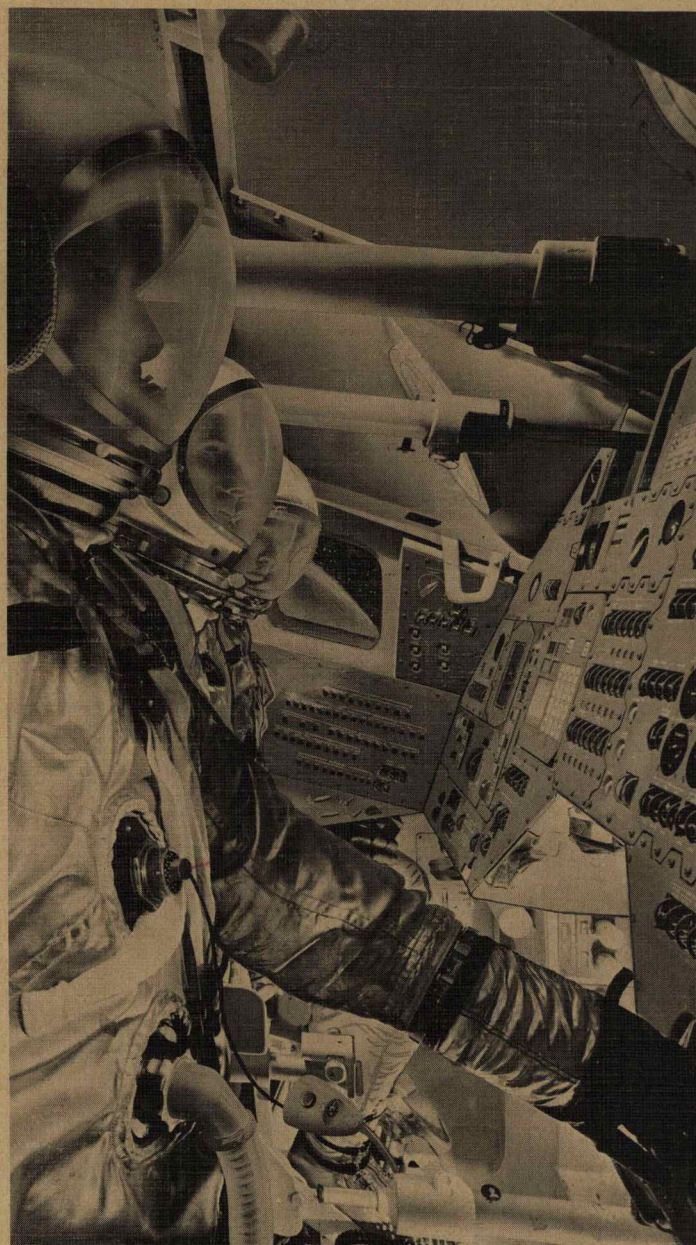


Preliminary

APOLLO MISSION SIMULATOR INSTRUCTOR HANDBOOK

VOLUME I — DESCRIPTION



Prepared by:

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PRELIMINARY

APOLLO MISSION SIMULATOR

INSTRUCTOR HANDBOOK

(INITIAL DELIVERED CONFIGURATION)

VOLUME I: DESCRIPTION

Contract NAS9-150
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Prepared by North American Aviation, Inc.
Space and Information Systems Division
Apollo Site Activation and Logistics
Field Engineering and Training — Dept. 671

APOLLO MISSION SIMULATOR INSTRUCTOR HANDBOOK

FOREWORD

Paragraph 10.10 of Exhibit I to Contract NAS9-150 specifies that NAA will provide training procedures and handbooks for the NASA conducted training associated with training equipment provided by NAA. This book is Volume I of a three-volume Instructor Handbook for the initial delivered configuration of the Apollo Mission Simulator in compliance with the exhibit. Compatibility of contents with the simulator equipment is to be accomplished by hardware verification during acceptance demonstration at the subcontractor's facility. Prior to such verification, the accuracy and validity of the handbook contents are unconfirmed. Under these circumstances, it must be understood that where the AMS is not as described, and/or will not provide the simulation required by the handbook contents, the handbook is to be adjudged in error. Under no circumstances shall any of the handbook contents be interpreted as design requirements data.

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APOLLO MISSION SIMULATOR INSTRUCTOR HANDBOOK

VOLUME I

INTRODUCTION

The purpose of this handbook is to provide detailed instructions for using the initial delivered configuration of the Apollo Mission Simulator (AMS) to train flight crew personnel for Apollo mission 204A. The handbook is comprised of three volumes. This volume (Volume I, Description) describes the AMS and the systems and missions simulated. Volume II (Operation and Utilization) provides instructions for operating the simulator, instructor data on computer programs, and a recommended syllabus of training sessions for accomplishing flight crew training for mission 204A in the AMS. Volume III (Scripting Material) contains the material for making up a complete instructor-operator data package for each training session in the syllabus. Volume III is loose-leaf bound to permit removal of contents for copying.

Volume I is divided into three sections. Section 1 (AMS Description) describes the simulator in terms and depth sufficient to allow the instructor to become thoroughly familiar with the equipment. The description is supplemented with illustrations of the major equipment groups and operating stations. Tables, keyed to the illustrations, identify the controls and displays and briefly state the function of each.

Section 2 (System Simulation) contains a description of each simulated spacecraft system. Each discussion is supported with a spacecraft system data flow diagram in which the simulated malfunctions and telemetry points are depicted. The descriptions and flow diagrams are for two purposes: as a briefing media for flight crew members using the simulator and as instructor background for effective use of malfunctions and realistic simulation of MSFN.

Section 3 (Nominal Training Mission) provides a description of the overall Apollo mission to be used as a training media in the AMS. The mission is comprised of mission 204A events as performed in the initial delivered AMS configuration. All sessions in the syllabus in Volume II are with respect to the nominal training mission.

TECHNICAL REPORT INDEX/ABSTRACT

ACCESSION NUMBER						DOCUMENT SECURITY CLASSIFICATION		
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DESCRIPTIVE TERMS								
<p>Consists of three volumes, this being Volume 1. This volume contains descriptions of the Apollo Mission Simulator: Instructor Operator Station, Simulated Command Module, Computer Complex (including Peripheral Equipment), Visual Simulation System, Spacecraft Systems Simulated, Simulation of Spacecraft Systems, and the Nominal Training Mission (including Program Initiation Points).</p>								
ABSTRACT								
<p>This handbook is Volume 1 of a preliminary edition of the Apollo Mission Simulator Instructor Handbook to be used by NASA instructors in operating the simulator for training purposes. This volume provides an instructor oriented description of the simulator.</p>								

APOLLO MISSION SIMULATOR INSTRUCTOR HANDBOOK

SECTION 1

DESCRIPTION

1.1 GENERAL DESCRIPTION

The purpose of this section of the handbook is to provide sufficient Apollo Mission Simulator (AMS) descriptive information to the instructor-operator for effective operation of the simulator without resource to other AMS documentation.

The AMS is a fixed-base training device capable of simulating the characteristics of space vehicle systems performance and flight dynamics. Space vehicle flights are simulated in a one-gravity environment by means of computer-controlled simulation of system parameters, flight dynamics, and visual perspective. Instructor observation and control are performed at the operator station. The simulator provides training of Apollo flight crew members in the operation of spacecraft systems, space navigation, and crew procedures for space missions. In addition to normal spacecraft operation, the AMS simulates malfunctioning systems and degraded systems performance.

There are two complete simulators. The initial AMS will be located at the Manned Spacecraft Control Center (MSCC), Houston, Texas. The second will be at Cape Kennedy, Florida. Configuration of both simulators is essentially the same with the only significant difference being in facility layout.

A facility layout drawing for the MSC is depicted in figure 1-1. Identified in the layout drawing and table 1-1 are the major subsystems and each AMS unit. Conditioned air is supplied by the housing facility directly to the simulator. The range of equipment operating air temperature is preset. Each cabinet unit excluding computer and IOS consoles has temperature sensing circuits which prohibit operating under excessive temperature conditions. Warning horns are located at the IOS and cabinet 38.

The computer housing area is a clean area with cooling air supplied through filters at the air intake of the computers. Cable entry and exit is from the bottom rear of each cabinet-console assembly. Subflooring is used to accommodate cabling and act as a plenum for cooling-air exhaust outlets. Figure 1-1 includes AMS cable-run layout.

1.2 POWER

The power for the AMS is delivered to power cabinet 32 by the facility where it is distributed to the various subsystems. The facility power available is 60-cycle 3-phase 4-wire 120/208 volts up to a maximum of 500 kva. The facility power is routed through circuit breakers to two major distribution points, simulator power and utility power.

APOLLO MISSION SIMULATOR INSTRUCTOR HANDBOOK

1.2.1 UTILITY POWER

There is a set of bus bars for utility power routed independently from the rest of the system. This power supplies all of the convenience outlets located throughout the AMS. It also supplies the utility 26-volt power used to operate lights and relays which should be enabled even when the rest of the system is off, for example, cabinet overhead lights and relays, power status lights, and emergency off lights.

1.2.2 SIMULATOR POWER

The simulator power, except of utility power is routed through a main circuit breaker, which can disconnect the entire simulator. After the main circuit breaker are the main power buses from which the power is divided into six groups.

- Life support
- 400-cycle motor generator
- Computer complex
- Data conversion equipment
- Peripheral
- Visual

Each group has four lines coming from the main power buses. There is a circuit breaker and a contactor in series for each group. Switching of power to these groups is accomplished by the sequencing circuitry, which operates in two modes controlled by switch lights on the main power panel located in cabinet 33.

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Table 1-1. AMS Equipment Arrangement

Unit No.	Unit Name	Description
<u>POOLED COMPUTER AREA</u>		
51	DDP-224	
59	DDP-224 fully buffered channel (FBC)	
50	DDP-24 and direct memory access (DMA)	
58	Card reader	
60	Card punch	
57	Printer	
54	Magnetic tape units 3 and 4	
53	Magnetic tape units 1 and 2	
55	DDP-24 FBC	
52	CCC input/output (I/O) (3)	
49	DDP-24 and DMA	
48	DDP-24 FBC	
28	Peripheral cabinet, data conversion equipment (DCE)	Contains portions of the internal DCE. These are SCS hand control electronics, which provide hand control inputs to the computer, and the G&N word buffer, which permits computer to interface with PCM-TM encoder (cabinet 30) for G&N 40-bit word.
44	Malfunction insertion unit (MIU)	Contains Computer Control Corporation (CCC) logic cards, relay cards, and associated power supplies. Unit provides for entry of malfunction codes to computer.
41	Digital bit input	Contains CCC logic cards and associated power supplies. Unit provides for entry of single-bit switch closures to computer.
47	Analog-to-digital (A/D) converter - integrated up-data link (IUDL) - G&N buffer	Contains CCC logic cards, associated power supplies, and switching panel. IUDL section provides data tie-in with integrated mission control center (IMCC). The A/D section converts analog information to digital information to be used by computer. G&N buffer provides serial G&N word for telemetry simulation.
43	Digital bit input	Contains CCC logic cards and associated power supplies. Unit provides for entry of single-bit switch closures to computer.
46	Computer interface control box	Contains CCC logic cards and associated power supplies. Unit directs signals between computers and all other units concerned with data conversion.
45	Interface junction box	Contains cabling and connectors. Unit serves as patch panel between data conversion equipment and remainder of simulator.

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Table 1-1. AMS Equipment Arrangement (Cont)

Unit No.	Unit Name	Description
<u>POOLED COMPUTER AREA (Cont)</u>		
81	Digital word input (DWI)	Contains CCC logic cards and associated power supplies. Unit provides for entry of multi-bit words to computer.
42	Digital system output	Contains CCC logic cards and associated power supplies. Unit provides for outputs of single bit and multi-bit messages from computer to simulator.
82	Digital system output	Same as unit 42.
65	Digital systems output	Same as unit 42.
66	Digital-to-analog (D/A) converter	Contains CCC logic cards and associated power supplies. Unit converts digital information to analog information for display use.
67	D/A converter	Same as unit 66.
68	D/A converter	Same as unit 66.
75	D/A converter	Same as unit 66.
77	Peripheral cabinet, DCE	Contains analog-to-digital (A/D) converters and digital-to-analog (D/A-F) (fast), which are used to convert analog signals to digital information and vice versa.
56	Peripheral cabinet, DCE	Contains analog resolver (A/R) units which accept analog signals from digital-to-analog (D/A) converters and drive synchro resolvers and control transformers, primarily in instruments.
40	Switching cabinet (guidance and navigation)	Contains relay logic cards, and circuit interrupter cards. Unit drives digital displays in the IOS. Unit contains relays that are associated with the command module, stabilization control system (SCS), inertial measurement unit (IMU), Greenwich mean time (GMT), and computer control system.
39	Switching cabinet (in-flight test subsystem and voice communications)	Contains amplifiers, filters, relays, and network cards. Unit simulates audio signals representative of radio frequency, VHF/AM, and S-band communication systems, interphone system, and astro loops (to GSE umbilical) and the emergency key.
62	Peripheral cabinet, DCE-DWO	Same as unit 42.
34	Peripheral cabinet (up-data link telemetry and simulation of digital command system)	Contains relay cards, network cards, and the 400-cycle inverter. Provides information for telemetry and 400-cycle power to data storage unit in the C/M.
30	Telemetry cabinet 1	Contains line drivers, associated power supply, pulse code modulation fault controls, attenuator, monitor test shelf. Unit accepts system faulting control signals from computer and IOS to provide for systems faulting.
76	Peripheral cabinet, biomedical	Contains GFE biomedical tape recorder used to supply bio-med signals to PCM telemetry system.

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Table 1-1. AMS Equipment Arrangement (Cont)

Unit No.	Unit Name	Description
<u>POOLED COMPUTER AREA (Cont)</u>		
32	Power cabinet	Contains meters, switches, bus bars, contactors, motor starters, circuit breakers, and the main power control panel. Provides power to complete simulator.
33	Power cabinet	Same as unit 32.
37	Peripheral cabinet (switching and power distribution)	Contains circuit breakers, relay logic cards and switching cards. Provides power distribution and necessary electronic switching for proton detection system and delta V.
36	Servo cabinet	Contains servos, servo amplifiers, network cards and power supplies. Unit provides signals to drive instruments and displays in the C/M and IOS.
35	Peripheral cabinet (switching)	Contains crystal can relays, mercury relays, and power relays. Unit provides information to magneline indicator in IOS, sequence control group, emergency detection system, and caution warning system (CWS).
38	Peripheral cabinet (aural simulation)	Contains audio mixer preamp, power amp, noise generator, voltage controlled attenuator, and filter, plus associated power supplies. Simulates noise representing booster, escape, and aerodynamic effects during launch and re-entry.
80	Switching cabinet	Contains D/R units, resolver-digital units, and relay cards. Unit drives instruments in C/M and receives resolver-type information from C/M, and transforms information to digital data for computer use.
63	Peripheral cabinet, DCE	Contains digital resolver units (D/R), which accept digital words and provide output signals representing analog functions that drive displays using 400-cps power as input signals.
<u>TELEMETRY CONSOLE</u>		
29	Telemetry console	
<u>RECORDERS AND PLOTTERS</u>		
27	X-Y plotter	
26	X-Y plotter	
25	X-T recorder 3	
24	X-T recorder 2	
23	X-T recorder 1	
<u>VISUAL PERIPHERY EQUIPMENT</u>		
74	Switching cabinet	Contains D/R units and relay cards. Unit drives instruments in the visual system.

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Table 1-1. AMS Equipment Arrangement (Cont)

Unit No.	Unit Name	Description
<u>VISUAL PERIPHERY EQUIPMENT (Cont)</u>		
73	Rendezvous window 4 equipment cabin cabinet	Contains electronics for celestial sphere, electronics for mission effects projector, electronics for sun shafting and associated power supplies. Unit provides necessary signals for infinity image system display.
72	Rendezvous window 2 equipment cabinet	Same as unit 73.
71	Landing window 5 equipment cabinet	Same as unit 73.
70	Landing window 1 equipment cabinet	Same as unit 73.
10	Telescope mission effects projector (MEP) equipment cabinet	Contains electronics for MEP and for celestial sphere and associated power supplies. Unit provides signals to simulate visual display in conjunction with telescope.
9	Sextant and telescope equipment cabinet	Contains electronics for shaft and trunnion angle readout, plus electronics for sextant and telescope; also, associated power supplies.
8	Power equipment cabinet	Contains relay assembly, circuit breaker panel, variac panel and bus bar assembly. Unit provides controls for all power in visual system.
7	Visual equipment cabinet	Contains video monitor, video slide pickup, camera control maintenance control panel, sync generator, and associated power supplies. Unit controls TV pickup for rendezvous and docking model house, and also, controls video display presentation for C/M.
6	Servo equipment cabinet	Contains servo amplifier, summing cards, test panel, and associated power supplies. Unit provides servo drive signals for rendezvous and docking model house.
61	Visual power cabinet	Provides power control and subpower distribution for all visual equipment. Receives power inputs from main power distribution cabinet 32. Contains contactors, circuit breakers, control switches, and bus bars.
11	Rendezvous and docking house	Contains model of target vehicle, TV camera equipment, and drive system for target vehicle. Provides C/M with visual display of simulated target vehicle during rendezvous and docking maneuver.
<u>INSTRUCTOR STATION</u>		
14	IOS console 1	
15	IOS console 2	
16	IOS console 3	
17	IOS console 4	
18	IOS console 5	
19	IOS console 6	

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Table 1-1. AMS Equipment Arrangement (Cont)

Unit No.	Unit Name	Description
<u>INSTRUCTOR STATION</u>		
20	IOS console 7	
4	Interface cabinet, SCM and IOS	Used for patching signals to SCM and IOS from other AMS cabinets. Contains connectors, jumper wires, terminal boards, and convenience outlets.
64	Camera control unit	Contains electronics associated with cameras for closed circuit television system.
<u>SIMULATED COMMAND MODULE</u>		
3	Compressor cabinet	Contains equipment to furnish air supply for life system equipment in C/M.
5	Window optical assembly	Contains relay mirrors, lens, and other optical imaging devices that form infinity imaging system for that particular window. The MEP for each assembly is also included.
83	Window optical assembly	Same as unit 5.
2	Command module base	
1	Apollo mission simulator command module	
12	Sextant	
<u>SIMULATED COMMAND MODULE (Cont)</u>		
13	Telescope	
85	Window optical assembly	Contains relay mirrors, lens, and other optical imaging devices that form infinity imaging system for that particular window. The MEP for each assembly is also included.
86	Window optical assembly	Same as unit 85.

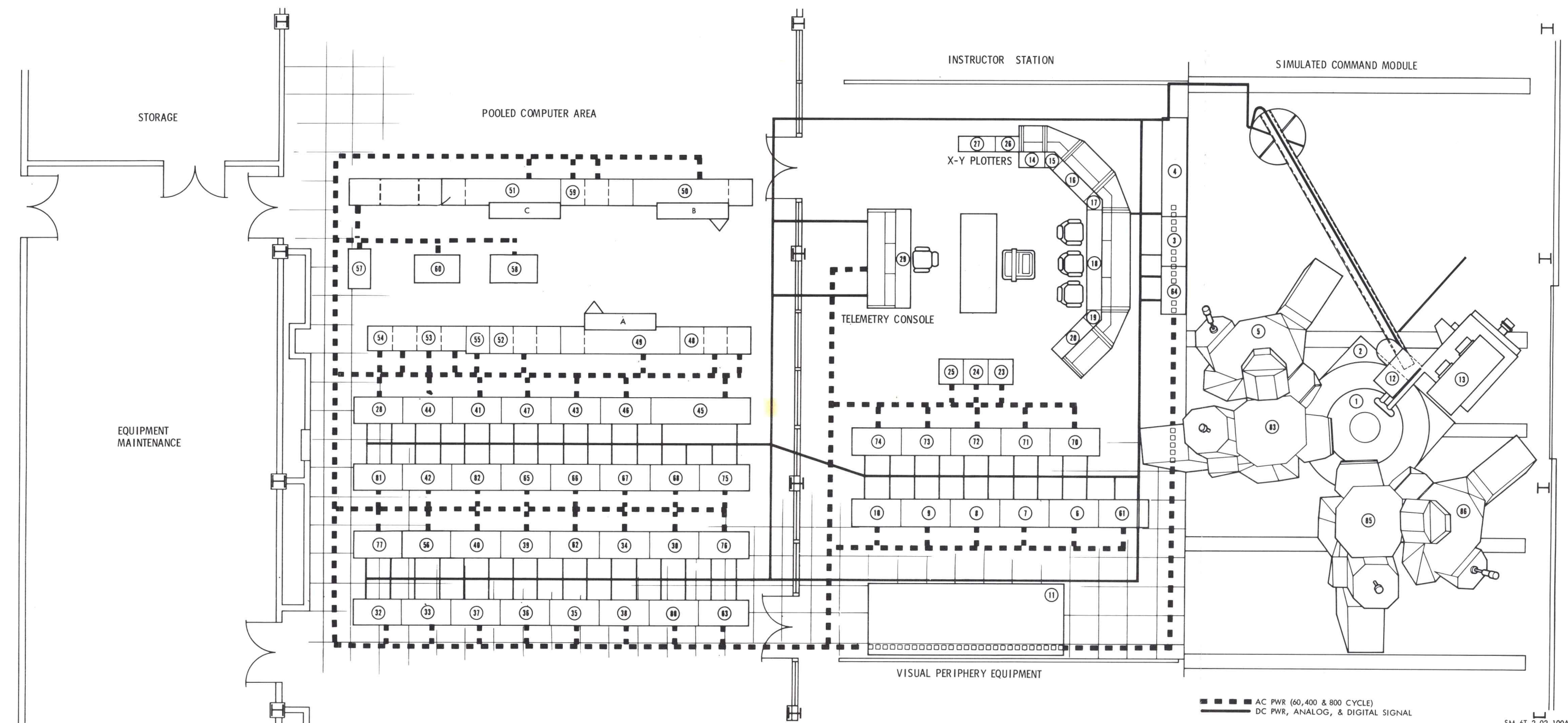


Figure 1-1. Facilities Layout

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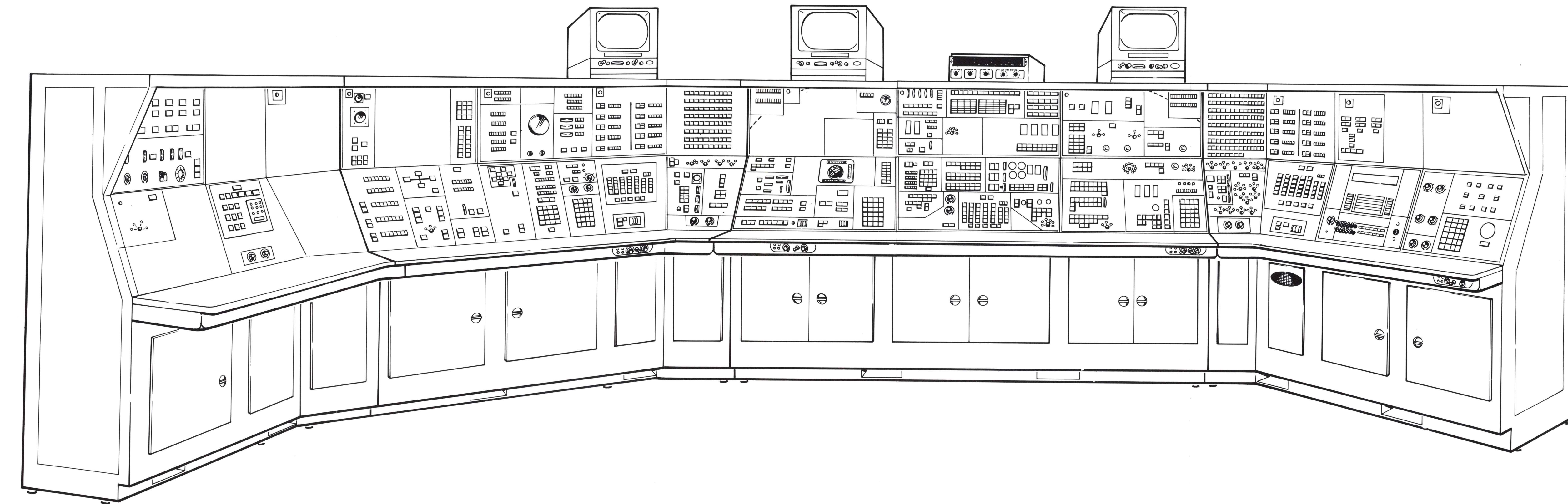
1.3 INSTRUCTOR-OPERATOR STATION.

The station provides the instructor-operator with the means to control the simulator, monitor the performance of the flight crew, and provide aural cues required for crew training. The instructor-operator consoles provide the following capabilities:

1. Control simulator operation.
2. Record training evaluation parameters.
3. Select and control simulated malfunctions.
4. Control computer operation.
5. Communicate with flight crew and support personnel.
6. Monitor and control trainer support systems.

The instructor-operator station (IOS) is a U-shaped console structure designed to accommodate three instructor-operators. The purpose of the wrap-around design is to provide maximum visibility of all control panels from the master (center) instructor station. Each console section has independent fluorescent overhead lighting and storage space under the desk area. Console-cabinet sections are slope-faced surfaces partitioned to allow transport by forklift.

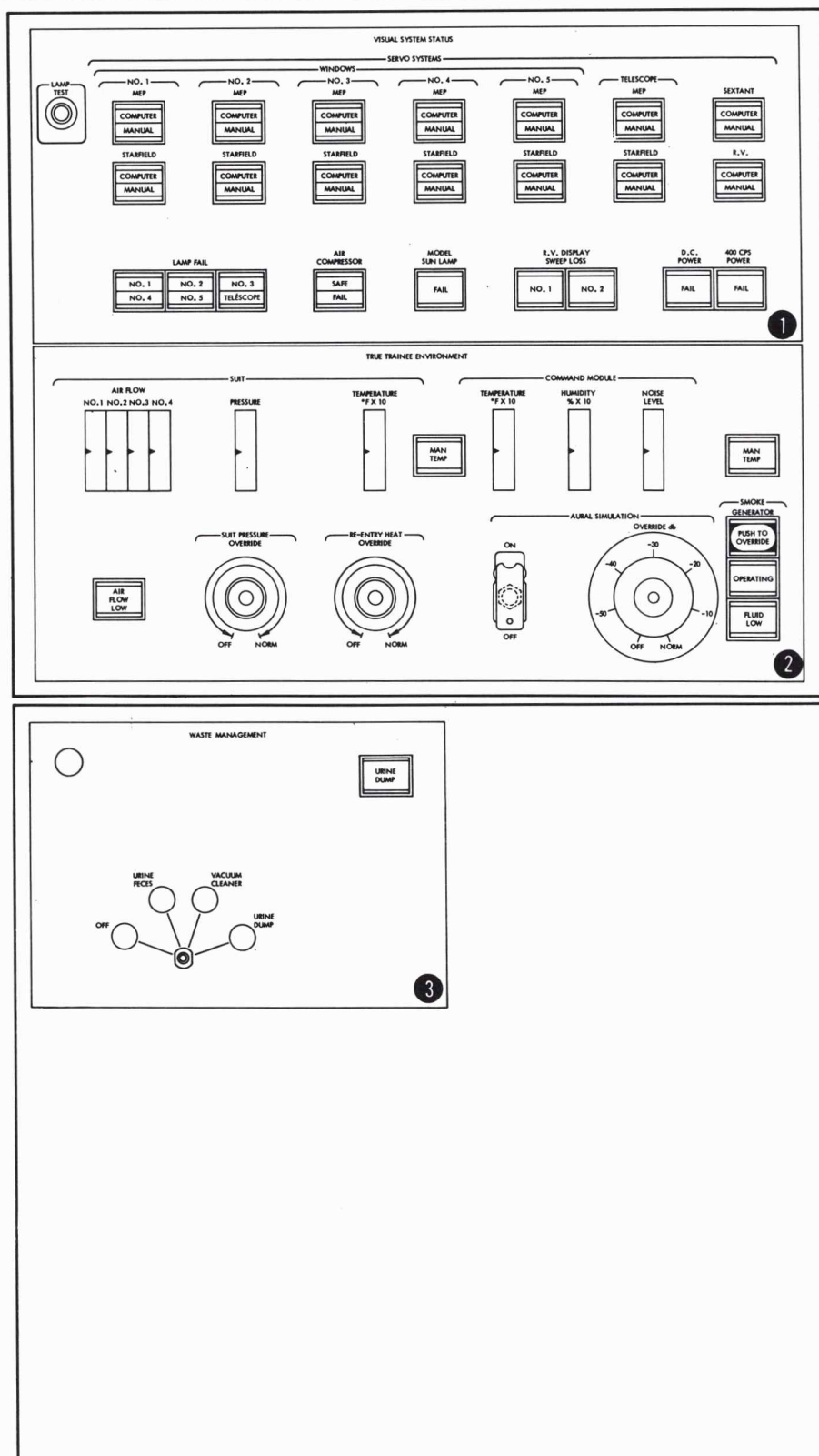
The IOS (figure 1-2) contains repeater displays of the instruments within the simulated command module (SCM) and additional controls and displays as required to enable the instructors to monitor and direct effectively the training situations. Figures 1-3 and table 1-2 identify each of the panels located on the IOS. These panels are grouped in sections that perform separate identifiable functions.



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Figure 1-2. Instructor-Operator Simulator Console Physical Perspective

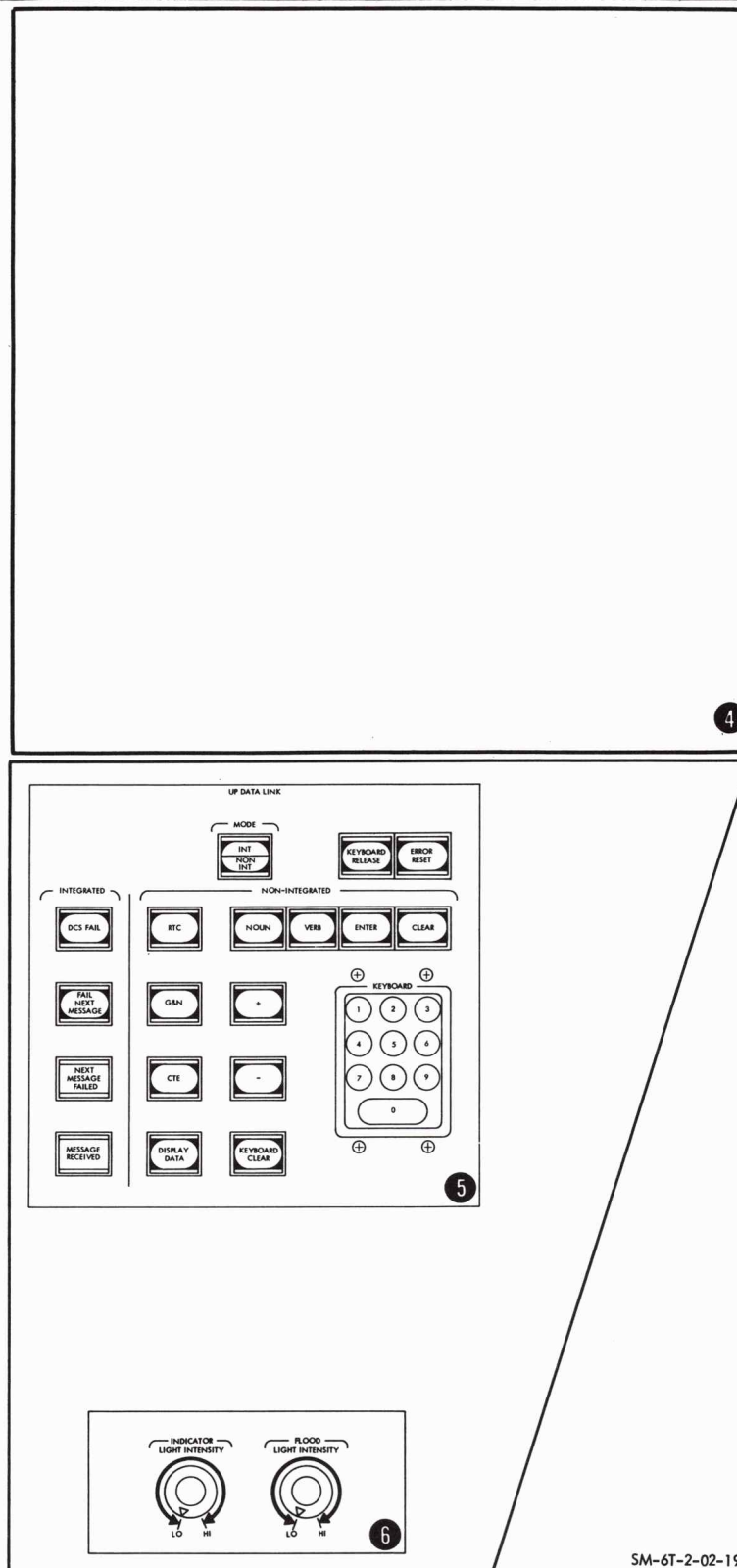
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Figure 1-3. Instructor-Operator Simulator Console (Sheet 1 of 14)

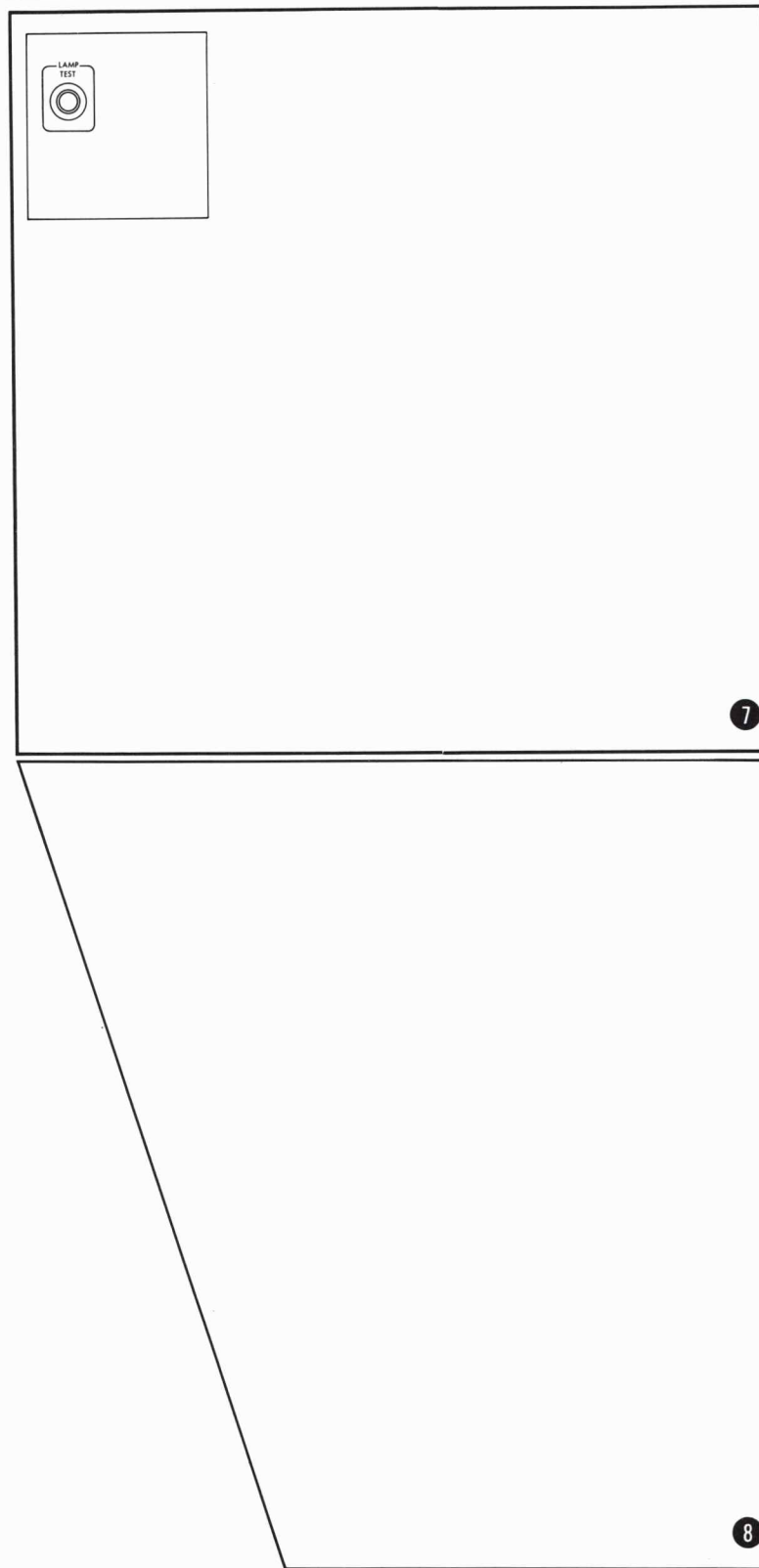
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Figure 1-3. Instructor-Operator Simulator Console (Sheet 2 of 14)

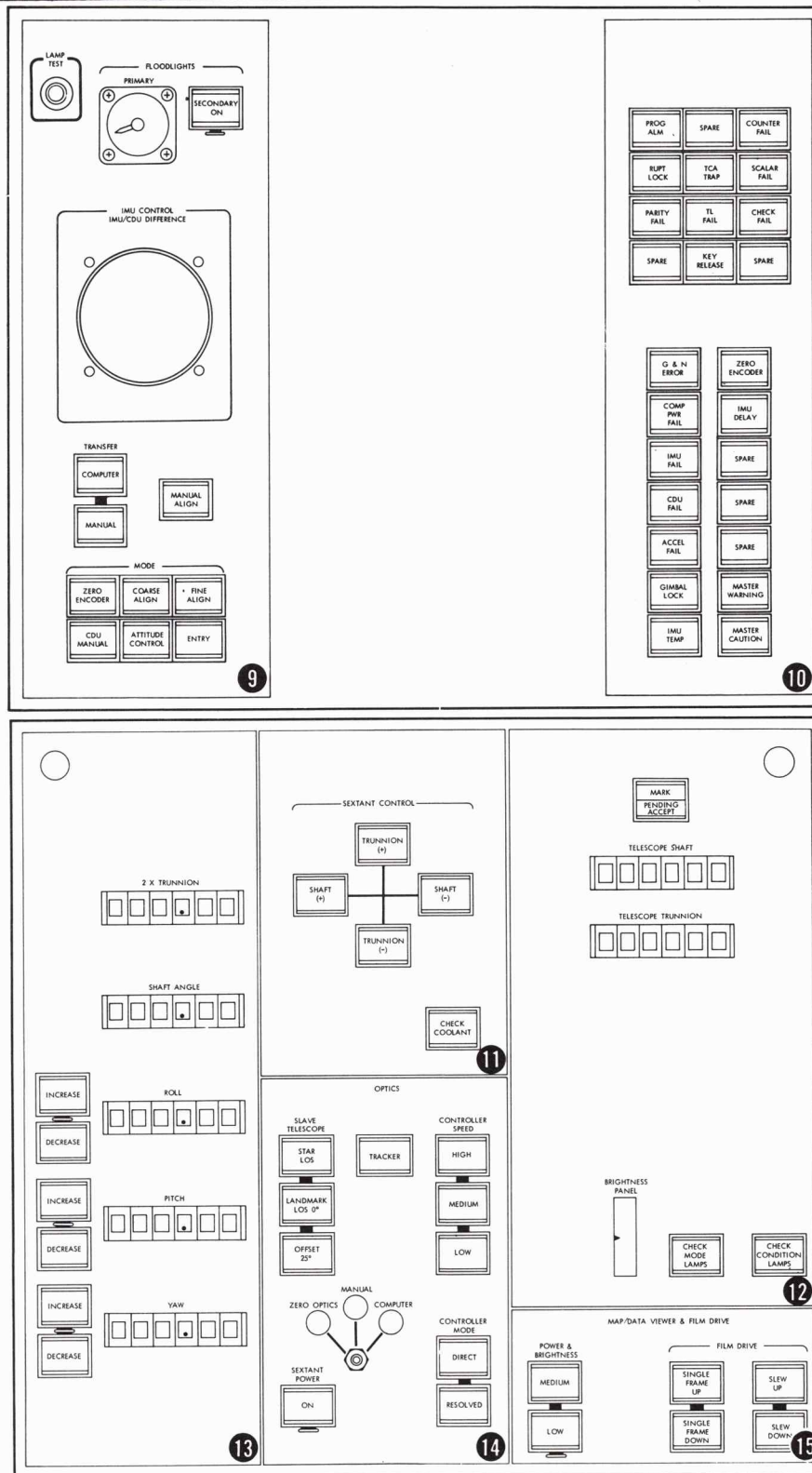
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Figure 1-3. Instructor-Operator Simulator Console (Sheet 3 of 14)

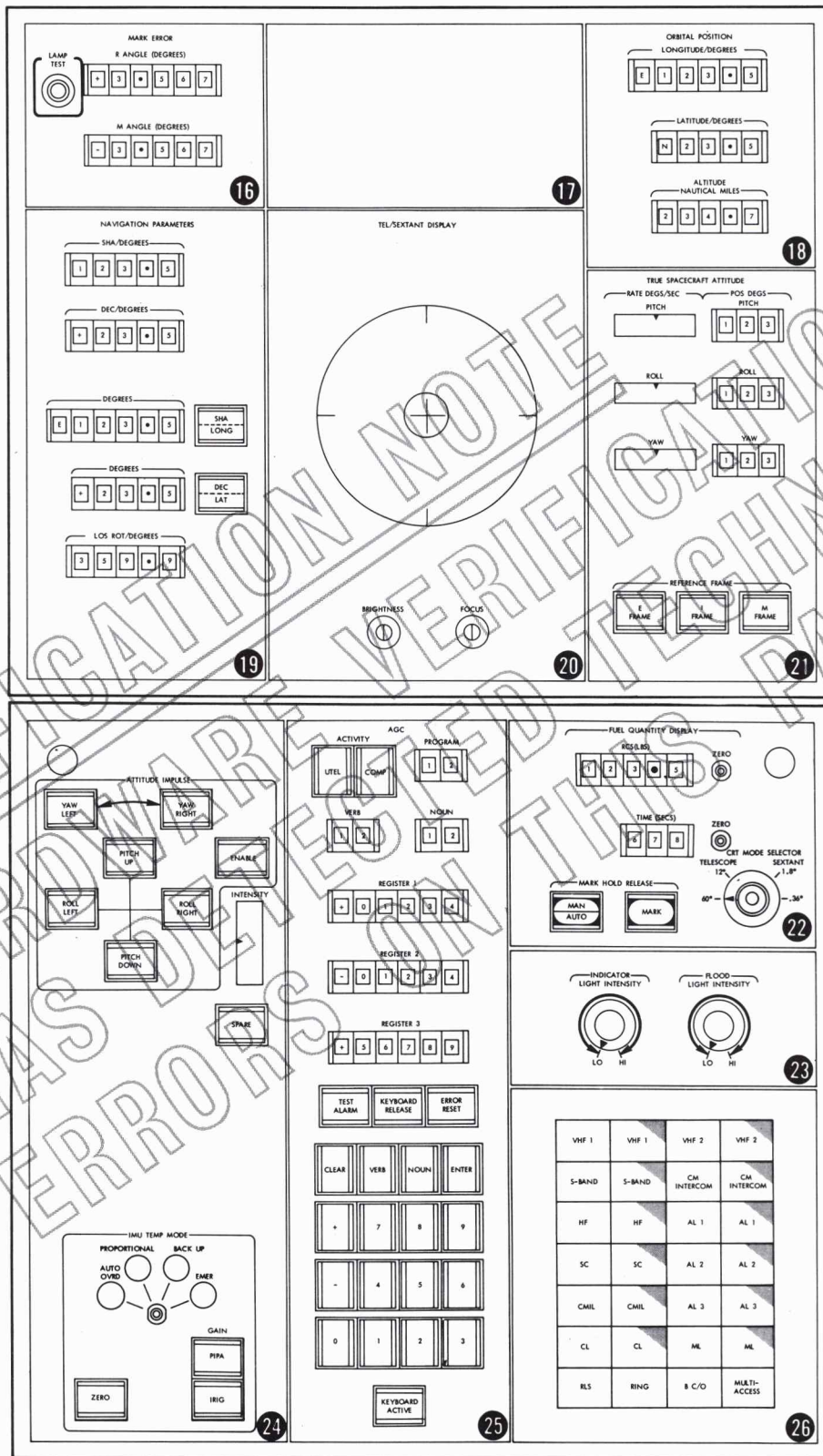
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Figure 1-3. Instructor-Operator Simulator Console (Sheet 4 of 14)

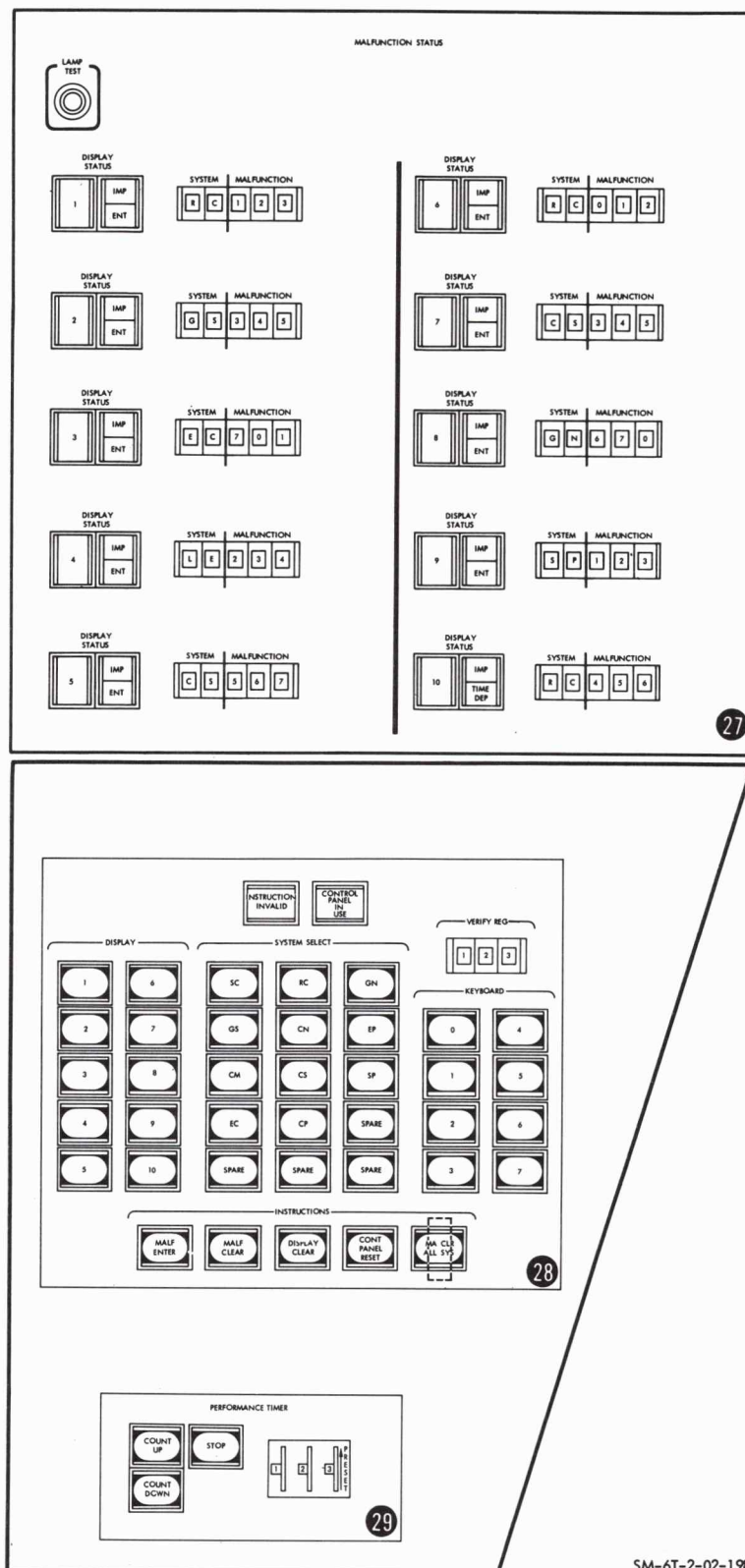
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Figure 1-3. Instructor-Operator Simulator Console (Sheet 5 of 14)

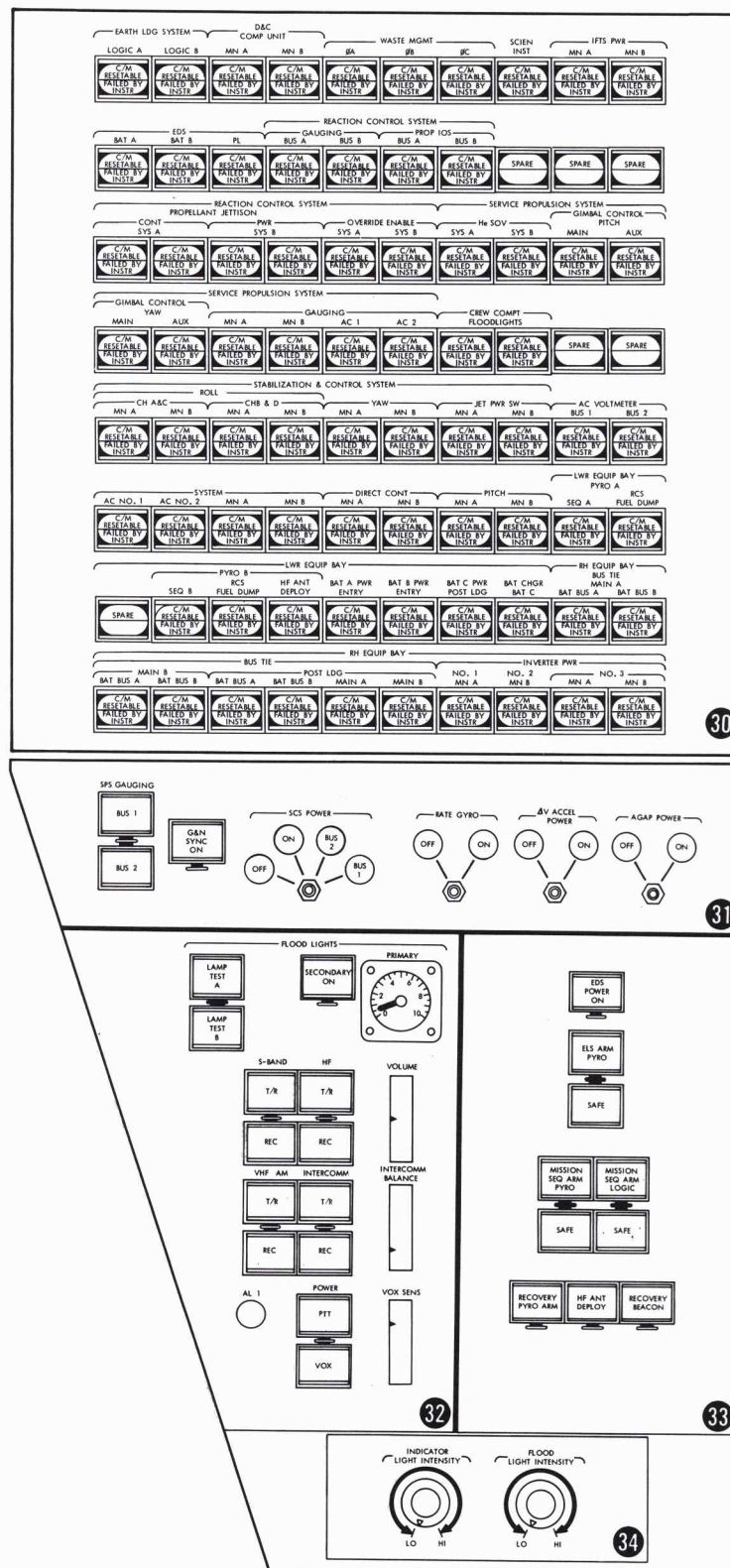
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Figure 1-3. Instructor-Operator Simulator Console (Sheet 6 of 14)

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Figure 1-3. Instructor-Operator Simulator Console (Sheet 7 of 14)

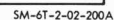
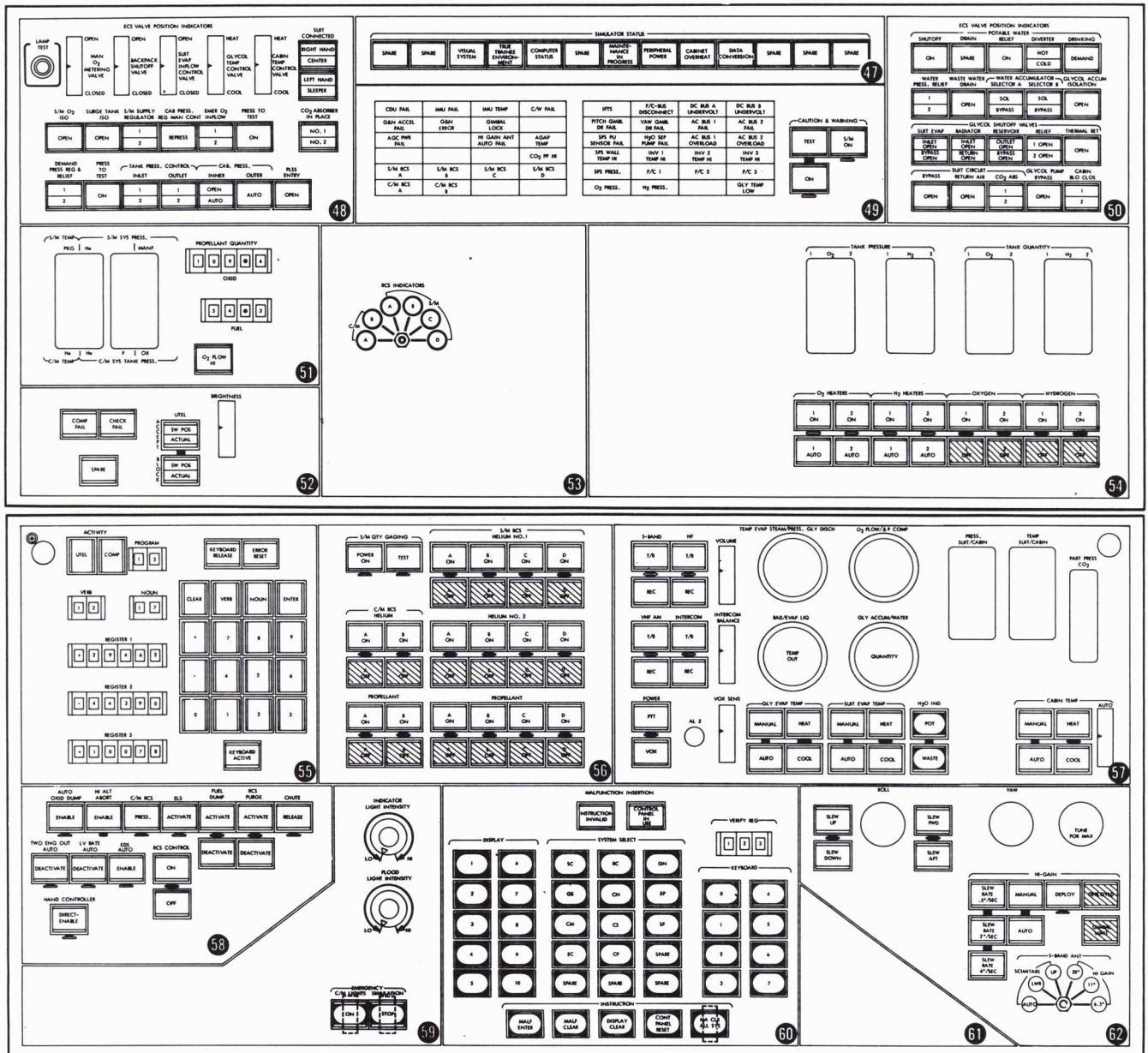


Figure 1-3. Instructor-Operator Simulator Console (Sheet 8 of 14)

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Figure 1-3. Instructor-Operator Simulator Console (Sheet 9 of 14)

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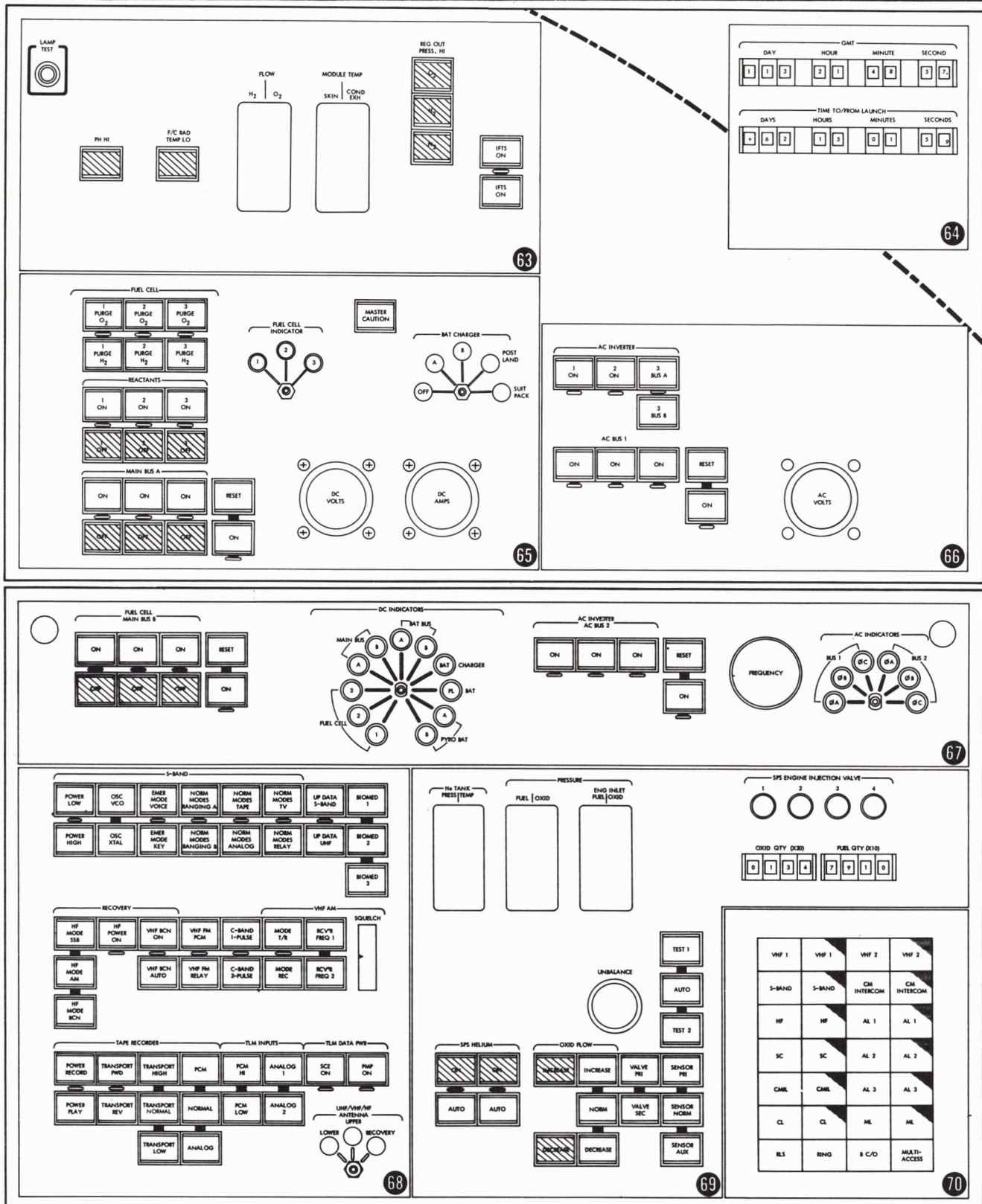
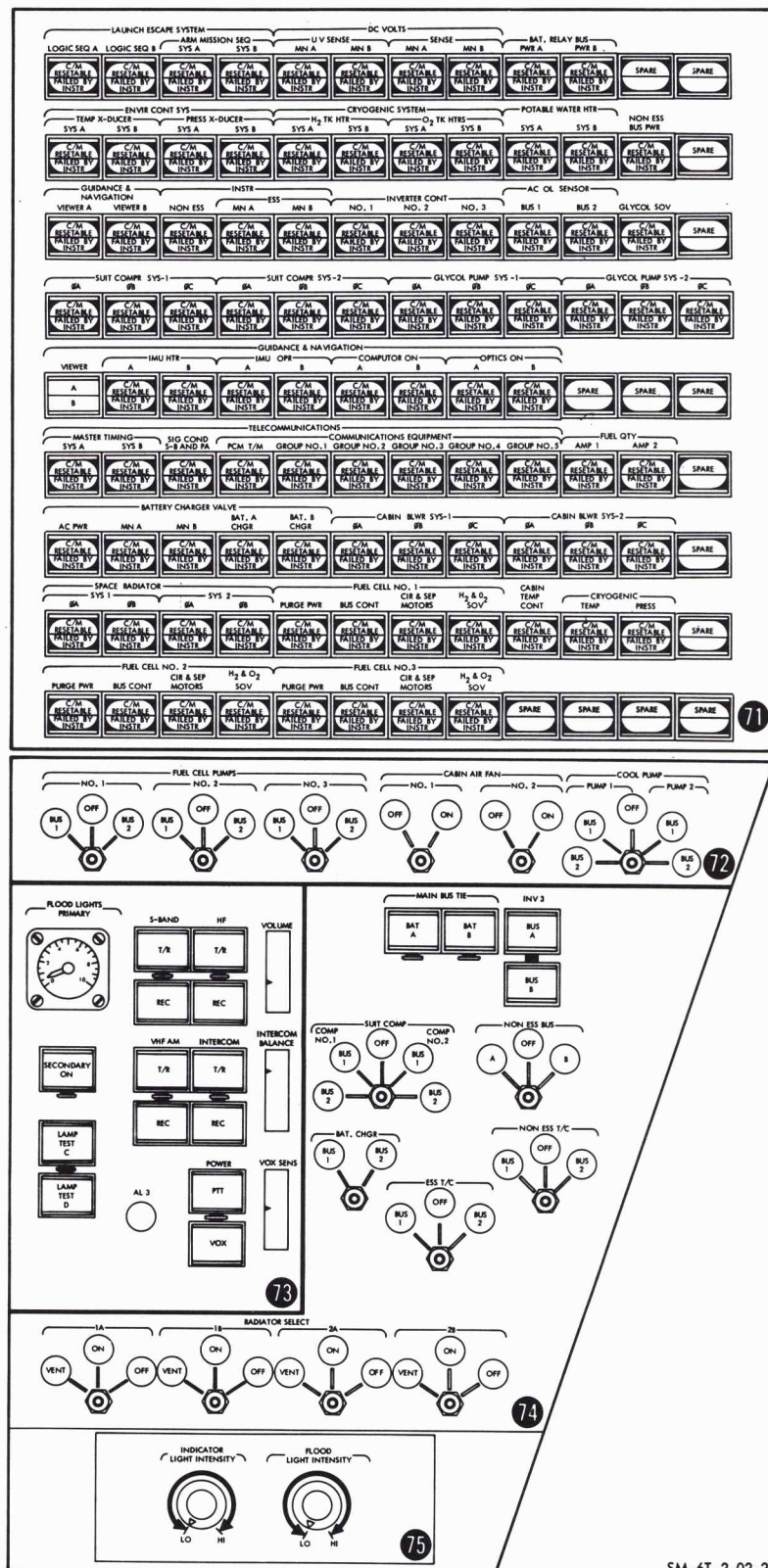


Figure 1-3. Instructor-Operator Simulator Console (Sheet 10 of 14)

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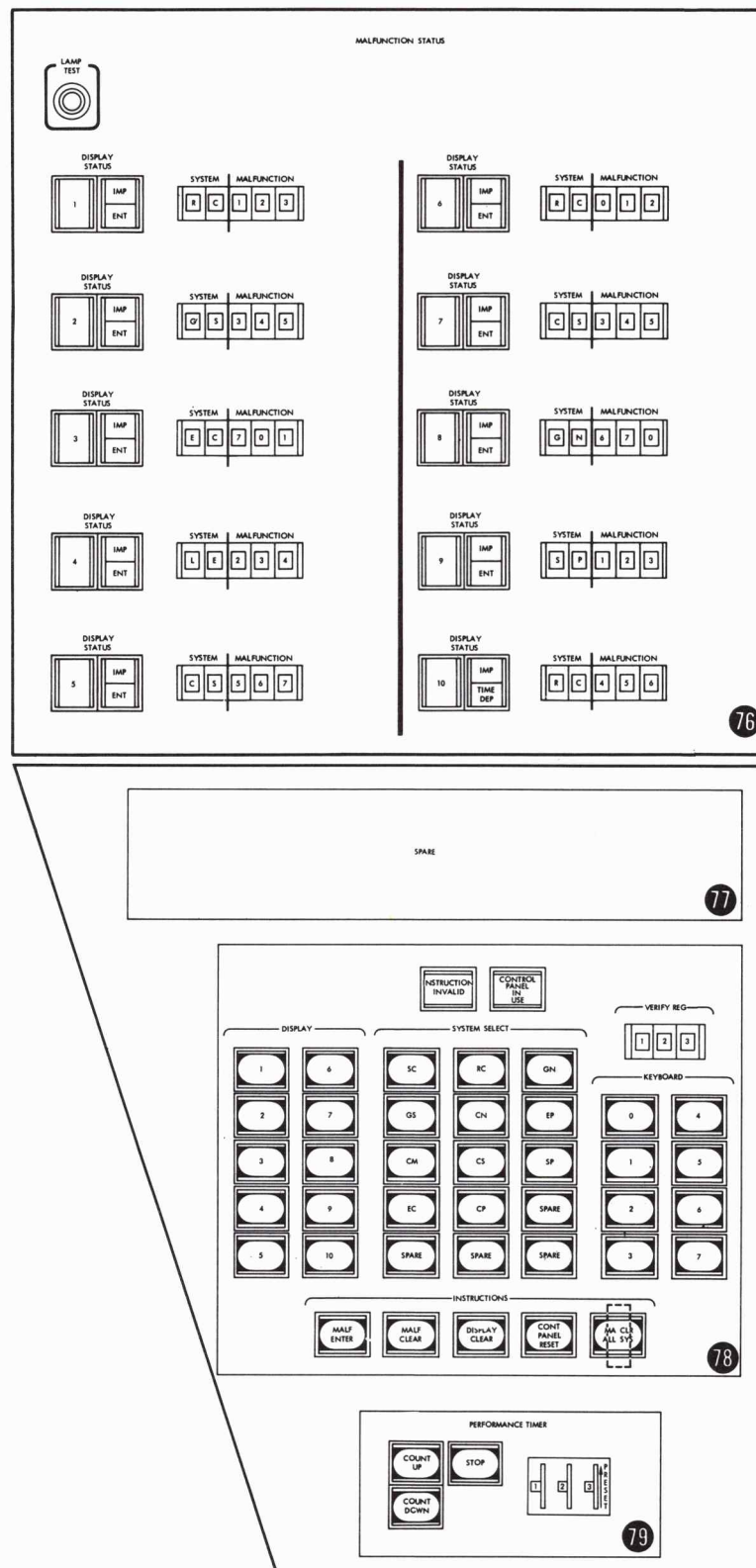
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Figure 1-3. Instructor-Operator Simulator Console (Sheet 11 of 14)

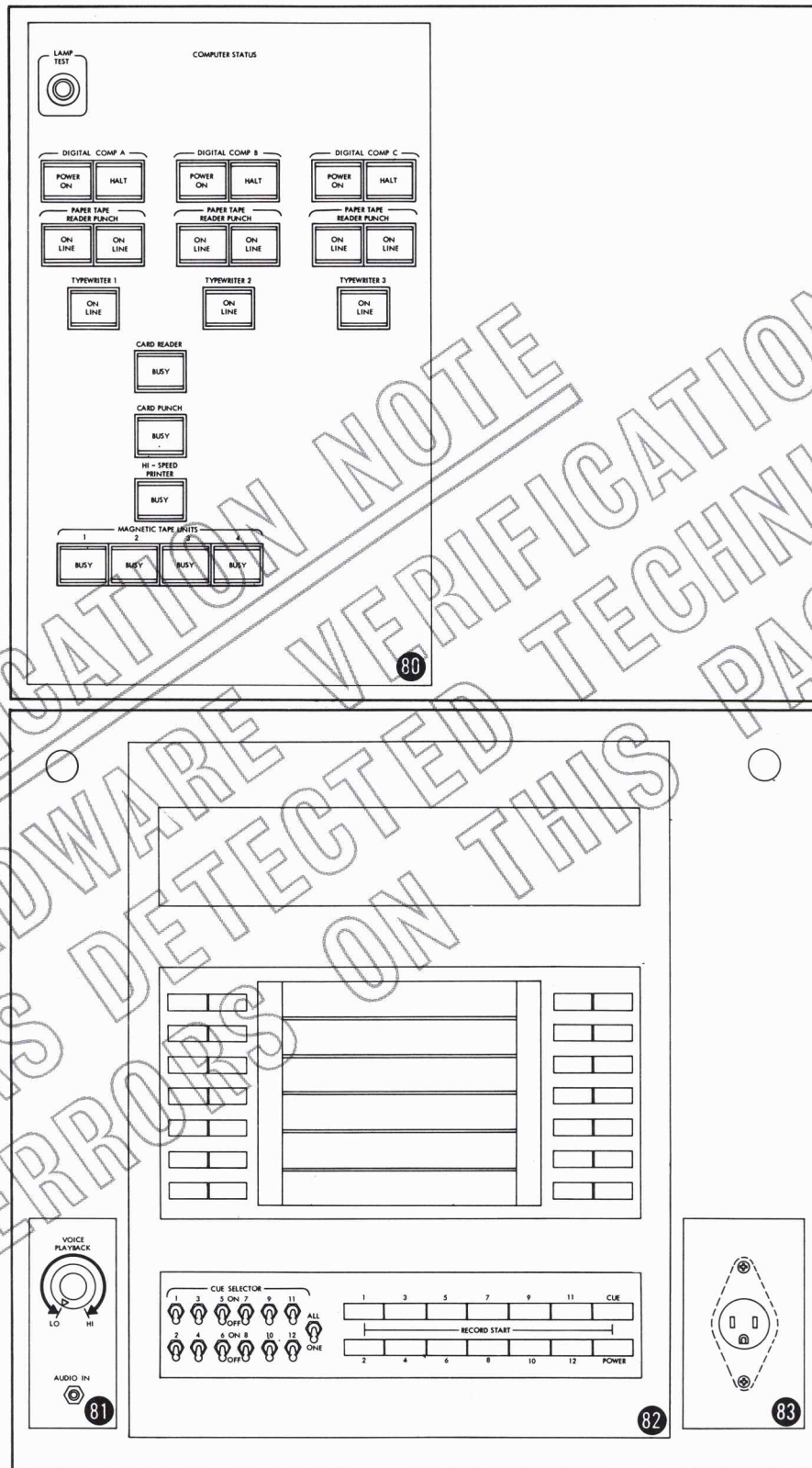
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Figure 1-3. Instructor-Operator Simulator Console (Sheet 12 of 14)

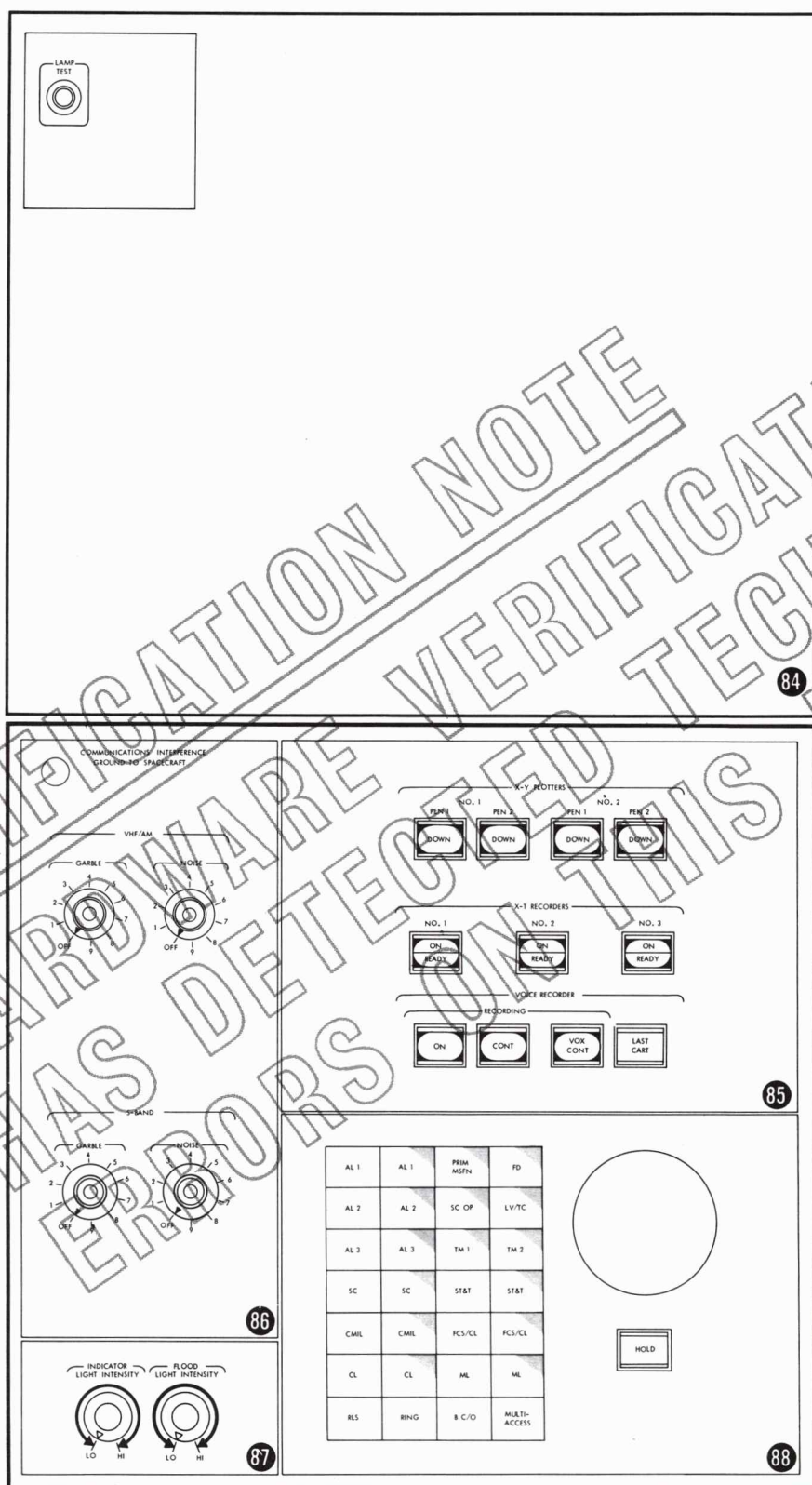
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Figure 1-3. Instructor-Operator Simulator Console (Sheet 13 of 14)

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Figure 1-3. Instructor-Operator Simulator Console (Sheet 14 of 14)

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Table 1-2. Instructor-Operator Station - Controls and Displays

Panel	Nomenclature	Function
1	VISUAL SYSTEM STATUS	Controls and displays (C&D) of visual displays.
2	TRUE TRAINEE ENVIRONMENT	C&D of suit pressure, temperature, cabin temperature, aural simulation, and smoke generation.
3	WASTE MANAGEMENT	C&D of waste management system.
5	UP DATA LINK	C&D of up-data.
6	LIGHTING CONTROLS	Lighting controls.
9	IMU-CDU repeater	IMU-CDU repeater and SCM flight control repeater.
10	G&N computer status	Indication of G&N alarms and faults.
11	SXT CONTROL	Indication of SCM SXT control operation.
12		Repeat of lower equipment bay (LEB) optics control panel, lighting controls, lamp check switch, and SCT shaft and trunnion readouts.
13	CDU repeater	Repeat of SCM CDU indications.
14	OPTICS	Indication of operation of optics controls in LEB.
15	MAP/DATA VIEWER & FILM DRIVE	Indication of map and data viewer (MDV) control operation.
16	MARK ERROR	Indication of optical axis angle error.
18	ORBITAL POSITION	Latitude, longitude, and altitude indicators.
19	NAVIGATION PARAMETERS	Display of sidereal hour angle (SHA), declination, SHA/longitude, declination/latitude, and LOS rotation.

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Table 1-2. Instructor-Operator Station - Controls and Displays (Cont)

Panel	Nomenclature	Function
20	TEL/SEXTANT DISPLAY	CRT display of optics positioning.
21	TRUE SPACECRAFT ATTITUDE	True rate and position indications and reference frame being used.
22		Fuel quantity display, timer, and mark hold release.
23		Flood and indicator lighting controls.
24		Indication of attitude impulse and IMU temperature control operation.
25	AGC	Apollo guidance computer display and keyboard (AGC DSKY) and three register readouts.
26	CONSOLE COMMUNICATIONS PANEL	Communications control (trainer).
27	MALFUNCTION STATUS	Display of malfunction, and indication of malfunction status.
28	MIU (malfunction insertion unit)	Keyboard (KYBD) to insert malfunction.
29	PERFORMANCE TIMER	
30		Display of circuit breaker status.
31		Indication of position and operation of SPS, and SCS controls.
32		Repeater indicators of floodlight controls and SCM audio control panel.
33		Repeater indicators of EDS panel controls.
34		Controls for IOS flood and indicator lighting.
35		Central timing equipment.
36		Baro and digital altimeters.
37		

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Table 1-2. Instructor-Operator Station - Controls and Displays (Cont)

Panel	Nomenclature	Function
38	FDAI	SCM panel 5 repeater.
39		SCM panel 3 repeaters.
40		Indication of simulated S/C attitude and rates.
41		SCM panel 5 lower repeaters.
42		SCM panel 6 repeaters.
43		SCM panel 9 repeaters.
44		SCM panel 7 repeaters.
45	CONSOLE COMMUNICATION PANEL	Control of simulator computer complex-performance timer.
46		Trainer communications.
47		Indication of trainer status.
48		Indication of ECS valve position.
49		Repeater indicators of SCM panels 10 and 11
50		Repeater indicators of SCM ECS valve positions.
51		SCM panel 12 repeater.
52	SIMULATOR STATUS	Repeat of SCM AGC up-data link controls.
53		Reaction control system (RCS) selector switch position indicator.
54		Repeater indicators of service propulsion system (SPS) portion of SCM panel 13.
55		Main display AGC DSKY repeater.
56	ECS valve position indicators	SCM panel 15 repeaters.

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Table 1-2. Instructor-Operator Station - Controls and Displays (Cont)

Panel	Nomenclature	Function
57	MIU	Repeaters of SPS and C&D portions of SCM panel 13.
58		SCM panel 16 repeaters.
59		AMS emergency stop control, flood and indicator intensity controls.
60		Selection and insertion of malfunction.
62		SCM panel 19 repeaters.
63		SCM panel 18 repeaters.
64		Central timing equipment.
65		SCM panel 18 repeaters.
66		SCM panel 18 repeaters.
67		SCM panel 18 repeaters.
68		Repeaters of communications portion of SCM panel 20.
69	CONSOLE COMMUNICATIONS PANEL	Repeaters of SPS portion of panel 20.
70		Trainer communications.
71		Circuit breaker indications and status.
72	AUDIO CONTROL CENTER	SCM panel 22 repeaters.
73		Repeater indicators of SCM panel 26.
74	LIGHTING CONTROL	Repeater indicators of SCM panel 21.
75		Flood and indicator light intensity controls.
76	MALFUNCTION STATUS	Indication and status of malfunction SCM panel 22 repeaters.
78	MIU	Selection and insertion of malfunction.
79	PERFORMANCE TIMER	

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Table 1-2. Instructor-Operator Station—Control and Display Panels (Cont)

Panel	Nomenclature	Function
80	COMPUTER STATUS	Indication of status of AMS computers.
81	Voice playback	Jack plug and volume control for tape recorder playback unit.
82	KRS stact recorder	Voice recording equipment (trainer).
83		Electrical power connection for tape recorder playback unit.
84		Lamp test.
85		Status indications of data recording equipment (trainer).
86	COMMUNICATIONS INTERFERENCE	Voice communications interference.
87		Panel lighting intensity controls.
88	CONSOLE COMMUNICATIONS PANEL	Trainer communications.

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1.3.1 SIMULATOR SUPPLEMENTARY CONTROLS AND DISPLAYS.

Those IOS controls and displays that are other than spacecraft repeater instruments can be generally identified in two groups.

1. Those controls and displays used by the instructor-operator to operate the simulator and monitor the status of simulator systems.
2. Those displays, other than repeater instruments, that are used by the instructor-operator to monitor crew performance.

The IOS panels containing such simulator controls and supplementary displays are identified in the following illustrations. Controls and indicators located, thereon, are functionally described in the associated tables.

1.3.1.1 G&N Supplementary Displays.

The nature of flight crew operation of the simulated G&N system is such that IOS repeater instruments do not provide sufficient visibility for effective instructor-operator monitoring. For this reason, the G&N system repeater instruments have been augmented with the following supplementary displays (figure 1-4) functionally described in table 1-3.

- Panel 16 The mark error panel provides indication of SCT positioning error during a navigation sighting in the angular coordinates of the landmark with respect to the telescope crosshairs.
- Panel 18 The orbital position panel provides an indication of vehicle longitude, latitude and altitude.
- Panel 19 This panel displays navigational parameters. Three of the displays provide celestial coordinates for the sextant's landmark line-of-sight indicated in sidereal hour angle, declination, and rotation angles. The other two displays are shared between the SCT and SXT. In midcourse, the sextant's star LOS sidereal hour angle and declination are indicated. In orbit, the intersection point coordinates of the telescope line-of-sight with respect to earth or moon are indicated.
- Panel 20 This panel is a 5-inch CRT display of SXT/SCT error signals. Respective fields-of-view are manually controlled with respect to a small circle as the landmark representation.
- Panel 21 The true spacecraft attitude panel provides readouts of attitude rate and position as reference to the indicated reference frame.

1.3.1.2 Navigation Evaluation Panel.

The controls and indicators on this panel relate to the fuel consumed during a navigation sighting maneuver. The mark hold and release controls provide

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selection of manual or automatic operation of the performance evaluation parameters used during a navigation sighting. Control of the CRT display representation is manipulated from this panel.

Functional description of the controls and indicators located on this panel is tabulated in table 1-4 and depicted in figure 1-5.

1.3.1.3 Simulator Status Panel.

Status indicators are included on the IOS to enable a gross and rapid verification of correct operation and status of all significant AMS components and subsystems. This status panel is illustrated in figure 1-6. The function of each indicator is listed in table 1-5.

1.3.1.4 Simulator Control Panel.

The controls located on the simulator control panel, illustrated in figure 1-7, permit the instructor to perform the following:

1. Start or stop the simulated mission at any point.
2. Reset, then restart, the simulated mission at specific points.
3. Run the simulated mission, or portions thereof, at other than real-time rates.
4. Control the X-T recorder.

The functions of each control and indicator located on this panel are described in table 1-6.

1.3.1.5 Lighting Controls.

The individual work stations for the IOS are provided with console lighting controls. Console lighting fixtures are recessed in the hood areas overhead, providing floodlighting through styrene diffuser panels. Six control panels, one of which is illustrated in figure 1-8, are provided for variable control of floodlighting and panel lights. These are functionally described in table 1-7.

1.3.1.6 Performance Timer.

Each of the three instructor stations is provided with a bidirectional timer as illustrated in figure 1-9. These are intended for use by the instructors in timing applications for training purposes. A functional description of the performance timer is provided in table 1-8.

1.3.1.7 Computer Status Panel.

The computer status panel, illustrated in figure 1-10, provides the instructor with an indication of the status of the peripheral equipment associated with the computer system. Table 1-9 lists a functional description of each indicator on this panel.

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1.3.1.8 Recorder and Plotter Panel.

The instructor is provided with remote control of the X-Y and X-T plotters. Figure 1-11 illustrates the panel which enables this control. In addition to the pen recorders, controls are also included for the IOS audio tape recorder. This instrument, independent of the S/C data storage equipment (DSE) allows continuous recording of a complete training exercise. Functional descriptions of the controls and indicators on this panel are listed in table 1-10.

1.3.1.9 True Trainee Environment Panel.

This panel provides the instructor-operator with both monitor and control capability for the environmental conditions for the suits at each of the four SCM stations and the SCM cabin. Indicators and controls are for the actual environment and are completely independent of the simulated environmental control system (ECS). Also included are instructor-operator controls for the simulator smoke generator system and the aural simulation system.

The aural cue simulation system reproduces those characteristic sounds of an Apollo mission that are external to communications and sounds normally heard in the headsets. These sounds include:

- Booster engines aerodynamic noise (frequency and amplitude)
- Launch escape main engine (frequency and amplitude)
- Entry aerodynamic noise (frequency and amplitude)
- 400 Cycle inverter noise

These sounds are produced in a speaker in the SCM as a function of event and time under program control. A talkback indicator displaying noise level is provided on the IOS. The instructor may override the program and manually control the decibel level of noise within the SCM. With the exception of an ON-OFF control, the instructor has no other inputs to the aural cue system. Figure 1-12 illustrates the controls and display, and table 1-11 provides a functional description of each control and display.

The smoke generator system contains a non-toxic liquid smoke, a heater unit, and an auxiliary blower. Smoke is produced by heating the liquid smoke and ducting it through the AMS environmental control system air conditioning ducts. This function is under program control with instructor override to inhibit smoke generation. Initiation of the smoke generator system can be accomplished manually through the MIU in conjunction with specific malfunctions. Controls for this system are depicted in figure 1-12 and functionally described in table 1-11.

1.3.1.10 Visual Systems Status Display.

This panel provides operational status and malfunction detection data on the visual systems to the instructor-operator. The panel is illustrated in figure 1-13 and each indicator is functionally described in table 1-12.

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1.3.1.11 Up-Data Line Panel.

The purpose of the up-data link panel is three-fold. During nonintegrated operation of the AMS, the instructor is provided a means of inserting up-telemetry information through this panel. The instructor can obtain the up-telemetry information by querying the simulated on-board computer for this data. As a result, the computer reads out the data to be used on the typewriter. In addition, the instructor must also use the up-data link keyboard to inform the on-board computer as to the identity of the star or landmark that the trainee is currently using for navigation purposes. This function also is implemented in the integrated mode in such a manner as to avoid conflict with trajectory link up-data signals. During the integrated mode, the panel provides the capability to introduce up-data signal faults or inhibit up-telemetry signals. The identity and function of each control and display on the up-data link panel is provided in figure 1-14 and table 1-13.

1.3.1.12 Voice Communications Interference Panel.

The controls located on this panel enable the instructor to insert noise and garble effects into voice transmission by manual control. This effect is limited to one direction only, ground-to-spacecraft. This effect enables the simulation of space communication conditions, distance, antenna position, and spacecraft orientation. The controls are identified in figure 1-15 and the function of each control is described in table 1-14.

1.3.1.13 Console Communications System.

The console communications system (CCS) provides the IO with a variety of voice communication services interconnecting the AMS instructor station with parallel and support organizations in the simulation complex. The CCS consists of a number of independent loops and stations functionally strapped together such that they compose a network for each simulator. The entire CCS is not discussed here except in relation to the AMS operation. The communications circuits for the AMS consist of various talk-listen loops that enable the instructors to interface with major subsystem personnel and intraface with related simulators and training units during integrated operations.

The CCS for the AMS consists of six key-set and six trainer communication control stations. Two each of these stations are located at the telemetry console and the remaining four each are mounted at the IOS. Figure 1-16 depicts the key-set stations and their related locations. Each key (switch) provides the IO with a talk-listen capability over the associated loop. The function of each key is tabulated in table 1-15. The trainer communication control stations, illustrated in figure 1-17, provide loop selection for switching, volume controls, and headset jacks. The function of each of the controls depicted in the figure are listed in table 1-16.

1.3.1.14 Malfunction Insertion Unit.

The malfunction insertion unit (MIU) provides control over and monitoring of simulated spacecraft malfunctions. The MIU consists of control and display panels, located on the IOS and T/M console, and the associated electronic logic circuitry.

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The unit provides the instructor with the capability to perform the following functions:

1. Enter or clear simulated malfunctions in the computer program.
2. Display the status of any selected simulated malfunction.
3. Erase any selected simulated malfunction or clear all active malfunctions from the program.

For purposes of discussion, the MIU is divided into its three major portions: control panels, display panels, and logic circuitry.

MIU Control Panel.

Three control panels, one at each instructor station, are located on the IOS. These panels permit the instructor to initiate instructions regarding simulated malfunctions to the computer via the logic circuitry. Simulated malfunctions are coded alphanumerically. The system designation appears as the lettered portion of the code with eleven systems so identified. This coding identifies the 800 simulated malfunctions presently under consideration plus an expansion capability of up to 1500 computer-stored simulated malfunctions. Figure 1-18 illustrates the MIU control panel. The functions of the controls are described in table 1-17.

MIU Display Panel.

This panel displays information pertaining to simulated malfunction selection and status. Three panels are provided; one on the T/M console, and the other two are located in the right and left-hand pie sections of the IOS. From these panels, the instructors can determine the status of any simulated malfunction in the computer program or that he has manually entered. Panel arrangement is shown in figure 1-19 and the functions of the indicators are provided in table 1-18.

1.3.1.15 Time Displays.

There are two time display panels located on the IOS, as shown in figure 1-20. Each display contains two digital readouts whose functions are described in table 1-19. These displays are not repeaters of on-board timers. They function to aid the instructor in various applications to the training problem.

In addition to the timers mentioned above, there is a digital time code translator, supplied as GFE, located on top of the central IOS console. This unit is the interface between the AMS Central Timing Equipment and the IMCC/SCATS equipment. In addition to providing a visible readout of real GMT time, that is coordinated within the FCSD simulation complex, it also provides the 1 KC, 1 pps, and the 1 ppm timing signals derived from WWV for the AMS. The Time Code Translator is illustrated in figure 1-21 and each control and display is functionally described in table 1-20.

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1.3.1.16 Closed Circuit Television System.

The closed circuit television (CCTV) is a black and white TV system consisting of three GPL model 800 cameras, three monitors, and the interconnection between cameras and monitors. The cameras are fixed in the SCM with no zoom capabilities. Each TV camera uses a vidicon tube and operates down to a light level of one foot-candle at the lens. The location of the cameras is illustrated in figure 1-22. Camera 2 is located behind the left shoulder of the trainee in the commander's station. Camera 1 is located near the left foot of this station. Camera 3 is located behind the right shoulder of the trainee in the right couch. Cameras 2 and 3 cover the main display panel, overlapping in the center, and also provide a front view of the G&N lower equipment bay. Camera 1 provides a view of the three trainees in the interior of the SCM.

The three monitors are mounted above the respective flight crew stations at the IOS. Each monitor has controls which are not part of the IOS. Their location is similar functionally to those of any commercial set. The camera controls are located beneath each monitor atop the IOS. These controls are illustrated in figure 1-23, and functionally described in table 1-21.

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1.3.2 SYSTEM DISPLAYS.

The following paragraphs describe SCM simulated spacecraft system controls and displays and their IOS repeater indicator counterparts. There is a one-to-one relationship between those system controls and displays used by the flight crew and the IOS system displays. Instructor data on system displays in this handbook has been organized by SCM panels. Figures 1-24 through 1-57 and descriptive tables 1-22 through 1-52 are provided to define both SCM and IOS system controls and displays and the manner in which SCM data is manifested to the instructor-operator.

1.3.2.1 Main Display Panel.

The main display panel located in the SCM (figure 1-24) is a replica of the actual S/C main display console. In appearance, function, and operation, the controls and displays on this panel duplicate those of the spacecraft. These controls and displays provide inputs to the computer programs, which enable simulated operation of the S/C systems. The computer programs output signals to maintain proper indication of displays associated with system operation on the main display panel.

1.3.2.2 IOS System Displays.

The one-to-one relationship between SCM controls and displays and IOS system displays is provided, in most instances, through computer program control. SCM system control inputs to the program inform the computer to activate repeater indicators or instruments on the IOS for instructor monitoring. In some cases, there is a direct input to the IOS repeater indicators from the SCM switches that bypass the computer. However, the computer program always controls the positioning of the IOS repeater displays associated with SCM system operation.

A functional description of the controls and displays related to simulated systems operation is provided in the tables. The description is that of the SCM display panels which illustrate the relationship to IOS display panels and define instructor visibility at the IOS. Whenever a control or display is evident on a SCM panel and not on the related IOS panel, this is indicated by the control or display number being circled with reversed coloring. Wherever the control or display is located on the IOS panel and not on the related SCM panel, a square containing a reversed colored number is used.

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1.4 TELEMETRY CONSOLE.

The telemetry console depicted in figure 1-58 contains data word displays for analog, bilevel and GMT digital words. Other parallel digital words are displayed bit-by-bit on the bilevel display. The console contains displays of the actual PCM encoder status; repeater light displays of the SCM C&D and the MIU, which are driven in parallel with identical displays on the IOS; and two time displays. In addition, the T/M console includes provisions to fault individual data words (analog, bilevel, or digital words within the format). A functional description of the control panels on the T/M console is included in the following paragraphs.

1.4.1 MONITOR CONTROL.

The controls and displays on these panels allow the instructor-operator to monitor any of the computer or periphery equipment data inputs to the PCM encoder unit on each of the meters. However, only 20 analog channels can be monitored at any one time. It also allows monitoring of a selected faulted channel. The panels are illustrated in figures 1-59 and 1-60 and the controls are functionally tabulated in tables 1-53 and 1-54.

1.4.2 FAULT CONTROLS.

Fault controls are provided for the introduction of faults into the data lines between the AMS computer and the PCM units. Each fault control panel includes monitor lights and selection controls. A functional description of those controls located on the fault panels is listed in table 1-55.

Twenty analog fault controls (figure 1-61) are provided on the panel. Each is capable of introducing the following:

1. Drift at a controlled rate
2. Offset of a preset amount
3. Fixed level substitution to a present level
4. Channel loss.

Sixteen bilevel fault controls are provided on the digital fault control panel (figure 1-62). These controls functionally described in table 1-56 are used to introduce bit failure into the parallel word signal lines. In addition, six digital word fault controls are provided to simultaneously fail all bits of the word.

1.4.3 TIME DISPLAY.

Two time displays are provided on the telemetry console. The time displays are repeater displays of the previously described time displays located on the IOS. These displays are illustrated in figure 1-63 and functionally described in table 1-57.

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1.4.4 COMMUNICATIONS CONTROL.

The two panels depicted in figure 1-64 are duplicates of IOS panels 62 and 68 and are repeaters of these same SCM main display panels. They provide the telemetry console operator with an indication of the operational configuration employed for C&D by the flight crew (including antenna position). The console communications panels located on the T/M console are depicted and explained in this section as trainer supplementary displays and controls, paragraph 1.3.1.13, figure 1-16. Table 1-58 provides a description of these panels.

1.4.5 TELEMETRY STATUS.

This panel provides an indication as to the condition of the PCM units. In addition, lighting controls for the console are located here as well as control of television picture transmission to IMCC. Figure 1-65 illustrates this panel as well as one other. However, the other panel is a repeater of an IOS panel and need not be discussed again (figure 1-19). Table 1-59 provides a functional description of the controls and displays located on this panel.

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1.5 RECORDING EQUIPMENT.

1.5.1 X-T RECORDER.

These paragraphs describe and illustrate the major component controls incorporated into the Brush Mark 200 recording system, which is employed for the X-T recorder. The Brush recorder is an eight-channel recording system which incorporates an oscillograph installed horizontally in a drawer in the unit pedestal. Attenuator and recorder functions (including the remote-operate) are actuated by pushbutton controls. Rectilinear pen motion produces records on rectangular coordinate charts graduated in 50 divisions. Recorder pens utilize pressurized fluid. The oscillograph has 12 selectable chart speeds. The complete system, illustrated in figure 1-66, is contained in a 54-inch high console with a sloped front control panel and casted base. There are three such recorders included with each AMS.

The attenuator and control panel (figure 1-67) is an input signal device located on the top front of the console. It contains external function switches to enable remote operation of the system. The functional description of the controls on this panel are listed in table 1-60.

The oscillograph contains pens, penmotor, chart paper and the writing table. The oscillograph is mounted at desk level and displays up to 11 inches of chart on a flat writing surface. The oscillograph controls are illustrated in figure 1-68 and are functionally described in table 1-61.

The level light panel is located directly above the oscillograph on the front of the unit (figure 1-66). The panel components are illustrated in figure 1-69 and functionally described in table 1-62.

The control functions for the Brush recorder should be thoroughly understood before operation. For additional information, refer to vendor documents on the instrument.

1.5.2 X-Y PLOTTERS.

Two plotter models, 205T and 1110E, are supplied by Electronic Associates, Inc to be used with the AMS. They are located at the extreme left end of the IOS where they are readily accessible by the instructor/operator for adjustment or observation. Each plotter is mounted in a standard vertical rack with vertical plotting surfaces and dual pens for versatility. The plotting surface for the 205T, illustrated in figure 1-70, is 30 x 30 inches. The controls and displays for this unit are functionally described in table 1-63. The plotting surface for the 1110E model, illustrated in figure 1-71, is 11 x 17 inches. The controls and displays for this unit are functionally described in table 1-64. The control functions for these units should be thoroughly understood before operation. For additional information, refer to the vendor documents on these instruments.

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1.5.3 AUDIO TAPE RECORDER.

The tape recorder is an unmodified four-channel KRS data-stack DR-2 unit. It will record the earphone output, including side-tone, of each astronaut on a separate channel. The fourth channel may be used to record the instructor conference loop. Playback of the tapes will be accomplished on a portable playback unit stored in the IOS area. Being portable, the playback and astronaut performance evaluation may be accomplished in other areas as long as 115-volt 60-cps power is available. This allows simultaneous recording of one training session, while the tape from a preceding session is being evaluated.

The stacked tape automatic cartridge transport (STACT) recorder system (figure 1-72) contains six magnetic tape cartridges of 1200-foot 1-mil mylar tapes. Each tape provides 2.2 hours continuous recording time or much more when using the VOX circuitry. Tape cartridges are changed automatically so that when cartridge one becomes fully recorded, cartridge two begins recording. This cycle continues through tape five, at which time a last cartridge indication is provided prior to taping cartridge six. Sequencing of cartridge taping results in at least 13 hours recording time (continuous record), without destroying previously recorded information. As the cartridges are manually replaced after they are recorded, unlimited recording time becomes available. When the record command is given by VOX or continuous record command, the capstan will read full speed of 1-7/8 inches per second in 40 milliseconds. IOS controls are provided for all voice recorder functions. These controls are described in table 1-65. The playback unit is stored under the IOS console containing the recorder. Electrical connections for the playback unit are provided adjacent to the recorder. (See figure 1-72.)

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1.6

SIMULATED COMMAND MODULE (SCM).

The SCM consists of two major equipment items: the command module itself and the vertical insertion mechanism. The interior of the SCM is a replica of the Apollo command module. Equipment arrangement, controls and displays, crew couches, and other characteristics of the crew compartment are authentically duplicated for purposes of providing the flight crew with an apparent actual spacecraft environment.

The cockpit area of the SCM contains the crew couches, main control panel, lower equipment bay, waste management system, and utility equipment storage facilities identical to those of the actual spacecraft. The crew couches in the left and right hand stations are permanently installed. The center couch is removable but the removed couch cannot be stowed and must be removed from the SCM when not in use.

The Lower Equipment Bay is configured to resemble AFRM-011 with certain exceptions. The photometer components installed on the G&N control panel are not functional. The rate gyro package and attitude gyro accelerometer package are also dummied. Blank panels cover the following equipments:

- Inverters
- Batteries
- PLSS Battery Charger
- Junction Box

These items are, however, hidden by the CO₂ absorber boxes and are not seen. Also covered by blank panels are the scientific and flight qualification equipment, the radiation detection equipment, and two food storage compartments. In addition to the above, the following list of items will duplicate S/C counterparts in appearance but will not be functional:

- AGAP ECA
- YAW ECA
- PITCH ECA
- ROLL ECA
- AUXILIARY ECA
- POWER SERVO ASSEMBLIES
- AGC (excluding DSKY)

The IFTS connectors in the LEB are located on the panels, but there are no connections to them and the IFTS umbilical is missing as well. The PCM units and the DSE located in the LEB are actual S/C components, completely operational.

The Aft Equipment Bay is configured basically to AFRM-011 except that the PLSS packs are not supplied and that the electronic spares storage boxes will be supplied. The spares, however, are dummied.

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The Left Hand Equipment Bay has some dummied plumbing displaced with respect to the actual S/C position to accommodate the CCTV cameras. Otherwise, the bay appearance conforms to AFRM-011. The following S/C system components in this bay are dummied:

- Cabin Vent Control
- Surge Tank
- Cabin Pressure Release Valve

The Right Hand Equipment Bay conforms to AFRM-011. However, the IFTS panel will be blank.

The outer configuration of the SCM is entirely functional within the simulator configuration and does not, and is not, intended to approximate that of the Apollo spacecraft. This is illustrated in figure 1-73.

Egress from and ingress to the SCM will be through the normal entry hatch or through the tunnel hatch at the apex of the SCM. The hatch door is accordian pleated to provide a larger entrance when opened. When it is closed, the hatch area resembles S/C appearance on the interior. Appropriate access platforms and personnel ladders are provided on the exterior structure of the SCM. The tunnel hatch connects to a catwalk above the SCM with a helical stairway providing access to the ground level. An expanding stairway enables personnel to reach the main hatch when the SCM is locked in the operating position.

The simulated command module and the vertical insertion mechanism are mounted on a V rail trolley to allow them to be moved away from the Visual Systems. This enables maintenance of the SCM and Visual Systems. The only connections to the moving unit are the electrical cables and the flexible compressed air line for the oxygen pressure suit system. The cables and the flex air line are supported through an overhead boom that pivots as the SCM withdraws horizontally. The cables simply flex during vertical motions. The boom structure is physically connected to the SCM.

The SCM also has a vertical insertion unit illustrated in figure 1-74 capable of motion up to 27 inches. This vertical motion must be completed prior to starting any simulator horizontal motion, i.e., horizontal motion is locked out until vertical retraction is completed. The horizontal motion consists of approximately 12 feet with all power cables connected. Unlimited motion of the SCM on its casters is possible when connecting cables are removed. The SCM motions are electrically powered: horizontally, through its two forward wheels and clutch mechanism; vertically, through four interconnected lead screw jacks. With no power available, horizontal and vertical motions are possible by means of the hand cranks located on the control panel on the right side of the SCM base. The crank mechanism is also interlocked to assure that no horizontal motion is possible when vertical motion is either incomplete or in progress.

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Beneath the base of the SCM are the components of the Waste Management System and the simulated Environmental Control System. This includes the air conditioning equipment, smoke generator, potable water tank, and waste material storage.

The AMS Waste Management System interfaces with the controls and equipment of the spacecraft waste management system located within the Simulated Command Module. This system for AMS #1 (Houston facility) contains a functional vacuum cleaner, urinal and fecal canister and their associated controls.

For AMS #2, (Kennedy Facility) these will be dummied units. The storage filter and disposable containers for the functional units are components of the simulator Waste Management System that are external to the SCM (i. e., suspended beneath it). The entire system is provided by General American Transportation Company. The controls for the system are those normally used in the operation of the spacecraft system and are included under that heading, figure 1-50 depicts these controls which are functionally described in table 1-46.

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1.7 COMPUTER COMPLEX.

The AMS computer complex is comprised of three groups of equipment. These are the computer system, the peripheral equipment used to operate and monitor the computers, and the data conversion equipment used to link the computers with the simulated command module, the visual systems, the Instructor-Operator Station, and other parts of the AMS. (See figure 1-75.)

1.7.1 COMPUTER SYSTEM.

The computer system of the AMS is used to simulate the spacecraft systems, compute and display spacecraft dynamics, control and position visual displays and recorders, and to receive and respond to signals transmitted from the Command Module, Instructor-Operator Station, and other units of the AMS. The computer system also executes predetermined sequence of events, drive displays and indicators through data conversion units, and inserts and responds to malfunctions injected from the AMS. These functions are executed under control of computer programs stored in the computer memory.

The computer system consists of two models of the DDP-24 and one model of the DDP-224 general purpose digital computers supplied by Computer Control Corporation. (See figures 1-76 and 1-77.) As illustrated in the block diagram in figures 1-78 and 1-79 both computers are very similar in design and operation with the major difference being in the operating speed. The DDP-224 operates approximately 2-1/2 times faster than the DDP-24.

Basically, each computer is composed of four functional units: the memory unit, the input/output unit, the control unit, and the arithmetic unit. Figure 1-80 shows the basic arrangement with the data flow and control signal distribution.

1.7.1.1 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 the actual solution is attempted by the computer. Similarly, as with spacecraft simulation, all the information relative to the spacecraft and the sequence of events must also be stored in the computer before starting a training mission. This information is in the form of two types of digital words, a data word and an instruction word. A series of instruction words make up a computer program. The memory unit is the device in which these words are stored.

A magnetic core unit is the basic memory of the two computer types. Each magnetic core unit is capable of storing 4096 24-bit words. In the AMS each DDP-24 computer has been expanded to eight units totaling 32,768 word locations, whereas the DDP-224 memory capacity has been enlarged to store 40,960 24-bit words.

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A memory address register (MAR) and a 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 memory; the MIR furnishes temporary storage while the words are being transferred into or out of memory.

1.7.1.2 Input/Output Unit.

As described in the previous paragraph the computer program and data must be stored in memory before the execution of a program. A function of the input unit is to provide the means of inserting the program into memory from peripheral devices, such as the typewriter, magnetic tape units, etc. The output unit is used to connect output devices, such as the card or tape punches and magnetic tape units, to the computer in order to record data on tapes or cards. The transfer of information between the data conversion units and computer is also made possible through the input/output unit.

Included as part of the input/output unit of each computer are the parallel input/output channels, input/output character channels, sense lines and interrupt control, and command signal generation. Each computer in the AMS has also been equipped with fully-buffered channels (FBC) and direct memory access (DMA) channels.

Parallel Input/Output Channels.

The parallel input/output channels are gating devices used in conjunction with the FBCs and DMAs to transfer data between the memory and the peripheral equipment and data conversion equipment.

Input/Output Character Channel.

The input/output character channel is a gating device used to connect the computers with the typewriter, paper tape reader, and paper tape punch.

Sense Lines and Interrupt Control.

The interrupt control and sense lines are used to detect conditions within or external to the computers which require alterations to the computer programs.

Command Signal Generation.

The input-output unit also generates command signals (OCP commands) which are used to control external equipment, such as typewriter and paper tape punch, as well as for use by internal sources.

Fully-Buffered Channel.

A fully-buffered channel (FBC) is a unit containing a data register and a control section that once it is set up from an external source can transfer data

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directly to or from memory independent of the main frame of the computer. In the AMS each computer is equipped with an FBC which is used to transfer data between the data conversion units and the computers. The FBCs are also used for intercomputer data transfer.

The transfer of data between these sources takes place without interference to the computer program. In situations where the FBC and the computer program address the same memory location at the same time, the FBC will take priority.

Direct Memory Access Channel.

The direct memory access (DMA) channel is similar to the FBC in design and operation. It is used to transfer data between the peripheral equipment (magnetic tape units, card reader and punch, tape reader and punch, line printer, typewriter) and the computer. Each DDP-24 is equipped with four DMA's, the DDP-224 contains one.

1.7.1.3 Control Unit.

As explained previously, a computer program consists of a series of instructions words which are stored in memory. A function of the control unit is to "fetch" each instruction word in sequence from memory, translate the word, and issue commands to other parts of the computer that will execute the task defined by the instruction word. The execution of the instruction word depends on timing pulses which are generated in the control unit. The control unit is also capable of modifying an instruction before it is executed.

In the AMS computer system, the control unit of each computer contains an operation-code register (OP-code), an operation code matrix (OCM), program register (P-register), index registers, shift registers (S-registers), control unit clock, and clock matrix. The function of the operation-code register is to store that portion of the instruction word that defines the task to be performed. Also index bits and indirect addressing bits are stored in the register. The operation code matrix is the gating network that decodes the contents of the operation code register and produces control signals to execute the task to be performed.

The program register stores the memory location of the next instruction to be performed. Each time a new instruction word is taken from memory the register is incremented by one. The index registers are used when it is desired to modify an address of the instruction word. The shift registers are used when the position of a word is shifted within the A-register or between the A and B register. The control unit clock is the generator of the timing pulses necessary to execute the instruction. The clock matrix gates the timing pulses from the control clock with the output of the operation code matrix to provide the proper timing sequence to execute an instruction.

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1.7.1.4 Arithmetic Unit.

The function of the arithmetic unit is to perform the computations when commanded by the instruction word. Registers and adders are the devices used to perform the arithmetic functions. Registers are temporary storage devices used to hold data received from memory while it is being processed, and to hold the results of the computation before its transfer to other parts of the computer. The registers also work in conjunction with the adder to perform the arithmetic functions. The adder is the actual counting device.

The arithmetic unit of each computer contains three registers: A, B, and Z, and an adder. A high-speed adder is additional to the DDP-224. The A-register is the main register; the B is the auxiliary register. The Z register acts as the link between the memory and the other parts of the arithmetic unit by receiving each word from memory before it is processed.

1.7.1.5 Word Format.

As mentioned in previous paragraphs, two types of digital words are used in the computer program, the instruction word and the data word. Both are binary words containing 24 bits. Figure 1-81 illustrates the format of the instruction and data word. The instruction word consists of an operation code, an address, index bits, and the indirect addressing bit. The operation code is a two-digit binary number which specifies what command is to be executed. The address is a binary number which 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 will indicate the polarity of the number, a one (1) indicates a negative, a zero (0) indicates a positive number. The remaining 23 bits will indicate the magnitude of the number.

1.7.1.6 Computer Controls.

Figures 1-82 and 1-83 illustrate the control panel configuration for the DDP-24 and DDP-224 computers. A functional description of the controls and displays for each panel are described in Table 1-66 and 1-67.

1.7.2 PERIPHERAL EQUIPMENT.

The following list is the peripheral equipment used with the DDP-24 and DDP-224 computers.

Item	Quantity
Magnetic tape unit	4
Printer	1
Card reader	1
Card punch	1

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Item	Quantity
Paper Tape Reader	1 per computer
Paper Tape Punch	1 per computer
Typewriter	1 per computer

The devices listed are all input/output devices used for inserting or reading out computer data. Figure 1-84 illustrates the peripheral equipment and its interface with the AMS computer system.

1.7.2.1 Magnetic Tape Unit (MTU).

The magnetic tape units used in the AMS are Model M3000 supplied by Midwestern. (See figure 1-85.) The units will record or play back digital information at a rate of 200 or 556 bits per inch at a tape speed of 75 inches per second. The units will be primarily used to load the computer memories with operational and diagnostic programs.

As illustrated in figure 1-84, each MTU is connected to the computer system through MTU interface logic, a word-forming buffer, and a data and control switch. The data and control switch gives control of an MTU to either computer upon interrogation of the status of the switch. The word-forming buffer converts the incoming or outgoing word into a compatible form for use by the computer or the MTU. The interface logic controls the mode of MTU operation, transmit or record, determined by program control.

All manual controls are located on a single, central panel on the front center of the cabinet shown in figure 1-86. The functions of the controls are listed in table 1-68.

1.7.2.2 Line Printer.

The line printer provides a permanent record of printed copy of desired computer system outputs. The model used with the AMS is the model DP/P3300 supplied by Data Products Corporation. Figure 1-87 shows the printer contained in a single console housing two major components: the printer chassis and the electronics gate assembly.

The printer prints out 120 characters per line at 300 lines per minute. The drum and hammer technique is utilized. Sixty-one characters are contained in the drum. A continuous moving ribbon of paper is passed between the drum and hammer bank. The hammer provides the print impact upon coded input signals to provide a readout.

As shown in figure 1-84, the line printer interfaces with the line printer buffer. The buffer converts the words received from the DMA into a proper form for use by the line printer.

The control panel for the line printer is located on the front of the printer chassis. These controls, used for normal operation of the printer, are illustrated in figure 1-88 and functionally listed in table 1-69.

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1.7.2.3 Card Reader.

The card reader serves to input information into the computer program and/or memory. Data is prepared in Hollerith punched cards for insertion into the computer system via the card reader. The reader used with the AMS is the Burroughs, Model B122 (figure 1-89).

A general operational description is as follows. The card reader feeds standard punched cards from the hopper, through the read station into the stacker at a rate of 200 cards per minute. The feed mechanism can be operated either locally or from a remote station. Figure 1-84 shows the interface between the card reader and computer.

The operator's panel is illustrated in figure 1-90 and the function of controls are listed in table 1-70. All switches with the exception of VALIDITY ON switch are momentary make switches. For the one exception, one depression of the switch initiates the ON condition; the second depression is the OFF condition.

1.7.2.4 Card Punch.

In addition to manual key punches, a card punch is supplied as peripheral equipment to assist in program preparation. The Model B303 card punch illustrated in figure 1-91 is supplied by Burroughs. The card punch has the capability to process 100 cards per minute. The card punch operation is divided into four cycles: card feed, card punch, checking, and stacking. The card punch interface (figure 1-84) receives, stores, and processes the data from the DMA for use by the card punch.

The card punch control panel is located on the front of the unit as shown by figure 1-91. The panel controls, illustrated in figure 1-92, are functionally listed in table 1-71.

1.7.2.5 Paper Tape Reader.

Included with each computer is the Digitronic, Model 2500 paper tape reader. The reader is an unidirectional perforated tape reader using standard or mylar tape. The unit reads eight data channels plus a sprocket hole. The tape reader, illustrated in figure 1-93, has two modes of operation: continuous or pulsed. In the continuous mode, the units read at a rate of 300 characters per second. In the pulsed mode, the unit stops after reading each character. The interface logic (figure 1-84) between the tape reader and the character channel converts the character pulses into a form compatible for use by the computer.

The paper tape reader may be loaded without removing power to the unit by placing the READY-LOAD switch (figure 1-93) to the LOAD position. The READY position of this switch enables the normal operation of the unit.

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1.7.2.6 Paper Tape Punch.

A self-contained, high speed paper tape perforator manufactured by Tally is supplied with each computer. The punch is an asynchronous unit capable of punching eight-channel paper recording tape at a rate up to 60 characters per second. Data from the computer is transmitted to the paper tape punch via the input/output character channel and the tape punch interface. The interface converts the data into octal-coded character pulses compatible for use by the tape punch. The unit is illustrated in figure 1-94 and the interface with the computer is shown in figure 1-84.

1.7.2.7 Typewriter.

An IBM Series 73 Selectric Typewriter is supplied with each computer. The typewriter is a 15 character-per-second revolving ball machine that utilizes a type head and keyboard arrangement intended for use with each computer. The carriage of the typewriter is 15 inches with a 13 inch writing line. The type ribbon and spool are contained in a snap-in carriage to allow easy replacement.

The typewriter contains machine functions, i.e., top, space, upper case, backspace, etc., and coded characters similar to a standard typewriter. Communication with the computer utilizes the binary-coded-decimal form. The typewriter is connected to the computer via the typewriter interface logic and input/output character channel. (Figure 1-84.) The typewriter interface logic converts the characters into a form compatible for use by the computer and functions in reverse for data being transmitted to the typewriter. Operation of the typewriter is controlled and monitored by OCP commands and sense lines. Interlock controls are provided to inhibit typewriter use except when selected. Figure 1-95 illustrates the Selectric typewriter and table 1-72 presents a listing of keyboard functions.

To assist the instructor/operator, the typewriter is capable of performing the following functions:

- During the freeze mode, change the variable being recorded on the X-T or X-Y recorders.
- During the freeze mode, interrogate and print out contents of any memory location.
- Notification 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 of special messages, e.g., notifying instructor that MTU requires new tape reel.

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1.7.3 DATA CONVERSION EQUIPMENT.

The purpose of the data conversion equipment is to accept and convert signals transferred between the AMS and the computers into a form compatible for use by each area. Input signals from the AMS are in one of three forms, analog, digital bits, and digital words. Outputs from the computers are in word-serial, 24-bit parallel words. Figure 1-96 illustrates the signal flow between the major components of the AMS and the DCE in terms of spacecraft functions.

The data conversion equipment has been divided into two categories, internal and external. The external DCE, in contrast to the internal, is defined as those units which are located electrically on the same side of the Interface Patch Panel as the command module, instructor/operator station, visual system, etc., and are driven by or driven into portions of the DCE located electrically on the computer side of the Interface Patch Panel. (See figure 1-97.)

The internal DCE consists of:

1. Digital-to-analog converters
2. Digital-to-analog converters (fast)
3. Analog-to-digital converters
4. Digital bit input
5. Digital bit input (memory)
6. Digital word input
7. Digital bit output
8. Digital word output (direct)
9. Digital word output (relay)
10. Guidance and navigation word buffer
11. Computer-to-computer buffer
12. Stabilization and control system hand controller input system
13. DCE control unit

The external DCE consists of:

1. Malfunction insertion unit
2. Central time equipment
3. Integrated up-data link
4. Digital-to-resolver converter
5. Analog-to-resolver converter

Figure 1-97 illustrates the flow of information from the digital computers via the control unit and to and from the individual conversion devices. Transfer of information between the computers and the control unit takes place via the fully-buffered channel of each computer. Transfer of data is under control of the real time input/output program, which is initiated 20 times per second.

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1.7.3.1 DCE Control Unit.

The DCE control unit acts as the switching center between the DCE and the computers. The control unit responds to requests from the different computers to communicate with specific devices and makes the connection when the particular device is free to communicate.

1.7.3.2 Digital-to-Analog Converter.

The purpose of the digital-to-analog converter is to convert to analog signals, the 24-bit data words received from the computer. The digital-to-analog (fast) converters are used in situations where the analog values must follow changes in the digital word within a few microseconds, such as FDAI rate and error indicators.

1.7.3.3 Analog-to-Digital Converter.

The purpose of the analog-to-digital (A/D) converter is to convert analog signals into 12-bit digital words to be transmitted to the digital computers via the DCE control unit.

1.7.3.4 Digital Bit Input.

The function of the Digital Bit Input (DBI) is to receive the digital bit inputs from switches or circuit breakers of the AMS, place the bit in the least significant bit position of the 24-bit word, and then transmit the word to the computer.

The Digit Bit Input (memory) (DBIM) performs the same function as the DBI except the inputs to the DBIM are from momentary switches whose activation may be less than 50-millisecond iteration rate of the computer. Flip-flop storage is the memory device used to record the depression of the momentary switches.

1.7.3.5 Digital Word Input.

The function of the Digital Word Input (DWI) is to transfer to the computers 24-bit words originating at the AMS. Examples of AMS functions that originate as DWIs are inputs from the CDUs, MIUs, Attitude Set Controls, etc.

1.7.3.6 Digital Bit Output.

The purpose of the Digital Bit Output (DBO) is to receive a single bit transmitted from the computer as the least significant bit of a 24-bit word, store the bit in a one-bit register, and then direct the output of the register to a relay driver. The contacts of the relay are used to control simulator functions, such as flag indicators, indicator lamps, and other devices requiring a discrete signal.

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1.7.3.7 Digital Word Output (Direct).

The Digital Word Output (DWD) receives and stores 24-bit words received from the computer via the control unit. The words are then transferred to the simulator to drive items such as CDUs, telescope and sextant. The Digital Word Output (Relay) performs the same function as the DWD except the inputs to the simulator are held by relay action.

1.7.3.8 Guidance and Navigation Word Buffer.

The purpose of the Guidance and Navigation Word Buffer is to receive parallel data words representing the output of the simulated G&N computer, convert the words into serial form, and transmit the words to the PCM telemetry equipment. Parallel data words are received as 17-bit words at a rate of 100 words per second. These words are converted in serial form and are sent to the PCM telemetry as 40-bit words. Hand switches on the telemetry console can introduce failures of any of the 40 bits.

1.7.3.9 Computer-to-Computer Buffer.

The Computer-to-Computer Buffer is used to transmit trajectory data between the AMS and the GSSC complex. The buffer is essentially a serial-to-parallel and parallel-to-serial converter which uses a magnetic core memory and shift register to accomplish the conversion. The information to be exchanged is in parallel form in the computers but is transmitted in a serial form.

1.7.3.10 SCS Hand Controller Input System.

The purpose of the SCS Hand Controller Input System is to receive, store, and transmit to the DDP-224 computer inputs received from the rotation, translation, and minimum impulse controls. In some cases, the duration of these inputs is timed in one-millisecond intervals. Another function of the SCS input system is to store any failure indications transmitted to the SCS system from the computer and to restore the system to normal after completion of data transfer.

1.7.3.11 Malfunction Insertion Unit.

The purpose of the Malfunction Insertion Unit (MIU) is to provide the means for initiating and monitoring simulated malfunctions. The MIU is used to perform the following functions:

- Enter any malfunctions into the computer program
- Interrogate the status of any active malfunction
- Clear any active malfunction from the computer program
- Clear all active malfunctions from the computer program

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Keyboard-initiated malfunctions will be entered during the mission by means of a 24-bit word formed by the activation of the MIU control panel switches. (See figure 1-18.) The DISPLAY switch, which indicates where the malfunction shall be displayed on the MIU Control & Display Panel, sets bits 4 through 7 of the word. The SYSTEM SELECT switch sets bits 8 through 15, which will be the alphabetic portion of MIU code number. The KEYBOARD switches will insert the numerical portion of the MIU code number on the verify register and set bits 16 through 24. The word will enter all computers via a digital word input (DWI) under control of the real time input/output program. Each computer will then enter a routine to determine the validity of the malfunction. The result of the validity check is transmitted from the computer via a Digital Word Output-Relay (DWOR) to the MIU Control and Display Panels.

If the malfunction is valid, other action can now be taken with the instruction switches. Depression of the MALFUNCTION ENTER switch will activate the malfunction by setting bit two of the DWI and setting a sense line. The malfunction can be removed from the system by depression of the MALFUNCTION CLEAR switch. Bit one of the DWI and a sense line are set by this action.

If the validity check results in an invalid malfunction, the INSTRUCTION INVALID light will be illuminated by means of a Digital Word Output-Relay (DWOR) from the computer. At this point depressing the CONTROL PANEL RESET switch will extinguish all lights and reset conditions to initiate another malfunction.

All active malfunctions with the exception of those time dependent may be cleared by depression of the MASTER CLEAR ALL system switch. Time dependent malfunctions can be cleared within 90 seconds of the prior to activation by depressing the 10 DISPLAY switch and the MALFUNCTION CLEAR switch.

1.7.3.12 Central Timing Equipment.

The purpose of the Central Timing Equipment (CTE) is to produce the following signals for use in the AMS.

1. 512 kc
2. 6.4 kc
3. One-second pulses
4. 50-millisecond real time interrupt signal
5. Binary time word
6. Binary-coded-decimal time word

The 512-kc signal is the basic timing signal used in the simulation of the PCM telemetry system. The one-second pulses are also used in the PCM telemetry simulation as synchronizing pulses. The 6.4-kc signal is used in the simulation of the 400-cycle frequency synchronization of the

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three power inverters. The 50-millisecond real time interrupt, the binary time word, and binary-coded-decimal time word are all used in the computer system.

As illustrated in figure 1-98, alternate reference frequency sources are available to the CTE. During a nonintegrated mission, a 1024-kc crystal clock supplies the reference frequency to the CTE. During an integrated mission, a 1000-cps signal is received from the NASA facilities and multiplied to 1024 kc. The signal is then divided into the frequencies desired and gated out with provision for simulating failures. The time words are developed from the 50-millisecond pulses gated into a counter chain which counts half-seconds, seconds, minutes, hours, and days-of-the-month. The resulting time words are converted into BCD and binary form before being transmitted to the computers.

Provision is made through switches and buffers to enable the times to be initialized from external sources. Switches can be set up to indicate a particular minute; the one-minute trap and one-pulse-per second signal will then automatically start the counters on the next integral minute.

1.7.3.13 Integrated Up-Data Link.

(Operational description of Integrated Up-Data Link is included under "Communication and Data System" system description, section 2 of this volume).

1.7.3.14 Digital-to-Resolver Converter.

The digital-to-resolver converter is used to accept and convert binary angles (sign and magnitude) from the DDP-24 computer to analog 400-cycle signals compatible with the resolvers used in the telescope simulation of the AMS.

1.7.3.15 Analog-to-Digital Shaft Position Encoder.

The purpose of the analog-to-digital shaft position encoder is to accept and convert a shaft angle to equivalent binary digital signals compatible for use in the DDP-24 computer.

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1.8 VISUAL SYSTEMS.

The visual systems of the AMS provide realistic exterior scenes for viewing through the landing and docking windows and through the optical instruments of the simulated G&N system. The views simulated by the visual systems include the following:

1. Earth and lunar orbit scenes for circular and eccentric orbits or various altitudes
2. Earth and lunar scenes from various ranges
3. Celestial star fields and specific navigation stars
4. Sun shafting, sunrise, sunset, moving cloud cover, and earth-moon terminator effect scenes
5. Rendezvous, transposition, and docking LEM image scenes.

The visual systems are arranged about the SCM as depicted in figure 1-1. The illustration indicates the general arrangement and location of the visual systems with respect to the remainder of the training complex and identifies major components. Figure 1-99 provides further component clarification of the visual systems with respect to the SCM windows and optics.

The visual displays use an infinity image system as the basic device for displaying simulated scenes with a large viewing angle. Each display (window and G&N optics) is focused at infinity with the exception of the rendezvous display. The images for the windows and G&N optics are provided by separate image generation sources, which are combined via the optical systems input assemblies. These assemblies include spherical mirrors, beam splitters, and corrective lenses. A typical arrangement is depicted in figure 1-100.

The infinity image system combines image inputs while projecting them at infinity, or in the case of rendezvous, at a variable finite distance. The field of view is limited by a zero thickness exit window having the following outline: docking window, 6 by 12 inches; landing window, circular with a 12-inch diameter. For the docking window the field of view is 70° by 100° and for the landing windows, 50° by 88°. The arrangement of the individual IIS (figure 1-99) is such that these fields of view are provided for. The minimum brightness of any point within the field of view is not less than half of the maximum brightness observed from any viewing angle and does not vary more than half the maximum brightness. There is no noticeable variation in size, shape, or position of any object in the visual field as the viewer's eye moves across the exit pupil.

For ease of discussion, the visual systems are grouped into three major headings, landing windows, docking windows, and G&N optics. Each of these functional groups is described in the following paragraphs.

