Barnes

EASEP-MT-01

EARLY APOLLO SCIENTIFIC
EXPERIMENTS PACKAGE
(EASEP)

FLIGHT SYSTEM
FAMILIARIZATION MANUAL

PREPARED FOR

LUNAR SURFACE PROJECT OFFICE
MANNED SPACECRAFT CENTER

THE BENDIX CORPORATION
AEROSPACE SYSTEMS DIVISION

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INTRODUCTION

The Early Apollo Scientific Experiments Package (EASEP) will be used to obtain long-term scientific measurements of various physical properties and geophysical dynamics of the Moon consistent with the scientific objectives of the Apollo Program. EASEP will be transported to the lunar surface aboard the Apollo Lunar Module (LM) and will remain on the lunar surface after the return of the astronauts. EASEP will transmit scientific and engineering data to the Manned Space Flight Network (MSFN), and will establish a point reflector for precise measurement of Earth-Moon distance through laser ranging.

The purpose of the EASEP Flight System Familiarization Manual is to familiarize the reader with the scientific objectives of EASEP, equipment make-up, system deployment, and operation. This manual describes the EASEP mission and system in Section I, EASEP packages in Section II, and Section III, and operations in Section IV. Supplementary command and measurement data is provided in the Appendices.

The information contained in this manual includes formalized data released and available prior to the publication date: 25 April 1969.

Section I

EASEP MISSION DESCRIPTION

1-1. EASEP MISSION INTRODUCTION

The Early Apollo Scientific Experiments Package (EASEP) is a group of scientific experiment and support subsystems which will be deployed on the surface of the Moon by an Apollo crewman. The EASEP will measure lunar seismic activity and transmit the data to receiving stations on Earth. It will establish a fiducial point consisting of an array of optical retro-reflectors to provide laser ranging for precise measurement of Earth-Moon distances. This data will be used to derive information on the composition and structure of the lunar body, its origin, and geophysical dynamics.

1-2. EASEP MISSION PROFILE

The EASEP will be transported to the Moon in the Apollo spacecraft on the first manned lunar landing mission. The Apollo spacecraft consists of three basic modules; the service module (SM), command module (CM), and lunar module (LM). The EASEP packages will be mounted in the Scientific Equipment (SEQ) bay of the LM as shown in Figure 1-1.

A Saturn V launch vehicle will place the Apollo spacecraft in trans-lunar trajectory. After insertion of the spacecraft into lunar orbit, two crewmen will transfer from the CM to the LM for lunar descent. The third crewman will maintain the command and service module combination (CSM) in lunar orbit. The LM will be separated from the CSM and be piloted to a preselected landing site on the lunar surface.

After landing, a crewman will extract the EASEP packages from the LM and deploy them on the lunar surface. He will then verify with MSFN that the receiving, processing, and power supply subsystems are operable.

The LM will be launched from the lunar surface to rendezvous with the CSM in lunar orbit. The two crewmen will transfer from the LM to the CSM, jettison the LM in lunar orbit, and initiate the CSM transEarth maneuver. The SM will be jettisoned before re-entry and the three crewmen will re-enter the Earth atmosphere and land in the CM.

The Passive Seismic Experiment Package (PSEP) of the EASEP, on the lunar surface, is controlled by ground command from the manned space flight network (MSFN). Commands from Earth and automatically generated commands will direct PSEP operation. The Laser Ranging Retro-Reflector Experiment (LRRR) will operate in conjunction with earth based laser transmitting and receiving equipment.

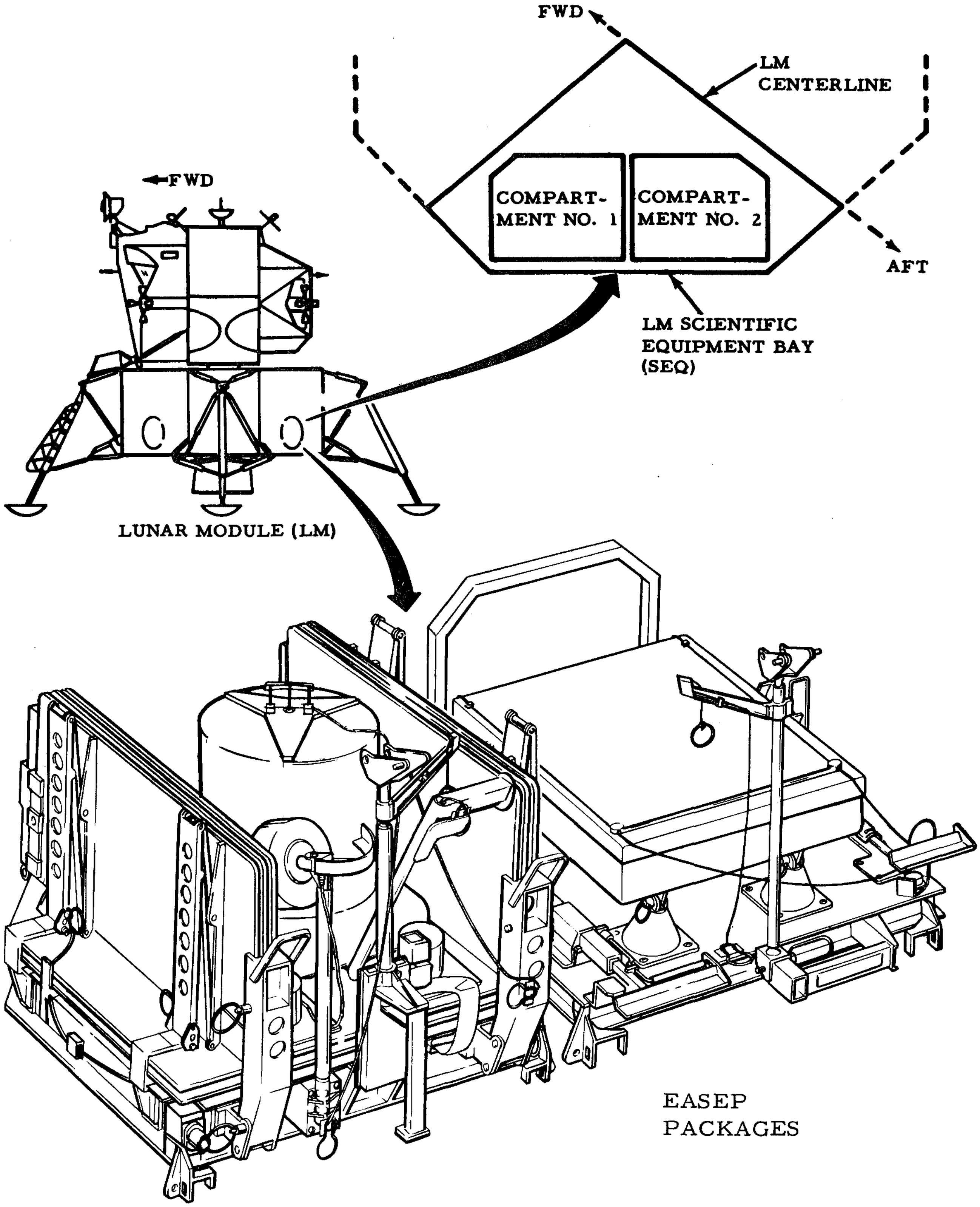


Figure 1-1. EASEP/LM Interface

1-3. EASEP MISSION OBJECTIVES

Major objectives of lunar exploration include determination of:

a. The structure and state of the lunar interior
b. The composition and structure of the lunar surface and modifying processes
c. The evolutionary sequence of events leading to the present lunar configuration.

Specific EASEP mission objectives are:

a. Deploy the Passive Seismic Experiment Package (PSEP)
b. Deploy the Laser Ranging Retro-Reflector Experiment (LRRR)
c. Acquire rf transmission from PSEP at MSFN ground stations
d. Acquire scientific data at MSFN ground stations from PSEP
e. Establish and verify response of PSEP to commands from MSFN ground stations.

To initiate partial attainment of these objectives the EASEP includes two experiments to measure a number of geophysical characteristics. The various physical and environmental properties to be measured and method of measurement are listed in Table 1-1.

1-4. EASEP SYSTEM DESCRIPTION

The EASEP is a self-contained system of scientific instruments and supporting subsystems designed to acquire lunar physical data and transmit the information to Earth. The EASEP will be deployed on the lunar surface by an Apollo crewman as described in Section IV of this manual.

1-5. EASEP PHYSICAL DESCRIPTION

The EASEP consists of two independent, self-contained experiment packages; the Passive Seismic Experiment Package (PSEP, and Laser Ranging Retro-Reflector experiment (LRRR). The EASEP packages weigh approximately 164 pounds, and occupy approximately 12 cubic feet.

1-6. PSEP Physical Description. The PSEP consists of the following subsystems:

a. Structure/thermal subsystem
b. Electrical power subsystem
c. Data subsystem
d. Passive seismic experiment subsystem.

The PSEP weighs approximately 112 pounds, and occupies approximately 7.7 cubic feet in the stowed configuration. The physical characteristics of PSEP are illustrated in Figure 1-2.

1.7. LRRR Physical Description. The LRR consists essentially of a pallet assembly and a retro-reflector array assembly. It weighs approximately 52 pounds, and occupies approximately 4.5 cubic feet in the stowed configuration. The physical characteristics of LRRR are illustrated in Figure 1-3.

Table 1-1. EASEP Scientific Objectives

Measurement Objective	Experiment/Measurement Method
Natural seismology (meteoroid inpacts and moonquakes). Properties of lunar interior (existence of core, mantle)	Passive Seismic Experiment Package - Uses three long period seismometers in an orthogonal arrangement and one vertical short period seismometer.
Determination of: 1. Center of mass motion of moon. 2. Selenophysical information a. Forced physical librations b. Lunar radius 3. Geophysical information a. Fluctuation in earth rotation rate b. Chandler wobble of earth axis c. Intercontinental drift rate 4. Gravity and relativity a. Secular change of gravitational constant g 5. Cartography 6. Space communication technology	Laser Ranging Retro-Reflector Experiment - Retro-reflector array serves as fiducial point on surface of moon for precise measurement of distance from surface of earth using laser ranging.

1-8. EASEP FUNCTIONAL DESCRIPTION

The EASEP objective of obtaining lunar physical data is accomplished through employment of the two experiment packages, the manned space flight network (MSFN), and laser transmitting and receiving stations. (See Figure 1-4.)

The MSFN stations at Goldstone California, Carnarvon Australia, Ascension Island, Hawaii, Guam, and KSC Florida are the Earth terminals for communications. Mission Control Center (MCC) participates in the network for activation of the experiments, initial calibration sequences, and for the duration of the mission. Communications consist of an uplink (Earth-Moon) for command transmission to control the PSEP functions, and a downlink (Moon-Earth) for transmission of scientific experiment and engineering housekeeping data. The MSFN stations will record the downlink data.

The Air Force Electro-Optical Surveillance and Research Facility at Cloudcroft, New Mexico and the ARPA Observatory at Haleakala, Maui, Hawaii are the Earth stations for laser ranging to the LRRR. Foreign scientists are also making plans to utilize the LRRR.

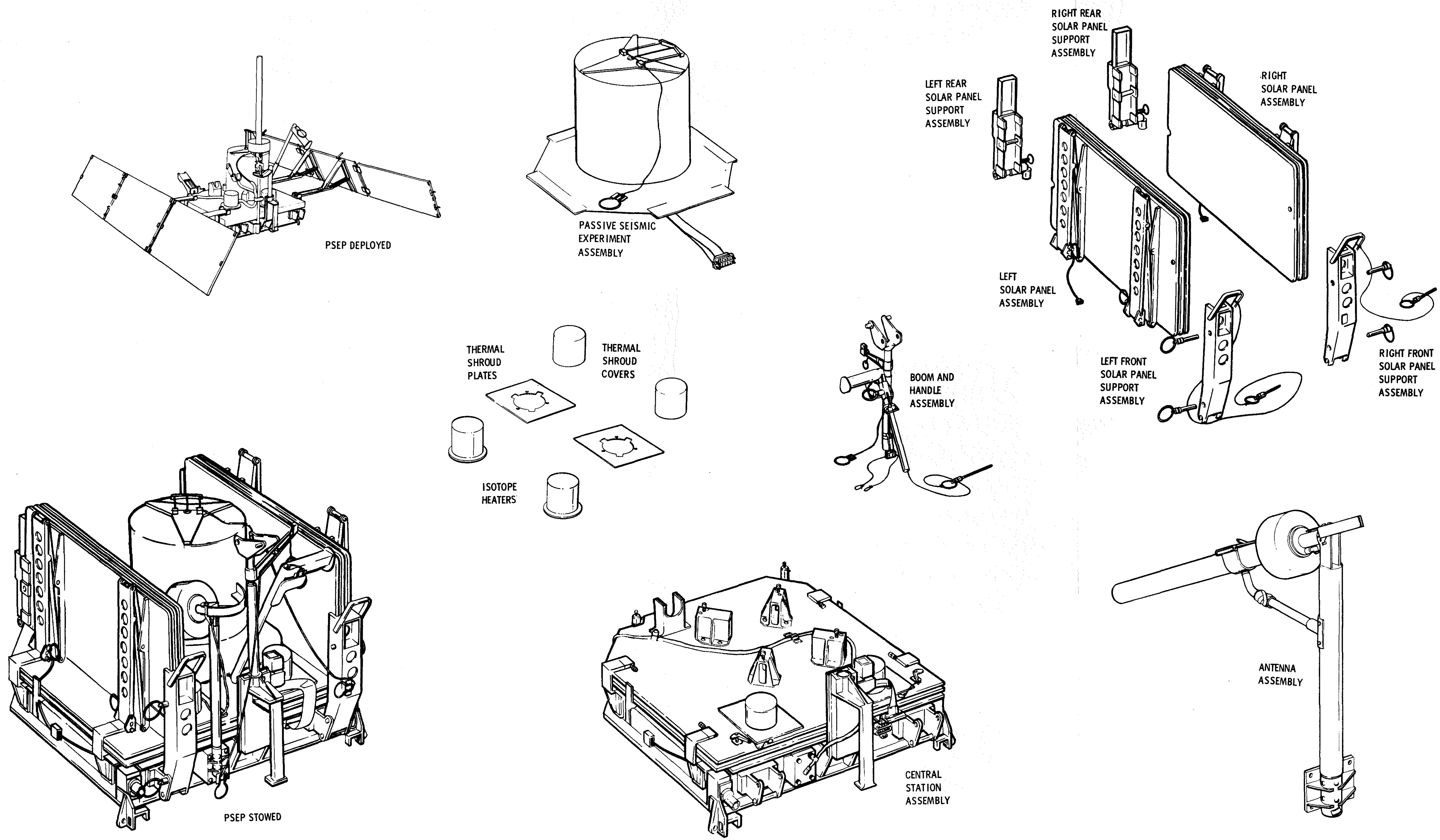


Figure 1-2. Passive Seismic Experiment Package

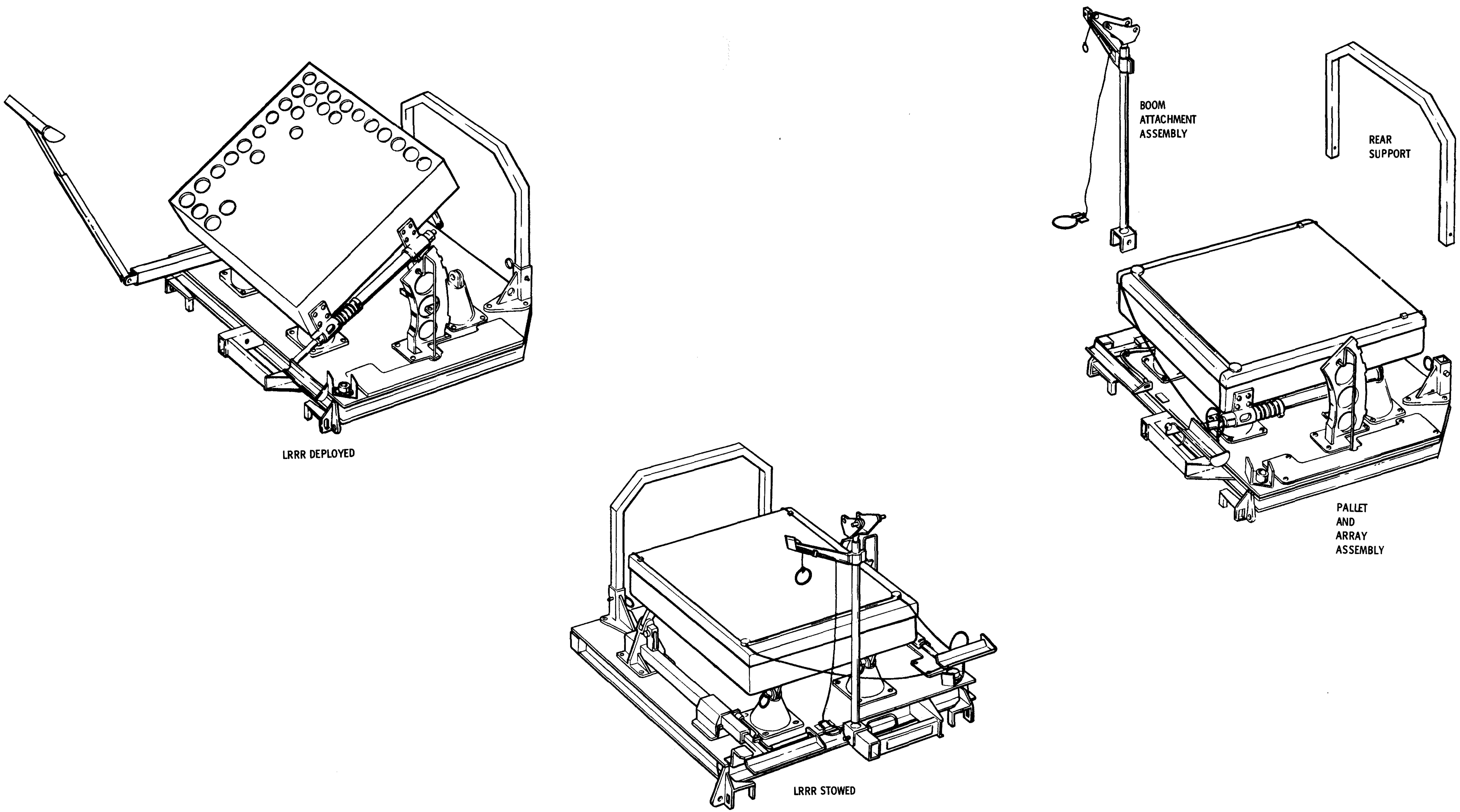


Figure 1-3. Laser Ranging Retro-Reflector Experiment

1-9. PSEP Functional Description. The functional operation of PSEP is illustrated in Figure 1-4. The following paragraphs describe the function, on a system level, of the PSEP subsystems.

1-10. Structure/Thermal Subsystem - The structure/thermal susbystem provides structural integrity and thermal protection of PSEP in transport and in the lunar environment (-300°F to +250°F). This includes packaging, structural support, and isolation from heat, cold, shock, and vibration. A dust detector monitors accumulation of lunar dust. Isotope heaters aid in the survival of the PSEP electronics during the lunar night.

1-11. Electrical Power Subsystem - The electrical power subsystem generates 30 to 45 watts of electrical power for operation of the PSEP. The power is developed by a solar panel array. The power is regulated, converted to the required voltage levels, and supplied to the data subsystem for distribution to the support and experiment subsystems. Analog housekeeping data is supplied to the data subsystem for downlink telemetry.

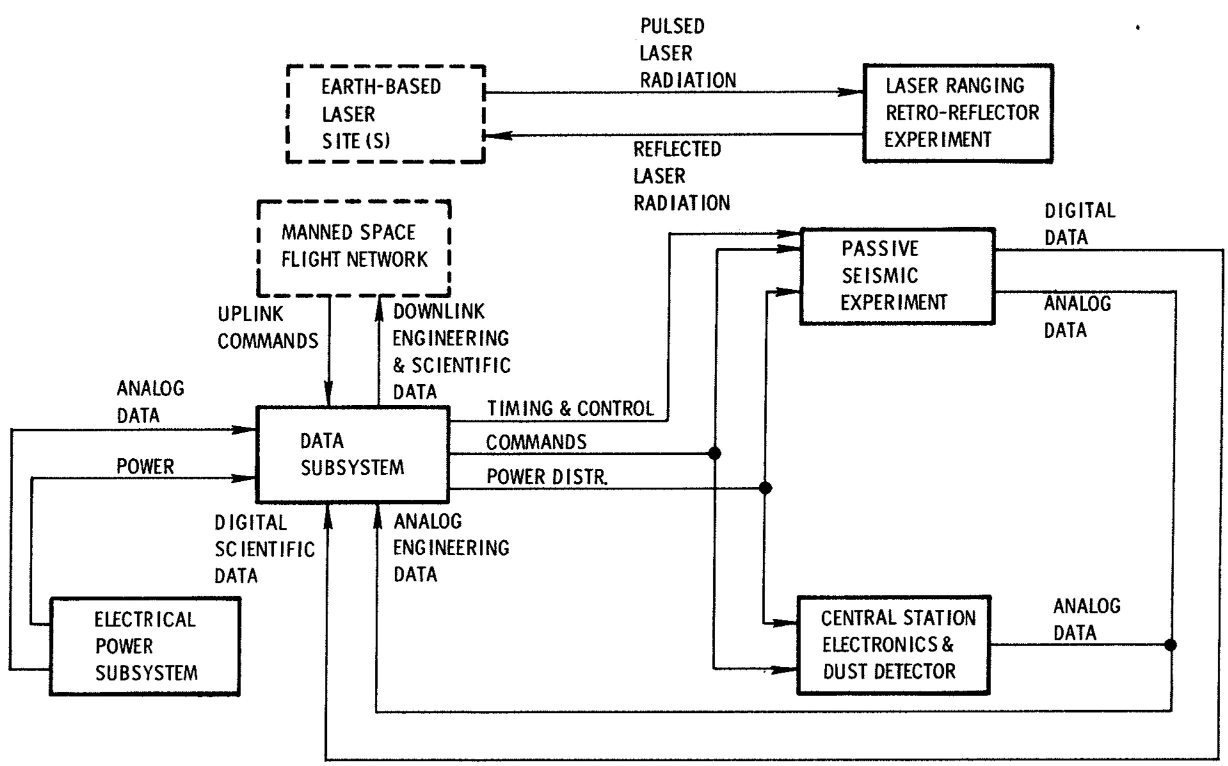


Figure 1-4. EASEP Simplified Block Diagram

1-12. Data Subsystem - The data subsystem receives, decodes, and applies discrete logic commands from the MSFN. These commands are used to perform power switching, thermal control, operating mode changes and experiment control. The data subsystem accepts and processes scientific data from the experiment, engineering status data from itself and all the subsystems, and transmits the data to the MSFN receiving stations. The data subsystem also performs the function of switching and distributing operating power to the experiment and support subsystems.

1-13. Passive Seismic Experiment Subsystem - The passive seismic experiment (PSE) will measure seismic activity of the Moon to obtain information regarding the physical properties of the lunar crust and interior. Seismic energy is expected to be produced in the lunar surface by meteoroid impacts and tectonic disturbances.

The seismic activity is measured by long period and short period seismometers which monitor the displacement of inertial masses from a zero position relative to sensitive transducers.

1-14. LRRR Functional Description. The LRRR will serve as a fiducial point on the surface of the moon for precise measurement by laser ranging of the distance from sites on earth. The retro-reflector array will be aimed toward the earth. Laser radiation incident upon the retro-reflectors is reflected on a path nearly parallel to the incident beam.

The pallet assembly provides structural integrity and contributes to thermal isolation of the array assembly in the lunar environment. It provides for aiming and alignment of the array assembly.

The array assembly provides passive thermal control to minimize thermal gradients in the retro-reflectors.

1-15. PRINCIPAL INVESTIGATORS.

Each EASEP experiment has been designed by a principal investigator (PI), in some cases in conjunction with one or more co-investigators. The investigators, identified by experiment, are listed in Table 1-2.

Table 1-2. EASEP Principal Investigators

Experiment	Principal Investigator and Co-Investigators
Passive Seismic	Principal Investigator Dr. Gary Latham - Lamount Geological Observatory Co-Investigators Dr. George Sutton - University of Hawaii Dr. Frank Press - Massachusetts Institute of Technology Dr. Maurice Ewing - Columbia University
Laser Ranging Retro-Reflector	Principal Investigator Dr. C. O. Alley - University of Maryland Co-Investigators Dr. P. L. Bender - National Bureau of Standards University of Colorado Dr. R.H. Dicke - Princeton University Dr. J.E. Faller - Wesleyan University Dr. G. J. F. MacDonald - University of California Santa Barbara Dr. H.H. Plotkin - Goddard Space Flight Center Dr. D. T. Wilkinson - Princeton University Dr. W.M. Kaula - University of California Los Angeles

SECTION II

PASSIVE SEISMIC EXPERIMENT PACKAGE DESCRIPTION

2-1. INTRODUCTION

This section describes the four (one experiment and three support) subsystems which comprise the passive seismic experiment package (Figure 2-1). A listing of the subsystems follows:

a. Structure/thermal subsystem
b. Electrical power subsystem (EPS)
c. Data subsystem (DS/S)
d. Passive seismic experiment subsystem (PSE)

All subsystems are described in terms of their physical characteristics, functional operation, and system interfaces.

2-2. STRUCTURE/THERMAL SUBSYSTEM

The structure/thermal subsystem provides the structural integrity and thermal protection required by the PSE and support subsystems to withstand the environments encountered in storage, transportation and handling, testing, loading on LM, space flight, and lunar deployment. During operation on the Moon, the structure/thermal subsystem will continue to provide structural support and thermal protection to the data subsystem, the electrical power subsystem, and the passive seismic experiment.

2-3. STRUCTURE/THERMAL SUBSYSTEM PHYSICAL DESCRIPTION

The structure/thermal subsystem comprises the central station assembly which is the basic structural assembly of the PSEP. It includes the primary structure, mounting plate, thermal plate, thermal bag, isotope heaters, modified dust detector, and boom and handle assemblies as shown in Figure 2-2. Structure/thermal leading particulars are listed in Table 2-1.

2-4. STRUCTURE/THERMAL SUBSYSTEM FUNCTIONAL DESCRIPTION

2-5. Primary Structure. The primary structure provides tie points for securing the PSEP in compartment 1 of the SEQ bay of the LM. It is recessed to receive the central station electronics which are mounted on the thermal plate and enclosed by the thermal bag. Thermistor temperature sensors monitor the primary structure temperature during operation. Temperature signals are supplied to the data subsystem for insertion into the PSEP telemetry data. Tie-points are provided for the modified dust detector, solar panels, antenna and positioning mechanism, and boom and handle assembly.

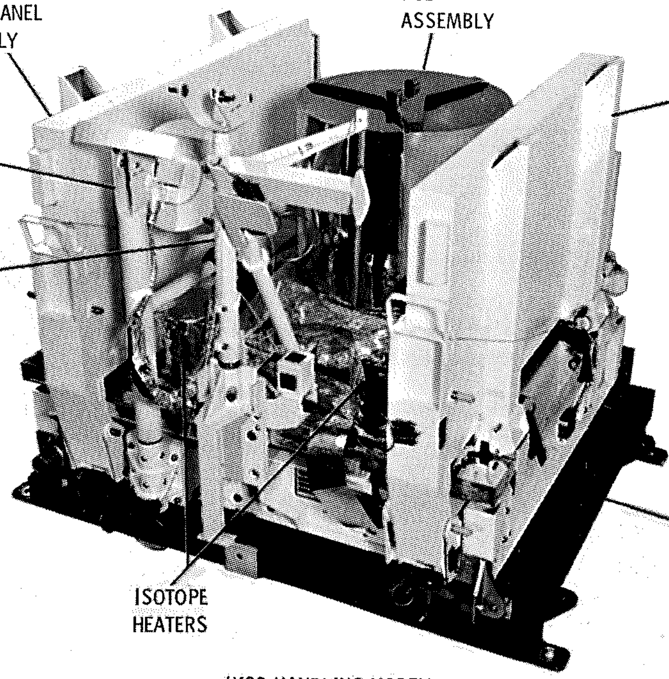


Figure 2-1. Passive Seismic Experiment Package

2-6. Mounting Plate. The mounting plate provides tie points for mounting the PSE sensor assembly and isotope heaters. The mounting plate provides thermal protection for the PSEP through the use of thermal control paint, second-surface mirrors, and insulation.

2-7. Thermal Plate and Thermal Bag. The thermal plate and thermal bag provide thermal protection for the central station electronics. A thermistor temperature sensor monitors thermal plate temperature during operation and supplies temperature signals to the data subsystem for insertion into the PSEP telemetry data.

2-8. Isotope Heaters. Two radioisotope heaters generate 30 (± 0.5) watts of thermal energy to aid in the survival of the PSEP electronics during the lunar night when the central station is not operating.

2-9. Boom and Handle Assembly. The PSEP is lowered from compartment No. 1 of the LM SEQ bay to the lunar surface by means of the boom and handle assembly. During deployment, the astronaut handle is extended to allow emplacement (alignment and leveling) of the PSEP. Lanyards protruding through the astronaut handle release the solar panel and antenna deployment mechanisms.

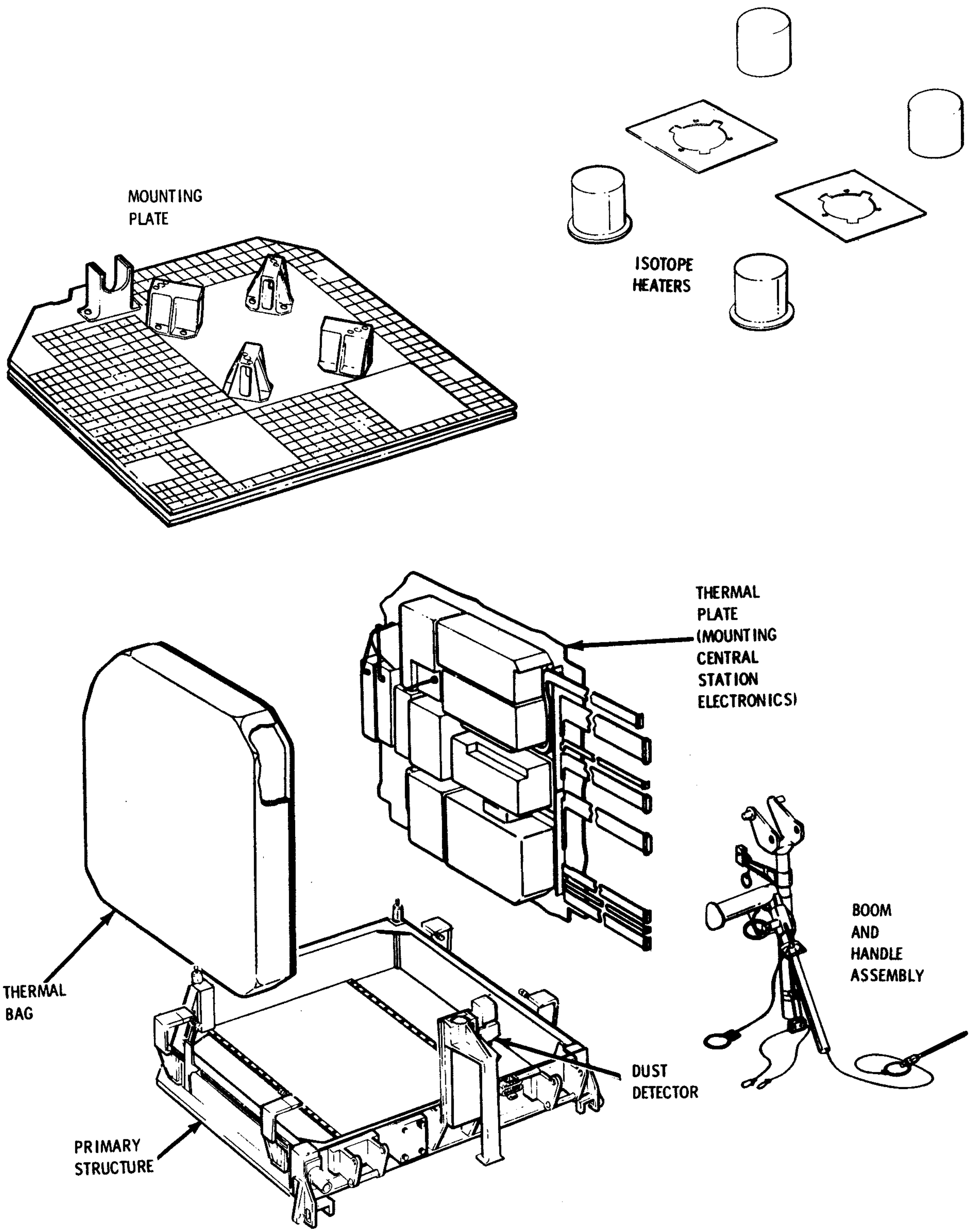


Figure 2-2. Structure/Thermal Subsystem

Table 2-1. Structure/Thermal Subsystem Leading Particulars

Component	Characteristic	Value
Central Station Assembly (primary structure, mounting plate, thermal plate, electronics, thermal bag)	Size (inches)	L 26.75 W 27.37 H 6.87
	Weight (pounds)	87.38
Isotope Heater	Size (inches)	H 3.20 D 3.00
	Weight (pounds)	2.20
	Thermal Output (watts)	15.00
Boom and Handle Assembly	Length (inches)	16.00
	Weight (pounds)	1.90
Modified Dust Detector	Power Requirements	
	On mode	245 mw maximum + and -12 vdc.
	Off mode	45 mw maximum, + and -12 vdc.
	Analog Outputs	0 to +5 vdc.
Sensor Package	Size (inches)	1.75 x 1.75 x 1.75
	Weight (pounds)	0.35
Circuit Board	Size (inches)	3.3 x 6.1
	Weight (pounds)	0.26

2-10. MODIFIED DUST DETECTOR DESCRIPTION

The modified dust detector (Lunar Degradation Experiment) will obtain data for assessment of dust accretion on EASEP, the radiation environment, and the degradation rate of thermal coatings.

2-11. Modified Dust Detector Physical Description. The modified dust detector has two components; a sensor package (Figure 2-3), and a printed circuit board. The sensor package is mounted on the PSEP central station. It has three 1 cm by 2 cm solar cells located on the top, horizontal, surface. One cell has a 20 mil radiation shield cover glass, one cell has a 6 mil cover glass, and one cell has no cover glass. A thermister is attached to the rear of the two outboard cells, and a third thermister is mounted on the outboard vertical side of the package. The sensor package is connected through an H-film cable to the printed circuit board which is located in the power distribution unit of the data subsystem.

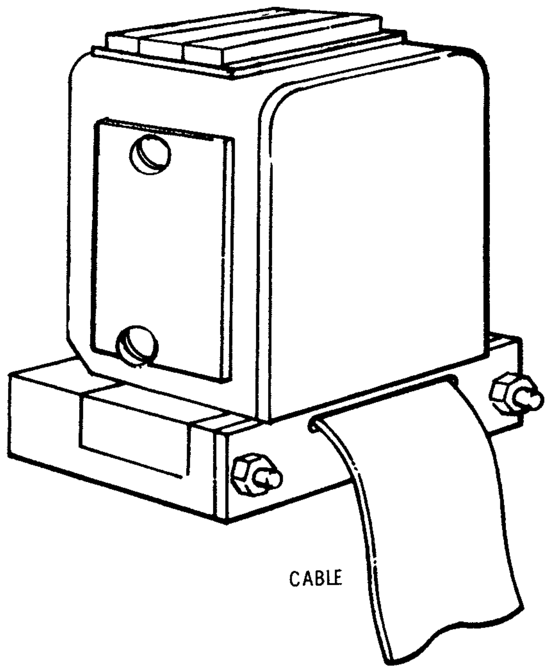


Figure 2-3. Modified Dust Detector Sensor Package

2-12. Modified Dust Detector Functional Description. Dust accretion on the solar cells will reduce the intensity of solar radiation reaching the three cells. This can be measured by an equal reduction in output from the cells as a function of the amount of dust.

The radiation environment will be measured by the reduction of solar cell output voltages due to radiation degradation of the cells. One solar cell has no cover glass radiation shield, and is used as a base cell. The other two cells have radiation shields of different thickness. The different thicknesses of radiation shield cover glasses on the cells will provide different degrees of radiation protection dependent upon the particle energies, so that they form a simple spectrometer.

Two thermisters will measure solar cell temperatures, and the thermister on the sensor side will measure lunar surface temperature in the range of -308°F to 274°F.

The outputs of the solar cells are applied to three amplifiers which condition the signals and apply them to three subcommutated analog data channels of the data subsystem. (See Figure 2-4.) The thermistor outputs are applied to three subcommutated analog data channels of the data subsystem.

Modified dust detector operation is controlled by on and off commands from Earth. These commands are applied to the command memory through the data subsystem. The command memory stores the command and controls the operation of the power

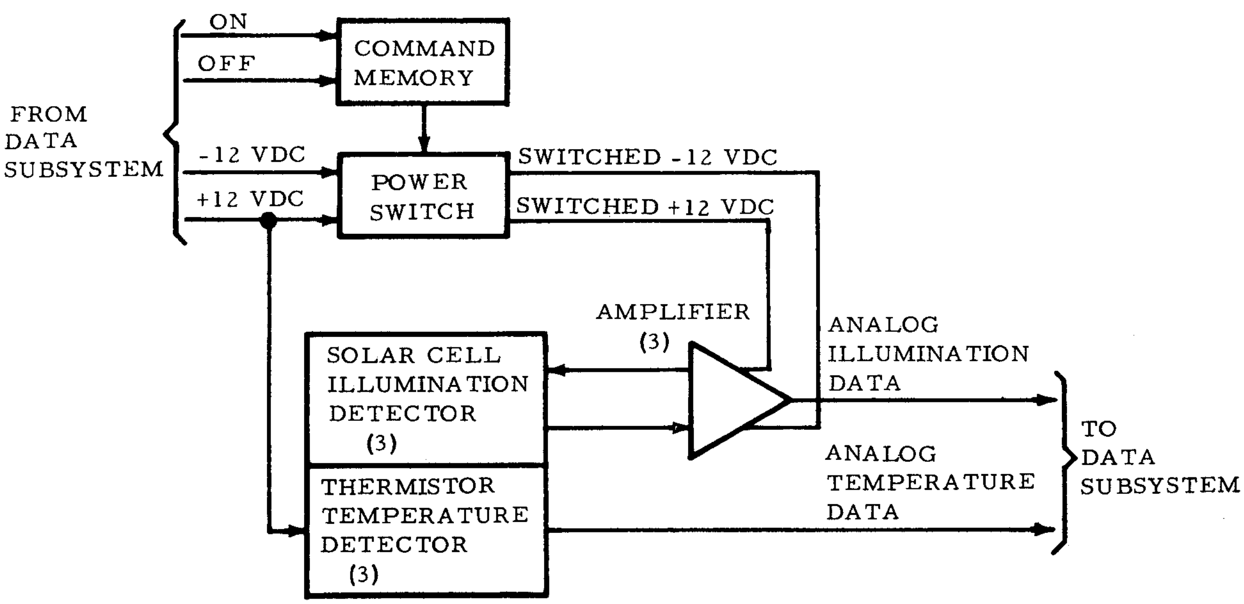


Figure 2-4. Dust Detector, Simplified Block Diagram

switches in accordance with the command. The two solid state switches control the application of +12 vdc and -12 vdc operating power from the data subsystem. Individual fusing protection is provided on each of the two voltages.

2-13. ELECTRICAL POWER SUBSYSTEM

The electrical power subsystem (EPS) provides power for lunar operation of the PSEP. Primary electrical power is developed by two solar panel arrays. Primary power at 16.2 ± 0.02 volts is supplied to the power conditioning unit (PCU). Voltage conversion circuits in the PCU convert the primary power to regulated and filtered operating voltages for the experiment and support subsystems.

2-14. EPS PHYSICAL DESCRIPTION

Major components of the electrical power subsystem are shown in Figure 2-5. The components are the solar panel array and power conditioning unit.

2-15. EPS Solar Panels. The solar panel array consists of six solar panels. Two solar panel assemblies of three panels each are attached to the primary structure by deployment linkages which erect the panels to the correct operational attitude of 60° with the horizontal lunar surface. Electrical cables connect the solar panels to the PCU. In the stored configuration, the outboard solar panels fold on the center panel, and are secured with front and rear supports.

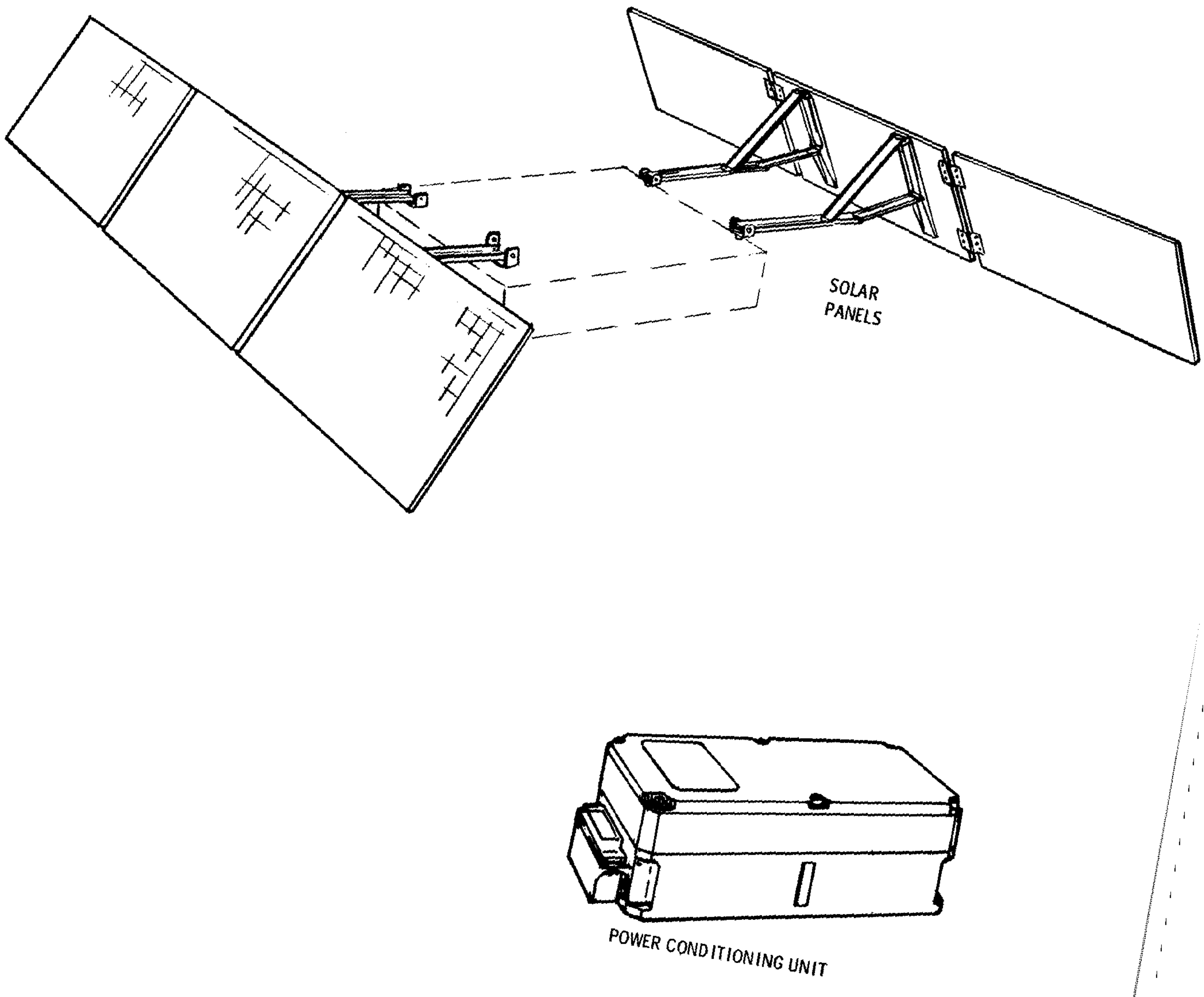


Figure 2-5. Electrical Power Subsystem

2-16. EPS Power Conditioning Unit (PCU). The functional elements of the PCU are redundant dc voltage converters and shunt regulators, filters, and two command control amplifiers. The elements are mounted on printed circuit boards and attached to the center and lower sections of the PCU case.

Shunt regulator load and dissipative elements are mounted in a power dissipation module external to the central station along the rear of the primary structure.

2-17. EPS Leading Particulars. The physical and electrical characteristics of the electrical power subsystem are given in Table 2-2.

2-18. EPS FUNCTIONAL DESCRIPTION

As shown in Figure 2-6, the solar panels supply primary power at 16 volts to the PCU. Voltage conversion circuits in the PCU convert the primary power to the six PSEP operating voltages. The PCU starts automatically when there is an output from the solar panels.

Commands CU-01 and CU-02 from the data subsystem signal control circuits to activate one of the other of the redundant converter-regulator circuits in the PCU.

Analog voltages from the PCU provide temperature, voltage, and current status to the data subsystem.

2-19. EPS DETAILED FUNCTIONAL DESCRIPTION

2-20. EPS Solar Panels. Operation of the solar panels is illustrated in the block diagram of Figure 2-7. Solar energy is converted to electrical power by the solar panel array. The electrical power produced by the solar panels provides 30 to 45 watts to the PCU.

Each solar panel is composed of 420 solar cells wired in a series parallel configuration to provide high reliability. Blocking diodes located on the back side of the center panels prevent reverse currents in the solar panels. There are three paralleled diodes in series with each solar panel to provide higher reliability by redundancy.

2-21. EPS Power Conditioning Unit. The power conditioning unit performs two major functions:

a. Voltage conversion
b. Voltage regulation

The PCU contains redundant power conditioners. As shown in Figure 2-8, each power conditioner consists of a dc-to-dc power converter (inverter and rectifiers), which converts the 16-volt input to the six operating voltages, and a shunt voltage regulator to maintain the output voltages within approximately ±1%. The input voltage is also regulated by this action because of the fixed ratio converter.

Table 2-2. Electrical Power Subsystem Leading Particulars

Component	Characteristic	Value
Solar Panels	Output Power	34 to 46 watts
	Output Voltage	16.0 ± 0.2 vdc
	Length (each panel)	23.75 inches
	Height (each panel)	13.0 inches
	Thickness (each panel)	0.375 inches
	Weight (Total, 6 panels)	12.24 pounds
	Solar Cells per panel	420 (2520 Total)
Power Conditioning Unit	Nominal Outputs	+29 vdc at 0.63 amps
		+15 vdc at 0.01 amp
		+12 vdc at 0.21 amp
		+5 vdc at 0.48 amp
		-6 vdc at 0.04 amp
		-12 vdc at 0.05 amp
	Output Voltage Regulation	±1 percent
	Length	8.36 inches
	Width	4.14 inches
	Height	2.94 inches
	Weight	4.5 pounds

The +16 volts from the solar panels is applied through the switching circuit to the selected dc-to-dc converter, applying power to the inverter and completing the shunt regulation circuit. Applying power to the inverter permits it to supply ac power to the rectifiers that develop the dc voltages applied to the filters. The outputs from the filters are the six operating voltages applied to the data subsystem power distribution unit. Output and input voltages are regulated by feedback from the +12 volt output to the shunt regulator.

