can be varied to change dynamic characteristics, as required.

#### 2.4.2.2.5 Landing Radar Section. (See figure 2-6.)

Complex and critical integration techniques are required for simulation of the LR. The basis equations of motion (attitude, position, and velocity) are transposed within the simulator computers to a lunarcentric coordinate system. These values are then used to drive the LR visual displays seen through the LMS forward cabin windows and to precisely position the lunar landmass simulator (LLS) transparency assembly. The LLS provides the precision terrain clearance data needed for final lunar descent and hovering guidance. The radar altitude (above the simulated lunar terrain) and altitude rate constitute the principal inputs to the LR simulation program.

The equations of motion supply most of the data that would be displayed and transmitted to the LGC if the LR were error-free. These data include the simulated LM velocity components and the range-along-beam to the lunar surface. The LR computer program adds error and/or malfunction effects so that the outputs realistically resemble real-world data. In addition, signals are generated to indicate internal conditions (data good, data no good, antenna position, power on, heater caution, etc.) of the simulated LR.

The velocity components and range signals, which are sent to the LM LGC, are processed by a digital counter that delays the data by approximately a tenth of a second. This effect is realistically simulated in the LMS. Errors are normally incurred in measuring the velocity and range with each of the four LR beams and corresponding servo trackers. Such errors are treated in the computer program as being random and limited in nature. The velocity "data good" and the range "data good" conditions are essentially the result of comparison of computed distance with the maximum distance from the target surface at which a return can be sensed (provided that a zero-velocity condition does not exist for any radar beam). Normally the LR antenna position is in a descent state during translunar flight; it is automatically switched by LGC command to a hover state. The astronaut may override the LGC, as a backup procedure. If the instructor desires to start a training lesson in the hover phase, he has the capability of starting the LR antenna in the hover position. The LR computer complex circuitry uses the same digital-to-analog converters as the RR. This is possible because



both radars use the same panel meters; the astronaut selects the data to be displayed. The LR computer program includes simulation of radar self-test and monitoring capabilities, antenna heaters, thermodynamic parameters, caution and warning indications, and intersystem and telemetry functions.

The provision for failure and degraded operation effects have been included in the simulation. The range of acquisition is reduced for reduced RF power output of the velocity and range sensors. Antenna heater limits (heaters on continuously or open circuited) are introduced to display out-of-tolerance temperature conditions and to degrade the accuracy of the velocity and range data.

#### 2.4.2.3 GN&CS Controls and Displays.

All LMS cabin controls and indicators are located in the exact configuration of those in LM2. Crew control inputs and subsystem output displays are continuously monitored at the instructor console. The instructor console instrumentation related to the GN&CS includes fully operational repeaters of the DSKY and DEDA panels. A RADAR panel indicates all control settings of the LM radar group and repeats the radar SIGNAL STRENGTH meter (displaying either the value seen by the crew or the time reading). All astronaut switch settings, indicators, and caution and warning lights related to the GN&CS are monitored at the instructor console. The console also includes a panel area for monitoring the accuracy of the readings made by the astronauts with the AOT. When the crew takes a sighting on two navigational stars, the sighted value is compared with the true value by the simulator computer; the deviation (error) is displayed for each star, on the instructor console. If the astronaut knowingly errs, he presses a reject button, which is then displayed at the instructor console. The instructor may clear his 4-digit error display by actuating an adjoining RESET switch.

#### 2.4.2.4 Malfunction Control.

Numerous malfunction modes are available in the LMS to reproduce LM GN&CS failures. These malfunctions may be programmed into the simulation routines before the training mission, or may be manually initiated at the instructor console with the Malfunction Insertion Unit (MIU) panel. Every major component of the GN&CS may be intentionally malfunctioned individually or in combination. A warning pilot lamp over each of the instructor console displays informs the instructor that a false value is displayed because a malfunction has been inserted. The correct reading may be obtained at the instructor console by pressing a TRUE READING push-button. The instructor console circuit breaker panels enable failure of any of the GN&CS circuit breakers in the LMS cabin. The malfunctions consist basically of system faults and instrumentation errors. A step-ahead mode may be initiated during the training exercise, to advance the simulated mission to a desired time at an accelerated rate. All programmed maneuvers and malfunctions are initiated during this advance time interval. A complete list of malfunctions available for insertion in the GN&CS simulation is included in section 2, volume II, of this handbook.

### 2.5 REACTION CONTROL SUBSYSTEM.

The LM Reaction control subsystem (RCS) provides small rocket thrust impulses to stabilize the LM during descent and ascent and to control LM attitude and translation about, or along, all axes during hover, rendezvous and docking maneuvers. (See figure 2-7.) The RCS may be operated in either a pulsed or steady-state mode on command from the Guidance, Navigation, and Control Subsystem (GN&CS) and the three-axis attitude controller.

The RCS consists basically of 16 thrust chamber assemblies (TCA's), which are supplied by two separate propellant supply systems. The TCA's and the dual propellant supply systems make up two parallel, independent systems (A and B). Systems A and B each contain their own helium pressurization section, propellant section, and TCA's.

The 16 TCA's are arranged in clusters of four, mounted on four outriggers that are equally spaced around the LM ascent stage. (See figure 2-8.) In each cluster, two of the TCA's are mounted parallel to the LM X-axis, facing in opposite directions; the other two are spaced 90° apart, in a plane normal to the X-axis. Two of the TCA's are supplied by system A; the other two, by system B. Normally, both systems are operated together, but the arrangement of the TCA's is such that complete operating control in all axes is possible despite a failure in either system.

Electrical protection for critical RCS components is afforded by circuit breakers distributed between two circuit breaker panels on the Commander's and Systems Engineer's upper side consoles.

A detailed description of the RCS is given in paragraph 2.4 of Apollo Operations Handbook, LMA790-3-LM2.

#### 2.5.1 REACTION CONTROL SUBSYSTEM CONFIGURATION REFERENCE.

The Reaction Control Subsystem of the LMS accurately simulates the LM-2 RCS.



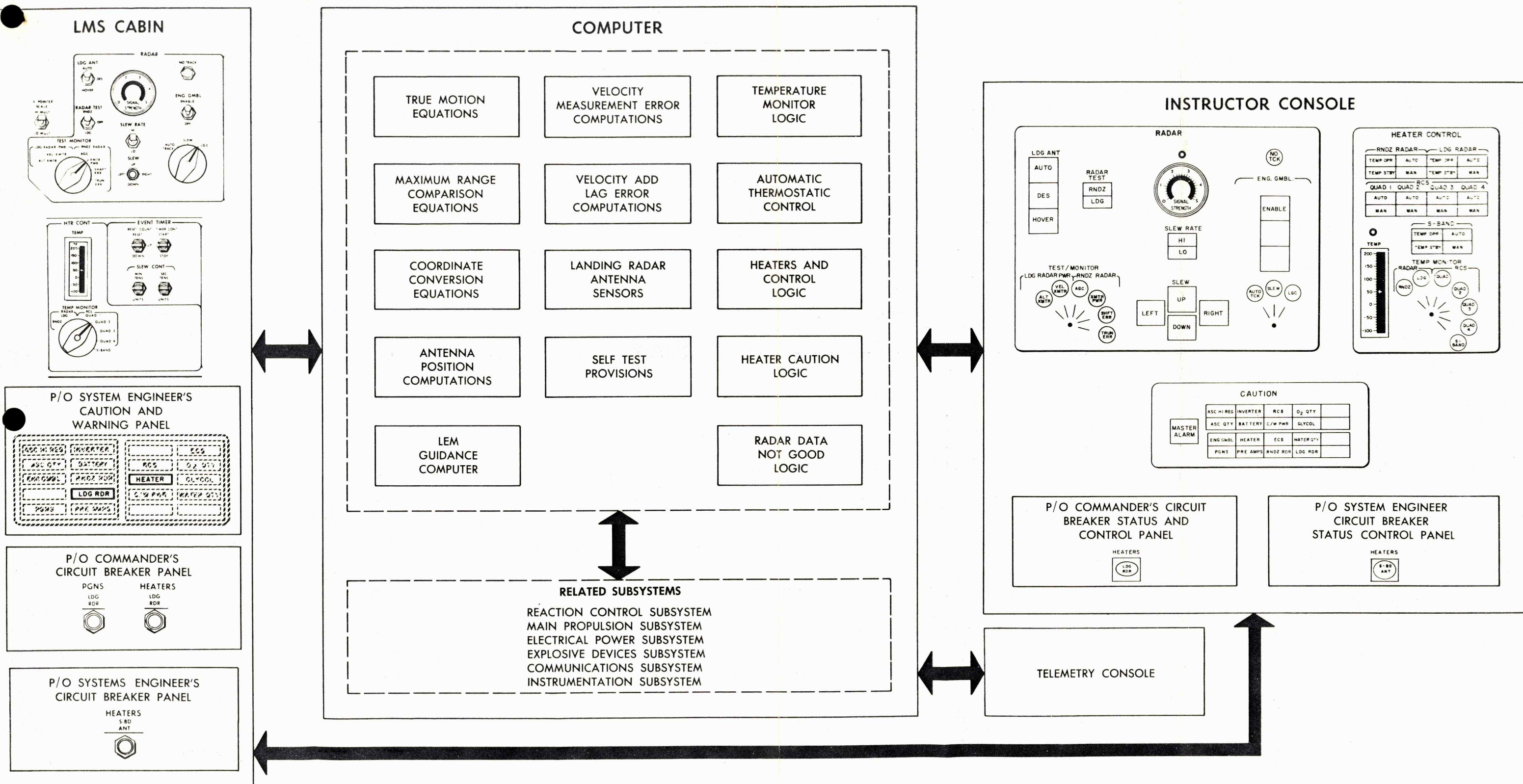
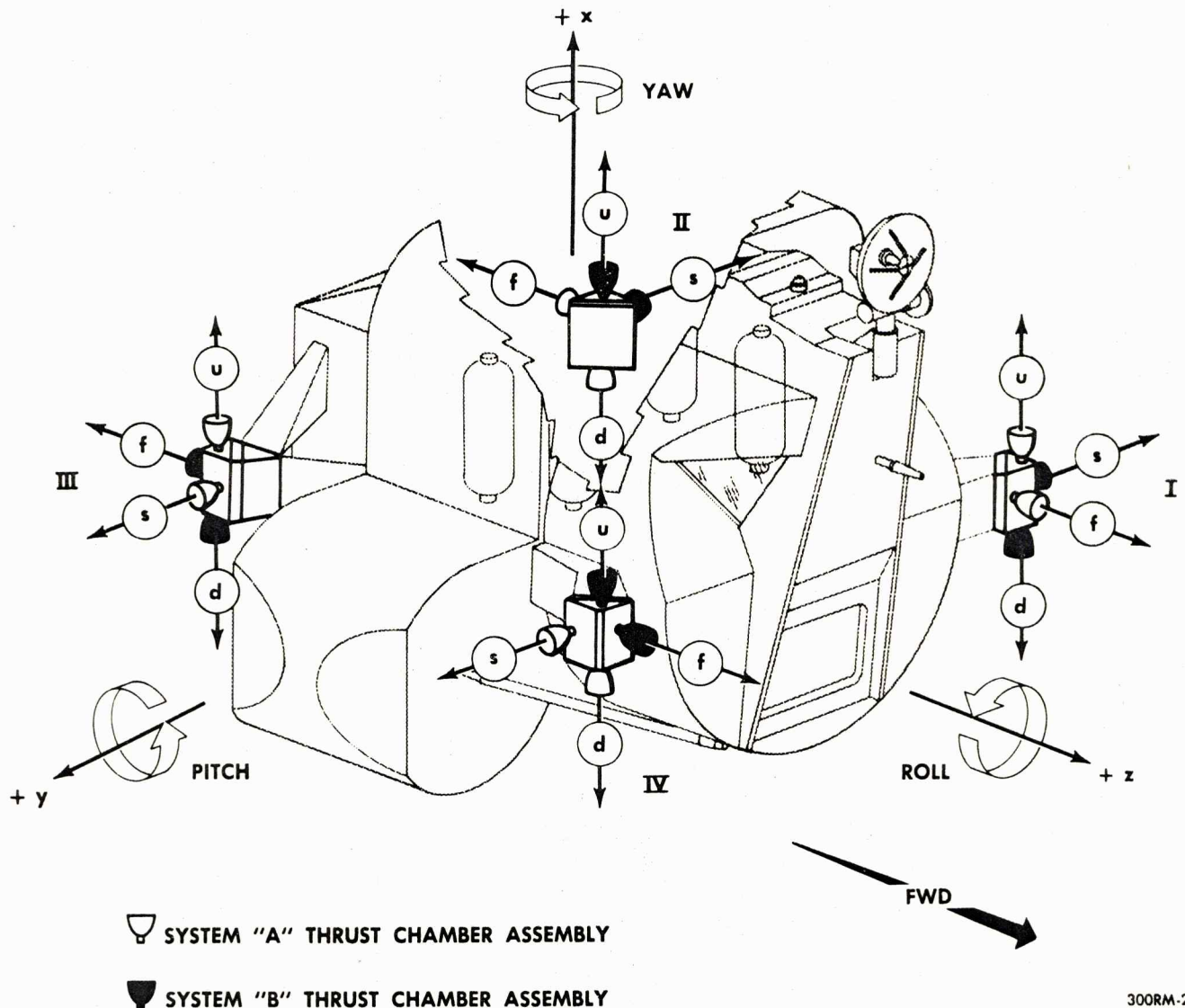


Figure 2-6. LMS Landing Radar Section, Flow Diagram





300RM-28

Figure 2-7. LM Reaction Control Subsystem Thrust Chamber Assemblies, Location Diagram

## 2.5.2 SIMULATED REACTION CONTROL SUBSYSTEM. (See figure 2-9.)

### 2.5.2.1 General

The RCS in the LMS provides simulated orientation and translation thrusting. The dynamics of temperatures, pressures, fuel and oxidizer consumption and control are simulated. The response of the simulated LM to reaction jet thrusting for all control modes is indicated to the flight crew by RCS and simulated LM flight control indicators and by external visual display equipment (EVDE) image generation. LMS response of the simulated vehicle is perceptually the same as the LM response to identical control inputs.

The following details are significant in the simulation of the RCS.

- In the thruster section, fuel must lead the oxidizer into the TCA. Under reverse conditions, the thruster would be destroyed.
- If the propellant tanks are depleted of either fuel or oxidizer, a thruster that is fired will be destroyed.
- When malfunctioning valves, the LMS can fail oxidizer or fuel valves individually.

- Valve malfunctions are considered event-dependent, not time-dependent.
- The telemetry quantity will indicate all 1's when a malfunction occurs or when the tanks are filled over 102% of capacity.
- The telemetry quantity will not indicate less than 0.4%.

#### 2.5.2.2 Simulation Methods.

A comprehensive analog for all elements of the LM RCS is programmed into the LMS so that each element of the RCS is accurately and realistically simulated. LMS programs for RCS systems A and B include complete parametric computations for each of the fuel, oxidizer, and helium subsystems involved. The temperature, pressure, mass, volume, and operating state functions are calculated for each system. These computations are based on a detailed thermodynamic analog, which includes environmental heat transfers, valve-throttling functions, and regulator expansions. The LMS RCS programs are integrated with calculations of the Main Propulsion Subsystem (MPS) ascent section propellant storage, which can be coupled into the RCS in normal operations. The RCS analog program includes all of the simulated LM valving logic, which, in turn, depends on the simulated Electrical Power Subsystem (EPS) bus and circuit breaker logic. All of the crew's control inputs are assessed by the LMS computer complex; all appropriate responses to these inputs are simulated. The LMS cabin control switch positions and circuit breaker settings are displayed at the instructor console. The instructor also has repeaters of all cabin instrumentation related to the RCS, such as status flags, numerical displays, and meters. The repeater indicators normally display the same values as those seen by the crew in the cabin. A step-ahead mode may be initiated during the training exercise, to advance the simulated mission to a desired time at an accelerated rate. All programmed maneuvers will be initiated during this advance interval.

The flight crew in the LMS cabin uses all the normal LM RCS instruments and controls. Responses to the control inputs are displayed on the telemetry console, as well as in the LMS cabin and on the instructor console. The telemetry data for the simulated RCS are given in table 2-4. The MSFN symbols used in table 2-4 are identified in volume II.

Table 2-4. LMS Reaction Control Subsystem Telemetry Data

MSFN No.	Description	Low	Range Nominal	High	Unit or Type
GR1085	System A propellant quantity	0		108.3	%
GR1095	System B propellant quantity	0		108.3	%
GR1101	Helium tank A pressure	0		3,500	psia
GR1102	Helium tank B pressure	0		3,500	psia
GR1121	Helium tank A temperature	+20		+120	° F
GR1122	Helium tank B temperature	+20		+120	° F
GR1201	Helium system A regulated pressure	0		350	psia
GR1202	Helium system B regulated pressure	0		350	psia
GR2121	Fuel tank A temperature	+20		+120	° F
GR2122	Fuel tank B temperature	+20		+120	° F
GR2141	Fuel tank A quantity	0		100	%



Table 2-4. LMS Reaction Control Subsystem Telemetry Data (cont)

MSFN No.	Description	Low	Range Nominal	High	Unit or Type*
GR2142	Fuel tank B quantity	0		100	%
GR2201	Fuel system A manifold pressure	0		350	psia
GR2202	Fuel system B manifold pressure	0		350	psia
GR3141	Oxidizer tank A quantity	0		100	%
GR3142	Oxidizer tank B quantity	0		100	%
GR3201	Oxidizer system A manifold pressure	0		350	psia
GR3202	Oxidizer system B manifold pressure	0		350	psia
GR6001	Thrust chamber assembly quad I temperature			+200	° F
GR6002	Thrust chamber assembly quad II temperature			+200	° F
GR6003	Thrust chamber assembly quad III temperature			+200	° F
GR6004	Thrust chamber assembly quad IV temperature			+200	° F
GR9609	System A main shutoff valve closed				CC
GR9610	System B main shutoff valve closed				CC
GR9611	System A ascent section interconnect valve open				CC
GR9612	System B ascent section interconnect valve open				CC
GR9613	Crossfeed valves open				CC
GR9661	System A isolation valve No. 1 closed				CC
GR9662	System B isolation valve No. 1 closed				CC
GR9663	System A isolation valve No. 2 closed				CC
GR9664	System B isolation valve No. 2 closed				CC
GR9665	System A isolation valve No. 3 closed				CC
GR9666	System B isolation valve No. 3 closed				CC
GR9667	System A isolation valve No. 4 closed				CC
GR9668	System B isolation valve No. 4 closed				CC
*CC = Contact closure.					

## 2.5.2.3 RCS Controls and Displays.

The RCS controls and readouts are located on the Systems Engineer's main instrument panel in the LMS cabin. The Commander and Systems Engineer each have paralleled hand controllers, and related circuit control through their individual circuit breaker panels. At the top of the RCS panel is a continuously operating QUANTITY meter for measuring propellant quantities of systems A and B.

Below the quantity display are two dual indicators that display temperature and pressure readings. Each indicator has a common scale face with dual pointers at opposite sides: one for system A; the other, for system B. A rotary switch at the base of the RCS panel is used to select the pressure-temperature readings of either the helium tanks, the fuel or oxidizer tanks, or the fuel or oxidizer manifolds (downstream of the individual tank shutoff valves). Beneath these indicators is a control group that includes switches that open or close the main shutoff valves (fuel and oxidizer) for system A or B. This group also has two switches that simultaneously open



the fuel and oxidizer lines into the ascent propulsion section to supply RCS system A or B. Status flags are provided for the four switches in this group. Another two rows of switches and their related status flags control the pairs of thrusters in each TCA cluster. Each switch controls two isolation valves (oxidizer and fuel) for the two system A or B jets in each quadrant of the simulated LM. The panel area is divided with the four system A THRUSTER PAIR switches and flags on the left and the four system B switches and flags on the right. At the bottom of the RCS panel area is a crossfeed switch (CRSFD) and associated warning flag. This switch simultaneously controls two solenoid valves that tie together the fuel and oxidizer manifolds of systems A and B.

To prevent binding of the TCA jet valves, each cluster of four thrusters is equipped with redundant heating circuits. Eight individual circuit breakers are provided in the LMS cabin to control power to the quad heaters. In addition, a heater control (HTR CONT) panel group includes a multiplexed temperature meter and selector switch to indicate the heat level for each cluster. Additional crew control for the simulated RCS is provided in the related system circuit breakers at the Commander's circuit breaker panel and at the Systems Engineer's circuit breaker panel. The simulated RCS also provides several trouble displays on the Commander's and Engineer's caution and warning panels. A total system indicator lamp, labelled RCS, indicates low system helium pressure. The Commander's emergency warning panel includes displays of regulator failure for the systems A and B helium pressurization manifolds, as well as an RCS TCA indicator lamp that indicates failure of one or more thrusters. Either of these malfunctions would require immediate attention by the astronauts.

The instructor console includes repeater panels of all RCS-related LMS cabin controls and displays, in addition to the malfunction insertion and display units.

#### 2.5.2.4 Malfunction Control.

The RCS simulation includes a wide variety of programmed and instructor-initiated malfunctions. (Refer to volume II.) The malfunctions initiated from the MALFUNCTION INSERTION UNIT include system faults and instrumentation errors, as well as circuit-breaker-popping signals for any of the RCS circuit breakers. In addition, the instructor may manually initiate circuit breaker failures at the corresponding console panel. A warning pilot lamp over each display informs the instructor that a false value is being displayed because a simulated malfunction has been inserted. The correct reading may be obtained on the instructor console by activating the TRUE READING pushbutton.