1.8.1 LANDING WINDOWS.

The landing windows are the two windows located to the side of the reclining astronauts. These windows provide the crew with the capability

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of viewing celestial or orbital scenes that assist them in orientation, attitude maneuvering and scientific observation. Visual scene inputs to the landing windows in the AMS are generated within the mission effects projector (MEP) and the celestial sphere (starfield).

1.8.1.1 Mission Effects Projector.

The mission effects projector is utilized to project scenes of the earth and moon including both near and distant body views. These views are transferred onto a spherical translucent rear projection screen, which is then viewed through the infinity image system. The MEP scenes include the following:

- Full color image of the earth for midcourse; black and white image of the moon
- Earth and lunar orbit
- Celestial bodies in their proper phase
- Sunrise, sunset, and day-night terminator
- Moving solid cloud cover.

All the above image presentations are arranged in such a manner as to provide blending and continuity that would occur under natural viewing conditions. The scenes are generated separately from film strips and projected upon the MEP screen. The scene is moved across the face of the screen by the use of mirrors and prisms, which simulate the attitude motions of the spacecraft. Servos are used to drive and position the film, zoom lens assemblies, and attitude functions.

The arrangement of the MEP is illustrated in figure 1-101. Illumination is provided by two mercury-xenon (Hg-Xe) arc lamps whose light is gathered through a lens and mirror system and relayed to the film. The film is housed in two turrets, each of which contain four film cassettes with a capability of 90 feet of film per cassette. The images from the films are projected through a varifocal lens system, blended, and relayed to the screen. Continuous image projection is used out to 1400 miles, after which earth scenes are presented frame by frame by periodically alternating between turrets. Scale factor changes and zoom lenses make the entire presentation appear continuous. The alternating between turrets allows moon scenes to be interspersed with earth scenes.

Visual scenes encompass an area centered above the nadir and subtending an angle of 90 degrees for the window displays and 107 degrees for the G&N optics. This area, depicted in figure 1-102, is surrounded by a peripheral area extending to the limb of the earth or moon. The peripheral area consists of moving solid clouds for earth scenes, and of an apparent central image with no specific landmark detail for moon scenes. All scenes are synchronized with attitude and direction control to produce apparent motion of the central and peripheral scenes coincidental with attitude changes.

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The earth orbital films center on an orbital flight path based upon a nominal launch azimuth. A five-inch film strip is used to represent a comparable 1000-mile wide band. At an altitude of 100 nautical miles, this allows a minimum ± 400 nm variation in ground trace presentation to simulate orbital freedom, drift, sliding, and results of launch attitude variations. The MEP films can simulate variation in the flight path by variation of selected film in compliance with computer control. A 2.15:1 altitude range variation is required for each film.

Maximum simulated spacecraft attitude rates are during tumbling at up to 40 degrees per second in any axis or combination of axes with acceleration of 40 degrees/sec/sec. Minimum simulated attitude variations are in response to minimum impulse control in conjunction with G&N optics. The overall accuracy of the MEP positioning servos is such that the repeatability of any point in the film plane at the MEP screen is within 1.02 nautical miles (35 arc minutes) at an altitude of 100 nautical miles for earth orbit and at a scaled altitude (1:0.273) for lunar orbit. The MEP system has an angular resolution of three arc minutes as seen by the viewer. Spherical, perspective, and projection distortion is definable at all ranges and altitudes of the spacecraft. Maximum deviation from the real-world presentation does not exceed 60 arc minutes over the total MEP screen. All motions which effect the MEP are controlled by the computer.

The effects of day-night termination are provided by the real time simulation of sunlight and moonlight illumination for earth scenes with correct orbital angle relationships. For moon scenes, the simulation provides the proper relationship between earthlight and sunlight illumination to produce the terminator effect. Sunrise and sunset effects are provided as a function of the sun position. Whenever an earth limb presentation is viewed, which does not fill the complete field of view, the remaining portion is black and the appropriate portion of the celestial sphere superimposed. Window filter emplacement is simulated by reducing the apparent incident light by 77 percent.

1.8.1.2 Starfield.

The starfield display consists of a model celestial sphere whose radius is 13.58 inches at the focal surface. Situated on the sphere are 998 stars up to and including stars of the fifth magnitude. The simulated stars are reflective ball bearings tinted to present the correct spectral characteristics and mounted on a black surface. When illuminated the balls produce a star-like spot of light.

The starfield is viewed through an infinity image system at the windows and simulated telescope. The stars are visible over the entire field-of-view unless occulting occurs. Simulated occultation is included under computer control on the basis of spacecraft configuration, attitude, and position.

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The apparent size of the star is 2 arc minutes or less for zero magnitude or smaller stars. When viewed through the infinity image system, the star patterns are without apparent distortion. Positioning of non-navigational stars is maintained with 0.5 degrees and the navigational stars are located within one milliradian accuracy relative to each other as measured on the sphere.

1.8.1.3 Solar Generator and Sun Shafting.

This equipment is provided to simulate the effect of the sunlight entering the command module windows. Control of the sun shafting is accomplished through the computer system which defines position, direction and intensity functions. The apparent sun angle must be simulated for each window, but since the simulation is for general effect rather than measurement, the angular position, sun size, and collimation of light is not precise. The angular position is accurate to within ± 2 degrees.

The sun shafting simulation is intended to cause the flight crew to cope with problems in spacecraft operation that result from lack of visibility due to direct or reflected sunlight. The simulated sun is of sufficient brilliance to cause momentary blindness (approximately 5 seconds) if directly viewed. This is accomplished with a relative brightness of 50 foot-lamberts to an astronaut who is dark adapted to a level of 1.0 foot-lambert.

The solar generator consists of a self-contained projector, which produces a simulated image of the sun at the screen of the MEP. This simulated sun subtends an angle with a minimum diameter of 32 arc minutes, which is superimposed on the main MEP display. The simulation allows for the sun entering, traversing, and leaving the field of view from any direction and by any path. The illumination source is a 300-watt xenon arc lamp set off axis to minimize interference with the main MEP beam. The optical path is folded to allow a more compact design with the solar lamp axis parallel to the axis of the other arc lamps within the MEP. A continuously variable, computer-controlled, focusing drive for the projection lens is used to keep the sun image in focus.

Occultation of the sun occurs whenever it would appear behind any of the objects visible out the window (i.e., earth, moon, LEM). A rotary, controlled shutter, operating in conjunction with computer signals, is used to control sunlight and effect occultation.

1.8.2 DOCKING WINDOWS.

The docking windows are located forward of the right and left reclining astronauts. These windows enable the crew to observe scenes directly in front of the SCM in the direction of the X axis (apex). Visual scene inputs to these windows are supplied through the infinity image system. The scenes are generated by the MEP and starfield as described for the landing windows. In addition to these inputs, are those supplied by the LEM rendezvous and docking image generation equipment.

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1.8.2.1 LEM Rendezvous and Docking Generator.

The lunar excursion module image generation equipment consists of two television cameras viewing one-twentieth scale models of the LEM and S-IVB booster in all three pertinent configurations. The models are gimbaled for 3 degrees of motion to simulate attitude variations of the vehicles. The models are illuminated by a sun simulator gimbaled for 2 degrees of freedom. Two lamps are used to minimize shadows. Two cameras are used to present parallax effects when viewed through the infinity image system at the docking windows. Range and aspect changes are simulated by actual relative motion between the cameras and the model, and through the use of zoom lenses.

For completed docking phases, a slide image is used for continuous projection. The slide remains observable through the docking windows until either separation for descent or abandonment of the LEM occurs. The simulation of the separation is accomplished by the camera model image generation equipment operated in reverse.

1.8.3 G&N OPTICS.

The visual display system associated with the G&N optics includes both the presentation of perceptual images and the hardware components located within the SCM lower equipment bay. The housing for the simulated G&N optics is designed to provide a firm mounting for the MEP and starfield (celestial sphere) subsystems so that specific alignment can be achieved and maintained. The composite assembly of SXT/SCT optics and image input assemblies, illustrated in figure 1-103, is mounted on a rigid boom suspended from the overhead catwalk which allows the SCM to be lowered away from it and traverse beneath it.

1.8.3.1 Telescope.

The simulated telescope (SCT) consists of simulated telescope optics and reticle arrangements along with a fixed optical system, which permits simultaneous viewing of the starfield and the MEP. The starfield and MEP provide the necessary images by presenting proper images on fixed surfaces under computer control. Apparent motion resulting from SCT operation and spacecraft attitude changes is simulated by moving the images. Sun blinding is not incorporated in the SCT but an indication of the line-of-sight approach to the suns position is provided by lighting within the SCT optics. The suns reflective effect is also provided.

Landmarks for telescope viewing are provided through the MEP film inputs. To prevent undesirable ghost images at the SCT, the infinity imaging system associated with the SCT is a refractive system rather than reflective. The landmarks to be used in the AMS are listed in table 1-73. The longitude and latitude coordinates of the film landmark, as calibrated, are used as the true coordinates of these landmarks. These are supplied to the simulated

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G&N system to be used in computational functions. Star scenes for the SCT are provided by the celestial sphere starfield as previously described.

The simulated telescope shaft and trunnion axis measurements are obtained directly from the computer or the image generation equipment. The accuracy of the simulated telescope is determined by the Optical System (IIS), plus the accuracy of the reticle-shaft axis alignment and the alignment of these to the optical center of the starfield and the MEP (i.e., mechanical factors). The reticle positioning accuracy is $\pm 0.5^\circ$, and the total displacement of SCT scenes because of mechanical factors is ± 4 arc minutes.

1.8.3.2 Sextant.

The simulated G&N sextant (SXT) is physically and functionally integrated into the command module of the AMS. The arrangement of the components of the simulated SXT, mounted adjacent to the simulated telescope equipment, is illustrated in figure 1-103. The simulated SXT includes those portions of the operational S/C equipment necessary to fully simulate the operation, performance and appearance of the spacecraft SXT. The simulated SXT mounting is a rigid structure designed for long-term optical alignment.

The computer systems control the visual simulation for the SXT by solving real time vehicle dynamics. Signals from the computer control movements, scene selection, shaft readouts, lighting control for sun reflection, and image centering for the simulated SXT. All angle computations are performed by the AMS computer; therefore, accuracy requirements for the simulated SXT are limited to repeatability and stability of the optical system commensurate with the requirements imposed by a navigation sighting or IMU alignment. To permit measurements to a degree of accuracy commensurate with the requirements of a navigation sighting or IMU alignment, the overall repeatability of SXT measurement for star sightings is ± 7 arc seconds, and star to landmark is ± 15 arc seconds. These figures include all factors due to image resolution, positioning, and degradation caused by time, maintenance, etc. Reticle positioning accuracy within the SXT is the same as that for the SCT, 0.5 degrees. Image motion rates for the SXT are 0.7° per second maximum and 3.0 arc seconds per second minimum. These allow the simulated SXT motions to be compatible with S/C minimum impulse rates.

Since specific landmark images are not observed through the SXT until they are clearly identified and located by the telescope, only fixed images contained on a slide encompassing a 4-degree solid angle are used in the simulation. Slide selection of appropriate landmark images occurs whenever the telescope line-of-sight falls within the center 2.2 degrees of any fixed landmark image plate, otherwise no scene is available to the SXT. Image plate selection is performed in conjunction with appropriate computer signals. The slides are positioned with correct relationships between the sextant and telescope lines-of-sight. Flight crew control commands of shaft and trunnion

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motions are processed by the computer to modify image positions so that proper landmark image alignment occurs during operation. Landmark scenes (slides) are restricted to a plane located within 30 degrees of the line-of-sight. These slides will contain specific unobscured landmarks containing moon or earth phase lighting effects. In all, a total of 90 slide images are available for sextant usage.

Star scenes for the sextant are developed by a navigational star generator. This generator uses a single plate with a variable density filter to produce the appropriate navigational star of the proper magnitude. Associated celestial star backgrounds are developed by a starfield pattern generator. Under computer control, the appropriate background starfield for the selected navigational star is illuminated. The two scenes are then combined via a beam splitter and presented to the simulated SXT variable line-of-sight optics.

The specific landmarks to be used during earth orbit navigation sightings and lunar orbit navigation sightings are listed in tables 1-73 and 1-74. These same landmarks (i.e., specific selections from these landmarks) are used in conjunction with midcourse navigation sightings involving sextant usage. The navigation stars to be used for either IMU alignment or midcourse navigation sightings involving the sextant are listed in table 1-75. Only 28 are tabulated of the total of 57 located on the celestial sphere. These 28 stars are generated within the SXT optics assembly as previously described.

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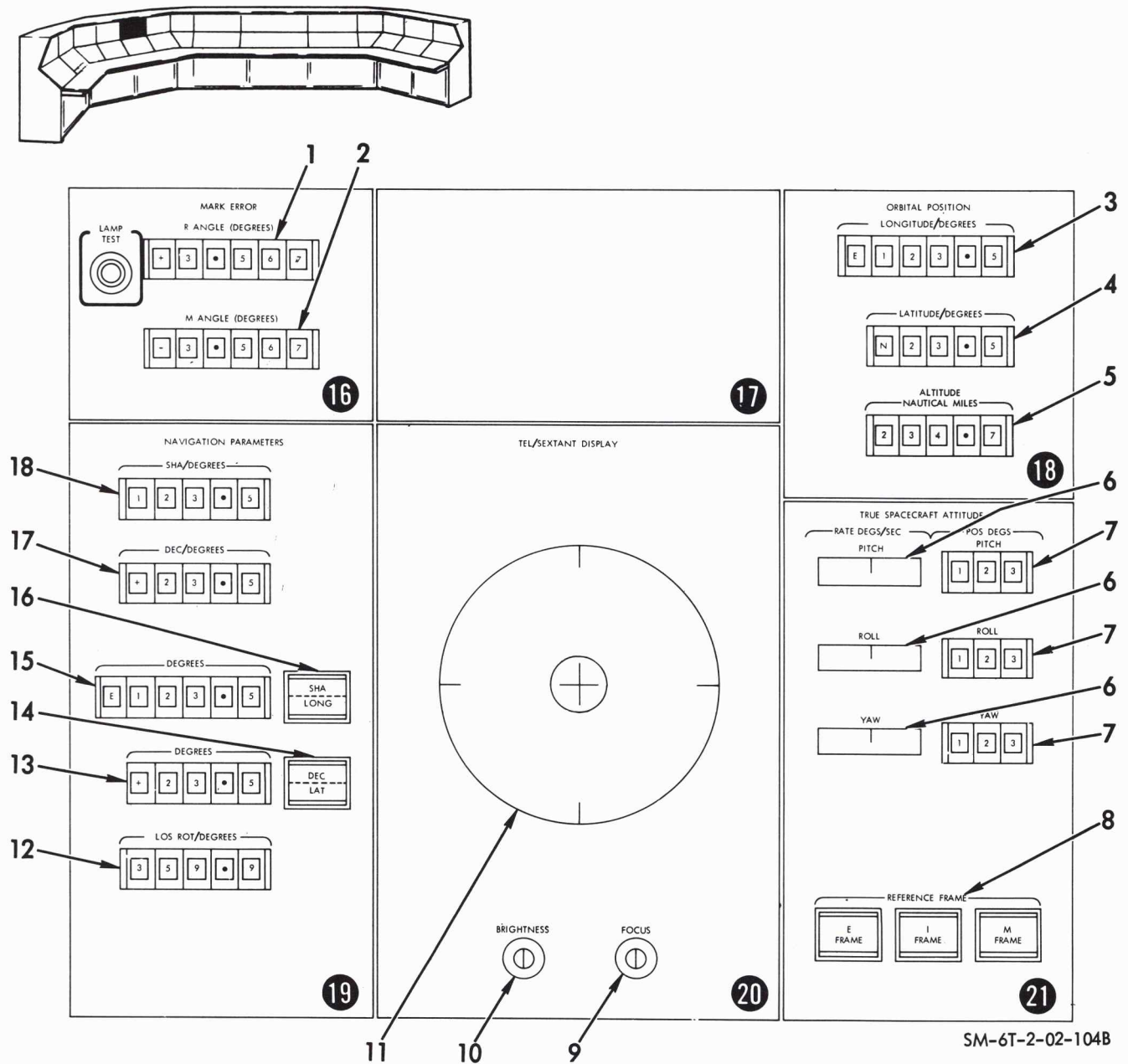


Figure 1-4. Guidance and Navigation Supplementary Displays

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Table 1-3. G&N Supplementary Displays - Controls and Displays

Key	Nomenclature	Function	Remarks
1	MARK ERROR—R ANGLE (DEGREES) display	Displays angular coordinates of a landmark with respect to scanning telescope crosshairs or angular coordinates of a star with respect to sextant crosshairs.	For midcourse navigation these readouts provide alignment displacement in terms of angles using sextant M and R lines as coordinates.
2	MARK ERROR—M ANGLE (DEGREES) display	Same as key 1.	Same as key 1.
3	ORBITAL POSITION—LONGITUDE DEGREES display	Five-digit alphanumeric display which indicates longitude of S/C orbital position.	
4	ORBITAL POSITION—LATITUDE DEGREES display	Four-digit alphanumeric display which indicates latitude of S/C orbital position.	
5	ALTITUDE NAUTICAL MILES display	Four-digit numeric display of S/C orbital altitude.	
6	TRUE SPACECRAFT ATTITUDE—RATE DEGS SEC display	Three analog meters indicating PITCH, ROLL, and YAW components of true S/C attitude rates.	
7	TRUE SPACECRAFT ATTITUDE—POS DEGS display	Three-digit readouts indicating PITCH, ROLL, and YAW components of true S/C altitude.	
8	REFERENCE FRAME lt	Provides indication as to whether inertial reference is E FRAME, I FRAME or M FRAME.	
9	TEL/SEXTANT DISPLAY—FOCUS control	Provides means to adjust focus of cathode ray tube (CRT) display.	
10	TEL/SEXTANT DISPLAY—BRIGHTNESS control	Controls brightness of CRT display.	
11	TEL/SEXTANT DISPLAY	Presents analog of SXT/scanning telescope (SCT) view.	
12	NAVIGATION PARAMETERS—LOS ROT DEGREES display	Provides four-digit indication of amount of rotation about shaft axis.	
13	NAVIGATION PARAMETERS—DEGREES display	Five-digit alphanumeric readout which indicates coordinates of point of intersection of associated line-of-sight and earth/moon/celestial sphere.	
14	NAVIGATION PARAMETERS—DEC-LAT lt	Split-screen lt which shows whether associated display is reading latitude (landmark sighting - SCT) or declination (star sighting - SXT).	

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Table 1-3. G&N Supplementary Displays - Controls and Displays (Cont)

Key	Nomenclature	Function	Remarks
15	NAVIGATION PARAMETERS—DEGREES display	Five-digit alphanumeric readout which indicates coordinate of point of intersection of associated line-of-sight and earth/moon/celestial sphere.	
16	NAVIGATION PARAMETERS—SHA- LONG lt	Split-screen lt which shows whether associated display is reading longitude (landmark sighting - SCT) or sidereal hour angle (star sighting - SXT).	
17	NAVIGATION PARAMETERS—DEC/ DEGREES display	Provides four-digit readout of declination of SXT shaft line-of-sight (LOS).	
18	NAVIGATION PARAMETERS—SHA/ DEGREES display	Provides four-digit readout of sidereal hour angle of SXT shaft LOS.	

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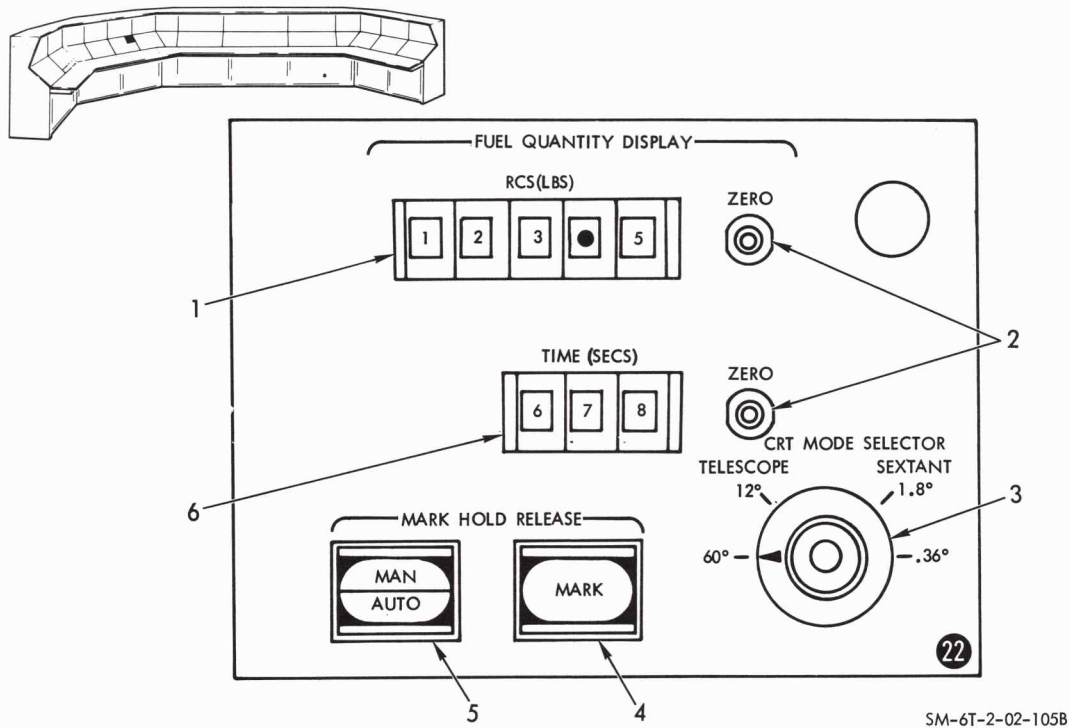
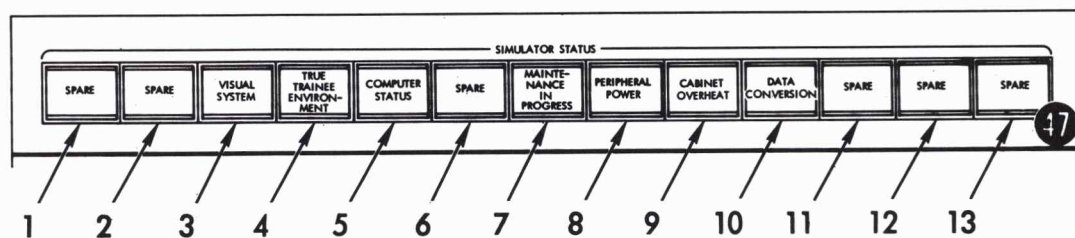
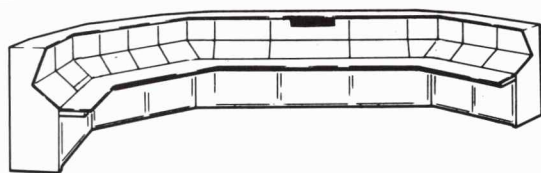


Figure 1-5. Navigation Evaluation Panel

Table 1-4. Navigation Evaluation Panel—Controls and Displays

Key	Nomenclature	Function	Remarks
1	FUEL QUANTITY DISPLAY—RCS (LBS) display	Four-digit indicator which records amount of fuel consumed during navigation sighting.	
2	FUEL QUANTITY DISPLAY—ZERO display	Manual control (two) for zeroing related digital displays.	
3	FUEL QUANTITY DISPLAY—CRT MODE SELECTOR sw	Rotary switch that selects reference and field-of-view for CRT display.	
4	MARK HOLD RELEASE—MARK sw - lt	Depressing the sw - lt will cause displays of items 1, 2, 10, 22, and 23 to "freeze" until switch is again depressed.	
5	MARK HOLD RELEASE—MAN-AUTO sw - lt	Depressing the sw - lt determines whether indicators controlled by MARK switch are under control of computer or MARK switch.	
6	FUEL QUANTITY DISPLAY—TIME (SECS) display	Three-digit timer, actuated by MINIMUM IMPULSE control that times navigation sighting.	

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Figure 1-6. Simulator Status Panel

Table 1-5. Simulator Status Panel—Controls and Displays

Key	Nomenclature	Function	Remarks
	SIMULATOR STATUS		
1	SPARE		
2	SPARE		
3	VISUAL SYSTEM lt	When on, indicates malfunction in window display and SXT/SCT.	
4	TRUE TRAINEE ENVIRONMENT lt	When on, indicates malfunction in trainee environment systems.	
5	COMPUTER STATUS lt	When on, indicates malfunction in computer systems.	
6	SPARE		
7	MAINTENANCE IN PROGRESS lt	Indicates maintenance is being performed on AMS.	
8	PERIPHERAL POWER lt	Indicates malfunction in power supplies to peripheral equipment.	
9	CABINET OVERHEAT lt	Indicates insufficient cooling in cabinets.	
10	DATA CONVERSION lt	Indicates malfunction in data conversion equipment (DCE).	
11	SPARE		
12	SPARE		
13	SPARE		

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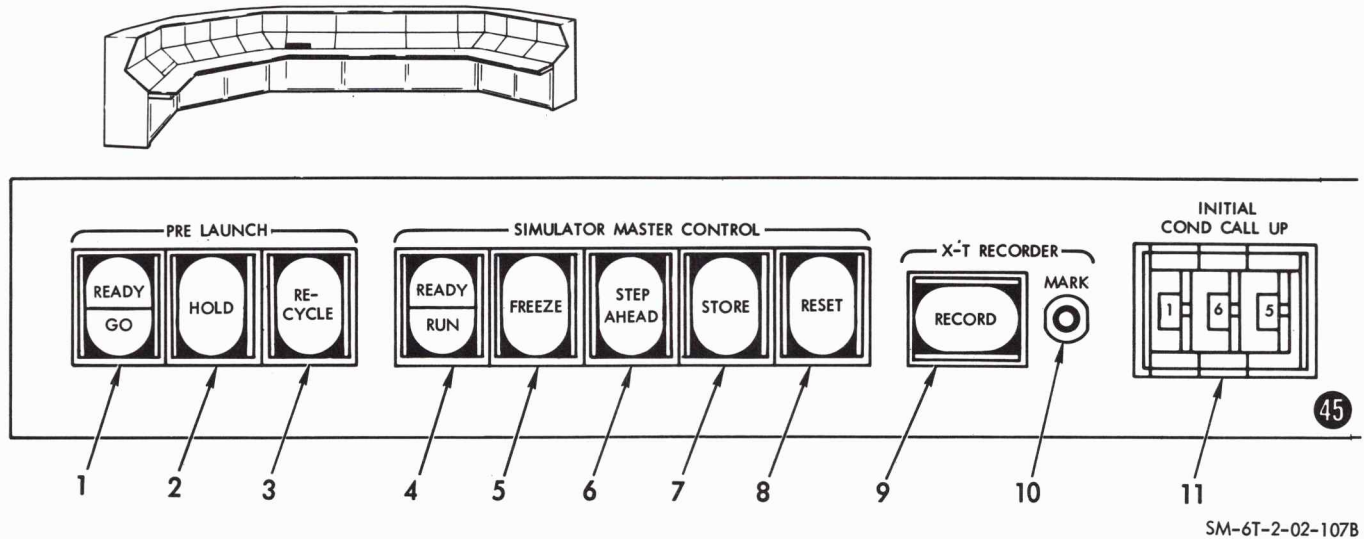


Figure 1-7. Simulator Control Panel

Table 1-6. Simulator Control Panel—Controls and Displays

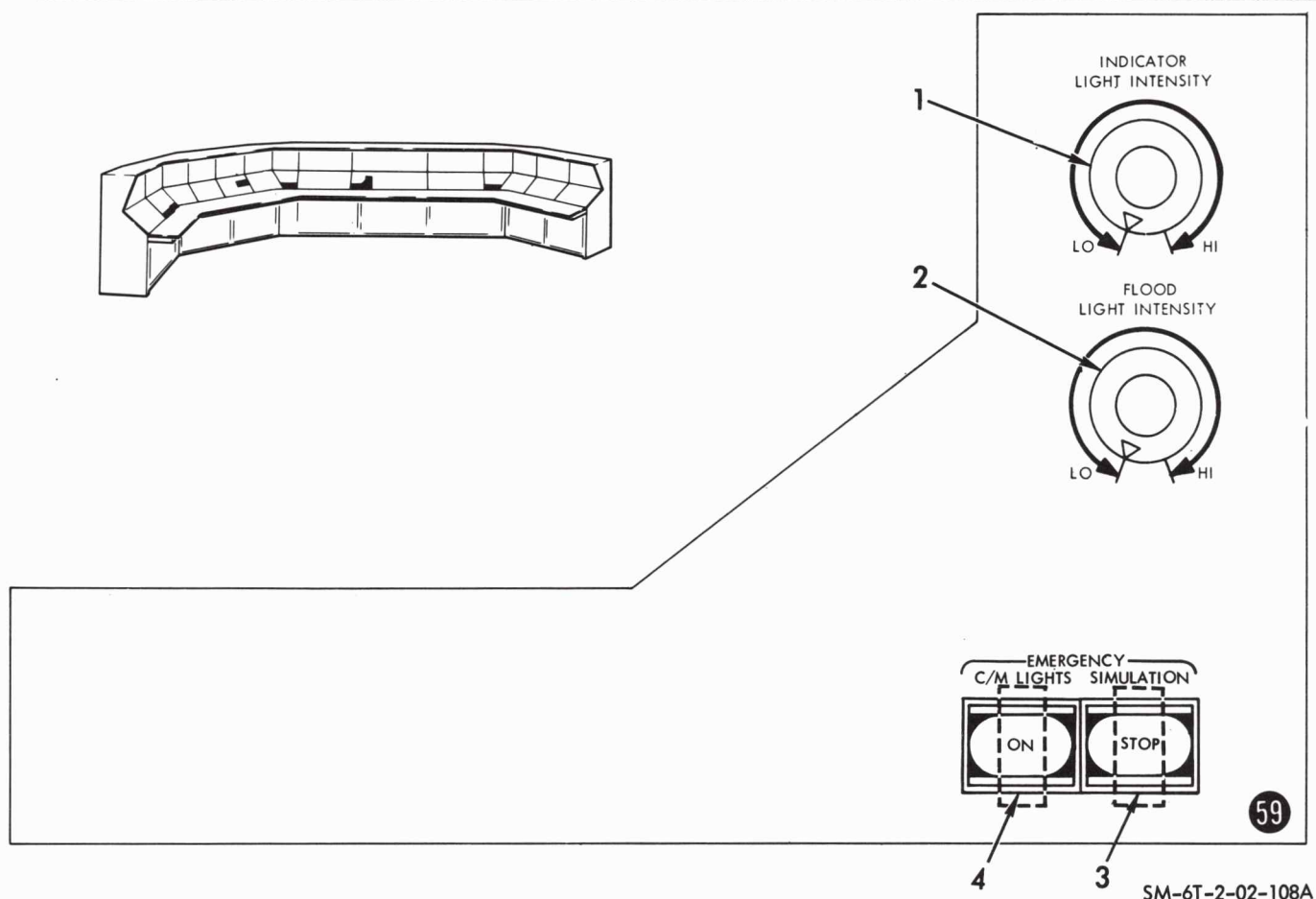
Key	Nomenclature	Function	Remarks
	PRE LAUNCH —		
1	GO sw - lt	Split level indication. Switch action initiates dynamic simulation. READY lt indicates IO must depress sw within next minute.	
2	HOLD sw - lt	Will inhibit dynamic simulation at point of depression. Real time simulation (procedural) not involving integrations can be accomplished. Malfunctions may be inserted through either MIU or C/B. To/from launch clocks are stopped.	
3	RECYCLE sw - lt	Will remove inhibit impressed by HOLD function and reset dynamic simulation to T- 60 sec. point. Initiation of simulation returns to GO function.	

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Table 1-6. Simulator Control Panel—Controls and Displays (Cont)

Key	Nomenclature	Function	Remarks
4	SIMULATOR MASTER CONTROL — RUN sw - lt	Split level indicator. READY lt indicates IO must depress sw within next minute. In prelaunch phase, sw action initiates program operation with dynamic simulation contingent upon GO switch. Initiates dynamic real time simulation in other than launch boost phases upon completion of initial condition setup.	
5	FREEZE sw - lt	Stops all simulation. No real time nor dynamic simulation capabilities exist in this state.	
6	STEP AHEAD sw	Enables simulation to step ahead to a prescribed point in time, as specified, at other than real time rates.	
7	STORE sw	Enables recording of set block of memory (parameters) to be used on new reset (start) point. Must be identified with initial condition digiswitches which are also recorded (stored).	
8	RESET sw	Causes computer to read in initialization parameters as defined by INITIAL CONDITION CALL UP thumbwheels. At completion of this function, trainer is returned to a "freeze" condition.	
9	X-T RECORDER — RECORD sw	Pertains to X-T recorders. Permits individual control of X-T recorders from their separate panels. When depressed (OFF) overrides individual controls and places X-T recorders in standby.	
10	Mark pushbutton	Places a "mark" alongside each parameter being recorded on the X-T recorder.	
11	INITIAL COND CALL UP — thumbwheels	Three octal thumbwheel digiswitches that select set of initial conditions to which AMSC program is set.	

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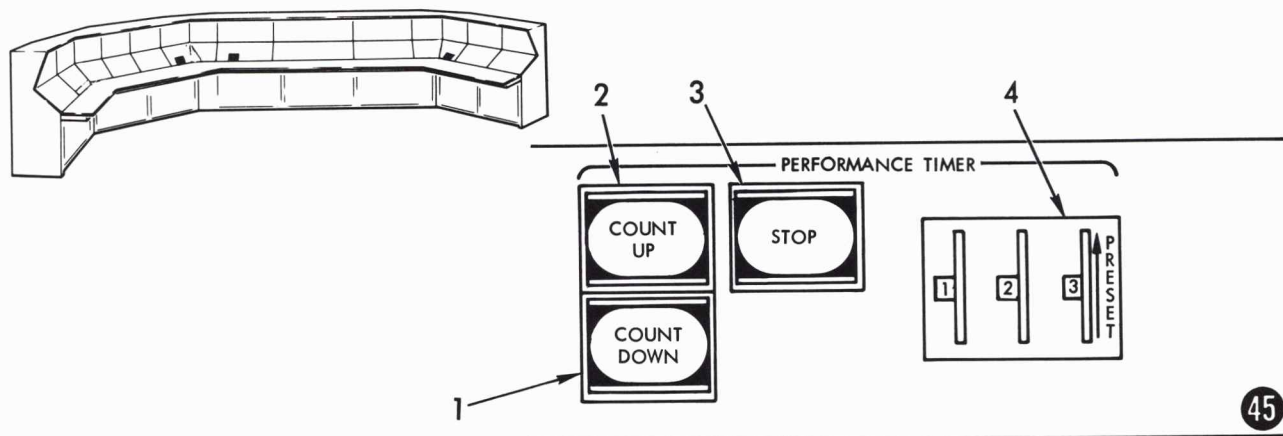
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Figure 1-8. Lighting Control Panel

Table 1-7. Lighting Control Panel—Controls and Displays

Key	Nomenclature	Function	Remarks
1	INDICATOR LIGHT INTENSITY control	Variable control for lt intensity setting.	
2	FLOOD LIGHT INTENSITY INTENSITY control	Varies intensity of overhead lighting.	
3	EMERGENCY-SIMULATION—STOP sw - lt	Causes trainer to perform emergency shutdown process.	
4	EMERGENCY-C/M LIGHTS—ON sw - lt	Provides egress lighting within SCM in event of power loss.	

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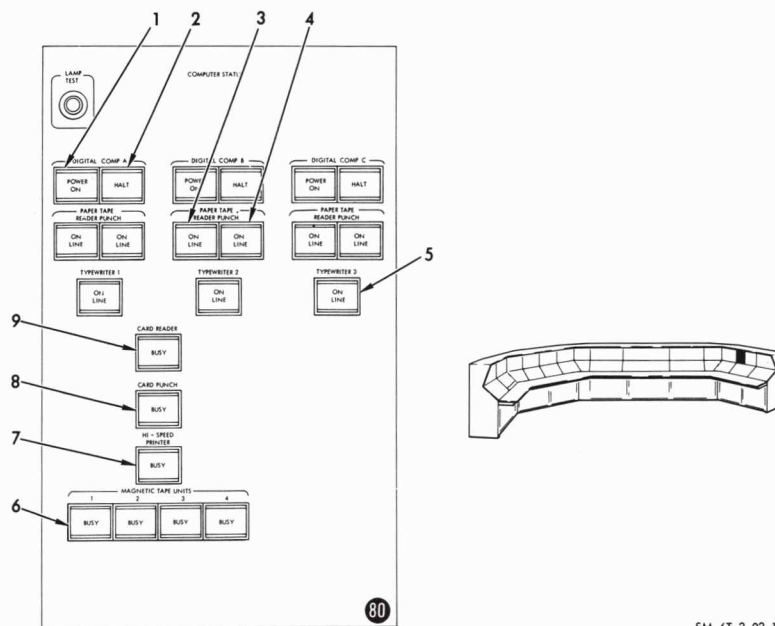
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Figure 1-9. Performance Timer

Table 1-8. Performance Timer Panel—Controls and Displays

Key	Nomenclature	Function	Remarks
	PERFORMANCE TIMER		
1	COUNT DOWN sw - lt	Depressing sw - lt causes counter to count down from variable setting.	
2	COUNT UP sw - lt	Depressing sw - lt causes counter to count up from variable setting.	
3	STOP sw - lt	Stops counter.	
4	Digital thumbwheel	Provides control for setting of desired time from 0 to 999. Indicates elapsed time from initial setting.	

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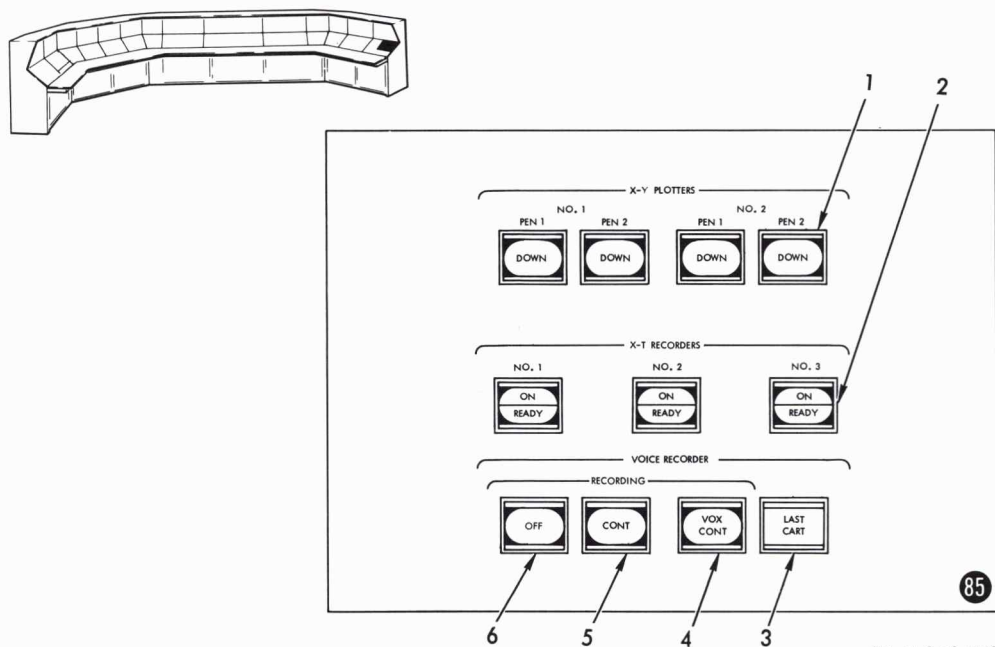
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Figure 1-10. Computer Status Panel

Table 1-9. Computer Status Panel—Controls and Displays

Key	Nomenclature	Function	Remarks
1	DIGITAL COMP POWER ON lt	Indicates power has been applied to related computer.	
2	DIGITAL COMP HALT lt	Indicates related computer is in halt mode.	
3	PAPER TAPE-READER—ON LINE lt (3)	Indicates related paper tape reader is being used by program.	
4	PAPER TAPE-PUNCH—ON LINE lt (3)	Indicates related paper tape punch is being used by computer program.	
5	TYPEWRITER 1, 2, AND 3—ON LINE lt	Indicates related typewriter is being used by program.	
6	MAGNETIC TAPE UNITS—1, 2, 3, AND 4—BUSY lt	Indicates related magnetic tape unit (MTU) is being used by program.	
7	HI-SPEED PRINTER—BUSY lt	Indicates printer is being used by program.	
8	CARD PUNCH-BUSY lt	Indicates punch is being used by program.	
9	CARD READER-BUSY lt	Indicates card reader is being used by program.	

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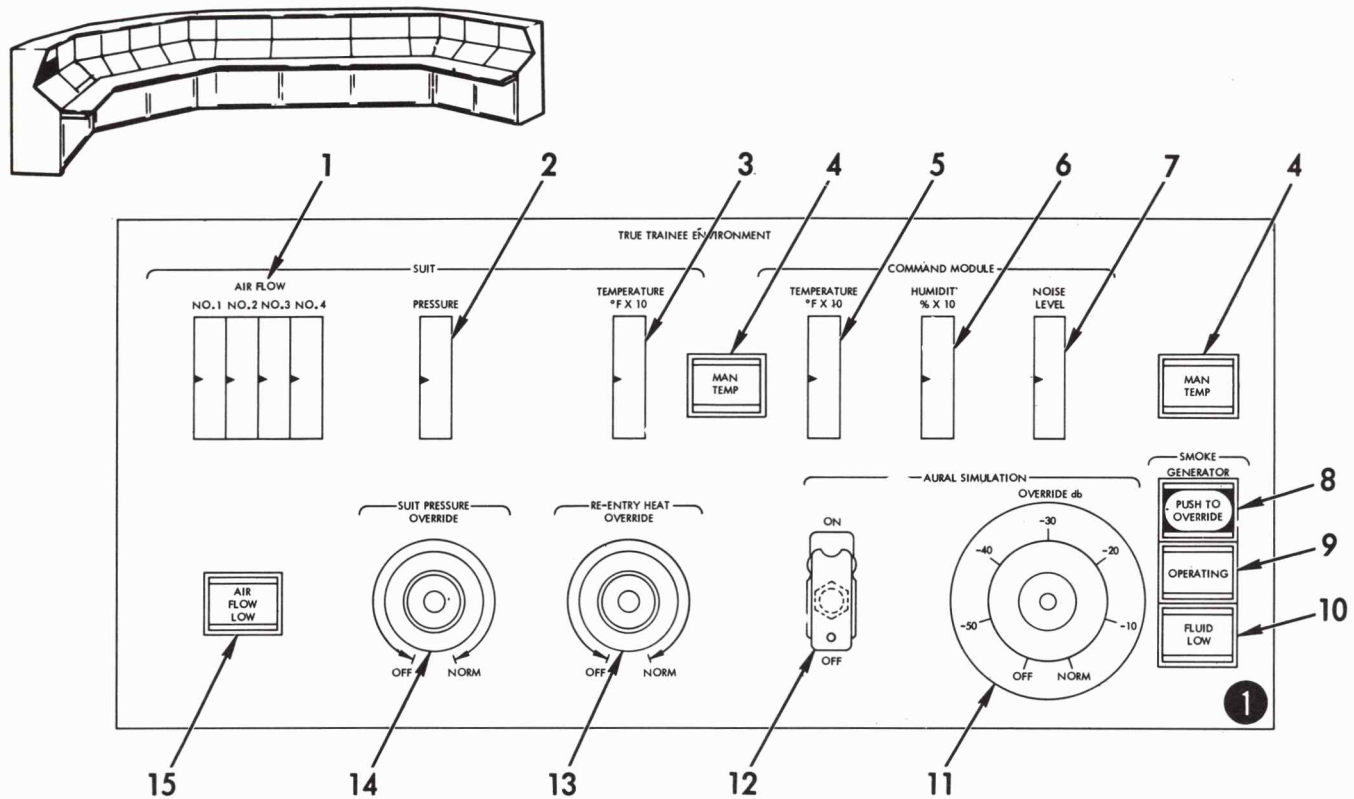
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Figure 1-11. Recorder and Plotter Panel

Table 1-10. Recorder and Plotter Panel—Controls and Displays

Key	Nomenclature	Function	Remarks
1	X-Y PLOTTERS-NO. 1 AND NO. 2—PEN 1 AND PEN 2—DOWN sw - lt	Places recorder pens on writing surface.	
2	X-T Recorders NO. 1, NO. 2 and NO. 3—READY sw - lt	Stops recorder operation.	
	X-T Recorders NO. 1, NO. 2, and NO. 3—ON sw - lt	Permits remote start of recorder operation.	
3	VOICE RECORDER LAST CART lt	Indicates audio tape recorder is using last available empty cartridge.	
4	TAPE TRANSPORT VOX CONT sw - lt	Enables audio tape recorder to operate in conjunction with voice operated relay.	
5	CONT sw - lt	Provides continuous recording on audio tape recorder.	
6	OFF sw - lt	Provides power control for KRS audio tape recorder.	

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Figure 1-12. True Trainee Environment Panel

Table 1-11. True Trainee Environment Panel—Controls and Displays

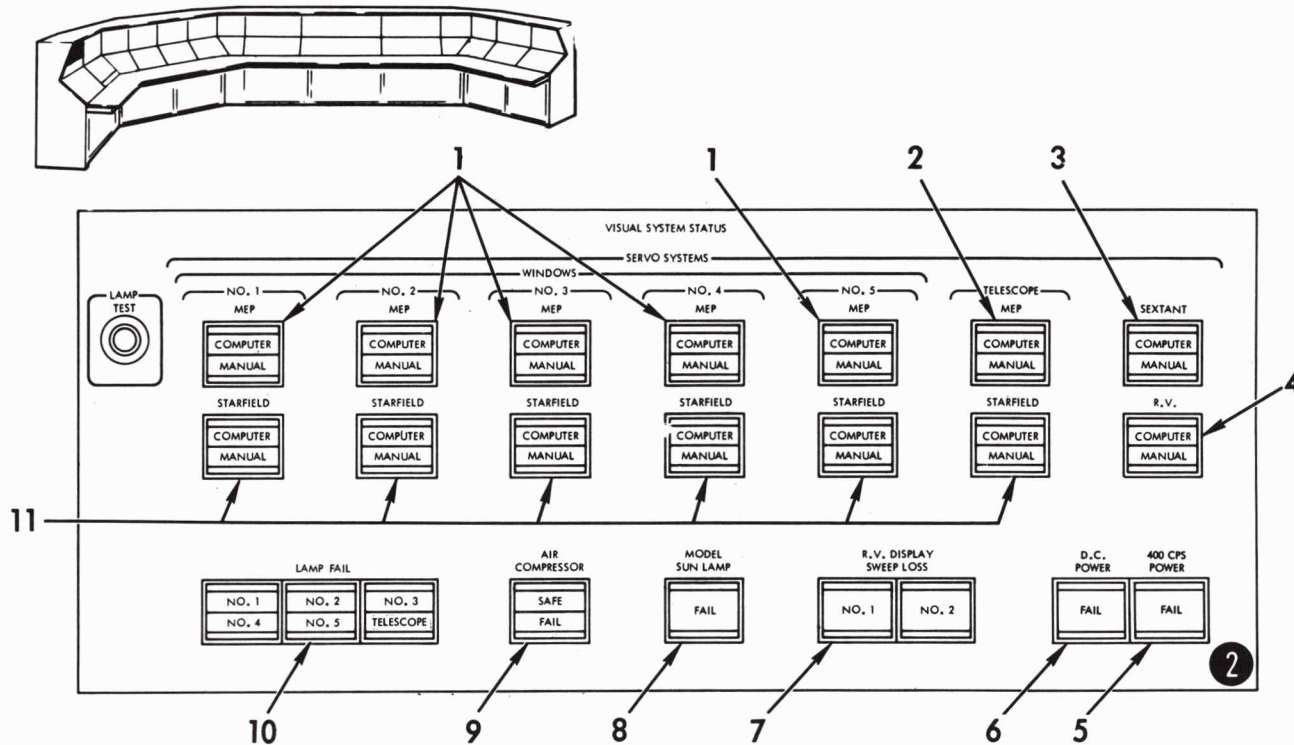
Key	Nomenclature	Function	Remarks
1	SUIT-AIR FLOW—NO. 1, NO. 2, NO. 3, and NO. 4 meters	Indicates actual air flow through each pressure suit.	
2	SUIT-PRESSURE meter	Indicates suit pressure at suit inlet manifold.	
3	SUIT-TEMPERATURE °F X10 meter	Indicates temperature at suit inlet manifold.	
4	MANUAL TEMPERATURE lt	Indicates that trainee is providing manual control of suit or cabin temperature.	

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Table 1-11. True Trainee Environment Panel — Controls and Displays (Cont)

Key	Nomenclature	Function	Remarks
5	COMMAND MODULE — TEMPERATURE °F x 10 meter	Indicates actual SCM temperature.	
6	COMMAND MODULE — HUMIDITY % x 10 meter	Indicates actual SCM humidity.	
7	COMMAND MODULE — NOISE LEVEL meter	Indicates actual SCM noise.	
8	SMOKE GENERATOR — PUSH TO OVERRIDE sw - lt	Prevents operation of smoke generator, when depressed.	
9	SMOKE GENERATOR — OPERATING lt	Indicates that smoke generator is operating.	
10	SMOKE GENERATOR FLUID LOW lt	Indicates low-liquid smoke level for smoke generator.	
11	AURAL SIMULATION — OVERRIDE db control	Overrides computer initiate aural simulators. A small blue lt in center goes on when knob is not in normal position.	
12	AURAL SIMULATION — ON OFF sw	Provides manual activation of aural simulation controls.	
13	RE-ENTRY HEAT OVERRIDE control	Provides a remote override of computer-controlled SCM cabin temperature. Red lt in center of control goes on when control is not in normal position.	
14	SUIT PRESSURE OVERRIDE control	Provides remote override of trainee's suit pressure. Small red light indicates control is not in normal position.	
15	AIR FLOW LOW lt	Indicates low air flow through one or more of pressure suits whenever flow drops below predetermined level.	
11	AURAL SIMULATION — OVERRIDE db control		

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Figure 1-13. Visual Systems Status Panel

Table 1-12. Visual System Status Panel—Controls and Displays

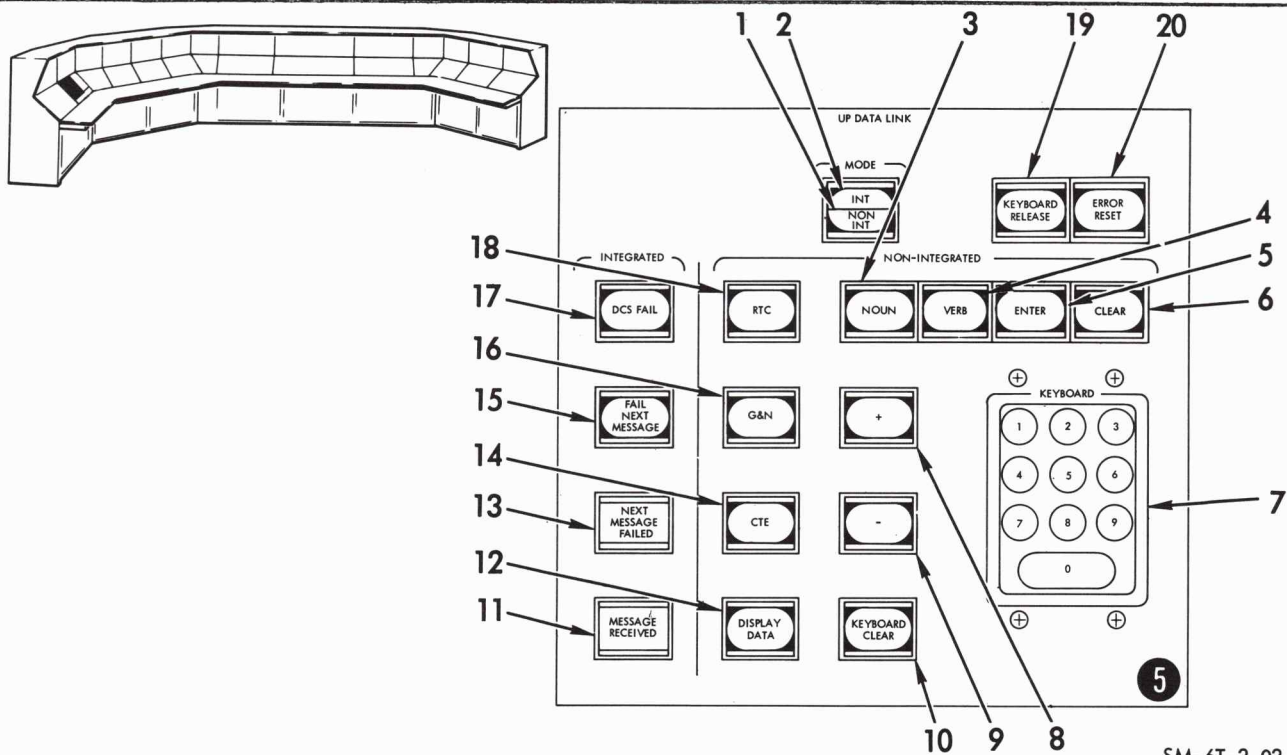
Key	Nomenclature	Function	Remarks
1	SERVO SYSTEMS — WINDOWS MEP COMPUTER — MANUAL It	Indicates that associated MEP is either under computer or manual control.	
2	SERVO SYSTEMS TELESCOPE — MEP — COMPUTER — MANUAL It	Indicates that associated MEP is either under computer or manual control.	
3	SERVO SYSTEMS SEXTANT COMPUTER — MANUAL It	Indicates that sextant cassetts are either under computer or manual control.	

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Table 1-12. Visual System Status Panel - Controls and Displays (Cont)

Key	Nomenclature	Function	Remarks
4	R. V. — COMPUTER — MANUAL lt	Indicates that rendezvous image generator is either under computer or manual control.	
5	400 CPS POWER lt	Indicates a failure of 400 cps power supply.	
6	DC POWER lt	Indicates a failure of the d-c power supply.	
7	R. V. DISPLAY SWEEP LOSS — NO. 1 and NO. 2 lt	Indicates sweep loss (failure) in rendezvous image generator systems.	
8	MODEL SUN LAMP — fail lt	Indicates failure of rendezvous model sun source lamp.	
9	AIR COMPRESSOR — SAFE — FAIL lt	Indicates operating status of air compressor.	
10	LAMP FAIL lt	Indicates lamp failure in each of window display systems.	
11	STARFIELD — COMPUTER — MANUAL lt	Indicates that related starfields are either under computer or manual control.	

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Figure 1-14. Up-Data Link Panel

Table 1-13. Up-Data Link Panel—Controls and Displays

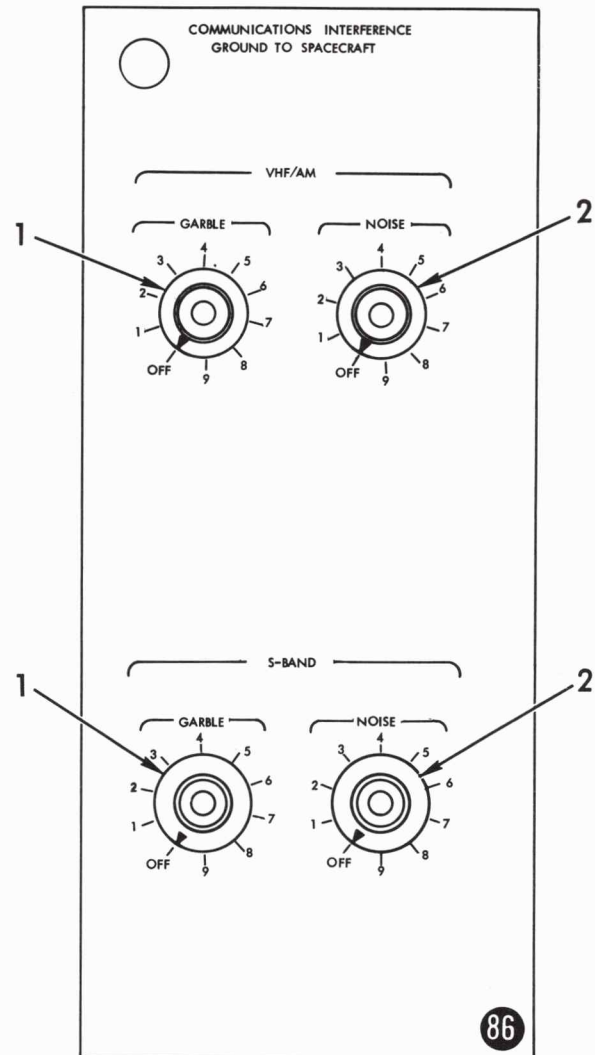
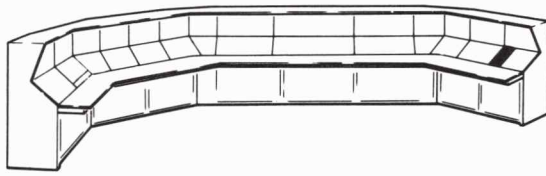
Key	Nomenclature	Function	Remarks
	MODE —		
1	NON-INTEGRATED sw - lt	Permits instructor to input via keyboard panel.	
2	INTEGRATED sw - lt	Enables UDL panel to operate in conjunction with IMCC.	
	NON-INTEGRATED —		
3	NOUN sw - lt	Identifies word format for G&N message.	
4	VERB sw - lt	Identifies word format for G&N message.	
5	ENTER sw - lt	Enters up-data link (UDL) digital keyboard information into computer.	
6	CLEAR sw - lt	Clears UDL digital keyboard only.	

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Table 1-13. Up-Data Link Panel—Controls and Displays (Cont)

Key	Nomenclature	Function	Remarks
7	KEYBOARD momentary contact pushbutton	Supplies 0 to 9 decimal digits for word forming.	
	NON-INTEGRATED		
8	+ (plus) sw - lt	Algebraic code.	
9	- (minus) sw - lt	Algebraic code.	
10	KEYBOARD CLEAR sw - lt	Unlatches system selected (above) and resets UDL panel.	
	INTEGRATED —		
11	MESSAGE RECEIVED lt	Indicates failed message has been transmitted more times than it has failed	
	NON-INTEGRATED —		
12	DISPLAY DATA sw - lt	Informs computer that data output is required and activates computer interface circuit.	
	INTEGRATED —		
13	NEXT MESSAGE FAILED lt	Indicates that next message has been failed.	
	NON-INTEGRATED —		
14	CTE sw - lt	Informs computer that up-coming message is CTE word and activates computer interface circuitry.	
	INTEGRATED —		
15	FAIL NEXT MESSAGE sw - lt	Next message after switch closure will be failed. Repeated depressions indicate number of times message failed.	
	NON-INTEGRATED —		
16	G&N sw - lt	Informs computer that upcoming message is G&N word and activates computer interface circuitry.	
	INTEGRATED —		
17	DCS FAIL sw - lt	Disables decoder to simulate failure to ground transmission link.	
	NON-INTEGRATED —		
18	RTC sw - lt	Informs computer that upcoming message is real time command word and activates computer interface circuitry.	
19	KEYBOARD RELEASE sw - lt	Resets keyboard during integrated mode.	
20	ERROR RESET sw - lt	Resets UDL panel during integrated mode.	

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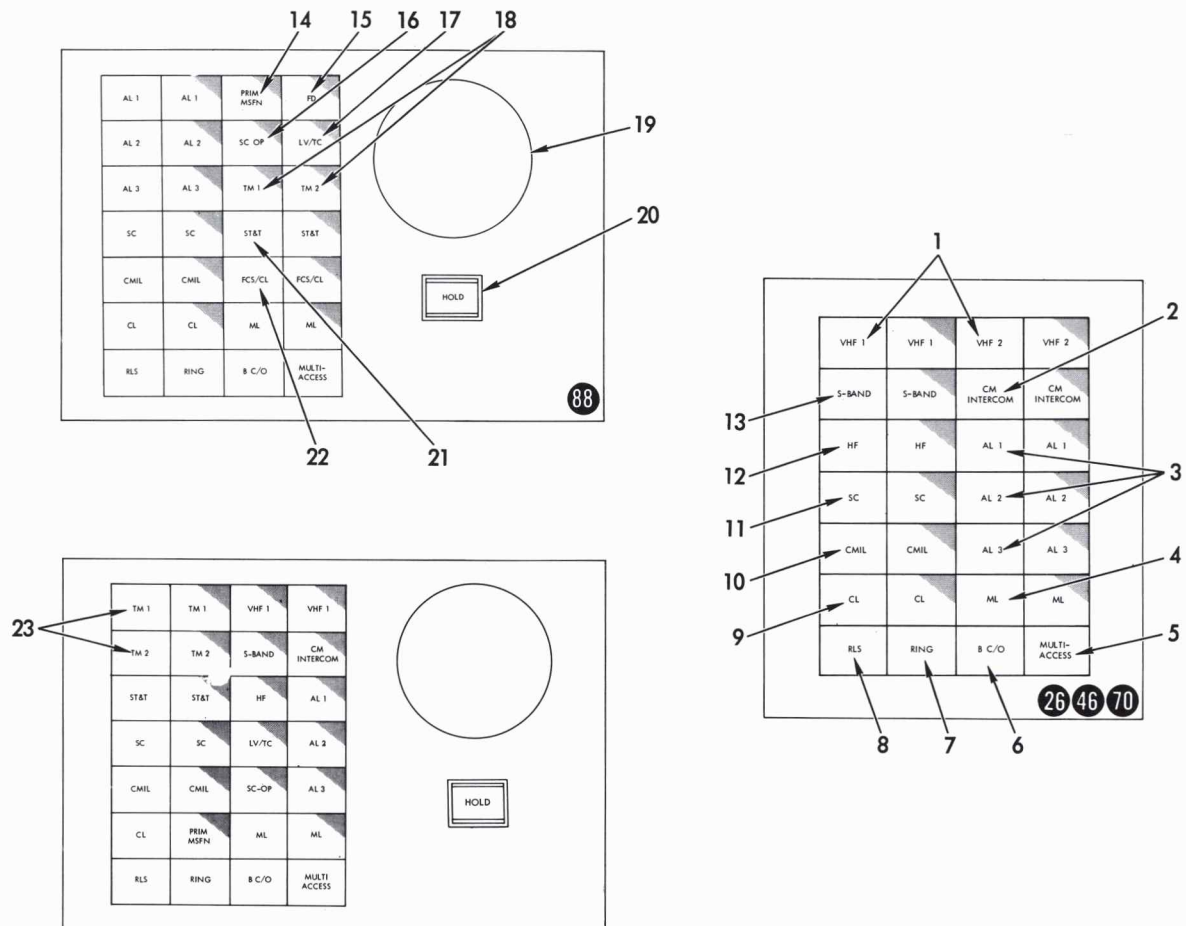
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Figure 1-15. Voice Communications Interference Panel

Table 1-14. Voice Communications Interference Panel—Controls and Displays

Key	Nomenclature	Function	Remarks
1	GARBLE control	Varies amount of garble on VHF-AM or S-BAND up-link voice communications.	
2	NOISE control	Varies noise level on VHF-AM or S-BAND up-link voice communications.	

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Figure 1-16. Console Communications Control System

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Table 1-15. Console Communications System Panels—Keys

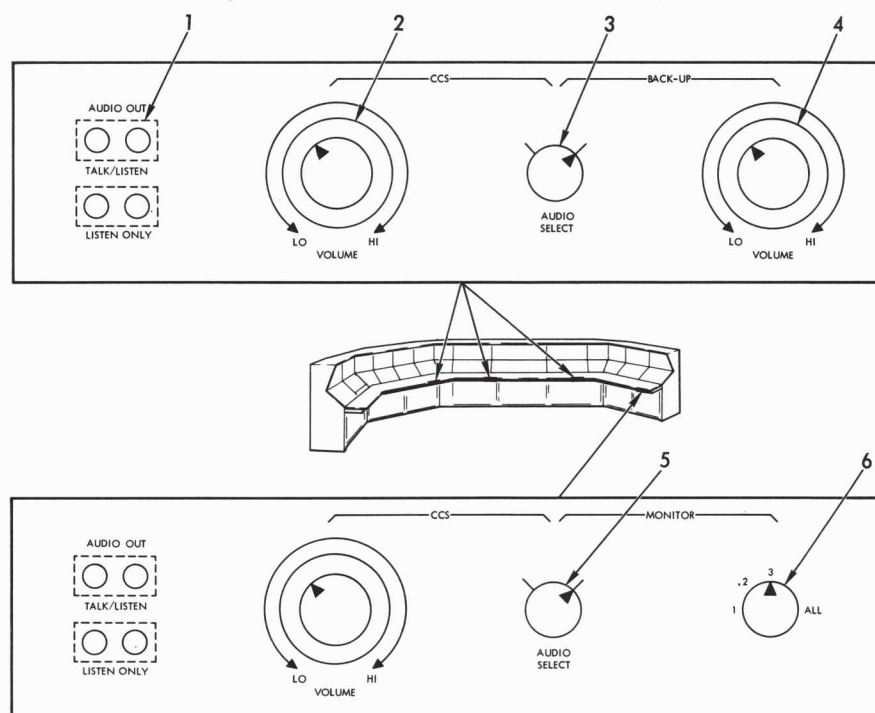
Key	Nomenclature	Function	Remarks
		NOTE Switches with shaded corners indicate monitor circuits. Depression provides access to associated loop and key is lighted. Any combination of monitor keys may be operated at one time.	
1	VHF 1 and 2 keys	Provides simulated RF voice transmission loop with SCM, manned spacecraft flight network (MSFN) and SCM crew stations.	
2	CM INTERCOM key	Provides access to SCM intercommunications loop and simulates GSE hardline for pre-launch.	
3	AL (1, 2, and 3) keys	Provides communications between individual astronaut and AMS instructor.	
4	ML key	Monitor loop key provides IO with access to Manned Spacecraft Control Center (MSCC) and MSFN stations.	
5	MULTI-ACCESS key	Enables IO to select up to three talk-listen keys at one time.	
6	B C/O key	Buzzer cutoff key disables buzzer operation.	
7	RING key	Establishes outgoing signaling on intersite loops after desired key has been operated.	
8	RLS key	Release key releases established talk circuit.	
9	CL key	Computer loop provides communications between IOS and support positions.	
10	CMIL key	Command module instructor's loop provides conferencing capability between instructors.	
11	SC key	Simulator conference loop provides conferencing between AMS instructors and simulation control area (SCA) instructors during integrated training.	
12	HF key	Provides simulation of RF voice transmission loop with SCM and MSFN stations.	

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Table 1-15. Console Communications System Panels—Keys (Cont)

Key	Nomenclature	Function	Remarks
13	S-BAND key	Provides simulated duplex voice transmission between SCM and MSFN stations.	
14	PRIM MSFN key	Prime MSFN loop provides monitoring capability of entire MSFN range.	
15	FD key	Flight director loop provides monitoring capability of flight director.	
16	SC OP key	Spacecraft operations loop provides AMS instructor with monitoring capabilities of simulated activities of blockhouse spacecraft test conductor personnel.	
17	LV/TC key	Launch vehicle-test conductor loop provides monitoring capabilities of launch vehicle test conductor.	
18	TM (1 and 2) keys	Telemetry keys provide monitoring capabilities of telemetry conference loops.	
19	DIAL	Not used. Growth capability which allows for future use of telephone dial.	
20	HOLD key	Enables hold of any talk-listen key selected.	
21	ST&T key	Simulation tracking and trajectory loop provides conferencing capability between AMS instructors and simulation control area (SCA).	
22	FCS/CL key	Flight crew simulator computer loop provides conferencing capability for coordinating AMSC and MSCC computer operations.	
23	TM (1 and 2) keys	Telemetry loops provide conferencing capability between AMS telemetry console operators and MSCC operators.	

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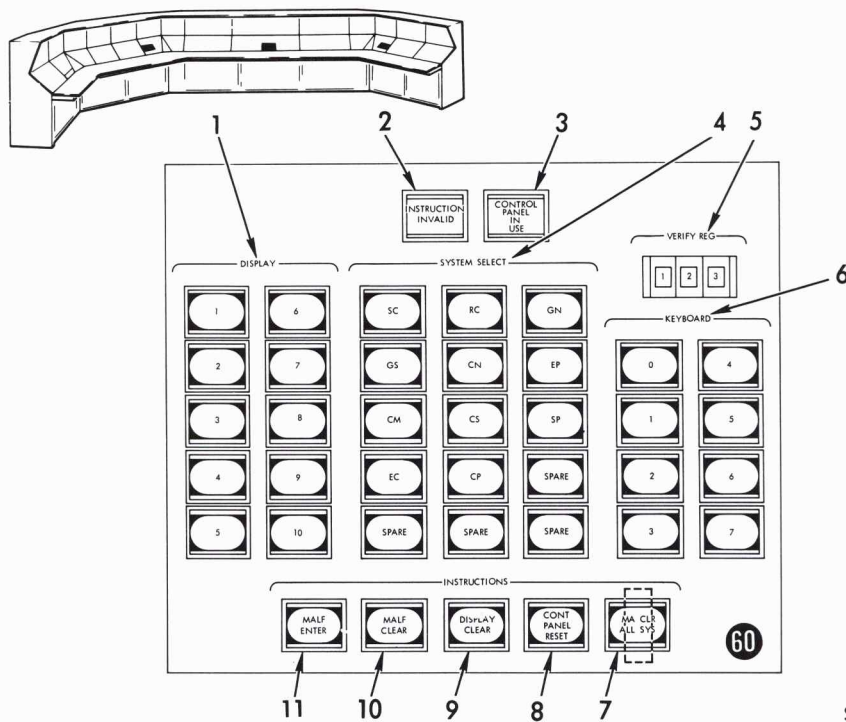
SM-6T-2-02-118

Figure 1-17. Communication Control Panel (Trainer)

Table 1-16. Communications Control Panel (Trainer)—Controls and Displays

Key	Nomenclature	Function	Remarks
1	AUDIO OUT headset jacks	Provide connections for dual prong headset plug to CCS for listen only or talk/listen capability.	
2	CCS VOLUME control	Provides rotary control of selected channel volume.	
3	AUDIO SELECT sw	Provides for selection between communication loops available through CCS keyboard and backup loop.	
4	BACKUP VOLUME control	Provides rotary control of backup loop audio volume.	
5	AUDIO SELECT sw	Provides selection between communication loops available through CCS keyboard and monitor loop.	
6	MONITOR SELECT sw	Enables operator to select any of individual monitor loops (astro) or all of them simultaneously.	

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Figure 1-18. MIU Control Panel

Table 1-17. MIU Control Panel—Controls and Displays

Key	Nomenclature	Function	Remarks
1	DISPLAY sw - 1t	Selects location in which malfunction code and status is to be displayed.	
2	INSTRUCTION INVALID lt	Indicates an invalid malfunction code has been selected.	
3	CONTROL PANEL IN USE lt	Goes on whenever any one of three control panels is operated.	
4	SYSTEM SELECT sw - 1t	Selects and indicates system into which malfunction is to be inserted.	
	CM	Communications	
	CN	Cryogenic storage	

... continued

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Table 1-17. MIU Control Panel—Controls and Displays (Cont)

Key	Nomenclature	Function	Remarks
4 (cont)	CP	SIVB control and propulsion	
	CS	Crew safety	
	EC	Environmental control	
	EP	Electrical power	
	GN	Guidance and navigation	
	GS	Sequence control group	
	RC	Reaction control	
	SC	Stabilization and control	
	SP	Service propulsion	
5	VERIFY REGISTER display	Displays octal numeric code keyed upon keyboard.	
6	KEYBOARD sw - lt	Enables selection of octal numeric portion of malfunction code.	
	INSTRUCTION —		
7	MASTER CLEAR ALL SYSTEMS sw - lt	Removes all malfunctions from computer program.	
8	CONTROL PANEL RESET sw - lt	Resets all switches and lights on control panels.	
9	DISPLAY CLEAR sw - lt	Clears all lights on MIU display panel.	
10	MALFUNCTION CLEAR sw - lt	Removes displayed malfunction corresponding to DISPLAY switch selected from computer program.	
11	MALFUNCTION ENTER sw - lt	Enters displayed malfunction corresponding to DISPLAY switch selected into computer program.	

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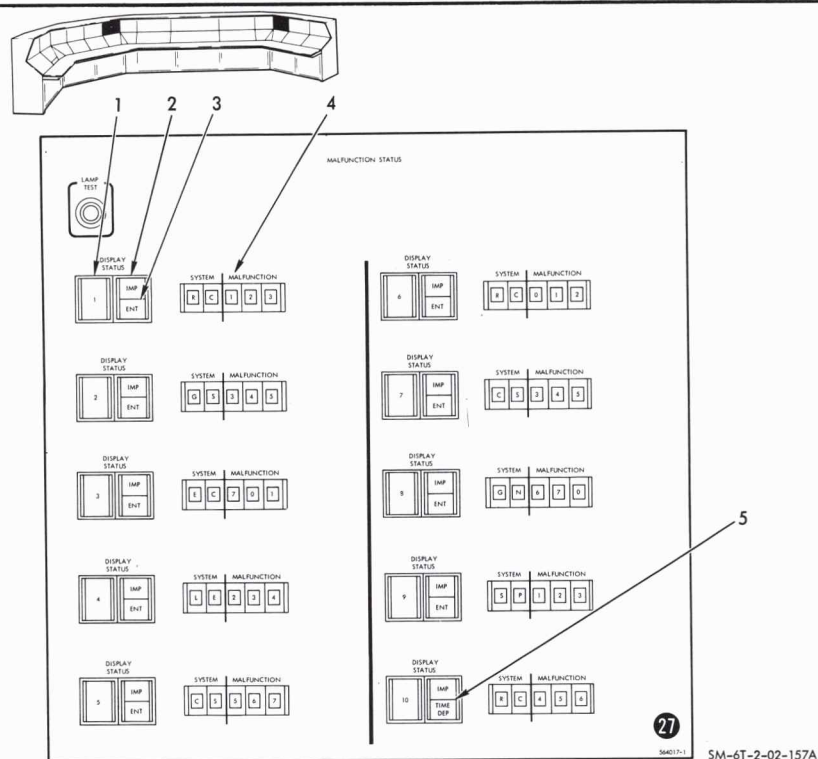
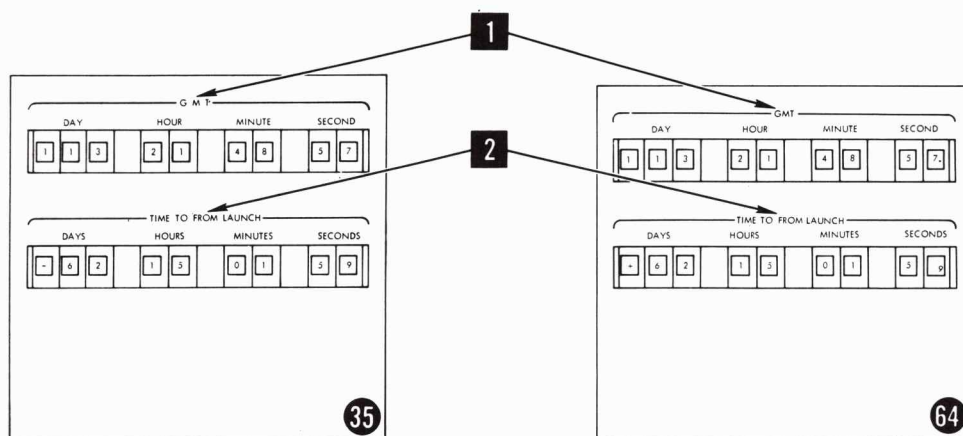


Figure 1-19. MIU Display Panel

Table 1-18. MIU Display Panel—Controls and Displays

Key	Nomenclature	Function	Remarks
1	DISPLAY STATUS lt Display lt	Numeric readout of selected display.	
2	IMP lt	Indicates that malfunction code selected is valid and further instructor action is required.	
3	ENT lt	Goes on whenever a manually selected malfunction is activated. Goes on to indicate that selected malfunction was previously entered into program.	
4	MALFUNCTION display	Magnaline display which provides an alphanumeric readout of selected malfunction code.	
5	TIME DEP lt	For manual or preprogrammed malfunctions, this lt functions as 3 above. For time dependent malfunctions, this lt will flash off and on for ninety seconds prior to activation of malfunction.	

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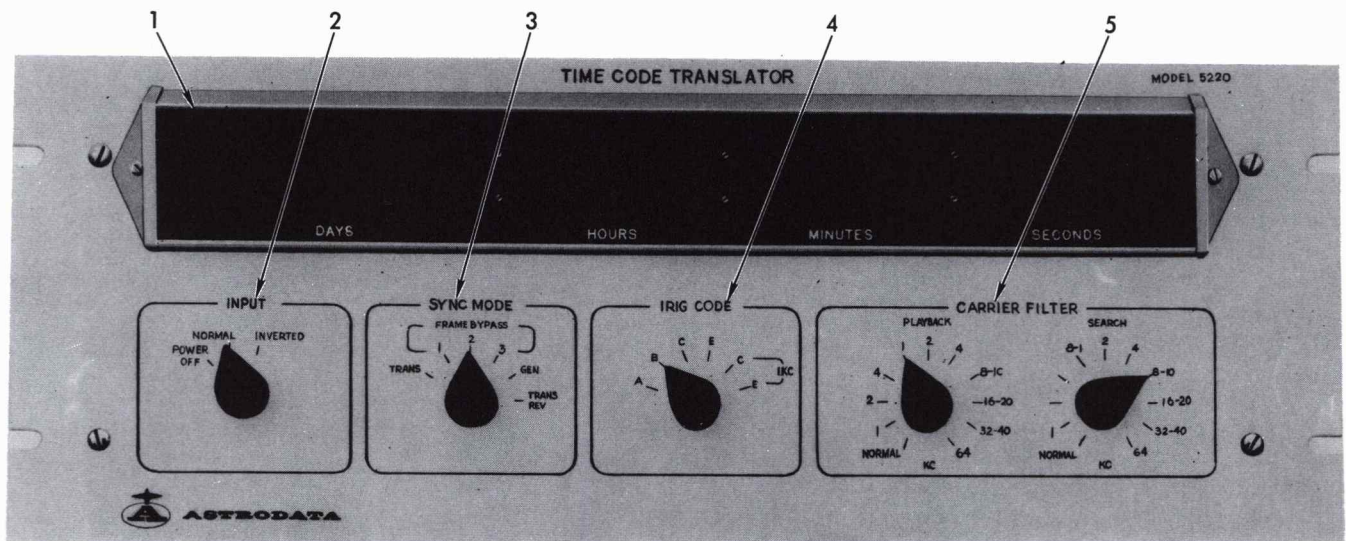
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Figure 1-20. Central Timing Equipment

Table 1-19. Central Timing Equipment Panel—Controls and Displays

Key	Nomenclature	Function	Remarks
1	GMT display (IOS only)	Digital readout of second, minute, hour and day referenced to GMT.	
2	TIME TO/FROM LAUNCH display (IOS only)	Digital readout of second, minute, hour, and day referenced to launch time.	

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Figure 1-21. Digital Time Code Translator

Table 1-20. Time Code Translator Panel—Controls and Displays

Key	Nomenclature	Function	Remarks
1	DIGITAL display	Presents digital readout of time in days, hours, minutes, and seconds.	
2	INPUT rotary sw	Serves as power switch and selects either normal or inverted signal input.	
3	SYNC MODE rotary sw	Sets up carrier decoder circuits to accommodate an input time code presented to unit.	
4	IRIG CODE rotary sw	Selects format control signals to control internal mark counter.	
5	CARRIER FILTER rotary sw	Used to insert filters in automatic gain control circuits for different carrier frequencies, recording and playback speeds.	An external filter sw on rear of panel is placed to INT when these sw are used. If external filters are to be used, these sw are placed to NORMAL and the external filter sw is placed to EXT.

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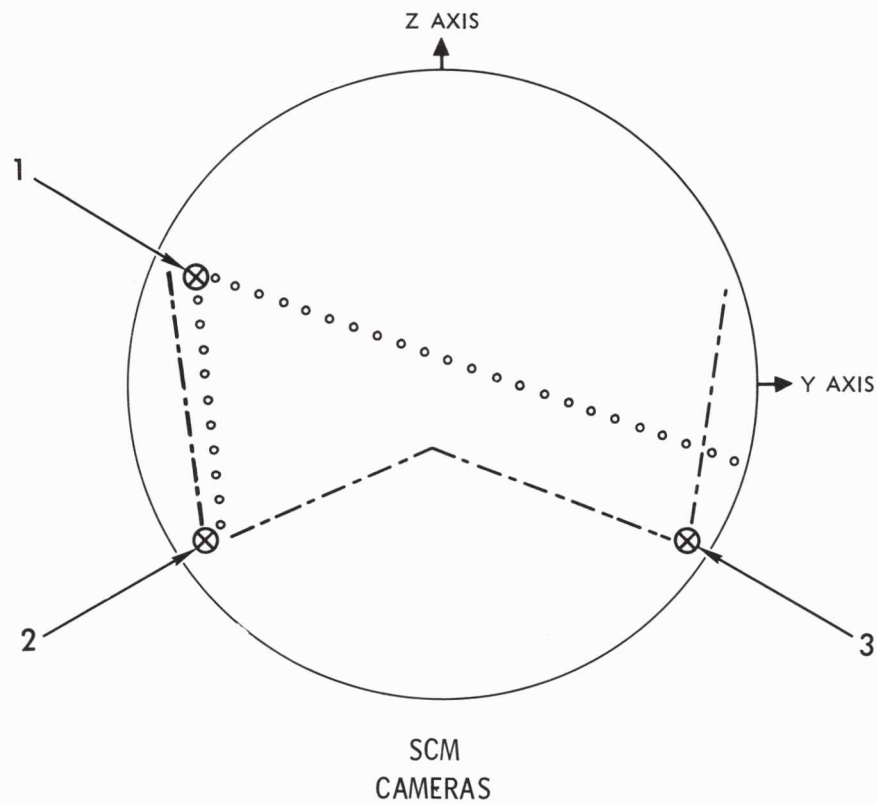
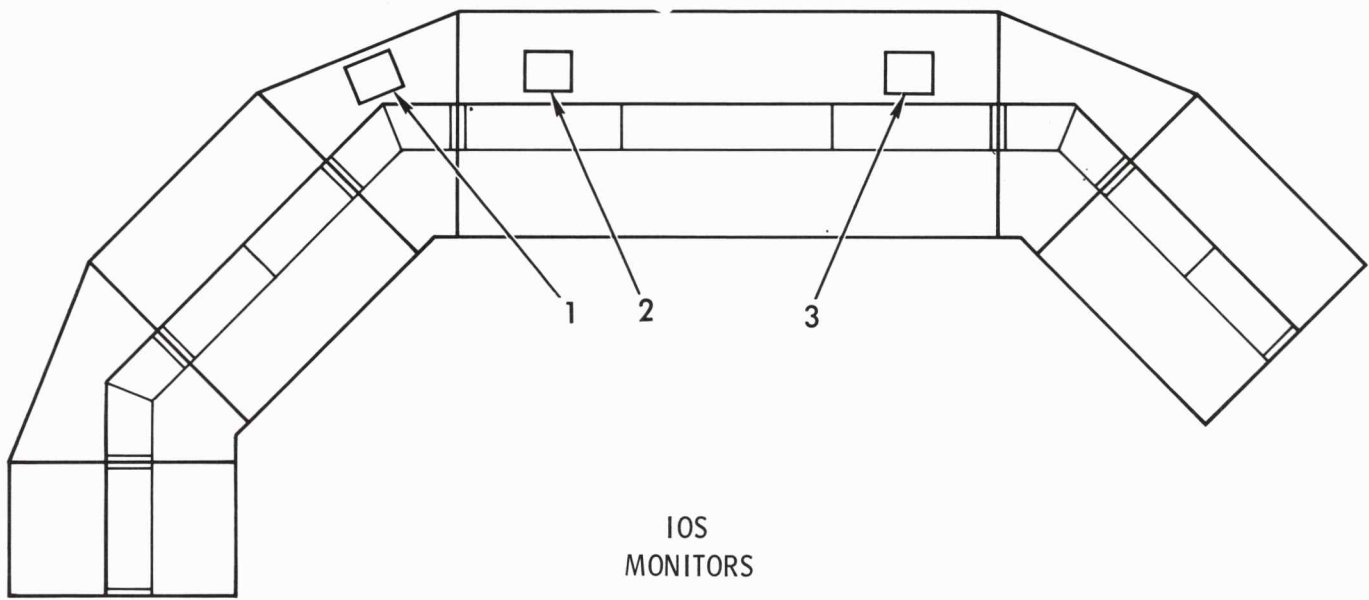
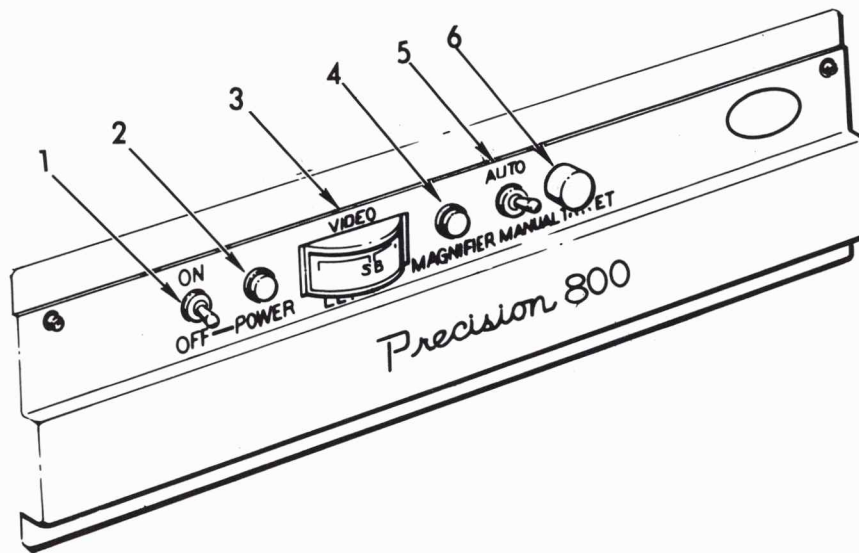


Figure 1-22. CCTV Location

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Figure 1-23. Camera Control Module

Table 1-21. Camera Control Module—Controls and Displays

Key	Nomenclature	Function	Remarks
1	ON-OFF sw	Power control for camera operation.	
2	POWER lt	Indicates power-on situation.	
3	VIDEO LEVEL gage	Gain indication of camera video level.	
4	MAGNIFIER pushbutton	Expands center area of picture for close observation.	
5	AUTO-MANUAL sw		
	AUTO position	Camera adjusts automatically to varying light conditions.	
	MANUAL position	Provides manual control for camera light conditions with potentiometer.	
6	TARGET control	Operates in conjunction with MANUAL position of sw to control light intensity of camera view.	

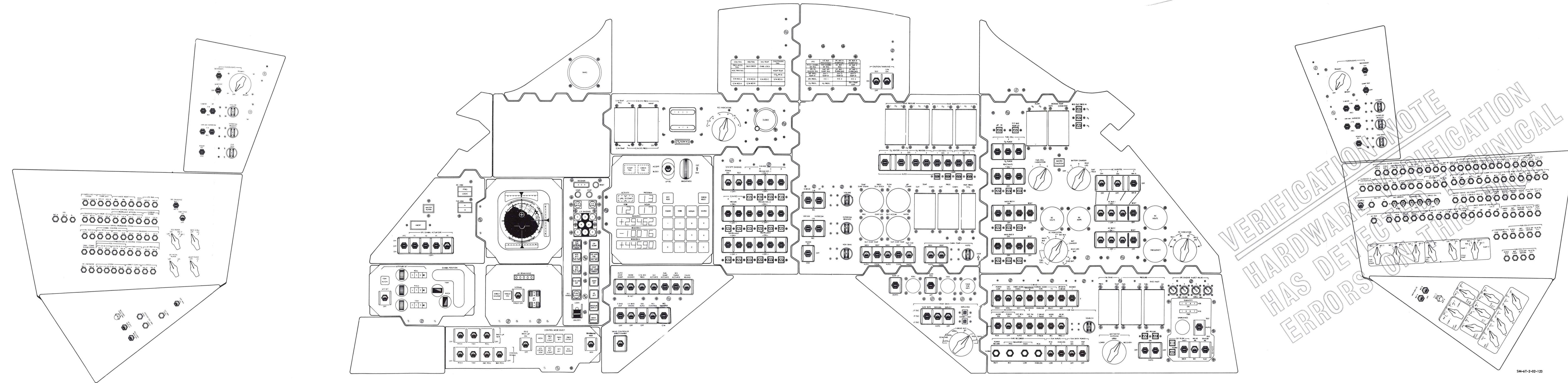


Figure 1-24. SCM Main Display Panel

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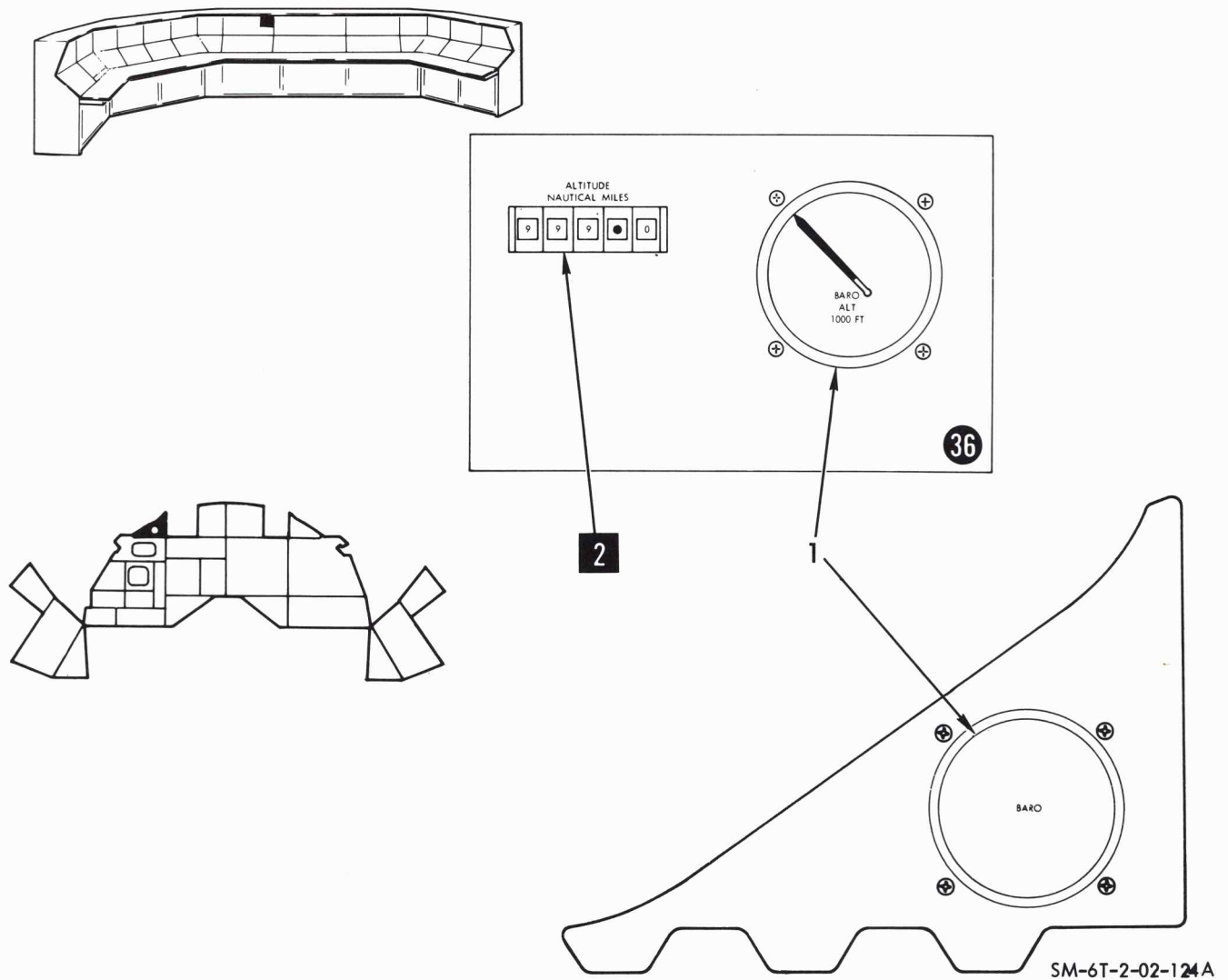
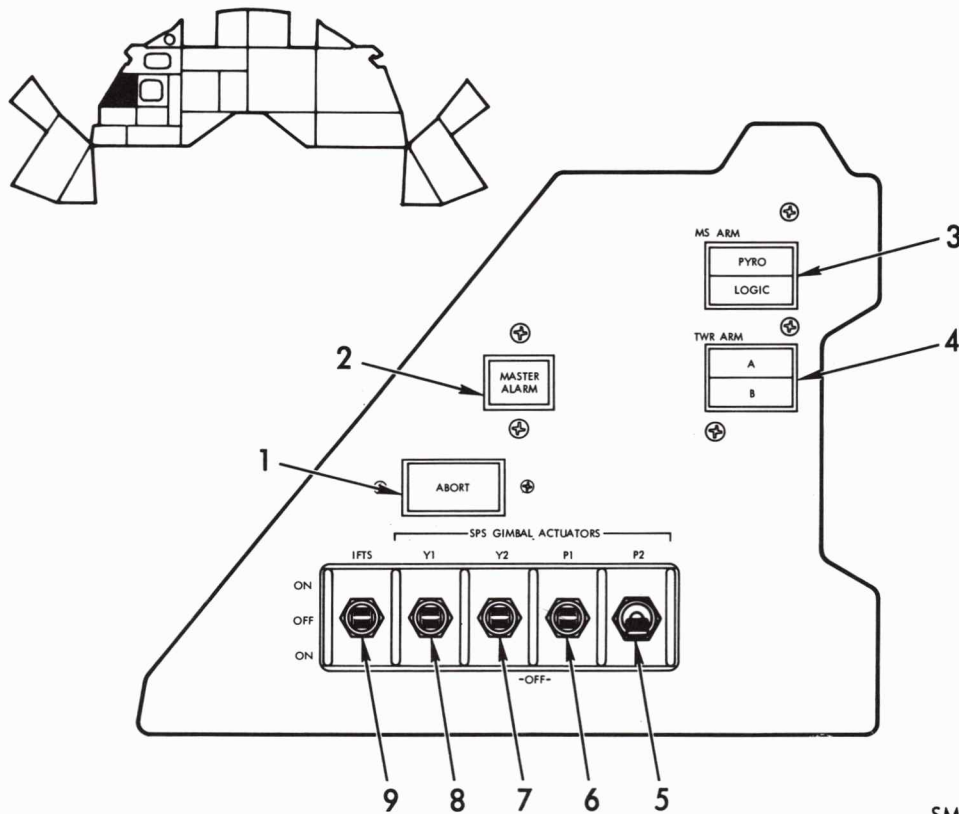
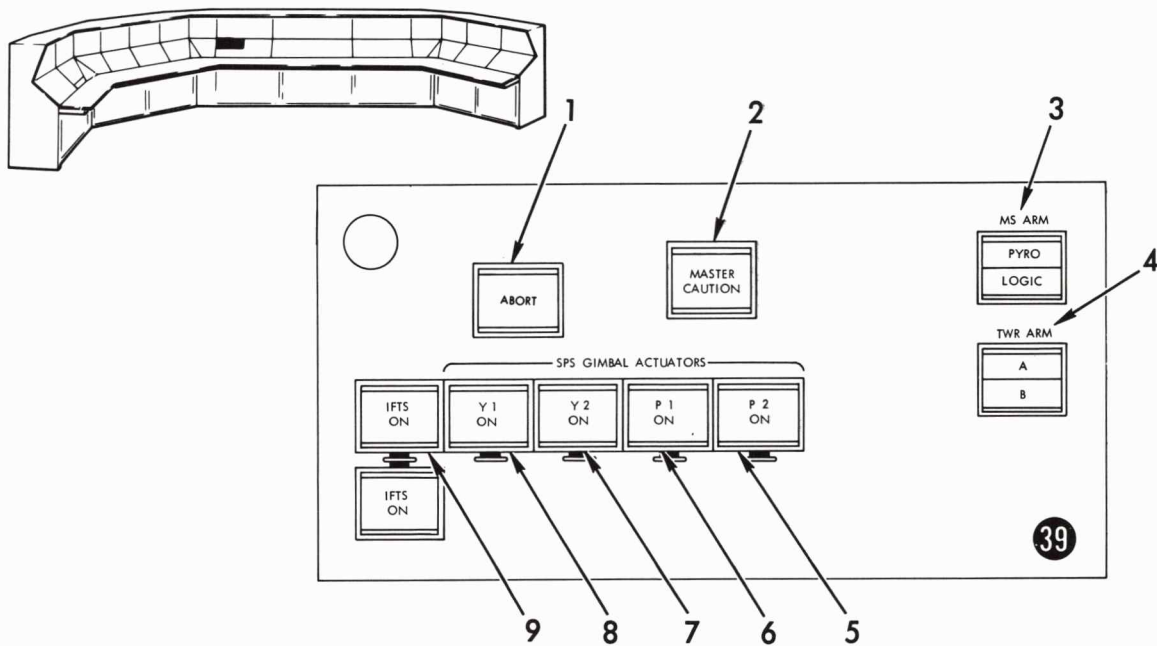


Figure 1-25. Barometric Altimeter Panel

Table 1-22. Barometric Altimeter Panel—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	Barometric altimeter	Provides indication of vehicle altitude.	SCM repeater instrument	Meter range 0 to 100,000 feet. Markings for FWD H.S. jettison at 25,000 feet and main chute deploy at 15,000 ft.
2	ALTITUDE NAUTICAL MILES digital altimeter (IOS only)	Provides four-digit readout of vehicle altitude.	Digital display (IOS only)	

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Figure 1-26. Spacecraft Panel 3

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Table 1-23. Spacecraft Panel 3—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	ABORT lt	Indicates that abortive situation exists and abort should be initiated.	Repeater lt	Light is backup to voice communication.
2	MASTER ALARM lt	Indicates caution condition.	MASTER CAUTION lt	Accompanied by audio warning tone in headset. Lights on panel 65 and LEB are on simultaneously.
3	MS ARM — PYRO-LOGIC lt	Goes on when mission sequencer pyro or logic buses are armed	Repeater lt	
4	TWR ARM — A-B lt	Goes on when tower sequencers A and B are armed.	Repeater lt	
	SPS GIMBAL ACTUATORS sw	Provide gimbal motor start capability		
5	P2 (pitch 2) sw	Applies power to pitch 2 gimbal actuator.	Repeater lt	Four operationally identical switches (Also applies to 6, 7, and 8.)
6	P1 (pitch 1) sw	Applies power to pitch 1 gimbal actuator.		
7	Y2 (yaw 2) sw	Applies power to yaw 2 gimbal actuator.		
8	Y1 (yaw 1) sw	Applies power to yaw 1 gimbal actuator.		
9	IFTS sw	Not operational		

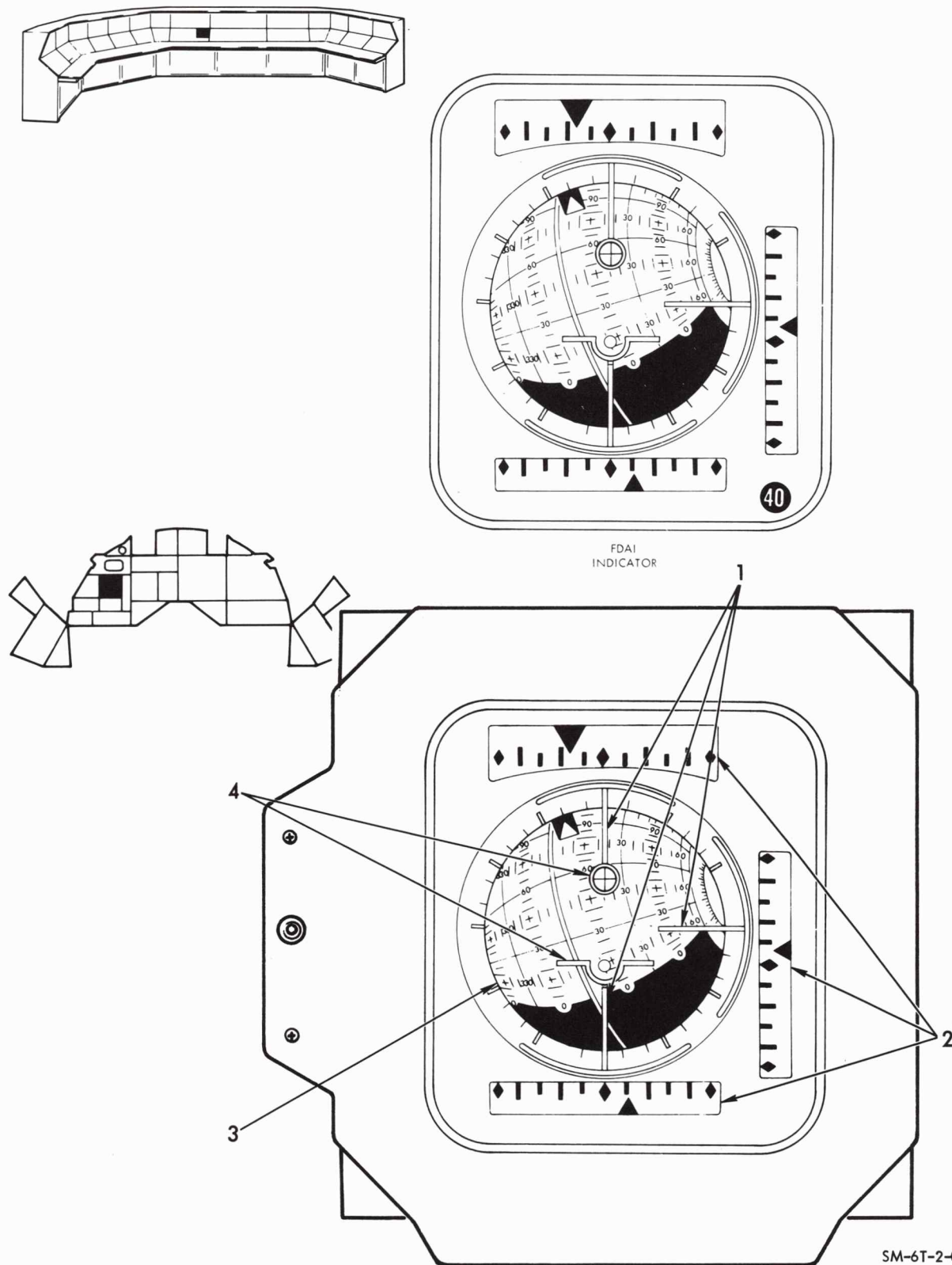


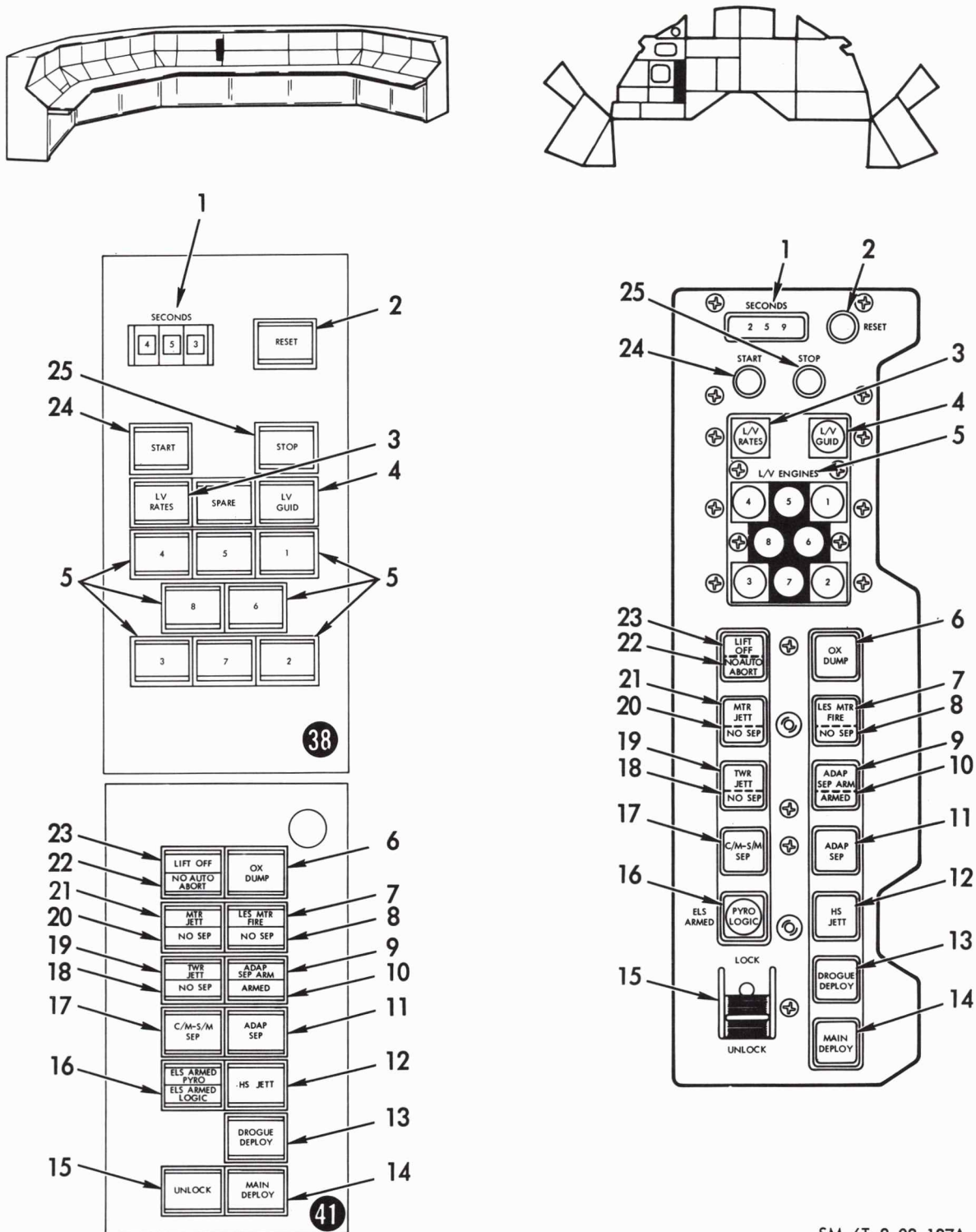
Figure 1-27. Flight Director Attitude Indicator

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Table 1-24. Flight Director Attitude Indicator—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	Attitude error indicators	Displays pitch, roll, and yaw attitude errors due to drift or deviation from present attitude.	Repeater indicator	Attitude error is derived from CDUs in G&N modes and BMAGs in SCS modes.
2	Attitude rate indicators	Displays rate of change of attitude in pitch, roll and yaw due to drift or deviation from present position.	Repeater indicator	Angular rates are generated by RGP or BMAGs in backup mode.
3	Attitude ball display	Displays S/C attitude referenced to inertial space, in terms of body or navigation axes.	Repeater instrument	Ball face is marked in degrees of latitude and longitude; latitude indicating pitch attitude and longitude indicating yaw attitude. Gimballing permits 360 degrees of freedom in roll, pitch, and yaw axes. Roll attitude is indicated by pointer referenced to scale marked in increments of 10 degrees about inner circumference of FDAI face.
4	Reference indices	Provide basis for referencing attitude indications to either body or navigational axes.	Repeater indicator	Horizon level indice represents body axes orientation with respect to IMU stable element. Crosshair indices represents navigation axes displacement from IMU stable element. Two indices are displaced approximately 33 degrees in pitch axis.

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Figure 1-28. Spacecraft Panel 5

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Table 1-25. Spacecraft Panel 5—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	SECONDS timer display	Displays time in seconds from liftoff.	Repeater display	
2	RESET pushbutton	Resets events timer to zero	Repeater lt	Automatically resets to zero when abort is initiated.
3	L/V RATES lt	Indicates warning of excessive launch vehicle rates in roll, pitch and yaw.	Repeater lt	In conjunction with FDAI, will indicate necessity for manual abort initiation.
4	L/V GUID lt	Indicates warning of malfunction conditions rated in launch vehicle guidance unit.	Repeater lt	
5	L/V ENGINES lt	Eight lt indicate when on, that an engine has dropped below 90 percent of rated thrust level.	Repeater lt	
6	OX DUMP sw	Manual override to automatic dumping of C/M RCS oxidizer.	Repeater lt	If auto oxidizer dump sw in SCM panel 16 is enabled, oxidizer will be dumped automatically in abort up to 42 seconds after liftoff.
7	LES MTR FIRE sw - lt	Indicates LES TWR has not jettisoned and provides manual backup to automatic LES tower jettison.	Repeater lt	
8	NO SEP lt	Goes on when LES tower fails to separate.	Repeater lt	
9	ADAP SEP ARM sw - lt	Activates adapter separation circuitry prior to LES tower jettison.	Repeater lt	
10	ARMED lt	Indicates LES tower adapter circuitry is armed.	Repeater lt	
11	ADAP SEP sw	Provides manual emergency destruction of tower adapter.	Repeater lt	
12	HS JETT sw	Manual backup to automatic forward heat shield jettison.	Repeater lt	Used only if automatic system fails during abort or entry.
13	DROGUE DEPLOY sw	Manual backup to automatic drogue chute deployment.	Repeater lt	Drogue chutes should deploy automatically within 2 seconds after fwd heat shield jettison.
14	MAIN DEPLOY sw	Manual backup to automatic main chute deployment.	Repeater lt	Main chute deployment occurs at 10,000 ft.
15	LOCK — UNLOCK sw	When locked, inhibits switching functions of this panel.	Repeater lt	
16	ELS ARMED PYRO-LOGIC sw - lt	Goes on when ELS logic or pyro buses are armed.	Repeater lt	

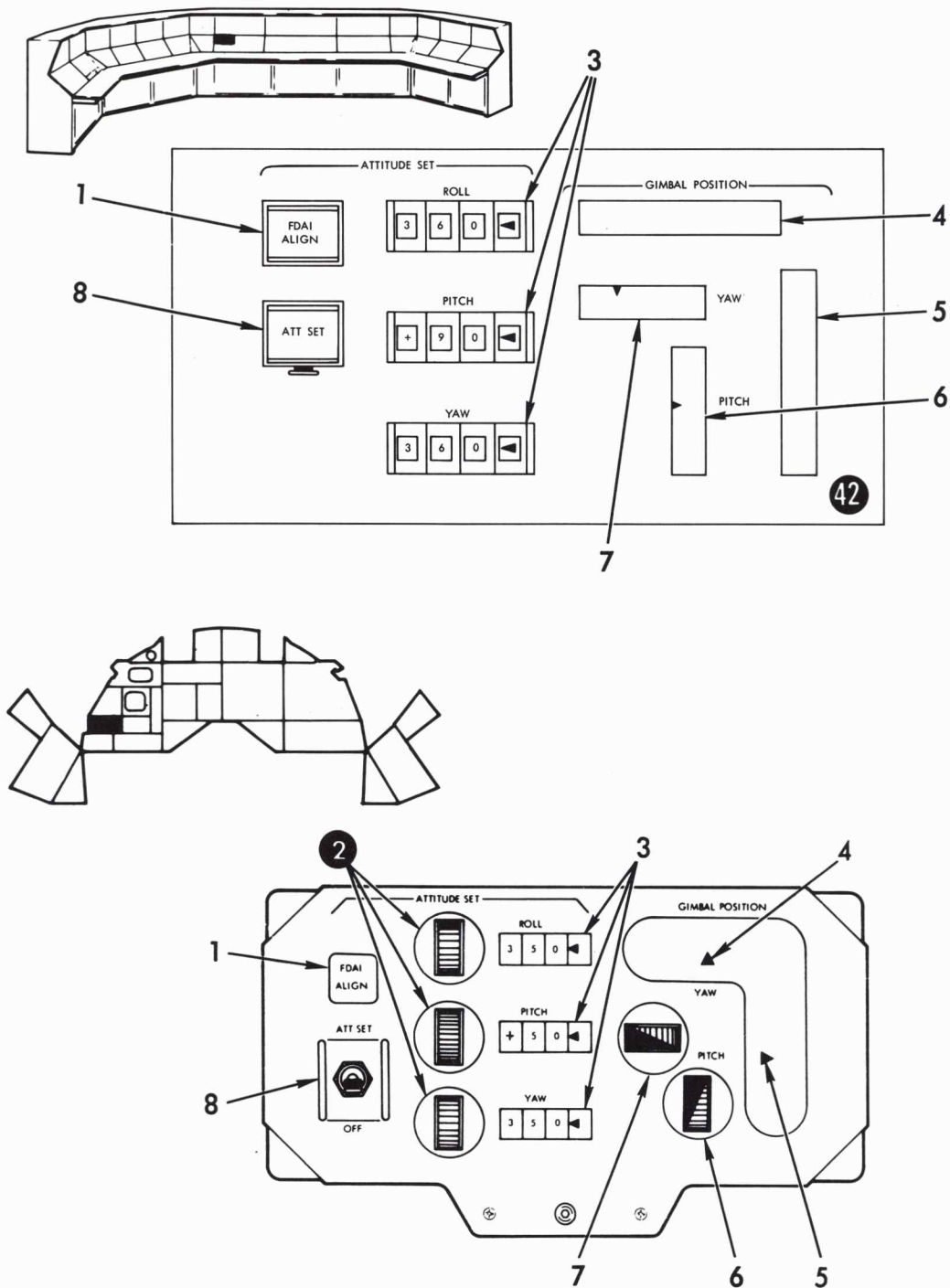
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Table 1-25. Spacecraft Panel 5—Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
17	C/M-S/M SEP sw - lt	Goes on when depressed to initiate C/M-S/M separation.	Repeater lt	Used as backup to automatic function. Can be used as manual backup to LES automatic abort.
18	NO SEP lt	Goes on when LES tower fails to separate after jettison.	Repeater lt	
19	TWR JETT sw - lt	Goes on when LES tower has been jettisoned. Provides normal manual jettisoning of LES tower.	Repeater lt	
20	NO SEP lt	Goes on when LES motor fails to separate after being jettisoned.	Repeater lt	
21	MTR JETT sw - lt	Provides manual backup to motor jettison. Goes on when LES motor has not been jettisoned.	Repeater lt	
22	NO AUTO ABORT sw - lt	Goes on to indicate auto abort capability has not been enabled. Depressing sw will re-enable the auto abort function.	Repeater lt	
23	LIFT OFF lt	Goes on at lift-off.	Repeater lt	Light goes out 5 seconds after liftoff.
24	START pushbutton	Starts events timer counting.	Repeater lt	Event timer starts automatically at liftoff.
25	STOP pushbutton	Stops events timer.	Repeater lt	

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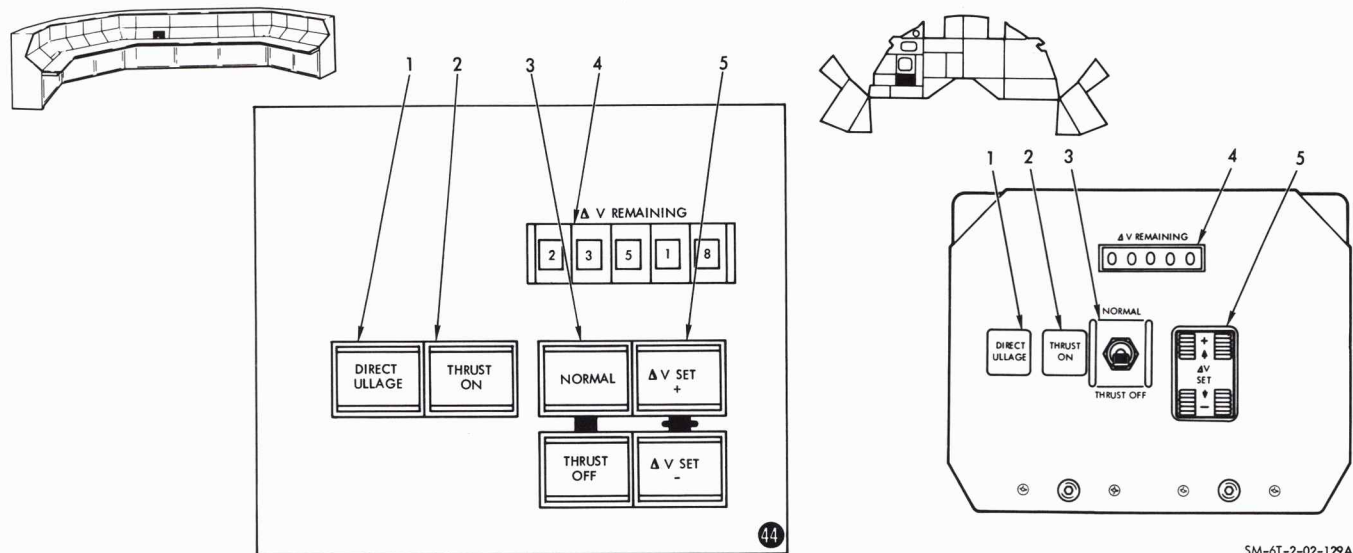
Figure 1-29. Attitude Set/Gimbal Position Indicator

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Table 1-26. Attitude Set/Gimbal Position Indicator—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	ATTITUDE SET — FDAI ALIGN sw	Enables alignment of attitude gyro coupling unit (AGCU) resolvers and FDAI to attitude displayed on ATTITUDE SET indicators.	Repeater lt	
2	ATTITUDE SET thumb-wheel	Enables desired pitch, roll, yaw angles to be set into SCS attitude reference system.	Variation in attitude indications	These thumbwheels are not located or indicated on IOS panel.
3	ATTITUDE SET display	Display roll, pitch, and yaw settings in degrees.	Repeater display	
4	GIMBAL POSITION — YAW indicator	Indicates SPS thrust chamber yaw position in degrees.	Repeater indicator	Utilized when aligning engine thrust vector with vehicle center of gravity.
5	PITCH indicator	Indicates SPS thrust chamber pitch position in degrees.	Repeater indicator	
6	PITCH thumbwheel	Provides manual control of pitch SPS engine gimbal position.	Repeater indicator	Utilized when aligning engine thrust vector with vehicle center of gravity.
7	YAW thumbwheel	Provides manual control of yaw SPS engine gimbal position.	Repeater indicator	
8	ATT SET sw — ATT SET position OFF position	Locks attitude set verniers (pitch, yaw, roll) and in SCS mode connects AGCU difference outputs to attitude error needles. Unlocks attitude set verniers and in SCS modes connects BMAG outputs to attitude error needles.	Repeater lt	Attitude error needles (FDAI) now indicate difference between value set by thumbwheels and present S/C attitude in SCS modes.

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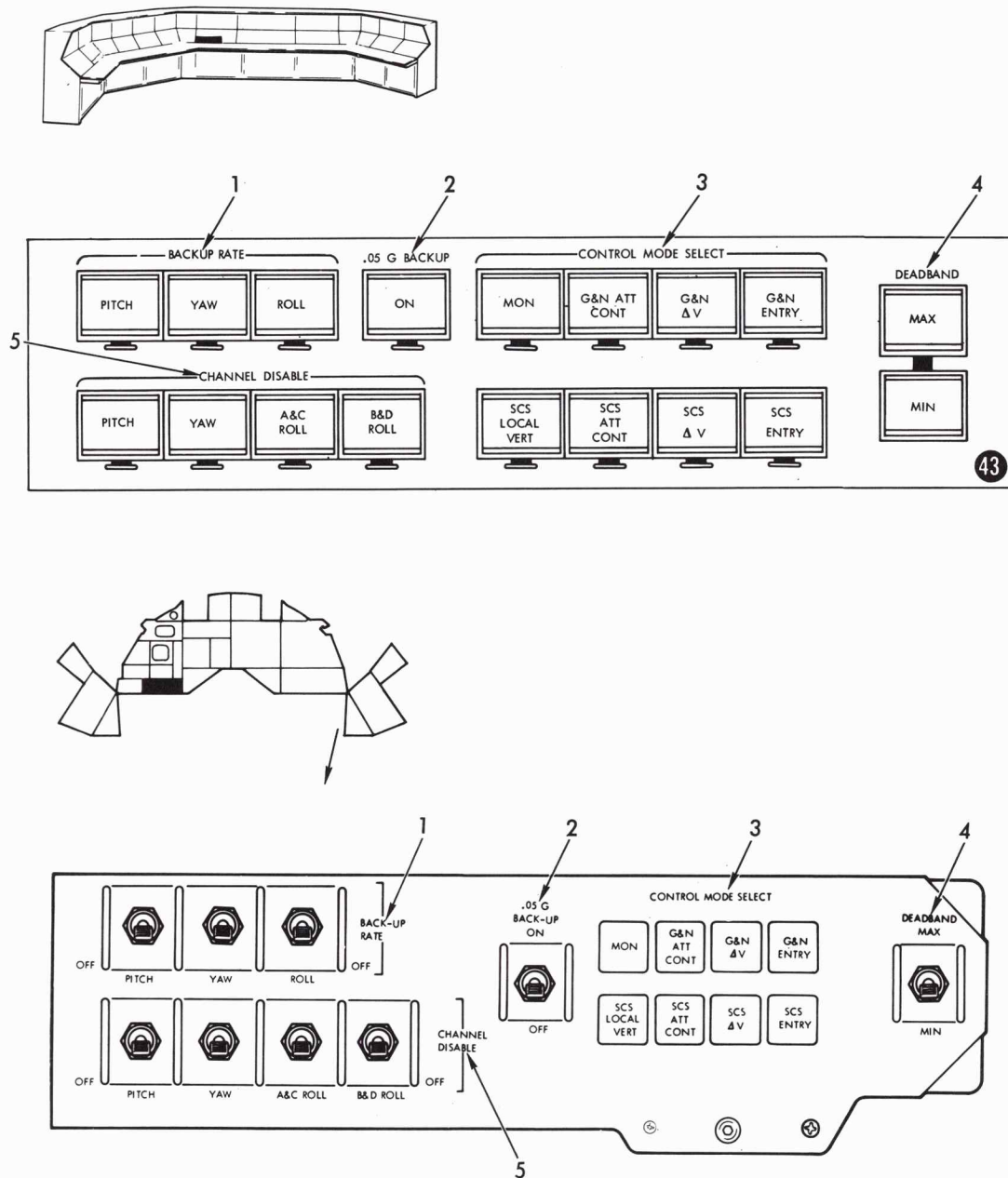
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Figure 1-30. Delta V Panel

Table 1-27. Delta V Panel—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	DIRECT ULLAGE sw	When depressed, actuates all four +X S/M RCS engines.	Repeater lt	
2	THRUST ON sw	Applies power to SCS circuitry, which actuates SPS engine control circuits.	Repeater lt	Manual backup for SPS ignition in G&N delta V mode. Normal SPS ignition sw when in SCS delta V mode.
3	NORMAL-THRUST OFF sw —			
	NORMAL position	Allows normal operation of SCS thrust logic circuit for SPS ignition.	Repeater lt	
	THRUST OFF position	Provides capability to terminate SPS engine firing.		
4	ΔV REMAINING indicator	Displays delta V remaining and/or delta V magnitude in ft/sec.	Repeater indicator	When SPS engine is thrusting, delta V remaining indicator is driven towards zero by signals from SCS X-axis accelerometer.
5	ΔV SET sw —			
	(+) position	Enables increase of delta V remaining display at slow or rapid rate.	Repeater lt	Five-position sw. Slow rate in either direction is two digits per second and fast rate is 64 digits per second in either direction with center-off position.
	(-) position	Enables decrease of delta V remaining display at slow or rapid rate.		