The shunt regulator consists of amplifiers inside the power conditioning unit and resistors in the power dissipation module outside the central station. With the resistors outside the central station, some of the excess power is radiated to space and does not contribute heat to central station. Power dissipation resistance PDR 1 will dissipate 5 watts of power, and PDR 2 will dissipate 10 watts. The range of the regulators is 36 watts. All the output voltages are regulated by the 12-volt feedback since they are coupled in the output transformer. The +12 volt is applied to the switching circuit for determining over or under voltage and switching to the redundant inverter and regulator, if necessary.

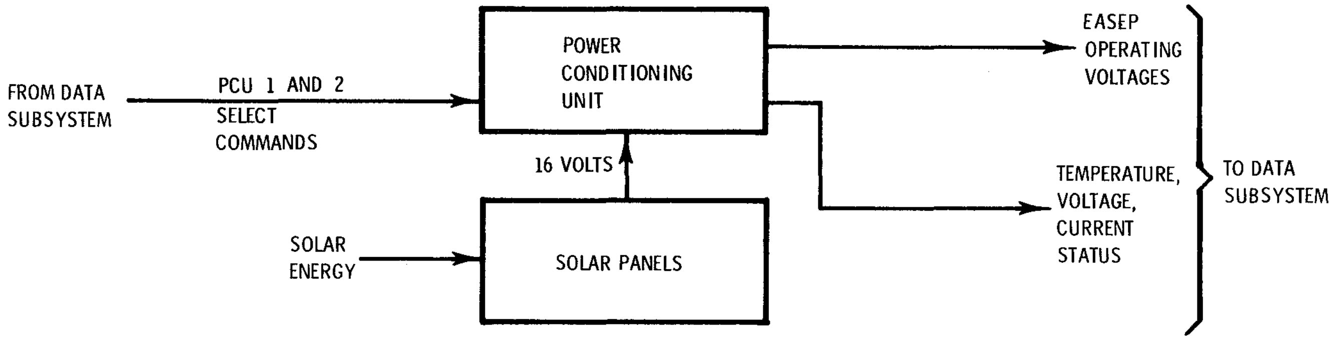


Figure 2-6. Electrical Power Subsystem, Functional Block Diagram

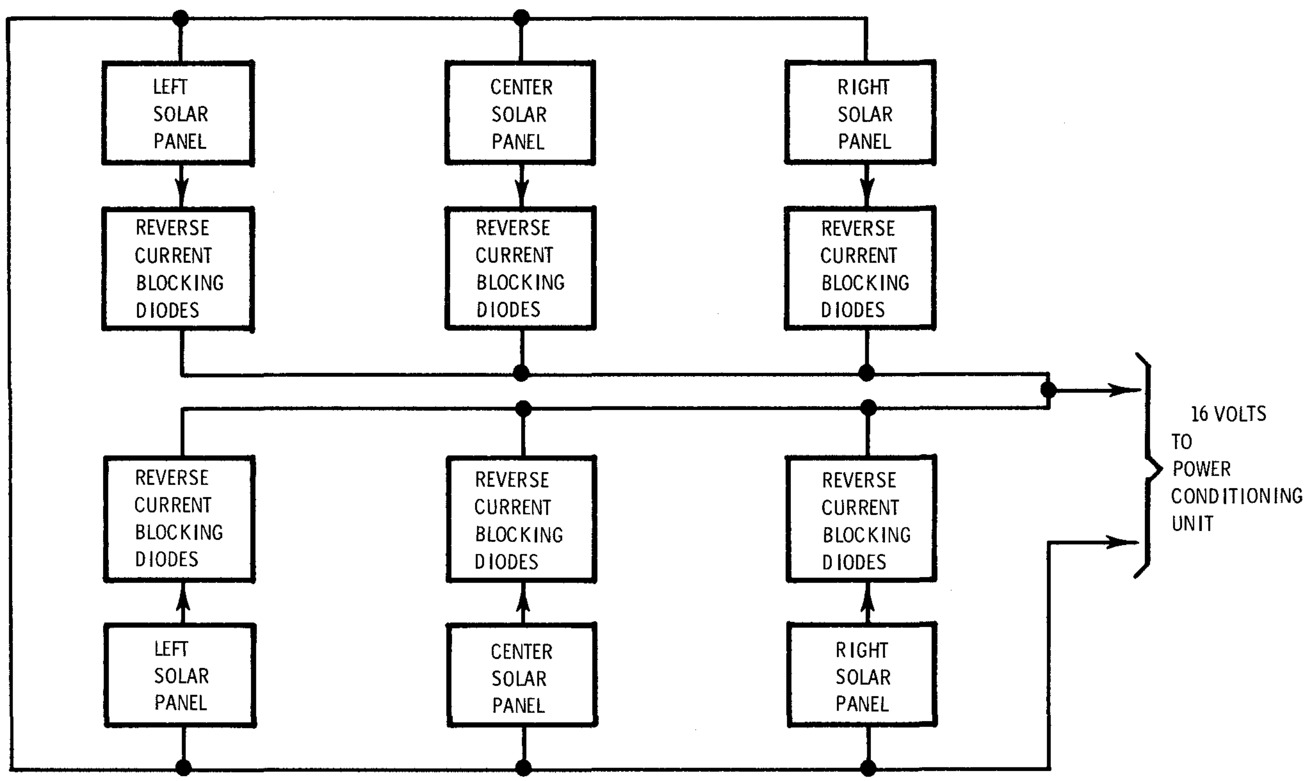
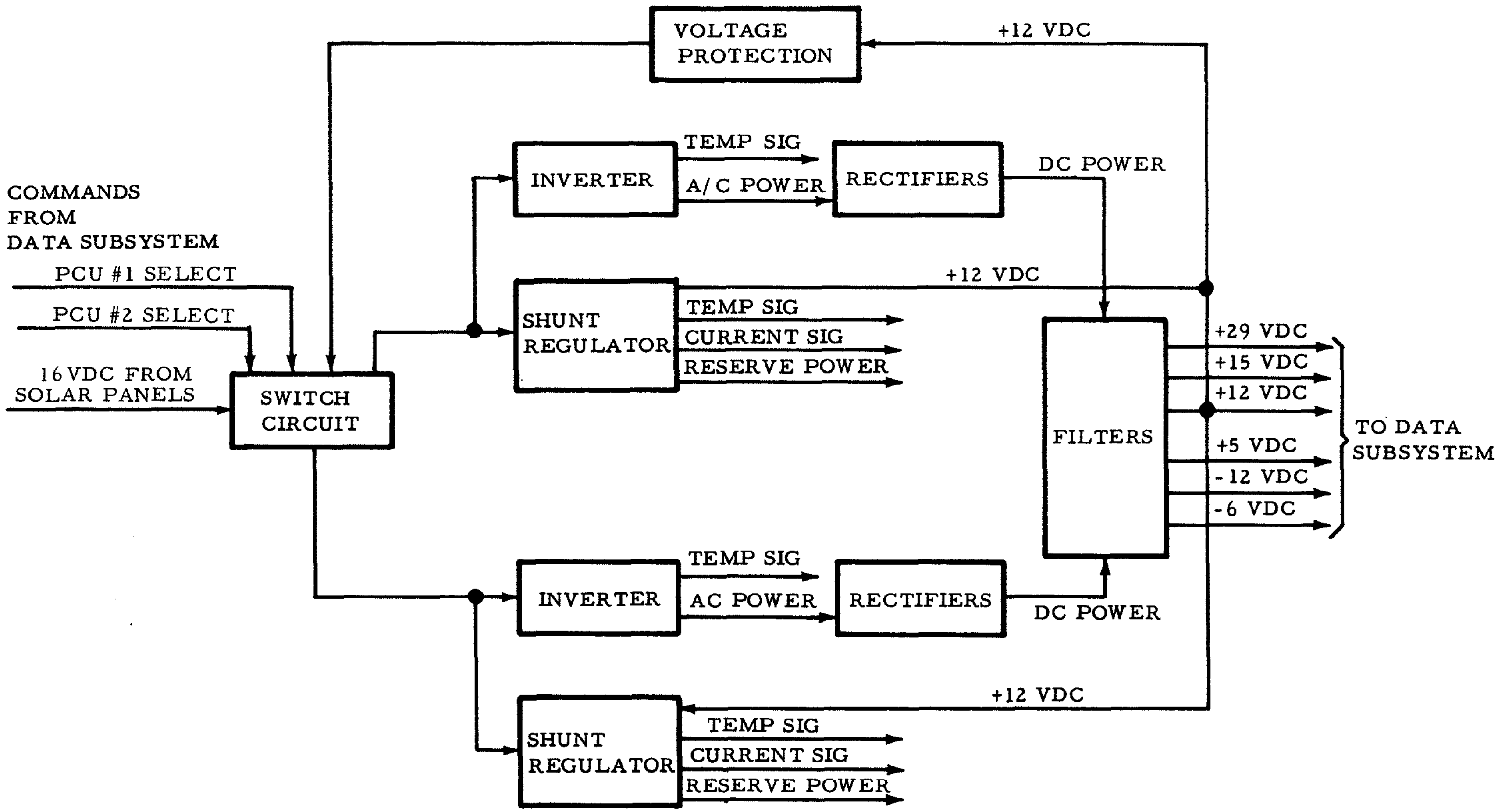


Figure 2-7. EPS Power Generation Function, Block Diagram

Separate filters for each of the six dc voltages are common to the conversion-regulation circuits. The filter outputs, +29, +15, +12, +5, -12, and -6 volts, are all applied to the data subsystem.

Analog voltages from the inverters provide temperature signals. Voltages from the shunt regulators provide current, reserve power, and temperature signals. The voltage at the input of the PCU is used as a reference in the reserve power measurement circuit. All of these analog signals are applied to the data subsystem for subcommutation into the telemetry frame.



NOTE: ANALOG TEMPERATURE AND POWER MEASUREMENT SIGNALS ARE APPLIED DIRECTLY TO THE DATA SUBSYSTEM.

Figure 2-8. EPS Power Regulation Function, Block Diagram

2-22. DATA SUBSYSTEM

The data subsystem is the focal point for control of the PSE sensor and the collection, processing and transmission of scientific data and engineering status data to the Manned Space Flight Network (MSFN). To accomplish the basic functions of (a) reception and decoding of uplink (Earth-to-Moon) commands, (b) timing and control of PSEP subsystems, and (c) the collection and transmission of downlink (Moon-to-Earth) scientific and engineering data, the data subsystem consists of an integration of units interconnected as shown in Figure 2-9. The uplink shown in Figure 2-9 requires the antenna, diplexer, command receiver, and command decoder components of the data subsystem. The downlink requires the data processor, transmitter, diplexer and antenna components. The major components of the data subsystem and associated functions are listed in Table 2-3.

2-23. DATA SUBSYSTEM PHYSICAL DESCRIPTION

The data subsystem components are mounted on a section of the central station thermal plate. Figure 2-10 shows data subsystem component location within the central station. A pre-formed harness electrically connects the components. The harness is attached to each component with a multipin connector. Power for each unit and electrical signals are conducted to and from each component via the harness. Coaxial cables connect the command receiver and transmitters to the diplexer switch and thence to the antenna. Other items installed within the central station include five central station temperature sensors.

The overall weight of the data subsystem is approximately 25 pounds and the power consumption is approximately 15 watts.

2-24. DATA SUBSYSTEM FUNCTIONAL DESCRIPTION

Uplink command data transmitted from the MSFN is received by the data subsystem antenna, routed through the diplexer, demodulated by the command receiver, decoded by the command decoder, and applied to the experiment and support subsystems as discrete commands. The discrete commands control experiment and support subsystem operations and initiate command verification functions.

Downlink data consists of analog and digital data inputs to the data processor from the experiment and support subsystems in response to periodic demands from the data processor. Scientific inputs to the data processor from the PSE subsystem are in digital form. Engineering data is usually analog and consists of status and housekeeping data such as temperatures and voltages which reflect operational status and environmental parameters. The data processor accepts binary and analog data from the experiment and support subsystems. It generates timing and synchronization signals, converts analog data to digital form, formats digital data, and provides data in the form of a split-phase modulated signal to the transmitter. The transmitter generates the downlink transmission carrier and phase

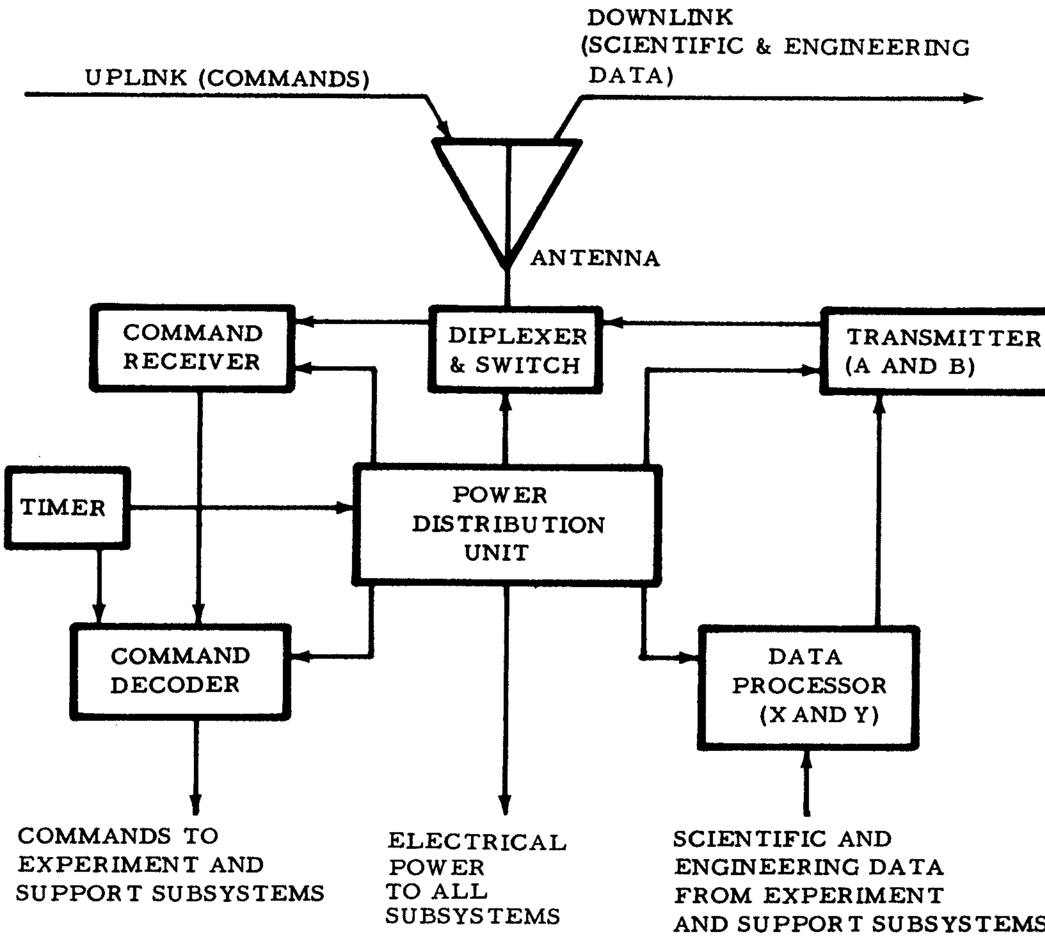


Figure 2-9. Data Subsystem, Simplified Block Diagram

modulates that carrier with the signal from the data processor. The transmitter signal is selected by the diplexer switch and routed to the antenna for downlink transmission to the MSFN.

Figure 2-11 shows a functional diagram of the data subsystem and its interfaces with the PSE subsystems. Redundant channels are provided for the transmitter and portions of the command decoder and data processor to improve system reliability.

The uplink transmission from MSFN is a 2119 MHz RF carrier with a 2 KHz data subcarrier modulated to a 1 KHz synchronizing subcarrier. The command receive receiver demodulates the carrier and provides the composite 2 KHz and 1 KHz subcarrier to the command decoder. The command decoder demodulator section detects the 2 KHz command data subcarrier and 1 KHz timing signal and applies both to the redundant digital decoder sections (A and B) of the command decoder. The digital decoder sections identify correct address codes, decode the digital data commands, issue command verification signals to the data processor, and apply command signals to the PSE and support subsystems.

Table 2-3. Data Subsystem Component Functions

Component	Function
Antenna	Provides simultaneous uplink reception and downlink transmission of PSEP signals.
Diplexer switch	Connects either transmitter to the antenna.
Diplexer filter	Connects receiver input and transmitter output to the antenna.
Transmitter	Generates Moon-to-Earth downlink signals.
Command receiver	Accepts Earth-to-Moon uplink signal.
Command decoder	Decodes received command signals and issues commands to the system.
Central station timer	Provides backup timing signals following departure of astronauts. Switch transmitter off after 720 days ± 30 days.
Data processor	Collects and formats scientific data inputs from the experiments. Collects and converts analog housekeeping data into binary form.
Power distribution	Controls power switching and conditions engineering status data.

The central station timer provides timing signals to the command decoder delayed command sequencer which are used to initiate a series of delayed commands to activate certain system operations. The specific functions of the delayed commands are discussed in the detailed command decoder paragraph.

Analog signals from the experiment and support subsystems are applied directly to the analog multiplexer or indirectly through the signal conditioning section of the power distribution unit to the analog multiplexer. The 90-channel analog multiplexer processes the analog inputs and applies them to the inputs of redundant analog-to-digital converters (X and Y). The digital outputs from the analog-to-digital converters are applied to redundant digital data processors (X and Y) along with digital data from the command decoder and the experiment subsystems.

The digital data processor generates timing and control signals for use throughout the system and formats the scientific and engineering data from the experiment and support subsystems for downlink transmission. Redundant transmitters (A and B) receive the PCM signal from the data processors. A diplexer switch connects the transmitter in use to the antenna for downlink transmission to Earth.

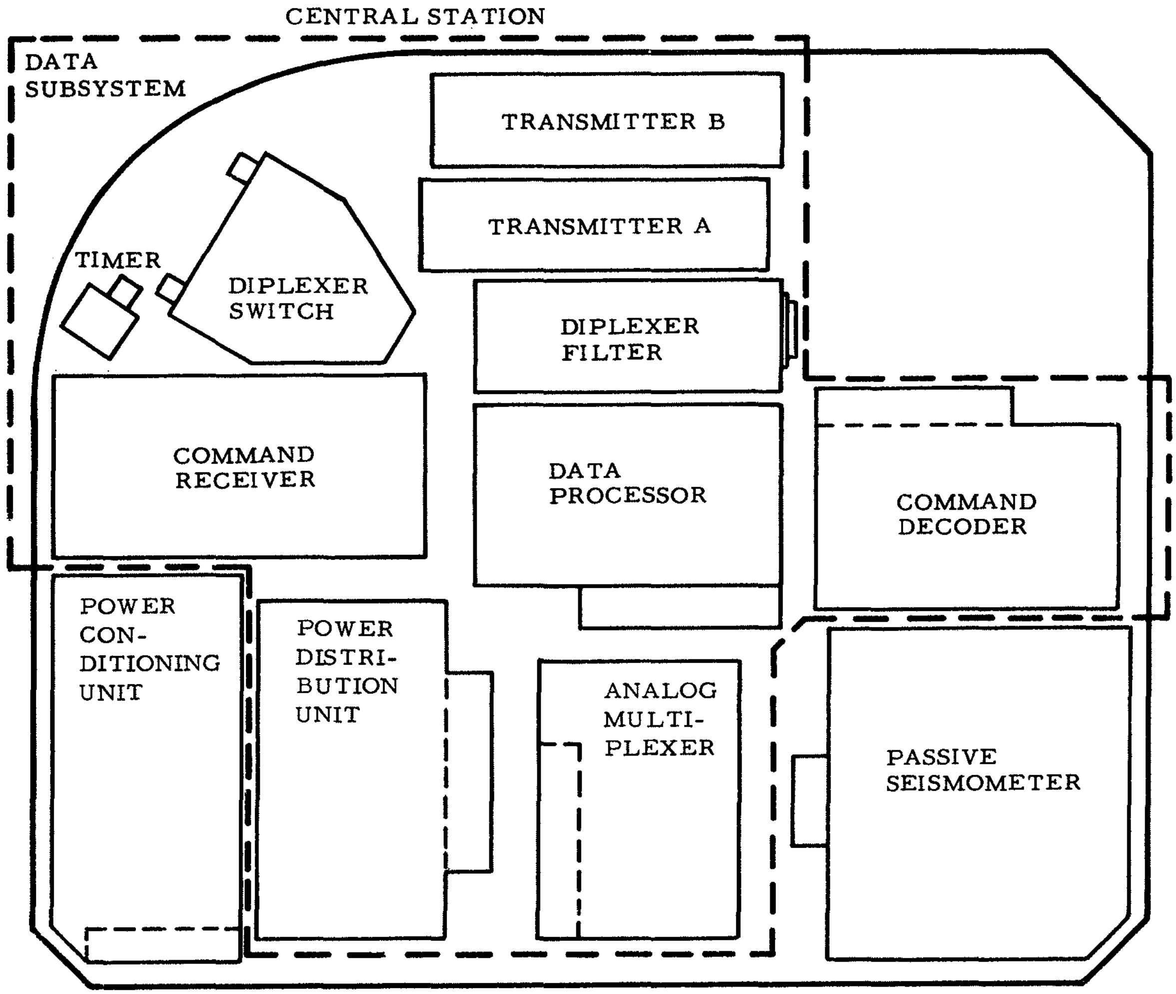


Figure 2-10. Data Subsystem Component Location

2-25. ANTENNA DESCRIPTION

The antenna is a modified axial helix designed to receive and transmit a right-hand circularly polarized S-Band signal. This antenna type was selected because it has a relatively high gain over a moderately narrow beamwidth.

2-26. Antenna Physical Description. The antenna consists of a copper conductor bonded to a fiberglass-epoxy tube for mechanical support. Figure 2-12 shows the antenna. The helix is 23 inches in length and 1-1/2 inches in diameter. A 5-inch ground plane with a 2-inch-wide cylindrical skirt is attached to one end of the helix and functions as a wave launcher for the electromagnetic wave in the transition from coaxial transmission line mode to the helix mode. An impedance matching transformer is located at the antenna feed point to match the higher impedance of the helical antenna to the 50-ohm coaxial transmission line. The weight of the antenna, including cables, is 1.28 pounds.

The entire antenna is coated with a white, reflecting thermal paint for thermal protection during the high temperature range of lunar day. Antenna leading particulars are listed in Table 2-4.

Antenna gain is referenced to a right hand circularly polarized isotropic level and does not include coaxial cable loss which is typically 1.1 db.

Table 2-4. Antenna Leading Particulars

Characteristic	Transmit	Receive
Gain		
on boresight	16.0 db	15.2 db
beamwidth at 11.0 db gain		36°
beamwidth at 11.5 db gain	33°	
Axial ratio	1.3 db	1.0 db
Input VSWR	1.20:1	1.20:1
Sidelobe level	-11 db	-11.3 db

2-27. Antenna Functional Description. The antenna receives command signals from Earth on a frequency of 2119 MHz and transmits telemetry data on the frequency of 2276.5 MHz. Antenna gain is in the order of 15.2 db and the beamwidth is sufficiently broad to cover the Earth at all times.

2-28. Antenna Positioning Mechanism - The antenna will be pointed to Earth by means of the antenna positioning mechanism. Elevation angle of the antenna depends on the lunar site selected. The antenna is manually positioned to the appropriate elevation angle corresponding to any one of five lunar sites. Detents on the index plate retain the position selected. Antenna position is indicated by the index pointer and site-numbered marks on the index plate.

2-29. DATA SUBSYSTEM DIPLEXER

The diplexer consists of the diplexer filter and the diplexer circulator switch.

2-30. Data Subsystem Diplexer Physical Description. The diplexer filter and circulator switch are shown in Figures 2-13 and 2-14, respectively. Figure 2-15 shows a diagram of the circulator switch. The diplexer filter contains a transmit frequency bandpass filter, a receiver frequency bandpass filter and a common path antenna lowpass filter. The three filters are coupled at a common junction at the end opposite the circulator switch, receiver, and antenna ports. The input and output connectors are miniature, coaxial, right-angle connectors made of gold-plated stainless steel. Matching impedance for the antenna, transmit and receive connectors is 50 ohms. Leading particulars of the diplexer filter are listed in Table 2-5.

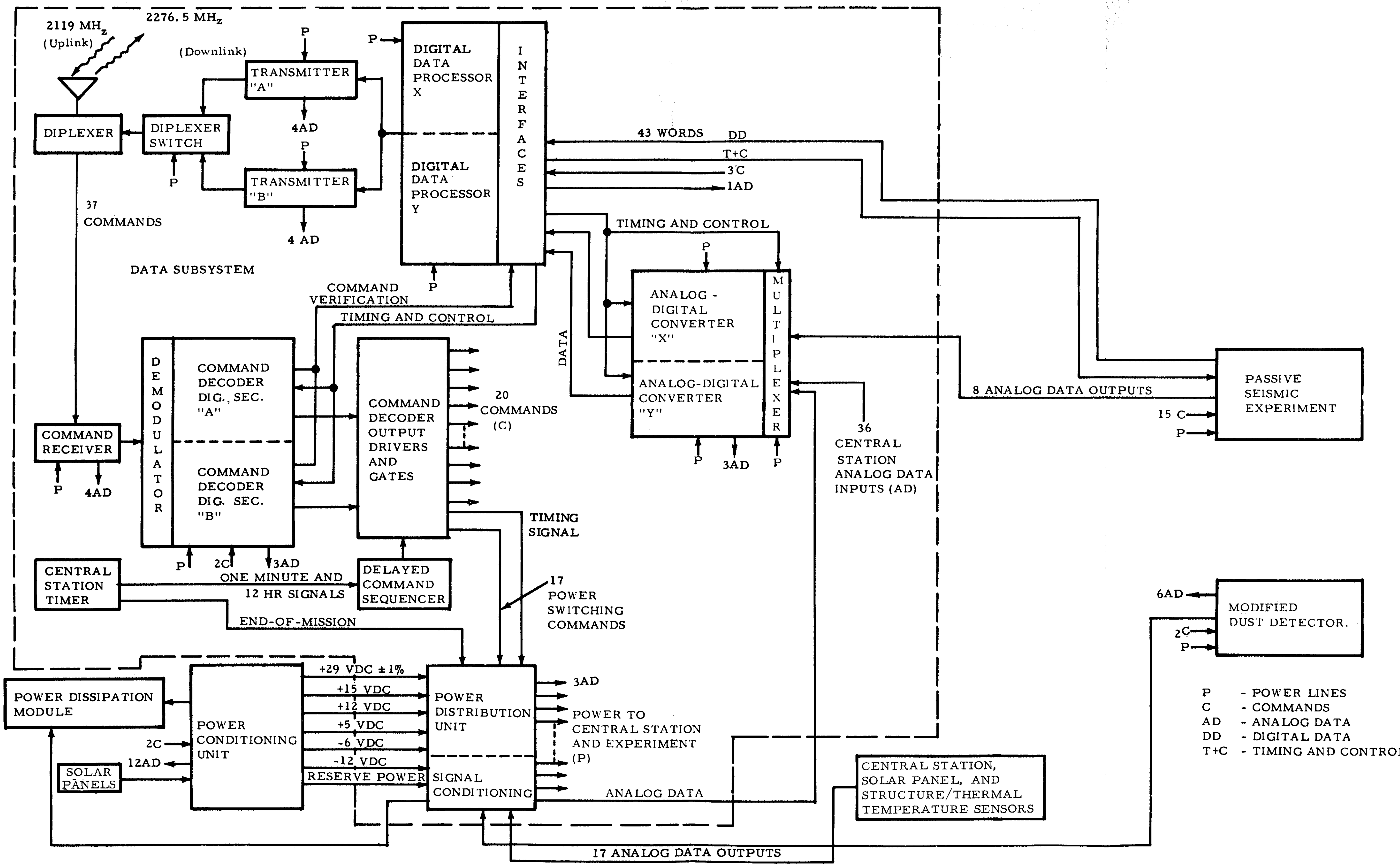
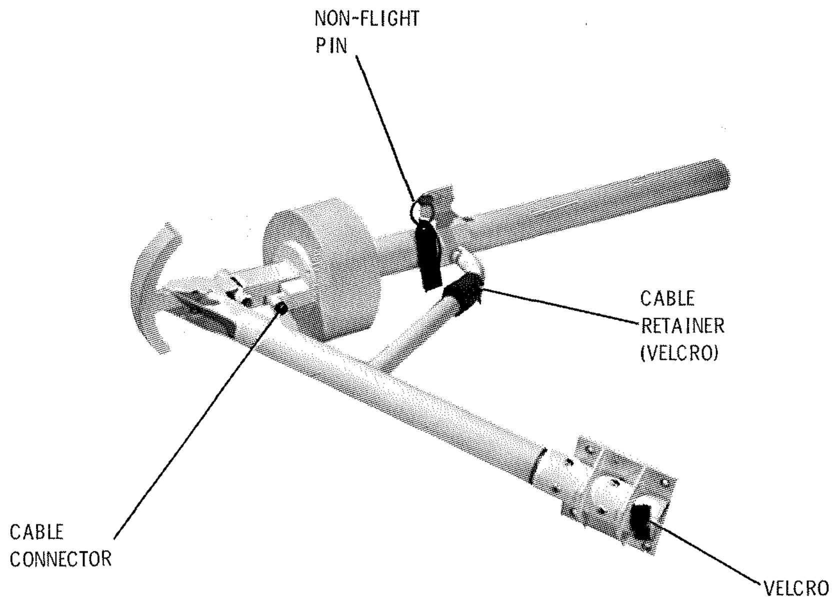


Figure 2-11. Data Subsystem Functional Block Diagram



(KSC HANDLING MODEL)

Figure 2-12. Antenna and Positioning Mechanism

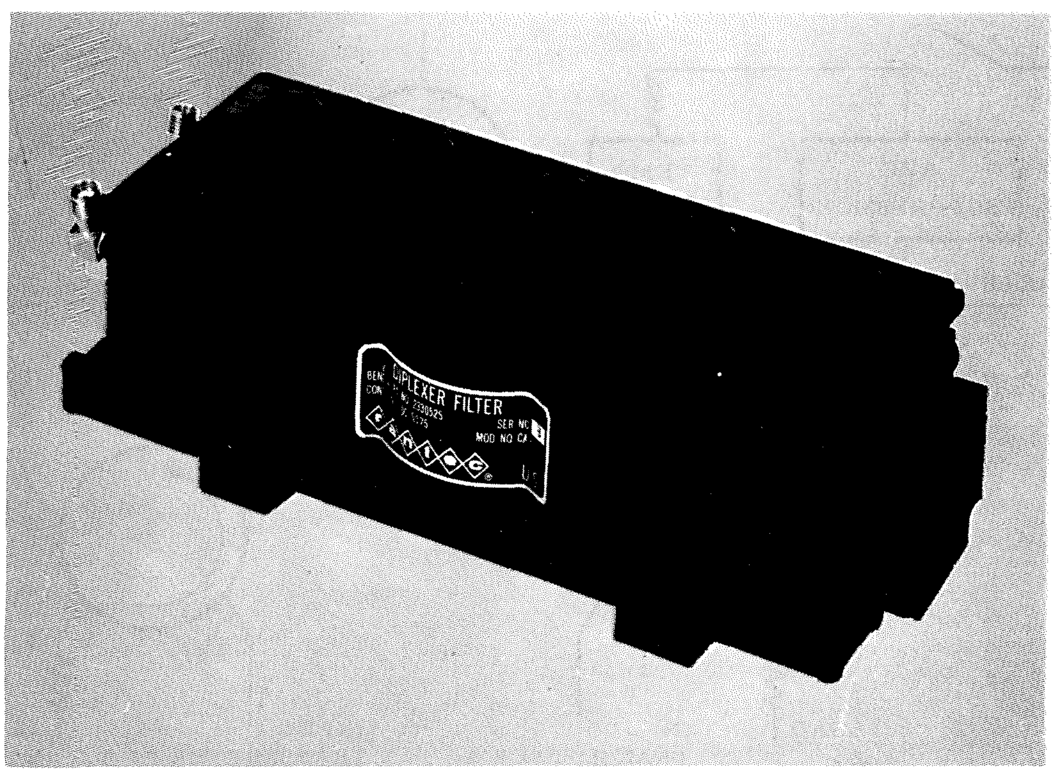


Figure 2-13. Data Subsystem Diplexer Filter

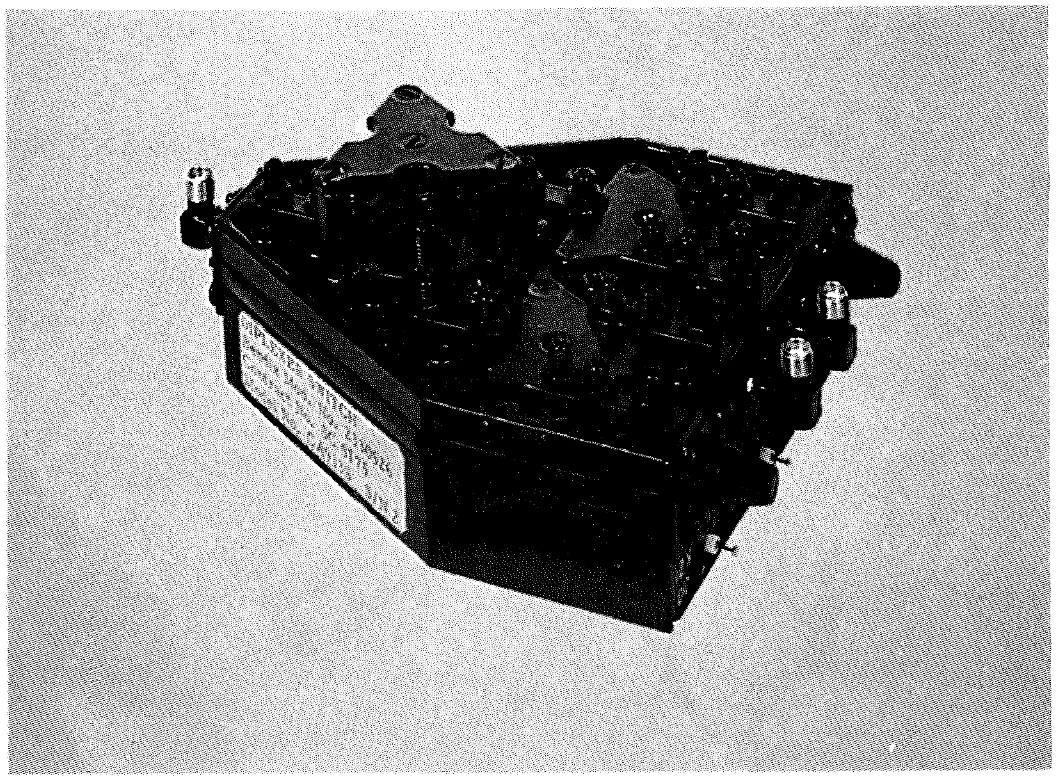


Figure 2-14. Data Subsystem Diplexer Switch

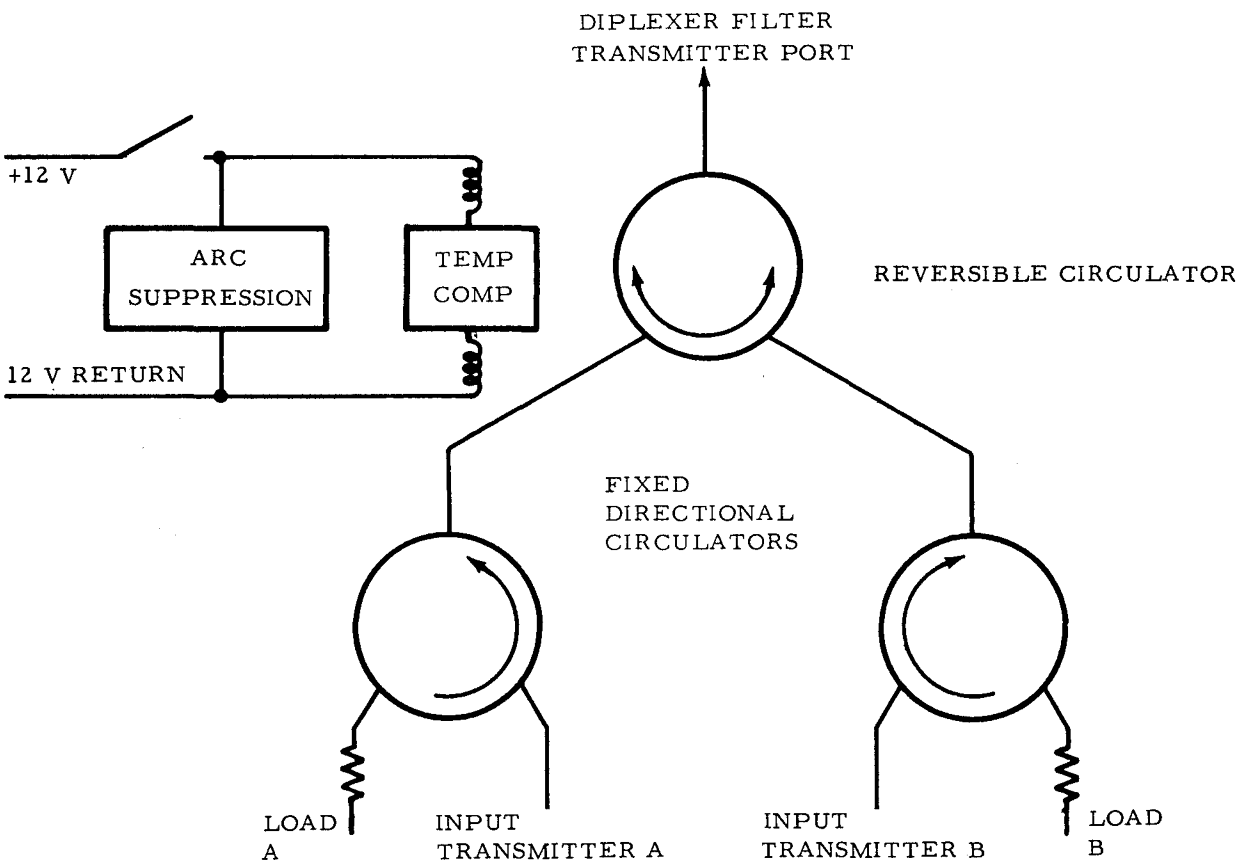


Figure 2-15. Data Subsystem Diplexer Switch Diagram

Table 2-5. Data Subsystem Diplexer Filter Leading Particulars

Characteristic	Value
Receiver path (includes band-pass and low-pass filter)	
Insertion loss	1.30 db
VSWR	1.10:1
Center frequency	2119 MHz
Max 3 db bandwidth	11.0 MHz
Min 3 db bandwidth	11.0 MHz
Transmitter path (includes band-pass and low-pass filter)	
Insertion loss	0.70 db
VSWR	1.10:1
Center frequency	2275-2280 MHz
Max 3 db bandwidth	45 MHz
Min 3 db bandwidth	4.5 MHz
Power handling capability	20.0 watts
Weight	0.9 pounds
Form factor	6.8 x 2.5 x 2.5 inches

The diplexer switch consists of three circulators, two loads, and three external ports. The circulator uses copper-clad dielectric board stripline techniques. The input and output connectors consist of three right angle connectors; one for the interconnecting line to the diplexer filter section, and one each to the two transmitters. Two solder terminals are provided for the ±12 volt switching power. Leading particulars of the diplexer switch are listed in Table 2-6.

Table 2-6. Data Subsystem Diplexer Switch Leading Particulars

Characteristic	Value
Insertion loss	0.5 db
VSWR	1.14:1
Center frequency	
Isolation for 3 db bandwidth (4 MHz)	30-40 db
Switching voltage	12 vdc
DC power (position B)	150 MW
DC power (position A)	0
Switching time	120 milliseconds
RF power capability	1.5 watts
Weight	1.28 pounds
Stray magnetic field (steady-state)	10 gamma at 3 feet
Form factor	4 x 4.5 x 1.3 inches

2-31. Data Subsystem Diplexer Functional Description. The bandpass filter for the transmit and receive arms of the diplexer filter consist of five elements coupled to provide the attenuation required at the transmit frequencies, receive frequencies, image, and local oscillator and transmitter spurious frequencies. The low-pass filter is an unbalanced ladder filter intended to augment the transmitter bandpass filter in suppressing the above-center-frequency spurious transmitter outputs. The diplexer circulator switch assembly couples the selected transmitter (A or B) through the diplexer filter assembly to the antenna. The switch also provides isolation protection to the transmitters and connecting equipment from opens, shorts, or simultaneous transmitter antenna feed. The circulator switch is reversible to serve as a transmitter selector switch and requires a +12 vdc signal to switch the back-up transmitter into operation.

2-32. DATA SUBSYSTEM COMMAND RECEIVER

The command receiver demodulates the 2119 MHz phase-modulated uplink carrier transmitted from MSFN, provides a combined bi-phase modulated 2 KHz data subcarrier and 1 KHz synchronizing subcarrier to the command decoder, and supplies analog status data to the data processor.

2-33. Data Subsystem Command Receiver Physical Description. Figure 2-16 shows the command receiver. The command receiver contains foam-potted individually shielded circuit modules mounted on a milled magnesium base plate. Module interconnections are routed through channels milled into the base plate. Receiver leading particulars are listed in Table 2-7.

2-34. Data Subsystem Command Receiver Functional Description. Figure 2-17 shows a detailed block diagram of the command receiver. The 2119 MHz phase-modulated uplink carrier is received by the central station antenna, coupled through the diplexer, and applied to the command receiver mixer. The input signal is mixed with a crystal controlled 2059 MHz local oscillator signal to produce a 60 MHz intermediate frequency signal. Two local oscillator/driver amplifier circuits are used to provide redundant operation. The oscillator/driver amplifier output frequency of 128.7 MHz is increased to 2059 MHz by a multiply-by-16 frequency multiplier. The two 2059 MHz signals from the frequency multipliers are applied to a stripline hybrid which is the redundancy combiner for the redundant local oscillators. From the hybrid, the 2059 MHz local oscillator frequency is applied to the mixer.

The level sensor and local oscillator switch circuits determine which local oscillator provides the local oscillator signal. Mixer circuit diodes apply bias voltage to an amplifier which controls an integrated circuit flip-flop. When the bias voltage falls below an acceptable threshold, the amplifier causes the flip-flop to change state. The flip-flop change of state deenergizes one local oscillator chain and energizes the redundant local oscillator chain. Adequate time delays are provided to prevent switching during receiver turn-on and signal transients.

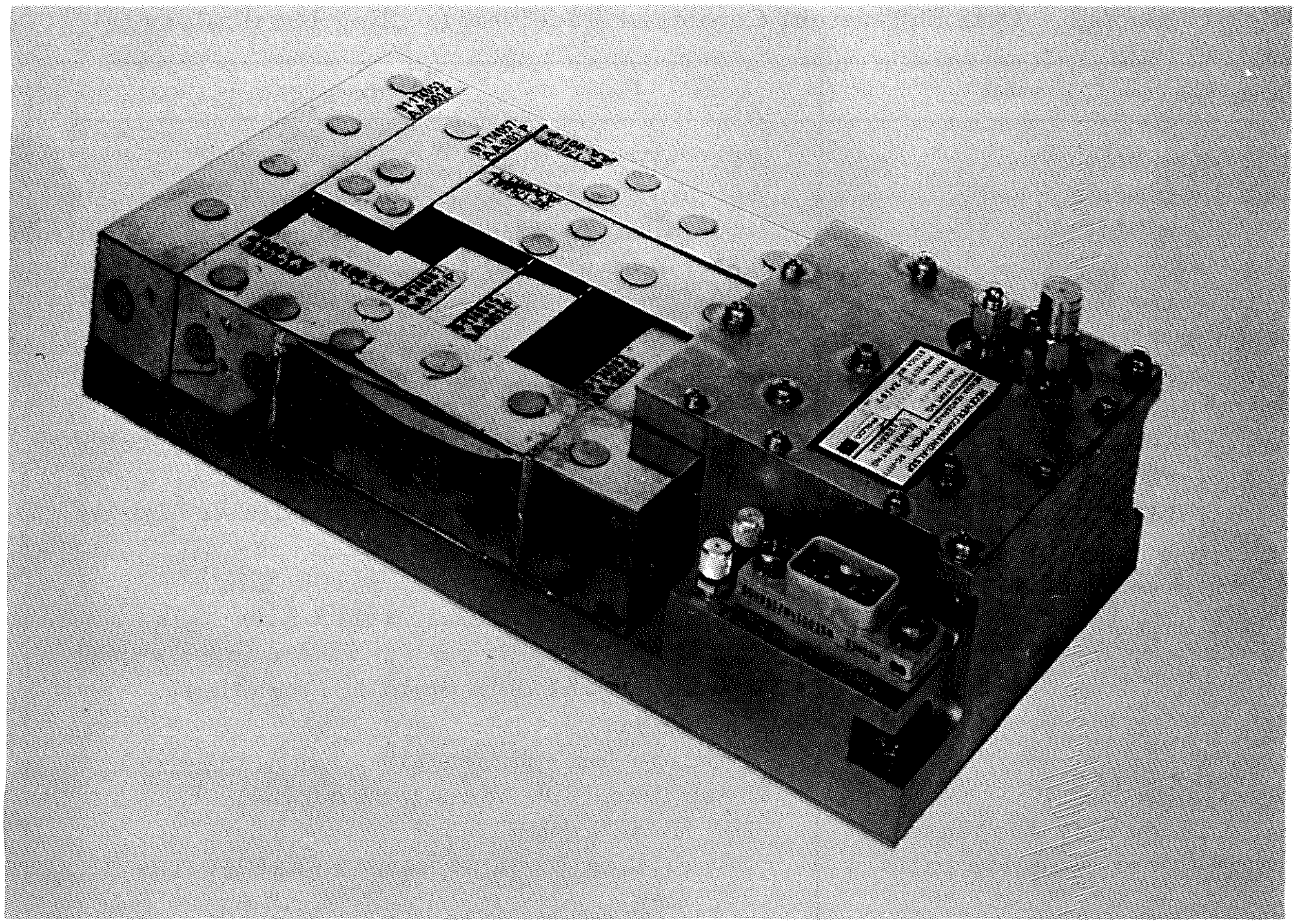


Figure 2-16. Data Subsystem Command Receiver

The 60 MHz IF signal from the mixer is amplified in the IF preamplifier and filter module and in the IF amplifier module before being applied to the amplifier and discriminator module. The discriminator is a double tuned diode discriminator which provides FM detection. The integrator circuit in the output amplifier and integrator module provides phase detection of the FM detected signal. The output signal from the command receiver is a combined 2 KHz data subcarrier and a 1 KHz synchronization subcarrier which is applied to the command decoder. Receiver output characteristics are shown in Figure 2-18.