### 2.6 MAIN PROPULSION SUBSYSTEM.

The LM Main Propulsion Subsystem (MPS) consists of a descent and an ascent propulsion section. Each section is complete and independent of the other and consists of a liquid-propellant rocket engine with its propellant storage, pressurization, and feed components. The descent propulsion section, within the descent stage, uses a throttleable, gimbaled engine for powered descent to the lunar surface. The ascent propulsion section, within the ascent stage, uses a fixed, constant-thrust engine to separate the ascent stage from the descent stage at lunar launch, and for rendezvous and docking with the CSM.

The Guidance, Navigation, and Control Subsystem (GN&CS) provides automatic on-off commands for both engines and initiates gimbal-drive-actuator and thrust-level commands for the descent engine. Though each of the MPS sections are normally under computer control, the onboard guidance systems can be manually overridden. In addition to the manual propulsion controls, the astronauts are provided with comprehensive instrumentation of both propulsion sections. Both propulsion sections use hypergolic propellants: the fuel is a 50-50 mixture of hydrazine ( $N_2H_4$ ) and unsymmetrical dimethylhydrazine (UDMH); the oxidizer, nitrogen tetroxide ( $N_2O_4$ ). The engine-injection mixture ratio of oxidizer to fuel is 1.6 to 1, by weight. In both stages, the propellants are supplied from tanks, with helium as the tank pressurant.

The descent propulsion section (figure 2-10) consists of two fuel tanks and two oxidizer tanks with the associated propellant pressurization and feed components, and a throttleable rocket engine that develops a maximum thrust of 9,800 pounds and can be operated continuously within a range of 1,050 to 6,250 pounds of thrust. The engine can be shut down and restarted, as required by the mission. The engine is mounted in the center compartment of the descent stage cruciform, suspended at the throat of the combustion chamber on a gimbal ring that is an integral portion of the engine assembly. The gimbal ring is pivoted in the descent stage structure, along an axis normal to that of the engine pivots. The engine can be gimballed  $+6^\circ$  and  $-6^\circ$  by means of gimbal drive actuators controlled by the GN&CS, to provide trim control in the pitch and roll axes during powered descent to the lunar surface.

The ascent propulsion section (figure 2-11) consists of a fixed, constant-thrust rocket engine and the associated propellant storage, pressurization, and feed components installed along the centerline of the ascent stage midsection. The engine develops 3,500 pounds of thrust in a vacuum, sufficient to launch the ascent stage from the lunar surface and place it in orbit. Two main propellant tanks are used: one for fuel; the other, for oxidizer. The tanks are installed on either side of the ascent stage structure. The propellant supply sections include provisions for fuel and oxidizer crossfeed, as a backup propellant supply, to the RCS.

A detailed description of the MPS is given in paragraph 2.3 of Apollo Operations Handbook, LMA790-3-LM2.



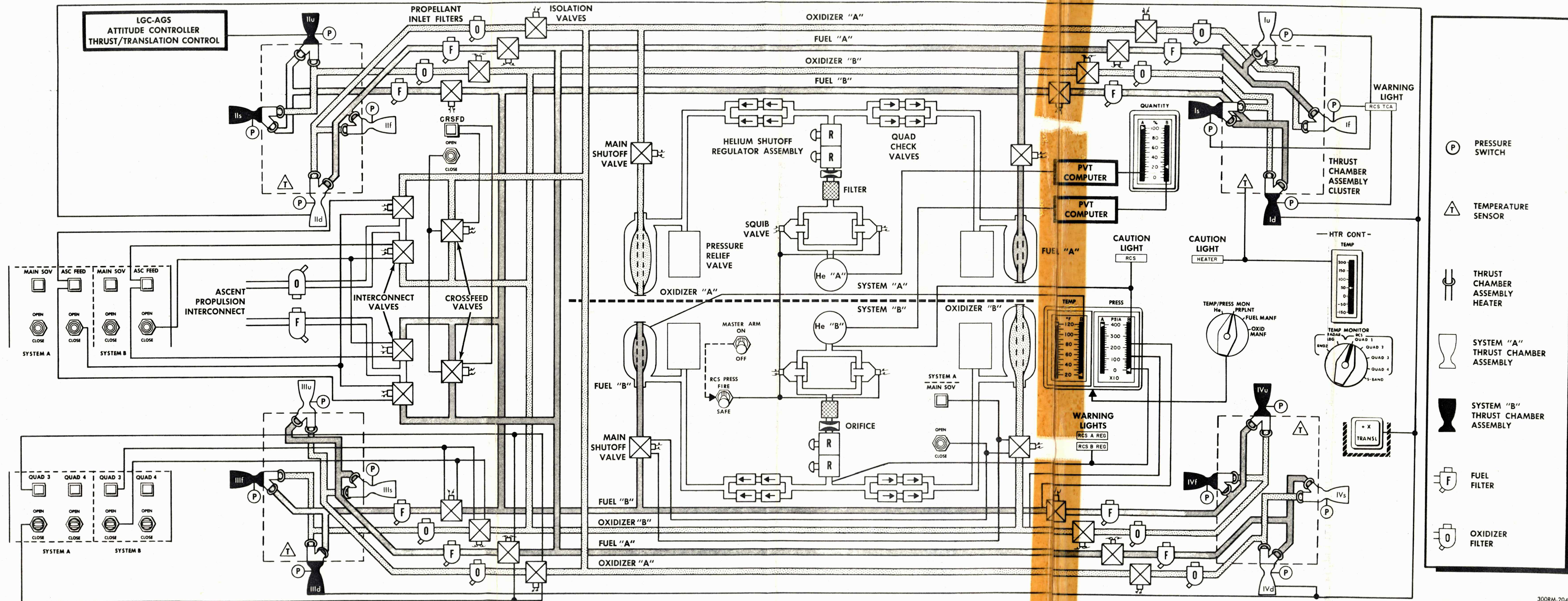


Figure 2-8. LM Reaction Control Subsystem, Simplified Flow Diagram



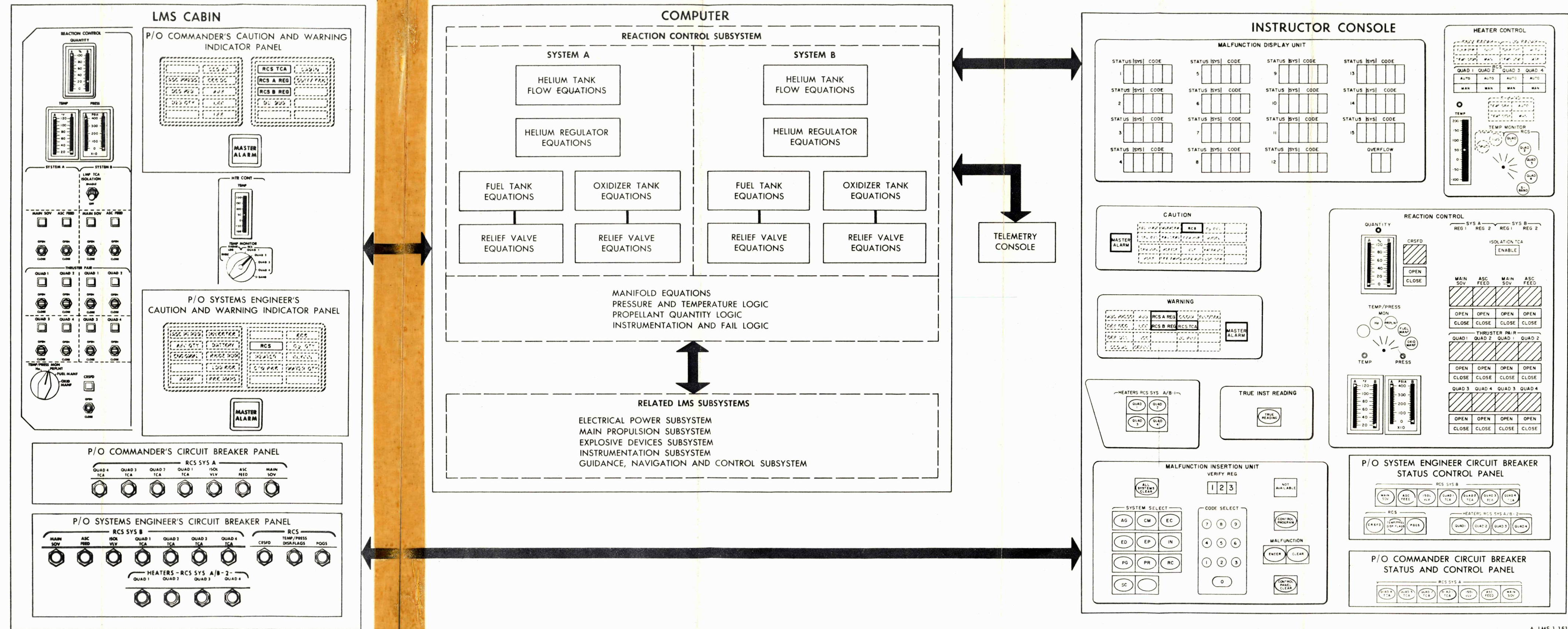
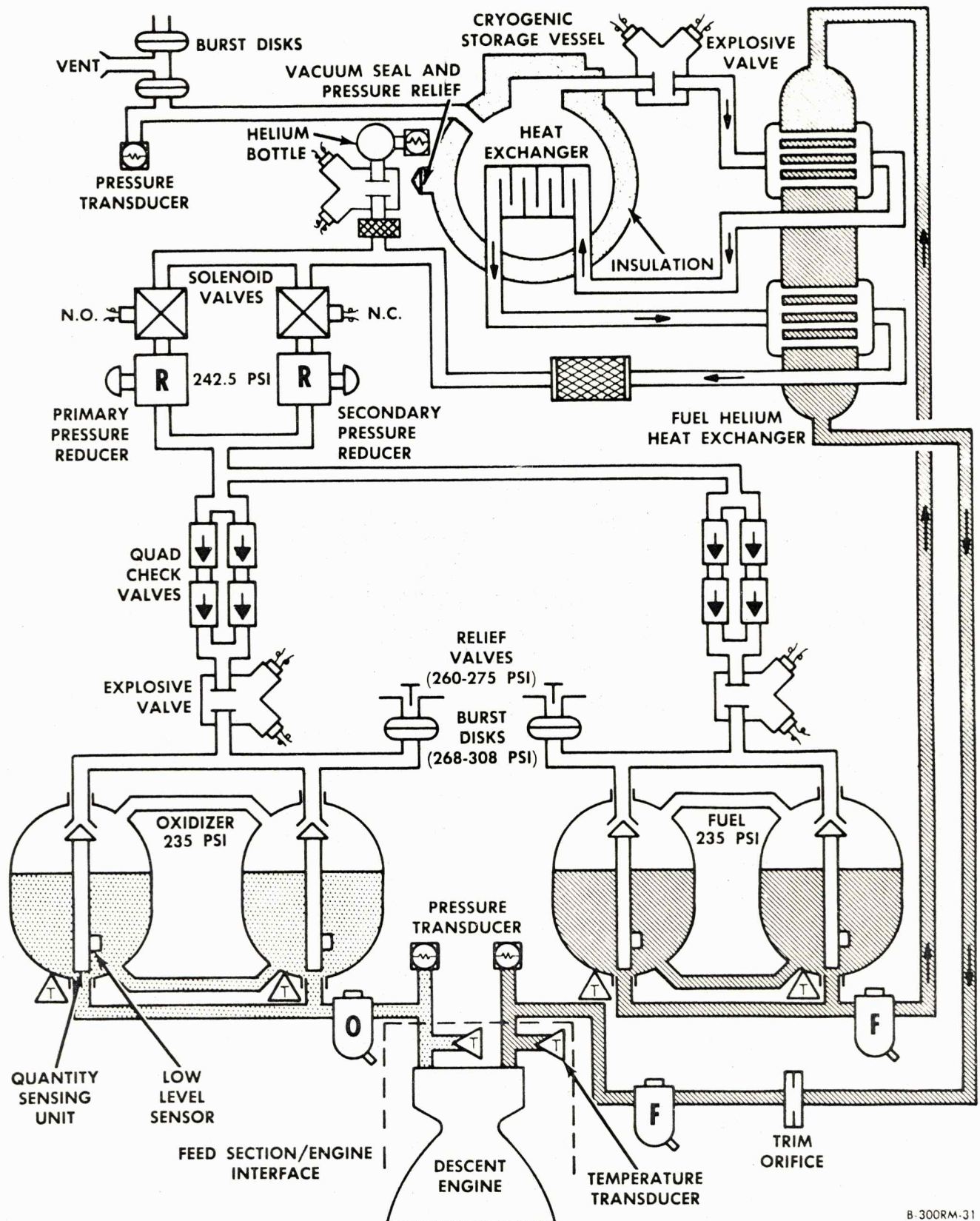


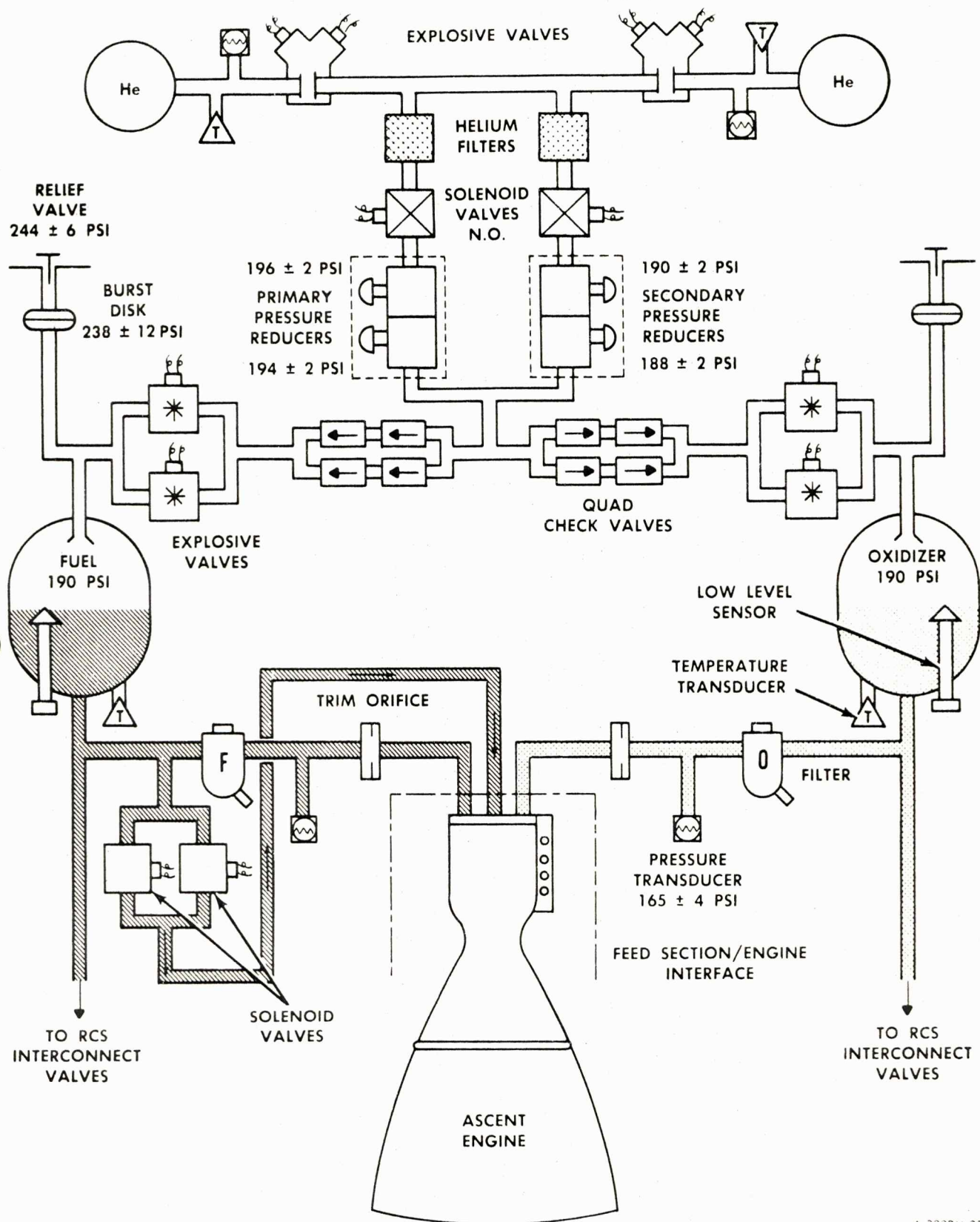
Figure 2-9. LMS Reaction Control Subsystem, Flow Diagram





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Figure 2-10. LM Descent Propulsion Section, Simplified Flow Diagram



A 300RM 33

Figure 2-11. LM Ascent Propulsion Section, Simplified Flow Diagram



### 2.6.1 MAIN PROPULSION SUBSYSTEM CONFIGURATION REFERENCE.

The Main Propulsion Subsystem of the LMS accurately simulates the LM-2 MPS.

### 2.6.2 SIMULATED MAIN PROPULSION SUBSYSTEM. (See figure 2-12.)

#### 2.6.2.1 General.

The simulated MPS includes all ascent and descent section instrumentation that indicates dynamic relationships of temperature, pressure, and propellant consumption and control. Responses of the simulated LM to automatic and manual propulsion subsystem commands are indicated to the flight crew by propulsion instrumentation, rate indicator readings, and by the EVDE. The simulated dynamics and response tolerances of the ascent and descent engines are perceptually the same as those of the LM.

Simulation of the descent propulsion section is based upon significant parametric computations programmed for each of the following major elements:

- Fuel tanks - Mass, pressure, and temperature based on thermodynamics of tank environment, outlet porting, relief valving, and simulated leakage
- Oxidizer tanks - Mass, pressure, and temperature based on thermodynamics of tank environment, outlet porting, relief valving, and simulated leakage
- Helium tank - Mass, pressure, and temperature based on the operational state of helium and thermodynamics of the section
- Low-pressure helium manifolds - Pressure calculated from flow rates and regulator logic based on crew regulator selection or simulated malfunctions
- Fuel and oxidizer flow rates - Flow rate based on valve logic, porting hydrodynamics, and fluid pressures in the section.

Simulation of the ascent propulsion section is based upon significant parametric computations programmed for each of the following major elements:

- Fuel tank - Mass, pressure, and temperature based on thermodynamics of tank environment, outlet porting, relief valving, and simulated leakage.
- Oxidizer tank - Mass, pressure, and temperature based on thermodynamics of tank environment, outlet porting, relief valving, and simulated leakage
- Helium tanks No. 1 and 2 - Dual computations of mass, pressure, and temperature programmed for each tank, based on the operational state of gaseous helium thermodynamics of the section
- Helium low-pressure manifolds - Pressure calculated from flow rates and regulator logic based on crew regulator selection and simulated malfunctions
- Fuel and oxidizer flow rates - Flow rates based on valve logic, porting hydrodynamics, and fluid pressures in the section
- Manifolding logic - Digital valving expressions based on control inputs, tank pressures (relief valves), available electric switching (circuit breakers and switch settings), and simulated malfunction inputs.

#### 2.6.2.2 Simulation Methods.

The flow diagram of the simulated MPS (figure 2-12) is based on the assumption that the LM MPS is limited to the controls and displays in the LM cabin. The ascent and descent propulsion sections are mathematically simulated; they provide computerized outputs for the LMS cabin displays and other subsystem requirements.

The pressure, temperature, and quantity of helium in the two ascent section helium tanks are determined by solving the perfect gas equation (with a correction for the behavior of the gas), the energy equation, and the tank quantity equation within the LMS computer. Helium consumption from these helium tanks is determined by the regulator flows, which depend upon propellant tank pressures and valve positions. The simulated pressures at various points in the helium pressurization network are determined from perfect gas equations and pressure drop equations. The flows are considered to be turbulent so that line resistances are constant. The helium temperature in each ascent propellant tank is determined from the computed energy balance equation. The



pressures at the bottom of the ascent propellant tanks are determined from the helium pressure in the tank and the pressure head resulting from spacecraft acceleration and lunar gravity. The simulated ascent engine parameters are determined from a simultaneous solution of thrust, chamber pressure, and propellant flow equations. The engine thrust is inhibited by an excessive off-nominal mixture ratio or by insufficient time to settle the propellants.

The descent engine is simulated in a similar manner; however, since there are two propellant tanks for both fuel and oxidizer, the crossflow between tanks is considered. Since the crossflow is considered to be small, the flow equations are modified accordingly. The effect of throttling the engine is considered in determining the descent engine parameters.

The LMS flight crew uses all the normal LM MPS instruments and controls. Responses to the control inputs are displayed in the LMS cabin, on the instructor console, and on the telemetry console. The telemetry data for the simulated MPS are given in table 2-5. The MSFN symbols used in table 2-5 are identified in volume II. The instructor console includes repeater indicators for all flight crew MPS indicator lamps and instruments, such as dual dial meters for fuel and oxidizer temperature and pressure, digital readouts for helium display and indicators for switch and circuit breaker settings.