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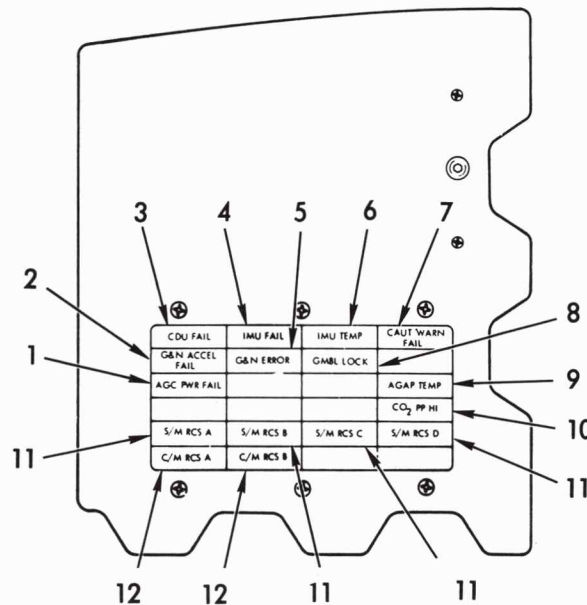
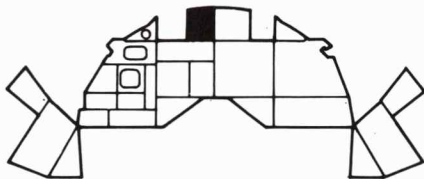
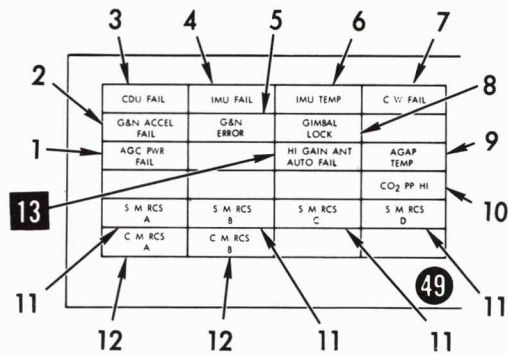
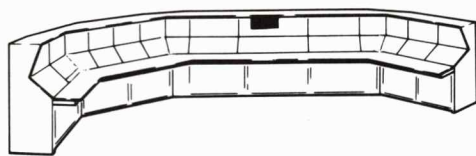
Figure 1-31. Control Mode Selector Panel

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Table 1-28. Control Mode Select Panel—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	BACKUP RATE — sw PITCH sw YAW sw ROLL sw	Enables BMAGs to furnish S/C attitude rate information rather than attitude information for selected axis.	Repeater lt	Attitude error signal input to FDAI is removed.
2	.05 G BACKUP — sw	Provides manual backup for .05g switching signal.	Repeater lt	Switch works in conjunction with G&N and SCS ENTRY mode sw. With .05 G sw ON, pitch, yaw, and roll attitude error signals will null in SCS entry mode. In G&N entry mode, pitch and yaw attitude error indicators null, but roll indicator will continue to display roll attitude error as supplied by G&N system.
3	CONTROL MODE SELECT — MON sw - lt G&N ATT CONT sw - lt G&N ΔV sw - lt G&N ENTRY sw - lt SCS LOCAL VERT sw - lt SCS ATT CONT sw - lt SCS ΔV sw - lt SCS ENTRY sw - lt	Enables selection of desired control mode of operation. Lights go on, when depressed, to indicate operating mode.	Repeater lt	Depressing any sw will release mode previously held in by latching circuit.
4	DEADBAND sw — MAX position MIN position	Enables attitude sensitivity of ± 5 degrees. Enables attitude sensitivity of ± 0.5 degree.	Repeater lt	Prevents attitude correction signals from being sent to RCS until attitude errors exceed selected deadband.
5	CHANNEL DISABLE — PITCH sw YAW sw A&C ROLL sw B&D ROLL sw	Disables selected attitude axis attitude control channel.	Repeater lt	

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Figure 1-32. Caution/Warning System Panel 10

Table 1-29. Caution/Warning System Panel 10—Controls and Displays

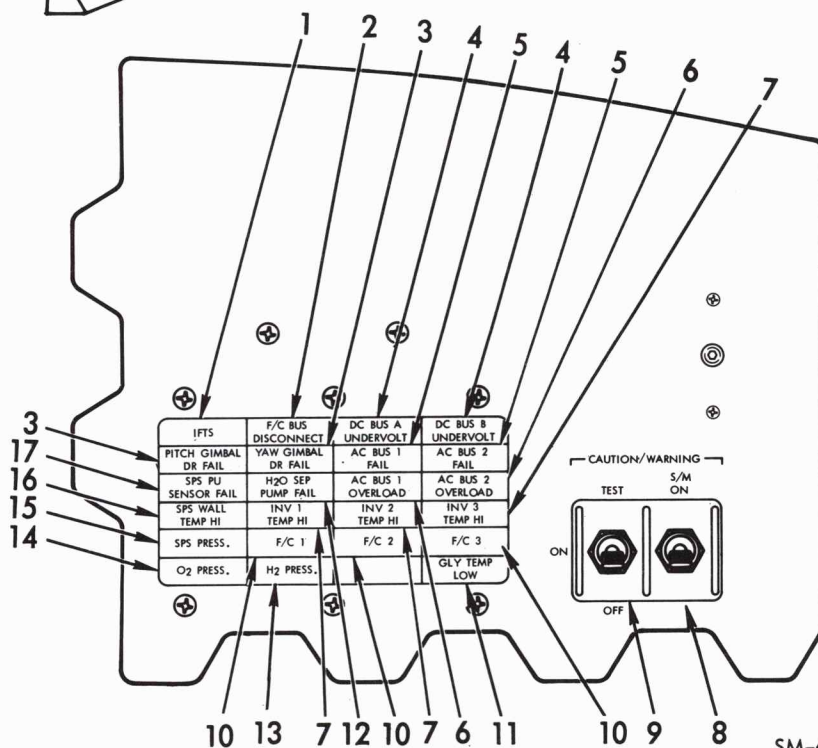
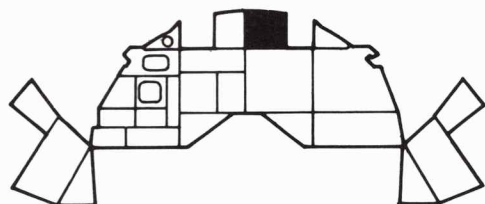
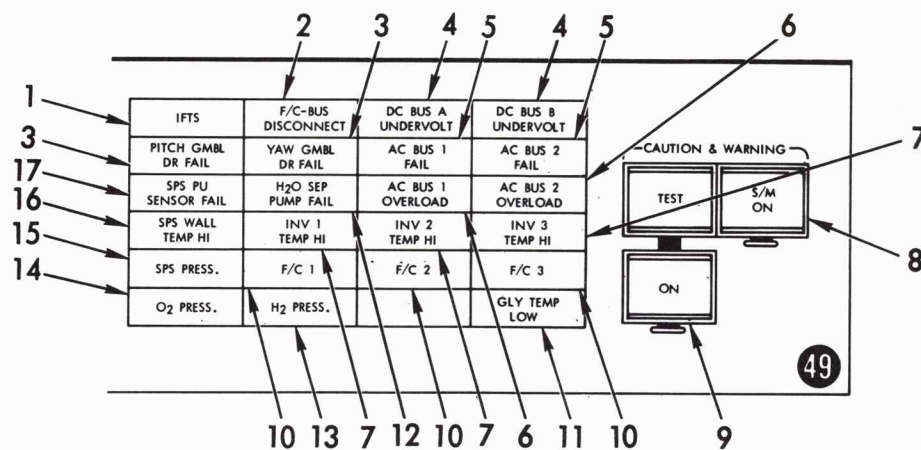
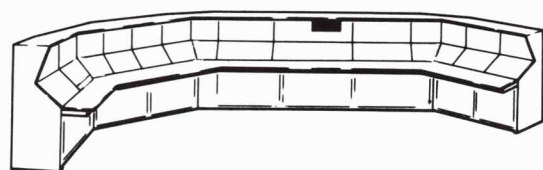
Key	Nomenclature	Function	Instructor Visibility	Remarks
1	AGC PWR FAIL lt	Indicates loss of +3-volt power supply.	Repeater lt	
2	G&N ACCEL FAIL lt	Indicates pulsed input pendulous accelerometer (PIPA) error signal is greater than 6.5 volts.	Repeater lt	
3	CDU FAIL lt	Indicates coupling display unit (CDU) error signal is greater than 5.4 volts or loss of 25.6 kc encoder excitation.	Repeater lt	
4	IMU FAIL lt	Indicates middle gimbal angle is greater than +60 degrees or in gimbal lock.	Repeater lt	

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Table 1-29. Caution/Warning System Panel 10—Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
5	G&N ERROR lt	Indicates error in one or more of following units: IMU, accelerometer, CDU, or AGC.	Repeater lt	
6	IMU TEMP lt	Indicates temperature sensor fails in inertial reference integrating gyro (IRIG). Indicates temperature control magnetic unit fails.	Repeater lt	
7	C/W FAIL lt	Indicates failure in caution and warning system.	Repeater lt	
8	GIMBAL LOCK lt	Indicates middle gimbal angle greater than +60 degrees or in gimbal lock.	Repeater lt	
9	AGAP TEMP lt	Indicates attitude gyro accelerometer package (AGAP) has exceeded $170 \pm 2^{\circ}\text{F}$.	Repeater lt	
10	CO ₂ PP HI lt	Indicates CO ₂ partial pressure has exceeded 5 mm Hg.	Repeater lt	MASTER CAUTION light goes on and audio tone is audible in headsets when this light goes on.
11	S/M RCS (A, B, C, D) lt	Indicates S/M system has failed because of the following: <ul style="list-style-type: none"> a. Regulated helium pressure manifold, under or overpressure b. Package temperature, over or under-temperature c. Oxidizer-to-fuel ratio not within 2:1 ratio by ± 3 percent 	Repeater lt	
12	C/M RCS (A, B) lt	Indicates C/M system has failed because of the following: <ul style="list-style-type: none"> a. Regulated helium pressure manifold prior to pressurization, over or under b. Regulated helium pressure after pressurization, over or under 	Repeater lt	
13	HI GAIN ANT AUTO FAIL lt	Indicates failure of high gain antenna automatic positioning circuitry.		Light is not incorporated on SCM main display panel 10.

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Figure 1-33. Caution/Warning System Panel 11

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Table 1-30. Caution/Warning System Panel 11—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	IFTS lt	Inoperative		
2	F/C-BUS DISCONNECT lt	Indicates fuel cells 1, 2, or 3 have been disconnected from main bus A or B due to fuel cell overload or reverse current.	Repeater lt	
3	GIMBAL DR FAIL lt (PITCH and YAW)	Indicates gimbal motor 1 has experienced overcurrent or undercurrent condition.	Repeater lt	
4	DC BUS UNDERVOLT lt (A and B)	Indicates d-c undervolt condition exists on main bus.	Repeater lt	
5	AC BUS FAIL lt (1 and 2) (1 and 2)	Indicates ac bus power failure.	Repeater lt	
6	AC BUS OVERLOAD lt	Indicates a-c overload exists on bus.	Repeater lt	Inverter supplying bus will be automatically disconnected when light goes on.
7	INV TEMP HI lt (1, 2, and 3)	Indicates respective inverter temperature has exceeded operation heat limits.	Repeater lt	
8	CAUTION/WARNING — S/M sw			
	ON position	Permits monitoring of those systems housed in S/M through caution and warning (C/W) indicators.	Repeater lt	
	OFF position	Disconnects sensor inputs to C/W indicators from S/M.		
9	CAUTION/WARNING — TEST sw			
	TEST position	Functions as lamp test for SCM panels 10 and 11.	Repeater lt	
	ON position	Permits normal operation of C/W system		
10	F/C (1, 2, and 3) lt	Indicates one of following for respective cell. a. Fuel cell (F/C) module skin temperature 500°F. b. H ₂ regulator out pressure 75 psia.	Repeater lt	

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Table 1-30. Caution/Warning System Panel 11—Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
10 (cont)		c. H_2 flow exceeds 0.090 lb/hr. d. F/C water is contaminated. e. Module skin temperature 460°F. f. H_2 regulator out pressure is below tolerance. g. N_2 pressure is 70 psia. h. N_2 pressure is below tolerance. i. O_2 flow exceeds 0.72 lb/hr.		
11	GLY TEMP LOW lt	Indicates glycol temperature has dropped to -20°F.	Repeater lt	MASTER CAUTION light goes on and audio tone is audible in headsets when light goes on.
12	H_2O SEP PUMP FAIL lt	Indicates H_2O sep pump diaphragm has ruptured.	Repeater lt	MASTER CAUTION light goes on and audio tone is in headset when light goes on. If H_2O accumulator diaphragm ruptures, oxygen at 100 psig will enter waste water system.
13	H_2 PRESS. lt	Indicates H_2 tank 1 or 2 pressure is above 270 psia or below 220 psia.	Repeater lt	
14	O_2 PRESS. lt	Indicates O_2 tank pressures are above 950 psia or below 800 psia.	Repeater lt	
15	SPS PRESS. lt	Indicates SPS propellant tank pressure is above 218 psia.	Repeater lt	
16	SPS WALL TEMP HI lt	Indicates SPS wall temperature has exceeded 500°F.	Repeater lt	
17	SPS PU SENSOR FAIL lt	Indicates 2:1 ratio has exceeded 3 percent above or below. Indicates fuel or oxidizer sensor has failed.	Repeater lt	

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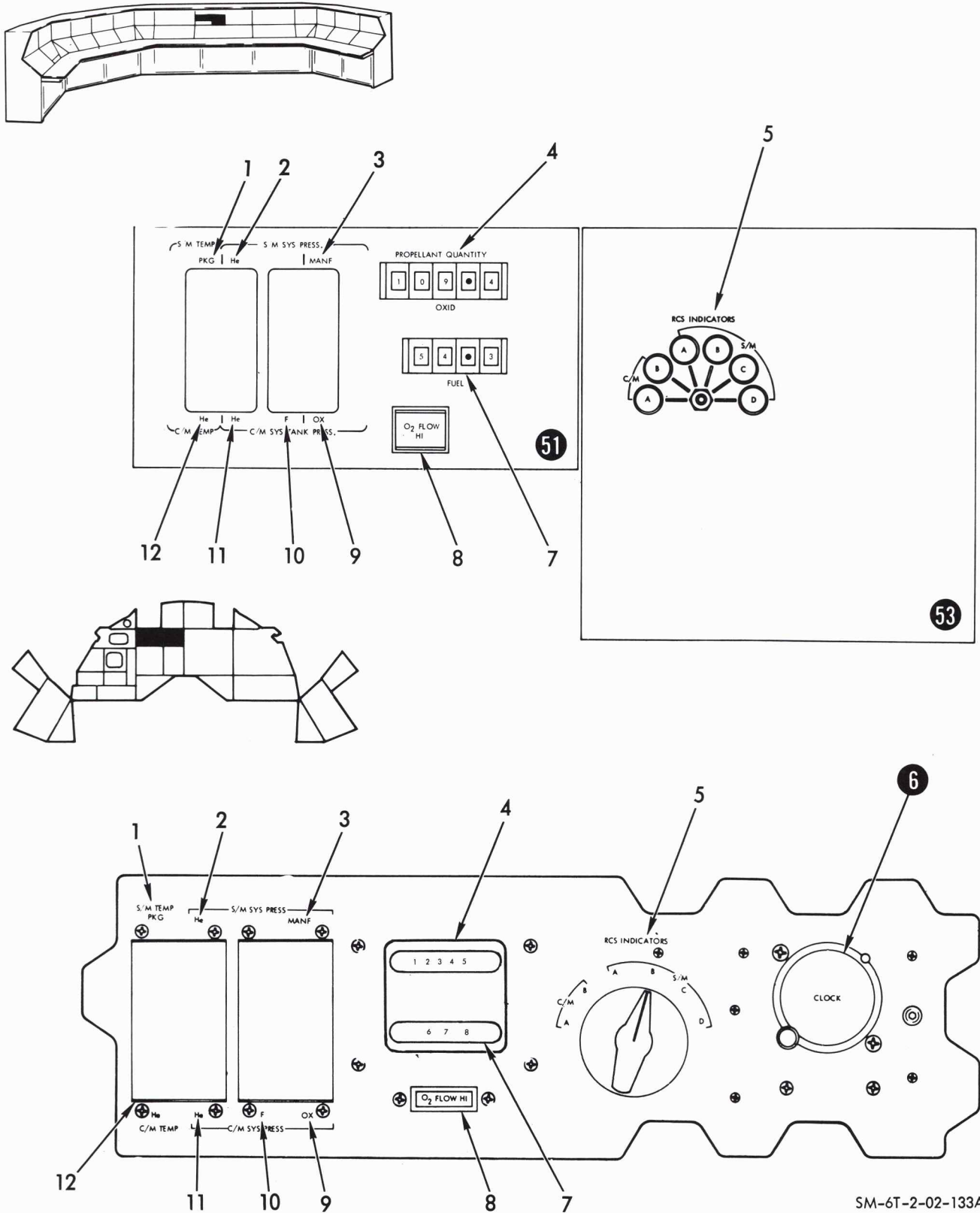


Figure 1-34. Spacecraft Panel 12

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Table 1-31. Spacecraft Panel 12—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	S/M TEMP — PKG meter	Indicates temperature of S/M package A, B, C, D, as selected by RCS INDICATORS sw.	Repeater display	
2	S/M SYS PRESS — He meter	Indicates helium tank pressure of S/M RCS package A, B, C, or D as selected by RCS INDICATORS sw.	Repeater display	
3	S/M SYS PRESS — MANF meter	Indicates regulated helium manifold pressure of S/M RCS package A, B, C or D as selected by RCS INDICATORS sw.	Repeater display	
4	Oxidizer quantity display	Displays digital readout of S/M quantities remaining in oxidizer tank of system selected by RCS INDICATORS sw.	Propellant Quantity-OXID repeater display	Digital readouts indicate propellant quantity in pounds. No indication is supplied when RCS INDICATORS sw is in C/M positions.
5	RCS INDICATORS rotary sw C/M — A and B position S/M — A, B, C, and D position	Controls inputs to propellant indicating devices. C/M and S/M sections are identical within their respective systems with exception of no propellant readout for C/M RCS.	Repeater sw - lt	Position of SCM sw is indicated by lighted lamp. However, I/O may read other parameters than those selected by trainee by depressing any momentary pushbutton light. The SCM indicator light remains on but IOS selected parameters are displayed to IO. SCM displays are not affected.
6	CLOCK indicator (C/M only)	Eight-day mechanical clock for time reference.	(C/M only)	
7	Fuel display	Displays digital readout of S/M quantities remaining in fuel tank of system selected by RCS INDICATORS sw.	Fuel repeater display	Digital readouts indicate propellant quantity in pounds. No indication is supplied when RCS INDICATORS sw is in C/M positions.
8	O ₂ FLOW HI lt	Indicates O ₂ total flow has exceeded that amount considered critical. Provides indication of leak or mismanagement.	Repeater lt	Light goes on at 1.0 lb/hr flow, which indicates oxygen leakage or mismanagement of oxygen system.
9	C/M SYS PRESS — OX meter	Indicates regulated helium pressure prior to entering oxidizer tanks of C/M RCS system selected by RCS INDICATORS sw.	C/M SYS TANK PRESS. — OX repeater display	
10	C/M SYS PRESS. — F meter	Indicates regulated helium pressure prior to entering fuel tank of C/M RCS system as selected by RCS INDICATORS sw.	C/M SYS TANK PRESS. — F repeater display	Indicates zero when RCS INDICATORS sw is in any S/M position.

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Table 1-31. Spacecraft Panel 12—Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
11	C/M SYS PRESS. — He meter	Indicates C/M RCS system helium tank pressure as selected by RCS INDICA- TORS sw.	C/M SYS TANK PRESS. — He repeater display	
12	C/M TEMP — He meter	Indicates helium tank tem- perature of C/M RCS sys- tems as selected by the RCS INDICATORS sw.	Repeater display	

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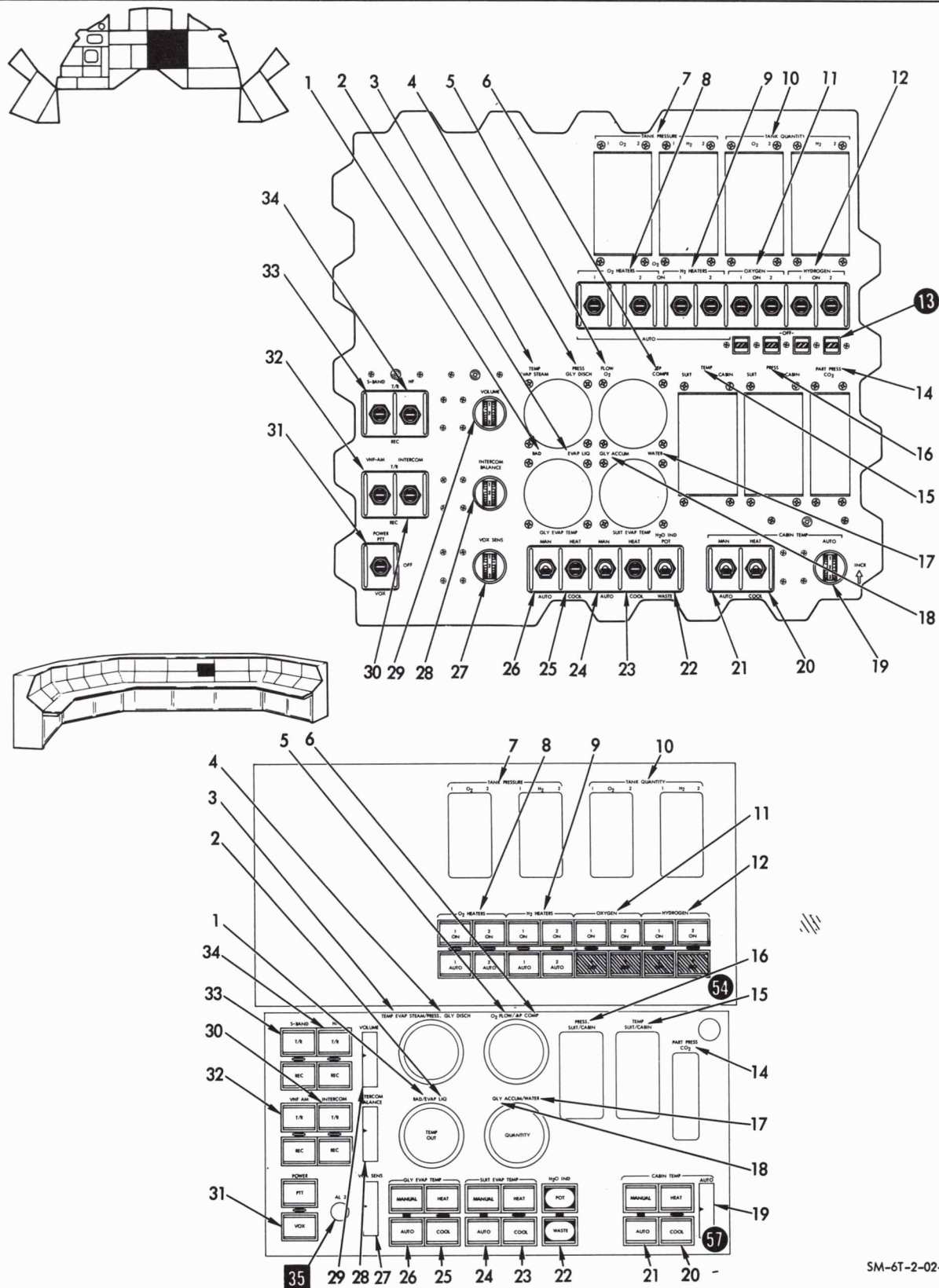


Figure 1-35. Spacecraft Panel 13

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Table 1-32. Spacecraft Panel 13—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	RAD — TEMP OUT meter	Provides temperature readout of water-glycol from S/M space radiators.	Repeater meter	
2	EVAP LIQ — TEMP OUT meter	Provides temperature readout of water-glycol at glycol evaporator outlet.	Repeater meter	
3	TEMP EVAP STEAM meter	Provides temperature readout of steam discharge from water-glycol, evaporator and/or suit heat exchanger.	Repeater meter	
4	PRESS GLY DISCH meter	Provides static pressure readout of water-glycol pump discharge.	Repeater meter	
5	FLOW O ₂ meter	Provides total rate of flow readout of O ₂ supplied to ECS.	Repeater meter	
6	ΔP COMP meter	Provides pressure differential readout between inlet and outlet of unit compressors.	Repeater meter	
7	TANK PRESSURE gages	Used to determine heater performance and detect leaks.	Repeater gages	
	O ₂ gage 1	Displays pressure of O ₂ tank 1.		
	O ₂ gage 2	Displays pressure of O ₂ tank 2.		
	H ₂ gage 1	Displays pressure of H ₂ tank 1.		
	H ₂ gage 2	Displays pressure of H ₂ tank 2.		
8	O ₂ HEATERS sw (1 and 2)		Repeater lt	
	ON position	Controls d-c power to O ₂ tank heaters.		
	AUTO position	Enables automatic pressure sw to control d-c power to O ₂ tank heaters.		
9	H ₂ HEATERS sw (1 and 2)		Repeater lt	
	ON position	Controls d-c power to H ₂ tank heaters.		
	AUTO position	Enables automatic pressure sw to control d-c power to H ₂ tank heaters.		

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Table 1-32. Spacecraft Panel 13—Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
10	TANK QUANTITY gages		Repeater gage	
	O ₂ gage 1	Displays quantity of O ₂ remaining in tank 1.		
	O ₂ gage 2	Displays quantity of O ₂ remaining in tank 2.		
	H ₂ gage 1	Displays quantity of H ₂ remaining in tank 1.		
	H ₂ gage 2	Displays quantity of H ₂ remaining in tank 2.		
11	OXYGEN sw (1 and 2)		Repeater lt	
	ON position	Actuates shutoff valve to open position.		
	Normal position	Removes power from shutoff valve solenoid.		
	OFF position	Actuates shutoff valve to closed position.		
12	HYDROGEN sw (1 and 2)		Repeater lt	
	ON position	Actuates shutoff valve to open position.		
	Normal position	Removes power from shutoff valve solenoid.		
	OFF position	Actuates shutoff valve to closed position.		
13	EVENT INDICATOR flags (hydrogen 1 and 2) (oxygen 1 and 2)	Indicates position of hydrogen and oxygen shutoff valves.	Indicated by reduced intensity of associated sw position	
14	PART PRESS CO ₂ meter	Provides partial pressure readout of CO ₂ in suit circuit atmosphere.	Repeater meter	
15	TEMP meter		Repeater meter	Temperature and pressure sensors not normal to suit are provided in simulation at air inlet to pressure suits. These sensors are used to indicate conditions to instructor.
	SUIT meter	Provides temperature readout of suit supply manifold.		
	CABIN meter	Provides average temperature readout of cabin atmosphere.		
16	PRESS meter		Repeater meter	(Same as for 15.)

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Table 1-32. Spacecraft Panel 13—Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
16 (cont)	SUIT meter	Provides pressure readout of suit circuit atmosphere at demand regulator sensing port.		
	CABIN meter	Provides pressure readout of cabin atmosphere.		
17	WATER-QUANTITY meter	Provides readout of waste or potable water quantity as selected by H ₂ O IND sw.	Repeater meter	
18	GLY ACCUM-QUANTITY	Provides quantity readout of water-glycol in accumulator.	Repeater meter	
19	CABIN TEMP-AUTO thumb wheel	Permits manual adjustment of cabin temperature automatic control unit.	Repeater display	
20	CABIN TEMP sw		Repeater lt	
	HEAT position	Closes heat exchanger temperature control valve and decreases amount of cool glycol flowing to heat exchanger.		
	Normal position	Removes power from valve actuator.		
	COOL position	Opens temperature control valve and increases amount of cool glycol flowing to heat exchanger.		
21	CABIN TEMP sw		Repeater lt	
	MANUAL position	Removes power from temperature control unit permitting manual control of water-glycol temperature control valve.		
	AUTO position	Applies power to glycol temperature control unit.		
22	H ₂ O IND sw	Selects waste or potable water for quantity display meter.	Repeater lt	Switching action of IOS indicators enables instructor to override display presentation as selected by trainee. This action does not effect SCM displays.

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Table 1-32. Spacecraft Panel 13—Controls and Displays (Cont)

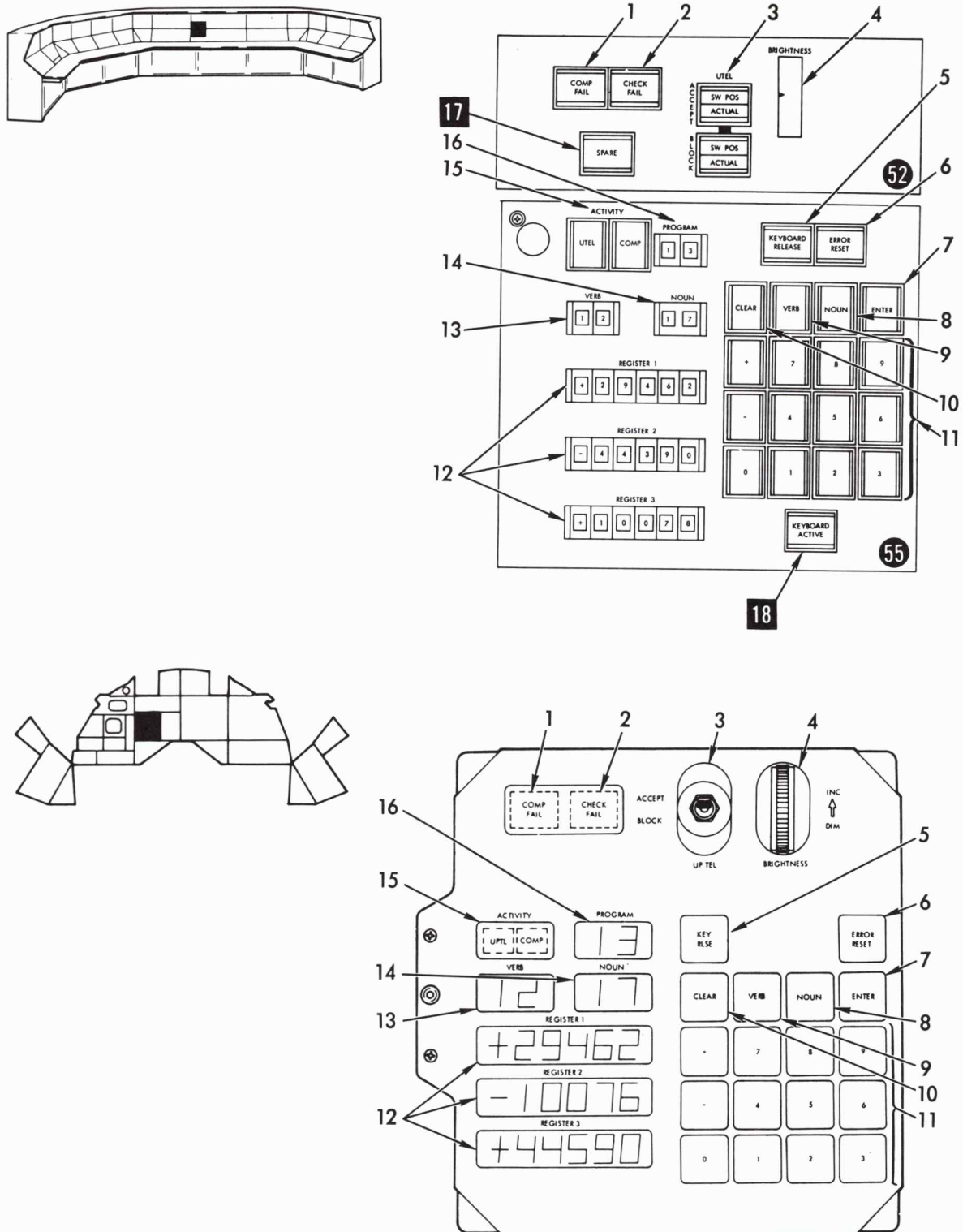
Key	Nomenclature	Function	Instructor Visibility	Remarks
23	SUIT EVAP TEMP sw		Repeater 1t	
	HEAT position	Actuates evaporator water inflow valve closed to decrease water flow in suit heat exchanger.		
	COOL position	Actuates water inflow valve open to increase water flow in suit heat exchanger for evaporative cooling.		
	Normal position	Removes power from valve actuator.		
24	SUIT EVAP TEMP sw		Repeater 1t	
	MANUAL position	Removes power from temperature control amplifier and applies power to SUIT EVAP TEMP-HEAT-COOL sw.		
	AUTO position	Applies power to temperature control amplifier and removes power from HEAT-COOL sw.		
25	GLY EVAP TEMP sw		Repeater 1t	
	HEAT position	Actuates back-pressure control valve closed to decrease rate of evaporation in water-glycol evaporator.		
	COOL position	Actuates back-pressure control valve open to increase rate of evaporation in water-glycol evaporation.		
	Normal position	Removes power from valve actuator.		
26	GLY EVAP TEMP sw		Repeater 1t	
	MANUAL position	Removes power from back-pressure control unit and applies power to HEAT-COOL sw.		
	AUTO Position	Applies power to back-pressure control unit and removes power from HEAT-COOL sw.		
27	VOX SENS thumbwheel	Adjusts sensitivity of voice-operated relay.	Repeater indicator	

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Table 1-32. Spacecraft Panel 13—Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
28	INTERCOM BALANCE thumbwheel	Adjusts balance between received signals and intercom bus signals.	Repeater indicator	
29	VOLUME thumbwheel	Adjusts volume of audio signal.	Repeater indicator	
30	INTERCOM sw		Repeater lt	
	T/R position	Permits headset to receive and transmit over intercom system.		
	REC position	Permits headset to receive only outputs of intercom system.		
31	POWER sw		Repeater lt	
	PTT position	Applies power to audio center.		
	VOX position	Closes VOX control circuitry and applies power to audio center.		
32	VHF/AM sw		Repeater lt	
	T/R position	Permits headset to receive and transmit over VHF/AM equipment.		
	REC position	Permits headset to receive only over VHF/AM equipment.		
33	S-RAND sw		Repeater lt	
	T/R position	Permits headset to transmit and receive over S-band equipment when in voice mode.		
	REC position	Permits headset to receive only over S-band equipment when operating in voice mode.		
34	HF sw		Repeater lt	
	T/R position	Permits headset to transmit or receive over HF receiver in AM or SSB mode.		
	REC position	Permits headset to receive only output of HF receiver in AM or SSP mode.		
35	AL 2 lt (IOS ONLY)	Indicates that astronaut loop 2 is in use.		Operates in conjunction with console communications system AL talk-listen keys.

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Figure 1-36. AGC Display and Keyboard

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Table 1-33. Apollo Guidance Computer—Display and Keyboard Panel—
Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	COMP FAIL lt	When on, indicates AGC has failed.	Repeater lt	Upper half of these two indicators repeats SCM UPTL sw position. Lower halves are actuated under program control and indicate functional status of AMS with respect to block uplink function.
2	CHECK FAIL lt	Indicates improper operating condition in DSKY program.	Repeater lt	
3	UP TEL sw		Repeater lt	
	ACCEPT position	Allows AGC to accept data received on up-link.		
	BLOCK position	Prohibits AGC from accepting up-link information.		
4	BRIGHTNESS thumbwheel	Controls AGC DSKY lt intensity.	Repeater lt	
5	KEY RLSE pushbutton	Releases registers 1, 2, and 3 from displaying keyboard data and allows displays of program data.	Repeater lt	In event that keyboard is failed or AGC is off, keyboard repeats will still be present at IOS but KEYBOARD ACTIVE light will not be on. (Also applies to 6, 7, 8, 9, 10, and 11.)
6	ERROR RESET pushbutton	Causes lighted computer alarm displays to go out.	Repeater lt	
7	ENTER pushbutton	Causes data or noun/verb command to be entered in computer.	Repeater lt	
8	NOUN pushbutton	Prepares computer to accept noun code.	Repeater lt	
9	VERB pushbutton	Prepares computer to accept verb code.	Repeater lt	
10	CLEAR pushbutton	Allows erasure of erroneous number keyed during data loading.	Repeater lt	
11	0-9 pushbutton	Enter octal code of decimal digits keyed.	Repeater lt	
12	REGISTER display (1, 2, 3)	Display selected source data or component of multi-component data.	Repeater lt	In event of simulated electroluminescent lamp failure, IOS repeaters will continue to display commanded AGC characters.

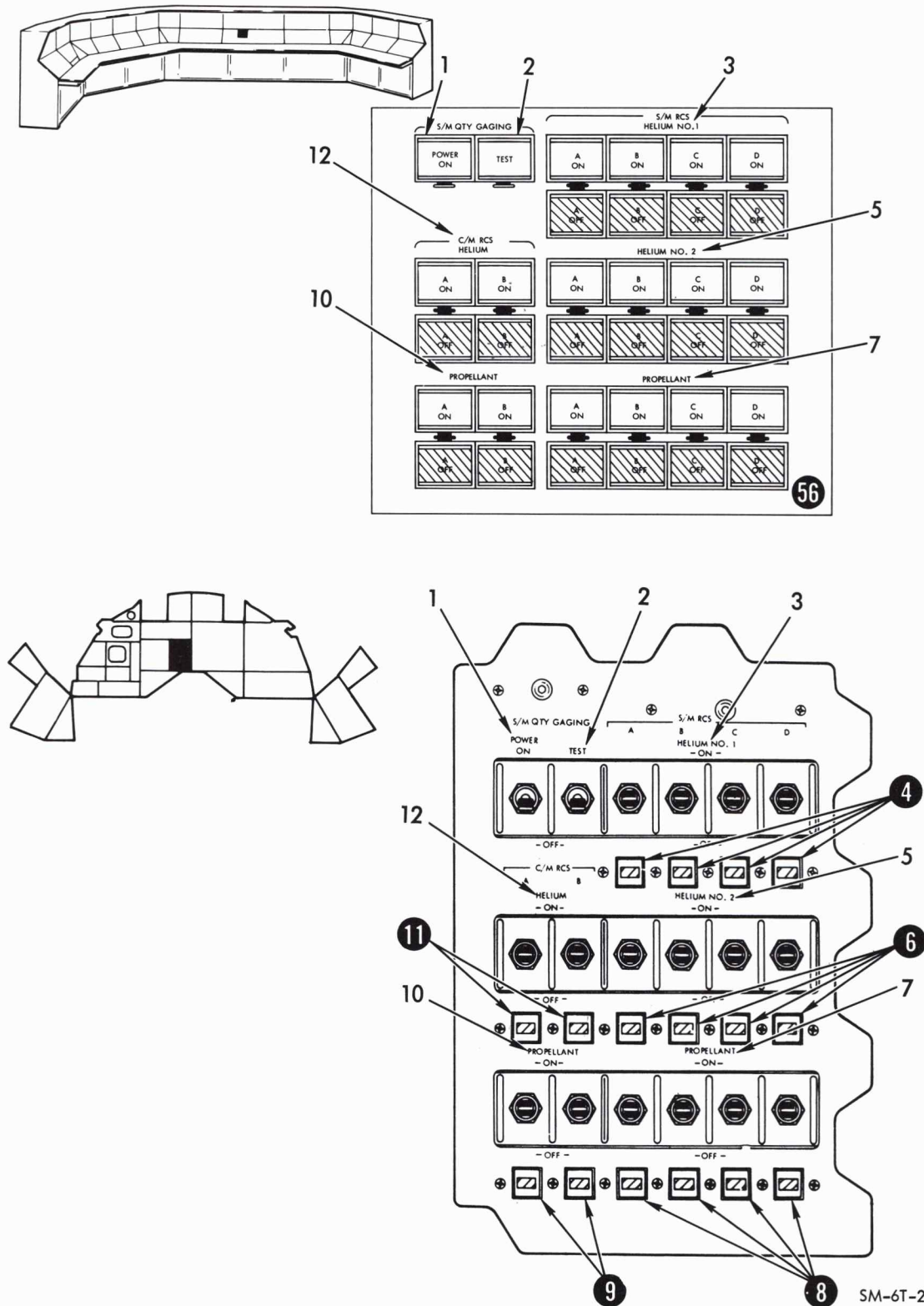
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Table 1-33. Apollo Guidance Computer—Display and Keyboard Panel—
Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
13	VERB display	Indicates number (octal) of selected verb code.	Repeater display	(Same as 12)
14	NOUN display	Indicates number (octal) of selected noun code.	Repeater display	(Same as 12)
15	ACTIVITY lt	Indicates activity computer is presently engaged in.	Repeater lt	
	UPTL lt	Indicates computer is receiving up-telemetry data.	UTEL repeater lt	
	COMP lt	Indicates computer is engaged in a test routine.	Repeater lt	
16	PROGRAM display	Indicates number (decimal) of program presently in progress.	Repeater display	(Same as 12)
17	Spare			
18	KEYBOARD ACTIVE indicator (IOS only)	Indicates that a keyboard entry is in progress, eminent or required.		Cues IO that keyboard entries are being made or are expected.

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Figure 1-37. Spacecraft Panel 15

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Table 1-34. Spacecraft Panel 15—Controls and Displays

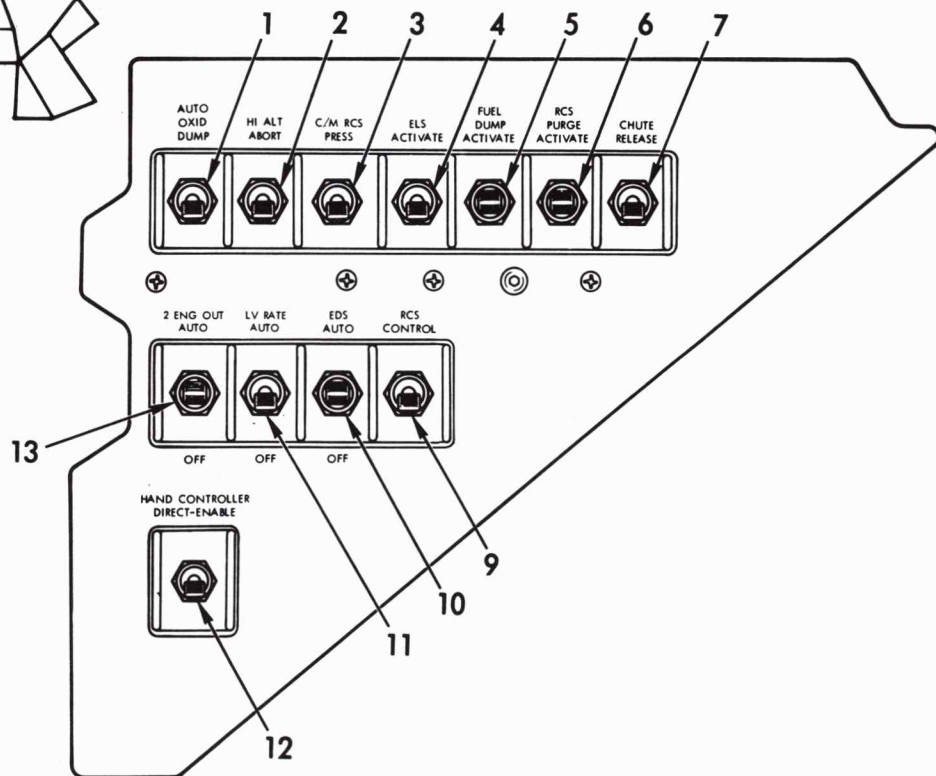
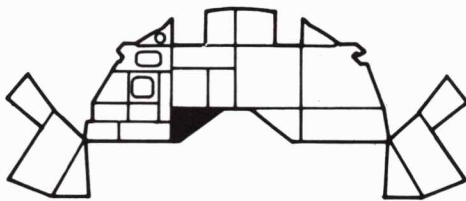
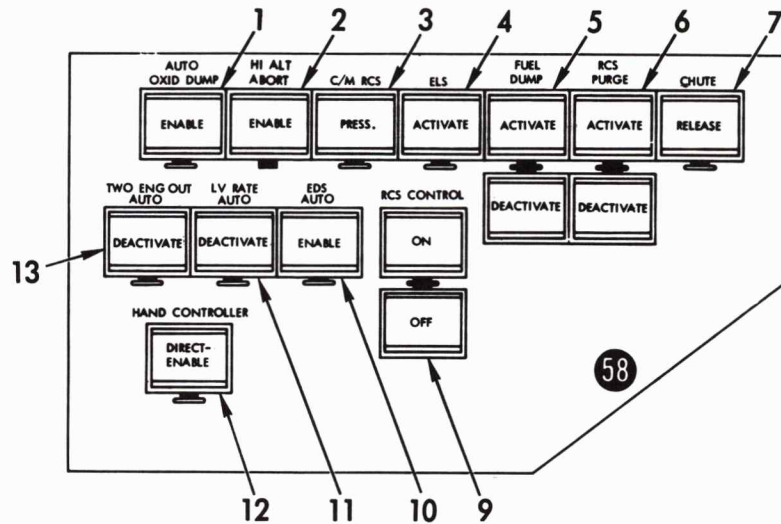
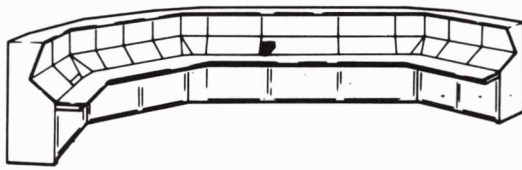
Key	Nomenclature	Function	Instructor Visibility	Remarks
1	S/M QTY GAGING — POWER ON sw	Applies power to S/M gaging system.	Repeater lt	
2	S/M QTY GAGING — TEST sw			
	TEST position	Resets quantity sensing circuitry.	Repeater lt	
	OFF position	Starts test mode.	No lt	
3	S/M RCS — HELIUM NO. 1 sw	Four identical sw each controlling two helium isolation valves for 1 side of parallel pressurization system.	Repeater lt	
	A (B, C, D)			
	ON position	Actuates helium isolation valves to open position.		
	Normal position	Removes solenoid actuation power.		
	OFF position	Actuates helium isolation valve to closed position.		
4	Event indicator flags (C/M only)	Indicates position of He 1 valves.	Reduced or increased intensity of related IOS sw repeater lt	
5	S/M RCS HELIUM No. 2 (A, B, C, D) sw	Function identical to He 1 sw for 2 path.	Repeater lt indicator	
6	Event indicator flags (C/M only)	Indicates position of He 2 valves.	Reduced or increased intensity of related IOS sw repeater lt	
7	PROPELLANT sw	Four identical sw; each controlling two shutoff valves (F, O).	Repeater lt	
	A (B, C, D)			
	ON position	Actuates propellant shutoff valves in respective system to open position.	Repeater lt	
	OFF position	Actuates propellant shutoff valves in respective systems to closed position.		

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Table 1-34. Spacecraft Panel 15—Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
7 (Cont)	NORMAL position	Removes solenoid excitation power		
8	Event indicator flags (C/M only)	Indicates position of propellant shutoff valves.	Repeater 1t	
9	Event indicator flags (C/M only)	Indicates position of propellant shutoff valves.	Repeater 1t	
10	PROPELLANT sw	Two functionally identical sw; each controlling two propellant shutoff valves in respective systems.	Repeater 1t	
	ON position	Opens two propellant shut-off valves in respective system.		
	OFF position	Closes two propellant shut-off valves in respective system.		
	Normal position	Removes actuation power.		
11	Event indicator flags (C/M only)	Indicates position of He isolation valve.	Repeater 1t	
12	C/M RCS HELIUM sw	Two identical sw which control activation of two each helium isolation valves.	Repeater 1t	
	ON position	Actuates two helium isolation valves to open position in respective system.		
	OFF position	Closes two helium isolation valves in respective system.		
	Normal position	Removes valve actuating power.		

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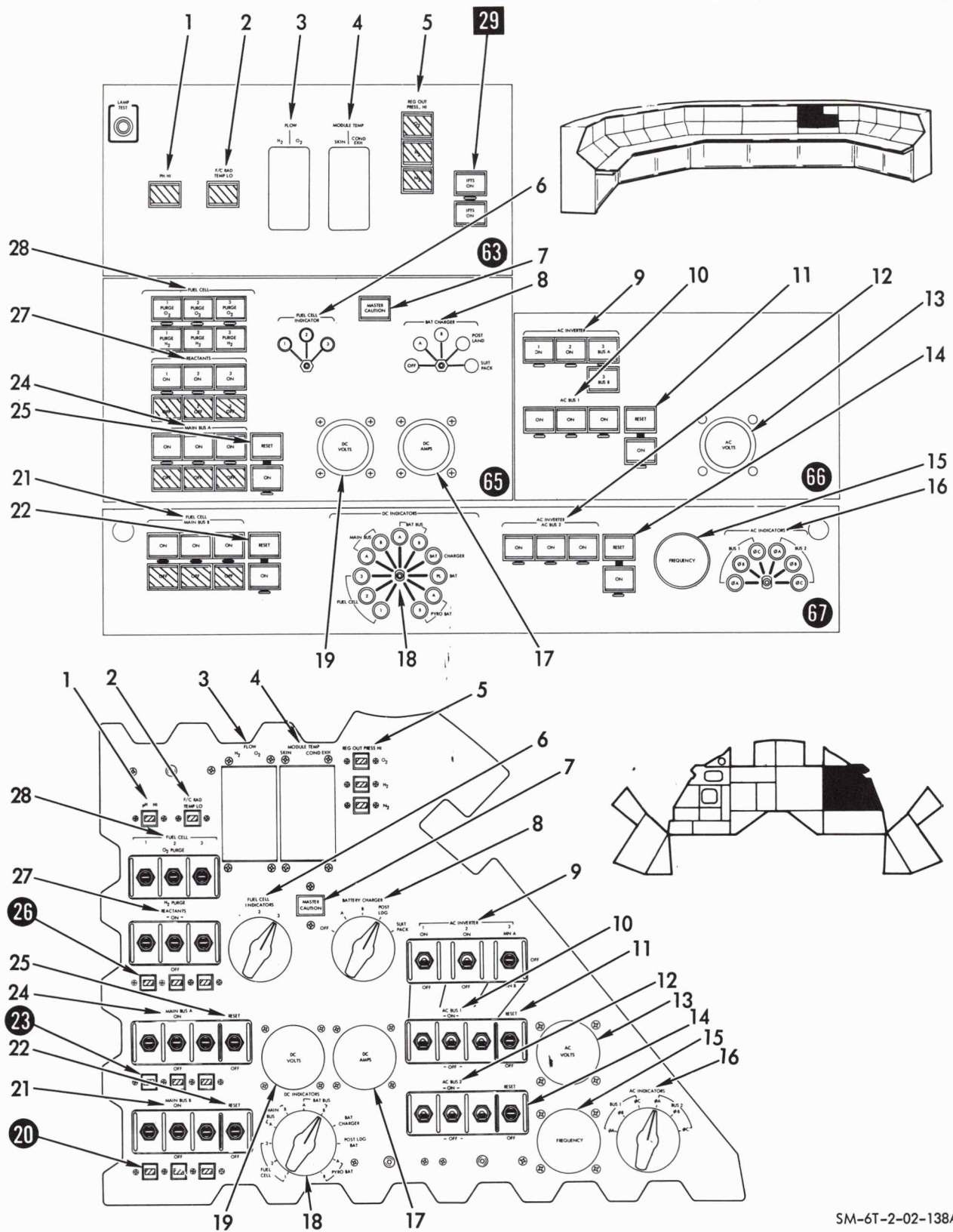
Figure 1-38. Spacecraft Panel 16

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Table 1-35. Spacecraft Panel 16—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	AUTO OXID DUMP sw	Backup sw to dump C/M RCS oxidizer when not dumped automatically during abort.	AUTO OXID DUMP — ENABLE repeater lt	
2	HI ALT ABORT ENABLE sw	Enables or disables EDS automatic abort capability.	Repeater lt	
3	C/M RCS PRESS. sw	Backup to normal automatic function of pressurization C/M RCS.	Repeater lt	
4	ELS ACTIVATE sw	Backup to mission sequencer should it fail to activate ELS following abort or C/M-S/M separation.	Repeater lt	
5	FUEL DUMP-ACTIVATE sw	Activates dumping or burning of RCS fuel following main chute deploy.	FUEL DUMP - ACTIVATE — DEACTI- VATE	
6	RCS PURGE ACTIVATE sw	Purges C/M RCS with helium after fuel dump or burn.	RCS PURGE - ACTIVATE — DEVACTI- VATE	
7	CHUTE RELEASE sw	Manually releases main chutes after landing.	Repeater lt	
8	(Deleted)			
9	RCS CONTROL sw	Manual backup to normal automatic latching of SCS circuitry to the jet selection logic whenever C/M-S/M separation occurs.	Repeater lt	
10	EDS AUTO sw	Deactivates EDS automatic abort capability.	Repeater lt	
11	LV RATE AUTO sw	Deactivates capability of EDS to initiate abort caused by excessive rate condition.	Repeater lt	
12	HAND CONTROLLER DIRECT-ENABLE sw	Enables direct (emergency) use of manual control of RCS jets.	Repeater lt	
13	2 ENG OUT AUTO sw	Deactivates capability of EDS to initiate abort caused by two-engine-out condition.	Two eng out repeater lt	

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Figure 1-39. Electrical Power System Panel

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Table 1-36. Electrical Power System Panel—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	PH HI event indicator flag	Indicates Ph factor of potable water from selected fuel cell is over 9.5.	Repeater lt	
2	F/C RAD TEMP LO flag	Indicates selected fuel cell radiator temperature is below -30°F.	Repeater lt	
	FLOW gages		Repeater gage	
3	H ₂ gage	Indicates flow rate of hydrogen.		
	O ₂ gage	Indicates flow rate of oxygen.		
	MODULE TEMP gages		Repeater gage	
4	SKIN gage	Indicates skin temperature of fuel cell.		
	COND EXH gage	Indicates temperature of fuel cell condenser exhaust.		
	REG OUT PRESS. HI flags		Repeater lt	
5	O ₂ flag	Indicates output pressure of O ₂ regulator exceeds 75 psia.		
	H ₂ flag	Indicates output pressure of H ₂ regulator exceeds 75 psia.		
	N ₂ flag	Indicates output pressure of N ₂ regulator exceeds 70 psia.		
6	FUEL CELL INDICATORS rotary sw	Selects desired fuel cell to be monitored by display indicators.	Repeater lt	Selected SCM position of switch is indicated at IOS. However, IO may, by depressing any unlighted pushbutton associated with the switch, read other parameters. SCM displays are not affected by IO action.
7	MASTER CAUTION lt	Indicates a caution condition exists.	Repeater lt	Warning tone is audible in astronaut headset and MASTER CAUTION light on IOS Panel 39 goes on.
8	BATTERY CHARGER rotary sw	Energizes battery charger and selects battery to be charged.	Repeater lt	

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Table 1-36. Electrical Power System Panel—Controls and Displays (Cont)

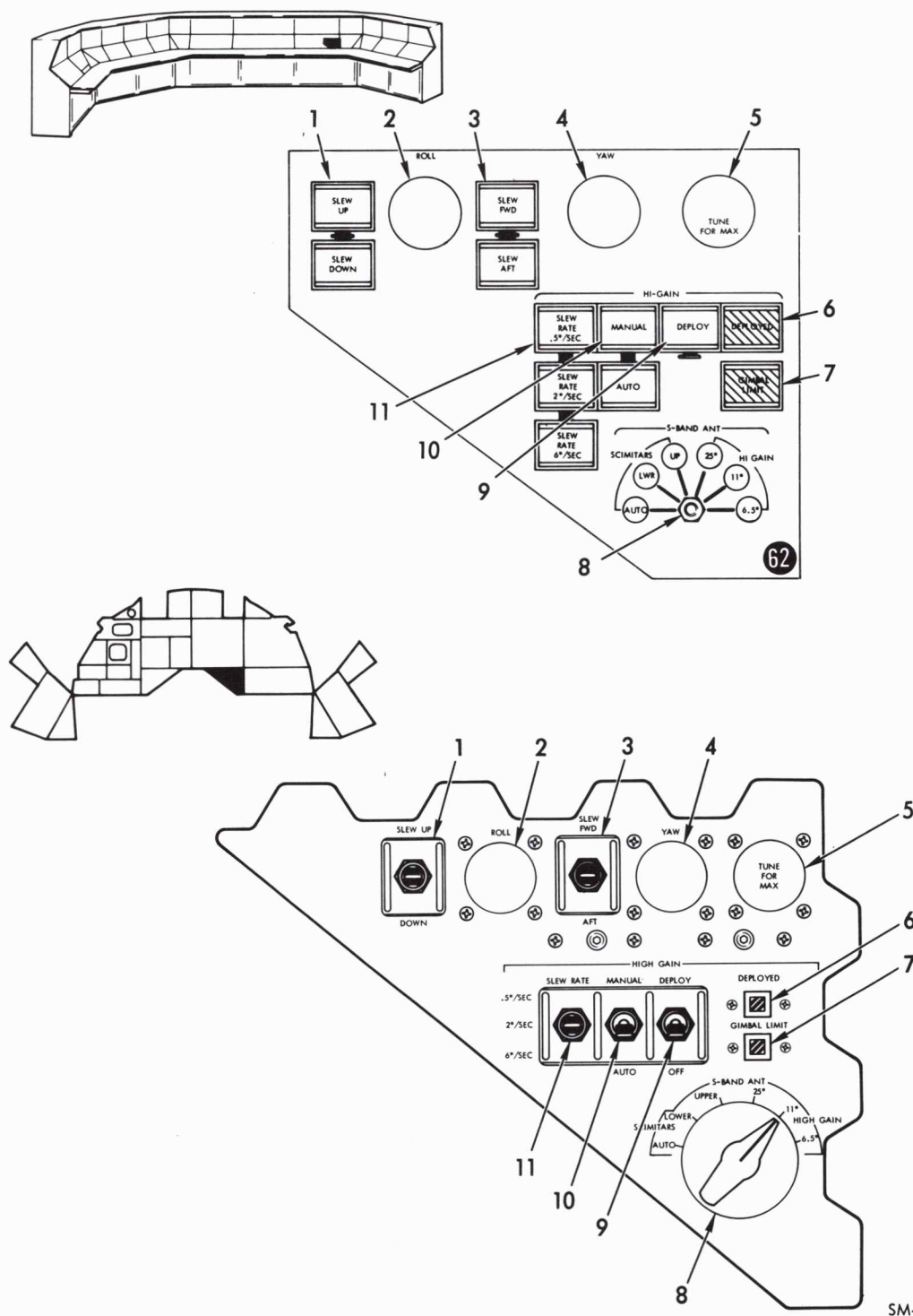
Key	Nomenclature	Function	Instructor Visibility	Remarks
9	AC INVERTER sw	Provides on-off control of d-c power to selected a-c inverter.	Repeater lt	Switch is duplicated within SCM at Panel 21; therefore, repeater indications of switch position are also located on IOS Panel 72.
10	AC BUS 1 sw	Provides on-off control of selected inverter a-c output to bus 1.	Repeater lt	
	RESET-OFF sw		Repeater lt	
11	RESET position	Resets a-c bus 1 over-undervoltage and overload sensing unit.	Repeater lt	
	On position	Energizes a-c bus 1 over-undervoltage and overload sensing unit.	ON repeater lt	
	OFF position	Disconnects a-c bus 1 over-undervoltage and overload sensing unit.	No lt	
12	AC BUS 2 sw	Provides on-off controls of selected inverter a-c output to bus 2.	AC INVERTERS — AC BUS 2 repeater lt	
13	AC VOLTS meter	Indicates a-c voltage of selected source and phase.	Repeater meter	
	RESET-OFF sw		Repeater lt	
14	RESET position	Resets a-c bus 2 over-undervoltage and overload sensing unit.	Repeater lt	
	On position	Activates a-c bus 2 over-undervoltage and overload sensing unit.	ON repeater lt	
	OFF position	Deactivates a-c bus 2 over-undervoltage and overload sensing unit.	No lt	
15	FREQUENCY meter	Indicates frequency of selected source and phase.	Repeater meter	
16	AC INDICATORS rotary sw	Provides means of monitoring 3Ø voltage and frequency output of a-c inverters. Controls inputs to a-c meter displays.	Repeater sw - lt	(Same as 6)
17	DC AMPS meter	Indicates d-c current of selected source, unit or bus.	Repeater meter	

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Table 1-36. Electrical Power System Panel—Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
18	DC INDICATORS rotary sw	Selects power source bus or unit to be monitored by DC VOLTS or DC AMPS meters.	Repeater sw - lt	(Same as 6)
19	DC VOLTS meter	Provides on-off control of selected source output to bus.	Repeater meter	
20	Event indicator flags (C/M only)	Indicates whether or not a fuel cell is connected to main bus B.	Reduced or increased intensity of related IOS sw repeater lt	
21	MAIN BUS B sw	Provides on-off control of selected F/C output to d-c main bus B.	Repeater lt	
22	RESET sw	Provides capability of resetting d-c main bus B undervoltage protection circuitry.	Repeater lt	
23	Event indicator flags (C/M only)	Indicates whether or not a fuel cell is connected to main bus A.	Repeater lt	
24	MAIN BUS A sw	Provides on-off control of selected F/C output to d-c main bus A.	Repeater lt	
25	RESET sw	Provides capability of resetting d-c main bus A undervoltage protection circuit.	Repeater lt	
26	Event indicator flags (C/M only)	Indicates the position of the reactant shutoff valves	Repeater lt	
27	REACTANTS sw	Provides on-off control of reactant flow for selected fuel cells.	Repeater lt	
28	FUEL CELL sw	Accomplish purging of selected cell.	Repeater indicator	
29	IFTS indicator (IOS only)	Not operable.		

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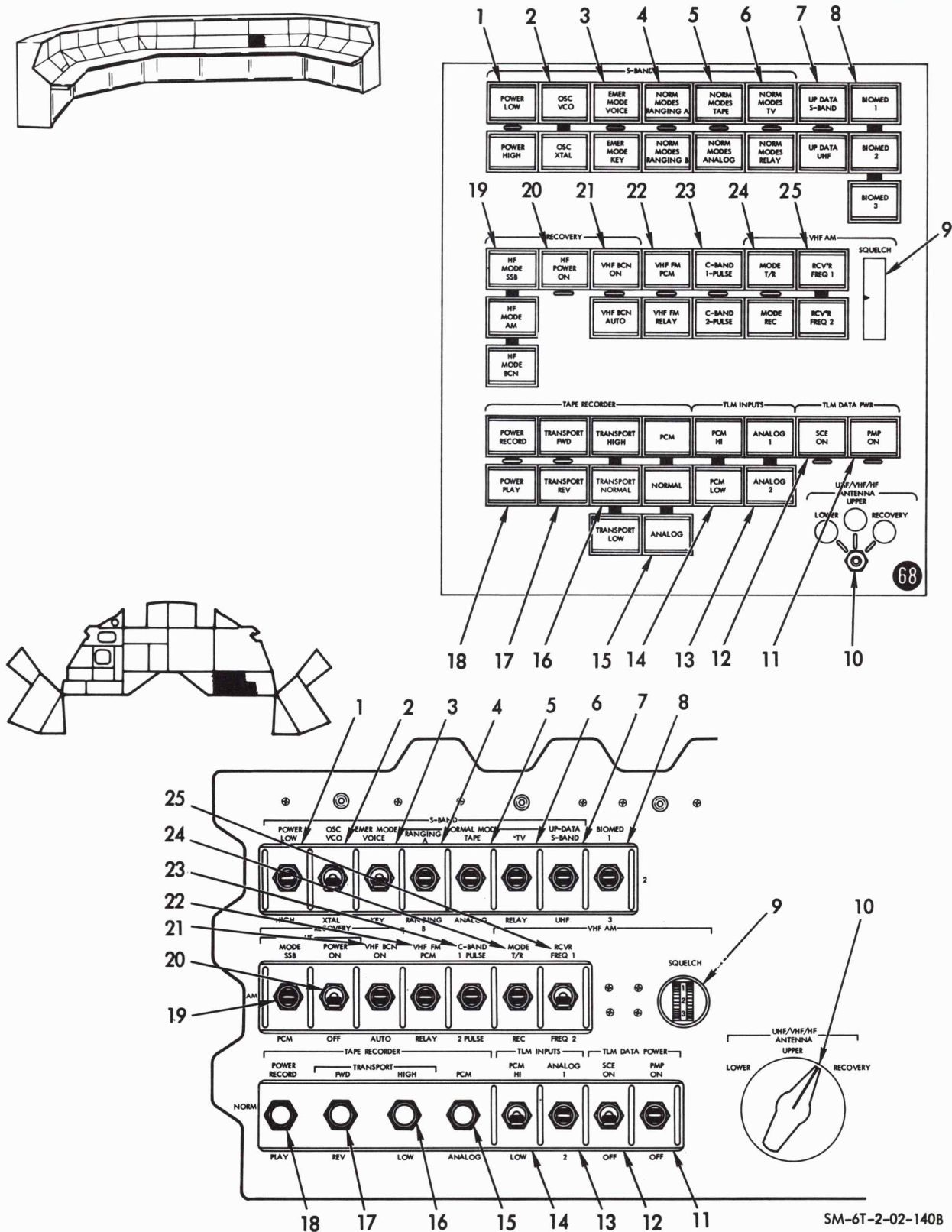
Figure 1-40. Antenna Control Panel

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Table 1-37. Antenna Control Panel—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	SLEW UP-DOWN sw	Provides manual up-down control of high-gain antenna ($\pm Z$ axis).	Repeater 1t	
2	ROLL meter	Indicates high-gain antenna roll angle referenced to Y axis.	Repeater meter	
3	SLEW FWD-AFT sw	Provides manual slew control of high-gain antenna in forward and aft directions ($\pm X$ axis).	Repeater 1t	
4	YAW meter	Indicates yaw angle of high-gain antenna referenced to X axis.	Repeater meter	
5	TUNE FOR MAX meter	Indicates relative strengths of received unified S-Band equipment (USB E) signal.	Repeater meter	
	HI-GAIN			
6	DEPLOYED flag	Indicates high-gain antenna full deployment.	Repeater 1t	
7	GIMBAL LIMIT flag	Indicates antenna has reached a gimbal limit stop.	Repeater 1t	
8	S-BAND ANT rotary sw		Repeater 1t	
	HI-GAIN position	Provides selection of three different beam widths for high-gain antenna.		
	SCIMITARS positions	Provides for manual or automatic selection of VHF/2 KMC antennas. VHF is manual selection.		
9	DEPLOY sw	Initiates high-gain antenna deployment.	Repeater 1t	
10	MANUAL-AUTO sw	Enables selection of either manual or auto positioning control for high-gain antenna.	Repeater 1t	
11	SLEW RATE sw	Provides selection of maximum manual slew rates.		
	.5/SEC position		Repeater 1t	
	2°/SEC position		Repeater 1t	
	6°/SEC position		Repeater 1t	

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Figure 1-41. Communications Control Subpanel

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Table 1-38. Communications Control Subpanel—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	S-BAND sw		Repeater 1t	
	POWER—HIGH position	Actuates transponder and power amplifier for USBE.		
	POWER—LOW position	Actuates only USBE transponder.		
2	OSC—VCO-XTAL sw	Selects either voice-controlled oscillator or auxiliary crystal oscillator for use with USBE.	Repeater 1t	
3	EMER MODE—VOICE-KEY sw	Provides selection of emergency voice communications or emergency key operation.	Repeater 1t	
4	NORMAL MODE sw		Repeater 1t	
5	RANGING A position	Provides simultaneous ranging function in conjunction with voice and pulse-coded modulation (PCM) transmission.		
	RANGING B position	Allows only voice and ranging functions.		
	TAPE—ANALOG sw		Repeater 1t	
	TAPE position	Enables data transmission through S-band to be controlled by tape recorder switches.		
	ANALOG position	Enables transmission of real time analog, PCM or voice via S-band equipment.		
6	TV—RELAY sw		Repeater 1t	
7	TV position	Enables transmission of TV, voice, and PCM via USBE.		
	RELAY position	Enables transmission of voice, PCM, and relay extra-vehicular astronaut (EVA) biomedical data.		
	UP-DATA sw		Repeater 1t	
	S-BAND position	Enables reception of up-data via USBE in deep space.		
8	UHF position	Enables reception of up-data via UHF equipment while near earth.		
	BIOMED sw	Selects hardline biomedical data from one of three crew positions for PCM transmission via S-band.	Repeater 1t	

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Table 1-38. Communications Control Subpanel—Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
9	VHF AM—SQUELCH thumbwheel	Changes turnoff level of VHF/AM receiver to eliminate noise.	Repeater indicator	
10	UHF/VHF/HF ANTENNA rotary sw		Repeater 1t	
	LOWER position	Selects scin antenna on the +Z axis for UHF/VHF use.		
	UPPER position	Selects scin antenna on the -Z axis for UHF/VHF use.		
	RECOVERY position	Selects the recovery antenna for VHF/HF use.		
	TLM DATA POWER			
11	PMP—ON-OFF sw	Provides on-off control of premodulation processor (PMP)	Repeater 1t	
12	SCE—ON-OFF sw	Provides on-off control of signal conditioning equipment.	Repeater 1t	
	TLM INPUTS			
13	ANALOG sw	Selects analog 1 or analog 2 data mode in PMP.	Repeater 1t	
14	PCM sw		Repeater 1t	
	HI position	Selects normal PCM mode in PCM equipment and high assurance mode of data storage equipment (DSE).		
	LOW position	Selects H-band TLM data mode in PCM equipment and low-assurance mode of DSE.		
	TAPE RECORDER		Repeater 1t	
15	PCM-ANALOG sw			
	PCM position	Selects PCM playback mode of PMP from DSE.		
	NORMAL position	Selects PCM and analog playback mode of PMP from DSE.		
	ANALOG position	Selects analog playback mode of PMP from DSE.		
	TAPE RECORDER—TRANSPORT			
16	HIGH-NORMAL-LOW	Provides control of tape transport speed.	Repeater 1t	

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Table 1-38. Communications Control Subpanel—Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
17	FWD-REV sw	Provides forward and reverse control tape motion.	Repeater 1t	
18	TAPE RECORDER—POWER sw		Repeater 1t	
	RECORD position	Selects record mode of PMP; switches power to energize DSE.		
	PLAY position	Selects playback mode of PMP; switches power to energize DSE.		
	RECOVERY			
19	HF-MODE sw		Repeater 1t	
	SSB position	Selects single sideband mode of HF transceiver.		
	AM position	Selects AM mode of HF transceiver.		
	PCM position	Selects AM mode of HF transceiver and closes keying circuit of HF transceiver.		
20	HF—POWER ON-OFF sw	Closes power circuit to HF transceiver.	Repeater 1t	
21	VHF BCN sw		Repeater 1t	
	ON position	Activates VHF beacon.		
	AUTO position			
22	VHF FM sw		Repeater 1t	
	PCM position	Allows transmission of PCM via VHF-FM.		
	RELAY position	Allows transmission of biomed information from EVA in earth orbit.		
23	C-BAND sw	Energizes equipment in C-band transponder and selects either 1 or 2 pulse mode.	Repeater 1t	
24	VHF AM—MODE sw		Repeater 1t	
	T/R position	Applies power to both receiver and transmitter circuitry.		
	REC position	Enables reception only via VHF-AM equipment.		
25	VHF AM—RCVR sw	Selects either receiver 1 or receiver 2 frequency for VHF-AM equipment	Repeater 1t	

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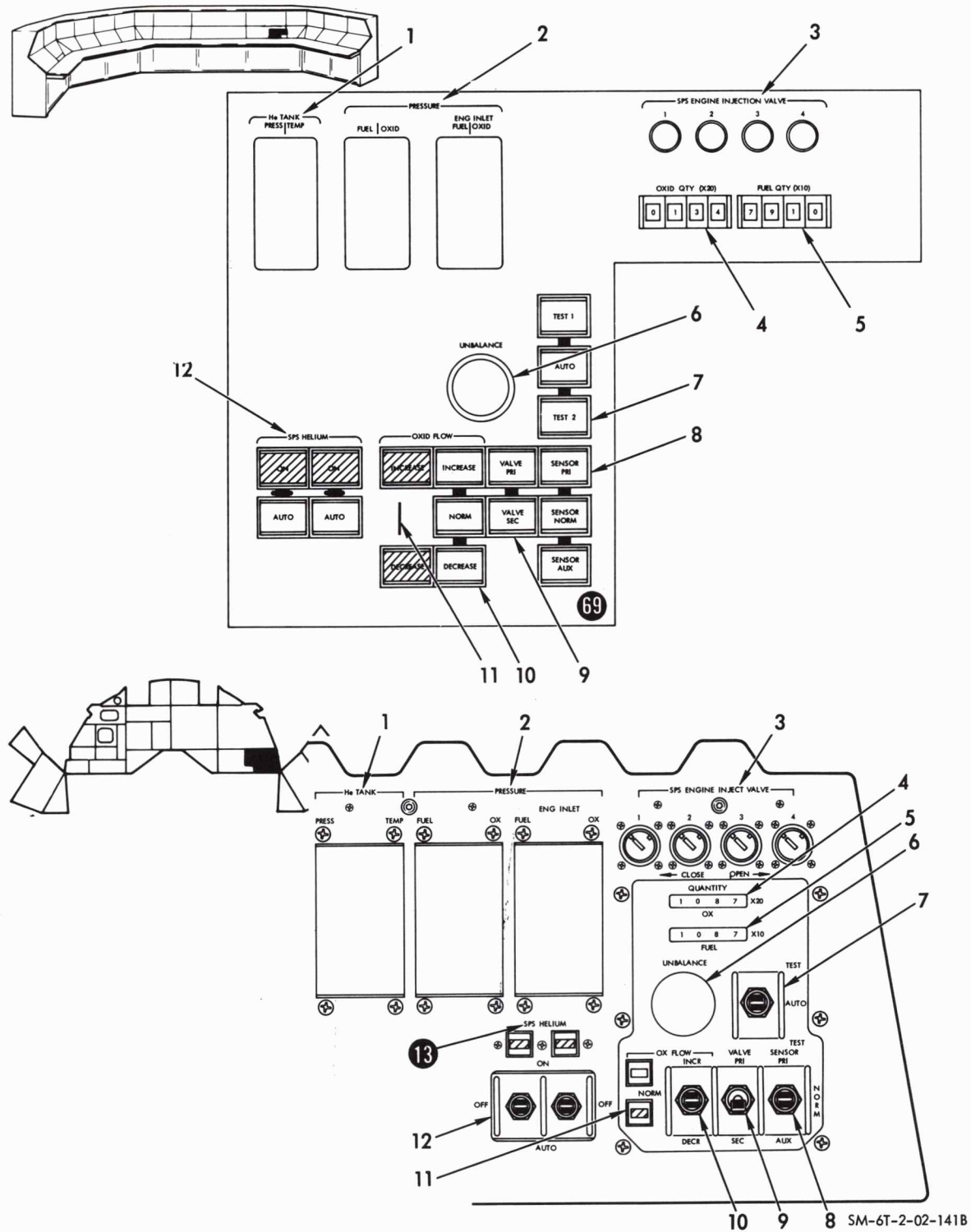


Figure 1-42. SPS Quantity Gauging Subpanel

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Table 1-39. SPS Quantity Gauging Panel—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	He TANK indicator		Repeater indicator	
	TEMP indicator	Provides constant monitoring of unregulated helium tank temperature.		
	PRESS indicator	Provides constant monitoring of unregulated helium tank pressures.		
2	PRESSURE indicator		Repeater indicator	
	FUEL indicator	Provides monitoring of unregulated helium tank pressure prior to entering fuel tanks.		
	OX indicator	Provides monitoring of unregulated helium tank pressure prior to entering oxidizer tanks.		
	ENG INLET--FUEL indicator	Provides monitoring of fuel pressure at engine interface.		
	ENG INLET--OX indicator	Provides monitoring of oxidizer pressure at engine interface.		
3	SPS ENGINE INJECT VALVE (1, 2, 3, 4) indicators	Provides indication of SPS main propellant valve position.	Repeater lt	
4	QUANTITY--OX indicator	Displays remaining oxidizer tank quantity.	Repeater indicator	
5	QUANTITY--FUEL indicator	Displays remaining fuel tank quantity.	Repeater indicator	
6	UNBALANCE meter	Graduated meter indicating propellant mixture unbalance.	Repeater lt	
7	AUTO-TEST sw		Repeater lt	
	TEST (up) position	Applies simulated test input to PU gaging system causing UNBALANCE meter and digital displays to function.		
	TEST (down) position	Similar function as TEST (up) except with reverse polarity.		
	AUTO position	Normal operating position.		
8	SENSOR sw PRI position AUX position NORM position	Selects either one of primary or auxiliary sensing systems or both to input to PU gaging system.	Repeater lt	

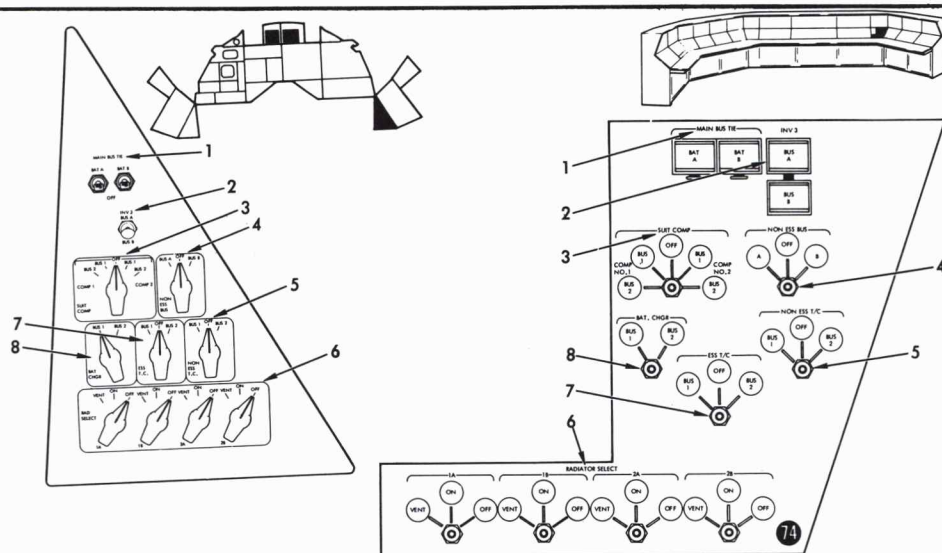
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Table 1-39. SPS Quantity Gauging Panel—Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
9	VALVE sw PRI position SEC position	Energizes either primary or secondary servo amplifier for propellant utilization valve.	Repeater 1t	
10	OX FLOW sw INCR position DECR position NORM position	Regulates oxidizer flow rate (increase, decrease, or normal) to obtain proper propellant mixture ratio.	Repeater 1t	
11	Event indicator flags	Indicates position of propellant utilization valve.	Reduced or increased intensity of related IOS sw repeater 1t	
12	SPS HELIUM sw ON position OFF position AUTO position	Control power application to helium isolation valve solenoid.	Repeater 1t	
13	SPS HELIUM event indicators (two) flags (C/M only)	Provides indication of position of valve solenoid controlled by switch located directly below flag.	Reduced or increased intensity of related IOS sw repeater 1t	

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Figure 1-43. Spacecraft Panel 21

Table 1-40. Spacecraft Panel 21—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	MAIN BUS TIE sw (BAT A and BAT B)	Controls application of related battery to d-c main buses.	Repeater 1t	
2	INV 3 sw BUS A position BUS B position	Enables selection of either bus A or bus B power to inverter 3.	Repeater 1t	Repeater 1t is duplicate of repeater 1t on IOS Panel 66.
3	SUIT COMP rotary sw	Provides a selection of either suit compressor 1 or 2. Also enables powering of selected compressor from either bus 1 or bus 2.	Repeater sw - 1t	
4	NON ESS BUS rotary sw	Enables connecting non-essential bus to either bus A or bus B or OFF.	Repeater sw - 1t	
5	NON ESS T/C rotary sw	Enables selecting a-c power power input to nonessential telecommunications equipment.	Repeater sw - 1t	
6	RADIATOR SELECT rotary sw (1A, 1B, 2A, and 2B)	Provides on-off control of selected ECS radiators.	Repeater sw - 1t	
7	ESS T/C rotary sw	Provides a capability of selecting a-c power input to essential telecommunications equipment.	Repeater sw - 1t	
8	BAT CHGR rotary sw.	Selects a-c power input to battery charger from either bus 1 or bus 2.	Repeater sw - 1t	

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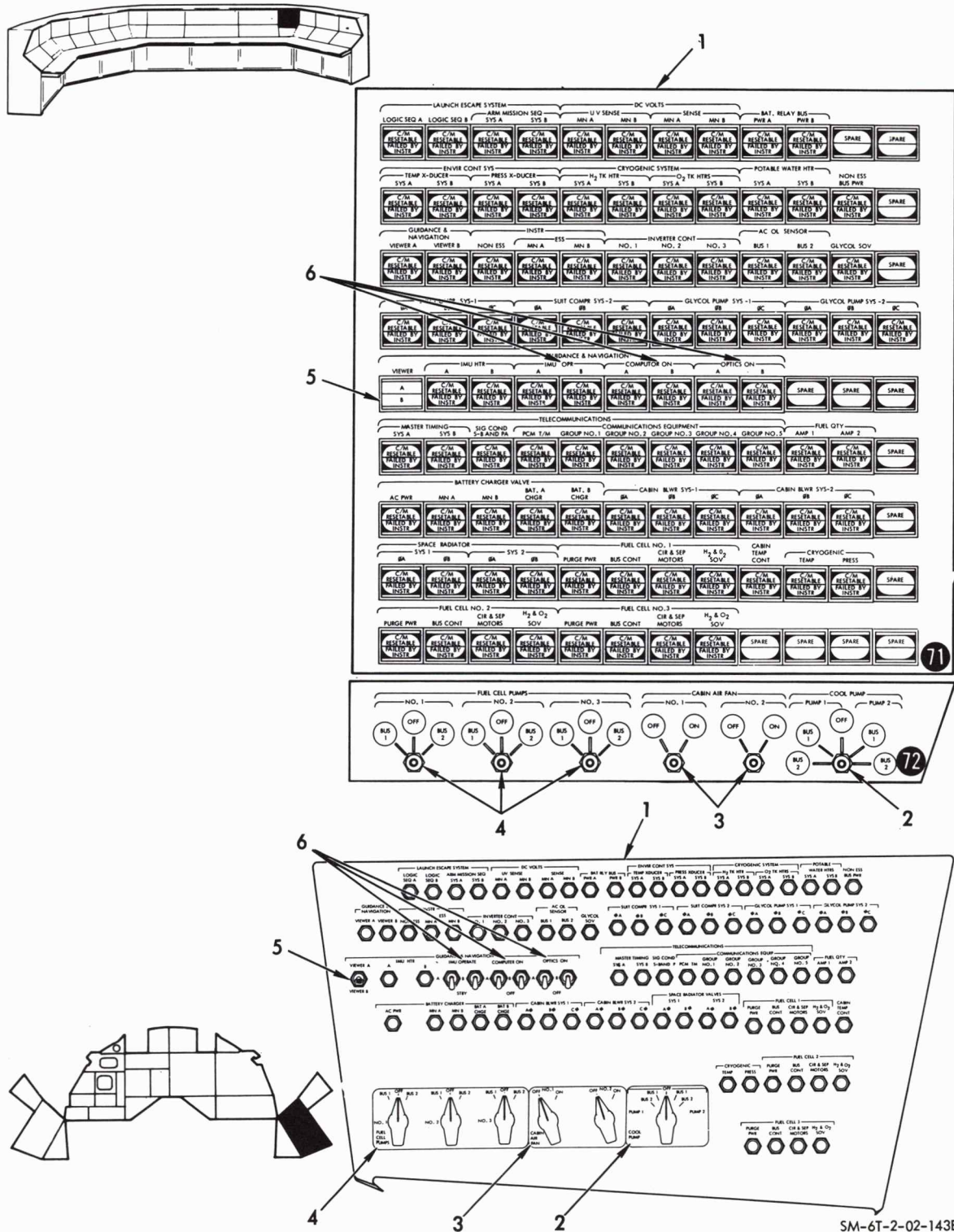


Figure 1-44. Circuit Breaker Panel 22

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Table 1-41. Circuit Breaker Panel 22— Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	Circuit breaker panel	Each C/B provides a protective circuit path for related indicated system or provides an indication when circuit is disengaged or inoperative.	Repeater sw - 1t when circuit is disengaged or inoperative. Sw enables instructor to disable circuit breaker remotely.	
2	COOL PUMP rotary sw	Provides selection of either pump 1 or 2 and also allows an off control function and selection of a-c bus 1 or bus 2 to power selected pump.	Repeater sw - 1t	
3	CABIN AIR FAN (1 and 2) rotary sw	Provides on-off control for cabin air fans.	Repeater sw - 1t	
4	FUEL CELL PUMPS rotary sw (1, 2, and 3)	Provides a selection of either bus 1 or bus 2 a-c power to fuel cell pumps and enables deactivation of pumps.	Repeater sw - 1t	
5	VIEWER A-B sw	Provides a capability to select bus 1 or bus 2 to power viewer.	Repeater sw	
6	Switch breakers	Provides a remote on-off capability for respective system as well as functioning as circuit breakers.	Repeater sw - 1t	

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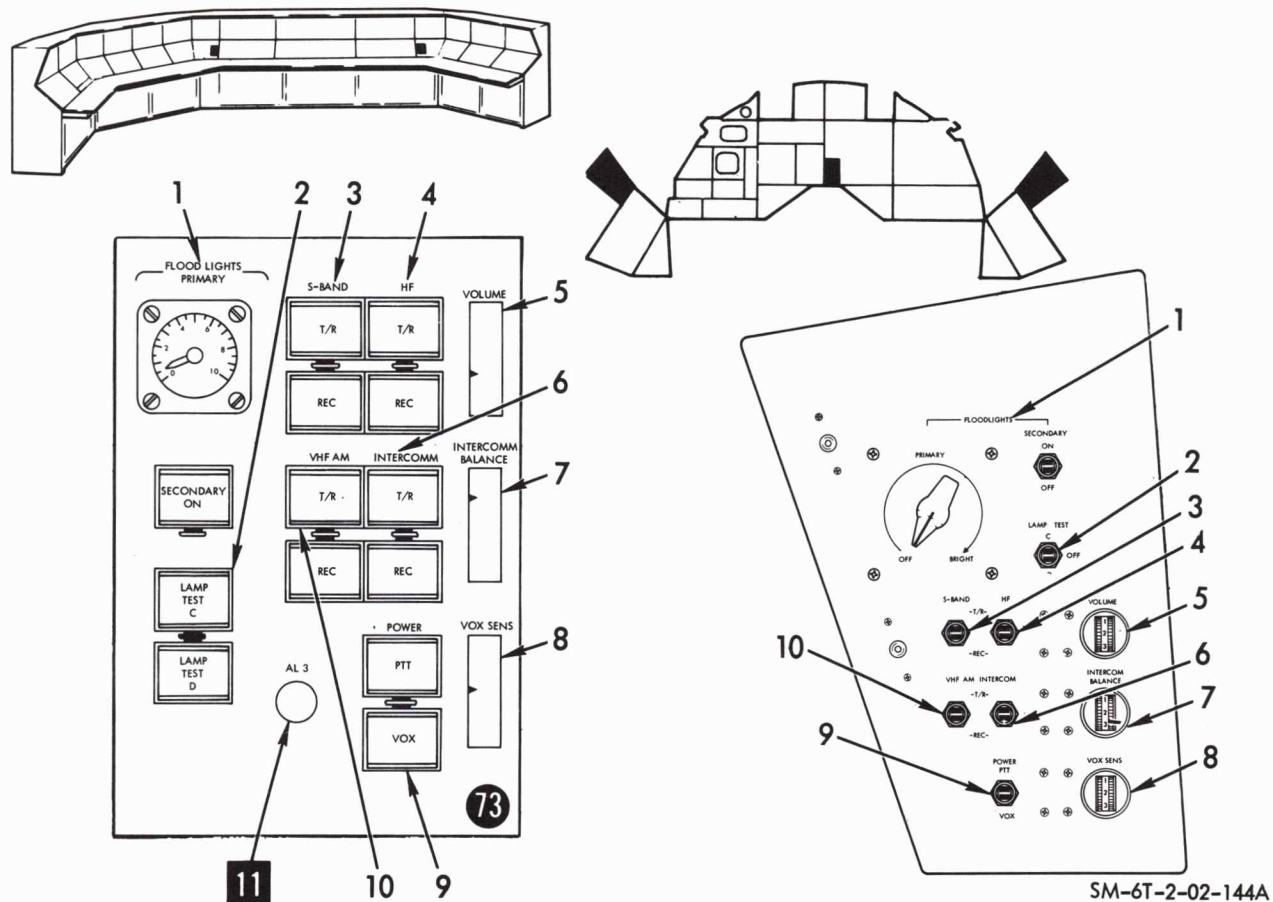


Figure 1-45. Audio Control Center Panel 26

Table 1-42. Audio Control Center Panel 26—Controls and Displays

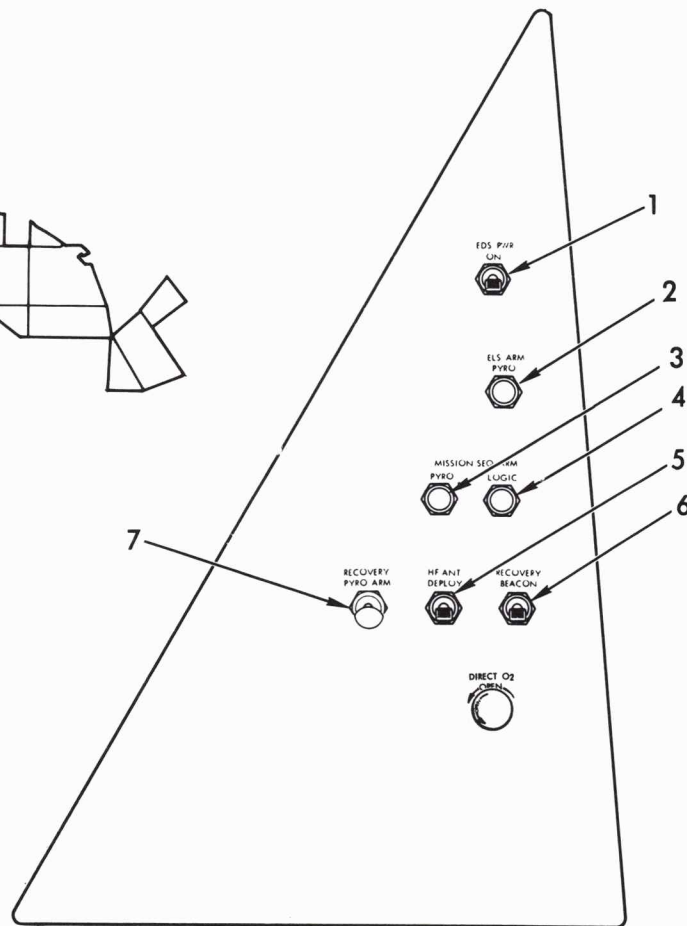
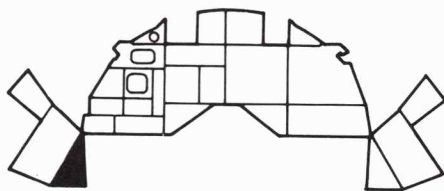
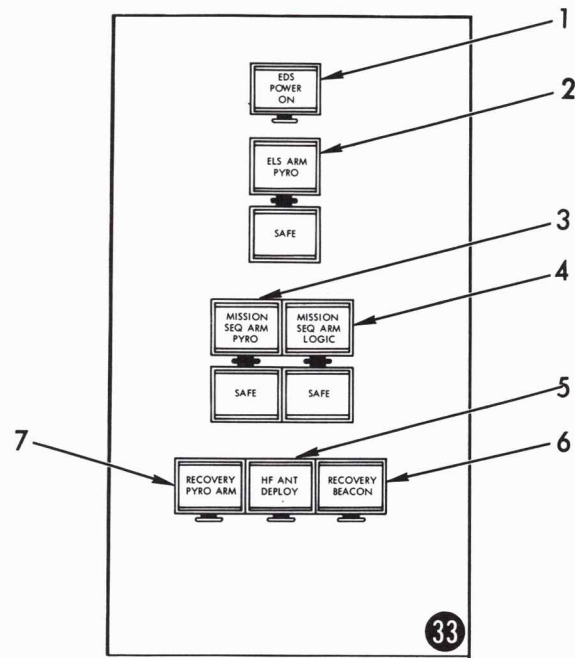
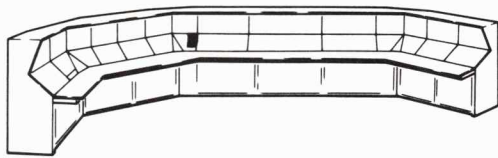
Key	Nomenclature	Function	Instructor Visibility	Remarks
1	FLOOD LIGHTS			
	PRIMARY potentiometer control	Provides variable intensity control for floodlights.	Repeater meter	
	SECONDARY sw	Provides on-off control for floodlights.	Repeater lt	
2	LAMP TEST sw	Provides test of C/M lamps.	Repeater lt	
3	S-BAND sw			
	T/R position	Permits headset to transmit and receive over S-band equipment when in voice mode.	Repeater lt	

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Table 1-42. Audio Control Center Panel 26—Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
3 (cont)	REC position	Permits headset to receive only over S-band equipment when in voice mode.		
4	HF sw		Repeater 1t	
	T/R position	Permits headset to transmit and receive on H/F equipment in AM or SSB mode.		
	REC position	Permits headset to receive only over HF when in voice mode.		
5	VOLUME thumbwheel	Adjusts volume of audio signal.	Repeater 1t	
6	INTERCOM sw		Repeater 1t	
	T/R position	Permits headset to receive and transmit over intercom system.		
	REC position	Permits headset to receive only over intercom system.		
7	INTERCOM BALANCE thumbwheel	Adjusts balance between received signals and intercom bus signals.	Repeater 1t	
8	VOX SENS thumbwheel	Adjusts sensitivity of voice operated relay.	Repeater 1t	
9	POWER sw		Repeater 1t	
	PTT position	Applies power to audio center.		
	VOX position	Closes VOX control circuitry and applies power to audio center.		
10	VHF/AM sw		Repeater 1t	
	T/R position	Permits headset to receive and transmit over VHF/AM equipment.		
	REC position	Permits headset to receive only over VHF/AM equipment.		
11	AL 3 lt (IOS only)	Indicates that astronaut communication loop 3 is in use.	(IOS only)	Light operates in conjunction with console communications system AL talk/listen keys.

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Figure 1-46. Spacecraft Panel 24

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Table 1-43. Spacecraft Panel 24—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	EDS POWER ON sw	Provides on-off control for power application to EDS.	Repeater	
2	ELS ARM PYRO sw	Provides control for activating or deactivating power to ELS pyro technics only.	Repeater lt	
3	MISSION SEQ ARM PYRO sw	Provides control for activating or deactivating pyro battery power to sequencers.	Repeater lt	
4	MISSION SEQ ARM LOGIC sw	Provides control for activating or deactivating battery power to logic busses of mission sequencer.	Repeater lt	
5	H-F ANT DEPLOY sw	Activates H-F antenna deploy circuitry.	Repeater lt	
6	RECOVERY BEACON sw	Activates external recovery beacon lt.	Repeater lt	
7	RECOVERY PYRO ARM sw	Applies pyro battery power to H-F antenna deploy sw.	Repeater lt	
8	DIRECT O ₂ control	Provides emergency oxygen directly to suit circuits for purging of contaminants or suit pressure regulator failures.		Repeater indicator for this SCM control is located on IOS panel 48.

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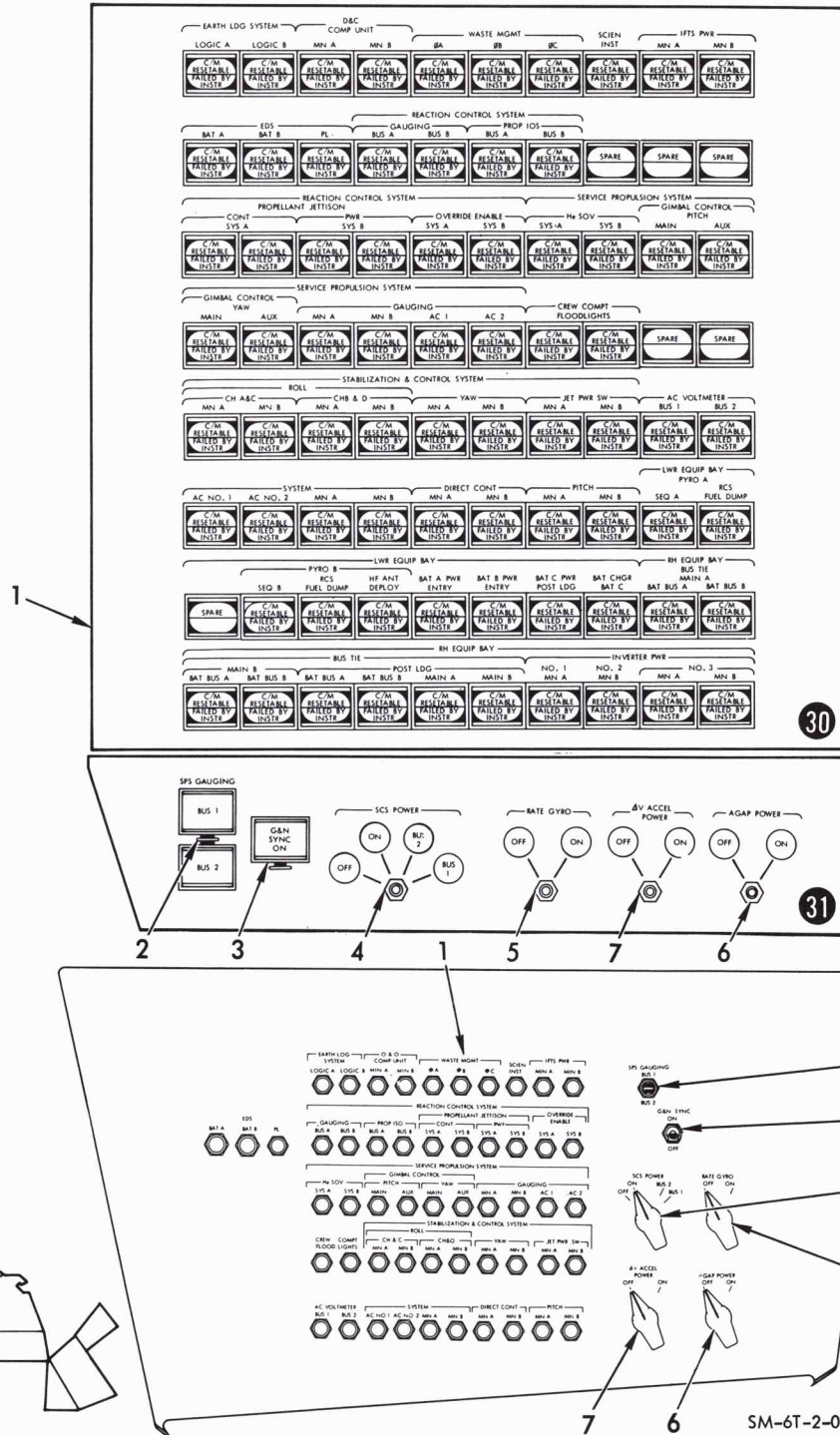
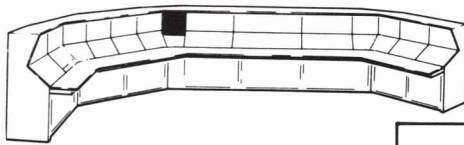


Figure 1-47. Circuit Breaker Panel 25

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Table 1-44. Circuit Breaker Panel 25—Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	Circuit breakers panel	Each C/B provides a protective circuit path for related indicated system or circuit. Also provides an indication when circuit is disengaged or disabled.	Repeater sw-lt when the circuit is disengaged, or inoperative. Sw enables instructor to disable C/B remotely.	
2	SPS GAUGING sw	Allows selection of a-c power from bus 1 or bus 2.		
	BUS 1 position		SPS GAUGING—BUS 1 repeater lt	
	BUS 2 position		SPS GAUGING—BUS 2 repeater lt	
3	G&N SYNC sw	Enables manual use of SCS hand control for maneuver while in a G&N attitude control mode of operation.	Repeater lt	
4	SCS POWER rotary sw			
	OFF position	Removes all power from SCS.	Repeater sw-lt	
	ON position	Applies all power to SCS and enables automatic switching from a-c bus 1 to a-c bus 2 in event of a power failure.		
	BUS 1 and BUS 2 positions	Applies a-c power to SCS from selected a-c bus and disengages automatic switching function, also applies d-c power.		
5	RATE GYRO rotary sw	Provides on-off power control for rate gyro package.	Repeater sw-lt	
6	AGAP POWER rotary sw	Provides on-off power control for attitude gyro accelerometer package.	Repeater sw-lt	
7	ΔV ACCEL POWER rotary sw	Provides on-off power control for delta V accelerometer package.	Repeater sw-lt	

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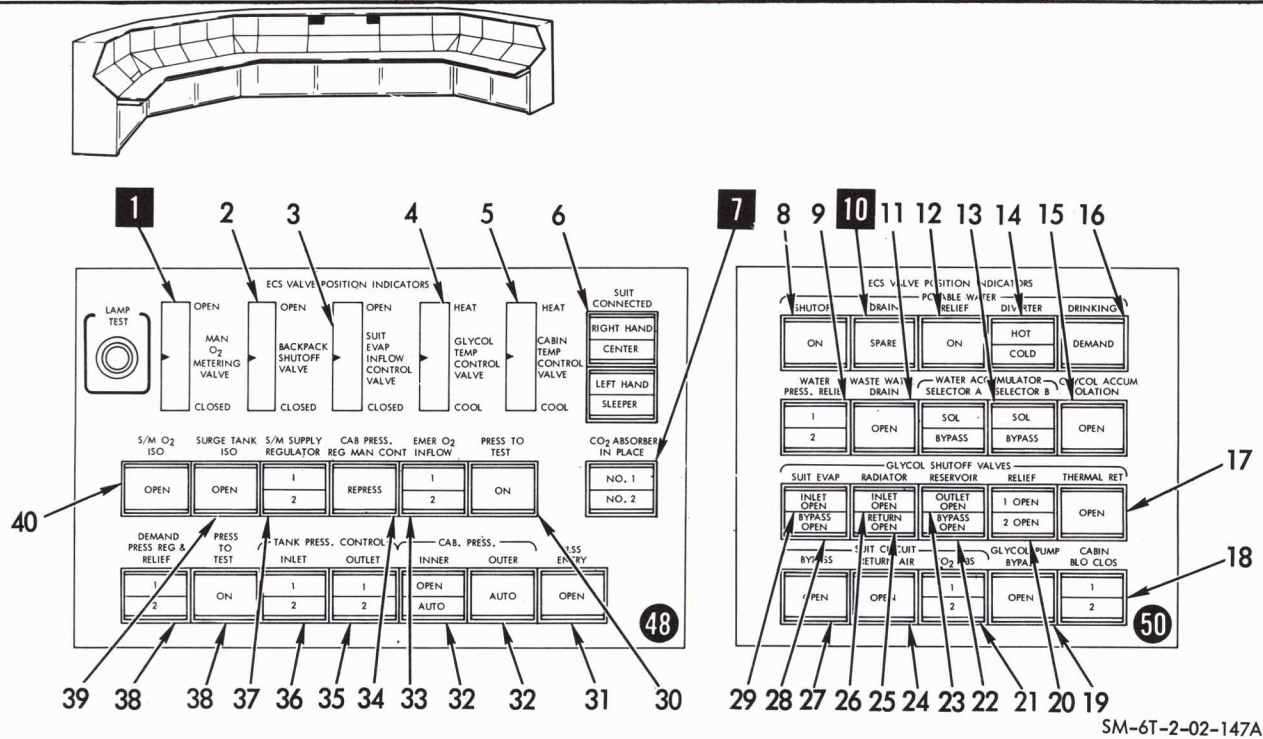


Figure 1-48. ECS Valve Position Indicators

Table 1-45. ECS Component Panels - Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
				NOTE
				The descriptive title listed under Nomenclature pertains to the item located within the SCM. The descriptive title under Instructor Visibility, where different, pertains to the item repeater indication at the IOS.
1	MANUAL O ₂ METERING valve OPEN CLOSED	Increases flow of O ₂ into suit circuit. Isolates suit circuit from manual O ₂ supply.	Repeater indicator	Control is located on SCM panel 24. (See figure 1-46, item 8.)
2	PLSS SUPPLY VALVE	Manual shutoff valve controlling filling of PLSS backpacks with oxygen from supply in S/M.	Back Pack shutoff valve indicator	

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Table 1-45. ECS Component Panels - Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
3	SUIT EVAP WATER CONTROL valve		SUIT EVAP INFLOW CONTROL VALVE position indicator	
	HEAT	Manual override mode position of suit heat exchanger water control valve to increase suit temperature.		
	COOL	Manual override mode position of suit heat exchanger water control valve to decrease suit temperature.		
4	COOLANT TEMP CONTROL valve		GLYCOL TEMP CONTROL VALVE indicator	
	HEAT	Manual override mode position of water-glycol temperature control valve to increase temperature of water-glycol entering evaporator.		
	COOL	Manual override mode position of water-glycol temperature control valve to decrease temperature of water-glycol entering evaporator.		
5	CABIN TEMP CONTROL valve		CABIN TEMP CONTROL VALVE indicator	
	HEAT	Manual override mode position of cabin temperature control valve to increase cabin temperature.		
	COOL	Manual override mode position of cabin temperature control valve to decrease cabin temperature.		
6	Suit connector valves	One for each suit station.	SUIT CONNECTED indicators	Flow gauges monitoring suit air flow are located on IOS panel 2
	OFF	Closes valve, shutting off flow of oxygen to suit connector.		

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APOLLO MISSION SIMULATOR INSTRUCTOR HANDBOOK

Table 1-45. ECS Component Panels - Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
6 (cont)	CABIN FLOW	Partially opens valve, permitting oxygen flow into cabin at a rate compatible to metabolic requirements of one crewman.		
	SUIT FULL FLOW	Fully opens valve, permitting oxygen flow to suit at a rate compatible to metabolic requirements of one crewman.		
	CONTROL LEVER RELEASE	Permits free movement of valve control lever by releasing lever locking mechanism.		
7	CO ₂ ABSORBER IN PLACE indicator (IOS only)			Indicator enables IO to be cognizant that trainee has physically removed CO ₂ canisters.
	NO. 1	Indicates that No. 1 canister is in place in SCM.		
	NO. 2	Indicates that No. 2 canister is in place in SCM.		
8	POTABLE TANK SHUT-OFF valve		Repeater indicator	
	ON	Permits flow of water from fuel cells into potable water tank.		
	OFF	Shuts off flow of water from fuel cells into potable water tank.		
9	WASTE WATER S/M SUPPLY SHUT-OFF valve		WATER PRESSURE RELIEF indicator	
	ON	Permits flow of water from fuel cells into waste water when relief valve differential pressure reaches 6.0±0.5 psi. (Refer to water subsystem of ECS-SYSTEM DATA section.)		
	OFF	Shuts off flow of water from fuel cells to differential pressure relief valve and waste water tank.		
10	Spare			

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Table 1-45. ECS Component Panels - Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
11	WASTE TANK SERVICING SHUTOFF valve		WASTE WATER DRAIN indicator	
	ON	Permits flow of water into waste water tank from ground servicing connection.		
	OFF	Shuts off flow of water into waste water tank from ground servicing connection.		
12	OVERBOARD PRESSURE RELIEF valve		POTABLE WATER RELIEF indicator	
	1 and 2	Directs flow of excess potable or waste water to No. 1 and No. 2 overboard pressure relief valves. (Refer to water subsystem of ECS-SYSTEMS DATA.)	ON	
	1	Directs flow of excess potable or waste water to No. 1 overboard pressure relief valve.	ON	
	OFF	Shuts off flow of excess potable and waste water to No. 1 and No. 2 overboard pressure relief valves.		
	2	Directs flow of excess potable or waste water to No. 2 overboard pressure relief valve.	ON	
13	CYCLIC ACCUM SELECTOR valves		WATER ACCUMULATOR SELECTOR indicator	There are no switches on SCM main display panel to operate cyclic accumulator.
	Valve 1			
	MAN	Directs regulated oxygen (100±10 psig) to solenoid shutoff valve bypass line of No. 1 cyclic accumulator selector valve assembly.	SELECTOR A SOL	
	OFF	Shuts off regulated oxygen (100±10 psig) to solenoid shutoff valve and bypass line of No. 1 cyclic accumulator selector valve assembly.		

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Table 1-45. ECS Component Panels - Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
13 (cont)	AUTO	Directs regulated oxygen (100±10 psig) to solenoid shutoff valve of No. 1 cyclic accumulator selector valve assembly for automatic operation.	SELECTOR A BYPASS	
	Valve 1			
	MAN	Directs regulated oxygen (100±10 psig) to solenoid shutoff valve bypass line of No. 2 cyclic accumulator selector valve assembly.	SELECTOR B SOL	
	OFF	Shuts off regulated oxygen (100±10 psig) to solenoid shutoff valve and bypass line of No. 2 cyclic accumulator selector valve assembly.		
	AUTO	Directs regulated oxygen (100±10 psig) to solenoid shutoff valve of No. 2 cyclic accumulator selector valve assembly for automatic operation.	SELECTOR B BYPASS	
14	WATER SUPPLY valve		POTABLE WATER DIVERTER indicator	
	HOT	Directs hot water (154±4°F) from water heater to food reconstitution nozzle.	HOT	
	OFF	Shuts off supply of hot and cold water to food reconstitution nozzle		
	COLD	Directs cold water (50°F) from water chiller to food reconstitution nozzle.	COLD	
15	GLYCOL ACCUM ISO valve		Repeater indicator	
	ON	Permits flow of water-glycol from system to and from water-glycol accumulator.	OPEN	
	OFF	Shuts off flow of water-glycol from system to water-glycol accumulator		

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Table 1-45. ECS Component Panels - Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
16	WATER DELIVERY valve		DRINKING DEMAND indicator	
	ON	Permits flow of potable water to water delivery unit.	DEMAND	
	OFF	Shuts off flow of potable water to water delivery unit.		
17	THERMAL LOAD RETURN valve		THERMAL RET indicator	
	ON	Permits flow of hot water-glycol to cabin heat exchanger.	ON	
	OFF	Shuts off flow of hot water-glycol to cabin heat exchanger.		
18	CABIN BLOWER valve	Manually operated shutter for adjusting direction of cabin blower airflow.	CABIN BLO CLOS indicator	
			1 and 2	
19	PUMP INLET valve		GLYCOL PUMP BYPASS indicator	
	on	Permits flow of water-glycol from reservoir into system.	OPEN	
	off	Shuts off flow of water-glycol from reservoir into system.		
20	GLYCOL PRESSURE RELIEF BYPASS		GLYCOL SHUTOFF RELIEF indicator	
	Valve 1			
	ON	Permits flow of water-glycol to No. 1 water-glycol pressure relief valve.	1 OPEN	
	OFF	Shuts off flow of water-glycol to No. 1 water-glycol pressure relief valve.		
	Valve 2			
	ON	Permits flow of water-glycol to No. 2 water-glycol pressure relief valve.	2 OPEN	
	OFF	Shuts off flow of water-glycol to No. 2 water-glycol pressure relief valve.		

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APOLLO MISSION SIMULATOR INSTRUCTOR HANDBOOK

Table 1-45. ECS Component Panels - Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
21	CO ₂ ABSORBER diverter valve	Indicates which one of the two canisters is in the suit circuit.	CO ₂ ABSORBER 1 and 2 indicator lt	Units are not functional within system.
22	GLYCOL RESERVOIR BYPASS valve		GLYCOL SHUTOFF RESERVOIR BYPASS indicator	
	ON	Opens bypass line permitting flow around water-glycol reservoir.	BYPASS OPEN	
	OFF	Closes bypass line that permits flow around water-glycol reservoir.		
23	GLYCOL RESERVOIR OUTLET valve		GLYCOL SHUTOFF RESERVOIR OUTLET indicator	
	ON	Permits flow of water-glycol from outlet of reservoir into system.	OUTLET OPEN	
	OFF	Shuts off flow of water-glycol glycol from outlet of reservoir into system.		
24	SUIT CIRCUIT RETURN AIR CHECK valve		Repeater indicator	
	0	Permits flow of cabin gases to enter suit circuit for processing.	OPEN	
	C	Provides isolation between suit circuit and cabin atmosphere and will prevent contamination of suit circuit.		
25	GLYCOL RESERVOIR INLET valve		GLYCOL SHUTOFF RADIATOR RETURN indicator	
	ON	Permits flow of water-glycol from system into reservoir.	OPEN	
	OFF	Shuts off flow of water-glycol from system into reservoir.		

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Table 1-45. ECS Component Panels - Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
26	RADIATOR ISOLATION valve		GLYCOL SHUTOFF RADIATOR INLET indicator	
	ON	Permits flow of water-glycol from C/M into space radiators in S/M.	OPEN	
	OFF	Shuts off flow of water-glycol from C/M into space radiators in S/M.		
27	SUIT BYPASS ACTUATOR valve		Repeater indicator	
	ON	Removes spring tension from hinged flapper, permitting automatic pressure-relief action to take place.		
	OFF	Applies spring tension to hinged flapper holding valve in closed position.		
28	BYPASS valve		SUIT EVAP	
	on	Opens bypass line permitting water-glycol to flow directly from inlet to outlet lines of suit heat exchanger.	BYPASS OPEN	
	off	Closes bypass line that permits water-glycol to flow directly from inlet to outlet lines of suit heat exchanger.		
29	SUIT EVAP INLET CONTROL valve		SUIT EVAP indicator	
	on	Permits flow of water-glycol from system into suit heat exchanger.	INLET OPEN	
	off	Shuts off flow of water-glycol from system into suit heat exchanger.		
30	PRESS TO TEST push-button	Permits No. 1 and No. 2 emergency oxygen inflow regulators to be simultaneously tested for operational verification.	Repeater indicator	

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APOLLO MISSION SIMULATOR INSTRUCTOR HANDBOOK

Table 1-45. ECS Component Panels - Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
31	PLSS ENTRY valve		PLSS ENTRY indicator	
	ON	Permits flow of oxygen from PLSS tank into C/M oxygen system.	OPEN	
	OFF	Closes off line from PLSS tank connector to C/M oxygen system.		
32	COMPARTMENT PRESSURE REGULATOR valve		CABIN PRES-SURE RELIEF ASSY indicator	
	CLOSE	Manual override position to close cabin pressure-relief valves.		
	AUTO	Neutral position of override mechanism permitting cabin pressure-relief valves to function automatically.		
	OPEN	Manual override position to open one cabin pressure-relief valve.		
33	EMERGENCY INFLOW REGULATOR valve		EMER O ₂ INFLOW REPEATER indicator	
	1 and 2	Directs regulated oxygen (100±10 psig) to No. 1 and No. 2 emergency inflow regulators.		
	1	Directs regulated oxygen (100±10 psig) to No. 1 emergency inflow regulator.		
	OFF	Shuts off regulated oxygen (100±10 psig) to No. 1 and No. 2 emergency inflow regulators.		
	2	Directs regulated oxygen (100±10 psig) to No. 2 emergency inflow regulator.		
34	CABIN PRESSURE REGULATOR valve	Facilitates cabin repressurization without depleting the surge tank.	CABIN PRES-SURE REG. MAN. CONT indicator	

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Table 1-45. ECS Component Panels - Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
35	TANK PRESSURE REGULATOR valve		TANK PRESSURE CONTROL indicator	
	1 and 2	Directs excessive oxygen pressure flow from potable and waste water tanks to No. 1 and No. 2 tank pressure regulator relief valves.	OUTLET 1 and 2	
	1	Directs excessive oxygen pressure flow from potable and waste water tanks to No. 1 tank pressure regulator relief valve.	1	
	OFF	Shuts off excessive oxygen pressure flow from potable and waste water tanks No. 1 and No. 2 tank pressure regulator relief valves.		
	2	Directs excessive oxygen pressure flow from potable and waste water tanks to No. 2 tank pressure regulator relief valve.	2	
36	TANK PRESSURE REGULATOR valve		TANK PRESSURE CONTROL indicator	
	1 and 2	Directs regulated oxygen (100±10 psig) to No. 1 and No. 2 tank pressure regulators for reduction to 20±2 psig tank pressure. (Refer to oxygen subsystem of ECS - SYSTEMS DATA.)	INLET 1 and 2	
	1	Directs regulated oxygen (100±10 psig) to No. 1 tank pressure regulator for reduction to 20±2 psig tank pressure.	1	
	OFF	Shuts off regulated oxygen (100±10 psig) to No. 1 and No. 2 tank pressure regulators.		

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Table 1-45. ECS Component Panels - Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
36 (Cont)	2	Directs regulated oxygen (100±10 psig) to No. 2 tank pressure regulator for reduction to 20±2 psig tank pressure.	2	
37	S/M SUPPLY REGULATOR valve		Repeater indicator	
	1 and 2	Directs supply of oxygen from S/M to No. 1 and No. 2 supply pressure regulator and relief valves. (Refer to oxygen subsystem of ECS-SYSTEMS DATA.)		
	1	Directs supply of oxygen from S/M to No. 1 supply pressure regulator and relief valve.		
	OFF	Shuts off supply of oxygen from S/M to No. 1 and No. 2 supply pressure regulator and relief valves.		
	2	Directs supply of oxygen from S/M to No. 2 supply regulator and relief valves.		
38	Demand pressure regulator selector		DEMAND PRESSURE REGULATOR and RELIEF indicator	
	1 REG	Directs regulated oxygen (100±10 psig) to No. 1 suit circuit oxygen demand pressure regulator.	REPEATER	
	BOTH	Directs regulated oxygen (100±10 psig) to No. 1 and No. 2 suit circuit oxygen demand pressure regulators.		
	2 REG	Directs regulated oxygen (100±10 psig) to No. 2 suit circuit oxygen demand pressure regulator		
	PRESS TO TEST plate	Permits No. 1 and No. 2 oxygen demand pressure regulators to be simultaneously tested for operational verification.	PRESS TO TEST ON	

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Table 1-45. ECS Component Panels - Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
39	SURGE TANK valve		SURGE TANK ISO indicator	
	ON	Permits flow of oxygen to and from surge tank.	OPEN	
	OFF	Shuts off flow of oxygen to and from surge tank.		
40	OXYGEN S/M SUPPLY valve		S/M O ₂ ISO indicator	
	ON	Permits flow of oxygen to C/M from supply in S/M.	OPEN	
	OFF	Shuts off flow of oxygen to C/M from supply in S/M.		

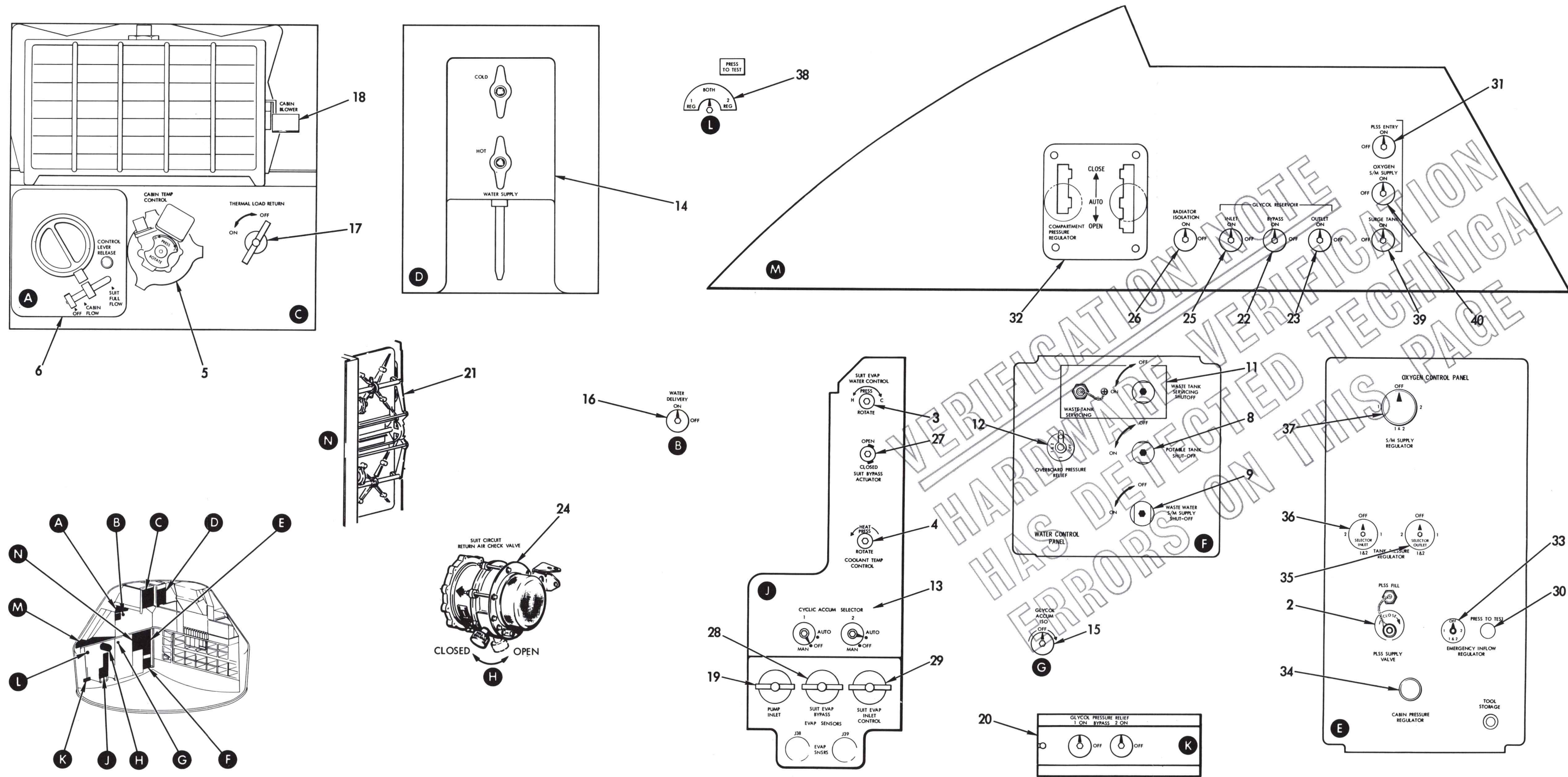
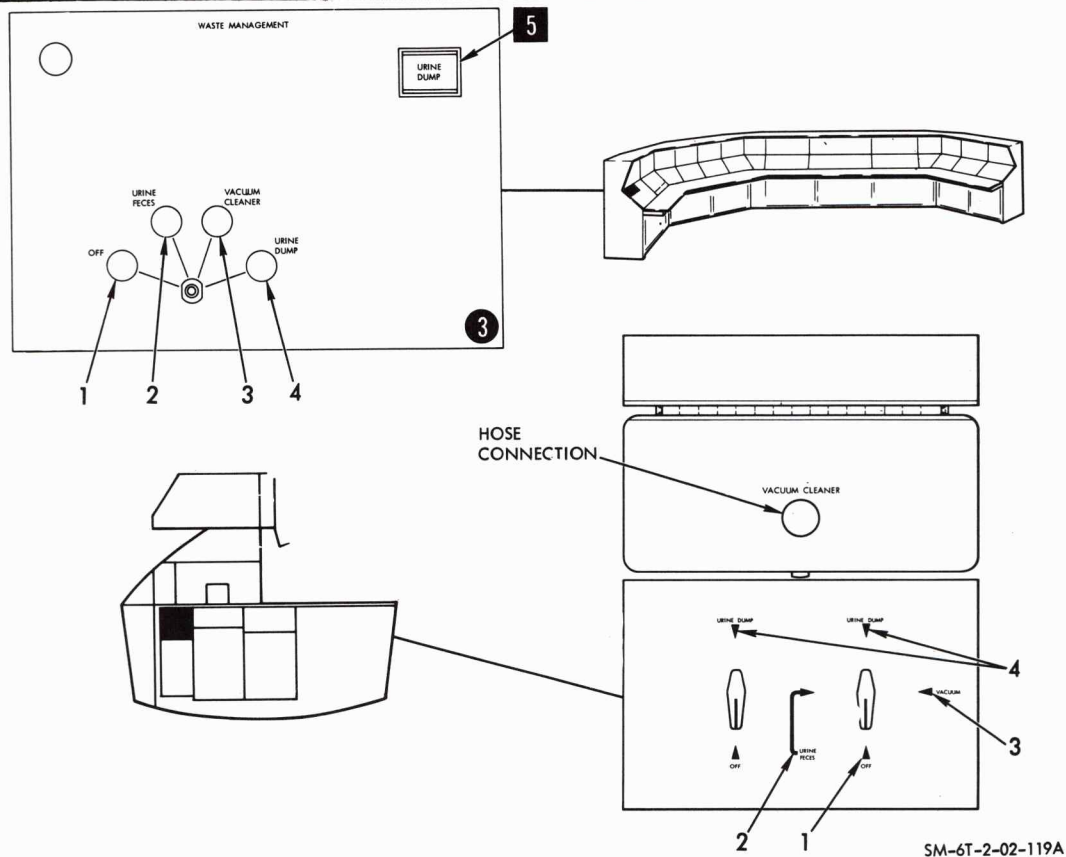


Figure 1-49. ECS Component Location

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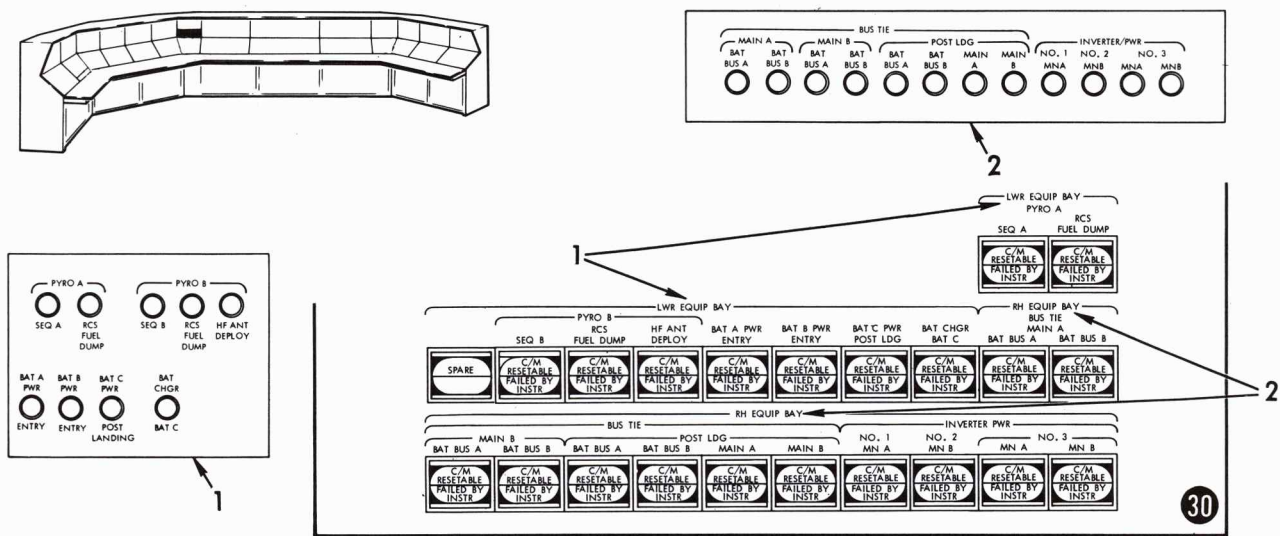
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Figure 1-50. Waste Management System.