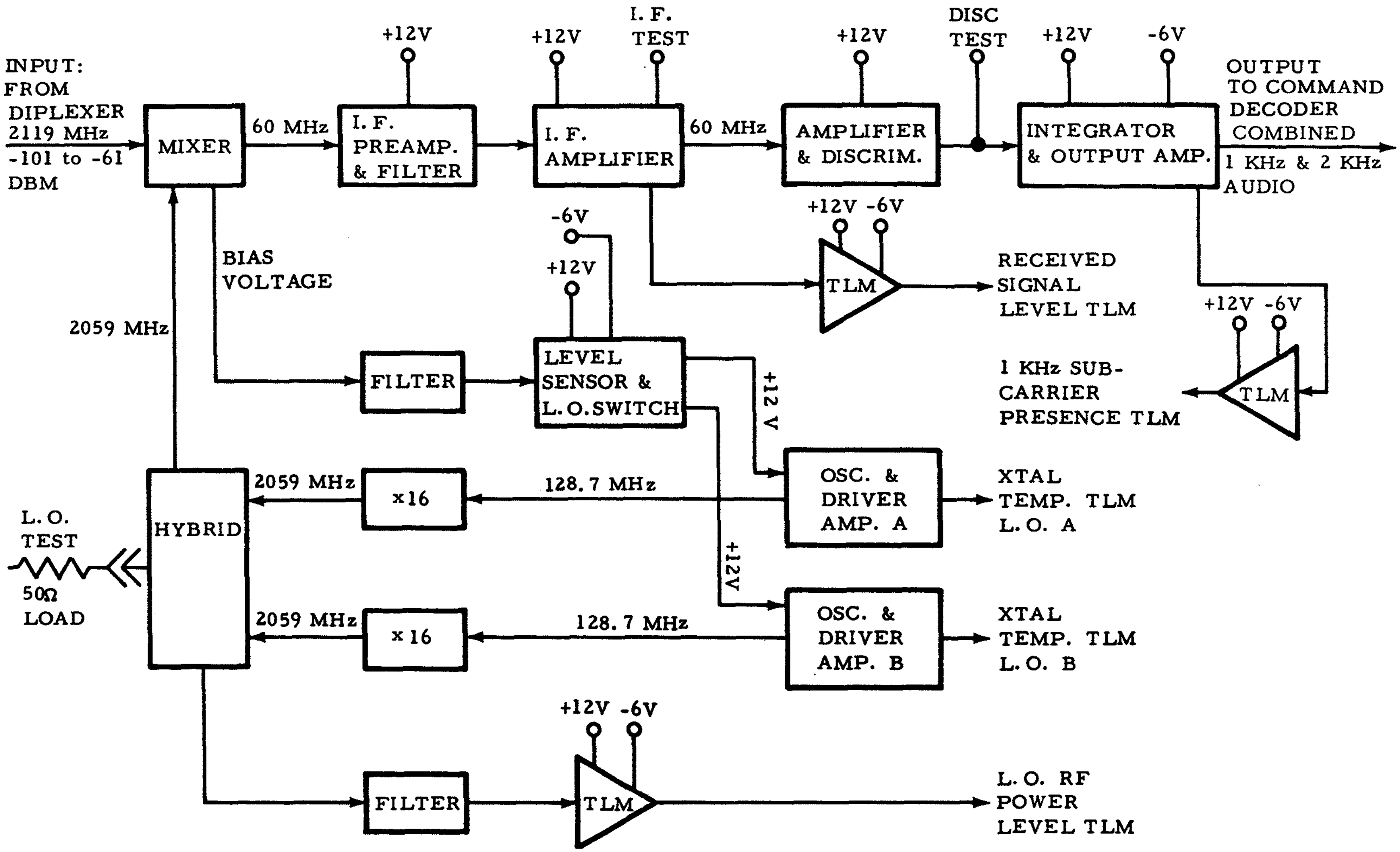
Monitoring circuits provide telemetry data to the data processor on the status of: the received signal level, local oscillators A and B crystal temperatures, the local oscillator RF power level, and the presence of the 1 KHz subcarrier.

2-35 DATA SUBSYSTEM COMMAND DECODER

The command decoder receives the combined 2 KHz command data subcarrier and 1 KHz synchronization signal from the command receiver, demodulates the

Table 2-7. Data Subsystem Command Receiver Leading Particulars

Characteristic	Value
Input frequency	2119 MHz ± .001%
Input impedance	50 ohms at 2119 MHz
Input signal level	-101 dbm to -61 dbm
Input VSWR	1.5:1 max at 2119 MHz ± 1 MHz 2.0:1 max at 2119 MHz ± 10 MHz
Noise figure	10 db max
Local oscillator frequency	2059 MHz ± .0025%/year
Intermediate frequency	60 MHz
IF 3 db bandwidth	350 KHz max for input signals near threshold (-100 dbm)
IF rejection	60 db min at 3.4 MHz for signals as high as -50 dbm
Demodulation linearity	Better than ±5.0% at f_o ± 100 KHz Better than ±10% at f_o ± 175 KHz
Audio output level	0.8 volt per radian ± 12.5% for input signals of -101 to -61 dbm up to ±3.0 radians deviation
Output polarity	+voltage for +phase shift
Output impedance	Less than 1000 ohms (ac coupled)
Output frequency response	100 Hz to 5 KHz
Output signal-to-noise ratio	Better than 15 db at input signal level of -97 dbm
Supply voltages	+12 vdc ±1%, -6 vdc ±1%
Supply power	1.32 watts maximum (1.25 watts nominal = 0.15 w @-6 v + 1.1 watts @12 v)
Telemetry outputs	(2.5 vdc nominal, 5 vdc max) a) Crystal temperature for local oscillator A ON-OFF b) Crystal temperature for local oscillator B ON-OFF c) Local oscillator RF power level d) IF pre-limiting signal level (input signal level) e) 1 KHz subcarrier presence
Test points	a) Local oscillator RF output (local oscillator frequency) b) Pre-limiting IF output (bandpass and noise figure) c) Discriminator output (demodulation linearly)
Weight	1.84 pounds
Form factor	8.0 x 4.0 inches mounting surface by 1.75 inches in height exclusive of connectors



NOTE: 1 POWER SUPPLIED FROM POWER DISTRIBUTION UNIT AT + 12 VDC and -6 VDC.

2 ENGINEERING STATUS TELEMETRY SIGNALS TO DATA PROCESSOR

Figure 2-17. Data Subsystem Command Receiver Block Diagram

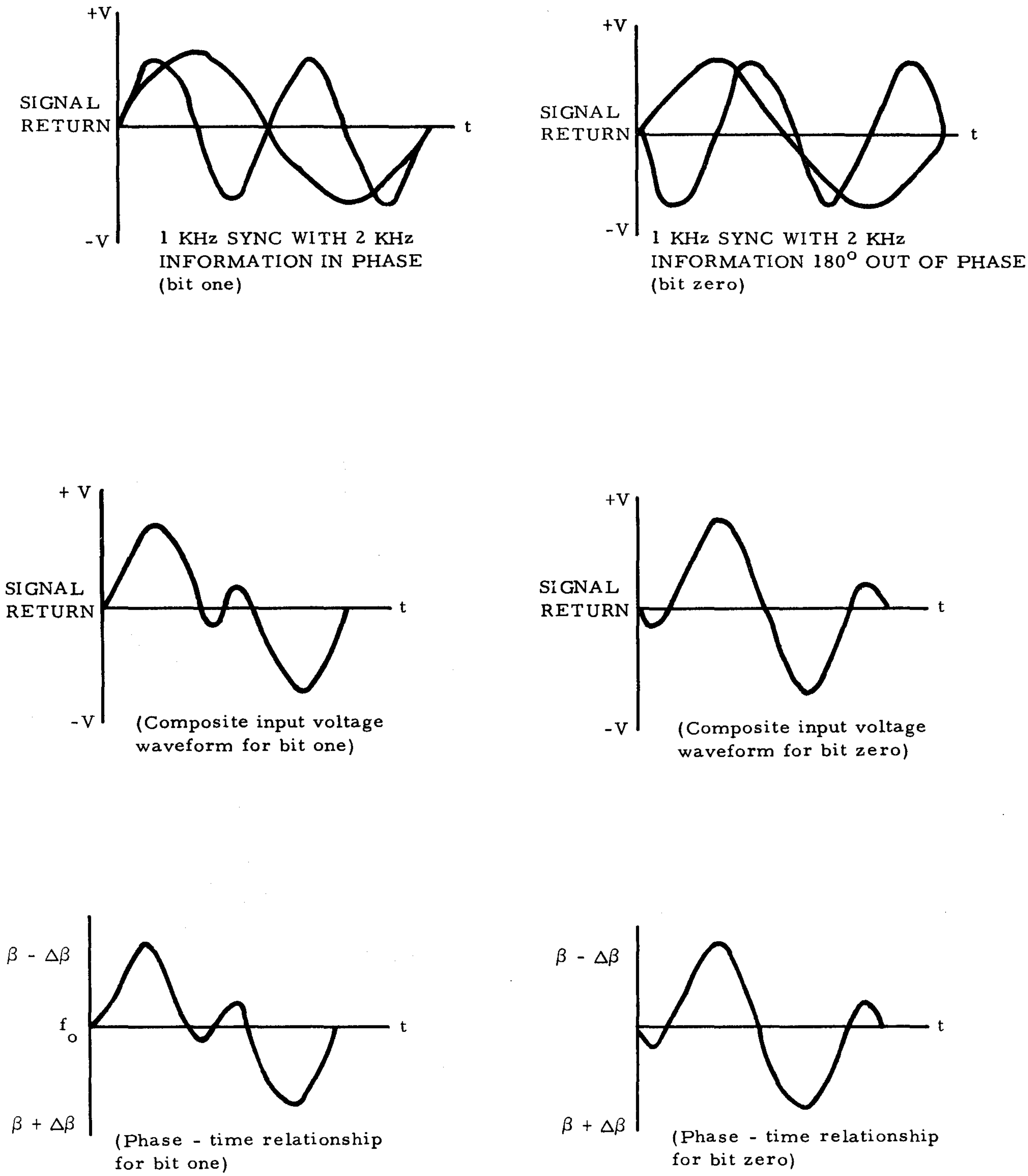


Figure 2-18. Data Subsystem Command Receiver
Output Signal Characteristics

subcarrier to provide digital timing and command data, decodes the command data, and applies the discrete commands required to control PSEP operations.

2-36. <u>Data Subsystem Command Decoder Physical Description.</u> Figure 2-19 shows the command decoder. Multilayer printed circuit boards are used throughout the command decoder. The unit contains four 12-layer boards, four six-layer boards, one three-layer board, and one two-layer board. Leading particulars of the command decoder are listed in Table 2-8.

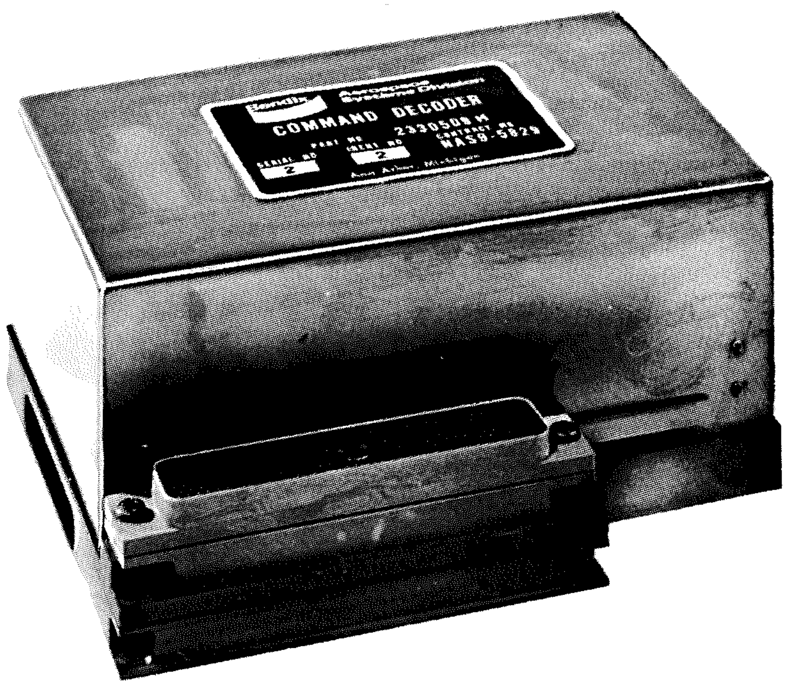


Figure 2-19. Data Subsystem Command Decoder

Table 2-8. Data Subsystem Command Decoder Leading Particulars

Characteristic	Value
Height	2.8 inches
Width	4.81 inches
Length	6.25 inches
Weight	2.7 pounds
Power consumption	less than 1.4 watts

2-37. <u>Data Subsystem Command Decoder Functional Description</u>. The command decoder consists of a demodulator section and digital decoder sections. Figure 2-20 is a functional block diagram of the command decoder.

The demodulator accepts the composite audio subcarrier from the command receiver. The composite audio subcarrier is the linear sum of the data and synchronization subcarriers, where the 2 KHz data subcarrier is bi-phase modulated by a 1000 bit per second data stream and the synchronization signal is a 1 KHz subcarrier. The demodulator is divided into three sections; the sync detection section, the data detection section, and the threshold detection section.

A voltage controlled oscillator phase-lock-loop in the sync detection section establishes bit synchronization by comparing the 1 KHz input with a 1 KHz reference signal. The filtered sync phase detector output is used to control the operation of the oscillator. This technique establishes phase lock-on within 18 milliseconds after the audio input is applied. Synchronized 1 KHz, 2 KHz and 4 KHz signals are applied to the digital section for sub-bit timing purposes. Each one-millisecond timing interval can be partitioned into eight parts.

Data detection and extraction is accomplished in the data detection section by comparing the 2 KHz audio input with a synchronized 2 KHz reference signal. The data phase detector output is fed to an integrator and dumped at a 1 KHz repetition rate. Mark or space decisions are stored in the data flip-flop.

The threshold function indicates sync carrier and local oscillator phase-loc, and enables the output of valid data. It uses a threshold phase detector, an integrator and a Schmitt trigger circuit. A threshold decision is made within 20 milliseconds after the audio input is applied.

The digital section of the command decoder consists of a decoder controller, a decoder programmer with an address detector gate, an address memory flip-flop, parity check circuitry, an eight-stage shift register, 100 command decoding gates, and a delayed command sequencer.

To improve the reliability of the digital logic, redundant subsections provide an alternate path to decode a command message. These redundant subsections are referred to as A and B. Each of the subsections functions identically, but the address gates respond to different address information. To further improve the reliability, the delayed command sequencer provides limited means of generating commands in the event of an uplink failure.

Figure 2-21 illustrates the functional flow chart of the command decoder and depicts the complete routines and subroutines from initiation through reset cycle.

In the normal (non-active seismic) mode, the serial data enters shift registers A and B, and continually shifts through these registers. The decoder remains in this search mode until a valid address has been detected by either one of the address gates. For example, if address gate A detects a valid address code in shift register A, it immediately sets address memory flip-flop A which simultaneously starts decoder programmer A and inhibits address gate B from responding. After seven timing periods, programmer A activates parity comparator A which

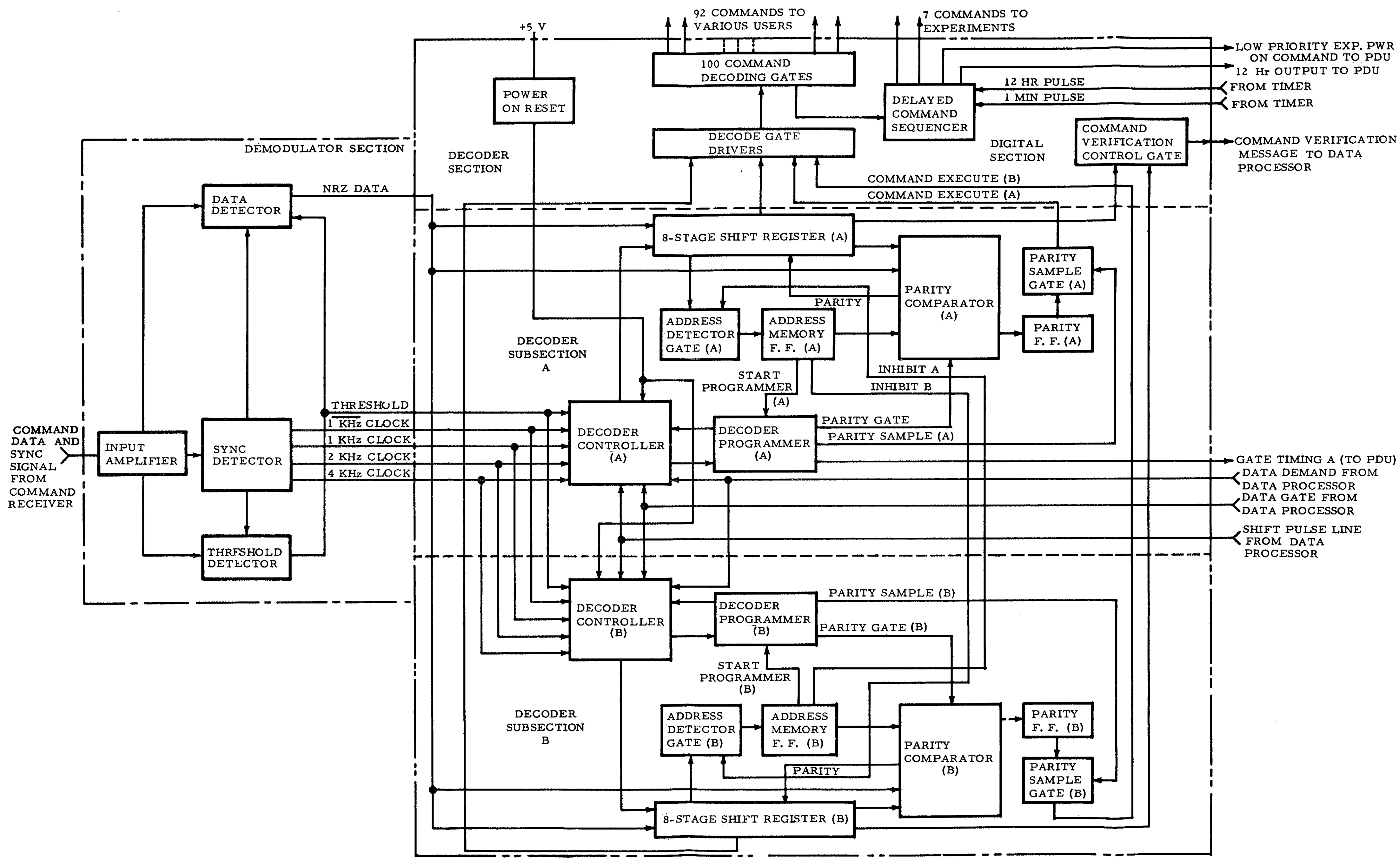


Figure 2-20. Data Subsystem Command Decoder, Functional Block Diagram

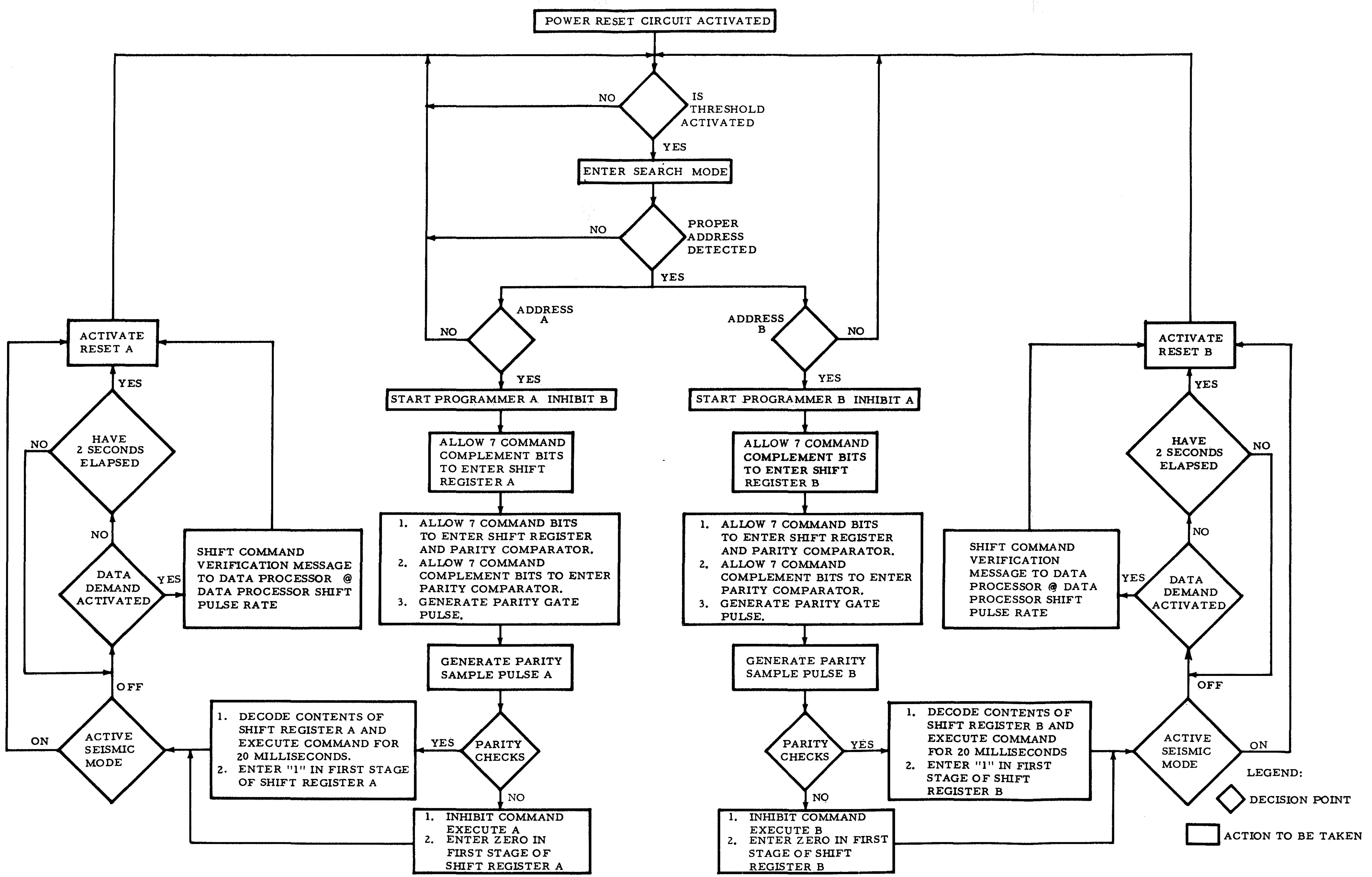


Figure 2-21. Data Subsystem Command Decoder Flow Diagram

performs a bit-by-bit comparison of the seven command and seven command complement bits. At the end of this comparison, a parity check takes place. If correct, the appropriate command decode gate is activated for 20 milliseconds and a command execute pulse sets the first stage of shift register A to a one. This signifies that a proper command has been received. If parity does not check, the command is inhibited and the first stage of shift register A is set to a zero.

Normally at this time, shift register A contains the seven bit command and the parity information. This information, named the command verification message, stays in the register until the data processor requests transfer (data demand) of this data. As soon as the transfer takes place, a master reset signal returns the command decoder to the search mode. Likewise, the command verification message is inhibited if the data demand is not activated during the following two-second timing interval.

In contrast to the normal mode of operation, the active seismic mode inhibits the command verification message from reaching the data processor. The command decoder receives an active seismic ON command to operate in this mode and an active seismic OFF command to operate in the normal mode. The foregoing description applies equally to subsection B whenever address gate B detects its own address.

2-38. Data Commands - Commands are transmitted as a 61-bit message with the following format:

a.	Preamble	20 bit minimum (all zeros or all ones for synchronization)
b.	Decoder address	7 bits (selects decoder subsection)
c.	Command complement	7 bits (for parity check)
d.	Command	7 bits
e.	Timing	20 bits (all zeros or all ones - command execution interval)

The demodulator section achieves phase and bit synchronization during the first eighteen timing bits of the preamble and maintains synchronization during the entire command timing interval.

The 64, 32, 16, 8, 4, 2, 1 binary weighted code is used to decode the seven-bit decoder address group, the seven-bit command complement group, and the seven-bit command group.

Seven address bits are used to command PSEP. The command decoder shall respond to two address codes; one for section A and another for section B. The selected address codes are No. 14, and No. 78. The binary weighted code patterns are 0001110, and 1001110 respectively.

The seven-bit command complement group is transmitted after the address and is followed with the seven bit-command group. The command decoder performs a bit-by-bit parity check over the command complement and command bits. A decoder command is executed if parity is correct and is rejected if incorrect.

Twenty timing bits are transmitted to allow for a 20 millisecond command execution timing interval.

The command decoder is capable of accepting 128 different command messages and is designed to provide 33 commands for PSEP operation. Following is the distribution of commands:

a.	PSE	15
b.	Power distribution	15
c.	Power conditioning unit	2
d.	Data processor	3
e.	Command decoder	2
f.	Commands not assigned	8
g.	Commands not assignable	28
h.	Commands assigned to ALSEP	55

The command decoder stores an eight-bit command verification message which consists of seven command bits and a parity bit. The command verification message is sampled by, and shifted to, the data processor once every frame time, if a command has been received.

The command word rate is limited to approximately one message per second during a DP normal mode of operation and to approximately one message per two seconds during the DP slow mode of operation.

No special requirements exist for intercommand operation. Loss of synchronization between commands does not affect the operation of the command decoder.

A list of the discrete commands issued by the command decoder is presented in the Appendix.

The command decoder automatically generates seven one-time commands after a 96-hour delay. The delayed command functions and time of execution are listed in Table 2-9. A flow chart of delayed command sequences is shown in Figure 2-22.

Monitoring circuits provide telemetry data to the data processor on the status of command decoder internal, base and demodulator oscillator temperatures.

Table 2-9. Data Subsystem Delayed Command Functions

Command	Function	Time of Execution
75	Not used for PSEP	96 hours + 2 minutes
69	Not used for PSEP	"
59	Uncage PSE	"
72	Not used for PSEP	96 hours + 3 minutes
82	Not used for PSEP	96 hours + 4 minutes
71	Not used for PSEP	"
72	Not used for PSEP	96 hours + 5 minutes
89	Not used for PSEP	108 hours + 1 minute, then every 12 hours
42	"Exp 4" Operate Select (not functional for PSEP)	108 hours + 7 minutes, then every 12 hours

2-39. DATA SUBSYSTEM CENTRAL STATION TIMER

The central station timer provides predetermined switch closures used to initiate specific functions within PSEP and the data subsystem when the uplink is unavailable for any reason.

2-40. Data Subsystem Central Station Timer Physical Description. The central station timer consists of a Bulova model TE-12 Accutron clock and a long life mercury cell battery.

The timer is housed in a black anodized aluminum case approximately 2.6 inches long and 1.3 inches in diameter. Weight of the unit is slightly more than 0.25 pounds. Solder terminals provide electrical connection. Figure 2-23 shows the central station timer.

2-41. Data Subsystem Central Station Timer Functional Description. Figure 2-24 shows a block diagram of the timer. A tuning fork controls the frequency of a transistorized 360 Hz oscillator which provides the basic timing frequency. This timing frequency drives the electromechanical arrangement used to provide three back-up timing switch closures. The switch closures are at one minute, 12-hour, and 720-day intervals. The one-minute and 12-hour closures are continuously repetitive and are applied to the delayed command sequencer in the command decoder. The 720-day closure occurs only once and initiates a permanent off command to the PSEP transmitter. The commands activated by the command decoder delayed command sequencer are listed in Table 2-9.

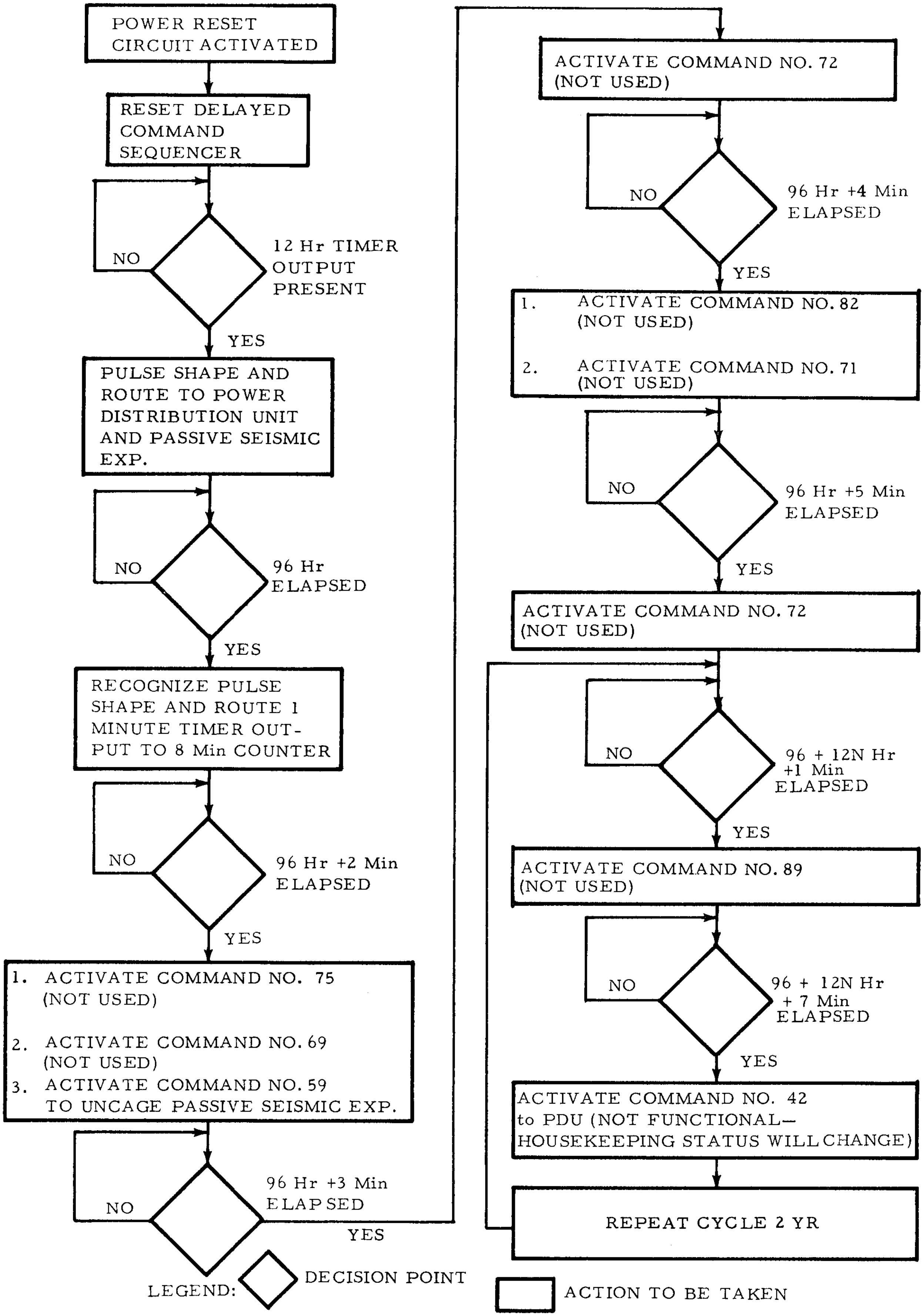


Figure 2-22. Data Subsystem Delayed Command Sequence, Functional Flow Chart

Figure 2-23. Data Subsystem Central Station Timer

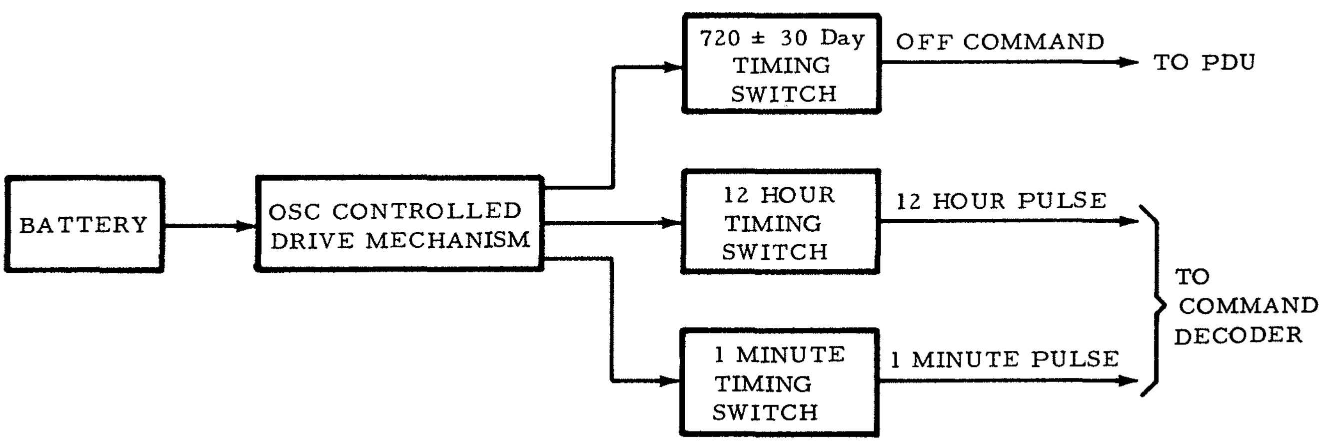


Figure 2-24. Data Subsystem Central Station Timer, Block Diagram

2-42. DATA SUBSYSTEM DATA PROCESSOR

The data processor generates PSEP timing and control signals, collects and formats both analog and digital data, and provides split-phase modulated data used for phase modulation of the downlink RF carrier.

2-43. Data Subsystem Data Processor Physical Description. The data processor consists of two physical components: (a) digital data processor, (b) analog multiplexer/converter. Figures 2-25 and 2-26 show the digital processor and analog multiplexer/converter. Multilayer printed circuit boards are used throughout the digital data processor and analog multiplexer/converter. The analog multiplexer/converter uses 15, two-layer boards. The digital data processor uses seven twelve-layer boards, one six-layer board and one three-layer discrete component board. Leading particulars are listed in Table 2-10.

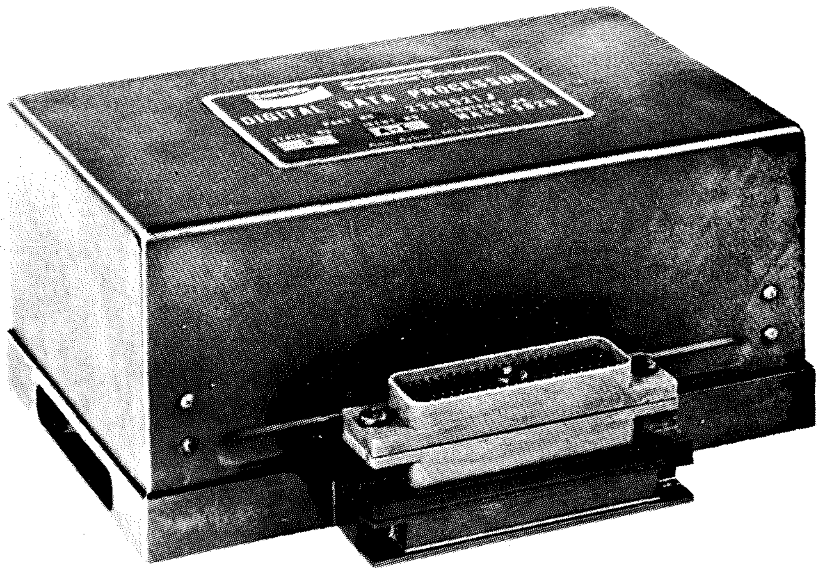


Figure 2-25. Data Subsystem Digital Data Processor

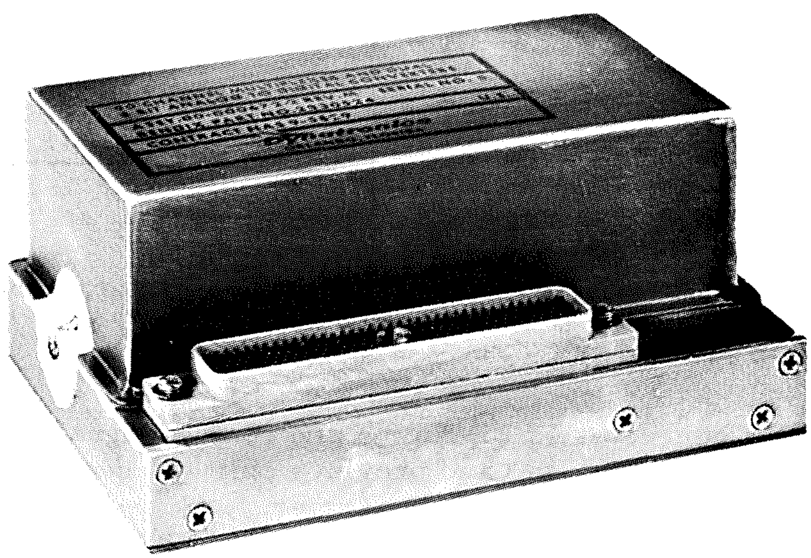


Figure 2-26. Data Subsystem Analog Data Multiplexer/Converter

Table 2-10. Data Subsystem Data Processor Leading Particulars

Characteristic	Value
Digital Data Processor	
Height	2.8 inches
Width	4.81 inches
Length	6.25 inches
Weight	3.03 pounds
Power consumption	Less than 0.5 watts
Analog Multiplexer/Converter	
Height	2.62 inches
Width	4.2 inches
Length	5.9 inches
Weight	2.20 pounds
Power consumption	Approx. 1.44 watts

2-44. Data Subsystem Data Processor Functional Description. Functionally, there are two redundant data processing channels (data processor X and data processor Y) which process both analog and digital data. Either processor channel may be selected to perform the data processing function. Figure 2-27 is a block diagram of the data processor showing redundant data processor channels X and Y. Digital data is applied directly to the processor channels. Analog engineering (housekeeping) data is applied to the 90-channel analog multiplexer. Figure 2-28 shows a block diagram of the analog multiplexer/converter. Multiplexer channels 1-15 are considered high reliability channels because of the redundant gating provided. Channels 16-90 are normal channels without redundant gating. An advance pulse from the timing and control circuits of the X and Y processor channels is applied to the multiplexer sequencer logic. The sequencer logic applies timing signals to the multiplexing circuitry, and an end-of-frame signal to the frame counter when the frame advance reaches ninety. Multiplexed analog outputs from the multiplexing circuitry are applied through two parallel buffer stages to the analog-to-digital converters in data processors X and Y. The channel assignments of the analog multiplexer/converter are listed in Appendix A.

Analog data inputs from the analog multiplexer are received by the analog-to-digital converter. (See Figure 2-27.) The analog-to-digital converter digitizes the PAM output signal from the analog multiplexer. The analog-to-digital converters use a ramp generation technique to encode the analog signal into an eight-bit digital word. A single eight-bit conversion is made every telemetry frame. Processor timing and control circuits provide signals which assure that the conversions are made at the appropriate time. The digitized output data is applied to the digital multiplexer in parallel data form.

The digital multiplexer consists of a ten-bit shift register which accepts eight parallel bits from the analog-to-digital converter or eight serial bits from the command decoder and serially shifts them as a ten-bit word with zeros inserted in the two most significant figures. The bits are shifted high order first. Gates are included in the digital multiplexer circuitry which gate serial input data directly from the experiments. The gate outputs and the ten-bit shift register outputs are "OR'd" and presented to a two-bit shift register which accepts either serial data from experiments or parallel control word coding.

The two-bit shift register presents the experiment and control word data in serial form to the PCM format converter. A PCM "0" is represented by a "01" and a PCM "1" is represented by a "10". The split phase signal phase modulates the transmitter so that a PCM "0" causes a positive phase transition and a PCM "1" causes a negative phase transition.

Table 2-11 lists the characteristics of PSEP timing and control signals.

2-45. Operating Modes - The data processor can be commanded into one of three modes:

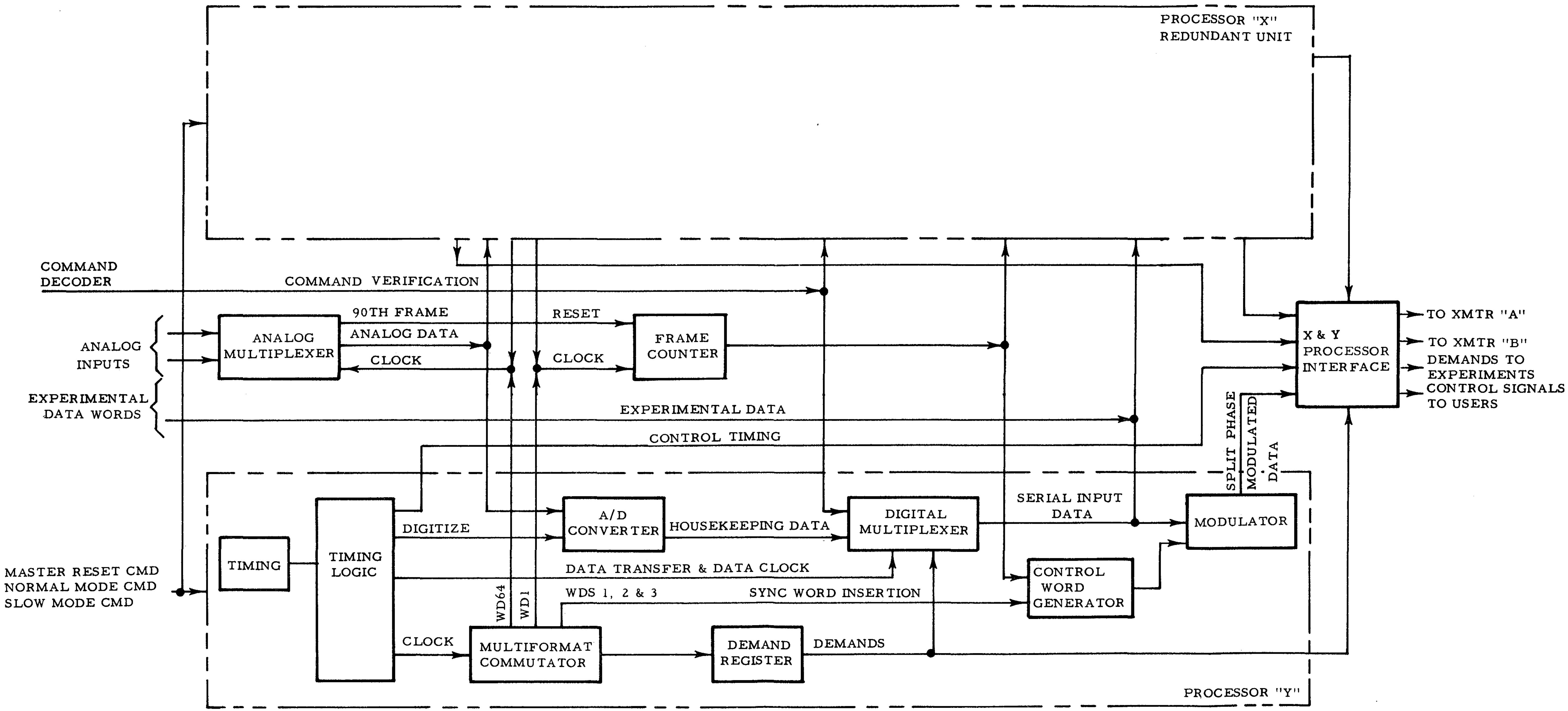
a. Normal mode (1060 bps)
b. Slow mode (530 bps)
c. Active Seismic mode (10600 bps) (not used). If this mode is selected, all data (digital and analog) will be suppressed.

The normal mode is the standard operating mode which has a data rate of 1060 bps (106 words/second). In the normal mode, the demand signals to the data sources (experiments) are one word in length and approximately 9.45 milliseconds in duration. Other timing signals such as the data gate and the various frame marks are approximately 118 microseconds in duration.

The slow mode provides backup operation at one-half the normal mode data rate. The slow mode data rate is 530 bps with 53 words per second. Slow mode demand and timing signals are 18.9 milliseconds and 236 microseconds, respectively.

The data processor formats the data collected from the experiments into a telemetry format as shown in Figure 2-29. The frame rate in the normal mode is 1 and 21/32 frames/second. A complete frame of data is collected approximately every 0.6 second. Each frame contains 64 words of ten bits each giving 640 bits/frame. The basic bit rate is 1060 bps. In addition to the words assigned to the experiments, the first three ten-bit words are used as a 30-bit control word and a single ten-bit word is used for command verification purposes. Experiment word and frame assignments are listed in the Appendix.

