ALSEP–MT–06

APOLLO LUNAR SURFACE
EXPERIMENTS PACKAGE
(ALSEP)

APOLLO 16 ALSEP ARRAY D FLIGHT SYSTEM FAMILIARIZATION MANUAL

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INTRODUCTION

The Apollo 16 Lunar Surface Experiments Package (ALSEP) will be used to continue long-term scientific measurements of various physical and environmental properties of the Moon consistent with the scientific objectives of the Apollo Program. The measurement data will be analyzed in conjunction with that obtained from the Apollo 12, 14, and 15 ALSEP systems already deployed on the lunar surface.

The Apollo 12, 14, and 15 ALSEP systems are described in the ALSEP Flight System Familiarization Manual, ALSEP-MT-03.

The purpose of this Apollo 16 ALSEP, Array D Flight System Familiarization Manual is to familiarize the reader with the scientific objectives of ALSEP, equipment make-up, system deployment, and operation. This manual describes the Apollo 16 ALSEP mission and system in Section I, subsystems in Section II, maintenance in Section III, and operations in Section IV. Supplementary command and measurement data are provided in the Appendices. A brief account of the operational experience of the Early Apollo Scientific Experiments Package (EASEP) of Apollo 11, and the ALSEP systems of Apollo 12 and 14 is included in Section I.

The information contained in this Apollo 16 ALSEP, Array D Flight System Familiarization Manual includes formalized data released and available prior to the publication date, 15 July 1971.

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SECTION I

ALSEP MISSION DESCRIPTION

1-1. ALSEP MISSION INTRODUCTION

The Apollo Lunar Surface Experiments Package (ALSEP) is a group of scientific experiment and support subsystems which will be deployed on the surface of the Moon by the Apollo 16 crewmen. The ALSEP will measure lunar physical and environmental characteristics and transmit the data to receiving stations on Earth. This data will be used to derive information on the composition and structure of the lunar body, magnetic field, atmosphere, and the solar wind.

1-2. ALSEP MISSION PROFILE

The ALSEP will be transported from Earth to the Moon in the Apollo 16 spacecraft manned by three crewmen. The Apollo spacecraft consists of three basic modules; the service module (SM), command module (CM), and lunar module (LM). The ALSEP subpackages will be mounted in the scientific equipment (SEQ) bay of the LM, and the fuel cask will be mounted adjacent to the SEQ bay on the exterior of the LM as shown in Figure 1-1.

A Saturn V launch vehicle will place the Apollo 16 spacecraft in 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 the lunar landing site in the vicinity of the crater Descartes.

After landing, the crewmen will extract the ALSEP from the LM, deploy the instruments and subsystems, and activate the power subsystem. They 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 reenter the Earth atmosphere and land in the CM.

The ALSEP, on the lunar surface, is controlled by ground command from the manned space flight network (MSFN). Commands from Earth and internally generated commands will direct ALSEP operation.

1-3. ALSEP 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.

To accomplish partial attainment of these objectives the Apollo 16 ALSEP includes four experiments to measure a number of geophysical characteristics. The various physical and environmental properties to be measured, applicable experiment, and method of measurement are listed in Table 1-1.

Table 1-1. Apollo 16 ALSEP Scientific Objectives

Measurement Objective	Experiment/Measurement Method
Natural seismology (meteoroid impacts and moonquakes). Properties of lunar interior (existence of core, mantle).	Passive Seismic Experiment - Uses three long period sensors in an orthogonal arrangement and one vertical short period sensor.
Physical properties of lunar materials at shallow depths (elastic properties of lunar near-surface materials).	Active Seismic Experiment - Uses artificial seismic energy sources (grenade launcher assembly and thumper device) and detection equipment (geophones and amplifiers).
Magnetic field and its temporal variations at the lunar surface.	Lunar Surface Magnetometer Experiment - Uses tri-axis flux-gate magnetometer instrument. Three booms each with flux-gate sensors, are separated to form a rectangular coordinate system and gimballed to allow alignment in parallel or orthogonal configurations.
Rate of heat flow through lunar surface that together with information from other sources, will refine hypotheses concerning: a. the physical and chemical composition of the lunar surface b. the thermal distribution of the Moon c. the radioactivity of material at various lunar depths, and d. the thermal history of the Moon.	Heat Flow Experiment - Uses two heat flow probe assemblies, emplaced in lunar crust. Probes contain temperature sensors and heating elements.

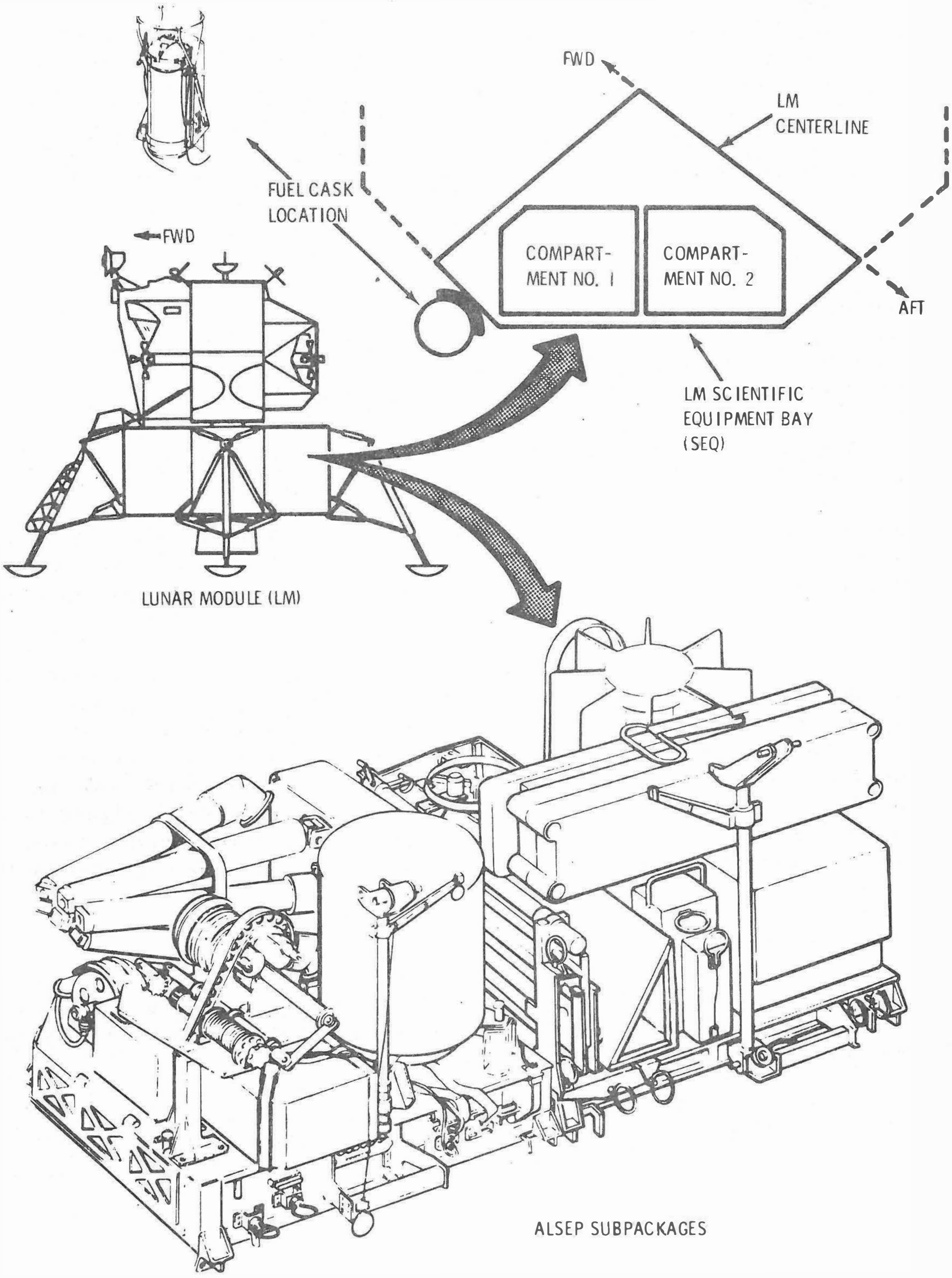


Figure 1-1. ALSEP/LM Interface

1-4. ALSEP SYSTEM DESCRIPTION

The ALSEP is a self-contained package of scientific instruments and supporting subsystems designed to acquire lunar physical and environmental data and transmit the information to Earth. The ALSEP is deployed on the lunar surface by the Apollo crewmen as described in Section IV of this manual.

1-5. ALSEP PHYSICAL DESCRIPTION

The Apollo 16 ALSEP is comprised of the following subsystems:

a. Structure/thermal subsystem
b. Electrical power subsystem
c. Data subsystem
d. Four experiment subsystems:
    1. Passive Seismic (PSE)
    2. Active Seismic (ASE)
    3. Lunar Surface Magnetometer (LSM)
    4. Heat Flow (HFE).

The experiment and support subsystems of the ALSEP system are mounted in two subpackages as shown in Figure 1-1 for storage and transportation in the LM. The fuel cask (part of the electrical power subsystem) is attached to the exterior of the LM.

Subpackage No. 1 is comprised of the central station (data subsystem, power conditioning unit, and experiment electronics), the antenna, the passive seismic (PSE), active seismic (ASE), and magnetometer (LSM) experiments as shown in Figure 1-2. Subpackage No. 2 is comprised of the radioisotope thermoelectric generator (RTG), heat flow experiment (HFE), mortar package pallet, antenna aiming mechanism, handling tools, and the antenna mast as shown in Figure 1-3. The Apollo 16 ALSEP packages, including fuel capsule and cask, weigh approximately 300 pounds and, excluding the fuel capsule and cask, occupy approximately 15 cubic feet.

1-6. ALSEP FUNCTIONAL DESCRIPTION

The ALSEP objective of obtaining lunar physical and environmental data is accomplished through employment of the various experiment combinations, the supporting subsystems, and the manned space flight network (MSFN).

The MSFN stations, such as those at Goldstone, California, Carnarvon and Canberra Australia, Ascension Island, Hawaii, Guam, Madrid Spain, and KSC Florida, are the Earth terminals for ALSEP communications. Data is recorded

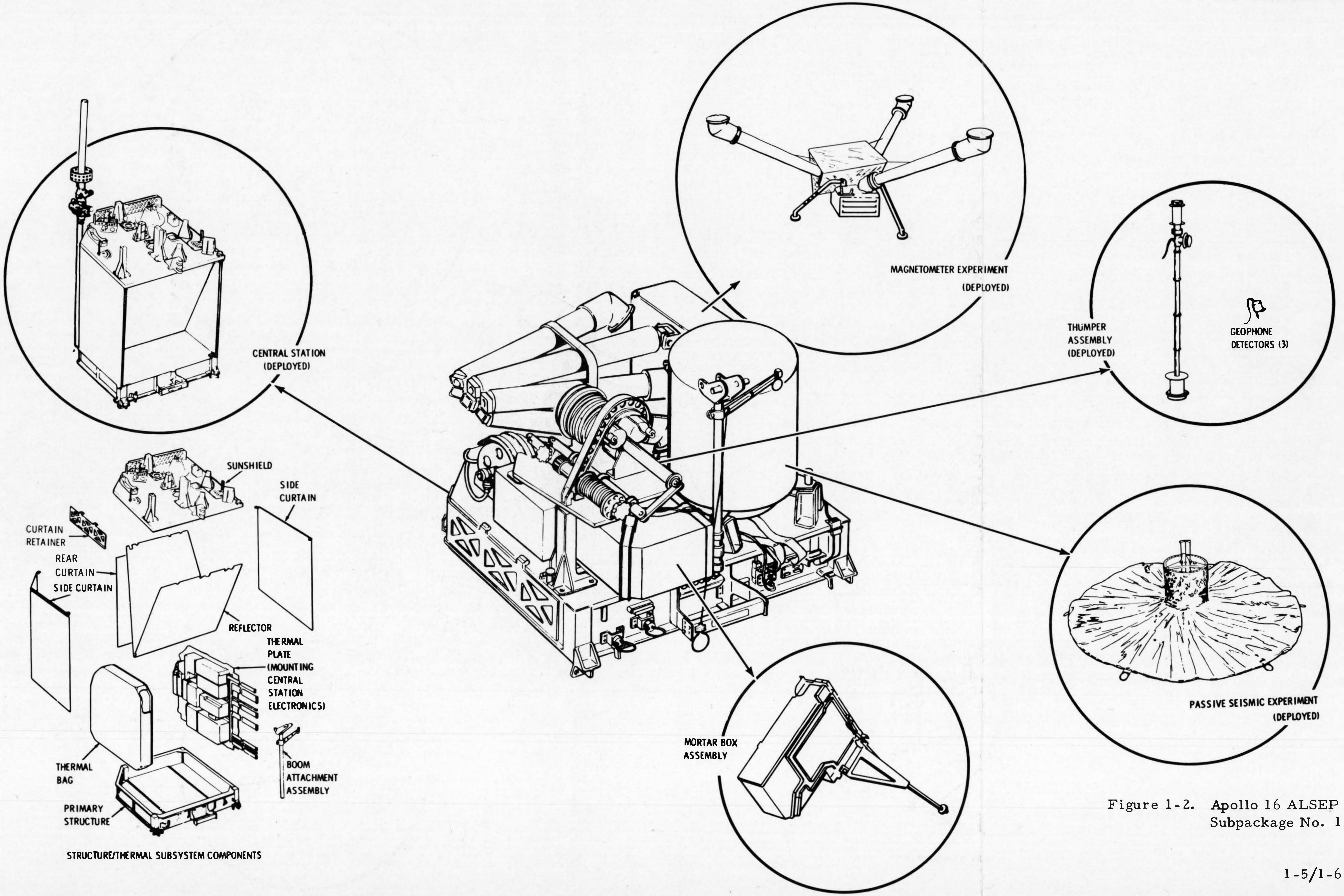


Figure 1-2. Apollo 16 ALSEP
Subpackage No. 1

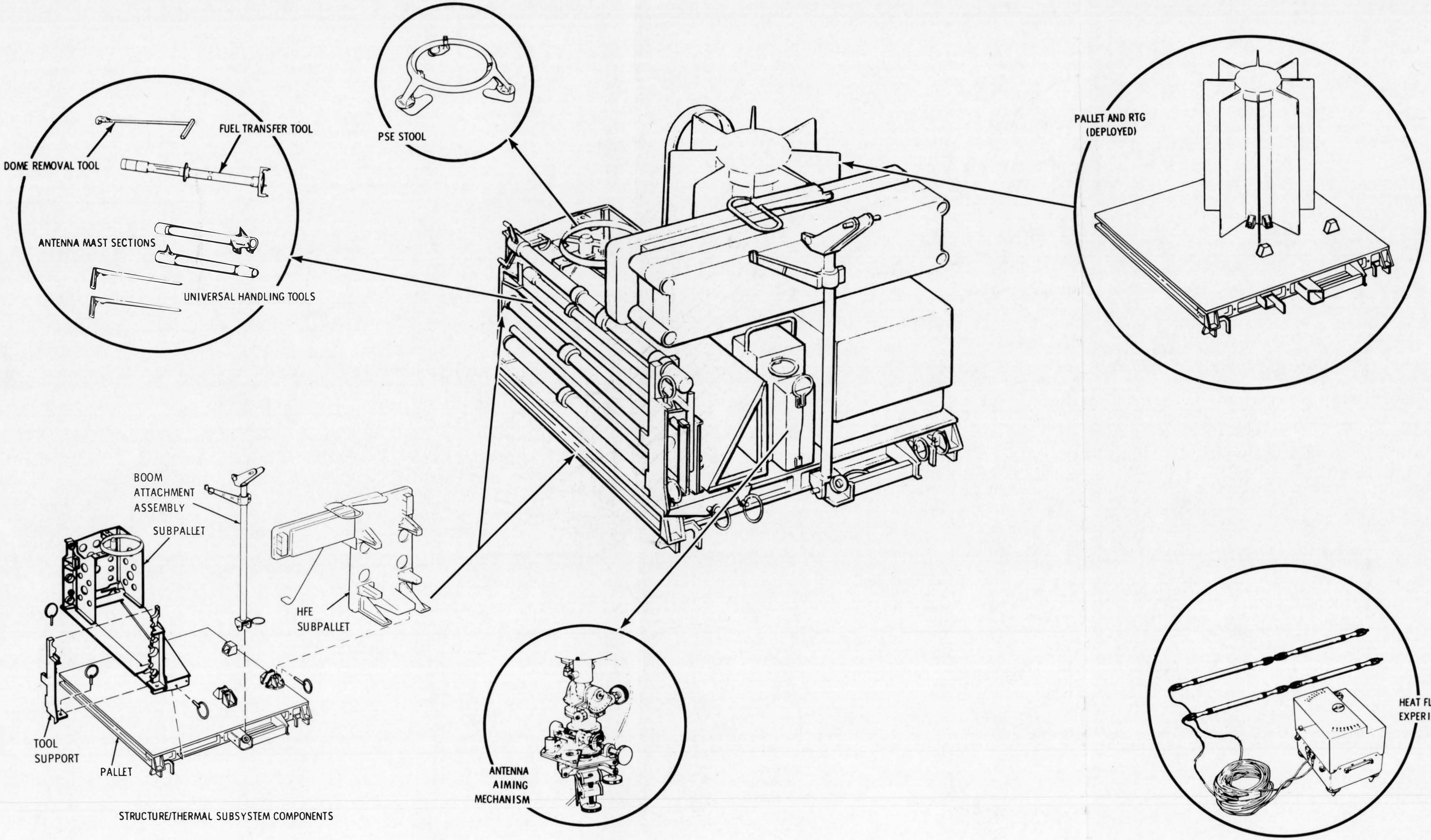


Figure 1-3. Apollo 16 ALSEP Subpackage No. 2

at the Earth terminals and relayed to Mission Control Center (MCC) at MSC in near real time. Communications consist of an uplink (Earth to Moon) for command transmissions to control the ALSEP functions, and a downlink (Moon to Earth) for transmission of scientific experiment and engineering housekeeping data. The MSFN stations will record all downlink data in real time.

The downlink telemetry of each of the ALSEP systems will operate at a different assigned frequency within the S-band. The Apollo 16 ALSEP downlink telemetry frequency is 2276 MHz. The uplink frequency for all systems is 2119 MHz. The command format addresses each ALSEP specifically, precluding inadvertent activation of the other systems.

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

1-7. Structure/Thermal Subsystem. The structure/thermal subsystem provides structural integrity and thermal isolation of the ALSEP equipment and LM 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.