Table 1-46. Waste Management System Panels - Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	OFF position	Disables function of waste management controls.	Repeater 1t	
2	URINE FECES position	Enables suction blower to operate for fecal cannister.	Repeater 1t	
3	VACUUM CLEANER position	Enables operation of on-board vacuum cleaner.	Repeater 1t	
4	URINE DUMP position	Enables urine to be dumped overboard when both switches are operated.	Repeater 1t	
5	URINE DUMP indicator 1t (IOS only)	Indicates that both switches in SCM are in DUMP position (Key 4 above)	Repeater 1t	

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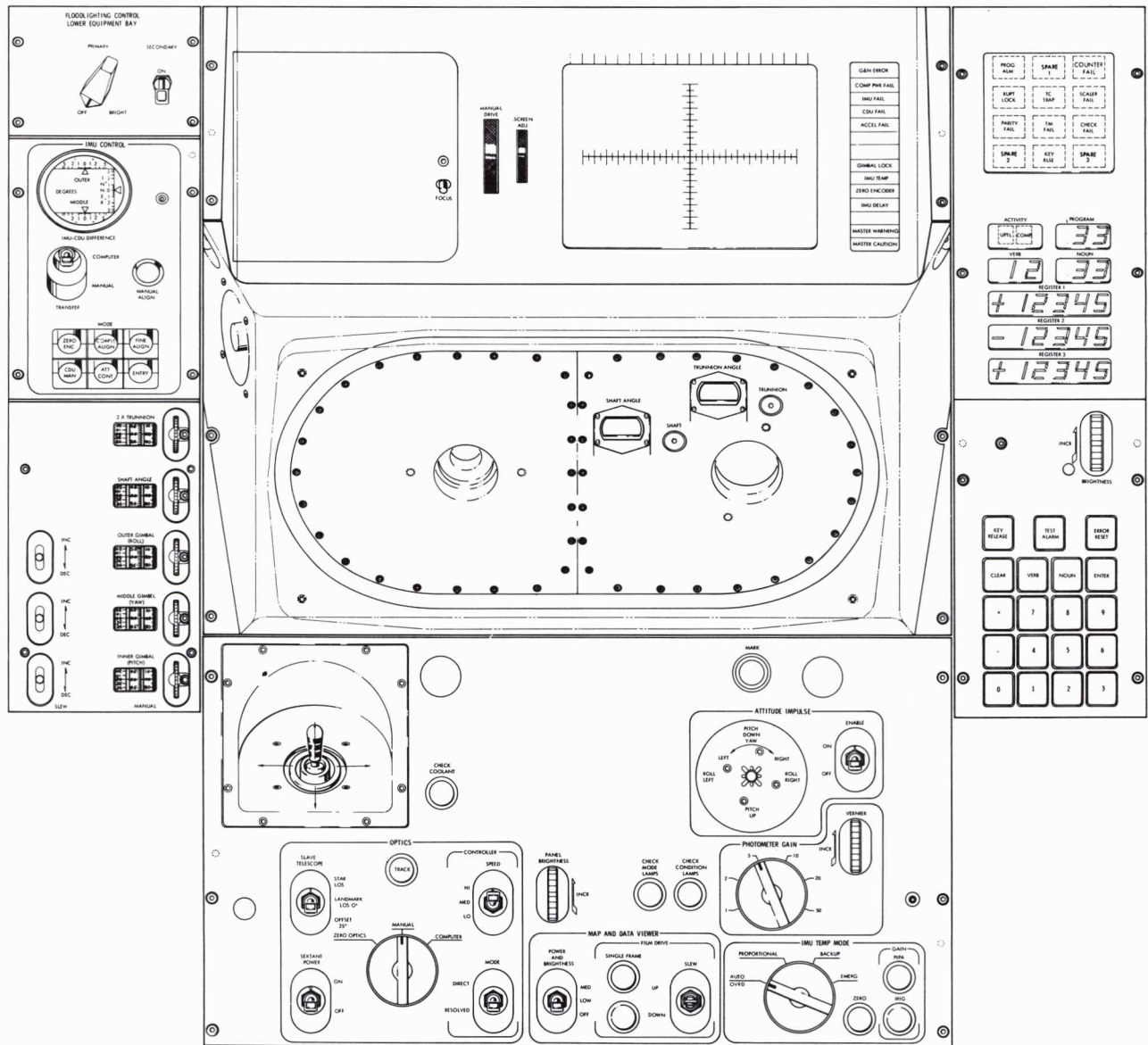
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Figure 1-51. LEB Circuit Breaker Panel

Table 1-47. Lower Equipment Bay Circuit Breakers - Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	LOWER EQUIPMENT BAY circuit breakers	Each C/B provides protective circuit path for related system or circuit. Provides indication whenever system is disengaged or inoperative.	Repeater sw - lt when circuit is disengaged or inoperative. Switch enables instructor to remotely disable C/B.	
2	RIGHT HAND EQUIPMENT BAY circuit breakers	Each C/B provides protective circuit path for related system or circuit. Provides indication whenever system is disengaged or inoperative.	Repeater sw - lt when circuit is disengaged or inoperative. Switch enables instructor to remotely disable C/B.	

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Figure 1-52. LEB G&N Panel

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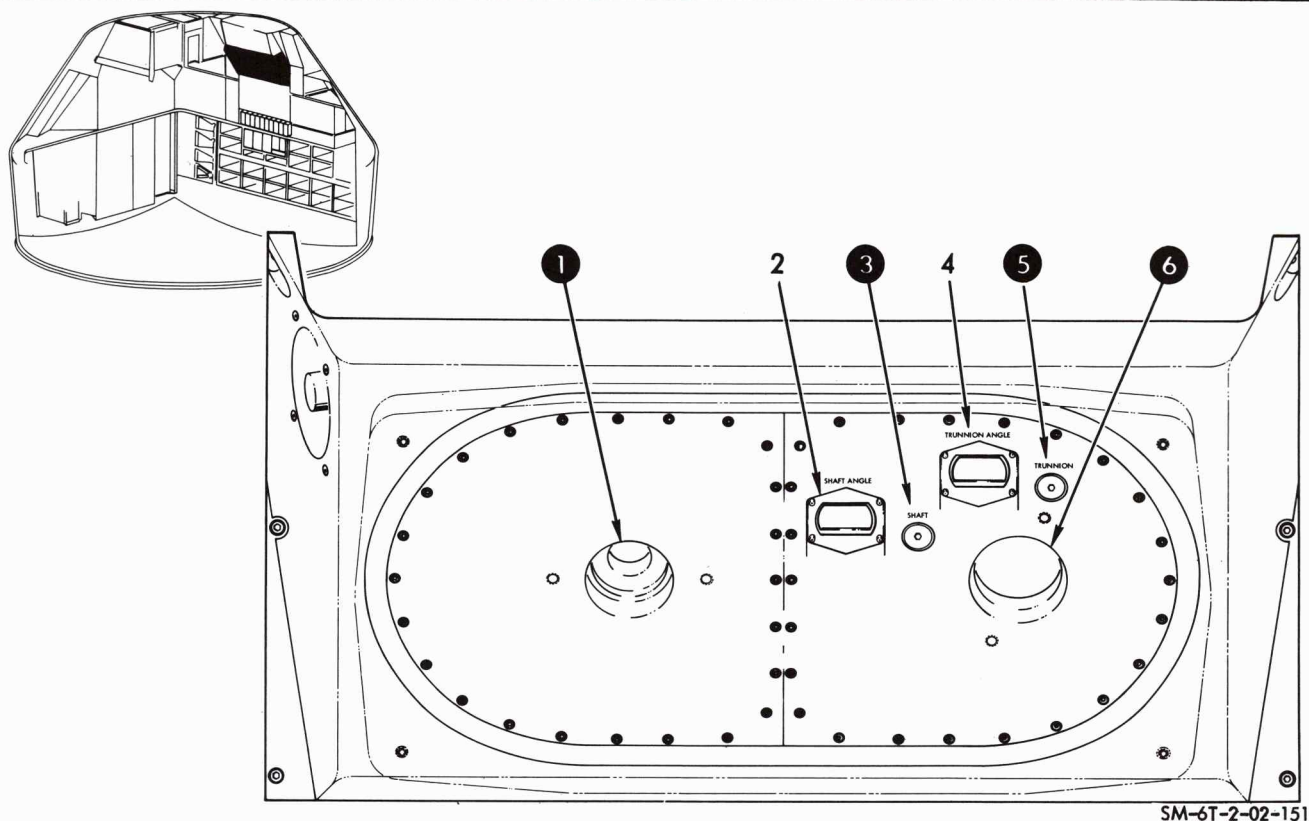
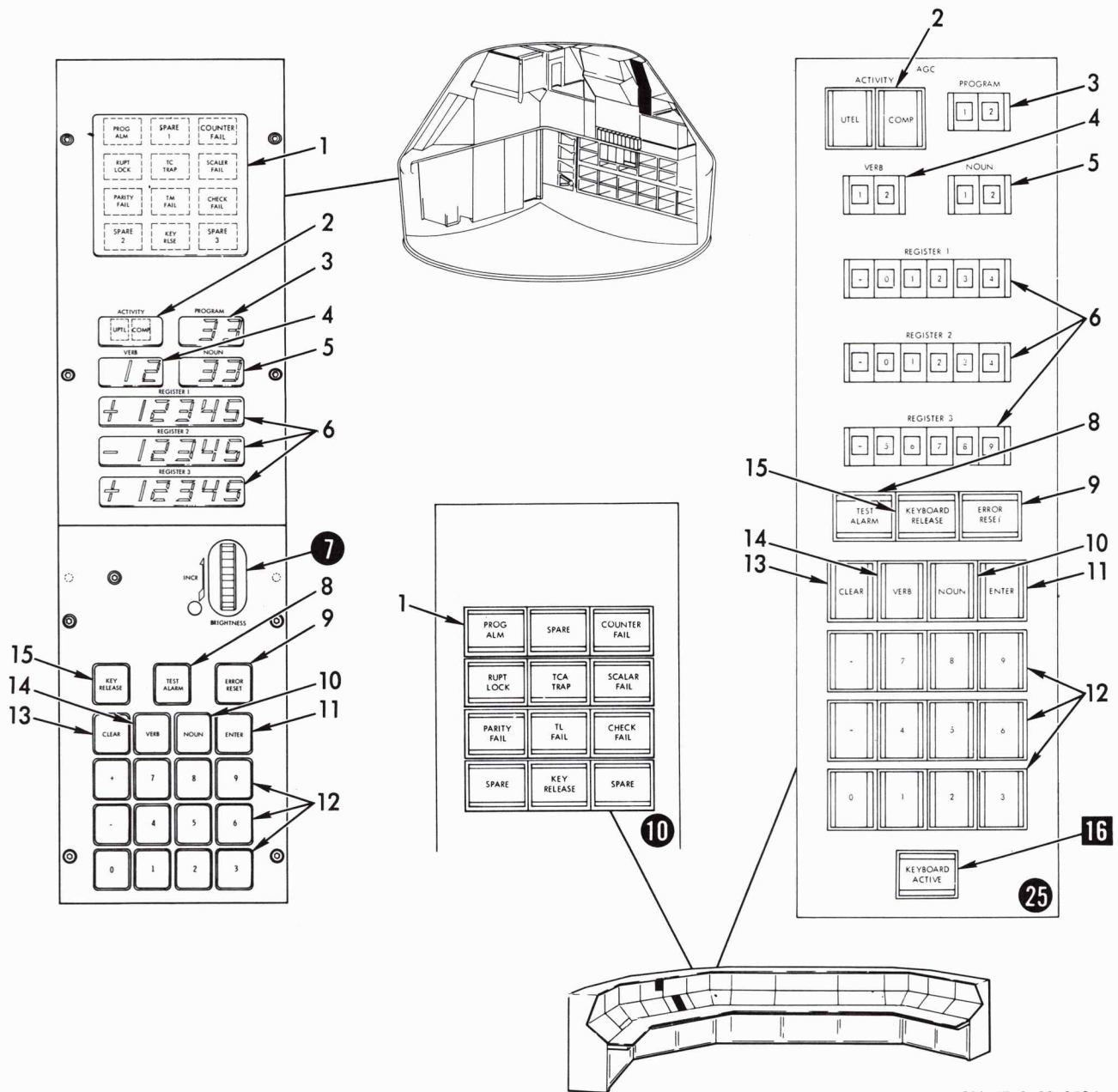


Figure 1-53. Optics Panel

Table 1-48. Optics Panel - Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	SEXTANT	Sextant eyepiece fitting for observing position of target with respect to line-of-sight.		
2	SHAFT ANGLE display	Provides a mechanical readout of SCT shaft angle that is commanded by crew or computer.	Repeater display	Repeater displays for digital readouts are located on IOS Panel 12.
3	SHAFT control	Enables crew to manually position shaft angles.		
4	TRUNNION ANGLE display	Provides a mechanical readout of SCT trunnion angle that is commanded by crew or computer.	Repeater display	Repeater displays for digital readouts are located on IOS Panel 12.
5	TRUNNION control	Enables crew to manually position trunnion angles.		
6	SCANNING TELESCOPE	Fitting for SCT that is used to assist crew in obtaining proper target identification for sextant.		

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Figure 1-54. LEB AGC Display and Keyboard

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Table 1-49. Lower Equipment Bay Apollo Guidance Computer Display and Keyboard

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	Alarm condition lt	When on, indicates a specific alarm condition of computer.	Repeater lt	
	PROG ALM lt	TBD.	Repeater lt	
	COUNTER FAIL lt	Indicates an increment counter instruction has been in progress longer than 20 msec.	Repeater lt	
	RUPT LOCK lt	Indicates computer is locked up in an interrupt state.	Repeater lt	
	TC TRAP lt	Indicates computer is in a transfer control trap.	TCA TRAP repeater lt	
	SCALER FAIL lt	Indicates that oscillator has failed or 100 pps source is not active.	Repeater lt	
	PARITY FAIL lt	Indicates that a parity check has failed.	Repeater lt	
	TM FAIL lt	Indicates a failure in processing telemetry data.	Repeater lt	
	CHECK FAIL lt	Indicates that DSKY program encounters an improper operating condition.	Repeater lt	
	KEY RLSE	Indicates activation of KEY RELEASE pushbutton.	KEY RELEASE repeater lt	
2	ACTIVITY lt	When on, indicates activity computer is presently engaged in.	Repeater lt	In event of simulated electro luminescent lamp failure, IOS repeaters will continue to display commanded AGC characters
	UPTL lt	Indicates computer is receiving information from telemetry up-data link.	Repeater lt	
	COMP lt	Indicates the computer is engaged in test routine.	Repeater lt	
3	PROGRAM display	A two-digit display, indicating the number of the program presently in progress.	Repeater display	
4	VERB display	A two-digit display, indicating the characters of the verb code selected.	Repeater display	
5	NOUN display	A two-digit display, indicating the characters of the noun code selected.	Repeater display	
6	REGISTER 1 display	Displays selected source data or first component of multi-component data.	Repeater display	In event of simulated electro luminescent lamp failure, IOS repeaters will continue to display commanded AGC characters.

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Table 1-49. Lower Equipment Bay Apollo Guidance Computer Display and Keyboard (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
6 (Cont)	REGISTER 2 display	Displays selected source data or second component of multi-component data.	Repeater display	
	REGISTER 3 display	Displays selected source data or third component of multi-component data.	Repeater display	
7	BRIGHTNESS thumbwheel	Varies brightness of electro-luminescent data displays, register No. 1, register No. 2, and register No. 3,	Repeater indicator	Repeater indicator for this control is located on IOS Panel 24.
8	TEST ALARM sw - lt	When pressed, lights the alarm displays.	Repeater lt	In event that keyboard is failed or AGC is off, keyboard repeats will still be presented at IOS but KEYBOARD ACTIVE light will not be illuminated.
9	ERROR RESET sw - lt	When pressed, causes computer alarm display to go out.	Repeater sw - lt	
10	NOUN pushbutton	Prepare computer to accept noun code.	Repeater indicator	
11	ENTER pushbutton	Causes data or noun/verb command to be entered into computer.	Repeater indicator	
12	KEYBOARD + pushbutton	Provides capability of identifying data to be placed in computer as positive.	Repeater indicator	
	KEYBOARD -pushbutton	Provides capability of identifying data to be placed in computer as negative.	Repeater indicator	
	KEYBOARD 0 to 9, pushbutton	Place in computer binary equivalents of octal or decimal digits shown.	Repeater indicator	
13	CLEAR sw - lt	Allows operator to erase an erroneous number placed in during data loading.	Repeater indicator	
14	VERB sw - lt	Prepares computer to accept verb code.	Repeater indicator	
15	KEY RELEASE sw - lt	Releases registers No. 1, 2, and 3 from displaying keyboard data and allows display of program data.	KEYBOARD RELEASE repeater lt	In event that keyboard is failed or AGC is off, keyboard repeats will still be presented at IOS but KEYBOARD ACTIVE light will not be illuminated.
16	KEYBOARD ACTIVE lt (IOS only)	Indicates a keyboard entry is required, in progress, or impending.		Cues IO that keyboard entries are being made or a are expected.

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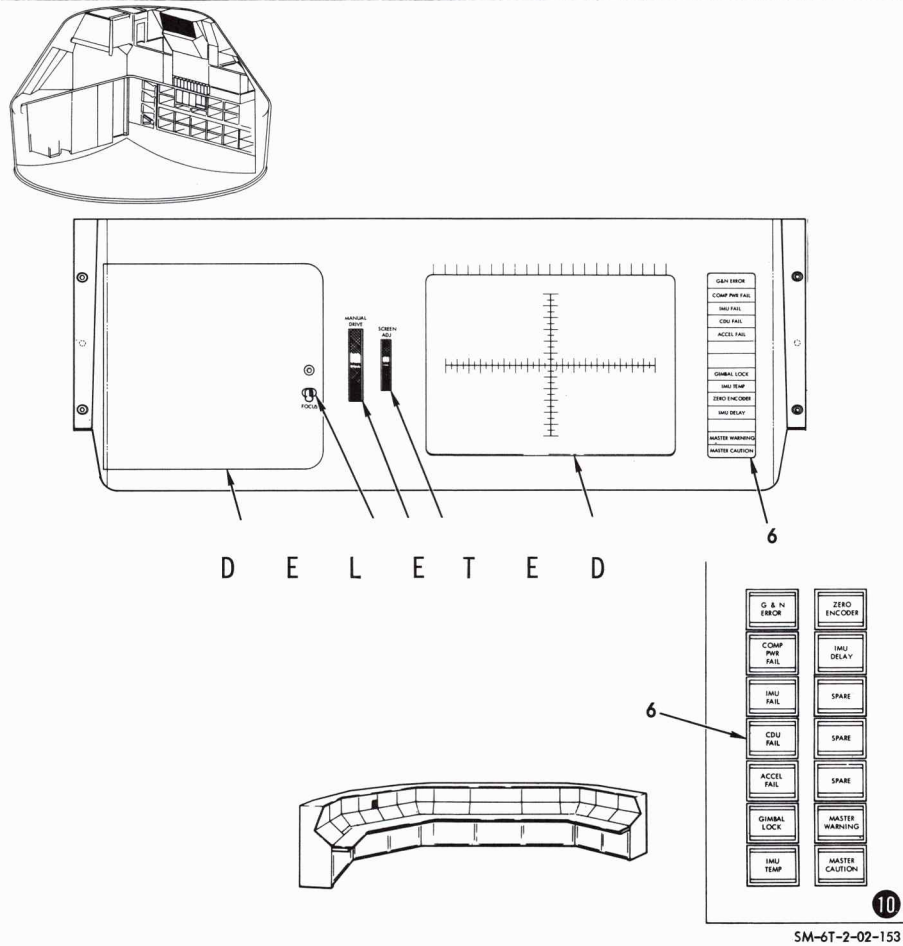


Figure 1-55. Map and Data Viewer

Table 1-50. Map and Data Viewer - Controls and Displays

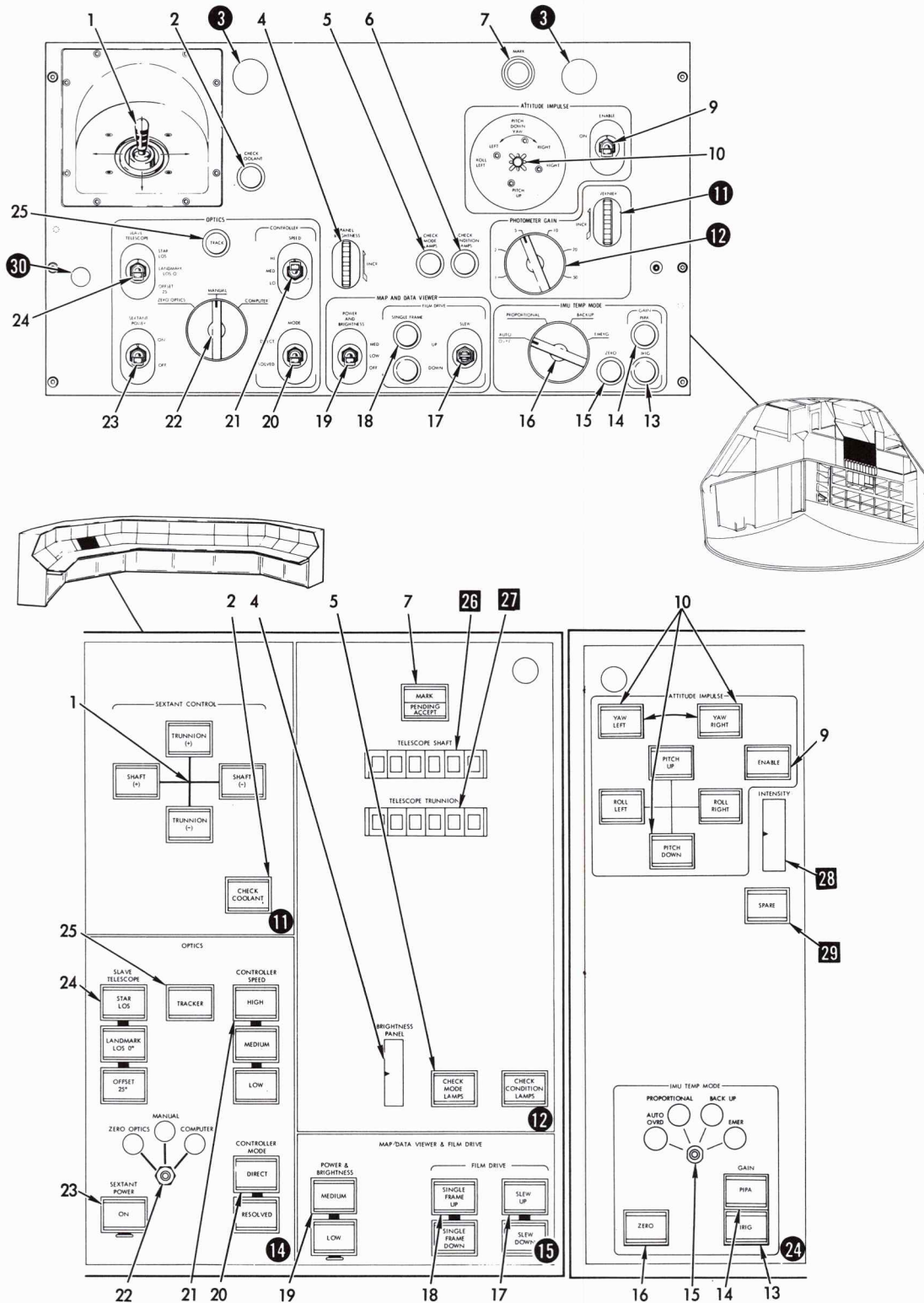
Key	Nomenclature	Function	Instructor Visibility	Remarks
1	Deleted			
2	Deleted			
3	Deleted			
4	Deleted			

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Table 1-50. Map and Data Viewer - Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
5	Deleted			
6	G&N caution and warning lt	Enables status of G&N equipment to be monitored.		
	G&N ERROR lt	Indicates an IMU, CDU and/or AGC error.	Repeater lt	
	COMP PWR FAIL lt	Indicates a power failure in Apollo guidance computer.	Repeater lt	
	IMU FAIL lt	Indicates a failure in inertial measurement unit.	Repeater lt	
	CDU FAIL lt	Indicates a failure in one or more of coupling display units.	Repeater lt	
	ACCEL FAIL lt	Indicates a failure in one or more of X, Y, Z and pulsed input pendulous (PIP) accelerometers.	Repeater lt	
	(Blank)	TBD		
	(Blank)	TBD		
	GIMBAL LOCK lt	Indicates a potential gimbal lock condition in the IMU (middle gimbal angle is greater than +60° with respect to outer gimbal).	Repeater lt	
	IMU TEMP lt	Indicates that IMU temperature is out of tolerance.	Repeater lt	
	ZERO ENCODER lt	Indicates that CDU encoders are being zeroed; lamp is extinguished after all encoders have been zeroed.	Repeater lt	
	IMU DELAY lt	Indicates IMU gyro warmup time lamp goes out approximately 40 seconds after IMU turn-on.	Repeater lt	
	(Blank)	TBD		
	MASTER WARNING lt	Indicates that one or more S/C caution and warning indicators are on.	Repeater lt	
	MASTER CAUTION lt	Indicates that one or more caution and/or warning indicators for G&N system are on.	Repeater lt	

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Figure 1-56. Optics Control Panel

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Table 1-51. Optics Control Panel - Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
1	Optics hand controller	Provides electrical commands from crew to optics shaft and trunnion axes.	Repeater lt	
2	CHECK COOLANT sw	When depressed, applies power to floodlamps behind lower panel. This enables crew to physically monitor condition of IMU coolant supply system.	Repeater lt	
3	Check coolant windows (two) (C/M only)	Permit observation of IMU coolant supply system quick-disconnect hoses for purpose of detecting leaks.	(C/M only)	
4	PANEL BRIGHTNESS thumbwheel	Provides adjustment of light level of all integrally lighted G&N system controls and displays.	Repeater lt	
5	CHECK MODE LAMPS sw	When depressed, applies power to all mode lt on IMU control panel (LEB-1)	Repeater lt	
6	CHECK CONDITION LAMPS sw	When depressed, applies power to all check condition (caution and warning) lt on map and data viewer panel (LEB-3).	Repeater lt	
7	MARK sw	When depressed, supplies an interrupt signal to AGC which commands it to read optics angle, time; and if IMU is operating, IMU gimbal angles.	This lt is split at IOS. The MARK lt provides indication of stated function. The COMPUTER TIMER lights when computer has registered mark information.	Lower portion of indicator informs IO that although MARK has been accomplished, data has not been entered into AGC.
8	(Deleted)			
9	ENABLE sw	Activates attitude impulse controller.	Repeater lt	
	ON position	Supplies a signal to G&N and SCS systems which disables active S/C attitude control mode, allowing S/C to drift freely, and enables attitude impulse controller.		

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Table 1-51. Optics Control Panel - Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
9 (Cont)	OFF position	Disables attitude impulse controller		
10	ATTITUDE IMPULSE controller	A stick controller used to apply small impulses to spacecraft by means of service module reaction jets.	Repeater 1t	
11	VERNIER thumbwheel (C/M only)	Not operable.		Photometer components will be dummied units inserted for appearance only.
12	PHOTOMETER GAIN sw (C/M only)	Not operable.		Same as 11.
	IMU TEMP MODE — GAIN			
13	IRIG sw	When depressed, replaces IRIG thermistor with a fixed resistance equal to resistance of thermistor operating at 5 F below normal temperature. This will simulate temperature errors and check out temperature alarm circuit.	Repeater 1t	
14	PIPA sw	Same as function as IRIG, except that resistance is equal to thermistor operating at 5 F above normal temperature.	Repeater 1t	
	IMU TEMP MODE			
15	IMU TEMP MODE rotary sw	Allows crew to select any one of four modes of IMU temperature control.	Repeater 1t	
	PROPORTIONAL position	This is normal mode with IRIG and PIPA temperature controlled to 135.0 ± 0.5 F.		
	BACKUP position	In this mode, IRIG and PIPA control circuit thermistors are replaced by temperature indicating circuit thermistors and a backup control circuit amplifier is utilized. The average IRIG and PIPA temperature is controlled to 135 ± 1 F in this mode.		
	AUTO OVRD position	This mode permits the crew to use the IFT METER to monitor the temperature error signal from the IRIG and PIPA.		

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Table 1-51. Optics Control Panel - Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
15 (Cont)	EMER position	In this mode IRIGs and PIPAs are maintained at 135 ± 5 F through utilization of emergency control circuitry.		
16	ZERO sw	Used to calibrate 25 IRIG and 16 PIPA temperature monitoring devices. When depressed, replaces IRIG and PIPA thermistors with fixed resistors in temperature control bridge. This permits measurement of noise level within circuit.	Repeater 1t	
17	MAP AND DATA VIEWER — FILM DRIVE SLEW sw	Slews map and data viewer film.	Repeater 1t	
	UP position	Slews film forward.		
	DOWN position	Slews film backward.		
18	SINGLE FRAME sw			
	UP position	Slews map and data viewer film one frame upward.	Repeater 1t	
	DOWN position	Slews map and data viewer film one frame downward.		
19	MAP AND DATA VIEWER POWER AND BRIGHTNESS sw		Repeater 1t	
	MED	Applies power to map and data viewer drive electronics and projection bulb.		
	LOW position	Applies power to map and data viewer drive electronics and projection bulb.		
	OFF position	Power is removed from map and data viewer display.		
20	OPTICS — CONTROLLER-MODE sw		Repeater 1t	
	DIRECT position	Applies control stick drive rates directly to integrating lopps to position CDU.		

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Table 1-51. Optics Control Panel - Controls and Displays (Cont)

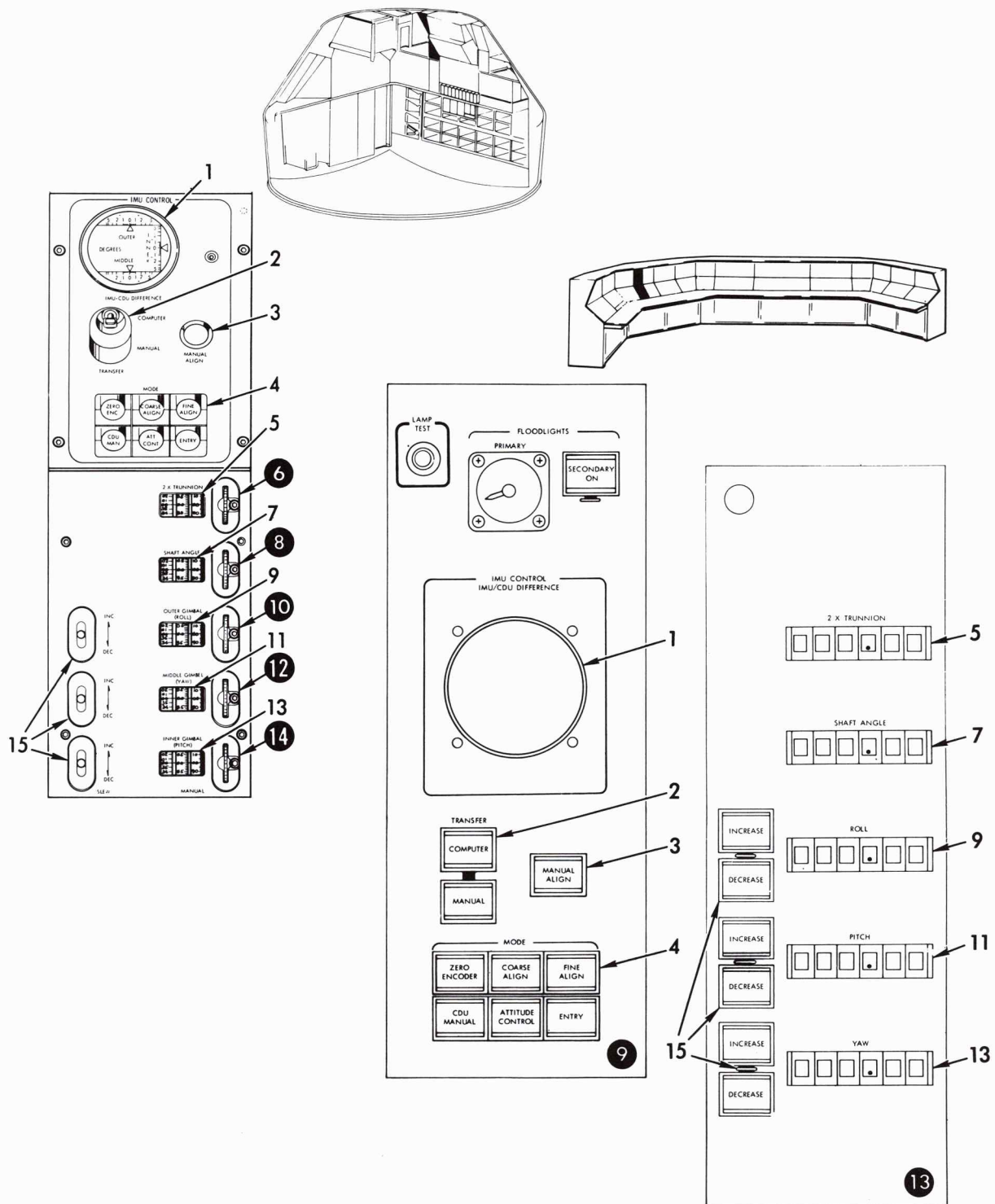
Key	Nomenclature	Function	Instructor Visibility	Remarks
20 (cont)	RESOLVED position	Drive commands are routed through resolvers to CDU drives modifying signal as function of shaft and trunnion angle.	Repeater lt	
21	OPTICS — CONTROLLER-SPEED sw	Provides for attenuation of shaft and trunnion slew commands from optics hand controller.		
		<div>Direct Mode Resolved Mode</div> <div>Maximum Maximum</div> <div>Drive Drive</div> <div>Rates Rates</div>		
	HI position	8.56°/sec 17.1°/sec	Repeater lt	
	MED position	1.0°/sec 1.0°/sec	Repeater lt	
	LOW position	0.1°/sec 0.1°/sec	Repeater lt	
22	OPTICS mode, rotary sw	Selects desired optics mode of operation.	Repeater sw	
	ZERO OPTICS position	Reference signal is switched into integrating loop which drives CDUs to a zero position.		
	MANUAL position	Allows crew to position optics by means of optics hand controller.		
	COMPUTER position	Optics are automatically positioned by AGC; panel mounted controls are disconnected from optics.		
23	OPTICS — SEXTANT POWER sw	In ON position, provides power for operation of sextant.	Repeater lt	
24	OPTICS — SLAVE TELESCOPE sw		Repeater sw - lt	
	STAR LOS position	SCT and SXT are slaved to each other.		
	LANDMARK LOS 0° position	Drives telescope trunnion repeater to zero independently of trunnion CDU.		
	OFFSET 25° position	Telescope trunnion is driven to a 25° offset from shaft axis.		

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Table 1-51. Optics Control Panel - Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
25	OPTICS — TRACK sw	Switches trunnion and shaft slew command from optics hand controller to photo-meter circuitry. (Not used at present time).	Repeater lt	
26	SHAFT display (IOS only)	Provides repeater indication of SCT shaft angle.	SHAFT display (IOS only).	SCM displays which these repeat are located on LEB optics panel.
27	TRUNNION display (IOS only)	Provides repeater indication of SCT trunnion angle.	TRUNNION display (IOS only).	SCM displays which these repeat are located on LEB optics panel.
28	INTENSITY indicator (IOS only)	Provides repeater indication of AGC DSKY panel intensity in LEB.	INTENSITY lt (IOS only)	The SCM control which this display repeats is located on the LEB AGC DSKY.
29	SPARE			
30	SXT/SCT window access	Provides access to drive mechanism which opens optics window with the use of universal tool.		Manual tool is required within the SCM to open the optics window.

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Figure 1-57. IMU/CDU Control Panel

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Table 1-52. IMU/CDU Control Panel - Controls and Displays

Key	Nomenclature	Function	Instructor Visibility	Remarks
	IMU CONTROL			
1	IMU-CDU DIFFERENCE indicator	Displays difference in degrees between actual IMU gimbal angles and CDU shaft angles.	Repeater indicator	
2	TRANSFER sw	Selects mode by which CDUs may be operated.		
	MANUAL position	Ground side of CDU relays are connected to manual CDU mode switches.	Repeater lt	
	COMPUTER position	Ground side of CDU relays are connected to computer.	Repeater lt	
3	MANUAL ALIGN sw - lt	Allows crew to manually drive IMU gimbal to any desired position.	Repeater lt	
4	MODE sw - lt			
	ZERO ENC sw - lt	CDU shafts and CDU registers in computer are set to zero.	Zero encoder repeater lt	
	COARSE ALIGN sw - lt	Positions stable member (IMU) to an approximate orientation as defined by CDU angles.	Repeater lt	
	FINE ALIGN sw - lt	Causes CDUs to follow and repeat IMU gimbal angles. CDU incremental encoders transmit IMU gimbal angles and angular changes to computer.	Repeater lt	
	CDU MAN sw - lt	Provides a backup capability for manual alignment of IMU without use of AGC.	CDU manual repeater lt	
	ATT CONT sw - lt	Difference between IMU gimbals and CDUs 1X resolver angles is fed to SCS, which orients the spacecraft to desired attitude as given by the spacecraft to desired attitude as given by CDU angles.	Attitude control repeater lt	
	ENTRY sw - lt	Steering signals are transmitted from G&N to SCS for control of spacecraft during entry into the earth's atmosphere.	Repeater lt	
5	2X TRUNNION angle readout display	Provides visual representation of IMU gimbal angles and optic angles that are commanded by computer or by crew.	Repeater display	

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Table 1-52. IMU/CDU Control Panel - Controls and Displays (Cont)

Key	Nomenclature	Function	Instructor Visibility	Remarks
6	MANUAL thumbwheel (C/M only)	Provides mechanical drive to CDU motor shafts for fine positioning of resolvers within CDU.	(C/M only)	Manual controls are not repeated at IOS. Instructor is aware of trainee operation of these controls by variations occurring in digital readouts.
7	SHAFT ANGLE angle readout display	Provides visual representation IMU gimbal angles and optic angles that are commanded by computer or by crew.	Repeater display	
8	MANUAL thumbwheel (C/M only)	Provides mechanical drive to CDU motor shafts for fine positioning of resolvers within CDU.	(C/M only)	Manual controls are not repeated at IOS. Instructor is aware of trainee operation of these controls by variations occurring in digital readouts.
9	OUTER GIMBAL (ROLL) angle readout display	Provides visual representation of IMU gimbal angles and optic angles that are commanded by computer or by crew.	ROLL repeater display	
10	MANUAL thumbwheel (C/M only)	Provides mechanical drive to CDU motor shafts for fine positioning of resolvers within CDU.	(C/M only)	Manual controls are not repeated at IOS. Instructor is aware of trainee operation of these controls by variations occurring in digital readouts.
11	MIDDLE GIMBAL (YAW) angle readout display	Provides visual representation of IMU gimbal angles and optic angles that are commanded by computer or by crew.	PITCH repeater display	
12	MANUAL thumbwheel (C/M only)	Provides mechanical drive to CDU motor shafts for fine positioning of resolvers within CDU.	(C/M only)	Manual controls are not repeated at IOS. Instructor is aware of trainee operation of these controls by variations occurring in digital readouts.
13	INNER GIMBAL (PITCH) angle readout display	Provides visual representation of IMU gimbal angles and optic angles that are commanded by computer or by crew.	YAW repeater display	
14	MANUAL thumbwheel (C/M only)	Provides mechanical drive to CDU motor shafts for fine positioning of resolvers within CDU.	(C/M only)	Manual controls are not repeated at IOS. Instructor is aware of trainee operation of these controls by variations occurring in digital readouts.
15	SLEW sw	Supplies proper voltage to CDU servo amplifiers to drive motors to desired angles on readouts.	INCREASE-DECREASE repeater lt	

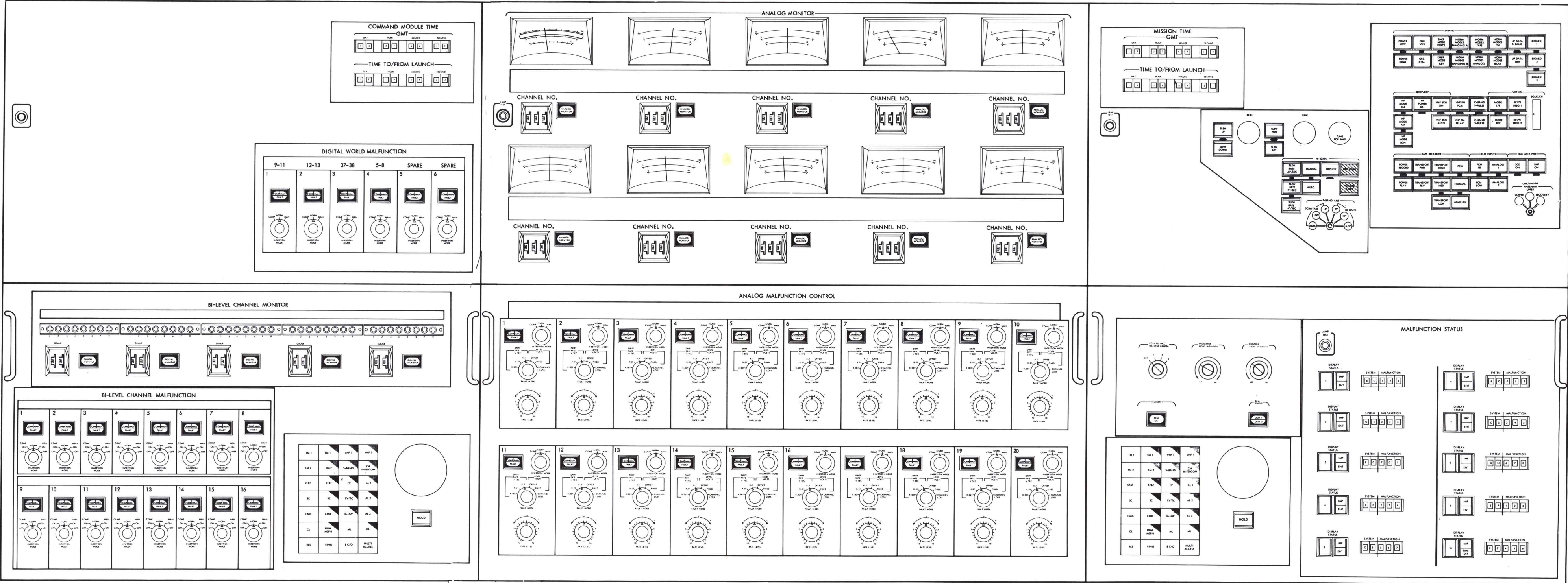
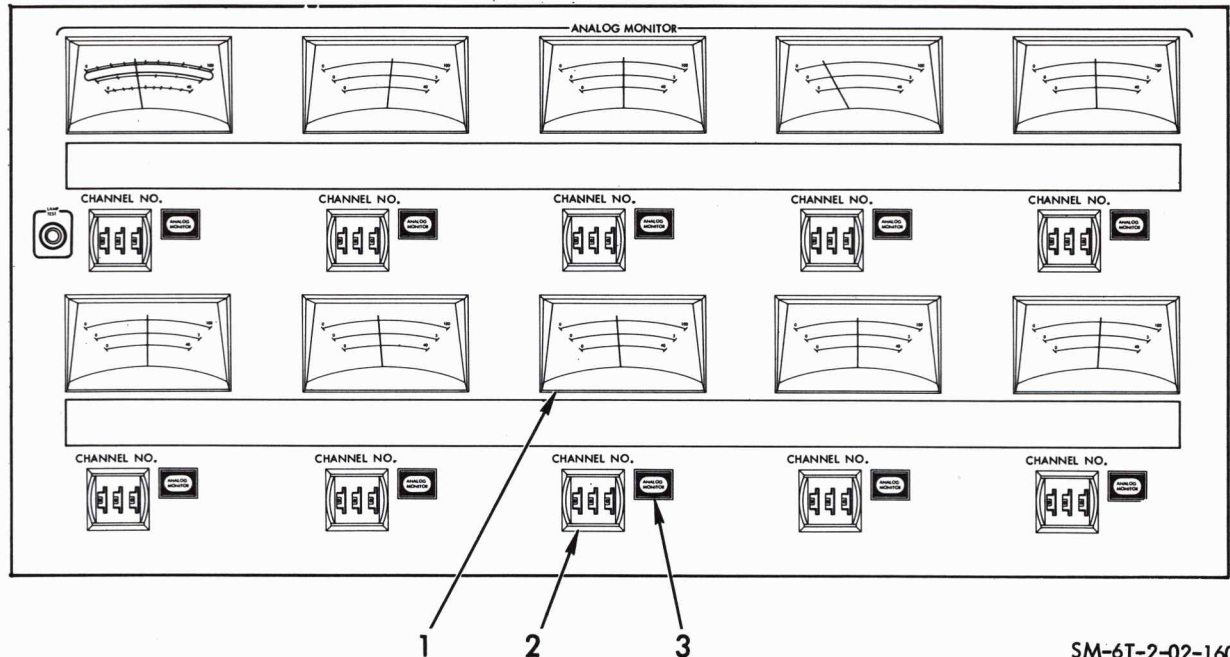
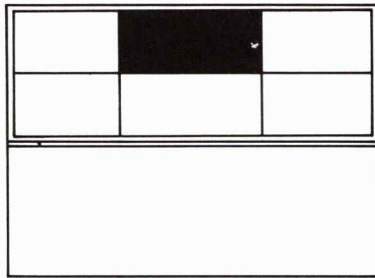


Figure 1-58. Telemetry Console

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Figure 1-59. Analog Monitor Control Panel

Table 1-53. Analog Monitor Control Panel - Controls and Displays

Key	Nomenclature	Function	Remarks
1	MONITOR meter	Provides metered analog indications of selected channel.	10 panel-mounted volt meters scale reading 0 to 100% 0 to 5 volts 0 to 40 mv
2	DIGITAL CHANNEL sw	Selects one of 320 analog lines to be monitored by meter. Each sw selects one line of a group of ten lines. These are the hundreds, tens, and ones.	10 3-digit channel No. thumbwheels. Full capability is 384 analog channels
3	ACTUATOR sw-lt	Allows metering of channel selected by digital sw.	Analog monitor pushbutton

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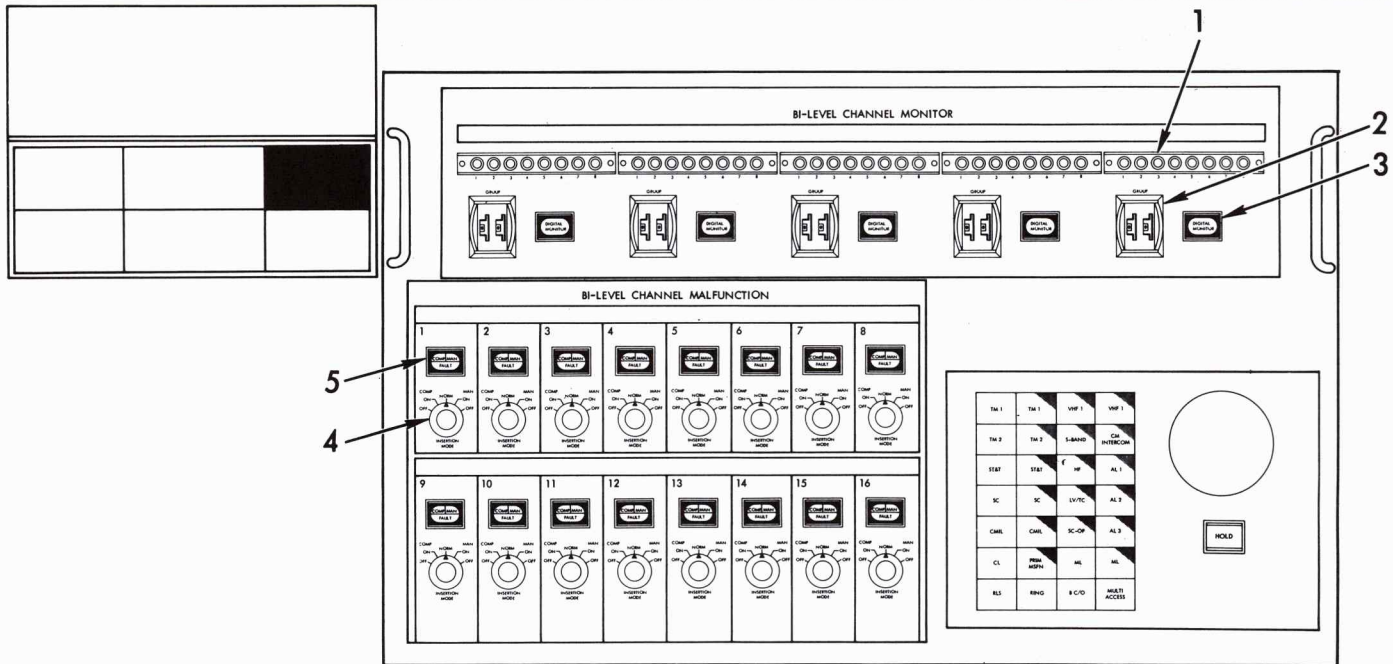


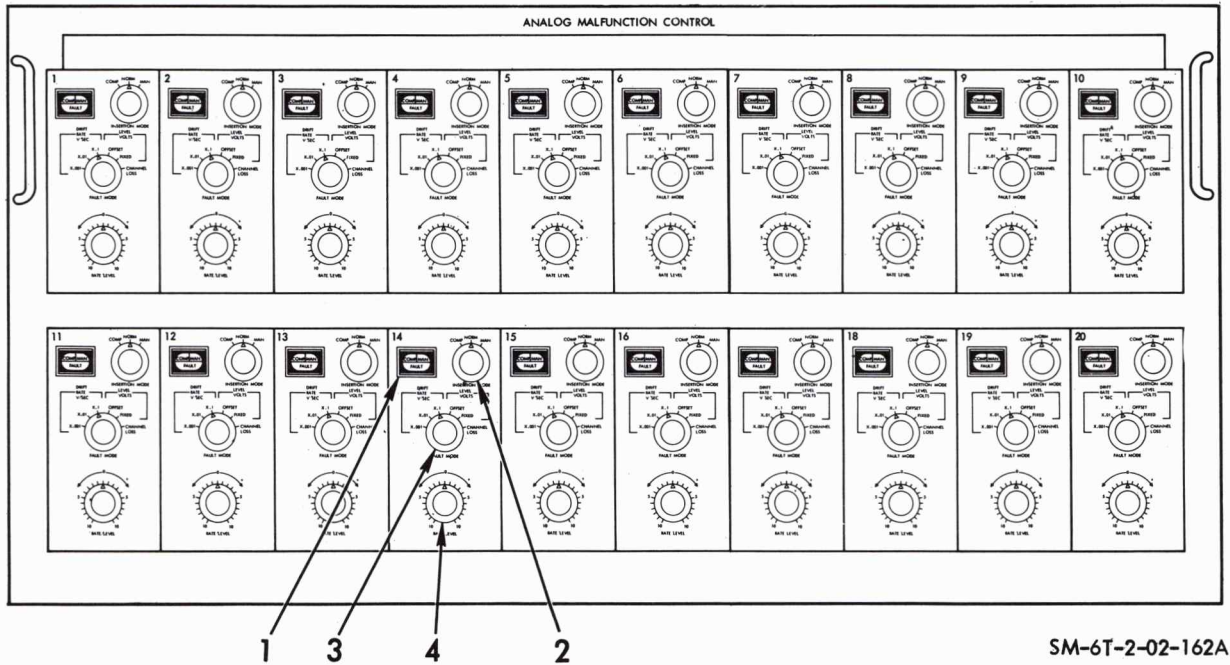
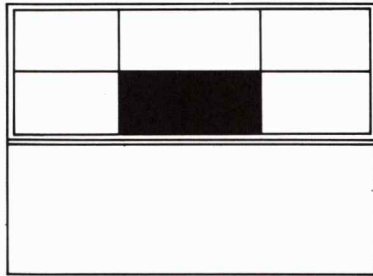
Figure 1-60. Digital Monitor Control Panel

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Table 1-54. Digital Monitor Control Panel - Controls and Displays

Key	Nomenclature	Function	Remarks
1	DIGITAL READOUT display (5 groups)	Displays selected 8-bit digital group readout.	Binary "1" is represented by lighted lamp
2	GROUP digi-switches (5)	These two digital sw for each of five groups select one of 39 input groups to be displayed on 8-bit readout.	
3	ACTUATOR sw - lt	Activates group of eight lines selected by digital sw of related readout.	
4	INSERTION MODE sw ON/OFF position	Enables fault of entire word to all "1's" (ON) or all "0's" (OFF).	
	NORM position	Provides continuity for data line and prevents fault insertion.	
	MAN position	Provides insertion of fault under manual control.	
	COMP position	Provides automatic fault insertion.	
5	COMP/MAN/FAULT sw - lt	Indicates that fault insertion is under COMP or MAN control. Indicates fault has been inserted.	

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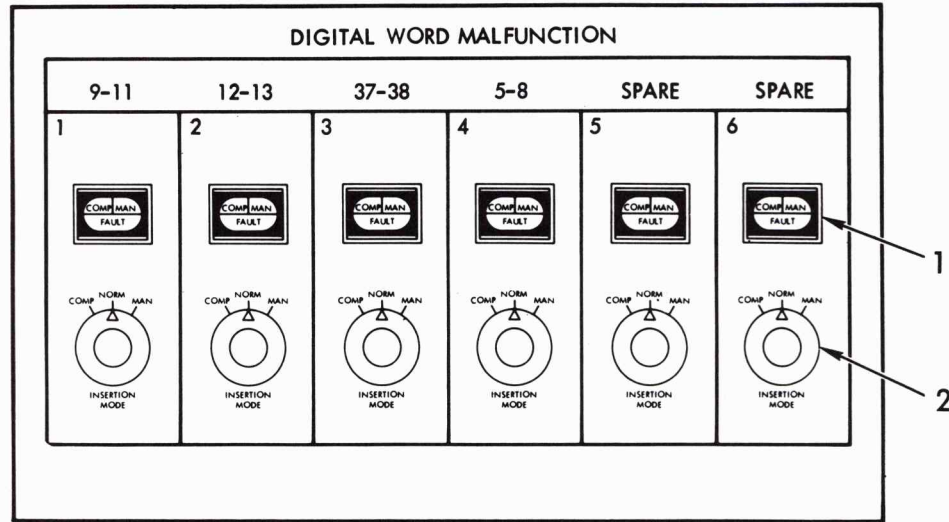
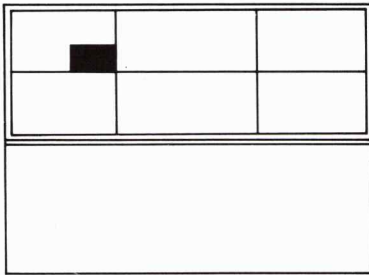
Figure 1-61. Analog Malfunction Control Panel

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Table 1-55. Analog Malfunction Control Panel - Controls and Displays

Key	Nomenclature	Function	Remarks
1	COMP/MAN/FAULT sw - lt	Provides an indication of the following: a. Whether computer or operator is controlling fault insertion b. Fault insertion. Provides switching action to insert fault manually.	
2	INSERTION MODE sw		
	NORM position	Provides series continuity for data line and prevents fault insertion.	
	COMP position	Provides computer insertion of faults.	
	MAN position	Provides manual insertion of faults.	
3	FAULT MODE sw		
	DRIFT RATE positions	Allows for a preset variable offset of d-c reference of data signal.	
	LEVEL VOLT positions		
	OFFSET position	Provides for a preset fixed offset of d-c reference of data signal.	
	FIXED position	Provides for a preset fixed level to replace data signal.	
	CHANNEL LOSS position	Provides for opening data line.	
4	RATE/LEVEL sw 0 - ± 10	Provides variation of rate or level selected by FAULT MODE sw.	

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Figure 1-62. Digital Word Malfunction Control Panel

Table 1-56. Digital Word Malfunction Control Panel - Controls and Displays

Key	Nomenclature	Function	Remarks
1	COMP/MAN/FAULT sw - lt	Indicates whether fault insertion is under computer or manual control. Indicates fault has been inserted. Provides switching action for manual insertion of faults.	
2	INSERTION MODE sw	Allows selection of either computer or manual fault insertion control.	
	COMP position	Enables computer control of fault insertion.	
	NORM position	Allows normal operation of PCM.	
	MAN position	Enables manual control of fault insertion.	

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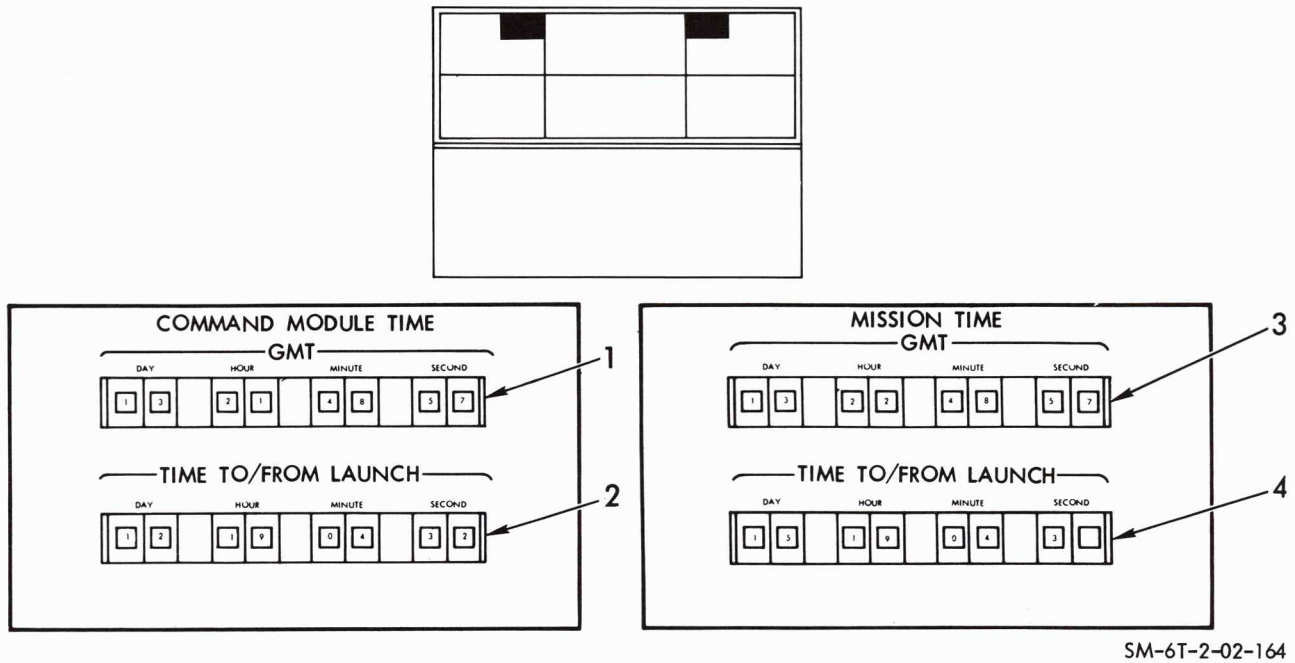
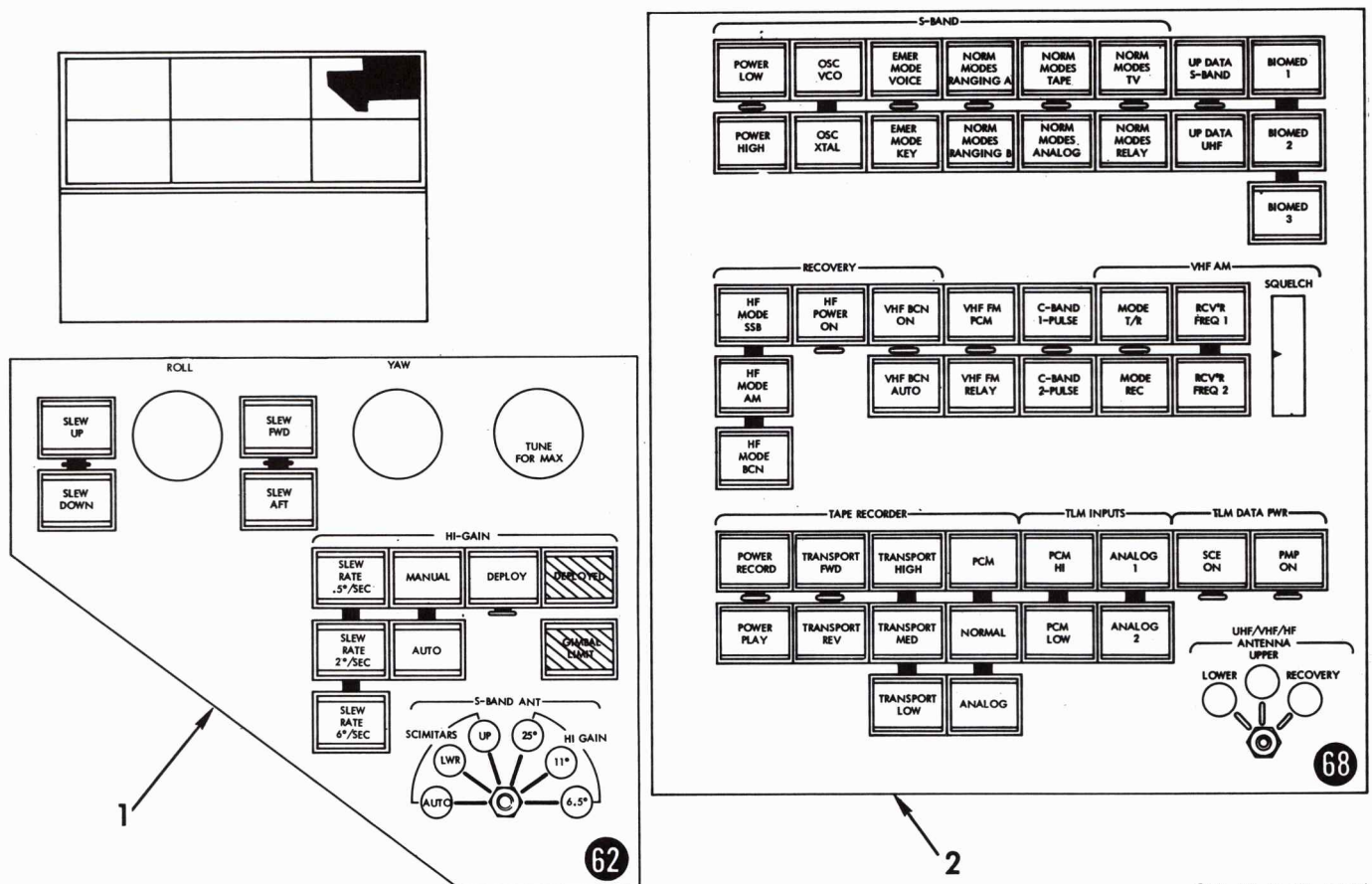


Figure 1-63. Time Display Panels

Table 1-57. Time Display Panels - Controls and Displays

Key	Nomenclature	Function	Remarks
	COMMAND MODULE TIME display	Repeater of TIME display in SCM and does include any fault effects introduced through faulting media.	
1	GMT timer display	Digital display of GMT signal encoded in PCM data and including word or bit failure introduced at T/M console.	
2	TIME TO/FROM LAUNCH timer display	Digital display of time to or from launch.	
	MISSION TIME display	These timers show simulated mission time (GMT and TIME TO/FROM LAUNCH) and will not include fault to on-board clocks.	
3	GMT timer display	Digital display of GMT signal encoded in PCM data.	
4	TIME TO/FROM LAUNCH timer display	Digital display of time to or from launch.	

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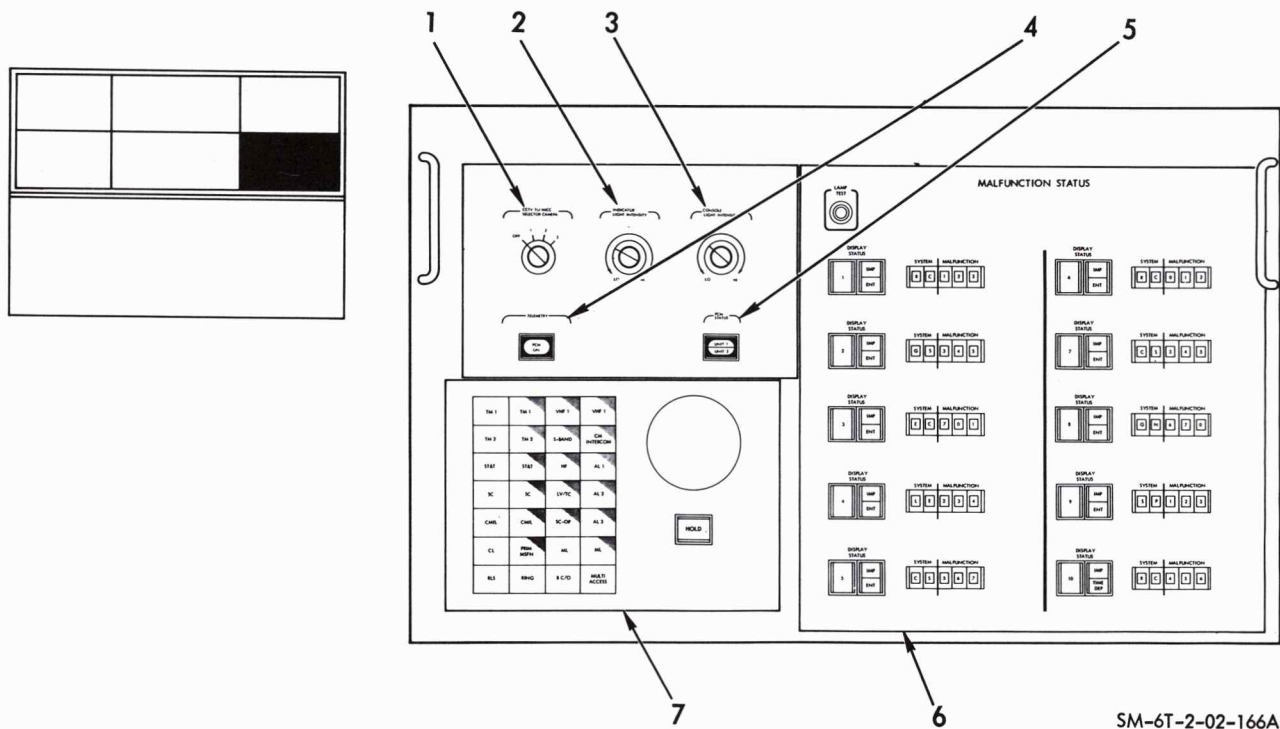
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Figure 1-64. Communications Control Panels

Table 1-58. Communications Control Panels - Controls and Displays

Key	Nomenclature	Function	Remarks
1	Antenna Control Panel	Repeater of IOS antenna control panel.	
2	Communications Panel	Repeater of IOS communications subpanel.	

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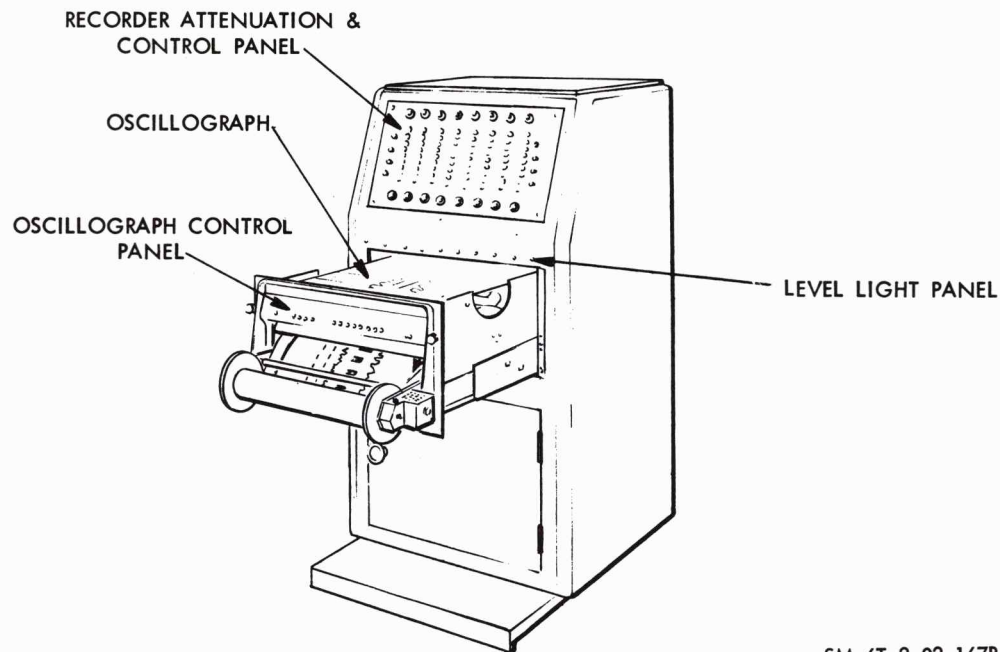
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Figure 1-65. Telemetry Status Panel

Table 1-59. Telemetry Status - Controls and Displays

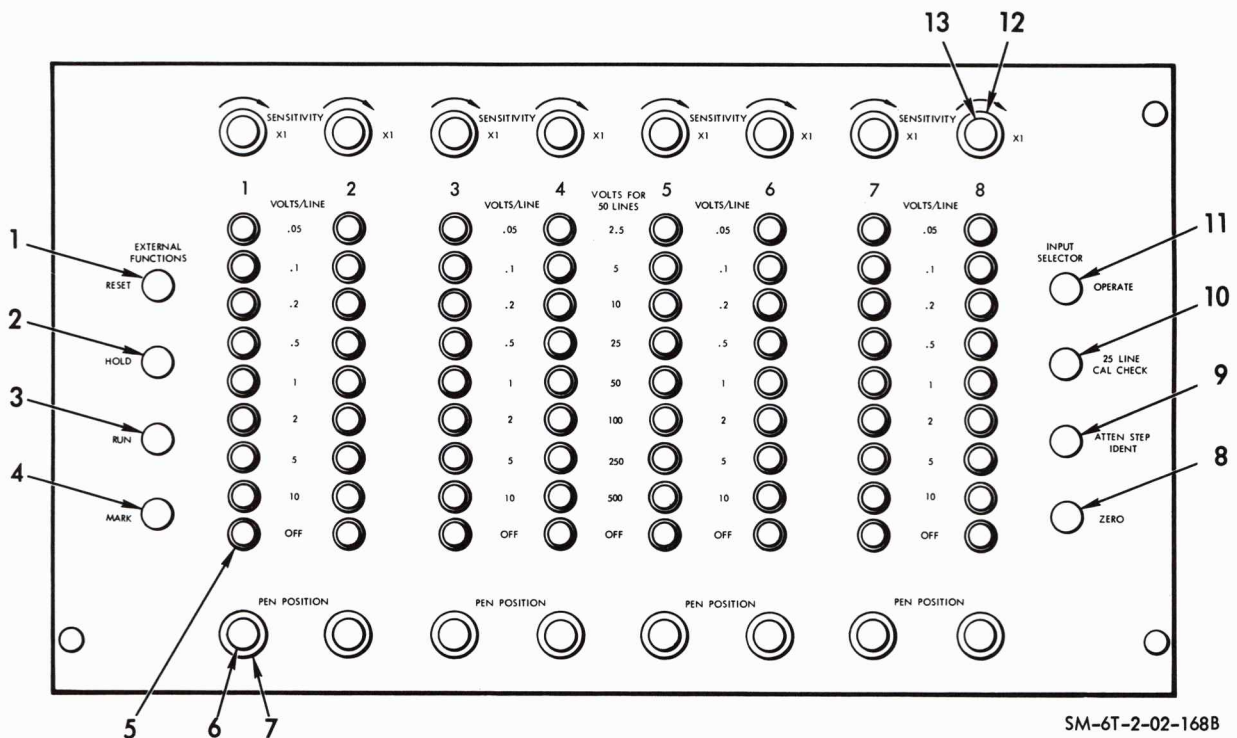
Key	Nomenclature	Function	Remarks
1	CCTV to IMCC CAMERA SELECTOR sw	Position of this sw determines which TV camera picture is presented to IMCC.	
2	INDICATOR LIGHT INTENSITY control	Allows variation of T/M indicator lighting intensity.	
3	CONSOLE LIGHT INTENSITY control	Allows variation of T/M console overhead lighting intensity.	
4	TELEMETRY sw - lt	Enables activation of PCM unit.	
5	PCM STATUS sw - lt	Provides GO NO-GO status indication of actual PCM encoder and enables resetting of malfunctioned unit.	
6	MIU DISPLAY panel	Panel is a repeater panel of IOS MIU; and is under IOS operator control.	
7	CONSOLE COMMUNICATIONS panel	Function of this panel is described under Console Communications System (CCS)	

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Figure 1-66. X-T Recorder



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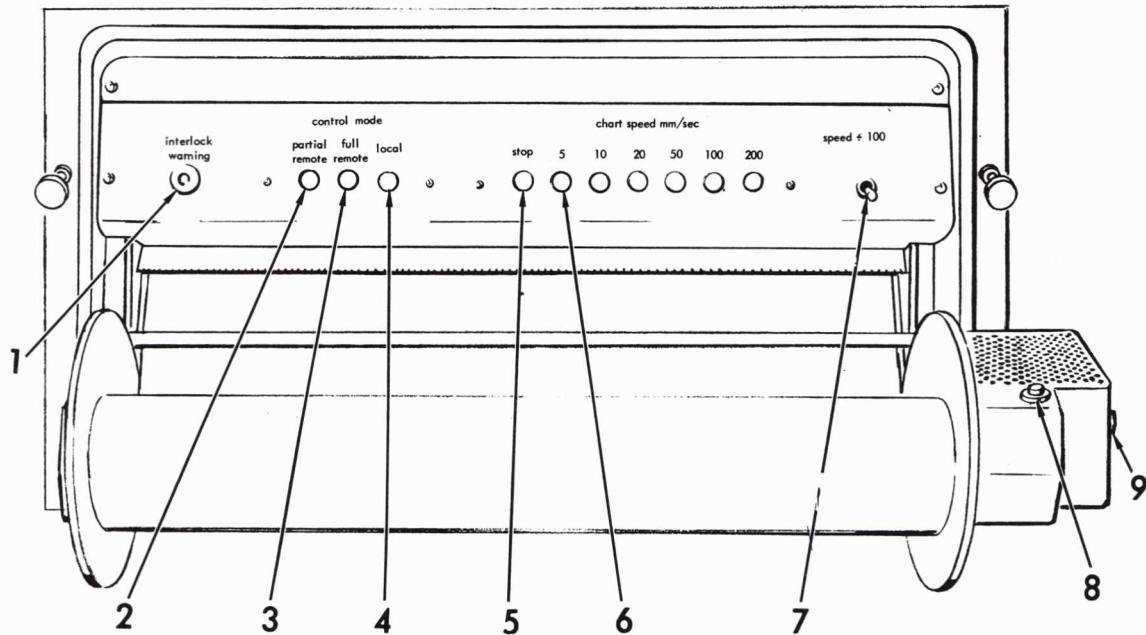
Figure 1-67. Attenuator Control Panel

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Table 1-60. Attenuator Control Panel - Controls and Displays

Key	Nomenclature	Function	Remarks
	EXTERNAL FUNCTIONS		
1	RESET pushbutton	Resets pens to initial conditions.	
2	HOLD pushbutton	Enables computer hold of operation from recorder.	
3	RUN pushbutton	Enables control of computer run mode of recorder operation.	
4	MARK pushbutton	Operates left-hand event marker and deflects its pen toward center of chart.	
5	Attenuator pushbuttons 64	Enables selection of volts per chart line for each channel.	
6	PEN POSITION controls (8)	Permits each pen to be positioned anywhere within channel and use this position as a zero base.	
7	PEN POSITION locking knob	Locks pen in selected position to prevent inadvertent movement.	
8	INPUT SELECT ZERO pushbutton	Causes pens of all channels to return to selected zero positions.	
9	ATTEN STEP IDENT pushbutton	Causes all active pens to deflect and record attenuator settings and pen polarity sw settings.	
10	25 LINE CAL CHECK pushbutton	Used to check or calibrate drive amplifier system. Supplies a standard calibration input to all channels.	
11	OPERATE pushbutton	Enables normal operation of system.	
12	SENSITIVITY control	Allows intermediate sensitivities to be selected between fixed pushbutton values. Controls must be fully CW to obtain pushbutton attenuation value.	
13	Locking knob	Prevents inadvertant movement of sensitivity control.	

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Figure 1-68. Oscillograph Control Panel

Table 1-61. Oscillograph Control Panel - Controls and Displays

Key	Nomenclature	Function	Remarks
1	INTERLOCK WARNING lt	Indicates one or both of interlock sw are open.	
	CONTROL MODE		
2	PARTIAL REMOTE pushbutton	Transfers chart drive on-off control to a remote location. Does not transfer speed control.	
3	FULL REMOTE pushbutton	Chart speed and on-off control is transferred to a remote location.	
4	LOCAL pushbutton	Full control of unit is enabled at control panel.	
	CHART SPEED MM/SEC		
5	STOP pushbutton	Stops chart drive and disables power to pens.	
6	CHART SPEED pushbuttons	Enables chart drive speed relative to pushbutton pressed. Releases STOP pushbutton.	
7	SPEED ÷ 100 sw	Divides selected chart drive speeds by 100 when enabled.	

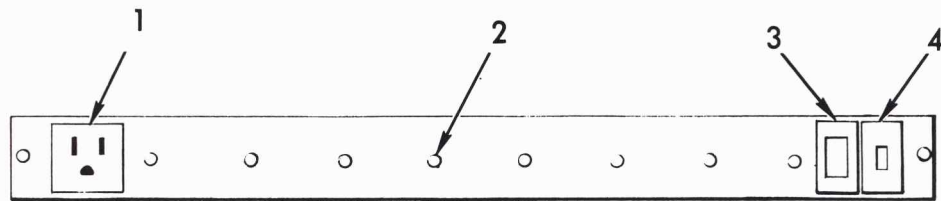
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Table 1-61. Oscillograph Control Panel - Controls and Displays (Cont)

Key	Nomenclature	Function	Remarks
8	PAPER TAKE UP pushbutton	When depressed, takes up slack in paper and actuates paper take up reel drive.	
9	TAKE UP SPEED control	Provides three speed control of paper drive.	

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Figure 1-69. Light Level Panel

Table 1-62. Light Level Panel - Controls and Displays

Key	Nomenclature	Function	Remarks
1	Convenience outlet	Supplies 115-volt, 60-cycle power for use with any electrical device. Does not turn off with power sw.	
2	Amplifier level lt	Indicates by lamp intensity output magnitude of related amplifier.	
3	Main power lt	Light goes on when power is on to unit.	
4	Main power sw	Applies power to entire unit.	

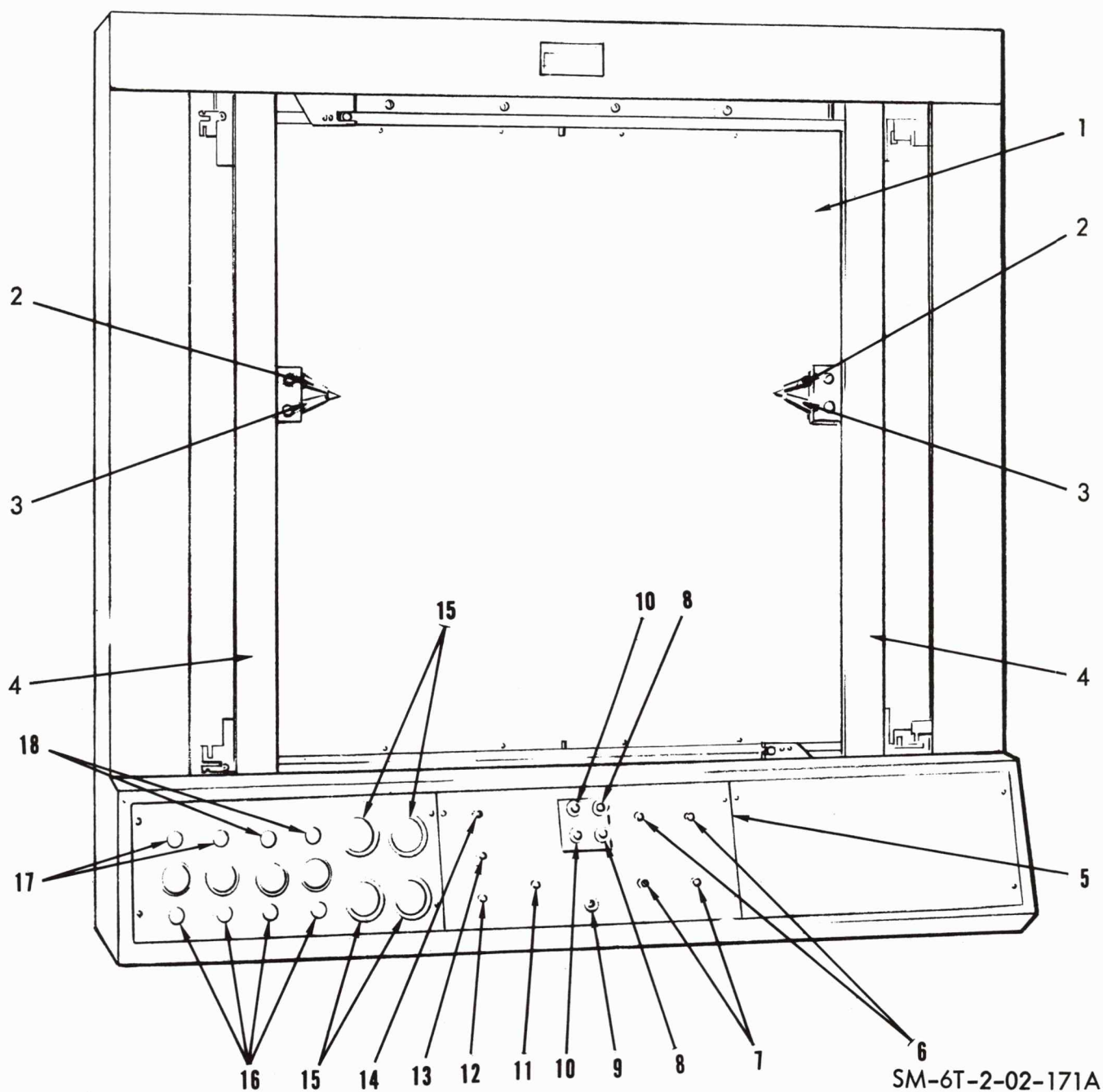


Figure 1-70. X-Y Variplotter (30 x 30)

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Table 1-63. X-Y Variplotter (30 X 30) - Controls and Displays

Key	Nomenclature	Function	Remarks
1	PLOTTING SURFACE	Plastic surface with grooves connected to a vacuum pump, providing a plotting surface.	
2	TIMING PENS	Solenoid controlled, allowing recording of timing pulses.	
3	WRITING PENS	Allows plotting (inked lines) of one variable voltage as a function of a second variable voltage (move vertical Y).	
4	ARMS	Allows plotting of one variable voltage as a function of a second variable voltage (move horizontal X).	
5	CONTROL PANEL	Power control; see figure.	
6	PEN 1 and PEN 2 UP DOWN/REMOTE sw		
	UP position	Lift coils de-energized to raise pens from plotting surface.	
	DOWN position	Lift coils energized to lower pens to plotting surface.	
7	PEN OPERATE-STANDBY — REMOTE sw	Controls input voltages applied to arm and pen servos.	
	STANDBY position	Drives pens to control panel end of arms and drives arms to opposite sides of plotting surface.	
	OPERATE position	Normal data voltages are applied to servos.	
	REMOTE position	Switches standby/operated control lines to a remote control tie in	
8	115V, 60 CPS FUSES	Protection of 115-volt 60-cps power source; glows if fuse open.	
9	POWER ON lt	Indicates power is applied to recorder.	
10	115V, 400 CPS FUSES	Protection of 115-volt 400-cps power source; glows if fuse open.	
11	PEN INTERCHANGE sw	Controls interchange of data supplied to pen and arm servos.	

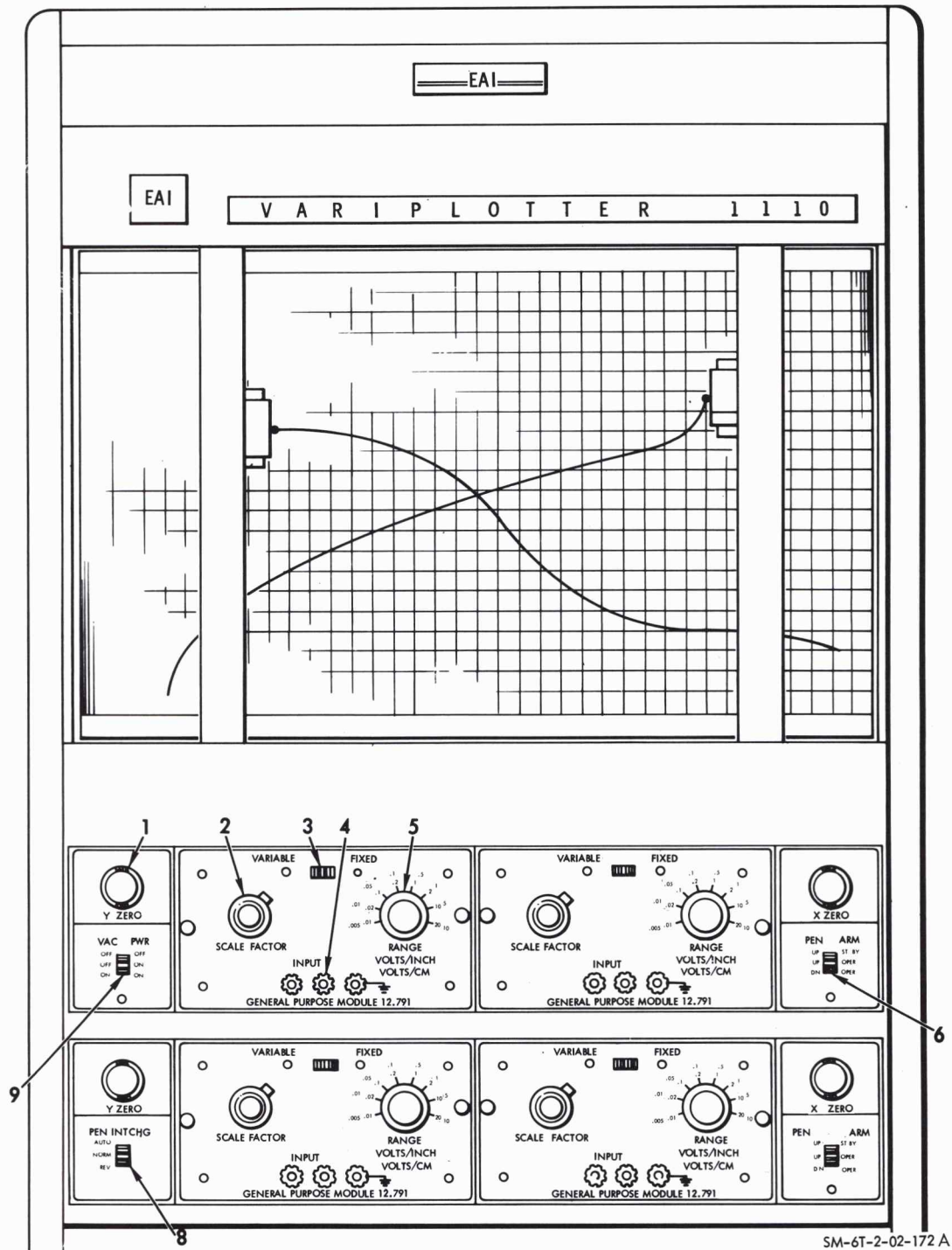
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Table 1-63. X-Y Variplotter (30 X 30) - Controls and Displays (Cont)

Key	Nomenclature	Function	Remarks
12	POWER sw	Controls application of primary power to plotter circuits.	
13	LIGHTS sw		
	ON position	Supplies primary power to back-lighting lamps.	
	OFF position	Removes power to back-lighting lamps.	
14	VACUUM sw		
	ON position	Supplies primary power to vacuum pump motor.	
	OFF position	Removes power to vacuum pump motor.	
15	PARALLAX CONTROLS PENS 1 and 2, ARMS 1 and 2	Ten-turn potentiometers, providing control of initial position of pens and arms.	
16	PAPER ADJUST potentiometers	Provide adjustment of reference voltages in each servo.	
17	SCALE FACTOR SWITCH PEN 1 and ARM 1	Rotary selector sw (8-position) providing control of plotter scale factor in each channel.	
18	SCALE FACTOR SWITCH PEN 2 and ARM 2	Rotary selector (8 position) providing control of plotter scale factor in each channel.	

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Figure 1-71. X-Y Variplotter (11 x 17)

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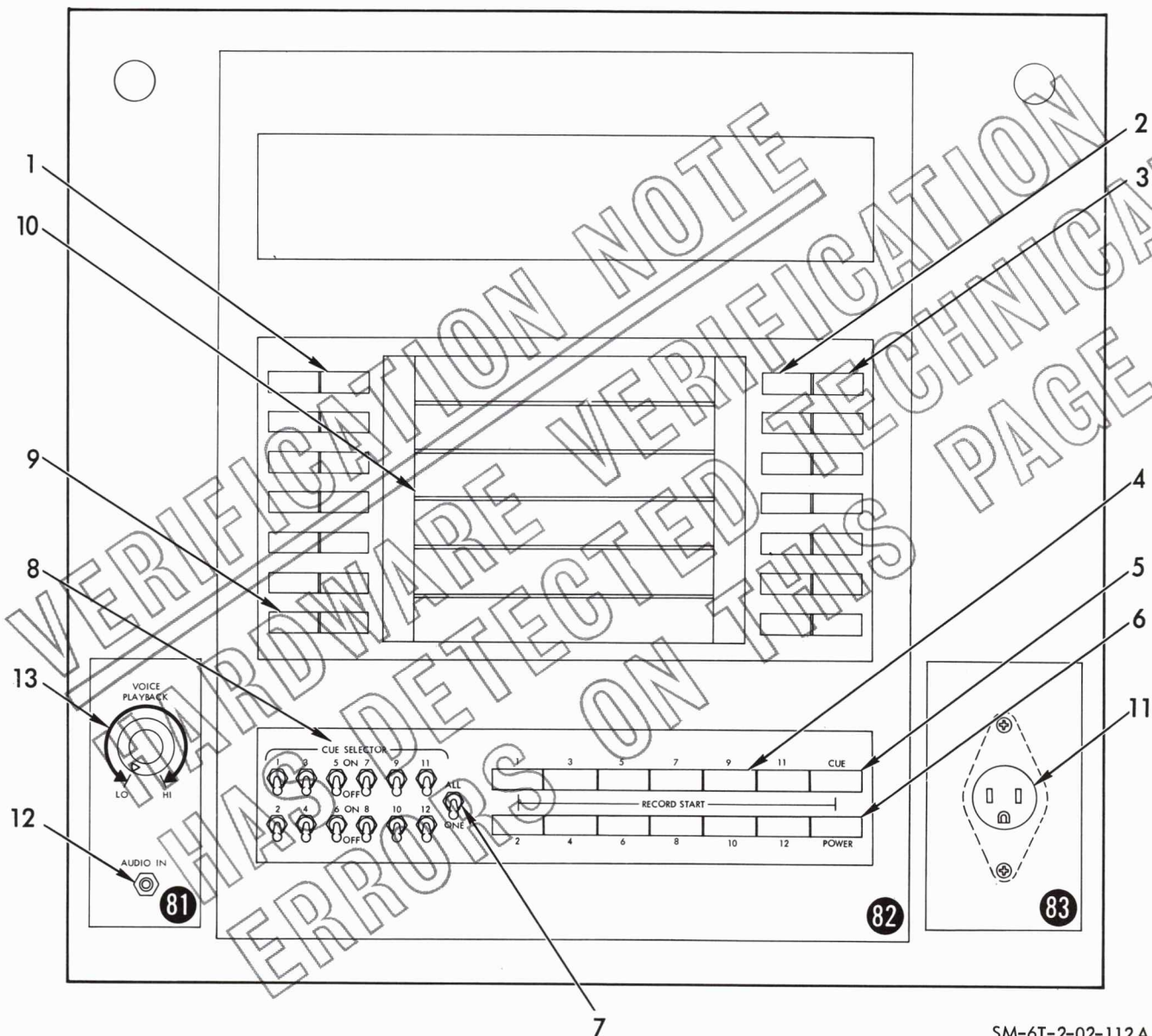
Table 1-64. X-Y Variplotter (11 X 17)

Key	Nomenclature	Function	Remarks
1	ZERO potentiometers	Permits setting location of X=0, Y=0 (0, 0 point) anywhere within a 30 x 45-inch area centered about plotting surface.	
2	SCALE FACTOR control	Enables attenuation of variable scale for plotted parameter.	
3	VARIABLE — FIXED sw	Provides selection of scale factor control to either manually variable or fixed.	
4	External INPUT plugs	Provide input connection and either chassis or floating ground.	
5	RANGE control	Enables setting of plot range in either volts/cm or volts/inch. The plug-in module must be removed for access to sw for scale change.	
6	PEN ARM sw		
	UP-STBY position	Lifts pen from plotting surface and positions it to center of arm. Arm is positioned to extreme side of travel.	
	UP-OPER position	Lifts pen from plotting surface and moves carriage in response to input signals. Arm moves in response to input signals.	
	ON-OPER position	Positions pen on plotting surface. Pen carriage and arm move in response to input signals.	
7	(Deleted)		
8	PEN INTCHG sw		
	AUTO position	Enables automatic interchange of pen and arm functions in event of an arm interception.	
	NORMAL position	Disables pen-arm interchange function.	
	REV position	Interchanges data inputs and parallax networks regardless of position of arms.	
9	VAC PWR sw		
	OFF-OFF position	Primary power is removed from all plotter and vacuum systems.	

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Table 1-64. X-Y Variplotter (11 X 17) (Cont)

Key	Nomenclature	Function	Remarks
9 (cont)	OFF-ON position	Plotter circuitry is energized but vacuum systems remain off.	
	ON-ON position	Primary power is applied to both vacuum and plotter systems.	



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Figure 1-72. KRS Audio Tape Recorder

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Table 1-65. KRS Audio Tape Recorder Panel - Controls and Displays

Key	Nomenclature	Function	Remarks
1	Eject pushbutton	Ejects tape cartridge from front loading guide rails.	
2	Drive pushbutton	Provides tape forward drive signal on selected cartridge.	
3	Reverse pushbutton	Provides tape reverse drive signal on selected cartridge.	
4	Channel record pushbuttons	Selects channel to be used to record.	
5	Cue tone master sw	Performs the above function for all channels simultaneously.	
6	Primary power sw	Provides power on/off control	
7	Master record sw	Selects all channels to be used to record simultaneously.	
8	Cue tone channel select sw	Records a short cue tone on selected channel for identification purposes.	
9	Stop pushbuttons	Stop operation of selected channel.	
10	Tape cartridge	Provides canister of magnetic recording tape.	
11	Electrical plug	Provides 115V, 60 cps power connection for audio playback unit.	
12	AUDIO IN jack plug	Connection to volume control for audio playback unit.	
13	VOICE RECORDER control	Provides volume control for audio playback unit.	

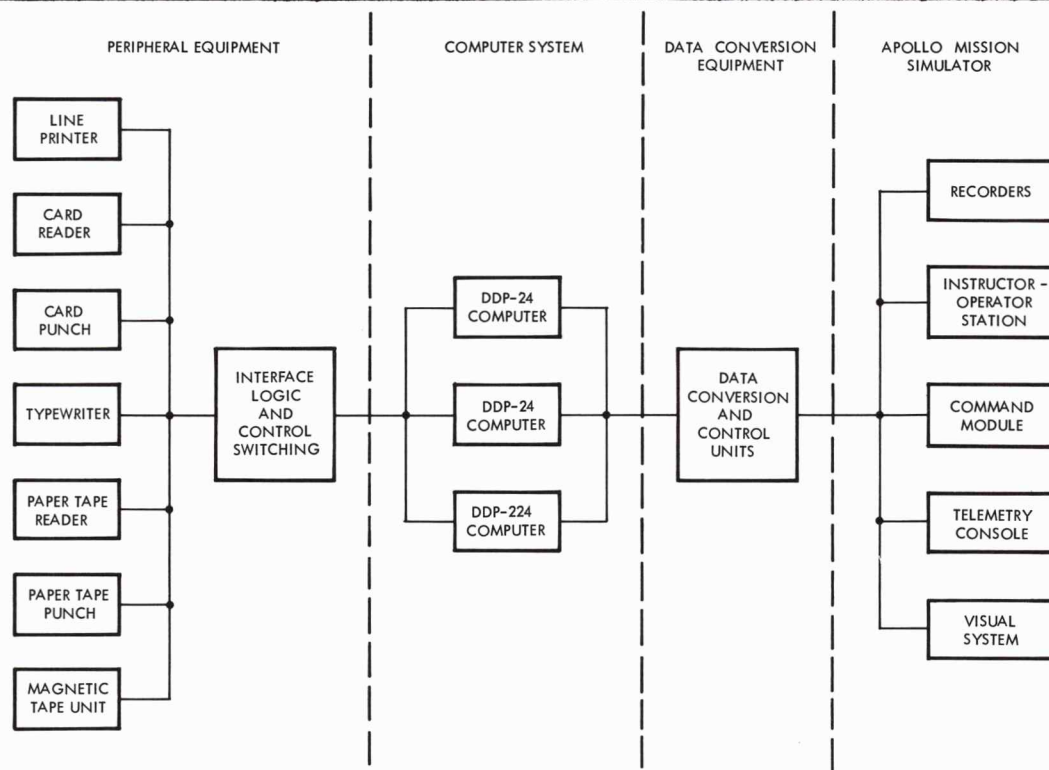
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Figure 1-73. Simulated Command Module

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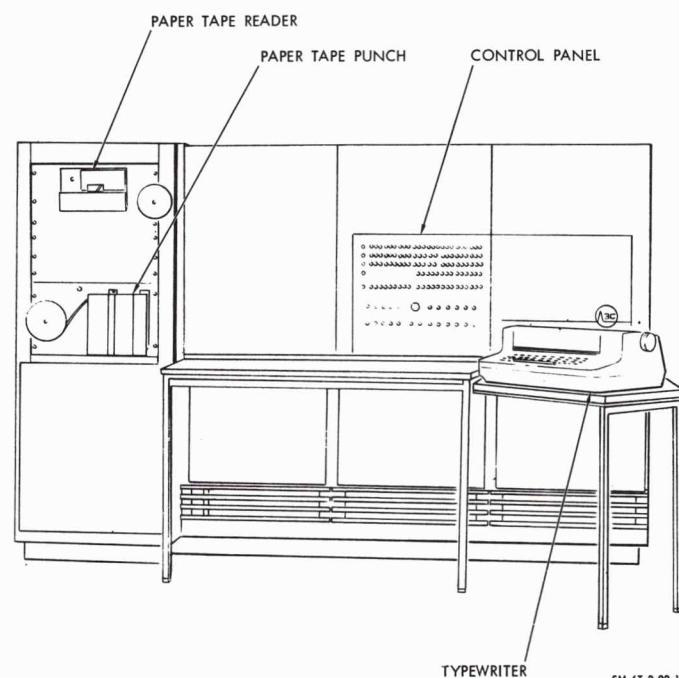
Figure 1-74. Vertical Insertion Unit

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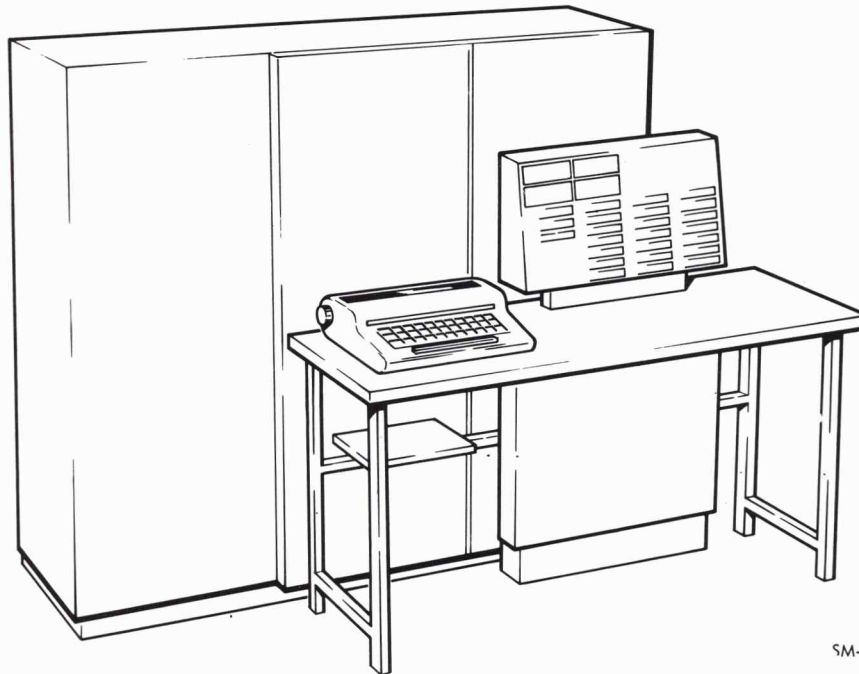
Figure 1-75. AMS Computer Complex



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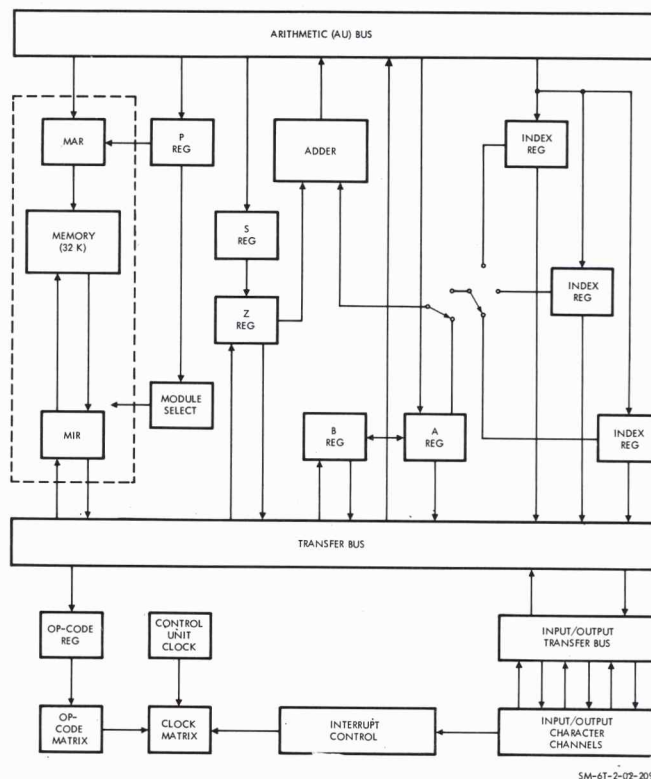
Figure 1-76. DDP-24 Computer

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Figure 1-77. DDP-224 Computer



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Figure 1-78. DDP-24 Block Diagram

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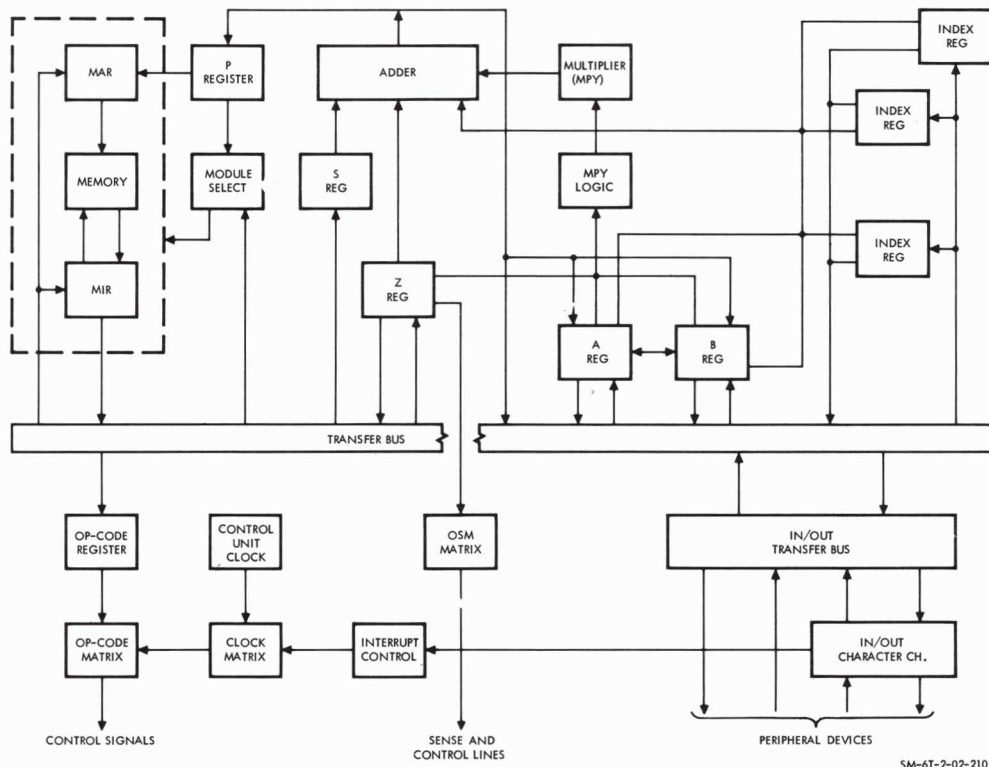


Figure 1-79. DDP-224 Block Diagram

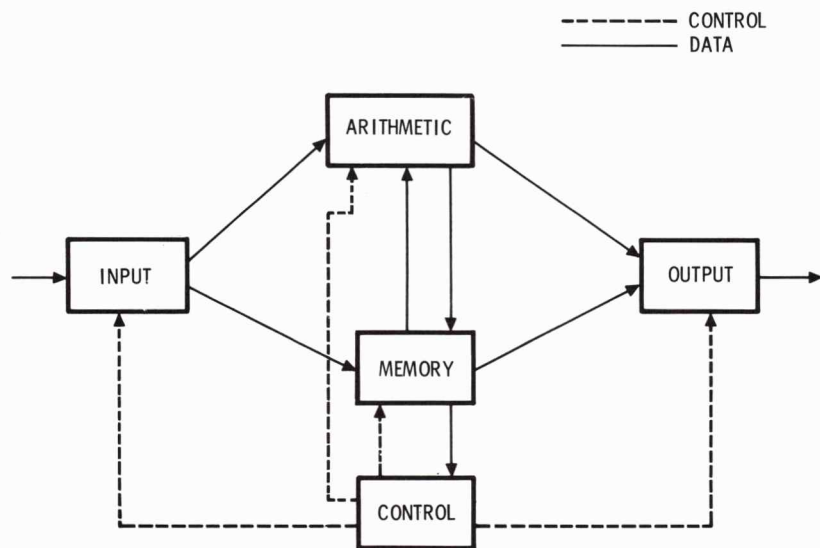
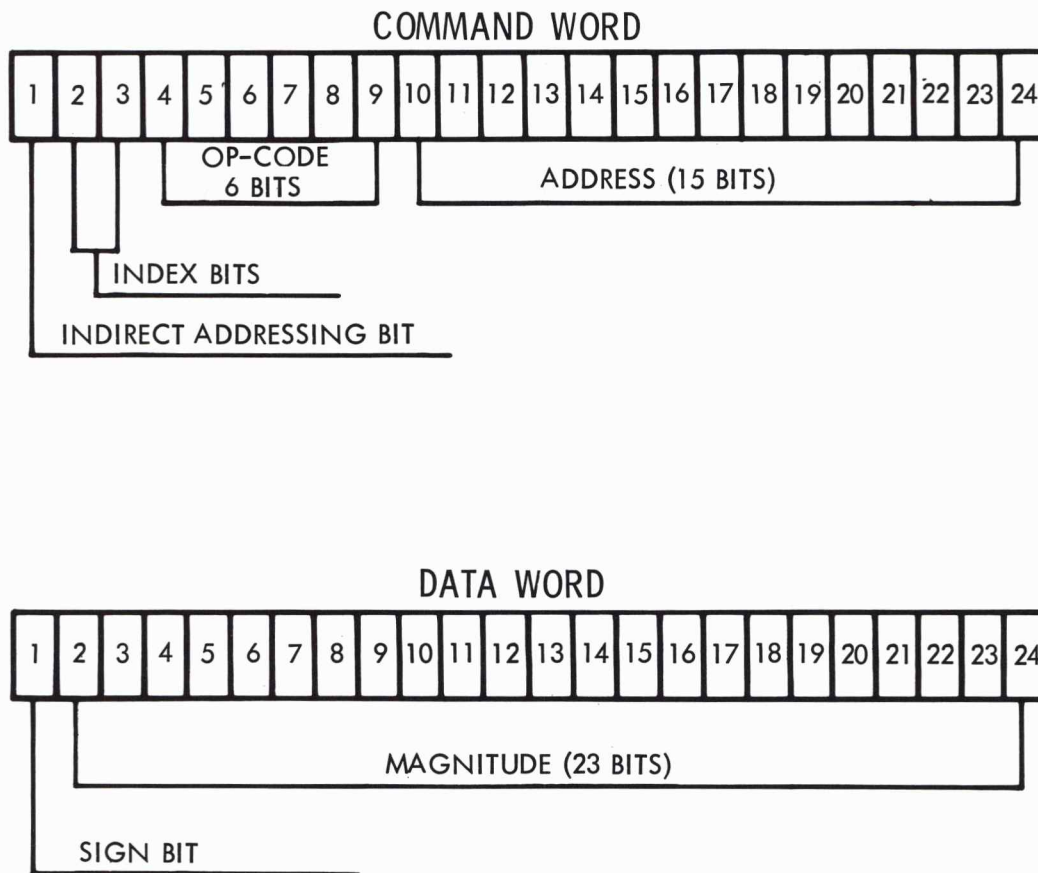


Figure 1-80. Digital Computer Simplified Block Diagram



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Figure 1-81. Computer Word Format

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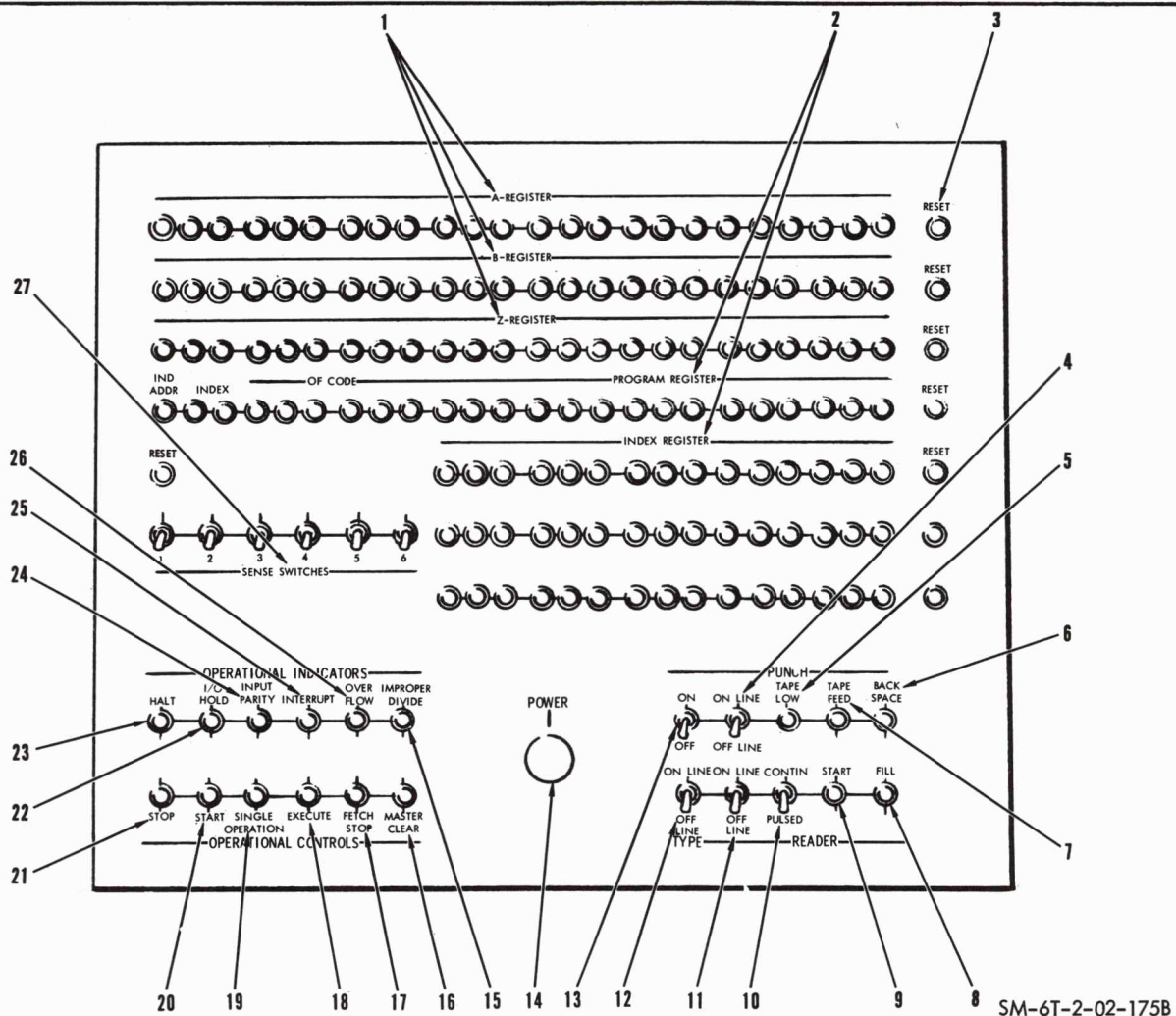


Figure 1-82. DDP-24 Computer Control Panel

Table 1-66. DDP-24 Computer Control Panel - Controls and Displays

Key	Nomenclature	Function	Remarks
1	A, B, and C REGISTER(S) sw - 1t	Shows binary content of registers and allows bit-by-bit entry.	
2	PROGRAM and INDEX REGISTER(S) sw - 1t	Shows binary content of registers and allows bit-by-bit entry.	
3	RESET sw -	Clears related register to all zeros.	
	PUNCH		
4	ON LINE — OFF LINE sw	Controls on-line or off-line paper tape punch operation.	

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Table 1-66. DDP-24 Computer Control Panel - Controls and Displays (Cont)

Key	Nomenclature	Function	Remarks
5	TAPE LOW - lt	Indicates that level of paper tape in punch has reached a predetermined low level.	
6	BACKSPACE sw - lt	Backspaces paper tape one sprocket hole at a time.	
7	TAPE FEED sw - lt	Permits tape advance while only sprocket holes are punched.	
	READER		
8	FILL sw - lt	Allows entering data from paper tape or typewriter without use of stored program.	
9	START sw - lt	Starts movement of paper tape in reader.	
10	CONTIN-PULSED sw	Allows either continuous or pulsed tape reader operation.	
11	ON LINE — OFF LINE sw	Allows either on-line or off-line reader operation.	
	TYPE		
12	ON LINE — OFF LINE sw	Controls on or off-line operation of input-output typewriter.	
	PUNCH		
13	ON-OFF sw	Turns paper tape punch motor on-off.	
14	POWER sw	Switches computer power on and off.	
	OPERATIONAL INDICATORS		
15	IMPROPER DIVIDE	Indicates the following: a. A division operation in which numerator in A register is larger than or equal to denominator (magnitude only). b. In binary to BCD conversion, when resulting BCD number is greater than 799,999.	
	OPERATIONAL CONTROLS		
16	MASTER CLEAR sw - lt	Sets half flip-flop; resets the following: all displayed registers, program counter, index bits, indirect address bit flip-flops, control unit clock, ready and enable flip-flops of	

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Table 1-66. DDP-24 Computer Control Panel - Controls and Displays (Cont)

Key	Nomenclature	Function	Remarks
16 (Cont)		all input-output channels; the interrupt enable, input parity, overflow, and improper divide flip-flops. Also stops paper tape reader.	
17	FETCH STOP sw - 1t	Fetches contents of memory location specified by program register and places information in Z register. Adds one to program register after fetch. Does not execute instruction fetched.	
18	EXECUTE sw - 1t	Executes instruction in OF code register.	
19	SINGLE OPERATION sw - 1t	Causes program to start where it left off, but only accomplishes one command.	
20	START sw - 1t	Causes program to start, beginning with command stored in memory location indicated by program register.	
21	STOP sw - 1t	Stops program after current instruction is completed.	
	OPERATIONAL INDICATORS		
22	I/O HOLD - 1t	Indicates one or more input-output device is busy.	
23	HALT - 1t	Indicates that halt flip-flop is set and that no operations can take place except for handling of interrupts.	
24	INPUT PARITY - 1t	Allows detection of an error while reading character information.	
25	INTERRUPT - 1t	Indicates execution of an interrupt subroutine.	
26	OVERFLOW - 1t	Indicates that an overflow fault has occurred in computation and that overflow flip-flop is set.	
27	SENSE SWITCHES 1 through 6	Provides accessible manual control of certain options during running of programs.	

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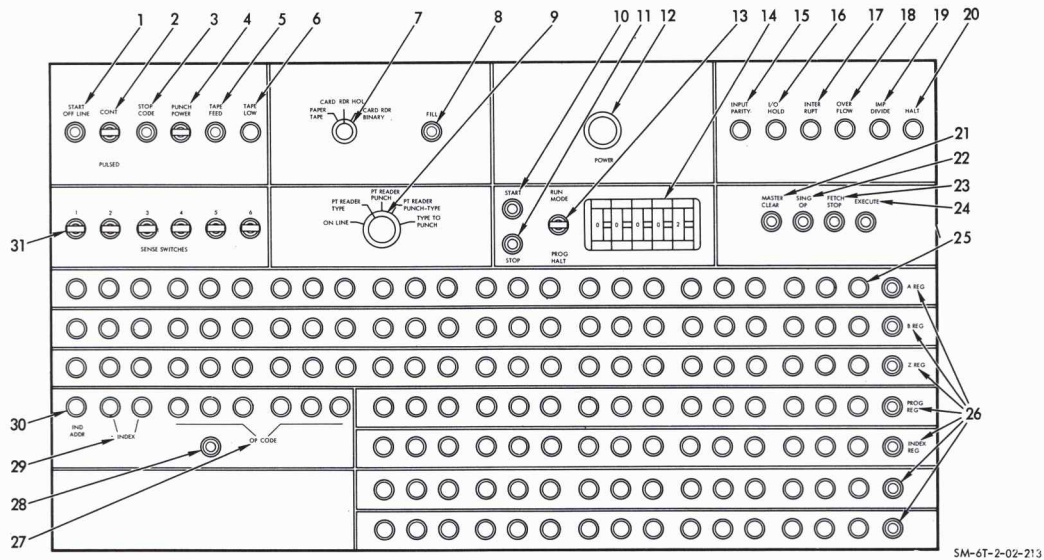


Figure 1-83. DDP-224 Computer Control Panel

Table 1-67. DDP-224 Computer Control Panel - Controls and Displays

Key	Nomenclature	Function	Remarks
1	START/OFF-LINE pushbutton	Starts operation enabled by I/O function select switch.	
2	CONT/PULSED sw	CONT position enables continuous operation of paper tape punch or reader. PULSED position allows pulsed operation of paper tape punch or reader.	
3	STOP CODE pushbutton	"Stop code" punched on paper tape when depressed.	
4	PUNCH POWER sw	Turns power to paper tape punch motor on or off.	
5	TAPE FEED pushbutton	Advances paper tape and punches sprocket holes only.	
6	TAPE LOW light	Indicates low level of paper tape on reel.	
7	(Fill Selection rotary sw)	Selects device (card reader or paper tape reader) from which program will be loaded into memory.	
	PAPER TAPE	Selects paper tape reader to load program into memory upon depression of FILL pushbutton.	

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Table 1-67. DDP-224 Computer Control Panel - Controls and Displays (Cont)

Key	Nomenclature	Function	Remarks
7 (cont)	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 memory.	
8	FILL pushbutton	Loads computer memory from device selected by FILL selection rotary switch.	
9	(I/O function selection rotary sw)	Provides for on-line connection of peripheral devices, or off-line data transfer between devices.	
	ON-LINE	Allows computer to select and control operation of paper tape reader, paper tape punch, and typewriter.	
	P. T. READER TYPE	Information from paper tape is read out on typewriter.	
	P. T. READER PUNCH	Allows duplication of paper tape data by simultaneous reading and punching of tape.	
	P. T. READER PUNCH-TYPE	Permits typewriter to print out information as it is punched on paper tape.	
	TYPE TO PUNCH	Typed information will be punched on paper tape.	
10	START pushbutton	Causes computer to start operation.	
11	STOP pushbutton	Causes computer to halt after current instruction is completed.	
12	POWER pushbutton lt	Turns power off and on to main computer and auxiliary equipment.	
13	RUN MODE — PROG. HALT sw	RUN MODE position inhibits program halt address register.	
		PROG HALT position controls effect of program halt address register.	
14	(PROGRAM HALT ADDRESS REGISTER) thumbwheels	Allows address to be selected at which a program will halt.	

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Table 1-67. DDP-224 Computer Control Panel - Controls and Displays (Cont)

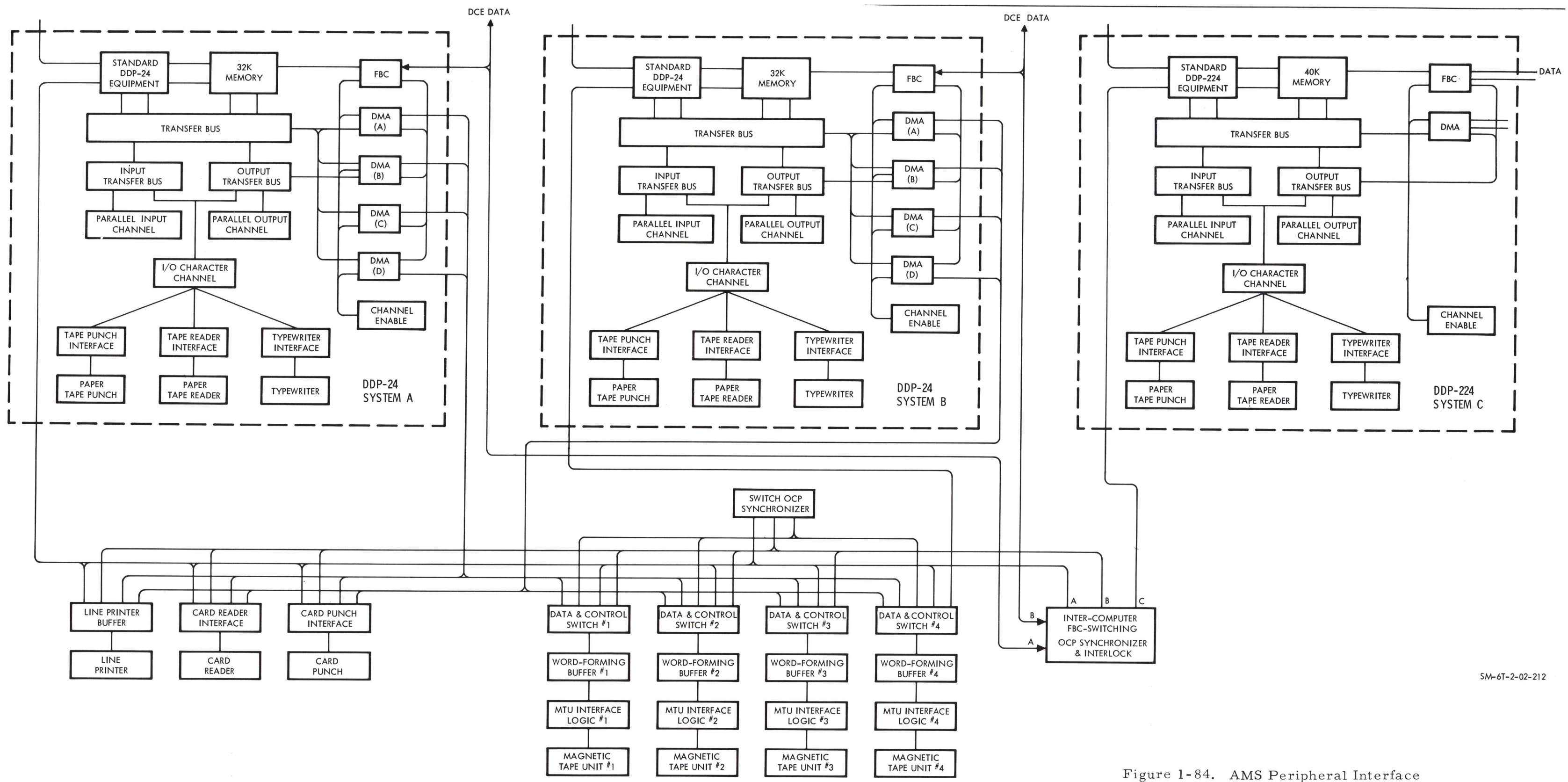
Key	Nomenclature	Function	Remarks
15	INPUT PARITY lt	Allows detection of error while reading character information.	
16	I/O HOLD lt	Indicates that computer is delaying until I/O device is ready.	
17	INTERRUPT lt	Indicates execution of interrupt subroutine.	
18	OVERFLOW lt	Indicates that overflow fault has occurred in computation.	
19	IMP DIVIDE lt	Indicates improper divide has occurred or improper binary-to-BCD conversion has been attempted.	
20	HALT lt	Indicates that the halt flip-flop is set and no operations can take place except for interrupts.	
21	MASTER CLEAR pushbutton	Halts the computer, resets all registers, control clock unit, ready and enable flip-flops of an input/output channels, interrupt enable, input parity, overflow, and improper divide flip-flops. Stops all peripheral devices.	
22	SING OP pushbutton	Causes the computer to execute the command stored in the memory location indicated by the program register.	
23	FETCH STOP pushbutton	Causes the computer to execute the fetch cycle only.	
24	EXECUTE pushbutton	Causes the computer to execute the command set in the OP-code register.	
25	A, B, Z, PROG, INDEX REG pushbutton lt	Indicates the contents of the A, B, Z, Program and Index registers and allows bit-by-bit entry.	
26	(Reset) pushbuttons	Enables each register to be cleared to zero.	
27	OP-CODE Register Pushbutton lt	Indicates the contents of the OP-code register and allow bit-by-bit entry.	
28	(Reset) pushbutton	Clears OP-code register, index bits and indirect addressing bit to zero.	