The bit assignments for the control word are shown in Figure 2-30. A 22-bit word consisting of an 11-bit Barker code, followed by the same code



NOTE: 1 POWER DISTRIBUTION UNIT SUPPLIES:
+5 VDC
+15 VDC
-12 VDC
2 CONTROL SIGNALS:
EVEN FRAME MARK
FRAME MARK
SHIFT PULSE LINE
DEMAND LINE
DATA GATE
90TH FRAME MARK

Figure 2-27. Data Subsystem Data Processor, Functional Block Diagram

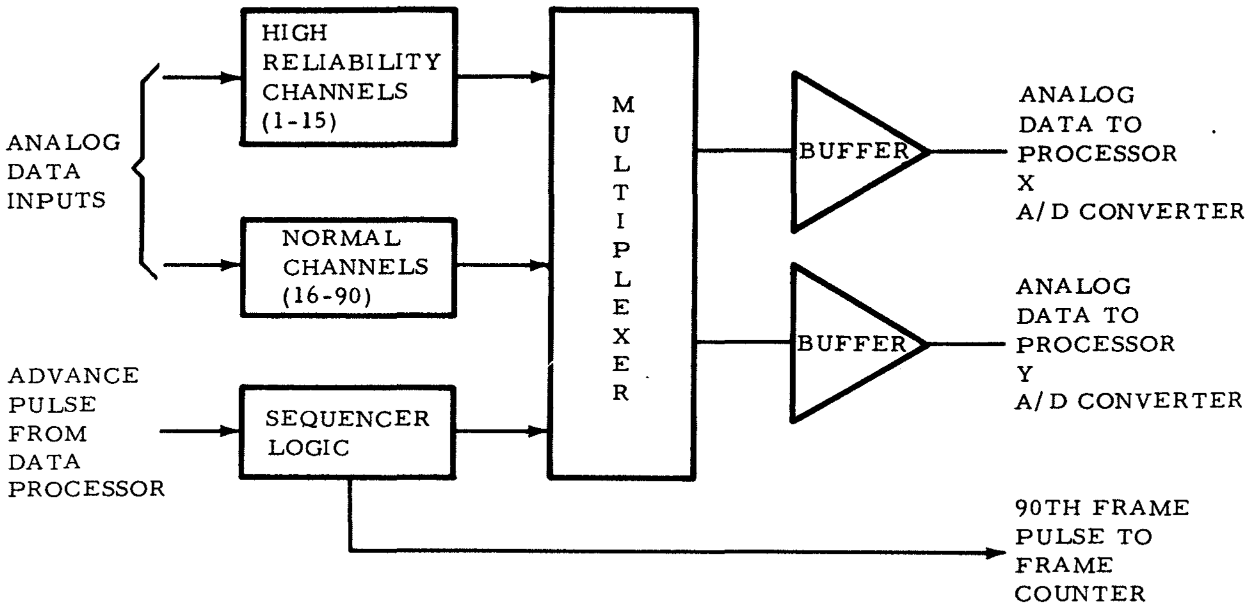


Figure 2-28. Data Subsystem Analog Multiplexer/Converter, Block Diagram

Table 2-11. Data Subsystem Timing and Control Pulse Characteristics in Normal PSEP Data Mode

Pulse Type	Duration* (μ sec)	Repetition Rate*	Timing Relative to Frame Mark
Frame mark	118	Once per PSEP frame	Occurs at start of word 1 of each frame
Even frame mark	118	Once every other frame	In coincidence with frame mark
90th frame mark	118	Once every 90th frame	In coincidence with frame mark
Data gate (word mark)	118	64, once per each ten-bit word in frame	Data gate of word 1 is in coincidence with frame mark
Data demand	9434	Once per experiment word in PSEP frame	Occurs asymmetrically (Figure 2-29)
Shift pulse	47	640 pulses per frame 1060 pulses per second	Continuous 1060 pulses per second Symmetrical square wave

Amplitude: High "or" logic "1"—+2.5 to 5.0 volts
Low "or" logic "0"—0 to +0.4 volts

Rise and Fall Times: 2 to 10 μ sec 10% to 90% points and 90% to 10% points

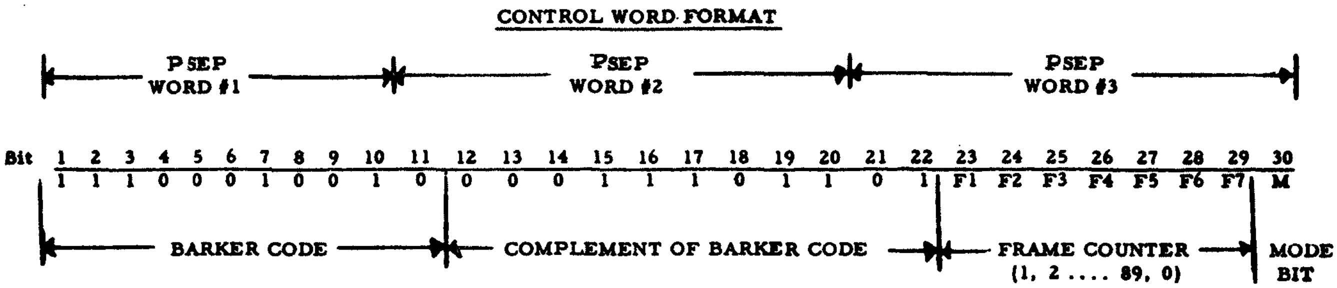
*In slow PSEP data mode, duration is twice the normal mode and repetition rate is one-half normal mode.

1 x	2 x	3 x	4 X	5 NA	6 X	7 NA	8 X
9 -	10 X	11 -	12 X	13 -	14 X	15 NA	16 X
17 NA	18 X	19 NA	20 X	21 NA	22 X	23 NA	24 X
25 -	26 X	27 -	28 X	29 -	30 X	31 NA	32 X
33 H	34 X	35 ●	36 X	37 ●	38 X	39 NA	40 X
41 -	42 X	43 -	44 X	45 -	46 CV	47 NA	48 X
49 NA	50 X	51 NA	52 X	53 NA	54 X	55 NA	56 NA
57 -	58 X	59 -	60 X	61 -	62 X	63 NA	64 X

WORD TOTALS	LEGEND	
3	x	- CONTROL
29	X	- PASSIVE SEISMIC - SHORT PERIOD
12	-	- PASSIVE SEISMIC - LONG PERIOD
2	●	- PASSIVE SEISMIC - LONG PERIOD TIDAL AND ONE TEMPERATURE
1	CV	- COMMAND VERIFICATION (UPON COMMAND, OTHERWISE ALL ZEROS)
1	H	- HOUSEKEEPING
16	NA	- NOT ASSIGNED (ALL ONES WILL BE TRANSMITTED)
64		

EACH BOX CONTAINS ONE TEN-BIT WORD
TOTAL BITS PER FRAME - 10 X 64 - 640 BITS

Figure 2-29. PSEP Telemetry Frame Format



Symbol	Name	PSEP Words	Range	Bits/ Sample	Samples/ Second
DA-1	Barker Code and Complement	1, 2, and bits 1 and 2 of word 3	NA	22	1.67
DA-2	Frame Count	Bits 3 to 9 inclusive of word 3	0-89	7	1.67
DA-3	Bit Rate ID	Bit 10 of word 3		1	1/54
DA-4	PSEP ID	Bit 10 of word 3		3	1/54

DA-3 Bit Rate ID:

Frame	Mode Bit	Meaning
1	1	Normal data rate
2	1	Slow data rate

DA-4 PSEP ID:

Frame	Mode Bit	
3	0 (MSB)	Data processor ID number
4	1	
5	1	

Figure 2-30. PSEP Telemetry Control Word Bit Assignments

complemented, is used to attain synchronization. The next seven bits provide frame identification for one through 90 frames for correlation of the analog multiplexer data. The 30th bit provides normal or slow mode information during the first two frames of the 90-frame sequence, and data processor serial number identification during the third through fifth frames of the 90-frame sequence. For the sixth through 90th frames the 30th bit has no information and reads logic zero.

2-46. Timing and Control Signals - Timing and control circuits provide synchronization signals for use throughout the PSEP.

The basic clock is a 169.6 KHz oscillator. A master flip-flop divides the clock frequency down to 84.8 KHz. The 84.8 KHz signal drives a divide-by-eight counter to obtain a 10.6 KHz signal. This counter is gated to produce the 42.4 KHz signal used in the slow data mode of 530 bps.

The 84.8 KHz signal or the 42.4 KHz also drives a divide-by-ten counter. The outputs from this counter are used to drive the sub-bit counter and the timing logic. The sub-bit counter is a divide-by-eight counter with output frequencies of

1060 Hz or 530 Hz depending upon the operational mode. This output establishes the bit rate, drives a bit time counter, and provides timing signals for the timing logic.

The bit time counter is a divide-by-ten counter with an output frequency of 106 Hz or 53 Hz which establishes the word rate. Outputs of this counter are used in generating the control words and signal timing throughout the processor.

The multiformat commutator determines the specific assignments of each word within the 64 word telemetry format. The commutator provides signals (demand pulses) of one word length and multiples of one word length in duration so that data may be gated from the experiments and command decoder through the split-phase modulator and into the transmitter in a predetermined sequence. The output of the multiformat commutator is applied to the demand register and the control word generator.

The demand register performs the following functions:

a. Provides memory for the demand signal while the commutator is being switched.

b. Acts as a master switch turning off all demands while allowing the format generator and all control signals to function normally while in active seismic mode.

c. Acts as a buffer between the demand decoder assembly eliminating any gating transients from the demand lines.

The control word generator generates the synchronization code and provides the information to the output register during the proper bit times of the control word. Mode, frame, and data processor serial number information is provided to the output register at the appropriate bit times.

The frame counter generates the frame bits. The frame counter is essentially a ripple-through counter which is advanced one step whenever the first word of each frame occurs. Reset is accomplished by means of the 90th frame end-of-frame signal generated by the analog multiplexer.

A flow chart of the data processor is presented in Figure 2-31.

2-47. DATA SUBSYSTEM TRANSMITTER

The data subsystem transmitter generates an S-band carrier frequency of 2276.5 MHz which is phase modulated by the split-phase serial bit stream from the data processor.

2-48. Data Subsystem Transmitter Physical Description. Two identical transmitters are used in each data subsystem to provide standby redundant operation. Either transmitter can be selected to transmit downlink data. A transmitter is shown in Figure 2-32. Most circuit modules are mounted on a milled out magnesium base plate. Some modules and other components are located inside the base plate. Transmitter leading particulars are listed in Table 2-12.

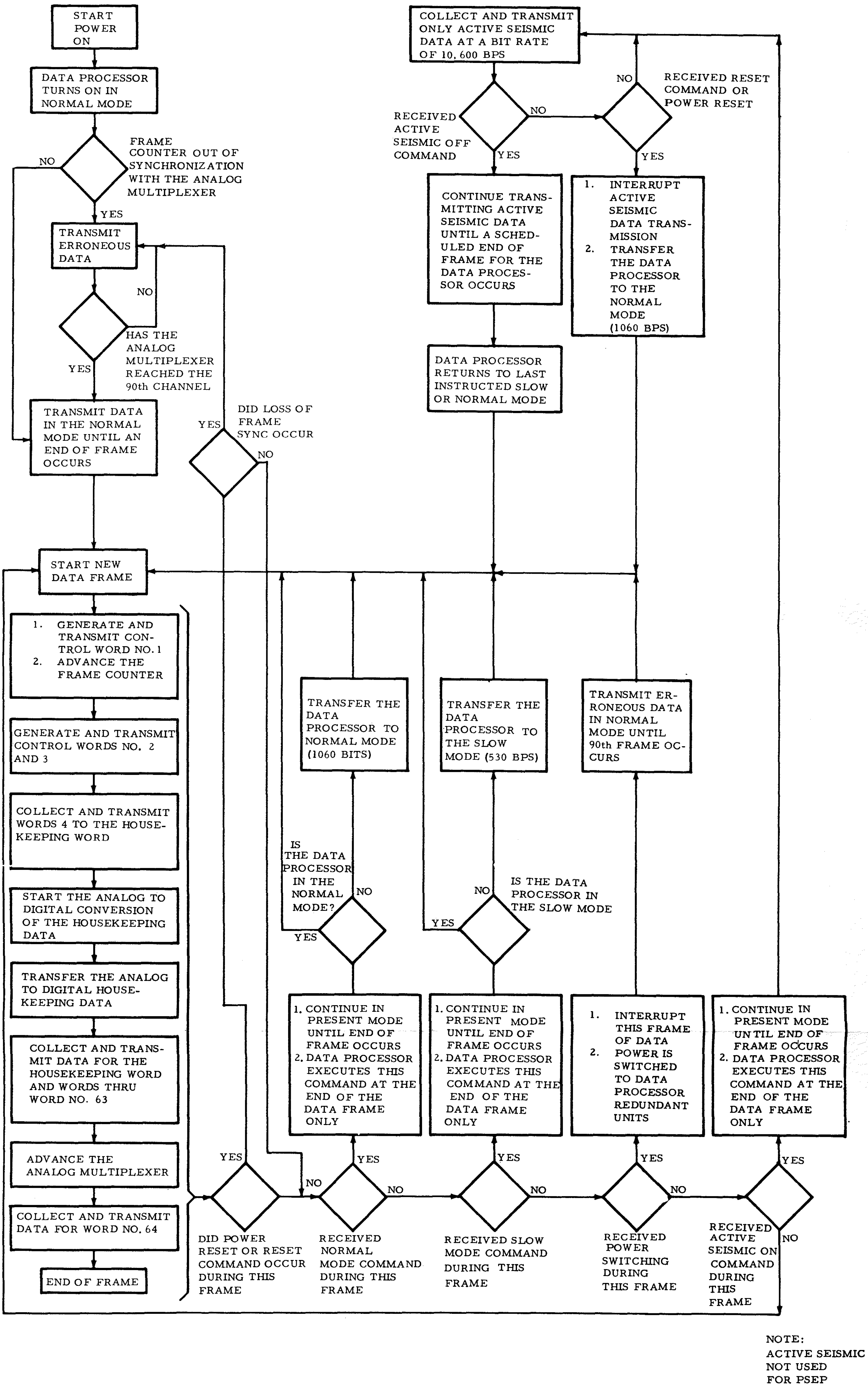


Figure 2-31. Data Subsystem Data Processor Flow Chart

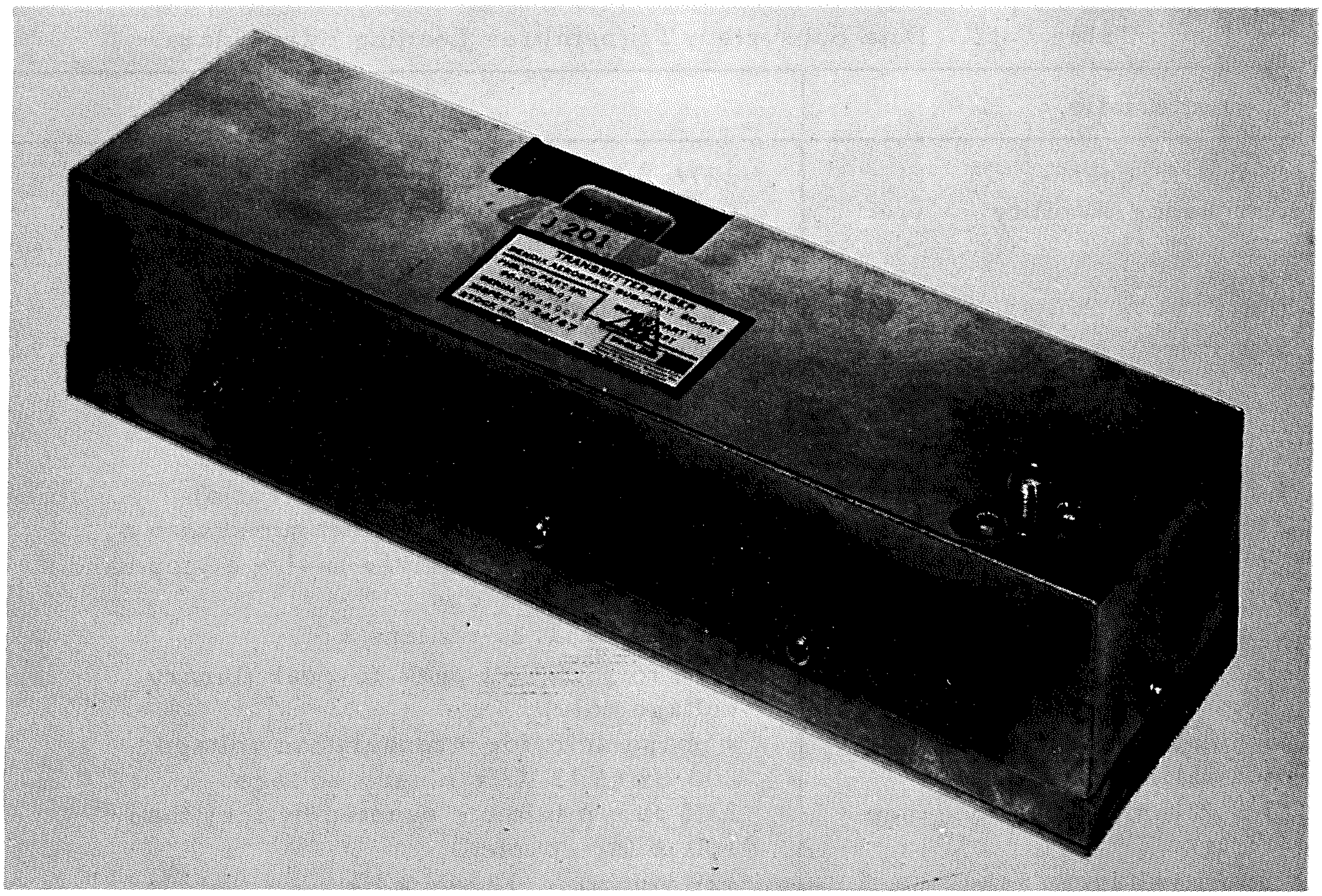


Figure 2-32. Data Subsystem Transmitter

2-49. Data Subsystem Transmitter Functional Description. Figure 2-33 shows a block diagram of the transmitter circuit. Transmitter output frequency is a function of the oscillator crystal and tuning. An oscillator frequency of 142 MHz is used as an example in this discussion. The crystal-controlled oscillator in the oscillator-buffer-phase modulator generates a 142 MHz frequency which is phase modulated by the binary data from the data processor. A buffer amplifier between the 142 MHz oscillator and the phase modulator provides impedance matching and circuit isolation which enhance modulator stability. The analog phase modulator contains a pair of back-to-back varactor diodes which vary the capacitance of a parallel resonant tank circuit by varying the diode back bias at the modulating frequency. A modulator driver maintains the proper diode bias voltages for binary modulation voltage variations from 2.5 volts to 5.5 volts peak-to-peak.

Table 2-12. Data Subsystem Transmitter Leading Particulars

Characteristic	Value
Output frequence	2276.5 MHz
Frequency stability	(a) ± .0025%/year (long term) (b) 2.2 x 10^{-10} parts/second (short term)
Output power	1 watt minimum into 50 ohm load with maximum VSWR of 1.3:1
Output spurious	(a) Harmonically related: 0 dbm, 2-7 GHz (b) Other: -50 dbm above 2-GHz -10 dbm, 7-10 GHz (c) All: 0 dbm below 2 GHz
Incidental AM	Less than 3% (0.25 db power ratio)
Phase noise	Less than 4.5° rms as measured with a phase coherent receiver having a loop bandwidth 2 B_L = 50 cps
Carrier deviation	Fixed at ± 1.25 radians ±5%
Modulation drive	+2.5 to +5.5 volt peak-to-peak (binary voltage only)
Modulation polarity	+ phase shift for + modulation voltage
Modulation frequency	200 Hz to 12 KHz/binary voltage
Modulation input impedance	22K ohm minimum shunted by less than 100 pf (ac coupled)
Supply voltages	+29 vdc ± 1% +12 vdc ± 1%
Supply power	9.5 watts maximum (9.2 watts nominal = 8.7 w @ +29 v + 0.5 watts @ +12v)
Telemetry outputs	(a) Oscillator crystal temperature (b) Heat sink temperature at highest power stage (c) RF level at output (AGC voltage) (d) Supply current to power doubler
Weight	1.13 pounds
Form factor	7.5 x 2.0 inches mounting surface x 1.50 inches in height exclusive of connectors

The output of the phase modulator is applied to buffer amplifier, AGC-controlled amplifier, and frequency doubler stages. The buffer amplifier stage between the phase modulator output and the AGC-controlled amplifier inputs prevents modulator tank circuit detuning which would be caused by amplifier input impedance changes resulting from temperature and aging. The times two frequency multiplier stage increases the carrier frequency to 284 MHz.

The 284 MHz output from the frequency multiplier is amplified by the power amplifier, and doubled in frequency by the power doubler. A times four varactor frequency multiplier then quadruples the carrier frequency. The output frequency of 2276.5 MHz is generated by the crystal-controlled oscillator. A stripline

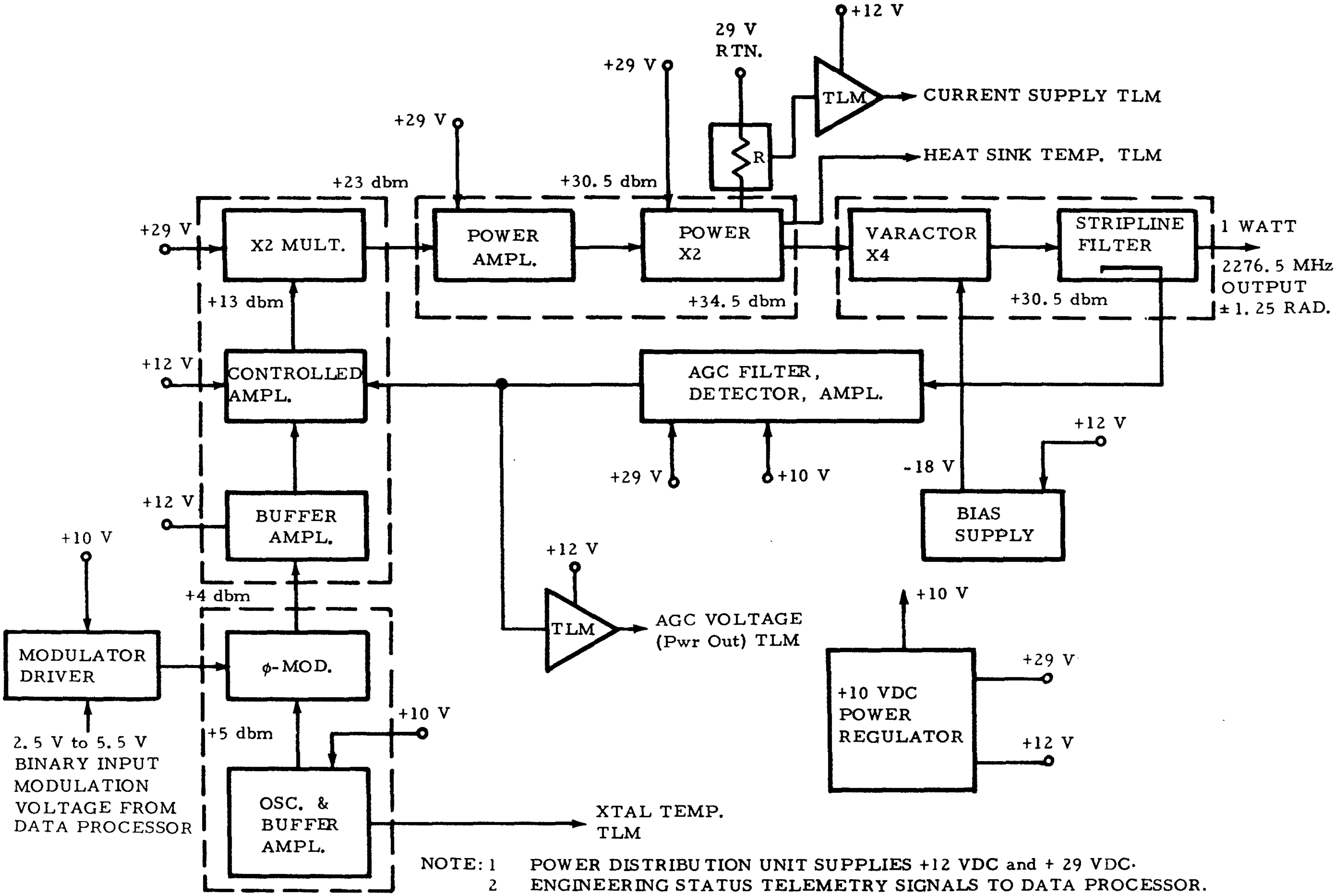


Figure 2-33. Data Subsystem Transmitter, Block Diagram

filter reduces spurious harmonics of the output signal to 30 db below the carrier. Additional spurious rejection is provided by the interfacing diplexer. A directional coupler built into the filter provides an RF output to the AGC circuit.

Monitor circuits provide analog signals to the data processor indicating the status of current supply, AGC voltage and the temperatures at the oscillator crystal and the power heat sink.

2-50. DATA SUBSYSTEM POWER DISTRIBUTION UNIT

The power distribution unit (PDU) distributes power to experiment and central station components and provides circuit overload protection and power switching of selected circuits. The PDU also provides signal conditioning of selected central station monitor signals prior to input to the analog multiplexer for analog-to-digital conversion and subsequent data transmission to earth.

2-51. Data Subsystem Power Distribution Unit Physical Description. A PDU is shown in Figure 2-34. The power distribution unit is comprised of five printed circuit cards, a mother board to provide interconnection between the individual boards, the component connector, a case, and a cover. All electrical inputs are made through a rectangular, screw-lock, 244-pin connector.

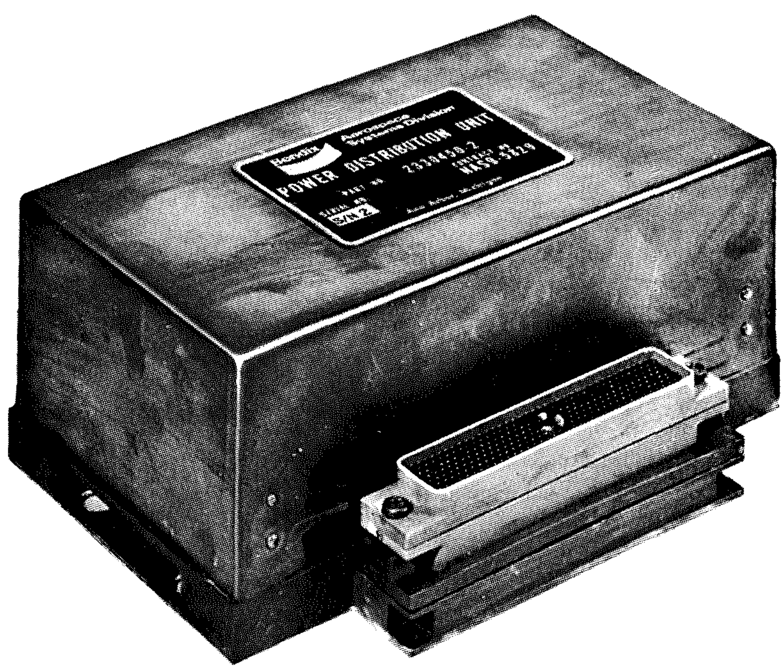


Figure 2-34. Data Subsystem Power Distribution Unit

The amplifier board mounts six sensing bridges and amplifiers, the power reserve sequencer comparator, and one experiment power control circuit.

The experiment drive card contains the relay driver, relays, fuses, and associated circuit components for the power control of five experiments (only one of which is functional).

The signal conditioning and logic card comprises the resistive dividers used for thermistor temperature sensing, nickel wire temperature sensing and voltage monitoring. Additionally, the required gates, flip-flops, and gate expanders used for counting and decoding in the reserve power sequencer, are mounted on this card.

The central station power control card provides mounting for the relays, drivers, and circuit overload sensing relays associated with the transmitter, receiver, data processor, power dissipation module load No. 1 and No. 2, and backup heater power control.

Circuitry for the dust detector electronics is mounted on a single card. Leading particulars of the power distribution unit are listed in Table 2-13.

Table 2-13. Data Subsystem Power Distribution Unit Leading Particulars

Characteristic	Value
Form factor:	2.8 x 4.0 x 7.25 inches
Weight:	2.4 pounds
Power consumption:	1.75 watts
DC input voltages:	+29 vdc
	+15 vdc
	+12 vdc
	+5 vdc
	-6 vdc
	-12 vdc

2-52. <u>Data Subsystem Power Distribution Unit Functional Description.</u> The functional description of the power distribution unit is divided into three major functions:

a. Power-off sequencer
b. Temperature and voltage monitor circuits
c. Power control to experiment and central station.

Figure 2-35 shows a block diagram of the PDU.

2-53. Power Off Sequencer - The power off sequencer of the PDU detects minimum reserve power and sequentially turns off up to three preselected experiments to bring the power reserve within acceptable limits. The minimum reserve power is detected by monitoring the voltage across a power conditioning unit resistor. This voltage is applied to an operational amplifier used as a level detector. An RC delay network is employed at the output of the level detector. The output of the delay is applied to a second level detector which drives the power-off sequencer logic. This arrangement turns on the power-off sequencer logic input gate when the reserve power drops below acceptable levels.

The power-off sequencer logic input gate passes a 1 KHz clock signal to a five-stage binary counter. The counter accumulates the 1 KHz count until the reserve power becomes greater than the minimum level. The counter output is fed to decoding gates which sequentially turn off up to three preselected experiments.

The sequencer decoding gates are connected so that upon turn-on of the logic input gate, an output ground level signal is provided during the count between 1 and 9 milliseconds to the experiment No. 4 standby-on relay driver. This relay removes experiment prime power and applies power to the standby line. If the IPU overload persists, the ground level signal supplied to the experiment No. 4 standby line is removed and a ground level signal is applied to the experiment No. 3 standby-on command input during the next 8-millisecond period (when the count is between 9 and 17 milliseconds). The sequencer could continue in the same manner until a third experiment (No. 1) is in the standby mode if overloading persists. If, however, the overload is removed within the sequence, the counter will be reset when a satisfactory power reserve signal is obtained. On PSEP there is one experiment, the PSE, connected to No. 1 position.

2-54. Temperature and Voltage Sensor Circuits - Each thermistor temperature sensing network consists of a 3010 ohm, one percent resistor in series with a 15K ohm (25°C) thermistor and a second 3010 ohm resistor to ground. The divider excitation is 12 vdc. The output is taken across the 3010 ohm resistance connected to ground. The resultant output, although not perfectly linear over the -50°F to +200°F temperature span of measurement, provides an output measurement with very low dissipation of power. The maximum sensor current is less than 2 milliamperes.

The nickel wire temperature sensors (2000 ohms at the ice point) are used in dividers to monitor exposed structural temperature, multilayer bag insulation temperatures, and solar panel temperatures. The circuit is a simple divider consisting of 12 vdc supplied through 5900 ohms and the sensor to ground. The output analog signal is taken across the sensor, providing a reasonably linear response from -300°F to +300°F. The maximum current through the sensor is less than 2 milliamperes.

Voltage monitors are provided for each of the six voltage outputs of the power conditioning unit. The positive voltages are monitored with resistive dividers with an output impedance less than 10K ohms. The two negative voltages lines are also monitored by dividers. The 29-vdc supply is used as a bucking voltage to a positive output of 0 to 5 vdc as required by the multiplexer. The output impedance is less than 10K ohms.

2-55. Power Control - Four transistorized relay drivers, magnetic latching relays, and one magnetic latching relay acting as an overload sensor (circuit breaker) perform the control and circuit breaking function for each experiment prime power line. The experiment standby power line is fused at 500 ma. and has no reset capability. Spike suppression and steering diodes are also

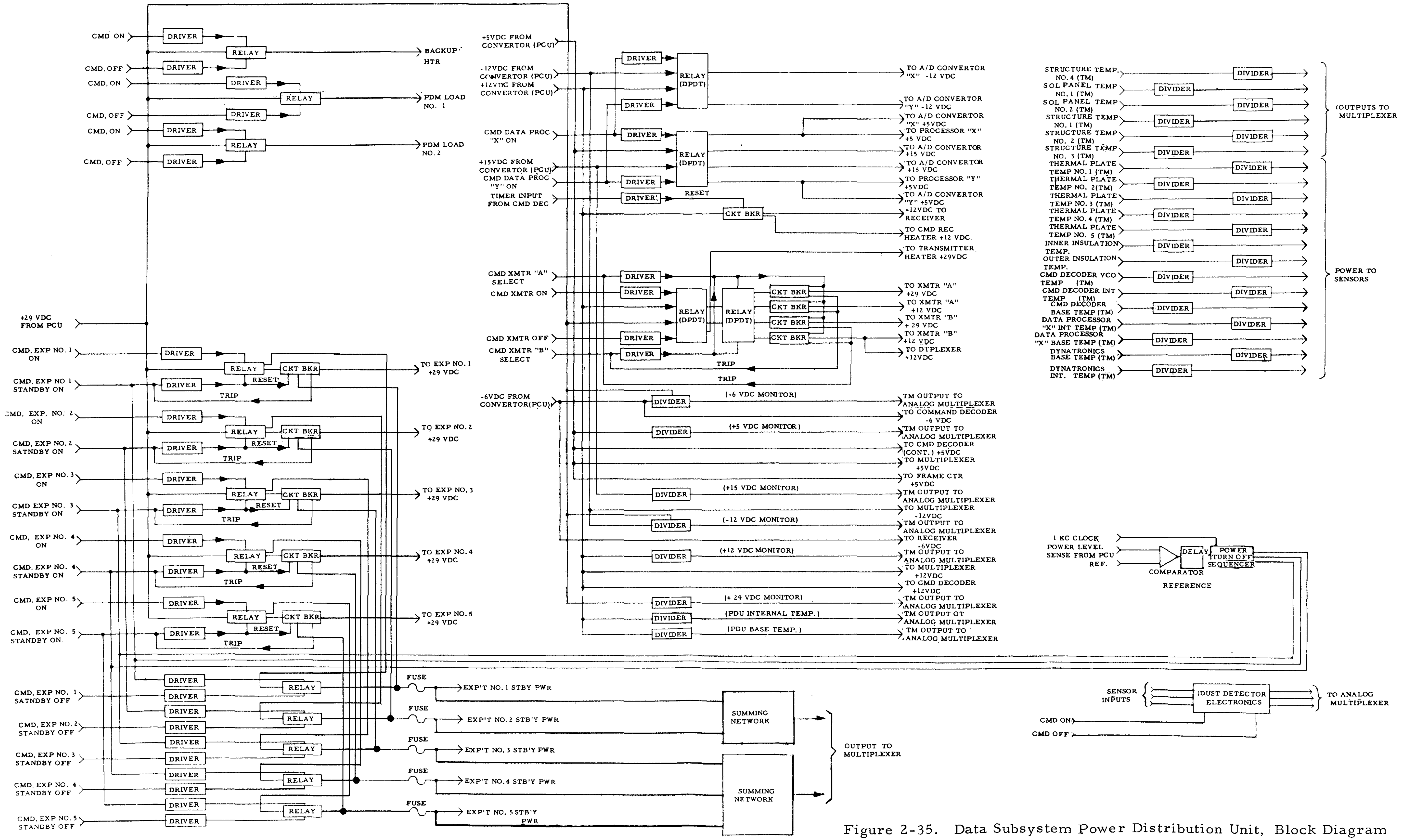


Figure 2-35. Data Subsystem Power Distribution Unit, Block Diagram

incorporated. The steering diodes provide isolation between command lines and astronaut control lines (not used) where required. Three command inputs are provided for each experiment power control circuit as follows:

a. Experiment operational power-on command
b. Standby power-on command
c. Standby power-off command.

The three command inputs operate one or both of two power switching relays, depending on the command received. One relay provides the selection of either standby power or operational experiment power. The other interrupts the standby power line. The receipt of an experiment operational power-on command will transfer the power select relay to a position which provides power through the current sensing coil of the circuit breaking relay to the experiment electronics. A separate manually operated switch is provided to supply the experiment operational power-on command for each experiment in the event of uplink failure. A second command (standby power-off) operates the relay coil of the standby power interruption relay to open the circuit supplying power to the standby line. The standby power-on command, however, operates on both relays. The standby power-on command closes the selector relay contacts supplying power to the standby power relay contacts and also closes that relay's contacts so that power is applied to the standby line. If the selector relay is in the position which supplies operational power to the experiment power line and the standby power interruption relay contacts are closed, two commands must be initiated to interrupt all power to an experiment. These commands are the standby power-on command followed by standby power-off command.

Circuit breaker operation is provided by internally generating a standby-on command using the contacts of a current sensing relay. Should an overcurrent condition exist through the sensing coil in series with the experiment operational power line, the contacts of the sensing relay break the normal standby-on command line and apply a ground signal to each of two relay drivers. One relay driver operates the power select relay to the standby-on position. The other driver operates the standby power interruption relay to close the contacts supplying power to the standby power line. Operation of the standby power interruption relay provides power to the reset coil of the overload sensing relay thereby resetting its contacts to permit normal standby-on command inputs. Provisions have been made to shunt each current sensing coil to provide a 0.5 amp capability to all experiments.

A high conductance diode is paralleled (in a forward biased condition) with the current sensing coil of the overload sensing relay. This diode permits an extension of the dynamic range of the overload sensor to high transient overloads. Two resistive summing networks provide a telemetry output to indicate the presence or absence of standby power for all experiment power switching circuits.

Transmitter power control and overload protection as shown in Figure 2-36 uses two power control relays, four overload sensing relays, and associated relay drivers. Four commands are required:

a. Transmitter on
b. Transmitter off
c. Transmitter A select
d. Transmitter B select.

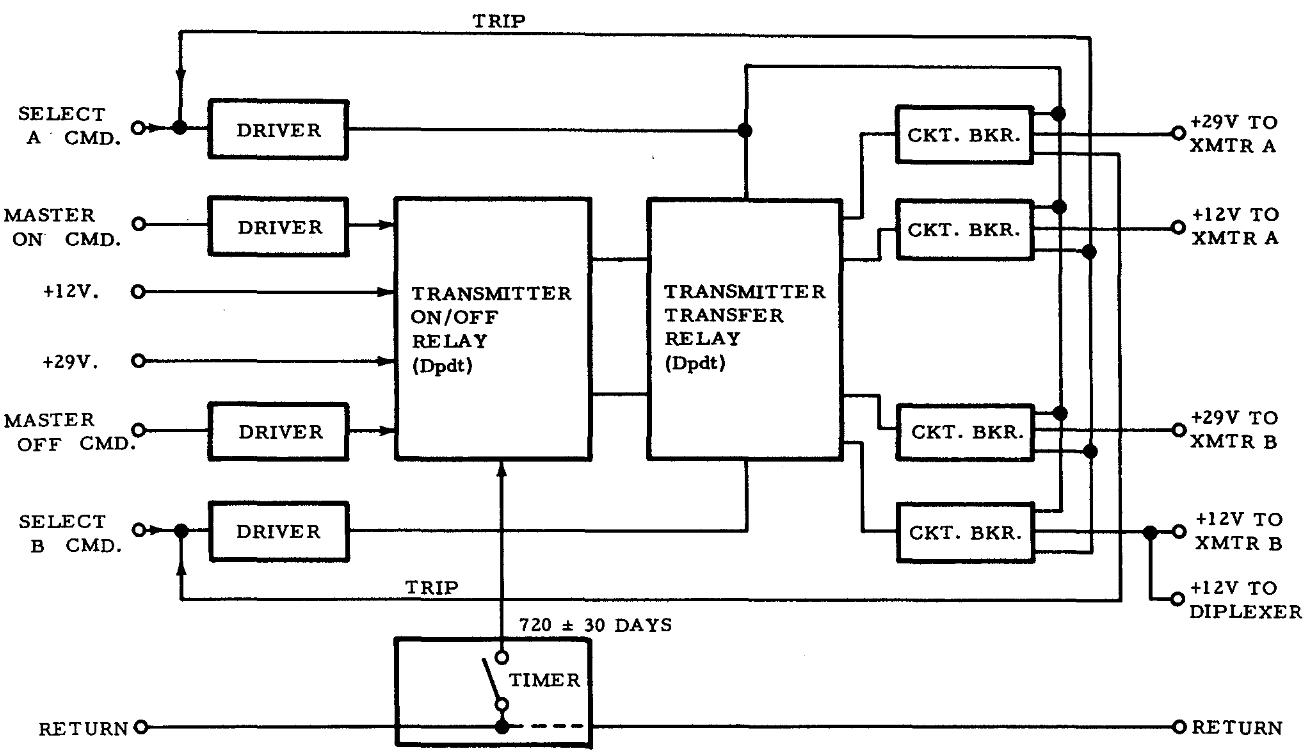


Figure 2-36. Data Subsystem Transmitter Power Control

The transmitter on and off commands operate the double-pole, double-throw relay which switches both 12 vdc and 29 vdc to the transmitter transfer relay. Two power lines to either of two transmitters are selectable via transmitter A or transmitter B select commands as appropriate. If either power line to either transmitter is overloaded, the contacts of the overload sensing relay transfers the transmitter select relay to supply power to the alternate transmitter. When power is transferred to the alternate transmitter, the circuit overload sensing relays are both reset and the normal command link inputs are restored. Diplexer switching power, required only when transmitter B is selected, is obtained directly from the 12 vdc transmitter power line.

The command receiver requires both 12 vdc and -6 vdc for operation (Figure 2-37). The -6 vdc line is not provided with circuit protection because of the high reliability of the -6 volt line load. The 12 vdc line is provided with overload protection which uses a magnetic latching circuit breaker relay. The sensing coil of this device will interrupt the 12 vdc of the receiver when current is excessive. Since no redundancy of receivers exists, a 12-hour reset pulse is supplied to the breaker every 12 hours. If the receiver is tripped off, a receiver heater load is energized by the transfer of the circuit breaker contacts to maintain thermal balance.

For data processor power control (Figure 2-37), redundant electronics are switched using standard magnetic latching relays. These relays are controlled by standard commands. Overload protection is not provided.

Power dissipation resistor 1, and power dissipation resistor 2 of the power dissipation module are switched off and on by ground command only.

Electronics for the dust detector are mounted on a printed circuit card in the PDU and consist of the following three functional areas:

a. Power switching
b. Operational amplifiers
c. Temperature measurement.

The power switching function switches 12 vdc and -12 vdc power to the amplifiers upon receiving a ground command. Power protection for the card is provided by individual fuses on each of the two voltages.

The operational amplifier consists of an integrated circuit differential amplifier with added circuitry to establish a closed loop fixed gain configuration. Its functional purpose is to condition the output of the photocell detectors, which act as variable current sources of a 0 to +5 vdc varying dc level for telemetry information. Temperature measurement is accomplished with a thermistor attached to the photocell and a series resistor, located on the card to optimize thermistor sensitivity and provide a 0 to +5 vdc telemetry signal.

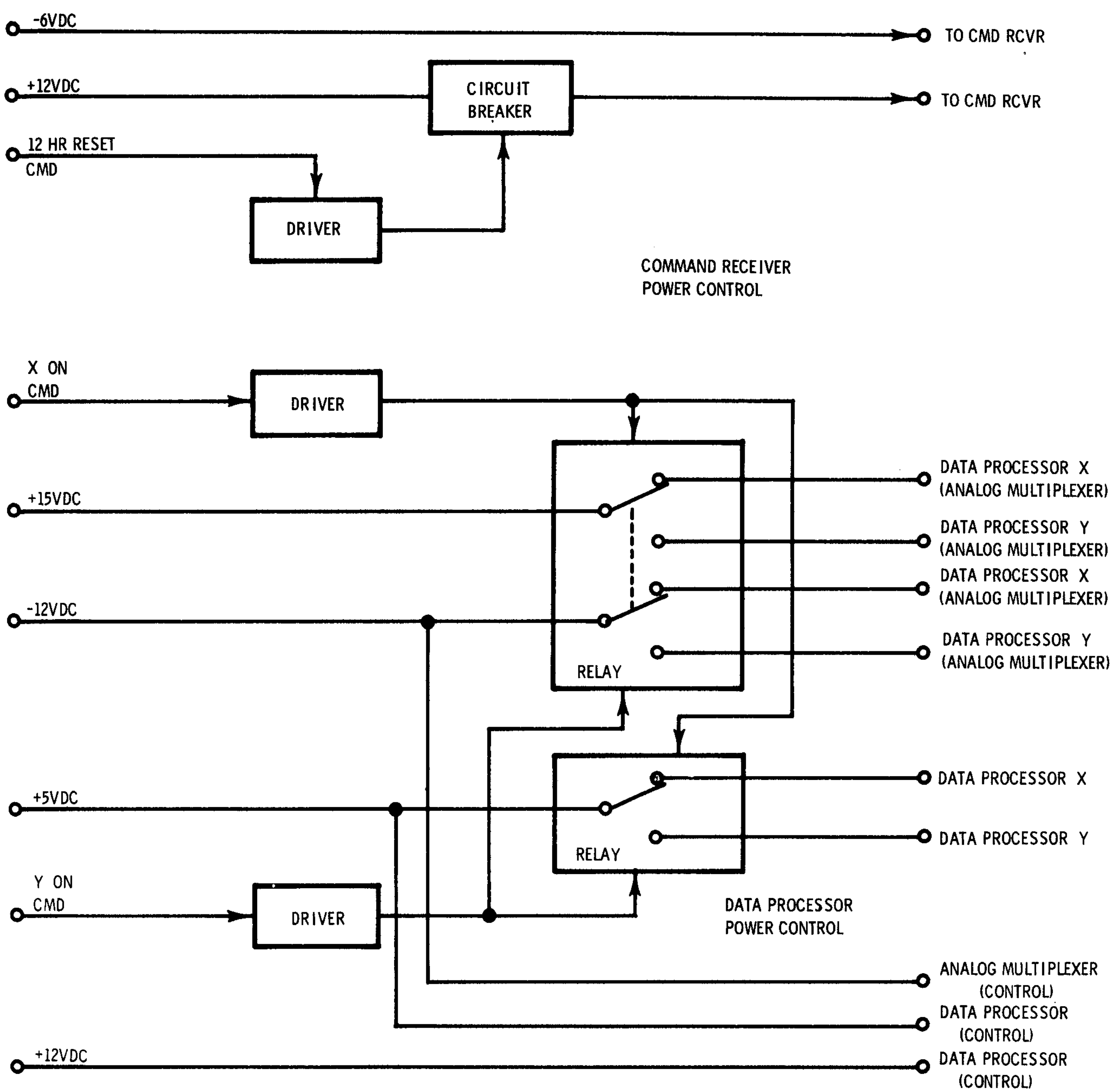


Figure 2-37. Command Receiver and Data Processor Power Control

2-56. PASSIVE SEISMIC EXPERIMENT

The passive seismic experiment (PSE) is designed to monitor seismic activity, and it affords the opportunity to detect meteoroid impacts and free oscillations. It may also detect surface tilt produced by tidal deformations which result, in part, from periodic variations in the strength and direction of external gravitational fields acting upon the Moon, and from changes in the vertical component of gravitational acceleration.

NOTE

> The detection of tidal motion is not a requirement for PSEP because the PSE is mounted on the central station. The seismometer tidal outputs will be used by the PSE for leveling the seismometers.

Analysis of the velocity, frequency, amplitude, and attenuation characteristics of the seismic waves should provide data on the number and character of lunar seismic events, the approximate azimuth and distance to their epicenters, the physical properties of subsurface materials, and the general structure of the lunar interior.

In the lower frequency end (approximately 0.004 to 3.0 Hz) of the PSE seismic signal spectrum, motion of the lunar surface caused by seismic activity is to be detected by tri-axial, orthogonal displacement amplitude type sensors. These sensors and associated electronics comprise the long period (LP) seismometer. In the higher frequency end (approximately 0.05 to 20 Hz) of the PSE seismic signal spectrum, vertical motion of the lunar surface caused by seismic activity is to be detected by a one-axis velocity sensor. This sensor and associated electronics comprise the short period (SP) seismometer.

Two separate outputs are produced by each axis of the LP seismometer. The primary output is proportional to the amplitide of low frequency seismic motion and is referred to as the seismic output. The secondary output is proportional to very low-frequency accelerations and is referred to as the tidal output. The tital output in the two LP horizontal axes is proportional to the amount of local tidal tilting of the lunar surface along these axes, as indicated by changes in dc signal level. The tidal output in the LP vertical axis is proportional to the change in the lunar gravitational acceleration as determined by that axis, again as related to changes in dc signal levels. The SP seismometer yields a seismic output proportional to seismic motion in the vertical axis of the instrument.