#### 2.6.2.3 MPS Controls and Displays.

The MPS controls and readouts are located on the Commander's main instrument panel in the LMS cabin. The Commander and Systems Engineer each have paralleled hand controllers, and related circuit control through their individual circuit breaker panels. The MAIN PROPULSION panel contains pairs of switches that control the helium supply of the descent and ascent propulsion sections. The panel also has status flags to display which helium regulator path is open. In addition to these controls, the LM crewmen have several instruments for monitoring the MPS. The pressure and temperature of the propellant tanks are monitored on two dual gages. Each gage has a single scale traversed by dual meter dials: one for fuel; the other, for oxidizer. A three-position toggle switch selects the ascent propellant tanks or either set of descent propellant tanks for display on these gages. Descent engine thrust is monitored on a dual dial instrument, which compares the true engine thrust (as computed from the chamber pressure sensors) with commanded thrust. The input to command thrust may be either the onboard LM guidance computer (LGC), which is part of the GN&CS, or manual input from the crewman's hand controller. The setting of the throttle control switch on the Commander's ENGINE THRUST CONT panel determines the source of the command input displayed. Several caution and warning annunciators are associated with the MPS. When any of these displays are illuminated, they also light the MASTER ALARM switch-lights, and initiate an audible warning in the crew headphones. The Systems Engineer's caution panel includes an annunciator that indicates ascent engine high helium pressurization; another alerts the crew when propellants are sufficient for only 10 seconds of further ascent engine thrusting. The Commander's warning panel displays indications of abnormal ascent or descent propellant pressures, as well as a warning when the descent engine fuel supply is sufficient for only 120 seconds of additional thrusting. A numerical readout monitors the propulsion helium pressurization network. The HELIUM MON seven-position rotary switch at the lower portion of the MAIN PROPULSION panel selects pressure readouts for either ascent stage helium tank. The pressure of the main propulsion stage high-pressure helium manifold or ambient pressure may be selected, or the pressure of either ascent stage helium tank. The electrical loads of the MPS are distributed among circuit breakers divided between the Commander's and Systems Engineer's power buses.

The instructor console includes repeater panels of all MPS-related LMS cabin controls and displays, in addition to the malfunction insertion and display units.

#### 2.6.2.4 Malfunction Control.

The instructor may use his MALFUNCTION INSERTION UNIT (MIU) to manually initiate a variety of simulated MPS problems, or he may leave the crew under automatic computer program control. The major component of the ascent and descent propulsion sections (propellant and helium tanks, pressure regulators, valves, transducers, etc.) may be intentionally malfunctioned individually or in combinations. (Refer to volume II.) A warning pilot lamp over each instructor console display informs the instructor that a false value is displayed because a simulated malfunction has been inserted. The correct reading may be obtained on the instructor console by initiating the TRUE READING pushbutton. The instructor console circuit breaker panels enable failure of any circuit breaker in the LMS cabin. The malfunctions initiated from the MIU are basically system faults and instrumentation errors. A step-ahead mode may be initiated during the training exercise, to advance the simulated mission to a desired time at an accelerated rate. All programmed maneuvers and malfunctions will be initiated during this advance time interval.



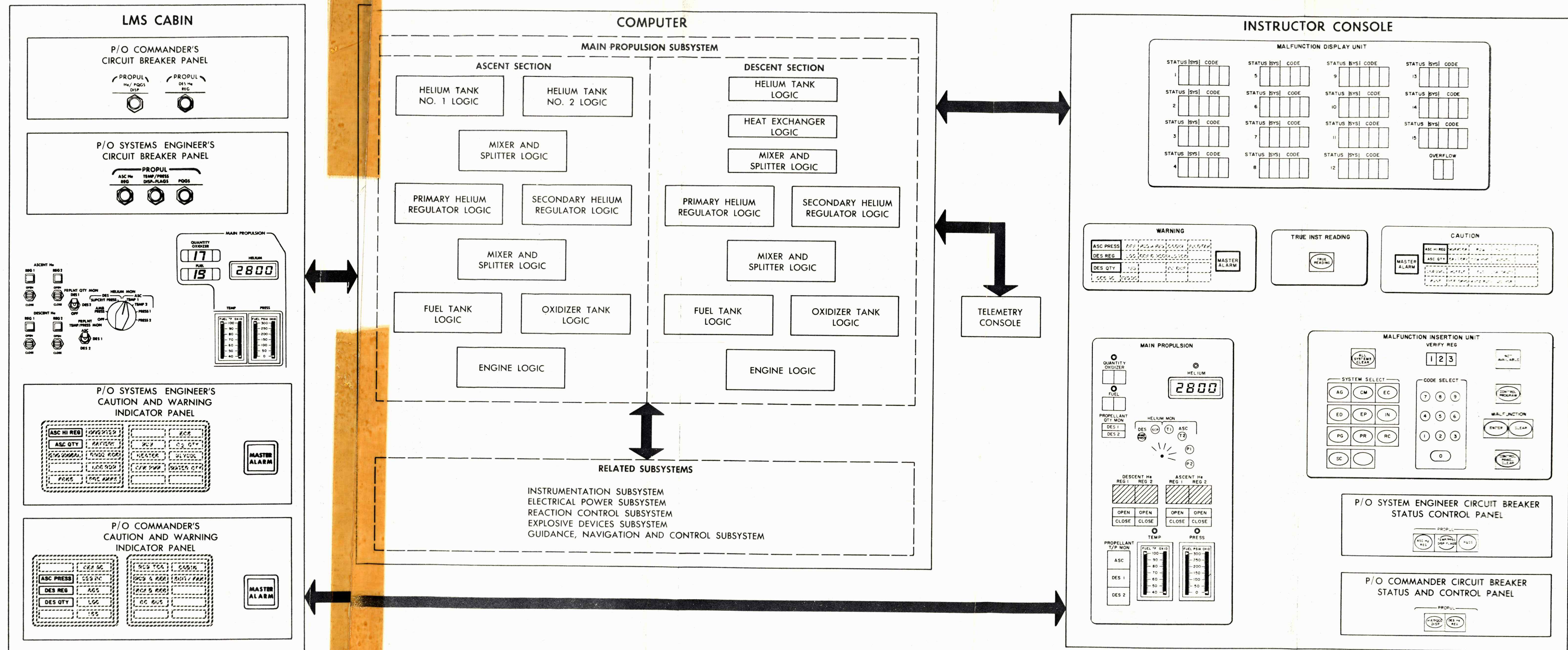


Figure 2-12. LMS Main Propulsion Subsystem, Flow Diagram



Table 2-5. LMS Main Propulsion Subsystem Telemetry Data

MSFN No.	Description	Low	Range Nominal	High	Unit or Type*
GP0001	Ascent section helium tank No. 1 pressure	0		4,000	psia
GP0002	Ascent section helium tank No. 2 pressure	0		4,000	psia
GP0025	Ascent section regulated helium pressure	0		300	psia
GP0201	Ascent section helium tank No. 1 temperature	+20		+200	° F
GP0318	Ascent section helium primary valve closed				CC
GP0320	Ascent section helium secondary valve closed				CC
GP0718	Ascent section fuel tank temperature	+20		+120	° F
GP0908	Ascent section fuel tank level low				CC
GP1218	Ascent section oxidizer tank temperature	+20		+120	° F
GP1408	Ascent section oxidizer tank low				CC
GP1501	Ascent section fuel valve pressure	0		250	psia
GP1503	Ascent section oxidizer valve pressure	0		250	psia
GP2010	Ascent section thrust chamber pressure	0		150	psia
GP2997	Isolation B propulsion valves A mismatch				CC
GP2998	Isolation B propulsion valves B mismatch				CC
GQ3018	Descent section regulated helium pressure	0		300	psia
GQ3435	Descent section helium supply pressure	0		1,750	psia
GQ3603	Descent section fuel tank No. 1 quantity	0		95	%
GQ3604	Descent section fuel tank No. 2 quantity	0		95	%
GQ3611	Descent section engine fuel pressure	0		300	psia
GQ3718	Descent section fuel tank No. 1 temperature	+20		+120	° F
GQ3719	Descent section fuel tank No. 2 temperature	+20		+120	° F
GQ4103	Descent section oxidizer tank No. 1 quantity	0		95	%
GQ4104	Descent section oxidizer tank No. 2 quantity	0		95	%

\*CC = Contact closure.



Table 2-5. LMS Main Propulsion Subsystem Telemetry Data (cont)

MSFN No.	Description	Low	Range Nominal	High	Unit or Type*
GQ4111	Descent section engine oxidizer pressure	0		300	psia
GQ4218	Descent section oxidizer tank No. 1 temperature	+20		+120	° F
GQ4219	Descent section oxidizer tank No. 2 temperature	+20		+120	° F
GQ4455	Descent section propellant tanks low				CC
GQ6510	Descent section thrust chamber pressure	0		200	psia
GQ6806	Descent section variable injector position	0		100	%
GQ7498	Shutoff valves A/B midposition				CC
GQ7499	Shutoff valves C/D midposition				CC

\*CC = Contact closure.

## 2.7 ELECTRICAL POWER SUBSYSTEM.

The LM Electrical Power Subsystem (EPS) provides all electrical power necessary for the LM to complete its planned lunar mission. The LM supplies its own power from T-30 minutes through the ascent phase of the mission. The LM is supplied power from the CSM after transposition and docking. Functionally, the EPS consists of a d-c section and an a-c section. Primary d-c electrical power within the LM is supplied by two batteries in the ascent stage and four batteries in the descent stage. (See figure 2-13.) Two additional silver oxide-zinc batteries, separate from the EPS, supply power for activation of LM explosive devices. Each ascent and descent battery is partially discharged before launch, to avoid possible overvoltage damage to LM subsystem electronics. Either ascent battery can supply all ascent electrical power loads during normal mission operations and an abort. All four descent batteries are required to provide the electrical power necessary to perform the complete mission from T-30 minutes up to the ascent phase of the mission. A curtailed mission can be executed, using three descent batteries. If two descent batteries fail, the mission must be aborted. The total electrical requirements of the LM are such that approximately 47 kilowatt-hours (kwh) are supplied by the four descent batteries; approximately 18 kwh, by both ascent batteries. Two solid-state inverters supply 115-volt, 400-cycle power to LM electronic equipment. In addition to the primary ascent and descent batteries and a-c inverters, the EPS comprises four electrical control assemblies (ECA's), a relay junction box (RJB) that contains deadface relays (DFR's) and abort stage relays, and control and circuit breaker panels.

Two ECA's in the ascent stage and two in the descent stage provide control of, and protection for, ascent and descent stage battery power. Each descent ECA provides control of, and protection for, a pair of descent batteries and the associated power distribution system; each ascent ECA provides similar control of, and protection for, an ascent battery and the associated power distribution system.

The RJB provides power control logic for the ascent and descent ECA's and deadfacing control for some of the main power paths between the LM ascent and descent stages. The remaining power paths are controlled by the DFR's, which are manually controllable from the ELECTRICAL POWER control panel on the Systems Engineer's center side console and are automatically opened (interrupting these power paths) upon receipt of an abort stage command. The RJB also provides control logic and power feed junction points for connection of external power to the LM via the launch umbilical tower.

The ELECTRICAL POWER control panel contains switches and displays for control and monitoring of all a-c and d-c power sources in the LM. The a-c and d-c power feed circuits are protected by circuit breakers on the Commander's and Systems Engineer's circuit breaker panels.

The LM lighting system comprises all interior and exterior lighting on the LM and the lighting control panels. Interior lighting equipment includes floodlighting, electroluminescent back lighting for instruments,



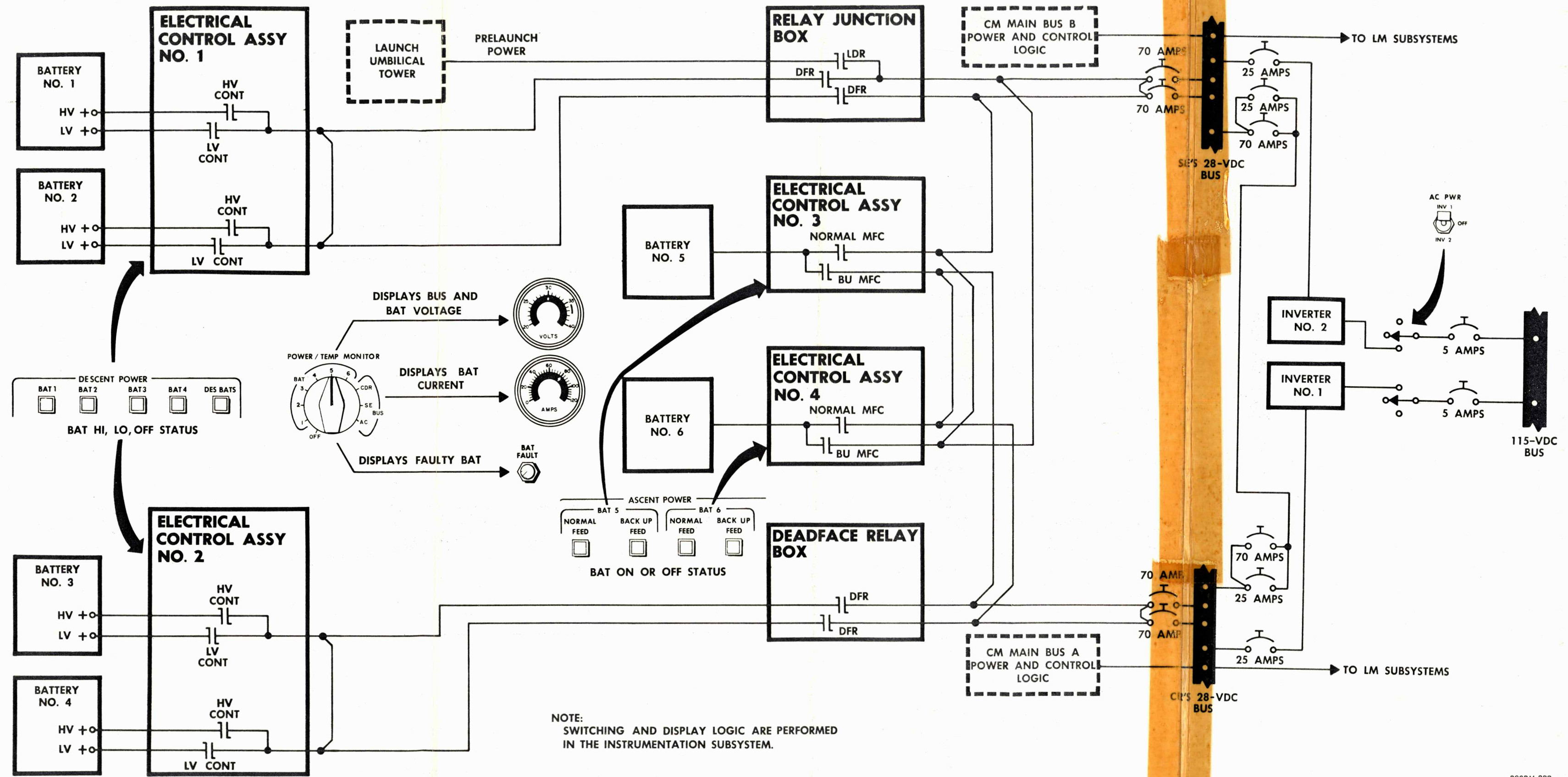


Figure 2-13. LM Electrical Power Subsystem, Simplified Block Diagram



advisory lights, and caution and warning lights. Each set of lights is associated with a variable control. The floodlights, and advisory, caution, and warning lights are supplied 28-volt d-c power. The electroluminescent lighting requires 115-volts, 400-cps, a-c power. Power to all interior lights, except the advisory, caution, and warning lights, can be shut down. Docking lights and a tracking light are provided on the LM exterior to aid in recognition, navigation, and docking. These lights are all controlled from either of the two LIGHTING panels at the LM crew station. A detailed description of the EPS is given in paragraph 2.5 of Apollo Operations Handbook, LMA790-3-LM 2.

### 2.7.1 ELECTRICAL POWER SUBSYSTEM CONFIGURATION REFERENCE.

The simulated Electrical Power Subsystem realistically reproduces the operation of the LM-2 EPS. Batteries are not used in the LMS as a power source, although the effects and indications of battery operation are realistically simulated.

### 2.7.2 SIMULATED ELECTRICAL POWER SUBSYSTEM. (See figure 2-14.)

#### 2.7.2.1 General.

EPS simulation realistically reproduces the effects of steady-state operation, perceptual response to certain transient conditions and equipment failure. Subsystem simulation includes indications of electrical power generation, availability, distribution, and operating status. Batteries are not used in the LMS as a power source. The effects and indications of battery operation, however, are realistically presented to the crew. Crew station controls and indicators, gross data flow, and instructor station controls and indicators peculiar to the EPS are shown in figure 2-14. All simulated LM subsystems that are dependent upon electrical power must access the core addresses reserved for the computed values of the EPS outputs. When power bus faults exist, these power-dependent subsystems simulate a subsystem failure. The EPS controls and indicators in the LMS cabin are mounted in the same configuration as those in the actual LM. Crew control inputs and subsystem output displays are monitored at the instructor console. The status of all switches, flags, and annunciators is also repeated at the instructor console.

Simulation of the EPS is based upon detailed parametric computations of each of the following major elements:

- Battery impedance
- Battery current
- Battery open-circuit voltage
- Battery terminal voltage under load
- Battery temperature
- Battery state of charge
- Commander's d-c bus voltage and current load
- Systems Engineer's d-c bus voltage and current load
- A-C power bus voltage and current load
- Bus power availability logic.

#### 2.7.2.2 Simulation Methods.

The EPS descent and ascent electrical control assemblies (ECA's) are the framework, as in the LM, for the computation and determination of power paths from the batteries to the d-c power distribution buses. The computation of overcurrent and reverse-current relay logic is also performed in the ECA-related complexes. Simulated battery parameters such as voltage and current are calculated in the battery complexes. In addition, computations to determine available power of each simulated battery to the simulated LM subsystems are performed in these complexes. The relay junction box (RJB) complex contains the computations of deadfacing and abort relay logic, thus providing the same RJB link in the LMS as in the actual LM. The electrical power distribution bus complex is made up of computations that determine the availability of electrical power at the distribution buses, the availability of electrical power to the subsystems, the dc-to-ac inverter logic, and distribution of a-c power, and the computation of electrical power used by the subsystems at the distribution buses. The circuit breaker logic complex continually receives information from the circuit breaker panels,



regarding the status of each circuit breaker. This information is then transmitted to the electrical power distribution bus complex for use in determining electrical power available to each subsystem or major component. The circuit breakers are remotely controlled by the instructor from a circuit breaker and status control panel, which also indicates the status of each EPS circuit breaker. The indicator logic complex performs the duties of a clearing house for all parameter and malfunction indications. All these indications are routed to this complex for use in determining the transmission of these signals and the allowable associated tolerances.

The LMS cabin includes all controls, indicators, and meters, which are on the actual LM ELECTRICAL POWER control panels. The instructor console includes repeaters of all LMS cabin indicators, controls, and meters. Responses to the control inputs are displayed on the telemetry console, in the LMS cabin, and on the instructor console. The telemetry data for the simulated EPS are given in table 2-6. MSFN symbols used in table 2-6 are identified in volume II.

#### 2.7.2.2.1 Simulated D-C Section.

Descent Batteries. The simulated descent battery (batteries No. 1 through No. 4) power supplies subsystem power for LMS activity up to the lunar ascent phase of the mission. If a battery failure occurs (instructor-inserted malfunction), curtailed mission objectives may be pursued with the three remaining simulated batteries.

Ascent Batteries. The simulated ascent battery (batteries No. 5 and No. 6) power supplies required subsystem power for LMS activity for a normal mission, from the powered ascent phase of the mission to docking, or during an abort, which requires ascent stage separation.

Descent Electrical Control Assemblies. Two descent electrical control assemblies (ECA's) are simulated in the LMS. Each ECA controls and protects two descent batteries and associated circuitry. The descent ECA logic complexes compute and determine power paths from the simulated descent batteries to the d-c power distribution buses. The ECA complexes also compute EPS reverse current and overcurrent in the descent stage.

Ascent Electrical Control Assemblies. Two ascent ECA's are simulated. Each ECA controls and protects an ascent battery and its associated wiring. The ascent ECA logic complexes compute and determine power paths from the simulated ascent batteries to the d-c power distribution buses.

Relay Junction Box. The relay junction box (RJB) logic complex computes required deadfacing between the ascent and the descent stage, and abort relay logic.

Circuit Breakers. The circuit breaker logic complex receives status information from the LMS cabin circuit breaker panels. This information is routed to the power distribution logic complex, where it is used in determining electrical power available to the subsystems. Crew circuit breaker status is displayed at the instructor console. The instructor can fail all LMS cabin circuit breakers, at the instructor console.

Electrical Power Distribution. The electrical power distribution bus logic complex computes availability of electrical power at the distribution buses, to the subsystems and to the dc-to-ac inverters. The inverter logic, a-c power distribution, and the power available to the subsystems is computed in this logic complex.

Switch Position Indicator Logic. This complex supplies the instructor console with switch position information associated with the LMS cabin momentary switches.

Indicator Logic. This complex processes all EPS parameter and malfunction indication data.

AMS Interface. This complex provides a tie point for integrated LMS-AMS operation.

#### 2.7.2.2.2 Simulated A-C Section.

The LMS a-c section simulates the operation of two d-c to a-c inverters and distribution of a-c power to various subsystems. In the LMS, the a-c power generation and distribution is processed in the electrical power distribution bus logic.

#### 2.7.2.2.3 Lighting Logic.

The logic complex of the simulated lighting section contains the signals required for exterior lighting (docking and tracking lights) and power-available signals for the interior lighting. The operating signals for the navigation lights are fed to the AMS interface. These signals are used by the AMS visual system during integrated training.