1-8. Electrical Power Subsystem. The electrical power subsystem generates 63 to 75 watts of electrical power for operation of the ALSEP system. The power is developed by a thermopile system which is heated by a radioisotope fuel capsule. The power is regulated, converted to the required voltage levels, and supplied to the data subsystem for distribution to the support and experiment

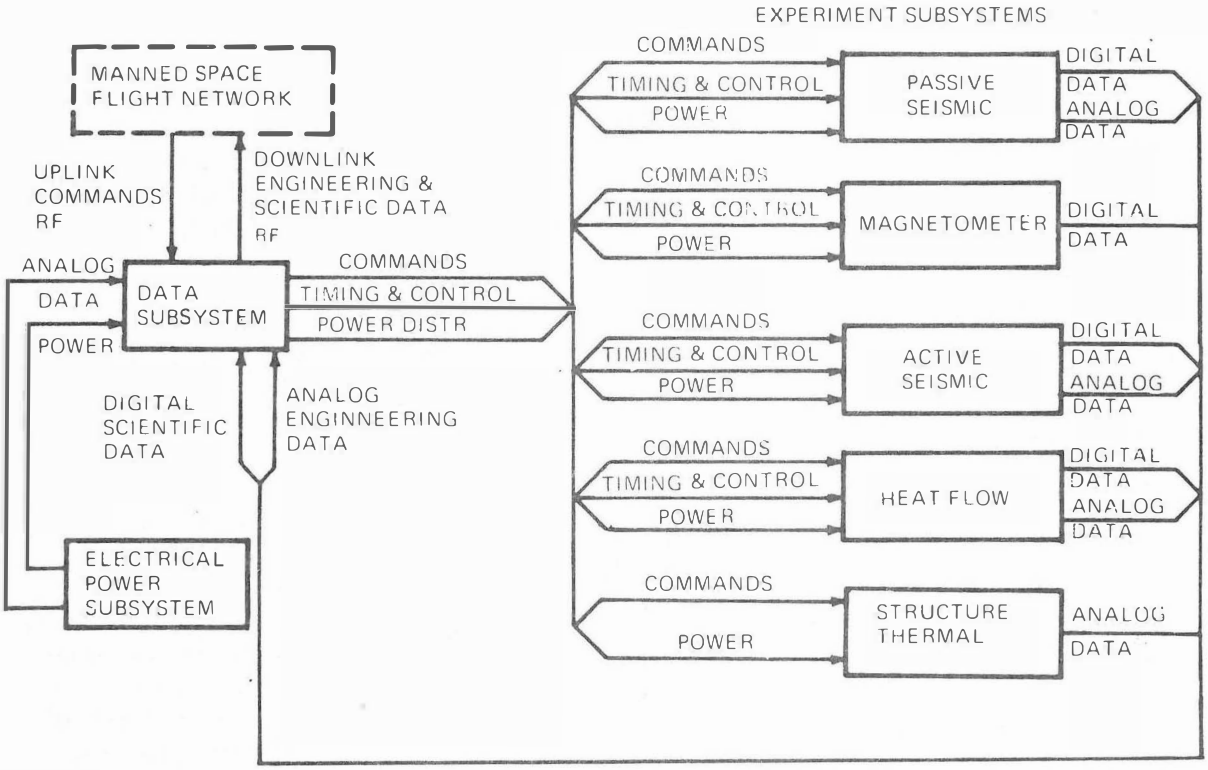


Figure 1-4. Apollo 16 ALSEP System, Simplified Block Diagram

subsystems. Analog housekeeping data from the electrical power system is supplied to the data subsystem for downlink telemetry.

1-9. Data Subsystem. The data subsystem receives, decodes, and applies discrete logic commands from the MSFN to the deployed units of ALSEP. 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 experiments, engineering status data from all the subsystems and transmits the data to the MSFN receiving stations. The data subsystem also switches and distributes operating power to the experiment and support subsystems.

1-10. 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 produced in the lunar surface by meteoroid impacts and by 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.

1-11. Active Seismic Experiment Subsystem. The active seismic experiment subsystem (ASE) will provide controlled seismic lunar exploration using artifically produced seismic energy of known distances, charge sizes, and timing. It will provide data pertaining to the physical properties, structure, elasticity, and bearing strength of lunar surface and near surface materials by measuring velocity of propagation, frequency spectra, and attenuation of seismic compression waves through the lunar surface.

1-12. Lunar Surface Magnetometer Experiment Subsystem. The lunar surface magnetometer (LSM) will provide data pertaining to the magnetic field at the lunar surface by measuring the magnitude and temporal variations of the lunar surface equatorial vector magnetic field. Electromagnetic disturbances originating in the solar wind and subsurface magnetic material near the magnetometer site will also be detected.

1-13. Heat Flow Experiment Subsystem. The heat flow experiment (HFE) will provide data pertaining to the structure, possible stratification, and heat balance of subsurface materials by measuring the net outward heat flux from the interior of the Moon, the thermal conductivity and diffusivity of lunar surface material, and heat fluctuations at the lunar surface.

Two, two-section probes with heat sensors and a heater at each end of each section are used in conjunction with the HFE electronics package to measure absolute and differential temperatures and thermal conductivity of the lunar material. The probes are inserted into holes bored three meters deep into the lunar surface by the astronaut using the Apollo lunar surface drill (ALSD). The sensors monitor the temperature at known locations in the bore hole, and the difference in temperature between the locations. The heaters produce a known amount of heat at known locations, while the dissipation rate is monitored. By determining temperatures, temperature differences, and thermal dissipation rate, the thermal conductivity of the lunar subsurface can be calculated.

1-14. ALSEP PRINCIPAL INVESTIGATORS

Each ALSEP 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, and whether the experiment is government furnished equipment (GFE) or contractor furnished equipment (CFE) are listed in Table 1-2.

Table 1-2. Apollo 16 ALSEP Principal Investigators

Experiment	GFE or CFE	Principal Investigator and Co-Investigators
Passive seismic	CFE	Dr. Gary Latham - Lamount-Doherty Geological Observatory Dr. George Sutton - University of Hawaii Dr. Frank Press - Massachusetts Institute of Technology Dr. Maurice Ewing - Columbia University
Magnetometer	GFE	Instrument: Dr. Palmer Dyal - NASA-Ames Research Center Data: Dr. Charles P. Sonett - NASA-Ames Research Center
Active seismic	CFE	Dr. Robert Kovach - Stanford University
(Thumper)		Dr. Joel Watkins - Massachusetts Institute of Technology
Heat Flow	CFE	Dr. Marcus G. Langseth - Columbia University Dr. Sidney Clarke - Yale University Dr. M. Eugene Simmons - Massachusetts Institute of Technology

1-15. OPERATIONAL EXPERIENCE

The crew of Apollo 11 put the Early Apollo Scientific Experiments Package (EASEP), described in EASEP-MT-01, into operation at Tranquility Base in Mare Tranquillitatis on 21 July 1969. (See Figure 1-5.) The Apollo 12 ALSEP was deployed by the crew at the site of Surveyor 3 in Oceanus Procellarum, and began operating on 19 November 1969. The Apollo 14 ALSEP was deployed in the vicinity of the crater Fra Mauro, and began operating on 5 February 1971. The locations of these equipments are illustrated in Figure 1-5.

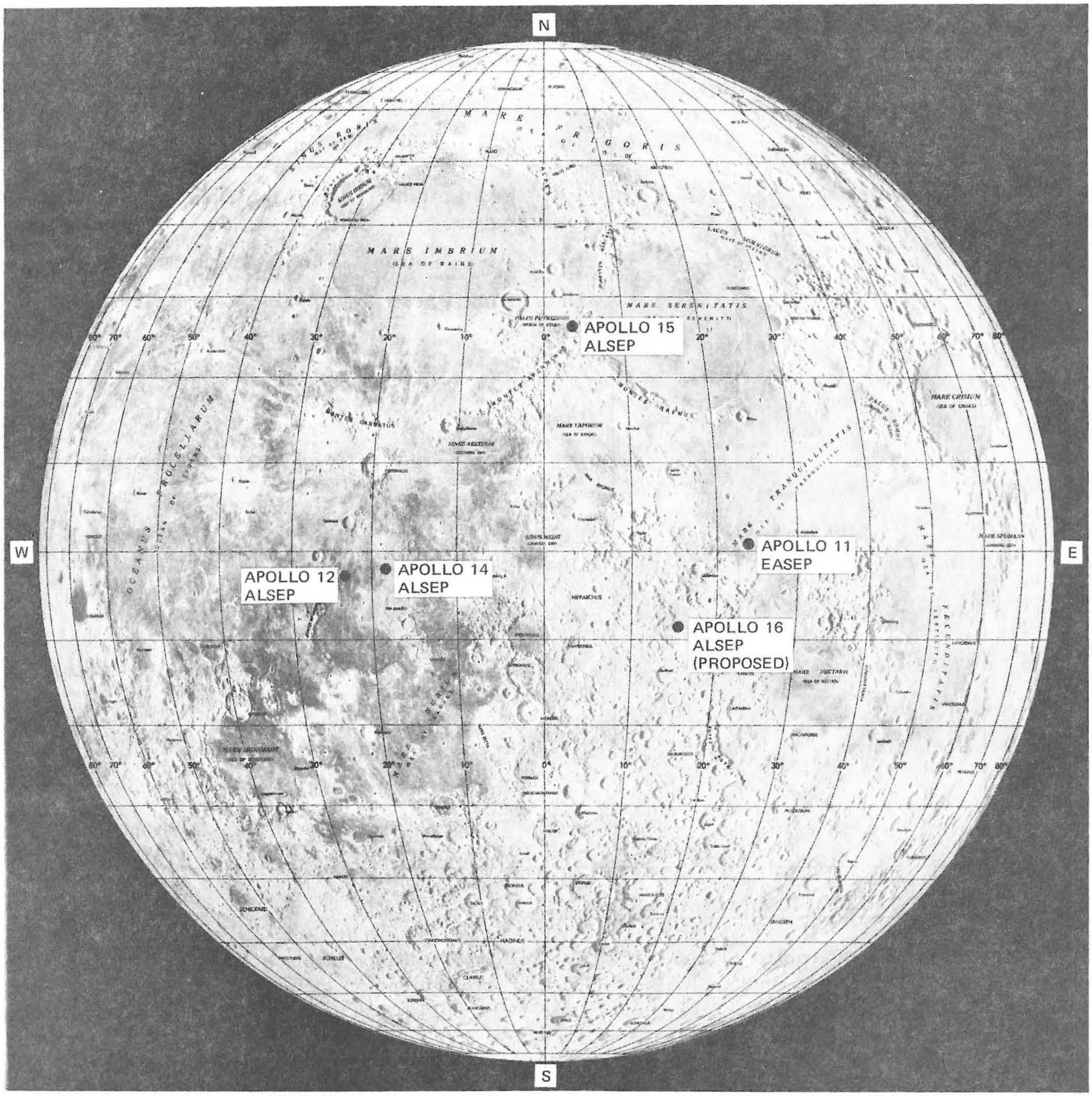


Figure 1-5. ALSEP Locations on Moon

The receipt of live data from moon-based science equipment is now a routine reality. Since the deployment of EASEP on 21 July 1969, there has been a continuous flow of measurements transmitted to Earth from these lunar laboratories. During this period the Manned Space Flight Network has recorded the data transmissions and the Mission Control Center of NASA has monitored and controlled the performance of the equipment.

These paragraphs summarize the operational experience accumulated with these lunar-based systems. The following documents contain comprehensive descriptions of EASEP and ALSEP operating experiences:

a. Apollo 11 Preliminary Science Report, NASA SP-214

b. Science, Vol. 167, No. 3918 (30 January 1970)

c. Apollo 12 Preliminary Science Report, NASA SP-235

d. Apollo 14 Preliminary Science Report, NASA SP-272.

1-16. EASEP OPERATIONAL EXPERIENCE

EASEP is a modified version of ALSEP which was prepared for the Apollo 11 mission. The operating lifetime and scientific scope were reduced to obtain a minimum deployment time. The two subpackages of ALSEP were modified to each carry an experiment. Subpackage 1, the Passive Seismic Experiment Package (PSEP), comprised a passive seismic sensor and a solar-powered central station. Subpackage 2 comprised a Laser Ranging Retro-Reflector (LRRR) which is electrically passive. Both packages met their operational requirements as shown in Table 1-3.

1-17. PSEP Operation. The Passive Seismic Experiment Package was deployed 70 feet from the LM as shown in Figure 1-6. Immediately after the solar panels were unfolded the system was electrically activated and a downlink signal was detected by the MSFN. During the next five lunations, PSEP transmitted data to Earth when the sun was shining on the panels. The solar panels provided the equipment with almost exactly the design values of electrical power throughout the operating periods. These values were well above the minimum power required for normal operation of the equipment.

An abnormally high rate of rise of central station temperature was detected shortly after LM lift-off, and it became evident that the equipment would be subjected to very high temperatures during lunar noon operation. The electronic units operated at temperatures up to 50° F above the design limit value.

All functions performed normally throughout the first lunar day. The system was commanded off at sunset, and was dormant throughout the lunar night. When reactivated at lunar dawn, the system provided full performance until noon of that lunar day when the command decoder failed to respond to uplink command. The net result of the loss of the command link was (1) inability to level the seismometer or to reactivate it when placed in STANDBY mode by the "ripple" circuit during a power dip, (2) inability to reactivate the dust, thermal, and radiation engineering measurements package (DTREM I) which was turned off when the sun went down on the second lunar day, and (3) inability to exercise thermal control through use of the power dump resistors.

Table 1-3. EASEP Operating Experience

	Deployment Time		Operating Time	
	Req'd	Actual	Req'd	Actual
LRRR	5 minutes	3 minutes	1 year	still functioning
PSEP	5 minutes	4 minutes	first lunar daytime	through noon 2nd lunar day*

*Complete engineering data thru dawn on 6th lunar day.

Temperature, voltage, current, and calibration status data were transmitted throughout the next five lunar daytime periods from all sensors except those associated with the seismometer and the DTREM I. This data has been used to evaluate the operation of the equipment in the harsh extremes of the lunar environment.

The PSEP system executed 916 commands during the first lunar day operation. Another 615 commands were implemented on the second day before loss of uplink capability. All redundant facilities (data processors, power converters, transmitters, and command decoders) built into the central station were exercised successfully. Over 800 more commands were directed at PSEP throughout the remaining operational period to determine if the uplink had recovered.

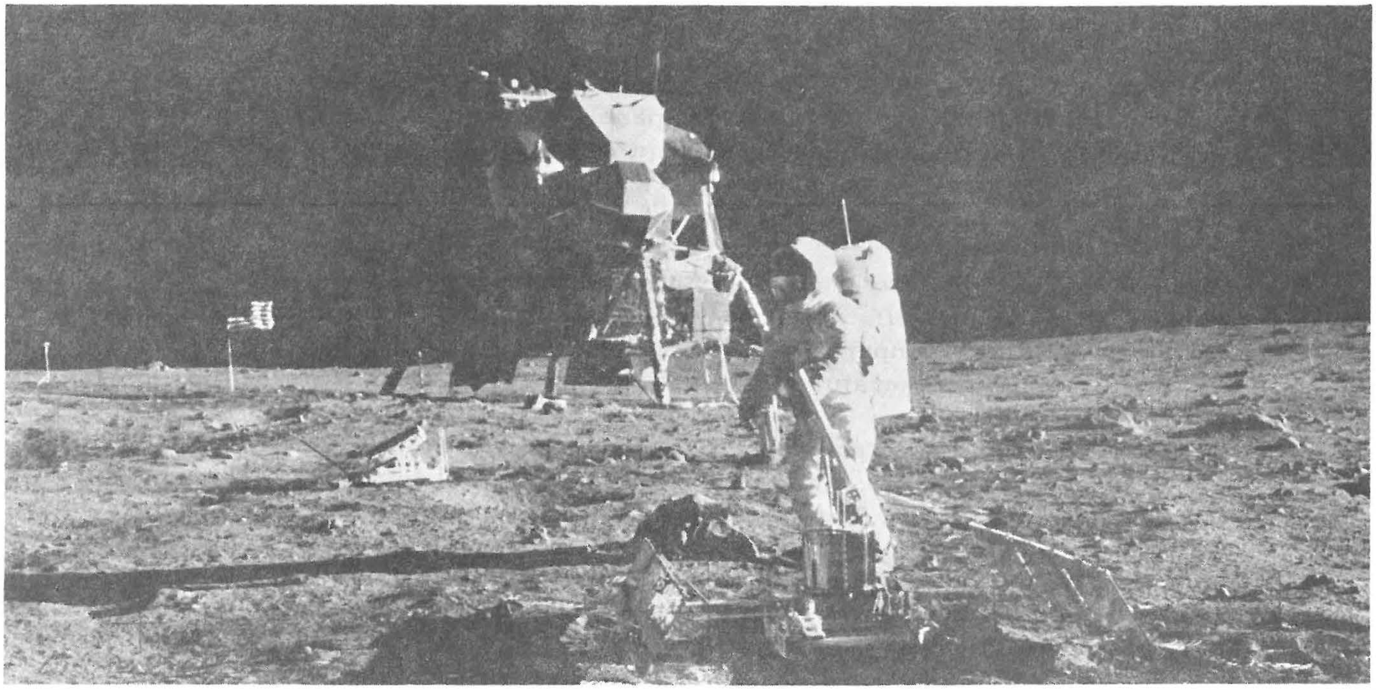


Figure 1-6. EASEP Deployed on Lunar Surface

At 10:14 CST on 14 December 1969 (90 minutes after sunrise on the 6th lunar day) the downlink signal from PSEP was lost and has not been detected since.

1-18. LRRR Operation. The LRRR was deployed 55 feet from the LM as shown in Figure 1-6. It was aligned with the sun and leveled with precision sufficient to provide overall pointing of the array to within one degree of the center of the Earth libration pattern.

Reflected signals from the LRRR were first acquired with the 120-inch telescope of the Lick Observatory at Mount Hamilton, California on 1 August 1969. Initial acquisition with the 107-inch telescope of the McDonald Observatory at Mount Locke, Texas was on 20 August 1969.

These, and subsequent observations demonstrated that the LRRR did not suffer major degradation from debris generated during lift-off of the LM. Continued observations at the McDonald Observatory have demonstrated the successful performance of the LRRR at several sun illumination angles, as well as during and after lunar night.

1-19. APOLLO 12 ALSEP OPERATIONAL EXPERIENCE

The Apollo 12 ALSEP was carried approximately 600 feet from the Apollo 12 LM and deployed on the lunar surface as shown in Figure 1-7. The deployment operation required 90 minutes from opening the LM SEQ bay until data was being received by the MSFN on Earth. This was 13 minutes longer than nominal, but did not exceed the 18-minute buffer period scheduled into the timeline for deployment

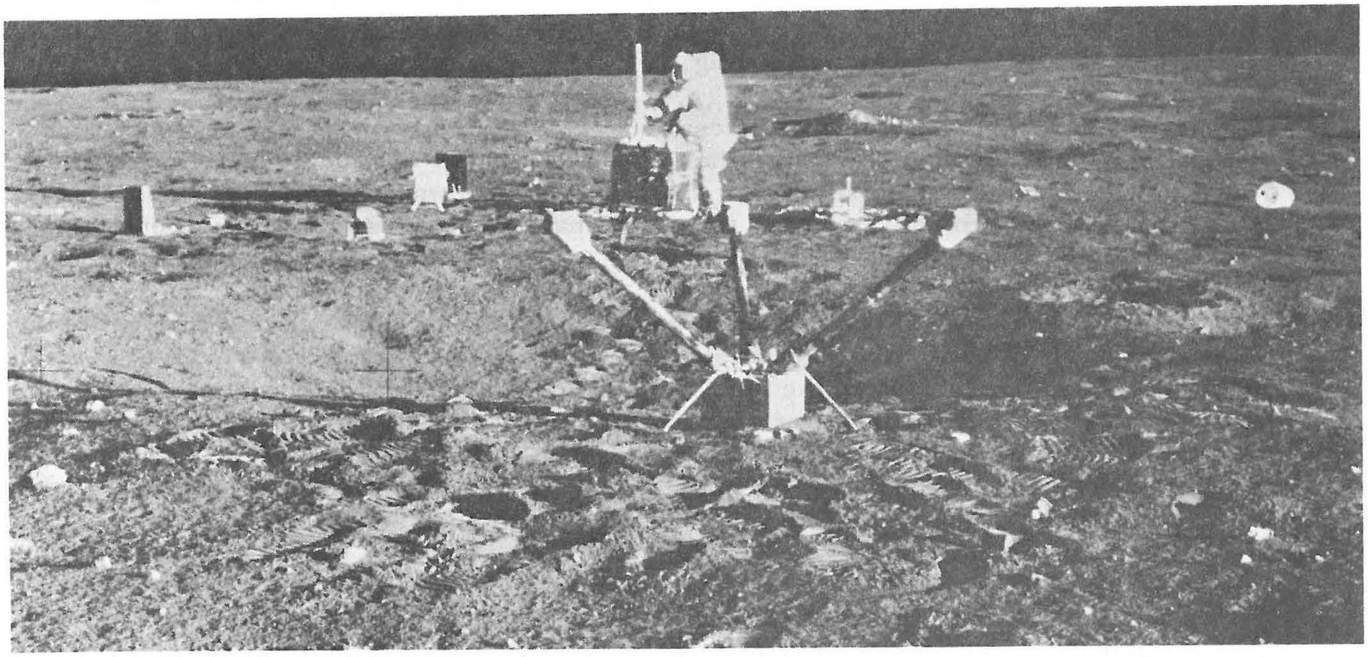


Figure 1-7. Apollo 12 ALSEP Deployed on Lunar Surface

uncertainties. Some difficulty was encountered with releasing the fuel capsule from the cask assembly, and with the deployment of the CCIG and the PSE shroud. Also, the lunar dust posed some problems during the deployment operation. Design changes have been incorporated in subsequent systems as a result of these experiences.