Electronics associated with each seismometer amplify and filter the four seismic and three tidal output signals. These seven signals are converted by the PSE subsystem to digital form, and released upon receipt of a demand pulse to the PSEP data subsystem for transmission to Earth. The temperature of the PSE sensor assembly is monitored and provided as the eighth PSE digital data output. Each PSEP telemetry format contains 64 words; 43 are used to transmit the eight PSE scientific data output signals to the MSFN stations on the Earth. In addition, eight analog signals conveying engineering data from eleven sources in the PSE are routed over separate lines to the PSEP data subsystem, multiplexed into the PSEP housekeeping telemetry word (No. 33), and transmitted to Earth to permit PSE status to be monitored.

Initiation and control of certain PSE internal functions is accomplished by 15 discrete commands relayed from Earth through the PSEP data subsystem.

2-57. PSE PHYSICAL DESCRIPTION

The PSE (Figure 2-38) comprises three major physical components. The sensor assembly and thermal shroud are mounted on top of the mounting plate. A separate electronics assembly is located in the PSEP central station, and provides the electrical interface with the data subsystem.

2-58. PSE Sensor Assembly. The sensor assembly is generally cylindrical in form, and is fabricated principally of beryllium to achieve light weight and long term stability. The long period (LP) and short period (SP) seismometers, the sensor leveling platform, the caging mechanism, and associated electronics are contained in the sensor assembly. The principal structural elements of the sensor are the base and the gimbal-platform assembly on which the LP seismometer is mounted. The LP seismometer comprises three orthogonally oriented, capacitance type seismic sensors; two horizontal axes and one vertical axis.

Each of the LP horizontal axis sensors comprise a 1.65-pound mass mounted on the end of a horizontal boom. The boom and mass assembly is suspended from the sensor frame so that it is free to rotate through a very limited portion of the horizontal plane in the manner of a swinging gate. Inertia of the mass causes it to tend to remain fixed in space when motion of the supporting frame occurs due to seismic motion of the lunar surface. The capacitance type transducer attached to the inertial mass produces an output proportional to the amount of displacement of the frame with respect to the mass. The LP vertical axis sensor differs from the horizontal sensors in that the boom-mounted mass is suspended from the frame by a zero length spring. The spring is adjusted so that the weight of the boom/mass assembly is compensated by the spring tension.

The LP leveling platform is gimballed through Bendix flexures, and is positioned by leveling motors along two horizontal axes. This permits leveling of the LP seismometers to within three arc-seconds of level. Independent positioning of the sensor in the LP vertical axis to the same tolerance is provided by a separate leveling motor which adjusts the tension of the suspension spring.

The SP seismometer is a single-axis device containing one vertically mounted, coil-magnet type seismic sensor mounted directly to the base of the sensor assembly. Leveling of the SP seismometer is accomplished by leveling the entire assembly, eliminating the need for separate internal leveling devices.

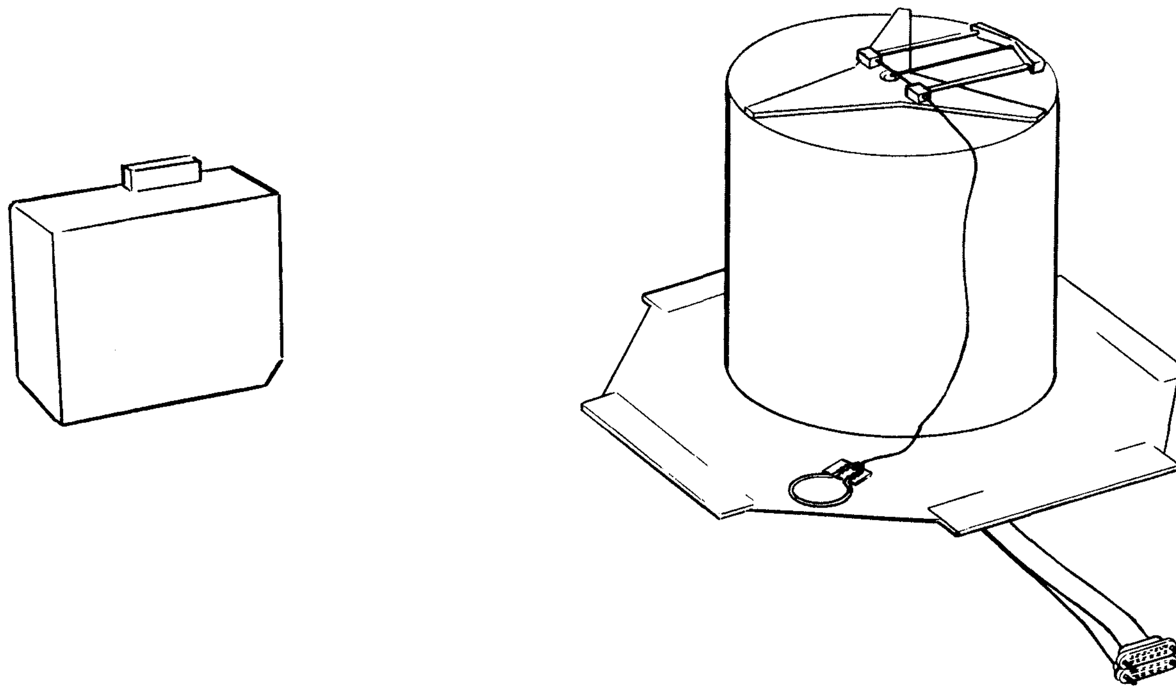


Figure 2-38. Passive Seismic Experiment Subsystem

Caging is provided by a pressurized bellows. When pressurized, pins are inserted into each inertial mass, raising the mass and thereby unloading the suspension system of each sensor. Pressure in the caging mechanism is released by firing a piston actuator by Earth command, after departure of the LM, to uncage the sensors and free them for operation.

The seismometer electronics are contained in part in the sensor assembly and the remainder is located in the PSEP central station. In the sensor, four printed circuit board subassemblies are mounted in the base, surrounding the SP seismometer. These subassemblies provide circuitry associated with amplification demodulation, and filtering of the outputs of each of the four seismic sensors. In addition, the sensor electronics provide for LP sensor leveling, and sensor assembly temperature monitoring and heater control. The heater control circuits regulate power to a heater located in the base of the sensor assembly to compensate for loss of thermal energy.

2-59. PSE Thermal Shroud. The thermal shroud has the shape of a flat-crowned hat. The crown portion covers the sensor, while the brim portion is secured to the mounting plate with velcro. The shroud is made of 20 layers of aluminized mylar, separated by alternate layers of silk cord, and wound on a perforated, aluminum support. The shroud covers the sensor assembly and the adjacent mounting plate to aid in stabilizing the temperature of the sensor assembly. A ball level and a sun compass are provided on the top surface of the shroud for leveling and azimuthal alignment of the PSEP.

2-60. PSE Electronics Assembly. The PSE central station electronics (CSE) module is located in the PSEP central station. Eleven printed circuit board subassemblies are contained in the CSE which provide the command logic circuits for the fifteen commands regulating or controlling the PSE internal functions. Also, the CSE contains circuitry associated with attenuation, amplification, and filtering of the seismic signals, processing of the PSE scientific and engineering data outputs, and its internal power supplies. The CSE is physically and thermally part of the central station, but electrically and functionally part of the PSE.

2-61. PSE Leading Particulars. Table 2-14 lists the physical characteristics and power requirements of the PSE and the performance characteristics of the eight PSE scientific data channels.

2-62. PSE FUNCTIONAL DESCRIPTION

The PSE instrumentation employed to detect seismic disturbances in the lunar surface is functionally divided into three long period seismic data channels, three tidal data channels, one short period seismic data channel, and a sensor assembly temperature monitoring channel. These scientific data channels are supported by sensor assembly heater control, data handling, uncaging and leveling, and power functions. (See Figure 2-39.)

Table 2-14. PSE Leading Particulars

Characteristic	Value
Physical Data	
Sensor Assembly, including Thermal Shroud:	
Height	15.25 inches
Diameter	11.75 inches
Weight	20.9 lbs.
Sensor	18.3 lbs.
Thermal Shroud	2.4 lbs.
Central Station Electronics:	
Height	2.75 inches
Width	7.25 inches
Depth	6.5 inches
Weight	4.1 lbs.
Power Requirements	
Analog Electronics	1.61 watts
Digital Electronics	1.21 watts
Power Converter Loss	1.71 watts
Heater	2.50 watts
Level System	3.60 watts
Functional Power and Heater	7.03 watts
Functional Power and Level	8.13 watts
Voltage	29.0 ± 0.58 vdc

Table 2-14. PSE Leading Particulars (cont)

Characteristic	Value
Scientific Data Signal Characteristics	
Dynamic Range:	
SP and all LP seismic signals	1.0 mμ to 10μ
Sensor assembly temperature	0.02° to 20°C
Sensitivity at Maximum Gain:	
SP and all LP seismic signals	5.0 v/μ
Sensor assembly temperature	0.25 v/°C
Frequency Response:	
SP seismic signal (0 db = 5 v/μ, maximum gain)	-40 db @ 0.038 sec. +42 db/oct. 0.038 to 0.1 sec. +20 db @ 0.1 sec. -6 db/oct. 0.1 to 1.0 sec. -18 db/oct. 1.0 to 20 sec. -78 db @ 20 sec.
All LP seismic signals (0 db = 0.5 v/μ, feedback factor = -33.1 db, post-amplified gain = 1)	-60 db @ 0.3 sec. +48 db/oct. 0.3 to 0.7 sec. 0 db 0.7 to 15 sec. -12 db/oct. 15 to 100 sec. -18 db/oct. 150 to 250 sec. -60 db @ 250 sec.
All LP tidal output signals	-74 db @ 1.2 sec. +6 db/oct. 1.2 to 15 sec. -52 db @ 15 sec. -6 db/oct. 15 to 150 sec. -72 db @ 150 sec. -12 db/oct. 150 to 750 sec. 100 db @ 750 sec.
Sensor assembly temperature	107 - 143°F ±1%

μ = micron
mμ = millimicron
v/μ = volts per micron

Control is achieved through 15 separate ground command channels governing the following:

a. Signal calibration and gain in the four seismic data channels
b. Filtering in feedback circuits in the three long period channels
c. Leveling and uncaging of the PSE seismometers
d. Sensor assembly heater.

The commands are discrete (on-off or sequential stepping) and are transmitted from MSFN stations on the Earth, through the PSEP data subsystem. A discussion of these commands and their basic functions is provided in paragraph 2-65.

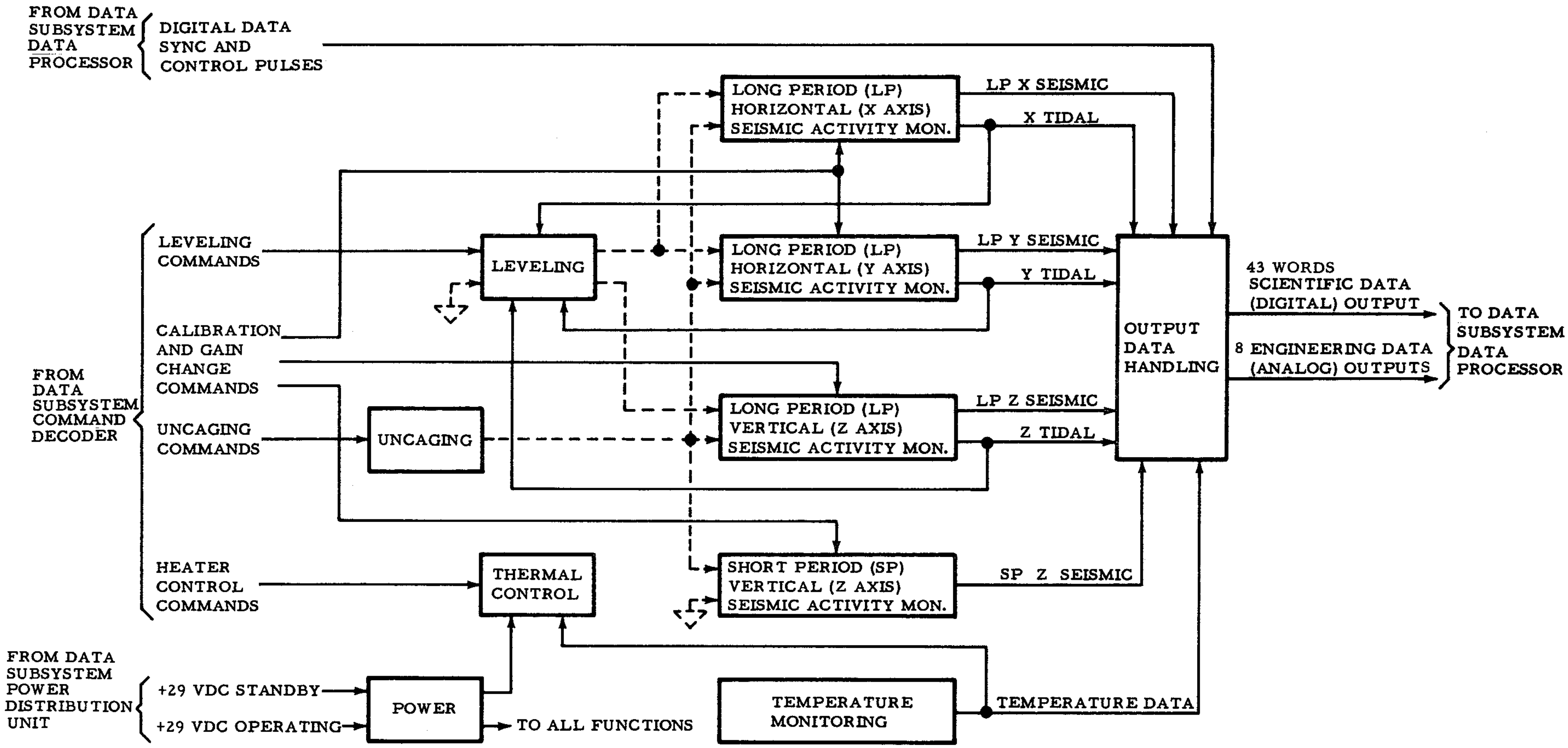


Figure 2-39. Passive Seismic Experiment, Functional Block Diagram

2-63. PSE Monitoring Functions. The three long period seismic data channels are similar, differing only in sensor orientation in the horizontal channels, and principally in sensor type in the vertical channel. The swinging gate type sensors in the horizontal channels respond to tilting as well as lateral displacement of the lunar surface, while the LaCoste spring suspension of the vertical sensor enables it to measure changes in gravitational acceleration as well as its primary function to detect surface displacement in the vertical axis. Seismic data is obtained in the following manner: a capacitance type transducer in each LP sensor provides a phase-referenced, output signal proportional to the amplitude of displacement of the sensor frame from its seismic mass. This signal is amplified, phase-demodulated, and filtered to produce the LP seismic output signal for that axis. Very low frequency filtering of this signal produces its tidal component. The short period channel is generally similar to the long period channels, although a coil-magnet type transducer is employed to produce a single seismic output proportional to the velocity rather than the amplitude of displacement of its seismic mass. The seismic mass in each of the four channels has a separate coil-magnet assembly associated with command-controlled step voltages to produce known input accelerations to each inertial mass for calibration purposes. In the LP sensors the coil-magnet assemblies are also used for damping and stabilization of the LP seismic masses by means of negative feedback of the tidal signal. Signal amplification in each of the four data channels is command controlled. Fixed steps of attenuation may be switched in and out of the signal path as required. The two output signals from each of the three LP channels, plus the output signal from the SP channel, are provided as analog signals to the PSE data handling circuits. The signals are digitized and supplied to the PSEP data subsystem as seven of the eight PSE scientific data output signals.

The relative positions of the LP sensors varies with temperature. The temperature of the sensor assembly is monitored by a temperature sensor in its base, together with a circuit which is capable of detecting changes as small as ±0.02°C. The output of this circuit is applied to the PSE data handling circuits as the eighth PSE scientific data output signal, where it is digitized prior to routing to the PSEP data subsystem. It is also applied to the sensor assembly heater control circuits.

2-64. PSE Supporting Functions. The sensor assembly heater control circuits control the heater operating mode which is selected by Earth command. Three thermal control modes are provided; automatic, thermostat bypass (manual on), and off. The automatic mode is the normal mode of operation, and connects power to the heater through a thermostatic control circuit which maintains the temperature of the sensor assembly within a preset level. The thermostat bypass (manual on) mode applies continuous power to the heater. On PSEP the PSE temperature will be controlled by the mounting plate temperature. PSE heater power will be turned off after system turn-on.

The PSE data handling circuits comprise an analog-to-digital converter which converts the eight analog scientific data signals to digital form. The digital data is then formatted by the PSE into 10-bit digital words for insertion by the PSEP data processor into the 43 assigned spaces in each of the 64-word PSEP telemetry word frames. Synchronization and control pulses which control the formatting and readout of the digital data, are received from the PSEP data processor. Eleven analog status signals from the PSE logic circuits and from the uncaging mechanism are combined into eight analog signals by the PSE data handling circuits for transmission to the PSEP data processor/multiplexer. The data are inserted into housekeeping word number 33 of each of the eight PSEP telemetry word frames assigned for transmission of this data.

The PSEP must be leveled to within ±5° before the platform can be uncaged. Further platform leveling is accomplished through automatic and/or command (manual) positioning of the LP gimbal platform in its horizontal axes, and the spring in the LP vertical axis by means of independent, two-speed, leveling servos in each LP axis. The tidal output signal of each axis may be used as its leveling error signal in both the automatic and command modes. Mode selection and command mode positioning commands affect all three servos; however, power to the leveling motor of each servo is controlled by separate commands. The ability to activate leveling motors separately provides for independent leveling in each axis. Both the automatic and command modes have two leveling speeds, coarse and fine in the automatic, and high and low in the command mode. The coarse and/or high speed mode(s) are normally used only to reduce leveling errors to less than three minutes of arc, and the remainder of the leveling process is done in the fine and/or low speed mode(s).

The sensors of the SP and LP seismometers must be uncaged before they become operable. Uncaging is accomplished by a pyrotechnic piston actuator which breaks the pressure seal in the pressurized bellows type caging mechanism in response to Earth command. Breaking the pressure seal allows the caging system gas to escape, deflating the bellows, releasing the caging pins, and unlocking the inertial masses.

The PSEP power distribution unit furnishes 29 vdc operating and standby (survival) power to the PSE. Application of this power to the PSE is controlled by the power distribution unit (PDU) of the data subsystem, which also connects standby power to the PSE heater circuit in the event of interruption of operating power. Separate PSE power converters, located in the PSE central station electronics module, convert PSEP +29 vdc operating power into the various voltages required in the PSE circuits, as described in paragraph 2-75.

2-65. <u>PSE Command Functions</u>. The following functions of the PSE are controlled by commands from Earth: signal calibration and gain in the four seismic data channels; filtering in the LP feedback circuits; leveling mode, speed, direction, and axis selection during leveling of the LP sensors; and control of the sensor assembly heater operating mode. A total of 15 commands are used for these purposes. The commands are channeled over 15 separate command lines connecting the PSEP command decoder to the PSE central station electronics. The PSE CSE routes the commands over separate lines to the sensor assembly.

The transmission of a command from an MSFN station on the Earth to the PSE results in the generation of a command pulse by the PSEP command decoder on the appropriate command line to the PSE. Each of the 15 incoming PSEP command lines is terminated in the PSE central station electronics by a logic circuit which has two or more stable states, one of which is preset by the application of PSEP power to the PSE. Each of the two or more logic states represents a certain command, such as power on or power off to the associated circuit. Receipt of the command pulse from the command decoder causes the logic circuit to advance to the next stable state, changing the control voltage it applies to the associated circuit. The preset function ensures that the signal or power circuit element associated with each command is in the desired state when power is applied. The preset state of each command is listed with the associated function in Table 2-15. (Refer to Appendix A.)

All of the 15 command logic circuits are comprised of one or more flip-flops. Four of the logic circuits consist of a two-bit, serially connected counter which provides four stable output states. Three of these counters control switches which select sections of step attenuators in the signal paths and in the calibration circuits of the four seismic data channels. The fourth counter controls switching relays in the sensor assembly heater control circuits. The eleven remaining flip-flops control switches applying power to associated circuits.

The preset logic circuit is a form of one-shot multivibrator, which generates the preset pulse to the other logic circuits when triggered by the application of operating power.

Table 2-15. PSE Command Functions

Commands		Functions	Preset State
CL-9	Uncage (ARM/FIRE)	The simultaneous uncaging of all four seismic sensors. Requires separate arm and fire commands.	CAGED
CL-13	Feedback Filter (IN/OUT)	Switches the feedback (tidal) filters in all three LP channels in or out simultaneously.	OUT
CL-15	Leveling Mode (AUTOMATIC/MANUAL)	Switches leveling mode of operation from automatic to manual, or the reverse, in all three LP axes.	AUTOMATIC
CL-11	Leveling Speed (LOW/HIGH)	Switches leveling speed in all three LP axes from low to high, or the reverse, while leveling in the manual mode.	LOW

Table 2-15. PSE Command Functions (cont)

Commands	Functions	Preset State
CL-10 Leveling Direction (PLUS/MINUS)	Switches leveling direction in all three LP axes plus, or minus, while leveling in the manual mode.	PLUS
CL-14 Coarse Level Sensor (IN/OUT)	Switches power to coarse level sensors on or off.	OUT
CL-6 Leveling Power, X Motor (ON/OFF)	Switches power on or off to leveling motor in LP X horizontal axis.	OFF
CL-7 Leveling Power, Y Motor (ON/OFF)	Switches power on or off to leveling motor in LP Y horizontal axis.	OFF
CL-8 Leveling Power, Z Motor (ON/OFF)	Switches power on or off to leveling motor in LP Z vertical axis.	OFF
CL-1 Gain Change, LP X, LP Y	Progressively cycles the attenuators in the X and in the Y axes signal channels through 0, -10, -20, and -30 db steps. Requires one command per step, or a total of four for a complete cycle. The attenuators in the X and in the Y axes calibration circuits are cycled through -30, -20, -10, and 0 db steps at the same time.	**Signal** -30 db **Calibrate** 0 db
CL-2 Gain Change, LP Z	Same as CL-1, except that only two attenuators, one in the signal, and one in the calibration circuit, are involved.	Same as CL-1
CL-5 Gain Change, SP Z	Same as CL-2	Same as CL-1
CL-4 Calibration, LP (ON/OFF)	Switches power on or off to the step attenuators in the calibration circuits of all three LP axes.	OFF
CL-3 Calibration, SP (ON/OFF)	Switches power on or off to the step attenuator in the SP calibration circuit.	OFF
CL-12 Thermal Control Mode (AUTO/MANUAL)	Progressively steps the heater control circuits through four steps, automatic mode ON, OFF, and thermostat bypass mode ON, OFF.	AUTO

2-66. PSE DETAILED FUNCTIONAL DESCRIPTION

The seven seismic and tide monitoring channels and the temperature monitoring channel may be described as the monitoring function. The output data handling, uncaging and leveling, thermal control, and power functions may be described as the supporting functions. The following paragraphs provide detailed functional descriptions of the monitoring and supporting functions.

2-67. PSE Monitoring Functions. The long period (LP) seismometer monitoring channels are described first, followed by descriptions of the short period (SP) seismometer channels and the sensor assembly temperature monitoring channel.

2-68. Long Period (LP) Channels - Each LP sensor channel (Figure 2-40) contains signal processing, electromechanical feedback, and calibration circuits. The sensors in the two PSE horizontal channels (X and Y) are identical, employing swinging gate boom and mass assemblies with capacitor signal pickoff. These sensors are mounted at right angles to each other on the LP leveling platform. The boom of the X channel sensor is oriented along the Y axis of the platform, and the boom of the Y channel sensor is oriented along the X axis of the platform. Displacement of the X sensor frame with respect to its seismic mass occurs in the X axis of the platform; at right angles to its boom. The Y axis sensor functions similarly with respect to the Y axis. The gimbal platform is oriented during deployment so that its X and Y axes are horizontal and are located along known lunar azimuths. The vertical (Z) component seismometer is a LaCoste type spring suspension. The suspension spring is mounted between the horizontal X and Y axes. All three sensors must be leveled by adjustments to the platform and centering motors before they can produce useful output data. (Refer to paragraph 2-73.)

Lateral displacement of the horizontal sensors is controlled both by restoring from a centering Bendix flexure support and by feedback of the tidal signal to the damping coil of the sensor. The frequency of the electrical feedback loop is normally reduced to near dc levels by insertion of a feedback filter in order to produce the tidal output signal for that axis. However, displacement resulting from surface tilting cannot be entirely compensated for by feedback. If the tilting is large enough, releveling of that axis will be required.

Each of the LP sensors contains a transducer consisting of three parallel capacitor plates. The center plate is mounted on the sensor frame, while the two outer plates are mounted on the seismic mass. The outer plates are connected to the balanced output of a 3 KHz oscillator. When the sensor is properly leveled the center plate is centered midway between the outer plates, in a null voltage plane. Displacement of the frame shifts the center plate away from the null plane, inducing a voltage in the plate in phase with that on the outer plate it is approaching. The amplitude of the induced voltage is proportional to the amplitude of displacement. The voltage induced in the center plate is applied to the signal processing circuits at that sensor. These circuits which comprise a preamplifier, phase demodulator, second amplifier, step attenuator, post-amplifier, and low pass filter, convert the voltage into the seismic output signal for that channel.

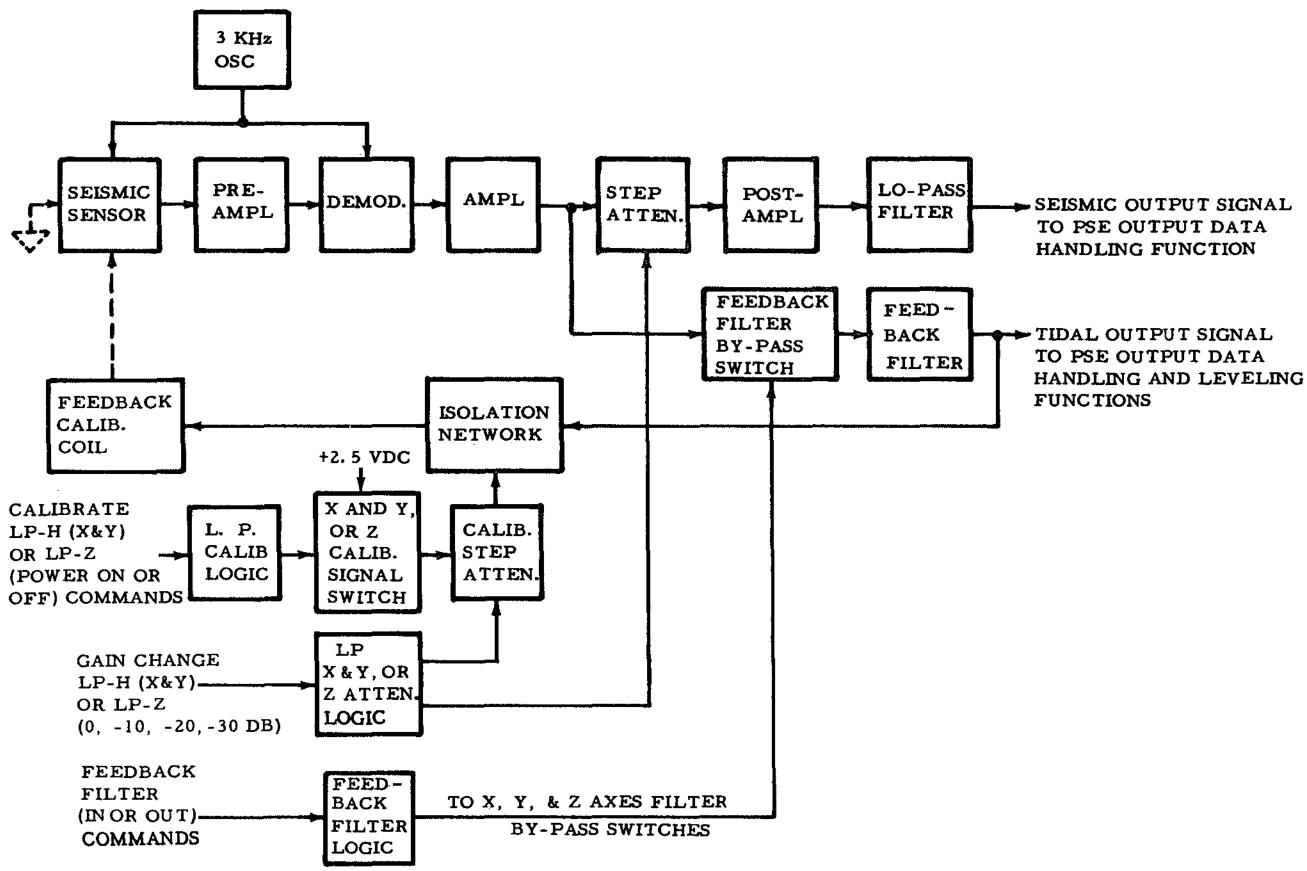


Figure 2-40. PSE Long Period Seismic Activity Monitoring Function, Block Diagram

The preamplifier provides the necessary amplification of the sensor output prior to its demodulation. The phase demodulator demodulates the preamplifier output signal with reference to the phase of the 3 KHz oscillator signal on one of the outer sensor plates. The phase demodulator also provides a dc output voltage whose polarity and amplitude are proportional to the direction and amount of displacement of the sensor elements. The output of the demodulator is amplified in the second amplifier and is then applied to the following two separate units. The first of these units is the step attenuator in the seismic signal path. The step attenuator provides fixed steps of 0, -10, -20, and -30 db attenuation of the signal according to commands received from Earth. The signal passed by the attenuator is amplified in the post-amplifier for application to the low pass filter which highly attenuates signal components above 1 Hz. The output of the low pass filter is supplied to the output data handling circuits as one of the eight PSE scientific data outputs. The second separate unit is the filter bypass switch in the electromechanical feedback signal path. The filter bypass switch is operated by command. The output of the second amplifier may be applied either through the low pass filter and isolation network of the feedback circuit to the feedback coil of the seismic sensor, or the filter may be bypassed and the signal applied directly to the network and coil. The filter separates the tidal component from the seismic signal for use as (a) one of the experiment scientific data outputs, (b) a long period feedback signal for stabilization and re-centering of the sensor following periods of seismic activity, and (c) a position error signal for leveling the channel sensor. The filter is bypassed when high rates of damping of the sensor movement are required, such as during coarse automatic or high speed command (mannual on) leveling of the horizontal sensors, or periods of unusually high seismic activity. The filter bypass switches in the feedback paths of all three of the LP channels are operated simultaneously by being connected to one flip-flop logic circuit terminating the feedback filter command line. The preset state of the logic circuit closes the bypass switches.

The gain control and signal calibration functions are identical in all three LP axes. The gain control function in each axis is independent of the calibration function; however, individual calibration voltages in the calibration function are selected through the gain change commands of the gain control function.

The gain control function controls the total amplifier gain in each seismic channel by switching individual sections of the step attenuator channel in and out of the seismic signal path. The attenuators in the two horizontal axes are switched together. An attenuator logic circuit consisting of a serially connected flip-flop counter terminates the X and Y axes gain change command line. This counter is stepped by individual gain change commands through four sequential states. Each state provides a combination of output voltages controlling solid-state switches in the step attenuators of the horizontal axes. The counter advances one step each time a command pulse is received, increasing the total impedance of the attenuator in 10 db steps, from 0 db through -30 db. A separate logic circuit, identical to that controlling gain in the two horizontal channels, terminates the Z axis gain change command line and controls gain in the LP vertical channel. The functioning of the gain control circuits of this channel are identical to those of the horizontal channels previously described.

Alternate outputs of the logic circuits controlling seismic signal gain in each of the three LP channels are applied to attenuator circuits in the signal calibration circuits of each channel. The signal calibration function is used together with the gain control function to generate LP output signals with amplitudes which represent known sensor displacements. The signal calibration circuits of each LP sensor are comprised of a calibration logic circuit, two calibration signal switches, two step attenuators, three isolation networks, and the feedback calibration coils. The calibration logic circuit consists of a flip-flop. In its preset state the logic opens the two solid-state calibration signal switches (X and Y, and Z). The logic state may be changed by command. When closed by the LP calibrate command, the switches apply a +2.5-volt reference signal from the PSE power distribution system to the step attenuator in each of two calibration circuits.

One calibration circuit applies the reference signal to the sensors in the two horizontal channels and the other calibration circuit applies the reference signal to the sensor in the vertical channel. The impedance of each attenuator is controlled by the gain change commands, which vary the alternate output of the gain control function logic (counter) governing seismic signal gain in the same channels. The alternate outputs are used to provide minimum attenuation (0 db) of the calibration signal with maximum attenuation (-30 db) of the seismic signal conversely. The preset state of the gain control logic switches the calibration step attenuator to the -30 db step. The outputs of the attenuators are applied to the isolation networks, and then to the feedback calibration coil of the sensor involved. The isolation networks prevent feedback of the calibration signal into the seismic signal path. However, when the dc voltages are applied to the feedback calibration coil, steady displacements of known amplitude are produced which in turn produce a dc output signal in the associated channel representing the known amount of applied acceleration.

2-69. Short Period (SP) Channel - The SP channel (Figure 2-41) is similar to the long period channels, differing primarily in the type and frequency range of its sensor, the number of components, and the character of its output signal. The SP seismometer comprises a velocity type sensor and signal processing and calibration circuits.

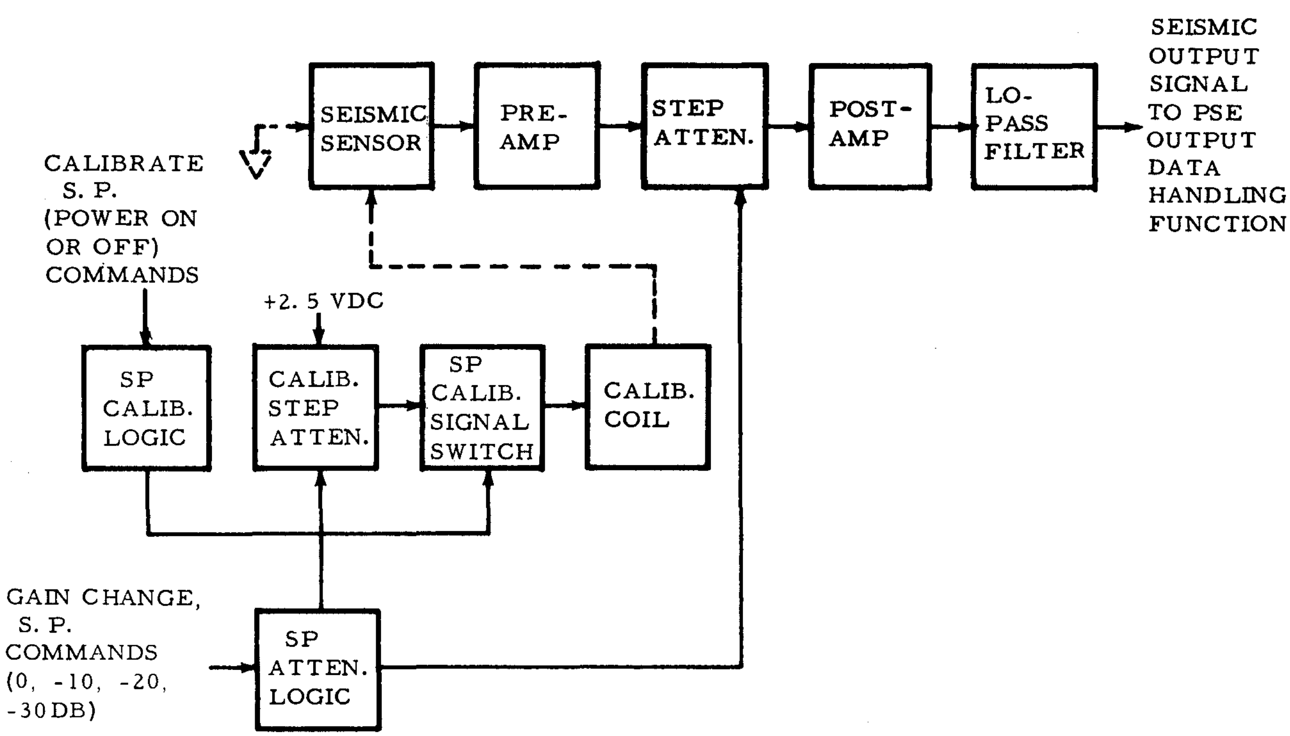


Figure 2-41. PSE Short Period Seismic Activity Monitoring Function, Block Diagram

The SP sensor is comprised of a permanent magnet seismic mass suspended by a leaf spring and stabilizing delta rods. The mass is designed to move vertically within a coil mounted vertically in one hemispherical base of the sensor. This configuration is sensitive to rate of motion in the vertical axis, but less sensitive to lateral or tilting motions, and does not require leveling beyond that provided during deployment (±5° of vertical). A sensor coil magnet assembly similar to those of the LP sensors is used for calibration purposes.

The voltages induced in the SP sensor output coil by motion of the lunar surface in its vertical plane are applied to the SP signal processing circuits. These circuits consist of a preamplifier, step attenuator, post-amplifier, and low pass filter. The preamplifier provides amplification of the sensor output signal, prior to transmission of this signal from the sensor assembly to the remaining signal processing circuits which are located in the PSE central station electronics subassembly. Control of the total amplification of the SP seismic signal is provided by the step attenuator, as in the LP channels. The signal passed by the attenuator is amplified in the post-amplifier for application to the low pass filter. Since higher frequency components are present in the SP signal than in the LP signals, the SP low pass filter has a higher cutoff frequency. The filter output is applied to the PSE output data handling circuits as one of the PSE scientific data output signals. No tidal signal is produced by the SP sensor.

The SP gain control function is like that of the LP channel. A counter logic circuit terminates the SP gain change command line controlling a step attenuator in the SP seismic signal processing circuits.

The SP signal calibration function is similar but not identical to that of the LP vertical axis. A logic circuit, step attenuator, calibration signal switch, and one coil magnet assembly in the SP sensor are employed. The logic circuit which terminates the SP calibrate command line is a flip-flop which controls the calibration signal switch. In the SP calibration circuits, the 2.5-volt reference signal from the PSE power converter is applied to the step attenuator (instead of to the calibration signal switch) and the output of the attenuator is then applied to the switch. The impedance of the SP step attenuator is controlled by the alternate output of the logic (counter) terminating the SP gain change command line, as in the LP calibration circuits. When the calibration signal switch is commanded on, by its logic circuit, the attenuator output is connected to the calibration coil on the SP sensor. The calibration voltage is a step function producing a known acceleration of the SP sensor seismic mass.

Two command lines from the data subsystem are provided for control of the SP calibration function. The primary SP calibrate command is routed through the PSEP command decoder and carries Earth-originated command pulses. In the event of uplink failure, a second calibrate command is provided from the central station timer in the data subsystem. These backup pulses provide automatic calibration of the SP channel signal every 12 hours, using the existing attenuator settings.

2-70. Temperature Monitoring Channel - The PSE temperature monitoring channel develops an output signal porportional to the temperature of the sensor assembly. It consists of a temperature sensing bridge circuit and a differential amplifier. A 3 KHz signal, from the 3 KHz oscillator in the LP seismic channels, is applied to the input of the bridge circuit which is balanced at 125°F. Two thermistors in the bridge arms are mounted on the base of the sensor assembly, and sense changes in its temperature. Changes as small as 0.02°C are enough to unbalance the bridge circuit sufficiently to develop a temperature output signal from the differential amplifier which is proportional to the direction and amount of change. This signal is applied to the PSE output data handling circuits as one of the experiment scientific data outputs.

2-71. PSE Supporting Functions. The supporting functions comprise data handling, uncaging and leveling, thermal control and power functions.

2-72. Data Handling - The output data handling function circuits (Figure 42) handle the conversion of the analog output signals of the eight scientific data channels into digital form, the formatting of the digital data into 10-bit words for serial insertion into each of the 90 PSEP telemetry frames in one cycle, and the combining of 11 analog status signals into eight analog channels for insertion into housekeeping work number 33 of each of eight PSEP telemetry frames.

The output data handling circuits consist of eight major functional blocks, which are program control and buffer amplifiers, frame position counter, data channel selector, analog multiplexer, analog-to-digital converter transfer gates, shift register, and housekeeping data addition and transfer networks.

The program control and buffer amplifier subfunction provides timing and control pulses to the other subfunctions. It is the interface between the PSE data handling circuits and the PSEP data subsystem. The buffer amplifiers terminate the input and output lines to and from the PSEP data subsystem, providing isolation of these lines from the PSE circuits.

The frame position counter provides telemetry frame and word position pulses to the data channel selector, enabling it to select the multiplexer data channel assigned to each of the 43 PSE data words in each PSEP telemetry frame at the appropriate times.

The data channel selector decodes the frame position counter outputs and uses them to control the gating of each of the eight PSE scientific data outputs through the analog multiplexer to the analog-to-digital converter in the PSE central station electronics module. The data channel selector causes the multiplexer to sample

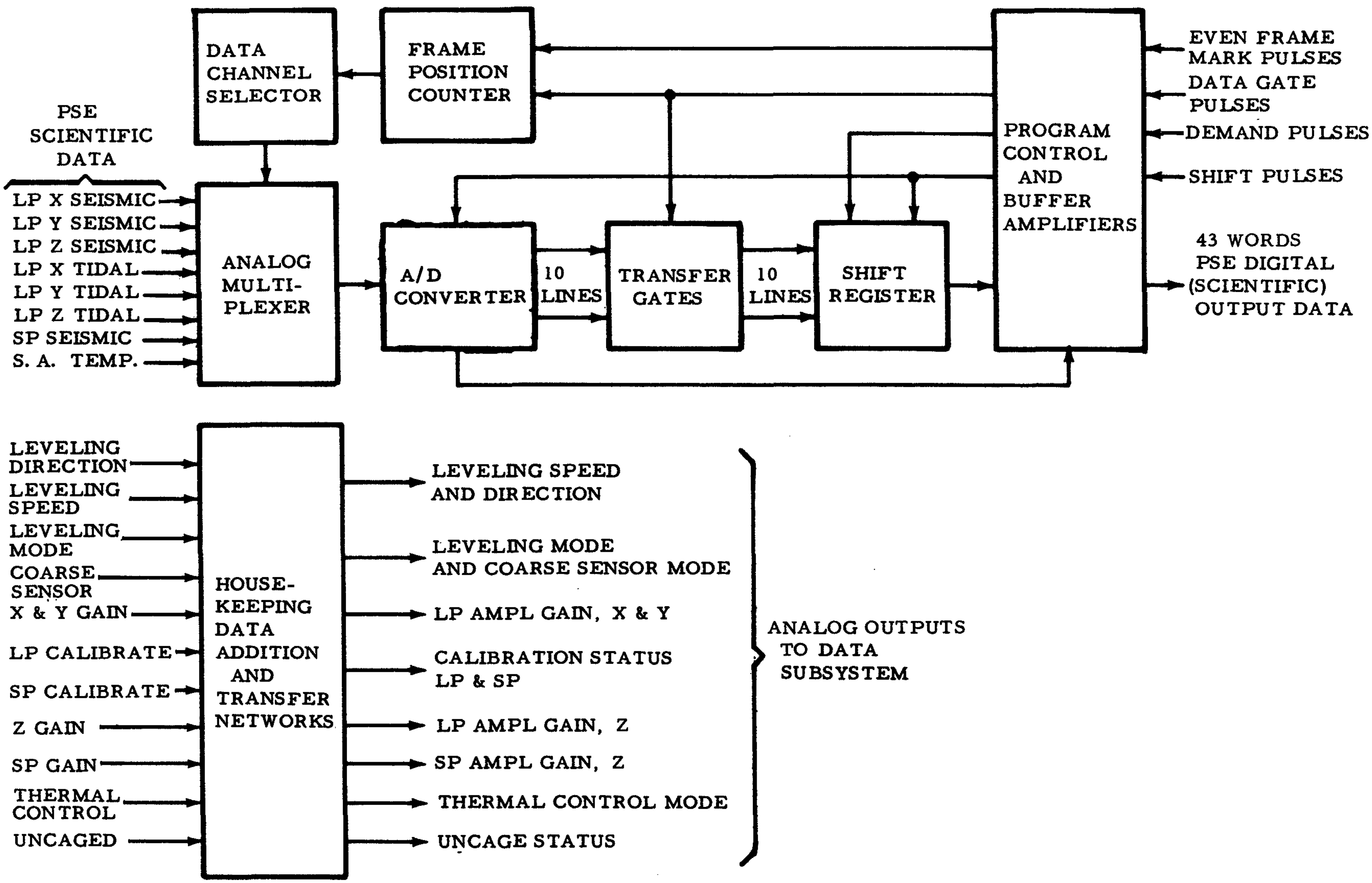


Figure 2-42. PSE Data Handling Function, Block Diagram

the short period seismic signal a total of 29 word-times in each PSEP telemetry frame. The three long period seismic signals are each sampled four word-times in each PSEP frame. The tidal signals in each of the two LP horizontal axes are sampled once every even frame. The tidal signal in the LP vertical channel and the sensor assembly temperature signal are sampled every odd frame.

The analog multiplexer gates each of the eight scientific data output signals to the analog-to-digital converter in the PSE central station electronics module according to the control pulses received from the data channel selector.

The transfer gates are enabled by program control pulses to shift the 10-bit data words out in parallel from the digital-to-analog converter and into the shift register at the appropriate times.

The PSE digital scientific data comprises 43 of the 64 words in each PSEP telemetry frame. Each data word consists of 10 NRZ bits. A listing of PSE telemetry word assignments is given in Table 2-16 and in the Appendix. PSE data word locations in the PSEP telemetry frame are shown in Figure 2-43. The normal PSEP bit repetition rate is 1060 bps. Under difficult telemetry communications conditions, the slow PSEP bit rate, which is half the normal rate, may be used.

The housekeeping data addition and transfer networks combine 11 status signals into eight channels and transfer these analog data to the PSEP data processor analog multiplexer. Three pairs of command status signals are added in resistor networks to form three combination signals. These three signals and the five single signals are applied to the data processor. The three summed pairs of signals are the outputs of the logic circuits terminating certain command lines and in each case are a change in level expected as the result of the transmission of associated commands. The eight analog signals are listed in Table 2-16 along with the telemetry frame in which they are transmitted in housekeeping word number 33.