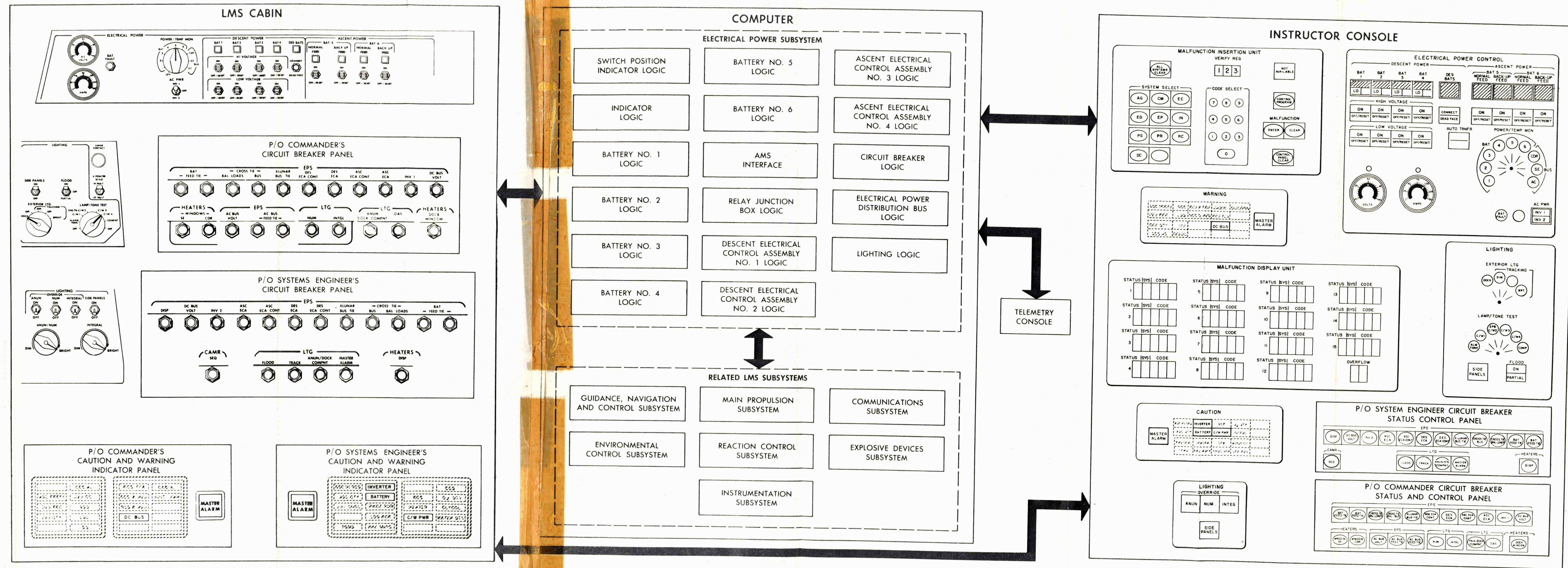


Figure 2-14. LMS Electrical Power Subsystem, Flow Diagram



Table 2-6. LMS Electrical Power Subsystem Telemetry Data

MSFN No.	Description	Range			Units or Type*
		Low	Nominal	High	
GC0071	A-C bus voltage	0		125	volts
GC0155	A-C bus frequency	380		420	cps
GC0201	Battery No. 1 voltage	0		40	volts
GC0202	Battery No. 2 voltage	0		40	volts
GC0203	Battery No. 3 voltage	0		40	volts
GC0204	Battery No. 4 voltage	0		40	volts
GC0205	Battery No. 5 voltage	0		40	volts
GC0206	Battery No. 6 voltage	0		40	volts
GC0301	Commander's bus - d-c volts	0		40	volts
GC0302	Systems Engineer's bus - d-c volts	0		40	volts
GC1201	Battery No. 1 current	0		60	amperes
GC1202	Battery No. 2 current	0		60	amperes
GC1203	Battery No. 3 current	0		60	amperes
GC1204	Battery No. 4 current	0		60	amperes
GC1205	Battery No. 5 current	0		140	amperes
GC1206	Battery No. 6 current	0		140	amperes
GC4361	Battery No. 1 high tap				CC
GC4362	Battery No. 1 low tap				CC
GC4363	Battery No. 2 high tap				CC
GC4364	Battery No. 2 low tap				CC
GC4365	Battery No. 3 high tap				CC
GC4366	Battery No. 3 low tap				CC
GC4367	Battery No. 4 high tap				CC
GC4368	Battery No. 4 low tap				CC
GC4369	Battery No. 5 on Commander's bus				CC
GC4370	Battery No. 6 on Commander's bus				CC
GC4371	Battery No. 5 on Systems Engineer's bus				CC
GC4372	Battery No. 6 on Systems Engineer's bus				CC
GC9961	Battery No. 1 fail				CC
GC9962	Battery No. 2 fail				CC
GC9963	Battery No. 3 fail				CC
GC9964	Battery No. 4 fail				CC
GC9965	Battery No. 5 fail				CC
GC9966	Battery No. 6 fail				CC

\*CC - Contact closure.



### 2.7.2.3 EPS Controls and Displays.

The LMS cabin source of electrical energy is a group of six simulated batteries. In the LMS cabin, four of these batteries may be operated in a high- or low-output mode. The EPS control panel includes eight 3-position switches for the simulated descent section batteries. Four of these switches (one for each battery) provide selection for high voltage output or off. The switches are spring loaded to the center position. Raising any switch against a momentary contact results in latching the battery control relay into the high-voltage configuration. When released to the center position, the high-output on setting is maintained. Setting the switch downward to the lower momentary contact drops out the battery control relay, disconnecting the battery from the power bus. When the control switch returns to the center position, the OFF/RESET setting is maintained. A set of four similar switches (one for each battery) is used by the astronauts to select the low-voltage setting for each battery. Four status flags above the battery switches indicate which batteries are on line, by a gray display. The off-line condition is indicated by a barberpole display. Two 3-position switches (spring loaded to the center position) provide control of the normal output path for each of the two ascent batteries. Set upward to ON against one momentary contact, the switches latch up the battery control relay to the normal feed connection. When released, the switch returns to the center position, leaving the control relay latched. Momentarily setting the switch downward drops out the control relay, disconnecting the battery from the power bus. The OFF/RESET setting is maintained when the switch returns to its center position. Two other similar switches connect the backup feed outputs of the batteries to the power bus. Four 2-position flag indicators display the mode selection for the two ascent stage batteries. The flag is a grey display over the FEED switch selected ON, and displays a barberpole over the FEED switches that have been cut off. The flight crew may monitor the EPS, using a voltmeter and ammeter mounted adjacent to these switches. A POWER TEMP MON 10-position rotary selector switch connects these indicators with each of the six batteries, with the Commander's power bus, the Systems Engineer's bus, or with the a-c bus. The tenth (off) position disconnects the meters.

Directly below the rotary selector switch is a three-position (center off) toggle switch for selecting simulated a-c inverter No. 1 or No. 2. A three-position (spring loaded to center) switch and status flag are provided for the crew to control the power bus connections. (Bus transfers are normally under completely automatic control, assuring power continuity without manual inputs by the astronauts.) This switch will disconnect the input from the descent stage to the power buses. Momentarily deflected to the DEADFACE position, the four simulated descent stage batteries are disconnected from the LMS cabin electrical load. Deflected to the CONNECT momentary contact, the switch causes the descent stage batteries to be reconnected to the normal bus control circuitry. As the switch returns to its center position, the system remains at the setting last selected. A status flag mounted above this switch displays a barberpole when the simulated descent stage batteries are disconnected. The ELECTRICAL POWER control panel also includes a BAT FAULT lamp, which warns the crew of abnormal conditions of the battery chosen for monitoring with the meter selection switch. Emergency power situations are displayed on the Systems Engineer's and Commander's caution and warning annunciator panels. Four indicator lamps warn of malfunction conditions. These emergency condition signals also trigger the audible MASTER ALARM system. Circuit breakers provided for all major EPS functions, are monitored on the instructor console.

The EPS lighting controls are divided between LMS cabin panels. The Commander controls the dimming of the cabin interior lights. He has a potentiometer to adjust the brightness level of the annunciators (caution/warning) and the numerical readouts. Another knob varies the brightness of the electroluminescent integrally lighted markings and displays. In the event of dimming potentiometer failure, three override switches are provided, which give full brightness to the annunciators, the numerical readouts, or the integrally lighted displays. Though the brightness level of cabin side panels is controlled by the Commander, either crewman may extinguish his side panel lighting with separate on-off toggle switches. The Systems Engineer controls the exterior lights, the lighting test function, and the cabin floodlights. A three-position toggle switch adjusts the cabin overhead lamp lighting to partial, full, or off settings. A EXTERIOR LTG five-position rotary switch adjusts the tracking beacon from 1% to 100% of full brilliance. The same knob also supplies power to the docking light. The lamp test functions are controlled by the LAMP/TONE TEST eight-position rotary selector switch (with "off" settings at both extremes for crew convenience). One position tests the lamps in both MASTER ALARM indicators and sounds the MASTER ALARM audio tone. Four other settings individually light all lamps in the four clusters of caution warning annunciators. One of these four settings also switches on the engine stop-start button lamps. The remaining setting lights all component caution pilot lamps simultaneously for bulb checking. Repeaters of all LMS cabin controls, indicators, and displays are included on the instructor console.

### 2.7.2.4 Malfunction Control.

The instructor may use his MALFUNCTION INSERTION UNIT (MIU) to manually initiate a variety of simulated EPS problems, or he may leave the crew under automatic computer program control. Every major component of the EPS may be intentionally malfunctioned either individually or in combinations. A warning pilot lamp over each of the instructor console displays informs the instructor that a false value is displayed because a malfunction has been inserted. The correct reading may then be obtained (on the instructor console)



by activating a TRUE READING pushbutton. The instructor console circuit breaker panels also enable failure of any of the crew's EPS circuit breakers in the LMS cabin. The malfunctions consist basically of system faults and instrumentation errors. A step-ahead mode may be initiated during the training exercise to advance the simulated mission to a desired time, at an accelerated rate. All programmed maneuvers and malfunctions are initiated during this advance time interval. A complete list of malfunctions available for insertion into the EPS simulation is in section 2 of volume II.

## 2.8 INSTRUMENTATION SUBSYSTEM.

The LM Instrumentation Subsystem (IS) monitors all LM subsystems during manned missions, performs in-flight checkout, prepares LM status data for transmission to MSFN, provides timing frequencies and correlated synchronizing data for LM subsystems, stores voice, and, during the lunar mission, performs lunar surface checkout and scientific instrumentation for lunar experiments.

The IS consists of the LM subsystem sensors, a signal-conditioning electronics assembly (SCEA), a pulse-code-modulation and timing electronics assembly (PCMTEA), a caution and warning electronics assembly (CWEA), and a data storage electronics assembly (DSEA). (See figure 2-15.)

The subsystem sensors used in conjunction with the IS are located in the individual LM subsystems. These sensors continually check subsystem status by sensing physical data (temperature, valve action, pressure, switch position voltage, and current). These sensed data are changed into electrical signals (digital or analog) compatible with the requirements of the SCEA or PCMTEA.

The SCEA converts all unconditioned sensor output signals to the proper level and format required by the PCMTEA and the CWEA. The SCEA also provides the initial excitation power to sensors located throughout the LM, which are not supplied by their individual subsystems. The unconditioned signals are routed to applicable converter, demodulator, attenuator, and buffer circuits that generate the proper digital or analog outputs.

The PCMTEA consists basically of pulse-code-modulation equipment and timing equipment. The PCMTEA converts and combines all the data inputs generated by LM subsystem sensors into one serial digital output signal. These signal trains are routed to the Communications Subsystem (CS) for transmission to MSFN or the CSM. The timing electronics of the PCMTEA provides timing frequencies and correlated synchronizing data to all LM subsystems requiring this input. Input signals for the pulse-code-modulation equipment are of three types: high-level analog, parallel digital, and serial digital. Some parallel digital and high-level analog inputs are supplied directly to the PCMTEA from subsystem sensors; all other signals are first processed through the SCEA. PCMTEA output data is routed to the CS in nonreturn-to-zero (NRZ) format at a high or low bit rate, and in return-to-zero (RZ) format at a low bit rate. The CS transmits the NRZ data to MSFN via S-band; the RZ data, to the CSM via VHF. The timing generator supplies the timing signals required for generating digital signal frame sync, frame identification, and format identification data.

The CWEA provides the LM astronauts and MSFN with a continuous rapid check of LM status during lunar missions. By continuously monitoring the subsystem status data supplied by the SCEA, malfunctions are immediately detected. When a malfunction is detected, the CWEA provides signals that light the appropriate caution lights (on the Systems Engineer's center panel) or warning lights (on the Commander's center panel), and MASTER ALARM lights (on both panels). Detected malfunctions also activate tone generators that provide the astronauts with an audible signal in their headsets and supply the PCMTEA with a related telemetry signal. The LM cabin warning lights indicate subsystem malfunctions that jeopardize astronaut safety and require immediate action; the caution lights indicate malfunctions that are not of an emergency nature and do not require immediate action.

The DSEA is a single-speed, four-track, magnetic tape recorder with associated electronics that stores voice and time-correlation data (elapsed time of the mission) during periods of transmission blackout to MSFN or the CSM. A maximum of 10 hours of recording time is provided, 2.5 hours on each track.

The IS accepts subsystem status data temperature, valve action, pressure, switch position, voltages, and current) obtained by subsystem sensors. The sensors convert physical data to analog or digital signals and route these signals to the SCEA, or directly to the PCMTEA if signal conditioning is not required. The SCEA accepts unconditioned analog signals and processes these data into high-level analog form (0 to +5 volts dc) or digital form (+3.4 to +6 volts dc for logic 1; 0 to +0.5 volt dc for logic 0). These data are then routed to the PCMTEA and, in the case of a malfunction, also to the CWEA.

The conditioned signals supplied by the SCEA, or directly from the subsystem sensors to the PCMTEA, are changed to serial digital form for transmission to earth at one of two bit rates: 1,600 bits per second (low rate) or 51,200 bits per second (high rate). Subcarrier frequencies, time reference signals, and sync pulses are generated in the PCMTEA and supplied to all other subsystems that require them for proper operation.



Analog and digital signals supplied from the SCEA to the CWEA are constantly monitored and compared to internally generated limits. On detecting an out-of-limit condition (malfunction), the CWEA provides output signals to light the associated caution or warning indicator lamp and the MASTER ALARM lamp, and to trigger a tone generator. Malfunction indications are in two distinct categories: warnings, for malfunctions that jeopardize astronaut safety and require immediate action; cautions, for malfunctions that do not require immediate action, but do require remedial attention.

The DSEA provides voice recording during transmission blackout. The audio signal is supplied from the astronaut's bus in the CS to the DSEA, where it is recorded along with time reference signals (mission elapsed time). Ten hours of recording time are provided in this assembly. There are no provisions for playback during the mission; playback is accomplished upon returning to earth.

A detailed description of the IS is given in paragraph 2.9 of Apollo Operations Handbook, LMA790-3-LM 2.

### 2.8.1 INSTRUMENTATION SUBSYSTEM CONFIGURATION REFERENCE.

The instrumentation Subsystem of the LMS accurately simulates the LM-2 IS.

### 2.8.2 SIMULATED INSTRUMENTATION SUBSYSTEM. (See figure 2-16.)

#### 2.8.2.1 General.

The LMS Instrumentation Subsystem (IS) provides simulated LM subsystem sensor data for transmission to the simulated MCC via the telemetry console. This data is transmitted at a rate and format identical with that of the actual LM subsystem. All sensor values displayed on the LMS cabin panels are simulated by the LMS computer complex. Only the telemetry measurements, which have a real-time display requirement, are dynamically simulated for telemetry transmission to the simulated MCC. In addition, actual biomedical sensor data and/or prerecorded biomedical telemetry data are transmitted to the simulated MCC.

The signal-processing section of the simulated IS accepts computer-generated sensor outputs and converts them into a pulse-code-modulated (PCM) format of eight-bit word lengths with code frame and rate identical with that of the actual LM. The DSEA in the LM is a magnetic tape recorder, used to record voice and digital time data. The DSEA is simulated in the LMS with a wooden mockup. Though the signal-processing and telemetry assemblies of the vehicle are not monitored by the crew during the mission, the LMS provides full telemetry instrumentation for the simulated MCC complex. All normal system status and biomedical data are generated within the LMS in authentic PCM format at the high or low bit rate of data transfer. The telemetry console monitors all the discrete and analog telemetry data, and deliberately distorts this data, when desired, to simulate various malfunctions of the simulated LM telemetry equipment.

#### 2.8.2.2 Simulation Methods.

The IS sensors are simulated within the LMS computer and the computation results stored in the memory. The computer memory stores approximately 400 different high-level, low-level, and discrete sensor values, which are continuously updated in accordance with the latest input signals. These data are then transmitted via a buffer stage to the telemetry console. The master alarm logic accepts subsystem malfunction outputs from the LMS computer and generates a signal to simulate the MASTER ALARM display (visual and audio). The PCM, DSE, and PCMTEA turn-on logic generates signals based on control positions in the LMS cabin and power-available signals from the simulated EPS. These signals are fed to the EPS to indicate that the PCM, DSEA, and PCMTEA are on. The IS timing logic generates the simulated sync pulses fed to other simulated subsystems.

The telemetry console comprises recorders, a data display unit, interface equipment, PCM telemetry simulator problem readout, and associated equipment. The telemetry console input from the LMS computer buffer is via the PCM telemetry simulator, which conditions the inputs and forms them into the PCM format code frame and rate identical with that of the LM, for simulated transmission to MCC. The telemetry console is capable of the following:

- Monitoring all telemetry data (except ISLGC data) before their conversion to a final telemetry format
- Monitoring LMS instrumentation control/switch positions that govern PCM rates and modes
- Inserting faults into the LMS (except ISLGC) telemetry system
- Displaying modified data (except ISLGC data)
- Displaying bilevel parameters or indications (other than ISLGC)



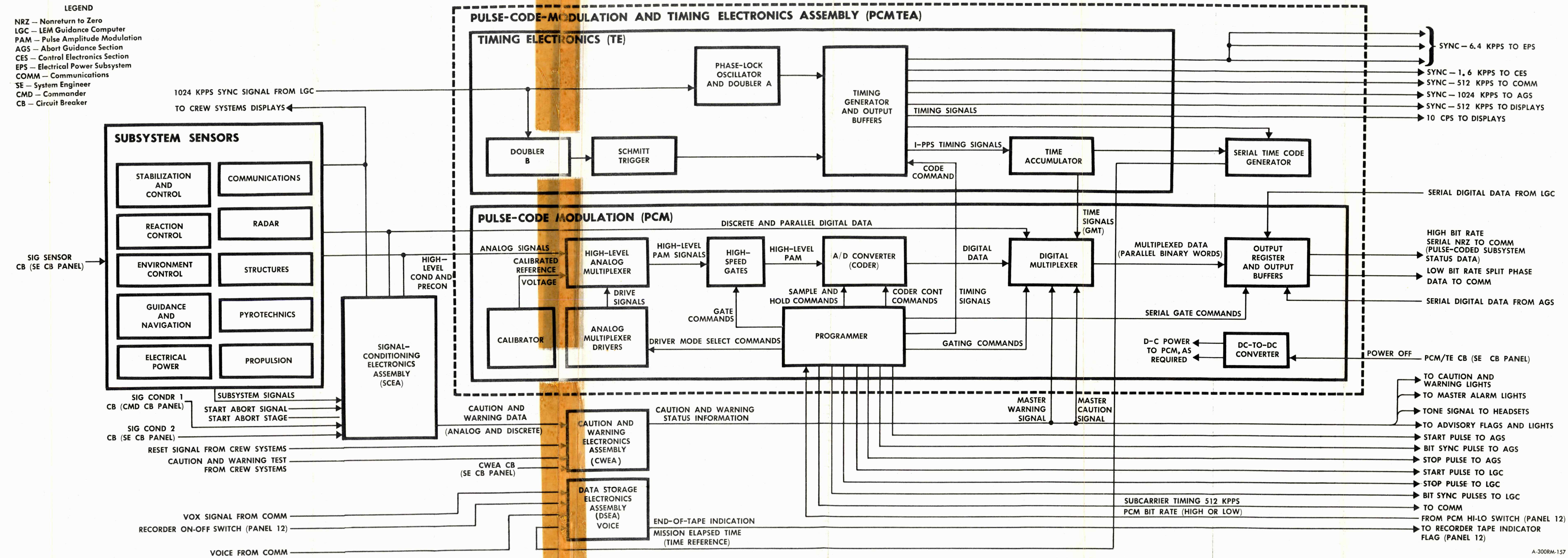


Figure 2-15. LM Instrumentation Subsystem, Block Diagram



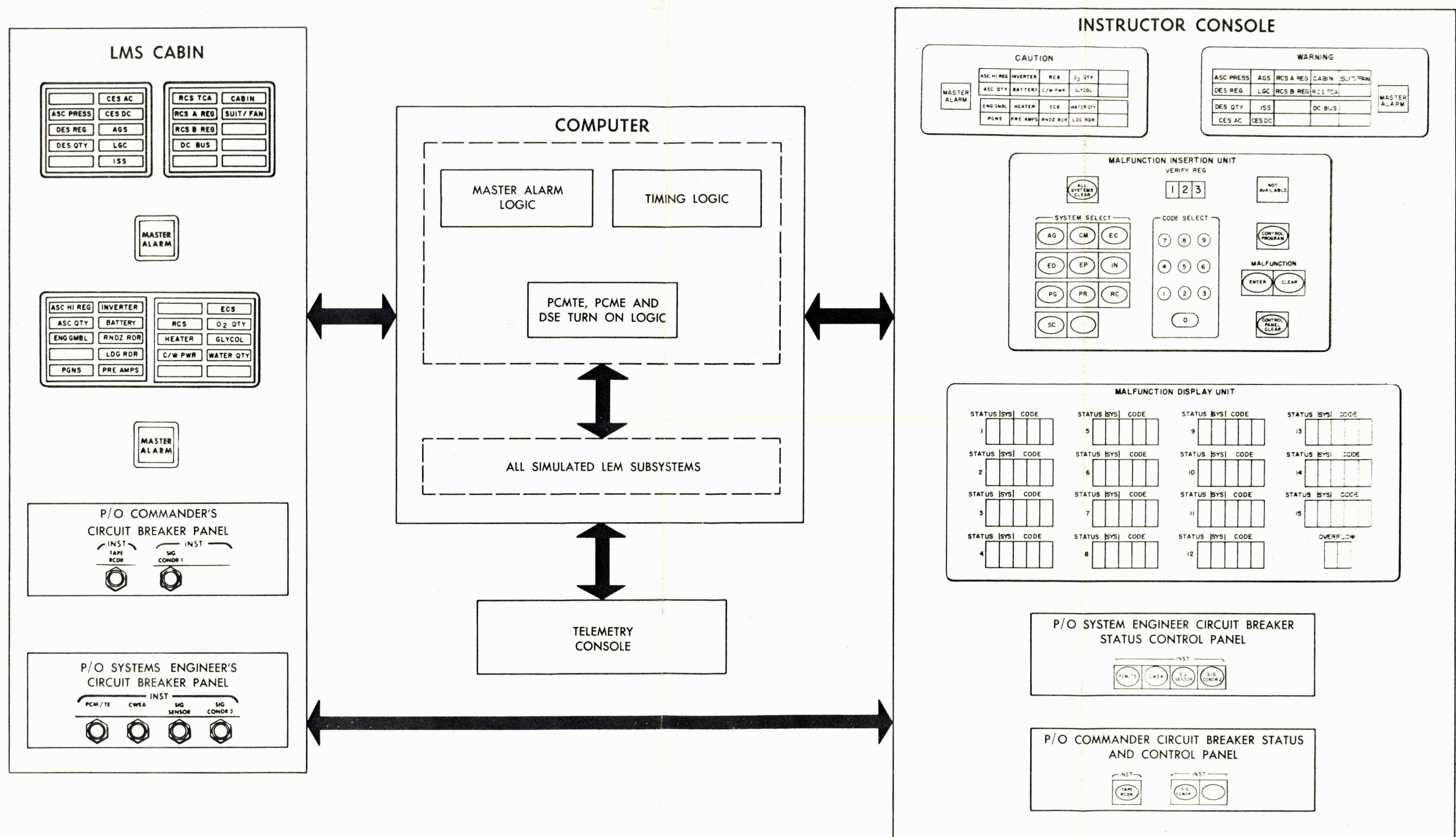


Figure 2-16. LMS Instrumentation Subsystem, Flow Diagram

- Selecting and displaying digital and/or analog values (other than ISLGC)
- Controlling and displaying normal fault and fault inserted telemetry data (except ISLGC data)
- Monitoring ground tie-in controls
- Providing problem-time readout.