1-20. System Operation. During the first 603 days of operation of the Apollo 12 ALSEP lunar laboratory, almost 6 billion measurements from the Moon were recorded on magnetic tape as they were received at each station of the MSFN. These measurements were made during 21 complete traverses of the Moon through the geomagnetic tail of the Earth (Figure 1-8), 21 complete day-night cycles of the thermal environment of the Moon, and the seasonal thermal variations caused by the changes in distance from the Sun during the year. The measurements provided a detailed record of the solar change and thermal transients at the lunar surface during three solar eclipses.

The only breaks in the continuous flow of this data occurred during the three solar eclipses which were viewed from Earth on 7 March 1970, 31 August 1970, and 10 February 1971. During these solar eclipses the MSFN antennas pointed at ALSEP looked into the sun which is a strong source of noise. During these periods (about 3 hours) the network receivers were unable to discriminate the ALSEP signal from the solar noise and the measurement data were lost.

The MSFN stations have consistently reported the downlink signal strength to be -139 (±1) dbm. Downlink signal strength variations attributable to lunar librations have not been detected.

During the 603 days, over 10,000 functional changes were initiated by command from the mission control center at Houston as part of the operation and calibration of the laboratory. Over 97% of these functional changes were made in the performance of the scientific experiments. The remainder were made in the process of normal laboratory housekeeping.

The system has experienced 38 functional changes when no command was transmitted by the MSFN. These changes have been attributed to "spurious commands" which result from an RF noise effect. The spurious commands have not otherwise impacted system operation and the functional status in each case has been restored by command.

The facilities of the mission control center were mobilized continuously during the first 45 days of operation to monitor the data in "real" time as it was received from the Moon, and to control the operation of the instruments. After the first 45 days the mission control center was mobilized for a minimum of 2 hours per day during lunar daytime periods, 1 hour every other day during lunar nighttime periods, and for 24 hours during terminator crossings. Support was also provided during periods of special interest such as lunar noon and solar eclipse.

The central station timer failed after 2,200 hours of operation. This terminated the automatic backup command functions normally initiated by the 12-hour pulse. System operation was otherwise uneffected except that the end-of-mission signal will not occur.

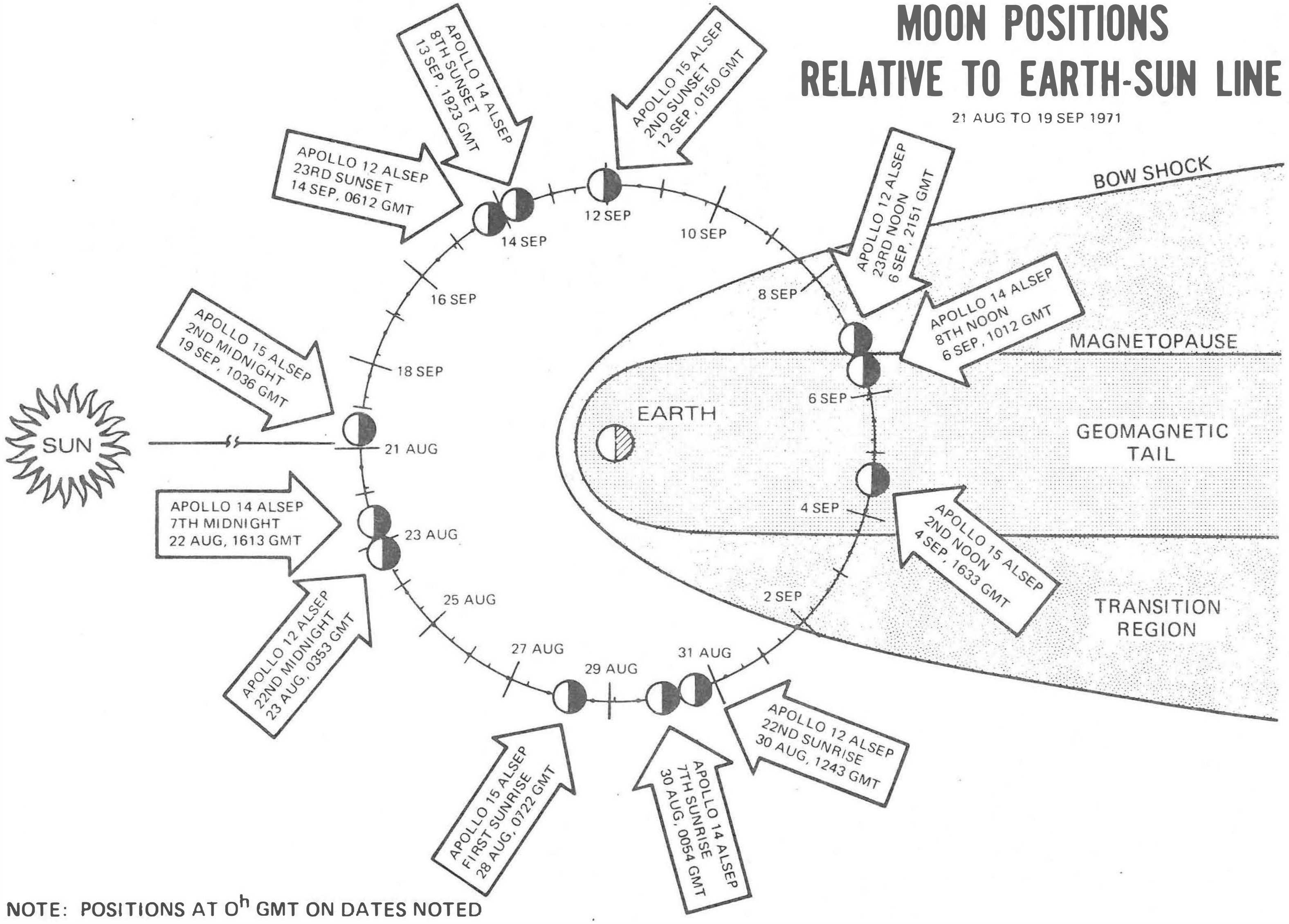


Figure 1-8. ALSEP/Lunar Day Relationship

The electrical performance of the RTG has been remarkably stable in spite of the severe temperature excursions of the lunar surface. The day-night power output variations were less than 0.5 watt. The output dropped only 1.5 watts, from 74 to 72.5 watts, during the first year (8,780 hours) of operation, and has fluctuated about that value ever since.

The thermal control of the Apollo 12 ALSEP equipment has been generally acceptable. The central station electronics units were designed to operate at temperatures between 0°F and 125°F. Their average temperature has been maintained between 20°F and 100°F. The PSE sensor temperatures have been higher than expected around lunar noon, and required heater augmentation to maintain the nighttime minimum temperature. The temperature excursions of the experiments are shown in Table 1-4.

The Dust Detector has not as yet provided evidence of appreciable dust accretion. It has provided a sensitive indication of lunar sunrise and sunset as an on-site measurement. These events are significant in the functional and operational control of ALSEP and serve to permit accurate correlation from lunation to lunation of data which are sun-angle dependent.

1-21. PSE Operation. The PSE operation during the first year was nominal except for low sensitivity of the short period seismometer, and above normal sensor temperatures during high sun-angle periods (145°F, rather than the desirable 126°F). This has had no impact on instrument functioning, but has made the interpretation of the tidal information more difficult. The Z axis sensor leveling motor has been used as an additional heat source during lunar night to maintain the sensor temperature at 126°F. After 603 days of operation, the PSE continues to provide long-period data continuously and short-period data during lunar daytime only. Data from the PSE has revealed that the Moon is an extremely quiet and stable body as compared to the Earth. The data indicates that the Moon is not stratified like the Earth, but is a rubble of rock clumps which have not congealed.

The major seismic events recorded by the PSE have been the impacts of the Apollo 12 LM, the Apollo 13 S-IVB stage, and the Apollo 14 LM and S-IVB stage. The S-IVB impact signals exhibit an extremely large peak amplitude and persist for several hours. Many meteroid impacts were recorded. Analysis of this data eventually will lead to a quantitative estimate of numbers and masses of such pieces of rock material in near lunar space.

Table 1-4. Apollo 12 ALSEP Experiment Temperature Extremes

Equipment	Nighttime Minimum (°F)	Daytime Maximum (°F)
Magnetometer Electronics	-20	171.1
Solar Wind Spectrometer Electronics	0.3	151.0
SIDE Electronics	38.6	130
PSE Sensor Assembly	126	145

Analysis of the data has identified nine types of seismic events which occur every month at or near the time the Moon comes nearest the Earth in its monthly orbital cycle. These events are believed to be moonquakes triggered by tidal strain. All events within a type are identical in every aspect throughout the length of the record. This indicates that each type of event originates at a specific point on the lunar surface.

1-22. Solar Wind Spectrometer Experiment. The SWS operation was normal throughout the 603 days, with no indication of degradation. The SWS detected solar wind plasma striking the Moon during all the periods of the lunar day-night cycle that it would be expected to do so. (See Figure 1-8.) No plasma is detected during the lunar night, when the Moon is between the Sun and the SWS. A second period of no measurable plasma occurs for 4-1/2 days while in the geomagnetic tail, when the Earth is nearly between the Sun and the SWS. Plasma that is less strongly perturbed by the Earth's field is measured for about three days on either side of the geomagnetic tail (in the transition region). During the remaining five days of each lunar cycle, outside the bow shock wave, the observed plasma parameters are consistent with interplanetary space probe observations. The plasma density is very small, with measurements ranging from 1 to 25 particles per cubic centimeter. The solar wind is seldom the same for more than a few minutes at a time.

The Moon does not appear to have a major effect on the solar wind. The plasma sweeps in, impacts the Moon, and is absorbed by the surface.

The SWS detected a complicated gas flow pattern resulting from the impact of the Apollo 13 S-IVB stage 135 kilometers to the west. Although the resulting gas cloud was expected to be swept away by the solar wind, two clouds were observed; they arrived at the SWS from the north and northeast directions. Particle energies of about 35 to 50 electron volts (ev) were measured.

1-23. LSM Operation. After 603 days of operation, the LSM field sensor outputs and engineering data continue to provide valid science data during lunar daytime periods. The LSM has experienced loss of data output at low temperatures since June 1970. The sensors detected magnetic field intensities in the 100 gamma and the 200 gamma sensitivity ranges. No field intensities were detected in the 400 gamma range.

The LSM detected a steady magnetic field of about 35 gammas immediately after deployment. The data indicates that this is a localized, probably fossil, field located from 0.2 to 200 kilometers from the LSM.

The data reveals that the LSM detects time-dependent field changes. Correlation of the changes with simultaneous measurements from Explorer 35 in lunar orbit indicates that large electric currents are generated deep in the interior of the Moon. The results correspond to a lunar temperature profile having an average value of 800°K down to about one-half the radius of the Moon and greater than 1200°K for material in the inner core.

1-24. SIDE Operation. The SIDE has operated normally, except for a temperature-dependent mode change characteristic, with no indication of degradation of performance or of thermal control capabilities. The mode changes are typical of high voltage arcing effects, and occurred when the instrument internal temperature reached approximately 55°C. The mode changes have been corrected by command after each occurrence. The SIDE operates throughout the lunar night, and during lunar daytime for periods of two hours followed by periods of power-off to allow for cooling.

Mass spectra of 50 ev ions were detected soon after deployment. These showed concentrations of ions in the 18 to 50 amu/q mass-per-charge range. Clouds of 10 to 250 ev ions have been detected, as well as other events, which suggest the operation of a general acceleration mechanism. Solar wind energy ions are detected several days before sunrise at this ALSEP site. Ions of 250 to 3,000 ev, presumed to be protons which escaped from the bow shock, are observed in the time period between lunar sunset and midnight. The SIDE detected ions of 250 to 500 ev from the impact of the Apollo 12 LM. It detected ions of 50 to 70 ev with a large number of ions of mass about 10 to 80 amu/q resulting from the impact of the Apollo 13 S-IVB.

The SIDE observed three major events of the Apollo 14 mission: The S-IVB impact, the LM ascent stage flight approximately 22 kilometers north of the Apollo 12 site at an altitude of approximately 15 kilometers, and the LM ascent stage impact.

The CCIG operated for approximately 14 hours after it was deployed on the lunar surface. It was shut off by apparent arcing in its 4500 volt power supply due to outgassing in the electronics as it became heated in the hot vacuum environment of the lunar day. During its operation, the CCIG detected a natural lunar atmospheric pressure of 9×10^{-9} torr. Measurements indicated that contaminant gases from the landing operation did not raise the local atmospheric pressure above 9×10^{-9} torr. The gas cloud around an astronaut exceeded the upper range of the gage (approximately 10^{-6} torr) as far as several yards from the astronaut. No perceptible residual contamination at the 10^{-8} torr level remained around the gage for longer than a few minutes after astronaut departure.

1-25. APOLLO 14 ALSEP OPERATIONAL EXPERIENCE

The Apollo 14 ALSEP was carried approximately 178 meters from the LM, and deployed on the lunar surface as shown in Figure 1-9. This placed the second ALSEP system on the Moon into operation 181 kilometers from the Apollo 12 ALSEP as shown in Figure 1-5.

The system was activated, and data was received by the MSFN on Earth. The received signal strength has varied between -142.7 and -136.8 dbm as a result of MSFN site characteristics, Moon/Earth libration pattern, and ALSEP antenna alignment.

1-26. System Operation. The Apollo 14 ALSEP lunar laboratory has responded to approximately 3,000 operation and calibration commands initiated by the MSFN during its first 160 days of operation on the Moon, and provided measurement data which was recorded on magnetic tape as it was received at each station of the MSFN. The system has experienced six complete traverses through the geomagnetic tail of the Earth (Figure 1-8), and six complete day-night cycles of the thermal environment of the Moon.

The power output of the RTG remained constant at 72.5 watts during the 160-day period, displaying only slight day-night output variations.

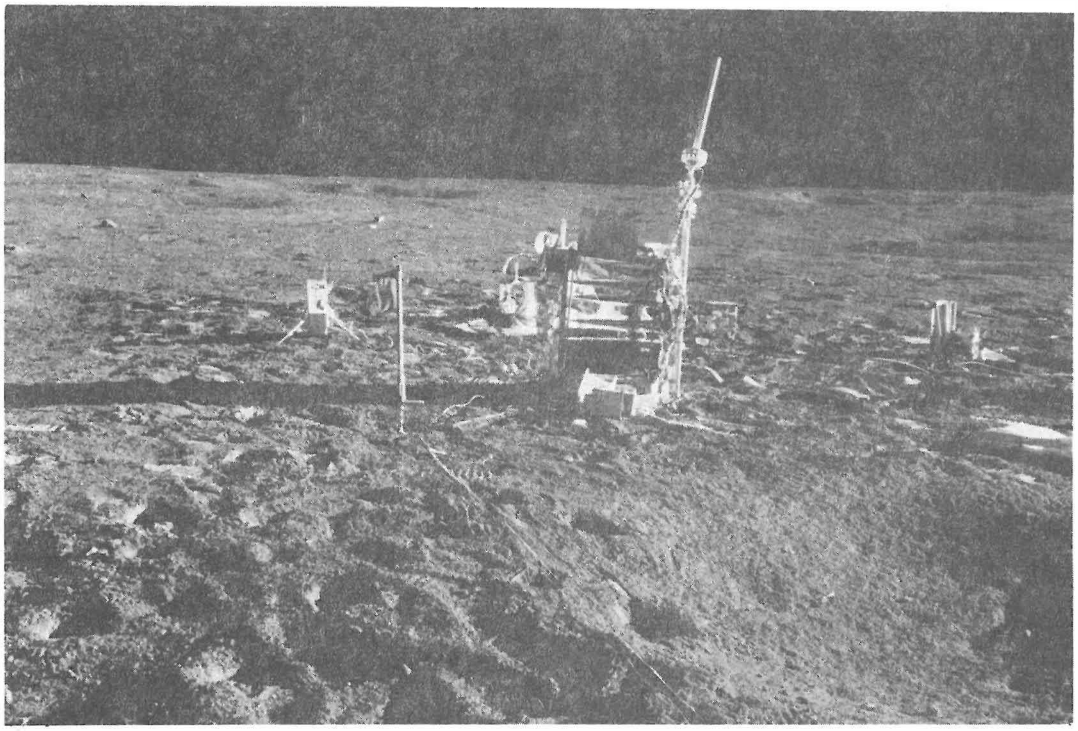


Figure 1-9. Apollo 14 ALSEP Deployed on Lunar Surface

The central station timer failed after providing the thirteenth 12-hour pulse at 22:17 GMT on 17 February 1971. This terminated backup command functions normally initiated automatically. System operation is otherwise unaffected except that the end-of-mission signal will not occur.

Thermal control of the ALSEP equipment has been satisfactory. Temperatures up to 180°F during lunar day and -295°F during lunar night have been recorded on the upward facing surfaces of this and the Apollo 12 ALSEP equipment. A yearly cycle of peak temperatures (summer-winter effect) has been established. During three lunar eclipses, ALSEP surface temperatures decreased rapidly, as much as 320°F in two hours, and returned less rapidly to the original temperature. Temperature excursions of the ALSEP 14 equipment are shown on Table 1-5.

Table 1-5. Apollo 14 ALSEP Temperature Extremes

Equipment	Nighttime Minimum (°F)	Daytime Maximum (°F)
Central Station (thermal plate)	39.0	116.5
PSE	124.2	130.1
SIDE	28.2	181.2
CCIG	-277.2	195.8
CPLEE	-21.3	156.6
ASE (GLA)	-74.7	158.0

1-27. PSE Operation. Operation of the Apollo 14 PSE has been normal throughout the first 160 days. The only problem has been irratic operation of the Y-axis leveling motor, which developed on 17 April 1971.

Crew activities produced detectable seismic signals for the Apollo 14 instrument throughout the EVA traverses. Venting gases and thermoelastic stress relief of the LM caused the expected seismic signals. The Apollo 14 S-IVB impact was detected by the Apollo 12 passive seismometer, and the LM ascent-stage impact was detected at both sites. These seismic events produced the characteristic, remarkably slow decay signals that had been previously detected by the Apollo 12 instrument; the signals persisted for several hours.

The Apollo 14 seismometer has detected natural seismic events at more than twice the frequency recorded by the Apollo 12 instrument, and all seismic events that have been recorded at the Apollo 12 site have also been detected by the Apollo 14 instrument. The greater sensitivity at the Apollo 14 site is thought to be a result of the thick layer of unconsolidated material that blankets this region. This layer of unconsolidated material may provide a more efficient coupling of seismic energy with the lunar surface. The Apollo 14 instrument appears to be sufficiently sensitive to detect the impacts (at any location on the Moon) of meteoroids that have masses in excess of approximately 1 kilogram. The detected natural events can be identified as meteoroid impacts and moonquakes. It is believed that not less than nine different locations are involved in the moonquakes that have been detected by both seismometers, although more than 80 percent of the total seismic energy detected has come from a single focal zone that is located perhaps 600 to 700 km from both stations and possibly at a considerable depth within the Moon. If the depth of the focal zone is confirmed by future data, fundamentally important information about the present state of the lunar interior will be made available.

1-28. ASE Operation. The geophones were aligned in a southerly direction from the central station, and the mortar package was positioned to fire the grenades in a northerly direction. Thumper operations produced 13 successful firings, 9 of which were recorded at all 3 geophones.

The data generated by the thumping operation indicate the existence of a surficial layer approximately 8.5 meters thick at the ALSEP site. This layer, which exhibits a P-wave velocity of meters per second, may be interpreted as the regolith in this area. The 8.5-meters thickness of the regolith is in good agreement with the thickness estimated from geological studies of small craters. The seismic propagation velocity observed during the thumping operation is in remarkable agreement with the propagation velocity derived at the Apollo 12 landing site (108 meters per second), where the elapsed time was recorded between LM ascent-engine ignition and arrival of the generated seismic signal at the Apollo 12 passive seismometer.

Below the regolith at the Apollo 14 landing site is another layer, which exhibits a P-wave velocity of 299 meters per second. The thickness of this layer is estimated to be approximately 50 meters, which is in substantial agreement with estimates of the thickness of the Fra Mauro Formation in this area. The relatively low compressional-wave velocities that have been measured are evidence against the existence of substantial permafrost near the surface in the landing region.