Both synchronization and data control pulses are received from the PSEP data processor for controlling the PSE output data handling functions. Even frame mark, data gate, and shift pulses are provided by the PSEP data processor to synchronoize and control the formatting of the PSE data into 10-bit words compatible with PSEP telemetry requirements. The even frame mark pulses mark the beginning of each even numbered telemetry frame and are used in the program control, frame position counter, and data channel selector subfunctions. The demand pulses are one 10-bit word in length and are generated by the data processor for use in the program control circuits to gate data out of the shift register, on demand, to the data processor.

2-73. Uncaging and Leveling - Uncaging and leveling are separate, but related functions which are grouped together in this description for the purpose of discussion. (See Figure 2-44.) Uncaging must be performed after deployment before

1	2	3	4 SP	5	6 SP	7	8 SP
9 LPX	10 SP	11 LPY	12 SP	13 LPZ	14 SP	15	16 SP
17	18 SP	19	20 SP	21	22 SP	23	24 SP
25 LPX	26 SP	27 LPY	28 SP	29 LPZ	30 SP	31	32 SP
33 ED	34 SP	35 $LPTX_E$ / $LPTZ_O$	36 SP	37 $LPTY_E$ / T_O	38 SP	39	40 SP
41 LPX	42 SP	43 LPY	44 SP	45 LPZ	46	47	48 SP
49	50 SP	51	52 SP	53	54 SP	55	56
57 LPX	58 SP	59 LPY	60 SP	61 LPZ	62 SP	63	64 SP

ONE 64 WORD PSEP TELEMETRY FRAME

SP = SHORT PERIOD SEISMIC DATA
LPX = LONG PERIOD SEISMIC DATA, X CHANNEL
LPY = LONG PERIOD SEISMIC DATA, Y CHANNEL
LPZ = LONG PERIOD SEISMIC DATA, Z CHANNEL
$LPTX_E$ = LONG PERIOD TIDAL DATA, X CHANNEL, EVEN FRAMES ONLY
$LPTZ_O$ = LONG PERIOD TIDAL DATA, Y CHANNEL, ODD FRAMES ONLY
$LPTY_E$ = LONG PERIOD TIDAL DATA, Y CHANNEL, EVEN FRAMES ONLY
T_O = TEMPERATURE DATA, ODD FRAMES ONLY
ED = ENGINEERING DATA IN 8 OUT OF 90 FRAMES

Figure 2-43. PSE Data Word Assignment in PSEP Telemetry Frame

data can be obtained from either LP or SP seismometers. After uncaging, leveling must be performed in all three axes of the LP seismometer before useful data can be obtained. The SP seismometer does not require leveling beyond that performed during deployment.

The sensors of both seismometers are caged upon completion of acceptance tests and following final assembly at the time of manufacture. The sensors are not uncaged until after deployment on the lunar surface. The pressurized bellows

Table 2-16. PSE Measurements

PSE Measurement Name	Symbol	PSEP Word No's	Frames
Scientific Data			
Long Period X	DL-1	9, 25, 41, 57	Every
Long Period Y	DL-2	11, 27, 43, 59	Every
Long Period Z	DL-3	13, 29, 45, 61	Every
Long Period Tidal X	DL-4	35	Even
Long Period Tidal Y	DL-5	37	Even
Long Period Tidal Z	DL-6	35	Odd
Instrument Temperature	DL-7	37	Odd
Short Period Z	DL-8	Every even except 2 46, and 56	Every
Engineering Data			
LP Ampl. Gain, X and Y	AL-1	33	23
LP Ampl. Gain, Z	AL-2	33	38
Leveling Direction and Speed	AL-3	33	53
SP Ampl. Gain, Z	AL-4	33	68
Leveling Mode and Coarse Sensor Mode	AL-5	33	24
Thermal Control Mode	AL-6	33	39
Calibration Status, LP & SP	AL-7	33	54
Uncage Status	AL-8	33	69

type caging mechanism inserts two locking pins in position into the bottoms of the seismic masses. The locking pins and caging bellows mechanism unload the sensor suspension systems, absorbing shock and acceleration which might otherwise damage the delicate mass suspension systems during handling on the Earth, the Moon, and during flight.

The uncaging function is a logic circuit and an uncaging mechanism which is comprised of a capacitive-discharge circuit, piston actuator, spring-loaded piston and a break-off valve in the bellows pressurization system. Two commands are required to complete the uncaging cycle. The first command (Arm) switches the logic circuit from its preset (caged) state to "uncage", which causes the charging of a capacitor in the capacitive-discharge circuit. After approximately 30 seconds, the second command (uncage) is sent, causing the charged capacitor to be discharged through the piston actuator bridgewire. The bridgewire initiates the piston actuator, breaking the breakoff valve, and depressurizing

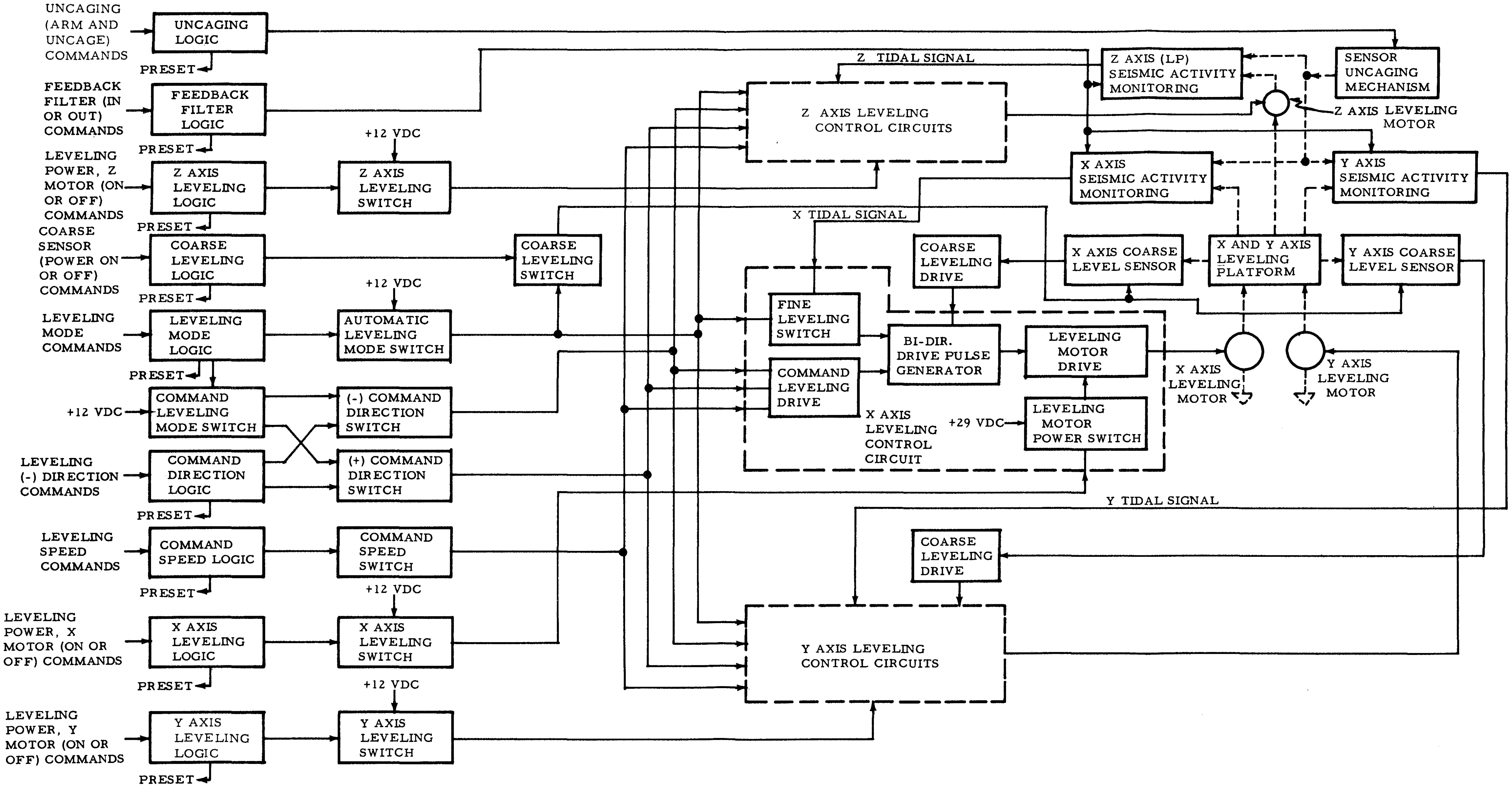


Figure 2-44. PSE Uncaging and Leveling Function, Block Diagram

the caging bellows. The bellows are collapsed by springs, withdrawing the locking pins from the inertial masses and loading the suspension system.

Position type servo mechanisms are employed to independently level each LP axis. The horizontal axes have identical leveling drives and the vertical axis is similarly centered by means of a motor drive. (See Figure 2-44.)

The X and Y axes leveling motors physically position the gimbal platform as well as their respective sensors, while the Z motor positions its sensor with respect to the platform. Changes in platform position in the horizontal axes thus affect the position of the vertical axis sensor, requiring that it be centered last.

The servo mechanisms used in each LP axis have two modes of operation; automatic and command. The automatic mode uses position-error signals generated within the PSE sensor, while the command mode uses positioning signals generated by Earth-command. Two speeds of operation are provided in each mode; coarse and fine in the automatic mode, and high and low in the command mode. The automatic-coarse mode is used with position error signals from the corresponding (X or Y) coarse level sensors on the leveling platform to achieve leveling in the X and Y axes. These position-error signals are used to reduce the relatively large initial off-level (± 5 degrees) which is possible from the manual leveling process during deployment. Following the coarse leveling sequence, the automatic-fine leveling mode is used. In this mode, the tidal output signal of the seismic channel is employed as the position-error signal. This process is designed to reduce leveling errors of the LP seismometers to less than three seconds of arc. The command mode leveling speeds may be similarly used for leveling by Earth positioning commands, using the telemetered tidal and seismic signal data from the channel being leveled as the position-error signal. A total of up to two hours may be required for completion of the fine leveling in all three axes after deployment and verification of system operation. Selection of the axis to be leveled, and leveling mode, speed, and direction are controlled by seven Earth commands. The vertical axis leveling modes are similar to those of the horizontal axes. However, the automatic-coarse speed leveling mode is not used for the vertical component.

Figure 2-44 shows the leveling function circuits of all three axes as well as their interrelationships. These circuits consist of command logic and switching circuits, leveling control circuits, their associated leveling motors, and position-error signal generation circuits.

The command logic and switching circuits terminating each of the command lines associated with leveling are shown in Figure 2-44. These circuits comprise logic circuits controlling the feedback filter bypass switches of each axis, power to the leveling motors of each axes, leveling mode, and command leveling speed and direction. The feedback filter logic circuit is used to switch the feedback filter out of the feedback loop (simultaneously in all three axes) during the automatic-coarse and command-high speed leveling modes. This is done to decrease the sensitivity of the seismometers during leveling. The leveling logic and switching circuits control application of operating power to the leveling motor drive circuits of their respective axes. The leveling mode, command leveling speed and direction logic, and switching circuits control these functions in all three axes.

Details of the leveling control circuits of the X axis are shown in a block in the center of Figure 2-44. The leveling control circuits of the Y and Z axes are indicated by a similar block. These circuits are identical for X and Y, and are similar for Z. The circuits comprise a leveling motor power switch, fine (automatic) and command leveling drive circuits, bi-directional pulse generator, and leveling motor drive circuits. The X and Y axes include coarse leveling drive circuits for leveling of the gimbal platform (these circuits are not required for the Z axis). The three (fine, command, and coarse) leveling drive circuits are each enabled in their associated leveling mode. The level drive circuits convert leveling position-error or direction and speed input signals into polarized outputs for operation of the bi-directional drive pulse generator. The bi-directional drive pulse generator generates a series of output pulses with width and polarity proportional to the amplitude and polarity of its input signals. The pulse generator output signals drive the leveling motor drive circuits by means of driving signals to the leveling motors which are proportional to the bi-directional pulse generator output. The level motor drive circuits are operated by + 29 volt power which is controlled by Earth command.

Figure 2-44 shows the relationship of the leveling platform and motors, the three LP seismic activity monitoring functions (which generate the position error signals for leveling in the automatic-fine mode), and the coarse sensors of the X and Y axes (which generate the position error signals for the automatic-coarse mode of leveling these axes.)

The functions of the leveling servo loops in the different modes of operation are described by following the leveling commands and error signals through the leveling servo circuits of the X axis. The circuits of the other axes function in a similar manner.

Leveling of the X axis requires that power be applied to the X axis leveling motor by command. A pulse must be applied to the logic circuit terminating the leveling power X motor command line because the preset state of this logic circuit results in the operating power circuit of the X axis leveling motor being open. The command pulse switches the logic circuit to its alternate state, closing the associated X axis leveling switch, and connecting a dc voltage to the leveling motor power switch in the X axis leveling control circuits. The leveling motor power switch is closed by the dc voltage and applies +29-volt operating power to the leveling motor drive circuits.

The leveling mode logic circuit selects either the automatic or command leveling mode according to its output state. The preset state of the leveling mode logic circuit closes the automatic leveling mode switch applying a dc voltage to the coarse leveling switch and to the fine leveling drive circuits. With the coarse leveling logic circuit in its preset state, the coarse leveling switch is open, and power is not applied to the coarse level sensors of the horizontal axes. This permits leveling in the automatic fine leveling submode. If relatively large leveling position-errors are present after deployment, the automatic coarse leveling submode can be selected by the coarse sensor command. This command pulse sets the coarse leveling logic to its alternate state, closing the coarse leveling switch and applying power to the X and Y coarse level sensors. These sensors are mercury switches mounted on the gimbal platform. The mercury switches generate relatively large leveling position-error signals of constant amplitude with a polarity dependent on that of the position error. The output of the X axis coarse level sensor is applied to the coarse leveling drive circuits in the leveling control circuits for the X axis. The output signal of the coarse leveling drive circuit controls the output of the bi-directional pulse generator. The generator produces a series of polarized pulses with width and polarity proportional to the amplitude and direction of the leveling position error. These pulses are applied to the leveling motor drive circuit along with +29-volt operating power from the leveling motor power switch as previously described. The leveling motor drive circuits apply operating power to the leveling motor in proportion to the pulse width and polarity of the drive signal from the bi-directional pulse generator. The leveling motor slowly repositions the leveling platform about its X axis reducing the leveling position error. During the final portion of the leveling process, particularly in the fine and low speed modes, position errors are reduced to less than three seconds of arc and the leveling rates are proportionately lower and thereby slower.

A second command (pulse) applied to the coarse sensor command line resets the coarse leveling logic to its original (preset) state, restoring the automatic fine leveling submode. The tidal output signal of the X axis seismic activity monitoring function is also applied to the fine leveling drive circuits. The fine leveling drive circuits generate an output signal proportional to the direction and amplitude of the leveling position error. This signal is applied to the bi-directional drive pulse generator, controlling its output in the same manner as the output signals of the coarse leveling drive circuits.

The command leveling mode is selected by the alternate state of the leveling mode logic circuits. The preset state of the logic circuit is changed to the alternate state by a command pulse on the leveling mode command line. The alternate state opens the automatic leveling mode switch and closes the command leveling mode switch. Opening the automatic leveling mode switch disables both the fine leveling drive circuit and the coarse leveling switch, effectively disabling both of the automatic leveling submodes. Closing the command leveling switch connects power to the plus and minus (leveling) direction switches. The preset state of the command (leveling) direction logic closes the plus direction switch and opens the minus direction switch. The output voltage of the plus direction switch is applied to the command leveling drive circuit in the X axis leveling control circuits enabling it and controlling the polarity of its output signal. A command pulse on the leveling direction command line causes the command direction logic circuit to change its alternate state, closing the minus direction switch and opening the plus direction switch. This reverses the polarity of the output signal of the command leveling drive circuit. The preset state of the command speed logic circuit opens the command speed switch and opens a ground circuit to the command leveling drive circuit. The output signal of the drive circuit is then the lower of the two preset amplitude levels. A command pulse on the leveling speed command line causes the command speed logic circuit to change to its alternate state, closing the command speed switch. Completion of this circuit causes the output of the command leveling drive circuit to be the higher of its two preset states. The output of the command leveling drive circuit is applied to the bi-directional drive pulse generator, which produces output pulses proportional to the amplitude and polarity of the drive circuit signal. The output of the pulse generator controls the leveling motor through its drive circuit as in the automatic mode.

The control and leveling functions of the Y axis are identical to those described for the X axis. Those in the Z axis are similar with the exception of the coarse leveling mode circuitry. These circuits are not required in the Z axis because their function is accomplished by those of the X and Y axes and the leveling of the leveling platform.

2-74. Thermal Control - The thermal control function circuits (Figure 2-45) control the application of operating power to the sensor assembly heaters which are located in the base of the assembly. Three modes of operation are provided; automatic, thermostat bypass (manual on), and power off. The thermal control circuits comprise a logic circuit, heater power relay, bypass relay, multivibrator, heater power switch, and the heater.

Operating power is applied to the heater power relay from the PSE power distribution circuits. This relay and the bypass relay control the operating mode of the heater, and are in turn controlled by the logic circuit. The logic circuit terminates the thermal control mode command line and consists of a two-bit, serially connected flip-flop counter. The counter has a total of four two-bit output voltage combinations. One of the bit-outputs controls the heater power relay and the other the bypass relay.

In both the automatic and thermostat bypass modes the heater power relay is closed connecting operating power to the heater power switch. In the power off mode this relay is open, interrupting the power circuit. The heater power switch is turned on and off at a 3 KHz rate by the multivibrator. When the heater power switch is on and the heater power relay closed, operating power is connected to the heater.

The proportion of time when power to the heater power switch is on, is varied by the multivibrator according to the temperature signal received from the temperature monitoring circuits. A decrease in temperature lengthens the power on

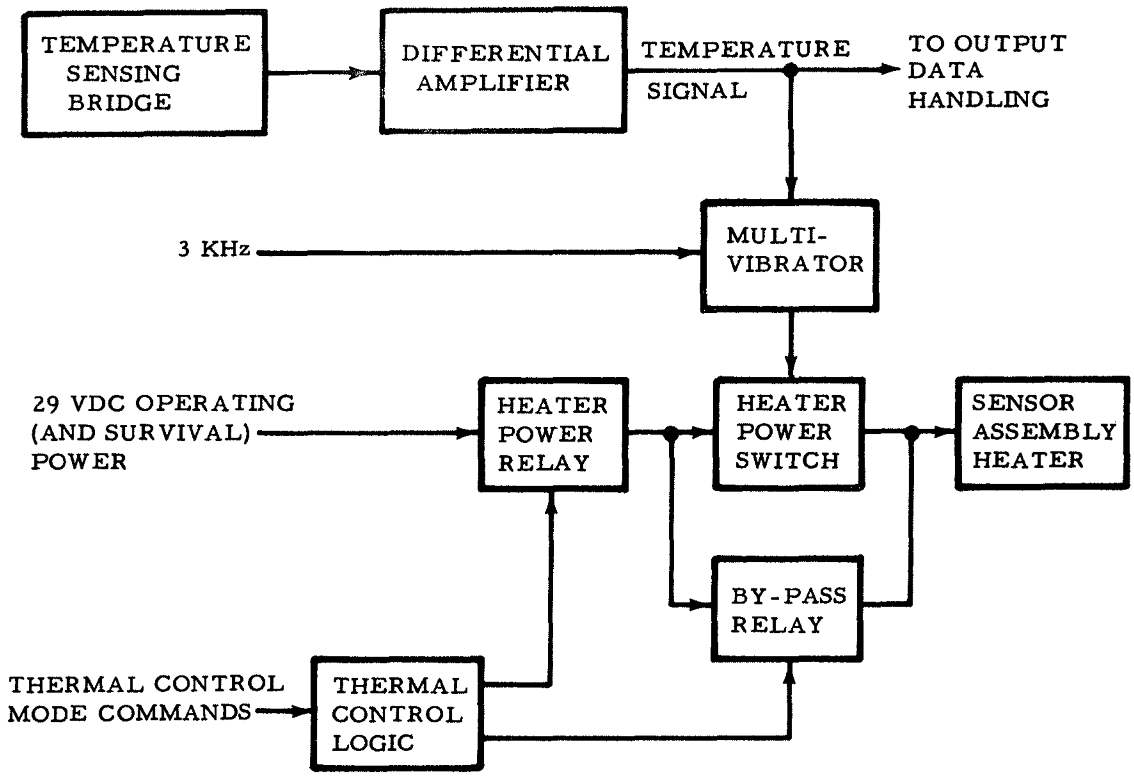


Figure 2-45. PSE Termal Control Function, Block Diagram

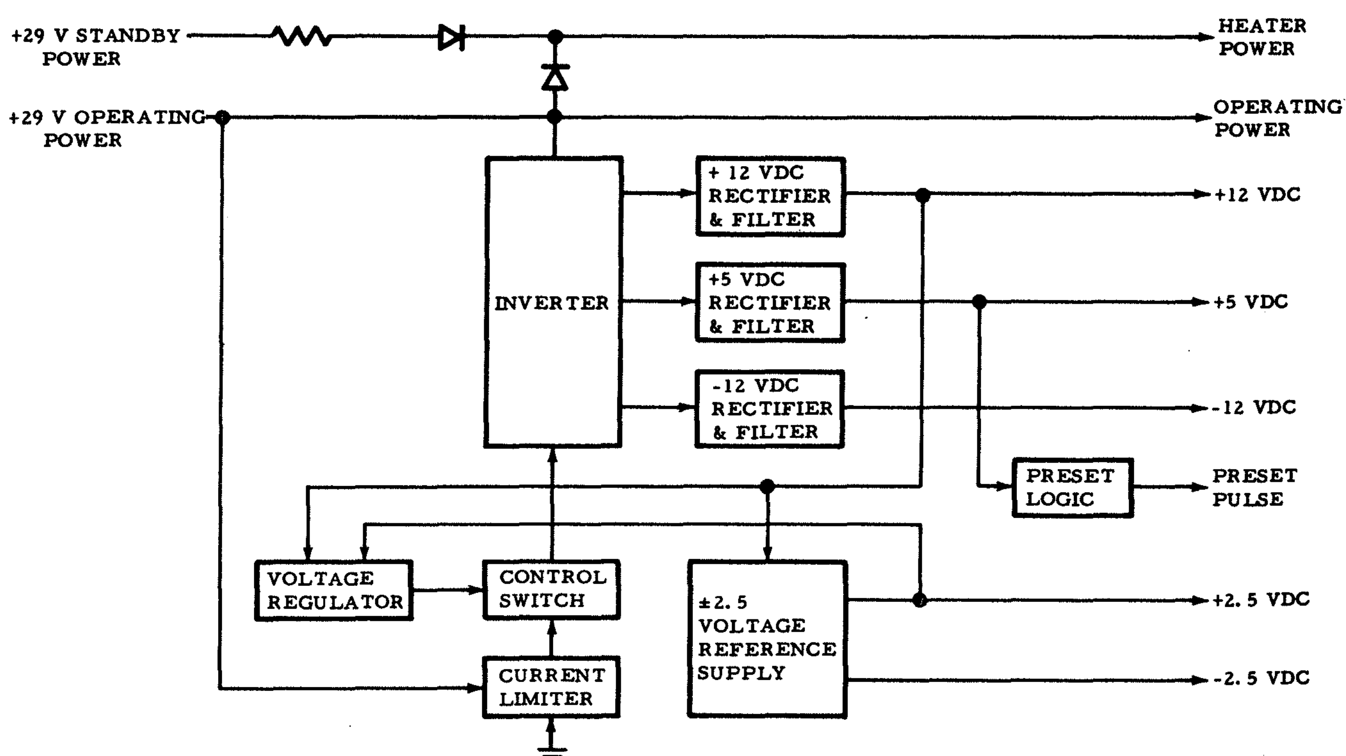


Figure 2-46. PSE Power Converter Function, Block Diagram

period and conversely. The multivibrator is driven at the 3 KHz rate by the 3 KHz oscillator in the LP seismic channels.

In the automatic mode the bypass relay is open, permitting the heater power switch to control application of power to the heater. In the thermostat bypass mode the bypass relay is closed, connecting power around the switch to the heater.

2-75. Power Converter - The power converter (Figure 2-46) converts PSEP +29-volt operating power to the +12, +5, -12, +2.5, and -2.5 dc voltage required in the PSE circuits, generates the command logic preset pulse, and provides isolation of the operating and standby power lines to the sensor assembly heater.

The power converter circuits comprise an inverter, three rectifier-filter circuits, voltage regulator and control switch, current limiter, ±2.5 vdc reference voltage supply, preset logic and standby power isolation network.

The inverter chops the +29-volt operating power into a series of pulses and applies these pulses as an input signal to the three rectifier-filter circuits. The rectifier-filter circuits each consist of a full wave bridge rectifier and low pass filter, and produce the +12, +5, and -12 volt outputs. The voltage regulator and control switch control the amplitude of these dc voltages by monitoring the +12-volt output. The regulator circuit contains a voltage comparator and multivibrator. The voltage comparator controls the multivibrator. The multivibrator drives the control switch to adjust the length of time power is applied to the inverter during each half of its output cycle. An increase in the amplitude of the +12-volt supply causes a decrease in the ratio of power on to power off time, and conversely. The current limiter functions as a series regulator, limiting the maximum amount of current drawn by the inverter.

The ±2.5-volt reference supply converts part of the output of the +12-volt supply to low ripple, low noise, +2.5 and -2.5 volt reference outputs for use in the PSE calibration circuits and in the PSEP data processor. It consists of a reference voltage source supplying the +2.5 and -2.5 volt outputs and electronic series voltage regulators in each output.

The preset logic circuit is a form of one-shot multivibrator triggered by the output of the +5 volt supply. It produces the command type preset pulse to the command logic circuits when operating power is first applied to the PSE.

The standby power isolation network connects operating power to other PSE circuits as well as the heater circuits, but connects standby power only to the heater circuits.

SECTION III

LASER RANGING RETRO-REFLECTOR EXPERIMENT

3-1. INTRODUCTION

The laser ranging retro-reflector experiment (LRRR) will reflect laser radiation incident upon it on a path nearly parallel to the incident beam. It will serve as a fiducial point on the surface of the moon to permit precise measurement by laser ranging of the distance from one or more sites on earth.

The LRRR (Figure 3-1) is a passive device requiring no electrical power source or telemetry capability.

Data obtained from this experiment will be utilized to expand knowledge in the following scientific areas:

a. The Moon's size and orbit can be more accurately determined by making a comparison of measured range data over long time periods (up to 10 years).
b. Geophysical information will be obtained by comparing range data from several Earth-based laser sites. Variations in the geocentric latitudes of the laser sites as well as their locations will be more accurately determined.
c. Measurements of the longitude of the Moon relative to Earth using the Earth's rotation and a single laser site or, better yet, two laser sites spaced 90 geo-longitudinal degrees apart, could help determine the possibility of a slow, secular decrease in the gravitational constant.

This section describes the LRRR in terms of its physical characteristics and functional operation. LRRR Leading Particulars are provided in Table 3-1.

3-2. LRRR PHYSICAL DESCRIPTION

The LRRR consists of a pallet and array assembly, boom attachment assembly, and rear support. The pallet and array assembly consists of the pallet assembly and the retro-reflector array assembly.

3-3. PALLET ASSEMBLY

The pallet assembly provides the structural base required for the LRRR to withstand the environments encountered in storage, transportation and handling, space flight, and lunar deployment. During operation on the Moon, the pallet assembly will provide continuing structural support as well as thermal isolation for the retro-reflector array for a survival period of up to 10 years.

Table 3-1.

LRRR Leading Particulars

Component	Characteristic	Value	
Pallet Assembly	Size (inches)	L	26.00
		W	27.25
		H	3.25
	Weight (pounds)		16.9
Angle Indicator Bracket	Size (inches)	H	9.12
		W	1.86
		D	4.50
	Weight (pounds)		0.4
Sun Compass Plate	Size (inches)	L	15.75
		W	3.37
	Weight (pounds)		0.1
Retro-Reflector Array Assembly:	Gross Form Factor (inches)	L	19.00
		W	19.50
		H	8.25
	Weight (pounds)		33.0
Retro-Reflectors	Quantity in Array		100
Rear Support	Size (inches)	H	13.75
		W	17.00
	Weight (pounds)		0.5
Boom Attachment Assembly	Size (inches)	H	22.25
		DIA	0.75
	Weight (pounds)		1.0

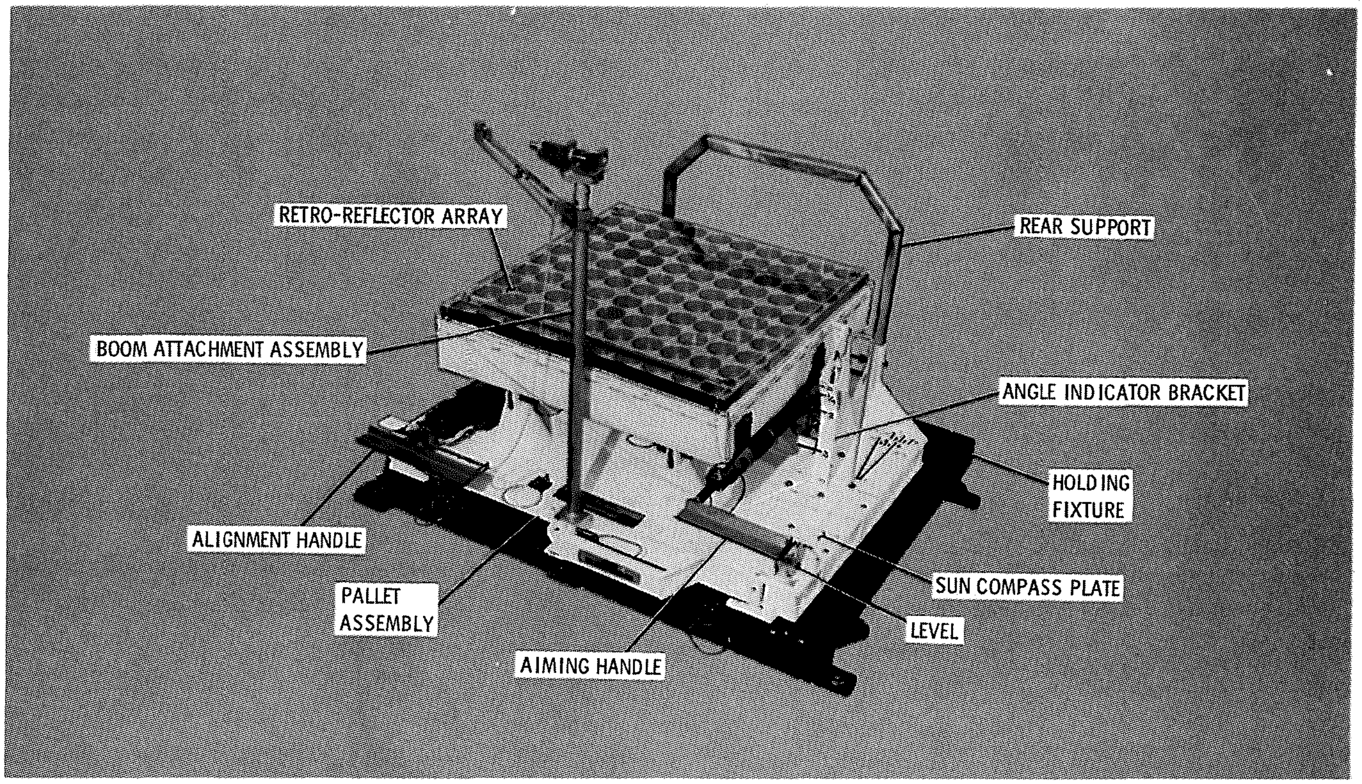


Figure 3-1. Laser Ranging Retro-Reflector Experiment

The pallet assembly provides tie points for securing the LRRR package in compartment #2 of the SEQ bay of the LM. Top surface tie points are provided for mounting the retro-reflector array, alignment handle, rear support, boom attachment assembly, angle indicator bracket, sun compass plate, and associated components. (See Figure 3-2.)

Thermal decoupling of the retro-reflector array from the lunar surface is provided by the pallet. White, thermal coating on the pallet provides a low temperature-gradient between the retro-reflector array and the pallet.

3-4. Angle Indicator Bracket. The angle indicator bracket has four index holes that relate to corresponding lunar sites. A pin on the aiming handle assembly is engaged with the appropriate hole during deployment. Index marks on the sector of the bracket identify site numbers.

3-5. Sun Compass Plate. The sun compass plate has three sets of index marks that are used to indicate correct lateral positioning of the LRRR by the shadow cast by the gnomen of the angle indicator bracket. Corresponding site numbers are adjacent to each set of index marks.

Three sun compass plates are provided to compensate for sun latitude variations that occur during a lunar year. Prior to launch, the appropriate sun compass plate for the calendar date is installed on the stowed LRRR.

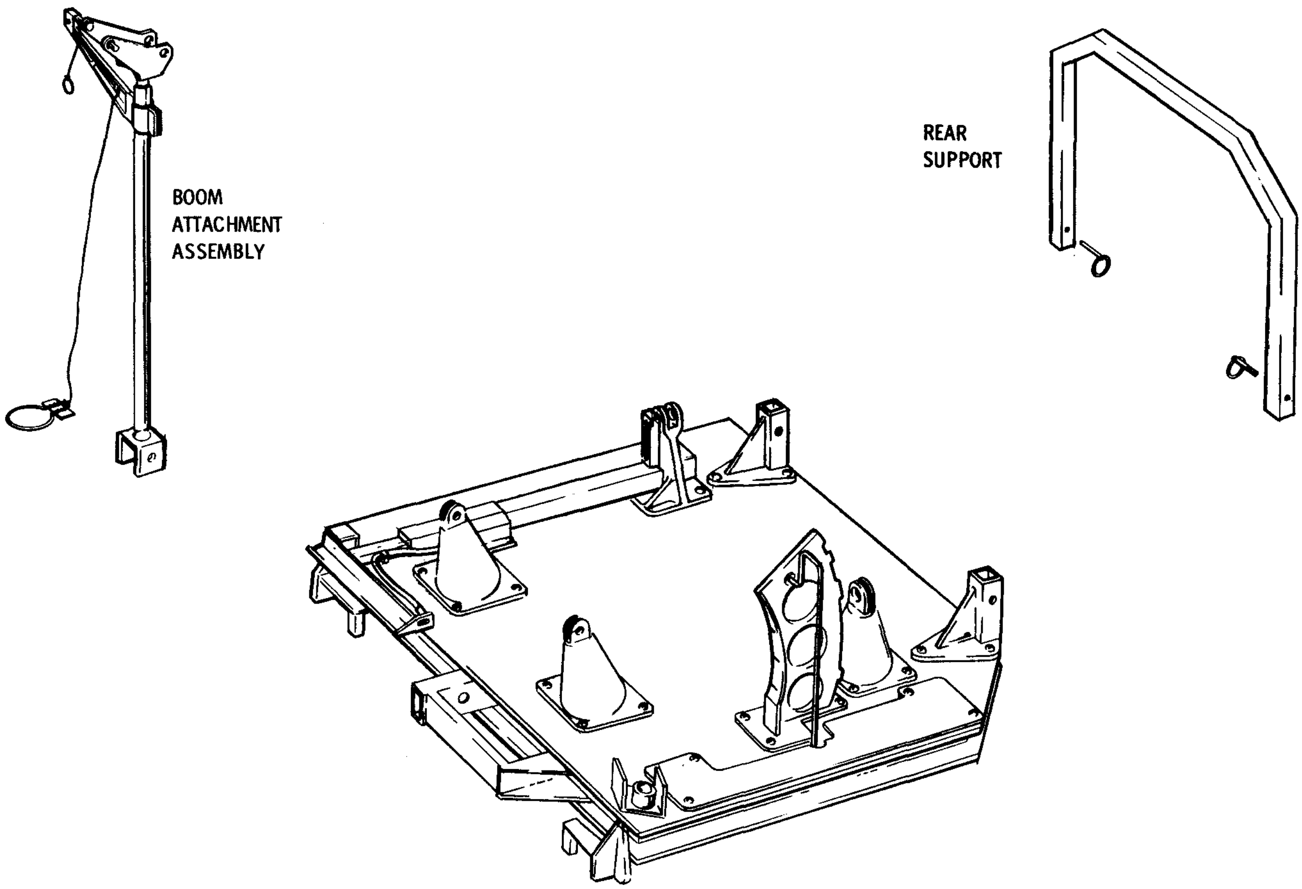


Figure 3-2. LRRR Pallet Assembly

3-6. RETRO-REFLECTOR ARRAY ASSEMBLY

The retro-reflector array assembly consists of an array panel structure incorporating 100 retro-reflectors and an aiming handle assembly as shown in Figure 3-3.

The array is designed to survive long term (up to 10 years) passive operation in the lunar environment. Thermal protection is provided by: a thermal insulation assembly covering the sides and bottom of the array panel structure; a highly-reflective, machined top surface of the panel structure; the reflective properties of the retro-reflector cavities.

A transparant polyester pre-deployment protective cover protects the array from dust debris and contaminants during storage, transportation, handling, and flight. The protective cover is removed by the astronaut during lunar deployment.

3-7. Panel Structure Assembly. The panel structure assembly is machined from a solid aluminum block to exacting dimensions that provide the required weight and thermal characteristics. One hundred cylindrical cavities are precisely aligned to retain the retro-reflectors.

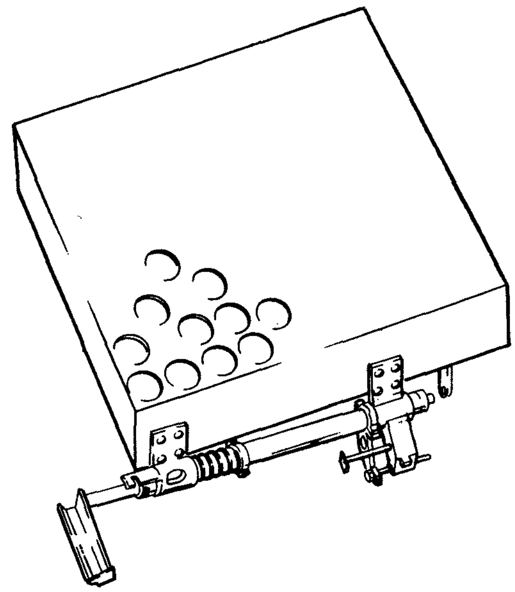


Figure 3-3. Retro-Reflector Array

A pair of hinge brackets and a pair of release brackets support the panel structure on the pallet. (See Figure 3-1.) The panel structure is secured in the stowed position by a tie-down pin on each of the astronaut handles. When the tie-down pins are disengaged from the release brackets, the panel structure can be pivoted on the hinge brackets to any tilt angle provided on the angle indicator bracket.

The sides and bottom of the panel structure are insulated by a multilayer insulation assembly attached to the panel with velcro tape. The insulation assembly consists of three double aluminized polyester radiation shields separated by three double-layer spacers of polyester netting, and a protective outer cover of dacron sailcloth.

3-8. Aiming Handle Assembly. The aiming handle assembly is attached to the right side of the panel structure. A pin on the outboard side of the handle assembly engages holes on the angle indicator bracket, and a tie-down pin at the end of the handle assembly secures the array to the release bracket on the pallet in the stowed condition.

3-9. Retro-Reflectors. The retro-reflectors are high precision, fused silica optical corners. One hundred retro-reflectors are mounted in individual cavities in the panel structure. Each retro-reflector is aligned in its cavity to within ±2° of angular deviation relative to the array pointing direction. Thermal protection is provided the retro-reflector by characteristics inherent in the design of the cavity and components as shown in Figure 3-4. The use of teflon for the upper and

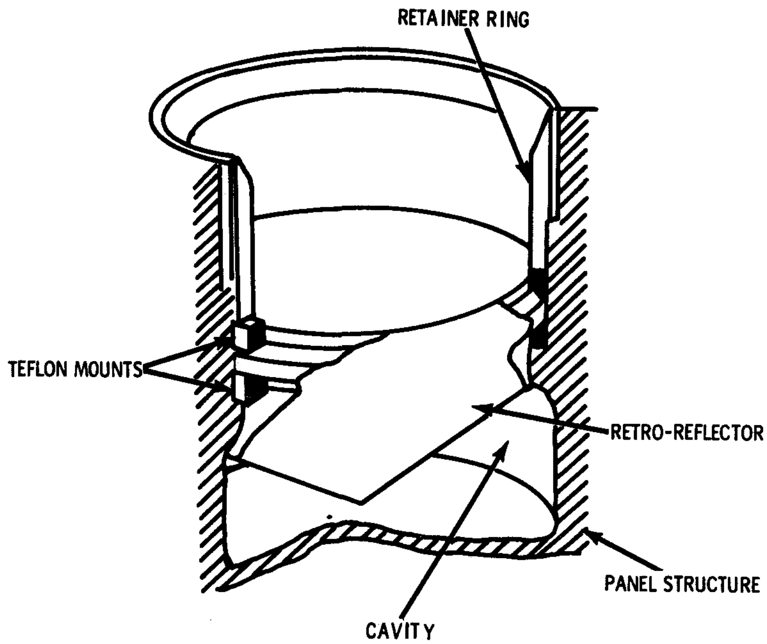


Figure 3-4. Retro-Reflector Mounting

lower mounting rings, and the aluminum retaining ring, adjusted to a predetermined pressure, allows for variations in temperature over a range of 40 °K to 400 °K and provides thermal isolation of the individual retro-reflectors.

3-10. BOOM ATTACHMENT AND REAR SUPPORT

The boom attachment assembly is a round, tubular, post with attachment assemblies at either end for mounting to the pallet assembly and interfacing with the LM boom. An arm-like release assembly and lanyard provide boom release for manual removal of the LRRR from LM for deployment. The boom attachment assembly is detached from the pallet during handling operations at KSC, and prior to lunar deployment.

The rear support is a square, tubular, structure that mounts in guide brackets on the pallet assembly with quick-release pins. It is detached from the pallet assembly only during handling operations at KSC.

3-11. LRRR FUNCTIONAL DESCRIPTION

The objective of the LRRR is to reflect laser radiation beamed from one or more Earth-based stations. Maximum return radiation will be reflected when the retro-reflector array is oriented as nearly normal to the incident radiation as possible.

The pallet assembly provides the functional capabilities of azimuthal orientation and leveling of the LRRR.

3-12. VERTICAL TILT ORIENTATION

The tilt angle of the retro-reflector array is set by the aiming handle assembly (Figure 3-1.) Before the array can be tilted, the two tie-down pins which secure it to the release brackets must be retracted by operating the astronaut handles. When the tie-down pins have been retracted, the array can be pivoted on its hinge brackets, by the aiming handle, to any tilt angle established by index holes in the angle indicator bracket. The site-numbered index marks on the sector of the angle indicator bracket interface with the pointer on the aiming handle to indicate the selected tilt angle.

3-13. AZIMUTH ORIENTATION AND LEVELING

The LRRR is oriented in azimuth and leveled on the lunar surface by using the alignment handle in the fully extended position (Figure 4-9.) A trigger release on the outboard side of the handle allows the handle to be fully extended by the astronaut. The astronaut then positions the LRRR on the lunar surface, using the alignment handle, so the shadow cast by the gnomon aligns with an appropriate index mark on the sun compass plate. At the same time, he observes the bubble level, mounted on the pallet, to ensure proper leveling of the LRRR. Three sun compass plates are provided; each with markings that correspond to specific lunar sites and provide compensation for sun latitude during the time periods for the lunar landing. The appropriate plate is installed prior to launch.

3-14. BOOM ATTACHMENT AND REAR SUPPORT

The LRRR will be lowered from compartment #2 of the LM SEQ assembly to the lunar surface by means of the boom attachment assembly. The boom attachment assembly will then be removed from the pallet and discarded.

The rear support allows the LRRR to stand on end, for a time, during the course of deployment. With the LRRR up-ended, the astronaut has access to the handles so that he can tilt the retro-reflector array to the selected tilt angle, then set the LRRR upright for alignment and leveling.

SECTION IV

EASEP OPERATIONS

4-1. INTRODUCTION

This section describes the operations required to enable the EASEP Flight System to accomplish its objectives of lunar scientific exploration. Operations subsequent to NASA acceptance of the EASEP flight hardware by DD-250 sign-off at Bendix will be described. This includes packaging and transportation, KSC operations, lunar surface operations, and post-flight operations.

Preservation, packaging and transportation requirements and operations will be provided in the EASEP Flight System Transportation and Handling Manual, EASEP-LS-02.

4-2. KSC OPERATIONS

KSC operations include those activities from receiving inspection of EASEP flight system packages through installation in the LM. These activities include receiving inspection, disassembly, transportation, handling, assembly, and installation as shown in Figure 4-1.

Receiving inspection of the EASEP packages and isotope heaters will be performed at the ALSEP Launch Preparation Site (ALPS) which is located in Hypergolic Test No. 2 Building, M7-1210.

The packages will be disassembled to the installation assembly level, and the assemblies will be assembled on the handling ground support equipment (GSE).

The EASEP assemblies in the GSE will be transported from the ALPS to the launch umbilical tower (LUT) on the launch pad. It will be elevated to the instrument unit (IU) level, and handed through the IU door into the spacecraft/LM Adapter (SLA) section of the launch vehicle. The assemblies are then hoisted to the XA 525 level where they are removed from the GSE. The EASEP packages are assembled on the GAEC installation fixture, and installed in the LM SEQ bay.

4-3. GROUND SUPPORT EQUIPMENT

The ground support equipment required to support EASEP operations is listed in Table 4-1 and illustrated in Figures 4-2, 4-3, 4-4, and 4-5.