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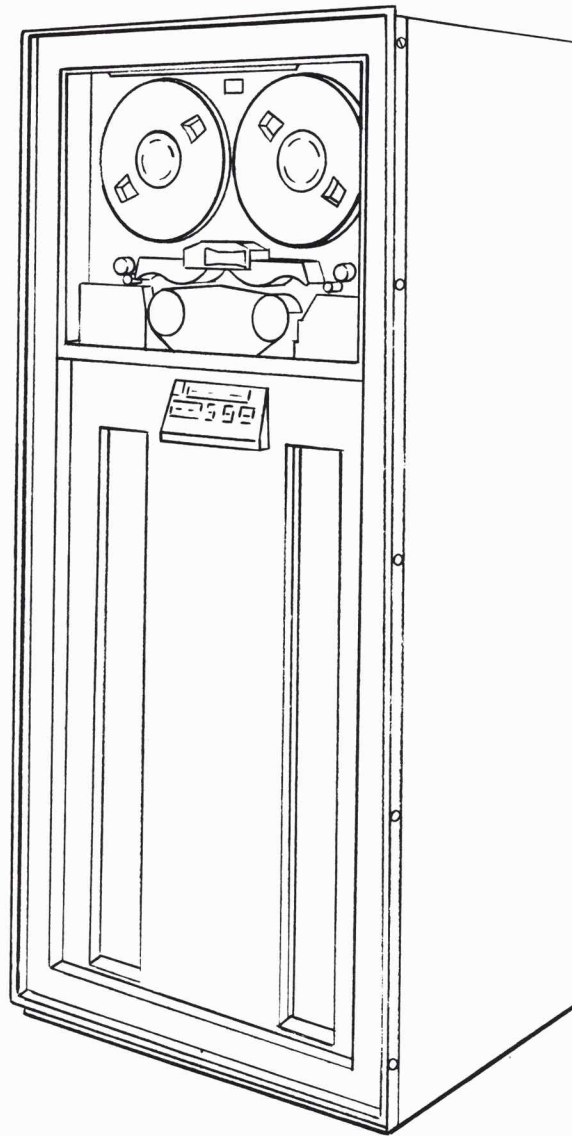
Table 1-67. DDP-224 Computer Control Panel - Controls and Displays (Cont)

Key	Nomenclature	Function	Remarks
29	INDEX pushbutton lt	Indicates whether index register is to be used; allows bit-by-bit entry.	
30	IND ADDR pushbutton lt	Indicates indirect address is part of instruction; allows manual entry.	
31	SENSE SWITCHES (1 through 6)	Provides manual control of programs.	



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Figure 1-84. AMS Peripheral Interface



SM-6T-2-02-176

Figure 1-85. Magnetic Tape Unit

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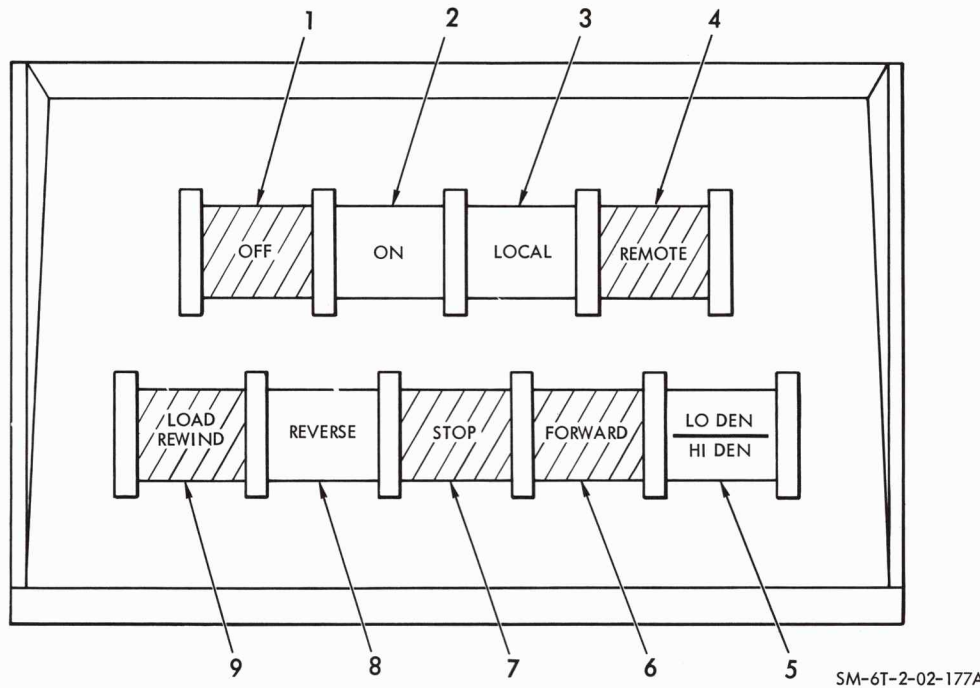
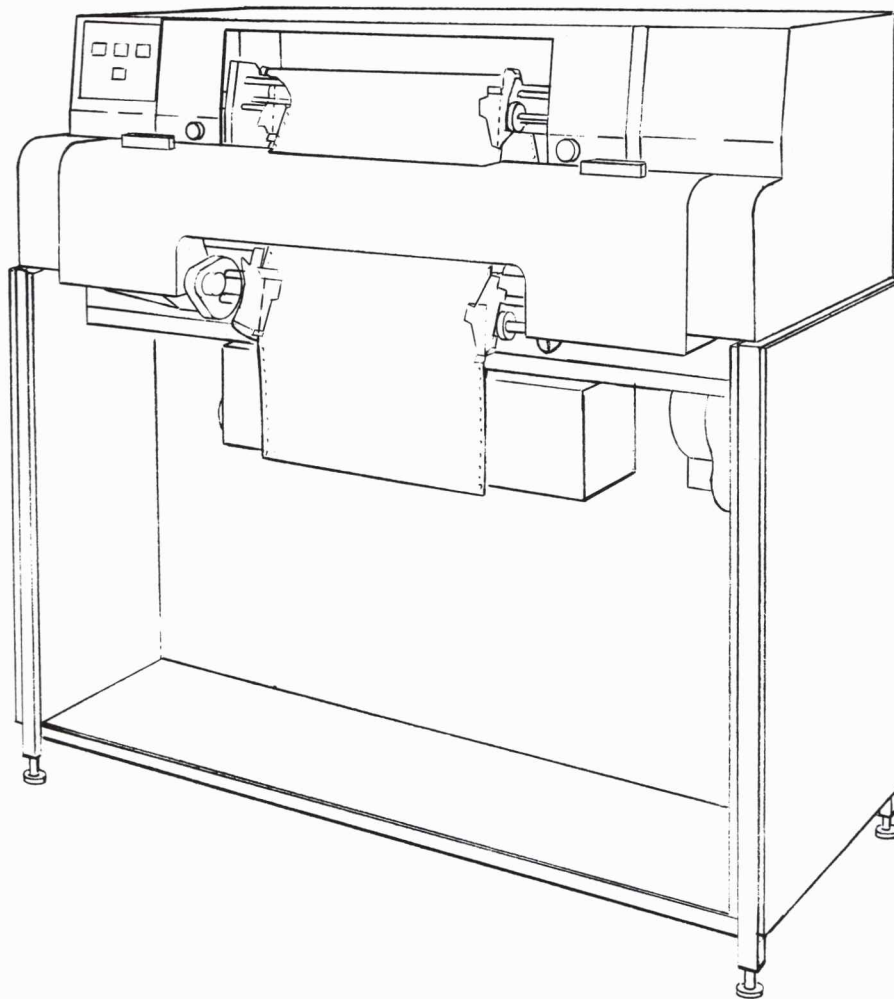


Figure 1-86. MTU Manual Control Panel

Table 1-68. Magnetic Tape Unit Manual Control Panel - Controls and Displays

Key	Nomenclature	Function	Remarks
1	OFF sw - lt	Removes power from entire unit.	
2	ON sw - lt	Applies power to entire unit.	
3	LOCAL sw - lt	Allows operation of MTU from MCP.	
4	REMOTE sw - lt	Enables operation of MTU from remote equipment.	
5	LO DEN — HI DEN sw, - lt	Provides selection and indication of density mode selected.	
6	FORWARD sw - lt	Causes tape to move left to right direction.	
7	STOP sw - lt	Stops operation of MTU.	
8	REVERSE sw - lt	Causes tape to move in right to left direction.	
9	LOAD/REWIND sw - lt	Causes tape on reels to be rewound until end of tape or stop signal is received.	



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Figure 1-87. DP/P3300 Line Printer

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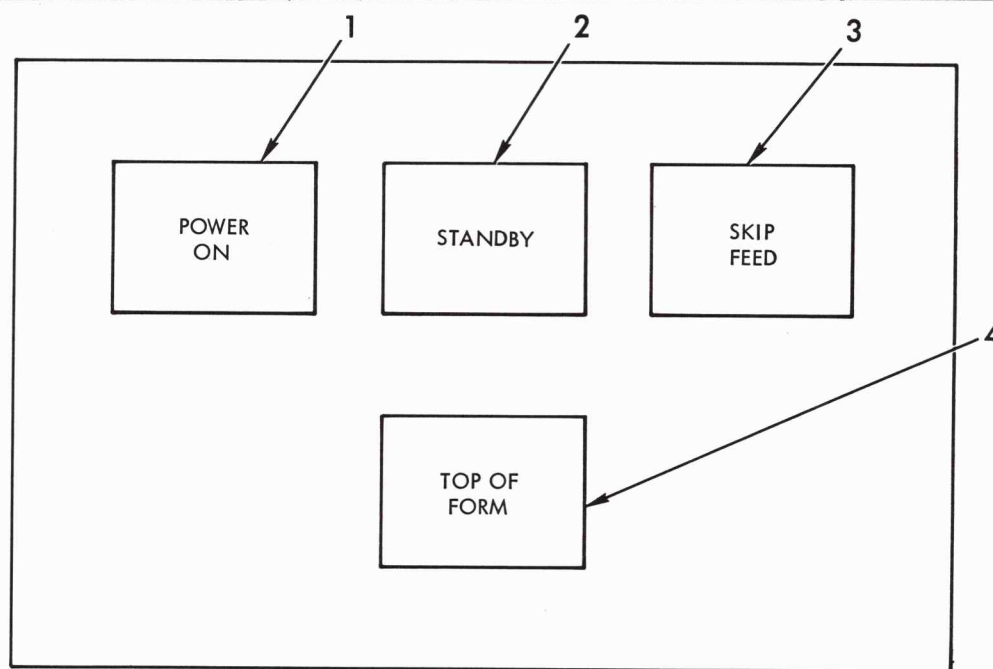
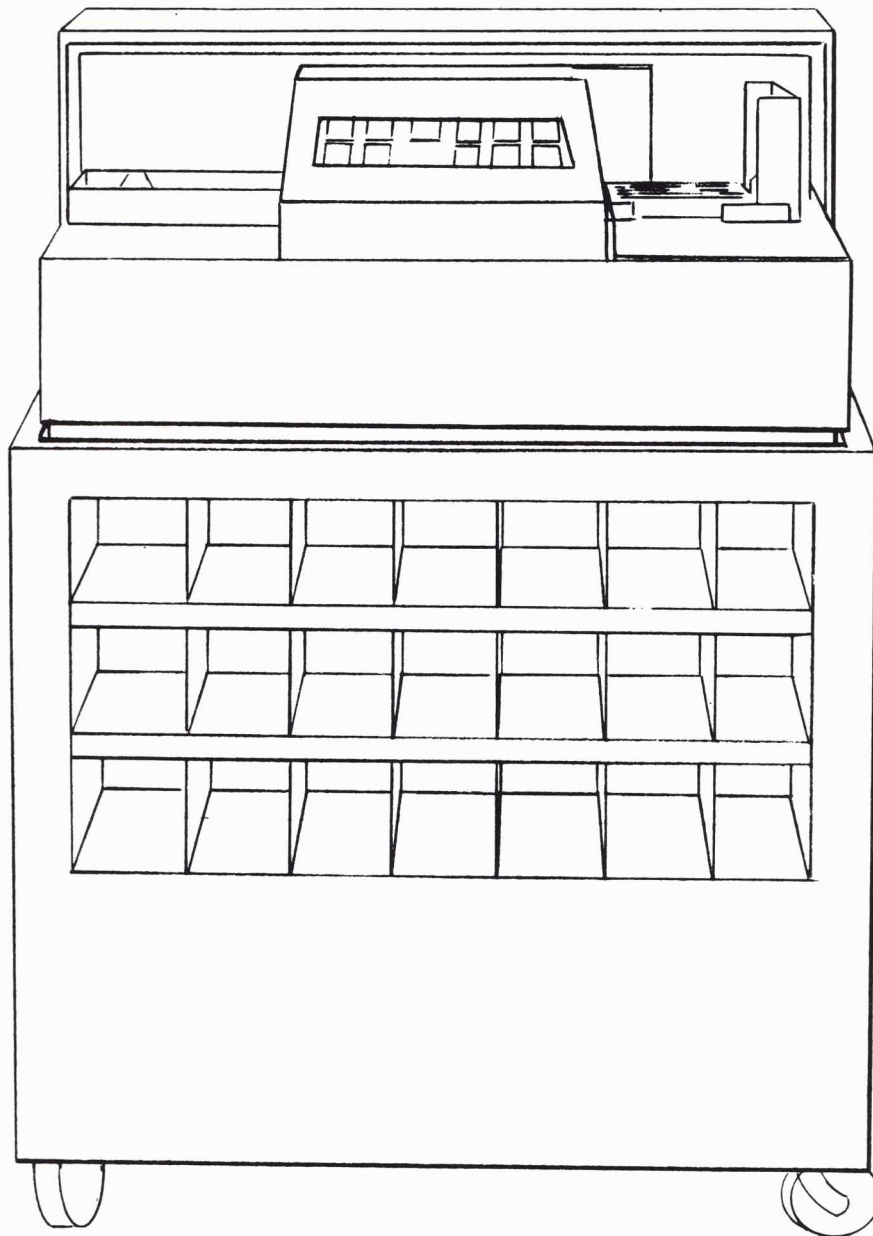


Figure 1-88. Printer Control Panel

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Table 1-69. Printed Control Panel - Controls and Displays

Key	Nomenclature	Function	Remarks
1	POWER sw - lt	Controls main power to printer unit.	
2	STANDBY sw - lt	Places printer in print inhibit mode.	
3	SKIP FEED sw - lt	Advances paper position at fast rate.	
4	TOP OF FORM sw - lt	Positions paper to top of form.	



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Figure 1-89. B122 Card Reader

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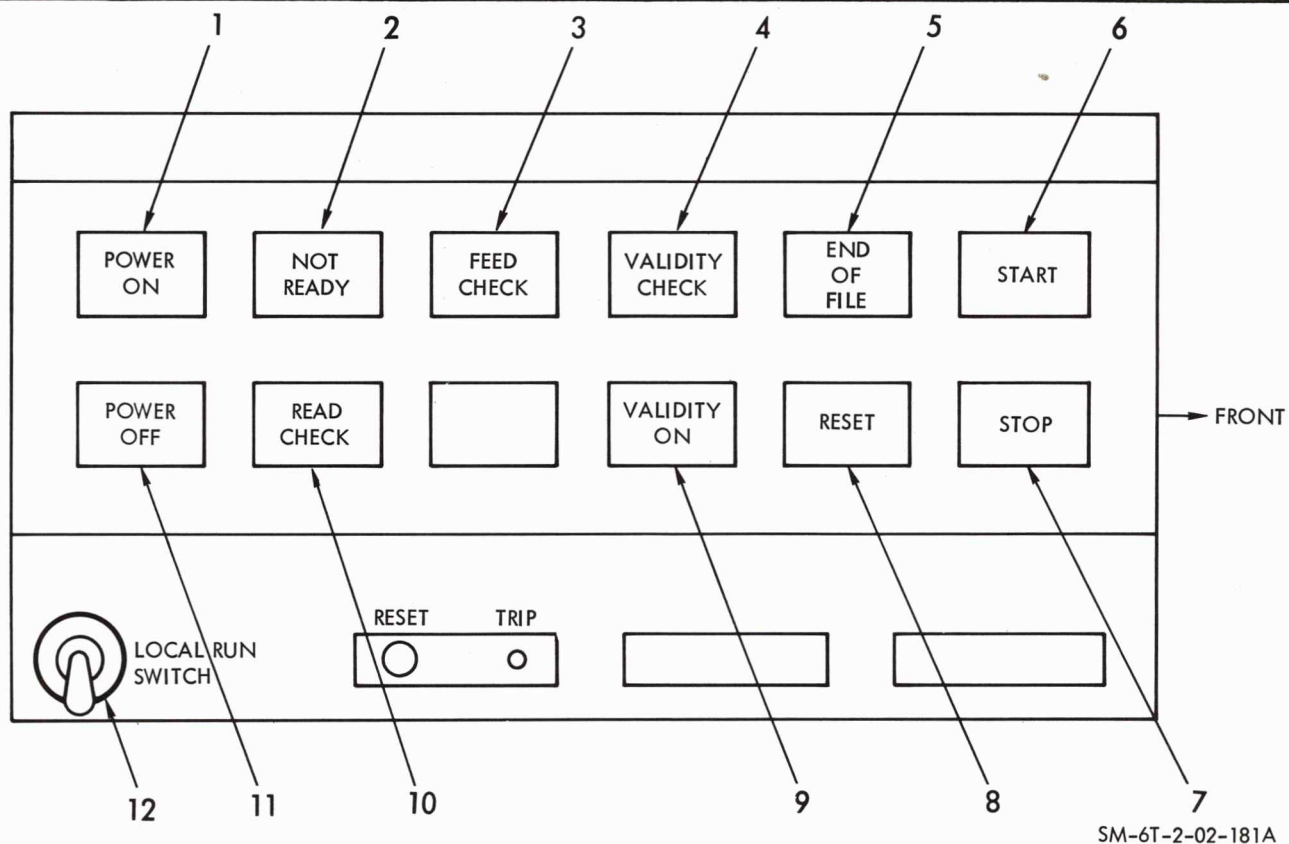


Figure 1-90. Card Reader Control Panel

Table 1-70. Card Reader Control Panel - Controls and Displays

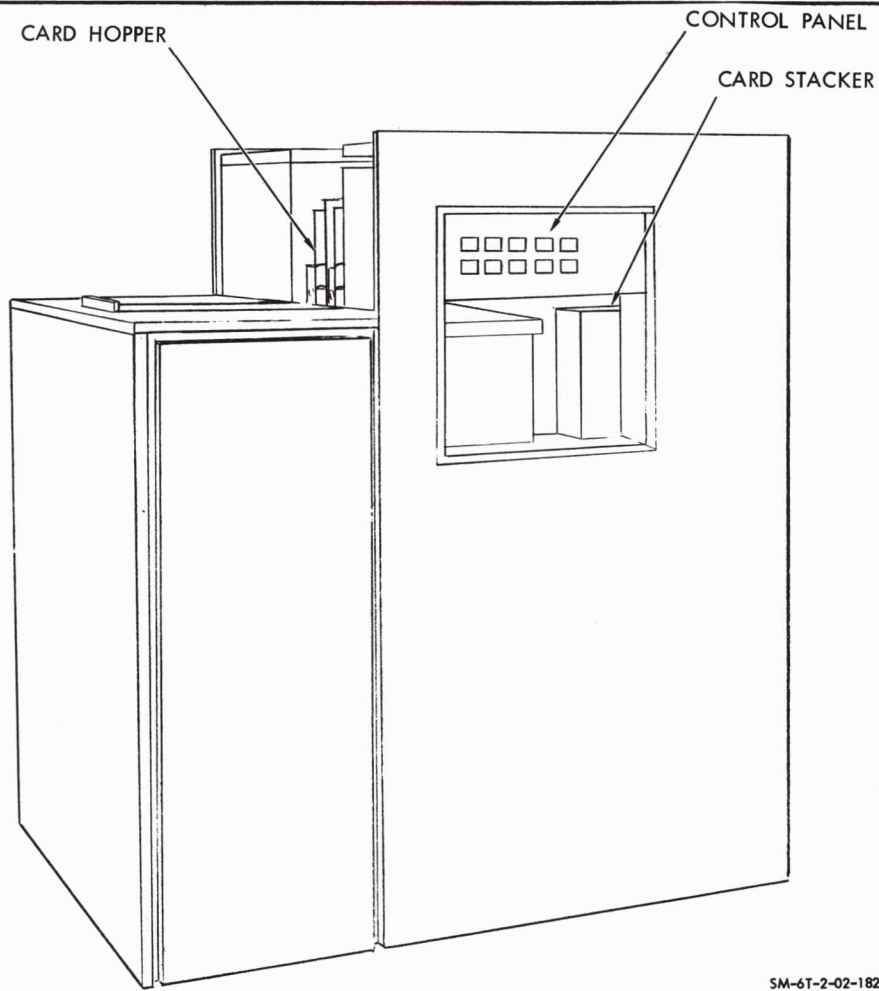
Key	Nomenclature	Function	Remarks
1	POWER ON sw - lt	Initiates power on sequence and lights NOT READY lt.	
2	NOT READY lt	Goes on whenever one of the following conditions exists: <ul style="list-style-type: none"> a. Power on sequence incomplete b. No cards in hopper c. Stacker full d. Read or validity check in progress e. Feed check in progress f. STOP sw enabled. 	

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Table 1-70. Card Reader Control Panel - Controls and Displays (Cont)

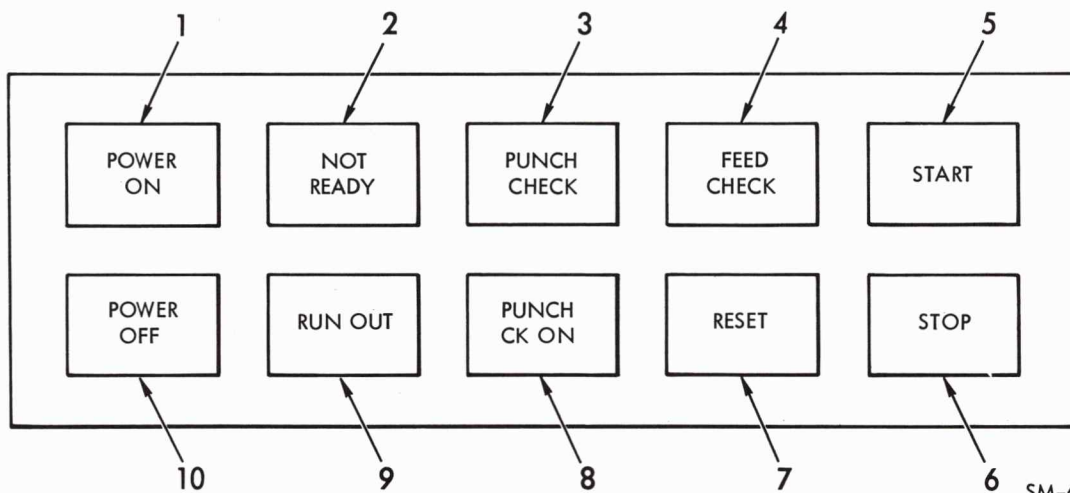
Key	Nomenclature	Function	Remarks
3	FEED CHECK lt	Goes on if card fails to feed.	
4	VALIDITY CHECK lt	Indicates invalid character is sensed.	
5	END OF FILE sw - lt	Enables processing of cards after last card is fed from hopper.	
6	START sw	Puts card reader in ready condition and extinguishes NOT READY lt.	
7	STOP sw	Places card reader in NOT READY condition.	
8	RESET sw	Extinguishes VALIDITY CHECK, READ CHECK and FEED CHECK lt.	
9	VALIDITY ON sw - lt	Causes validity check of each card character.	
10	READ CHECK lt	Indicates failure of exciter lamp or circuitry.	
11	POWER OFF sw - lt	Removes power from power supply and extinguishes POWER ON lt.	
12	LOCAL RUN SWITCH		
	LOCAL position	Enables continuous card feed from hopper.	
	RUN position	Enables remote operation of card reader.	

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Figure 1-91. B303 Card Punch



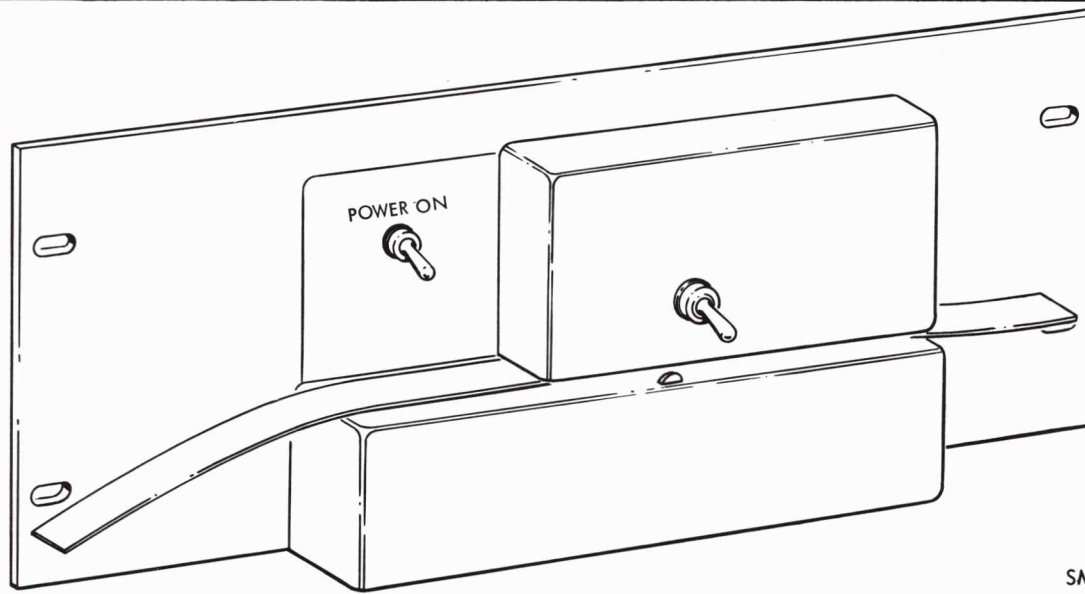
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Figure 1-92. Card Punch Control Panel

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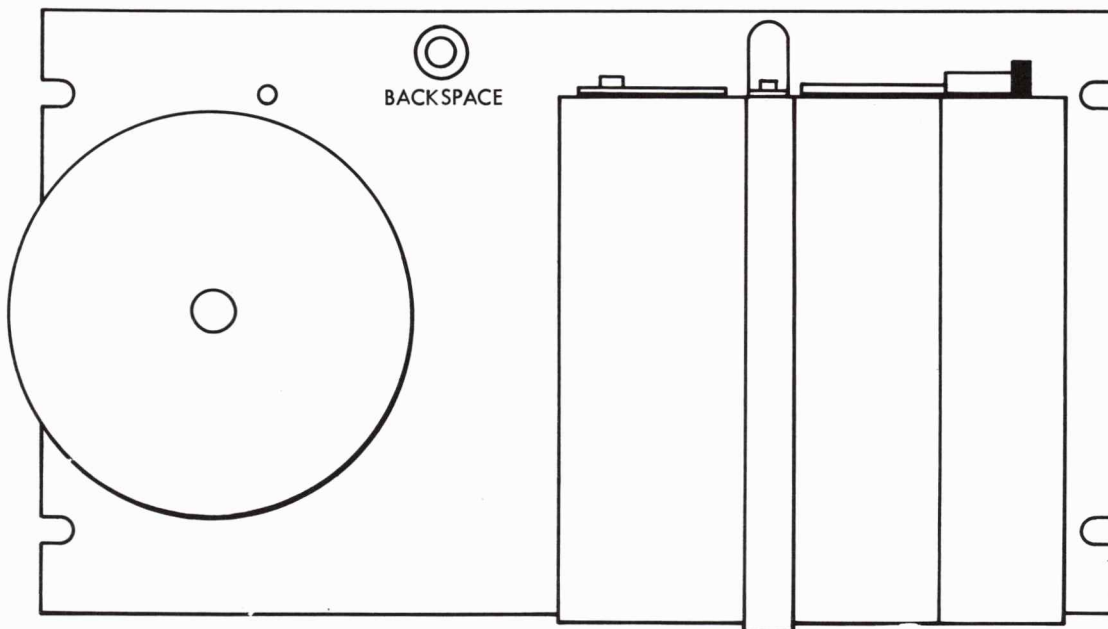
Table 1-71. Card Punch Control Panel - Controls and Displays

Key	Nomenclature	Function	Remarks
1	POWER ON START sw - lt	Applies line power to internal supplies. Lights NOT READY lt.	
2	NOT READY lt	Indicates unit is not ready for operation. Lights when any of the following conditions exist: <ul style="list-style-type: none"> a. Power-on sequence incomplete b. No cards in hopper c. START P/B not depressed d. Stacker full e. STOP sw depressed. 	
3	PUNCH CHECK lt	Indicates card has not been punched.	
4	FEED CHECK lt	Indicates failure in card feed or empty hopper.	
5	START sw - lt	Causes card to feed into ready station.	
6	STOP sw - lt	Stops operation of unit. Lights NOT READY lt.	
7	RESET sw - lt	Resets punch and feed check circuitry. Lights NOT READY lt.	
8	PUNCH CK ON lt	Indicates that punch check circuitry is operating.	
9	RUN OUT sw - lt	Causes last punched card to be fed to stacker. Clears cards from feed.	
10	POWER OFF sw - lt	Removes line power from unit.	



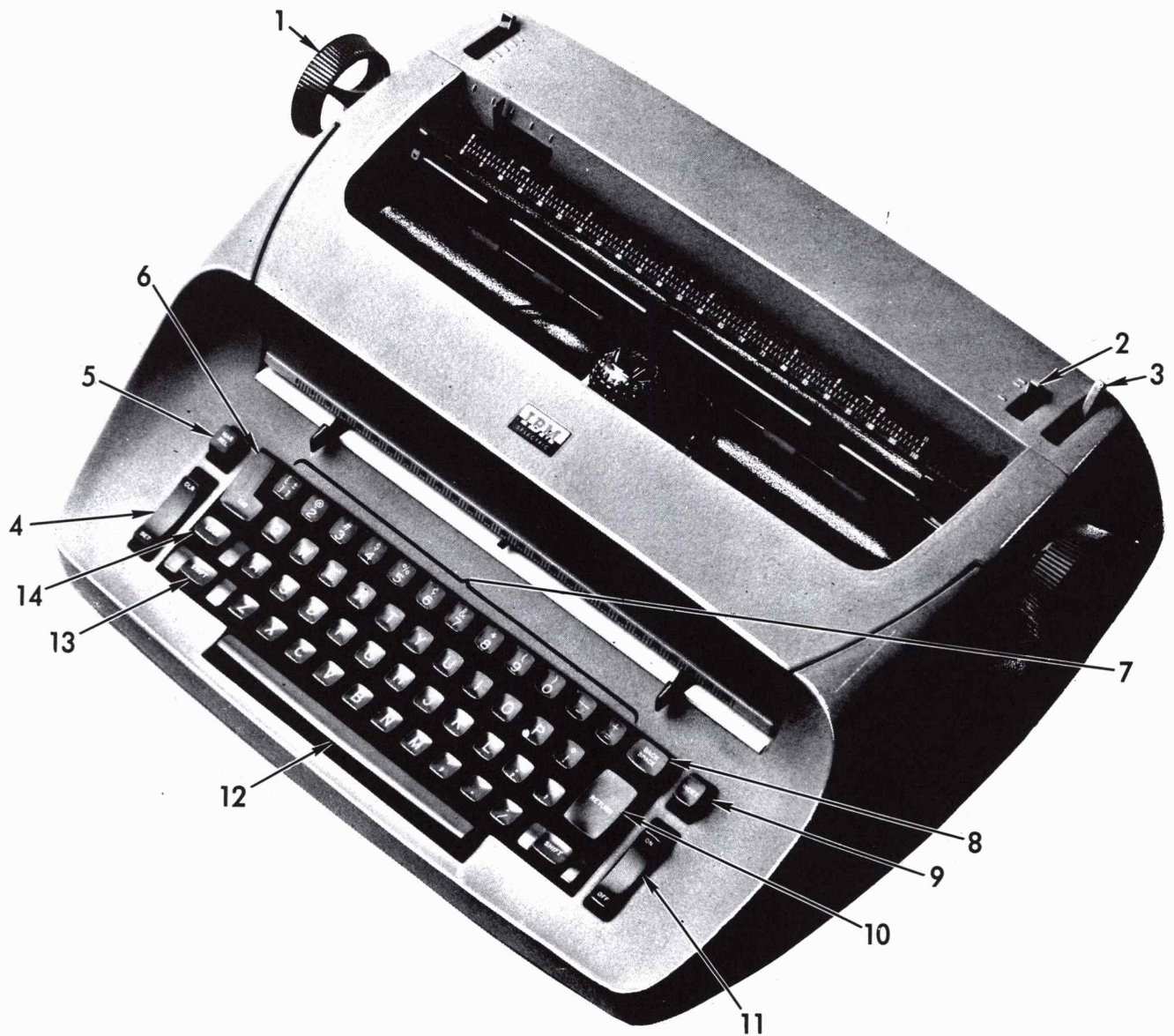
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Figure 1-93. Digitronics Paper Tape Reader



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Figure 1-94. Tally Papertape Perforator



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Figure 1-95. IBM Selectric Typewriter

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Table 1-72. IBM Selectric Typewriter

Key	Nomenclature	Function	Remarks
1	Platen control	Allows platen to be rotated freely in either direction.	
2	Line space lever	Allows selection of either single or double spacing.	
3	Paper release lever	Enables positioning or removal of paper.	
4	Tab control pushbutton	Enables a clear or set of tab settings.	
5	MARGIN RELEASE pushbutton	Allows releases of right and left margins	
6	Tab pushbutton	Moves carriage to a tab setting.	
7	Keyboard pushbuttons	Enable type of standard and special characters.	
8	BACKSPACE pushbutton	Moves carriage toward left margin.	
9	INDEX pushbutton	Permits vertical spacing.	
10	CARRIER RETURN pushbutton	Returns carriage to left margin.	
11	Motor control	Activates typewriter.	
12	Space bar	Advances carriage toward right margin.	
13	SHIFT key	Shifts type to upper case lettering.	
14	SHIFT LOCK	Locks shift key in position.	

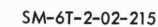


Figure 1-96. AMS Flow Diagram

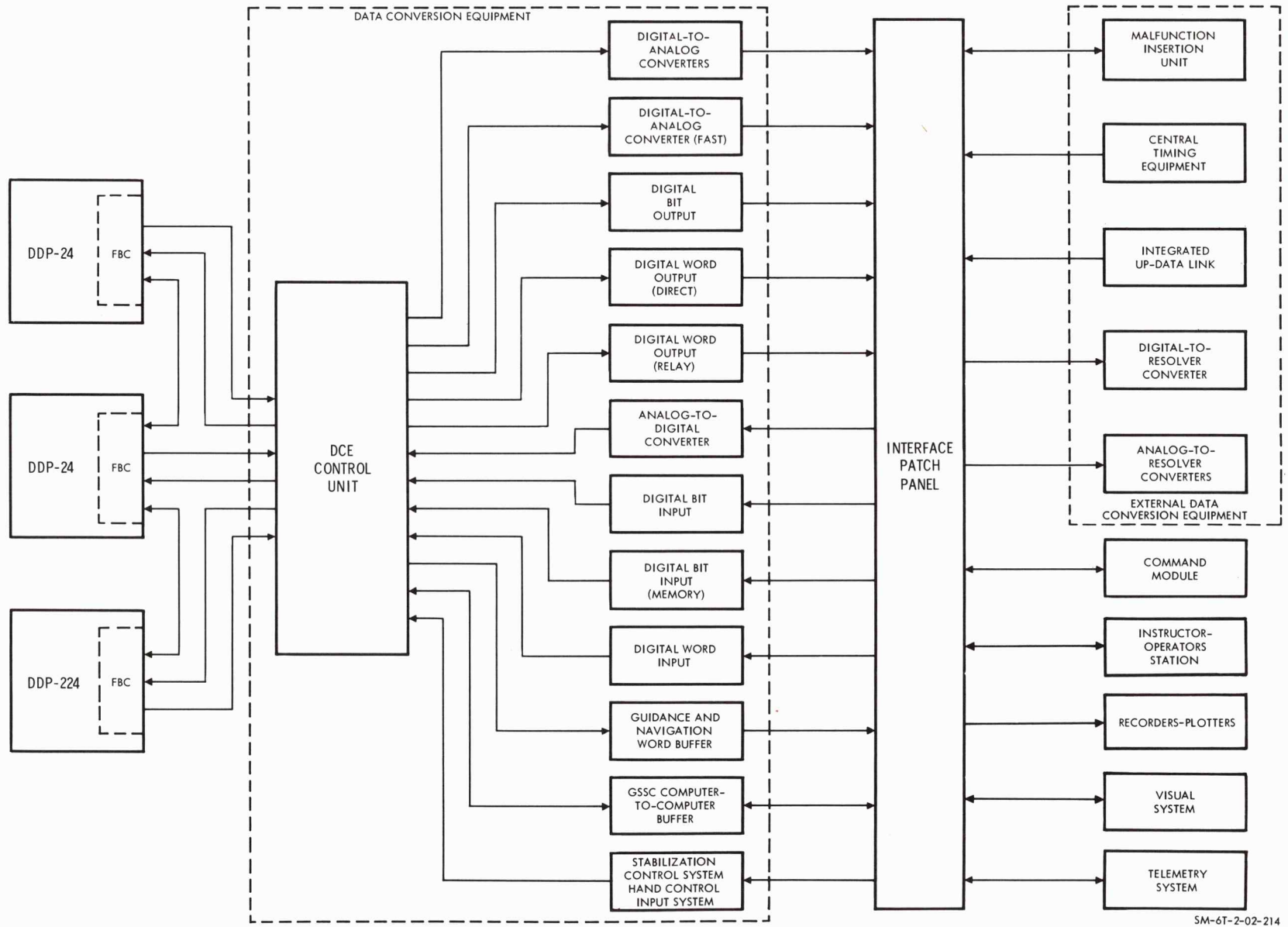
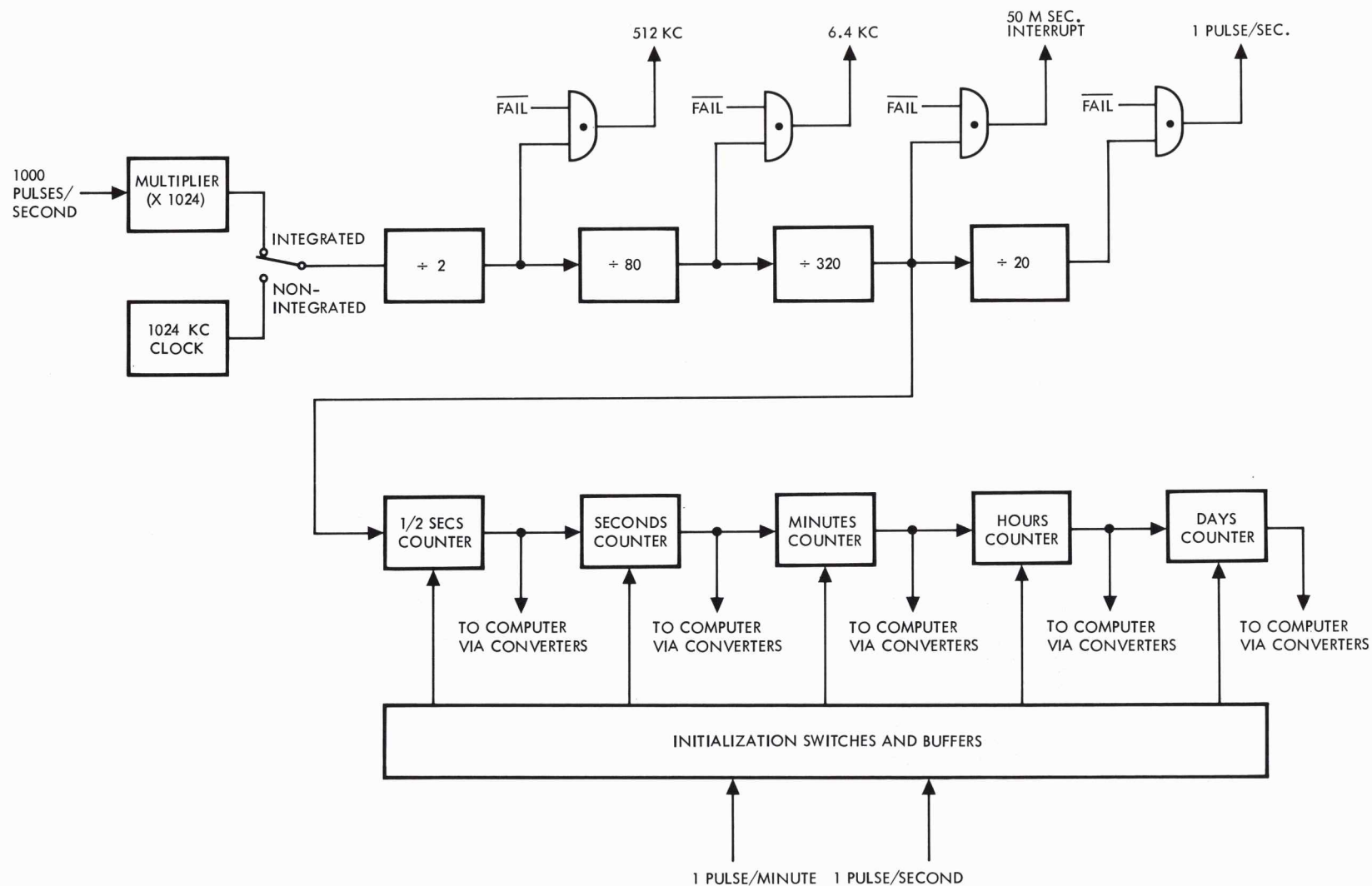


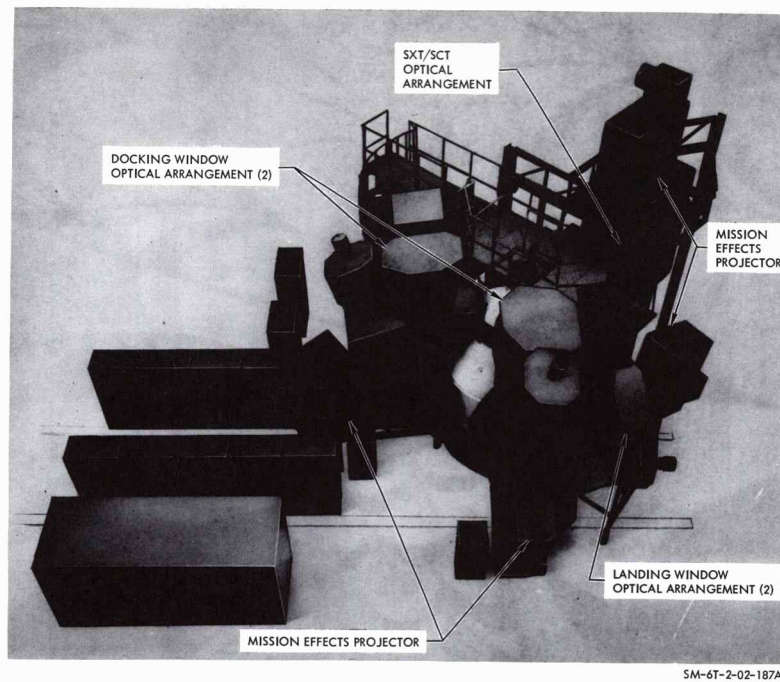
Figure 1-97. AMS Computer-DCE Interface



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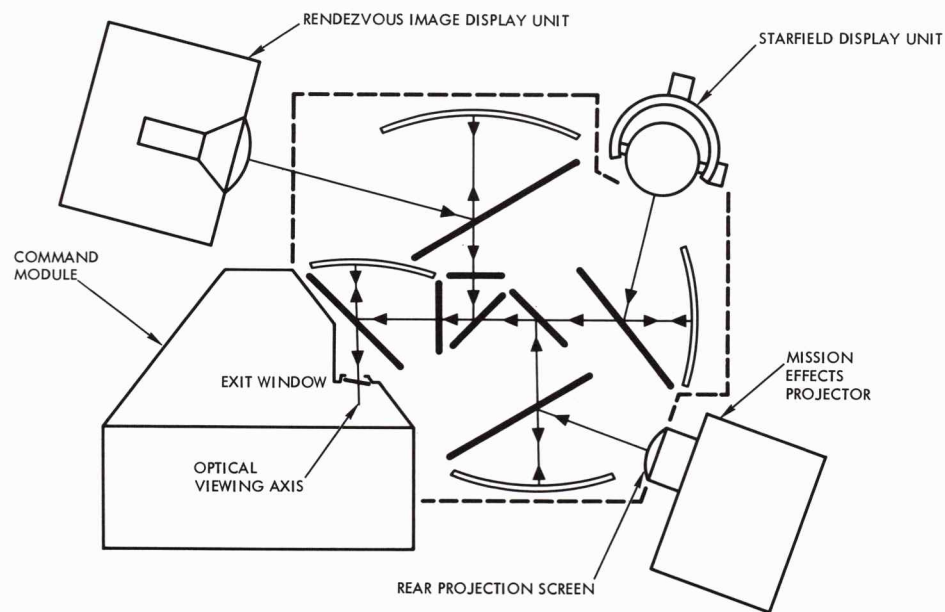
Figure 1-98. Central Timing Equipment Simplified Block Diagram

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Figure 1-99. Visual Systems



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Figure 1-100. Typical Infinity Image System

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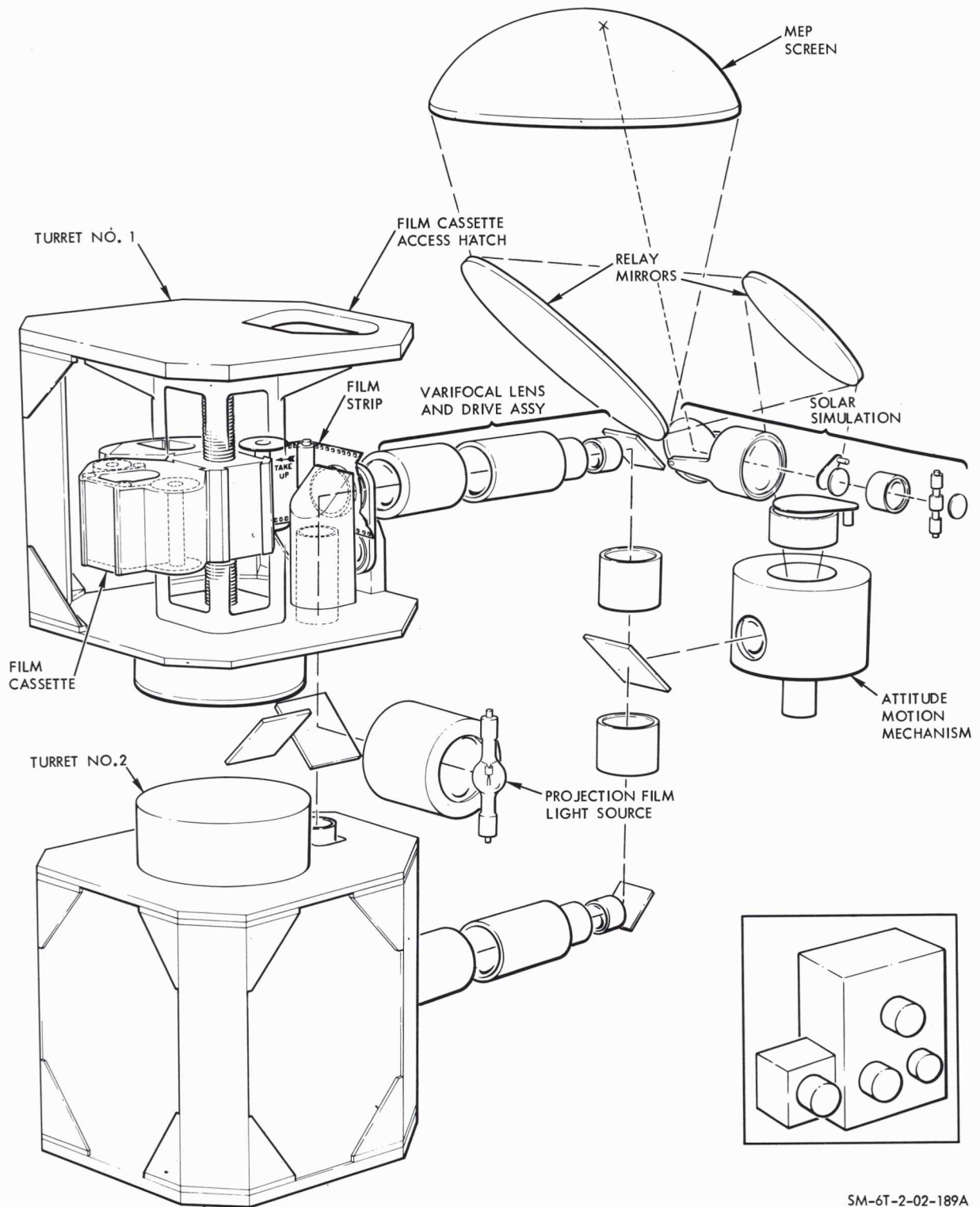
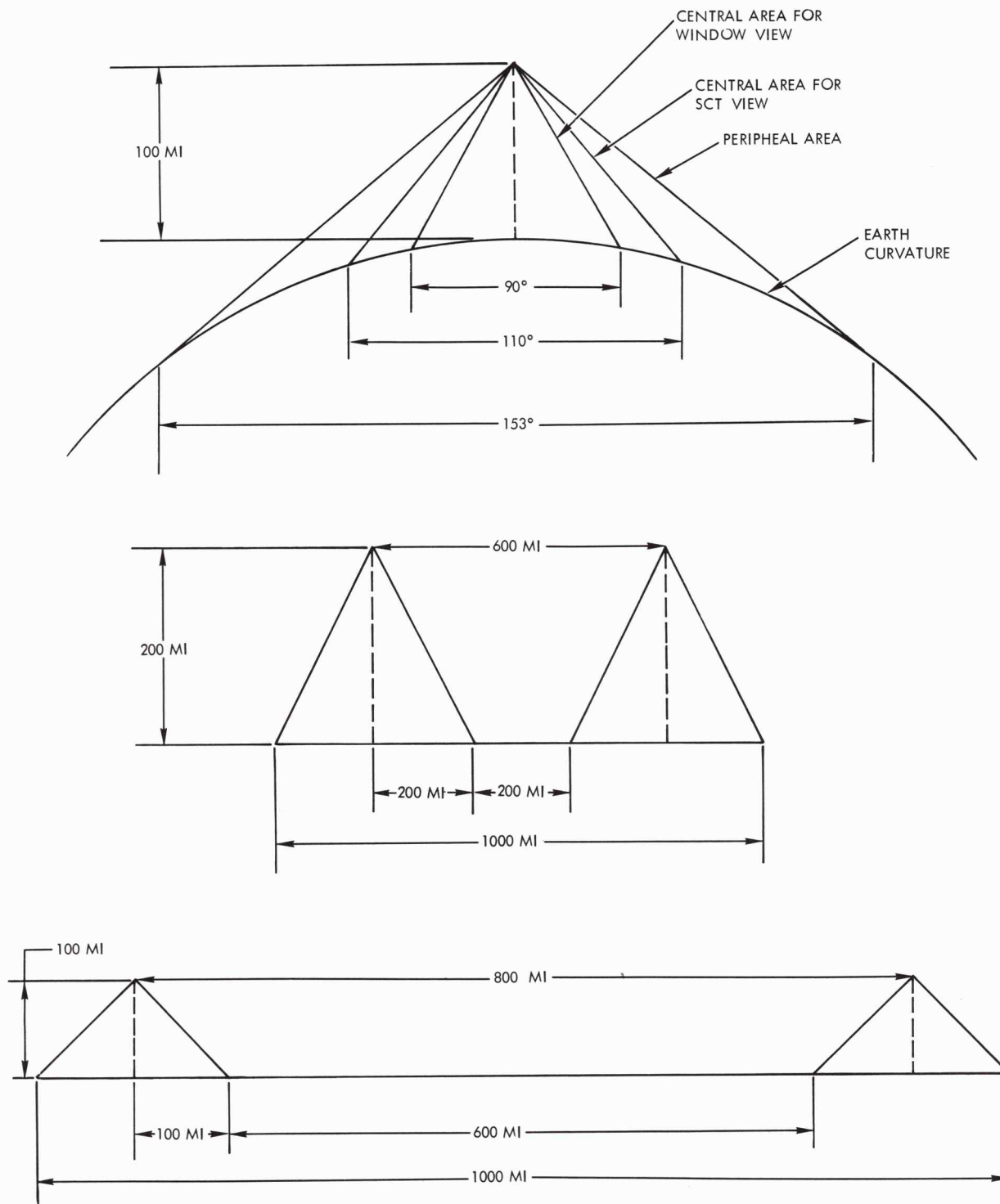


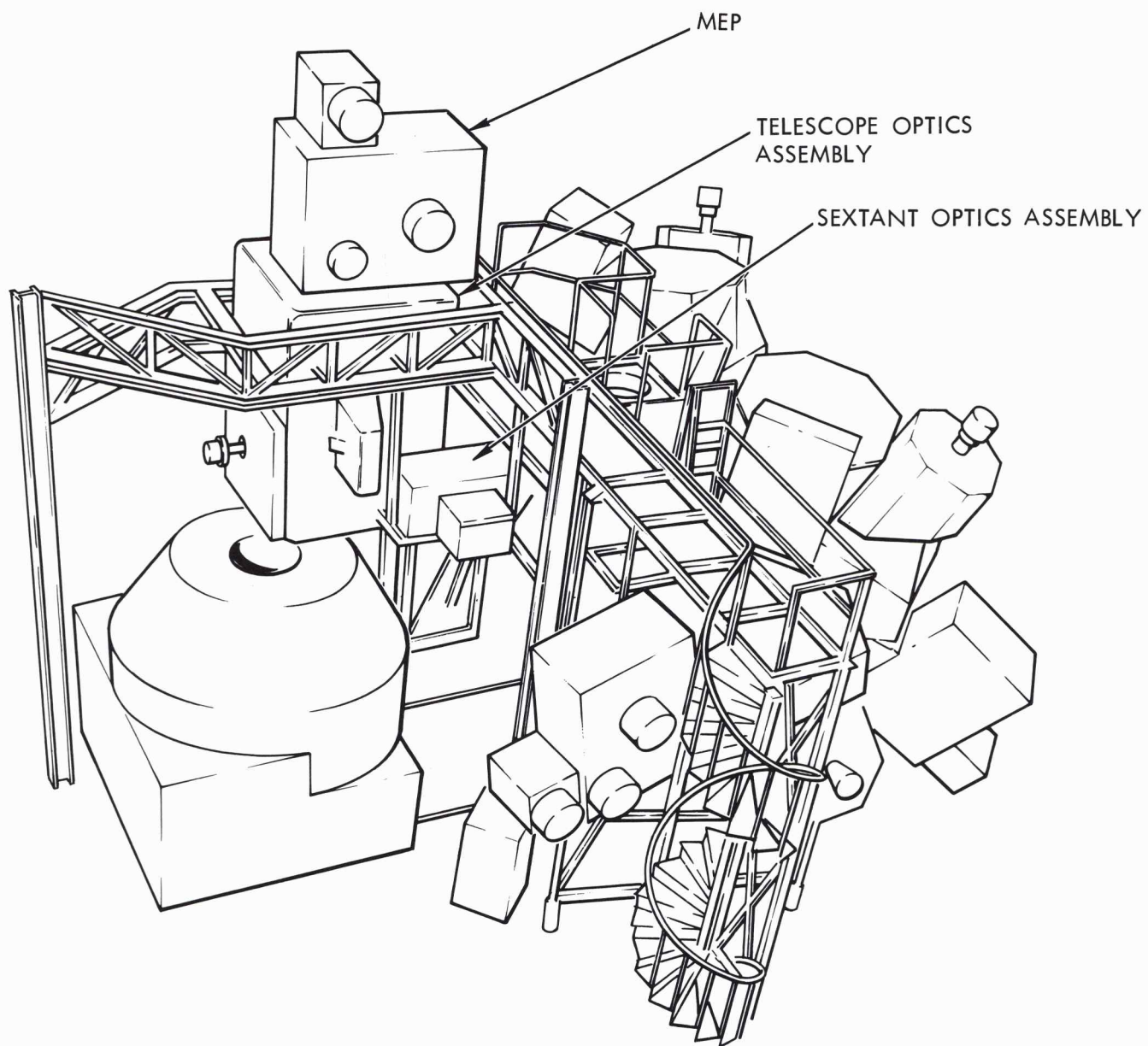
Figure 1-101. MEP Simplified Diagram

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Figure 1-102. Orbital Viewing Area



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Figure 1-103. SXT/SCT Optics Arrangement

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Table 1-73. AMS Terrestrial Landmarks (NAA)

L/M No.	Landmark	Latitude	Longitude	WAC Map	Country
1	Ponta Semepinguira	S 18° 10'	E 36° 50'	1175	Mozambique
2	Mouth of Ligonha River	S 16° 53'	E 39° 08'	1175	Mozambique
3	Utango	S 03° 58'	E 39° 45'	1031	Kenya
4	North tip Mafia Island	S 07° 38'	E 39° 55'	1031	Tanganyika
5	Mangrove	S 15° 58'	E 40° 08'	1175	Mozambique
6	Ras Ngomeni	S 02° 59'	E 40° 14'	931	Kenya
7	Lake Ihotry	S 22° 01'	E 43° 39'	1278	Malagasy Republic
8	Afombahy	S 12° 10'	E 44° 12'	1155	Malagasy Republic
9	Ambinany	S 22° 26'	E 47° 55'	1278	Malagasy Republic
10	North tip of Madagascar	S 11° 57'	E 49° 15'	1051	Malagasy Republic
11	Point of Andrangazave	S 16° 50'	E 49° 51'	1173	Malagasy Republic
12	Geraldton	S 28° 46'	E 114° 35'	1351	Australia
13	Cape Naturaliste	S 33° 32'	E 115° 00'	1461	Australia
14	Rockingham	S 32° 16'	E 115° 41'	1461	Australia
15	Cape Richards	S 18° 12'	E 146° 14'	1219	Australia
16	Long Island	S 22° 04'	E 149° 54'	1235	Australia
17	South tip Moreton Island	S 27° 22'	E 153° 26'	1340	Asutralia
18	Punta del Norte	N 29° 12'	W 118° 15'	472	Island off west coast of Mexico
19	Cap Rhir	N 30° 37'	W 09° 54'	454	Morocco
20	Cabo San Quintin	N 30° 22'	W 116° 00'	472	Baja California
21	Cabode San Agustin	N 28° 06'	W 115° 22'	472	Baja California
22	Puerto Penasco	N 31° 20'	W 113° 41'	472	Mexico

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Table 1-73. AMS Terrestrial Landmarks (NAA) (Cont)

L/M No.	Landmark	Latitude	Longitude	WAC Map	Country
23	South tip Isla Angel de la Guarda	N 29° 00'	W 113° 09'	471	Mexico
24	Punta Willard	N 28° 51'	W 112° 35'	471	Mexico
25	Punta Concepcion	N 26° 52'	W 111° 50'	520	Baja California
26	Punta Tosca	N 24° 19'	W 111° 42'	520	Baja California
27	Corpus Christi	N 27° 53'	W 97° 32'	522	USA
28	Tip on Galveston Bay	N 29° 33'	W 94° 48'	468	USA
29	Reservoir	N 30° 54'	W 94° 14'	468	USA
30	Point near Pensacola	N 30° 27'	W 87° 11'	467	USA
31	Island tip near Bull Bay	N 32° 56'	W 79° 34'	410	USA
32	Cape Fear	N 33° 50'	W 77° 58'	410	USA
33	Point on Western Bermuda	N 32° 18'	W 64° 52'	412	Island of Bermuda (G. B.)
34	Punta de la Fuencaliente	N 28° 27'	W 17° 51'	455	Canary Islands
35	Cap Blanc	N 20° 46'	W 17° 03'	575	Mauritania
36	Cap Timicis	N 19° 23'	W 16° 32'	658	Mauritania
37	Punta Durnford	N 23° 38'	W 16° 00'	575	Spanish Sahara
38	Punta de Jandia	N 28° 04'	W 14° 26'	455	Canary Islands
39	Ada	N 05° 46'	E 00° 40'	816	Ghana
40	South point of Ilhadesaotome	N 00° 02'	E 06° 31'	905	Sao Tome Island
41	Point on Ilhadoprincipe	N 01° 28'	E 07° 28'	905	Sao Tome Island
42	Point near Denis	N 00° 21'	E 09° 21'	905	Gabon
43	Punta da Marca	S 16° 31'	E 11° 42'	1179	Angola
44	Porto Alexandra	S 15° 47'	E 11° 47'	1150	Angola

. . . continued

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Table 1-73. AMS Terrestrial Landmarks (NAA) (Cont)

L/M No.	Landmark	Latitude	Longitude	WAC Map	Country
45	Ponta-do Giraul	S 15° 08'	E 12° 07'	1150	Angola
46	Cabo de Santa Marta	S 13° 52'	E 12° 26'	1150	Angola
47	But iaba	N 01° 50'	E 31° 19'	909	Uganda
48	Point near Nolimbi	N 01° 03'	E 30° 32'	909	Uganda
49	Durban	S 29° 52'	E 31° 04'	1398	South Africa
50	Point near Kanyiragya	N 01° 00'	E 31° 50'	932	Uganda
51	Shigrena	S 02° 48'	E 32° 55'	932	Tanganyika
52	Cabo da Inhaca	S 25° 58'	E 32° 59'	1299	Mozambique
53	Rugez	S 02° 07'	E 33° 12'	932	Tanganyika
54	Ilha do Bazaruto (Northend)	S 21° 31'	E 35° 29'	1276	Mozambique
55	Point south of Ilha Magarugue	S 22° 05'	E 35° 29'	1276	Mozambique
56	Gurada Fios	S 22° 55'	E 35° 34'	1276	Mozambique
57	Point Loma	N 32° 39'	W 117° 14'	404	USA
58	Santa Rosa Island West Tip	N 34° 00'	W 120° 15'	404	USA
59	Pueo Point	N 21° 54'	W 160° 04'	599	Niihau, Hawaiian Islands

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Table 1-74. AMS Selenograph Landmarks

Landmark	Longitude	Latitude
Pallas (west ridge, WR)	02° 02' West (W)	05° 30' North (N)
Gambart C (WR)	12° 00' W	03° 20' N
Eratosthenes (WR)	12° 20' W	14° 34' N
Gambart (WR)	15° 37' W	00° 50' N
Copernicus (WR)	21° 38' W	09° 50' N
Rheinhold (WR)	23° 32' W	03° 10' N
Tobias Mayer A (WR)	28° 36' W	15° 15' N
Encke (small crater east ridge, ER)	37° 00' W	04° 35' N
Bessarian (WR)	37° 31' W	14° 50' N
Kepler (WR)	38° 27' W	08° 10' N
Marius (WR)	51° 30' W	12° 00' N
Reiner (WR)	55° 26' W	06° 55' N
Cavalerius (high point, WR)	67° 51' W	04° 52' N
Alpetragius (WR)	05° 07' W	15° 50' South (S)
Ialande (WR)	08° 57' W	04° 40' S
Parry A (WR)	16° 12' W	09° 30' S
Darey (WR)	23° 46' W	14° 36' S
Iansberg (WR)	27° 14' W	00° 18' S
Gassendi A (WR)	40° 19' W	15° 40' S
Flamsteed (WR)	44° 37' W	04° 30' S
Hansteen (WR)	52° 42' W	10° 27' S
Hermann (WR)	57° 43' W	00° 56' S
Sirsalis (WR)	61° 06' W	12° 25' S
Lohrmann (WR)	67° 48' W	00° 30' S
Ukert (WR)	01° 02' East (E)	07° 45' North (N)
Hyginus (knee of Hyginus Rima)	06° 10' E	07° 45' N
Minilus (WR)	08° 25' E	14° 30' N
Godin (WR)	09° 33' E	01° 45' N
Arago (WR)	21° 00' E	06° 20' N
Plinius (WR)	22° 52' E	15° 25' N
Maskelyne (WR)	29° 40' E	02° 27' N
Taruntis (WR)	45° 30' E	05° 30' N
Halley (WR)	05° 10' E	08° 00' S
Abulfeda (WR)	12° 50' E	13° 35' S
Delambre (WR)	16° 34' E	02° 00' S
Kant (WR)	19° 42' E	10° 40' S
Theophilus (WR)	24° 40' E	11° 30' S
Capella (WR)	34° 08' E	07° 36' S
Goclenius (WR)	43° 46' E	09° 47' S
Messiar A (half moon ridge west of crater)	46° 37' E	02° 00' S
McClure C (WR)	49° 53' E	15° 20' S

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Table 1-75. AMS Navigation Stars

Noun Code	Generic Name	Star Name	Magnitude	Right Ascension	Declination
01	α Andromedae	Alpheratz	2.1	0:06:28.2	+28°53'10"
02	β Ceti	Deneb Kaitos (Diphda)	2.2	0:41:43.9	-18°11'22"
03	α Eridani	Achernar	0.6	1:36:20.3	-57°25'28"
04	* α Ursae Minoris	Polaris	2.1	1:57:53.8	+89°5'33"
05	α Arietis	Hamal	2.2	2:05:04.9	+23°17'18"
06	* α Fornax	Alpha Fornax	3.9	3:10:29.9	-29°7'55"
07	α Persei	Marfak	1.9	3:21:40.2	+49°43'52"
08	α Tauri	Aldebaran	1.1	4:33:47.7	+16°26'11"
09	α Canis Majoris	Sirius	-1.6	6:43:31.1	-16°39'50"
10	β Geminorum	Pollux	1.2	7:43:03.3	+28°7'2"
11	* γ Velorum	Gamma Velorum	1.9	8:08:23.5	-47°13'37"
12	α Carinae	Mioplacidus	1.8	9:12:48.2	-69°33'53"
13	α Hydrae	Alphard	2.2	9:25:46.1	-8°29'51"
14	α Leonis	Regulus	1.3	10:06:24.2	+12°8'55"
15	α Ursae Majoris	Dubhe	1.9	11:01:27.6	+61°57'4"
16	* γ Centauri	Gamma Centauri	2.4	12:39:28.0	-48°45'25"
17	α Virginis	Spica	1.2	13:23:14.4	-10°58'8"
18	η Ursae Majoris	Alkaid	1.9	13:46:05.0	+49°29'50"
19	α Bootis	Arcturus	0.2	14:13:58.4	+19°22'27"
20	α Centauri	Rigil Kentaurus	0.1	14:37:04.3	-60°41'2"
21	α Scorpii	Antares	1.2	16:27:08.1	-26°21'6"
22	α Ophiuchi	Rasalhague	2.1	17:33:12.9	+12°35'8"
23	α Lyrae	Vega	0.1	18:35:41.1	+38°44'53"
24	* β Capricornus	Beta Capricornus	3.2	20:18:56.0	-14°53'59"
25	α Pavonis	Peacock	2.1	20:22:43.9	-56°51'20"
26	α Cygni	Deneb	1.3	20:40:10.1	+45°8'50"
27	ϵ Pegasi	Enif	2.5	21:42:22.0	+9°42'16"
28	α Piscis Austrini	Fomalhaut	1.3	22:55:36.6	-29°49'8"

*Not accurately positioned for navigation purposes on the celestial sphere.

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SECTION 2

SYSTEM SIMULATION

2.1 PURPOSE AND SCOPE.

This section of the instructor handbook is provided to familiarize the instructor-operator with the extent and manner of simulation of spacecraft systems in the AMS. Such understanding is required for three purposes.

- a. To effectively use simulated malfunctions in accordance with the syllabus outlined in section 3 (AMS Utilization) of Volume II and the training session data provided as section 1 of Volume III
- b. To debrief flight crewmembers after training sessions in which simulated malfunctions and MSFN telemetry data have been used
- c. To plan simulation/training runs above and beyond those outlined in the syllabus.

Each system simulated is supported with the following descriptive information:

- a. A description of the spacecraft system simulated by the AMS. The description includes a spacecraft system flow diagram depicting the simulated malfunctions, system controls and displays, and telemetry instrumentation points.
- b. A description of the manner and extent of simulation of each spacecraft system.
- c. A table of simulated malfunctions for the spacecraft system including identifying number, title, description, and crew response information. This table is bound in section 4 of Volume III for quick-reference use at the IOS.
- d. A table of simulation output data for use in selecting output parameters to be assigned to pen recorders, TM fault channels, on-line digital devices, etc. The table defines each parameter, provides correlated computer address and switching data, and includes scaling requirements, if any. This table is bound as section 5 of Volume III for quick-reference use at the IOS.

2.2 SYSTEMS CONFIGURATION.

The simulated spacecraft systems configuration in the initial delivered AMS is a function of the date of AMS design freeze. In general, the systems configuration is that of AF006 with some remnants of BP014 and some post-AF006 characteristics based on preliminary design data for manned AF011. Table 2-1 lists the spacecraft systems represented in the AMS and identifies the specific spacecraft (or boilerplate) configuration of each simulated system. Simulated spacecraft configuration with respect to operational spacecraft (or boilerplate) is also the subject of the Configuration Reference discussions provided for each system in this section of the handbook.

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Table 2-1. Simulated Systems Configuration Reference Data

Spacecraft System	Spacecraft Simulated	Remarks
C/M and S/M reaction control system	AF006 and BP014	Some minor switch difference from AF006/BP014 (See paragraph 2.3.1.)
Stabilization and control system	AF006	AMS: mode selection by push-button, no-limit cycle switch, SCS power switching.
Sequence control group (LES, ELS, AS)	BP014	AMS has different controls and displays arrangement than BP014. AMS has NO AUTO ABORT not in BP014.
Environmental control system	AiResearch Dwg. No. 848140 (no specific AF or BP)	Significant difference in controls and displays between AMS and AF006, BP014, and AF012.
Service propulsion system	AF006	None
Electric power system	BP014	Minor controls and displays differences with BP014. Significant controls and displays differences with AF012.
Communications and data system	AF012	Minor differences in controls and displays.
Guidance and navigation system	AF012	Photometer controls in IDC, not in AF011.

The purpose of the Preliminary AMS Instructor Handbook is to provide instructions for the use of the AMS initial delivered configuration in training flight crews for mission 204A. Since mission 204A is to be accomplished with AF012, there is a significant difference between spacecraft configuration for the operational mission and simulated systems configuration in the AMS. Table 2-2 lists the differences between the AF012 controls and displays and the SCM controls and displays. Each of the system simulation discussions in this section of the handbook includes a gross statement of comparison. More detailed analysis of the differences between AF012 and the AMS can be made by comparing the contents of this volume of the instructor handbook with SM2A-03 (Apollo Operations Manual).

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Table 2-2. Controls and Displays, AF 012 versus AMS

Panel	AF012	AMS
1	Altimeter panel	Same (baro)
2	FDAI brightness FDAI SELF TEST sw	Not provided Not provided
3	SPS-LV AOA panel LV AOA-SPS pc-sw LV AOA SPS pc-ind SPS INJECT PRE-VALUES A and B sw Not provided Not provided Not provided	Ind and sw not provided Not provided Not provided Not provided MS ARM PYRO and LOGIC lt TWR ARM A and B lt IFTS sw (inoperative)
4	FDAI (Block K)	Same (Block F)
5	EDS panel APEX COVER JETT sw LES MOTOR FIRE sw CANARD DEPLOY Panel 8 Panel 16 Not provided Not provided Not provided Not provided Not provided Not provided	HS JETT sw LES MTR FIRE-NO SEP sw-lt Not provided Timer controls C/M-S/M SEP sw OX DUMP sw TWR JETT-NO SEP sw-lt ELS ARMED - PYRO-LOGIC lt MOTOR FIRE-NO SEP sw-lt ADPT SEP ARM-ARMED sw-lt MOTOR JETT NO SEP sw-lt
6	Attitude set gimbal position panel	Same
7	Delta V panel	Same
8	Panel DIRECT MODE sw LIMIT CYCLE sw ELS LOGIC sw Digital timer sw COUCH UNLOCK PROPELLANT JETT-LOGIC sw PROPELLANT JETT-DUMP sw PROPELLANT JETT-PURGE sw	HAND CONTROLLER sw, panel 16 Not provided ELS sw, panel 16 Panel 5 Not provided Not provided FUEL DUMP sw, panel 16 RCS PURGE sw, panel 16
9	Combined with panel 8	Blank
10	LH C&W lt Panel 11	CAUT-WARN FAIL lt

. . . continued

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Table 2-2. Controls and Displays, AF012 Versus AMS (Cont)

Panel	AF012	AMS
11	RH C&W lights O ₂ FLOW HI lt CO ₂ PP HI lt CAUT-WARN FAIL lt Not provided C/W LAMP TEST sw, panel 23 Not provided Not provided	Panel 12 Panel 10 Panel 10 IFTS lt CAUTION-WARNING TEST-ON-OFF sw (TEST POSITION) O ₂ PRESS H ₂ PRESS
12	RCS quantity Panel 11	O ₂ FLOW HI lt
13	Cryogenics and ECS CAUTION-WARN sw H ₂ and O ₂ FANS sw (4) PRESS IND sw H ₂ O ACCUM sw (2) SUIT EVAP sw H ₂ O FLOW sw BACK PRESS sw (2) TEMP IN sw WASTE H ₂ O TK REFILL Not provided Not provided	Not provided Not provided Not provided Not provided Not provided Not provided Not provided Not provided Not provided OXYGEN shutoff sw and event ind (2) HYDROGEN shutoff sw and event ind (2)
14	AGC	Same
15	RCS controls	Same
16	Crew Safety LES MODE sw C/M-S/M SEP sw RCS-CMD sw ELS LOGIC sw, panel 8 DIRECT MODE sw, panel 8 Panel 8 Panel 8 Not provided	Not provided Panel 5 Not provided ELS sw HAND CONTROLLER sw FUEL DUMP sw RCS PURGE sw MODE sw
17	HF ANTENNA sw	Not provided
18	EPS	Same

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Table 2-2. Controls and Displays, AF012 Versus AMS (Cont)

Panel	AF012	AMS
19	S-band ant ind panel	Contains all S-band slew and deploy sw and ind
	Panel 20	S-BAND ANT selector sw
20	Comm-SPS panel	Not provided
	SPS TANK PRESS	Not provided
	PWR AMPL OSC - XPONDER sw	Panel 19
	S-BAND ANTENNA sw	
21	RH bus switching	Not provided
	RCS HEATERS C/B (4)	Not provided
	SNSR UNIT C/B (4)	Panel 22
	ECS GLYCOL PUMP sw	Panel 22
	CABIN AIR FAN sw	Not provided
	POT H ₂ O HEATER sw	MAIN BUS TIE - BAT A sw, BAT C connect not provided
	Panel 22	MAIN BUS TIE - BAT B sw, BAT C connect not provided
	Panel 22	INV 3 bus select sw (duplicate sw in AMS)
	Panel 18	BATT CHGR sw
	Panel 22	NON ESS BUS sw
	Panel 22	ESS T/C sw
	Panel 22	NON ESS T/C sw
	Panel 22	
22	RH circuit breaker	Not provided
	SCIEN EQUIP HATCH C/B	Not provided
	SCIEN EQUIP C/B (2)	Panel 21, no BAT C connect
	MAIN BUS TIE - BAT A and C sw	Panel 21, no BAT C connect
	MAIN BUS TIE - BAT B and C sw	Panel 21
	NON ESS BUS sw	Panel 21
	BAT CHGR sw	Panel 21
	ESS T/C sw	Panel 21
	NON ESS T/C sw	Panel 21
	CRYO SYST FANS C/B (6)	Not provided
	H ₂ O ACCUM C/B	Not provided
	INSTRUMENTS C/B, PAM XMTR	Not provided
	INSTRUMENTS C/B, GAS ANAL	Not provided
	INSTRUMENTS C/B, SCIEN	Panel 25
	TRANSDUCER - WASTE & POT	Not provided
	H ₂ O C/B (2)	
	TRANSDUCER - PRESS GROUPS	2 C/B
	C/B (4)	
	Not provided	CABIN TEMP cont C/B
	Not provided	CRYOGENIC C/B (2)

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Table 2-2. Controls and Displays, AF012 Versus AMS (Cont)

Panel	AF012	AMS
22 (Cont)	Panel 21 Panel 21 Not provided	CABIN AIR FAN sw (2) COOL PUMP sw Glycol SOV C/B
23	Comm and lighting COMM Lighting C/W LAMP TEST sw Not provided	Same Not provided LAMP TEST - C/D
24	LH bus switching TVC 1 POWER sw TVC 2 POWER sw ROTATION CONTROL POWER sw PARTIAL SCS POWER sw RATE GYRO sw BMAG POWER sw DIRECT O ₂ control Panel 25 Panel 25 Panel 25	Not provided Not provided Not provided Not provided Panel 25 Panel 25 Not provided RECOVERY PYRO ARM sw HF ANT sw RECOVERY BEACON sw
25	RH circuit breaker panel Float bag C/B (4) VENT FAN sw and C/B POST LAND - ANT PYRO sw POST LAND - ANT ARM sw POST LAND - BEACON lt Event timer C/B (2) SCS GP1 and GP2 C/B (4) BIO MED C/B (2) C&W C/B Not provided Not provided Panel 22 Not provided Not provided Not provided Not provided Panel 24 Panel 24 Not provided	Not provided Not provided Panel 24 Panel 24 Panel 24 Not provided Not provided Not provided Not provided D&C COMP C/B (2) WASTE MANGEMENT C/B (3) SCIENTIFIC INST C/B IFTS C/B (2) PROPELLANT JETT C/B (4) SCS JETT PWR C/B (2) SCS POWER sw RATE GYRO sw DELTA V ACCEL PWR sw AGAP POWER sw
26	RH comm and ltg panel EDS/SEQ lamp test sw Lighting Not provided	Not provided Same LAMP TEST - A/B sw

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2.3 C/M AND S/M REACTION CONTROL SYSTEM.

2.3.1 RCS CONFIGURATION REFERENCE.

The command module and service module reaction control systems in the AMS are basically the same as those found in AF006 and BP014. The RCS circuit breakers on panel 25 are, however, arranged differently.

With respect to AF012 controls and displays, the initial delivered configuration includes an RCS override enable switch. The switch is in accordance with AF006, but has been redesignated "RCS Command Switch" in AF012.

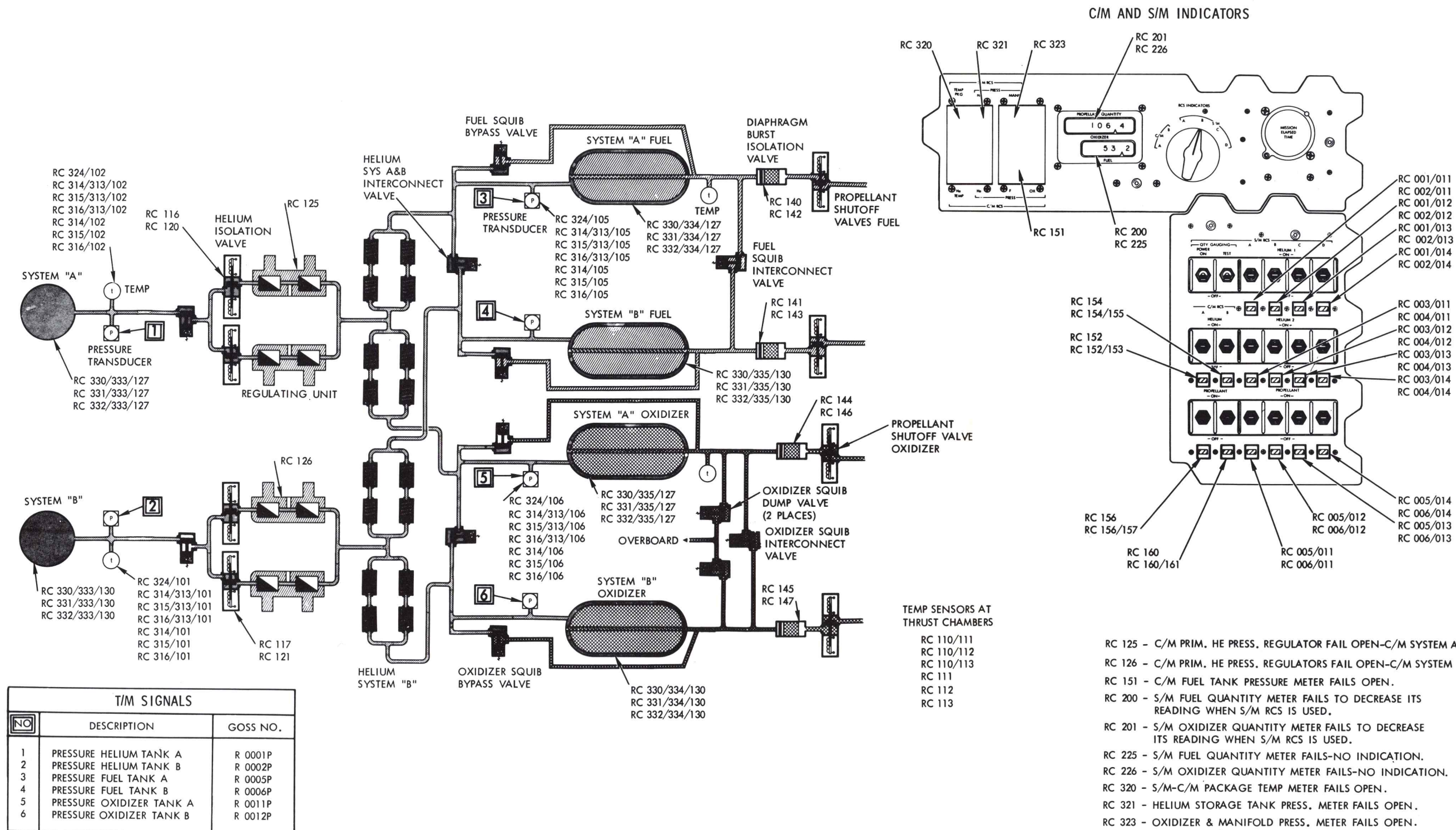
2.3.2 SIMULATED C/M-RCS (S/C EQUIVALENT).

Figure 2-1 illustrates the functional flow of the AF006-BP014 command module RCS system simulated in the initial delivered configuration of the AMS. The flow diagram includes identification of the simulated C/M-RCS telemetry points. Tables 1 thru 8 (in figure 2-1) identify the simulated C/M-RCS malfunctions in direct relationship to the flow diagram.

The C/M-RCS consists of two identical and independent systems. These are identified as system A and system B as shown in figure 2-1. Both systems are operated simultaneously and in case of a malfunction in one system, the remaining system can provide the impulse required to perform necessary pre-entry and entry maneuvers. In case of emergency, the two systems may be interconnected by squib valves. The major components of each system are a helium pressurization supply; check valves; relief valves; propellant tanks; propellant isolation valves; rocket engines; fill and vent valves; and pressure, temperature, and quantity sensors.

The systems are maintained in a depressurized state until ready for use prior to entry. At that time, squib valves are activated between each of the helium tanks and their regulators. Rupture disks in the propellant tank outlets will maintain a perfect seal until the tanks are pressurized. When the propellant tanks are pressurized at C/M-S/M separation, the burst diaphragms rupture to provide propellants to the shutoff valves. The solenoid-operated helium isolation valves are normally open. They may be closed by the crew if a malfunction develops downstream of the propellant tanks. This would cause the system to be inoperative.

The propellants may be jettisoned from the tanks in one of two sequences. In an abort between the pad and T + 35 seconds (42 seconds in AF012), the oxidizer will be expelled automatically through the oxidizer dump valve and line. At main parachute line stretch, the fuel will be dumped through the -X, +Y, -Y, +Z, and -Z RCS engines. In aborts later than T + 35 seconds or normal entry, both fuel and oxidizer are burned through the 10 RCS engines (-X, +Y, -Y, +Z, -Z). This burning is the result of manually activating the fuel dump switch.



HELIUM ISOLATION VALVE INDICATOR FAILS		
1	ON	OFF
S/M A #1	RC 001/011	RC 002/011
S/M B #1	RC 001/012	RC 002/012
S/M C #1	RC 001/013	RC 002/013
S/M D #1	RC 001/014	RC 002/014
C/M A	RC 152	RC 152/153
C/M B	RC 154	RC 154/155

C/M RCS SYS A&B TEMP CONTROL		
4	INCREASE	DECREASE
10°	RC 110/111	RC 111
15°	RC 110/112	RC 112
15°	RC 110/113	RC 113
THESE MALFS MAY BE COMBINED TO PROVIDE A MAX OF 40° INCREASE OR DECREASE.		

HELIUM ISOLATION VALVE #2 INDICATOR FAILS		
2	ON	OFF
S/M A	RC 003/011	RC 004/011
S/M B	RC 003/012	RC 004/012
S/M C	RC 003/013	RC 004/013
S/M D	RC 003/014	RC 004/014

C/M He ISOLATION VALVES FAIL		
5	OPEN	CLOSED
C/M A	RC 120	RC 116
C/M B	RC 121	RC 117

PROPELLANT ISOLATION VALVE POSITION IND. FAILS		
3	ON	OFF
S/M A	RC 005/011	RC 006/011
S/M B	RC 005/012	RC 006/012
S/M C	RC 005/013	RC 006/013
S/M D	RC 005/014	RC 006/014
C/M A	RC 156	RC 156/157
C/M B	RC 160	RC 160/161

6	C/M ISOLATION VALVES FAIL			
	FUEL		OXIDIZER	
	OPEN	CLOSED	OPEN	CLOSED
C/M A	RC 142	RC 140	RC 146	RC 144
C/M B	RC 143	RC 141	RC 147	RC 145

7	C/M RCS SYSTEM A		C/M RCS SYSTEM B	
SENSOR OUTPUT	He STORAGE TANK PRESS. SENSOR FAILS	OXIDIZER TANK PRESS. SENSOR FAILS	He STORAGE TANK TEMP SENSOR FAILS	FUEL TANK PRESS. SENSOR FAILS
ZERO	RC 324/102	RC 324/106	RC 324/101	RC 324/105
1/7TH HIGH	RC 314/313/102	RC 314/313/106	RC 314/313/101	RC 314/313/105
2/7TH HIGH	RC 315/313/102	RC 315/313/106	RC 315/313/101	RC 315/313/105
4/7TH HIGH	RC 316/313/102	RC 316/313/106	RC 316/313/101	RC 316/313/105
1/7TH LOW	RC 314/102	RC 314/106	RC 314/101	RC 314/105
2/7TH LOW	RC 315/102	RC 315/106	RC 315/101	RC 315/105
4/7TH LOW	RC 316/102	RC 316/106	RC 316/101	RC 316/105
NOTE: THESE MALFS MAY BE COMBINED TO PROVIDE A MAXIMUM OF 7/7TH HIGH OR LOW SENSING.				

8	HELIUM STORAGE TANK LEAK	FUEL TANK ULLAGE He LEAK	OXID TANK ULLAGE He LEAK	
LEAKAGE RATE	C/M A	C/M B	C/M A	C/M B
1/7TH MAX	RC 330/333/127	RC 330/333/130	RC 330/334/127	RC 330/334/130
2/7TH MAX	RC 331/333/127	RC 331/333/130	RC 331/334/127	RC 331/334/130
4/7TH MAX	RC 332/333/127	RC 332/333/130	RC 332/334/127	RC 332/334/130
SEE NOTE - CHART 7.				

Figure 2-1. C/M Reaction Control System

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Under normal operating conditions the engine firing commands come from the SCS or the rotational hand controller. The C/M-RCS is capable of making changes in spacecraft attitude only. All translation must be accomplished prior to C/M-S/M separation.

2.3.3 SIMULATED S/M-RCS (S/C EQUIVALENT).

Figure 2-2 illustrates the functional flow of the AF006-BP014 service module RCS simulated in the initial delivered configuration of the AMS. The flow diagram includes identification of the simulated S/M-RCS telemetry points. Tables 9 thru 15 (in figure 2-2) identify the simulated S/M-RCS malfunctions in direct relationship to the flow diagram.

The S/M-RCS consists of four mechanically independent quads located at 90-degree intervals about the service module. The spherical helium storage tank is manifolded to two parallel lines. In each parallel line there is a helium isolation valve and a pressure regulator. The reduced pressure outputs from the regulators are manifolded together and fed to two sets of parallel redundant check valves. These valves keep propellant vapors from mixing in the helium manifold. Propellants are stored in positive expulsion bladders within their respective tanks. Propellant shutoff valves are located at the propellant tank outputs and will be used in case of quad malfunction. The fuel and oxidizer shutoff valves are similar in operation to the C/M-RCS isolation valves and are controlled in the same manner.

Propellant quantities are read from the S/M-RCS by a nucleonic quantity sensing system inside each propellant tank. This system, consisting of radiation blankets and scintillator rods, provides fuel and oxidizer quantities at all times, even during coast periods.

2.3.4 C/M- AND S/M-RCS SIMULATION.

Switches on S/C panels 5, 15, and 16, and circuit breakers on S/C panel 25 constitute the discrete inputs to the RCS equations in the AMS. They will enable the computer to establish the condition of each system of the C/M and S/M-RCS. The computer will consider these switch and circuit breaker positions in determining the status and availability of each RCS reaction jet. The status of each RCS system will be displayed on S/C panel 12. Inputs from the SCS equations will control selection and firing time of the reaction jets.

A pressure or temperature out of tolerance in any RCS system will cause a warning indicator to illuminate on S/C panel 10. For further clarification on the type of malfunction existing, the crew must analyze the indicators on S/C panel 12.

Each of the helium isolation valves (eight in the S/M and two in the C/M) and each of the propellant isolation valves (four in the S/M and two in the C/M) activates a talk-back indication in the command module providing the crew with each valve position. These talk-back and warning indications are provided as outputs of the computer complex. The computer also integrates propellant flow

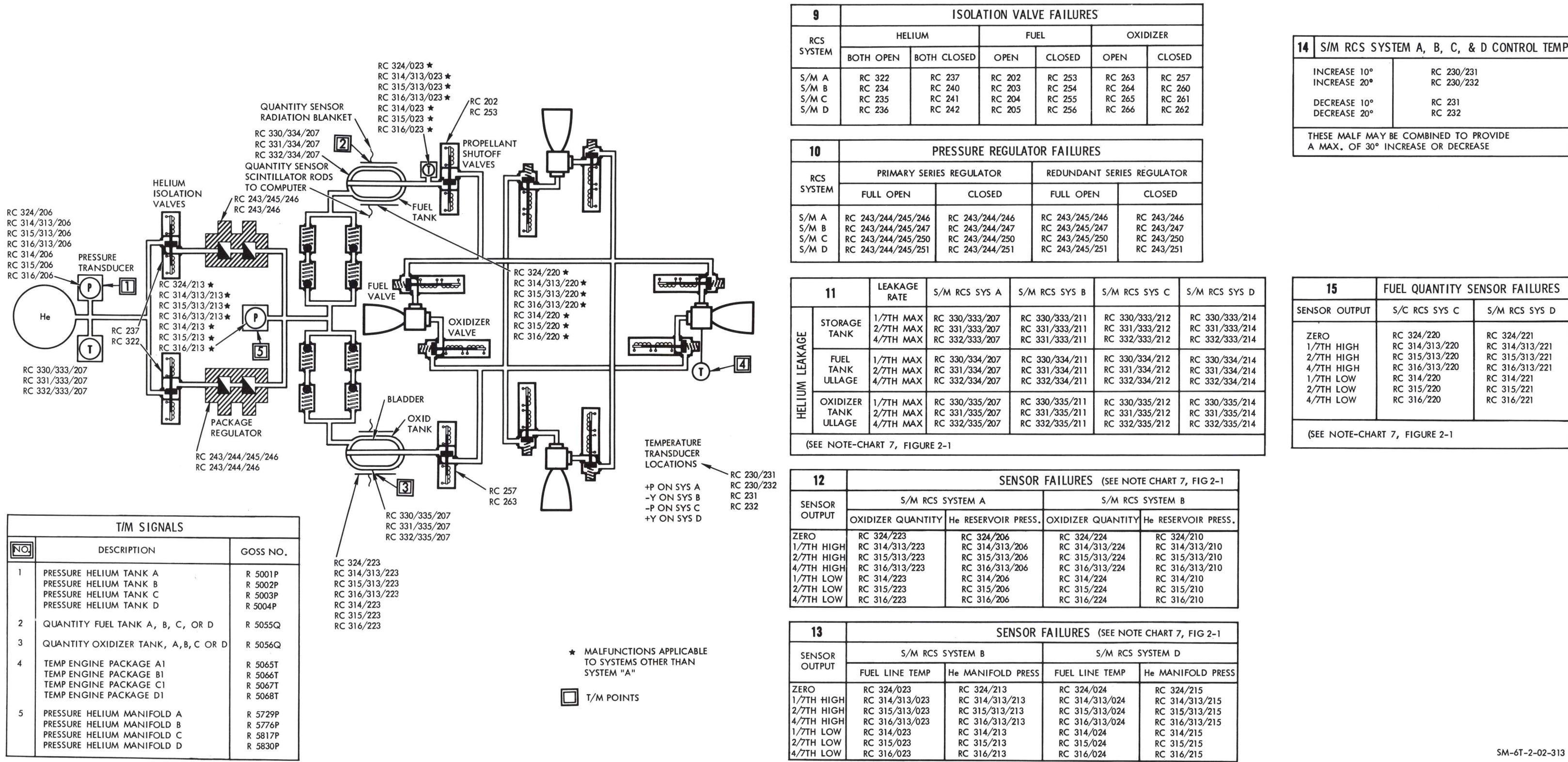


Figure 2-2. S/M Reaction Control System

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rates to give total fuel and oxidizer quantities remaining in each RCS system. The S/M-RCS propellant quantities are made available for display in the C/M and at the IOS.

2.4 STABILIZATION AND CONTROL SYSTEM.

2.4.1 SCS CONFIGURATION REFERENCE.

The stabilization and control system simulated in the AMS is similar to that of AF006 at the time of AMS design freeze. Changes in AF006 design after AMS freeze resulted in relocation of SCS POWER SWITCH BREAKERS, deletion of the JET POWER SWITCHES A and B on panel 25, and redesignation of the HAND CONTROL DIRECT ENABLE SWITCH. None of these three changes have been incorporated in the initial delivered configuration of the AMS.

The simulated SCS system further differs from AF012 in that AF012 includes a limit-cycle switch on panel 8 (which control pseudo rate feedback), and separate power switches for various SCS components. In addition, SCS mode switching in the AMS is by back-lighted pushbuttons whereas the SCS mode selection in AF012 is by toggle switches.

2.4.2 SIMULATED SCS (S/C EQUIVALENT).

The spacecraft SCS system performs four major dynamic functions. All are simulated in the AMS and all are discussed in this section of the instructor handbook. The four functions are as follows:

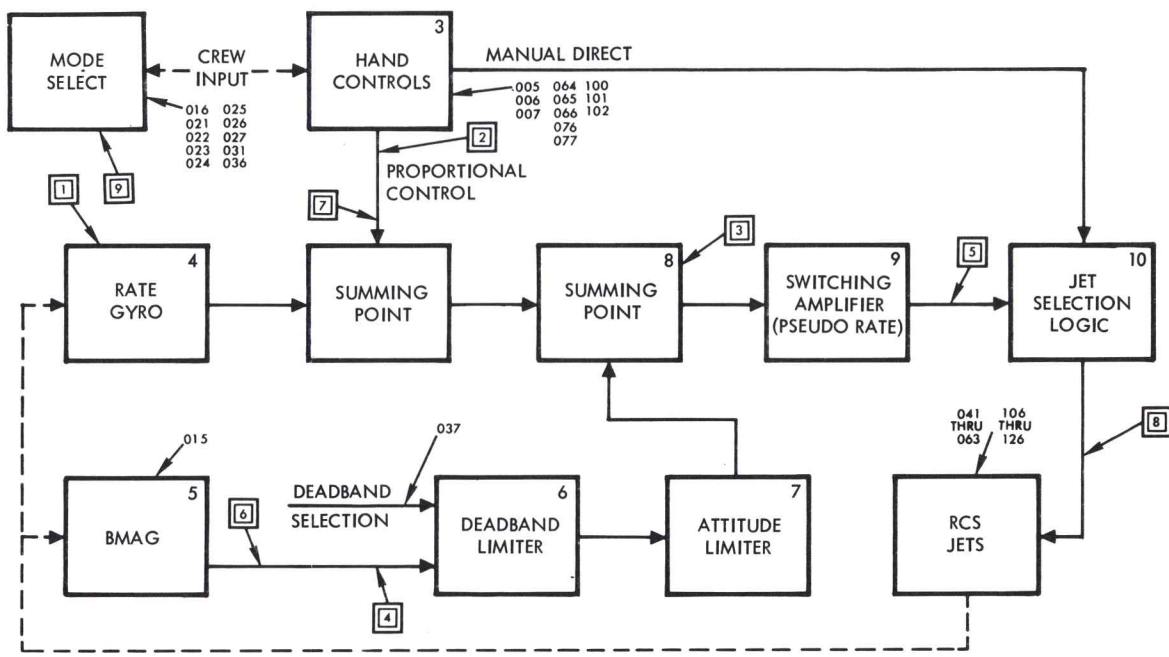
- a. Rotational and translational control in the automatic G&N mode, the semiautomatic SCS mode, and by direct manual control of the RCS reaction jets
- b. Stabilization of spacecraft under G&N control
- c. Thrust vector control while in SPS powered flight
- d. Display of dynamics information to the flight crew on the spacecraft display panels.

2.4.2.1 Attitude Control.

The flight crew may control spacecraft attitude in either the SCS or the G&N mode. The flight crew may also choose the sensitivity of the attitude control system by means of the DEADBAND SELECT SWITCH. The deadband inhibits the firing of the RCS in response to error signals of less than 0.5 degree or 5.0 degrees, thereby limiting the S/C movement during attitude control maneuvers.

Figure 2-3 illustrates the simulated attitude control system in block diagram form. The figure includes the simulated SCS malfunctions and telemetry points.

Under normal conditions spacecraft attitude signals are input to the SCS from the G&N system. SCS backup for attitude signals is the body-mounted attitude gyros (BMAG-block 5 of figure 2-3). Spacecraft attitude rate signals are provided by the SCS rate gyro package (RGP-block 4 of figure 2-3) with the BMAG acting as backup. If the G&N system should fail, the BMAGs may be



SCS ATTITUDE CONTROL SYSTEM T/M SIGNAL		
NO.	SIGNAL DESCRIPTION	GOSS NO.
1	PITCH RATE YAW RATE ROLL RATE	H0024V H1024V H2024V
2	PITCH MONITOR ROTATION CONTROL YAW MONITOR ROTATION CONTROL ROLL MONITOR ROTATION CONTROL	H0025V H1025V H2025V
3	PITCH INTEGRATOR/ATT. ERROR SUMMING YAW INTEGRATOR/ATT. ERROR SUMMING	H0067V H1067V
4	PITCH SCS ATTITUDE ERROR YAW SCS ATTITUDE ERROR ROLL SCS ATTITUDE ERROR	H0075V H1075V H2075V
5	ROLL ATTITUDE ERROR AMP. OUTPUT	H2070V
6	COMBINED ATTITUDE GYRO TEMP.	H3017T
7	ROLL ECA +Z TRANSLATION STICK CONDITION ROLL ECA -Z TRANSLATION STICK CONDITION ROLL ECA +Y TRANSLATION STICK CONDITION	H2081X H2082X H2083X
8	REACTION JET #9 SOLENOID DRIVER OUT REACTION JET #10 SOLENOID DRIVER OUT REACTION JET #11 SOLENOID DRIVER OUT REACTION JET #12 SOLENOID DRIVER OUT REACTION JET #13 SOLENOID DRIVER OUT REACTION JET #14 SOLENOID DRIVER OUT REACTION JET #15 SOLENOID DRIVER OUT REACTION JET #16 SOLENOID DRIVER OUT	H2087X H2088X H2089X H2090X H2091X H2092X H2093X H2094X
9	SCS LOCAL VERTICAL CONTROL MODE SCS DELTA V MODE G&N DELTA V MODE G&N DELTA V MODE SCS DELTA V MODE SCS LOCAL VERTICAL CONTROL MODE	H4201X H4337X H4338X H0100X H1100X H1103X

SCS ATTITUDE CONTROL SYSTEM MALFUNCTIONS			
MALF. NO.	MALFUNCTION DESCRIPTION	MALF. NO.	MALFUNCTION DESCRIPTION
SC 005	ROLL ROTATIONAL HAND CONTROLLER FAILS OPEN	SC 065	TRANSLATIONAL CONTROL (-Y DIRECTION) FAILS OPEN
SC 006	PITCH ROTATIONAL HAND CONTROLLER FAILS OPEN	SC 066	TRANSLATIONAL CONTROL (+Z DIRECTION) FAILS OPEN
SC 007	YAW ROTATIONAL HAND CONTROLLER FAILS OPEN	SC 076	ROTATIONAL CONTROL +P MICROSWITCH FAILS OPEN
SC 015	"g" LEVEL DETECTOR FAILS OPEN	SC 077	ROTATIONAL CONTROL -Q MICROSWITCH FAILS OPEN
SC 016	MINIMUM IMPULSE ENABLE SWITCH FAILS OPEN	SC 100	ROTATIONAL CONTROL +R MICROSWITCH FAILS OPEN
SC 021	MONITOR MODE SELECT SWITCH FAILS OPEN	SC 101	MIN. IMPULSE CONTROL - P MICROSWITCH FAILS OPEN
SC 022	SCS ATTITUDE CONTROL SELECT SWITCH FAILS OPEN	SC 102	MINIMUM IMPULSE CONTROL - R MICROSWITCH FAILS OPEN
SC 023	SCS LOCAL VERTICAL SELECT SWITCH FAILS OPEN	SC 106	REACTION JET #9 FAILS OFF (S/M-C/M)
SC 024	G&N ATTITUDE CONTROL SELECT SWITCH FAILS OPEN	SC 107	REACTION JET #10 FAILS ON (S/M-C/M)
SC 025	SCS ΔV MODE SELECT SWITCH FAILS OPEN	SC 111	REACTION JET #10 FAILS OFF (S/M-C/M)
SC 026	G&N ΔV MODE SELECT SWITCH FAILS OPEN	SC 112	REACTION JET #11 FAILS ON (S/M-C/M)
SC 027	SCS ENTRY MODE SELECT SWITCH FAILS OPEN	SC 113	REACTION JET #11 FAILS OFF (S/M-C/M)
SC 031	G&N ENTRY MODE SELECT SWITCH FAILS OPEN	SC 114	REACTION JET #12 FAILS ON (S/M-C/M)
SC 036	0.05g SENSE BACKUP SWITCH FAILS OPEN	SC 115	REACTION JET #12 FAILS OFF (S/M-C/M)
SC 037	DEADBAND SELECT SWITCH SHORTED TO 0.5° POS.	SC 116	S/M REACTION JET #13 FAILS ON
SC 041	REACTION JET #1 FAILS ON (S/M-C/M)	SC 117	S/M REACTION JET #13 FAILS OFF
SC 042	REACTION JET #1 FAILS OFF (S/M-C/M)	SC 121	S/M REACTION JET #14 FAILS ON
SC 043	REACTION JET #2 FAILS ON (S/M-C/M)	SC 122	S/M REACTION JET #14 FAILS OFF
SC 044	REACTION JET #2 FAILS OFF (S/M-C/M)	SC 123	S/M REACTION JET #15 FAILS ON
SC 045	REACTION JET #3 FAILS ON (S/M-C/M)	SC 124	S/M REACTION JET #15 FAILS OFF
SC 046	REACTION JET #3 FAILS OFF (S/M-C/M)	SC 125	S/M REACTION JET #16 FAILS ON
SC 047	REACTION JET #4 FAILS ON (S/M-C/M)	SC 126	S/M REACTION JET #16 FAILS OFF
SC 051	REACTION JET #4 FAILS OFF (S/M-C/M)		
SC 052	REACTION JET #5 FAILS ON (S/M-C/M)		
SC 053	REACTION JET #5 FAILS OFF (S/M-C/M)		
SC 054	REACTION JET #6 FAILS ON (S/M-C/M)		
SC 055	REACTION JET #6 FAILS OFF (S/M-C/M)		
SC 056	REACTION JET #7 FAILS ON (S/M-C/M)		
SC 057	REACTION JET #7 FAILS OFF (S/M-C/M)		
SC 061	REACTION JET #8 FAILS ON (S/M-C/M)		
SC 062	REACTION JET #8 FAILS OFF (S/M-C/M)		
SC 063	REACTION JET #9 FAILS ON (S/M-C/M)		
SC 064	TRANSLATIONAL CONTROL (+X DIRECTION) FAILS OPEN		

Figure 2-3. SCS Attitude Control System

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switched in to provide attitude reference. If the RGP should fail, switches are provided to connect the three BMAGs individually as rate gyros.

Input from the rotational hand control (block 3, figure 2-3), in the form of proportional control signals, have the output of the rate gyros (block 4, figure 2-3) subtracted from them in the first summing point. The composite rate-command signal is sent to the second summing point (block 8, figure 2-3). At the same time, attitude control commands continue to be fed from the G&N or BMAGs into the deadband limiter (block 6, figure 2-3). If the attitude control commands exceed the selected deadband they are sent to the attitude limiter. The attitude limiter (block 7, figure 2-3) controls the maximum change commands that can be read into the system as a result of attitude control operations.

The output of the first summing point (proportional signal - RGP output) is combined with the output of the attitude limiter at the second summing point (block 8, figure 2-3). This combination is input to the second summing point, which provides an integrated error signal to the switching amplifier (block 9). The switching amplifier converts the proportional d-c inputs to digital pulses. The pulse width is controlled by the pseudo rate feedback. This feedback is a negative feedback which cuts off the switching amplifier as a function of its being turned on. The amount of time the switching amplifier will remain on is controlled by the amplitude of its error signal input. This on-off pulsing of the switching amplifier will continue as long as the error input exists.

When the rotation control is used, the pseudo rate circuit is disabled. The switching amplifier output will be on one of two lines for each of the three axes. One-line commands simulated positive movement about the axis; the other commands a simulated negative movement about that axis. These pulses are sent on two lines to the jet selection logic (block 10, figure 2-3). One line is for positive movement, the other for negative movement, in the respective axis. Thus, a total of six command lines enter the jet selection logic from the attitude control system: two for pitch, two for yaw, and two for roll. The jet selection logic determines which reaction jets will be fired (block 10).

2.4.2.2 BMAG-AGCU-FDAI Subsystem.

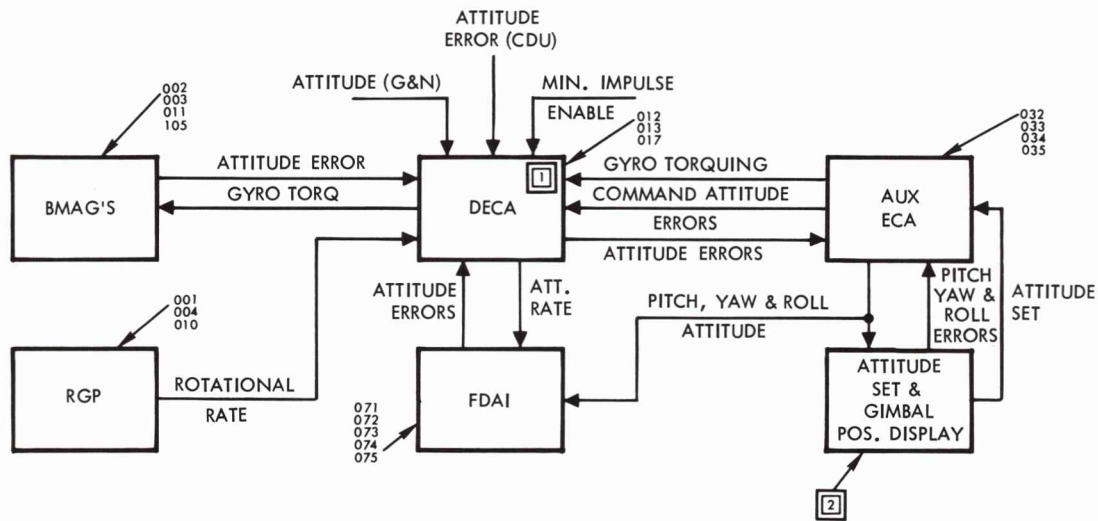
Figure 2-4 shows the relationship between the various SCS controls and displays in the AMS, the relationship between controls and displays intelligence and SCS attitude references (BMAG and AGCU), the simulated malfunctions of the systems involved, and the simulated PCM telemetry points relating to the subsystem.

Flight Director Attitude Indicator.

The FDAI combines three display functions pertaining to spacecraft orientation. Total attitude, attitude errors, and body angular rates are displayed for each axis.

Total attitude is displayed on the gimballed attitude ball. The ball has 360 degrees of freedom in the pitch, yaw, and roll axes, and is positioned by one of two sources. In the G&N mode, the ball serves as a repeater for the IMU gimbal angles. The second source of ball displays information is the AGCU.

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SCS BMAG-AGCU-FDAI SUBSYSTEM T/M SIGNALS			SCS BMAG-AGCU-FDAI SUBSYSTEM MALFUNCTIONS	
NO.	SIGNAL DESCRIPTION	GOSS NO.	MALF. NO.	MALFUNCTION DESCRIPTION
1	RESOLVER SIN OUTPUT-PITCH ATTITUDE	H4100H	SC 001	YAW RATE GYRO FAILS OPEN
	RESOLVER COS OUTPUT-PITCH ATTITUDE	H4101H	SC 002	YAW BMAG FAILS OPEN
	RESOLVER SIN OUTPUT-YAW ATTITUDE	H4102H	SC 003	PITCH BMAG FAILS OPEN
	RESOLVER COS OUTPUT-YAW ATTITUDE	H4103H	SC 004	PITCH RATE GYRO FAILS OPEN
	RESOLVER SIN OUTPUT-ROLL ATTITUDE	H4104H	SC 010	ROLL RATE GYRO FAILS OPEN
	RESOLVER COS OUTPUT-ROLL ATTITUDE	H4105H	SC 011	ROLL BMAG FAILS OPEN
2	PITCH POSITION FEEDBACK	H0034H	SC 012	PITCH GIMBAL POSITION FAILS-ZERO O.P.
	YAW POSITION FEEDBACK	H0035H	SC 013	YAW GIMBAL POSITION FAILS-ZERO O.P.
			SC 017	ATTITUDE GYRO COUPLER UNIT FAILS OPEN
			SC 032	A&C ROLL CHANNEL DISABLE SWITCH FAILS OPEN
			SC 033	B&D ROLL CHANNEL DISABLE SWITCH FAILS OPEN
			SC 034	PITCH CHANNEL DISABLE SWITCH FAILS OPEN
			SC 035	YAW CHANNEL DISABLE SWITCH FAILS OPEN
			SC 071	FDAI ROLL ERROR FAILS OPEN
			SC 072	FDAI YAW ERROR FAILS OPEN
			SC 073	FDAI PITCH RATE FAILS OPEN
			SC 074	FDAI ROLL RATE FAILS OPEN
			SC 075	FDAI YAW RATE FAILS OPEN
			SC 105	AGAP HEATER FAILURE - SHORTED

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Figure 2-4. BMAG-AGCU-FDAI Subsystem

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The roll attitude error indicator is at the top, pitch at the right, and yaw at the bottom of the FDAI ball. Attitude error information is derived from the coupling display unit (CDU) in the G&N mode and the BMAGs in the SCS mode of operation.

Attitude change rates are displayed about the face of the FDAI, roll rate indicators at the top, pitch at the right, and yaw at the bottom. Roll information is obtained from the rate gyros for all modes of operation. A secondary source of pitch and yaw attitude change rates is the BMAGs when the rate backup configuration is selected.

The FDAI receives its inputs of attitude error and attitude rate from the display electronic control amplifier (DECA). Normally, attitude error is provided by the G&N system and attitude rate by the RGP, as explained in the attitude control system in paragraph 2.4.2.1. Attitude errors from the FDAI and gyro torquing signals from the auxiliary ECA are used as driving signals to correct BMAG position.

Attitude Set-Gimbal Position Display Panel.

The attitude set and gimbal position display provides two distinct SCS functions. The gimbal position section provides visual display and manual control over the SPS engine gimbal null position. The three attitude set thumbwheels and adjacent displays allows setting the desired inertial reference attitude for the SCS modes of operation. The error between spacecraft attitude and the reference attitude on the attitude set indicators can be displayed on the FDAI when the ATTITUDE SET switch is used.

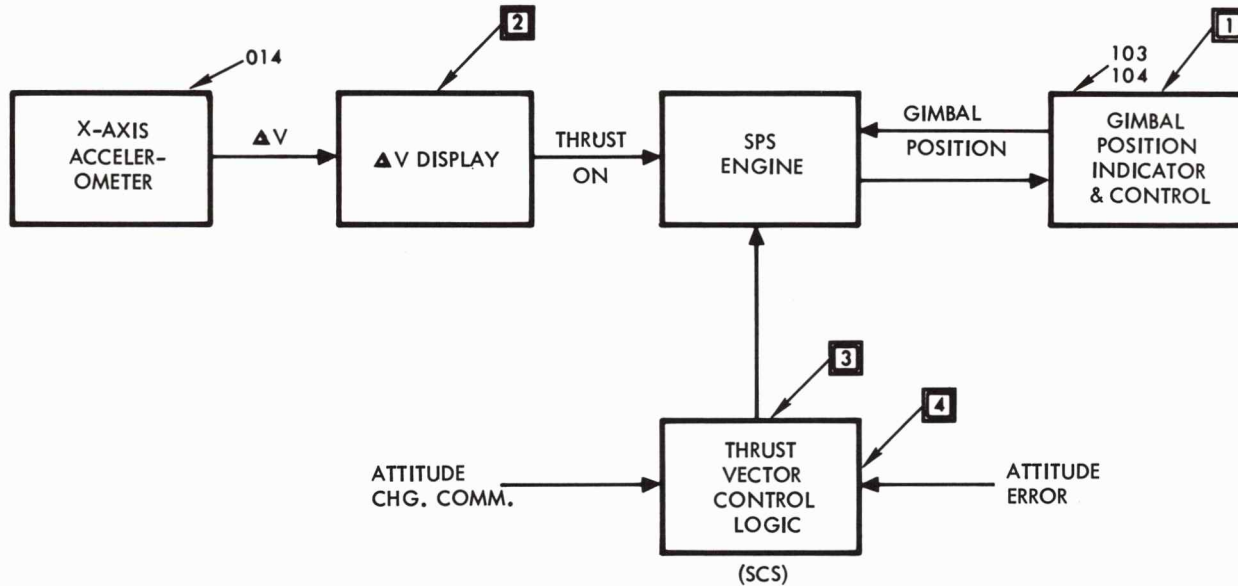
2.4.2.3 Thrust Vector Control Subsystem.

The thrust vector control (TVC) subsystem is required to position the gimballed SPS engine to maintain the engine thrust through the spacecraft center of gravity and maintain spacecraft attitude so that the thrust vector will be in the desired direction. Figure 2-5 is a block diagram of the thrust vector control system illustrating signal flow, telemetry points, and effective simulated malfunction insertion points in the AMS equivalent of this system.

Positioning the thrust vector through the center of gravity is complicated because of thrusting for long-burning times (lunar orbit injection and transearth injection). The total travel of the spacecraft center of gravity is approximately 120 inches along the X-axis, 12 inches along the Y-axis, and 7 inches along the Z-axis. The travel of the spacecraft center of gravity during the long-thrusting time causes undesired lateral accelerations and residual lateral velocities, which combined with initial alignment errors of the thrust vector and pointing errors in the two inertial sensors (IMU and SCS attitude reference system), in most incidents decrease the accuracy of the thrusting maneuver.

The thrust vector control system consists of two axes (pitch and yaw) control of the gimballed SPS engine and roll control provided by the reaction jets when roll attitude or rate errors exceed the specified deadband. The ability of the thrust vector control system to displace the SPS engine ± 8.5 degrees in yaw about a null offset of +4 degrees with respect to the spacecraft XY plane and

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SCS THRUST VECTOR CONTROL MALFUNCTIONS	
MALF. NO.	MALFUNCTION DESCRIPTION
SC 014	SCS ACCELEROMETER FAILS
SC 103	PITCH GIMBAL DRIVE FAILS
SC 104	YAW GIMBAL DRIVE FAILS

SCS THRUST VECTOR CONTROL SUBSYSTEM T/M SIGNALS		
NO.	SIGNAL DESCRIPTION	GOSS NO.
1	PITCH THRUST VECTOR DIFFERENTIAL CLUTCH VOLTAGE YAW THRUST VECTOR DIFFERENTIAL CLUTCH VOLTAGE	H0047V H1047V
2	DELTA V REMAINING POT. OUTPUT	H3184V
3	YAW THRUST VECTOR CONTROL TRANSFER RELAY-K10	H1209X
4	SPS SOLENOID DRIVER OUTPUT 1 SPS SOLENOID DRIVER OUTPUT 2	H4320X H4321X

Figure 2-5. Thrust Vector Control Subsystem

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± 6 degrees about zero with respect to the spacecraft XZ plane, allows the spacecraft to thrust through the center of gravity and in the desired direction.

The delta V display, S/C panel 7, enables the crew to set in required changes in velocity, observe velocity attained, and manually back up automatic SPS engine fire and cutoff signals. The X-axis accelerometer, which drives the delta V display, is actually part of the delta V display assembly. Its inter-relationship to the thrust vector control system is illustrated in figure 2-5.

The primary delta V mode (thrusting) will be the G&N delta V mode, which provides the most accurate trajectory corrections. During thrusting, three accelerometers of the G&N system IMU permit continuous trajectory corrections and compensation for any lateral accelerations or residual lateral velocities by the G&N computer integration of these accelerations and velocities to provide steering commands to the gimballed SPS engine. The G&N computer, when calculating the velocity required to correct the trajectory, considers the gravitational velocities effecting the spacecraft; therefore, the actual thrusting velocity will be of a different magnitude than the required velocity change, and result in a curved trajectory.

The backup delta V mode will be the SCS delta V mode which has the ability to perform fixed angle thrusting maneuvers, such that the thrust vector will be maintained inertially fixed. The normal action for a malfunction in the delta V mode would be to terminate thrust, investigate and realign, to complete the delta V maneuver. However, in lunar orbit injection and transearth injection phases, there are limitations and restrictions that require individual consideration. If these conditions exist, the backup mode can be selected to complete the delta V maneuver where it provides greater crew safety.

Attitude change commands may be initiated by the G&N system during a delta V maneuver. These commands, along with the attitude error signals, enter the TVC logic from the G&N during G&N delta V mode. The total attitude change signal is forwarded to the SPS engine gimbal. Initial gimbal positioning commands are generated by the gimbal position controls on spacecraft panel 6. Updated gimbal positions, after corrective signals are applied, are fed back to the gimbal position indicators.

Thrust on-off control is maintained by the delta V (ΔV) display. Inputs from the X-axis accelerometer will decrease the indicated ΔV required. When the ΔV required reaches zero, the thrust on signal is removed from the SPS engine.

Roll control during either delta V mode is maintained by the RCS in the same manner as during attitude hold modes. Therefore, roll control is not affected by this SCS subsystem. The pitch and yaw RCS channels, however, are automatically disabled during the delta V modes.

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2.4.3 SCS SIMULATION.

The simulation of the SCS in the Apollo mission simulator is primarily a software (computer program) function. The only spacecraft SCS hardware physically represented in the simulator are command module controls and displays. Some of the panels (and/or panel components) are actual spacecraft hardware while others are facsimiles especially fabricated for use in the simulator. Other hardware items in the SCS simulation are the simulator peculiar servomechanisms required to transmit control between the SCM, the IOS, and the computer complex.

Simulation of the SCS is divided into four subsystems. They are the dynamic subsystem, BMAG-AGCU-FDAI subsystem, thrust vector control subsystem, and modification subsystem. The dynamic subsystem deals primarily with power switching, mode selection, and dynamics of spacecraft motion. This includes simulation of rate gyros, command inputs, attitude and rate errors, limiting and jet selection logic. The BMAG-AGCU-FDAI subsystem simulates the backup attitude reference system (ARS) and drive equations for the FDAI. The thrust vector control subsystem provides simulated SCS control of the SPS engine. The modification subsystem provides computed results of RCS thrusting for use in the equations of motion and calculates a ratio for use in computing fuel usage.

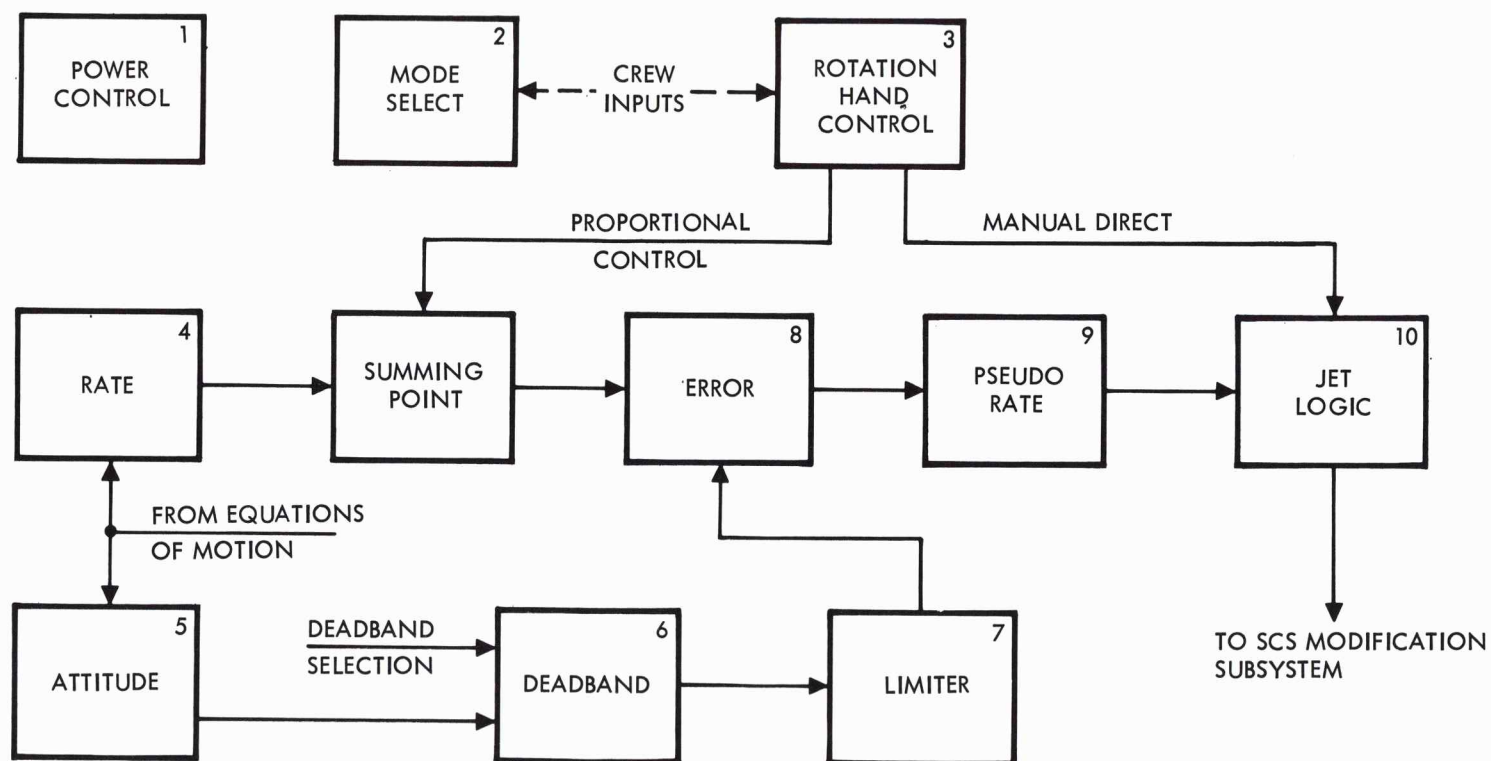
2.4.3.1 Dynamic Subsystem Simulation.

The simulated SCS dynamic subsystem provides 10 operations required to authentically represent the actual SCS. These operations are as follows:

- a. Determining power availability
- b. Determining SCS mode
- c. Analyzing hand control inputs
- d. Determining vehicle angular rates
- e. Determining vehicle attitude
- f. Computing deadband effect
- g. Limiting vehicle change rates
- h. Calculating error outputs
- i. Computing pseudo rate feedback and its effect
- j. Simulating jet selection logic operations

Figure 2-6 illustrates the interaction of these operations along with their actual system equivalent. Since each operation is not a direct simulation of a specific piece of hardware, the block diagram of the actual system does not directly correlate with the block diagram of the simulation. The small numbers in the block diagram correspond to numbers in figure 2-3. Using these numbers it can be seen how each section of the AMS dynamic subsystem corresponds to a section in the spacecraft SCS attitude control system.

The dynamic subsystem first checks to determine if proper a-c and d-c electrical power has been provided for the SCS. If simulated power is unavailable, SCS simulation is either inhibited or terminated (whichever is appropriate).



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Figure 2-6. SCS Dynamic Simulation

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The dynamic subsystem then determines which mode of SCS operation has been selected, establishes appropriate switching and scaling within the AMS for simulation of the selected mode, and accomplishes mode selection lockup to assure retention of the mode simulation.

The dynamic subsystem continuously analyzes rotation control outputs to determine their effect on simulated spacecraft attitude. Both proportional and manual direct commands from the hand controls are measured. Manual direct commands are sent to the jet selection logic. Normal proportional commands are sent to the jet selection logic. Normal proportional commands are integrated with the simulated rate gyro outputs generated within the computer as a function of rotational velocity in the X-, Y-, and Z-axes. The rotational velocity inputs to the SCS dynamic subsystem are outputs of the equations of motion.

Simulated spacecraft attitude, from the BMAG-AGCU-FDAI subsystem of the SCS, is fed to the deadband section. The deadband section inhibits all attitude error signals below the selected deadband level. The deadband allows the spacecraft to drift about the commanded attitude within a specified number of degrees without RCS firings for stabilization purposes. Signals exceeding the selected deadband level are fed to the attitude error limiter. Simulator operation from this point forward is the same as the actual system.

2.4.3.2 BMAG-AGCU-FDAI Subsystem Simulation.

A block diagram of the BMAG-AGCU-FDAI simulation subsystem is shown in figure 2-7. The first section of this subsystem simulates the body-mounted attitude gyros (BMAG) and their control logic. It determines the function of each BMAG (rate or attitude) depending upon manual switching. The BMAG is simulated by integrating the results of the rate gyro simulation in the dynamic subsystem to obtain attitude error. When in rate backup mode, the BMAG simulation is the same as the rate gyro simulation in the dynamic subsystem.

Operation of the attitude set panel and the attitude gyro coupling unit (AGCU) are simulated within this subsystem. This simulation begins with a transformation of the three axis body navigational rates to Euler rates in the AGCU as it follows the BMAGs. These equations also simulate the AGCU torquing of the BMAG during followup. Simulated torquing of the BMAG during local vertical mode and other transformations changes the attitude reference. This simulates correct alignment of the vehicle to the local vertical or to a point in space.