The ASE operational plan calls for standby status at all times except for brief periods of listening mode operation. Operation has been normal except for erratic output of geophone number 3, which was first observed on 26 March 1971.

The active seismic experiment includes a rocket-grenade launcher that is capable of launching four grenades to impact at known times and at known distances (up to approximately 1500 meters) from the seismometer. The rocket grenades will not be activated until data collection from the other Apollo 14 ALSEP experiments is virtually complete.

1-29. SIDE Operation. The SIDE operation has been normal except for a temperature-dependent mode change characteristic similar to that experienced by the Apollo 12 SIDE. Operation during lunar daytime has been limited to periodic intervals as a precaution against high-voltage arcing, with full-time operation during lunar nighttime. A malfunction which was first observed on 6 April 1971 has rendered the positive engineering data invalid.

By correlation of data returned by the Apollo 12 SIDE and the Apollo 14 SIDE, discrimination is possible between moving ion clouds and temporal fluctuations of the overall ion distribution. This discrimination capability enabled the interpretation of an ion event that was detected by both SIDE instruments on 19 March 1971. This ion event was the passage of a large (approximately 130 kilometers in diameter) ion cloud that moved westward at approximately 0.7 kilometers per second. The cloud was possibly associated with a relatively large seismic event that was recorded by the Apollo 14 passive seismometer approximately 37 minutes earlier.

Ions in the 250- to 1000-ev energy range have been detected streaming down the magnetosheath of the Earth as the Moon entered the magnetospheric tail. Intermittent intense fluxes of 50- to 70-ev ions with masses in the 17- to 24-amu/unit-charge range have been recorded approximately two days after sunrise. Energy and mass spectra were obtained during the venting of the oxygen atmosphere of the LM cabin.

The CCIG was deployed looking south toward Fra Mauro, with the LM just outside its field of view. Early results indicate that the lunar atmosphere concentration during lunar nighttime is approximately 2×10^5 atoms/cm^3, although transient increases by 1 to 2 orders of magnitude are fairly frequent and last from minutes to many hours. Some of these transient increases may be caused by venting or outgassing from the LM or from other equipment at the ALSEP site. The neutral-atom concentration rises rapidly at sunrise (2 orders of magnitude in 2 minutes); the concentration then decays, over a period of approximately 50 hours, to a mean daytime level of less than 10^7 atoms/cm^3. Numerous gas events have been observed during the lunar day. The mean neutral-atom levels observed may still be affected by outgassing from other ALSEP equipment, but the output from this source should decrease with time in an identifiable way.

1-30. CPLEE Operation. The CPLEE was deployed with no difficulty, and aligned to within 1.7° of level, tipped to the east, and 1° away from the east-west. Photographs show no visible dust accretion on the external surfaces.

The CPLEE operated normally until 9 April 1971, when the analyzer B high-voltage power supply output became erratic, rendering the science data invalid. Analyzer A, which points upward, continued to provide valid data until 6 June 1971, when its high-voltage supply became erratic. Troubleshooting revealed that analyzer A will operate for 35 to 55 minutes after turn-on and then deteriorate; so the CPLEE will be maintained in the standby mode and turned on only for significant events.

The CPLEE data revealed the presence of low-energy electrons whenever the landing site is illuminated by the Sun. The variation in the low-energy-electron flux during the lunar eclipse of 10 February 1971 provided strong evidence that the electrons are photoelectrons liberated from the lunar surface. The solar-wind flux observed by the CPLEE has exhibited rapid time variations (periods of approximately 10 seconds), both when the Moon is in interplanetary space and when it is in the magnetospheric tail of the Earth. Data collected during passage of the Moon through the magnetopause and magnetospheric tail indicates rapidly fluctuating low-energy (50- to 200-ev) electrons, fluxes of medium-energy electrons lasting from a few minutes to tens of minutes, and electrons that have energy spectra similar to those observed above terrestrial aurorae. Thus, auroral particles do appear to penetrate far into the magnetospheric tail, an observation that, if confirmed, contains important implications concerning the general topology of the magnetosphere.

After the Apollo 14 LM ascent-stage impact, two plasma clouds, which were separated in time by a few seconds, passed the CPLEE. These plasma clouds were traveling at approximately 1 kilometer per second and had diameters of 14 and 7 kilometers.

SECTION II

ALSEP SUBSYSTEM DESCRIPTION

2-1. ALSEP SUBSYSTEM INTRODUCTION

This section describes the eight (four experiment and four support) subsystems which comprise the Apollo 16 ALSEP system. 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)
e. Active seismic experiment subsystem (ASE)
f. Lunar surface magnetometer experiment subsystem (LSM)
g. Heat flow experiment subsystem (HFE)

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 passive thermal protection required by the ALSEP experiment 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 in the central station and to the electrical power subsystem.

2-3. STRUCTURE/THERMAL SUBSYSTEM PHYSICAL DESCRIPTION

The structure/thermal subsystem includes the basic structural assembly of the ALSEP system subpackages, the fuel cask structure assembly, handling tools, and antenna mast. Structure/thermal subsystem leading particulars are provided in Table 2-1.

2-4. STRUCTURE/THERMAL SUBSYSTEM FUNCTIONAL DESCRIPTION

2-5. Subpackage No. 1 Structure/Thermal. The structure/thermal portion of subpackage No. 1 consists of a primary structure, boom attachment assembly, thermal plate, sunshield, side curtains, rear curtain, reflector, and thermal bag as shown in Figure 2-1. The primary structure provides tie points for securing the subpackage in the SEQ bay of the LM. It is recessed to receive the central

Table 2-1. Structure/Thermal Subsystem Leading Particulars

Component	Characteristic	Value
Subpackage No. 1 Structure	Size (inches)	L 26.75 W 27.37 H 6.87
	Weight (pounds)	24.86
Subpackage No. 2 Structure	Size (inches)	L 25.87 W 27.14 H 3.37
	Weight (pounds)	25.15
Fuel Cask Support	Size (inches)	H 28.86 D 12.25
	Weight (pounds)	19.60
FTT	Length (inches)	24.12
	Weight (pounds)	1.51
UHT	Length (inches)	26.50
	Weight (pounds)	0.82
DRT	Length (inches)	23.67
	Weight (pounds)	0.65
Antenna Mast (two sections)	Section length (inches)	20.75
	Basic diameter (inches)	1.75
	Weight (pounds)	1.30

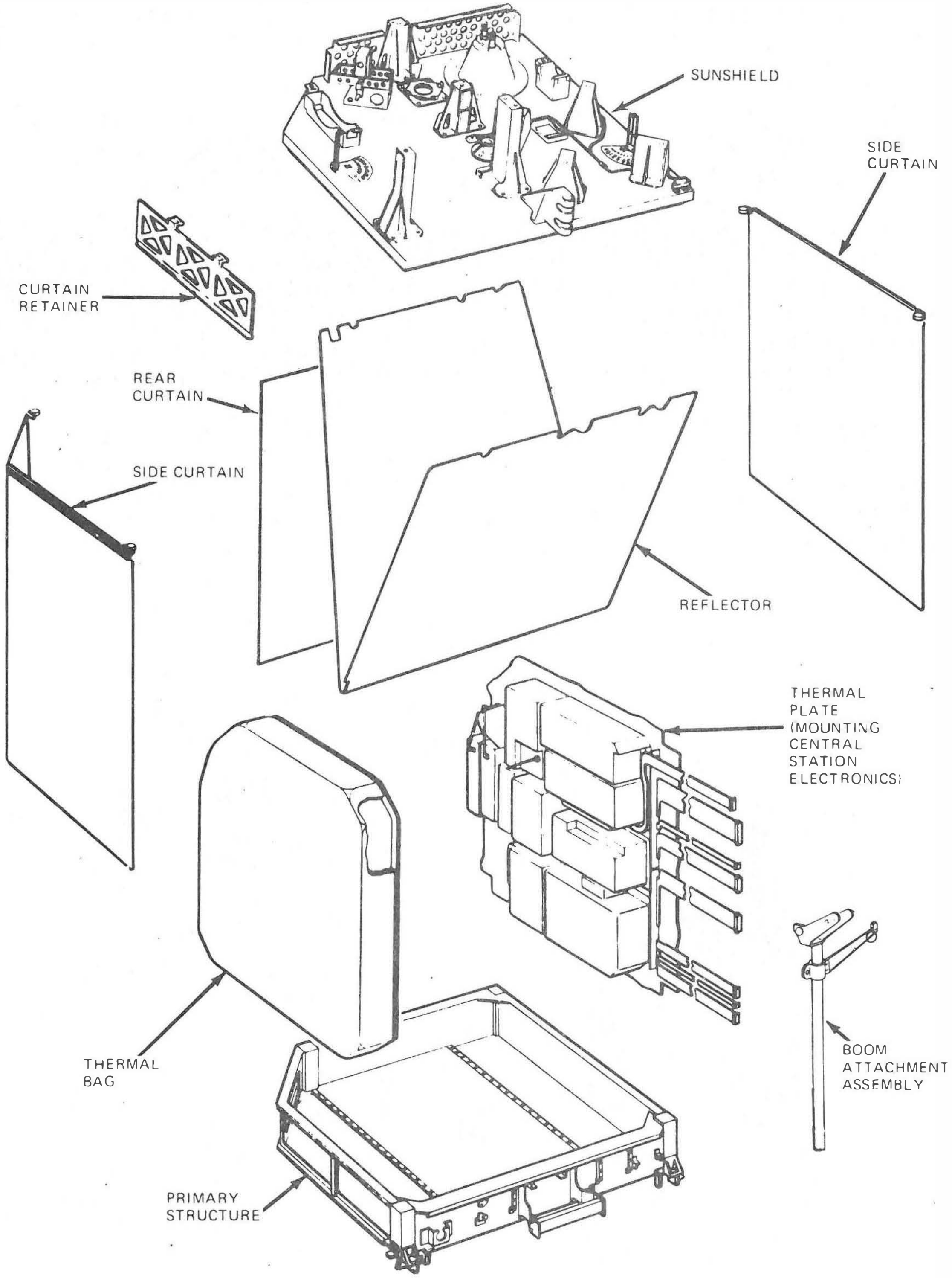


Figure 2-1. Structure, Subpackage No. 1

station electronics which are mounted on the thermal plate. The sunshield provides tie points for mounting the boom attachment assembly, experiment subsystems, and associated equipment. The sunshield, side curtains, and reflector are raised during deployment to provide thermal protection for the central station electronics.

Thermistor temperature detectors monitor thermal bag, primary structure, and sunshield temperatures during operation. These temperature signals are supplied to the data subsystem for insertion into the ALSEP telemetry data.

2-6. Subpackage No. 2 Structure/Thermal. The structure/thermal portion of subpackage No. 2 consists of boom attachment assembly, pallet, and subpallet as shown in Figure 2-2. It provides tie points to mount experiment and support subsystems, and to secure the subpackage in the SEQ bay of the LM. The pallet assembly protects the astronaut from the electrical power subsystem components during deployment, and serves as a base for that subsystem during operation.

2-7. Dust Covers. Dust covers have been added to the system to protect mechanisms and thermal coatings from lunar dust during the deployment operations. The dust covers (Figure 2-3) are installed during the preparation for flight operations at KSC. They are removed by the astronauts during the lunar deployment operations.

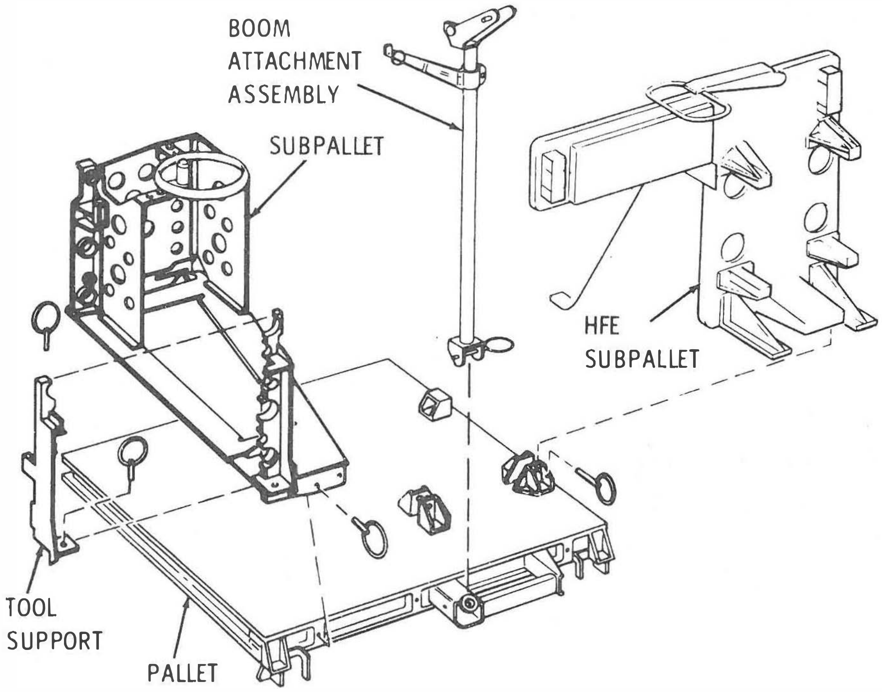


Figure 2-2. Structure, Subpackage No. 2

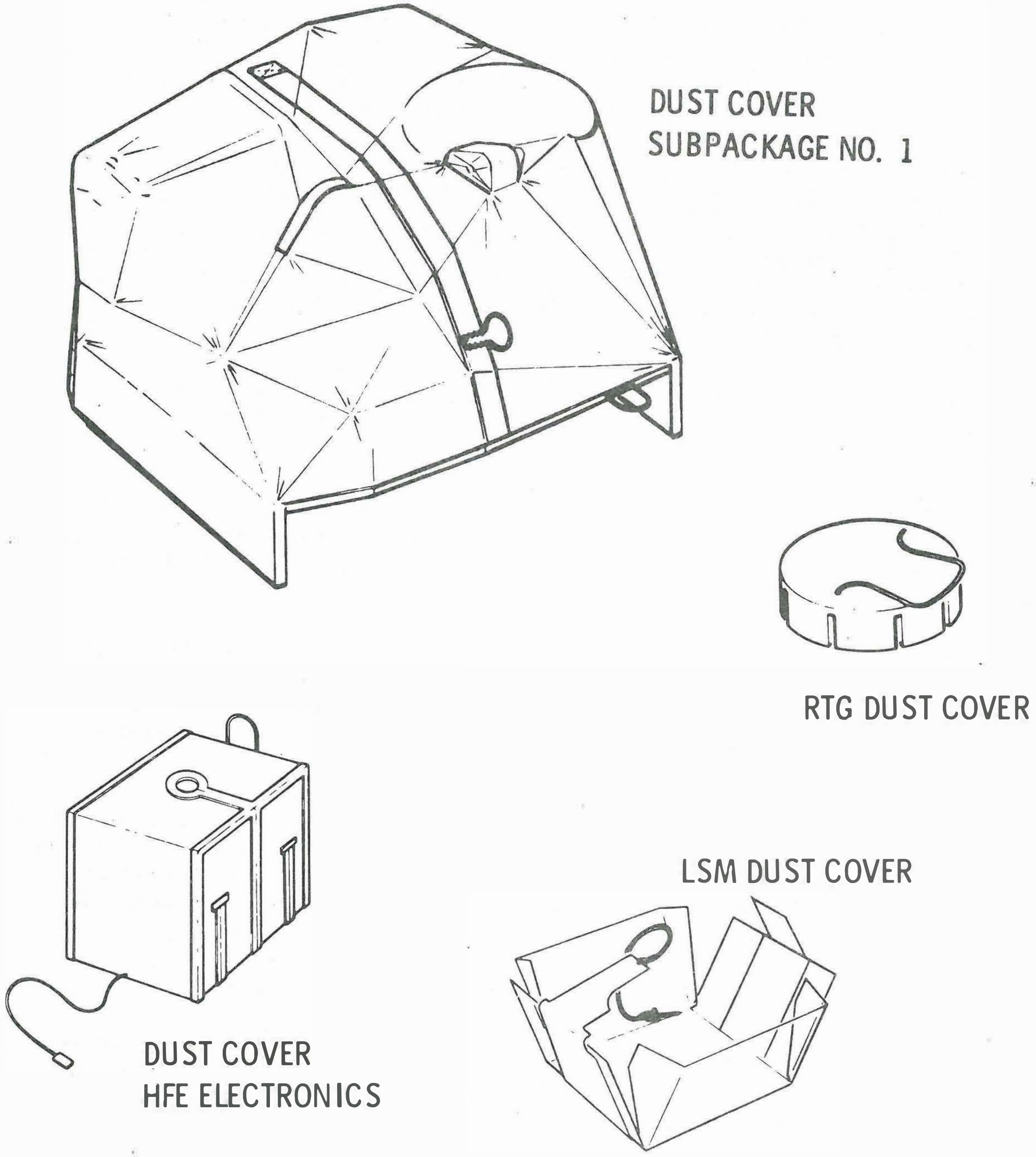


Figure 2-3. Dust Covers

2-8. Fuel Cask Structure Assembly. The fuel cask structure assembly consists of the structure, thermal shield, cask bands, and cask guard as shown in Figure 2-4. The structure provides tie points for attachment of the fuel cask to the exterior of the LM, and provides the thermal shield to reflect fuel capsule thermal radiation away from the LM. The cask bands are clamped onto the cask, and provide tie points for attachment to the structure. The lower band includes a mechanism to tilt the fuel cask for access to the fuel capsule. The guard is provided to prevent astronaut contact with the cask during deployment.

Two temperature transducers monitor thermal shield temperature. The temperature measurements are included in the Apollo telemetry data.

2-9. Handling Tools. The handling tools consist of a dome removal tool (DRT), two universal handling tools (UHT), and a fuel transfer tool (FTT) as shown in Figure 2-5. These tools are used by the astronaut to deploy the ALSEP system on the lunar surface.

The DRT is used to remove and handle the dome of the fuel cask. The tool engages, locks in, and unlocks a nut on the dome. Rotation of the nut releases the dome.

The FTT is used to transfer the fuel capsule from the fuel cask to the RTG. Three movable fingers engage the fuel capsule and are locked in place by rotating the knurled section of the handle. Release is accomplished by rotating the handle in the opposite direction.

The UHT is used to release the tie-down fasteners, and to transport and emplace the experiment subsystems. The Allen wrench tool tip engages the socket-head Boydbolt fasteners to rotate and release the bolt. A ball type locking device provides rigid interface between the tool and a receptacle on the subsystem. Operation is by a trigger-like lever near the handle.

2-10. Antenna Mast. The antenna mast is provided in two sections as shown in Figure 2-6. The sections lock together and provide locking devices for attachment to the subpackages. The antenna mast serves as the handle for the bar-bell carry of the ALSEP subpackages to the deployment site. It is then attached to subpackage No. 1 to support the aiming mechanism and antenna.

2-11. ELECTRICAL POWER SUBSYSTEM

The electrical power subsystem (EPS) provides the electrical power for lunar operation of the ALSEP. Primary electrical power is developed by thermoelectric action with thermal energy supplied by a radioisotope source. Primary power is converted, regulated, and filtered to provide six operating voltages for the ALSEP experiment and support subsystems.