Table 4-1. Ground Support Equipment

Nomenclature	Function	Part Number
Holding fixture, subpackage No. 1	Attaches to base of PSEP for shipping and handling operations. Mounts to handling cart for package movement (ALPS).	2335311
Holding fixture, subpackage No. 2	Attaches to base of LRRR for shipping and handling operations. Mounts to handling cart for package movement (ALPS).	2335338
Handling device, subpackage No. 1	Provides tie points for PSEP handling during transfer to PSEP handling fixture (ALPS).	2335312
Handling device subpackage No. 2	Provides tie points for LRRR handling during transfer to LRRR handling fixture (ALPS).	2335313
Handling cart	Provides mounting tie down for EASEP package on holding fixture during handling and disassembly (ALPS).	2332899
Hoisting device	Attaches to holding fixture or handling device for package hoisting operations (ALPS).	2335310
Handling fixture, PSEP	Attaches to central station assembly for transportation and handling operations (ALPS/SLA).	2340550
Handling fixture, LRRR	Attaches to pallet and array assembly for transportation and handling operations (ALPS/SLA).	2340562
Protective cover, LRRR	Provides environmental protection for pallet and array assembly during transportation and handling operations (ALPS/SLA).	2340583
Protective cover, PSEP	Provides environmental protection for central station assembly during transportation and handling operations (ALPS/SLA).	2340584

Table 4-1. Ground Support Equipment (cont)

Nomenclature	Function	Part Number
Carrying case, isotope heaters	Contains isotope heaters, shroud covers, and handling tool for transportation and handling operations (ALPS/SLA).	2340581
Handling tool, isotope heater	Provides means of handling isotope heaters for inspection, fit checks and installation (ALPS/SLA).	2340566
Carrying handle, handling fixture	Attaches to PSEP or LRRR handling fixture for transportation and handling operations (ALPS/SLA).	2340559
Belt, PSE	Retains skirt of thermal shroud and PSE cable during PSE removal and installation operations (ALPS/SLA).	2340582
Handling fixture,	Attaches to PSE assembly for handling operations.	2340551
Carrying case, PSE	Contains PSE in handling fixture for transportation and handling operations (ALPS/SLA).	2340564
Carrying case, left solar panel assy and brackets	Contains left solar panel assembly and brackets for transportation and handling operations (ALPS/SLA).	2340552-1
Carrying case, right solar panel assy and brackets	Contains right solar panel assembly and brackets for transportation and handling operations (ALPS/SLA).	2340552-2
Carrying case, antenna and boom and handle assembly	Contains antenna and boom and handle assembly for transportation and handling operations (ALPS/SLA).	2340553
Carrying case, rear support and boom attachment assembly	Contains LRRR rear support and boom attachment assembly for transportation and handling operations (ALPS/SLA).	2340561

Table 4-1. Ground Support Equipment (cont)

Nomenclature	Function	Part Number
Sling assembly	Attaches to handling fixture for hoisting LRRR or PSEP in horizontal attitude (ALPS/SLA).	2340585
Sling assembly	Attaches to handling fixture carrying handle for hoisting LRRR or PSEP in vertical attitude (ALPS/SLA).	2340586
Shipping container, PSEP experiment	Provides physical protection and controlled environment for shipment of PSEP to KSC.	2340556
Shipping container, LRRR experiment assembly	Provides physical protection and controlled environment for shipment of LRRR to KSC.	2340599
Shipping can, radioisotopic heater	Provides physical protection for radioisotopic heater during shipment to, and storage at KSC.	4-8028 (Monsanto)
Outer shipping container, radioisotopic heater	Provides physical protection for shipment of radioisotopic heater to KSC.	3-6938 (Monsanto)
Shipping container, radioisotopic heater	Provides physical protection and thermal insulation for shipment of radiosotopic heater to KSC.	3-6945 (Monsanto)
Hoisting device, monorail	Provides means of hoisting EASEP subassemblies in GSE to XA 525 level in SLA.	(GAEC)
Auxiliary scientific equipment support	Provides means for alignment of EASEP packages with rails of SEQ bay for installation.	LDW-420-11171-1 (GAEC)

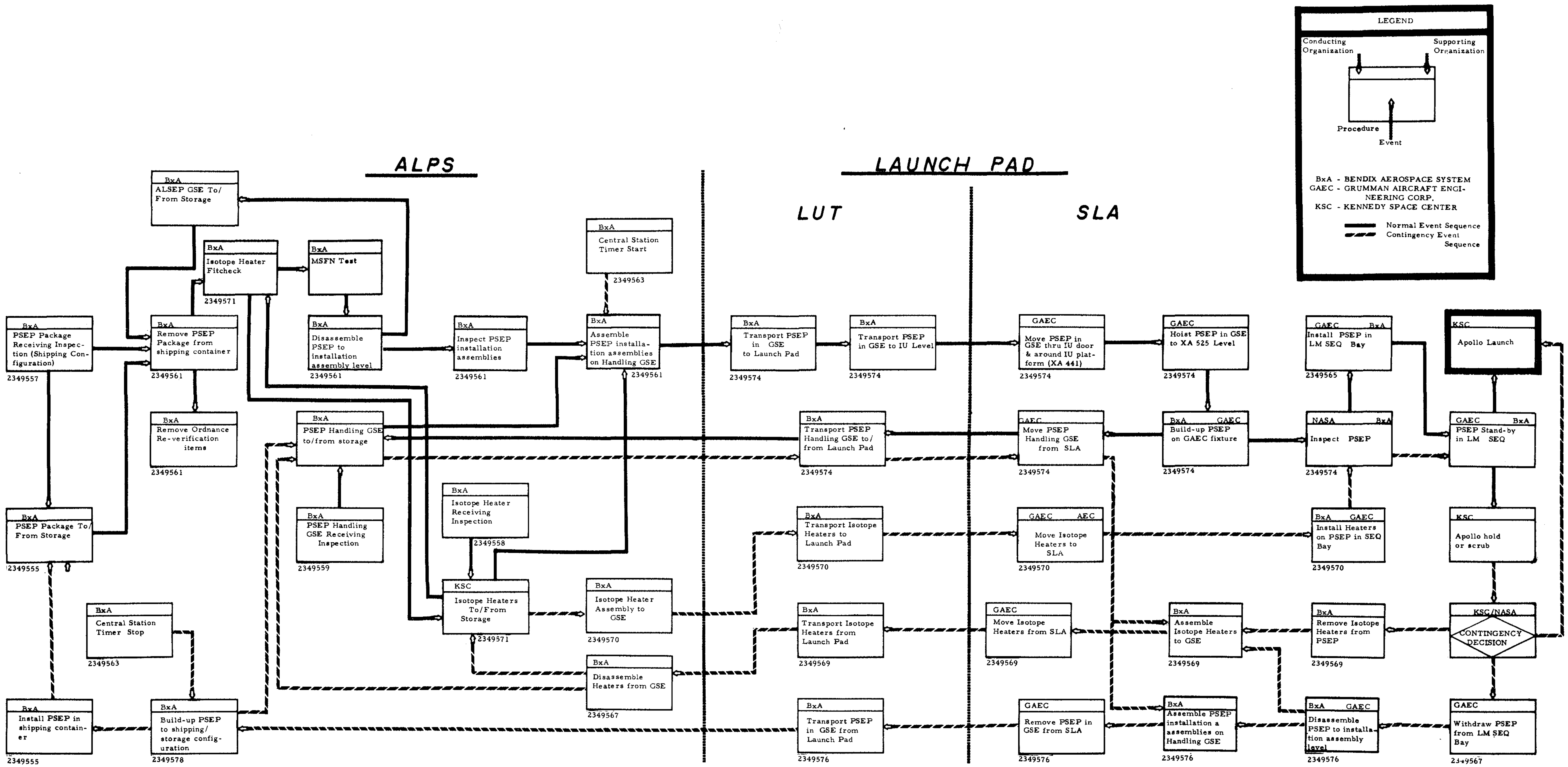


Figure 4-1. KSC Operations Sequence (Sheet 1 of 2)

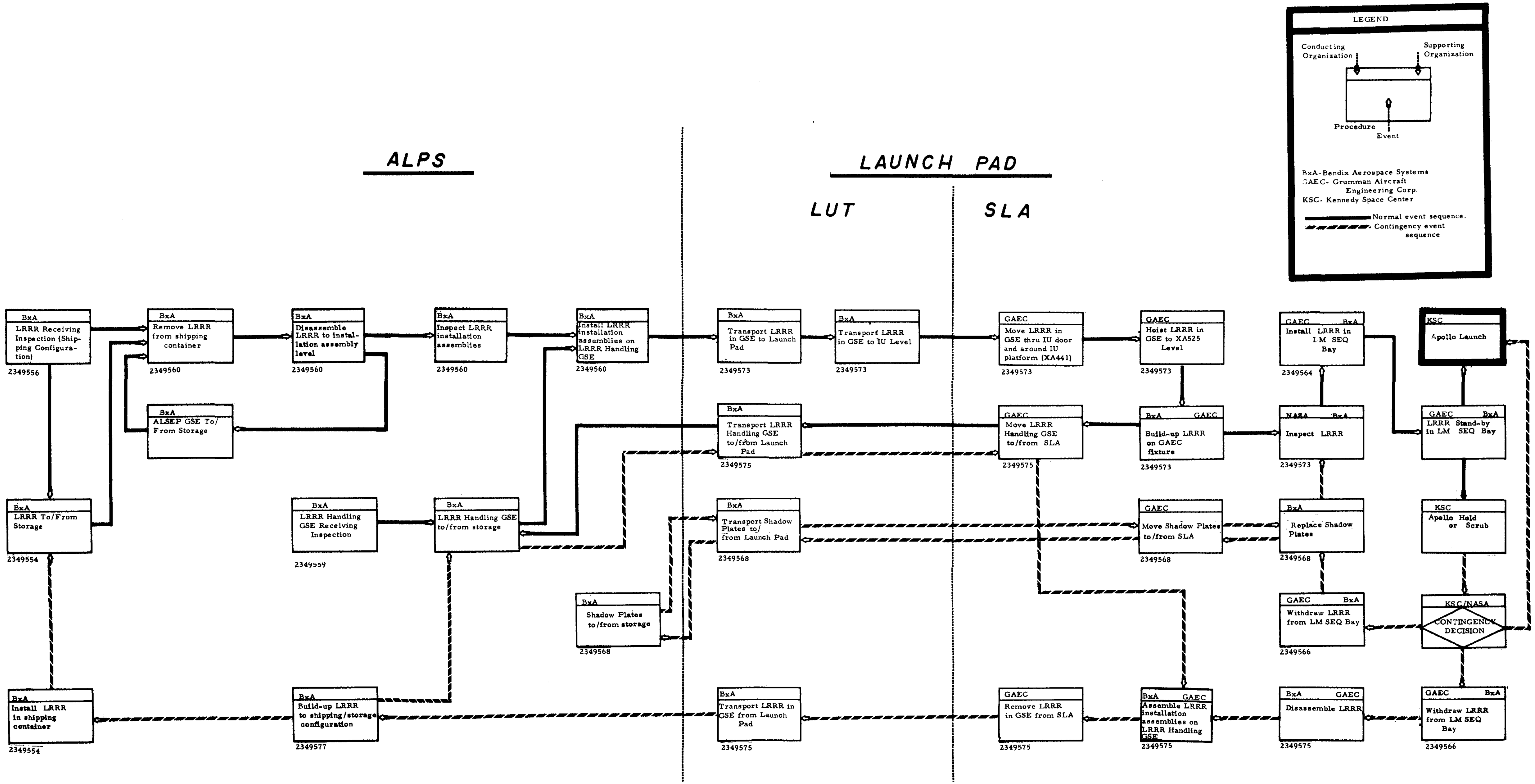


Figure 4-1. KSC Operations Sequence (Sheet 2 of 2)

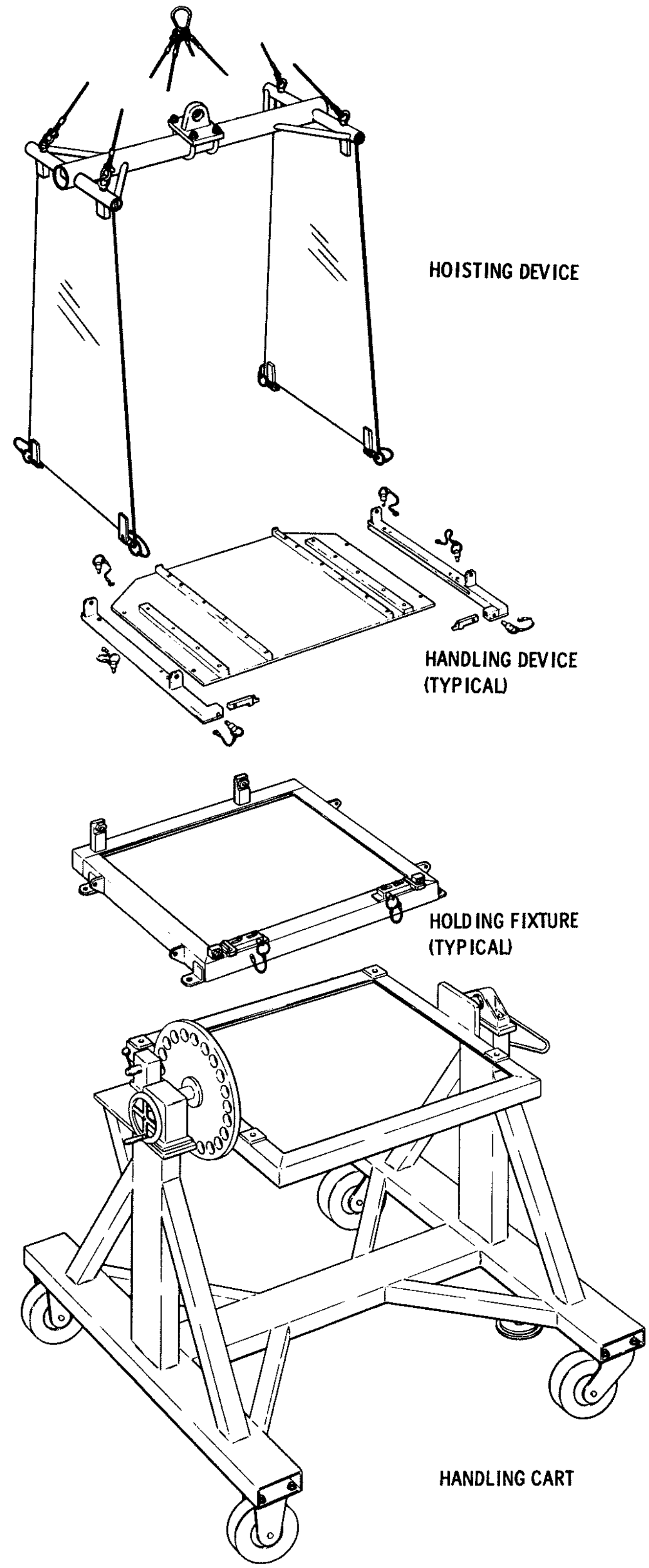


Figure 4-2. EASEP Package Handling GSE

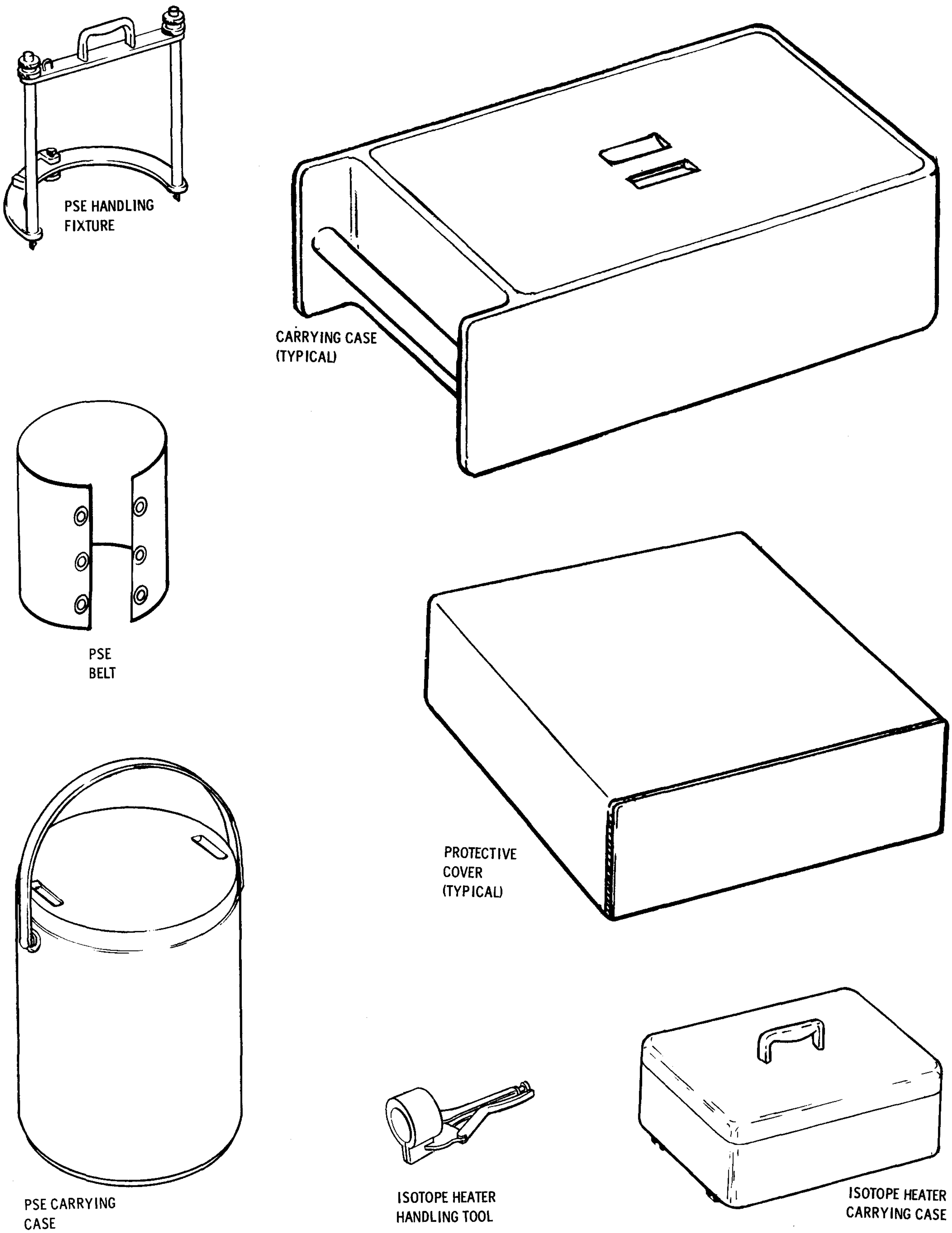


Figure 4-3. Assembly Handling GSE (Sheet 1 of 2)

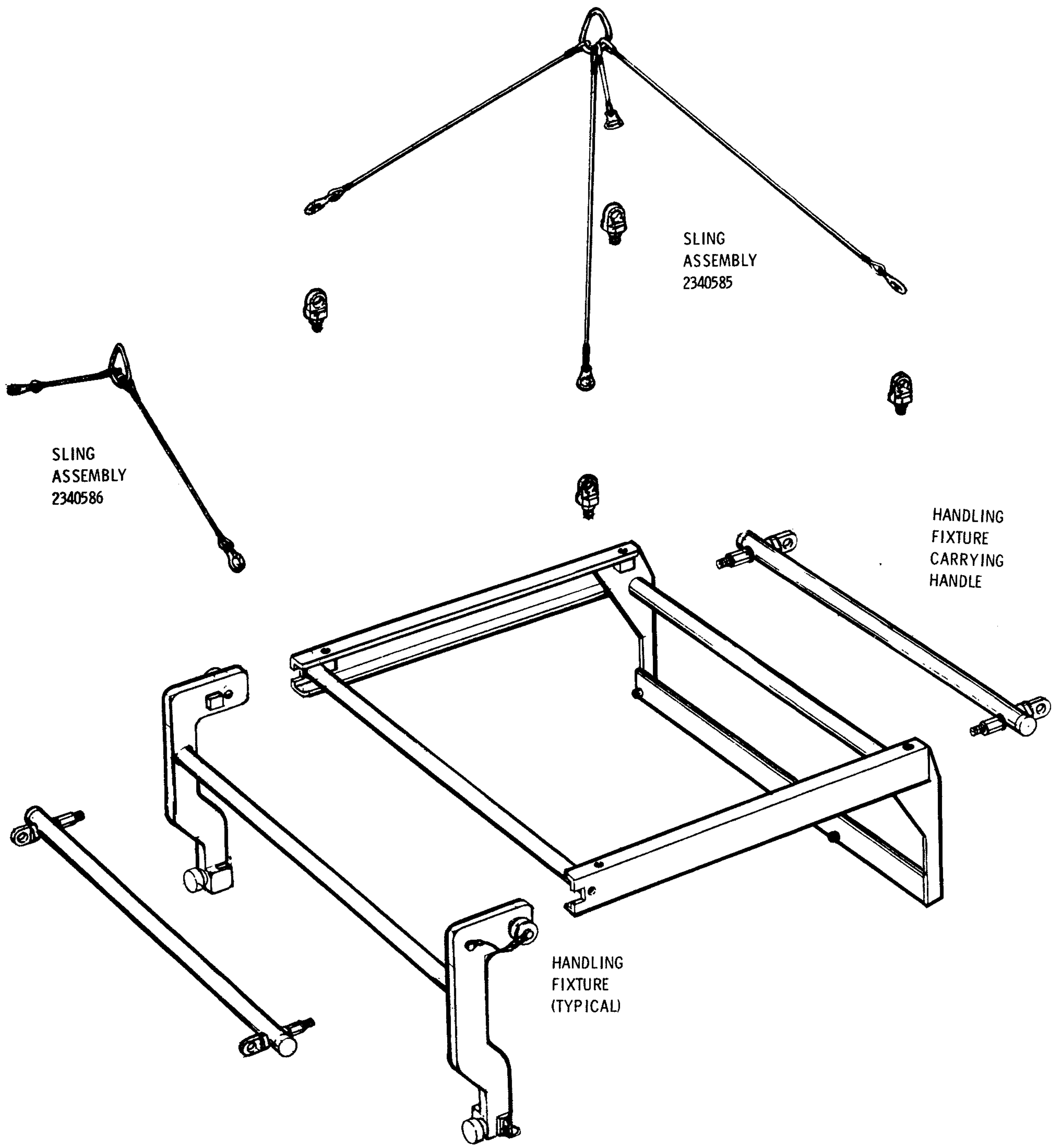


Figure 4-3. Assembly Handling GSE (Sheet 2 of 2)

4-4. LUNAR SURFACE OPERATIONS

Lunar environmental conditions impose constraints on EASEP hardware and its deployment by the astronaut. EASEP deployment procedures will be performed at a time when the sun angle from the lunar horizon is 7 to 22 degrees. At a sun angle of 7 degrees, the lunar surface temperature is approximately -50 to -60 degrees F. At a sun angle of 22 degrees, the lunar temperature is +80 to +100 degrees F. EASEP design allows deployment at a maximum sun angle of 45 degrees and a relative lunar surface temperature of approximately +165 degrees F.

The following paragraphs describe the events that take place from the time the LM lands on the lunar surface until the EASEP packages have been deployed. Included in the discussion are:

a. Flight mode - The in-flight configuration of EASEP.
b. Handling mode - The activity performed by the astronaut in removing the EASEP packages from the LM and transporting them to the emplacement area.
c. Deployment - The events performed by the astronaut in emplacing the EASEP packages.

The lunar surface operations as presented here reflect a combination deployment procedure where both packages are removed from theLM and deployed at the same time. Either package can be removed and deployed independently of the other. No order of priority as to which package is deployed first has been established.

4-5. FLIGHT MODE

During flight, the EASEP packages are inert except for the heat dissipation of the isotope heaters on PSEP.

The LRRR and PSEP are secured by retaining pins in separate compartments of the LM SEQ bay. The SEQ bay location in the LM descent stage is illustrated in Figure 1-1.

4-6. HANDLING MODE

The handling mode encompasses the tasks of removing the LRRR and PSEP from the LM SEQ bay, and traversing to the emplacement area.

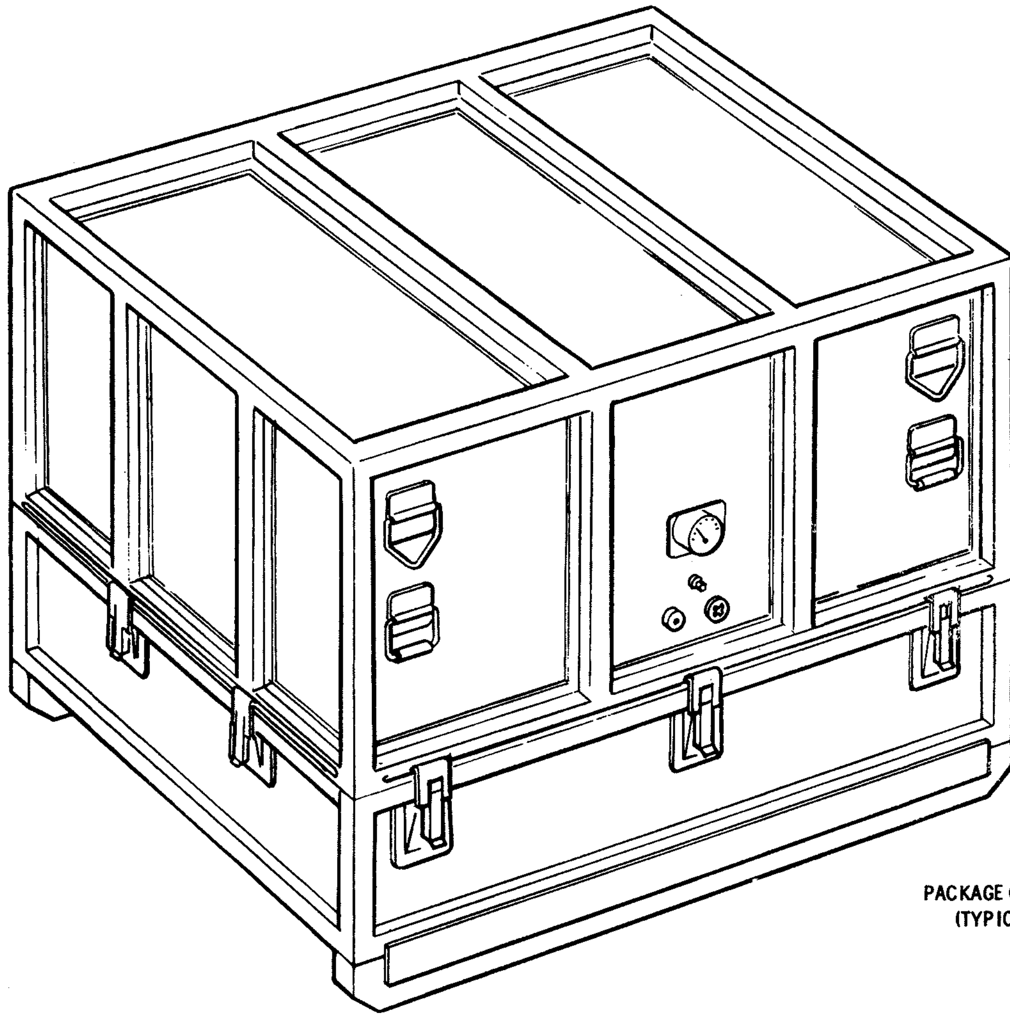


Figure 4-4. Shipping Container

The basic handling mode events, in chronological order, are:

a. Descent to lunar surface
b. Walk to descent stage stowage compartment (SEQ)
c. Unload EASEP packages
d. Locate correct traverse bearing
e. Walk 32 feet at selected bearing carrying packages.

4-7. Descent to Lunar Surface. The handling mode begins with the astronaut descending from the LM to the lunar surface.

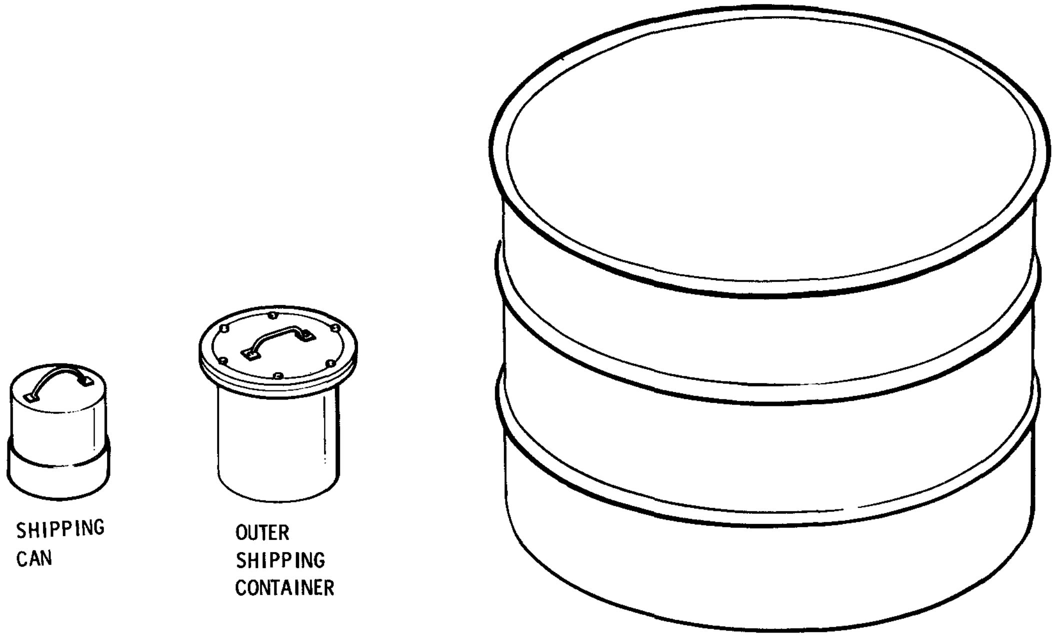


Figure 4-5. Radioisotopic Heater Shipping Containers

4-8. Remove EASEP packages from the LM. The astronaut walks to the LM SEQ bay, releases and raises the thermal door. The astronaut retrieves the LRRR deployment lanyard, walks 10 feet from LM, pulls deployment lanyard to release LRRR tie-downs and extend boom, lowers LRRR to the lunar surface, releases velcro and pulls lanyard to separate boom assembly from boom attachment assembly, and restows the boom. The astronaut then retrieves the PSEP deployment lanyard, walks 10 feet from LM, pulls deployment lanyard to release PSEP tie-downs and extend boom, lowers PSEP to lunar surface, pulls pin to release deployment handle and separate boom attachment assembly from PSEP, extends handle to 30-inch working height and rotates it 90° to lock in place, restows boom and deployment lanyard, and closes SEQ bay door.

4-9. Transport EASEP Packages to Emplacement Area. The astronaut lifts the PSEP and LRRR from the lunar surface using the carry handles as shown in Figures 4-6 and 4-7. He then walks to the LM - Y axis landing gear pad and surveys the lunar surface to select a suitable deployment site. He then walks approximately 32 feet from LM to selected site and lowers the EASEP packages to the surface on a N-S axis.

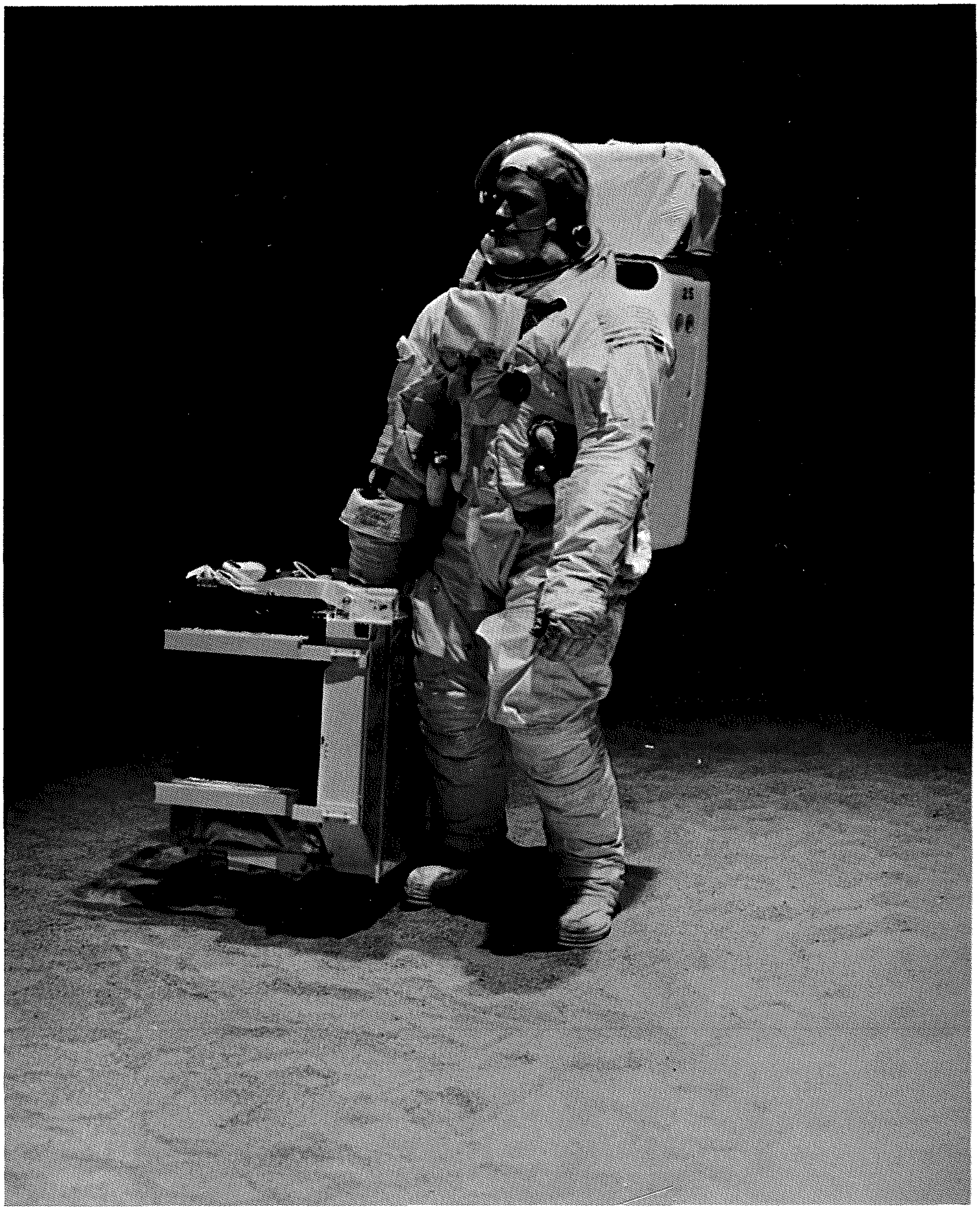


Figure 4-6. Astronaut Carrying PSEP

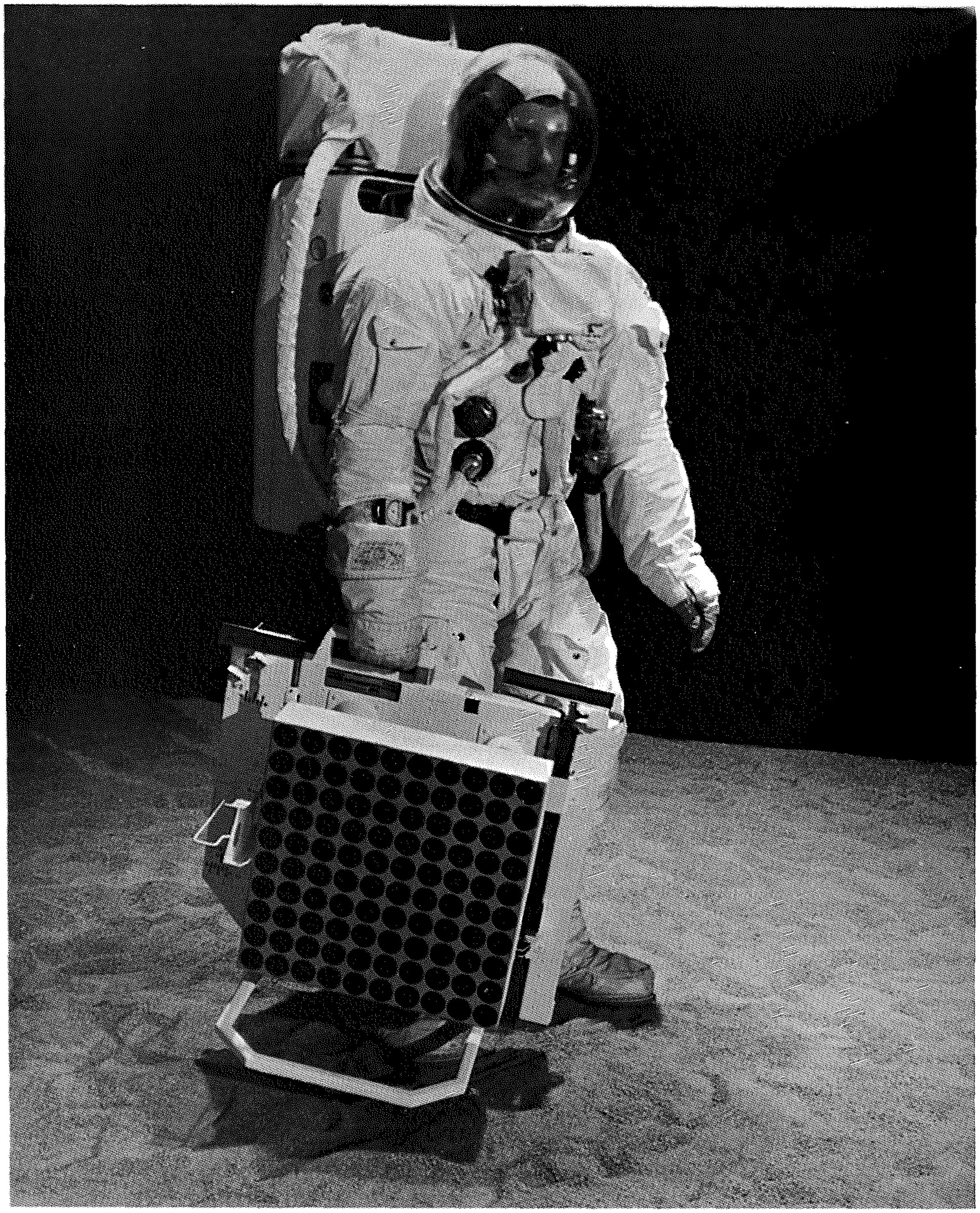


Figure 4-7. Astronaut Carrying LRRR

4-10. DEPLOYMENT OF LRRR

Performing the deployment sequence, the astronaut:

a. Positions the LRRR on an E-W axis,
b. pulls pin, and removes boom attachment assembly from LRRR,
c. pulls alignment handle to extend 6 inches, partially releasing retro-reflector array,
d. detaches velcro, and pulls cover release lanyard to separate cover from array assembly,
e. rotates aiming handle 45° and extends it to the detent position to completely release array,
f. observes index marks on the angle indicator as he tilts the array to the angle of the selected site, using aiming handle. (See Figure 4-8.)
g. extends alignment handle an additional 27 inches and uses handle to rotate LRRR 90° so that the pallet lies flat on the lunar surface, (See Figure 4-9.)
h. observes bubble level and shadow cast by the gnomon on sun compass plate as he levels and aligns the LRRR to within ±5° of the appropriate sun compass reference mark, using alignment handle.

4-11. DEPLOYMENT OF PSEP

Performing the deployment sequence, the astronaut:

a. Positions PSEP 10 feet north or south of the LRRR on an E-W axis with the bottom of pallet facing northward, (See Figure 4-10.)
b. pulls lanyard to release gnomon, then rotates gnomon to elevated position,
c. removes solar panel pull pins and front, and rear supports,
d. rotates PSEP 90° using carry handle so that pallet lies flat on lunar surface,
e. uses deployment handle to align PSEP to within ±5° of PSEP centerline while observing ball level and shadow cast by gnomon on the compass rose,
f. pulls antenna/ solar panel release lanyard to deploy antenna and solar panels,
g. rotates antenna to elevation of selected site while observing antenna tilt-angle indicator and pointer. (See Figure 4-11.)

4-12. POST-DEPLOYMENT OPERATIONS

Communication between MCC-H and PSEP passive seismic experiment package is established with the activation of the central station by solar energy. For two 14-day periods, PSEP (lunar day operation) is monitored continuously. Commands which initiate specific actions required for normal operation are sent to PSEP during this period. Commands are also sent to change or request status of PSEP.