Simulation of the FDAI drive is also accomplished in this subsystem. This includes the selection of rate, attitude, and attitude error peculiar to the mode selected in the dynamic subsystem simulation. Values for rate, attitude, and attitude error for display on the FDAI are computed as well as meter gain changes and conditioning.

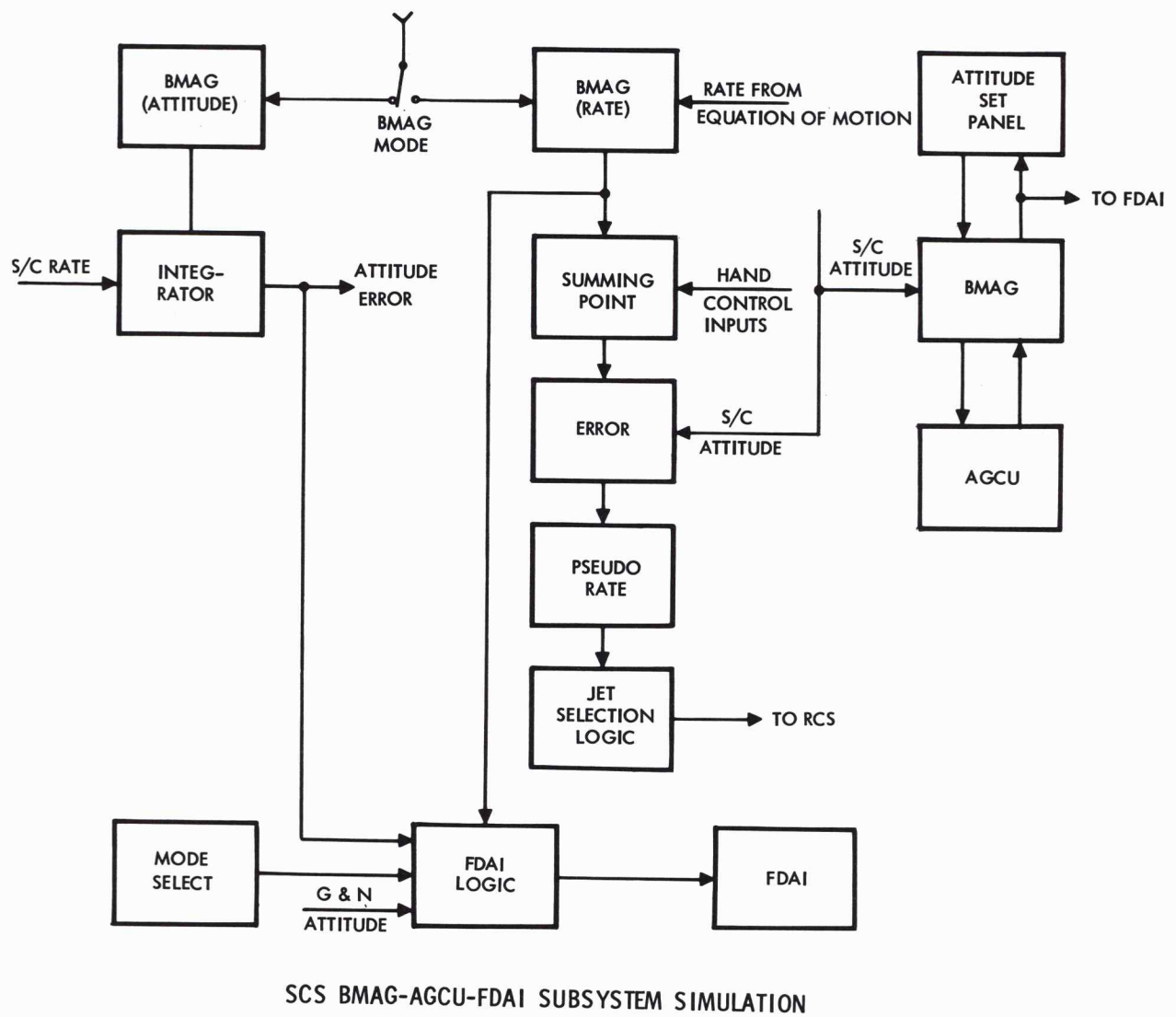


Figure 2-7. BMAG-AGCU-FDAI Simulation

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2.4.3.3 Thrust Vector Control Subsystem (TVC) Simulation.

This portion of the simulated SCS represents the control of the service propulsion engine.

Figure 2-8 illustrates the TVC simulation in block diagram form. This drawing may be compared with figure 2-5 showing the actual SCS-TVC system.

The power control and logic of the simulated thrust vector control subsystem ensures that all required inputs have been received before the THRUST ON light is illuminated in the C/M and on the IOS. The C/M switch position requirements are as follows: THRUST switch, NORMAL; DIRECT ULLAGE switch, ON or +X translation command from hand control; and THRUST ON switch, ON or a delta V mode selected. Simulated thrust on may be terminated by moving the THRUST switch to OFF, clockwise rotation of the hand control, or reaching zero on the delta V remaining indicator.

Control of the SPS engine gimbals is accomplished by the G&N or SCS as determined by the delta V mode selected. Two sets of equations are used to simulate this control: one set for G&N and the other for SCS. This allows simulated malfunctions to be inserted into either system.

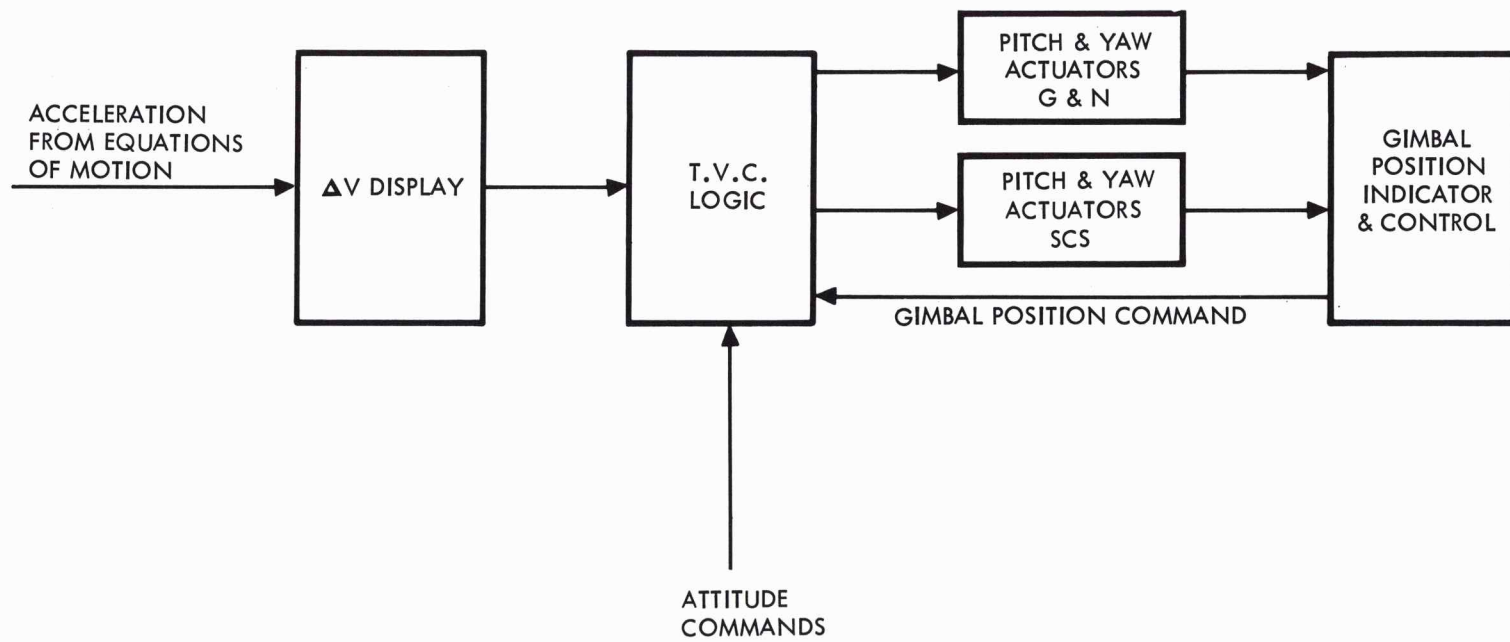
The pitch and yaw gimbals are initially positioned by the crew from the gimbal position thumbwheels. Where they are to be positioned, is calculated by the crew using a chart based on spacecraft configuration and weight at the time of firing. The analog gimbal position commands are sent through analog-to-digital converters to the IOS. The SPS gimbal actuator switches must be on for the thumbwheels or guidance command to position the actuators.

The simulated positions of the pitch and yaw actuators are computed, along with gimbal errors, in the SCS or G&N equations. In these computations body axis error, gyro gimbal angles, and rate gyro signals are all considered in changing the gimbal positions. Pitch and yaw actuator malfunctions are also computed separately for the SCS and G&N control sections. The products of these computations, the simulated gimbal actuator positions, are transmitted to the SCM control panel and the IOS. The equations-of-motion section of the computer also receives the gimbal angles for use in computing attitude change and rate change.

2.4.3.4 Modification Subsystem Simulation.

The basic task of the modification subsystem of the SCS is to modify RCS thrust outputs before they are sent to the equations-of-motion, and to compute a ratio for use in computing fuel consumption. The system actually simulates the reaction jets and their operations. Other functions are also performed by this subsystem, including power local computations and gyro overheat simulation. Figure 2-9 shows a block diagram of the modification subsystem.

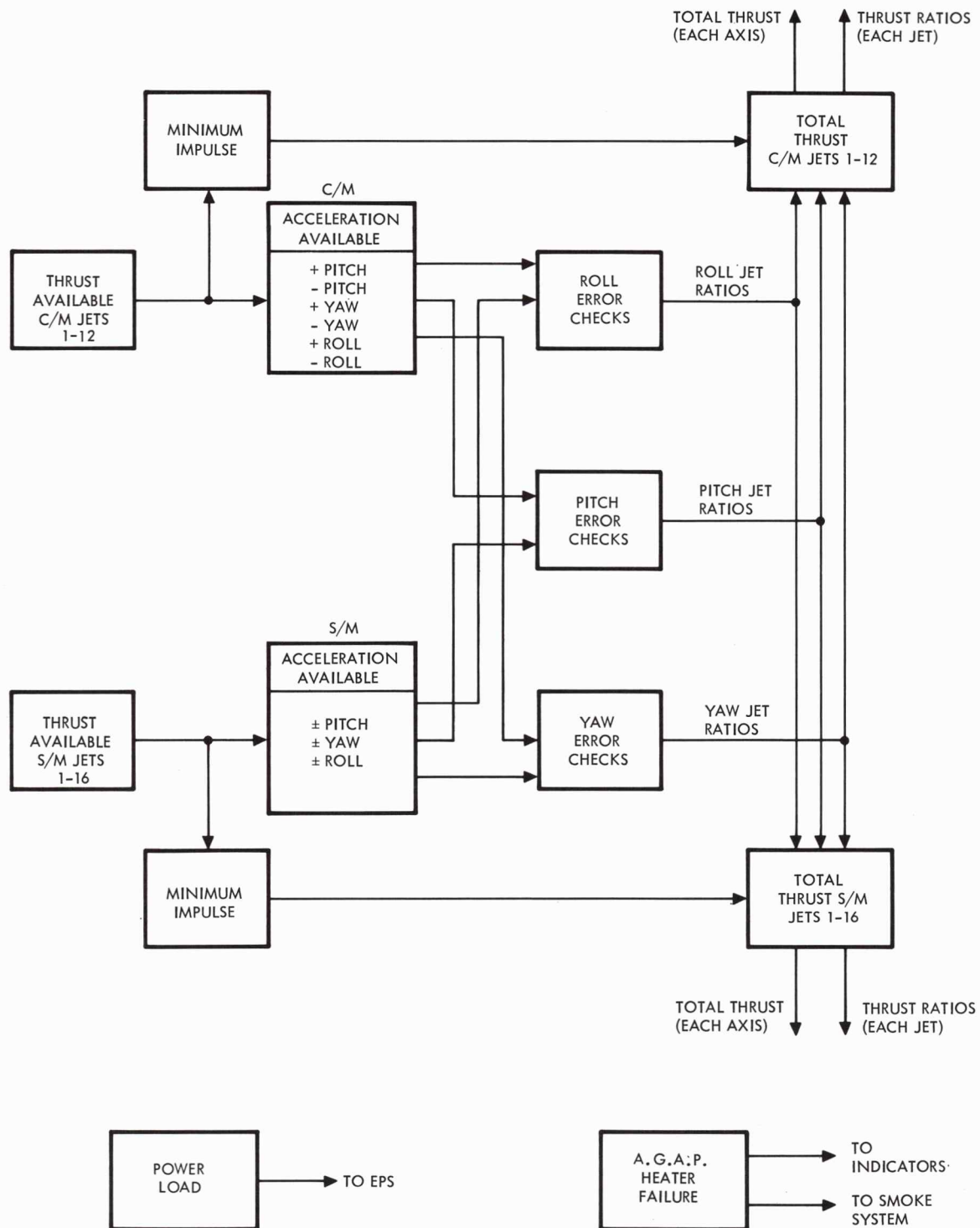
The main thrust modification is divided into two sections: RCS thrust modification and minimum impulse simulation.



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Figure 2-8. Thrust Vector Control Simulation

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Figure 2-9. Modification Subsystem

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Thrust modification calculations start by determining thrust available from each reaction jet. The data used in these computations are derived from the SCS dynamic subsystem. Thrust available is determined in groups for both S/M and C/M jets; that is, S/M-RCS quad A, B, C, or D or C/M-RCS system A or B may be unavailable or failed. All jets within each quad or system are, as a group, either available or unavailable for thrusting. Single jet malfunctions in the off condition are also within the capability of these calculations.

The thrust available section performs the logic operations and determines percentage of maximum thrust in accordance with rotation hand control position and vehicle rate. For the purpose of thrust modification, the effect of jet failure and center-of-gravity shift are computed as they pertain to spacecraft attitude control. Attitude control is maintained within the subsystem by establishing an error level, above which the proper reaction jet or jets will fire to return the spacecraft to the proper attitude. Unlike the deadband, this area of uncorrected error is not variable. It simulates accumulated system tolerance. If the attitude error exceeds this uncorrected error level, a comparison is made to determine the difference between the two. The result of this comparison will determine the acceleration to be used in correcting attitude. All calculations of acceleration and thrust requirements are dependent upon whether C/M-S/M separation has occurred.

If minimum impulse mode is selected, the thrust modifications normally performed are not computed. Special computations are performed to provide modification ratio summation and thrust output during the minimum impulse mode. The computer determines the percentage of available thrust which will be used during each thrust pulse. This percentage is based on system status, hand control inputs, and each reaction jet status simulation. The products of these calculations are sent to two other subsystems within the computer. Signals representing amount of thrust from each jet are sent to the equations of motion for use in calculating spacecraft motion, rate, and attitude. These same signals are sent to the RCS for use in computing propellant expenditures. Simulated electrical power loads are determined by considering SCS switch and circuit breaker positions. This information is used by the simulated EPS in its computations of overall power consumption.

Another function simulated by the SCS modification subsystem is the AGAP overheat malfunction. If this malfunction is selected by the IOS operator, an indicator will illuminate in the C/M and on the IOS informing the crew of the condition. This malfunction condition is also sent to the smoke generation subsystem.

2.5

SEQUENCE CONTROL GROUP.

The sequence control group consists of the mission sequencer, the earth landing system sequencer, and the tower sequencer. The purpose of these sequencers is to provide automatic sequencing of mission events during the suborbital mission phases. These mission phases are as follows:

- a. Launch escape tower jettison
- b. LES pad and low altitude abort

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- c. LES high altitude abort
- d. SPS abort
- e. C/M-S/M separation
- f. Post-entry to touchdown

2.5.1 SEQUENCING CONFIGURATION REFERENCE

Sequencing systems simulated in the AMS are basically those of Apollo BP014. Differences between the AMS and the BP014 configuration are primarily the arrangement of controls and displays. Also the AMS includes a NO AUTO ABORT light which is an AF012 feature not included in BP014.

The difference between the sequence control group simulated in the AMS and that of AF012 is substantial. This is a direct result of a complete redesign of the spacecraft sequencers between BP014 and AF012 after AMS design freeze. The major change affected sequence timing, crew performance requirements, and controls and displays at a gross level.

2.5.2 SIMULATED SEQUENCING SYSTEMS (S/C EQUIVALENT).

The sequence of events for normal launch is the subject of paragraph 3.3 of section 3 of this volume of the instructor handbook. Suborbital aborts (LES and SPS) are the subject of paragraph 3.4 of the same section.

2.5.3 SEQUENCING SIMULATION.

Both the spacecraft sequencer and the simulated sequencer provide identical sets of inter-related electrical impulses on the basis of crew activity, events in other systems, and elapsed time. Therefore, functional description of one is also a functional description of the other. Figure 2-10 is a block diagram of the sequence control group simulation in the AMS. The figure includes the simulated malfunctions which may be inserted into the system along with the telemetry points, which are sent to the PCM telemetry.

Prior to launch both the mission sequencer and the tower sequencer are enabled by the flight crew by means of mission sequencer circuit breakers and sequencer ARM switches (MS ARM PYRO and TOWER ARM A and B). A simulated launch and ascent to orbit is described as follows:

At T - 0 or ignition time, the eight L/V engine lights extinguish simulating 90 percent maximum thrust in each engine. The liftoff indicator illuminates a few seconds later, simulating launch. During the ascent phase, at T + 35 seconds, the crewmember in spacecraft station 1 disables the auto oxidizer dump.

When simulated altitude reaches 30,000 feet, the flight crew switches from low to high altitude abort mode. At T + 135 seconds, both the 2 ENGINE OUT switch and the L/V RATES EXCESSIVE switch should be placed to the OFF position. Approximately 3 seconds later, L/V ENGINE lights 5 through 8 illuminate followed by L/V ENGINE lights 1 through 4 at T + 144. Two seconds later, all ENGINE lights extinguish, and at T + 148 L/V ENGINE 1 light again



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illuminates. This indicator monitors S-IVB thrusting and will again extinguish when 90 percent of maximum thrust is simulated at T + 150. The TOWER JETT switch should be activated at T + 170. This causes simulation of LES tower and motor removal and also powers the ADAP SEP ARM light. After accomplishing this, the flight crew places the EDS switch, panel 16, to the OFF position. This precludes an automatic abort and illuminates the NO AUTO ABORT light. When orbit is attained at approximately T + 600 seconds, L/V ENGINE 1 light illuminates simulating S-IVB shutdown. Sometime during the first orbit, the S-IVB separation is simulated by depressing the ADAP SEP switch. This also causes the remaining L/V ENGINE light to extinguish. The crew then turns off the EDS POWER switch, the ELS PYRO ARM switch, and the two MISSION SEQUENCER ARM switches, all on panel 24.

If an abort is to occur during ascent, it will be initiated by one of three conditions: EDS, through automatic abort; crew action, in response to an abort request light; or crew action, in response to observable spacecraft conditions. EDS aborts and abort requests may be accomplished only by using booster tapes plus appropriate malfunctions. These malfunctions include L/V excessive rates, L/V guidance malfunction, L/V two engines out, and booster breakup. EDS aborts are automatically initiated unless the automatic function is disabled. Crew procedures call for disabling of the two engine out auto abort function prior to S-IB shutdown and staging. A switch is also provided in the C/M with which the excessive L/V rates abort capability may be disabled. Both of these will be disabled prior to S-IB-S-IVB staging. After manually jettisoning the launch escape tower, the astronaut will disable all EDS auto aborts.

Other aborts may be initiated while using the normal boost tape. LES sequencing indications during these aborts will vary as a function of altitude at the time of abort.

During a LES abort, neither the crew nor the IOS operator receive any direct indication of abort impending unless the abort is the result of an abort request. At pad or low-altitude abort initiation, the crew and the IOS operator will receive aural cues, through the intercom, indicating escape tower firing. At the same time, LES MTR FIRE and C/M-S/M separation will be simulated. If the LES MTR FIRE-NO SEP indicator should illuminate, the astronaut should depress LES MTR FIRE - NO SEP switch, manually overriding the simulated malfunction. The FDAI will also indicate rapid changes in S/C attitude. The C/M-RCS is pressurized by the abort signal and a rapid increase in system pressure is visible. Oxidizer dump is initiated as the system becomes pressurized. This is indicated by the decrease in C/M-RCS helium pressure.

Tower jettison occurs 15.6 seconds after tower motor burnout. The TWR JETT-NO SEP indicator illuminates only if a malfunction has been inserted to cause the command to fail. If this malfunction is inserted, the astronaut depresses the TWR JETT-NO SEP switch-light, overriding the malfunction.

In case of a high-altitude abort, LES operation is the same as low-altitude aborts except that motor jettison is simulated after LES motor instead of tower jettison. Motor jettison is also an automatic function which is provided with a

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MTR FIRE-NO SEP switch-light override. The C/M-RCS systems are pressurized during high-altitude aborts but, unlike low-altitude aborts, oxidizer dump is not initiated.

The mission sequencer automatically performs C/M-S/M separation during all aborts except SPS. This entails pressurizing the C/M-RCS, transferring SCS jet select commands to the C/M, and initiation of C/M-S/M physical separation. In case of SPS abort or normal entry, the separation is manually initiated through the C/M-S/M SEP switch.

The ELS is activated prior to launch and is used during aborts or normal entry. If a normal ascent to orbit is accomplished, the ELS is deactivated. It will not be reactivated until an altitude of 100,000 feet is reached during entry.

In order for the ELS to be activated, the ELS arm pyro and ELS activate switches must be on. Both halves of the ELS armed light (PYRO and LOGIC) should be illuminated at 100,000 feet during a normal entry indicating that the ELS system is activated. Prior to T - 0, in a normal launch, the ELS armed light will illuminate. If an abort occurs during launch and ascent, the ELS LOGIC light will illuminate automatically.

During pad or low-altitude abort, after LES operations, the ELS automatically simulate drogue chute deployment. This is indicated by an aural simulation of drogue mortar firing. A malfunction may be inserted to simulate failure of the drogue deployment. In this case, the astronaut depresses the DROGUE DEPLOY indicator, manually activating the firing circuit. Main chute deployment follows drogue deploy. At this time, the astronaut activates the fuel dump switch. This causes decrease in C/M-RCS helium pressure. During pad and low-altitude aborts, RCS oxidizer is dumped automatically during LES motor firing.

ELS operation during high-altitude aborts and entry differs from pad or low-altitude abort operation in that both oxidizer and fuel are burned off during chute descent. Aural cues simulate firing of the RCS jets during this time. This, plus the depleting helium pressure, will be the indications of propellant dump or burn. When all propellants have been depleted, the astronaut will activate the C/M-RCS PURGE switch to eliminate the line-trapped propellant from the system before impact. The visual indication for this will be the decreasing helium pressure, the caution and warning system C/M-RCS A and C/M-RCS B, and MASTER CAUTION lights.

2.6

ENVIRONMENTAL CONTROL SYSTEM.

The explanation of the environmental control system (ECS) has been divided into three parts. They are the simulated ECS, the ECS subsystem simulation and the environmental equipment used in the trainer to actually control cabin temperature, pressure, etc. There are four subsystems within the ECS. They are the oxygen supply, water storage, water-glycol, and pressure suit subsystems.

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2.6.1 ECS CONFIGURATION REFERENCE.

The ECS simulated in the AMS is the basic system design per AiResearch Co., Drawing 848140. The drawing is subcontractor input data to spacecraft design and was not addressed to, and is not representative of, any specific air-frame or boilerplate. The ECS reflected in the drawing and simulated in the AMS differs from the ECS in AF012 in the following ways:

- a. CABIN TEMPERATURE and SUIT EVAPORATOR HEAT-COOL switches in the AMS ARE NOT included in AF012.
- b. The H₂ and O₂ tanks 1 and 2 switches in the AMS ARE NOT included in AF012.
- c. The suit heat exchanger in AF012 utilizes a backpressure control system similar to that used in the water-glycol evaporator. The backpressure control in the suit heat exchanger IS NOT simulated in the AMS.
- d. The GLYCOL EVAPORATOR TEMPERATURE INPUT switch in AF012 IS NOT included in the AMS.
- e. The GLYCOL EVAPORATOR H₂O FLOW switch in AF012 IS NOT included in the AMS.
- f. The WATER ACCUMULATOR AUTO 1-MANUAL and ON-OFF switches in AF012 ARE NOT included in the AMS.
- g. The POTABLE WATER MANUAL-OFF-AUTO switch in AF012 IS NOT included in the AMS.
- h. The H₂ and O₂ FANS ON AUTO-OFF-ON switches provided for each tank in AF012 ARE NOT simulated in the AMS.
- i. The PRESSURE INDICATOR TANK 1-OFF-SURGE TANK switch in AF012 IS NOT included in the AMS.

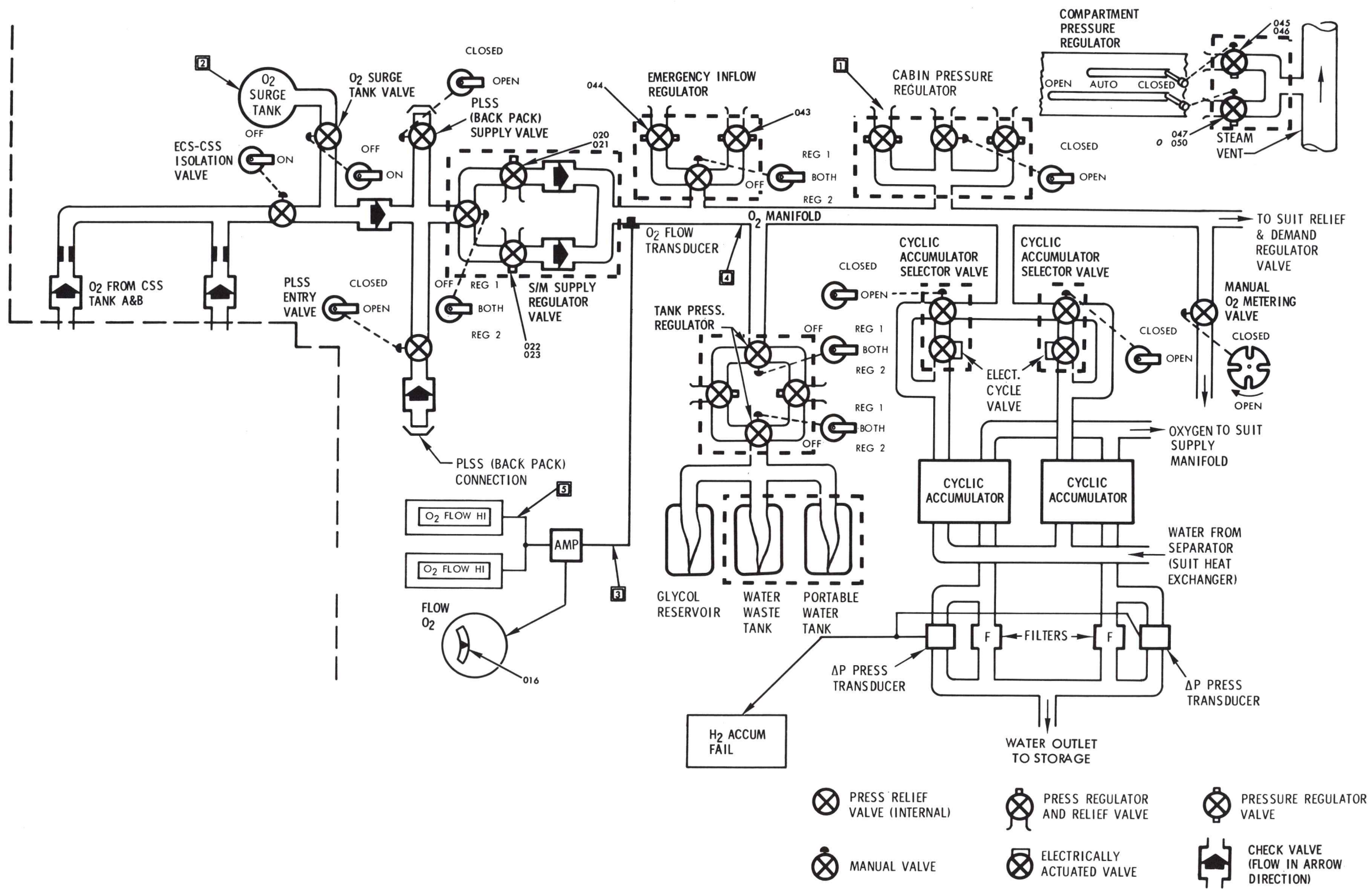
2.6.2 SIMULATED ECS (S/C EQUIVALENT).

2.6.2.1 Oxygen Supply Subsystem.

The purpose of the oxygen supply subsystem is to control oxygen flow for crew consumption and provide gas pressure for the cabin, glycol reservoir, potable water tank, waste water tank, water separator cyclic accumulators, and the suit circuit.

The subsystem receives oxygen at a pressure of 900 psi from the cryogenics storage system (CSS) in the S/M. This is shown in figure 2-11. The figure includes simulated malfunctions and telemetry points.

Oxygen enters the subsystem through the isolation valve and feeds a surge tank and the remainder of the O₂ system in parallel. The surge tank has a manual isolation valve which may remove it from the system in case of emergency. In the O₂ line to the rest of the oxygen supply subsystem, past the check valve, are two connections for the PLSS (back pack). One is to fill the PLSS, the other is connect the PLSS as an auxiliary surge tank. There are manual valves on both of these lines.



ECS OXYGEN SUBSYSTEM MALFUNCTIONS	
MALF. NO.	MALFUNCTION DESCRIPTION
EC 016	O ₂ FLOW INDICATOR FAILS (MIN.)
EC 020	S/M SUPPLY REGULATOR #1 FAILS OPEN
EC 021	S/M SUPPLY REGULATOR #1 FAILS CLOSED
EC 022	S/M SUPPLY REGULATOR #2 FAILS CLOSED
EC 023	S/M SUPPLY REGULATOR #2 FAILS OPEN
EC 043	EMERGENCY INFLOW REGULATOR #2 FAILS CLOSED
EC 044	EMERGENCY INFLOW REGULATOR #1 FAILS OPEN
EC 045	CABIN PRESSURE RELIEF VALVE (INNER) FAILS OPEN
EC 046	CABIN PRESSURE RELIEF VALVE (INNER) FAILS CLOSED
EC 047	CABIN PRESSURE RELIEF VALVE (INNER) FAILS
EC 047	CABIN PRESSURE RELIEF VALVE (OUTER) FAILS OPEN
EC 050	CABIN PRESSURE RELIEF VALVE (OUTER) FAILS CLOSED

ECS OXYGEN SUBSYSTEM T/M SIGNALS		
NO.	SIGNAL DESCRIPTION	GOSS NO.
1	PRESSURE-CABIN	F0001P
2	PRESSURE-SURGE TANK	F0006P
3	FLOW RATE-ECS O ₂	F0035R
4	PRESSURE-OUTLET O ₂ REGULATED SUPPLY	F0036P
5	EMERGENCY O ₂ FLOW INDICATION (DISCRETE)	F0105X

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Figure 2-11. Oxygen Subsystem

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The incoming O₂ is passed through either or both O₂ pressure regulator assemblies and check valves to the oxygen manifold. Regulator selection is controlled by the O₂ pressure regulator valve. This valve also has an OFF position.

Immediately following the O₂ supply regulator valves is a pair of emergency inflow regulator valves. These valves will provide high O₂ flow into the C/M in case of a leak. The rate of flow is limited only by the O₂ regulators. This allows approximately 40 pounds of O₂ per hour to flow into the cabin with a cabin pressure drop to 4.3 psi.

The oxygen fed to the water-glycol reservoir and the two water tanks to pressurize them is sent through another set of selectable redundant tank pressure regulators. These regulators are part of the water supply subsystem. The oxygen fed into the cabin also has redundant pressure regulators, but in addition has a manually controlled valve in parallel with these for repressurizing cabin from zero psi. The two cyclic accumulators receive oxygen through manual valves or manual and electric cycle valves in series.

The suit relief and demand regulator valve and the oxygen metering valve receive oxygen from the O₂ manifold.

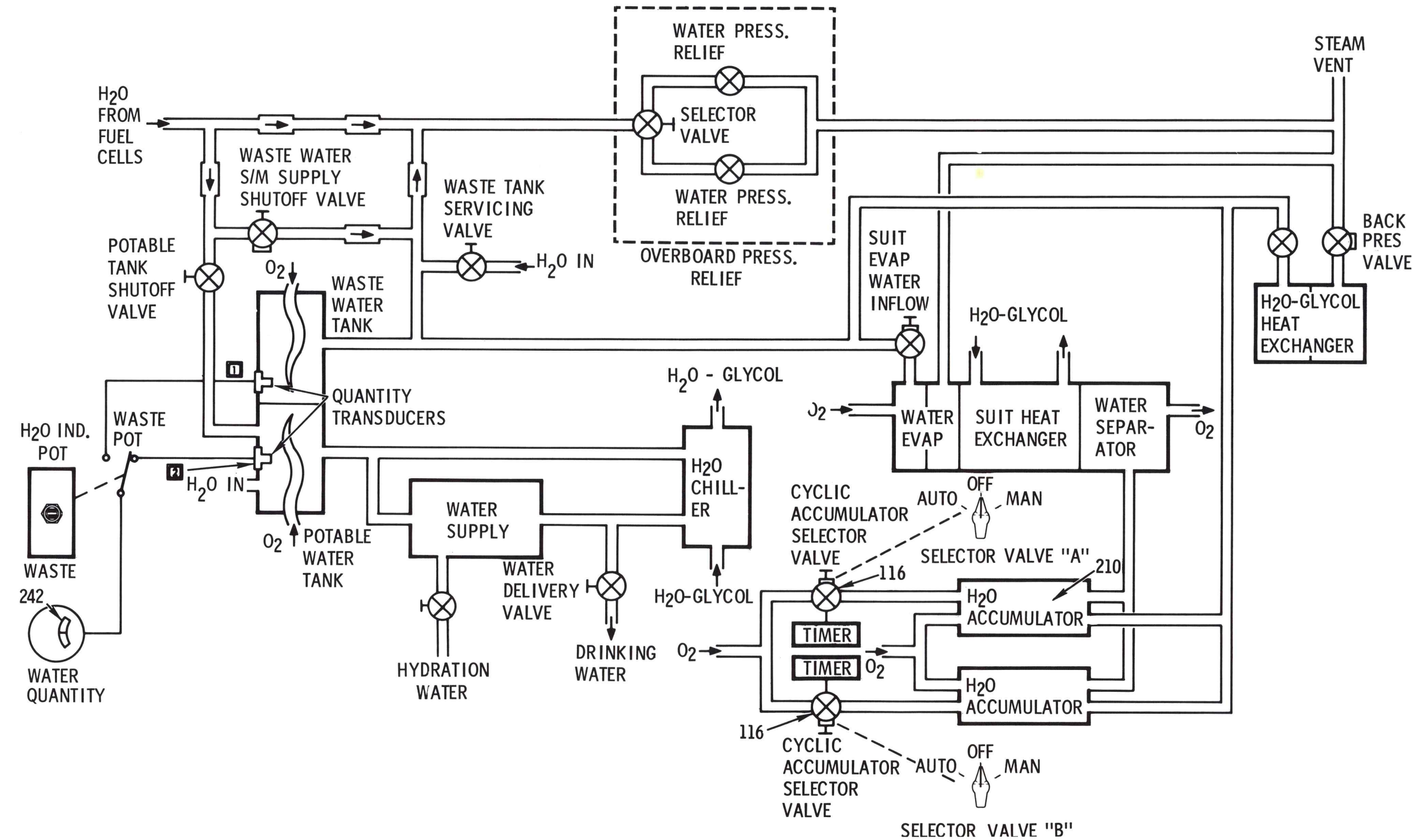
The cabin may be depressurized manually by the compartment pressure regulator valves in case of emergency or during LEM entry.

2.6.2.2 Water Supply Subsystem.

The main purpose of the water supply subsystem is to collect, store, and control water for use in cooling, and for crew use and consumption. A block diagram of this subsystem is shown in figure 2-12. The figure includes simulated malfunctions and telemetry points.

Two separate storage tanks are used to keep potable water separated from waste water. Potable water is generated as a by-product of the EPS fuel cells and, being pure, is used for crew consumption. The potable water tank is the only source of water for crew consumption. Separate valves are provided for obtaining drinking water and water for food reconstitution. The drinking water valve provides only cold water (45 to 50 degrees). The food reconstitution valve allows selection of hot (157 to 159 degrees) or cold water. Cold water is obtained by use of a water chiller between the potable water tank and the water valves. The cooling is provided by the water-glycol subsystem.

Waste water is made up of potable water tank overflow and condensed perspiration of the crew from the suit circuit. If the waste water tank is also filled, excess water is dumped overboard through the redundant selectable water pressure relief valves. Collection of waste water (perspiration) generated in the suit circuit is accomplished in two steps. First the vapors are condensed in the suit heat exchanger. Then, dual water accumulators separate the water from the oxygen of the suit circuit. The accumulators have two modes of operation: automatic and manual. In the automatic mode, the accumulators separate water from oxygen for approximately 10 minutes. Then, for a 10-second period, the accumulator is purged and the waste water collected during



ECS WATER SUBSYSTEM MALFUNCTIONS	
MALF. NO.	MALFUNCTION DESCRIPTION
EC 003	WATER SEPERATOR ACCUMULATOR DIAPHRAGM RUPTURED
EC 058	"WATER QUANTITY," INDICATOR FAILURE
EC 210	RUPTURED DIAPHRAM IN WATER ACCUMULATOR #2
EC 242	WATER QUANTITY INDICATOR FAILS (MIN.)
EC 116	ACCUMULATOR #1 AUTOMATIC VALVE FAILS CLOSED

ECS WATER SUBSYSTEM T/M SIGNALS		
NC	SIGNAL DESCRIPTION	GOSS NO.
1	QUANTITY WASTE WATER TANK	F0009Q
2	QUANTITY POTABLE WATER TANK	F0010Q

Figure 2-12. Water Supply Subsystem

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the 10-minute period is discharged into the waste water tank or, if the waste water tank is full, through the overboard relief valves. The waste water is used for cooling purposes in the water-glycol subsystem.

2.6.2.3 Water-Glycol Subsystem.

The water-glycol subsystem provides temperature control for the components of the command module. The subsystem uses a network of valves, pumps, space radiators, heat exchangers, and a water evaporator to provide temperature control for the cabin air, suit inlet air temperature, and C/M electronic equipment bays.

Two constant flow rate water-glycol pumps, in parallel, provide coolant circulation. The control switching allows these pumps to operate only one at a time. The operating pump forces the coolant, at a constant flow rate of 200 pounds per hour, into the space radiators, through the radiator isolation valve, and the relief valves, and heat bypass path, as shown in figure 2-13 (simulated malfunctions and telemetry points are included in the figure). The flow in each of the three parallel branches is a function of the control valve positions in each branch.

The normal flow is through the radiators and the heat bypass branches. The heat bypass branch contains an automatic control valve used to maintain the output temperature of the parallel branches at 45°F, if possible. If the temperature of the water-glycol flowing out of the space radiators is less than 45 degrees, the glycol pressure relief bypass valve opens allowing an appropriate amount of hot water-glycol to bypass the radiators and mix with the coolant flowing out of the space radiators. The valve continues to open until the temperature at the output of the parallel branches is 45 degrees. Normally, no flow occurs through the relief branch but will permit relief flow if the differential pressure across the parallel branches exceeds 10 psi.

Prior to launch and prior to entry, the water-glycol in the glycol reservoir is cold-soaked to approximately 45 degrees. During these two phases, the water-glycol storage tank serves as a heat sync to substitute for the unusable space radiators. During these phases of the mission, the input and output valves for the glycol reservoir are opened and the cold-soaked mixture flows into the system, while the hot water-glycol return flows into the storage tank. When the temperature of the coolant leaving the glycol reservoir reaches 45 degrees or above, the coolant temperature control valves close and no more coolant is allowed to flow directly from the pump to the parallel network output junction.

The water-glycol flowing out of the parallel cooling network, in all mission phases, is routed to the glycol evaporator. The glycol evaporator regulates the temperature of the incoming water-glycol, when it is too high, by a water evaporation process which cools the water-glycol. The energy required to vaporize a specific amount of waste water is removed from the water-glycol, causing the temperature of the coolant to drop.

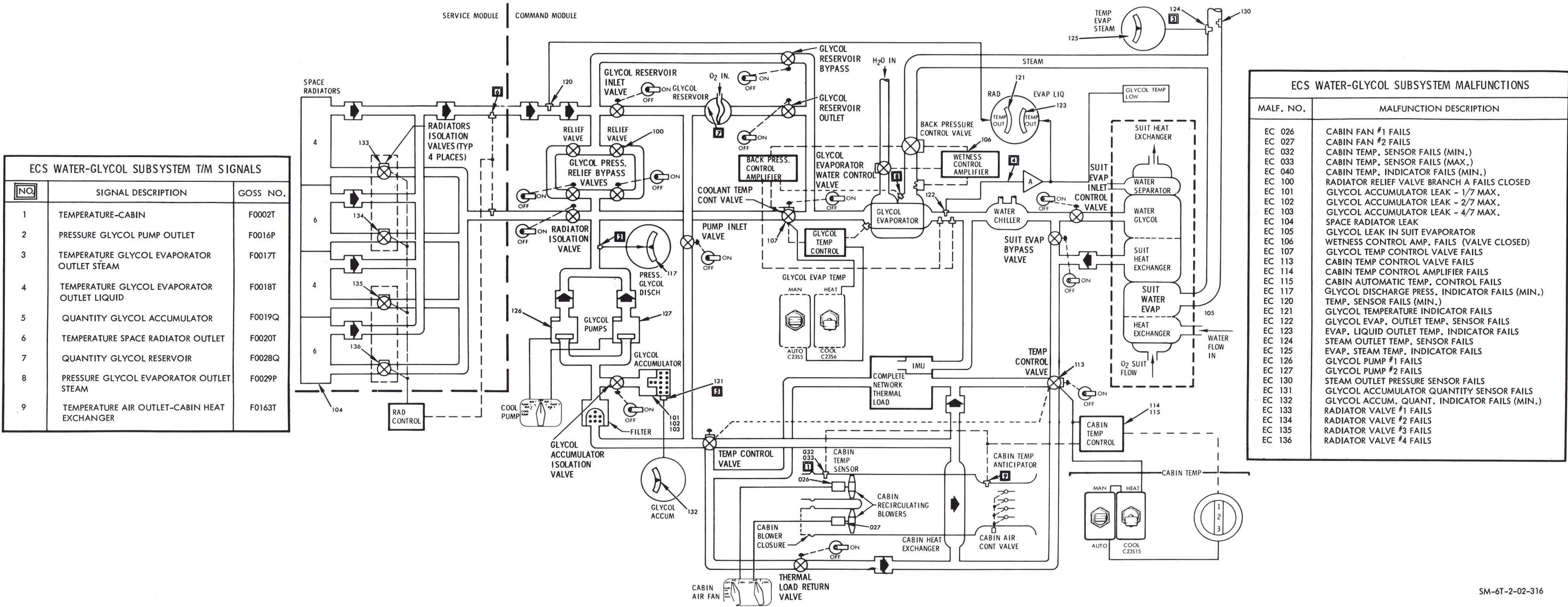


Figure 2-13. Water-Glycol Subsystem

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The coolant flows from the evaporator toward the main C/M coolant branch. Before reaching this branch, a small amount of the water-glycol is diverted and flows through the IMU cold plate to maintain the IMU electronics at a closely regulated temperature.

The flow into the main C/M coolant branch is routed through the water chiller heat exchanger, cooling the drinking water.

The water-glycol flows from the water chiller into the suit heat exchanger under normal conditions. There it cools the suit gas to approximately 50°F. If the heat transfer is not sufficient to lower the gas temperature to 50°F, a valve in the suit water evaporator is opened automatically. The valve opens until the energy removed from the coolant by the water evaporation lowers the coolant outlet temperature to 50°. Closing the suit evaporator inlet control valve and opening the suit evaporator bypass valve allows the suit circuit to be removed from the coolant circuit.

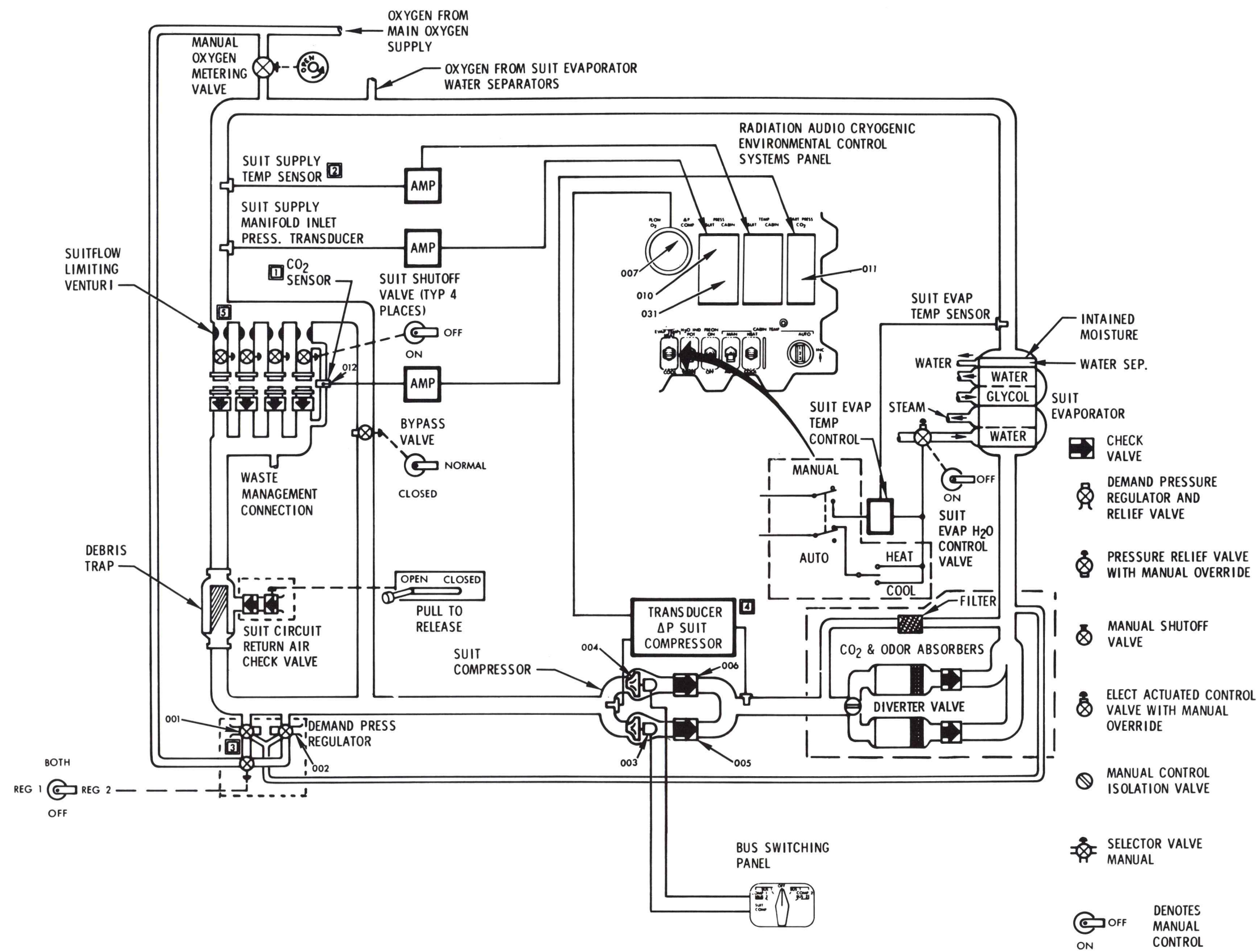
From this point, the coolant is routed to the cabin air temperature control valve. This two-part valve controls the input and output of the parallel cabin heat exchanger and cabin cold plates to maintain proper cabin temperature. The valve causes the incoming coolant at 50°F to flow directly through the cabin heat exchanger, when maximum cabin cooling is required, or through the cabin cold plates for preheating before it reaches the cabin heat exchanger if the cabin air requires maximum heating. In cases of less than maximum heating or cooling, the temperature control valve allows partial flow through each path. This allows the cabin heat exchanger to receive coolant at between 50° and 100°F, depending on temperature requirements. The cabin cold plates mentioned above are actually a group of small heat exchangers used to cool all electronic equipment in the C/M, except the IMU equipment.

The storage tank and glycol accumulator serves as system reservoirs to replace coolant lost from small leaks. Valves are provided to isolate each of these units.

2.6.2.4 Pressure Suit Subsystem.

The pressure suit subsystem provides a conditioned atmosphere for the crewmembers throughout the mission, including periods of complete cabin depressurization. Figure 2-14 illustrates the pressure suit subsystem or suit circuit and its components (including simulated malfunctions and telemetry points). The subsystem automatically controls suit gas flow, pressure, temperature, and humidity. It also removes debris, carbon dioxide, and odors from the suit and the C/M interior.

Oxygen enters the suit circuit from the main oxygen supply manifold through the manual O₂ metering valve and/or the demand pressure regulator and relief valve. The O₂ metering valve is used to purge the suit circuit. The demand regulator maintains the suit pressure at a few inches of water below cabin pressure down to 3.5 psi. Below that cabin pressure, the regulator will continue to regulate the suit pressure at 3.5 psi.



ECS PRESSURE SUIT SUBSYSTEM MALFUNCTIONS	
MALF. NO.	MALFUNCTION DESCRIPTION
EC 001	DEMAND PRESS. REGULATOR AND RELIEF VALVE #1 FAILS
EC 002	DEMAND PRESS. REGULATOR #2 FAILS
EC 003	SUIT COMPRESSOR MOTOR #1 FAILS
EC 004	SUIT COMPRESSOR MOTOR #2 FAILS
EC 005	SUIT COMPRESSOR OUTLET CHECK VALVE #1 LEAKING
EC 006	SUIT COMPRESSOR OUTLET CHECK VALVE #2 LEAKING
EC 007	DELTA P COMPRESSOR INDICATOR FAILS (MIN.)
EC 010	SUIT PRESSURE INDICATOR FAILS (MAX.)
EC 011	CO ₂ PARTIAL PRESSURE INDICATOR FAILS (MAX.)
EC 012	CO ₂ PARTIAL PRESSURE SENSOR FAILS
EC 025	CABIN PRESSURE SENSOR FAILS
EC 030	C/M INNER STRUCTURE PUNCTURED
EC 031	CABIN PRESSURE INDICATOR FAILS (MIN.)

ECS PRESSURE SUIT SUBSYSTEM T/M SIGNALS		
NO	SIGNAL DESCRIPTION	GOSS NO.
1	CO ₂ PARTIAL PRESSURE	F0005P
2	SUIT SUPPLY MANIFOLD TEMPERATURE	F0008T
3	SUIT DEMAND REGULATOR SENSOR PRESSURE	F0012P
4	SUIT COMPRESSOR DIFFERENTIAL PRESSURE	F0015P
5	SUIT INLET HUMIDITY SENSOR	F0100Q

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Figure 2-14. Pressure Suit Subsystem

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The suit compressor receives the oxygen from the regulator. Circulation of the suit gases is provided by the suit compressor. There are two compressors in parallel to provide redundancy.

The oxygen leaves the compressor and flows through the CO₂ and odor absorber assembly where the CO₂ is removed through chemical reaction with lithium hydroxide in the filterpack. Odors in the circulating gas are removed by absorption into the activated charcoal of the filterpack. Particles too small to be removed by the debris trap will be caught by the Orlon felt pads in the filterpack.

After leaving the absorbers and filters, the oxygen is passed through the suit evaporator where it is cooled and dehumidified as explained in the water-glycol subsystem section. During cooling of the O₂, its water content in excess of 50 percent relative humidity condenses on the plates of the suit evaporator and is separated out for use as waste water. From this point, the cleaned and cooled O₂ is sent to the suit connectors on the suit supply manifold where an astronaut may connect his suit to any of the four input points.

A debris trap is incorporated in the return line from the suit connectors to remove dust or other material which may be in the suit. Series-redundant return air check valves are connected to the debris trap to allow cabin oxygen to circulate through the suit circuit for cleaning and dehumidifying. As the suit circuit is maintained at a slightly lower pressure than the cabin, this circulation of cabin air will be continuous unless the cabin pressure drops below 3.5 psi. To compensate for the extra oxygen taken into the suit circuit, the demand pressure regulator and relief valve will relieve to the cabin.

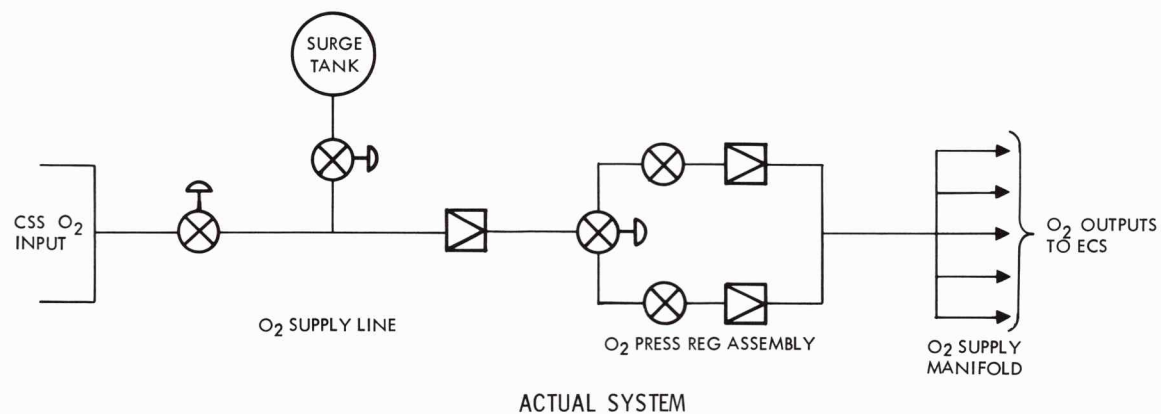
2.6.3 ECS SIMULATION.

ECS hardware in the AMS is limited to the controls and displays. All oxygen, water, coolant, waste water, and variables, such as masses, flow rates, quantities and temperatures are computed. The actual environment of the AMS command module is controlled by the AMS environmental system. The interface between these two systems is functional in that command module temperature controls, in addition to providing inputs to the ECS simulation section of the computer, establish the control temperature for the trainer air conditioner. Use of water from the potable water outlets will also provide inputs to the computer even though the water is provided from an external source.

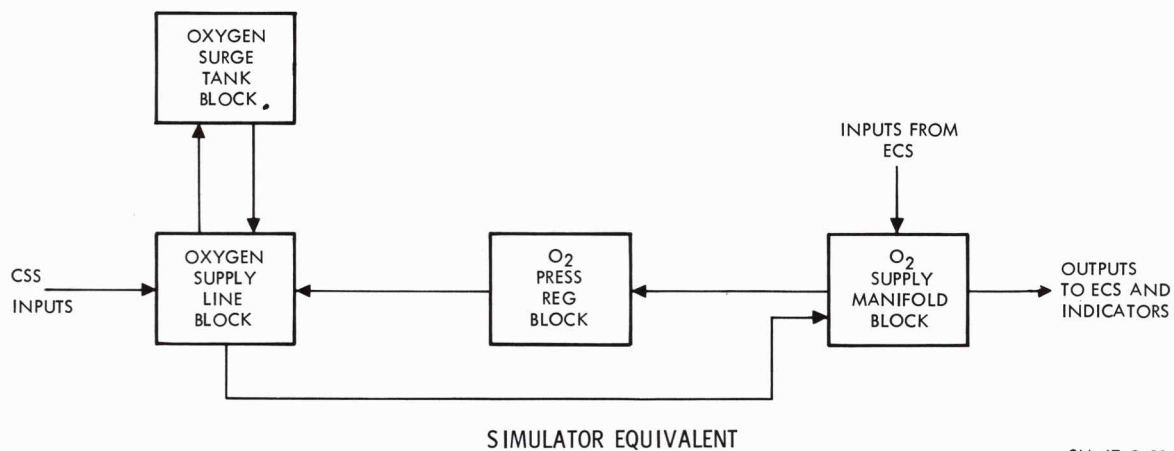
2.6.3.1 Oxygen Subsystem Simulation.

The oxygen subsystem has been divided into blocks for computer mechanization. These blocks are the oxygen high-pressure supply, oxygen high-pressure surge tank, primary ECS oxygen regulators, and ECS main oxygen distribution manifold blocks. Each block has a group of equations within the computer for maintaining temperatures, pressures, and quantities, and feeding these values to C/M and IOS readouts. Figure 2-15 shows each block of the oxygen subsystem simulation.

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ACTUAL SYSTEM



SIMULATOR EQUIVALENT

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Figure 2-15. Oxygen Subsystem Simulation

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The oxygen high-pressure supply block keeps track of the total simulated oxygen inflow to the ECS by summing the outputs from the two simulated cryogenic storage system (CSS) oxygen tanks. These two signals come from the CSS simulation section in the computer. The oxygen accumulated in the supply line is simulated by adding the oxygen inflow and subtracting the oxygen flow out through the regulator assembly from the previous oxygen mass within the supply line.

The oxygen high-pressure supply block of the oxygen subsystem controls simulation of oxygen volume, temperature, and pressure within the high-pressure supply line. This block considers oxygen demands by other ECS computations and simulated CSS inputs.

The high-pressure surge tank block determines the simulated mass flow rates, mass accumulation rate, mass content, pressure, temperature, and rate of temperature change within the oxygen surge tank.

The primary ECS oxygen regulators simulation block computes the mass flow rates through the oxygen regulators and pressure relief valves.

The ECS main oxygen distribution manifold block provides the means for determining simulated pressure and temperature within the oxygen supply manifold. Oxygen mass flow rate through the manifold is also computed within this block.

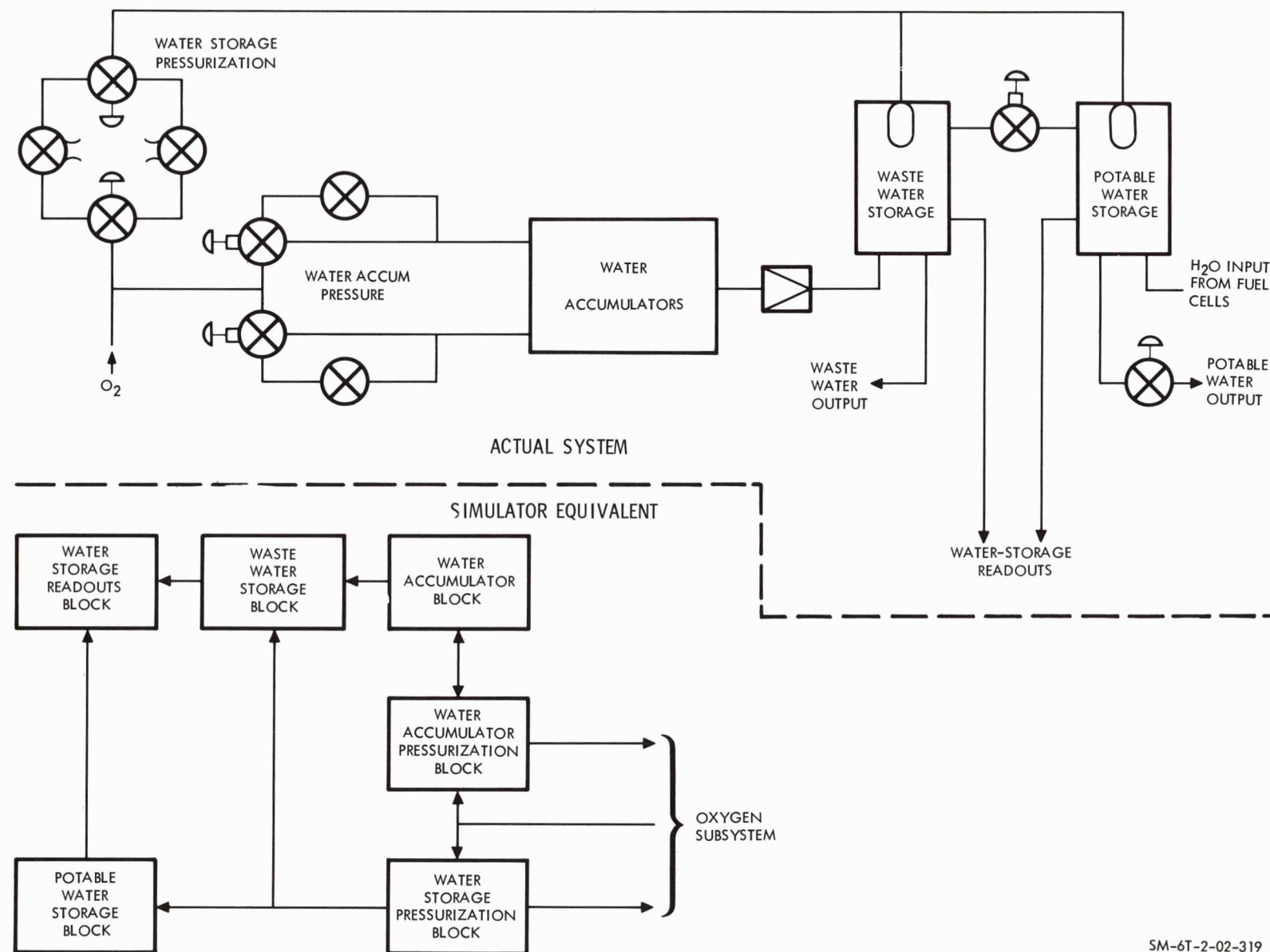
2.6.3.2 Water Supply Subsystem Simulation.

The water supply subsystem has six subdivisions or blocks to simulate the thermodynamics of the subsystem. Figure 2-16 shows the simulated water supply subsystem blocks along with their actual system equivalent in simplified form. These blocks are described in the following paragraphs.

The water storage pressurization block computes the simulated volume of oxygen within the water subsystem along with its weight. Also figured is the O₂ flow rate into and out of the subsystem and whether oxygen flow into the subsystem is possible, as determined by position of manual regulator select valves.

The potable water storage block is used to simulate all facts pertinent to the potable water supply: its weight, inflow rate, and temperature of food probe hot water. This block also determines whether fuel cell water will flow into the potable or waste water tank, whether water is available from the fuel cells, and if the water system can accept it. Electrical operations simulated include large and small food probe water heaters, heater power available and circuit breaker loads. Actual water flow through the food water probes and the water demand tubes is metered and fed into the computer to cause a decrease in the simulated potable water available.

Simulated water flow rate into the waste water tank and the weight of water in the waste water tank are computed in the waste water storage block.



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Figure 2-16. ECS Water Supply Subsystem Simulation

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The equations of the water accumulator block simulate the operation of the two water accumulators. Accumulator water inflow rates from the suit heat exchanger are integrated with accumulator water outflow to the waste water tank or overboard to calculate the amount of water in either accumulator. The timing cycle of 10 minutes of accumulation and 10 seconds of purge is also simulated by the block.

The water accumulator pressurization block determines the oxygen flow rates into and out of the accumulators and the weight of oxygen contained in the accumulators.

The water storage readout block provides command module and IOS water indications after it determines if indicator power is available for C/M indicators. Simulation to determine if waste water is available is also made here.

2.6.3.3 Water-Glycol Subsystem Simulation.

The function of the simulated water-glycol subsystem is to provide simulation of the required temperature control capabilities. Operation of AMS command module temperature controls by the crewmembers causes inputs to be sent to the ECS simulation section of the computer and also to the AMS air conditioning to actually control command module temperature. In the computer, these inputs act as independent variables to cause changes in simulated temperatures and flow rates. Prolonged or complete failure of the real system will cause catastrophic results if not corrected within a specific time. Malfunctions of this type are included in the capabilities of the simulated water-glycol subsystem.

The water-glycol subsystem simulation is accomplished in blocks of equations within the AMS computer, as are most spacecraft subsystem simulations. The relationship of each block to the other blocks is illustrated in figure 2-17. The blocks and their purposes are included in the following paragraphs.

The water-glycol flow block is used to determine possible flow paths for the coolant. It also determines if flow is possible through the space radiators, relief valves, storage tank bypass, and heat bypass valves, and the mass flow rates through each of these points. The glycol pump status is determined along with the differential pressure across the pump. The temperatures of the coolant into the storage tank and into the glycol evaporator are computed by equations within the block. Other equations provide the simulated position of the cabin temperature control valve. An electrical short circuit may be simulated in the water-glycol subsystem as a simulated malfunction. Two equations are required to consider this possibility: one to determine if a short circuit is possible and the other to determine if the condition exists.

The water-glycol mass block of the water-glycol subsystem is used to compute simulated flow rates between and mass within, the water-glycol storage tank, accumulator, and the flow rate into, and mass within the glycol system. Flow rates between the three mass containing portions of the system are computed as a function of the differential pressures involved.

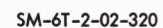


Figure 2-17. Water-Glycol Subsystem Simulation

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The glycol evaporator block provides the capability of operating the evaporator in either automatic or manual mode. In the automatic mode, the evaporator control regulates the position of the back-pressure valve in order to provide regulated water-glycol temperature simulation. In the manual mode, the position of the back-pressure valve is directly controlled by the astronaut. The output temperature of the water-glycol is computed as a function of this valve position.

The back-pressure valve manual control block computes and stores the amount of time the manual back-pressure valve is in the on position.

Mass flow rate and temperature computations for the water-glycol flowing into and out of the cold plate are the main function of the IMU cold plate block. The simulated transfer of heat is computed in the IMU portion of the computer.

Equations in the suit heat exchanger block describe in detail the operation of the suit heat exchanger. The automatic and manual modes of the heat exchanger are simulated in a manner similar to that used for the glycol evaporator. The two types of suit air cooling are simulated for the heat exchanger: normal exchange of heat between the suit air and the water-glycol, and evaporative cooling if the water-glycol exchange is unable to lower the suit air to the desired temperature. This block computes valve positions, oxygen input valves, oxygen and glycol output temperatures, waste water used, waste water generated, and evaporation variables.

Control and operation of the cabin heat exchanger is simulated by the cabin heat exchanger block of equations within the computer. Temperature and flow rate of the water-glycol flowing into and out of the exchanger are computed here. Position of the cabin temperature control valve is also computed in this block as a function of system status, desired cabin temperature, actual cabin temperature, and exchanger output temperature on the cabin air side.

The cabin temperature control valve positioning block simulates the positioning of this valve in the cabin heat exchanger assembly. Because of the rapid simulated changing of the valve position, a high interaction rate is used in the computations.

The cabin cold plate simulation calculates the glycol mass flow rate into the cabin cold plate. It also determines the cabin temperature into the cold plate and the rate of change in the cabin temperature. Other factors computed in this block include water-glycol temperature into and out of the cold plate.

The water-glycol readout block is used to provide computer outputs to drive indicators for most of the water-glycol portion of the ECS. This block also provides simulated water-glycol to the telemetry system.

Those ECS water-glycol indicators not driven by the water-glycol readout block are provided for by water-glycol high-iteration readout block. These indicators are driven by this block because of their high fluctuation rate in the actual system. Therefore, to provide authentic simulation, their indication voltages must be computed more often than normal.

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The water-glycol subsystem electrical loading and power available block is utilized to determine if the required power is available for the water-glycol subsystem electrical components. The electrical loading of each component of the water-glycol subsystem is computed to determine their affect on the electrical power system.

2.6.3.4 Pressure Suit Subsystem Simulation.

Pressure suit subsystem simulation is also accomplished in several blocks of equations within the computer. This simulated subsystem includes not only the pressure suit, but also the cabin air parameters and air conditioning unit control computations. Figure 2-18 describes the relationship between the blocks of equations. The following paragraphs explain the function of each of these blocks.

The cabin air mass block provides computation of air mass within the C/M and air mass flow into and out of the cabin. It also determines cabin air valve positions. Current drawn by these valves is provided to the EPS. Cabin air fans on-off condition and power requirements are determined here.

The cabin air temperature block calculates cabin heat exchanger energy transfer, radiation effect, entry heat effect, cabin temperature change rate, and the overall effect of these variables on cabin temperature.

Cabin pressure is computed in the cabin air pressure block using cabin air temperature and oxygen mass within the cabin.

Cabin temperature and pressure indicators in the C/M are controlled by the cabin air readout block. This block also provides telemetry signals for these two cabin air parameters.

The air conditioning unit control block is used to control the actual simulator environment. The equations within the block provide computer control of the simulator cabin and suit temperature. Maximum and minimum temperature limits are provided for crew safety.

The suit circuit demand regulator block simulates the oxygen flow characteristics from the regulator to the CO₂ absorber outlet manifold. This oxygen flow is required to replace gas which is decomposed by crew breathing, and to replace oxygen relief flow from the suit circuit to the cabin. Equations of this block also establish a suit circuit reference pressure.

The suit inlet manifold block combines oxygen inputs from the manual oxygen metering valve and the suit exchanger and, as a function of the suit inlet pressure, simulates the temperature, pressure, mass and flow rates to the suits, cabin, and/or the suit bypass valve.

The suit outlet manifold block combines gases from the suit return, cabin return, and suit bypass flow for its overall computations of pressure, gas flow, heat, temperature increase, and mass. Each of the branches of flow, each suit, cabin flow, and suit bypass is also calculated individually.

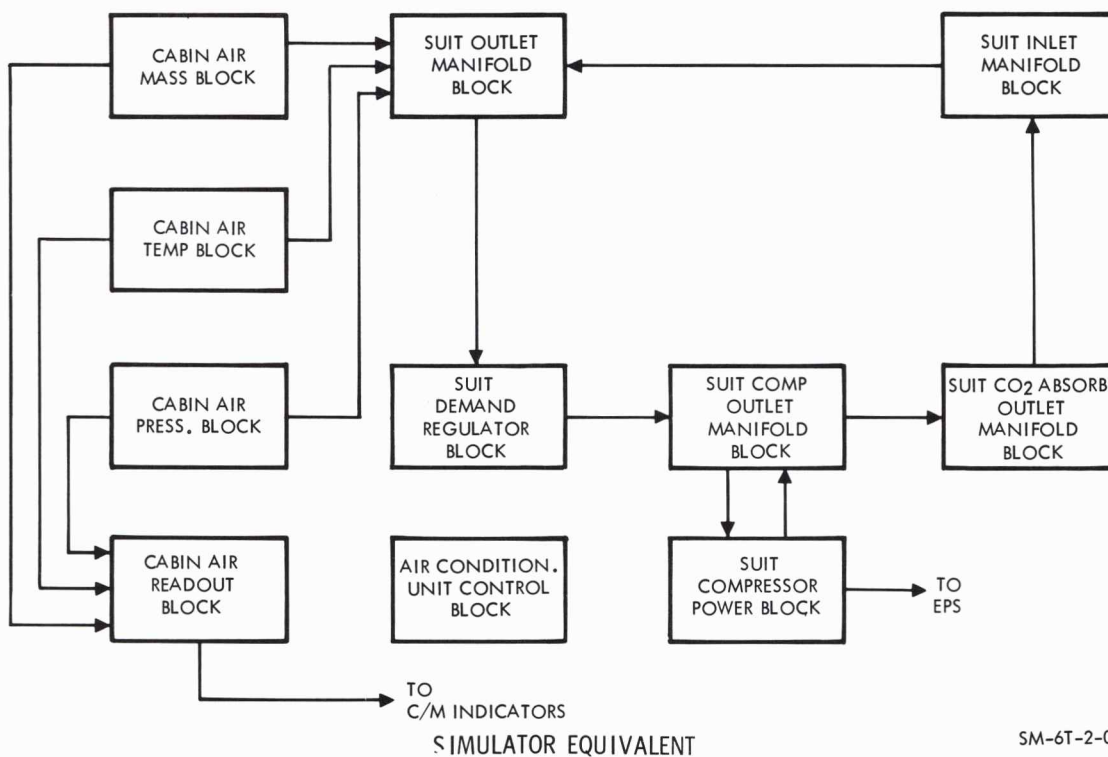


Figure 2-18. Pressure Suit Subsystem Simulation

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The suit compressor outlet manifold block determines the compressor differential pressure, compressor flow, compressor heat transfer and compressor output volume, pressure, and temperature.

The suit circuit CO₂ absorber outlet manifold block computes the mass content and flows through the CO₂ absorbers and absorber bypass. By considering the characteristics of the simulated incoming gas, these equations obtain simulated temperatures, pressure, outlet flow, and mass. The gas composition is also simulated in this block to furnish partial pressures and individual gas flows.

The suit circuit compressor power block computes the compressors power and current relationships for use in computations in the compressor outlet manifold block above. This information is also fed to the EPS section of the computer for total power consumption calculations.

2.6.4 AMS ENVIRONMENT SYSTEM.

2.6.4.1 SCM Environment.

The simulated ECS provides control for the simulator command module temperature, humidity, suit pressure, and cabin fans. It also provides waste management, water, and smoke for simulated command module fire.

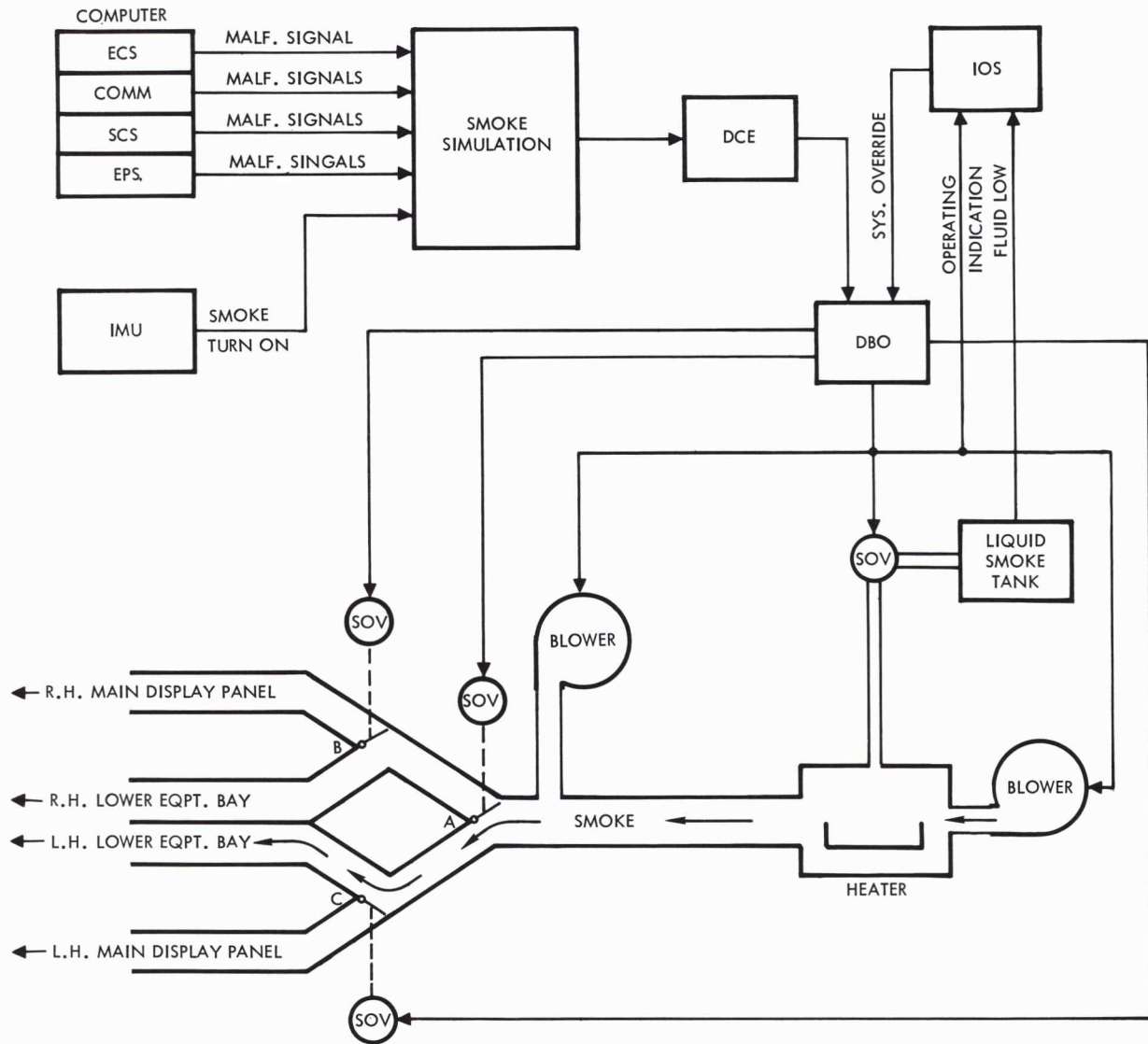
Command module temperature may be controlled either automatically or manually from a maintenance panel in the equipment racks. Nominal temperature establishment is a maintenance function. The astronaut also has a set of controls by which he may control cabin temperature. Both the maintenance panel automatic (normal) control and the astronaut (manual) control will be overridden by the computer during entry. This simulation of entry heat may be overridden or decreased by the IOS operator using the REENTRY HEAT OVERRIDE control. A safety temperature switch is provided to automatically shut off the heating unit if the cabin temperature should exceed safe limits. Humidity is also controlled by this air conditioning unit. A signal from the humidity sensor is sent through a signal conditioner to the command module humidity indicator.

Four compressors provide a pressurized air supply for the four command module suit connectors. The air is raised to a pressure slightly higher than that of the command module, filtered, and sent through the suit circuit. A blower is provided in the suit circuit exhaust to maintain circulation. The suit circuit compressors are also capable of producing increased pressure differentials for simulating malfunctions such as C/M structure punctures, etc. This is accomplished by positioning the suit pressure override dial on the true trainee environment panel of the IOS.

2.6.4.2 Smoke Simulation.

The smoke system (figure 2-19) operates in response to certain malfunction commands to provide smoke within the simulator command module. The smoke system includes heater, two blowers, and a fluid supply.

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Figure 2-19. Smoke Simulation Subsystem

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When certain malfunctions occur, the computer will activate the smoke system, liquid smoke will be placed in an evaporation disk, and the blowers activated. The smoke is expelled into the C/M in the general area of the simulated malfunction. The area in which the smoke is introduced into the C/M is controlled by three solenoid valves. These solenoids are positioned by the malfunction selection.

In addition to the programed smoke generating malfunctions, the instructor is able to cause smoke in the C/M through use of the MIU control panel. The instructor also has a smoke monitoring section on the IOS. This panel contains an override switch, an OPERATING light, and a FLUID LOW light.

Manual control of the smoke system from the MIU allows the instructor to add smoke to other malfunctions which are not programed to do so.

2.6.4.3 Waste Management System.

Waste management for the simulator ECS is controlled from the urine control panel in the lower equipment bay. There, two unlabeled switches determine system operation. Operation of the system is the same as AF006, AF008, and BP014 as far as the crew is concerned. A block diagram of the AMS waste management system is shown in figure 2-20. This drawing shows the main difference between the spacecraft system and the simulator system as being the urine storage tank in the simulator, rather than the overboard dump function in the actual system.

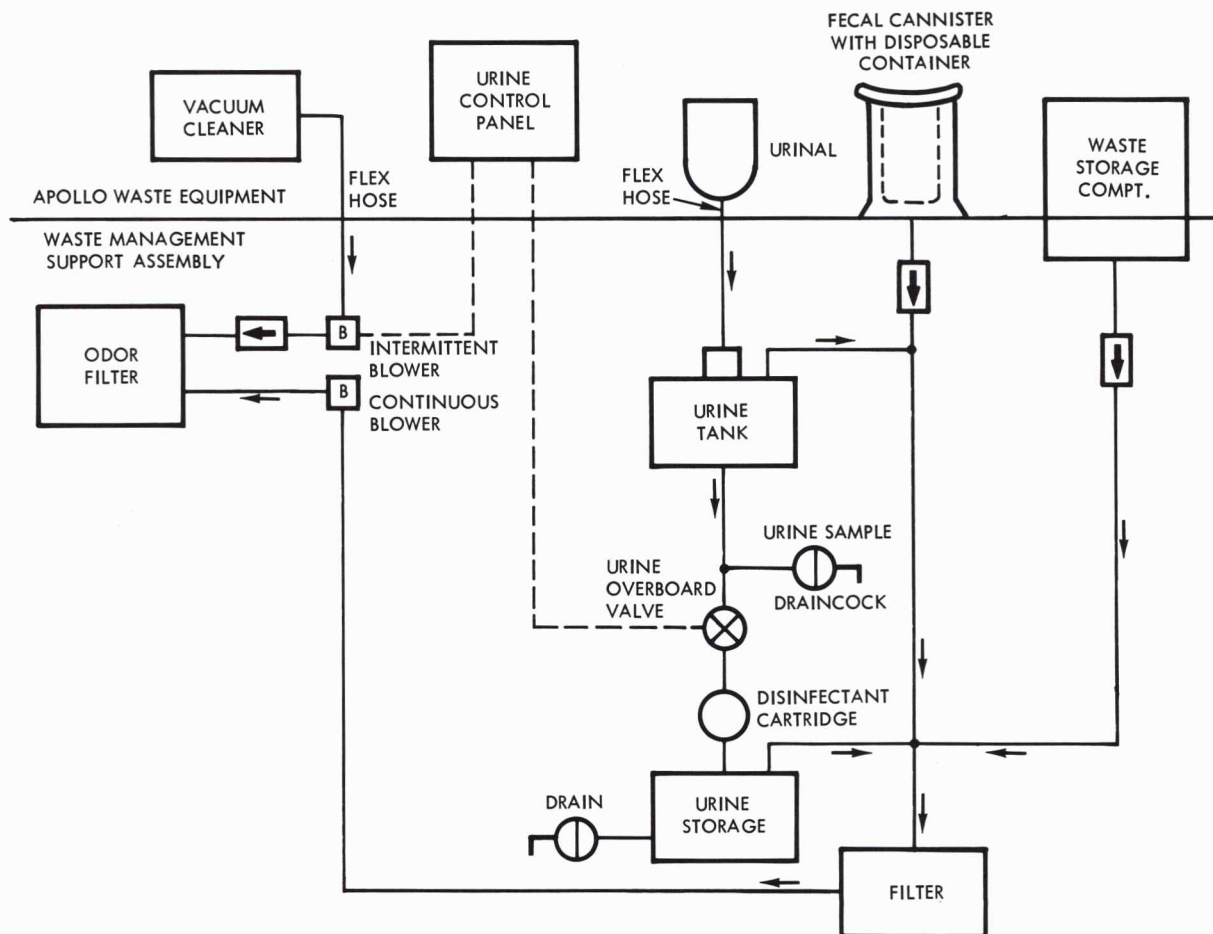
2.6.4.4 Aural Cue Simulation.

The aural cues system simulates the acoustic noises of the Apollo, external to the communications headsets. The sounds presently simulated are as follows:

- a. Launch boost
- b. Launch escape main motors
- c. Ambient command module sound level
- d. Entry aerodynamic noises

The aural cues system is controlled from the IOS. Manual switches provide on-off control and db override control to facilitate manual reduction of noise volume in the C/M. Figure 2-21 is a block diagram of the aural cues system. A white noise generator with a level frequency distribution will generate a random noise envelope. The output of the generator is fed to three circuits which control the output amplitude and frequency characteristics of the generator as a function of time and event occurrence. Each circuit consists of a voltage-controlled filter (VCF) and a voltage control attenuator. The voltages fed into the filters and amplifiers are outputs of the computer. These voltages control the frequency and amplitude of the output signal. An additional noise generator is used to simulate sounds arising during a-c power generation by the static inverters. This output plus the three outputs from the voltage-controlled amplifiers are fed through a mixer to another attenuator. The voltage to this attenuator is determined by the IOS override db control. The output of the VCA feeds the power amplifier, which is also controlled from the IOS, through the

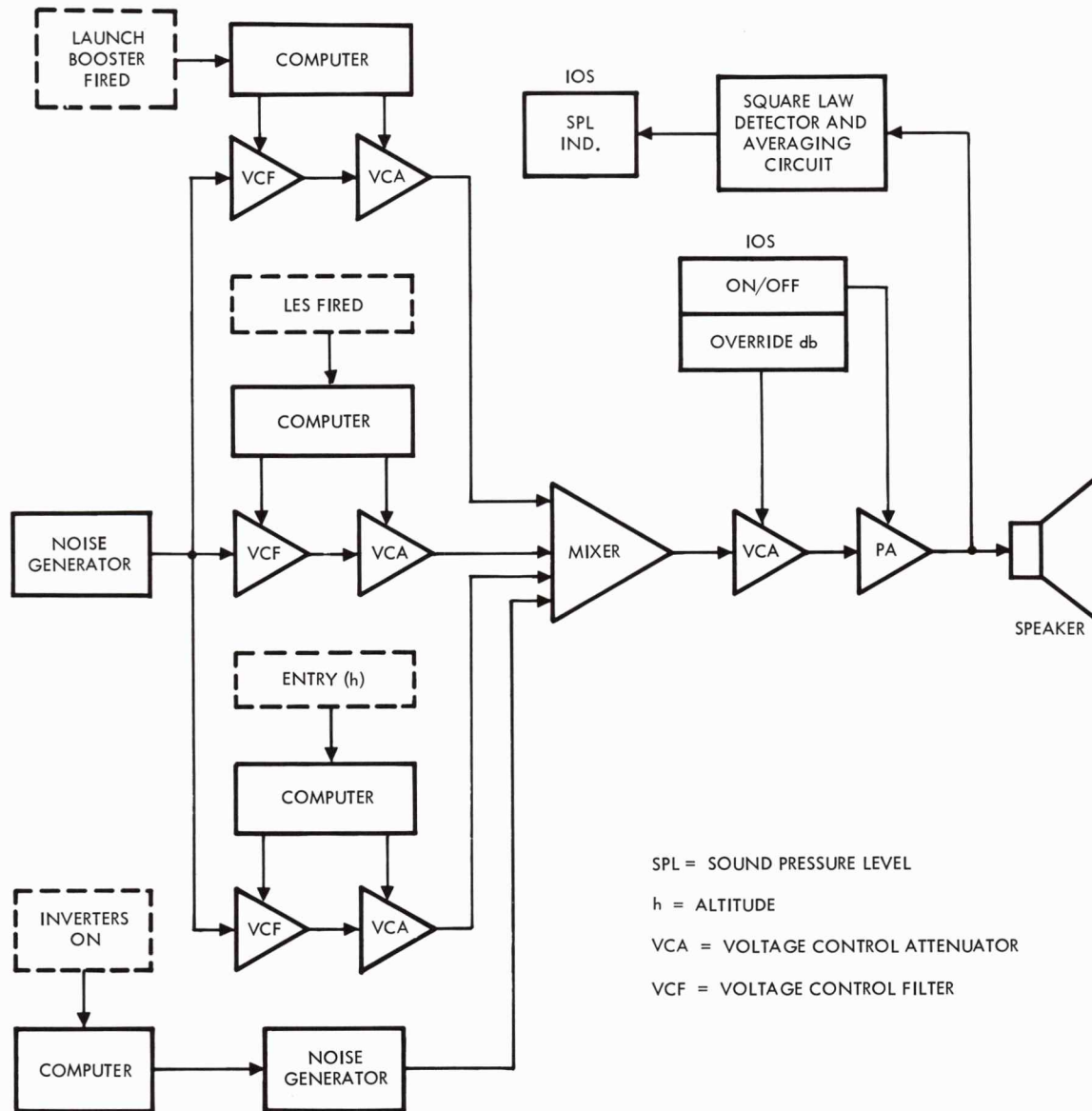
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Figure 2-20. Waste Management Subsystem

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Figure 2-21. Aural Cue Simulation System

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AURAL CUES ON-OFF switch. The power amplifier output drives the sound pressure level indicator and the speaker at the simulator C/M.

2.7 SERVICE PROPULSION SYSTEM (SPS).

The spacecraft SPS provides the thrust required for all major velocity changes after separation from the launch vehicle. Such changes include planar changes, orbital transposition, and retrograde in the earth orbital mission. The SPS consists of a rocket engine and a propellant storage and distribution system as shown in figures 2-22 and 2-23. The figures include simulated malfunctions and PCM telemetry points.

2.7.1 SPS CONFIGURATION REFERENCE.

The SPS simulated in the AMS-IDC is that designed for AF006. A redesign of the SPS between AF006 and AF012 has caused the following addition to appear in AF012.

- a. N₂ pressure indicator, shared with the existing helium pressure indicator, panel 20.
- b. H_e-N₂A-N₂B pressure indicator selector switch, panel 20.
- c. SPS chamber pressure switch and indicator, shared with L/V angle of attack, panel 3.
- d. Injector prevalues A & B ON-OFF switches, panel 3.

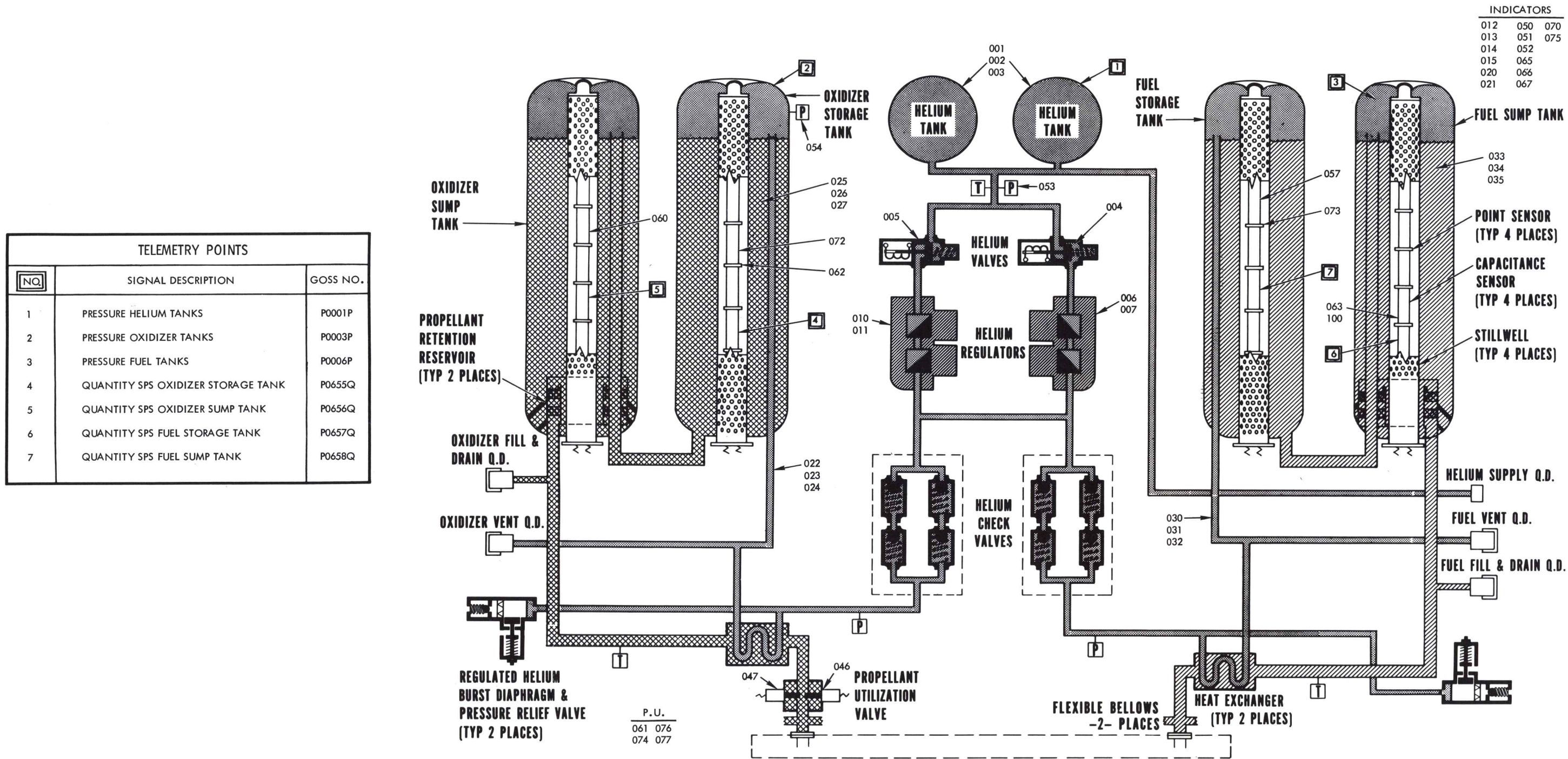
2.7.2 SIMULATED SPS (S/C EQUIVALENT).

Propellant flow to the engine is accomplished by pressurizing the fuel and oxidizer tanks with helium. The helium is supplied from two storage tanks connected in parallel. The propellant feed system is illustrated in figure 2-22.

Two solenoid-operated isolation valves are located in the helium lines between the storage tanks and the two paralleled sets of series pressure regulators. The two sets of series pressure regulators, connected in parallel, provide a double redundancy. The primary regulator in each set maintains a nominal pressure of 185 psia while the secondary regulator, used as backup, operates at a nominal 187 psia.

There are two sets of series-parallel check valves, below the distribution manifold, where the outputs of the two primary helium regulators are combined. The check valves prevent back flow of helium or propellant from the propellant tanks. The check valve network, operating individually, will allow helium to pass into the fuel and oxidizer tanks, pressuring them.

A propellant-to-helium heat exchanger is located in each of the two propellant feed systems. The helium side of the heat exchanger will receive its input from the appropriate set of check valves and its output is fed into the propellant tanks. The propellant side accepts fuel or oxidizer from the respective tank, heats the helium, and passes on toward the engine.



SPS MALFUNCTIONS			
MALIF. NO.	MALFUNCTION DESCRIPTION	MALF. NO.	MALFUNCTION DESCRIPTION
SP-001	HELIUM TANK LEAKAGE, 1/7 MAX. RATE	SP-034	FUEL SYSTEM FUEL LEAKAGE, 2/7 MAX. RATE
SP-002	HELIUM TANK LEAKAGE, 2/7 MAX. RATE	SP-035	FUEL SYSTEM FUEL LEAKAGE, 4/7 MAX. RATE
SP-003	HELIUM TANK LEAKAGE, 4/7 MAX. RATE	SP-046	PU PRIMARY VALVE FAILS
SP-004	HELIUM ISOLATION VALVE A FAILS OPEN/CLOSED	SP-047	PU SECONDARY VALVE FAILS
SP-005	HELIUM ISOLATION VALVE B FAILS OPEN/CLOSED	SP-050	PU VALVE POSITION INDICATOR FAILS IN PRESENT POSITION
SP-006	HELIUM REGULATOR A FAILS CLOSED	SP-051	PU VALVE POSITION INDICATOR FAILS, SLEWS TO MAX. ORIFICE
SP-007	HELIUM REGULATOR A, PRIMARY SECTION, FAILS OPEN	SP-052	PU VALVE POSITION INDICATOR FAILS, SLEWS TO MIN. ORIFICE
SP-010	HELIUM REGULATOR B FAILS CLOSED	SP-053	HELIUM TANK PRESSURE SENSOR FAILS OPEN
SP-011	HELIUM REGULATOR B, PRIMARY SECTION, FAILS OPEN	SP-054	OXIDIZER ULLAGE PRESSURE SENSOR FAILS OPEN
SP-012	HELIUM ISOLATION VALVE A POSITION INDICATOR FAILS INDICATING CLOSED	SP-057	FUEL STORAGE TANK SENSOR FAIL (PU PRIMARY)
SP-013	HELIUM ISOLATION VALVE B POSITION INDICATOR FAILS INDICATING CLOSED	SP-060	OXIDIZER SUMP TANK SENSOR FAIL (PU PRIMARY)
SP-014	HELIUM TANK PRESSURE INDICATOR FAILURE	SP-061	FUEL FLOW RATE INTEGRATOR FAIL (PU AUXILIARY)
SP-015	HELIUM TANK TEMPERATURE INDICATOR FAILURE	SP-062	OXIDIZER POINT SENSOR FAIL (PU AUXILIARY)
SP-020	OXIDIZER ULLAGE PRESSURE INDICATOR FAILURE	SP-063	FUEL SUMP TANK SENSOR FAIL (PU PRIMARY)
SP-021	FUEL ULLAGE PRESSURE INDICATOR FAILURE	SP-065	OXIDIZER QUANTITY INDICATOR (PU) SLEWS TO MAXIMUM
SP-022	OXIDIZER SYSTEM HELIUM LEAKAGE, 1/7 MAX. RATE	SP-066	OXIDIZER QUANTITY INDICATOR (PU) SLEWS TO ZERO
SP-023	OXIDIZER SYSTEM HELIUM LEAKAGE, 2/7 MAX. RATE	SP-067	PU UNBALANCE INDICATOR SLEWS TO MAXIMUM INCREASE
SP-024	OXIDIZER SYSTEM HELIUM LEAKAGE, 4/7 MAX. RATE	SP-070	PU UNBALANCE INDICATOR SLEWS TO MAXIMUM DECREASE
SP-025	OXIDIZER SYSTEM OXIDIZER LEAKAGE, 1/7 MAX. RATE	SP-075	PU UNBALANCE INDICATOR SLEWS TO ZERO
SP-026	OXIDIZER SYSTEM OXIDIZER LEAKAGE, 2/7 MAX. RATE	SP-072	OXIDIZER STORAGE TANK SENSOR FAILS (PU PRIMARY)
SP-027	OXIDIZER SYSTEM OXIDIZER LEAKAGE, 4/7 MAX. RATE	SP-073	FUEL POINT SENSOR FAILS (PU AUXILIARY)
SP-030	FUEL SYSTEM HELIUM LEAKAGE, 1/7 MAX. RATE	SP-074	OXIDIZER NORMAL FLOW FAILS (PU AUXILIARY SENSING)
SP-031	FUEL SYSTEM HELIUM LEAKAGE, 2/7 MAX. RATE	SP-100	FUEL SUMP TANK SENSOR FAILS (PU PRIMARY)
SP-032	FUEL SYSTEM HELIUM LEAKAGE, 4/7 MAX. RATE	SP-076	PU FAULT DETECTION SYSTEM #1
SP-033	FUEL SYSTEM FUEL LEAKAGE, 1/7 MAX. RATE	SP-077	PU FAULT DETECTION SYSTEM #2

Figure 2-22. SPS Propellant Subsystem

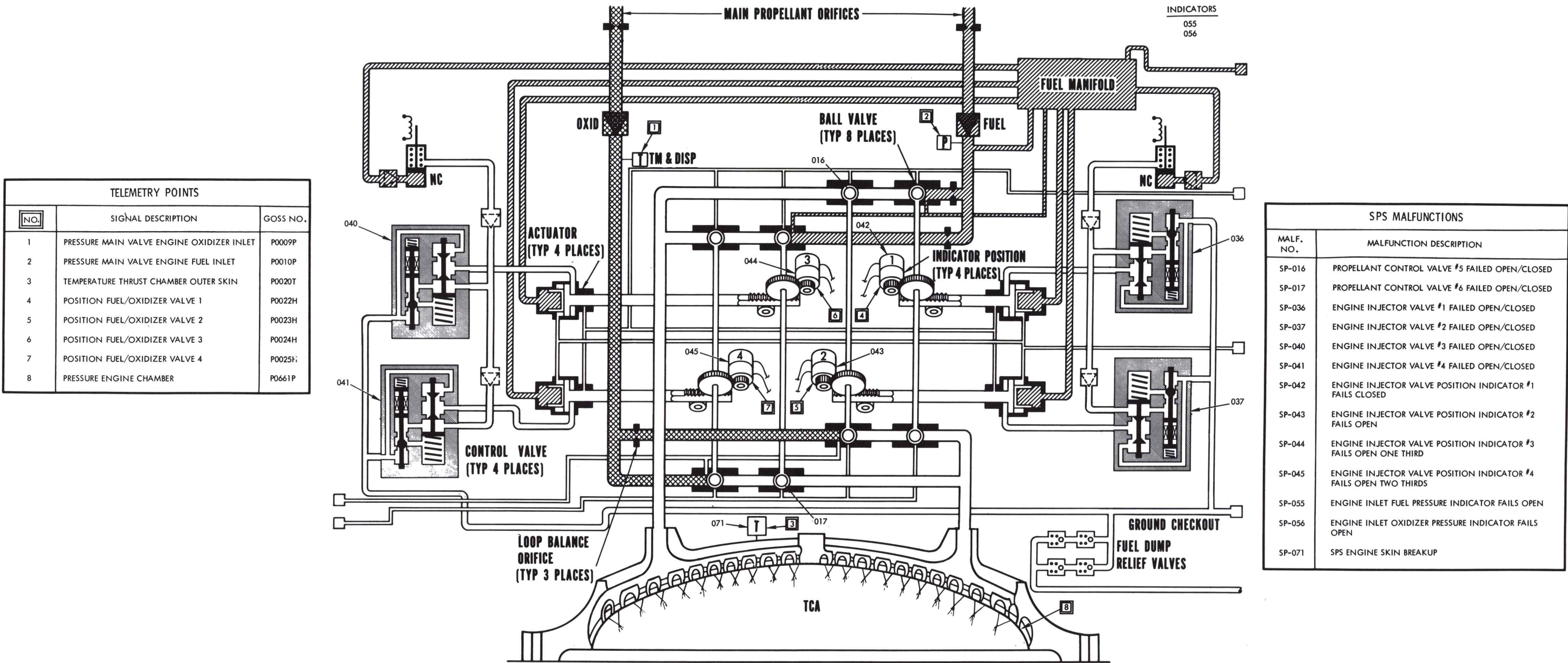


Figure 2-23. SPS Rocket Engine Subsystem

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The propellant feed system consists of two sets of propellant tanks and associated plumbing to the engine package. There are two tanks in the oxidizer set and two tanks in the fuel set. The oxidizer tanks are larger than the fuel tanks because twice as much oxidizer is used by the engine as fuel.

The engine package consists of four sets of engine control valves and the thrust chamber. The rocket engine subsystem is illustrated in figure 2-23. Each set of valves contains two mechanically-linked valves, one for oxidizer and one for fuel. These valve sets are connected in series-parallel such that a failure of any one set in the open or closed position will not cause an engine failure.

The propellant utilization (PU) valve is controlled by the propellant utilization system. This system measures the fuel and oxidizer remaining in the tanks. Using the known rate at which each propellant is used, a comparison is then made to determine if an unbalance exists between the remaining propellants. If there is an unbalance, the propellant utilization valve in the oxidizer line between the heat exchanger and the engine is positioned to compensate for this. The excess fuel or oxidizer will be burned over the remaining firing time by way of a revised fuel-oxidizer mixture proportion. The fuel and oxidizer quantities are measured by two different methods: capacitive sensors and point sensors. The capacitive sensors make up the primary sensing system while the point sensors make up the auxiliary sensing system. Normally, these two systems work together, the displayed quantity being a composite of both system outputs. In case of malfunction of either system, the astronaut may select either system to work individually. The PU valve may also be manually controlled from the command module.

2.7.3 SPS SIMULATION.

The SPS simulation is accomplished by means of component function simulation rather than the cause and effect simulation. This permits the combining or compounding of multiple malfunction within a given subsystem. The SPS simulation is divided into two sections. The dynamic simulation section simulates propellant and helium masses, flows, and flow rates, etc. The propellant utilization section simulates control of propellant burn rate.

2.7.3.1 SPS Dynamic Simulation.

The helium reservoir equations compute the characteristics of the helium in the storage tanks. The equations maintain the temperature, pressure, and mass relationships of the helium, and accounts for the compressibility factor of the gas at high pressures. The mass of helium remaining in the storage tanks is determined by integrating helium mass with helium mass flow rate times time. This determines a new helium mass for the following integration. The helium temperature is computed as a function of mass flow rate out of the system, and radiated and conducted heat transferred into the system. Reservoir pressure is determined by temperature, storage tank volume, helium mass, and several gas compressibility constants. Helium mass flow rates and helium temperature flow rates are functions of reservoir mass, pressure and temperature which causes these equations to be closed loop.

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The helium isolation valves and regulator operation equations compute the helium flow through the regulators. Through the use of malfunctions, these equations will determine that both regulator branches are functioning properly, one regulator branch is functioning properly, one or both branches have malfunctioned primary regulators, or no helium is flowing through the regulators (due either to regulator malfunction or to closed isolation valves).

The helium regulator equations are the most critical equations in the SPS from a stability and accuracy aspect. In solving these equations, the computer uses propellant tanks pressure predictors. Computations are made twice each iteration period to obtain maximum stability for the system. The helium regulator output pressures vary directly as a function of upstream pressure and inversely as a function of helium mass flow rate through the regulators.

Relief valve and heat exchanger equations are combined because of their common terms and because of their physical location in the actual system. The relief valves provide the propellant tanks with protection against overpressure. The relief valve equations are used to calculate simulated valve operation and amount of helium flow through them. The heat exchanger equations in this group are used to simulate the temperature change in the helium as it flows to the propellant tanks. The temperature of the propellants, the temperature of the helium, and the helium flow rate are all considered in these calculations.

The ullage equations determine the simulated characteristics of the pressurizing gases in the propellant tanks. The oxidizer vapor partial pressure is taken into account in the simulation of the oxidizer tank ullage pressure due to its varying effect on the overall tank pressure at different temperatures. Since fuel vapor partial pressure is small and changes only slightly over the system temperature range, it is not considered in the equations. These equations also allow the computer to keep track of the amount of helium or ullage in each propellant tank, the temperature and rate of temperature change of the ullage, and the flow rate of helium into each propellant tank. Leak rates in the propellant tanks are also computed by these equations.

The propellant tank equations are used to obtain the effect of resistance to propellant flow within the tanks and the propellant remaining in each tank. As quantity of fuel and oxidizer in the storage tanks decreases, propellant flow resistance also decreases because of the emptying of the stand pipe between the storage and sump tanks. This causes the thrust of the engine to increase during the latter part of the mission, both in the simulator and in the actual system. Propellant quantities remaining are obtained by integration of propellant flows. The quantity of propellants in the sump tanks are assumed to remain at the initial loaded level until the storage tanks are emptied.

The purpose of the engine equations is to compute the interrelation of propellant flow, chamber pressure, mixture ratio, and output thrust of the SPS engine. Since the terms of these equations are interrelated, an initial value must be applied to one of the variables when the engine is turned on. Thrust chamber pressure is selected for this term and is initialized at 103 psia. Engine starting and stopping transients are simulated by utilizing the ENGINE ON and ENGINE OFF clocks.

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The readout equations simulate the characteristics of the SPS sensors and indicators. The readout equations also simulate the effects of the various sensor and indicator malfunctions.

2.7.3.2 Propellant Utilization Subsystem (PUS).

The following equations simulate the propellant utilization system (PUS) in the SPS.

Through use of the power-available equations, the simulated PUS determines if a-c and d-c bus power is available for normal operating mode or test mode. To accomplish this, the system uses inputs from the SCS, SPS, and EPS equations and the PUS switches. Analysis of the switch positions and products of the power-available equations determine the system mode. Simulated current drain is derived from the a-c and d-c bus power available and the system mode. The remaining equations in this group will enable the simulated PUS sensors from the engine-on command and, after a time delay of 4.5 seconds, the PUS displays.

The propellant utilization valve equations, which are computed only during engine-on periods, use inputs from MIU and PUS switches. The PU valve position and several flow constants are ascertained and used to compute the PU valve flow resistance. The PU valve position indications are provided to the C/M and the IOS. The PU flow resistance is used in the SPS equations to determine the amount of oxidizer used. Two equations in this group are used to insert malfunctions into the simulated valve operation. One is used to malfunction the primary system and the other to malfunction the secondary system.

The PUS propellant quantity sensing equations use input information from the MIUs, the PUS switches, and the SPS equations. These equations are computed only during engine-on periods or when test mode is activated. They compute the weight of fuel and oxidizer remaining in each of the four propellant tanks. When the secondary sensing system is selected to provide propellant quantity outputs, two of the primary system outputs will maintain their present output while the other two will begin to transmit the secondary sensing system outputs. At the time this occurs, another equation allows the secondary system to take over control of the C/M indicators. The specific voltages sent to the C/M fuel quantity, oxidizer quantity, and unbalance indicator are determined through three other equations. The outputs for these three quantities to the IOS must be in binary form as they are processed through separate equations.

The PUS caution and warning equations use inputs from the MIU and PUS sensor equations and the PUS switches. These equations will compute a fuel-oxidizer ratio unbalance as determined by the primary or auxiliary quantity sensing system. The fuel and oxidizer quantities sensed by the primary and secondary quantity sensing system are then compared. If the sensed difference in quantity exceeds specified limits, a malfunction will be indicated. If any of the above equations sense an out-of-tolerance condition, the PUS caution-warning equation will activate the caution-warning indicator in the C/M.

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2.8 ELECTRICAL CONTROL SYSTEM.

The simulated spacecraft electrical system is divided into four separate subsystems: cryogenic storage, fuel cells, d-c power distribution, and a-c power generation and distribution. Each system is separately discussed.

2.8.1 EPS CONFIGURATION REFERENCE.

The EPS simulated in the AMS is representative of that projected for BP014 at the time of AMS design freeze. EPS design at that time included a NON-ESSENTIAL BUS circuit breaker (on panel 22), and an INVERTER 3 POWER SELECTOR switch (on panel 21). These are included in the AMS, but were not included in final BP014, and are not planned for AF012.

The AF012 electrical power system further differs from both BP014 and the AMS in that there are no H₂ and O₂ solenoid valves and fans and associated controls (panels 13 and 22) have been added to the cryogenic portion of the EPS.

2.8.2 SIMULATED EPS (S/C EQUIVALENT).

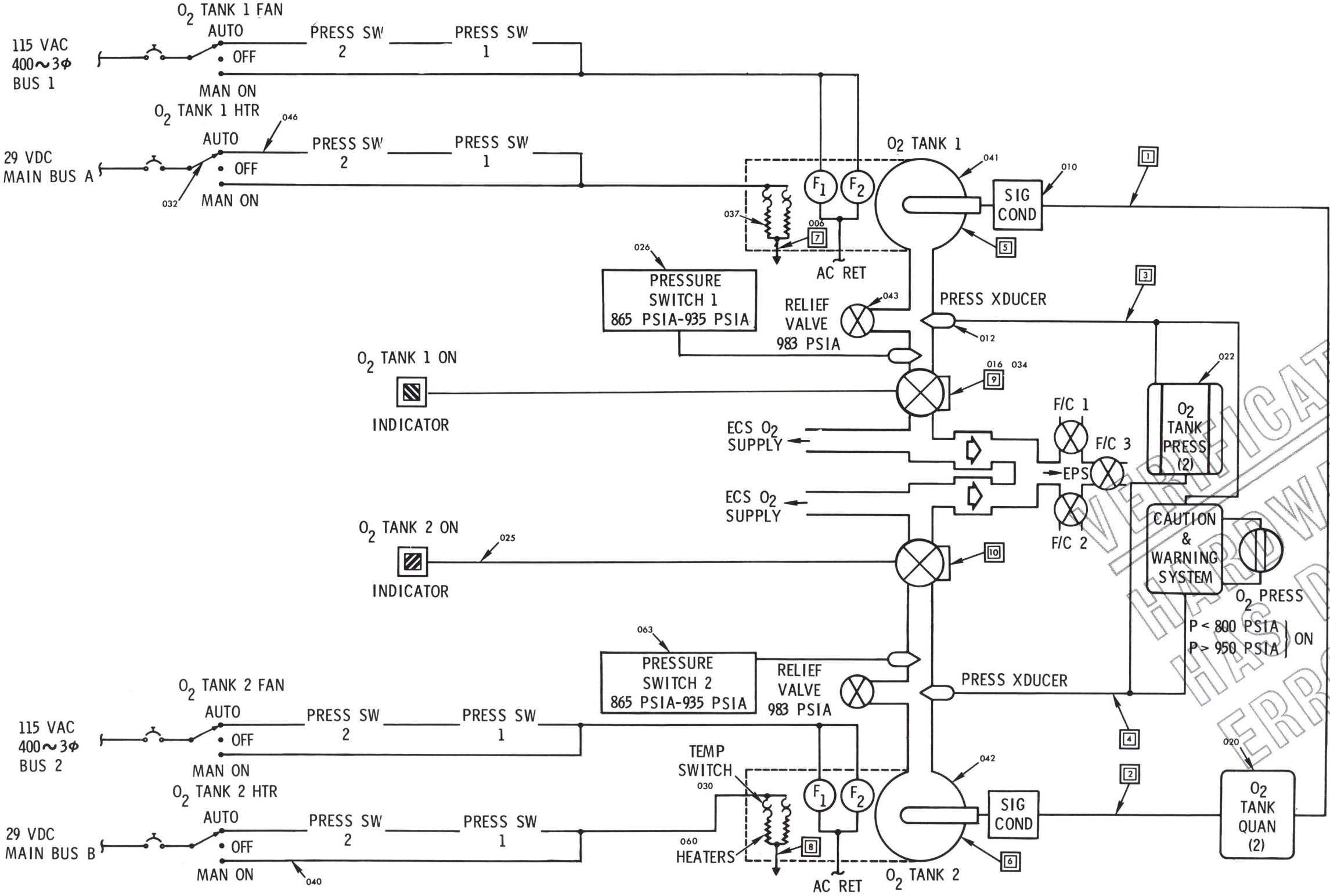
2.8.2.1 Cryogenic Storage System.


The cryogenic storage system provides a means of storing and supplying reactants to spacecraft systems. Hydrogen is supplied to the EPS, while oxygen is supplied to the environmental control system (ECS) as well as the EPS. The reactants are stored cryogenically in four Dewar vessels located in sector IV of the S/M. Two of the pressurized vessels contain oxygen, the other two contain hydrogen.

The oxygen system is schematically depicted in figure 2-24. Each tank contains 320 pounds of oxygen pressurized to 900±35 psia. Flow from the tanks into the system is governed by tank pressure. Tank isolation is provided by the check valves. Pressure of the oxygen is maintained by two parallel heaters. Uniform density is maintained by two parallel a-c circulating fans, which circulate the gas over the heating elements to provide even distribution of heat, thus maintaining equal density throughout the tank. Power to the heaters and fans can be automatically controlled. This is accomplished by a pair of pressure-sensitive switches connected in series. This circuit will apply power to the heaters and fans, or disconnect power, as a function of tank pressure and temperature.

Pressure transducers provide a means of monitoring tank pressures. They produce an analog signal representative of tank pressure, which positions the pressure gauges in the C/M, and is also applied as an input to the caution and warning system.

Reactant quantity is sensed by a capacitive probe inserted into the storage vessels. Capacitance of the probe is a function of gas density. Output of the probe is an electrical analog signal representing quantity, and after conditioning, is used to position the quantity indicators in the C/M.



OXYGEN STORAGE SUBSYSTEM MALFUNCTIONS		
MALF. NO.	MALFUNCTION DESCRIPTION	
CN006	HEATER CURRENT SENSOR FAILS - MAX. OUTPUT	
CN010	TANK 1 QUANTITY SIGNAL CONDITIONER FAILS - MAX. OUTPUT	
CN012	TANK 1 PRESSURE SIGNAL CONDITIONER FAILS - MAX. OUTPUT	
CN014	TANK 2 TEMPERATURE SIGNAL CONDITIONER FAILS-MAX. OUTPUT	
CN016	TANK 1 T/M SIGNAL INDICATES ISOLATION VALVE CLOSED	
CN020	TANK 1 OXYGEN QUANTITY METER READS ZERO	
CN022	TANK 1 OXYGEN PRESSURE METER READS ZERO	
CN025	TANK 2 ISOLATION VALVE INDICATOR READS OPEN	
CN026	TANK 1 PRESSURE SWITCH FAILS CLOSED	
CN030	TANK 1 HEATER TEMP. LIMIT SWITCH FAILS CLOSED	
CN032	TANK 1 HEATER "MAN/AUTO" SWITCH FAILS IN "MAN"	
CN034	TANK 1 ISOLATION VALVE CONTROL FAILS IN PRESENT POSITION	
CN037	TANK 1 HEATER FAILS OPEN	
CN040	TANK 2 HEATER POWER SWITCH "MAN" POSITION IS GROUNDED	
CN041	TANK 1 RUPTURE	
CN042	TANK 2 RUPTURE	
CN043	TANK 1 RELIEF VALVE FAILS CLOSED	
CN046	TANK 1 HEATER POWER SWITCH "AUTO" POSITION IS GROUNDED	
CN060	TANK 2 HEATER FAILS OPEN	
CN063	TANK 2 PRESSURE SWITCH FAILS CLOSED	
TELEMETRY SIGNALS		
	SIGNAL DESCRIPTION	GOSS. NO.
1	QUANTITY O ₂ TANK 1	F0032Q
2	QUANTITY O ₂ TANK 2	F0033Q
3	PRESSURE O ₂ TANK 1	F0037P
4	PRESSURE O ₂ TANK 2	F0038P
5	TEMPERATURE O ₂ TANK 1	F0041T
6	TEMPERATURE O ₂ TANK 2	F0042T
7	O ₂ TANK 1 HEATER CURRENT	F0050C
8	O ₂ TANK 2 HEATER CURRENT	F0051C
9	O ₂ TANK SHUTOFF VALVE 1 MONITOR	F0056X
10	O ₂ TANK SHUTOFF VALVE 2 MONITOR	F0057X

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Figure 2-24. Oxygen Storage Subsystem

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Each tank system contains a protective relief valve which will start venting when the pressure in that system reaches 983 psia. The valve will reseal when pressure decreases to 970 psia. The outer shell of each vessel has a burst disc, designed to burst at a pressure 30 percent below the structural limit of the tank.

As oxygen is consumed, the pressure within the tanks decreases. When pressure in both tanks decreases to 865 psia, pressure switches 1 and 2 close and apply power to the heaters and fans in the storage vessels. Since the pressure switches are electrically in series, the pressure in both tanks must decrease to 865 psia before power is applied to the heaters and fans. Heater and fan power will remain on until one of the tanks reaches 935 psia, at which time one of the pressure switches will open to remove power from the heater and fan circuit to both tanks.

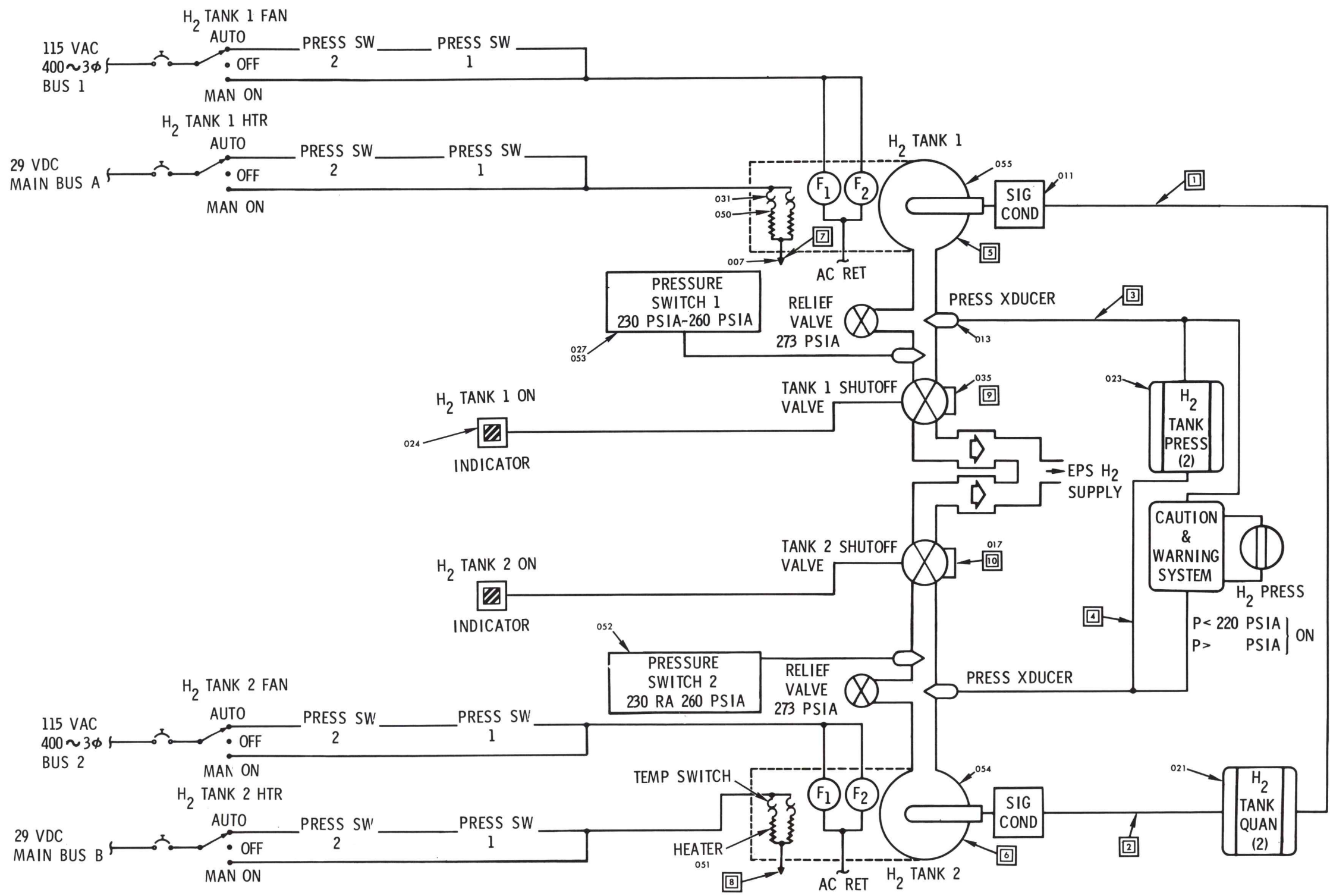
The ON position of the heater and the fan switches provides a means for manual operation of the circuit. This position bypasses the pressure switches, and would be used in case of a malfunction in the pressure switches or in one of the two heating elements within each tank.


Temperature sensitive interlock devices are located in series with the heating elements. These devices will open the heater circuit when the skin temperature of the inner shell of the Dewar vessel reaches 80°F. They will close the circuit when skin temperature decreases to 70°F.

The two pressure transducers provide the tank pressure gauges and the caution and warning system with a d-c analog signal representing tank pressure. The tank pressure gauge is a dual-scale vertical indicator. Tank 1 pressure or surge tank pressure can be applied to one of the scales by selection with a switch. Tank 2 pressure is applied to the other scale. If the pressure in either tank decreases below 800 psia or exceeds 950 psia, a lamp in the caution and warning system will illuminate notifying the astronauts of an abnormal condition.

The tank quantity sensing circuit and gauges provide a means of monitoring the amount of oxygen remaining. The quantity indicator is a dual-scale vertical reading instrument with a scale for each tank reading in pounds of reactant remaining.

The hydrogen system is illustrated in figure 2-25 and functions in the same manner as the oxygen system with the following exceptions. Temperature of the hydrogen during fill is -423°F and the system is pressurized to 245±15 psia. Temperature after initial pressurization is approximately -417°F. The two hydrogen tanks contain 28 pounds each and are constructed of titanium. Normal system operating pressures are from 230 to 260 psia. The caution and warning system will provide a warning indication when pressure decreases below 220 psia or exceeds 270 psia. The tank system relief valves will vent at 273 psia and will reseal at 268 psia.



HYDROGEN STORAGE SUBSYSTEM MALFUNCTIONS		
MALF. NO.	MALFUNCTION DESCRIPTION	
CN007	HEATER CURRENT SENSOR FAILS - ZERO OUTPUT	
CN011	TANK 1 QUANTITY SIGNAL CONDITIONER FAILS - ZERO OUTPUT	
CN013	TANK 1 PRESSURE SIGNAL CONDITIONER FAILS - ZERO OUTPUT	
CN015	TANK 2 TEMPERATURE SIGNAL CONDITIONER FAILS - ZERO OUTPUT	
CN017	TANK 2 T/M SIGNAL INDICATES ISOLATION VALVE CLOSED	
CN021	TANK 1 QUANTITY METER STICKS IN PRESENT POSITION	
CN023	TANK 1 PRESSURE METER STICKS IN PRESENT POSITION	
CN024	TANK 1 ISOLATION VALVE INDICATOR READS OPEN	
CN027	TANK 1 PRESSURE SWITCH FAILS OPEN	
CN031	TANK 1 HEATER TEMP LIMIT SWITCH FAILS OPEN	
CN035	TANK 1 ISOLATION VALVE WILL NOT OPEN	
CN050	TANK 1 HEATER FAILS OPEN	
CN051	TANK 2 HEATER FAILS OPEN	
CN052	TANK 2 PRESSURE SWITCH FAILS CLOSED	
CN053	TANK 1 PRESSURE SWITCH FAILS CLOSED	
CN054	TANK 2 RUPTURE	
CN055	TANK 1 RUPTURE	
TELEMETRY SIGNALS		
	SIGNAL DESCRIPTION	GOSS NO.
1	QUANTITY H ₂ TANK 1	F0030Q
2	QUANTITY H ₂ TANK 2	F0031Q
3	PRESSURE H ₂ TANK 1	F0039P
4	PRESSURE H ₂ TANK 2	F0040P
5	TEMPERATURE H ₂ TANK 1	F0043T
6	TEMPERATURE H ₂ TANK 2	F0044T
7	H ₂ TANK 1 HEATER CURRENT	F0052C
8	H ₂ TANK 2 HEATER CURRENT	F0053C
9	H ₂ TANK SHUTOFF VALVE 1 MON	F0062X
10	H ₂ TANK SHUTOFF VALVE 2 MON	F0063X

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Figure 2-25. Hydrogen Storage Subsystem

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2.8.2.2 Fuel Cells.

A single fuel cell system is shown in figure 2-26. There are three such systems in the spacecraft.

Nitrogen is supplied through the N₂ regulator to the H₂ and O₂ regulators where it is used as a reference pressure to the glycol accumulator to supply head pressure for the coolant system, and to each of the pressure jackets in each of the 31 fuel cell submodules.

Oxygen is fed through the supply valves and flow rate sensor to the pre-heater where its temperature is increased. From this point, the warmed oxygen is fed to the regulators where, using the N₂ reference pressure, the oxygen pressure is reduced and regulated closely. The regulated O₂ is then routed to the fuel cell submodules. The purge valve allows oxygen to be forced through the fuel cells and overboard through a dump line. This removes accumulated impurities in the oxygen side of the fuel cells.