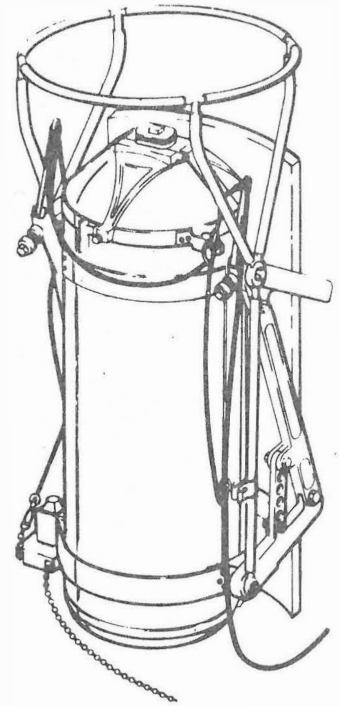


Figure 2-4. Fuel Cask Structure Assembly

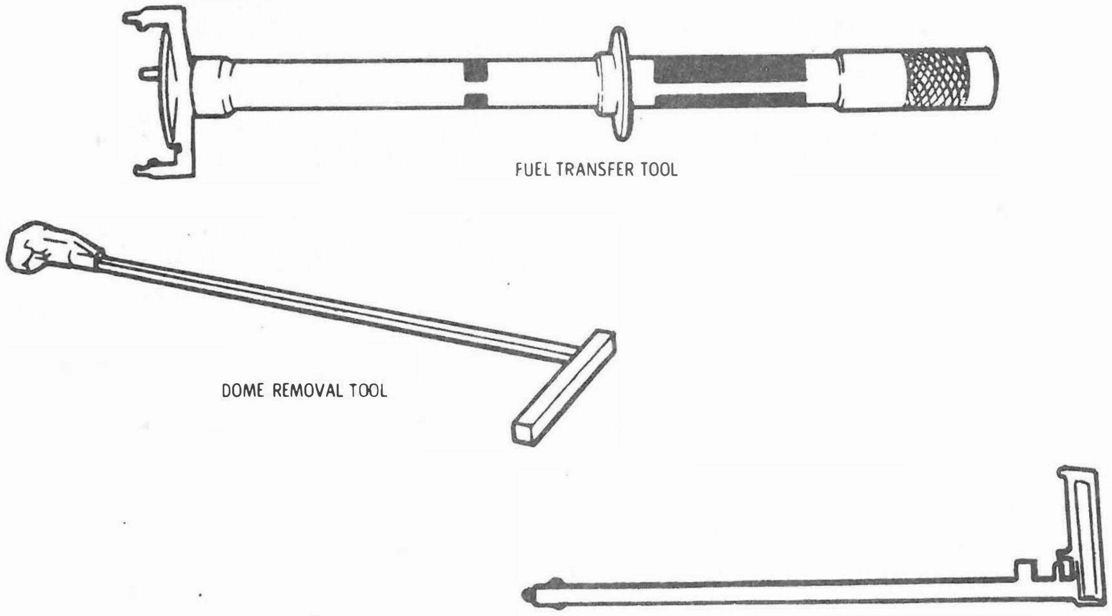


Figure 2-5. Handling Tools

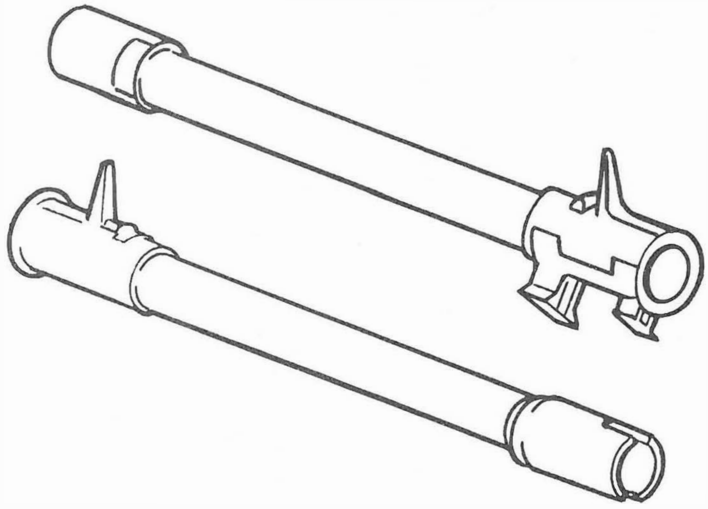


Figure 2-6. Antenna Mast Sections

2-12. EPS PHYSICAL DESCRIPTION

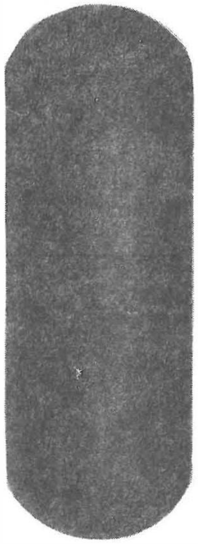
Major components of the electrical power subsystem are shown in Figure 2-7. The components are a radioisotope thermoelectric generator assembly, a fuel capsule assembly, a power conditioning unit, and a fuel cask.

2-13. EPS Radioisotope Thermoelectric Generator (RTG). The RTG is a cylindrical case with eight heat rejection fins on the exterior, and a central cavity to receive the fuel capsule. The active elements are a hot frame, a cold frame, and a thermoelectric couple assembly. The thermoelectric couple assembly is located between the hot frame, which surrounds the cavity, and the cold frame, which interfaces with the outer case and heat rejection fins.

2-14. EPS Fuel Capsule Assembly (FCA). The fuel capsule assembly is a thin-walled, cylindrical-shaped structure with an end plate for mating and locking in the fuel cask and in the RTG. It contains the radioisotope fuel, plutonium (Pu-238), encapsulated to meet nuclear safety criteria.

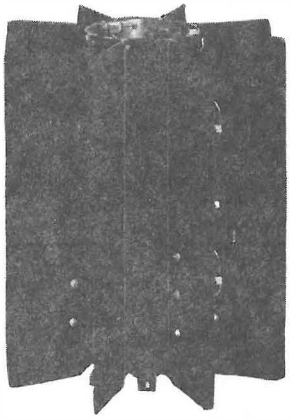
2-15. EPS Power Conditioning Unit (PCU). The functional elements of the PCU are redundant dc voltage converters and shunt regulators, filters, and two command control amplifiers. The elements are mounted in cordwood modules that are interconnected by printed circuit boards and attached to the center 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 back of subpackage No. 1.

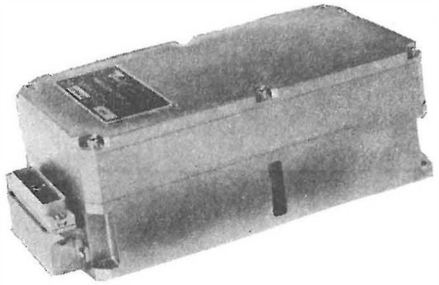


FUEL CASK ASSEMBLY

FUEL CAPSULE ASSEMBLY



GENERATOR ASSEMBLY



POWER CONDITIONING UNIT

Figure 2-7. Electrical Power Subsystem

2-16. EPS Fuel Cask. The cask is used to transport the fuel capsule assembly from the Earth to the Moon. The fuel cask is a cylindrical shaped structure with a screw-on end cover at the top end. The cask provides fuel capsule support elements and a free radiation surface for rejection of fuel capsule heat. The fuel cask provides re-entry protection in case of an aborted mission.

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

Table 2-2. Electrical Power Subsystem Leading Particulars

Component	Characteristic	Value
Radioisotope Thermoelectric Generator	Output power	63 to 74 watts
	Output voltage	16.1 ± 0.5 vdc
	Hot junction temperature, lunar day	900 to 1100 deg. F
	Cold junction temperature, lunar day	350 to 550 deg. F
	Length	18.12 inches
	Diameter	16 inches
	Weight	28 pounds maximum
Fuel Capsule	Length	16.92 inches
	Diameter	2.6 inches (except end plate)
	Weight	15.46 pounds maximum
	Thermal output	1430 to 1520 watts
Power Conditioning Unit	Nominal outputs	+29 vdc at 1.19 amps +15 vdc at 0.08 amp +12 vdc at 0.30 amp +5 vdc at 0.90 amp -6 vdc at 0.05 amp -12 vdc at 0.15 amp
	Output voltage regulation	±1 percent
	Length	8.36 inches
	Width	4.14 inches
	Height	2.94 inches
	Weight	4.5 pounds
Fuel Cask	Length	23 inches
	Diameter	8.0 inches
	Weight	25.0 pounds nominal

2-18. EPS FUNCTIONAL DESCRIPTION

The radioisotope thermoelectric generator (RTG) supplies +16 volts of primary power to the PCU as shown in Figure 2-8. Voltage conversion circuits in the PCU convert the primary power to the six ALSEP operating voltages. The PCU starts automatically when there is sufficient power for fixed loads.

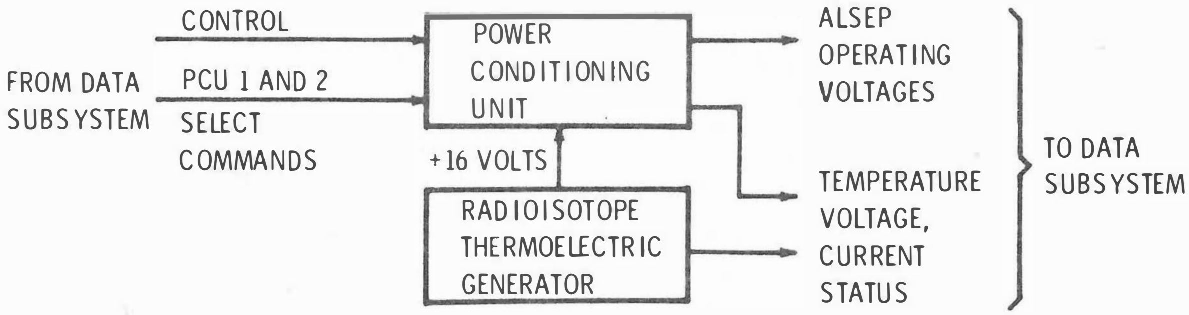


Figure 2-8. Electrical Power Subsystem, Functional Block Diagram

A manual control switch is provided as a back-up signal to allow the astronaut to start the PCU. PCU #1 and PCU #2 select commands from the data subsystem activate control circuits that switch the redundant circuits of the PCU.

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

2-19. EPS DETAILED FUNCTIONAL DESCRIPTION

2-20. EPS Radioisotope Thermoelectric Generator. The operation of the RTG is illustrated in the block diagram of Figure 2-9. A radioisotope source (fuel capsule) develops thermal energy that is applied to the hot frame (inner case). The difference in temperature between the hot frame and the cold frame causes the thermoelectric couple assembly (thermopile) to develop electrical energy through thermoelectric action. The electrical energy produced by the thermopile provides a minimum of 63 watts at 16 volts to the power conditioning unit.

Excess heat from the thermopile is conducted through a cold frame (outer case) to a thermal radiator (heat rejection fins) for dissipation into the lunar environment. This maintains the cold frame at a lower temperature than the hot frame so that thermoelectric action is maintained.

Temperatures are monitored at three cold frame and at three hot frame locations to provide six temperature signals to the data subsystem.

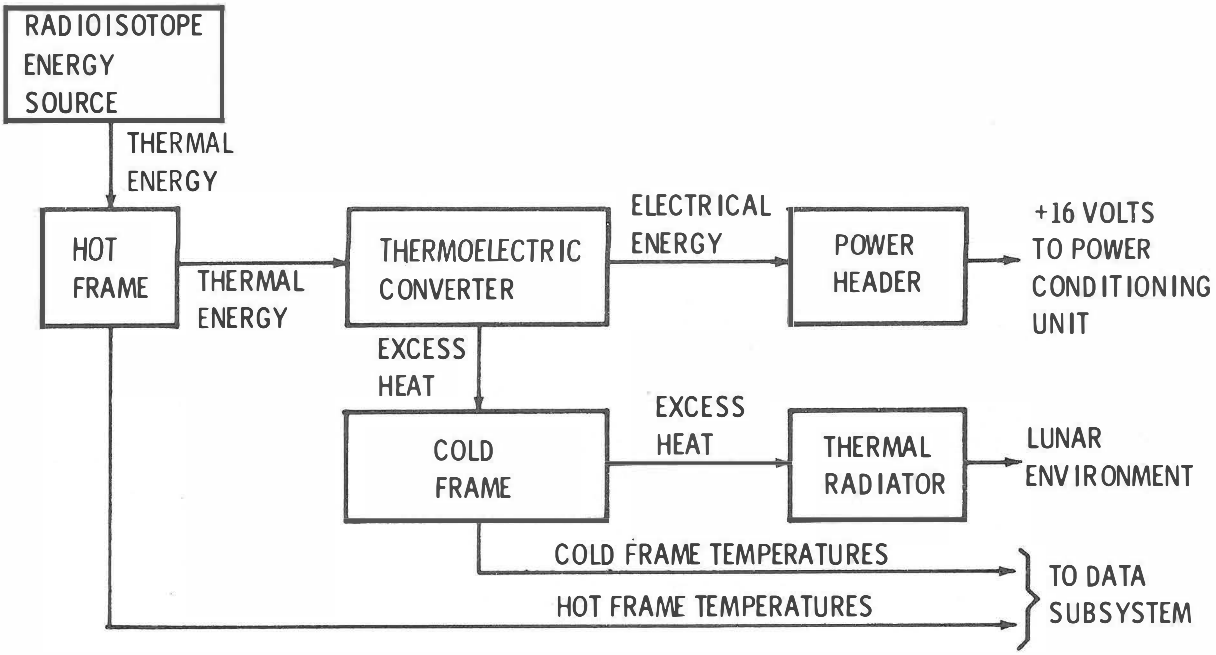


Figure 2-9. EPS Power Generation Function, Block Diagram

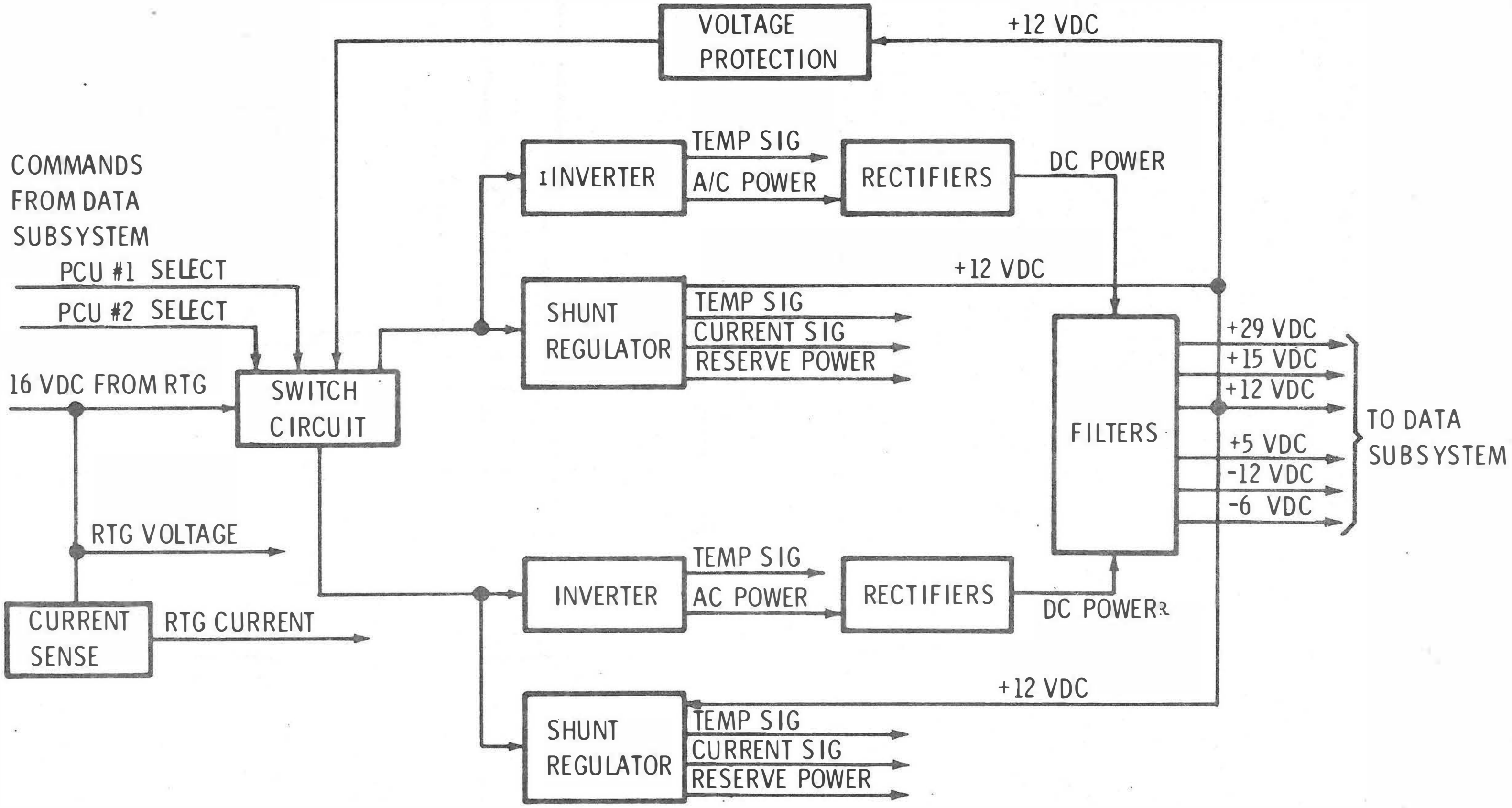
2-21. EPS Power Conditioning Unit. The power conditioning unit performs three major functions:

a. Voltage conversion
b. Voltage regulation
c. RTG protection.

The PCU contains redundant power conditioners. As shown in Figure 2-10, each power conditioner consists of a dc-to-dc power converter (inverter and rectifiers), which converts the RTG 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. The PCU keeps a constant load on the generator to prevent generator overheating.

The +16 volts from the RTG 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. 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 to central station dissipation. All the input 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.



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

Figure 2-10. EPS Power Regulation 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 +16 volts at the input of the PCU provide a reserve power reference. All of these analog signals are applied to the data subsystem for subcommutation into the telemetry frame.

2-22. DATA SUBSYSTEM

The data subsystem is the focal point for control of ALSEP experiments 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 experiment 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 2-11. The uplink 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.

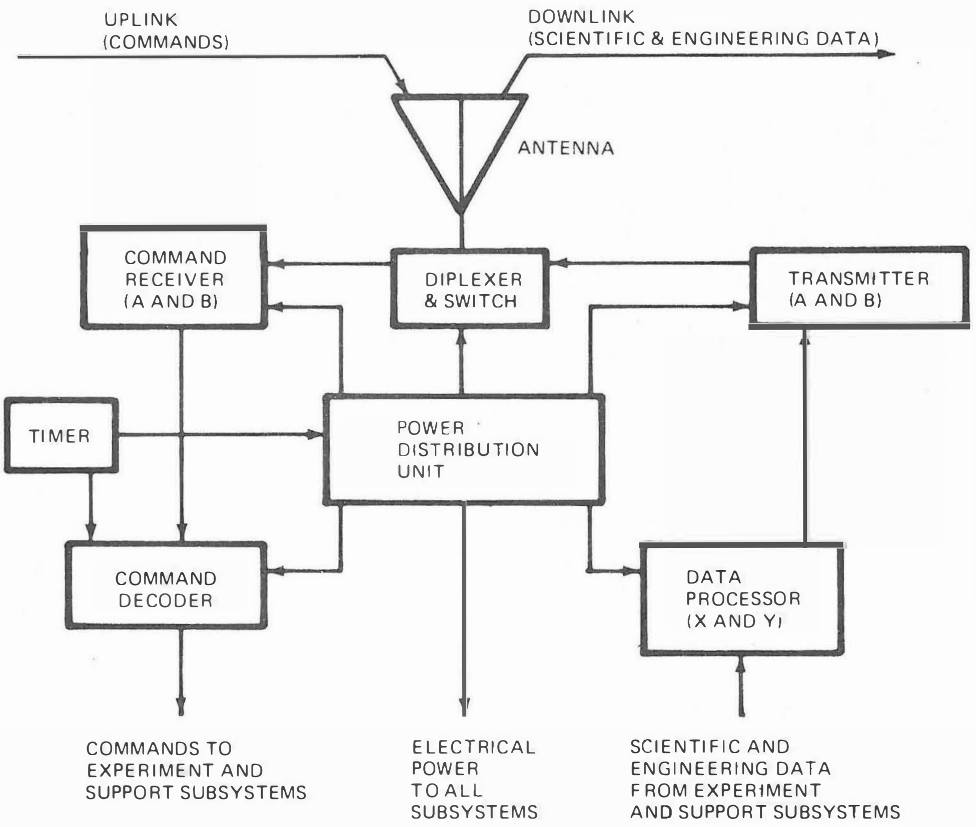


Figure 2-11. Data Subsystem, Simplified Block Diagram

Table 2-3. Data Subsystem Component Functions

Component	Function
Antenna	Provides simultaneous uplink reception and downlink transmission of ALSEP signals.
Diplexer switch	Connects either transmitter to the antenna.
Diplexer filter	Connects receiver input and transmitter output to the antenna.
Transmitter	Transmits 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.
Resettable solid state timer	Provides timing signals to initiate periodic automatic functions, and switch off transmitter after 97 (± 5) days. Reset by command.
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.