All data to be transmitted to the simulated MCC and AMS (except voice) passes through the telemetry console. Input data originates in the LMS computer through subsystem computer calculations. Output data may be classified into three groups, as follows:

- Normal live data
- Normal prerecorded biomedical data
- Data (live or prerecorded) modified by insertion of one or more malfunctions in one of the telemetry circuits.

Normal live data originates at one of the subsystem programs within the LMS computer and represents a clean signal (free of any purposely inserted defects or errors) or a signal modified by insertion of a malfunction, at the instructor console. This signal is fed to the telemetry console for further processing and/or operations.

Normal prerecorded biomedical data can be switched into the system in place of live data at the discretion of the instructor.

It is possible to degrade certain input data by insertion of a malfunction. A partial list of the type of malfunctions to which these signals can be subjected is as follows:

- Level change - analog (abrupt)
- Fixed level substitution - analog
- Drift rate substitution - analog (gradual)
- Manual variable - analog
- Inhibit word - digital
- Spurious events - bilevel abrupt switching; no event or inhibit event - bilevel (except ISLGC).

The flight crew in the LMS cabin uses all the normal LM IS displays and controls. Response to the control inputs is displayed in the LMS cabin, on the instructor console, and on the telemetry console. The telemetry data for the simulated IS are given in table 2-7.

#### 2.8.2.3 IS Controls and Displays.

The IS caution panel is on the Systems Engineer's upper console. Indicator lamps related to subsystem malfunctions (not requiring immediate action) are on this panel. The IS warning panel is on the Commander's upper console. Indicator lamps related to subsystem malfunctions (requiring immediate emergency action) are on this panel. When a subsystem fault causes any one of the caution or warning indicator lamps to light, the MASTER ALARM switch-light flashes, and a tone is heard in the astronaut headsets. Pressing the MASTER ALARM switch-light removes the MASTER ALARM light and tone, although the caution or warning lamp remains lit until the malfunction is rectified or remedial action is initiated. Circuit breakers that supply power to the IS are on the Commander's and Systems Engineer's circuit breaker panels.

All IS control settings and circuit breakers within the LMS cabin are monitored at the instructor console. The repeater displays on the console normally indicate the same data as that viewed by the astronauts. The instructor console includes repeaters of all caution/warning displays and the MASTER ALARM lights. These displays are also subject to simulated malfunctions. The caution/warning repeaters may be checked for bulb failure with the console lamp test switches.

The instructor console also includes malfunction insertion and display units for manual control of all simulated failures or instrument deviations. Dual breaker groups also make it possible to open all LMS cabin circuit breakers.



Table 2-7. LMS Instrumentation Subsystem Telemetry Data

MSFN No.	Description	Range			Unit or Type*
		Low	Nominal	High	
GL0300	Frame synchronization and identification				
GL0302	Format identification				
GL0401	Calibration 85%	0	4.25	5	vdc
GL0402	Calibration 15%	0	0.75	5	vdc
GL0501	Mission elapsed time				
GL4026	CES power supply failure				CC
GL4027	CWEA power - caution				CC
GL4028	AGS power failure				CC
*CC = Contact closure.					

#### 2.8.2.4 Malfunction Control.

The instructor may use his MALFUNCTION INSERTION UNIT (MIU) to manually initiate a variety of simulated IS problems, or he may leave the crew under automatic computer program control. Major components of the IS may be intentionally malfunctioned individually or in combinations. The instructor console circuit breaker and status control panels also enable failure of any of the circuit breakers in the LMS cabin. The malfunctions consist basically of system faults or instrumentation errors. A step-ahead mode may be initiated during the training exercise, to advance the simulated mission to a desired time at an accelerated rate. All programmed maneuvers and malfunctions are initiated during this advance time interval. A complete list of malfunctions available for insertion into the IS simulation is in section 2 of volume II.

### 2.9 COMMUNICATIONS SUBSYSTEM.

The LM Communications Subsystem (CS) provides communications links, during deep-space operations, between LM 2 and the Manned Space Flight Network (MSFN) and provides the only link between LM 2 and the CSM. The subsystem includes all equipment necessary to transmit and receive voices, as well as tracking and ranging data; and to transmit telemetry, television, and emergency keying. A combination of S-band, VHF, signal processing, and television equipment is used as the communications link. (See figure 2-17.)

The CS is divided into three groups: RF electronic equipment, signal-processing assembly (SPA), and the antenna equipment. The RF electronic equipment includes all subsystem equipment required to transmit and receive audio, video, pseudorandom noise (PRN), and telemetry data. The SPA is the common acquisition and distribution point for all CS received and transmitted data. It processes all voice and biomedical signals and provides the interface between the RF electronics and the IS. The CS antenna equipment consists of one steerable antenna and two omnidirectional antennas for S-band transceiving, and two in-flight antennas for VHF transceiving. A high-gain lunar-stay antenna for S-band transceiving and an extravehicular astronaut (EVA) antenna for EVA-LM VHF communications are also provided.

Voice communications between the LM and MSFN are provided by the S-band transceivers; between the LM and the CSM, by VHF/AM. Telemetry communications to MSFN via VHF/AM are possible during near-earth missions. Telemetry data are transmitted to MSFN via S-band (real-time operational instrumentation data), with the S-band equipment as the deep-space ranging and tracking transponder. The communications paths provided by the CS, and their purpose, are listed in table 2-8.

All voice communications are accomplished through the astronauts' microphone and headset equipment. Voice communication is used between the LM and the CSM; between the LM and MSFN; between the LM, the CSM, and earth (conference); and between the astronauts (hardwired when both are in the LM). Each astronaut controls the audio volume to his headset. The microphones, headset, and AUDIO control panels are connected to the audio center subassemblies (one for each microphone, headset, and control panel combination) of the SPA. Each audio center subassembly serves as the common acquisition and distribution center for all voice communications. Depending on the selected mode of operation, voice is transmitted to MSFN or the CSM, or stored on



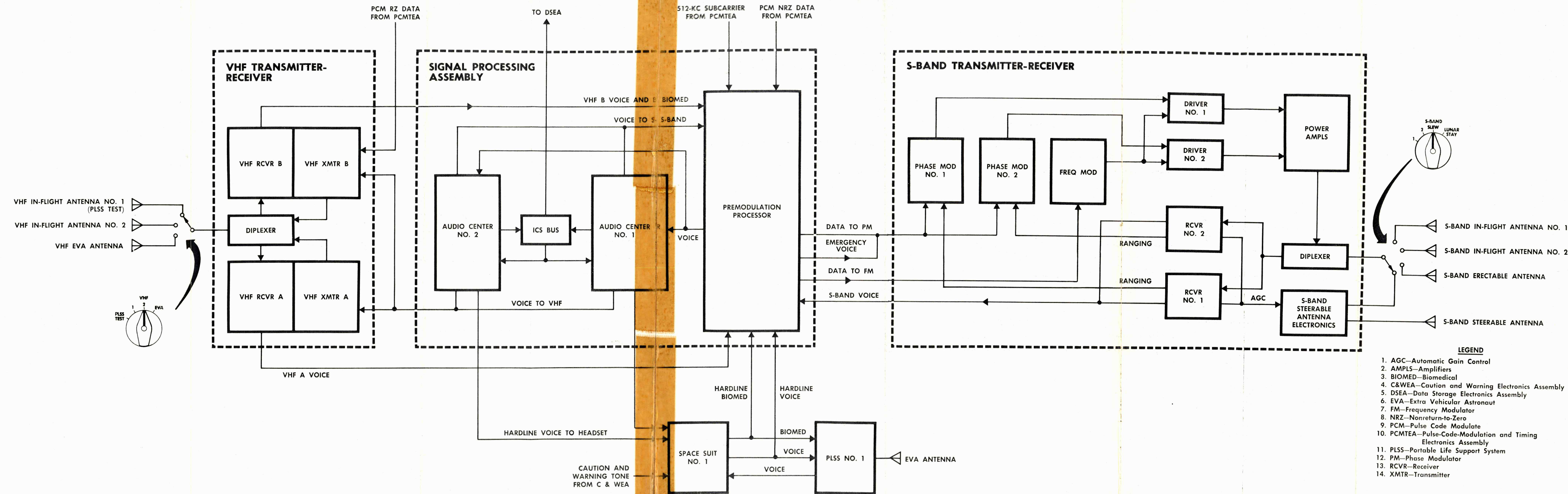


Figure 2-17. LM Communications Subsystem, Block Diagram



Table 2-8. LM Communications Links

Link	Mode	Band	Purpose
Earth-LM-earth	Pseudorandom noise	S-band	Ranging and tracking
LM-earth	Voice	S-band	In-flight communications
LM-CSM	Voice	VHF simplex	In-flight communications
LM-CSM-earth	Voice	VHF S-band	Conference (with CSM as relay)
LM-earth	Video	S-band/FM	Television
LM-CSM	Low-bit-rate telemetry	VHF (one way)	Record and retransmit to earth
Earth-LM	Voice	S-band	In-flight communications
LM-earth	Biomedical - telemetry (side-band transmission)	S-band	In-flight communications
LM-earth-CSM	Voice	S-band	Converence (with earth as relay)

tape in the DSEA of the Instrumentation Subsystem (IS). Two types of voice communication are used in the CS: S-band and VHF. These are line-of-sight (LOS) carriers; both ends of the communications path must be in a clear line of sight for reception and transmission.

LM 2 has transducers that sense and convert physical parameters from all subsystems into a form compatible with the signal-conditioning equipment in the IS. Biomedical data from sensors worn by the astronauts, and video from the television camera, are also processed through the IS and transmitted via the CS to MSFN. The IS processes signals supplied by the transducers, converts them to pulse-code-modulated digital form, and routes them serially to the CS for transmission to MSFN via the S-band FM and PM transmitters, or to the CSM via VHF transmitters. The LM-2 ranging and tracking equipment (S-band) enables MSFN to accurately determine the angular position and range of the LM.

A detailed description of the CS is given in paragraph 2-7 of Apollo Operations Handbook, LMA790-3-LM 2.

#### 2.9.1 COMMUNICATIONS SUBSYSTEM CONFIGURATION REFERENCE.

The Communications Subsystem of the LMS accurately simulates the LM-2 CS. The LMS CS simulation is performed without the use of RF equipment; all audio and data lines are hardwired to all related submits.

#### 2.9.2 SIMULATED COMMUNICATIONS SUBSYSTEM. (See figure 2-18.)

##### 2.9.2.1 General.

The LM Communications Subsystem (CS) is simulated to include duplication of phenomena peculiar to the frequency bands used, time delays, general operational characteristics of the specific equipment involved, and effects of vehicle position and attitude on communications capability. During simulated S-band LM earth communications (transmission and reception), the occultation effect of the moon between the simulated LM and earth, and the occultation effect of the simulated LM between the S-band steerable antenna and earth are not simulated. All S-band LM earth LOS calculations are computed to the center of earth.

The following details are significant in the simulation of the LM CS:

- A special communications audio control center provides voice-operated-switching (VOX) and all audio routing and amplifications. A tone generator for emergency keying is also provided.
- A backup voice loop between crew and instructor is provided for emergency use.
- Two delay recorders are provided at the instructor console for incoming and outgoing S-band-to-earth delay simulation.



- Sound effects (engine firing, staging, etc.) are generated to present aural cues to the crew; they are monitored by the instructor.
- A monitoring recorder is provided for future playback of voice communications that commenced during the training exercise.

#### 2.9.2.2 Simulation Methods.

The entire LM communications simulation within the LMS is accomplished without any RF equipment. All Audio and data lines are hardwired and tied by simple switching logic. LMS crew station controls and indicators, gross data flow, and instructor console controls and indicators (peculiar to the CS) are shown in figure 2-18. All LMS cabin controls and indicators are located in the exact configuration as those in the LM. Crew control inputs and subsystem output displays are monitored at the instructor console. System operation includes available power logic, based on the proper operation of simulated circuit breakers and EPS bus switching. LOS cutoff and range attenuation effects are also calculated for each of the radio communications channels. Either instructor or the Mission Coordinator may contact the astronauts the LMS cabin, using the simulated radio communications channels. The Mission Coordinator and the Commander Instructor also have an emergency backup audio loop, which permits direct contact with the astronauts, irrespective of the astronauts audio control settings, that is free of any signal degradation or interference.

LM communications from outer space with the MSFN traverses a significant time span due to the extensive distances encountered. To duplicate this effect, simulated S-band communications are delayed 1.2 seconds in each direction by a special-purpose tape record-playback unit. Further signal degradation may be introduced by the instructor by means of dual controls on the COMM INTERFERENCE panel. These controls permit the introduction of noise or message garbling in either VHF or S-band simulated communications. An illuminated switch and variable control knob are provided for each form of signal degradation. Noise signals are supplied from a filtered white noise source. Speech-garbling results from irregular audio filtering, which produces a peculiar harmonic response and results in less intelligible messages. These effects may be varied independently in the simulated VHF or S-band subsystems.

The LMS data acquisition system (DAS) includes an audio tape recorder, which is controlled by the instructor. This unit provides a permanent record of all audio communications carried on by the astronauts. The unit records in two modes: continuous recording, and VOX controlled (recorder on only when triggered by voice signals in the audio circuit). A panel-mounted warning light alerts the instructor when the tape unit is near the end of its recording capacity. The onboard dual-channel tape recorder aboard the LM is included as a mockup within the LMS cabin. The LMS is designed to interface with the controls of this simulated assembly, thereby permitting the astronaut training implementation.

All switch settings on the dual astronaut's AUDIO control panels and Systems Engineer's side panels are repeated at the instructor console. In addition, CS circuit breakers and malfunctions are displayed in detail on the instructor console. All LMS cabin communications switch settings are repeated here, as well as the status flag indicator for the simulated onboard tape recorder.

Yaw and pitch angles of the simulated steerable S-band antenna are continuously computed in the LMS, and displayed on the cabin indicators and instructor console instrument repeaters. The instructor console readouts are normally identical with those in the LMS cabin, although these parameters may be intentionally distorted (via the MALFUNCTION INSERTION UNIT). These indicators are provided with failure warning pilot lights. Correct readings will be displayed if the TRUE READING pushbutton on the instructor console is pressed. Pitch, yaw, and signal strength readouts are programmed to duplicate automatic or manual earth tracking procedures with this S-band antenna. These calculations are computed using the equations of motion, and ephemeris (astronomical data) programs of the LMS. The Systems Engineer's antenna slewing controls are monitored by indicators at the instructor console; no other CS potentiometers are similarly displayed.

The flight crew in the LMS uses all of the normal LM CS instruments and controls. Response to the control inputs are displayed in the LMS cabin, on the instructor console, and on the telemetry console. The telemetry data for the simulated CS is given in table 2-9. MSFN symbols used in table 2-9 are identified in volume II.

#### 2.9.2.3 CS Controls and Displays.

Except for the Commander's AUDIO panel and hand-operated translation controller, all CS controls and displays are operated and controlled by the Systems Engineer. An AUDIO panel (identical with the Commander's), COMMUNICATIONS panel, and a COMMUNICATIONS ANTENNAS panel are located on the Systems Engineer's side console, to control extravehicular and intravehicular communications. The S-band system includes dual driver multipliers and dual power amplifiers, with individual power supplies. These redundant systems are controlled by individual toggle switches on the COMMUNICATIONS panel. The Systems Engineer may select the primary or secondary transceiver, and the primary or secondary power amplifier, for use.







Table 2-9. LMS Communications Subsystem Telemetry Data

MSFN No.	Description	Low	Nominal	High	Unit or Type
GT0201	S-band power amplifier RF power output	0		25	watts
GT0202	S-band power amplifier RF reference power output	0		25	watts
GT0992	Transponder - steerable angle error	-15		+15	degrees
GT0993	S-band transmitter RF power output	0.5		1	watts
GT0994	S-band receiver AGC	0		4.2	vdc

Phase modulation or frequency modulation may be selected. Three center-off toggle switches are provided to set up the functional mode for the S-band equipment voice, voice backup (using an alternate frequency-modulation mode), range (in the PRN transponding mode), video, pulse code modulation (of telemetry data), or emergency keying. The emergency key function is used to transmit Morse code signals to MSFN if the simulated LM's audio equipment fails. The S-band carrier is then keyed by the astronaut's mike button. There are separate power switches for the two VHF transmitters and the two receivers. Separate SQUELCH control potentiometers are also provided for each receiver. Control of the telemetry data is provided by two panel switches. The high (S-band only) or low rate of pulse-code-modulated (PCM) data transfer is selected by a two-position toggle switch. A three-position, center-off toggle switch arms the biomedical suit sensor and signal-processing units for either the Commander or Systems Engineer. The LM is equipped with a four-track recorder to collect voice commentary of the LM communications when voice transmission is not possible (behind the moon). The tape recorder consists of a mockup in the LMS and is not functional. The tape unit is switched on by the SE (Systems Engineer). At the end of the simulated 10-hour tape capacity, a warning flag is displayed adjacent to the RECORDER power switch.

Four antennas are provided on the LM for S-band communications. The Systems Engineer COMMUNICATIONS ANTENNA panel includes a rotary switch for selection of the antenna to be used. The steerable disk antenna pitch and yaw angles (with respect to the LM body axis) are continuously displayed on angle meters. For manual steering, the Systems Engineer sets his TRACK MODE toggle switch to SLEW, which enables the PITCH and YAW control knobs to activate the antenna servomotors. The SIGNAL STRENGTH meter indicates the optimum position of the disk antenna (maximum signal strength) at any particular time. When the SE TRACK MODE switch is set to AUTO, the Systems Engineer also uses a rotary VHF selector switch on the panel to select either of the two omnidirectional antennas, the EVA antenna mast, or the portable life support system (PLSS) test connection jack, for necessary VHF signal coupling. (In the actual LM, the PLSS is tied into the CS, for testing, before egress to the lunar surface.)

The CDR and SE have AUDIO control panels, which have identical controls. Parallel mode switches are provided for each of the major audio functions. (The VHF (channels A and B), S-band, and intercom (ICS) networks each have a three-position toggle switch to provide transceive, receive only, or audio-off conditions. Each of these networks also has a VOLUME control to adjust the sound level of that particular input as it is heard in the astronaut's headset. A MASTER VOLUME control adjusts the total volume level. The redundant audio system includes a backup channel, which may be selected by either astronaut at his AUDIO control panel. Normal mike switching of the LM audio system may be automatically controlled by a voice-operated relay unit (VOX). When the VOX relay is selected at either astronaut's AUDIO panel, the intercom or transmitter "press-to-talk" function is automatically controlled by the sound of their voice in their microphones. The voice volume level required to trigger the "talk" switch is adjustable with an adjoining VOX SENS control. A three-position VOX toggle switch makes it possible to restrict the VOX automatic function to the intercom system only, or to disable the system such that the manual mike switch on the suit umbilical or attitude hand controller must be used to key the "talk" mode of the ICS and the transmitter.

The astronaut's audio system is also tied into the caution and warning indicator lamps of the IS. When abnormal or emergency situations are detected by the Instrumentation Subsystem (IS), caution or warning annunciators are illuminated on the Commander's and System Engineer's central consoles. An alerting audio tone is then introduced into the headsets to emphasize the visual display of any detected subsystem malfunctions. The CS electrical loads within the LM are energized by the two main power buses. Power distribution and control are provided by the respective circuit interrupters at the Commander's and Systems Engineer's circuit breaker



panels. The instructor console contains repeaters of all CS controls, indicators, and circuit breakers that are in the LMS cabin. Monitoring and evaluation of crew responses during a training mission are thereby possible. The CS indicator readouts at the instructor console are normally identical with those in the LMS cabin. Since these parameters may be intentionally distorted (due to inserted malfunctions), the indicators are provided with failure warning pilot lights. Actual, undistorted indicator readouts are displayed whenever the instructor presses the console TRUE READING pushbutton.