Hydrogen is fed through the supply valves, flow rate sensor, H₂ preheater, and pressure regulator, in much the same manner as the oxygen. The hydrogen is then supplied to the H₂ regeneration loop. This loop consists of the hydrogen side of the fuel cells, a sensor-controlled bypass valve, a condensor, a water separator-H₂ pump, and a heat exchanger or regenerator. Its purpose is to control cell temperature and extract water from the cells for use by the crew. The primary bypass valve determines the amount of gas which is sent through the H₂ regenerator (heat exchanger) and how much bypasses it. The valve position is determined by a temperature sensor. The gas is then cooled by the secondary loop in the condensor and sent to the water separator-H₂ pump. Here the water is extracted from the H₂ and fed to a storage tank in the ECS, while the hydrogen is restored to its higher pressure by the H₂ pump. The hydrogen is then routed back to the fuel cells. A hydrogen purge valve is provided in the H₂ regeneration loop for the same purpose as the O₂ purge valve in the oxygen system.

The secondary coolant loop is a water-glycol system used to radiate excess heat from the fuel cells into space. The secondary bypass valve controls the amount of incoming coolant, which bypasses the coolant regenerator. The temperature of the H₂ in the primary loop is sensed and used to control the valve position. The coolant passes to the glycol accumulator and coolant pump from the regenerator. From the coolant pump, the glycol mixture is sent through the O₂ preheater, H₂ preheater, and condensor, in series. In each of the preheaters, the coolant gives up heat to the incoming gas. In the condensor, the coolant absorbs heat from the primary loop. The heated coolant is then sent through the coolant regenerator back to the space radiators.

Each fuel cell module contains two overload-reverse current sensing circuits. (See figure 2-27.) The input from the fuel cell to each circuit is controlled by the BUS A and BUS B switches in the command module. The output of each overload-reverse current sensing circuit is connected to a main d-c bus. There is a time delay in the tripping of these sensors in case of overload or reverse current. When the sensor is tripped, the output of that fuel cell will be automatically disconnected from its load. Any disconnect will be displayed on

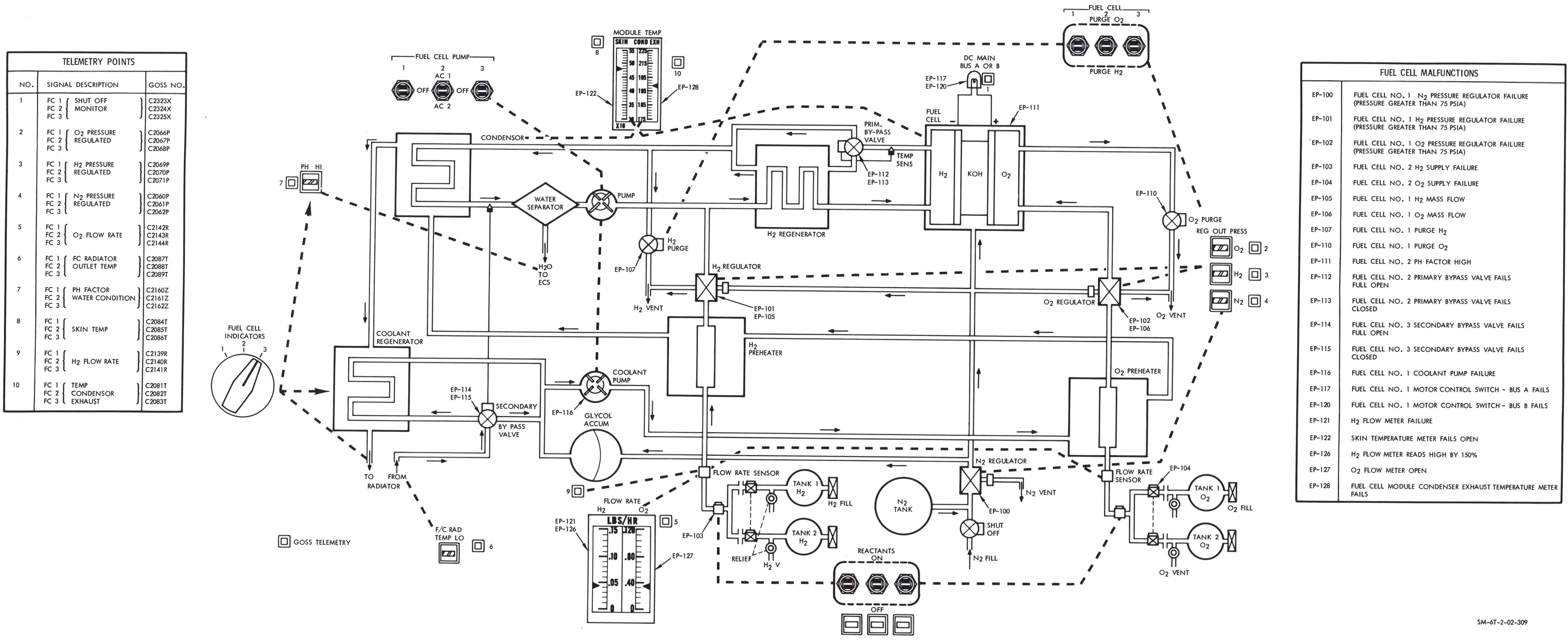
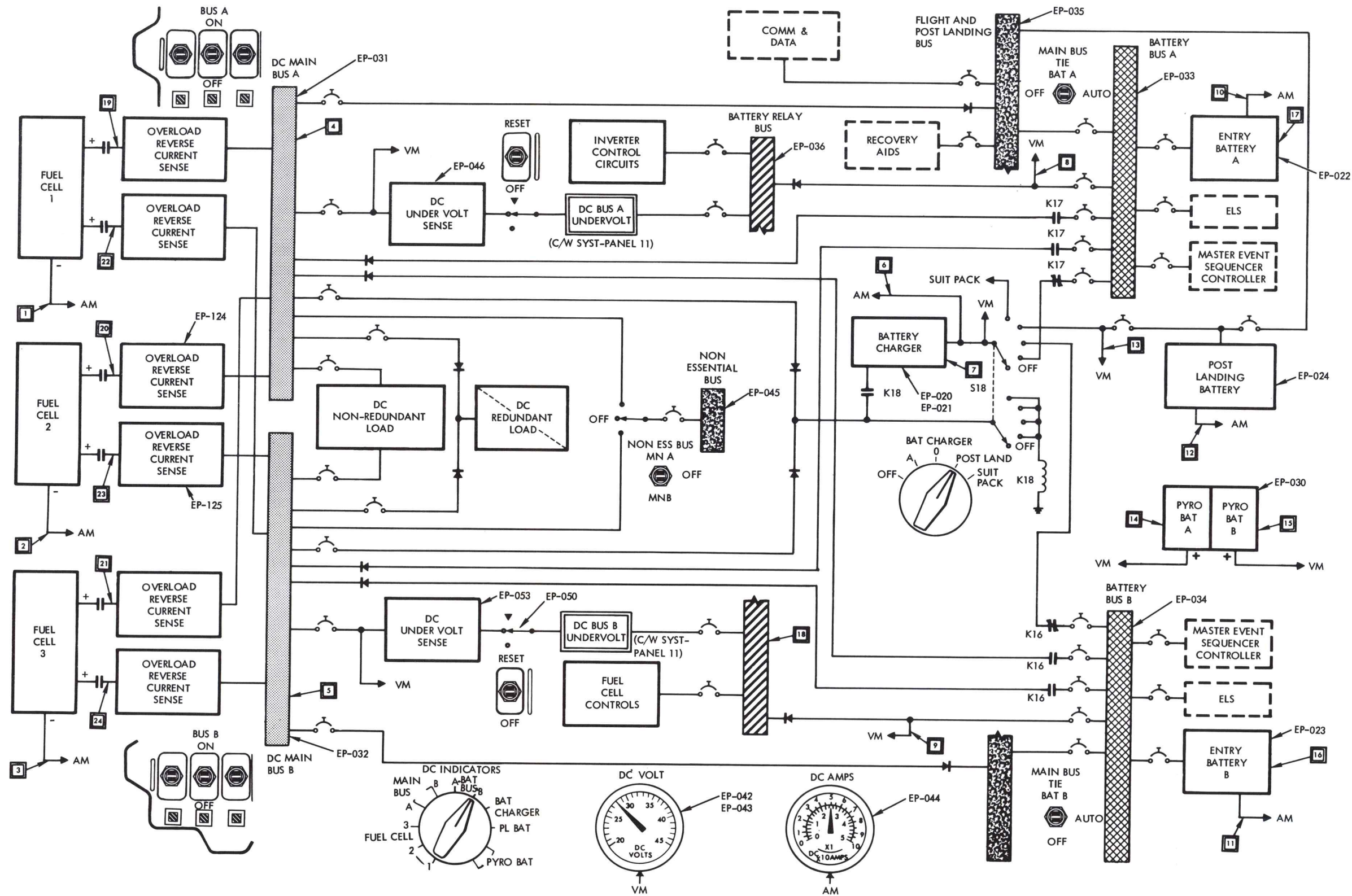


Figure 2-26. Fuel Cell Subsystem

TELEMETRY POINTS		
NO.	SIGNAL DESCRIPTION	GOSS NO.
1	D.C. CURRENT FC #1 OUTPUT	C2113C
2	D.C. CURRENT FC #2 OUTPUT	C2114C
3	D.C. CURRENT FC #3 OUTPUT	C2115C
4	D.C. VOLTAGE MAIN BUS "A"	C0206V
5	D.C. VOLTAGE MAIN BUS "B"	C0207V
6	D.C. CURRENT BATT. CHARGER OUTPUT	C0215C
7	D.C. VOLTAGE BATT. CHARGER	C0214V
8	D.C. VOLTAGE BATT. BUS "A"	C0210V
9	D.C. VOLTAGE BATT. BUS "B"	C0211V
10	D.C. CURRENT ENTRY BATT. "A"	C0222C
11	D.C. CURRENT ENTRY BATT. "B"	C0223C
12	D.C. CURRENT POST LANDING BATT.	C0224C
13	D.C. VOLTAGE POST LANDING BATT.	C0212V
14	D.C. VOLTAGE PYRO BATT. "A"	C0227V
15	D.C. VOLTAGE PYRO BATT. "B"	C0228V
16	CASE TEMP ENTRY BATT. "B"	C0179T
17	CASE TEMP ENTRY BATT. "A"	C0178T
18	DC VOLTAGE BATT. RELAY BUS	C0232V
19	FUEL CELL 1 BUS A DISCONNECT	C2120X
20	FUEL CELL 2 BUS A DISCONNECT	C2121X
21	FUEL CELL 3 BUS A DISCONNECT	C2122X
22	FUEL CELL 1 BUS B DISCONNECT	C2125X
23	FUEL CELL 2 BUS B DISCONNECT	C2126X
24	FUEL CELL 3 BUS B DISCONNECT	C2127X



DC MALFUNCTIONS	
EP-020	BATTERY CHARGER FAILURE (NO OUTPUT)
EP-021	BATTERY CHARGER FAILURE (LOW OUTPUT)
EP-022	ENTRY BATTERY "A" DISCHARGED
EP-023	ENTRY BATTERY "B" FAILURE (LOW OUTPUT-UNABLE TO RECHARGE)
EP-024	POST LANDING BATTERY "C" FAILURE (NO OUTPUT - UNABLE TO RECHARGE)
EP-027	PYRO BATTERY "A" FAILURE (NO OUTPUT)
EP-030	PYRO BATTERY "B" FAILURE (NO OUTPUT)
EP-031	MAIN DC BUS "A" FAILURE (NO VOLTAGE)
EP-032	MAIN DC BUS "B" FAILURE (NO VOLTAGE)
EP-033	BATTERY BUS "A" FAILURE (NO VOLTAGE)
EP-034	BATTERY BUS "B" FAILURE (NO VOLTAGE)
EP-035	FLIGHT AND POST LANDING BUS FAILURE (NO VOLTAGE)
EP-036	BATTERY RELAY BUS FAILURE (NO VOLTAGE)
EP-042	DC VOLTMETER OPEN
EP-043	DC VOLTMETER READS 25% LOW
EP-044	DC AMMETER OPEN
EP-045	NON-ESSENTIAL BUS FAILURE (NO VOLTAGE)
EP-046	DC UNDERVOLTAGE SENSING UNIT FAILURE BUS A
EP-050	MAIN DC BUS "B" RESET SWITCH FAILURE
EP-053	MAIN DC BUS "B" UNDERVOLTAGE SENSOR FAILURE (LOW VOLTAGE INDICATION)
EP-057	INVERTER NO. 1 FAILURE (NO OUTPUT)
EP-124	FUEL CELL NO. 2 OVERLOAD-REVERSE CURRENT SENSOR FAILURE (BUS A)
EP-125	FUEL CELL NO. 2 OVERLOAD-REVERSE CURRENT SENSOR FAILURE (BUS B)

Figure 2-27. D-C Distribution Subsystem

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one of six mechanical flag-type indicators located just below the BUS A and BUS B switches. The FUEL CELL BUS DISCONNECT caution and warning light will accompany any of these mechanical indications.

2.8.2.3 D-C Power Distribution.

Main d-c buses A and B in the service module interface with d-c main buses A and B in the command module. These buses are normally powered by the fuel cells. To supplement the fuel cells during peak loads and to provide primary power during entry, the entry batteries are also connected to the main buses. Either of the main d-c buses is capable of distributing d-c power for all spacecraft systems. Figure 2-27 is a flow diagram of the spacecraft d-c power system simulated in the AMS (including malfunctions and telemetry points).

Each d-c main bus has an undervoltage sensing circuit. If the bus voltage drops below 26.25 volts dc, the corresponding DC BUS UNDERVOLTAGE lamp (MASTER CAUTION and WARNING) will be illuminated by battery power. Manual depression of the corresponding bus reset switch will extinguish the light if the cause was a temporary bus overload. If the light does not extinguish, a malfunction exists in the EPS.

Both main d-c bus A and B provide power through circuit breakers to the d-c redundant load (on both buses in parallel) and through isolation diodes and circuit breakers, to the flight and post-landing bus, nonredundant load (on one bus or the other), and battery charger. Nonessential bus power is controlled through a switch that permits the selection of main bus A or B or an OFF position. Power should be manually removed from the nonessential bus if a power emergency condition exists; that is, two fuel cells become inoperative.

Entry batteries A and B are connected to their respective battery buses through circuit breakers. These buses are, in turn, connected to the battery relay bus through circuit breakers and isolation diodes. The batteries provide fuel cell backup when manually connected to main d-c buses A and B. The MAIN BUS TIE switch for each entry battery, when placed to the ON position, operates relays K16 and K17, which electrically connects the selected battery bus to both main d-c buses. Relays K16 and K17 also automatically prevent charging of the selected battery by the battery charger. Backup for the post-landing battery is provided by switch-breakers connecting the entry batteries to the post-landing load via the flight and post-landing bus. Connection of each of the entry batteries buses to the d-c main buses is made automatically at C/M-S/M separation.

The post-landing battery provides power to operate the recovery aids through the flight and post-landing bus. This is accomplished by manually closing the switch-breaker between the post-landing battery and the flight and post-landing bus.

The post-landing battery also can supply power to the d-c main buses in cases of power emergency. In order to accomplish this, the breaker between the post-landing battery and the flight and post-landing bus is actuated. The switch-breaker between the flight and post-landing bus and battery bus A or B

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must then be closed to connect the post-landing battery to those points normally receiving power from the entry batteries. Positioning MAIN BUS TIE-BATTERY A or B switch to ON will supply post-landing battery power to both main d-c buses.

The battery charger is used to recharge the post-landing, entry, and suit pack batteries, as required. The charger is controlled by the BATTERY CHARGER switch in the C/M. Each battery has a position on the BATTERY CHARGER switch. The OFF position removes power from the charger and disconnects it from all output circuits. All main d-c bus loads must be removed from a battery before the charger can apply a charging current.

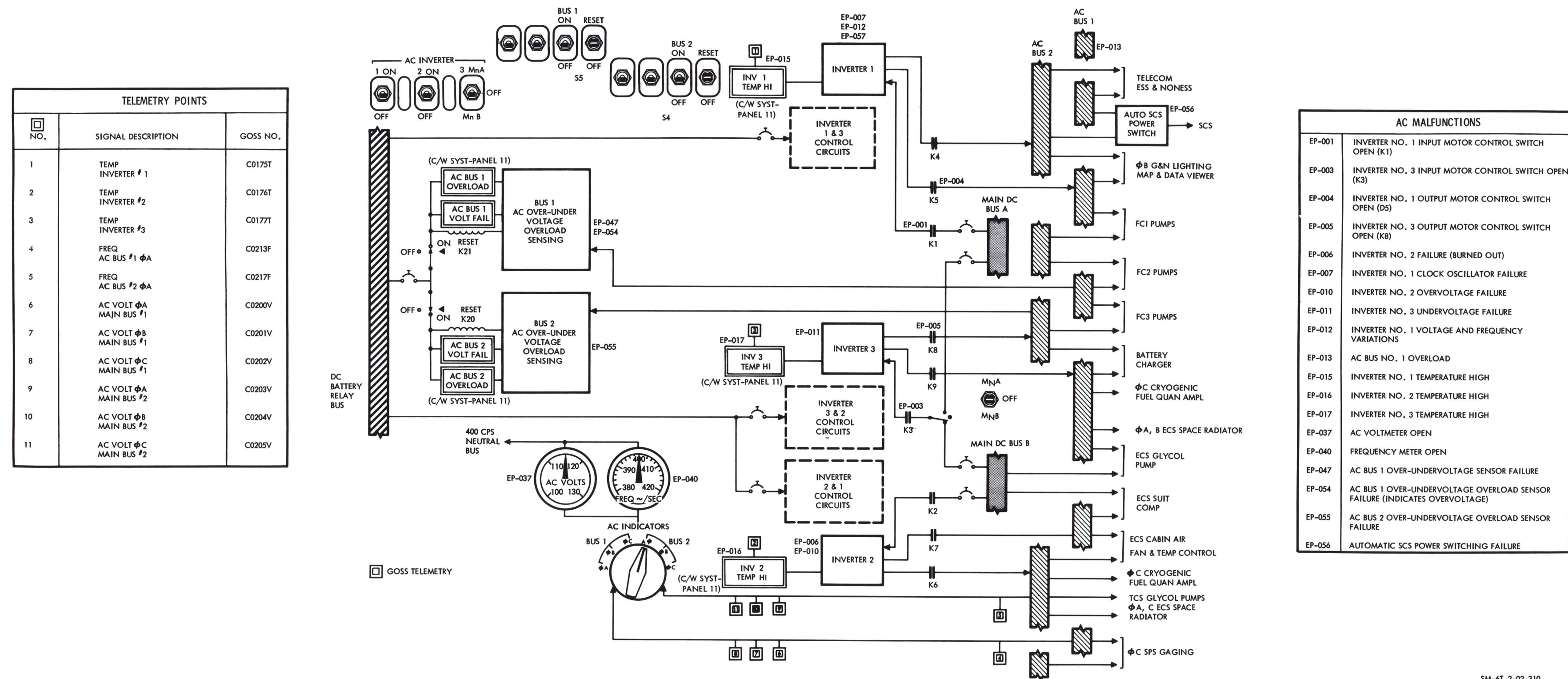
2.8.2.4 A-C Power Generation and Distribution.

The a-c power generation section consists of three static inverters, their associated controls, and safety circuitry. A-C power is distributed by redundant 3-phase 115-volt 400-cps buses. A flow diagram of the system is provided in figure 2-28. The diagram includes simulated malfunctions and telemetry points.

Each of the inverters provides 115/200-volt 3-phase 4-wire 400-cps power at a maximum power output of 1250 watts. Inverter No. 1 is powered by main d-c bus A, inverter No. 2 by bus B, and inverter No. 3 by bus A or B. A 6400-cps clock pulse from the central timing equipment (CTE) maintains inverter output frequency at 400 ± 0.5 cps. Upon loss of the CTE signal, the inverters revert to internal oscillator timing, which will maintain 400 ± 7 cps. Each inverter contains voltage sensing, current sensing, and regulatory circuitry.

Six over-undervoltage sensing circuits, one for each phase of a-c bus 1 and bus 2, monitor the inverter output voltages. These are packaged in two units, one for each a-c bus. A voltage below 100 volts ac or above 130 volts ac will cause activation of bus-disconnect relays for the proper a-c bus. The sensing circuits may be reset by positioning the a-c bus 1 or 2 RESET switch to the OFF or RESET position. Sensing an over or undervoltage in either bus will cause the respective BUS FAIL light to illuminate. An a-c bus 1 volt fail condition energizes the AUTO SCS POWER switch to transfer the SCS from a-c bus 1 to a-c bus 2. An overvoltage on either bus will disconnect that bus from the inverter supplying it power. If an undervoltage is sensed, the bus must be manually disconnected from its inverter.

Each inverter has an overcurrent sensor in its output circuits. This sensor detects the outgoing current from all three phases, additively. With a three-phase overload of 225 to 250 percent of rated current for 10 to 15 seconds or a single-phase overload of 300 percent of rated current for 4 to 6 seconds, the bus-disconnect relay will be energized removing the inverter from all three phases of the bus. If both a-c buses are tied to one inverter and an overload is sensed, the sensing circuit will disconnect only the a-c bus drawing the most current. Tripping the overload sensor also causes bus 1 or bus 2 AC OVERLOAD WARNING lamp to illuminate. Depressing the appropriate bus RESET switch resets the overload circuit as it resets the over-undervoltage sensor circuits.



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It is possible to have one inverter feeding both a-c buses or one inverter feeding each bus. The inverter control circuitry prevents the output of two inverters, whose phasing may be different, from being connected together on one bus. Inverter control is accomplished with relays K1 through K9. Inverter selection is controlled by switches in the command module. Each inverter has a motor-driven latching switch to apply d-c power to the inverter, and a motor-driven latching switch for connecting each a-c bus to the inverter output. Power must be applied to different coils of these three motor-driven switches to drive them from one position to another. The INVERTER ON switches have contacts in series with the INVERTER OUTPUT switches. These switches ensure that an inverter will not be placed on the line unless power has been applied to it.

2.8.3 EPS SIMULATION.

Simulation of the spacecraft EPS in the AMS is almost entirely accomplished by computer software. Only spacecraft controls and displays are physically and functionally represented in the AMS. The interaction between EPS controls and displays and the effects of operation of other systems on EPS status are accomplished by a cause and effect simulation of the EPS and its interface with other spacecraft system simulation. None of the system simulation in the AMS actually derives source power from the EPS simulation.

2.8.3.1 Cryogenic Storage Simulation.

The computer program computes the state of the oxygen and hydrogen in the cryogenics tanks at all times between launch minus 60 seconds and C/M-S/M separation. The program computes all functions occurring within the service module pertaining to the cryogenics system and provides outputs to drive corresponding SCM indicators and telemetered functions. All indicators within the command module are duplicated on the instructor console.

The computer program for the cryogenics system reads inputs from the ECS & EPS portions of the program and, in addition, all related SCM switch functions.

Figure 2-29 is a block diagram of the CSS simulation mechanized in the AMS. Crew inputs to the AMS cryogenics storage system (CSS) include oxygen and hydrogen tanks 1 and 2 solenoid valve commands and heater mode switch positions. Inputs from other portions of the EPS simulation include a-c and d-c power and power available, circuit breaker positions, oxygen flow rate demand, and hydrogen flow rate demand. The ECS simulation feeds this system inputs of C/M oxygen manifold pressure and oxygen manifold isolation valve status.

The computer reads the SCM inputs noted in figure 2-29 and the inputs from other subsystems simulation (also listed in figure 2-29), computes the values-status listed under "Compute" in the figure, and signal-conditions the computation results for use. Subsystem outputs and the subsystems to which they are addressed are noted in the figure.

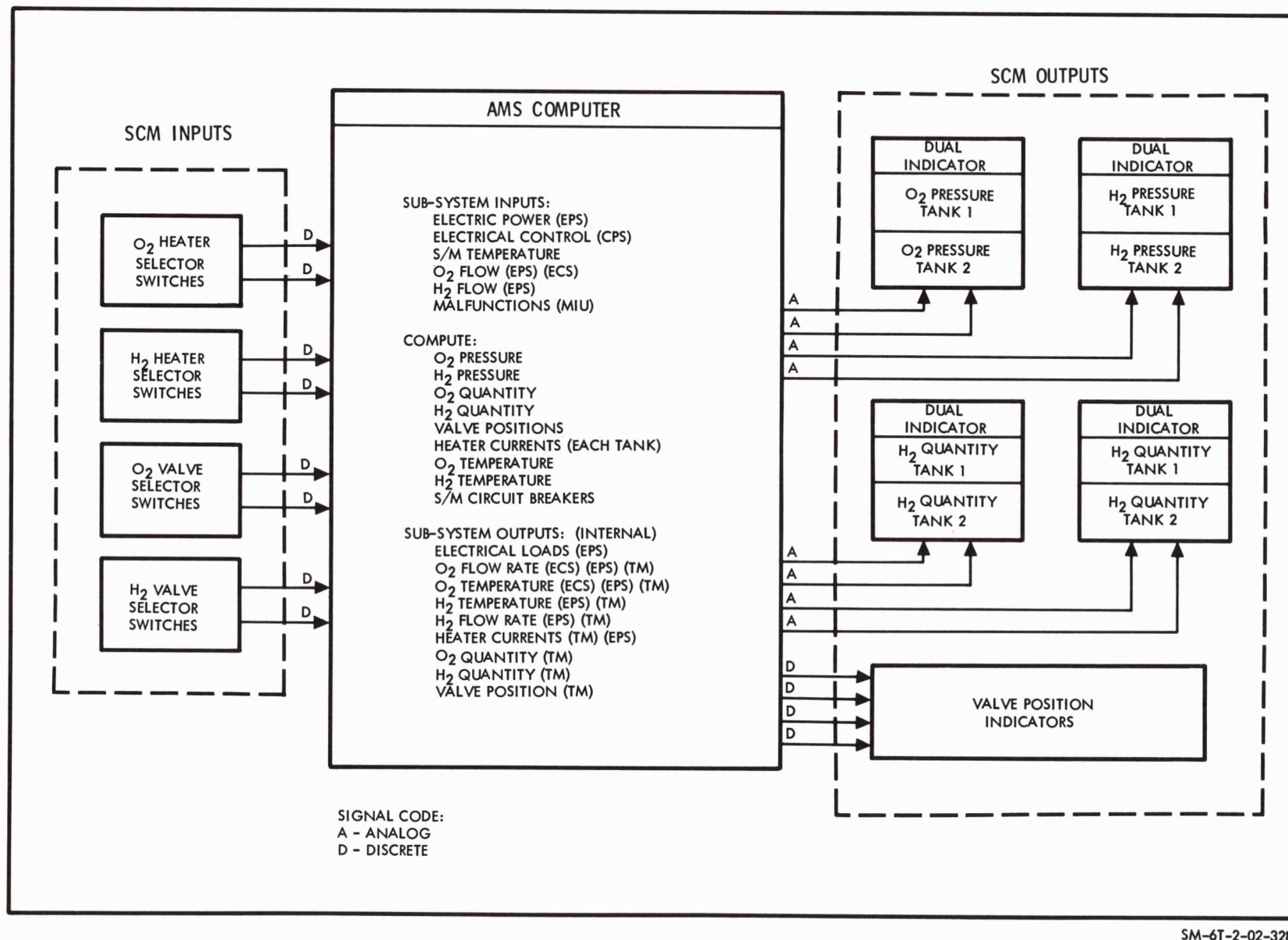


Figure 2-29. Cryogenic Subsystem Simulation

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SCM controls and displays functions driven by the cryogenic storage system simulation are shown in the right hand area of the flow diagram. Characteristics of the SCM input (analog or discrete) are also shown.

2.8.3.2 A-C and D-C Generation and Distribution Simulation.

Figure 2-30 is a block diagram of the simulation of the a-c and d-c electrical power generation and distribution provided in the AMS. The simulation of these electrical systems requires inputs from other simulation systems in the AMS, that is, equations of motion to determine space radiator temperature, cryogenic storage for H₂ and O₂ input characteristics, etc.

The simulation of the fuel cells is manifested to the crew in the form of H₂ and O₂ flow, modules skin temperature, and condenser exhaust temperature. Mechanical flags are used to indicate O₂, H₂, and N₂ regulator pressures—high; fuel cell radiator temperature—low; and water pH factor—high. The characteristics are separately computed and displayed for each of the three fuel cells; a selector switch determines which fuel cell will have its parameters displayed. Crew control of each of the three fuel cell simulations includes H₂ and O₂ PURGE and REACTANTS ON-OFF control, which is sent to AMS computer. When simulated fuel cell malfunctions are inserted into the program, appropriate effects are simulated not only in the fuel cells, but also in the affected systems of the electrical load.

The fuel cell simulation computes all variables relating to voltage, current, and H₂O output of each fuel cell. The fuel cell voltages and currents and their resultant d-c bus voltages and currents, as determined by switch positioning, are fed to undervoltage disconnect circuits and the d-c indicators select switch.

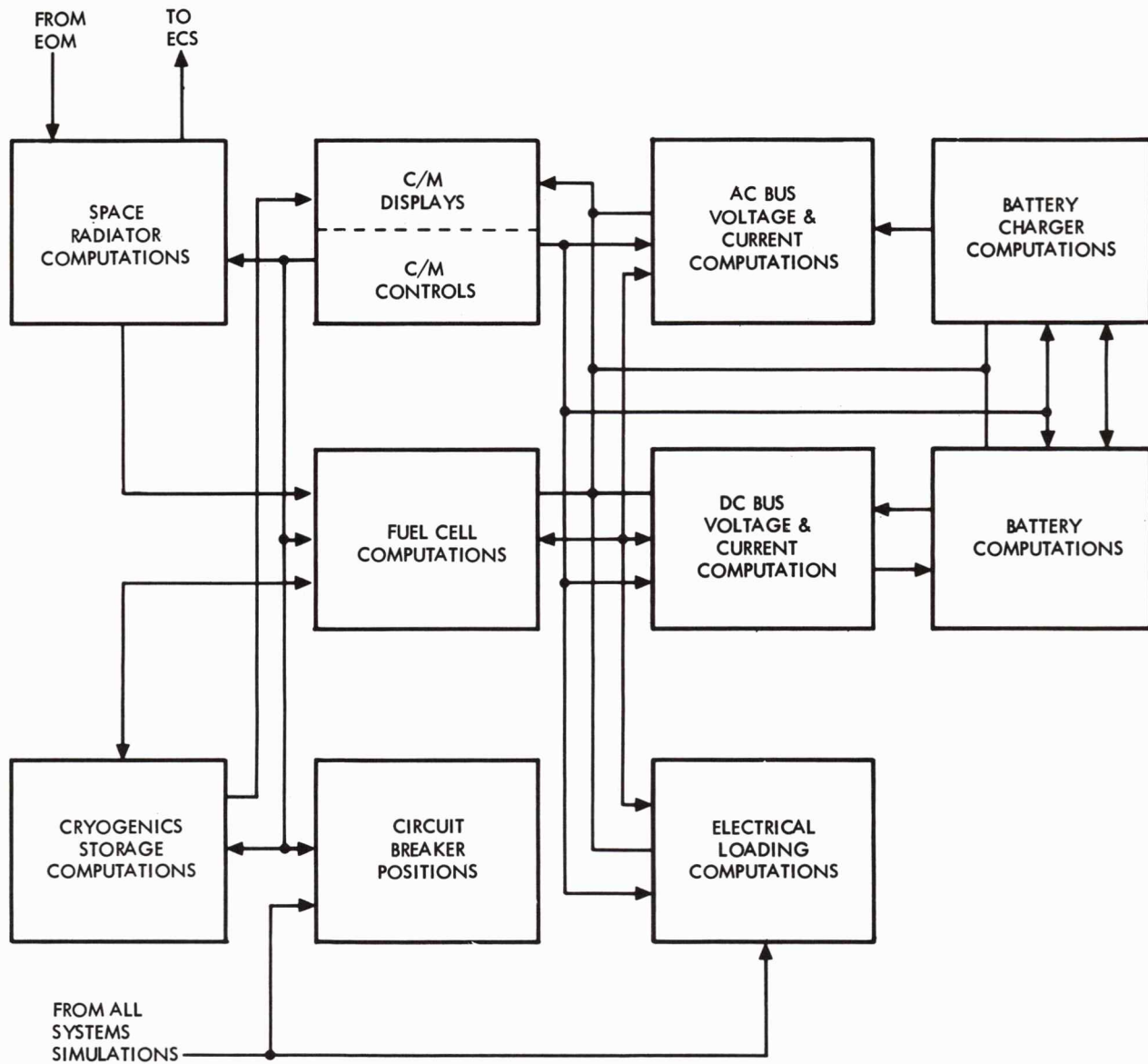
All major d-c components of the spacecraft, including d-c buses, batteries, and fuel cells, feed inputs to the d-c indicators selector. Simulated voltage and current displayed are determined by considering the position of all power switches, the amount of current normally drawn by each system, and the source of power chosen. All current calculations are compared with maximum load from each fuel cell to determine if overload disconnect should be initiated.

Operation of the battery charger is simulated using switch position inputs to determine which battery is being charged, if any, and which a-c bus is powering the charger. Malfunctions may be inserted in the charger to cause simulation of improper operation.

Pyro battery voltages are simulated and, although no means are provided to recharge these batteries, their voltage may be examined through the d-c voltmeter. Loss of one of the pyro batteries is an abort consideration for the crew.

A-C inverter simulation is controlled by the INVERTER POWER ON and OFF switch and switching of the output of each inverter. Each simulated inverter is equipped with an over-undervoltage sensor function. If a simulated malfunction is inserted into the inverter causing its output voltage to be out of

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Figure 2-30. A-C and D-C Generation and Distribution Simulation

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tolerance, the inverter will be disconnected from its load automatically. Other simulated malfunctions can be programed to cause the same effect-result from inverter temperature or frequency going out of tolerance. The effects that such electrical source variations would have on the actual spacecraft electrical load are also simulated.

The two a-c buses are fed through simulated overload disconnect circuits. If an overload is simulated, the disconnect circuits will remove power from the simulated systems which would normally receive it from the malfunctioned bus.

Each simulated system and subsystem receiving inputs from the EPS is connected to the EPS simulation through command module circuit breakers. Any one of the circuit breakers in the C/M may be tripped from the IOS. The instructor may accomplish this by depressing the desired circuit breaker indicator. The amber FAILED BY INSTRUCTOR light will illuminate in the IOS indicator and, in the simulator command module, the corresponding circuit breaker will trip. The computer will act upon this simulated power loss by deactivating the simulation of equipment normally receiving power through this circuit breaker. The crewmember should attempt to reset the circuit breaker, but will find it can not be reset. The astronaut should then decide if an abort will be necessary or alternate procedures should be used. From the IOS the instructor may also simulate temporary overloads through a circuit breaker by depressing the corresponding C/B indicator twice. The alternate action switch will cause the circuit breaker to trip. Also the amber failed by instructor section and the white C/M resetable section of the depressed IOS circuit breaker indicator will illuminate. In the simulator command module, the crewmember may reset the tripped circuit breaker by depressing it.

The computer is programed to trip 16 circuit breakers if their simulated currents should exceed their ratings. If, through system management, the crew can reduce the power required through the tripped circuit breaker, it may be reset. Figure 2-31 illustrates the circuitry used in the simulation of each circuit breaker. The circuit breakers which are programed to be tripped are as follows:

- a. Post-Landing Bus Tie, Battery Bus A (R.H. Eqpt. Bay)
- b. Post-Landing Bus Tie, Battery Bus B (R.H. Eqpt. Bay)
- c. Post-Landing Bus Tie, Main Bus A (R.H. Eqpt. Bay)
- d. Inverter Power No. 1, Main Bus A
- e. Inverter Power No. 2, Main Bus B
- f. Spares (4)
- g. Cryogenics System O₂ Tank Heater, System B
- h. Battery Relay Bus Power A
- i. Battery Relay Bus Power B
- j. Telecommunications, Communications Eqpt. - Group 2
- k. Telecommunications, Communications Eqpt. - Group 3
- l. Telecommunications, Communications Eqpt. - Group 4
- m. Telecommunications, Communications Eqpt. - Group 5

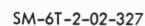


Figure 2-31. Simulated Circuit Breakers

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2.9 COMMUNICATIONS AND DATA SYSTEMS (C&D).

2.9.1 C&D SYSTEM CONFIGURATION REFERENCE.

The communications and data systems simulated in the AMS closely approximate those of AF012. Differences between AF012 and the AMS are explained in the following paragraphs.

AF012 has three output power levels for S-band transmission: 240 millivolts, 5 watts, and 20 watts. Power level is selected with the POWER AMPLIFIER HI-LO switch and the S-band TRANSPONDER, OFF, XPONDER POWER AMP switch. The AMS simulated S-band provides only two levels of output: 5 watts and 20 watts. Selection is with the S-band HI-OFF-LO switch.

The VHF-FM relay function provided in the AMS is not characteristic of AF012. The function was included in earlier systems design to relay information from the LEM (or extra vehicular crewmember) to MSFN via the VHF-FM link.

The S-band ANTENNA ROTARY switch on panel 20 in the AMS is reduced to a simple three-position toggle switch in AF012. The positions of the switch in AF012 are UPPER-LOWER-AUTO. The difference stems from the fact that the AMS communications and data system is for full lunar capability and AF012 is equipped only for earth orbital operations. The UHF-VHF-HF ROTARY ANTENNA switch on panel 20 in the AMS is reduced to a three-position toggle switch in AF012. Switch positions are UPPER-LOWER-RECOVERY in AF012.

AF012 includes an HF ANTENNA switch on panel 17. The switch has two positions: ORBITAL and RECOVERY. The HF ANTENNA switch is not represented in the AMS. The HF system in the AMS is inactively simulated only, that is, controls and displays are appropriately located but are not functional.

2.9.2 SIMULATED C&D SYSTEMS (S/C EQUIVALENT).

Figure 2-32 is a block diagram of the spacecraft communications and data (C&D) systems simulated in the AMS. The figure includes the R-F carrier systems (transmit and receive) and the modulating, demodulating, coding, decoding, antenna, and switching systems used to accomplish the up-data link, the PCM telemetry, and the voice links between the spacecraft and MSFN. Also included in the diagram are the C&D simulated malfunctions and their point of effect in the simulator equivalent of the system.

2.9.2.1 Transmitter and Receivers.

There are four transmitter-receiver units in the communication and data systems. They are the HF (dummy only)/ VHF-AM, S-band, and C-band units. Also included in the C&D system are the UHF-FM receiver and the VHF-FM transmitter.

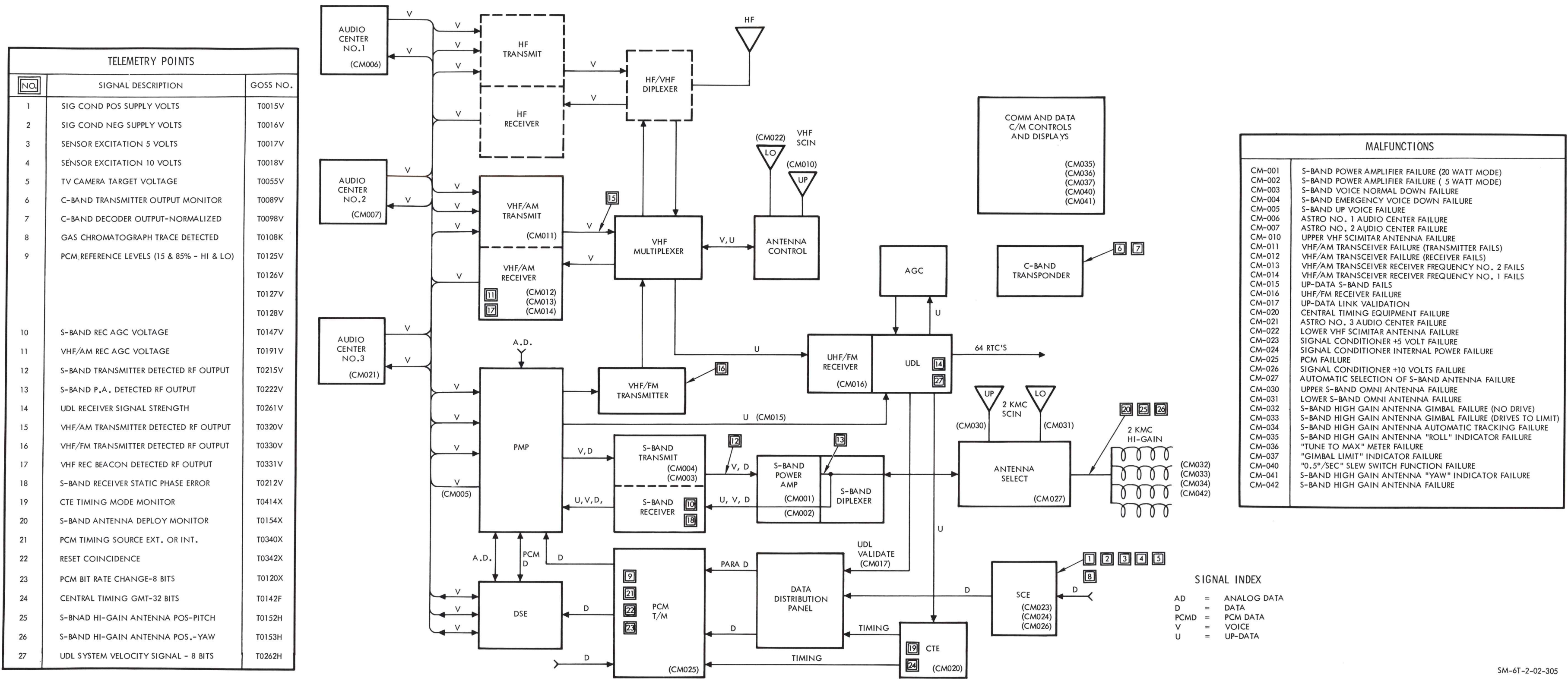


Figure 2-32. Communications and Data System Block Diagram

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The VHF-AM transmitter-receiver unit is used for voice communication during orbital phases of the mission because there are a large number of VHF-AM ground stations available. PCM telemetry is transmitted to earth during orbital phases via VHF-FM. The C-band transponder (transmitter receiver) is used for tracking during earth orbit. This unit automatically responds to a properly coded interrogation signal received from a ground station. This response will be in the form of a C-band pulse transmitted back at the ground station.

2.9.2.2 Up-Data Link (UDL).

Up-data is a method of updating systems or commanding specific operations within the spacecraft. When required, up-data is transmitted via S-band or VHF. VHF up-data enters the spacecraft loop through the VHF antenna, antenna control, and VHF multiplexer. The VHF-FM, or up-data, receiver demodulates the up-data signals and sends them to the UDL system for decoding and distribution as one of 64 possible real-time commands (RTC). When transmitted via S-band, the up-data signal enters the spacecraft through the 2 KMC antenna, the antenna select, the S-band power amplifier, the S-band receiver, the premodulation processor, and out directly into the UDL as a demodulated signal.

2.9.2.3 Telemetry Subsystem.

The T/M subsystem is used to inform ground operations personnel of conditions existing within the spacecraft system. This information is used to warn astronauts of improper spacecraft system operation and for scientific observation of mission activities.

The Apollo pulse-code-modulated (PCM) T/M equipment receives data from various locations within the spacecraft and converts it into a single serial digital output. These data inputs are of four varieties: analog, bilevel, parallel-digital, and serial-digital words.

Analog inputs to the PCM-T/M are of two types: high-level (0 to 5 vdc) and low-level (0 to 40 mvdc). These analog signals represent such variables as voltage, current, pressure, temperature, etc. Bilevel inputs to the PCM-T/M indicate such things as switch positions, event occurrence, etc.

Four parallel-digital words plus an eight-bit UDL verify word are fed to the PCM-T/M. Two 16-bit words relate quantities of fuel and oxidizer remaining in a selected S/M-RCS system. The system selected for T/M transmission is that selected for display in the C/M. One 24-bit word was allotted for IFTS use and has not been reassigned for another use since the deletion of the IFTS. One 24-bit word is used to transmit C/M time from the CTE (central timing equipment).

One 40-bit serial-digital word is generated in the G&N computer and fed to the PCM-T/M. This G&N word representing the computer output is changed to non-return-to-zero format and incorporated into the serial bit train (data) leaving the PCM-T/M. The serial bit train out of the PCM-T/M is sent to the

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premodulation processor (PMP) for subcarrier modulation or to the data storage equipment (DSE) for recording and later transmission to earth.

2.9.2.4 Voice Communications Subsystem.

Aboard the spacecraft, each astronaut has a headset consisting of two independent earphones and two independent microphones. Each headset is connected to an individual audio center and audio control panel. The audio system amplifies voice signals, then reduces these signals to their original condition to provide isolation. It also provides amplification of incoming signals. The audio equipment is located in a space electronics package and consists of three identical, replaceable audio center modules. Each module is a complete and independent unit operated by one astronaut. It contains a microphone amplifier, voice operated switch (VOX) circuitry, isolation pads, and diode switches. The audio center equipment operates with a complementary audio control panel to provide selection isolation and amplification of all spacecraft audio to and from the transmitters and receivers in the communications and data subsystems.

Audio input signals from the receiver portions of the VHF-AM transmitter-receiver, HF transceiver and unified S-band equipment, along with intercom bus inputs, are fed into an amplifier in the audio center. After passing through diode switching circuits, the selected audio signal is amplified and fed to the astronaut earphone.

Output signals from each astronaut microphone are fed to his microphone amplifier. There, as a function of power switch position PTT or VOX, the signal will be amplified and fed to the selected transmitter and/or the intercom bus. Which transmitter is to receive the voice signal is also determined by switches on the audio control panel.

2.9.3 C&D SYSTEM SIMULATION.

The AMS simulation of the communications and data systems is accomplished by complete simulation of modulation intelligence but does not include actual or simulated RF characteristics. However, a capability is provided at the IOS to simulate the effects of actual radio system attenuation, distortion, and interference on modulation intelligence. Also, malfunction simulation includes the effect of failure of RF carrier components on modulation intelligence in various C&D links.

2.9.3.1 Transmitters and Receivers.

VHF-AM Simulation.

During simulated near-earth operations voice communications are carried on via the VHF-AM equipment. Upcoming VHF-AM voice information is simulated by an audio signal from IMCC during the integrated mode of operation. As shown in figure 2-33, this signal is mixed with noise from the noise generator, after energizing a VOX switch. The signal is then subjected to distortion in the garble control. The amount of garble and noise is controlled automatically by

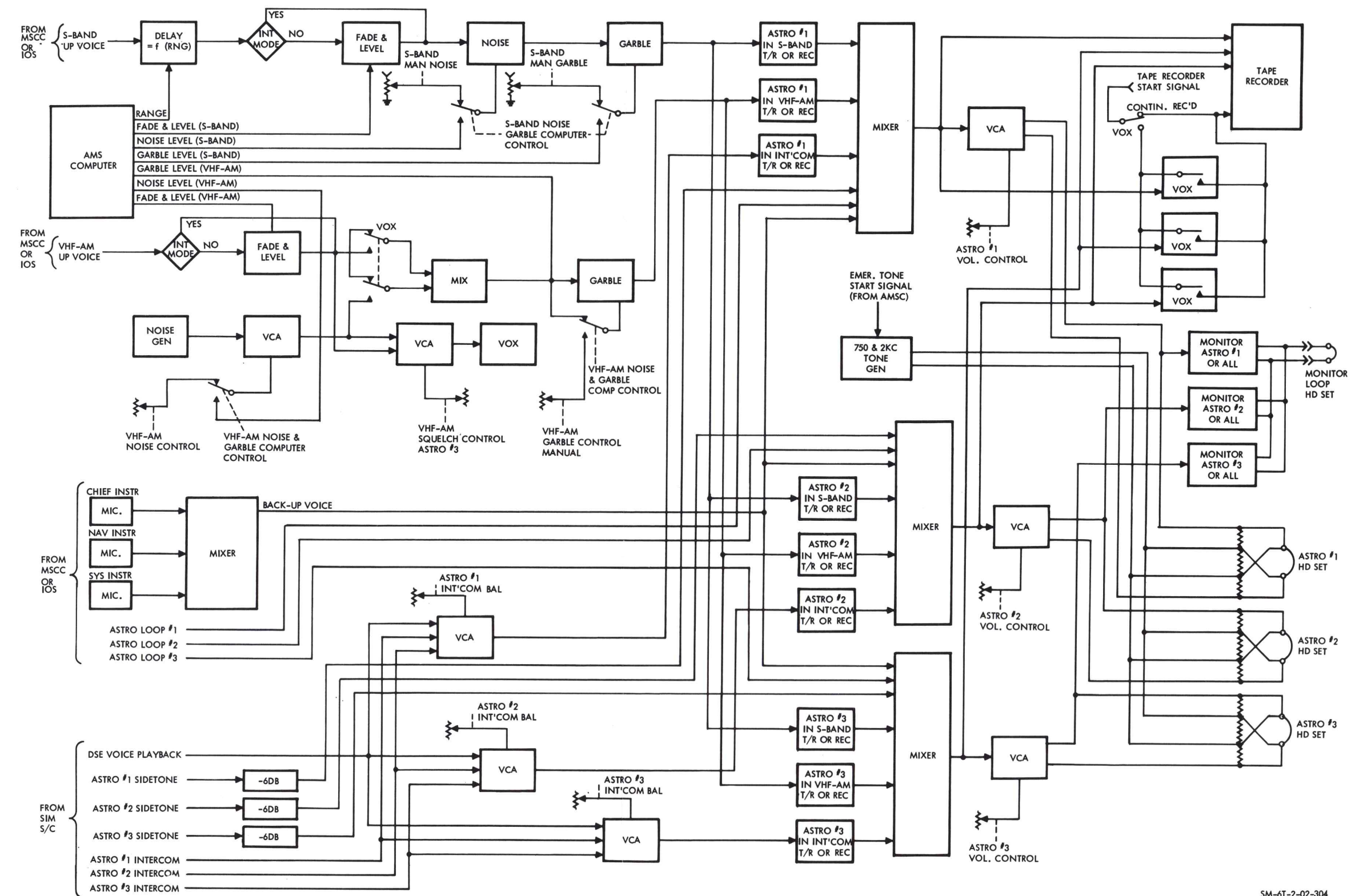


Figure 2-33. AMS Voice and Receiver Simulation

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the AMS computer or manually from the VHF-AM noise and garble controls on the IOS. From this point, the audio signal is sent through VHF-AM, TR/REC switch contacts at each astronaut's audio center and to three mixers.

If the AMS is in the nonintegrated mode, the simulated VHF audio signal is furnished by the IOS instructor-operator. The audio signal is subjected to fade and level modification as determined by the AMS computer. This function simulates distance of transmission, antenna alignment, and spacecraft trans- versing the far side of the moon. The audio signal is then fed into the VOX voltage control amplifier and VOX switch contacts. From this point, the audio signal is treated the same as the integrated mode VHF-AM signal. Up-link VHF-AM voice includes earth to S/C and LEM to S/C signals both of which will be simulated.

S-Band Simulation.

S-band up-voice (figure 2-33) enters the AMS from IMCC during integrated mode or the IOS in the nonintegrated mode, and is sent through a delay unit. This unit consists of a continuous loop tape recorder. The audio signal is recorded on one head and played back by a second head. The delay is a function of tape speed between the two heads. This speed is controlled by the AMSC and is representative of the distance between the S/C and earth. A third head, the erase head, is located after the playback head and prepares the tape for its next recording cycle.

The audio signal is then sent to a fade and level control circuit during the nonintegrated mode. This circuit will be controlled by the same parameters as the fade and level control circuit in the VHF-AM path. The fade and level control circuit is bypassed in the integrated mode because the signal fade and level is controlled by GSSC. In either mode the audio signal entering the noise generator unit provides level compensation for distance of transmission, antenna alignment, and spacecraft passing around the far side of the moon.

Noise simulation on the S-band audio signal is accomplished automatically by the computer or manually by the S-band noise control on the IOS.

The garble control for the S-band signal is much the same as the garble control for the VHF-AM signal, although the amount of garble, as the amount of noise, may vary because of the inherent qualities of different types of trans- mission. From the garble control the voice signal simulating the S-band up-voice is sent through switch contacts, controlled from each astronaut audio center.

Transmission of down link data and voice via S-band is simulated in the AMS without introduction of noise, garble, or delay. Voice signals are sent to the IOS or the IOS and MSCC, depending on simulation mode (nonintegrated or integrated). Data signals from the simulator command module are sent to the T/M console. The T/M console operation is explained in detail in section 1 of Volume II of this handbook, and a system explanation is provided in paragraph 2.9.3.4.

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UHF/FM Simulation.

The VHF/FM receiver in the command module receives UDL information only. No degradation of the carrier signal through noise, garble, or fade insertion is simulated. However, malfunctions may be inserted to simulate improper signal reception. This simulation is explained in paragraphs 2.9.3.2 and 2.9.3.3.

HF Simulation.

The HF system is not dynamically simulated in the AMS. Switches pertaining to HF transmission and reception are operable but control no circuitry.

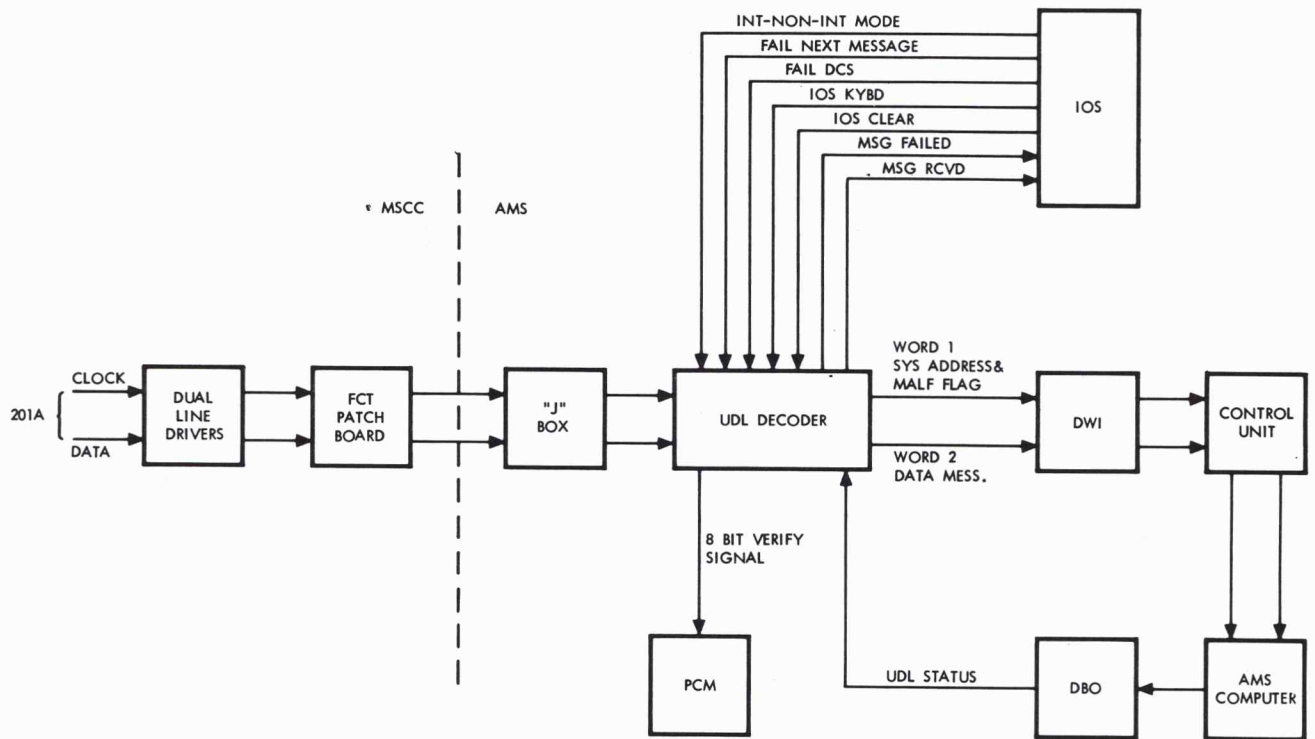
2.9.3.2 Up-Data Link Integrated Mode.

Figure 2-34 is a block diagram of the AMS up-data link simulation in the integrated mode. During the integrated mode, the AMS up-data link interfaces with the MSCC computer complex in the same manner as the spacecraft does in an actual Apollo mission.

All up-data messages from the MSCC are processed by the 201A data transmission equipment, conditioned for input to the AMS, appropriately patched at the flight crew trainer (FCT) patchboard, and received at the AMS J-box. Up-data messages are comprised of the message addressing, message data contents, and a simultaneous 1000-cps clock signal.

The UDL decoder receives the up-data message, changes the intelligence from serial to parallel format, and decodes it from MSCC subbit format to AMS format.

During the integrated mode, the IOS may still insert malfunctions into the UDL decoder. A digital command system failure is generated by depressing the DCS FAIL pushbutton indicator on the UDL panel of the IOS. This will cause the decoder to be held in the RESET condition until the malfunction is removed. The instructor-operator may also insert FAIL NEXT MESSAGE signal as a malfunction during the integrated mode from the IOS. This will cause the decoder to be held in the RESET condition until the malfunction is removed. The next message after insertion is faulted and the NEXT MESSAGE FAILED light on the IOS illuminates. This situation will continue until either the required number of failures is attained, or a different message is received in the decoder, at which time the fault generator is reset and the new word is handled normally. As a result of either of these two occurrences, a verification signal is sent to the PCM, and the MESSAGE RECEIVED indicator of the IOS UDL panel illuminates. The system is reset by closure of the KYBD CLEAR switch on the IOS.



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Figure 2-34. Up-Data Link Simulation, Integrated Mode

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2.9.3.3 Up-Data Link, Nonintegrated Mode.

Figure 2-35 is a block diagram of the AMS up-data link simulation in the nonintegrated mode. During nonintegrated operation, UDL simulation is accomplished by manipulation of the UP DATA LINK panel of the IOS. As the actual MSCC is not used, the UDL messages sent to the UDL decoder are in uncoded format rather than the MSCC subbits. Message contents will be the same as in the integrated mode, that is, vehicle address, system address, and information bits.

The four select buttons (RTC, G&N, CTE, and DATA DISPLAY) are interlocked to prevent selection of more than one system at a time. The panel will remain in the selected mode until the KEYBOARD CLEAR button is depressed, unlatching the selected system and resetting the panel.

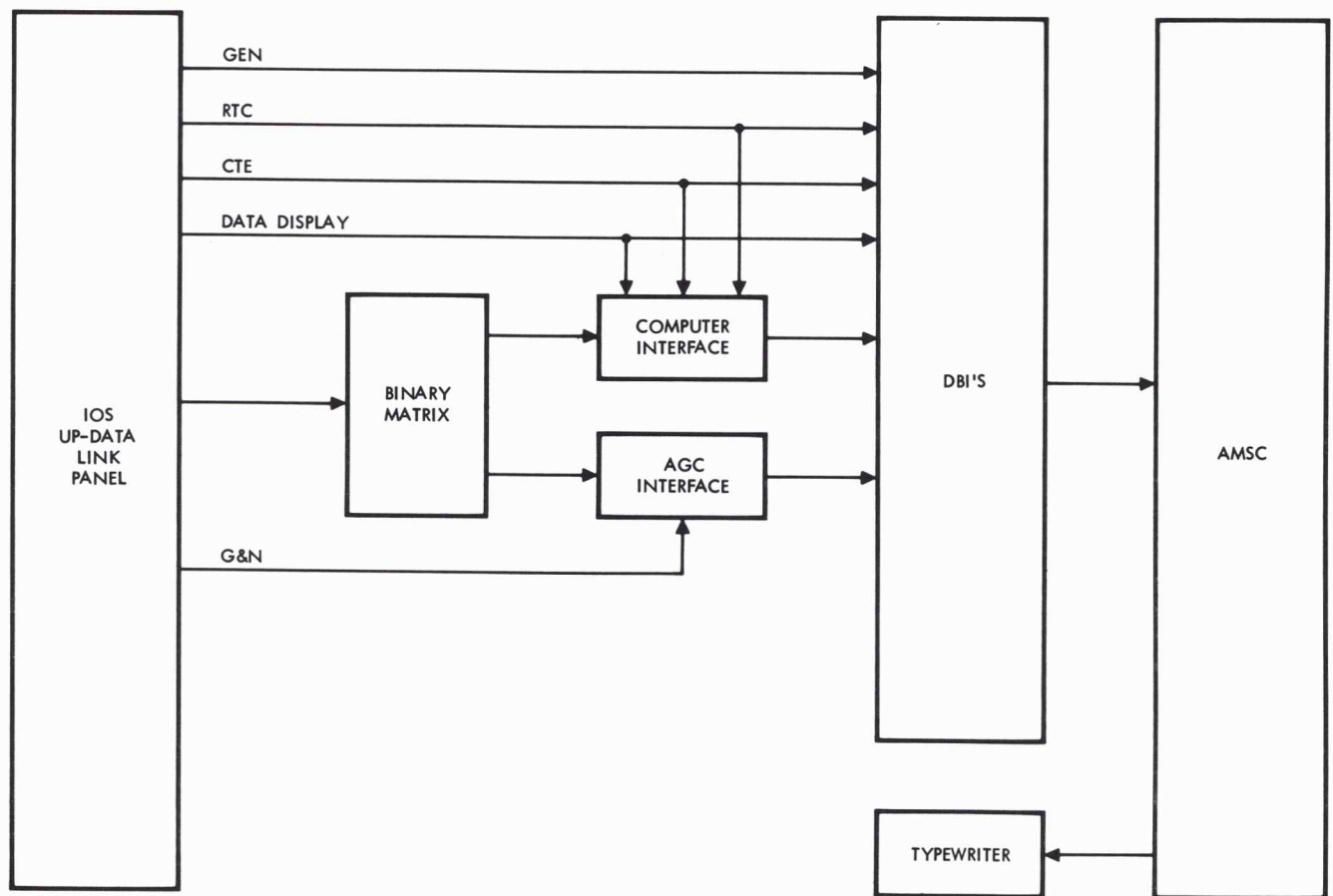
Depressing the RTC or CTE selector switch informs the computer of the type message upcoming and connects the nonintegrated panel controls to the computer. The same type operation occurs when the G&N selector switch is activated, except that the UDL word will be fed to that section of the AMSC which is simulating the S/C AGC. Depression of the DATA DISPLAY selector switch informs the computer that output data is required by the IOS UDL panel and activates the interface connections for this purpose. The information requested by the data display word will be printed out on the typewriter.

After the vehicle and system addresses have been determined, the remainder of the up-data word is made up by successive depressions of the NOUN, VERB, PLUS, MINUS, and 0 through 9 keys on the UDL panel. The word is then entered through a binary matrix, interface networks, and digital bit input circuits.

2.9.3.4 PCM Telemetry Subsystem.

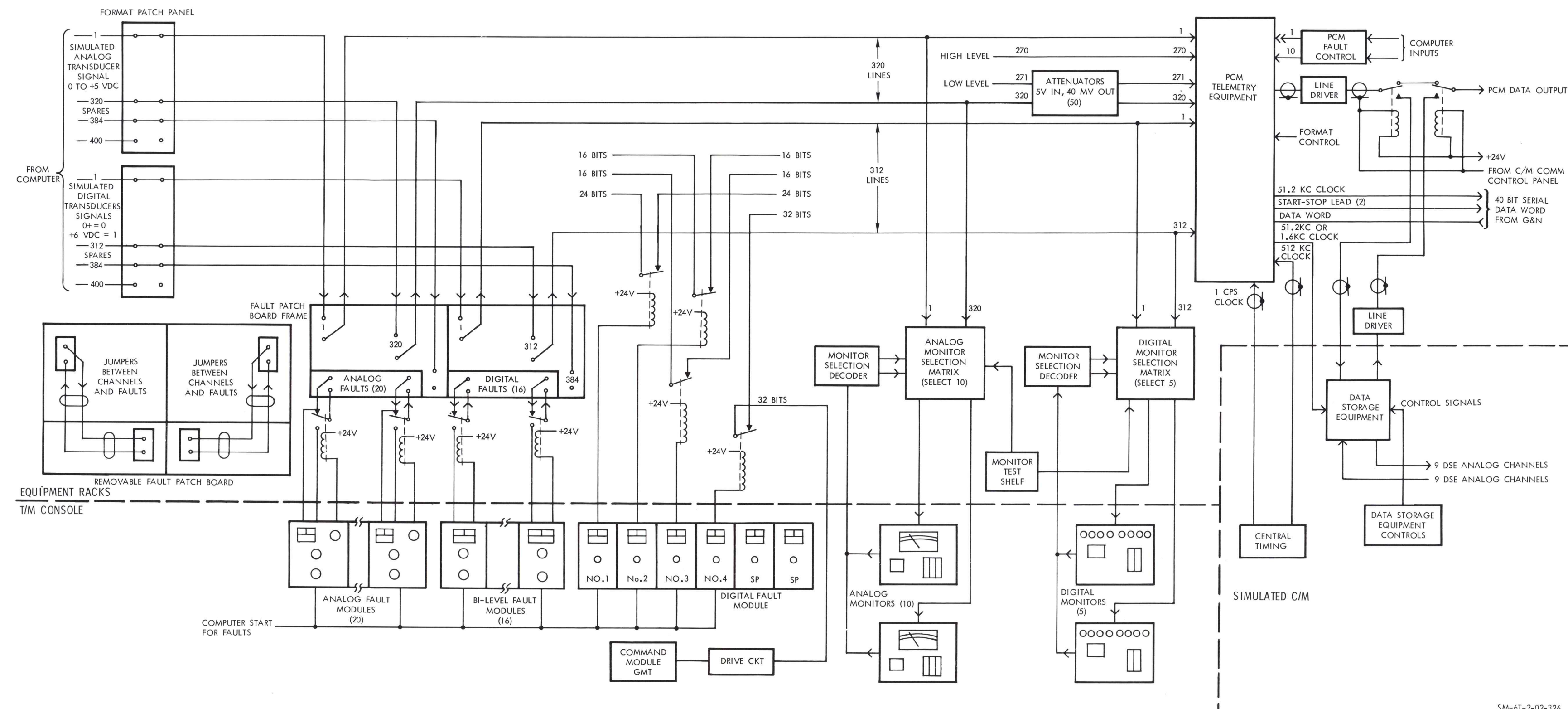
A block diagram of the telemetry simulation, along with the telemetry console, is shown in figure 2-36. The actual spacecraft PCM telemetry unit is used in the AMS. Only the inputs to the unit are simulated. These inputs are in the form of analog, bilevel (single digital bits), and digital words. Generated all within the AMS computer are 320 analog signals, 224 bilevel signals, four parallel-digital words, and one parallel-digital word. They simulate input from all the various S/C systems as shown on the system drawings throughout this section of the handbook. The information bit train from the PCM-T/M is available out of the AMS any time the T/M system is on. As the actual S/C unit is used, the output from the T/M system in the AMS will be the same as that of the actual S/C system, that is, 51,200 bits per second (bps), or 1600 bps as determined by command module switch position. This pulse train may be sent directly out of the AMS or to the data storage equipment (DSE) where it will be recorded for later transmission.

All C/M switches which affect PCM-T/M operation address themselves to the AMSC and light repeater indicators on the IOS and T/M console. The computer then generates and outputs the data signals required by the PCM-T/M for proper operation.



SM-6T-2-02-58

Figure 2-35. Up-Data Link Simulation, Nonintegrated Mode



SM-6T-2-02-326

Figure 2-36. PCM Telemetry Simulation and T/M Console

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Analog Inputs to PCM.

Analog inputs to the PCM-T/M are of two types: dynamic and nominal. The dynamic analog inputs are supplied by the computer through digital-to-analog (D/A) converters and are 0 to +5 volts d-c signals representing specific measurements normally made aboard the S/C. These are the analog signals which MSFN will monitor under normal mission conditions.

Nominal analog signals are generated by tying the output lines in the AMS peripheral equipment to +2.5 volts dc. The nominal analog signals are those not normally monitored by MSFN in an actual mission. By tying these lines to +2.5 volts dc, continuous zero readings in the PCM output pulse train are avoided.

The 320 analog signals, nominal and dynamic, received by the T/M fault control unit may be faulted or allowed to pass unhindered to the PCM-T/M unit. Of these 320 signals, 50 are fed through attenuators which lower their voltage levels to a range of 0 to +50 millivolts dc from their original 0 to +5 volts dc. These signals then simulate the low-level analog inputs to the PCM-T/M.

Bilevel Inputs to PCM.

Bilevel inputs to the PCM-T/M are also of dynamic and nominal types. The nominal bilevel inputs are tied indiscriminately to 0 to +6 volts dc so that some intelligence will appear on each input line to the PCM-T/M. The dynamic bilevel signals will be provided by the computer and represent simulated event occurrences within the S/C. The bilevel signals are routed through the digital bit output circuits to the T/M faulting circuit, and then on to the PCM-T/M. In the T/M unit the 224 bilevel input signals are sampled eight at a time, at specific intervals and treated as parallel-digital words. Each bilevel input may be faulted individually in the fault control unit.

Parallel-Digital Inputs to PCM.

Most parallel-digital words are provided to the computer through the digital word output circuits. These words will be in the form of multiples of eight parallel bits. Four parallel-digital words are fed into the PCM-T/M unit through the T/M fault control unit. Each of these words (two 16-bit, one 24-bit, and one 32-bit) may be faulted in its entirety by the fault control unit. One additional eight parallel bit word is supplied to the T/M unit by the UDL. This is the UDL verify word, and no provisions are made to malfunction it directly.

Serial-Digital Input to PCM.

The 40-bit serial-digital word from the S/C G&N to the PCM is simulated by the computer in the AMS. This signal is presently fed directly from the AMS computer to the PCM-T/M unit. There the serial-digital word is converted to non-return-to-zero format and integrated into the output pulse train.

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Other Inputs to PCM.

Other inputs to the PCM-T/M include nondata clock signals from the AMS computer simulating the spacecraft CTE. The bit rate control signals from the simulated C/M communications control panel will be sent to the PCM-T/M and will also light repeater indicators on the T/M console and the IOS. This signal controls the bit rate output from the PCM-T/M. The C/M communications control panel also contains a switch to determine which astronaut biomedical information is sent to the T/M unit on a set of four lines. The analog telemetry switch determines which set of analog transducers will provide signals to the premodulation processor (PMP) for subcarrier modulation but has no connection with the PCM-T/M.

PCM-T/M Output.

The PCM-T/M output is a continuous serial nonreturn to zero (NRZ) pulse train of either 51,200 bps or 1600 bps. The pulse train is amplified and sent through a switching network to either SCATS or the data storage equipment (DSE) for recording. The DSE is a standard S/C-DSE. It receives the PCM pulse train from the T/M unit upon selection from the communications control panel. This pulse train is then recorded on four tracks of the tape to be played back and transmitted later to SCATS. Regardless of the bit rate sent into the DSE, the output rate from the DSE will be 51,200 bps due to varying tape speeds.

Telemetry Console Operations.

Analog, bilevel, and parallel-digital words sent to the PCM by the computer are routed through the fault insertion networks in the T/M console, and associated equipment racks. Figure 2-36 contains a diagram of the T/M console which may be referred to during the following discussion.

Analog Fault Insertion.

The 320 zero to +5 volts dc analog signals are fed from the format patch panel to the fault patchboard in the equipment rack. The fault patchboard is wired by a plug-in preprogrammed patch panel. This panel directs both the 320 analog signals and the 312 digital bits which make up the bilevel and parallel-digital words. Of the 320 analog signals available at the patch panel, a maximum of 20 may be directed to the analog fault modules. Four different types of malfunctions may be simulated in each fault module:

- a. A drift in the d-c level of the data signal. The drift rate is variable over the range of ± 1 millivolt per second to ± 1.0 volt per second.
- b. A fixed level substituted for the data signal.
- c. A voltage offset of the data through an algebraic addition of a set voltage.
- d. A complete analog channel loss.

Provisions are made within the module to ensure that the output data signal does not exceed the maximum or minimum established for analog signals. The data signals will be routed through the fault module and back to the patch

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panel without any change to the information contained until the malfunction is inserted by the computer program or by manual switch activation.

As the analog signals are sent from the fault patchboard to the PCM-T/M unit, a parallel pickoff is taken from each of the 320 lines and fed to the analog monitor selection matrix. Through the use of digiswitches, the T/M console operator may select two analog signals for display on the ten voltmeter indicators. Monitoring of these signals will not interrupt their travel to the PCM-T/M unit.

Bilevel Fault Insertion.

The bilevel bits are produced by the AMS computer and are sent through the fault patchboard to the PCM-T/M unit. The fault patchboard is capable of patching 16 of the 224 bilevel signals to the bilevel fault modules. Normally closed contacts of a relay in each of the 16 fault modules provide series continuity for a digital event line until a fault is inserted either automatically, by the computer, or manually from the T/M console. Insertion of a bilevel fault substitutes a continuous "1" or "0" on the data line to replace the normal signal level.

The T/M console contains a five-position rotary switch for selecting COMP or MAN fault insertion and ON or OFF (+6 vdc or 0 vdc) fault levels for each of the 16 bilevel fault channels. Each control also has a NORMAL position which allows the incoming signal to pass through the module unaffected. From this point the bilevel signals are sent to the monitor unit in the T/M console and to the PCM unit.

Parallel-Digital Word Faulting.

Four parallel-digital words are generated in the AMS computer and fed out through the fault patchboard. There are two 16-bit words, one 24-bit word, and one 32-bit word. These are all parallel bit words, so there are a total of 88 lines running from the AMS computer to the digital word malfunction units in the T/M console as part of the 312 digital bits patched out of the computer. All four parallel-digital words pass directly from the format patch panel to the T/M console where they are fed through four digital fault modules. Normally, closed contacts of four multiple contact relays allow the digital words to pass through the module unaffected. When a fault is inserted, either manually or by computer command, into any of the four digital words the respective fault relay will energize causing all bits of the word to go to "0". Each fault module contains a three-part indicator to tell the T/M console operator when the fault has been inserted, and whether this was a manual or computer insertion. The parallel-digital words are routed from the fault modules to the PCM and T/M console monitor units. Operation of the monitor unit is explained in section 1 Volume II.

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2.9.3.5 Voice Communication Subsystem.

Simulation of voice communications within the AMS is accomplished in several parts. Those systems which are in the actual S/C include S-band, VHF-AM, HF, and the intercom. In addition to simulating these, the AMS also incorporates backup and astronaut loops. These simulations are described below and are also illustrated in figure 2-33.

Voice signals normally feeding the astronaut audio control center from S-band or VHF-AM are sent through distortion circuits as explained in paragraph 2.10.3.1. The incoming audio signal is fed to a voltage control amplifier (VCA) and on to the astronaut earphones. This path will be the same, regardless of which audio signal is selected. Backup and astronaut loops are not selectable from within the command module but will pass through the mixer and VCA.

The S/C intercom system is designed to provide communications between the astronauts within the C/M and between the astronauts and ground prior to liftoff. In the AMS the astronaut intercom system performs the same function by linking the simulated C/M with MSCC prior to simulated liftoff. At simulated liftoff, intercom communications between the ground and the astronauts will be broken. The intercom in the AMS is the same as that in the actual S/C except that an output is taken from each astronaut earphone and fed to the monitor loop at the IOS. Earphones for the monitor loop allow the instructor-operator at the console to hear what the astronaut hears. The monitor loop is equipped with a four-position switch which allows the console operator to select astronaut intercom line 1, 2, 3, or all. All voice signals entering the audio centers from the up-link receivers will be treated in the same manner as the intercom voice signals. The astronaut loops are not part of the Apollo communications systems but are supplementary links. These loops provide the IOS instructor-operator additional audio communications capability with the flight crew. Consisting of three independent audio links, the astronaut loops can provide astronaut communications at all times even though simulated mission conditions may inhibit all other audio modes. Each astronaut may control the volume of the loop through his audio center. The power switch must be in the PTT or VOX position for the astronaut to transmit to the IOS. The astronaut loops are distributed by the console communication system (CCS) which is GFE.

The backup loop is also a supplementary loop and is completely independent of the GFE CCS. This loop will provide astronaut communications when the CCS is inoperative. The backup loop allows the IOS systems management instructor-operator to monitor each astronaut earphone. To use the backup loop, the instructor-operator must plug his headset into a telephone jack on the IOS. The IOS has a volume control specifically for the backup loop as this signal is not under the control of the CCS volume control.

Emergency tone signals are fed into the astronaut headset from the emergency tone generator. Any malfunction inserted into the AMS will cause the AMS computer to generate a start signal to this generator. The stop signal must be initiated by the astronaut.

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The S/C omni antennas will be simulated in the AMS by assuming that the reception pattern for each of the two antennas is a hemispherical lobe. The simulated position of these antennas in space with respect to the ground based transmitter determines the amount of fade and level suppression exerted on the voice signal being sent to the astronauts. Each omni antenna has two parts, 200-mc VHF scimitar and the 2 kmc S-band notch. Selection of upper or lower antenna may be made in either case. The S-band switch also has an automatic position which allows the S-band circuits to select the antenna receiving the strongest signal. These switch positions are fed to the AMS computer for input into the up-voice fade and level determining program. The S-band high gain antenna is normally automatically oriented toward earth, but provisions are made to allow the astronaut to command a change in antenna alignment angle. These commands will also be sent to the AMS computer for integration into the computer program.

2.10 GUIDANCE AND NAVIGATION SYSTEM.

The spacecraft guidance and navigation (G&N) system performs the following functions:

- a. Establishes an inertial reference to be used for measurements and computations.
- b. Aligns the inertial reference by precise optical sightings.
- c. Calculates the position and velocity of the spacecraft by optical navigation and inertial guidance.
- d. Computes steering requirements and generates thrust commands necessary to maintain the required spacecraft trajectory.
- e. Provides the astronauts with a display of data which indicates the status of the guidance and navigation problem.

For purposes of this description the G&N has been divided into three major subsystems: inertial, optical, and computer.

2.10.1 G&N CONFIGURATION REFERENCE.

The G&N system and optical simulation for the initial delivered configuration of the AMS conform basically to the design and controls and displays of AF011. Deviation from AF011 and the operational constraints in the simulated G&N system of the AMS are as follows:

- a. The photometer control panel on the G&N lower equipment bay is installed in the AMS but has been removed from AF011.
- b. The capability of mechanically opening the optical instruments door has not been incorporated into the simulator.
- c. Simulated telescope sightings are limited to three orbits of earth land tracking from 100 to 215 n mi altitude and starfield sightings.
- d. Visual simulation in the sextant is limited to 28 stars for IMU alignment purposes only.
- e. The sextant can not be used for earth or lunar landmark sightings as there are no landmark slides provided.
- f. Visual simulation begins at orbit insertion and terminates at deorbit.

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g. Visual simulation of the LEM transposition, rendezvous, and docking maneuvers are not included in the IDC of the AMS.

h. In the spacecraft after a starsighting has been made and the angle "marked" into the AGC, the code name of the star is put into the computer via the DSKY keyboard. In the simulator, the name of the star must be verbally relayed to the instructor at the IOS, who inserts the code name into the up-data link for transmittal to the simulator computer.

The differences between the initial delivered configuration of the AMS G&N system simulation and AF012 are:

- a. A CONDITION LAMP POWER switch is provided in the G&N AF012 LEB panel.
- b. The SEXTANT POWER switch on the optic control panel is identified as TRACKER POWER in AF012.
- c. The signal conditioner annunciator panel is located on the upper left portion of the AF012 LEB G&N panel.
- d. On the CDU panel, the middle gimbal and inner gimbal assemblies are interchanged.

2.10.2 SIMULATED G&N SYSTEM (S/C EQUIVALENT).

2.10.2.1 Inertial Reference System.

The block diagram shown in figure 2-37 represents the normal inertial subsystem. AMS simulated malfunction insertion and telemetry points are shown in reference to the simulator equivalent of this system.

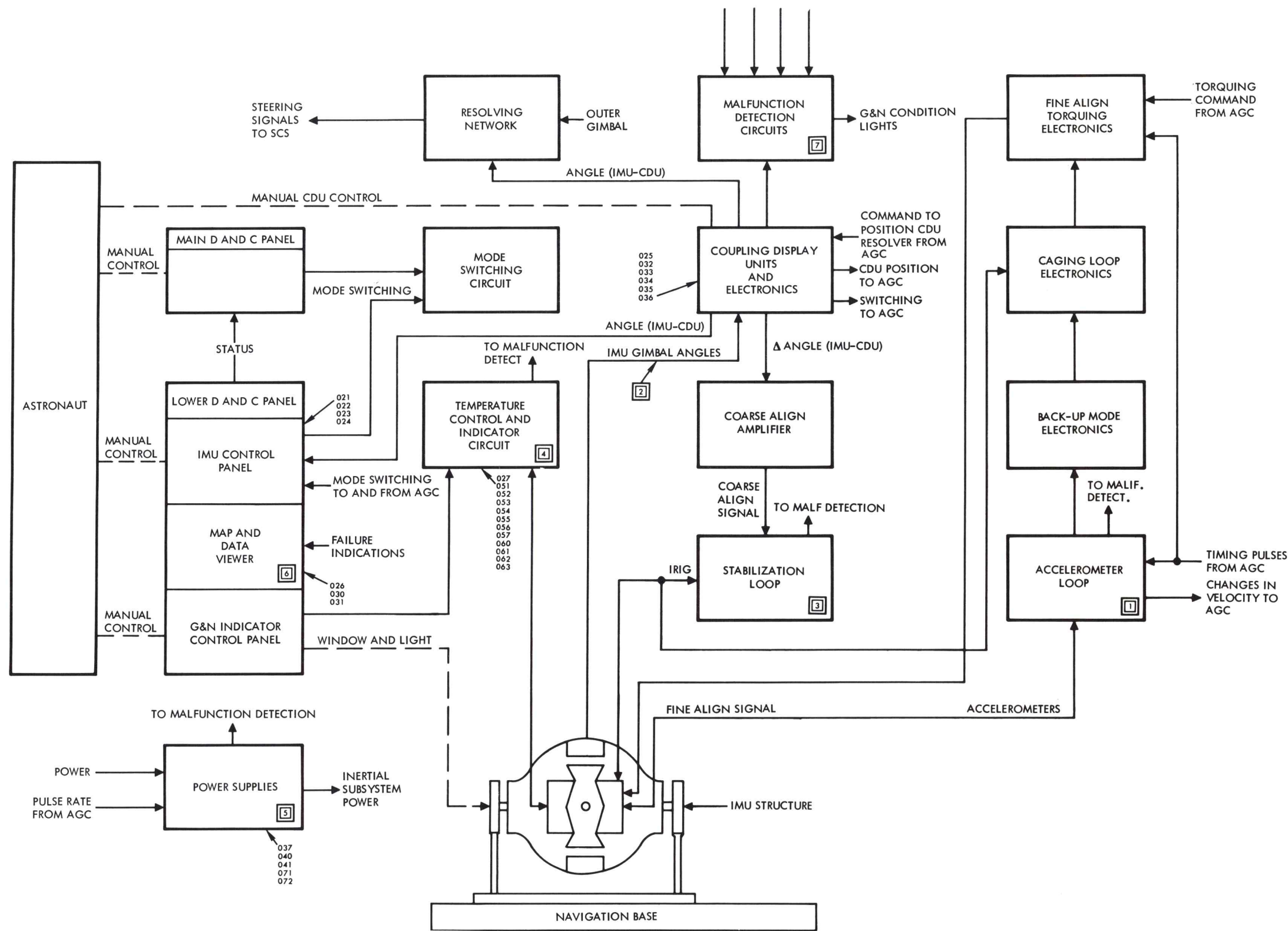
The primary functions of the inertial subsystem are to establish and maintain an inertial reference, to sense thrust for use in measuring velocity changes, and to enable the astronauts to control the attitude of the spacecraft with respect to constant reference axes. The inertial system is divided into five equipment subsystems:

- a. Inertial measurement unit (IMU)
- b. IMU temperature
- c. IMU mode select
- d. CDU
- e. Error warning

Inertial Measurement Unit (IMU).

The IMU is a three-degree-of-freedom gyroscopic stabilization system mounted on the navigation base through an outer, middle, and inner gimbal. The system is comprised of three inertial reference integrating gyros (IRIG), three pulse-integrating pendulous accelerometers (PIPA), the inner gimbal axis angular differentiating accelerometer (ADA), the emergency heater, and associated electronics mounted on the inner gimbal.

The IMU stabilization loop is used to maintain the inertial orientation of the stable member. Angular changes of the stable member caused by S/C attitude changes are sensed by the ADAs and IRIGs within the IMU. Their outputs



TELEMETRY POINTS		
NO	SIGNAL DESCRIPTION	GOSS NO.
1	X AXIS PIPA SIGNAL GENERATOR OUTPUT	G2001V
	Y AXIS PIPA SIGNAL GENERATOR OUTPUT	G2021V
	Z AXIS PIPA SIGNAL GENERATOR OUTPUT	G2041V
2	INNER GIMBAL ASSY 1X RESOLVER SINE OUTPUT	G2112V
	INNER GIMBAL ASSY 1X RESOLVER COSINE OUTPUT	G2113V
	MIDDLE GIMBAL ASSY 1X RESOLVER SINE OUTPUT	G2142V
	MIDDLE GIMBAL ASSY 1X RESOLVER COSINE OUTPUT	G2143V
	OUTER GIMBAL ASSY 1X RESOLVER SINE OUTPUT	G2172V
	OUTER GIMBAL ASSY 1X RESOLVER COSINE OUTPUT	G2173V
3	INNER GIMBAL ASSY SERVO ERROR	G2107V
	MIDDLE GIMBAL ASSY SERVO ERROR	G2137V
	OUTER GIMBAL ASSY SERVO ERROR	G2167V
	INNER GIMBAL ASSY TORQUE MOTOR INPUT	G2110V
	MIDDLE GIMBAL ASSY TORQUE MOTOR INPUT	G2140V
	OUTER GIMBAL ASSY TORQUE MOTOR INPUT	G2170V
	PIPA TEMPERATURE	G2300T
	IRIG TEMPERATURE	G2301T
4	IMU HEATER CURRENT	G2302C
	IMU BLOWER CURRENT	G2303C
	POWER SERVO ASSEMBLY TEMPERATURE	G2306T
	IMU TEMPERATURE	G2307T
	IMU +28 VDC OPERATE	G1503X
	IMU +28 VDC STANDBY	G1513X
	IMU DELAY LIGHT	G5007X
	IMU FAIL	G5001X
	CDU FAIL	G5002X
	GIMBAL LOCK WARNING	G5003X
5	IMU DELAY LIGHT	G5008X
	IMU TEMPERATURE LIGHT	G5006X
	COMPUTER POWER FAIL LIGHT	G5030X
	PIPA FAIL	G5000X
	ERROR DETECT	G5005X
7	IMU PRESSURE LIGHT	G5004X

INERTIAL SUBSYSTEM MALFUNCTIONS	
MALF. NO.	MALFUNCTION DESCRIPTION
GN-021	ZERO ENCODER LAMP FAILURE
GN-022	COARSE ALIGN MODE LAMP FAILURE
GN-023	CDU MANUAL MODE LAMP FAILURE
GN-024	ENTRY MODE LAMP FAILURE
GN-025	28 VDC FAILURE TO MANUAL LATCHING RELAYS
GN-026	IMU TEMPERATURE WARNING LIGHT POWER FAILURE
GN-027	IMU TEMPERATURE CONTROL RELAY FAILURE
GN-030	AGC PWR FAIL INDICATOR POWER FAILURE
GN-031	CDU FAIL LIGHT POWER FAILURE
GN-032	AGC ZERO ENCODER RELAY FAILURE
GN-033	AGC COARSE ALIGN RELAY FAILURE
GN-034	AGC FINE ALIGN RELAY FAILURE
GN-035	ATTITUDE CONTROL RELAY FAILURE
GN-036	AGC ENTRY RELAY FAILURE
GN-037	28V, 800 CPS 1% POWER FAILURE
GN-040	28V, 3200 CPS POWER FAILURE
GN-041	ENCODER EXCITATION (25.6 KC) FAILURE
GN-051	IMU BLOWER #1 FAILURE
GN-052	IMU BLOWER #2 FAILURE
GN-053	PIPA HEATER POWER FAILURE
GN-054	IMU CONTROL HEATER FAILURE
GN-055	IMU CONTROL HEATER CONTINUALLY ON
GN-056	IMU BACK-UP TEMPERATURE FAILURE
GN-057	IMU BACKUP TEMPERATURE CONTROL CONTINUALLY ON
GN-060	3200 CPS MAGNETIC AMPLIFIER EXCITATION FAILURE
GN-061	IMU TEMPERATURE ALARM FAILURE (K1)
GN-062	IMU TEMPERATURE ALARM (K2) FAILURE
GN-063	IMU TEMPERATURE (K2) FAILED CLOSED
GN-071	IMU 28V, 800 CPS 5% POWER SUPPLY FAILURE
GN-072	IMU 28V, 800 CPS GYRO WHEEL POWER FAILURE

Figure 2-37. G&N Inertial Subsystem

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are sent to the stabilization loop where they are amplified and resolved. The resulting signals are sent back to the IMU to activate the torque motors and drive the stable member back to its original position.

The caging loop electronics null the stabilization loop gyros to improve the accuracy of the manual alignment during the backup or emergency mode when the AGC is inoperative and not available for fine alignment of the stable member.

The coarse align amplifiers amplify and demodulate commanded IMU gimbal angles from the coupling display unit (CDU). During coarse alignment these signals are supplied to the stabilization loop where they are used to position the IMU stable platform, slaving the IMU to the CDU.

Acceleration of the spacecraft is sensed by the three pendulous accelerometers (PIPA's). These signals are amplified in the accelerometer loop and used to reposition the accelerometers to the null position and are also sent to the Apollo guidance computer (AGC) to compute incremental velocity changes.

IMU Temperature Control.

The temperature of the inertial components is held within specified limits by heating elements and temperature control sensors. The circuit has four modes of operation: proportional, auto-override, emergency, and backup. Selection of the modes and testing of circuit calibration is accomplished by controls on the IMU TEMP MODE panel.

The proportional temperature control circuit is the primary and most accurate mode of maintaining temperature. The backup temperature control mode is intended for use if the proportional mode controls fail and cannot be repaired. The emergency temperature control mode is for use during alarm condition which prevents use of the other modes.

If the inertial components temperature varies outside the set limits and the auto-override mode is in use, automatic switch-over to the emergency mode occurs, and the NO GO lamp will indicate an alarm. The operation and calibration of the alarm circuitry can be checked by the ZERO and GAIN buttons mounted on the IMU TEMP MODE panel.

IMU Mode Switching.

The inertial subsystem has six major modes of operation selected by mode pushbuttons located on the IMU control panel. These modes and functions are as follows:

- a. Zero Encoder. Positions the CDUs to the zero position.
- b. Coarse Align. Positions the stable member to the angles defined by the CDUs.
- c. Fine Align. Positions the stable member to a precise reference obtained by optical measurements.
- d. CDU Manual. Enables the astronaut to manually position the CDUs.

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e. Attitude Control. Generates steering and attitude commands, which maintain the IMU and CDU angle equal.

f. Entry. Reduces response time required for generating an attitude roll error signal.

In addition, a pushbutton for manual align and a transfer switch to select manual or computer control of the system are provided.

Coupling Display Units (CDU).

The coupling display units are used to translate rotational data into digital format and vice versa. Five are required in the G&N system. Three are used in the inertial subsystem; two are used in the optical subsystem. The CDUs couple the IMU and optics rotational displacement data to the AGC. They also display IMU and optic angular data to the astronaut. The inertial CDUs display the outer, middle, and inner IMU gimbal angles through a six-digit decimal readout. A slew switch and thumbwheel are located on the front of each inertial subsystem for inserting IMU gimbal positions. Each CDU is driven manually by the thumbwheel, or electrically by a motor.

Error Detection.

The error detection circuitry monitors the power supplies, temperature control and indicator circuits, stabilization loop electronics, accelerometer loop electronics, and CDU electronics. In the event of a malfunction, a failure signal is produced which lights status indicator lamps on the signal condition annunciator panel and the alarm lamps on the AGC panel. The status and alarm lamps and their monitoring functions are described in section 1 of Volume I of this handbook.

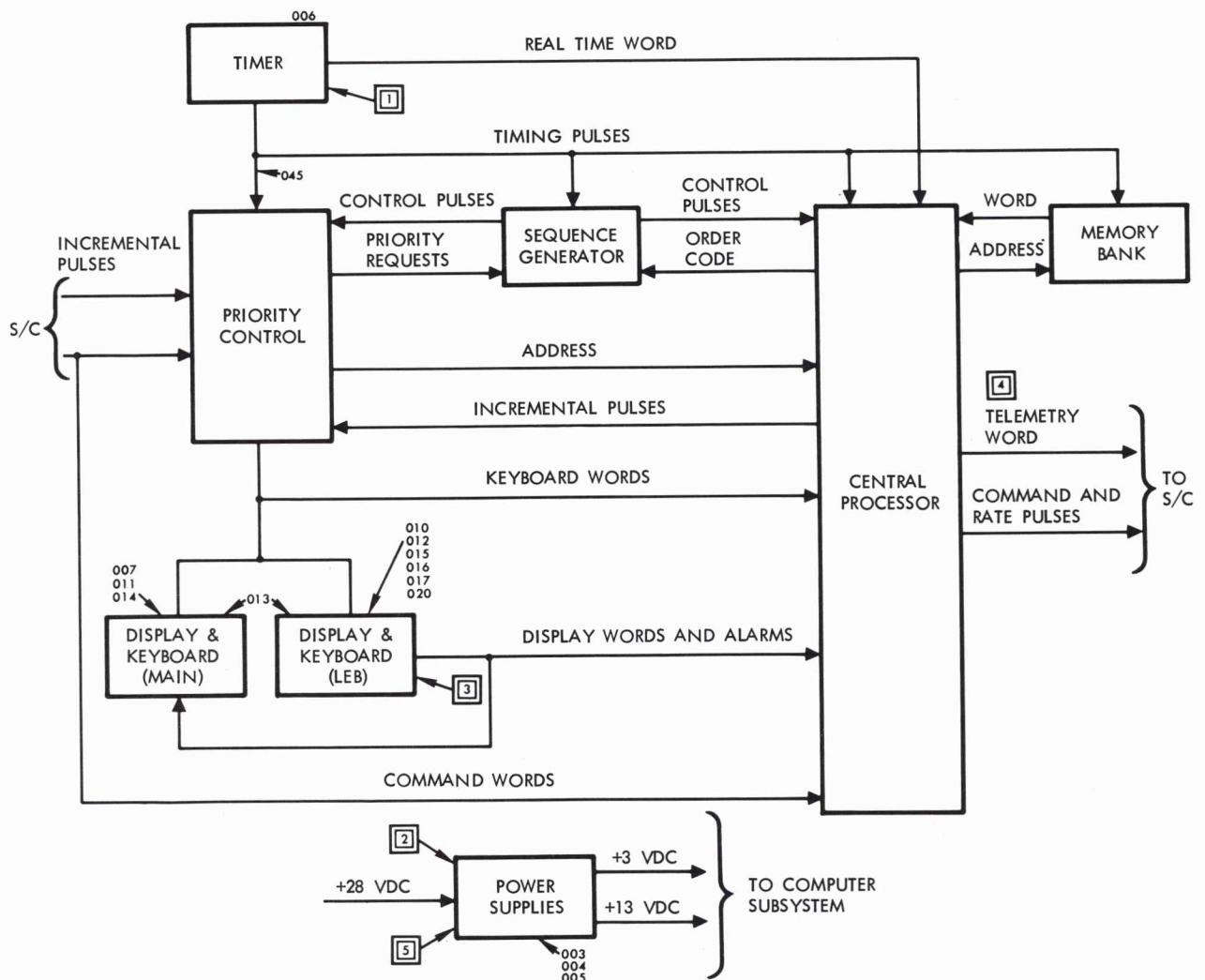
2.10.2.2 Computer System.

The computer system consists of the Apollo guidance computer (AGC) and two display and keyboard units (DSKY). The computer subsystem is the control and processing center of the G&N system. In this capacity the computer subsystem processes data and issues control signals for both the G&N system and other spacecraft systems. Figure 2-38 is a flow diagram of the AGC simulated in the AMS. The diagram includes simulated malfunctions and telemetry points.

The AGC is divided into the following functional areas: timer, central processor, sequence generator, priority control, and memory.

The timer generates all of the timing functions required for operation of the AGC. The central processor consists of central registers, the adder, input and output registers, parity block, and write amplifiers. The sequence generator executes the machine instructions or programs. The priority control is used to update the counters in the erasable memory and to transfer AGC control to one of five interrupt transfer subroutines stored in the fixed memory.

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TELEMETRY POINTS		
NO	SIGNAL DESCRIPTION	GOSS NO.
1	1024 KPPS MASTER FREQUENCY	G4017F
2	AGC +28 VDC	G1523X
3	AGC ALARM 1	G5020X
	AGC ALARM 2	G5021X
	AGC ALARM 3	G5022X
	AGC ALARM 4	G5023X
	AGC ALARM 5	G5024X
	AGC ALARM 6	G5025X
	AGC ALARM 7	G5026X
	AGC ALARM 8	G5027X
	AGC ALARM 9	G5028X
	AGC ALARM 10	G5029X
4	COMPUTER DIGITAL DATA 40 BITS	G0001
5	AGC TEMPERATURE MONITOR 1	G4300T

COMPUTER MALFUNCTIONS	
MALF NO.	MALFUNCTION DESCRIPTION
GN-001	UP-DATA LINK BLOCKED
GN-002	UP-DATA LINK BLOCK FAILURE
GN-003	AGC-13 VDC POWER FAILURE
GN-004	AGC 3 VDC POWER FAILURE
GN-005	AGC 28 VDC POWER FAILURE
GN-006	AGC OSCILLATOR FAILURE
GN-007	MAIN DSKY DISPLAY POWER FAILURE
GN-010	LEB DSKY DISPLAY POWER FAILURE
GN-011	MAIN KEYBOARD POWER FAILURE
GN-012	LEB KEYBOARD POWER FAILURE
GN-013	DSKY FLASHER FAILURE
GN-014	MAIN DSKY DISPLAY FAILURE (3RD DIGIT "4")
GN-015	LEB DSKY DISPLAY FAILURE (3RD DIGIT "8")
GN-016	LEB DSKY DISPLAY FAILURE (5TH DIGIT "0")
GN-017	LEB KEYBOARD (KEY "5") FAILURE
GN-020	LEB KEYBOARD (KEY "8") FAILURE
GN-042	AGC INTERRUPTER 30 MILLISEC
GN-043	AGC IN ENDLESS LOOP
GN-044	AGC PARITY FAILURE
GN-045	COUNTER INCREMENT IN PROGRESS 30 M SEC

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Figure 2-38. G&N Computer Subsystem

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The memory bank consists of a fixed memory with a capacity of 24,576 16-bit words and an erasable memory with a capacity of 1008 16-bit words. Information in the erasable memory can be updated or altered throughout the mission.

Control Programs.

The required tasks to be performed by the AGC are coordinated and synchronized by the executive control program. Programs included in this category are as follows:

- Executive. Supervises the execution of all programs which do not operate in the interrupt mode.
- Waitlist. Supervises the control of programs which must be executed at a specific time.
- Master Control. Initiates, terminates, and supervises restarts of all mission programs.

DSKY Operation (Input/Output Program).

The keyboards enable the astronauts to control the AGC. Computer instructions consist of combinations of verbs and nouns, each of which are entered and/or displayed as a two character octal number. The verb number indicates the action to be taken by the computer, such as display, load, etc., and the noun the quantity upon which the action is to be taken, such as memory address, gyro angles, etc. The numerical keys are used to make up the verb-noun combinations, data to be loaded, and to specify the AGC address not represented by nouns. The sign keys are used to indicate to the AGC that subsequent data entries are decimal; otherwise the computer would normally process the data as octal.

G&N Operating Modes.

The AGC executive and input/output program provide the timing and control of the following modes of operation.

- Prelaunch G&N systems checkout
- Launch boost monitor
- In-flight alignment
- Navigation
- Powered flight steering (major thrust and delta V)
- Entry maneuver

Prelaunch Alignment Program.

The stable member is aligned and at a predetermined orientation (earth reference) prior to launch. The alignment is performed in two steps, vertical erection and azimuth alignment. After the stable member is initially aligned, earth-rate compensation signals are continually applied to the stable member until liftoff.

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Boost Monitor Program.

During the boost phase of a mission, dynamic control is performed by the launch vehicle guidance computer. However, the G&N system monitors the behavior of the spacecraft for the purpose of assuming control should an abort situation occur. Upon receipt of the abort signal, the AGC initiates a mode switch and calls up an active guidance program in accordance with the particular conditions under which the abort occurred. At this time the boost monitor process is terminated.

Navigation Program.

The navigation program in the AGC provides the astronaut with vehicle position and velocity information any time during unpowered flight. Navigation during earth and lunar orbit is to be accomplished by telescope measurements of landmark angles. During the midcourse phases of the mission, sextant measurements of the angle between the landmark and a star are used for navigation.

In-Flight Alignment Program.

In-flight alignment is performed in the zero encoder mode. After zeroing of the IMU-CDUs has been completed, a sighting on two coarse align stars is made with the telescope. As each star is centered in the telescope the MARK button is pressed. This records the optical angles, time, and IMU gimbal angles in the AGC. The computer calculates the change in stable member alignment. Coarse alignment mode is selected, and the AGC drives the CDU to the calculated angles with the IMU following. The attitude control mode is then selected and the spacecraft is aligned to the stable member.

Next, two fine align star sightings are made with the sextant. The stable member is now aligned in the fine align mode and the CDUs are slaved to the IMU. For normal maneuvers the stable member orientation is such that the stable member X-axis is aligned to the SPS thrust axis. Finally attitude control mode is entered and the spacecraft is positioned to placing the thrust axis along the stable platform X-axis.

Powered Flight Steering Program.

This program provides signals to position the SPS engine. Cross product steering equations are solved in the AGC for steering angles used to drive the CDUs. The CDUs are then compared with the IMU resolvers. The differences between the two represent error signals which are transformed into spacecraft axis by a resolver chain. These signals are sent to the SCS system to generate commands to the SPS engine gimbal servos.

Entry.

The entry guidance system is capable of completely automatic operation. The astronaut only monitors the system indicators during G&N mode entry.

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However, should a requirement arise, backup entry modes are available. The entry program is divided into four phases:

- Initial descent
- Steer to exit
- Ballistic phase or constant attitude phase
- Final glide

The initial descent portion of the entry program selects a roll angle command and holds it until the second phase begins. The roll angle selection is determined by accuracy of the retrograde delta V. The initial descent phase ends when the indicated rate of descent is reduced to a preselected level. The second phase, steer to exit, is a computed reference trajectory based on simple analytic formulae. During the ballistic phase, no steering is possible due to the programed "atmosphere skip out." Correction of navigation information is performed by up-link telemetry. The fourth phase, the final glide, is an equilibrium glide with corrections for azimuth and range.

2.10.2.3 Optical System.

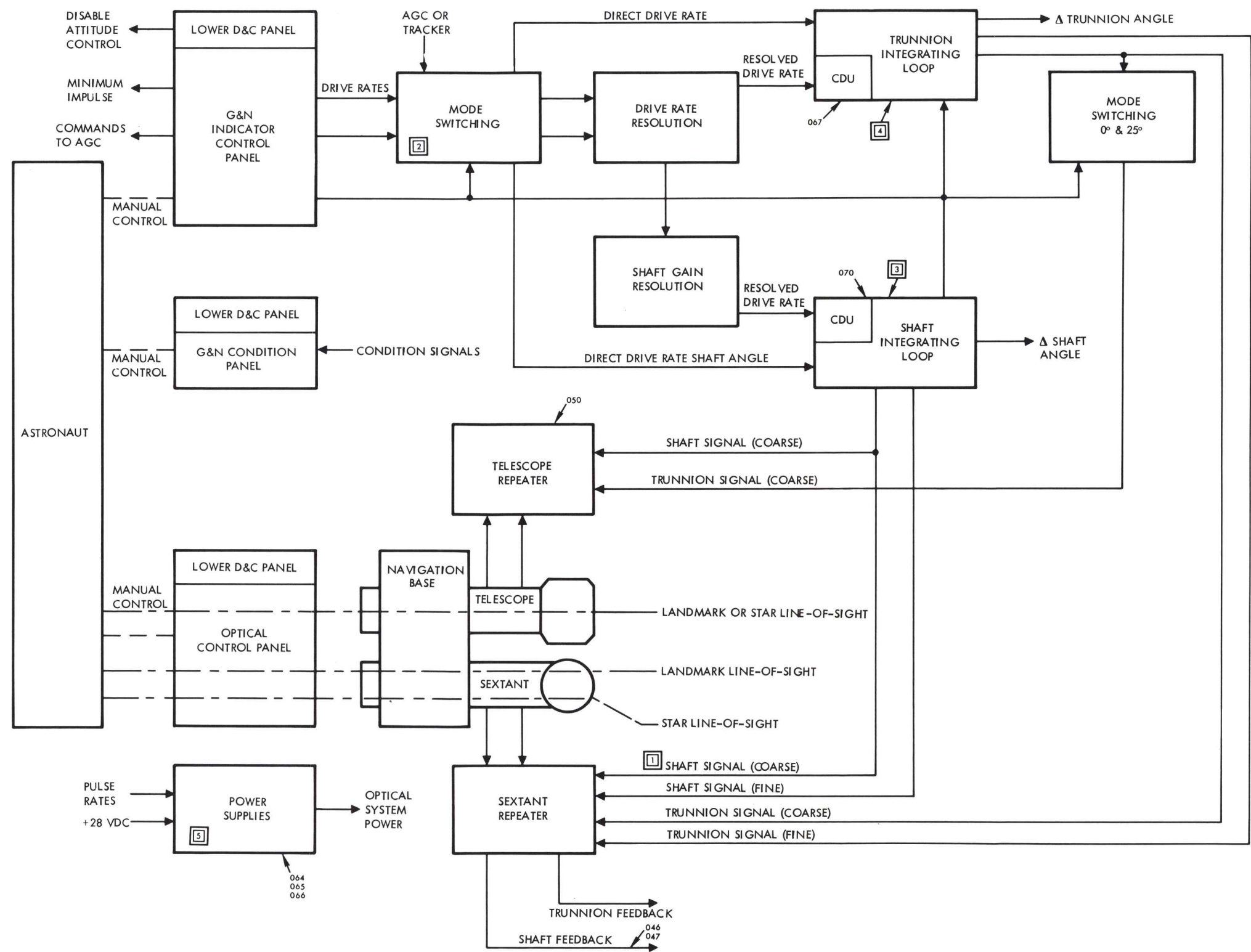
The optical subsystem enables the flight crew to take sightings on geographic and celestial objects by means of a telescope and sextant. The sightings are used, in conjunction with the AGC, to measure the spacecraft position and velocity vector and to align the IMU.

A block diagram of the G&N optical system simulated in the AMS is provided as figure 2-39. The diagram includes simulated malfunctions and telemetry points.

The telescope is used as for star acquisition during IMU coarse alignment and for tracking landmarks during earth and lunar orbit. The telescope has two degrees of rotational freedom about the shaft and trunnion axes. The sextant is more accurate than the telescope and is used primarily during the midcourse phase for measurement of angles between a landmark and a star (for navigation) or two stars for IMU alignment. The sextant has two lines of sight, landmark and star.

The shaft and trunnion integrating loops receive drive signals generated by the optical control sticks located on the G&N indicator control panel. The telescope and sextant repeaters display the positions commanded of the shaft and trunnion integrating loops. Signals from the integrating loops are applied to the repeater servos, which in turn drive the optical instruments.

The shaft gain resolution circuitry is used to produce a constant image motion rate in the eyepiece for a given rate input from the optical control stick. The drive rate resolution resolves the control stick drive rates so that the image motion in the eyepiece is independent of the shaft angle. Otherwise, the direction in which the image would move in response to the control stick would vary with the shaft angle.



OPTICAL SUBSYSTEM MALFUNCTIONS	
MALF. NO.	MALFUNCTION DESCRIPTION
GN-046	SEXTANT TRUNNION MOTOR DRIVE AMPLIFIER FAILURE
GN-047	SEXTANT SHAFT MOTOR DRIVE AMPLIFIER FAILURE
GN-050	TELESCOPE SHAFT AND TRUNNION MOTOR DRIVE AMPL FAILS
GN-064	OPTICS 28 V, 800 cps, 5%, POWER SUPPLY FAILURE
GN-065	OPTICS 28 V, 800 cps, 1%, POWER SUPPLY FAILURE
GN-066	OPTICS 25.6 KC POWER SUPPLY FAILURE
GN-067	OPTICS TRUNNION CDU MOTOR EXCITATION FAILURE
GN-070	OPTICS SHAFT CDU MOTOR EXCITATION FAILURE

TELEMETRY POINTS		
NO	SIGNAL DESCRIPTION	GOSS NO.
1	SEXTANT TRUNNION MOTOR DRIVE (RMS)	G3102 V
	SEXTANT SHAFT MOTOR DRIVE (RMS)	G3112 V
2	OPTICS DIRECT TRUNNION CONTROLLER (IN PHASE)	G3209 V
	OPTICS DIRECT SHAFT CONTROLLER (RMS)	G3227 V
	OPTICS DIRECT SHAFT CONTROLLER (IN PHASE)	G3229 V
3	SHAFT CDU MOTOR DRIVE (RMS)	G3220 V
4	TRUNNION CDU MOTOR DRIVE (RMS)	G3200 V
5	OPTICS +28 VDC	G1533 X

Figure 2-39. G&N Optical Subsystem

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The controls and displays associated with the optical subsystem are mounted in the optical panel, G&N indicator control panel, and the map and data viewer panel. The optical panel contains the optical eyepiece mountings and the readouts and manual control for the telescope shaft and trunnion angle. The G&N indicator control panel provides optical subsystem mode control, issues the mark commands to the AGC, applies minimum impulse signals to the SCS system, and controls drive rates to the optics. The status of the optical subsystem is displayed on the map and data viewer panel.

2.10.3 GUIDANCE & NAVIGATION SYSTEM SIMULATION.

2.10.3.1 Inertial System.

Inertial Measurement System.

Simulation of the IMU is accomplished by the computation of simulated gimbal angles. Once the inertial reference is established, drift components and failure effects are computed to complete the gimbal angle simulation. The simulated gimbal angles are developed from the inertial reference outputs of the equations of motion. The computation of the inertial reference and gimbal angles are computed continuously during simulation whether IMU power is on or off.

IMU Temperature Control.

Simulation of the IMU temperature control system entails the following computations: heat transfer into the water-glycol coolant at the specified coolant temperature, IRIG and PIPA temperatures, blower and heater currents for down-link telemetry and when required, alarm outputs to displays.

In determining the amount of heat transfer into the coolant, the maximum heat transfer possible and amount of heat generated for the specific conditions are determined. If the latter is less than the former, it is assumed that the total amount of heat generated will be transferred into the coolant. If the latter is greater than the former, a corresponding temperature rise will take place. If the heat generated in the IMU is not great enough to maintain temperature, the IRIG and PIPA temperatures will decrease. Should the temperature of either the IRIG or PIPA exceed its specified tolerance, the alarm will illuminate provided the temperature control mode switch is in either auto-override or proportional position.

IMU Mode Switching.

Simulated IMU mode switching is accomplished by boolean logic. Depression of a mode select pushbutton illuminates the mode light and latches the mode relay. The power available simulation and current drawn by the G&N subsystem (including malfunctions) are computed.

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Coupling Display Unit (CDU).

The CDU representation in the AMS is an electromechanical assembly consisting of a motor-tachometer, gear train, and readout dials, slew switch, a resolver, a thumbwheel, and a precision encoder.

The IMU-CDUs are driven manually by the use of the thumbwheel or electrically by a two-speed loop. Command signals for positioning the CDUs originate at the AGC, CDU resolver networks, or from the slew switches. The IMU-CDU operation is mechanized to operate in the modes selected at the IMU control panel as follows:

Selection of the zero encoder mode, made by either manually pressing the ZERO ENCODER pushbutton, or under AGC control, positions the CDU shaft angle to zero. The coarse align mode is entered by one of four means:

- Pressing the COARSE ALIGN button while in manual control.
- AGC command under computer control.
- IMU turned on for less than 40 seconds.
- Pressing MANUAL ALIGN button while in manual CDU mode.

During manual modes, an error signal developed from either the slew switch or thumbwheel is fed to the AMS computer via a resolver-to-digital converter. The CDU manual mode is activated by one of the following:

- Pressing the CDU manual button while in manual control.
- AGC command under computer control.
- Turning on the G&N SYNC switch on the main control panel.

The fine align mode is entered by:

- Pressing the FINE ALIGN button while under manual control.
- Fine align commands from the AGC under computer control.
- Turning on the G&N SYNC switch with the SCS mode energized.

Signals representing commanded IMU gimbal angles are transmitted from the AMS computer to a digital-to-resolver converter to position the CDUs.

The attitude control mode is entered by pressing the ATTITUDE CONTROL pushbutton while in manual control, or by AGC command while under computer control. The mechanization of this mode is identical to the coarse and fine align modes.

The entry mode is selected by pressing the ENTRY button while in manual control or by AGC command while under computer control. This mode is simulated in the same manner as the coarse and fine align modes.

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Error Detection.

The error detection simulation provides failure detection outputs to the C/M indicators, the AGC, and the telemetry. Simulation of the following malfunctions will cause discretes to be sent to the AGC:

- Loss of CDU encoder excitation or CDU tolerance error.
- PIPA tolerance error.
- Loss of 800-cps wheel excitation, loss of 3200-cps ducosyn excitation, or IMU gimbal lock.
- AGC power supply failures.

Any of the above failures will cause G&N warning lights to illuminate. Potential gimbal lock is simulated by illuminating the appropriate indicators on the signal annunciator panel and on panel 10 when the angle between the middle and outer gimbal exceeds 60° .

IMU temperature warning is simulated by illuminating the IMU temperature alarm in conjunction with simulated malfunctions involving excessive IMU temperature.

2.10.3.2 Computer System.

Executive Control Programs.

The AMS G&N executive control programs are limited to the master control and timing functions within the simulated AGC. The executive control program provides a simulated AGC clock for G&N mission program timing. The time value is equivalent to the CTE master clock as modified by delta time entry inputs from the keyboard or up-data link. Upon reset to a prelaunch condition, the time is reset to zero. The clock can be externally updated whenever the keyboards and simulated AGC are operational. A second clock is provided to count down to the time of powered flight and nominal entry point when a guidance maneuver has been commanded. The time value of both clocks can be monitored on the DSKYs.

The simulated G&N executive control program also controls and sequences the G&N mission programs, which are called up by keyboard or up-data link. The various mission programs are accomplished in seven different modes of AGC operation. The eighth spacecraft mode, G&N test monitor mode, is not simulated in the AMS. The seven modes, the programs accomplished in each, and the DSKY code for each program are provided in table 2-3.

Prelaunch G&N System Checkout.

Simulation of the prelaunch alignment will be accomplished by merely reading out a constant 33° to the inner gimbal CDU, 0° to the middle gimbal CDU, and 0° to the outer gimbal CDU. This is coincident with the spacecraft orientation 60 seconds before liftoff. No gyro drift is simulated during prelaunch since the AGC compensates for gyro drift in the actual spacecraft.

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Table 2-3. AGC Modes and Programs

<u>Mode 0. Prelaunch G&N System Checkout</u>		<u>Mode 4. Major Thrust Maneuver</u>	
01	Zero ICDU	40	Illegal
02	Coarse align	41	Circular velocity required
03	Fine align	42	Perigee velocity required
04	Vertical erection	43	Apogee velocity required
05	Gyro compassing	44	Plane change velocity required
00, 06, 07	Illegal	45	Abort A (entry)
		46	Abort B (orbital insertion)
		47	Illegal
<u>Mode 1. Launch Boost Monitor</u>		<u>Mode 5. Delta V Maneuver</u>	
10	Terminate	50	Illegal
11	Monitor	51	Circular velocity required
12 thru 17	Illegal	52	Perigee velocity required
		53	Apogee velocity required
		54	Plane change velocity required
		55	Fixed time of arrival velocity to be gained
		56	Perigee velocity to be gained
		57	Perilune velocity to be gained
<u>Mode 2. In-Flight Alignment</u>		<u>Mode 6. Entry Maneuver</u>	
20	Terminate	60	Illegal
21	Zero ICDU	61	Initial phase
22	Coarse align	62	Reference trajectory
23	Fine align	63	Constant altitude phase
24	Attitude control	64	Ballistic phase
25	Entry	65	Final phase
26 and 27	Illegal	66 and 67	Illegal
<u>Mode 3. Midcourse and Orbit Navigation</u>			
30	Terminate		
31	Landmark measurement (orbit)		
32	Star/landmark measurement (midcourse)		
33 thru 37	Illegal		

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Launch Boost Monitor.

The simulated monitor program is very nearly identical to the actual spacecraft program as both are digitally mechanized within a computer. If an SPS abort situation occurs during the boost phase, the simulated G&N switches from a passive to an active status. This mode switching terminates the boost monitor phase and the appropriate G&N program is called up. If an abort occurs prior to tower release, the monitor program continues to passively observe the dynamics of the LES sequence. This is done by reading the output of the simulated accelerometers.

The pre-established ascent trajectory is stored in the AMS computer. Attitude errors are displayed during ascent as a function of precalculated velocity, position, and attitude.

In-Flight Alignment.

The IMU in-flight alignment is performed in the coarse-fine align modes. A subroutine calculates the required gimbal angles that are necessary for attaining the desired stable member orientation. The align modes are entered by keyboard command, AGC automatic mode, or from the IMU mode select panel.

Midcourse and Orbit Navigation.

The AMS G&N navigation program computes the vehicle simulated position and velocity based on sextant and telescope measurement. The program also directly updates the simulated trajectory characteristics after a thrust maneuver based on the output of the powered flight program.

Major Thrust Maneuver.

Major thrust maneuvers during the earth orbital mission are Hohmann transfer, orbital circularization, and orbital plane changes. Thrusting requirements for each of these maneuvers are computed for minimum SPS firing time to transpose from present orbit to the known set of orbital characteristics comprising the thrusting objective. Solution of major thrust maneuver problems in the simulated AGC is by the same analytical techniques used in the real system.

Delta V Maneuver.

The delta V maneuver for purposes of the earth orbital mission is deboost or retrograde from orbit. In this maneuver the "fixed time of arrival to be attained" is the prime characteristic of the computation for SPS firing (rather than minimum firing time). Again, analytical techniques used are the same as in the real system.

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Entry Maneuver.

The entry trajectory computations are, of course, directly related to the "fixed time of arrival" delta V maneuver. As the simulation of engine shutoff occurs, the simulated AGC shifts from the delta V maneuver mode to the entry mode. Computations of the entry trajectory are by the same analytical methods as in the real system. Simulation of the aerodynamic lift-drag characteristics, as used for purposes of entry ranging, are accomplished by inputting the equations of motion to the aerodynamics forces and moments program.

2.10.3.3 Optical System.

Section 1 of this volume contains a detailed description of the usual simulation system of the AMS. Section 2 of Volume II describes the input/output interface between the visual simulation system and the equations of motion program. These two discussions describe the simulation of the spacecraft optical system in its entirety. No further discussion is required.

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SECTION 3

NOMINAL TRAINING MISSION

3.1 PURPOSE AND SCOPE

This section of the Apollo Mission Simulator Instructor Handbook defines the nominal training mission for the Apollo mission simulator (AMS) initial delivered configuration. The purpose of the mission is to provide a mission data base with which to plan and accomplish flight crew training for mission 204A with the AMS. Types of training and training sessions to be accomplished within the framework of the nominal training mission are the subject of section 3 (AMS Utilization), volume II of this handbook. The mission characteristics and events are dictated by the planned 204A mission and constrained by the simulation capabilities of the AMS.

3.2 BASIC MISSION EVENTS

Table 3-1 is provided to define the relationship between the nominal training mission and Apollo mission 204A as described in the May 1, 1965, revision to the Apollo Operations Manual (SM2A-03). Column 1 lists the 204A events in mission sequence. Column 2 identifies the corresponding events in the nominal training mission. The nominal mission events are not in mission sequence. Column 3 describes the variances and differences between 204A and the nominal training mission events.

Table 3-1. Mission Events, 204A Versus Nominal Training

Mission 204A Outline (Re: SM2A-03)	Nominal Training Mission Events	Remarks
S-1B ignition Launch vehicle liftoff Roll to 72° azimuth Maximum dynamic pressure S-1B inboard engines off S-1B outboard engines off S-IVB ignition Launch escape tower jettison	1. <u>Launch Boost</u> Launch site - KSC Azimuth - 72° Boost duration - 10 min.	AMS launch boost simulation very closely approximates 204A. Minor variances are in launch boost duration.
Insertion into 105 n mi orbit	2. <u>Orbit Injection</u> Altitude - 105 n mi Inclination - 32.58° Orbit duration - 90 min./orbit	AMS orbital characteristics very closely approximate 204A. Minor variances are in orbital inclination and the geographic displacement of the ground trace.

. . . continued

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Table 3-1. Mission Events, 204A Versus Nominal Training (Cont)

Mission 204A Outline (Re: SM2A-03)	Nominal Training Mission Events	Remarks
CSM simulated transposition and docking		Software required for transposition and docking visuals is not available in the initial delivered configuration of the AMS
S-IVB-CSM separation	4. Jettison S-IVB	No significant variances
RCS ullage SPS ignition (initiate Hohmann transfer to 140 n mi circular orbit)	5. <u>Delta V</u> Initiate Hohmann transfer from 105 n mi to 140 n mi	None
RCS ullage SPS ignition (complete Hohmann transfer to 140 n mi circular orbit)	7. <u>Delta V</u> Circularize orbit at 140 n mi	None
RCS ullage Ignite SPS (initiate plane change $\approx 1^\circ$)	5. <u>Delta V</u> Plane change - 1° to 31.58° inclination	None
RCS ullage SPS ignition (initiate plane change cancelling out previous plane change)	8. <u>Delta V</u> Plane change + 1° to 32.58° inclination	None
RCS ullage Ignite SPS (initiate transfer to 105 n mi circular orbit)	8. <u>Delta V</u> Initiate Hohmann transfer from 140 n mi to 105 n mi	None
RCS ullage Ignite SPS (complete Hohmann transfer to 105 n mi circular orbit)	10. <u>Delta V</u> Circularize orbit at 105 n mi	None

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Table 3-1. Mission Events, 204A Versus Nominal Training (Cont)

Mission 204A Outline (Re: SM2A-03)	Nominal Training Mission Events	Remarks
RCS ullage Ignite SPS (plane change 0.3°)		The reasons for this plane change and its effect on the recovery area are unknown at the time of publication. When data becomes available, it will be considered in future revisions to the nominal training mission.
RCS ullage Ignite SPS (initiate deorbit maneuver)	11. <u>Delta V</u> Retrograde from earth orbit	None
CM separation from SM	12. CM-SM separation	None
Entry interface at 400,000 ft 25,000 ft level	13. .05 G (start entry)	None
CM touchdown	14. Touchdown	None

Differences between mission 204A and the nominal training mission are primarily a result of constraining simulation capabilities of the AMS. The constraints directly affecting the nominal training mission are as follows:

- a. Visual simulation film for the mission effects projector is limited to three orbits.
- b. The systems simulated by the AMS are not precisely those of the mission 204A spacecraft (AF 012). The simulated systems are the subject of section 2 of this volume.
- c. There are to be no landmark slides provided for the sextant in the initial delivered configuration.
- d. The visual simulation system does not simulate the optical distortion of the atmosphere at the earth limb, thus precluding star refraction sightings in the AMS.
- e. The moon will not be visible in the telescope of the visual simulation system, thus precluding star occultation sightings in the AMS.
- f. The ephemeris simulated in the AMS for navigation purposes is September 17, 1969. This is several years after the mission 204A launch date.
- g. S-IVB and LEM models for the AMS visual simulation system will be available within initial delivered configuration of the AMS, but computer programs required to simulate rendezvous and docking will not be provided until the AF 012 modification.

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h. The abort trajectory characteristics of the AMS differ radically from those of mission 204A. The AF 012 will be equipped for the canard abort. The initial delivered configuration of the AMS will simulate prestrakes, precanard, purely ballistic aborts tentatively planned for the spacecraft at the time of AMS design freeze.

The three-orbit mission constraint established by the visual simulation system is prohibitive to accomplishing all of the mission 204A events in a single continuous simulated mission. Therefore, the nominal training mission is comprised of a basic mission containing only one delta V (retrograde), and three variations of that mission for purposes of incorporating simulation of all mission 204A events (including plane changes and Hohmann transfers). The phases and major mission events involved are shown in figure 3-1.

For purposes of part task, mission task, and typical mission training, the three-orbit mission is not a constraint. Part task and mission task training do not require continuous mission simulation. For purposes of typical mission training, anything longer than the four and three-quarter hour, three-orbit mission would be both unnecessary and inconvenient.