2-23. DATA SUBSYSTEM PHYSICAL DESCRIPTION

The data subsystem components are mounted on a 23.25-inch by 20-inch section of the central station thermal plate. Figure 2-12 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 central station temperature sensors, manual control switches, transmitter and receiver heaters, central station backup heaters, and a central station thermostat. Five thermal plate sensors are placed throughout the central station to monitor engineering temperature status data. Manual control switches are provided as a backup to permit the astronaut to start system operation in the event of uplink failure.

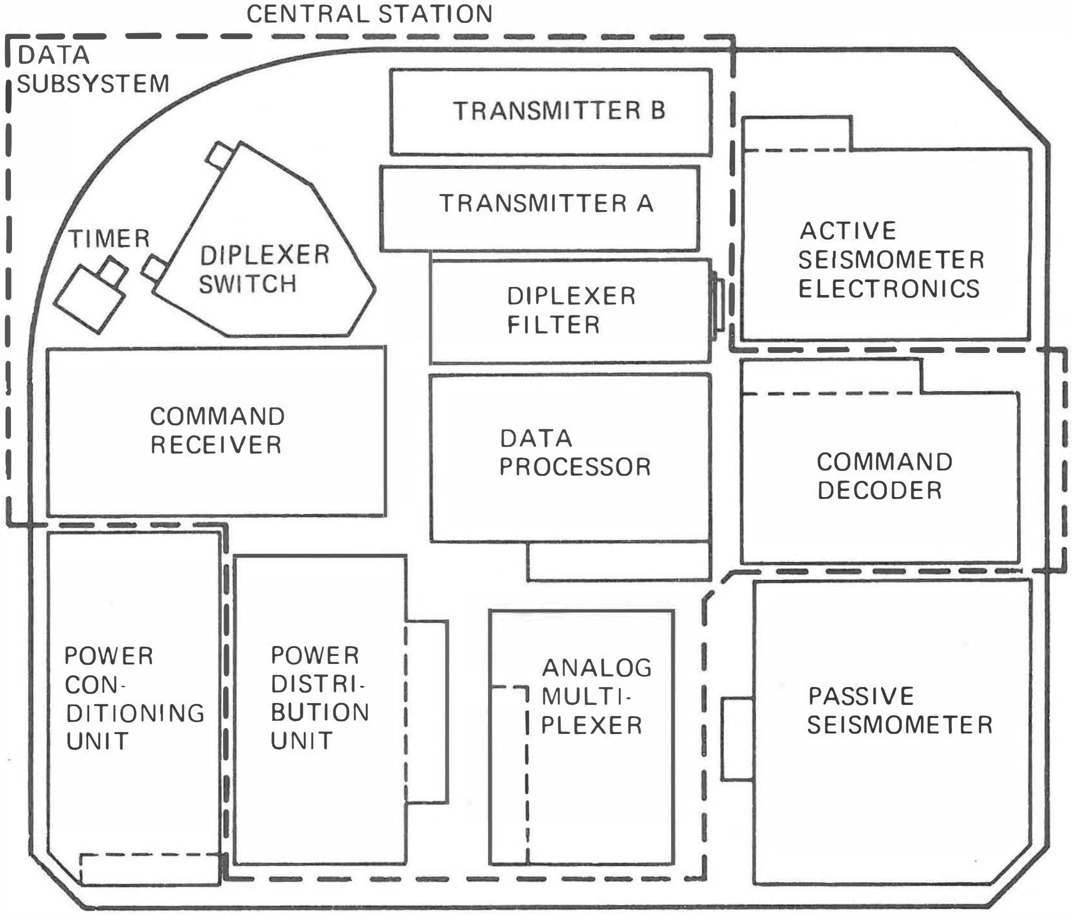


Figure 2-12. Data Subsystem Component Location

The overall weight of the data subsystem is approximately 25 pounds and the power consumption is approximately 20 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. Table 2-4 lists the uplink commands by subsystem termination.

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 experiment subsystem are primarily in digital form. Engineering data is usually analog and consists of status and housekeeping data such as temperatures and voltages which

Table 2-4. ALSEP Commands

Command Usage	Number
Active seismic experiment	7
Passive seismic experiment	15
Heat flow experiment	10
Magnetometer experiment	8
Command decoder	2
Data processor	5
Power distribution unit	27
Power conditioning unit	2
Timer	1

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 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 2-13 shows a functional diagram of the data subsystem and its interfaces with other ALSEP subsystems. Redundant channels are provided for the transmitter, receiver, and portions of the command decoder and data processor to improve system reliability.

The uplink transmission from MSFN is a 2119 MHz RF carrier which is phase modulated with a composite audio signal. The composite audio signal is 1,000 bps NRZ command data bi-phase modulated on a 2 KHz data tone, to which a 1 KHz synchronization tone is added linearly. The command 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 a 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 appropriate experiment and support subsystems.

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.

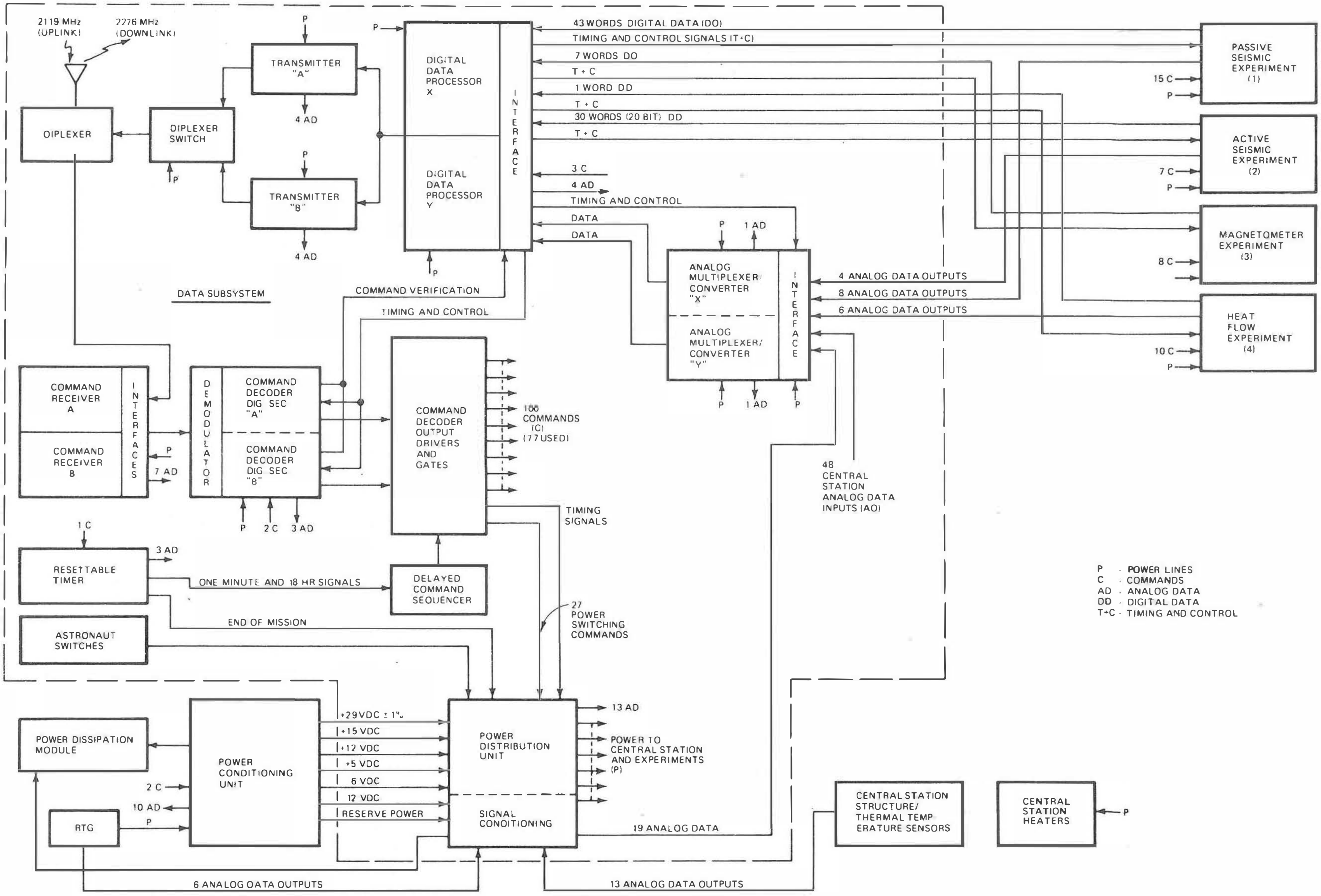


Figure 2-13. Data Subsystem Functional Block Diagram

Analog signals from the ALSEP experiment and support subsystems are applied directly to the analog multiplexer/converter or indirectly through the signal conditioning section of the power distribution unit to the analog multiplexer/converter. The dual 90-channel analog multiplexer (X and Y) gates the analog inputs, one per frame, to the redundant analog-to-digital converters. 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 experiments and 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.

2-25. ANTENNA ASSEMBLY 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 2-14 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 2-5.

2-27. Antenna Functional Description. The antenna receives command signals from Earth on a frequency of 2119 MHz and transmits telemetry data on a selected frequency within the frequency band of 2275 MHz to 2280 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 Aiming Mechanism - The antenna will be pointed to the Earth by means of the antenna aiming mechanism. This mechanism is a two-gimbal system which positions the antenna in azimuth and elevation. The azimuth is set in reference to a sun shadowgraph and the elevation is set in reference to a circular bubble level to position the antenna to a predetermined angle in elevation and azimuth. The azimuth and sun-shadow adjustments are on a common axis. The sun shadow adjustment, the azimuth angular adjustment, and the elevation

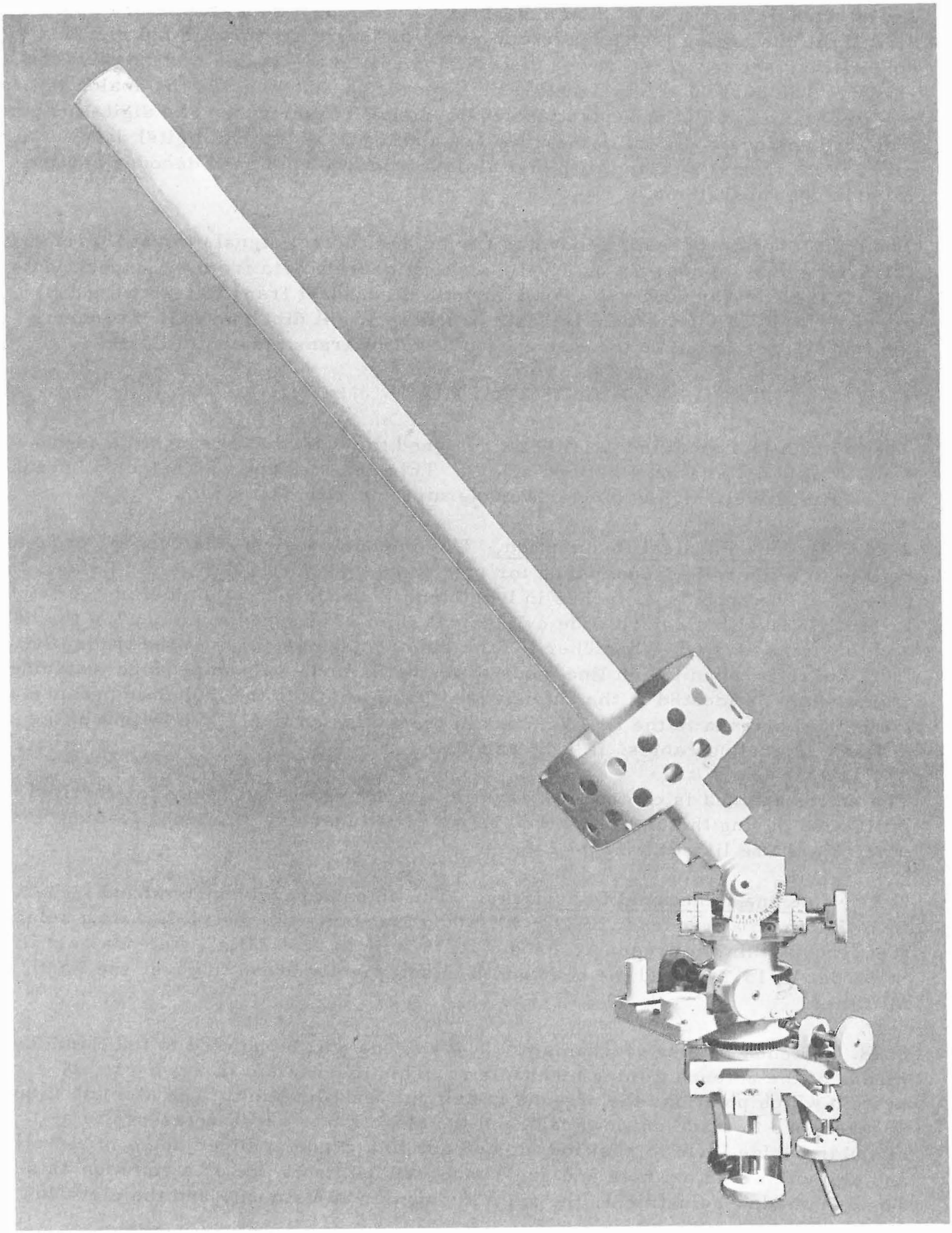


Figure 2-14. Antenna and Aiming Mechanism

Table 2-5. Antenna Leading Particulars

Characteristic	Transmit	Receive
Gain*		
on boresight	15.2 db	14.7 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	-11db	-11.3 db

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

angular adjustment are set by three separate 72:1 worm and wheel gears giving a range of ±15°, ±90°, and ±50°, respectively. The circular bubble level is set by two screw adjustments giving a range of ±6° from the horizontal with a sensitivity of 1° per revolution of the adjustment handle. The antenna aiming procedure is described in detail in Section IV.

The antenna and aiming mechanism are stowed separately on the ALSEP and their interface is a quick-action connection. The two parts are held together by spring-loaded balls on the aiming mechanism bearing on the lower face of a groove cut into an extended male post of the ground plane. A 3-inch diameter flange on the aiming mechanism butts against the underside of the ground plane to maintain stability.

2-29. DATA SUBSYSTEM DIPLEXER

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

2-30. Data Subsystem Diplexer Physical Description. The diplexer filter and circulator switch are shown in Figures 2-15 and 2-16, respectively. Figure 2-17 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 2-6.

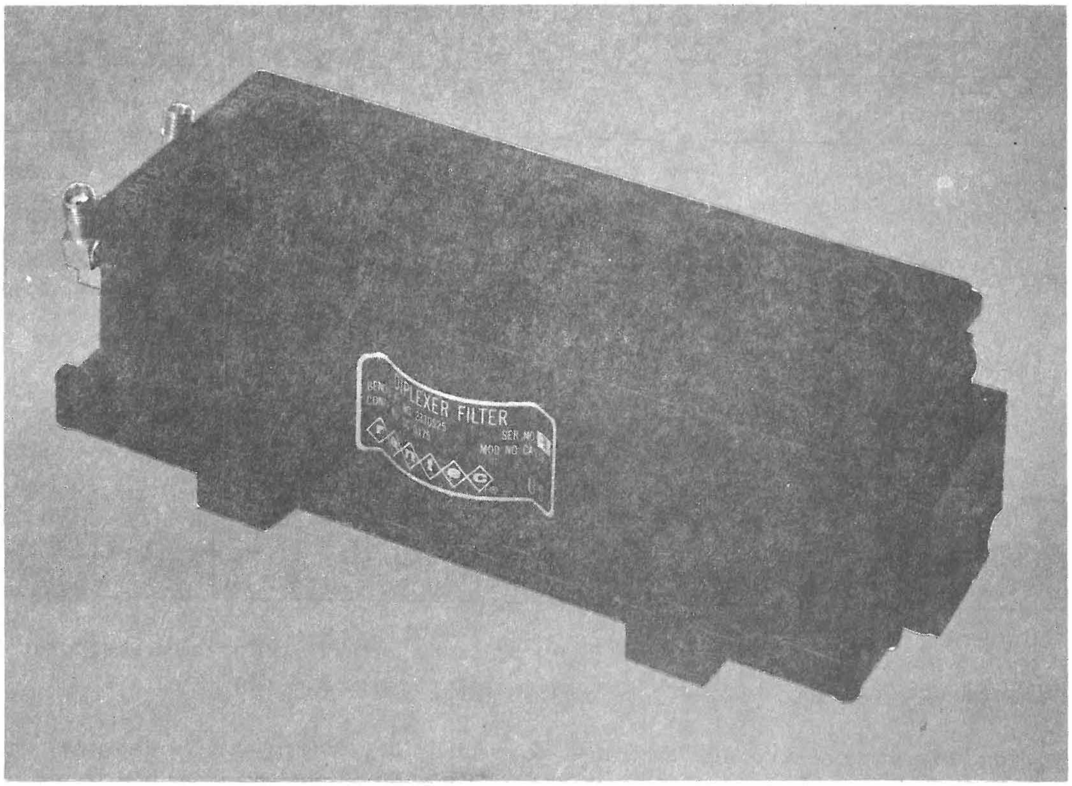


Figure 2-15. Data Subsystem Diplexer Filter

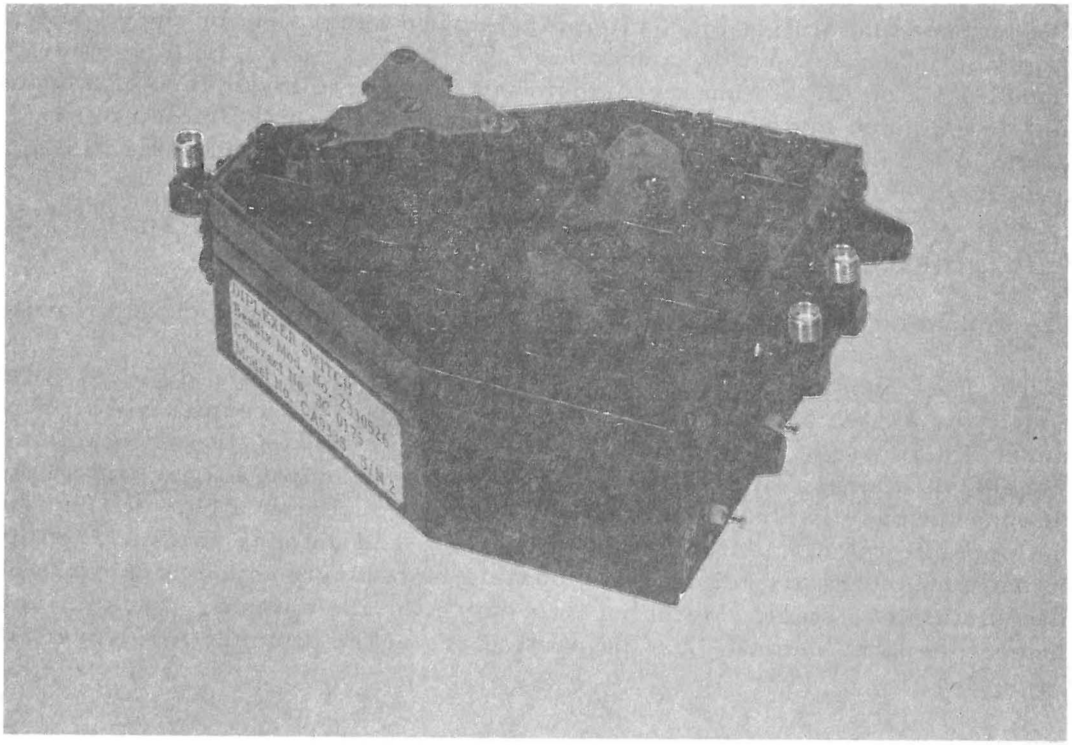


Figure 2-16. Data Subsystem Diplexer Switch

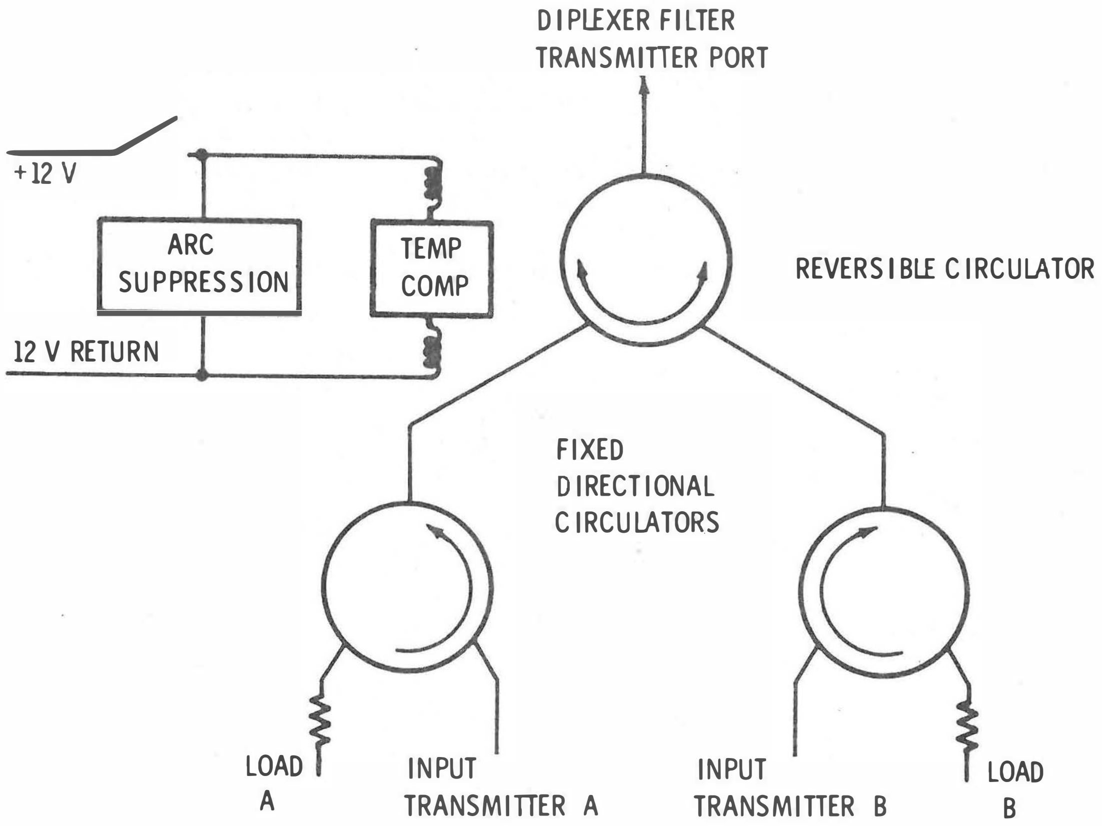


Figure 2-17. Data Subsystem Diplexer Switch Diagram

Table 2-6. 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 2-7.