#### 2.9.2.4 Malfunction Control.

The instructor may use his MALFUNCTION INSERTION UNIT to initiate a variety of simulated CS problems, or he may leave the crew under automatic computer program control. Every major portion of the CS may be intentionally malfunctioned either individually or in combinations. A warning lamp over each of the instructor console CS displays informs the instructor that a false value is being displayed because a malfunction has been inserted. The correct indicator readout may be obtained by pressing a TRUE READING pushbutton on the console. The instructor console circuit breaker panels also enable failure of any LMS cabin circuit breaker. The malfunctions consist basically of subsystem faults and instrumentation errors. A step-ahead mode may be initiated during the training exercise, to advance the simulated mission to a desired time at an accelerated rate. All programmed maneuvers and malfunctions are initiated during this advance time interval. A complete list of malfunctions available for insertion into the CS simulation is in section 2 of volume II.

#### 2.10 EXPLOSIVE DEVICES SUBSYSTEM.

The LM Explosive Devices Subsystem (EDS) provides the astronauts with the capability to operate or enable various LM equipment by explosive devices (Apollo standard initiators, commonly called pyrotechnic initiators). Some of the functions the explosive devices initiate are landing gear deployment; pressurization of the descent engine, ascent engine, and reaction control engine propellant tanks; and ascent and descent stage separation.

There are two complete and separate circuits for the EDS. (See figure 2-19.) Each circuit has its own +28-volt d-c battery, relays, bus, wiring, fuses, and initiators. Redundant features are incorporated throughout to provide safety and additional protection. Figure 2-20 indicates the general location and the type of components that the EDS comprises. Electrical protection of critical EDS components is afforded by circuit breakers on the Commander's and Systems Engineer's circuit breaker panels. Power to arm each circuit is provided by one of the d-c distribution busses (Commander's or Systems Engineer's).

The EDS consists of two batteries, a control panel, two fuse and relay boxes, two pyrotechnic power buses, and the pyrotechnic initiators. Power to actuate the relays in the relay boxes is drawn from the main power supply of the LM; power for the pyrotechnic initiators is supplied by the explosive devices (ED) batteries. The MASTER ARM switch operates two power relays that provide a continuous circuit between each battery and its power bus. Each EXPLOSIVE DEVICES panel function switch actuates two relays, one in each relay box. Each of these relays provides a circuit between its power bus and the associated pyrotechnic device. Each staging relay, when actuated, provides a circuit between its power bus and the associated pyrotechnic device. Each staging relay, when actuated, provides a circuit between a power bus and a redundant set of staging function relays (for the ascent and descent deadface, cable cutters, interstage connection bolts, and nuts). Each function is provided with two separate pyrotechnic initiators that use power from separate buses, for initiation. Each pyrotechnic initiator has two bridgewires, both able to explode the initiator. Each pyrotechnic initiator is capable of performing its task unaided; the second initiator provides the required redundancy. The system, with duplicate relays and redundant electrical circuits and initiators, provides complete redundancy and safety for the EDS.

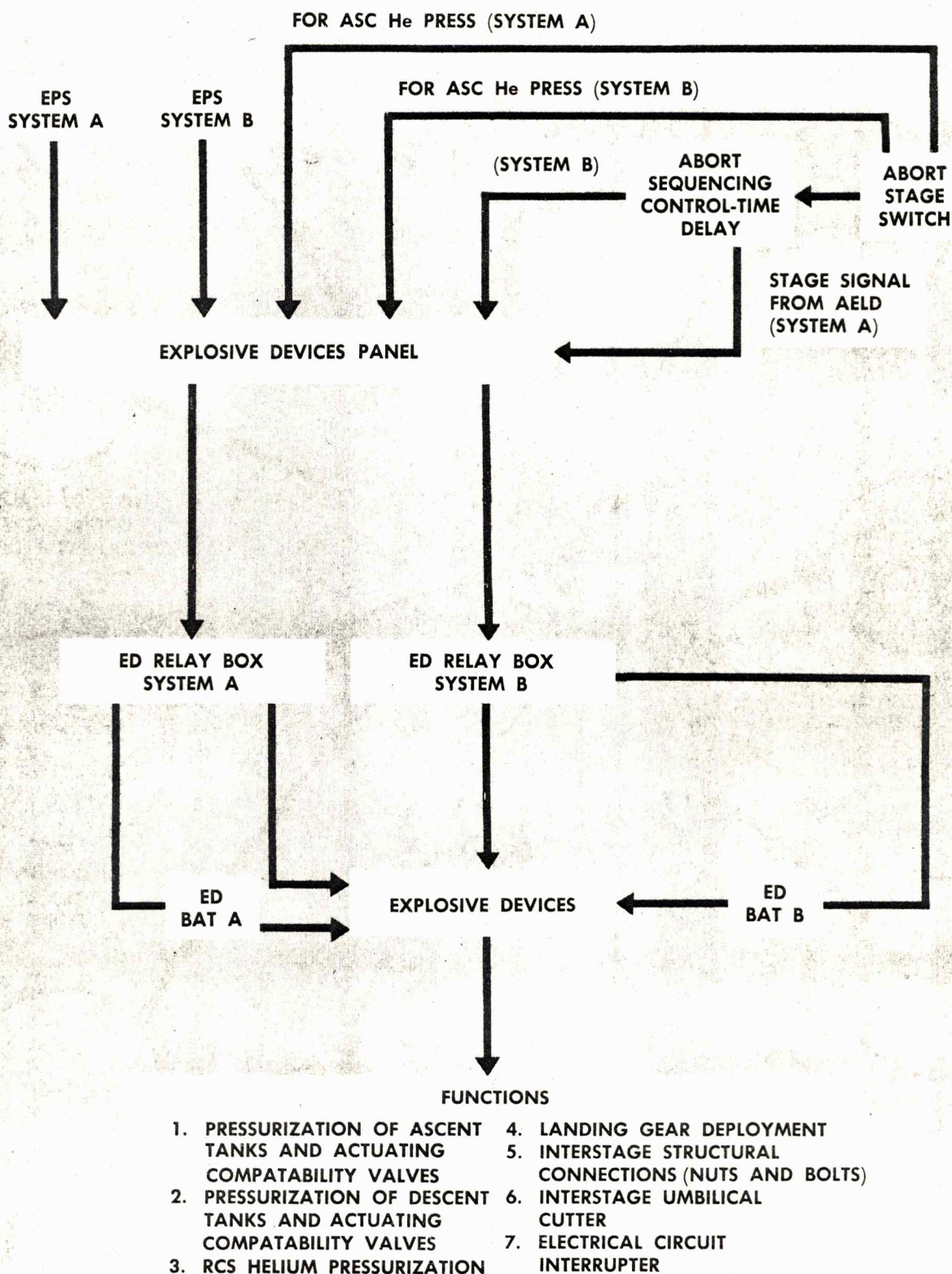
The EDS events occur in the following sequence:

- RCS pressurization
- Descent engine pressurization
- Ascent engine pressurization
- Nut and bolt and ascent stage deadfacing (occur simultaneously)
- Umbilical severed.

The following explosive devices separately, or in various combinations, accomplish the specified functions (figure 2-20):

- Apollo standard initiator (ASI). The electrically actuated ASI initiate all explosive functions required during this mission. This is a common usage device.

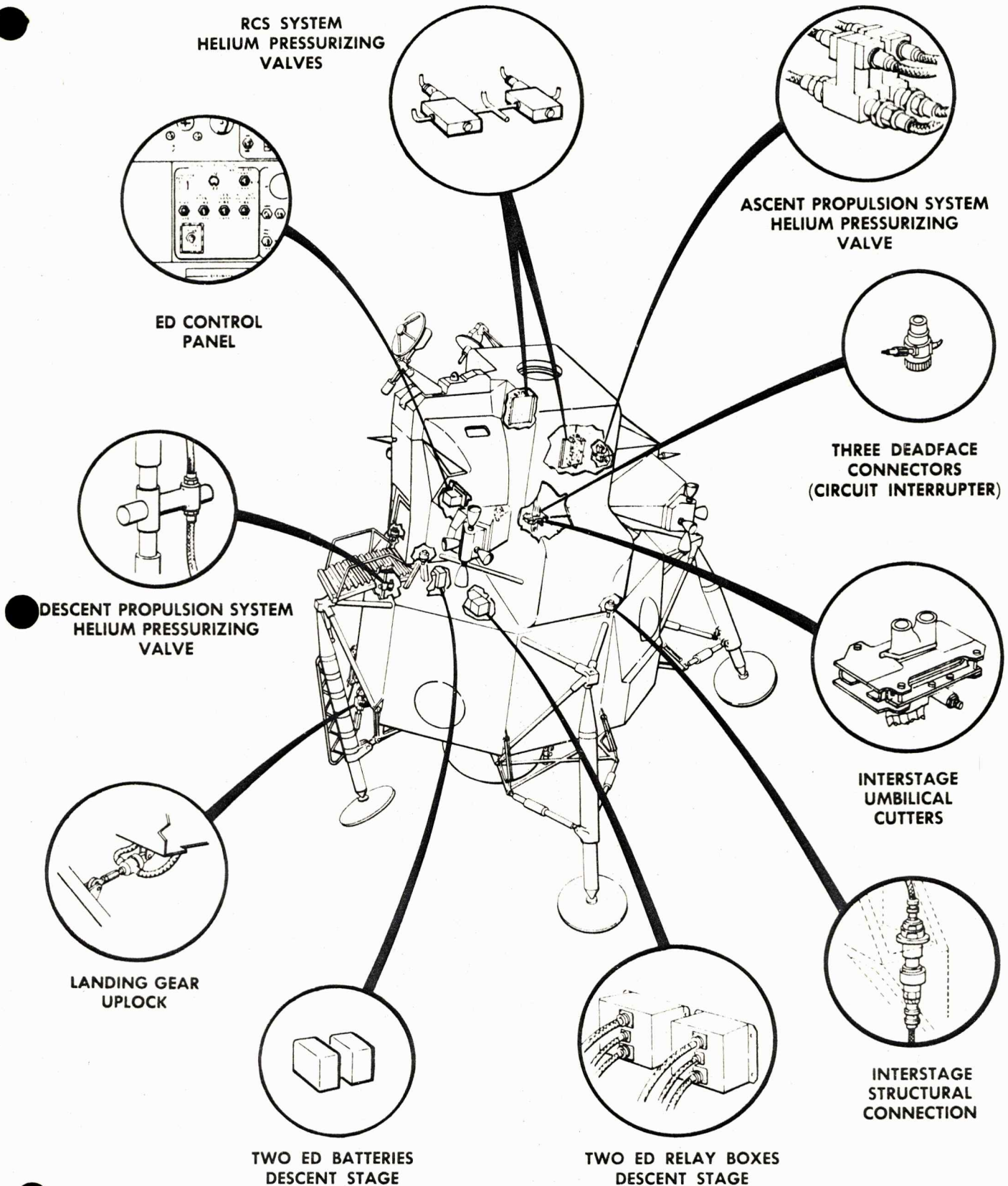




C-300RM-46

Figure 2-19. LM Explosive Devices Subsystem, Simplified Block Diagram





B-300RM-67

Figure 2-20. LM Explosive Devices and Component Locations

- Apollo standard detonator (ASD). The ASD is used to detonate all high-explosive charges in the LM. This is a common usage device.
- Mild detonating fuse (MDF). The MDF is a common usage device.
- RCS helium pressurization. The RCS explosive valve is actuated by Apollo standard initiators.
- Ascent propulsion subsystem valves. These explosive valves are actuated by Apollo standard initiators.
- Descent propulsion subsystem valve. This explosive valve is actuated by Apollo standard initiators.
- Circuit interrupter. Circuit interrupters are provided to terminate all signal and power leads running between the ascent and descent stages which are live at time of separation or which could subsequently become live due to activation of a circuit. These devices are initiated explosively 30 milliseconds after stage command is received. They are actuated by Apollo standard initiators.
- Explosive nut and bolt. The ascent and descent stages are structurally joined by four explosively actuated bolts and four explosively actuated nuts each with a single initiator. Upon receiving the stage separation signal, they actuate within a total elapsed time of 0.1 second.
- Guillotine. A dual initiation mode mild detonating fuse is used. A crossover network is provided to fire both modes should a failure occur in the normal initiation mode of one.
- Abort. Mission abort is initiated by manually pressing the ABORT button. This button initiates abort programs in the Guidance, Navigation, and Control Subsystem (GN&CS), and signals to the Instrumentation Subsystem (IS). It also provides descent engine and ED automatic arming commands.
- Abort stage. The ABORT STAGE button is used to abort the mission using the ascent engine. This button initiates the Guidance, Navigation, and Control Subsystem for an abort using the ascent engine and signals to instrumentation. It also provides ascent engine pressurization commands, ascent engine arm commands, descent engine off commands, and interstage deadface commands. Pressing the ABORT STAGE button enables the simulated LM to use computer outputs for operation with the ascent stage.
- Stage. This switch provides the capability to stage the LM by means of the explosive nut and bolt combinations and umbilical severance, without pressurizing the ascent engine.

A detailed description of the EDS is given in paragraph 2.8 of Apollo Operations Handbook, LMA790-3-LM2.

#### 2.10.1 EXPLOSIVE DEVICES SUBSYSTEM CONFIGURATION REFERENCE.

The Explosive Devices Subsystem of the LMS accurately simulates the LM-2 EDS.

#### 2.10.2 SIMULATED EXPLOSIVE DEVICES SUBSYSTEM. (See figure 2-21.)

##### 2.10.2.1 General.

Simulation of the EDS consists mainly of programmed switching logic. Normal operation of the simulated explosive devices is indicated to the flight crew by pressure, aural cue, or other indications for each explosively initiated function.

##### 2.10.2.2 Simulation Methods.

The associated control switch in the LMS cabin initiates a digital bit input to the EDS control logic program in the LMS computer. Operation of the simulated EDS is also dependent on the simulated EPS for three circuit breakers related to the EDS, and d-c power availability. Interface of the simulated EDS includes digital bit outputs to trigger the aural cue simulation of the pyrotechnic explosions, and visual simulations. Selection and initiation of firing switching equations are computed corresponding to a particular explosive device. An output is produced from these computations and transmitted to the programmed explosive devices equations. If EDS power is available, an "explosive devices fired" output results. This output is applied to the LMS computer program of the subsystem that uses those particular explosive devices. Switch position commands that initiate the firing of explosive devices associated with abort and staging operations initially flow to the LMS computer program of those subsystems that determine the sequence and timing of explosive device firings. The switching logic may be interrupted by any related simulated subsystem malfunctions.



The position of the EDS control switches and status flags in the LMS cabin is indicated at the instructor console. The flight crew in the LMS uses all of the normal EDS instruments and controls in the simulated LM cabin. Response to the control inputs is displayed on the telemetry console, as well as by the instructor console repeaters. The telemetry data for the simulated EDS is given in table 2-10. MSFN symbols used in table 2-10 are identified in volume II.

#### 2.10.2.3 EDS Controls and Displays.

The EDS control and displays in the LMS cabin are on the EXPLOSIVE DEVICES panel. Each function switch on the panel, except the stage switch, is of the two-position type: lever-lock in safe, and momentary in fire. The STAGE and MASTER ARM power switches are of the two-position type (lever-locking in both positions). The ASCENT helium select switch is of the three-position lever-locking type. Basically, these switches permit helium pressurization of the ascent and descent sections of the Main Propulsion Subsystem (MPS) and the Reaction Control Subsystem (RCS), landing gear deployment, and staging operations initialization. In addition, electrical circuit breakers on the Commander's and Systems Engineer's circuit breaker panel supply and control operating power to simulated EDS circuitry. Repeaters of all EDS controls and displays in the LMS cabin are provided on the instructor console, for continuous monitoring and evaluation.

#### 2.10.2.4 Malfunction Control.

The instructor may use his MALFUNCTION INSERTION UNIT to initiate a variety of simulated EDS problems, or he may leave the crew under automatic computer program control. Every major component of the subsystem may be intentionally malfunctioned either individually or in combinations. (Refer to volume II.) The instructor console circuit breaker panels also enable failure of any of the circuit breakers in the LMS cabin. The malfunctions initiated from the instructor's MALFUNCTION INSERTION UNIT are basically system faults. A step-ahead mode may be initiated during the training exercise, to advance the simulated mission to a desired time at an accelerated rate. All programmed maneuvers and malfunctions will be initiated during this advance time interval. A complete list of malfunctions available for insertion into the EDS simulation is in section 2 of volume II.

Table 2-10. LMS Explosive Devices Subsystem Telemetry Data

MSFN No.	Description	Low	Range Nominal	High	Units or Type*
GM5000	Landing legs deployed				CC
GY0050	Abort commanded				CC
GY0111	ED system A battery relay open				CC
GY0112	ED system B battery relay open				CC
GY0121	ED system A staging relay open				CC
GY0122	ED system B staging relay open				CC
*CC = Contact closure.					



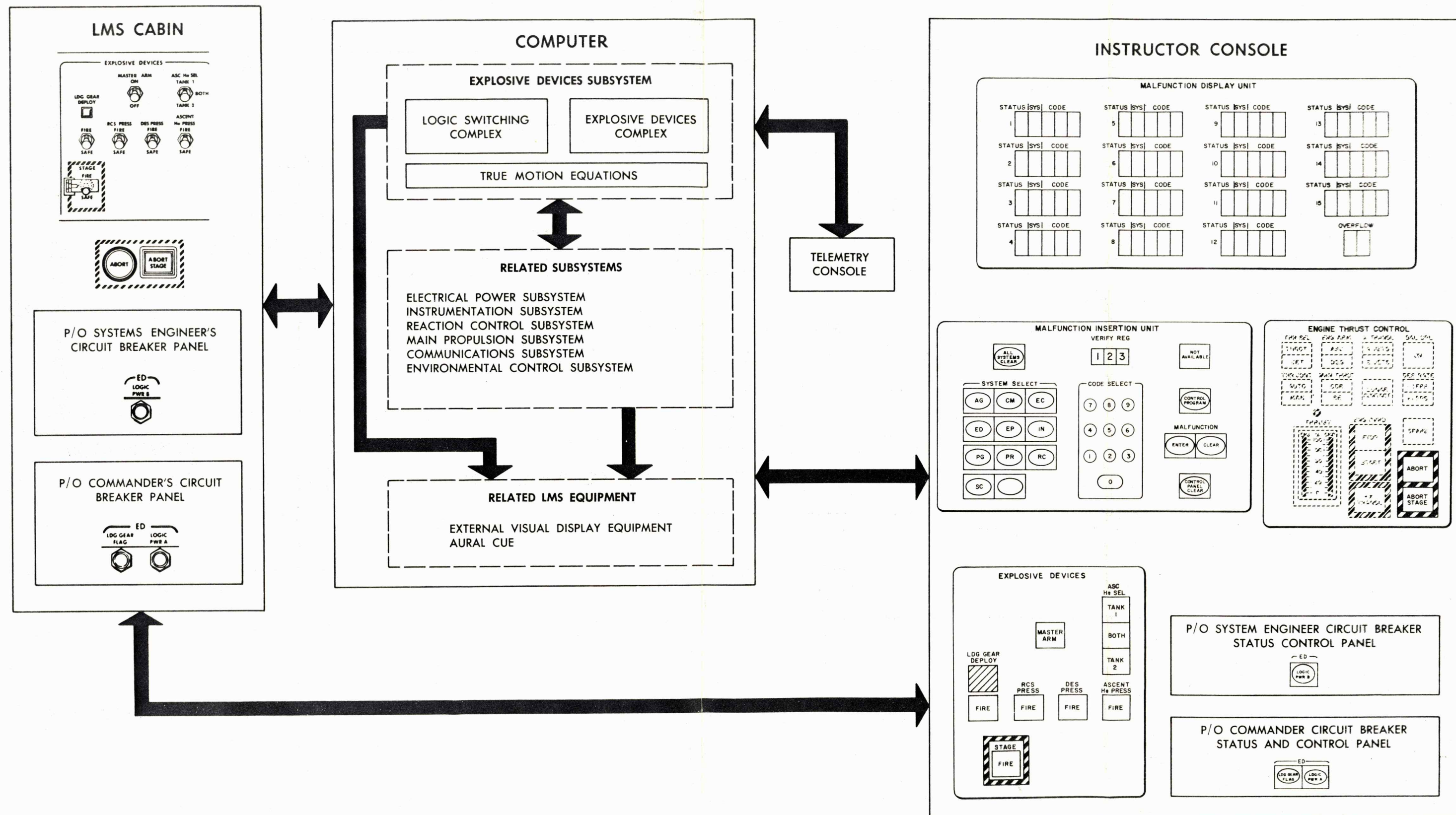


Figure 2-21. LMS Explosive Devices Subsystem, Flow Diagram



## SECTION 3

## TRAINING ACTIVITIES

3.1 PURPOSE AND SCOPE.

The training activities provide as comprehensive a series of LMS training exercises as possible, for use by LMS instructors in training flight crews for any of the manned LM missions. The recommended training syllabus is based on the lunar landing mission, which requires the flight crew to perform essentially all the tasks of the earlier missions, in addition to activities unique to the lunar landing mission. The syllabus will enable the instructor to select and prepare, with minimum modification, exercises applicable to the specific LM mission for which training is being conducted.