3.3

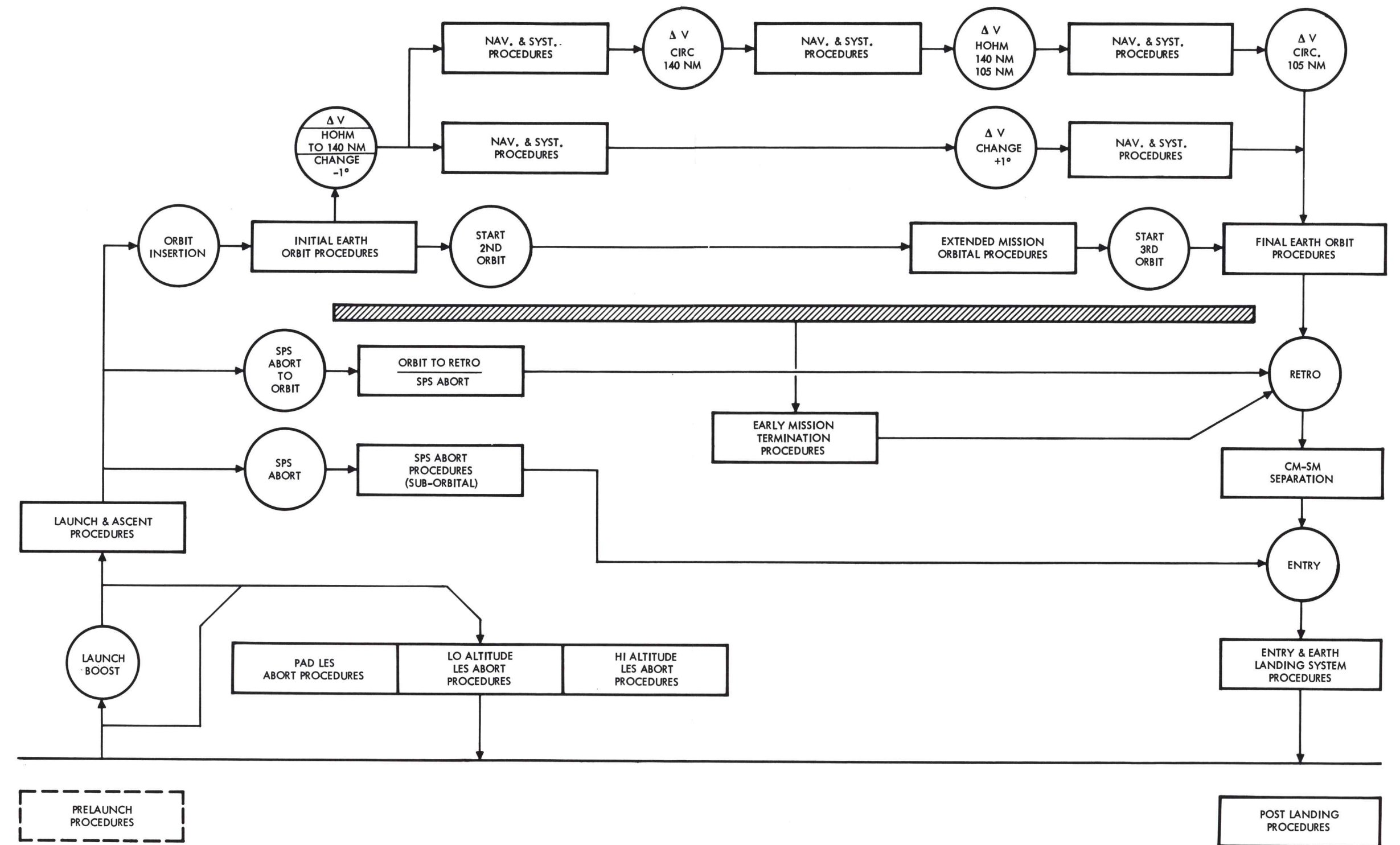
LAUNCH-BQOST PHASE

The launch-boost simulation in the AMS integrated mode is by direct input from the computer complex of the Manned Spaceflight Control Center (MSCC). In the nonintegrated mode, the input from the MSCC is synthesized by reading a prepared computer tape into the same AMS channels that are used for launch-boost input in the integrated mode.

Only one tape is provided for the initial delivered configuration of the AMS. The tape is representative of the launch-boost profile of mission 204A as defined at the time the tape was prepared. Figure 3-2 illustrates the surface range, velocity, and altitude characteristics of the simulated launch-boost with respect to time. Figure 3-3 illustrates the geographic trace of the simulated launch-boost. The numerical notes along the trace denote seconds after liftoff. The two figures are provided for general information. They should also be useful in instruction-operator simulation of MSFN during nonintegrated mode operation.

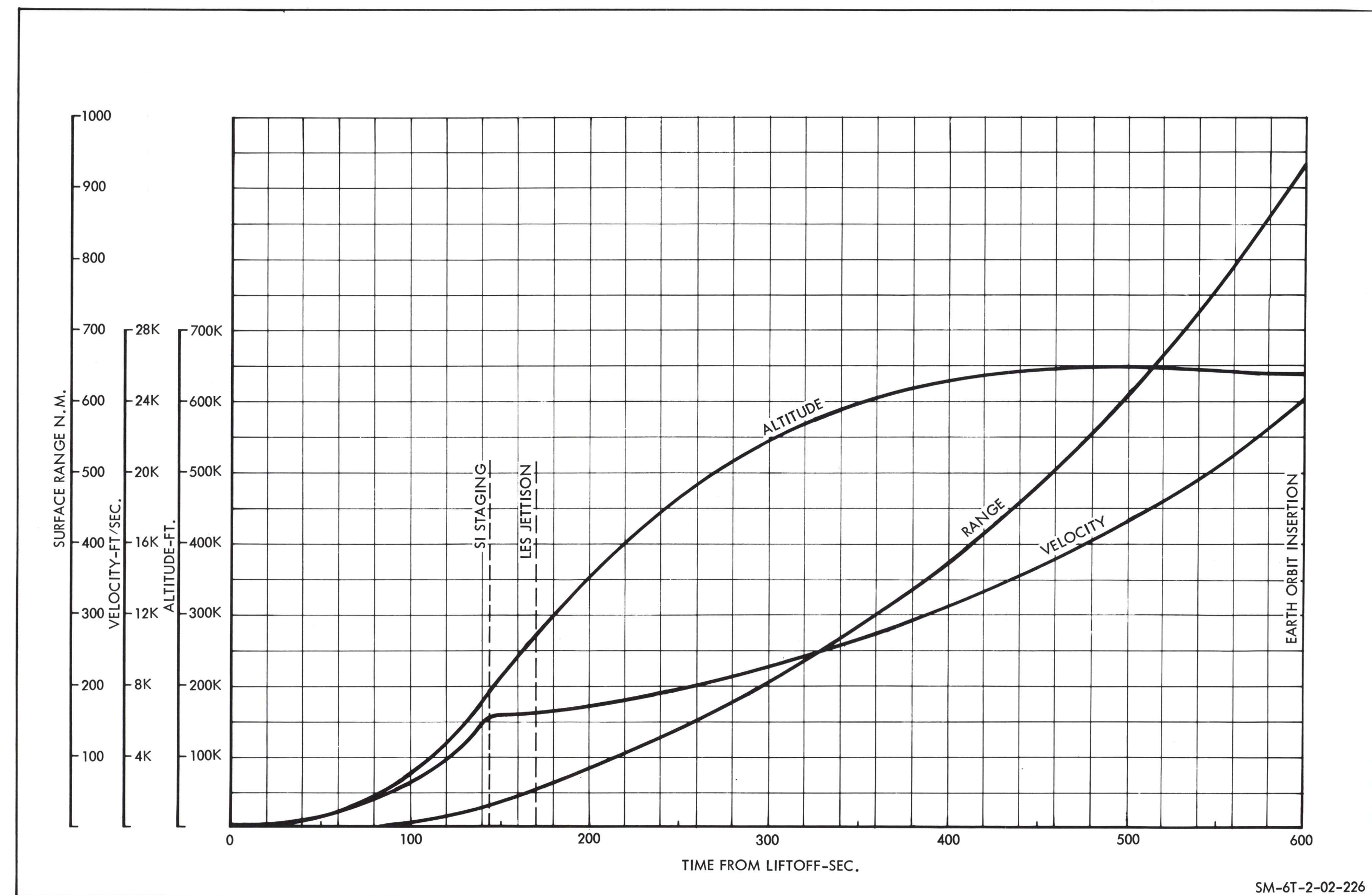
The launch-boost sequence of events is quite general in figures 3-2 and 3-3. A more specific list of events is as follows:

<u>Time/Seconds</u>	<u>Event</u>
0	Liftoff
138.16	Shutoff inboard engines
144.16	Shutoff outboard engines
149.06	Second stage ignition (first mixture ratio)
159.66	Second stage ignition (second mixture ratio)
169.66	LES jettison
363.66	Second stage ignition (third mixture ratio)
600.00	Earth orbit injection
EOI	31.41° N, 62.78° W



SM-6T-2-02-225

Figure 3-1. Nominal Training Mission Block Diagram



SM-6T-2-02-226

Figure 3-2. Launch Ascent Data

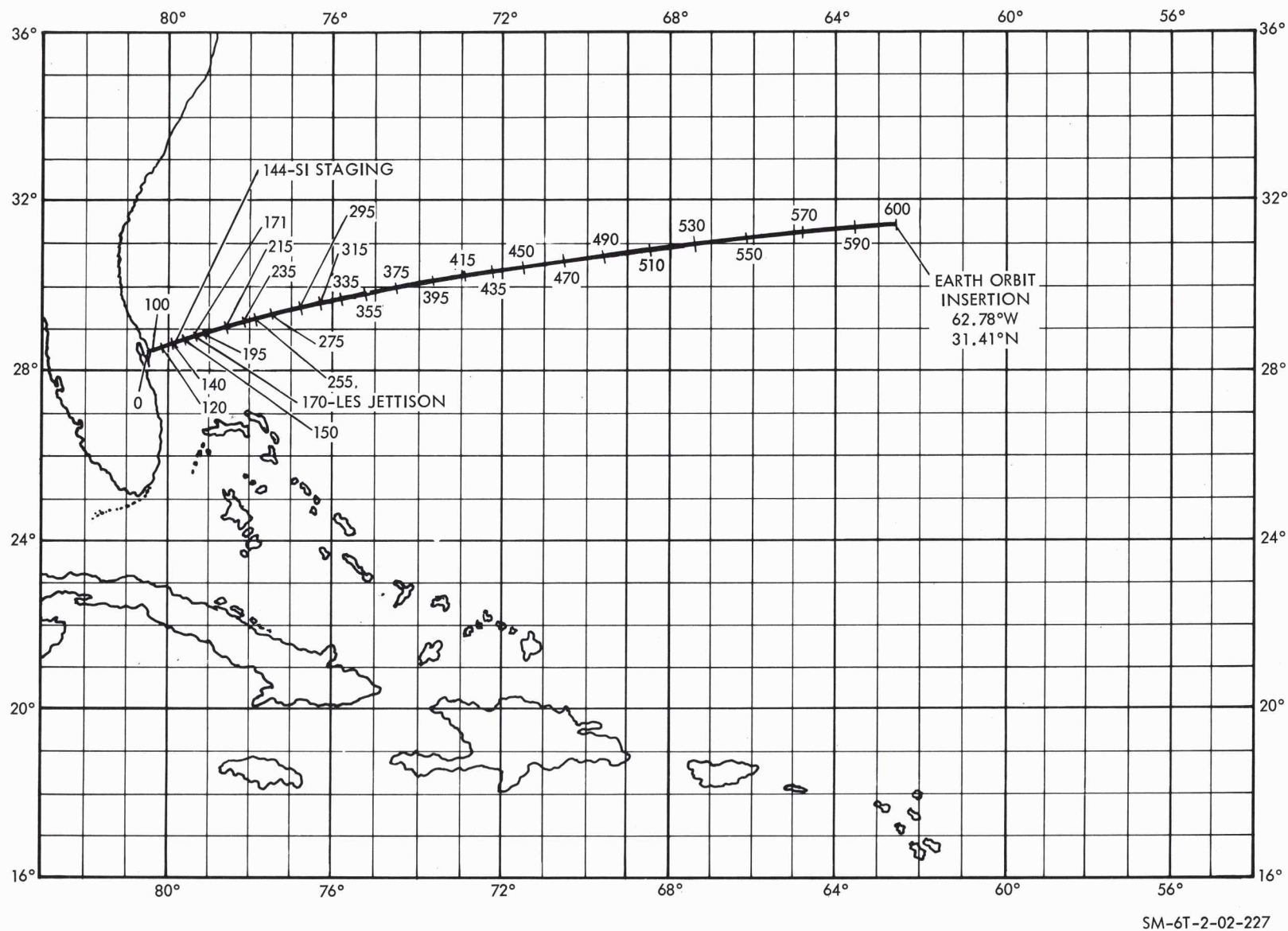


Figure 3-3. Launch Ascent Path

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3.4 SUBORBITAL ABORTS

As explained in paragraph 3.3, the simulated launch-boost program in the AMS is preprogrammed to a fixed profile representative of the mission 204A launch and ascent. This situation is prohibitive to dynamic simulation of ascents involving engine out, excessive rates, or low thrust/acceleration launch situations. However, this limitation does not preclude initiation and simulation of all types of suborbital aborts. Once abort initiation takes place, the preprepared launch-boost program is terminated and a full dynamic simulation of the abort is provided.

Simulated aborts can be accomplished by either crew or instructor-operator input. The crew initiation is accomplished in the same way as in the spacecraft, that is, by twisting the translational hand controller counterclockwise. Instructor simulation of autoabort is accomplished through the malfunction insertion unit of the IOS. It is desirable but not necessary, also, to program some indication of booster failure to occur immediately prior to the autoabort. However, time lapse from malfunction occurrence to abort initiation must be very short as the effects that booster failure would have on FDAI and AGC indicators will not materialize in the preprogrammed launch boost simulation. The MIU is also the means by which the ABORT REQUEST light in the simulator command module is illuminated. Instructions for instructor-operator use of the MIU in abort simulation are provided in section 1, volume II of this handbook.

Six different abort sequences are simulated in the AMS. All are depicted in illustrated flow diagrams. The different abort sequences and the figures in which they are illustrated are as follows:

- LES abort, below 5000 ft, before 35 seconds (figure 3-4)
- LES abort, 5000 ft to 25,000 ft (figure 3-5)
- LES abort, 25,000 ft to 30,000 ft (figure 3-5)
- LES abort, 30,000 ft to 220,000 ft (figure 3-5)
- SPS abort to suborbital trajectory (figure 3-6)
- SPS abort to orbit (figure 3-7)

It should be noted that the abort simulation in the AMS initial delivered configuration is not representative of the canard abort configuration provided with spacecraft AF 012 for mission 204A. The system is generally representative of an earlier configuration and is described in detail in section 2 of this volume of the handbook.

3.5 ORBITAL NAVIGATION

Navigation while in simulated orbit will be accomplished with the visual display system and the simulated guidance and navigation system described in sections 1 and 2 of this volume of the handbook. Stars and landmarks simulated for navigation purposes are listed in the tables provided in conjunction with the visual display system description in section 1.

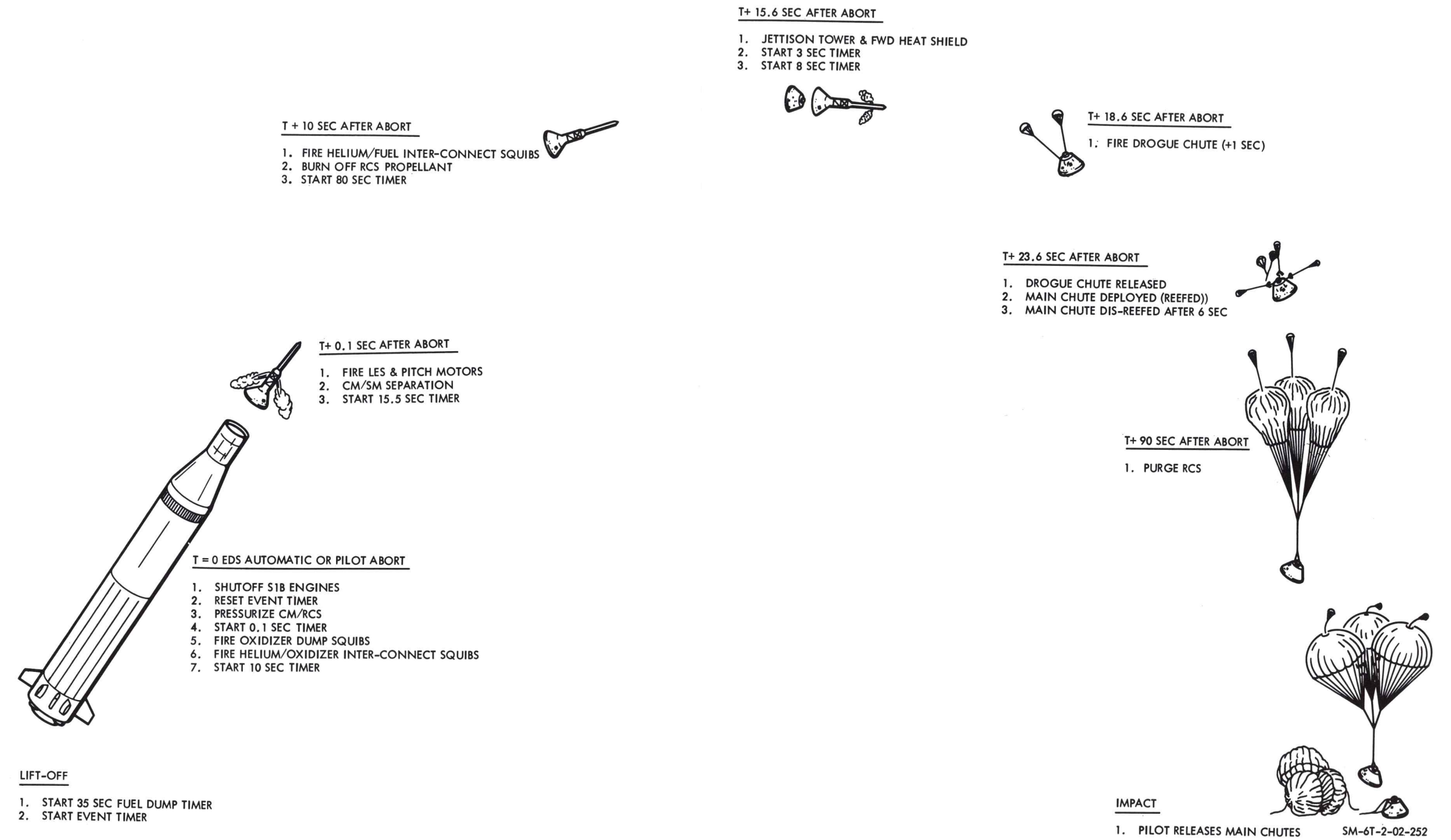


Figure 3-4. Simulated LES Aborts (Below 5000 Feet; Before 35 Seconds)

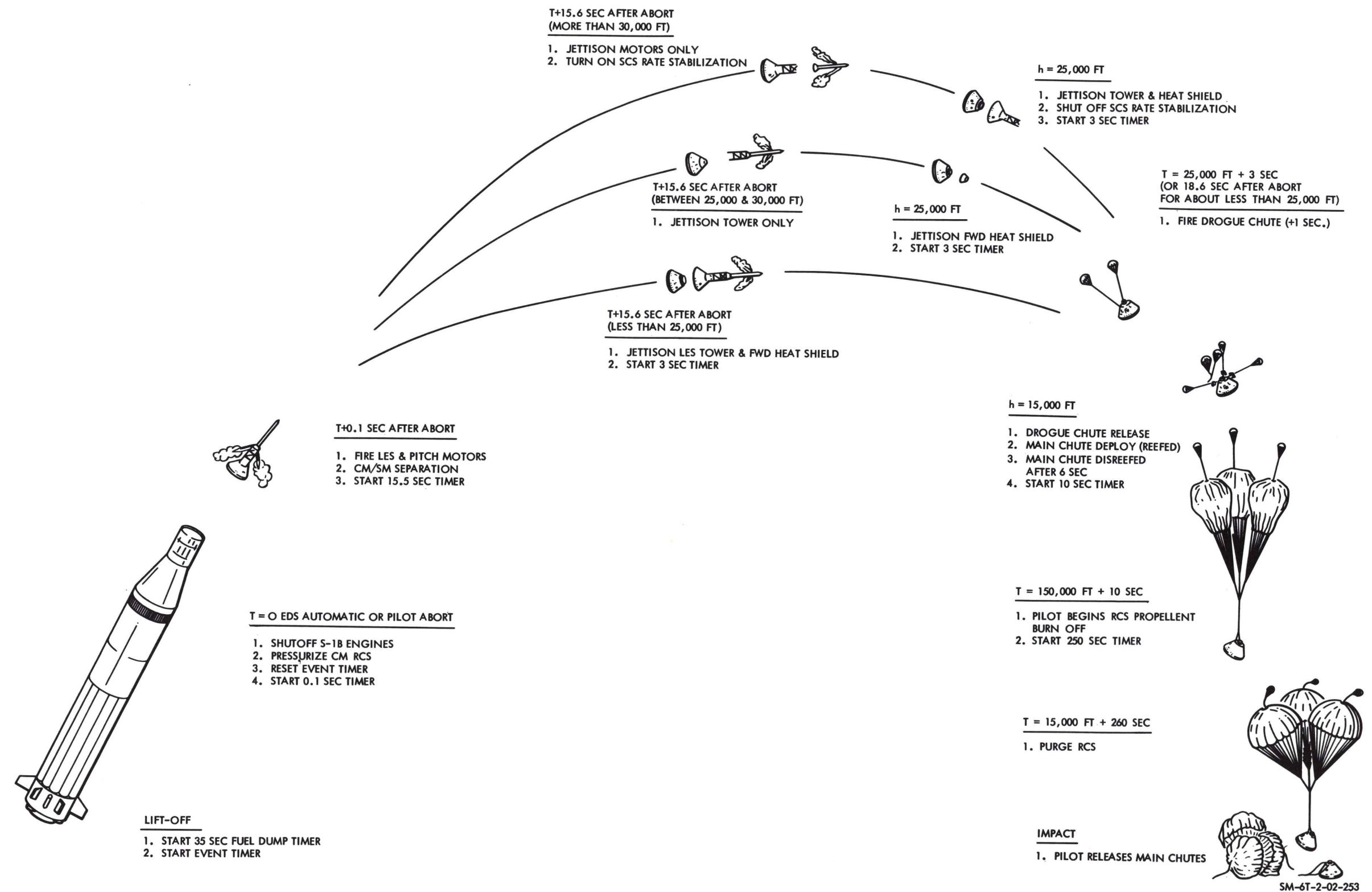


Figure 3-5. Simulated LES Abort (Above 5000 Feet)

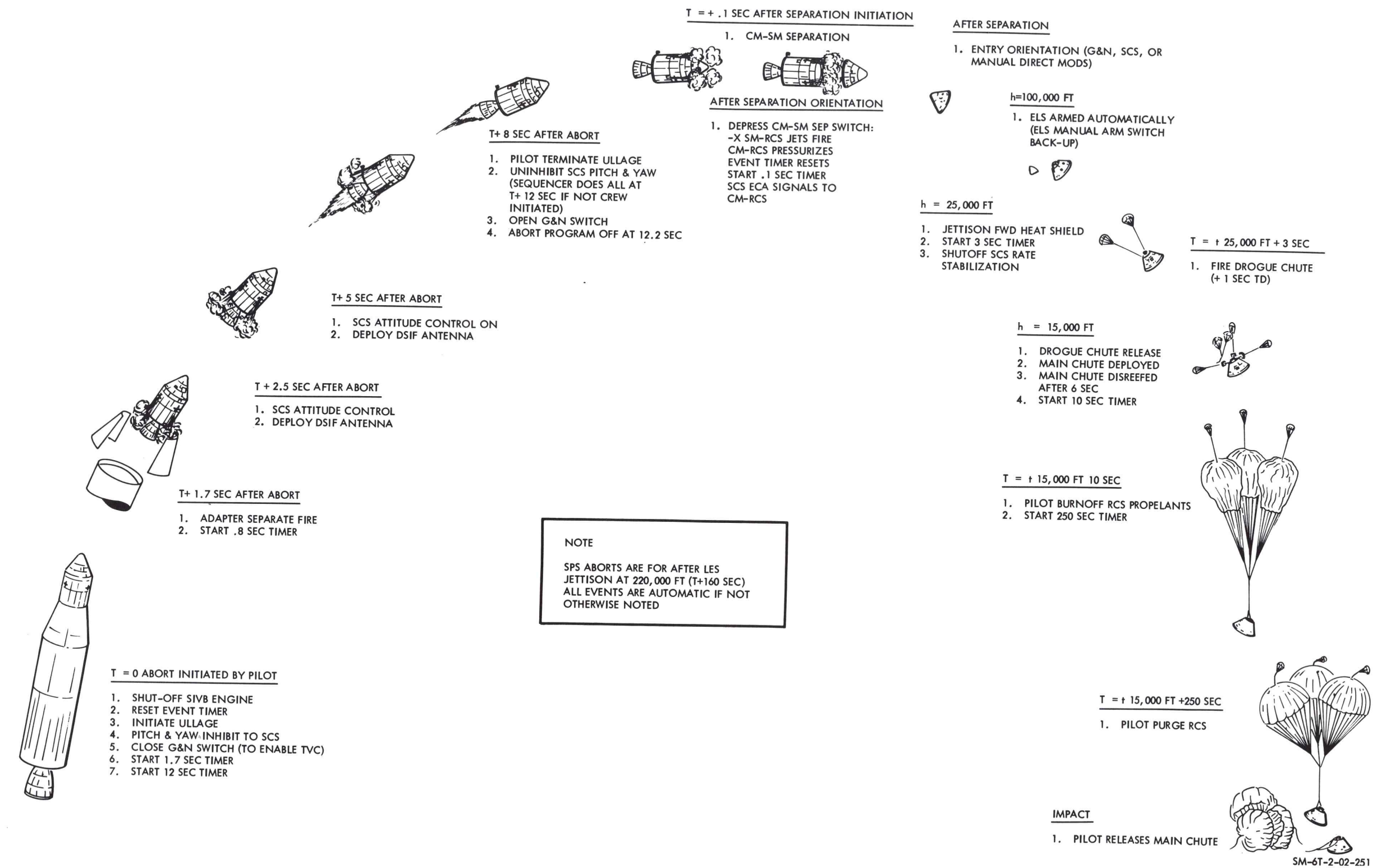


Figure 3-6. Simulated SPS Abort to Suborbital Trajectory

(To be supplied at a later date.)

Figure 3-7. SPS Abort to Orbit

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Simulated launch time and date is 12:49:16 (GMT) on September 17, 1969. Orbital injection is at 62.78 degrees West, 31.41 degrees North at an altitude of 105 n mi, with an orbital inclination of 32.58 degrees and an orbital duration of 90 minutes. Geographic orbital trace, day-night illumination, and the celestial view available for navigation are all direct outputs of these primary mission characteristics.

Orbital navigation in the initial delivered configuration of the AMS is accomplished with the simulated telescope by the landmark tracking method, that is, the crewmember views the MEP film through the telescope, aligns on preselected landmarks, and MARK inputs the simulated Apollo guidance computer (AGC). This is the primary means of orbital navigation for mission 204A. The alternate methods of orbital navigation for Block I spacecraft are not simulated in the initial delivered configuration. The constraint on the landmark-star method is that there are no landmark slides for the sextant. The limitation on the star refraction method is that the optical distortion characteristics of the earth atmosphere are not simulated. The star-horizon method cannot be used because the photometer is not actively simulated, and the star occultation cannot be practiced because the moon is not available in the telescope field.

Coarse and fine IMU alignment in the initial delivered configuration are accomplished by the same methods as in spacecraft AF 012.

Figures 3-8, 3-10, and 3-12 graphically describe the geographic trace for the three-orbit nominal mission. Each of the three figures is accompanied by a corresponding illustration identifying the navigational stars available for IMU alignment throughout the nominal training mission. These figures are 3-9 (orbit No. 1), 3-11 (orbit No. 2), and 3-13 (orbit No. 3). The stars listed are those provided in table 1-75. Figures 3-8, 3-10, and 3-12 illustrate the traces for orbits 1, 2, and 3, respectively. The figures include the spacecraft position with respect to geographic latitude and longitude, mission time, and simulated Greenwich Mean Time. Day-night phases for each orbit are also defined.

The small, numbered circles in the figures identify the landmarks available for navigation purposes throughout the nominal training mission. The numbers are with reference to table 1-73. Note that the nominal mission does not produce any daylight illumination of Australia and the Southwest Pacific. However, it is both possible and desirable to produce continuous daylight in the AMS, that is, no day terminators and no night illumination. The syllabus of training outlined in section 3 of volume III of this handbook makes use of this continuous daylight feature for two purposes. The first is training in landmark recognition and spacecraft navigation across Australia and the Southwest Pacific. The second use is to make continuous use of daylight for navigation training in simulated missions as none of the night navigation techniques are available in the initial delivered configuration of the AMS.

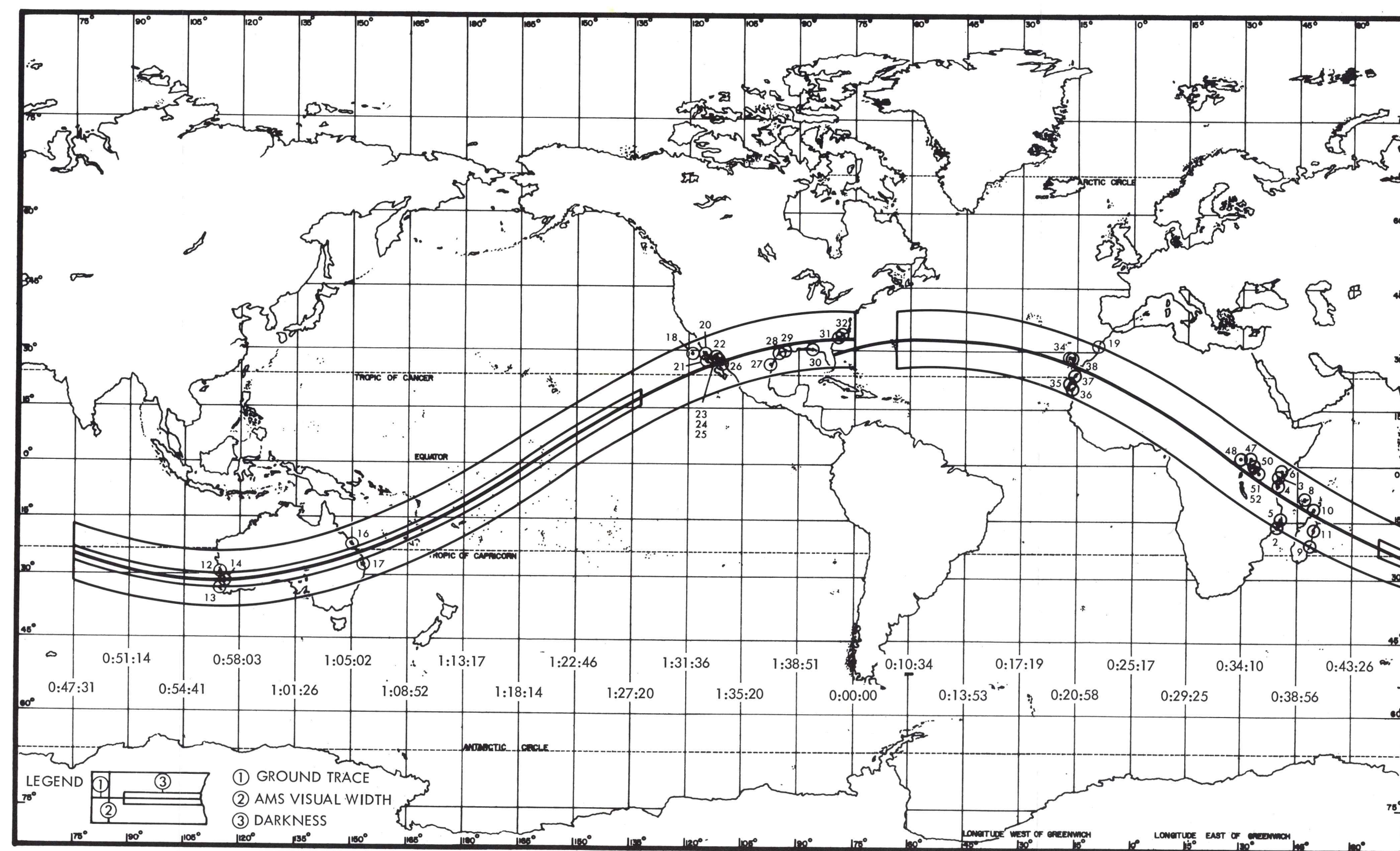


Figure 3-8. Nominal Training Mission Navigation Reference Data,
Orbit No. 1 (NAA)

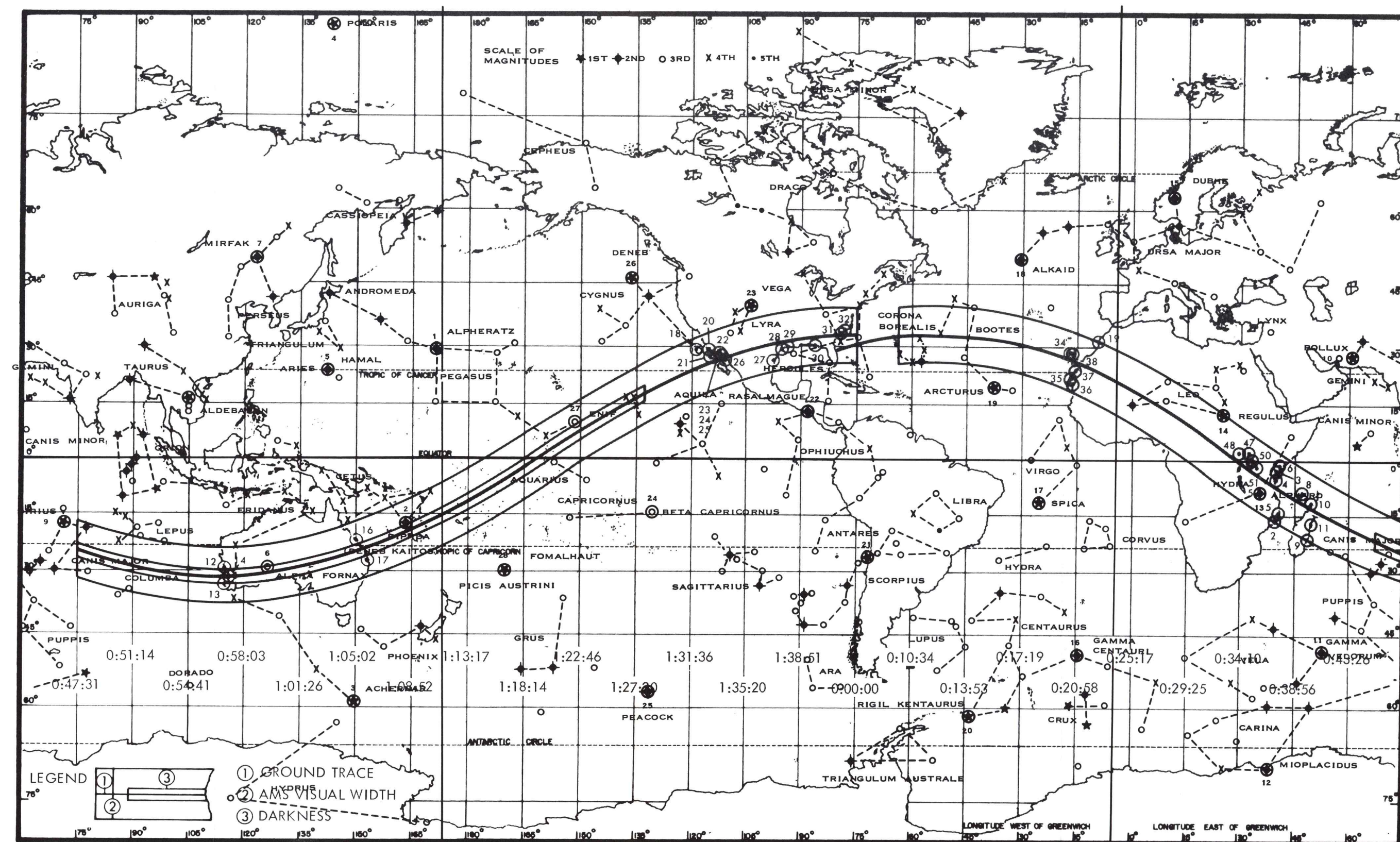


Figure 3-9. Star Data for Nominal Training Mission Navigation
Reference Data, Orbit No. 1

SM-6T-2-02-232/233

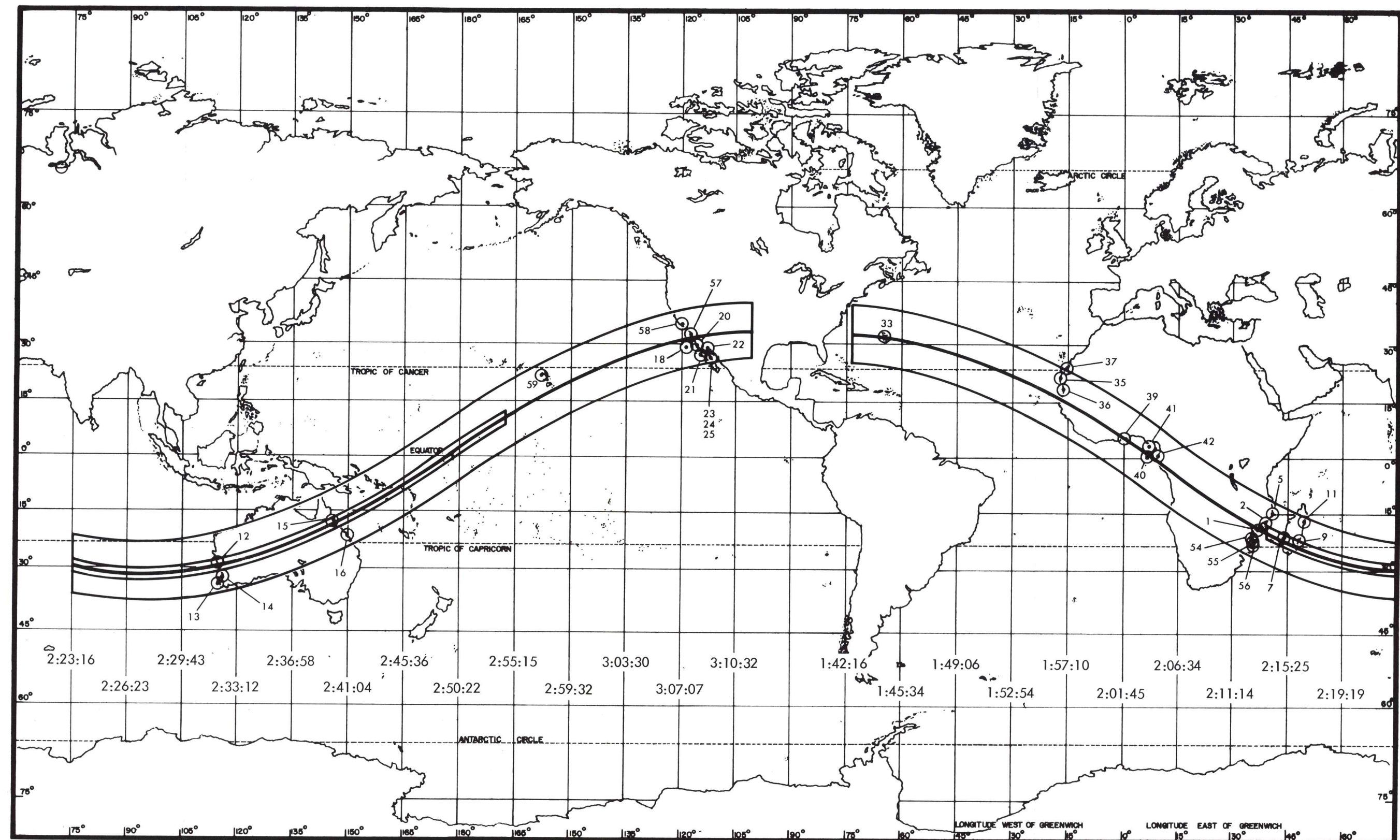
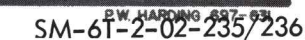
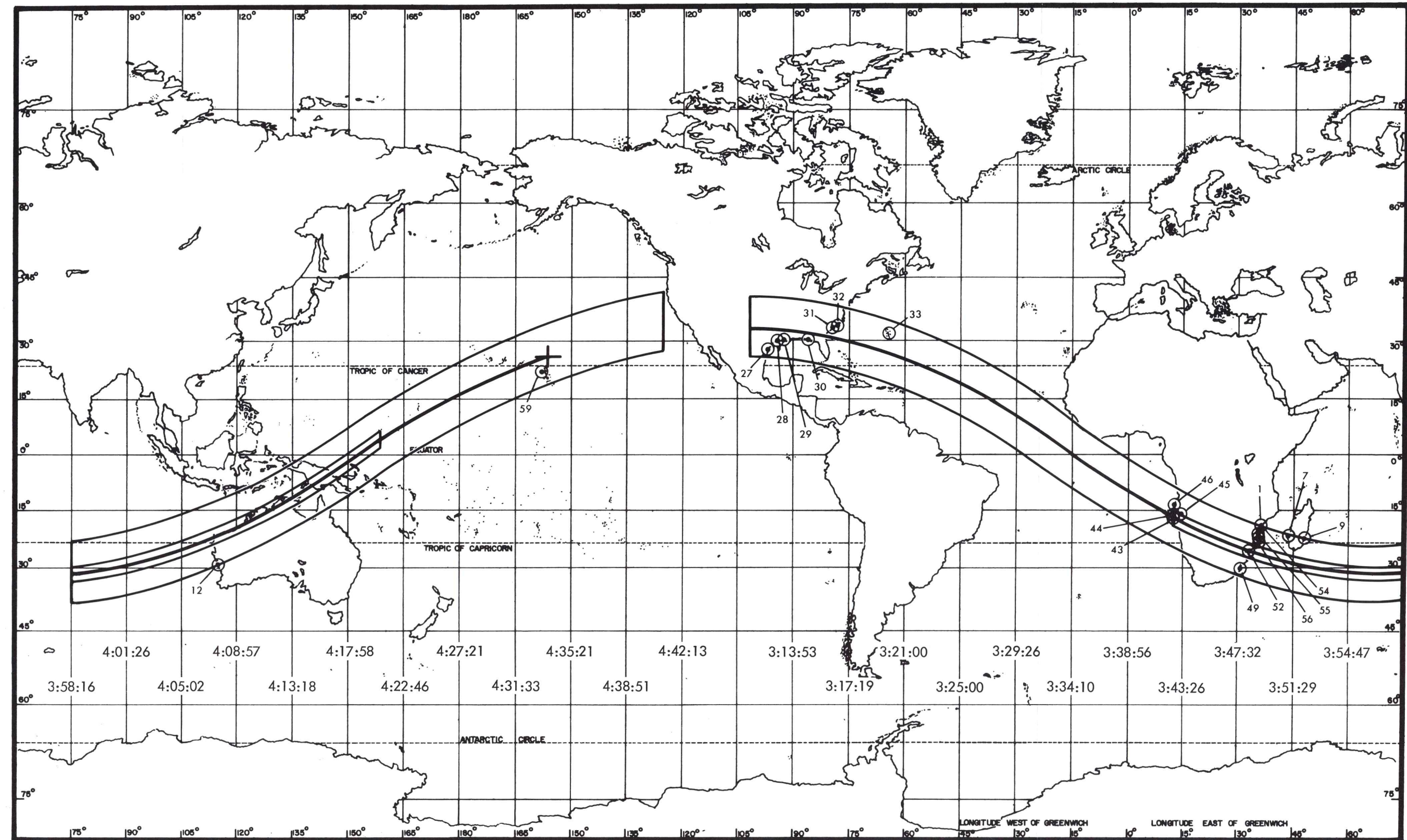


Figure 3-10. Nominal Training Mission Navigation Reference Data,
Orbit No. 2 (NAA)



3-25 / 3-26



SM-6T-2-02-238-N

Figure 3-12. Nominal Training Mission Navigation Reference Data,
Orbit No. 3 (NAA)

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NOTE

Landmark data provided in table 1-73 of section 1 and graphically depicted in figures 3-8 through 3-13 are for the NAA list of landmarks in general use at the time of AMS design freeze. At the time this handbook goes to press it is undetermined as to whether the initial delivered configuration of the AMS will use the NAA landmarks or the more recent and appropriate list of landmarks provided by MIT. Appendix B includes an alternate table 1-73 and alternate figures 3-8 through 3-13 depicting the MIT landmarks. Should the initial delivered configuration of the AMS make use of the MIT rather than the NAA landmarks, the alternate data in appendix B should be used to replace the equivalent NAA items.

3.6 RETROGRADE, ENTRY AND RECOVERY

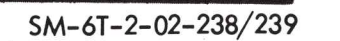
Mission 204A retrofire and entry are accomplished in a southeasterly direction from Japan toward Hawaii. This direction is a function of the cumulative orbital displacement throughout the mission. In the nominal training mission of three orbits, the orbital displacement is such that the entry trajectory is in a northeasterly direction from the Southwest Pacific toward Hawaii. Except for this discrepancy, the entry characteristics of the nominal training mission are representative of mission 204A. Velocity, altitude, and surface range data are shown with respect to time from retro in figure 3-14 (entry trajectory data 105 n mi). Data presented is for guidance and navigation mode entry from 105-n mi orbit.

Figure 3-15 illustrates the ground trace of the guidance and navigation mode retro and entry from 105-n mi orbit for Hawaii area recovery in the AMS. The numerical notes along the trace are seconds from deorbit firing.

Although the nominal training mission does not involve deorbit and entry from 140-n mi orbit, such data is required for orbital aborts from the altitude and should be useful in building additional variations of the nominal mission. (See paragraphs 3.11 and 3.12.) Velocity, altitude, and surface range data for retro and entry from 140 n mi are provided in figure 3-16. Figure 3-17 illustrates the corresponding ground trace data for Hawaii recovery.

3.7 SIMULATION INITIALIZATION

The initial delivered configuration of the AMS is capable of initiating simulation at eight different points in the nominal training mission. A ninth initialization point (number S1) is accomplished by a special procedure involving simulator operation in HOLD.



3-31 / 3-32

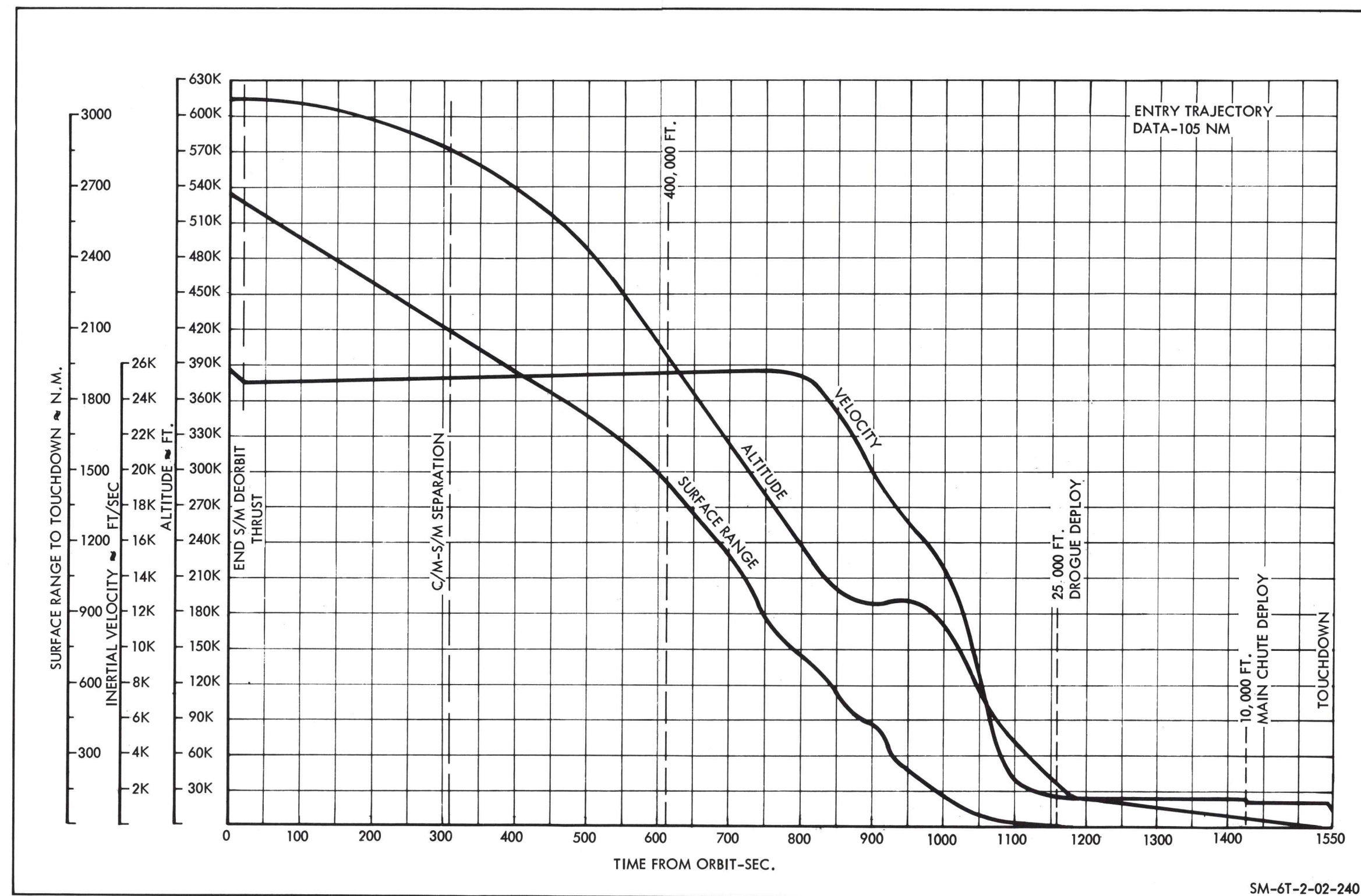
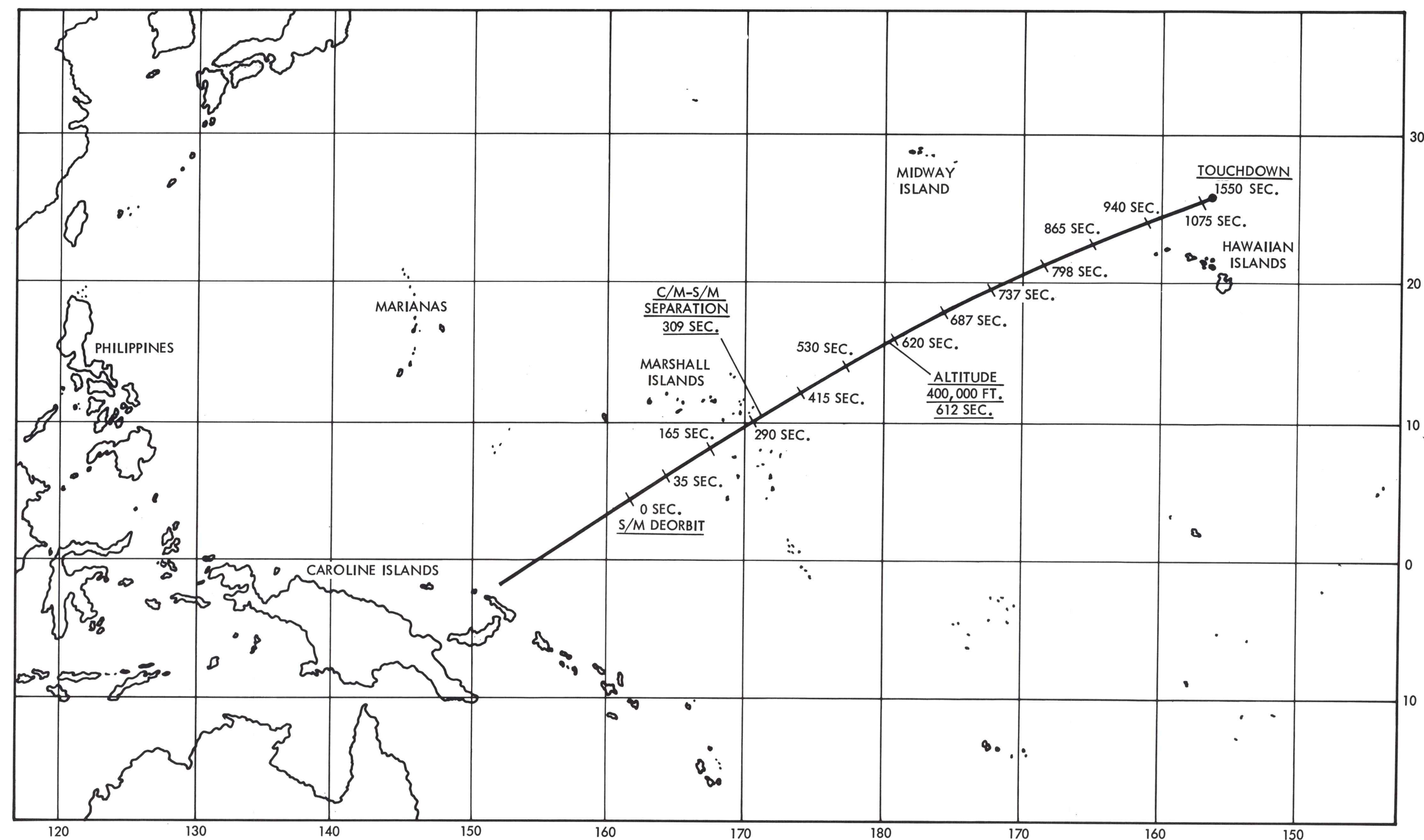


Figure 3-14. Entry Trajectory Data, 105 N MI



SM-6T-2-02-241

Figure 3-15. Geographic Trace, Entry from 105-N MI Orbit

(To be supplied at a later date.)

Figure 3-16. Entry Trajectory Data, 140 N MI

(To be supplied at a later date.)

Figure 3-17. Geographic Trace, Entry from 140-N MI Orbit

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Initialization of the simulator at each of the eight points in the mission involves two types of preparation. The first is the identification of initial conditions in the computer program. The second is the setting of SCM controls and displays to the appropriate simulated systems configuration for the initialization point.

Computer program initialization points and their defining parameters are listed in table 3-2 and are illustrated in figures 3-18, 3-19, and 3-20. Corresponding SCM-IOS controls and displays data for each initialization point is the subject of section 2, volume III of this handbook. A functional description of each initialization point is provided as follows:

3.7.1 PRELAUNCH (S1)

The initialization point is just prior to the final controls and displays checklist before launch. The point is used to initialize simulation/training in final preparations for launch. No computer program point has been established for this purpose. Initialization is accomplished by initializing for S2 and placing the simulator in HOLD until prelaunch procedures are complete. Simulation is not authentic in two respects. The first is that onboard expendable depletion rates and system contaminations do not accumulate as a function of time. The second is that the time in HOLD is not included in the GMT simulated time, and simulated launch time remains fixed regardless of the duration of prelaunch phase.

3.7.2 LAUNCH (S2)

All preparations for launch are complete. Ignition is impending at 60 seconds after initialization. Ascent characteristics are preprogrammed as a function of booster performance. This start point is used to initiate launch phase simulation, all simulations starting with launch and continuing into orbit, and all launches terminating in suborbital aborts.

3.7.3 ORBIT INSERTION (S3)

This initialization point is immediately following S-IVB cutoff. The initiation point is intended for training sessions where initial earth orbit procedures are involved. It can also be used as an initiation for daylight IMU alignment. Where it is desired to practice navigation sightings with North African landmarks, S3 is used in conjunction with accelerated time procedures. The start point off the African coast can also be used for training sessions encompassing orbit measurement, IMU alignment, and delta V.

3.7.4 FIRST ORBITAL ROUTINE POINT (S4)

Initialization point S4 occurs after initial orbital procedures (over Central Africa on first orbit). The initiation point is intended for starting training sessions in repetitive orbital routines without specific reference to or concern for the launch-boost. S4 can also be used as an initiation point for navigation with landmarks in Southeast Africa and Madagascar.

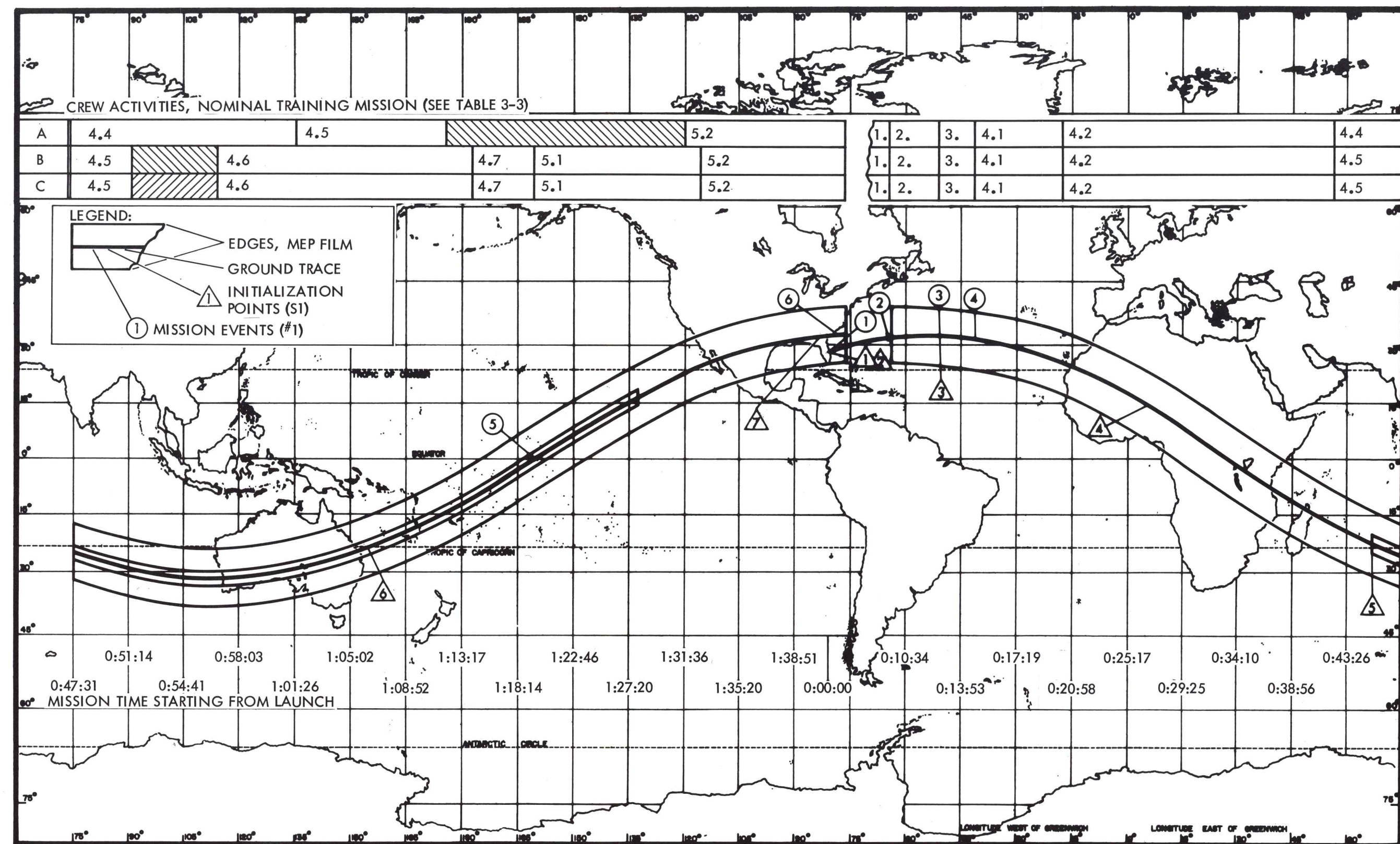
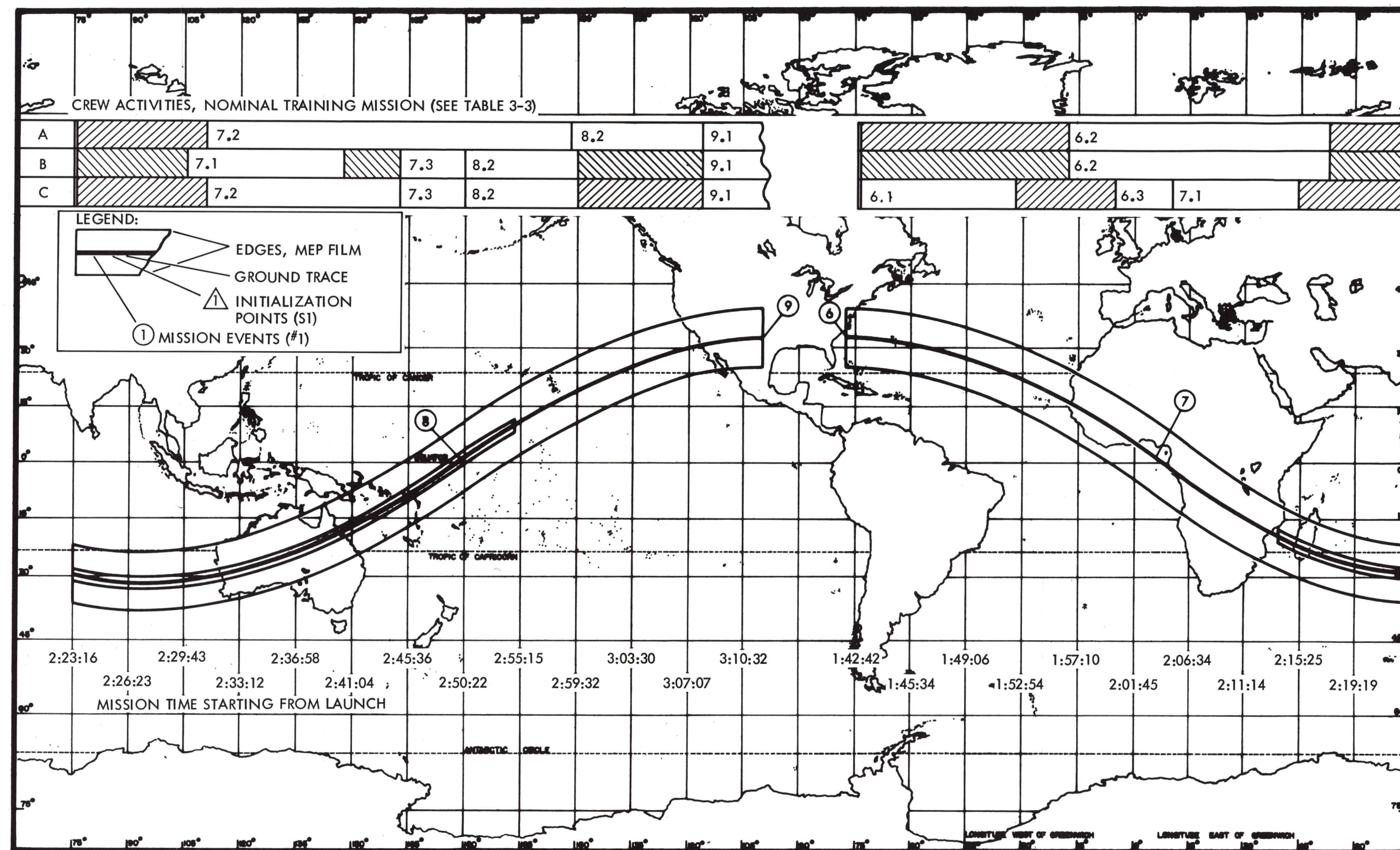


Figure 3-18. Nominal Mission Chart, Orbit No. 1



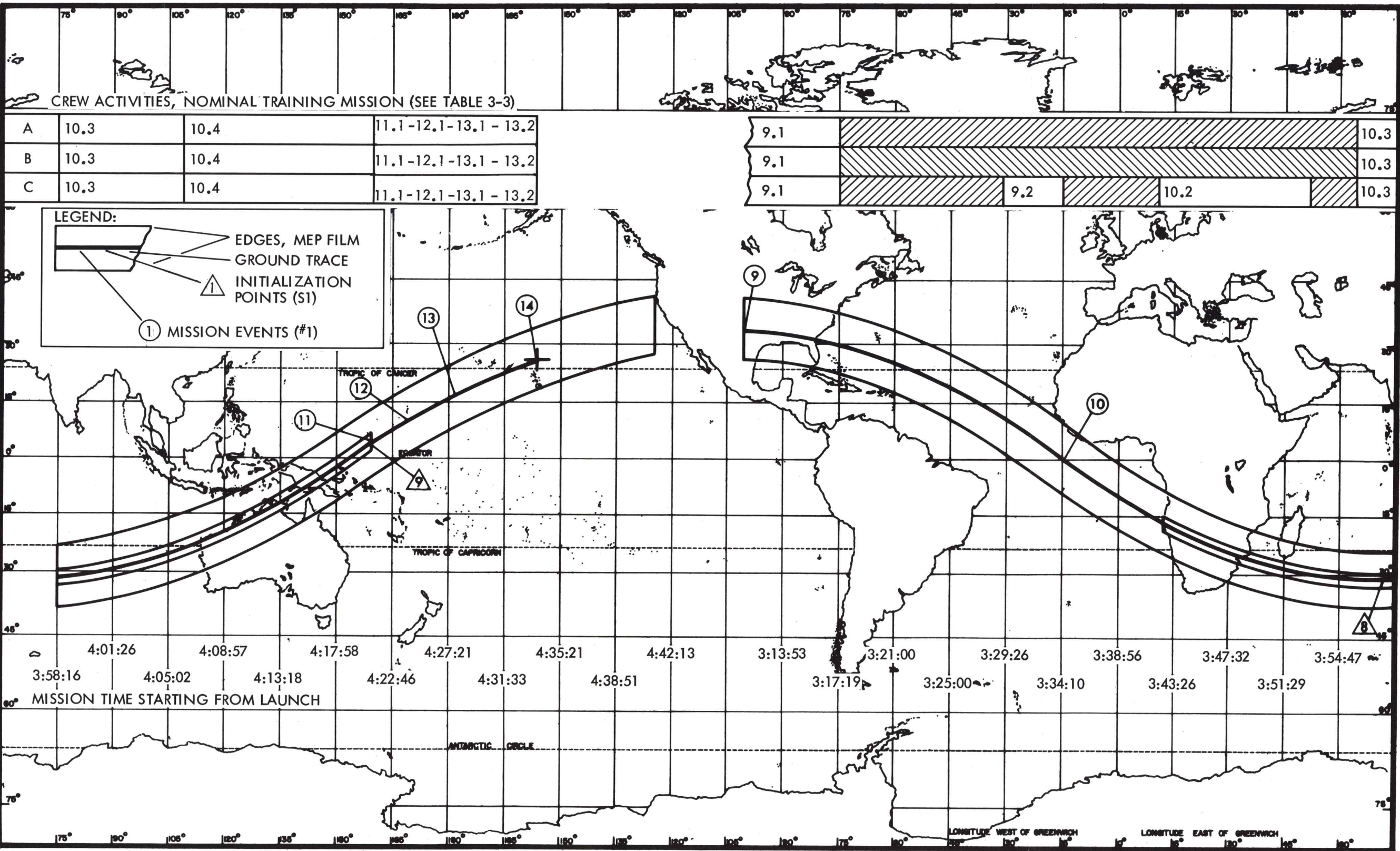


Figure 3-20. Nominal Mission Chart, Orbit No. 3

Table 3-2. Initialization Data

No.	Title	Call-Up Condition	GMT and Mission Time	Initializing Time	Position	
					Longitude	Latitude
S1	Prelaunch (See text for explanation.)	TBSL	NA	12:49:00	80.47° W	28.37° N
S2	Launch	TBSL	12:48:16 GMT (-0:01:00)	12:49:00	80.47° W	28.37° N
S3	Orbit injection	TBSL	12:59:16 GMT (+0:10:00)	12:59:00	62.78° W	31.41° N
S4	First orbital routine point	TBSL	13:15:50 GMT (0:26:34)	13:15:00	5.48° E	16.57° N
S5	Second orbital routine point	TBSL	13:33:50 GMT (0:44:34)	13:33:00	64.01° E	25.25° S
S6	Third orbital routine point	TBSL	13:45:50 GMT (0:56:34)	13:45:00	156.08° E	26.10° S
S7	Fourth orbital routine point	TBSL	14:29:00 GMT (1:39:44)	14:29:00	86.87° W	32.02° N
S8	Preparation for retro	TBSL	16:45:50 GMT (3:56:34)	16:45:00	68.35° E	32.55° S
S9	CM-SM separation	TBSL	17:10:39 GMT	17:10:00	173° E	11° N

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3.7.5 SECOND ORBITAL ROUTINE POINT (S5)

This point occurs just prior to day termination in the first orbit. The initiation point is intended for training in night alignment of the IMU. The alignment may be followed by a delta V as the spacecraft crosses the equator. When used in conjunction with accelerated time and an inhibit of the day termination, S5 may also be used to initiate navigation with Australian and Southwest Pacific landmarks.

3.7.6 THIRD ORBITAL ROUTINE POINT (S6)

This point occurs approximately 15 minutes before the spacecraft crosses the equator and midway through the dark (night) phase of the first orbit. The initiation point is intended for training in delta V procedures for planar change and Hohmann transfer. Where it is desired to practice navigation sightings with Mexican and Southwestern U.S. landmarks, S6 is used in conjunction with accelerated time procedures. The initiation point can also be used for IMU alignment at night, and IMU alignment combining darkness and daylight sightings.

3.7.7 FOURTH ORBITAL ROUTINE POINT (S7)

This initialization point occurs just prior to the start of the second orbit. The initiation point is used (in conjunction with accelerated time) for all second and third orbit orbital situations.

3.7.8 PREPARATION FOR RETRO (S8)

This initialization occurs approximately 25 minutes before retrofire. The initiation point is used for training in procedures for preparing for and accomplishing retrograde, CM-SM separation, entry, and parachute descent to touchdown.

3.7.9 CM-SM SEPARATION (S9)

This initialization occurs immediately after SPS deorbit cutoff. The point is used to initiate practice of procedures for preparing for CM-SM separation, accomplishing separation, preparing for and accomplishing entry, and monitoring-controlling the earth landing sequence.

3.8 BASIC NOMINAL MISSION

The nominal training mission for the initial delivered configuration of the AMS is comprised of a launch from KSC, approximately two and one-half orbits of space operations, retrograde, entry, and recovery north of Hawaii. Nominal orbital altitude and orbital angle of inclination are 105 n mi and 32.58 degrees, respectively.

Table 3-3 outlines the events for the nominal training mission including its planned variations. Geographic and time data correlating with table 3-3 is provided in figures 3-18, 3-19, and 3-20. Numbers circled in table 3-3 and figures 3-18 through 3-20 are the significant events of which the nominal training mission is comprised. Numbers in triangles in the figures are the

Table 3-3. Nominal Training Mission

Number-Mission			Mission Event	Crew Activity and Notes	GMT and Mission Time	Geographic Position
A	B	C				
①.	①.	①.	<u>Launch Boost</u> Launch site - KSC Azimuth - 72° Boost duration 0:10 min.	<u>Monitor Boost</u>	Sept. 17, 1969 12:49:16 GMT (0:00:00)	80.47° W, 28.39° N
②.	②.	②.	<u>Orbit Insertion</u> Altitude - 105 n mi Inclination - 32.58° Orbit duration - 90 min/orbit		12:59:16 GMT (0:10:00)	62.78° W, 31.41° N
③.	③.	③.	Start first orbit	<u>Confirm with MSFN</u>	13:01:20 GMT (0:12:04)	53.11° W, 32.58° N
④.	④.	④.	Jettison S-IVB	<u>Monitor Jettison</u>	13:04:16 GMT (0:15:00)	40° W, 31.72° N
4.1	4.1	4.1		<u>Initial Orbital Procedures</u> Four to 5 minutes of system setup and checks.	Approx (0:15:00) to (0:20:00)	
4.2	4.2	4.2		<u>Navigation Sightings</u> Measure orbit with African and Madagascar landmarks. Approx 22 minutes of landmark availability.	Approx (0:20:00) to (0:42:00)	Approx 20° W to 54° E
NA	4.3	4.3	<u>Inhibit Day Terminator</u> Prevent day-night terminator initiation	Permits landmark sightings over Australia and the SW Pacific.	Before (0:44:34)	Before 64.01° E
4.4	NA	NA		<u>Coarse Align IMU</u> Approx 20 minutes of crew procedures.	Approx (0:42:00) to (1:02:00)	Approx 54° E to 136° E

. . . continued

Table 3-3. Nominal Training Mission (Cont)

Number-Mission			Mission Event	Crew Activity and Notes	GMT and Mission Time	Geographic Position
A	B	C				
4.5	4.5	4.5		<u>Fine Align IMU and SCS</u> Approx 10 minutes of crew procedures	<u>Mission A</u> Approx (1:02:00) to (1:12:00) <u>Mission B & C</u> Approx (0:42:00) to (0:52:00)	Approx 136° E to 174° E Approx 54° E to 91° E
NA	4.6	4.6		<u>Navigation Sightings</u> Measure orbit over Australia and SW Pacific. Approx 18 minutes of landmark availability.	Approx (0:56:00) to (1:14:00)	Approx 110° E to 178° W
NA	4.7	4.7		<u>Preparation for Delta V</u> Approx 5 minutes of crew procedures to compute delta V and prepare systems.	Approx (1:14:00) to (1:19:00)	
4.8	NA	NA		Initiate two-man extended mission procedures (one man in rest cycle). Navigation sightings, IMU alignment, and system management.	Approx (1:12:00) to (3:08:00)	
NA	(5.)	(5.)	<u>Delta V</u> <ul style="list-style-type: none"> • Mission B-plane change of -1° to 31.58° inclination • Mission C- initiate Hohmann transfer from 105 n mi to 140 n mi 	<u>Monitor-Control Delta V</u>	14:08:32 GMT (1:19:46)	160.63° W, 0° Lat
NA	5.1	5.1		<u>Fine Align and SCS</u> Approx 10 minutes of crew procedures.	Approx (1:21:00) to (1:31:00)	Approx 157° W to 124° W

Table 3-3. Nominal Training Mission (Cont)

Number-Mission			Mission Event	Crew Activity and Notes	GMT and Mission Time	Geographic Position
A	B	C				
5.2	5.2	5.2		<u>Navigation Sightings</u> Measure orbit with Mexican and U.S. landmarks. Approx 10 minutes of landmark availability.	Approx (1:32:00) to (1:42:00)	Approx 120° W to 80° W
(6.)	(6.)	(6.)	<u>Start Second Orbit</u>		14:31:20 GMT (1:42:04)	75.67° W, 32.58° N
NA	NA	6.1		<u>Fine Align IMU and SCS</u> Approx 10 minutes of crew procedures.	Approx (1:42:00) to (1:52:00)	80° W to 35° W
6.2	6.2	NA		<u>Navigation Sightings</u> Measure orbit with African and Madagascar landmarks. Approx 22 minutes of landmark availability.	Approx (1:56:00) to (2:18:00)	Approx 20° W to 54° E
NA	NA	6.3		<u>Preparation for Delta V</u> Approx 5 minutes of crew procedures to compute delta V and prepare systems.	Approx (1:59:00) to (2:04:00)	
6.4	NA	6.4	<u>Inhibit Day Terminator</u> Prevent day-night terminator initiation	Permits landmark sightings over Australia and the SW Pacific.	Before 2:15:34	Before 41.51° E
NA	NA	(7.)	<u>Delta V</u> Circularize orbit at 140 n mi	<u>Monitor-Control Delta V</u>	14:54:02 GMT (2:04:46)	9.3° E, 0° Lat
NA	7.1	7.1		<u>Fine Align IMU and SCS</u> Approx 10 minutes of crew procedures.	<u>Mission C</u> Approx (2:05:00) to (2:15:00)	Approx 10° E to 40° E

. . . continued

Table 3-3. Nominal Training Mission (Cont)

Number-Mission			Mission Event	Crew Activity and Notes	GMT and Mission Time	Geographic Position
A	B	C				
					<u>Mission B</u> Approx (2:30:00) to (2:40:00)	Approx 105° E to 145° E
7.2	NA	7.2		<u>Navigation Sightings</u> Measure orbit with Australia and SW Pacific landmarks. Approx 28 minutes of landmark availability, mission A, 14 minutes for mission C.	<u>Mission A</u> Approx (2:30:00) to (2:58:00) <u>Mission C</u> Approx (2:30:00) to (2:44:00)	Approx 110° E to 155° W Approx 110° E to 160° E
NA	7.3	7.3		<u>Preparation for Delta V</u> Approx 5 minutes of crew procedures to compute delta V and prepare systems.	Approx (2:44:00) to (2:49:00)	
NA	(8.)	(8.)	<u>Delta V</u> <ul style="list-style-type: none"> Mission B-plane change +1° to 32.58° inclination Mission C-initiate Hohmann transfer from 140 n mi to 105 n mi 	<u>Monitor-Control Delta V</u>	15:39:08 GMT (2:49:52)	178.43° E, 0° Lat
8.2	8.2	8.2		<u>Fine Align IMU and SCS</u> Approx 10 minutes of crew procedures.	<u>Missions B & C</u> Approx (2:50:00) to (3:00:00) <u>Mission A</u> Approx (2:58:00) to (3:08:00)	Approx 180° Long to 150° W Approx 155° W to 118° W

Table 3-3. Nominal Training Mission (Cont)

Number-Mission			Mission Event	Crew Activity and Notes	GMT and Mission Time	Geographic Position
A	B	C				
8.3	NA	NA		Terminate extended mission procedures. All three crew members active in preparation for retro.	Approx (3:08:00)	
⑨.	⑨.	⑨.	<u>Start Third Orbit</u>		16:01:20 GMT (3:12:04)	98.13° W, 32.58° N
9.1	9.1	9.1		<u>Navigation Sightings</u> Measure earth orbit with U.S. landmarks. Approx 9 minutes of landmark availability.	Approx (3:08:00) to (3:17:00)	Approx 118° W to 75° W
NA	NA	9.2		<u>Preparation for Delta V</u> Approx 5 minutes of crew procedures to compute delta V and prepare systems.	Approx (3:29:00) to (3:34:00)	
NA	NA	⑩.	<u>Delta V</u> Circularize orbit at 105 n mi	<u>Monitor-Control Delta V</u>	16:24:02 GMT (3:34:46)	12.8° W, 0° Lat
NA	NA	10.1	<u>Inhibit Day Terminator</u> Prevent day-night terminator initiation	Permits landmark sightings with South African and Madagascar landmarks.	Before (3:45:34)	Before 19.01° E
NA	NA	10.2		<u>Navigation Sightings</u> Measure orbit with South African and Madagascar landmarks. Approx 12 minutes of landmark availability.	Approx (3:42:00) to (3:54:00)	Approx 10° E to 54° E
10.3	10.3	10.3		<u>Fine Align IMU and SCS</u> Approx 10 minutes of crew procedures.	Approx (3:56:00) to (4:06:00)	Approx 64° E to 107° E

. . . continued

Table 3-3. Nominal Training Mission (Cont)

Number-Mission			Mission Event	Crew Activity and Notes	GMT and Mission Time	Geographic Position
A	B	C				
10.4	10.4	10.4		<u>Preparation for Retrofire</u> Approx 15 minutes of crew procedures to compute retro and prepare systems.	Approx (4:06:00) to (4:21:00)	
(11.)	(11.)	(11.)	<u>Delta V</u> Retrograde from earth orbit	<u>Monitor-Control Delta V</u>	17:10:55 GMT (+4:21:39) T. D. -0:25:50	161.6° E, 4.56° N
11.1	11.1	11.1		<u>Preparation for CM-SM Separation</u> Approx 5 minutes of crew procedures to establish systems configuration for separation and CM independent operation.	Approx (4:21:00) to (4:26:00)	
(12.)	(12.)	(12.)	<u>CM-SM Separation</u>	<u>Monitor Separation</u>	Approx 17:16:05 GMT (+4:26:49) T. D. -0:20:40	Approx 170.2° E, 10.4° N
12.1	12.1	12.1		<u>Preparation for Entry</u> Approx 4 minutes of checks of CM systems independent operation.	Approx (4:27:00) to (4:31:00)	
(13.)	(13.)	(13.)	<u>.05 G (Start Entry)</u>	<u>Monitor .05 G</u>	Approx 17:21:10 GMT (+4:31:54) T. D. -0:15:35	179.6° E, 16° N
13.1	13.1	13.1		<u>Monitor-Control Entry</u>	Approx (4:31:54) to (4:40:59)	

Table 3-3. Nominal Training Mission (Cont)

Number-Mission			Mission Event	Crew Activity and Notes	GMT and Mission Time	Geographic Position
A	B	C				
13.2	13.2	13.2		Monitor-control chute deployment and earth landing sequences.	Approx (4:40:59) to (4:47:29)	
14.	14.	14.	<u>Touchdown</u>	Start postlanding procedures.	17:36:45 GMT (4:47:29)	156.6° W, 25.8° N

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initialization points defined in paragraph 3.7. Other numbers in the figures correspond to numbers in the first three columns in table 3-3 and identify crew activities and notes. Crew activities in the table are laid out with respect to time and geographic position across the top of the figures. The numbers identifying crew activities and notes contain no specific intelligence above and beyond establishing event-activity sequence.

For purposes of simplicity and adaptability of the nominal mission to more than one launch-boost profile, the orbit start point has been arbitrarily established at a point subsequent to insertion. The point used as the start of each orbit has been the orbits northern-most point or latitude 32.58 degrees north.

The first three columns of table 3-3 identify which events and activities are involved in the basic nominal mission and two planned variations. Mission A is the basic nominal mission discussed in this paragraph and missions B and C are the plane change and Hohmann transfer variations, respectively.

Crew activities for each of the three variations of the nominal training mission are also identified in the strip across the top of figures 3-18 through 3-20. The same code of A (basic mission), B (plane changes), and C (Hohmann transfers) applies. Crew activity numbers in the figures are with direct reference to table 3-3. Cross-hatched areas are time available for routine activities between mission events. Effective use of such time is defined in section 3 of volume II of this handbook.

A brief outline of the basic nominal mission is provided as follows:

<u>Mission Time (hour:minute)</u>	<u>Event-Activity</u>
0	Launch boost
0:10	Orbit insertion
0:12	Start first orbit
0:15	Jettison S-IVB
0:15 to 0:20	Initial orbital procedures
0:20 to 0:42	Navigation sightings (Africa and Madagascar)
0:42 to 1:12	Coarse and fine align IMU
1:12	Initiate two-man extended mission procedures
1:12 to 1:32	System management (or other)
1:32 to 1:42	Navigation sightings (Mexico and U.S.)
1:42	Start second orbit
1:42 to 1:56	System management (or other)
1:56 to 2:18	Navigation sightings (Africa and Madagascar)
Before 2:15	Inhibit day termination (permits navigation sightings over Australia and Pacific)
2:18 to 2:30	System management (or other)
2:30 to 2:58	Navigation sightings (Australia and Pacific)
2:58 to 3:08	Fine align IMU
3:08	Terminate extended mission activity
3:08 to 3:17	Navigation sightings (U.S.)
3:17 to 3:56	System management (or other)

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<u>Mission Time (hour:minute)</u>	<u>Event-Activity</u>
3:56 to 4:06	Fine align IMU
4:06 to 4:21	Preparation for retrofire
4:21	Retrofire
4:21 to 4:26	Preparation for CM-SM separation
4:27	CM-SM separation
4:32	Monitor entry
4:48	Touchdown

3.9 NOMINAL MISSION, PLANE CHANGES

Mission 204A entails three plane changes in orbit. The first two are a change of one-degree negative and an equal and opposite positive change later in the mission. The third is a 0.3-degree change near the end of the mission. The first two changes are included in the nominal mission. The inclusion of the third change is pending definition of the purpose of the plane change, the effect of the change on recovery location, and the training requirements (if any) related to the 0.3-degree change. Examination of figure 3-18 will show that, should the 0.3-degree change be required, there is ample time for it in the first half of the third orbit.

A brief outline of the plane changes variation of the nominal training mission is provided as follows:

<u>Mission Time (hour:minute)</u>	<u>Event-Activity</u>
0	Launch boost
0:10	Orbit insertion
0:12	Start first orbit
0:15	Jettison S-IVB
0:15 to 0:20	Initial orbital procedures
0:20 to 0:42	Navigation sightings (Africa and Madagascar)
Before 0:44	Inhibit day terminator (permits navigation sightings over Australia and SW Pacific)
0:42 to 0:52	Fine align IMU
0:52 to 0:56	Systems management (or other)
0:56 to 1:14	Navigation sightings (Australia and SW Pacific)
1:14 to 1:19	Preparation for delta V
1:19	*Delta V (plane change, -1-degree to 31.58-degree inclination)
1:21 to 1:31	IMU fine alignment
1:32 to 1:42	Navigation sightings (Mexico and U.S.)
1:42	Start second orbit
1:42 to 1:56	Systems management (or other)
1:56 to 2:18	Navigation sightings (Africa and Madagascar)
2:18 to 2:44	Systems management (or other)
2:44 to 2:50	Preparation for delta V

*Both delta Vs at the Pacific area orbital equinox.

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<u>Mission Time</u> <u>(hour:minute)</u>	<u>Event-Activity</u>
2:50	*Delta V (plane change, +1-degree to 32.58-degree inclination)
2:50 to 3:00	Fine align IMU
3:00 to 3:08	System management (or other)
3:12	Start third orbit
3:08 to 3:17	Navigation sightings (U.S.)
3:17 to 3:56	System management (or 0.3-degree plane change, or other)
3:56 to 4:06	Fine align IMU
4:06 to 4:21	Preparation for retrofire
4:21	Retrofire
4:21 to 4:26	Preparation for CM-SM separation
4:27	CM-SM separation
4:32	Entry
4:48	Touchdown

*Both delta Vs at the Pacific area orbital equinox.

3.10 NOMINAL MISSION, HOHMANN TRANSFERS

Mission 204A entails a Hohmann transfer from 105 n mi altitude to 140 n mi, a Hohmann transfer back to 105 n mi and circularization at that altitude. These four delta Vs are provided in the Hohmann transfer variation of the nominal training mission. A brief outline of that mission is provided as follows:

<u>Mission Time</u> <u>(hour:minute)</u>	<u>Event-Activity</u>
0	Launch boost
0:10	Orbit insertion
0:12	Start first orbit
0:15	Jettison S-IVB
0:15 to 0:20	Initial orbital procedures
0:20 to 0:42	Navigation sightings (Africa and Madagascar)
Before 0:44	Inhibit day terminator (permits navigation sightings over Australia and SW Pacific)
0:42 to 0:52	IMU fine alignment
0:52 to 0:56	Systems management (or other)
0:56 to 1:14	Navigation sightings (Australia and SW Pacific)
1:14 to 1:19	Preparation for delta V
1:19	*Delta V (initiate Hohmann transfer from 105 n mi to 140 n mi)
1:21 to 1:31	IMU fine alignment
1:32 to 1:42	Navigation sightings (Mexico and U.S.)

*Hohmann transfer delta Vs are accomplished at the second orbital equinox of the first orbit, the first and second orbital equinox of the second orbit, and the first equinox of the third orbit.

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<u>Mission Time</u> (hour:minute)	<u>Event-Activity</u>
1:42	Start second orbit
1:42 to 1:52	IMU fine alignment
1:52 to 1:59	System management (or other)
1:59 to 2:04	Preparation for delta V
Before 2:15	Inhibit day terminator (permits navigation sightings over Australia and SW Pacific)
2:05	*Delta V (circularize orbit at 140 n mi)
2:05 to 2:15	IMU fine alignment
2:15 to 2:30	Systems management (or other)
2:30 to 2:44	Navigation sightings (Australia and SW Pacific)
2:44 to 2:49	Preparation for delta V
2:50	*Delta V (initiate Hohmann transfer from 140 n mi to 105 n mi)
2:50 to 3:00	IMU fine alignment
3:00 to 3:08	Systems management (or other)
3:12	Start third orbit
3:08 to 3:17	Navigation sightings (U.S.)
3:17 to 3:29	Preparation for delta V
3:35	*Delta V (circularize orbit at 105 n mi)
Before 3:45	Inhibit day terminator (permits navigation sightings over Africa and Madagascar)
3:35 to 3:42	Systems management (or other)
3:42 to 3:54	Navigation sightings (Africa and Madagascar)
3:56 to 4:06	IMU fine alignment
4:06 to 4:21	Preparation for retrofire
4:21	Retrofire
4:21 to 4:26	Preparation for CM-SM separation
4:27	CM-SM separation
4:32	Entry
4:48	Touchdown

*Hohmann transfer delta Vs are accomplished at the second orbital equinox of the first orbit, the first and second orbital equinox of the second orbit, and the first equinox of the third orbit.

3.11 NOMINAL MISSION, ORBITAL ABORT

Mission 204A and the nominal training mission entail three varieties of abort from earth orbit. All can be simulated in the initial delivered configuration of the AMS. The three types of orbital abort are as follows:

- Retro and recovery from SPS abort to orbit during ascent.
- Early mission termination from 105-n mi orbit.
- Early mission termination from 140-n mi orbit.

Data on retro and entry from 105-n mi and 140-n mi orbits are the subject of paragraph 3.5. Specific technical description of retro and entry from 105-n mi orbit is provided in figure 3-14. Corresponding information data for

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retro and entry from 140-n mi orbit is provided in figure 3-16. For training planning purpose, the orbit resulting from SPS abort to orbit is assumed to approximate the 105-n mi circular orbit and the same orbital and retro and entry data is applied.

As retro from orbit can be accomplished from any point in orbit, the geographic location at which the various events take place is completely variable. However, the geographic relationship between the events themselves remains constant. Figures 3-15 and 3-17 include such time-range-event data. The trace in the two figures can be transposed to subtend from any orbital point and project along the orbital path to the point of touchdown.

3.12 BUILDING ADDITIONAL MISSIONS

This section of the AMS Instructor Handbook has defined the basic nominal mission and two variations of that mission in detail. Data has also been provided on suborbital and orbital aborts. However, the data contained in this section of the handbook can be transposed into many additional mission profiles. A few suggestions follow.

3.12.1 ORBITAL OPERATIONS AT 140 N MI

Mission variation C (Hohmann transfers) involves transferring from 105-n mi altitude to 140-n mi altitude and back again in the three-orbit mission. Where training in orbital operations at 140 n mi and retro and entry from that altitude is desired, the Hohmann transfer back to 105 n mi can be omitted. Data for entry from 140 n mi is included in paragraph 3.6 of this section.

3.12.2 OPERATIONS IN ELLIPTICAL ORBIT

Mission variation C (Hohmann transfers) involves transient operations in two elliptical orbits. By eliminating or postponing the circularization of these orbits, procedures during elliptical orbit can be practiced.

3.12.3 MISSION OF LESS THAN THREE ORBITS

Any of the three variations of the nominal training mission can be abridged to launch and ascent, selected orbital events, and retro and entry. The recovery north of Hawaii is not a constraint in the initial delivered configuration. Retro and entry can be accomplished from any point in orbit.

3.12.4 NAVIGATION OR SYSTEM MANAGEMENT EMPHASIS

The orbital phases of mission variation A (basic mission) can be arranged to provide a maximum emphasis on either navigation procedures or system management. This characteristic is used for training emphasis in the syllabus in section 3 of volume II.

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APPENDIX A

ABBREVIATIONS

A/D	Analog-to-digital	DSE	Data storage equipment
AGAP	Attitude gyro accelerometer package	DSIF	Deep space information facility
AGC	Apollo guidance computer	DSKY	Display and keyboard
AGCU	Attitude gyro coupling unit	DWI	Digital word input
AM	Amplitude modulation	DWO	Digital word output
AMS	Apollo mission simulator	DWOR	Digital word output relay
AMSC	Apollo mission simulator computer	EAI	Electronic Associates Incorporated
A/R	Analog resolver	ECS	Environmental control system
AS	Atmospheric system	EDS	Emergency detection system
AS/GPI	Attitude set-gimbal position indicator	ELS	Earth landing system
ATT	Attitude	ESS	Essential
BCD	Binary-coded decimal	EVA	Extra-vehicular astronaut
BCN	Beacon	FBC	Fully-buffered channel
BMAG	Body-mounted attitude gyro	F/C	Fuel cell
CCC	Computer control corporation	FDAI	Flight director attitude indicator
C&D	Communications and data system	GFE	Government-furnished equipment
CCTV	Closed circuit television	G&N	Guidance and navigation
C/B	Circuit breaker	GMT	Greenwich mean time
C/C	Computer-to-computer	GOSS	Global operational support system
CDU	Coupling display unit	GSE	Ground support equipment
C/M	Command module	GSSC	Ground system simulation computer
CP	Crew procedures	HS	Heat shield
CRT	Cathode ray tube	HF	High frequency
CCS	Console communications system	IGN	Ignition
CTE	Central timing equipment	IIS	Infinity image system
C/W	Caution and warning	IMCC	Integrated mission control center
CWS	Caution and warning system	IMU	Inertial measurement unit
DDP-24	Computer model number	IO	Instructor-operator
DDP-224	Computer model number	I/O	Input-output
D/A	Digital-to-analog	IOS	Instructor-operator station
DBI	Digital bit input	IRIG	Inertial reference integrating gyro
DBIM	Digital bit input (memory)	IUDL	Integrated up-data link
DBO	Digital bit output	INV	Inverter
DCE	Data conversion equipment	JETT	Jettison
DCS	Digital command system	KMC	Kilo megacycle
DEC	Declination	KYBD	Keyboard
DMA	Direct memory access		
D/R	Digital resolver		

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LAT	Latitude	SCT	Scanning telescope
LEB	Lower equipment bay	SEP	Separation
LEM	Lunar excursion module	SHA	Sidereal hour angle
LES	Launch escape system	SOC	Simulation operations computer
LONG	Longitude	SPS	Service propulsion system
LOS	Line-of-sight	SRS	Simulated remote sites
lt	Light	SSB	Single side band
LV	Launch vehicle	sw	Switch
MCP	Manual control panel	sw-lt	Switch-light
MDV	Map and data viewer	SXT	Sextant
MEP	Mission effects projector	TB	Talk back
MG	Motor generator	TBD	To be defined
MIU	Malfunction insertion unit	TBSL	To be supplied later
MOCR	Mission operations control room	T/C	Telecommunications
MSCC	Manned Spacecraft Control Center	T/L	Telemetry
MSFN	Manned spacecraft flight network	TM	Telemetry
MTR	Motor	T/R	Transmit-receive
MTU	Magnetic tape unit	TV	Television
NRZ	Nonreturn to zero	UDL	Up-data link
OCP	Output control pulse	UDS	Up-data system
P/B	Pushbutton	UPTL	Up-telemetry link
PCM	Pulse-coded modulation	USBE	Unified S-band equipment
PIP	Pulsed input pendulous	VCO	Voltage controlled oscillator
PIPA	Pulsed input pendulous accelerometer	VHF	Verify high frequency
PKG	Package	VOX	Voice operated
PL	Photometer level	WWV	Naval observatory time standard (radio)
PLSS	Portable life support system		
PMP	Premodulation processor		
PSIA	Pounds per square inch (absolute)		
PT	Part task		
PTT	Push-to-talk		
PU	Propellant utilization		
RAD	Radiator		
RCS	Reaction control system		
RCVR	Receiver		
REC	Receive(r)		
RTC	Real time command		
RV	Rendezvous		
S/C	Spacecraft		
SCATS	Simulation checkout and training system		
SCE	Signal conditioning equipment		
SCS	Stabilization control system		
SCM	Simulated command module		

APPENDIX B

AMS TERRESTRIAL LANDMARKS (MIT)

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Table 1-73. AMS Terrestrial Landmarks (MIT)

L/M No.	Landmark	Latitude	Longitude	WAC Map	Country/Area
1	Westernmost peninsula located in Luderitz Bay	S 26° 38'	E 15° 05'	1302	Southwest Africa
2	"Pelican Point" in Walvis Bay	S 22° 53'	E 14° 26'	1273	Southwest Africa
3	Western tip of Kilwa Island located in Lake Mweru	S 09° 15'	E 28° 29'	1055	Northern Rhodesia
4	Southern tip of the island called "Nosy Mangabe" located in the northern part of the bay called "Baie Antongil"	S 15° 31'	E 49° 46'	1156	Malagasy Republic
5	Southern tip of the island called "Ile Sainte-Marie" at the town of Talavia	S 17° 07'	E 49° 49'	1173	Malagasy Republic
6	The point called "Pointe Fem Fenambosy" located on the spit of land enclosing the Bay called "Baie De Fenambosy"	S 25° 15'	E 44° 21'	1297	Malagasy Republic
7	Northern tip of the shoreline in the estuary called "Estuaire Du Gabon"	N 00° 21'	E 09° 21'	905	Gabon-French Equitorial Africa
8	The tip of the peninsula in the harbor of Pointe Noire	S 04° 49'	E 11° 54'	1027	French Congo
9	The westernmost tip of the peninsula about three statute miles northwest of Dakar	N 14° 39'	W 17° 26'	697	Senegal-French West Africa
10	The southeastern tip of the island of "Anjouan"	S 12° 22'	E 44° 30'	1155	Senegal-French West Africa
11	The northern tip of the peninsula in Lake Tanganyika about two statute miles north of the town of Manga	S 04° 03'	E 29° 14'	1030	Republic of the Congo
12	The southern tip of the peninsula called "Cap Blanc"	N 20° 46'	W 17° 03'	575	Mauritania

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Table 1-73. AMS Terrestrial Landmarks (MIT) (Cont)

L/M No.	Landmark	Latitude	Longitude	WAC Map	Country/Area
13	Western "tip" of Boadzula Island in the southern part Lake Nyasa	S 14° 16'	E 35° 08'	1154	Mali
14	The northwesternmost tip of the coastline about three statute miles west of Freetown	N 08° 30'	W 13° 17'	780	Sierra Leone
15	The southern tip of the westernmost island in the group of islands called "Iles De Los," island is about six statute miles west of Conakry	N 9° 27'	W 13° 50'	780	Guinea
16	The southern tip of the peninsula jutting into the bay called "Baia De Inhambane"	S 23° 44'	E 35° 25'	1276	Mozambique
17	The shoreline at the mouth of the river "Rio Pungue" near the town of Beira	S 19° 51'	E 34° 50'	1176	Mozambique
18	The highest point (9760 ft) on the island of Fogo providing that this point can be clearly discerned to within 250 ft	N 14° 57'	W 24° 21'	699	Cape Verde Island
19	The northern tip of a peninsula jutting into the mouth of the Congo River. The peninsula is located at the town of Santa Antonio Da Zaire	S 06° 04'	E 12° 20'	1027	Angola
20	The northern tip of Rusinga Island	S 00° 24'	E 34° 17'	932	Kenya
21	Lake Rudolf	N 02° 38'	E 36° 37'	910	Kenya
22	Cape Rhir on the coast of Morocco	N 30° 37'	W 09° 54'	454	Morocco
23	The western tip of Goba Island in Lake Tanganyika	S 06° 28'	E 29° 50'	1030	Republic of Zanzibar and Tanganyika

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Table 1-73. AMS Terrestrial Landmarks (MIT) (Cont)

L/M No.	Landmark	Latitude	Longitude	WAC Map	Country/Area
24	Northernmost tip of the island of Gran Canaria at the port of the city of "Las Palmas"	N 28° 11'	W 15° 24'	455	Canary Islands
25	Southern tip of the peninsula called "Punta Dunford"	N 24° 40'	W 16° 02'	575	Spanish Sahara
26	Southern tip of peninsula jutting out from San Diego Harbor	N 32° 39'	W 117° 14'	404	USA
27	The peninsula south of Port Royal off the coast of South Carolina	N 32° 18'	W 80° 40'	409	USA
28	Galveston Island In Gulf of Mexico off the coast of Texas	N 29° 16'	W 94° 51'	468	USA
29	Tip of point jutting into bay near Corpus Christi, Texas	N 27° 41'	W 97° 14.5'	522	USA
30	Westernmost tip of Key West West Island	N 24° 32.5'	W 81° 48'	525	USA
31	Tip of Cabo Haro (South tip) near Guaymas in Gulf of California	N 27° 50'	W 110° 53'	520	Mexico
32	Tip of Punta Abreojos off Lower California in North Pacific Ocean	N 26° 43'	W 113° 37'	520	Mexico
33	Tip of Cabo San Lucas, at head of Lower California	N 22° 52'	W 109° 54'	591	Mexico
34	The southern tip of Castle Island about 4 statute miles south of Acklins Island	N 22° 07'	W 74° 20'	585	Bahama Islands
35	Hawaii Island at a point called "Ka Heiauo Kalalea" (South Cape)	N 18° 55'	W 155° 41'	634	USA (Hawaii)

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Table 1-73. AMS Terrestrial Landmarks (MIT) (Cont)

L/M No.	Landmark	Latitude	Longitude	WAC Map	Country/Area
36	"Kaena Point" on the western tip of Oahu Island	N 21° 34'	W 158° 17'	599	USA (Hawaii)
37	The northernmost tip of Kangaroo Island at "Point Marsden" which is about 60 n mi south west of the city of Adelaide.	S 35° 34'	E 137° 38'	1458	Australia
38	The southwest tip of Coffin Bay Peninsula at "Point Widbey"	S 34° 35'	E 135° 06'	1458	Australia
39	"Sugarloaf Point" approximately 110 n mi north east of Sidney	S 32° 26'	E 152° 31'	1456	Australia
40	The southernmost tip of "Cape Arid" which is south east of Tagon Harbour and south west of Sandy Bight	S 34° 02'	E 123° 09'	1460	Australia
41	"Cape Naturaliste" located in Geographs Bay	S 33° 32'	E 115° 00'	1461	Australia
42	"Cape Leeuwin" at Flinders Bay	S 34° 23'	E 115° 08'	1461	Australia
43	"Cape Peron" at the northern tip Peron Peninsula which is located midway between Dirk Hartog Island and the mainland	S 25° 32'	E 113° 29'	1346	Australia
44	"Point Lookout" which is the northeastern tip of North Stradbroke Island	S 27° 25'	E 153° 33'	1340	Australia
45	"Sandy Cape" located at the northern tip of Fraser Island.	S 24° 42'	E 153° 16'	1340	Australia
46	Pasco Island located off the southern tip of Barrow island	S 20° 58'	E 115° 21'	1229	Australia

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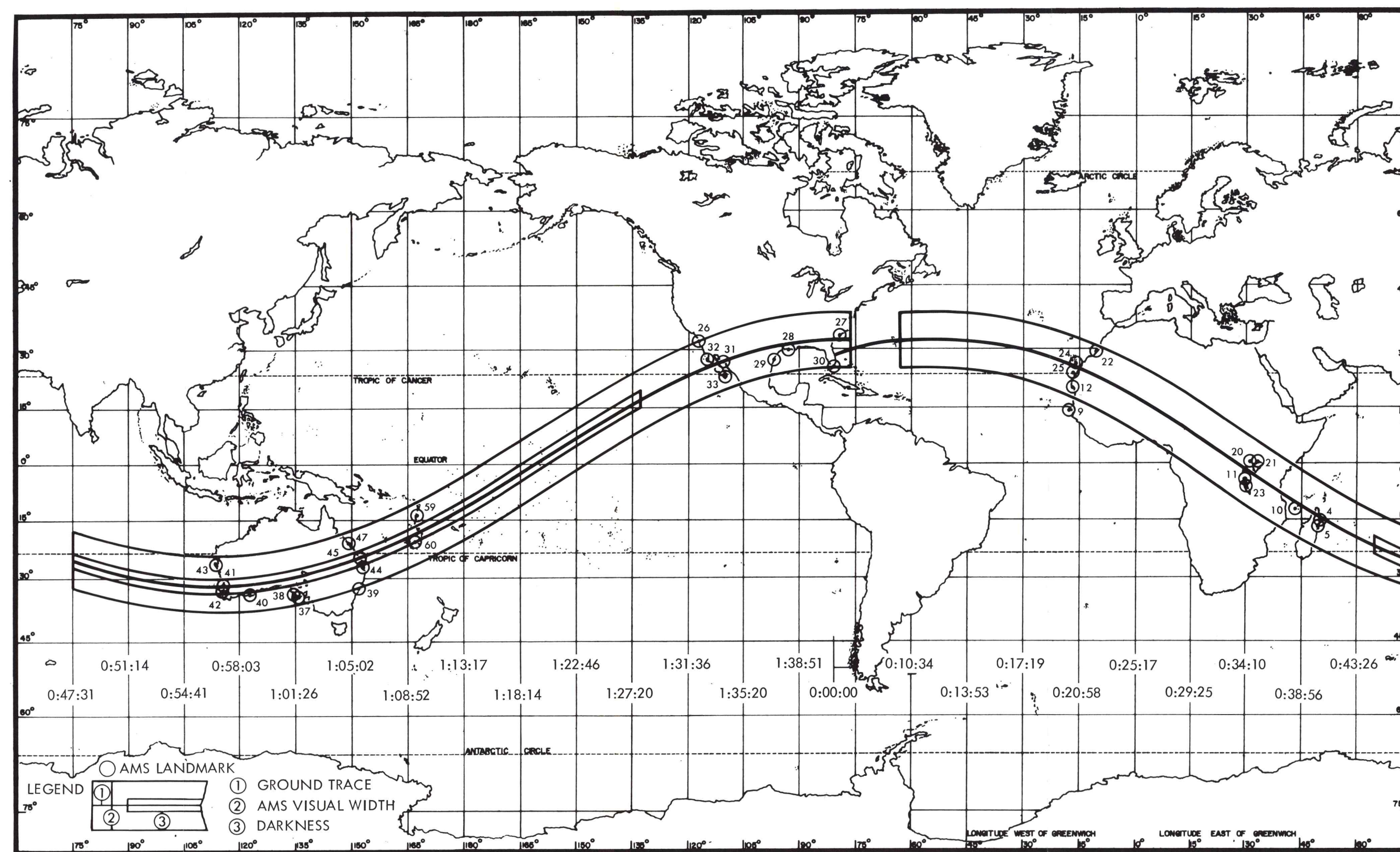
Table 1-73. AMS Terrestrial Landmarks (MIT) (Cont)

L/M No.	Landmark	Latitude	Longitude	WAC Map	Country/Area
47	The northern tip of "South Island" which is one of the Percy Islands	S 21° 43'	E 150° 21'	1235	Australia
48	"Gantheaume Point" just north of Roebuck Bay	S 17° 59'	E 122° 10'	1223	Australia
49	The eastern tip of "Great Palm Island" one of the Palm Islands off the eastern coast of Australia	S 18° 46'	E 146° 42'	1219	Australia
50	"Cape Ford" located south west of Anson Bay	S 13° 26'	E 129° 53'	1109	Australia
51	The south west tip of Maria Island which is located in Limmen Bight	S 14° 55'	E 135° 41'	1110	Australia
52	The southern tip of "Duifken Point" on the western coast of Cape Yorke Peninsula	S 12° 33'	E 141° 39'	1111	Australia
53	Poelau Jaco, a small island at the eastern tip of Timor Island. LM could be the highest point on the island (250 feet)	S 08° 26'	E 127° 19'	1100	Portuguese Timor
54	Southeast tip of "Poelau (Island) Adi" off New Guinea	S 04° 19'	E 133° 36'	986	New Guinea
55	The single island in Lake Widsom which is located in Long Island	S 05° 19'	E 147° 05'	988	New Guinea
56	"Cape Zelee" at the southern tip of Maramasike Island	S 09° 48'	E 161° 33'	1094	Southwest Pacific
57	The northern tip of a peninsula in Lake Dakataua near the northern coast of New Britain Island	S 05° 00'	E 150° 06'	989	Southwest Pacific

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Table 1-73. AMS Terrestrial Landmarks (MIT) (Cont)

L/M No.	Landmark	Latitude	Longitude	WAC Map	Country/Area
58	Motupena Point off the western coast of Bougainville Island	S 06° 31'	E 155° 10'	990	Southwest Pacific
59	Cape Cumberland at the northern tip of Espiritu Island	S 14° 37'	E 166° 37'	1115	Southwest Pacific
60	"Cap Lefevre" on the western tip of "Ile Lifou"	S 20° 55'	E 167° 02'	1238	Southwest Pacific



SM-6T-2-02-231-M

Figure 3-8. Nominal Training Mission Navigation Reference Data,
Orbit No. 1 (MIT)

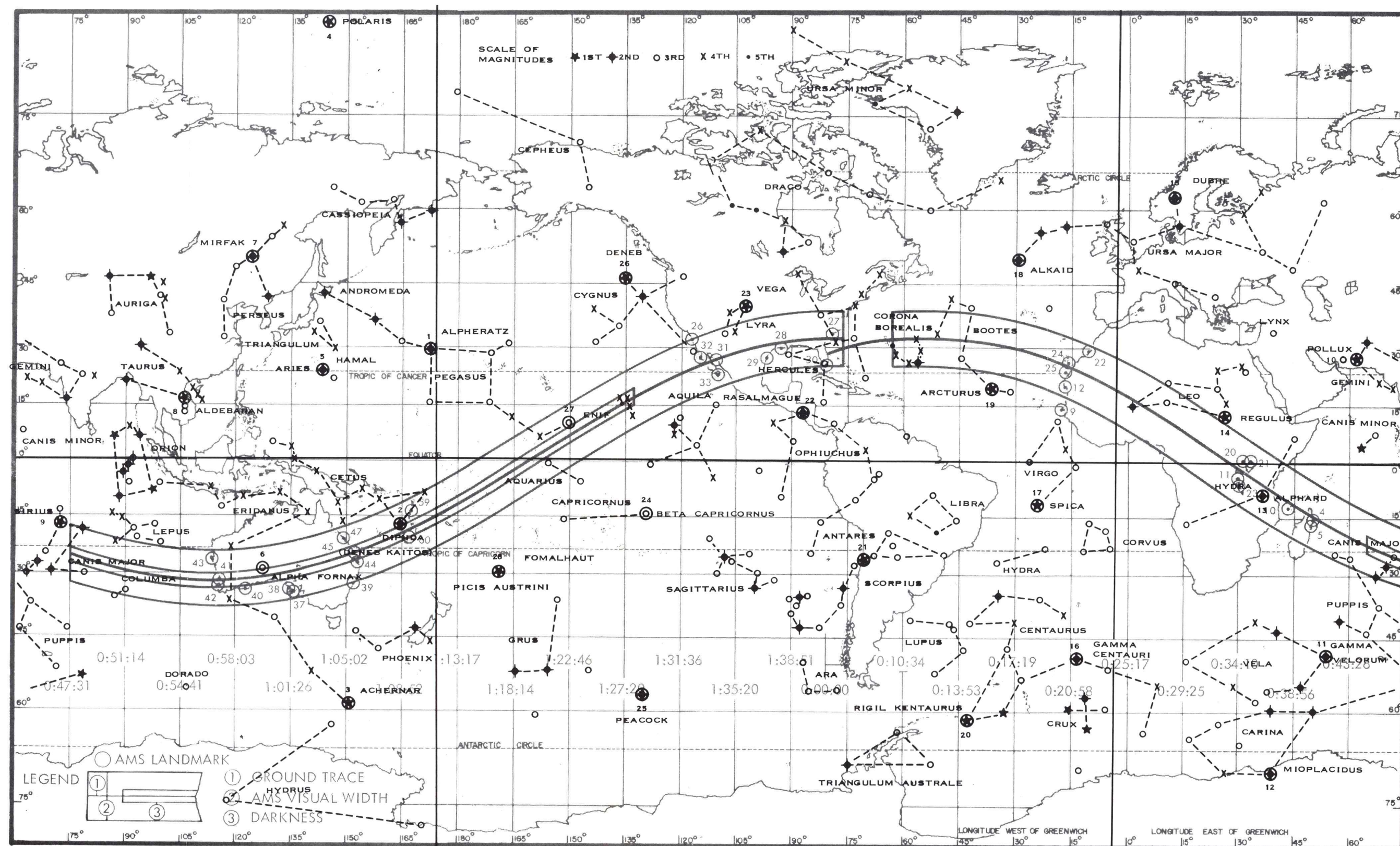
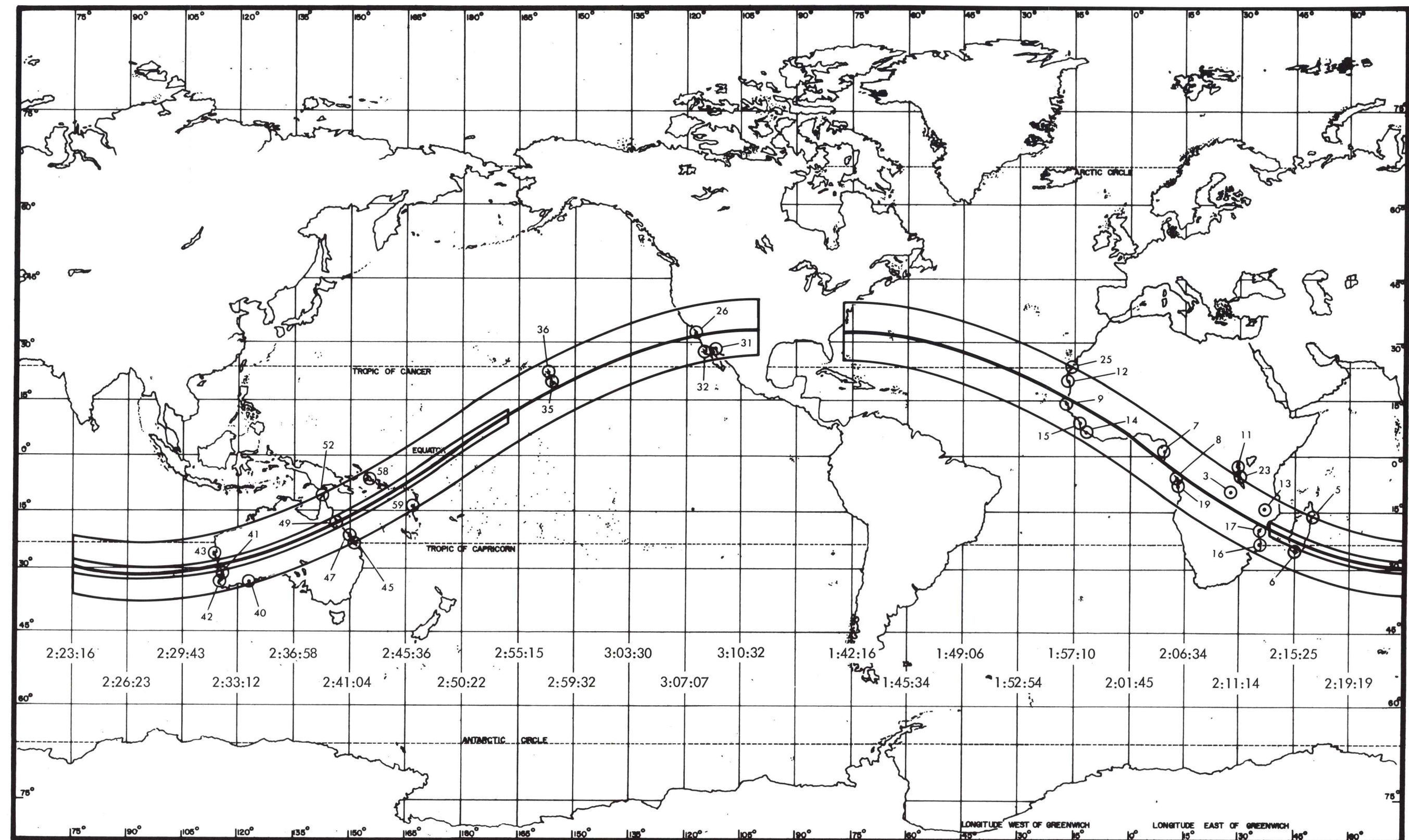


Figure 3-9. Star Data for Nominal Training Mission Navigation Reference
Data, Orbit No. 1 (MIT)

SM-6T-2-02-232/231



SM-6T-2-02-234-M

Figure 3-10. Nominal Training Mission Navigation Reference Data,
Orbit No. 2 (MIT)

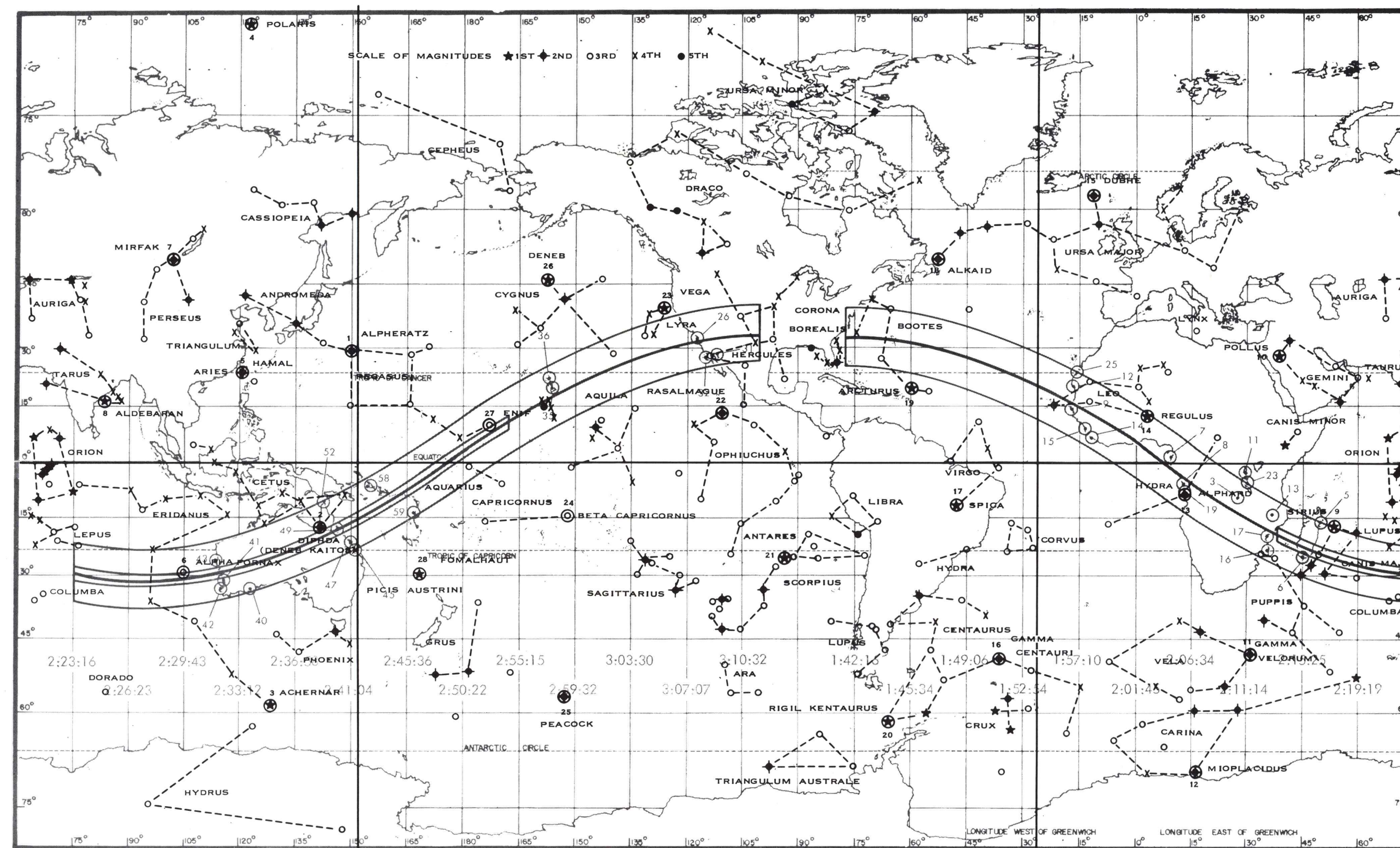
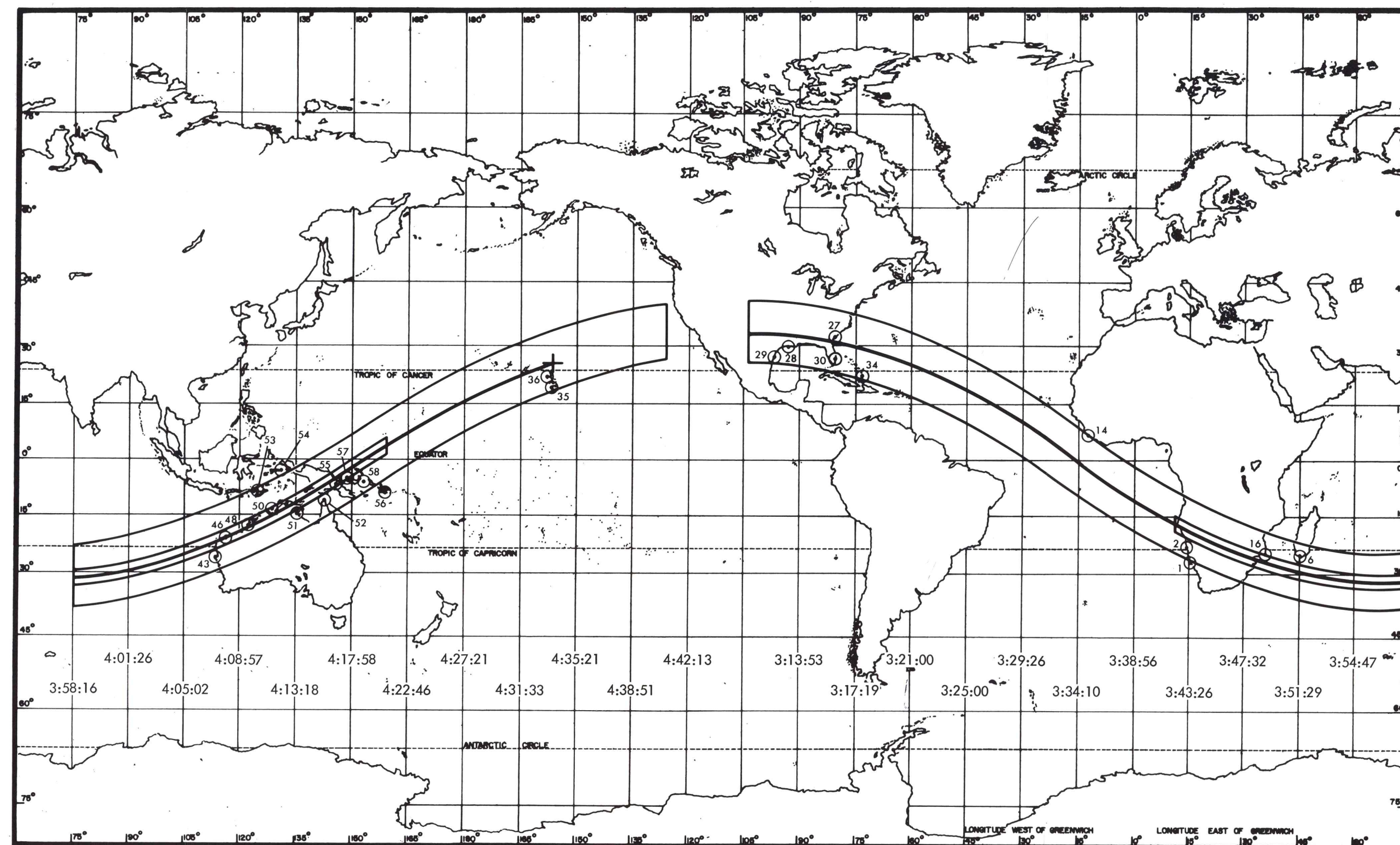


Figure 3-11. Star Data for Nominal Training Mission Navigation Reference Data, Orbit No. 2 (MIT)



SM-6T-2-02-237-M

Figure 3-12. Nominal Training Mission Navigation Reference Data,
Orbit No. 3 (MIT)

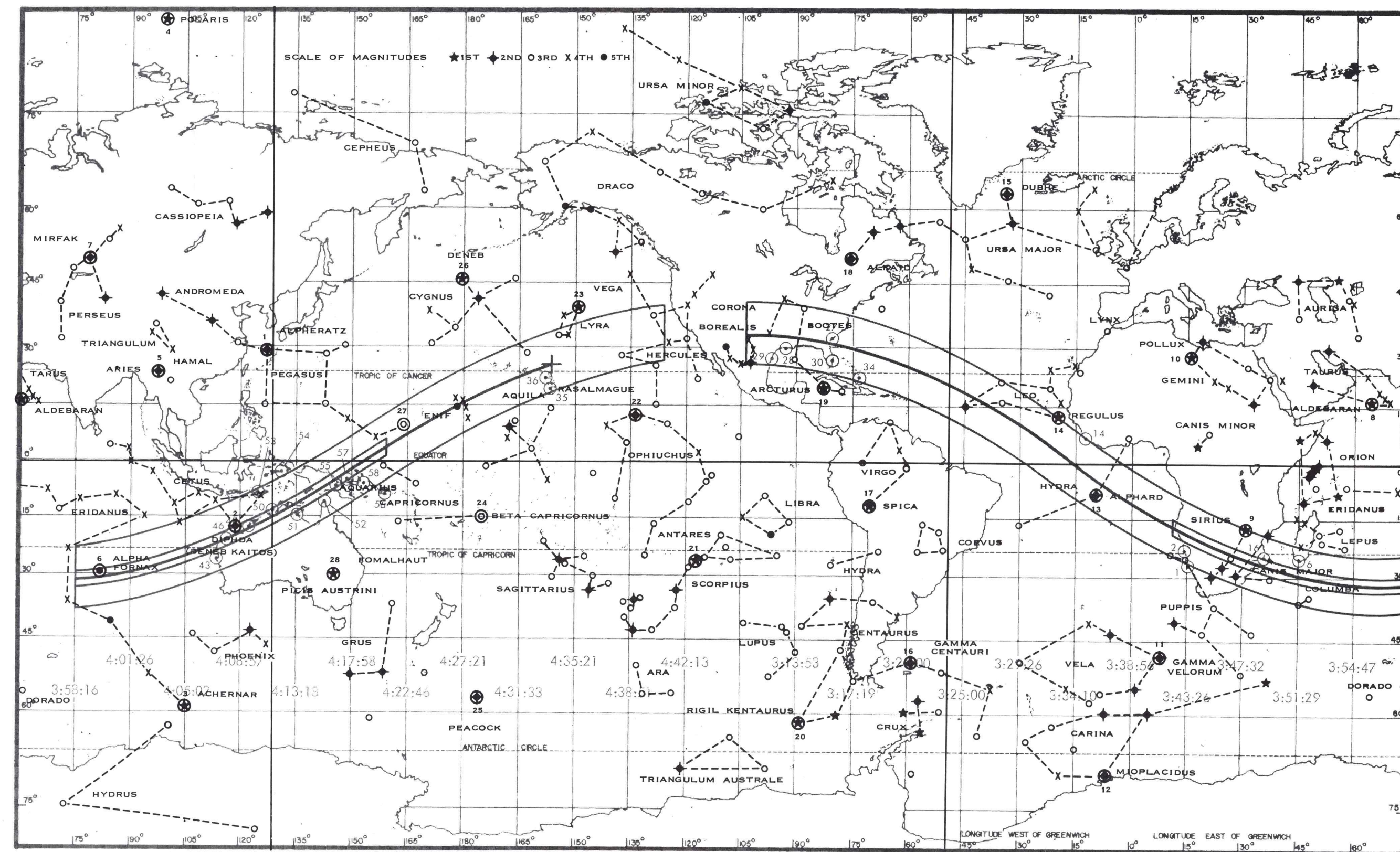


Figure B-13. Star Data for Nominal Training Mission Navigation Reference Data, Orbit No. 3 (MIT)