Table 2-7. 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 uplink command data signal from the MSFN. It applies a composite audio command data signal to the command decoder, and supplies analog engineering status data to the data processor analog multiplexer/converter.

The uplink signal is comprised of a 2119 MHz carrier which is phase modulated by the composite audio signal, which is 1,000 bps NRZ command data bi-phase modulated on a 2 KHz data tone. A 1 KHz synchronization tone is linearly added to the 2 KHz data tone. The 1 KHz tone power is equal to the 2 KHz tone power. The two tones are in phase at the zero voltage crossing for a logic 1, and are 180° out of phase at the zero voltage crossing for a logic 0. The receiver demodulates the uplink signal to provide the composite audio signal (bi-phase modulated 2 KHz data tone and a 1 KHz synchronization tone) to the command decoder.

The receiver is comprised of two receiver sections which have a common input and output interface. Both receiver sections are powered simultaneously and are fully operational. The output of receiver section A is applied to the interface when the 1 KHz synchronization tone is detected in its output. Absence of this tone causes the output of receiver section B to be selected.

2-33. Data Subsystem Command Receiver Physical Description. The configuration of the command decoder is shown in Figure 2-18. It is comprised of four modular assemblies mounted in a housing assembly. The chassis of the assemblies and the housing are machined aluminum structures which provide isolated chambers and mounting facilities for circuit components and component boards. The receiver makes extensive use of linear integrated circuits. Each receiver section is comprised of two modular assemblies. The two receiver sections are identical.

The uplink signal interface is through an RF connector. All other interfaces are through a 38-pin connector. The receiver leading particulars are listed in Table 2-8.

NOTE

> Receiver capabilities not used in the Apollo 16 ALSEP are not described.

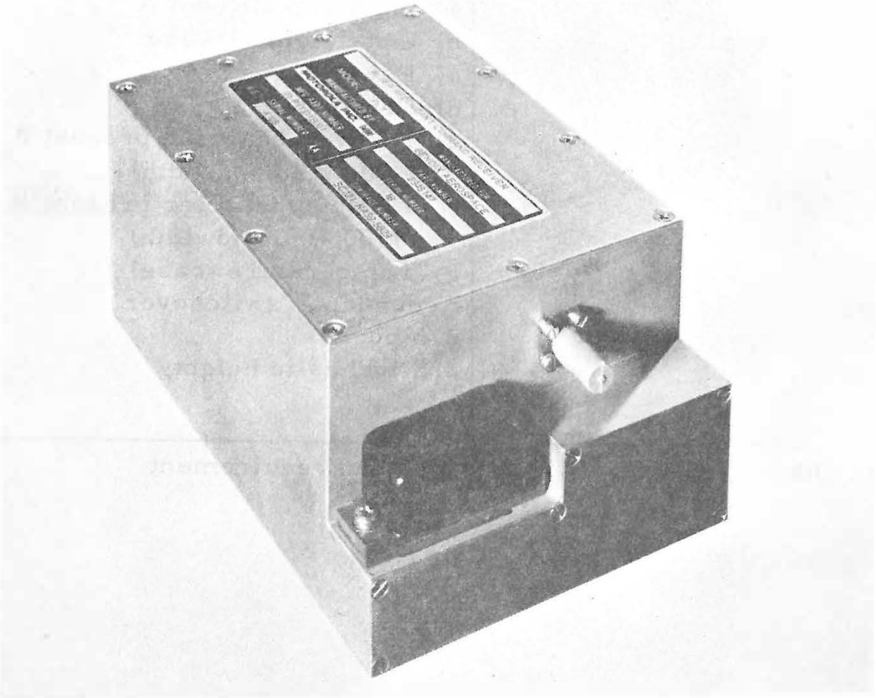


Figure 2-18. Data Subsystem Command Receiver

Table 2-8. Data Subsystem Command Receiver Leading Particulars

Characteristic	Value
Input Frequency	2119 MHz (± 21.19 KHz)
Input impedance	50 ohms at 2119 (± 5) MHz
Input signal level	-60 to -92 dbm
Input VSWR	1.5:1 max at 2119 (± 1) MHz 2.0:1 max at 2119 (± 5) MHz
Noise figure	*8db each receiver
Local oscillator frequency stability	± 0.0025%/2 yrs
First intermediate frequency	121.7 MHz
Second intermediate frequency	10.7 MHz
IF bandwidth	*480 KHz at 3 db *3 MHz at 70 db
Audio distortion	< ± 5.0%
Audio phase shift (between 1 KHz and 2 KHz)	± 6° max (± 16.7 μ sec)
Audio output level	5 volts p-to-p (± 20%) for input signals of -60 to -92 dbm
Output polarity	+ voltage for -phase shift or input
Output load impedance	>22K ohms (ac coupled)
Output noise bandwidth (nominal)	100 Hz to 10 KHz
Output signal-to-noise ratio	20 db minimum at input signals above -92 dbm
Supply voltage	+12 vdc (+1%, -3%)
Supply power	1.80 watts maximum (75 ma on each of two supply lines)
Telemetry outputs	+0.2 to +4.8 vdc a) Input signal level A b) Input signal level B c) Power A d) Power B e) 1 KHz subcarrier present A *(100 Hz bandwidth) f) 1 KHz subcarrier present B *(100 Hz bandwidth) g) Temperature (case)
Test points	Redundancy switchover
Weight	2.6 pounds
Form factor	2.8 inches in height

* A design characteristic—not a specification requirement

2-34. Data Subsystem Command Receiver Functional Description. Functionally, the command receiver is comprised of two redundant receivers which share common interface/control circuits as illustrated in Figure 2-19. The 2119 MHz phase modulated carrier uplink signal is received by the central station antenna, coupled through the diplexer, and applied to the command receiver RF coupler. The coupler is a stripline hybrid which applies the uplink signal to both receiver sections.

The uplink signal is passed through a low-pass filter, coupled through a tuned 3-pole pre-selector, and applied to the first mixer. The first mixer is a stripline hybrid which mixes the uplink signal with a 1997. 3 MHz crystal-controlled local oscillator signal to produce a 121. 7 MHz first IF signal. The IF signal is amplified and applied through a 3-stage IF bandpass filter to the second mixer. The second mixer is an integrated circuit which mixes the 121. 7 MHz first IF signal with a 110. 9 MHz crystal-controlled local oscillator signal to produce a 10. 7 MHz second IF signal.

The 110. 9 MHz local oscillator/amplifier output is increased in frequency to 1997. 3 MHz by a multiply-by-18 frequency multiplier, and coupled through a 2-pole tuned filter to the first mixer to develop the first IF. The local oscillator output is applied directly to the second mixer to develop the second IF.

The second IF signal is applied through a 5-stage IF bandpass filter to the second IF amplifier. The amplifier output is sampled by the AGC detector to develop the AGC feedback voltage. This voltage is also applied to the interface as a signal level telemetry signal to provide engineering data regarding the received signal carrier level. The amplifier output is applied to the first discriminator where it is demodulated. The composite 2 KHz data subcarrier and 1 KHz synchronization subcarrier signal is applied through the limiter and the final audio amplifier to the audio selector for output. The composite receiver output signal characteristics are shown in Figure 2-20.

The audio amplifier output is sampled by the 1 KHz tone detector to develop a command signal present voltage. The receiver A signal is applied to the audio selector as a control signal, and is output as a telemetry signal. The receiver B signal is output directly as a telemetry signal.

The audio selector receives the audio outputs from both receiver sections A and B, and applies one of these audio signals to the command decoder. The selected audio output is from receiver section A when the "command signal present A" signal is present. The absence of this signal causes the audio output from receiver section B to be selected.

The power line isolator provides redundant series regulator circuits, each of which receives +12 VDC from the PDU, and supplies +11 VDC operating power to its corresponding receiver section. Each operating power line is monitored for engineering data. The temperature of the receiver case is monitored by a thermistor for engineering data. The engineering data measurements are supplied to the multiplexer/converter.

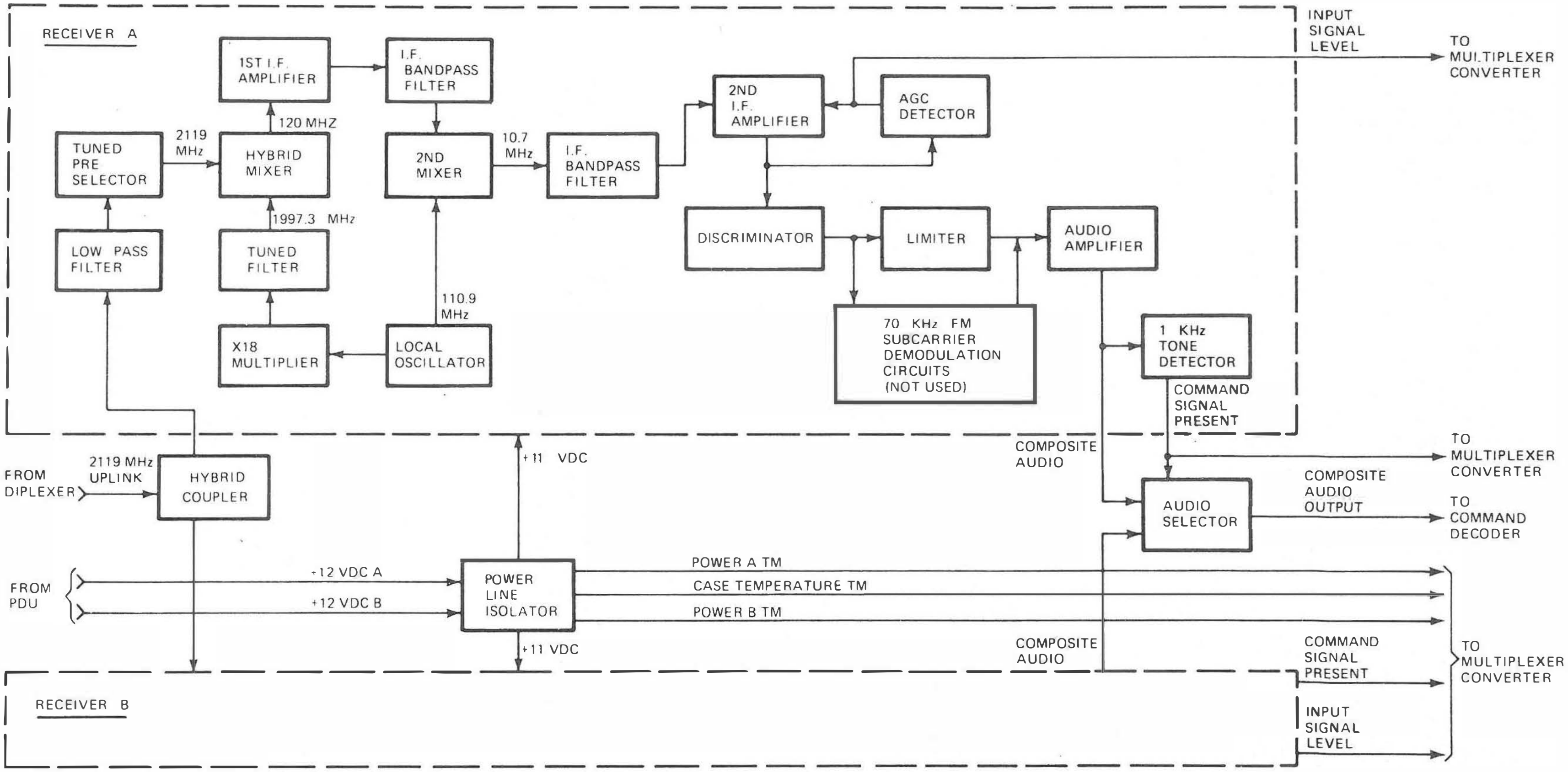
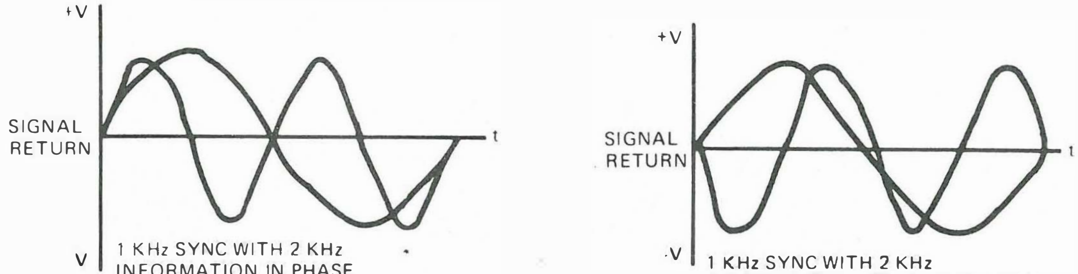


Figure 2-19. Data Subsystem Command Receiver Block Diagram

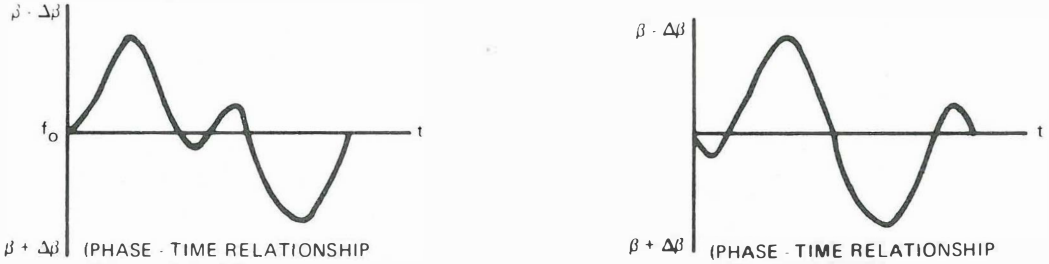


1 KHz SYNC WITH 2 KHz INFORMATION IN PHASE (LOGIC ONE)

1 KHz SYNC WITH 2 KHz INFORMATION 180° OUT OF PHASE (LOGIC ZERO)

(COMPOSITE INPUT VOLTAGE WAVEFORM FOR LOGIC ONE)

(COMPOSITE INPUT VOLTAGE WAVEFORM FOR LOGIC ZERO)



(PHASE - TIME RELATIONSHIP FOR LOGIC ONE)

(PHASE - TIME RELATIONSHIP FOR LOGIC ZERO)

Figure 2-20. Data Subsystem Command Receiver Output Signal Characteristics

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

2-36. Data Subsystem Command Decoder Physical Description. Figure 2-21 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 2-9.

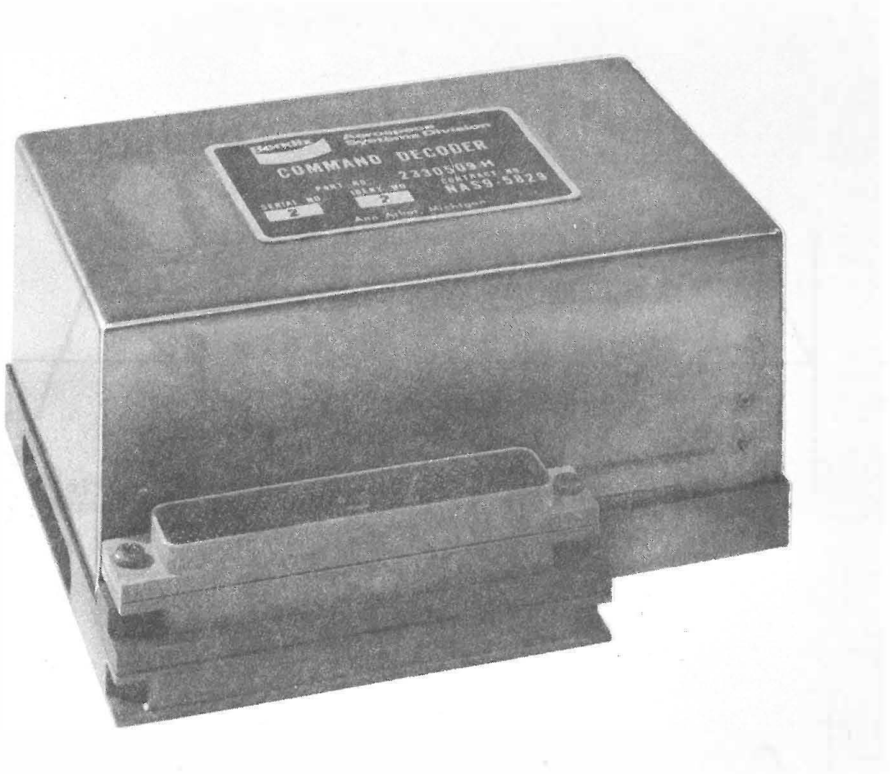


Figure 2-21. Data Subsystem Command Decoder

Table 2-9. 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. Data Subsystem Command Decoder Functional Description. The command decoder consists of a demodulator section and digital decoder sections. Figure 2-22 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-lock, 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 2-23 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