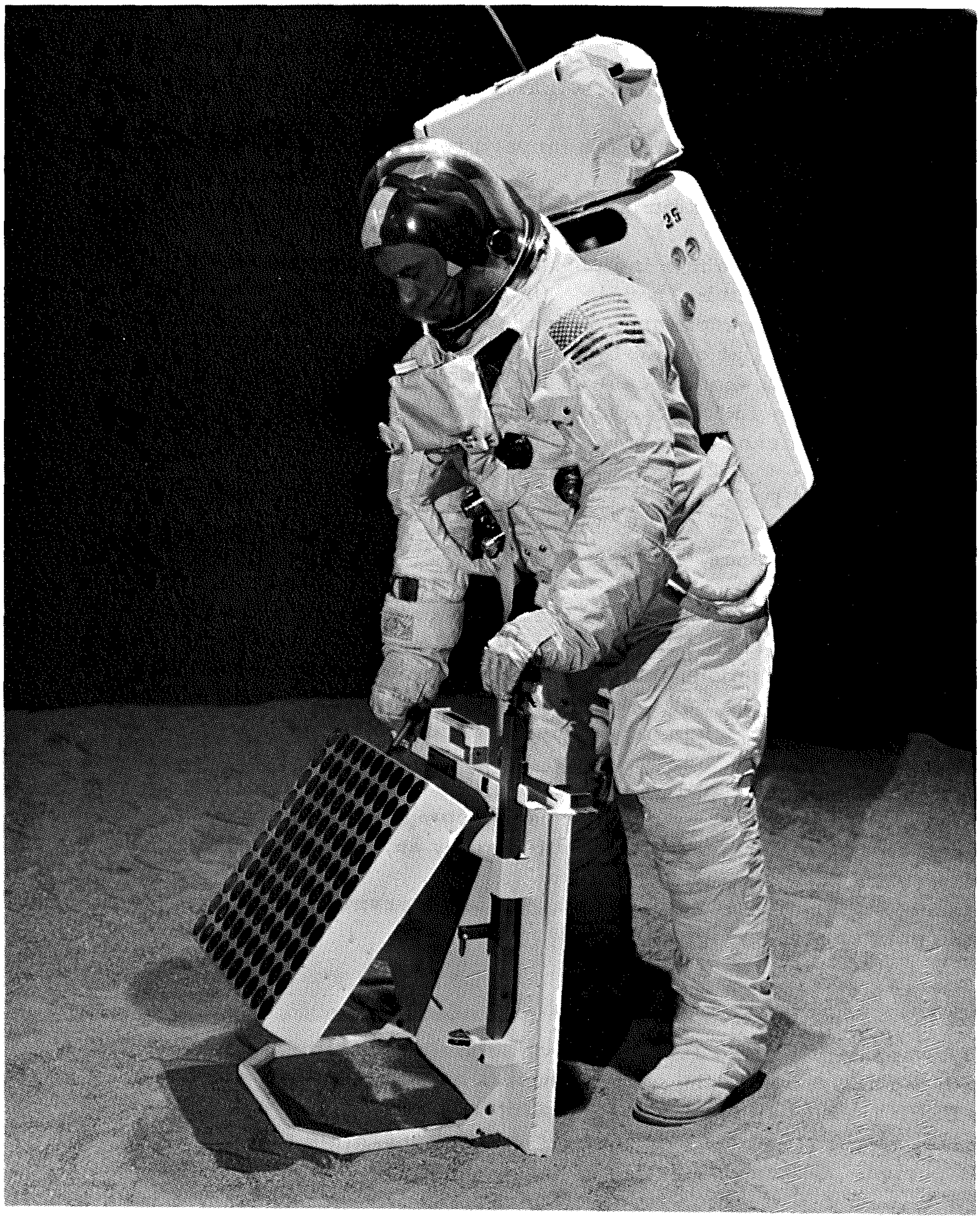


Figure 4-8. Astronaut Deploying LRRR

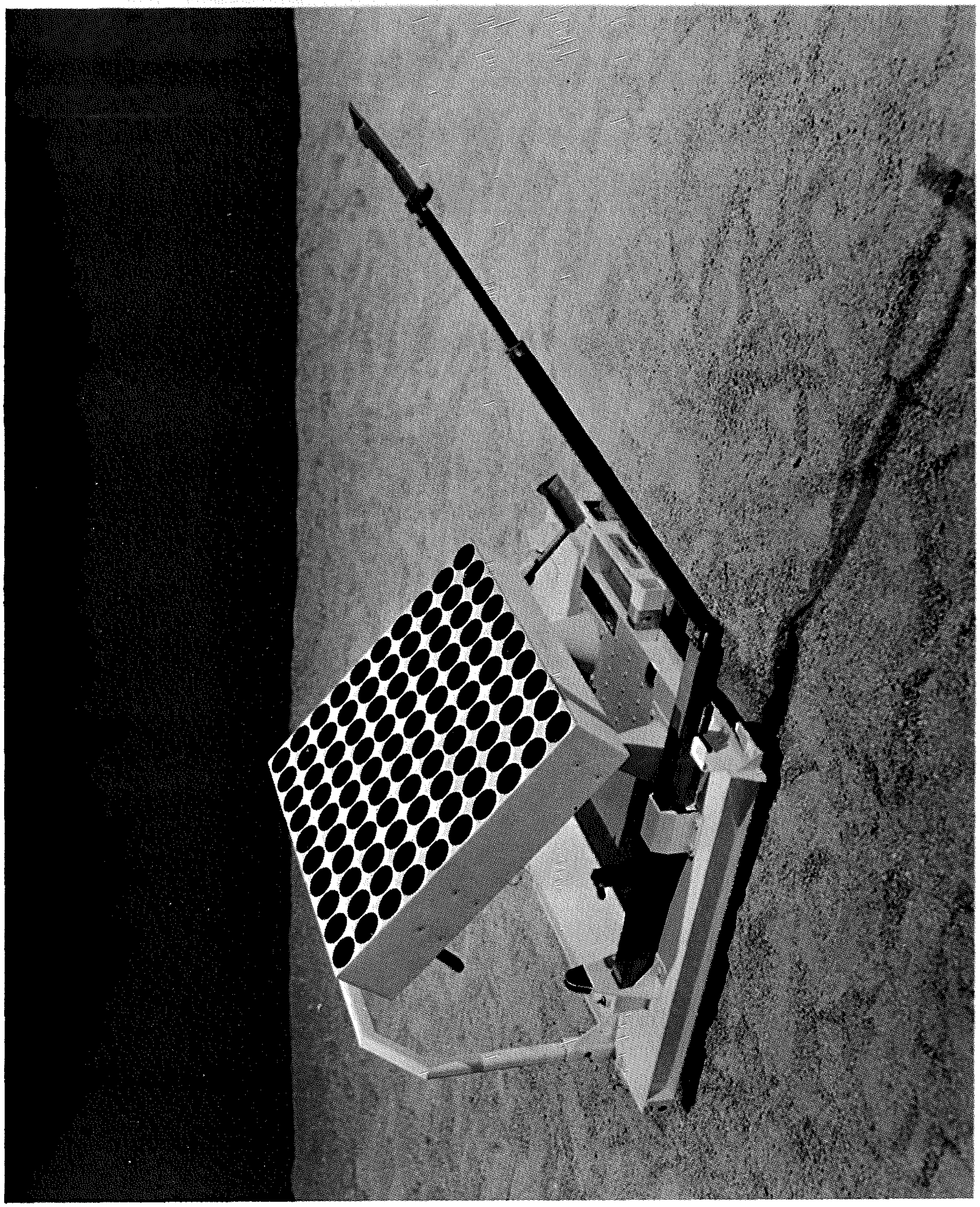


Figure 4-9. LRRR Deployed

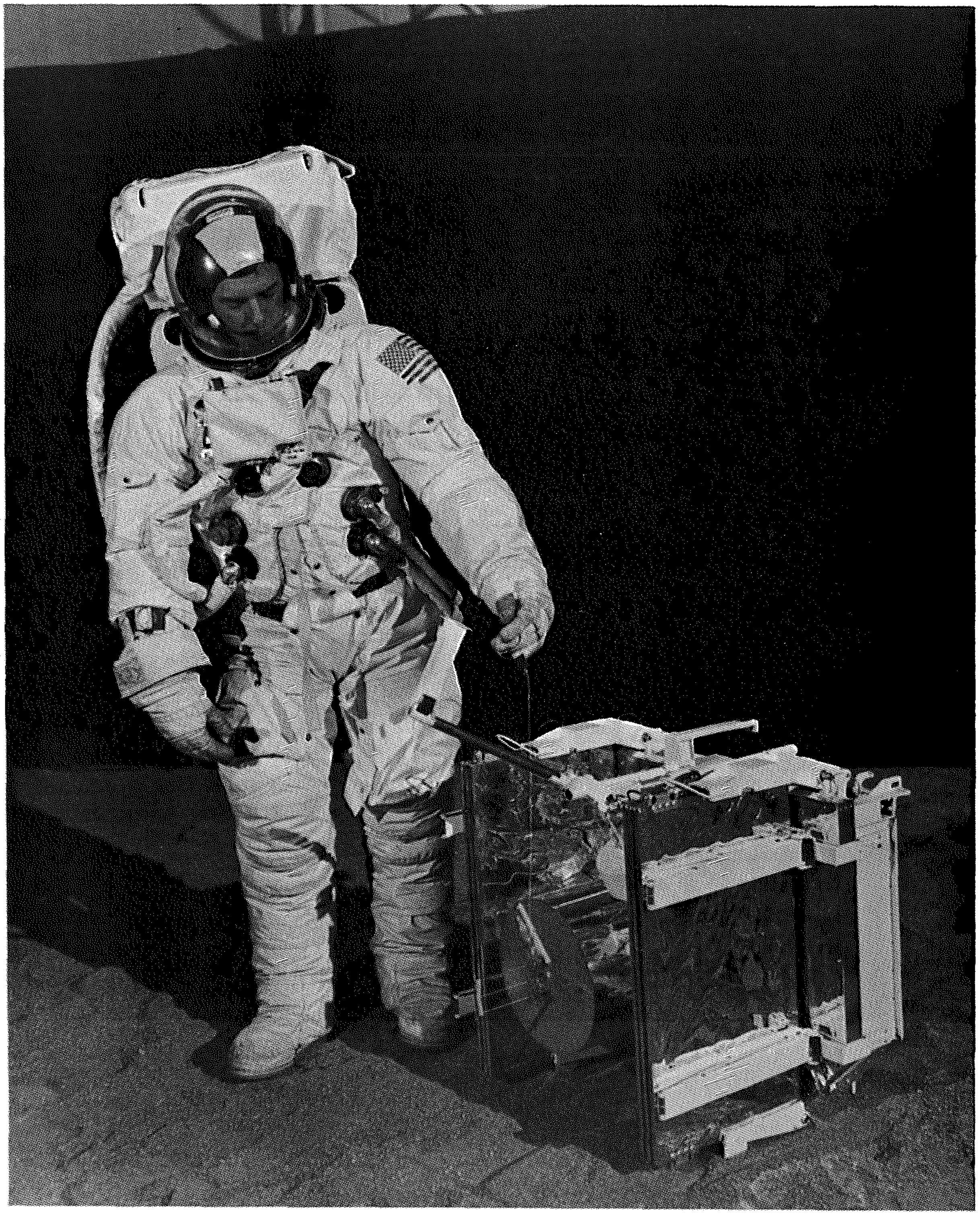


Figure 4-10 Astronaut Deploying PSEP

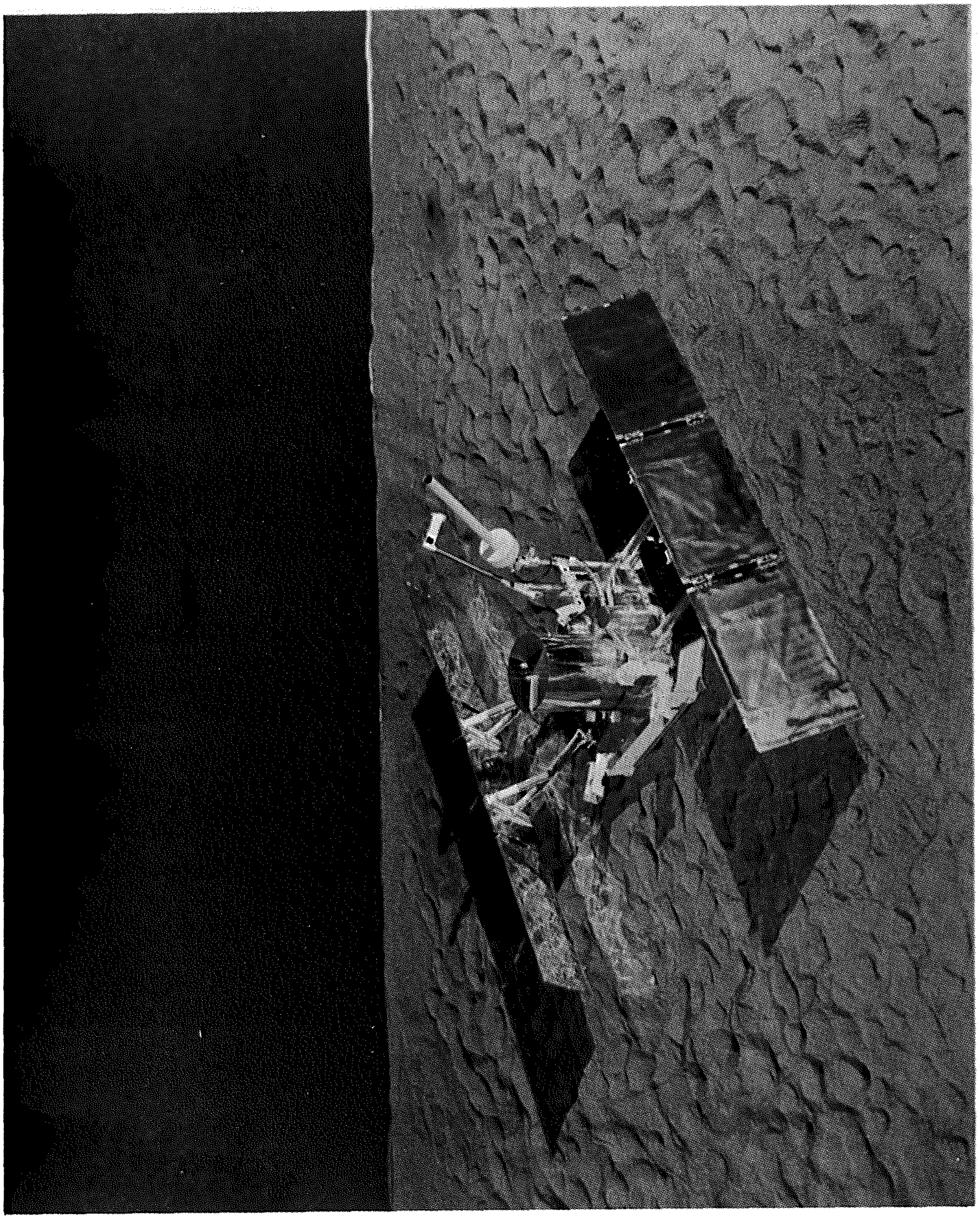


Figure 4-11. PSEP Deployed

PSEP transmission (downlink) is received by remote sites on Earth and relayed to MCC-H via tie line cables. Commands initiated by MCC-H are routed through another tie line cable to the remote site and are transmitted to PSEP. This communication system is referred to as the manned space flight network (MSFN).

Because of the Earth's rotation, it is necessary to establish remote sites around the Earth. Remote sites for PSEP will be selected from the following:

a. Goldstone, California (85-foot antenna)
b. Carnarvon, Australia (30-foot antenna)
c. Canberra, Australia (85-foot antenna)
d. Ascension Island (30-foot antenna)
e. Hawaii (30-foot antenna)
f. Guam (30-foot antenna)
g. Madrid, Spain (30- and 85-foot antennas).

At MCC-H the telemetry data are decoded by the computer control and telemetry system (CCATS) and fed into another computer where they are assimilated and routed to display in the LM staff support room (SSR) and the experiments room.

Principal investigators (PI) observe the display in the experiments room and make preliminary evaluations. The PI may advise the EASEP controller concerning problems with his experiment. After evaluating data, in near real time, the PI may suggest changes to the command procedure in order to gain additional data.

4-15. Uplink Transmission. Commands are generated by the console controller at the console command keyboard. The generated signal is routed through the command computer where it is programmed and routed over the tie line cable to GSFC. At GSFC the transmission is switched to another tie line cable and routed to the applicable switching station (Hawaii or London). The switching station routes the transmission to the applicable remote site. At the remote site, the command transmission is fed into a computer for formatting. The output of the computer is connected to the remote site transmitter and the command is transmitted to EASEP.

The stations selected will provide transmitters/receivers in latitude about the equator ranging from approximately 34 degrees north to 25 degrees south. It is probable that four receivers will be located in the northern hemisphere and two in the southern hemisphere.

The 30-foot dish antennas can be used for normal operations, but the 85-foot dish antennas will be used in the event that PSEP antenna aim-angle is in error.

4-13. MANNED SPACE FLIGHT NETWORK (MSFN)

Typical MSFN and MCC-H EASEP operations are described in the following paragraphs. Because specific responsibilities have not been defined, the description is typical only.

4-14. Downlink Transmission. Figure 4-12 provides a block diagram illustrating the EASEP functions of MSFN. Telemetry data (engineering status and scientific data) are transmitted by EASEP and received by the remote site 30- or 85-foot dish antennas. The signal is routed from the antenna to the receiver rf detection stage. The signal (T/M bit stream) from the detector stage is tape recorded as a backup in event the 14-channel tape recorder or receiver are inoperative. This tape is reused. The rf signal output from the detector stage is demodulated and routed to the site computer and to a 14-channel tape recorder. All EASEP data are recorded on this tape recorder for the full year regardless of whether MCC-H is monitoring or not. The audio frequency bit stream is recorded on one channel of the 14-channel tape recorder. Another channel is used to automatically record the time-of-day (Greenwich mean time). A third channel is used to insert voice annotations as required. This includes information pertinent to the recorded data (description of station abnormalities, time or signal gaps not caused by EASEP.

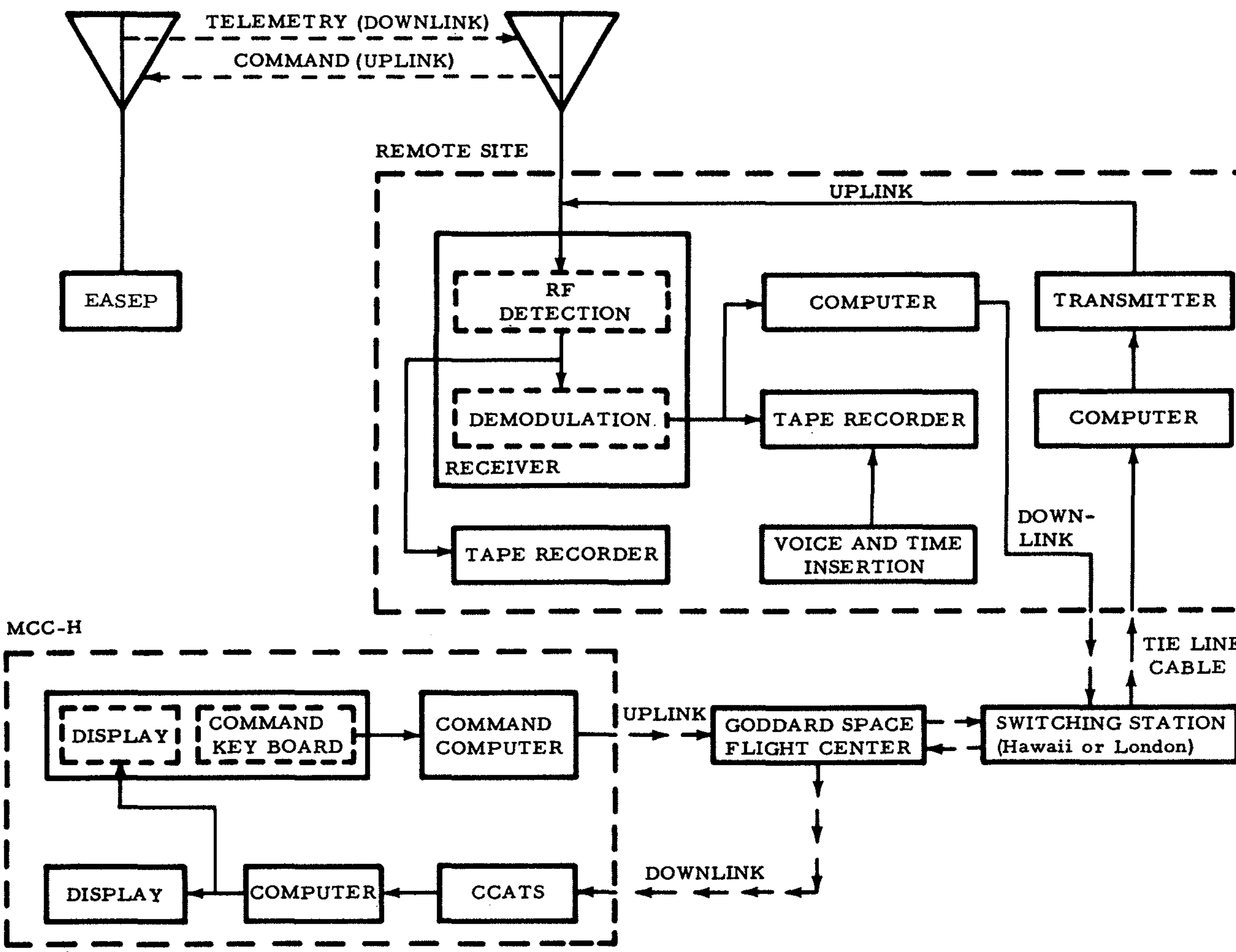


Figure 4-12. MSFN Functional Block Diagram

The 14-channel tape recorder is operated at 3-3/4 ips. When the recorder spool is expended, the tape is removed and shipped to NASA-Houston where it is converted to machine language for subsequent detailed analyses. When required, another tape recorder is connected into the same line and is started prior to shutting off the first recorder. This provides an overlap of the bit stream rather than a loss of data.

The modulated signal input to the site computer is encoded to format, supplied with a header (shows routing and address), and processed through the tie line cable. The computer process of converting the data to format and inserting the header results in a slight delay; therefore, the data processed over the tie line cable is not quite in real time. The tie line cable has a capacity of 2400 bps.

The tie line cable carrying the telemetry data terminates at a switching station (London or Hawaii) where the transmission is switched to another tie line cable and routed to the Goddard Space Flight Center (GSFC). At GSFC the switching procedure is repeated and the telemetry data are routed to MCC-H.

At MCC-H the telemetry data are decoded by the computer control and telemetry system (CCATS) and fed into another computer where they are assimilated and routed to display in the LM staff support room (SSR) and the experiments room.

Principal investigators (PI) observe the display in the experiments room and make preliminary evaluations. The PI may advise the EASEP controller concerning problems with his experiment. After evaluating data, in near real time, the PI may suggest changes to the command procedure in order to gain additional data.

4-15. Uplink Transmission. Commands are generated by the console controller at the console command keyboard. The generated signal is routed through the command computer where it is programmed and routed over the tie line cable to GSFC. At GSFC the transmission is switched to another tie line cable and routed to the applicable switching station (Hawaii or London). The switching station routes the transmission to the applicable remote site. At the remote site, the command transmission is fed into a computer for formatting. The output of the computer is connected to the remote site transmitter and the command is transmitted to EASEP.

4-16. MCC-H Operation. The PSEP console controller initiates commands to PSEP using the command keyboard. Telemetry data received from PSEP are displayed on the console. As data are received, the controller evaluates the status of PSEP and generates corrective commands as required. For example, PSEP may stop transmitting modulation on the carrier in which case the controller would probably issue a command for PSEP to switch data processors.

The PSEP console controller also inserts commands required for the normal operation of PSEP. (Refer to Appendix for a complete list of the normal commands).

As PSEP transmits engineering and scientific data back to Earth, the controller must evaluate the status of PSEP through interpretation of the data display. Depending on detail requirements and specific mechanization, the displays may include TV (charactron) formats, page printers, meters, X-Y plotters, analog strip charts, and event lights. The computer handling these displays can insert sensor calibration data, compare them against preset limit values, and perform other analysis functions.

GLOSSARY

Abbreviation	Definition
A/D	Analog to Digital
AFCRL	Air Force Cambridge Research Laboratory
ALPS	ALSEP Launch Preparation Site
ALSEP	Apollo Lunar Surface Experiments Package
BxA	Bendix Aerospace Systems Division
CFE	Contractor Furnished Equipment
CM	Command Module
CS	Central Station
DS/S	Data Subsystem
EASEP	Early Apollo Scientific Experiments Payload
EMU	Extravehicular Mobility Unit
EPS	Electrical Power Subsystem
FET	Field Effect Transistor
GAEC	Grumman Aircraft Engineering Corporation
GFE	Government Furnished Equipment
GHz	Gigahertz
GSE	Ground Support Equipment
IBM	International Business Machines
IU	Instrument Unit
Hz	Hertz; Cycles per Second
KHz	Kilohertz
KSC	Kennedy Space Center, Florida
LM	Lunar Module
LP	Long Period
LPOP	LM Pre-Flight Operations Procedure
LRRR	Laser Ranging Retro-Reflector Experiment
LUT	Launch Umbilical Tower
MCC-H	Mission Control Center-Houston
MSC	Manned Spacecraft Center

GLOSSARY (Cont)

MSFN	Manned Space Flight Network
MSOB	Manned Spacecraft Operation Building
NASA	National Aeronautics and Space Administration
NRZ	Non Return to Zero
PAM	Pulse Amplitude Modulation
PCM	Pulse Coded Modulation
PCU	Power Conditioning Unit
PDU	Power Distribution Unit
PI	Principal Investigator
PSE	Passive Seismic Experiment
PSEP	Passive Seismic Experiment Package
QA	Quality Assurance
RF	Radio Frequency
RFI	Radio Frequency Interference
SEQ	Scientific Equipment Bay in LM
SLA	Spacecraft LM Adapter
SM	Service Module
SP	Short Period
TCP	Test Checkout Procedure
USGS	United States Geologic Survey
VAB	Vehicle Assembly Building

APPENDIX A

COMMAND LIST

INTRODUCTION

This appendix presents the current inventory of commands applicable to the Passive Seismic Experiment Package. The initial issue has been revised in the following areas:

a. The annotation of the preset condition of certain commandable functions reflect the initial functional mode defined in the PSEP preliminary operational plan (EATM-38).

b. The significance of the High Data Rate command (CD-31) in inhibiting all data output has been flagged.

c. The classification of the commands has been expanded to identify those commands which are not significant in the operation of PSEP in the following groups.

- those which control power distribution functions which were in the ALSEP 2 central station but have been deleted from PSEP

- those which are assigned to control functions in experiments which are not provided

Table 1 lists the commands by symbol, nomenclature, number, and termination point. Table 2 provides a summary of command allocation. Table 3 cross-references command numbers and command functions.

The following notes are relevant to the data in each table as referenced:

Note 1 Operational mode inherent in equipment at power turn-on

Note 2 Operational mode preset during flight preparation

Note 3 Will inhibit all data output

Note 4 Will not alter functional mode (housekeeping status may change)

Note 5 Changes bit rate upon command execution

Note 6 Changes bit rate at end of data frame during which the command is executed

Note 7 Manual leveling sequence is as follows: Send CL-15 to change auto to manual leveling mode, change direction, and speed by CL-10 and CL-11 as necessary, and then leveling operating by sending appropriate leveling motor commands, CL-6, CL-7, or CL-8. Leveling operation is terminated by retransmission of CL-6, CL-7, or CL-8.

Note 8 Sequence of command is auto on[1]/auto off/manual on/manual off.

TABLE 1

Symbol	Command Nomenclature	Octal Command	Decimal Command	Termination Point	Notes
CD-31	ASE High Bit Rate ON	003	3	Data Processor	3, 6
CD-32	ASE High Bit Rate OFF	005	5	" "	1
CD-33	Normal Bit Rate[1]	006	6	" "	1
CD-34	Slow Bit Rate	007	7	" "	-
CD-35	Normal Bit Rate Reset	011	9	" "	5
CD-1	Transmitter "A" Select	012	10	Power Dist. Unit	2
CD-2	Transmitter ON	013	11	" " "	-
CD-3	Transmitter OFF	014	12	" " "	2
CD-4	Transmitter "B" Select	015	13	" " "	-
CD-5	PDR #1 ON	017	15	" " "	-
CD-6	PDR #1 OFF	021	17	" " "	2
CD-7	PDR #2 ON	022	18	" " "	-
CD-8	PDR #2 OFF	023	19	" " "	2
CD-9	DSS HTR 3 ON	024	20	" " "	4
CD-10	DSS HTR 3 OFF	025	21	" " "	2
CD-11	Data Processor "X" Select	034	28	" " "	2
CD-12	Data Processor "Y" Select	035	29	" " "	-
CD-13	Experiment 1 Operational Power ON	036	30	" " "	-
CD-14	Experiment 1 Standby Power	037	31	" " "	2

TABLE 1 (CONT.)

Symbol	Command Nomenclature	Octal Command	Decimal Command	Termination Point	Notes
CD-15	Experiment 1 Standby OFF	041	33	Power Dist. Unit	-
CD-16	Experiment 2 Operational Power ON	042	34	" " "	4
CD-17	Experiment 2 Standby Power	043	35	" " "	4
CD-18	Experiment 2 Standby OFF	044	36	" " "	2, 4
CD-19	Experiment 3 Operational Power ON	045	37	" " "	4
CD-20	Experiment 3 Standby Power	046	38	" " "	4
CD-21	Experiment 3 Standby OFF	050	40	" " "	2, 4
CD-22	Experiment 4 Operational Power ON	052	42	" " "	4
CD-23	Experiment 4 Standby Power	053	43	" " "	4
CD-24	Experiment 4 Standby OFF	054	44	" " "	2, 4
CD-25	DSS HTR 1 Select	055	45	" " "	4
CD-26	DSS HTR 2 Select	056	46	" " "	4
CD-27	DSS HTR 2 OFF	057	47	" " "	2, 4
CD-36	Timer Output Accept	032	26	Command Decoder	1
CD-37	Timer Output Inhibit	033	27	" "	-
CU-1	PCU #1 Select	060	48	Power Cond. Unit	2
CU-2	PCU #2 Select	062	50	" " "	-

TABLE 1 (CONT.)

Symbol	Command Nomenclature		Octal Command	Decimal Command	Termination Point	Notes
CL-1	Gain Change LPX, LPY (Steps through following sequence one step per command)		063	51	Passive Seismic Exp.	
	-30 db[1]					1
	0 db					-
	-10 db					-
	-20 db					-
CL-2	Gain Change LPZ (Steps through same sequence as CL-1)		064	52	" " "	1
CL-3	Calibration SP ON/OFF[1]		065	53	" " "	1
CL-4	Calibration LP ON/OFF[1]		066	54	" " "	1
CL-5	Gain Change SPZ (Steps through same sequence as CL-1)		067	55	Passive Seismic Exp.	1
CL-6	Leveling Power X Motor	ON/OFF[1]	070	56	" " "	1, 7
CL-7	Leveling Power Y Motor	ON/OFF[1]	071	57	" " "	1, 7
CL-8	Leveling Power Z Motor	ON/OFF[1]	072	58	" " "	1, 7
CL-9	Uncage	Arm/Fire	073	59	" " "	-
CL-10	Leveling Direction	Plus[1]/Minus	074	60	" " "	1, 7
CL-11	Leveling Speed	Low[1]/High	075	61	" " "	1, 7

TABLE 1 (CONT.)

Symbol	Command Nomenclature		Octal Command	Decimal Command	Termination Point	Notes
CL-12	Thermal Control Mode	Auto[1]/Manual	076	62	Passive Seismic Exp.	1, 8
CL-13	Feedback Filter	IN/OUT[1]	101	65	" " "	1
CL-14	Coarse Level Sensor	IN/OUT[1]	102	66	" " "	1
CL-15	Leveling Mode	Auto[1]/Manual	103	67	" " "	1, 7
CX-1	Dust Detector - ON		027	023	Power Dist. Unit	2
CX-2	Dust Detector - OFF		031	025	Power Dist. Unit	-

TABLE 2

COMMAND DISTRIBUTION

2a PSEP Commands

Termination Point		Number of Commands
Data Processor		3
Power Distribution Unit (Power Switching)		15
Power Conditioning Unit		2
Command Decoder		2
Passive Seismic		15
	Total	37

2b Special Commands - Not Assignable

Function	Octal Code	Number
Test Commands	1, 2, 4, 10, 20, 40 100, 77, 137, 157, 167, 173, 175, 176	14
Address	130, 30, 116, 16, 151, 51*	6
Address Complement	47, 147, 61, 161, 26, 126**	6
No Command	0, 177	2
	Total	28

2c Summary

Commands Assigned to PSEP		37
Commands Assigned to ALSEP		55
Commands Not Assignable		28
Commands Not Presently Assigned		8
	Total Commands	128

*Addresses for EASEP are 116, 16.
**Address Complements for EASEP are 61 and 161.

TABLE 3

CROSS REFERENCE OF COMMAND NUMBER TO COMMAND FUNCTION

Decimal Command	Octal Command	Command Symbol	PSEP	Test Cmds.	Address	Address Complement	Assigned To ALSEP	Not Presently Assigned
1	1			X				
2	2			X				
3	3	CD-31	(See Note 3)				X	
4	4			X				
5	5	CD-32					X	
6	6	CD-33	X					
7	7	CD-34	X					
8	10			X				
9	11	CD-35	X					
10	12	CD-1	X					
11	13	CD-2	X					
12	14	CD-3	X					
13	15	CD-4	X					
14	16				X			
15	17	CD-5	X					
16	20			X				
17	21	CD-6	X					
18	22	CD-7	X					
19	23	CD-8	X					
20	24	CD-9	(See Note 4)				X	
21	25	CD-10	(See Note 4)				X	
22	26					X		

TABLE 3 (CONT.)

Decimal Command	Octal Command	Command Symbol	PSEP	Test Cmds.	Address	Address Complement	Assigned To ALSEP	Not Presently Assigned
23	27	CX-1	X					
24	30				X			
25	31	CX-2	X					
26	32	CD-36	X					
27	33	CD-37	X					
28	34	CD-11	X					
29	35	CD-12	X					
30	36	CD-13	X					
31	37	CD-14	X					
32	40			X				
33	41	CD-15	X					
34	42	CD-16	(See Note 4)				X	
35	43	CD-17	(See Note 4)				X	
36	44	CD-18	(See Note 4)				X	
37	45	CD-19	(See Note 4)				X	
38	46	CD-20	(See Note 4)				X	
39	47					X		
40	50	CD-21	(See Note 4)				X	
41	51				X			
42	52	CD-22	(See Note 4)				X	
43	53	CD-23	(See Note 4)				X	
44	54	CD-24	(See Note 4)				X	
45	55	CD-25	(See Note 4)				X	
46	56	CD-26	(See Note 4)				X	

TABLE 3 (CONT.)

Decimal Command	Octal Command	Command Symbol	PSEP	Test Cmds.	Address	Address Complement	Assigned To ALSEP	Not Presently Assigned
47	57	CD-27	(See Note 4)				X	
48	60	CU-1	X					
49	61					X		
50	62	CU-2	X					
51	63	CL-1	X					
52	64	CL-2	X					
53	65	CL-3	X					
54	66	CL-4	X					
55	67	CL-5	X					
56	70	CL-6	X					
57	71	CL-7	X					
58	72	CL-8	X					
59	73	CL-9	X					
60	74	CL-10	X					
61	75	CL-11	X					
62	76	CL-12	X					
63	77			X				
64	100			X				
65	101	CL-13	X					
66	102	CL-14	X					
67	103	CL-15	X					
68	104						X	

TABLE 3 (CONT.)

Decimal Command	Octal Command	PSEP	Test Cmds.	Address	Address Complement	Assigned To ALSEP	Not Presently Assigned
69	105					X	
70	106					X	
71	107					X	
72	110					X	
73	111					X	
74	112					X	
75	113					X	
76	114					X	
77	115					X	
78	116			X			
79	117					X	
80	120					X	
81	121					X	
82	122					X	
83	123					X	
84	124					X	
85	125					X	
86	126				X		
87	127					X	
88	130			X			
89	131					X	
90	132					X	

TABLE 3 (CONT.)

Decimal Command	Octal Command	PSEP	Test Cmds.	Address	Address Complement	Assigned To ALSEP	Not Presently Assigned
91	133					X	
92	134					X	
93	135					X	
94	136					X	
95	137		X				
96	140					X	
97	141					X	
98	142					X	
99	143					X	
100	144					X	
101	145					X	
102	146					X	
103	147				X		
104	150						X
105	151			X			
106	152					X	
107	153						X
108	154						X
109	155						X
110	156					X	
111	157		X				
112	160						X

TABLE 3 (CONT.)

Decimal Command	Octal Command	PSEP	No Commands	Test Cmds.	Address	Address Complement	Assigned To ALSEP	Not Presently Assigned
113	161					X		
114	162						X	
115	163						X	
116	164						X	
117	165						X	
118	166						X	
119	167			X				
120	170						X	
121	171							X
122	172							X
123	173			X				
124	174							X
125	175			X				
126	176			X				
127	177		X					
0	000		X					
	Totals	37	2	14	6	6	55	8

APPENDIX B

MEASUREMENT REQUIREMENTS DOCUMENT

INTRODUCTION

This document tabulates the measurements to be telemetered from the EASEP system. The included tables indicate the functions measured, the designation symbol, the assigned channel, accuracy, range, number of bits per sample, and sample rate provided via the PCM telemetry link.

Operational data is defined as that data required to indicate the readiness of the equipment to perform its intended function. In keeping with this definition, all of the data transmitted on analog housekeeping channels are designated as operational.

The A/D converter provided in the data subsystem is capable of encoding analog housekeeping and science signals to 8-bit accuracy. The encoded word occupies 10 bit positions to fill word 33 in the EASEP format. Each housekeeping signal is read out once in 90 frames of the PCM format. The analog multiplexer advances one position each frame. Digital data derived from the experiment has an output consistent with the frame format section of the Data Subsystem.

The following tables categorize the telemetered measurements:

Table 1 (a)	-	Channel Assignments for the Analog Multiplexer (ALSEP Word 33)
Table 1 (b)	-	Analog Housekeeping Channel Usage
Table 1 (c)	-	Summary of Analog Channel Usage
Table 2	-	Passive Seismic Experiment

1 x	2 x	3 x	4 X	5 NA	6 X	7 NA	8 X
9 -	10 X	11 -	12 X	13 -	14 X	15 NA	16 X
17 NA	18 X	19 NA	20 X	21 NA	22 X	23 NA	24 X
25 -	26 X	27 -	28 X	29 -	30 X	31 NA	32 X
33 H	34 X	35	36 X	37 •	38 X	39 NA	40 X
41 -	42 X	43 -	44 X	45 -	46 CV	47 NA	48 X
49 NA	50 X	51 NA	52 X	53 NA	54 X	55 NA	56 NA
57 -	58 X	59 -	60 X	61 -	62 X	63 NA	64 X

Legend		Number of Words Per Frame
x	- Control	3
X	- Passive Seismic - Short Period	29
-	- Passive Seismic - Long Period Seismic	12
	- Passive Seismic - Long Period Tidal and One Temperature	2
CV	- Command Verification (upon command, otherwise all zeros)	1
H	- Housekeeping	1
NA	- Not Assigned (all 1's are transmitted)	16
	TOTAL	64

Each box contains one 10-bit word
Total bits per frame - 10 x 64 = 640 bits

Figure 1. EASEP Channel Assignment

CONTROL WORD FORMAT

PSEP WORD #1	PSEP WORD #2	PSEP WORD #3

Bit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	1	1	1	0	0	0	1	0	0	1	0	0	0	0	1	1	1	0	1	1	0	1	F1	F2	F3	F4	F5	F6	F7	M

BARKER CODE (bits 1–11) — COMPLEMENT OF BARKER CODE (bits 12–22) — FRAME COUNTER (1, 2 .... 89, 0) (bits 23–29) — MODE BIT (bit 30)

Symbol	Name	PSEP Words	Range	Bits/ Sample	Samples/ Second
DA-1	Barker Code and Complement	1, 2, and bits 1 and 2 of word 3	NA	22	1.67
DA-2	Frame Count	Bits 3 to 9 inclusive of word 3	0-89	7	1.67
DA-3	Bit Rate ID	Bit 10 of word 3		1	1/54
		Frame / Mode Bit	**Meaning**		
		1 / 1	Normal data rate		
		2 / 1	Slow data rate		
DA-4	PSEP ID	Bit 10 of word 3		3	1/54
		Frame / Mode Bit			
		3 / 0 (MSB)	Data processor Serial number		
		4 / 1			
		5 / 1			
DA-5***	Received Command Message	Bits 3 to 9 inclusive of word 46 *	0-127	7	**
DA-6	Command MAP	Bit 10 of word 46 *	"0" no parity "1" parity	1	**
DA-7	Filler Bits	Bits 1 and 2 of word 46 *	All zeros	2	**
		Bits 1 and 2 of word 33	All zeros	2	1.67

**One word sample is sent for each command received, other samples are all zeros. Maximum sampling rate is about once per second.

* Command verification word is 46

*** Verifies reception and decoding of commands by retransmission of command message.

Figure 2. Control and Command Verification Words

TABLE 1 (a)

CHANNEL ASSIGNMENTS FOR ANALOG MULTIPLEXER
(WORD 33)

Channel Number	Flight System	Channel Number	Flight System
1.	AE-3	39.	AL-6
2.	AE-1	40.	BLANK
3.	AE-2	41.	AX-6
4.	AT-3	42.	AT-2
5.	AE-4	43.	AT-5
6.	BLANK	44.	BLANK
7.	BLANK	45.	BLANK
8.	AE-5	46.	AT-29
9.	AB-1	47.	AT-30
10.	BLANK	48.	AT-31
11.	BLANK	49.	AT-32
12.	AB-4	50.	AE-9
13.	AE-6	51.	AE-15
14.	AB-5	52.	BLANK
15.	AT-10	53.	AL-3
16.	AT-21	54.	AL-7
17.	AT-22	55.	BLANK
18.	AT-23	56.	AX-3
19.	AT-24	57.	BLANK
20.	AE-7	58.	AT-6
21.	AE-13	59.	AT-8
22.	AE-18	60.	AT-12
23.	AL-1	61.	AT-33
24.	AL-5	62.	AT-34
25.	BLANK	63.	AT-35
26.	AX-5	64.	AT-36
27.	AT-1	65.	AE-10
28.	AT-4	66.	AE-16
29.	BLANK	67.	BLANK
30.	AX-2	68.	AL-4
31.	AT-25	69.	AL-8
32.	AT-26	70.	BLANK
33.	AT-27	71.	AT-7
34.	AT-28	72.	AT-13
35.	AE-8	73.	BLANK
36.	AE-14	74.	BLANK
37.	BLANK	75.	BLANK
38.	AL-2	76.	AT-37

TABLE 1 (a) (CONT.)

Channel Number	Flight System
77.	AT-38
78.	AT-39
79.	AE-11
80.	AE-12
81.	AE-17
82.	BLANK
83.	AX-1
84.	AX-4
85.	BLANK
86.	BLANK
87.	AT-9
88.	AT-11
89.	BLANK
90.	BLANK

TABLE 1 (b)
ANALOG HOUSEKEEPING CHANNEL USAGE

Symbol	Location/Name	Channel	Range	Sensor Accuracy	Bits/ Sample	Sample/ Sec.
	Structural/Thermal Temperatures					
AT-1	Solar Panel, East, Side 1	27	-300°F to +300°F	±15°F	8	.0185
AT-2	Solar Panel, West, Side 2	42	" "	"	"	"
AT-3	Thermal Plate #1	4	-50°F to +200°F	±10°F	"	"
AT-4	" " #2	28	" "	"	"	"
AT-5	" " #3	43	" "	"	"	"
AT-6	" " #4	58	" "	"	"	"
AT-7	" " #5	71	" "	"	"	"
AT-8	Left Side Structure #1	59	-300°F to +300°F	±15°F	8	.0185
AT-9	Right Side Structure #2	87	" "	"	"	"
AT-10	Bottom Structure #3	15	" "	"	"	"
AT-11	Back Structure #4	88	" "	"	"	"
AT-12	Inner Multilayer Insulation	60	-50°F to +200°F	±10°F	"	"
AT-13	Outer Multilayer Insulation	72	-300°F to +300°F	±15°F	"	"
	Electronic Temperatures					
AT-21	Local OSC. Crystal A	16	-50°F to +200°F	±10°F	8	.0185
AT-22	Local OSC. Crystal B	17	" "	"	"	"
AT-23	Transmitter A Crystal	18	" "	"	"	"
AT-24	Transmitter A Heat Sink	19	" "	"	"	"
AT-25	Transmitter B Crystal	31	" "	"	"	"
AT-26	Transmitter B Heat Sink	32	" "	"	"	"
AT-27	Analog Data Processor, Base	33	" "	"	"	"
AT-28	Analog Data Processor, Internal	34	" "	"	"	"
AT-29	Digital Data Processor, Base	46	" "	"	"	"
AT-30	Digital Data Processor, Internal	47	" "	"	"	"
AT-31	Command Decoder, Base	48	" "	"	"	"
AT-32	Command Decoder, Internal	49	" "	"	"	"
AT-33	Command Demodulator VCO	61	" "	"	"	"
AT-34	PDU, Base	62	" "	"	"	"
AT-35	PDU, Internal	63	" "	"	"	"
AT-36	PCU, Power OSC #1	64	" "	"	"	"
AT-37	PCU, Power OSC #2	76	" "	"	"	"
AT-38	PCU, Regulator #1	77	" "	"	"	"
AT-39	PCU, Regulator #2	78	" "	"	"	"

Total of 32 Central Station Temperatures

TABLE 1 (b) (CONT.)
ANALOG HOUSEKEEPING CHANNEL USAGE

Symbol	Location/Name	Channel	Range	Sensor Accuracy	Bits/Sample	Sample/Sec.
Central Station Electrical						
AE-1	ADC Calibration 0.25V	2	Octal Count 15 ± 1	0.5%	8	.0185
AE-2	ADC Calibration 4.75V	3	Octal Count 361 ±1	"	"	"
AE-3	Converter Input Voltage	1	0 to 20 VDC	±2%	"	"
AE-4	Converter Input Current	5	0 to 5 ADC	"	"	"
AE-5	Shunt Reg #1 Current	8	0 to 3.5 ADC	"	"	"
AE-6	Shunt Reg #2 Current	13	0 to 3.5 ADC	"	"	"
AE-7	PCU Output Voltage #1 (29V)	20	0 to 35 VDC	"	"	"
AE-8	PCU Output Voltage #2 (15V)	35	0 to 18 VDC	"	"	"
AE-9	PCU Output Voltage #3 (12V)	50	0 to 15 VDC	"	"	"
AE-10	PCU Output Voltage #4 (5V)	65	0 to 6 VDC	"	"	"
AE-11	PCU Output Voltage #5 (-12V)	79	0 to -15 VDC	"	"	"
AE-12	PCU Output Voltage #6 (-6V)	80	0 to -7.5 VDC	"	"	"
AE-13	RCVR., Pre-Limiting Level	21	-101 to -61 DBM	±1 DB	"	"
AE-14	RCVR., Local OSC Level	36	0 to 10 DBM	±0.5 DB	"	"
AE-15	Trans. A, AGC Voltage	51	0 to 5V	±5%	"	"
AE-16	Trans. B, AGC Voltage	66	0 to 5V	"	"	"
AE-17	Trans. A, DC, Power Doubler	81	100 to 200 ma	"	"	"
AE-18	Trans. B, DC, Power Doubler	22	100 to 200 ma	"	"	"
Central Station Bistatic						
AB-1	Receiver, 1 KHz Subcarrier Present "	9	No modulation Octal 57 Modulation Octal 275		8	.0185
AB-4 *	Power Distribution, Experiments #1 and #2 "	12	Exper. #1 / Exper. #2 / Octal Count		8	.0185
			Standby off / Standby off / 0-2			
			Standby on / Standby off / 76-122			
			Standby off / Standby on / 171-215			
			Standby on / Standby on / 264-314			
AB-5 *	Power Distribution, Experiments 3, 4, and DSS Heater #2 "	14	Exper. #3 / Exper. #4 / Heater #2 / Octal Count		8	.0185
			Standby off / Standby off / Off / 0-2			
			Standby off / Standby off / On / 31-55			
			Standby off / Standby on / Off / 73-117			
			Standby off / Standby on / On / 132-156			
			Standby on / Standby off / Off / 171-215			
			Standby on / Standby off / On / 226-252			
			Standby on / Standby on / Off / 262-306			
			Standby on / Standby on / On / 314-340			

*Experiments numbered as shown below:

Exp. No.	PSEP
1	PSE

Experiments 2, 3 and 4 are open.

TABLE 1 (b) (CONT.)

ANALOG HOUSEKEEPING CHANNEL USAGE

Symbol	Location/Name	Channel	Range	Sensor Accuracy	Bits/ Sample	Samples/ Sec.
	Dust Accretion					
AX-1	#3 (.020 Filter) Cell Temperature	83	30°C to 150°C	±8°C	8	.0185
AX-2	#1 (Bare) Cell Temperature	30	30°C to 150°C	"	"	"
AX-3	Lunar Brightness Temperature	56	-150°C to +130°C	"	"	"
AX-4	#1 Cell Output (No Filter)	34	0 - 150 mV	±1%	"	"
AX-5	#2 Cell Output (.006" Filter)	26	0 - 150 mV	"	"	"
AX-6	#3 Cell Output (.020" Filter)	41	0 - 150 mV	"	"	"
	Passive Seismic					
AL-1	L.P. Ampl. Gain (X & Y)	23	Discrete	See Table 2	8	.0185
AL-2	L.P. Ampl. Gain (Z)	38	"	See Table 2	"	"
AL-3	Level Direction and Speed	53	"	See Table 2	"	"
AL-4	S.P. Ampl. Gain (Z)	68	"	See Table 2	"	"
AL-5	Leveling Mode & Coarse Sensor Mode	24	"	See Table 2	"	"
AL-6	Thermal Control Status	39	"	See Table 2	"	"
AL-7	Calibration Status L.P. & S.P.	54	"	See Table 2	"	"
AL-8	Uncage Status	69	"	See Table 2	"	"

TABLE 1 (c)

SUMMARY OF ANALOG CHANNEL

Central Station	
Data and Power Subsystems	38
Experiment On-Off Status	2
Structural/Thermal	13
TOTAL	53
Experiments	
Passive Seismic	8
Not Assigned	29
TOTAL	90

TABLE 2

PASSIVE SEISMIC MEASUREMENT

Scientific Measurements:

Symbol	Location/Measurement	ALSEP Word	Frame	(Dynamic) Range	Sensor Accuracy	Bits/ Sample	Sample/ Sec	Sample/ Frame
DL-1	L. P. Seismic X	9, 25, 41, 57	Every	1 mμ to 10 μ	5% of reading	10	6.625	4
DL-2	L. P. Seismic Y	11, 27, 43, 59	"	1 mμ to 10 μ	" "	"	"	"
DL-3	L. P. Seismic Z	13, 29, 45, 61	"	1 mμ to 10 μ	" "	"	"	"
DL-4	Tidal: X	35	Even	.01 to 10" (arc)	" "	"	0.85	0.5
DL-5	Tidal: Y	37	Even	.01 to 10" (arc)	" "	"	0.85	0.5
DL-6	Tidal: Z	35	Odd	8 μgal to 8 mgal	" "	"	"	"
DL-7	Sensor Unit Temp.	37	Odd	107-143°F	±1% of reading***	"	"	"
DL-8	Short Period Seismic: Z	Every Even Word Except 2, 46, 56	Every	1 mμ to 10 μ	±5% of reading	"	48.0	29

Housekeeping Measurements

8 channels of Engineering Measurements included in ALSEP Word 33, all 0-5 VDC.

Symbol	Location/Measurement	Channel	Range		Octal Count	Bits/ Sample	Sample/ Sec
AL-1	L. P. Amp. Gain X, Y	23	0db	0-0.4V	0 to 25	8	.0185
			-10db	0.6-1.4	37 to 110		
			-20db	1.6-2.4	122 to 172		
			-30db	2.6-4.0	205 to 314		
AL-2	L. P. Amp. Gain Z	38	0db	0-0.4V	0 to 25	8	.0185
			-10db	0.6-1.4	37 to 110		
			-20db	1.6-2.4	122 to 172		
			-30db	2.6-4.0	205 to 314		
AL-3	Level Direction and Speed	53	+low	0-0.4V	0 to 25	8	.0185
			-low	0.6-1.4	37 to 110		
			+high	1.6-2.4	122 to 172		
			-high	2.6-4.0	205 to 314		
AL-4	S. P. Amp. Gain Z	68	0db	0-0.4V	0 to 25	8	.0185
			-10db	0.6-1.4	37 to 110		
			-20db	1.6-2.4	122 to 172		
			-30db	2.6-4.0	205 to 314		
AL-5	Leveling Mode and Coarse Sensor Mode	24	Automatic, coarse level out	0-0.4V	0 to 25	8	.0185
			Manual, coarse level out	0.6-1.4	37 to 110		
			Automatic, coarse level in	1.6-2.4	122 to 172		
			Manual, coarse level in	2.6-4.0	205 to 314		
AL-6	Thermal Control Status	39	Automatic Mode ON	0-0.4V	0 to 25	8	.0185
			Automatic Mode OFF	0.6-1.4	37 to 110		
			Manual Mode ON	1.6-2.4	122 to 172		
			Manual Mode OFF	2.6-4.0	205 to 314		
AL-7	Calibration Status LP & SP	54	Both ON	0-0.4V	0 to 25	8	.0185
			LP-ON SP-OFF	0.6-1.4	37 to 110		
			LP-OFF SP-ON	1.6-2.4	122 to 172		
			Both OFF	2.6-4.0	205 to 314		
AL-8	Uncage Status****	69	Caged	0-0.4V	0 to 25	8	.0185
			Arm	0.6-1.4	37 to 110		
			Uncage	1.6-2.4	122 to 172		

*** ±0.05°C resolution.
****Uncage locked-out on all ground tests.