The training exercises are based on, but not limited to, normal crew activities, beginning with entry into the LM during lunar orbit and ending with egress from the LM after final docking with the CSM. Extravehicular activities on the lunar surface are not included in the exercises. Because the training program must prepare the flight crew to cope with nonnominal or unexpected mission situations, extensive exercises involving correction of malfunctions, and mission contingency activities, are included.

The training exercises are intended to be oriented primarily toward the LM flight crew. Training benefits for Flight Controllers, the CSM crewman, and telemetry operators may be derived from some of these exercises, although the primary intent is to ensure effective interface performance by the LM flight crew.

## 3.1.1 CREW OPERATIONAL PROCEDURES.

To ensure effective training, the best available representation of the eventual flight crew operational procedures has been used in developing the training exercises. These procedures, in section 3 of volume II, have been developed as part of the Flight Crew Task Analysis effort and are based on the Apollo Mission Planning Task Force (AMPTF) Design Reference Mission IIA (DRM IIA). It is expected that, as the Apollo Operations Handbooks (LMA790-3-LM 2, 3, and 4) for LM 2, 3, and 4 become available, the crew procedures in these handbooks will be used for crew training instead of those in section 3 of volume II.

3.2 TRAINING SYLLABUS.

This portion of the handbook contains the syllabus for training with the LMS. Briefly, the syllabus organization is as follows. All training is categorized either as part task training or full mission training. Each of these exercises is subdivided into LMS training sessions; each session consists of one or more simulator runs. The purpose of each exercise and session is clearly indicated.

The training exercises and sessions are sequenced to permit a firm understanding of the LM, individual subsystem operation and management, and the crew procedures involved. Malfunctions are introduced in the exercise sequences to enhance subsystem understanding. Following this phase of the training sequence, the exercises and sessions progress to the integration of total subsystems operations and the introduction of certain contingency operations that require decisions affecting the mission plan. Once the preliminary exercises and sessions are completed, the events and operations of the mission for which the training is being conducted are adhered to as closely as possible.

## 3.2.1 PART-TASK-TRAINING EXERCISES AND SESSIONS.

Most of the recommended training exercises and sessions are in the part-task-training category. These include exercises devoted to management of particular subsystems, as required across the entire mission profile. For example, pressurization and checkout of the Reaction Control Subsystem (RCS) during the preseparation phase, monitoring of RCS helium and propellant during the coasting and powered descent phase, checkout before shutdown on the lunar surface, preparation for lunar ascent, monitoring of propellant quantity and subsystem status (e.g., TCA valves) during powered ascent, midcourse corrections, and, finally, management during final docking and system shutdown before egress to the CSM. Malfunctions appropriate to the specific mission phase being simulated are recommended for inclusion during the simulator runs. (Detailed malfunction data are in section 2 of volume II.)

Part-task-training exercises and sessions are also devoted to familiarizing the flight crews with the response of the LM to manual flight control, and to practicing those portions of the mission that require manual control. A sequence of sessions begins with familiarizing the command pilot with the pitch, yaw, and roll responses of the vehicle during docking; with rate command and direct mode operation; with controller breakout forces and displacements required to produce the desired rates; and with integration of the translation control capability with vehicle attitude control. Many of the runs are devoted to practicing the final docking maneuver to achieve LM-CSM closure within the allowable envelope of vehicle attitude variation, impact forces, and torques. Another sequence of sessions emphasizes manual control during the landing maneuver. Integrated use of the rate-of-descent control, the thrust controller, and the attitude controller are practiced, to gain experience with the effects produced with a gimbaled main engine thrusting. For this set of exercises, only those subsystem aspects directly related to the flight control maneuvers are initially included. Among these are flight display monitoring (altitude and altitude-rate, T/W indicator, DSKY-displayed parameters, FDAI, X-Pointer, lunar contact light) and use of the visual aids involved (AOT and CSM target during docking, visual display of lunar surface and window reticle during landing, etc). Final sessions include malfunctions and failures leading to contingency operations.

Other part-task-training exercises and sessions are devoted to crew procedures such as abort monitoring during powered descent, various checkout operations, IMU alignment procedures that involve use of the AOT, DSKY programs and the like.

The part-task-training exercises are identified by the letters "PT" and a whole number (for example, PT 1). Sessions related to a particular exercise are identified by additional decimal numbers (for example, PT 1.1) that indicate the sequence of the session within the exercise. The runs within a session are listed in the sequence in which they occur.

#### 3.2.1.1 PT 1 - Purpose.

This exercise familiarizes the LM crew with operation, monitoring, activation, checkout, and evaluation of the LM subsystems.

##### 3.2.1.1.1. PT 1.1 - Subsystem Controls and Displays Operation.

This session provides a walk-through familiarization with the location, function, and operation of subsystem controls and displays. The runs are as follows:

Walk-through - control/display activation and deactivation of the following:

- Run 1 - Reaction Control Subsystem (RCS)
- Run 2 - Ascent and descent propulsion sections (APS and DPS)
- Run 3 - Electrical Power Subsystem (EPS)
- Run 4 - Environmental Control Subsystem (ECS)
- Run 5 - Explosive Devices Subsystem (EDS)
- Run 6 - Communications Subsystem (CS)
- Run 7 - Primary guidance, navigation, and control section (PGNCS)
- Run 8 - Abort guidance section (AGS)
- Run 9 - Stabilization and control section (SCS)
- Run 10 - Flight control section (FCS)
- Run 11 - Caution and warning section (CWS).

##### 3.2.1.1.2 PT 1.2 - Reaction Control Subsystem Operations.

This session familiarizes the LM crew with operations involved in initial activation and checkout of the RCS before LM-CSM separation, in flight and during lunar stay. The runs are as follows:



Walk-through and practice.

- Run 1 - RCS activation, checkout, pressurization, pressure checks, caution and warning indicator check, and valve flag status checks
- Run 2 - RCS hot and cold firing, pressure and quantity monitoring, and operations during powered ascent

Walk-through

- RCS malfunction diagnostic techniques
- RCS malfunction corrective techniques

Practice

- Run 3 - RCS selected malfunction diagnoses and corrective action (run 1 with malfunctions)
- Run 4 - RCS selected malfunction diagnoses and corrective action (run 2 with malfunctions).

### 3.2.1.1.3 PT 1.3 - Ascent Propulsion Section Operations.

This session familiarizes the LM crew with, and provides practice in, operations involved in initial activation, checkout, and use of the APS during ascent firings. The runs are as follows:

Walk-through and practice

- Run 1 - Checkout and monitoring of APS status before pressurization and after pressurization
- Run 2 - APS arming; automatic and manual ascent engine ignition; propellant, gas, fluid, and engine-performance monitoring

Walk-through

- APS malfunction diagnostic techniques
- APS malfunction corrective techniques

Practice

- Run 3 - APS selected malfunction diagnoses and corrective action (run 1 with malfunctions)
- Run 4 - APS selected malfunction diagnoses and corrective action (run 2 with malfunctions).

### 3.2.1.1.4 PT 1.4 - Descent Propulsion Section Operations.

This session familiarizes the LM crew with operations involved in initial activation, checkout, and use of the DPS during descent firings. The runs are as follows:

Walk-through and practice

- Run 1 - DPS activation, checkout, pressurization, pressure checks, and helium and propellant monitoring
- Run 2 - DPS arming, automatic and manual engine ignition, and engine-performance monitoring
- Run 3 - DPS landing and postlanding shutdown and venting

Walk-through

- DPS malfunction diagnostic techniques
- DPS malfunction corrective techniques

Practice

- Run 4 - DPS selected malfunction diagnoses and corrective action (run 1 with malfunctions)
- Run 5 - DPS selected malfunction diagnoses and corrective action (run 2 with malfunctions)
- Run 6 - DPS selected malfunction diagnoses and corrective action (run 3 with malfunctions).

3.2.1.1.5 PT 1.5 - Environmental Control Subsystem Operations.

This session provides practice in operations involved in activation and checkout of the ECS, and in consumables control. The runs are as follows:

Walk-through and practice

- Run 1 - Cabin fan activation; suit checkout; water management section, oxygen cabin pressure section and waste management section activation and checkout; cabin and ARS pressurization and pressure checks; and heat transport section backup equipment checkout
- Run 2 - Heat transport section checkout, LiOH canister replacement, suit checkout, and cabin and ARS pressurization

Walk-through

- ECS malfunction diagnostic techniques
- ECS malfunction corrective techniques

Practice

- Run 3 - ECS selected malfunction diagnoses and corrective action (run 1 with malfunctions)
- Run 4 - ECS selected malfunction diagnoses and corrective action (run 2 with malfunctions).

3.2.1.1.6 PT 1.6 - Portable Life Support System Operations.

This session familiarizes the LM crew with operations involved in PLSS donning, checkout of the EMU, and PLSS doffing and charging. The run is as follows:

Walk-through and practice

- Run 1 - TMG donning and doffing; PLSS preparation and checkout with and without ECS attachment; PLSS donning. Doffing, and charging; EMU checkout; PLSS communications checkout; and EOS management.

3.2.1.1.7 PT 1.7 - Electrical Power Subsystem Operations.

This session familiarizes the LM crew with operations involved in activation and checkout of the EPS. The run is as follows:

Walk-through and practice

- Run 1 - EPS activation, battery checkout, descent and ascent battery management, and lighting activation and control

Walk-through

- EPS malfunction diagnostic techniques
- EPS malfunction corrective techniques

Practice

- Run 2 - EPS selected malfunction diagnoses and corrective action (run 1 with malfunctions).



## 3.2.1.1.8 PT 1.8 - Communications Subsystem Operations.

This session familiarizes the LM crew with operations involved in activation, checkout, and use of the CS. The runs are as follows:

## Walk-through and practice

- Run 1 - VHF transmission activation and checkout, S-band activation, S-band antenna activation and manual slewing, TV camera enablement, and telemetry enablement
- Run 2 - Set up of four major modes of VHF and S-band transmission

## Walk-through

- Communications malfunction diagnostic techniques
- Communications malfunction corrective techniques

## Practice

- Run 3 - Communications selected malfunction diagnoses and corrective action (run 1 with malfunctions).

## 3.2.1.2 PT 2 - Purpose.

This exercise familiarizes the LM crew with activation, checkout, evaluation, operation, and monitoring of the LM guidance equipment and flight control section.

## 3.2.1.2.1 PT 2.1 - Guidance, Navigation, and Control Subsystem Operations.

This session familiarizes the LM crew with operations involved in activation, checkout, and operation of PGNCs and AGS equipment, including use of the DSKY, DEDA, and LM radar. The runs are as follows:

## Walk-through and practice

- Run 1 - LGS startup and initialization, and IMU startup (for RCS hot firing) and deactivation
- Run 2 - IMU startup, orientation determination, and realignment; AGC startup, checkout, and initialization; LGC update; and LR checkout
- Run 3 - AGS alignment and calibration, DSKY and DEDA operations at separation, RR checkout and lock-on, and descent orbit insertion
- Run 4 - Trajectory monitoring with RR, RR deactivation, and PGNCs/AGS operation during powered descent and landing
- Run 5 - IMU alignment, radar operation on lunar surface, and AGS deactivation
- Run 6 - Prelaunch LGC and AGS update, IMU and AGS alignment, and powered ascent program operations
- Run 7 - PGNCs/AGS coelliptic and rendezvous operations

## Walk-through

- PGNCs and AGS malfunction diagnostic techniques
- PGNCs and AGS malfunction corrective techniques

## Practice

- Runs 8 through 14 - PGNCs and AGS selected malfunction diagnoses and corrective action (runs 1 through 7 with malfunctions).

## 3.2.1.2.2 PT 2.2 - Flight Control Operations.

This session familiarizes the LM crew with monitoring operations required during automatic flight control and provides practice in manual attitude and translation control. The runs are as follows:

#### Walk-through and practice

- Run 1 - Flight control display monitoring during and after MPS thrusting
- Run 2 - Manual attitude control with descent stage attached and descent engine not thrusting
- Run 3 - Manual attitude control with descent engine firing (site selection maneuvers)
- Run 4 - Manual attitude control with rate of descent (ROD) thrust control and with manual throttle control (low gate to touchdown maneuvers)
- Run 5 - Manual ullage maneuvers
- Run 6 - Manual attitude control during ascent engine firing
- Run 7 - Manual attitude and translation control after ascent engine burnout (midcourse corrections and terminal rendezvous and docking maneuvers)
- Run 8 - Manual flight control maneuvers in pulse and direct modes
- Run 9 - Manual flight control in pulse and direct modes, with one or more RCS thrusters failed

#### Walk-through

- Flight control malfunction diagnostic techniques
- Flight control malfunction corrective techniques
- RCS malfunction diagnostic and corrective techniques , involving flight control

#### Practice

- Runs 10 through 18 - Selected flight control malfunction diagnoses and corrective action (runs 1 through 9 with malfunctions).

#### 3.2.1.3 PT 3 - Purpose.

This exercise familiarizes the LM crew with separation, rendezvous, and docking techniques.

#### 3.2.1.3.1 PT 3.1 - Separation Operations.

This session provides a walk-through of those activities involved in preparation for separation and active separation. The run is as follows:

#### Walk-through

- Run 1 - Automatic-separation monitoring, including landing gear deployment and manual separation.

#### 3.2.1.3.2 PT 3.2 - Rendezvous Operations.

This session familiarizes the LM crew with, and provides practice in, operations involved in rendezvous with the CSM. The runs are as follows:

#### Walk-through and practice

- Run 1 - Midcourse correction maneuvers and monitoring with PGNCs
- Run 2 - Manual rendezvous maneuvers
- Run 3 - Selected midcourse correction maneuvers and monitoring with PGNCs malfunction diagnoses and corrective action (run 1 with malfunctions)
- Run 4 - Manual rendezvous maneuvers (run 2 with malfunctions).



## 3.2.1.3.3 PT 3.3 - Docking Operations.

This session familiarizes the LM crew with, and provides practice in, operations involved in manual docking. The runs are as follows:

## Walk-through and practice

- Run 1 - Manual soft dock with hard suit in all modes
- Run 2 - Manual soft dock with soft suit in all modes
- Run 3 - Hard dock operations.

## 3.2.1.4 PT 4 - Purpose.

This exercise familiarizes the LM crew with powered descent landing, powered ascent, and abort techniques.

## 3.2.1.4.1 PT 4.1 - Landing Operations.

This session provides familiarization and practice with the automatic and manual techniques and LPD operations involved in the lunar landing. The runs are as follows:

- Run 1 - Landing-site change, using LPD procedures; manual landing, using ROD, manual throttle, and three attitude control modes
- Run 2 - Landing-site change, using LPD procedures; manual landing, using ROD, manual throttle, and three attitude control modes with selected RCS malfunctions (run 1 with malfunctions).

## 3.2.1.4.2 PT 4.2 - Launch and Ascent Operations.

This session familiarizes the LM crew with the automatic and manual techniques involved in lunar launch and ascent. The runs are as follows:

## Walk-through and practice

- Run 1 - Prelaunch preparation, ascent stage launch, and ascent monitoring through ascent engine cutoff
- Run 2 - Prelaunch preparation, ascent stage launch, and ascent monitoring through ascent engine cutoff with selected PGNCS malfunctions (run 1 with malfunctions).

## 3.2.1.4.3 PT 4.3 - Abort Procedures Operations.

This session provides practice with abort sequences that may be used in various mission phases. The runs are as follows:

## Practice

- Run 1 - AGS abort from coasting descent (external  $\Delta$  mode)
- Run 2 - AGS abort from coasting descent (direct transfer with descent engine)
- Run 3 - AGS abort from powered descent, using descent engine
- Run 4 - AGS abort from powered descent, using ascent engine
- Run 5 - AGS abort: low and fast with descent engine
- Run 6 - AGS abort from lunar surface
- Run 7 - AGS abort during coasting (powered ascent)
- Run 8 - AGS takeover during coelliptic sequence
- Run 9 - AGS abort from orbit insertion burnout through CSI burn

- Run 10 - AGS abort from CSI burn to CDH
- Run 11 - AGS abort from CDH burn through TPI
- Run 12 - AGS abort after TPI burn
- Run 13 - Manual rendezvous maneuvers with AGS
- Run 14 - PGNCS abort: minimum-time abort from lunar surface
- Runs 15 through 27 - AGS abort sequences with selected stabilization and control malfunctions (runs 1 through 13 with malfunctions).

#### 3.2.1.5 PT 5 - Purpose.

This exercise familiarizes the LM crew with an integrated sequence of activities involved in performing the lunar mission. The exercise is divided into 24 sessions; the beginning of each session corresponds to 1 of the 24 reset points. The sessions may be implemented separately or in combined sequential order, as considered appropriate for training purposes. Implementation of all sessions in sequential order constitutes nominal training for the entire mission. Each session consists of at least one nominal run. Most sessions, however, contain runs with the insertion of selected malfunctions.

##### 3.2.1.5.1 PT 5.1 - Systems Engineer Entry Into LM and Subsystem Activation.

This session provides familiarization with the Systems Engineer's activities from ingress to the LM, through the initial subsystem activation and checkout. The runs are as follows:

###### Walk-through and practice

- Run 1 - Systems Engineer enters LM, activates and adjusts EPS and lighting, activates LM ECS and transfers from CSM ECS, activates and checks communications equipment, and activates and checks RCS quad heaters.
- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

##### 3.2.1.5.2 PT 5.2 - Commander Entry Into LM.

This session familiarizes the LM crew with subsystem activation and checkout activities following the Commander's entry into the LM. The run is as follows:

###### Walk-through and practice

- Commander enters LM, establishes VHF communication, passes equipment from CM to Systems Engineer, installs drogue, activates descent/ascent stage subsystem equipments, and activates cabin fans.

##### 3.2.1.5.3 PT 5.3 - LGC Initialization.

This session provides familiarization with startup and checkout of the DSKY and AGS, initialization of the LGC and AGS, hot and cold firing RCS checkout, and continues subsystems activation and checkout. The runs are as follows:

###### Walk-through and practice

- Run 1 - Initialize and check DSKY AGS, update navigational parameters, activate and check RCS (hot and cold firing), enable IMU warmup and deactivate, check rate gyro assembly and waste management section, activate and check MPS and RCS, activate S-band and VHF communications equipment, check out ARS pressure integrity and suit fan operation, perform battery checks and establish backup power capability, activate window heaters, prepare food, and eat.
- Run 2 - This is a repetition of run 1, with insertions of selected malfunctions.

##### 3.2.1.5.4 PT 5.4 - IMU Alignment and Guidance Equipment Updating.

This session includes the activities involved in IMU alignment, LGC and AGS updating, and radar activation and test. The run is as follows:



## Walk-through and practice

- Run 1 - IMU warmup and coarse and fine alignment, activate and check out abort guidance equipment, activate and test RR and LR, activate and check out descent engine gimbal alignment, update LGC, activate all descent batteries and S-band communication, and verify propulsion displays for separation readiness.
- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

## 3.2.1.5.5 PT 5.5 - LM Separation From CSM.

This session is devoted to practice of the activities required in preparation and performance of the separation maneuver. The runs are as follows:

## Walk-through and practice

- Run 1 - Calibrate and align AGS to PGNCs, cross-check FDAI's, verify LM soft-dock configuration, activate docking lights and secure for separation, select modes for auto separation, count down and observe separation maneuver, monitor  $\Delta V$  and RCS shutdown, monitor LM stable attitude, and check out cabin pressure integrity.
- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

## 3.2.1.5.6 PT 5.6 - Transfer Orbit Insertion Operations.

This session involves activation and checkout of the rendezvous radar and realignment of the primary and abort guidance equipment in preparation for the transfer orbit insertion (TOI) maneuver. The runs are as follows:

## Walk-through and practice

- Run 1 - Orient LM for inspection and monitor for TOI; update  $\Delta V$  and time-to-go to thrusting parameters; activate and check out RR and monitor parameters; activate data transmission to CM; deactivate S-band, RR, and docking light; perform attitude hold IMU and AGS-PGNCs alignment and alignment checks; secure; select modes for TOI; arm descent engine; count down; and monitor automatic ullage.
- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

## 3.2.1.5.7 PT 5.7 - Preparation for Powered Descent.

This session familiarizes the LM crew with the activities associated with confirming the transfer orbit, and the subsystems status checks in preparation for powered descent, primarily in areas of propulsion, radar, electrical power, and guidance. The runs are as follows:

## Walk-through and practice

- Run 1 - Monitor TOI maneuver and changes in LM orientation; monitor descent engine shutdown and disarm engine; adjust tracking light, activate RR, and monitor parameters; check EPS and ascent stage and descent stage fluids status; verify RCS valve flag status; test landing radar; deactivate VHF data transmission; update  $\Delta V$  and time-to-go to thrusting parameters; and perform IMU alignment.
- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

## 3.2.1.5.8 PT 5.8 - Powered Descent Activities to High Gate.

This session is concerned primarily with practice of the guidance systems and engine performance monitoring and trajectory monitoring, during powered descent to high gate (10,000 feet). The runs are as follows:

## Walk-through and practice

- Run 1 - Perform PGNS - AGS alignment, set EPS for powered descent, select modes for powered descent, arm descent engine, count down and monitor automatic ullage, monitor descent engine ignition and engine gimbal alignment, prepare for PGNCs AGS difference check, perform DSKY and

DEDA altitude and altitude-rate difference checks, compare PGNCs output with MSFN, monitor EPS, check RCS and DPS consumables, determine landing radar data available, verify LGC acceptance of landing radar altitude data, and monitor trajectory for landing radar and PGNCs differences.

- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

#### 3.2.1.5.9 PT 5.9 - High Gate to Low Gate Activities.

This session familiarizes the LM crew with guidance, trajectory, and engine performance monitoring and alternate site selection activity during powered descent from high gate (10,000 feet) to low gate (700 feet). The runs are as follows:

##### Walk-through and practice

- Run 1 - Set event timer to high gate - low-gate countdown, monitor RCS and ascent stage propellants, monitor trajectory for landing radar and PGNCs difference, count down, monitor programmed pitch attitude change at high gate, perform final approach, and count down.
- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

#### 3.2.1.5.10 PT 5.10 - Manual Landing.

This session familiarizes the LM crew with all activities associated with the manual landing maneuver. The runs are as follows:

##### Walk-through and practice

- Run 1 - Verify initial vehicle velocities and attitudes at low gate; monitor engine consumables; verify acceptability of landing site; reduce altitude-rate; null lateral, forward, and horizontal velocities; reduce altitude-rate; secure for landing; observe activation of lunar contact light, and shut down descent engine.
- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

#### 3.2.1.5.11 PT 5.11 - Postlanding Vehicle Checkout and Evaluation.

This session provides practice in postlanding vehicle subsystem checkout and evaluation. DSP fuel venting, and subsystem shutdown. The runs are as follows:

##### Walk-through and practice

- Run 1 - Test vehicle stability, check fluid consumables and EPS, align AGS, deactivate VHF, adjust RR thermal balance, check and/or disable remaining subsystems, and vent DPS fuel.
- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

#### 3.2.1.5.12 PT 5.12 - Guidance Systems Alignment and EVA Preparation.

This session involves PGNCs and AGS alignments, completion of DPS venting, internal preparations of PLSS and EMU for first lunar exploration and donning of the EVA garments. The runs are as follows:

##### Walk-through and practice

- Run 1 - Align IMU and guidance sections; check out ARS pressure integrity; prepare equipment for first lunar exploration; don and check out EVA garments and associated PLSS and EOS equipment; vent DPS oxidizer; perform cabin and EMU leak tests; establish radar tracking of CSM; connect back to LM subsystems; pressurize LM cabin, doff and stow EVA garments, and recharge PLSS; prepare food and eat; and erect sleep station and sleep.
- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

#### 3.2.1.5.13 PT 5.13 - Prelaunch Checkout.

This session provides practice in prelaunch checkout and vehicle readiness activities (excluding PGNCs). The runs are as follows:



## Walk-through and practice

- Run 1 - Activate LGC and IMU, secure equipment, activate subsystems, check out RCS equipment (including RCS hot fire) and propulsion consumables, check out heat transport section, and coarse-align IMU.
- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

## 3.2.1.5.14 PT 5.14 - Primary Guidance Alignment Before Launch.

This session includes alignment of the PGNCs and startup, checkout, and initialization of the AGS before lunar launch. The runs are as follows:

## Walk-through and practice

- Run 1 - Align and check out IMU and guidance equipment, activate S-band steerable antenna, check out C&W status, select EPS modes for powered ascent, activate ECS tanks, and update PGNCs.
- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

## 3.2.1.5.15 PT 5.15 - Launch and Powered Ascent Activities.

This session provides practice in crew procedures required to complete the readiness of the PGNCs and AGS for launch, the countdown and launch operations, and the guidance system and vehicle performance-monitoring procedures during the ascent engine burn. The runs are as follows:

## Walk-through and practice

- Run 1 - Select DSKY guidance displays, monitor RR parameters, activate VHF voice, align AGS to PGNCs and cross-check, secure for launch, establish radar tracking of CSM, arm ascent engine, count down, monitor lift-off and initial pitch profile, enable ascent tie, perform PGNCs and AGS difference checks, perform DSKY and DEDA altitude and altitude-rate difference checks, monitor flight and consumables displays, disable ascent tie, monitor engine shutdown and LM orientation, and confirm correct orbit.
- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

## 3.2.1.5.16 PT 5.16 - Ascent Coast Operations.

This session involves monitoring and confirmation of the coasting parameters, trajectory monitoring, and updating of the PGNCs and AGS in preparation for the concentric sequence initiation maneuver. The runs are as follows:

## Walk-through and practice

- Run 1 - Monitor fluid consumables, flight displays, and RCS valve flag displays; monitor LM stable attitude and trajectory parameters; set tracking light; cross-check and update PGNCs and AGS with CSM navigational parameters; confirm DSKY time and  $\Delta V$ -to-go thrusting with MCC; and prepare LGC for next thrust phase.
- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

## 3.2.1.5.17 PT 5.17 - Concentric Sequence Maneuver Activities.

This session provides practice in procedures involved in the countdown and performance of the concentric sequence maneuver, propellant checks, and periodic subsystem checks with primary emphasis on the PGNCs and EPS during the ascent coast. The runs are as follows:

## Walk-through and practice

- Run 1 - Secure for thrust, count down, monitor automatic RCS firing and shutdown, verify LM stable attitude, cross-check and align PGNCs and AGS, monitor RR via DSKY, scan-check subsystem status, activate VHF voice, deactivate S-band, check propulsion consumables, check out EPS and RCS valve flag status, monitor trajectory parameters via PGNCs and AGS and CSM, and perform IMU alignment.
- Run 2 - This is a repetition of run 1, with insertion of malfunctions.

## 3.2.1.5.18 PT 5.18 - Circularization Maneuver.

This session familiarizes the LM crew with the activities associated with the performance and monitoring of the circularization maneuver. The run is as follows:

## Walk-through and practice

- Run 1 - Set timer, prepare LGC for next thrust phase, monitor LM attitude, secure for thrust, count down, monitor automatic RCS firing and shutdown, enable S-band, and cross-check and align PGNCs and AGS.

## 5.2.1.5.19 PT 5.19 - Coasting Before Terminal Phase.

This session familiarizes the LM crew with the monitoring tasks during coasting before terminal phase initiation. The run is as follows:

## Walk-through and practice

- Run 1 - Monitor change in LM orientation, monitor RR via DSKY, deactivate VHF, align AGS and PGNCs and cross-check, check propulsion consumables and valve status, scan-check subsystem status, monitor trajectory parameters via PGNCs and AGS and CSM, confirm DSKY time and V-to-go to thrusting with MCC, and prepare LGC for next thrust phase.

## 3.2.1.5.20 PT 5.20 - Terminal Phase Maneuvers.

This session encompasses all activities associated with countdown, performance and monitoring of the terminal phase initiation maneuver. The runs are as follows:

## Walk-through and practice

- Run 1 - Set timer, monitor LM stable attitude, scan-check displays, secure for thrust, count down, monitor automatic RCS firing and shutdown, cross-check FDAI's.
- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

## 3.2.1.5.21 PT 5.21 - First Midcourse Correction.

This session provides practice in activities associated with preparation for, and performance of, the first midcourse correction. The run is as follows:

## Walk-through and practice

- Run 1 - Monitor RR parameters, verify V and time-to-go with MSFN, dim tracking light, scan-check displays and verify RCS valve flag and consumables status, receive estimate of miss distance from MCC and set event timer, prepare LGC for next thrust phase, receive trajectory parameters from CSM, secure for thrust, count down, monitor automatic RCS firing, and monitor change in LM orientation.
- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

## 3.2.1.5.22 PT 5.22 - Second Midcourse Correction.

This session familiarizes the LM crew with the activities associated with preparation for, and performance of, the second midcourse correction. The run is as follows:

## Walk-through and practice

- Run 1 - Monitor change in LM orientation, monitor RR parameters, verify V and time-to-go, scan-check displays and verify RCS status, check out EPS, receive estimate of miss distance from MSFN and set timer, prepare LGC for next thrust phase, receive trajectory parameters from CSM, secure for thrust, count down, monitor automatic RCS firing, and monitor change in LM orientation.

## 3.2.1.5.23 PT 5.23 - Terminal Rendezvous Maneuvers.

This session familiarizes the LM crew with the sequence of activities associated with preparation, performance, and monitoring of the rendezvous gate maneuvers during terminal rendezvous. The runs are as follows:



## Walk-through and practice

- Run 1 - Monitor RR parameters, verify V and time-to-go, scan-check displays and verify RCS status, receive trajectory parameters from CSM, receive estimate of miss distance, count down, notify CSM and MSFN if rendezvous gate is bypassed, reset LGC for next thrust phase, monitor altitude request for next thrust time, and monitor automatic RCS firing.
- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

## 3.2.1.5.24 PT 5.24 - Docking and Crew Transfer.

This session familiarizes the LM crew with all activities associated with performance of LM docking maneuvers, vehicle deactivation, transfer of crew and equipment to the CSM, and LM jettison. The runs are as follows:

## Walk-through and practice

- Run 1 - Perform manual docking; activate VHF data to CSM; deactivate S-band; receive soft-dock verification; activate overhead floodlighting and deactivate docking light; pressurize LM CM interlock; deactivate ascent stage subsystems after hard dock, while maintaining PGNCs in attitude hold mode; prepare for stowage of drogue and probe; prepare equipment for transfer to CSM; secure cabin interior; connect to transfer umbilical; prepare LM for postjettison data transmission; and transfer to CSM.
- Run 2 - This is a repetition of run 1, with insertion of selected malfunctions.

## 3.2.2 FULL-MISSION-TRAINING EXERCISES AND SESSIONS.

Full-mission-training exercises are recommended only to the extent necessary to ensure achievement of effective coordination among MCC, the CSM, and the LM for total mission operation and to demonstrate that the desired level of proficiency developed through the part-task-training exercises has been achieved. Failures that require variation in normal crew procedures, as well as initiation of contingency operations, should be liberally introduced in all full-mission-training sessions.

The full-mission-training exercises are identified by the letters "FM" and a whole number (for example, FM 1). Sessions related to a particular exercise are identified by additional decimal numbers (for example, FM 1.1) that indicate the sequence of the session within the exercise. The runs within a session are listed in the sequence in which they occur. Scripting Data Sheets are not supplied for the full-mission training sessions; performance of part-task-training sessions PT 5.1 through PT 5.24 constitutes the full mission.

3.2.2.1 FM 1 - Purpose.

The exercise is intended to demonstrate that the desired level of proficiency, developed through part-task-training exercises, has been achieved, and to develop effective coordination among the LM and CSM crew and MCC.

## 3.2.2.1.1 FM 1.1 - LM CSM Operations.

This session, requiring AMS LMS operation, provides practice in coordination of vehicle operations and communication between the CM and LM crew. Emphasis should be placed on intervehicular communications and relay of information to MCC, LGC initialization, synchronization and updating activities, alignment and tracking operations, separation, and terminal rendezvous and docking activities. Mission phases that do not require coordination between the two simulated vehicles can be conducted in accelerated time. The runs are as follows:

## Practice

- Joint LM CSM operations and communications in flying nominal mission
- Joint LM CSM operations and communications, with selected LM failures (for example, RR, S-band, RCS thruster)
- Mission contingency, requiring CSM rescue of LM from parking orbit after lunar ascent
- LM abort from powered descent
- LM abort from coasting descent

## 3.2.2.1.2 FM 1.2 - LM MCC Operations.

This session, requiring LMS and simulated MCC, provides practice in LM MCC communication. Emphasis is placed on MCC support of the mission and crew via telemetry detection of simulated LM failures and monitoring of LM trajectory, guidance, and subsystem performance, and on LM and MCC coordination of mission activities. The runs are as follows:

## Practice

- LM nominal mission with maximum inclusion of subsystem failures
- Single crewman lunar launch and return to CSM.

## 3.2.2.1.3 FM 1.3 - LM CSM MCC Operations.

This session provides "dry run" assurance of the level of proficiency in vehicle management and control, and intervehicle and ground coordination required for a successful mission. A single run is provided, requiring the AMS and LMS and simulated or live MSFN network. Portions of this run can be performed in accelerated time.

- Practice of the lunar landing mission from earth launch through splashdown.

3.3 INSTRUCTOR USE OF SYLLABUS.

This portion of the section contains a general description of how the instructor might use the training syllabus and other information in this handbook to develop a training program for a particular mission. The training syllabus provides the instructor with an overview of the LMS training recommended for preparing the flight crew for a lunar landing mission. From this syllabus, the instructor can make a preliminary selection of exercises and sessions considered appropriate for the mission being trained. (This determination implies availability of an Apollo Operations Handbook or other document that defines the test and operational requirements for this mission.)

After the sessions are selected, the instructor prepares a sequence of the required Scripting Data Sheets, available in section 6 of volume II. He then reviews the reference crew procedures (section 3 of volume II) associated with the sessions. It may be desirable to remove those pages of procedures to make a more compact working package, or to reproduce them for attachment to the Scripting Data Sheets. The instructor should be thoroughly familiar with the procedures in section 3 of volume II. The instructor has the option of using the malfunctions recommended for inclusion in the sessions or of selecting alternates from the Malfunction Data list (section 2 of volume II) or from the abort procedure supplement of section 3 of volume II. The Scripting Data Sheets indicate the LMS initialization points suitable for the sessions. The instructor can thus select checklists appropriate for the sessions selected. Other checklists (LMS startup, prerun initialization, peripheral equipment readiness, and LMS shutdown) are required, regardless of the sessions selected.

During preparation of the sequence of training sessions, the instructor should determine what measurements will be recorded. Recommendations of this kind are not included in this handbook. Because the progression of training is largely dependent on the speed with which individual proficiency is achieved, recommendations as to the number of repetitions of sessions or runs are not included in this handbook.

3.4 REFERENCE MISSIONS.

## 3.4.1 DESIGN REFERENCE MISSION.

The design reference mission major events are listed in the first column of table 3-1. These major events correspond to the major events in DRM IIA.

## 3.4.2 SIMULATED REFERENCE MISSION.

The simulated reference mission major events are listed in the second column of table 3-1. These major events, except the lunar extravehicular activities, correspond to the major events in DRM IIA.

3.5 ABBREVIATIONS DEFINITIONS.

Definitions of abbreviations used in this document are in LM Abbreviation List, LLI 790-1 which is supplied under separate cover.



Table 3-1. Major Mission Events, Design Reference Mission  
Versus Simulated Mission

Design Reference Mission	Simulated Reference Mission	Remarks
Systems Engineer transfers to LM	Systems Engineer enters LMS cabin	During training, both crewmembers may enter LMS cabin at same time, for convenience. Commander is inactive while Systems Engineer performs LM activation.
Systems Engineer begins LM activation	Systems Engineer begins LM activation	
Pass over LM landing site	Pass over LM landing site	
Begin S-band communication with MSFN	Begin S-band communication with MSFN	
Cross lunar terminator rightward	Cross lunar terminator rightward	
Start of sunset	Start of sunset	
End of sunset	End of sunset	
Commander transfers to LM	Commander becomes active	
Start of earthset	Start of earthset	
LOS Goldstone	LOS Goldstone	
LOS Canberra	LOS Canberra	
End of earthset	End of earthset	
Start revolution No. 3	Start revolution No. 3	
Start of sunrise	Start of sunrise	
End of sunrise	End of sunrise	
Cross lunar terminator dayward	Cross lunar terminator dayward	
Start of earthrise	Start of earthrise	
AOS Goldstone	AOS Goldstone	
AOS Canberra	AOS Canberra	
End of earthrise	End of earthrise	
Pass over LM landing site	Pass over LM landing site	
Cross lunar terminator rightward	Cross lunar terminator rightward	
Start of sunset	Start of sunset	
End of sunset	End of sunset	
Begin independent maintenance of LM cabin	Begin independent maintenance of LM cabin	

Table 3-1. Major Mission Events, Design Reference Mission Versus Simulated Mission (cont)

Design Reference Mission	Simulated Reference Mission	Remarks
RCS ignition for LM/CSM separation	RCS ignition for LM/CSM separation	
LM/CSM separation	LM/CSM separation	
LM RCS shutdown	LM RCS shutdown	
LM/CSM separation distance: 58 feet	LM/CSM separation distance: 58 feet	
Start of earthset	Start of earthset	
End of earthset	End of earthset	
Descent engine ignition, initial level	Descent engine ignition, initial level	
Descent engine thrusting, low level	Descent engine ignition, low level	
Descent engine thrusting, high level	Descent engine thrusting, high level	
Descent engine shutdown	Descent engine shutdown	
Start revolution No. 4	Start revolution No. 4	
Start of sunrise	Start of sunrise	
End of sunrise	End of sunrise	
Cross lunar terminator dayward	Cross lunar terminator dayward	
Start of earthrise	Start of earthrise	
End of earthrise	End of earthrise	
Descent engine ignition, initial level	Descent engine ignition	
Descent engine thrusting low level	Descent engine ignition, low level	
Descent engine thrusting, high level	Descent engine thrusting, high level	
Acquire LOS on LM landing site	Acquire LOS on LM landing site	
Attain 40,000-foot altitude above landing site	Attain 40,000-foot altitude above landing site	
Attain 25,000-foot altitude above landing site	Attain 25,000-foot altitude above landing site	
Attain high gate	Attain high gate	
Descent engine thrust reduction	Descent engine thrust reduction	
Attain low gate	Attain low gate	



Table 3-1. Major Mission Events, Design Reference Mission  
Versus Simulated Mission (cont)

Design Reference Mission	Simulated Reference Mission	Remarks
Descent engine thrust reduction	Descent engine thrust reduction	
Vertical descent	Vertical descent	
Lunar touchdown	Lunar touchdown	
LM postlanding checkout and preparation for first lunar exploration	LM postlanding checkout and preparation for first lunar exploration	
Begin first lunar exploration period		Not simulated
Commander first contacts lunar surface		Not simulated
Systems Engineer first contacts lunar surface		Not simulated
End first lunar exploration		Not simulated
Begin internal LM activity	Begin internal LM activity	
AOS - Madrid	AOS - Madrid	
LOS - Canberra	LOS - Canberra	
AOS - Goldstone	AOS - Goldstone	
End internal LM activity	End internal LM activity	
Begin second lunar exploration period		Not simulated
LOS - Madrid	LOS - Madrid	
AOS - Canberra	AOS - Canberra	
End second lunar exploration period		Not simulated
Begin internal LM activity	Begin internal LM activity	
End internal LM activity	End internal LM activity	
Begin third lunar exploration		Not simulated
LOS - Goldstone	LOS - Goldstone	
End third lunar exploration		Not simulated
Begin internal LM activity	Begin internal LM activity	
End internal LM activity	End internal LM activity	
Begin fourth lunar exploration		Not simulated
AOS - Madrid	AOS - Madrid	
LOS - Canberra	LOS - Canberra	
End fourth lunar exploration		Not simulated

Table 3-1. Major Mission Events, Design Reference Mission Versus Simulated Mission (cont)

Design Reference Mission	Simulated Reference Mission	Remarks
Begin prelaunch preparation period	Begin prelaunch preparation period	
Begin preascent checkout	Begin preascent checkout	
AOS - Grand Turk	AOS - Grand Turk	
AOS - Cape Kennedy	AOS - Cape Kennedy	
End lunar stay	End lunar stay	
Ascent engine ignition - begin vertical rise	Ascent engine ignition - begin vertical rise	
LM liftoff	LM liftoff	
Begin rapid pitchover maneuver	Begin rapid pitchover maneuver	
Lose LOS on LM landing site	Lose LOS on LM landing site	
Ascent engine shutdown	Ascent engine shutdown	
Cross lunar terminator rightward	Cross lunar terminator rightward	
Start of sunset	Start of sunset	
End of sunset	End of sunset	
AOS - Elgin	AOS - Elgin	
RCS ignition for concentric sequence initiation burn	RCS ignition for concentric sequence initiation maneuver burn	
Start of earthset	Start of earthset	
End of earthset	End of earthset	
RCS shutdown	RCS shutdown	
AOS - Corpus Christi	AOS - Corpus Christi	
Start of sunrise	Start of sunrise	
End of sunrise	End of sunrise	
Start of earthrise	Start of earthrise	
End of earthrise	End of earthrise	
RCS ignition for circularization maneuver burn	RCS ignition for circularization maneuver burn	



Table 3-1. Major Mission Events, Design Reference Mission Versus Simulated Mission (cont)

Design Reference Mission	Simulated Reference Mission	Remarks
RCS shutdown	RCS shutdown	
RCS ignition for terminal phase initiation maneuver burn	RCS ignition for terminal phase initiation maneuver burn	
RCS shutdown	RCS shutdown	
Acquire LOS on LM landing site	Acquire LOS on LM landing site	
RCS ignition for first mid-course correction	RCS ignition for first mid-course correction	
RCS shutdown	RCS shutdown	
RCS ignition for second midcourse correction	RCS ignition for second midcourse correction	
RCS shutdown	RCS shutdown	
AOS - Guaymas	AOS - Guaymas	
Lose LOS on LM landing site	Lose LOS on LM landing site	
Bypass first rendezvous gate	Bypass first rendezvous gate	
Cross lunar terminator rightward	Cross lunar terminator rightward	
RCS ignition for second rendezvous gate	RCS ignition for second rendezvous gate	
RCS shutdown	RCS shutdown	
Start of sunset	Start of sunset	
End of sunset	End of sunset	
RCS ignition for third rendezvous gate	RCS ignition for third rendezvous gate	
RCS shutdown	RCS shutdown	
RCS ignition for fourth rendezvous gate	RCS ignition for fourth rendezvous gate	
RCS shutdown and begin docking maneuver	RCS shutdown and begin docking maneuver	
Attain 500-foot range to CSM	Attain 500-foot range to CSM	
Start of earthset	Start of earthset	
LOS - Madrid	LOS - Madrid	
End of earthset	End of earthset	
Attain 50-foot range to CSM at zero-ft/sec range rate	Attain 50-foot range to CSM at zero-ft/sec range rate	

Table 3-1. Major Mission Events, Design Reference Mission  
Versus Simulated Mission (cont)

Design Reference Mission	Simulated Reference Mission	Remarks
Begin initial docking  Initial docking completed - begin final docking  Final docking completed - begin transfer of LM crew and equipment	Begin initial docking  Initial docking completed - begin final docking  Final docking completed - begin transfer of LM crew and equipment	





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