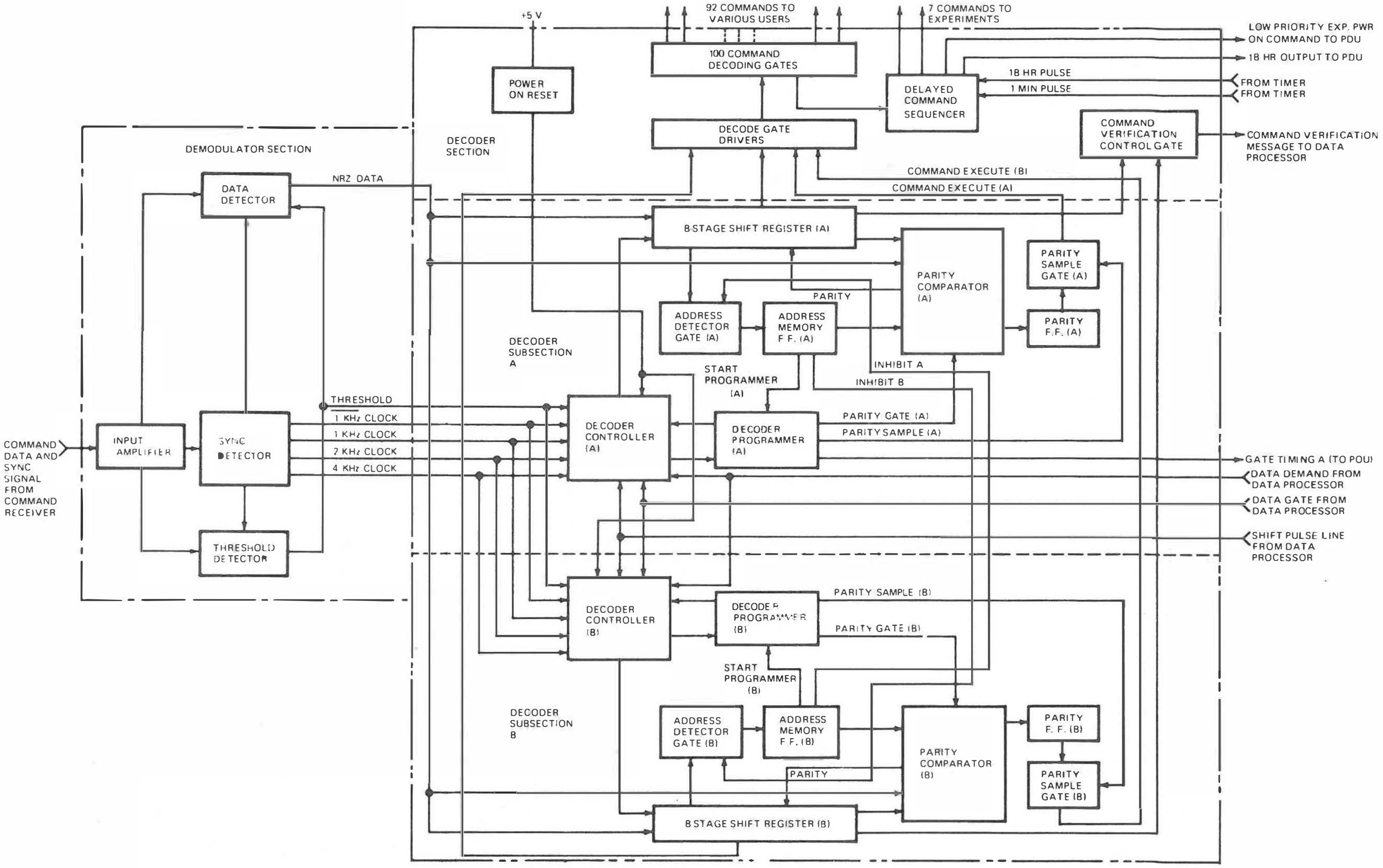


Figure 2-22. Data Subsystem Command Decoder Functional Block Diagram

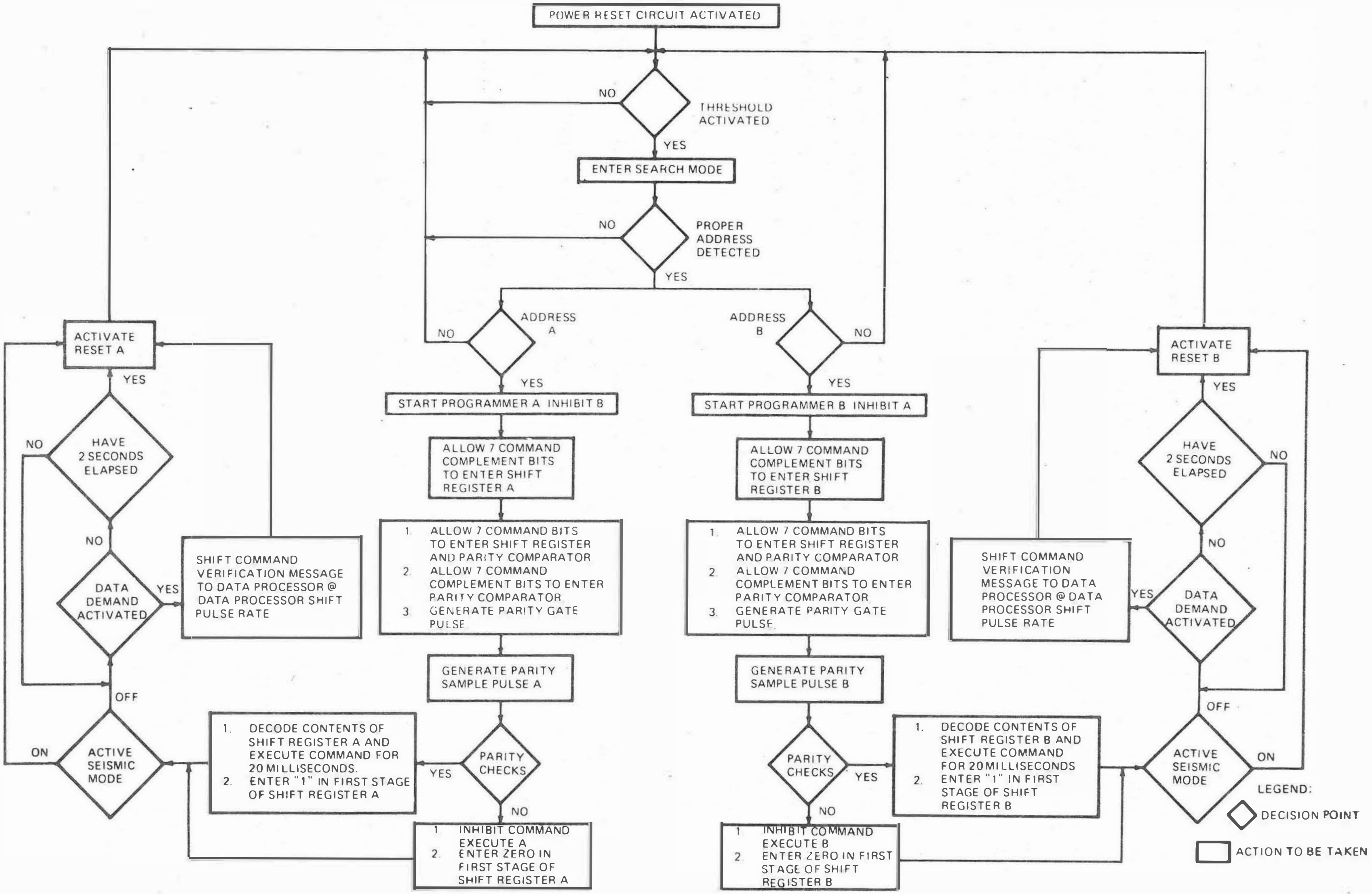


Figure 2-23. Data Subsystem Command Decoder Flow Diagram

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 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 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 uniquely command the ALSEP systems. Each command decoder shall respond to two address codes; one for section A and another for section B. Address codes have been assigned to the ALSEP systems as specified in Table 2-10.

Table 2-10. ALSEP Address Code Assignments

ALSEP System	Address Code			Command Decoder
	Decimal	Octal	Binary	
Apollo 12	88	130	1011000	A
	24	30	0011000	B
Apollo 14	21	25	0010101	A
	53	65	0110101	B
Apollo 15	78	116	1001110	A
	14	16	0001110	B
Apollo 16	50	62	0110010	A
	100	144	1100100	B

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 100 commands to ALSEP users. All command code numbers except the following are available to the users: 0, 1, 2, 4, 8, 14, 16, 22, 24, 32, 39, 41, 49, 63, 64, 78, 86, 88, 95, 103, 105, 111, 113, 119, 123, 125, 126, 127.

Provisions have been incorporated in the command decoder to accommodate a maximum of 113 discrete commands which have been allotted as follows:

a.	Experiments	40
b.	Power distribution	27
c.	Power conditioning unit	2
d.	Data processor	5
e.	Command decoder	2
f.	Timer	1
g.	Available for test purposes	14
h.	Not assigned	22

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 144-hour delay. The delayed command functions and time of execution are listed in Table 2-11. A flow chart of delayed command sequences is shown in Figure 2-24.

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

Table 2-11. Data Subsystem Delayed Command Functions

Command	Function	Time of Execution
59	Uncage PSE	144 hours + 2 minutes
69	Not used	"
75	"	"
72	"	144 hours + 3 minutes
82	"	144 hours + 4 minutes
71	"	"
72	"	144 hours + 5 minutes
89	Magnetometer flip calibrate	162 hours + 1 minute, then every 18 hours
42	Restore power to lowest priority experiment	162 hours + 7 minutes, then every 18 hours

2-39. DATA SUBSYSTEM RESETTABLE SOLID STATE TIMER

The resettable solid state timer is used to provide timing signals to the command decoder, to initiate backup automatic command functions, and to provide automatic termination of ALSEP transmission in case of loss of command uplink.

The timer generates its own reset signal upon initial application of +12 vdc power from the PCU so that it will begin its count at zero. It will retain its count during approximately 30 seconds of power loss. Its outputs are 1-minute, 18-hour, and 1.5-month timing and telemetry signals, and a 97(±5) -day transmitter off signal. A timer reset command from Earth will reset the timer count to zero to initiate an additional 97(±5)-day ALSEP transmission period.

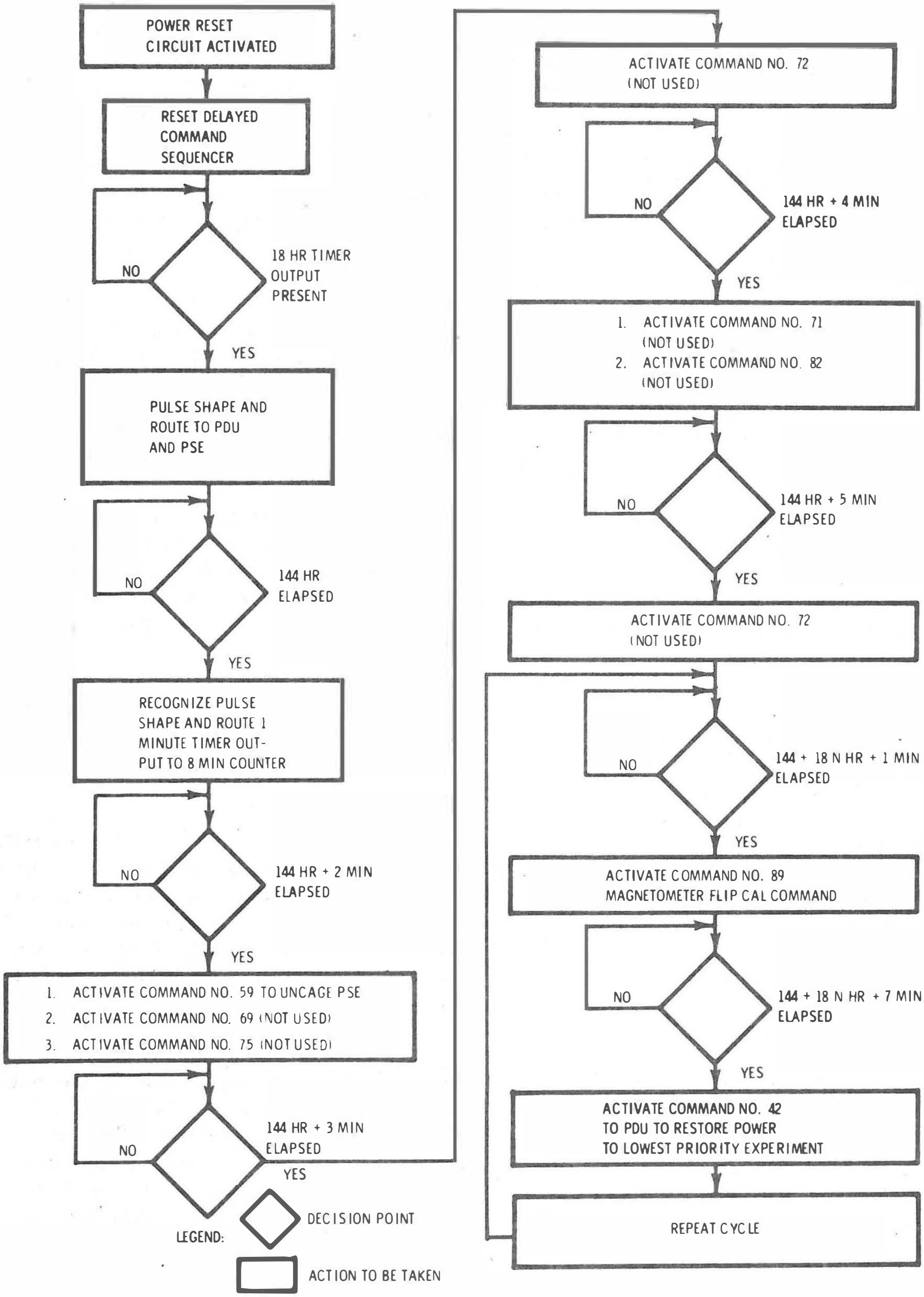


Figure 2-24. Data Subsystem Delayed Command Sequence, Functional Flow Chart

The transmitter off signal is irreversible in that it is generated by activation of a non-resettable relay. The uplink transmitter power control commands CD-2 and CD-3 (refer to Table 1, Appendix B) will remain effective even though this timer-generated signal has been activated.

2-40. Resettable Solid State Timer Physical Description. The resettable solid state timer (Figure 2-25) consists of three circuit boards housed in an aluminum case approximately 2. 8 inches high, 1. 4 inches wide, and 2. 2 inches long. Electrical connections are made through a 37-pin connector. Maximum weight of the unit is 7. 3 ounces.

2-41. Resettable Solid State Timer Functional Description. Figure 2-26 is a functional block diagram of the resettable solid state timer. An oscillator generated 16, 384 Hz (±5%) clock is divided down to drive two parallel 28-bit ripple counter divider chains at a 1-second rate. The count of divider chain no. 1 is decoded to generate the 1-minute and the 18-hour timing signals which are applied to the delayed command sequencer of the command decoder.

The three-month output (bit 23) of each of the divider chains is used to drive the transmitter turn-off relay, while ensuring that a premature turn-off does not occur. Operation of the relay applies a transmitter-off signal to the transmitter on/off relay in the PDU. Application of the timer reset command at any time prior to relay operation will reset the counters to zero to extend transmitter operation for a three month period.

The 1. 5 month count (bit 22) of each of the divider chains, and the 18 hour count are applied to the data processor analog multiplexer for downlink telemetry.

2-42. DATA SUBSYSTEM DATA PROCESSOR

The data processor accepts analog engineering status data and digital scientific experiment and status data from the experiments and data subsystem. It converts the analog inputs to digital values, and processes the digital data in 10-bit words. It formats the 10-bit data words into a 64-word frame, 90-frame sequence telemetry format. The data is split-phase modulated and supplied to the data subsystem transmitter for phase modulation of the downlink RF carrier. The data processor generates timing and control signals which are used throughout the ALSEP system.

2-43. Data Subsystem Data Processor Physical Description. The data processor consists of two physical components: a digital data processor (Figure 2-27), and an analog multiplexer/converter (Figure 2-28). Multilayer printed circuit boards are used throughout the digital data processor and the analog multiplexer/ converter. The digital data processor uses seven 12-layer boards, one 6-layer board, and one 3-layer discrete component board. The analog multiplexer/ converter uses ten 2-layer boards. Leading particulars are listed in Table 2-12.

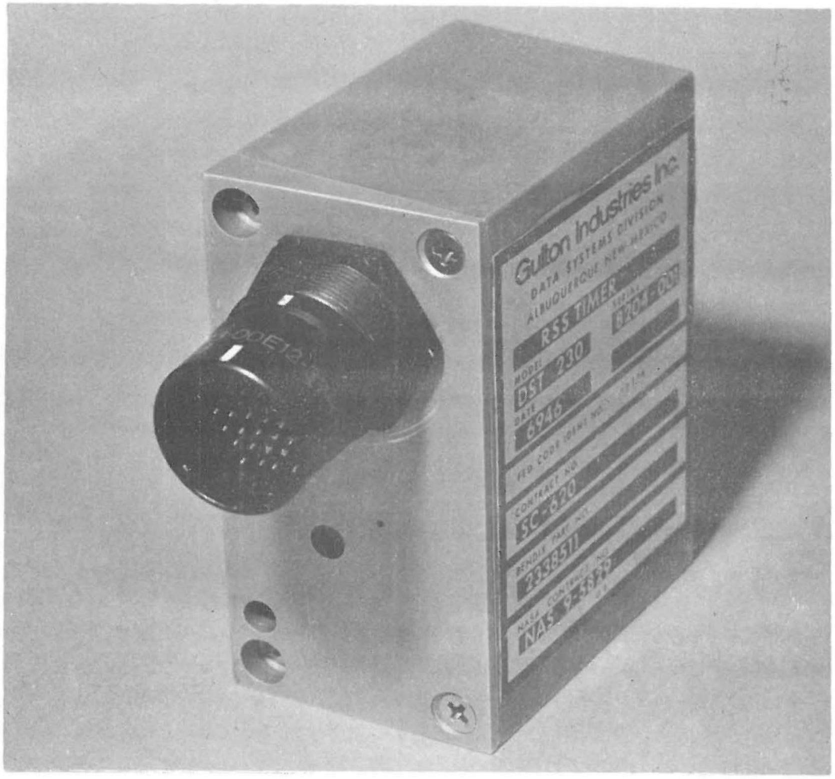


Figure 2-25. Resettable Solid State Timer

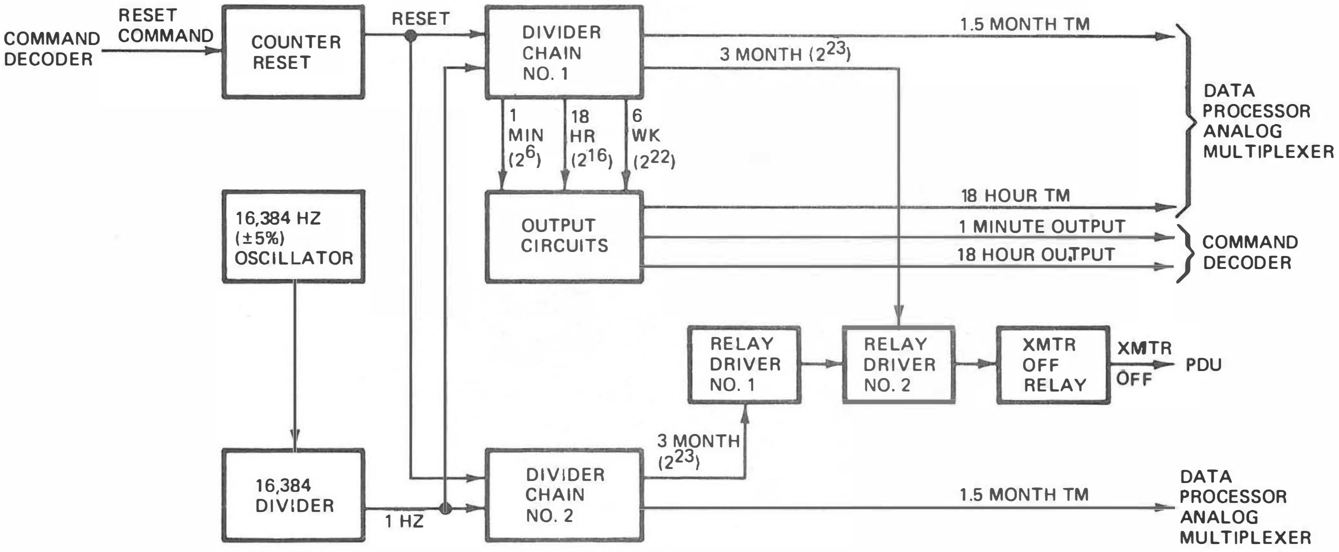


Figure 2-26. Resettable Solid State Timer, Block Diagram

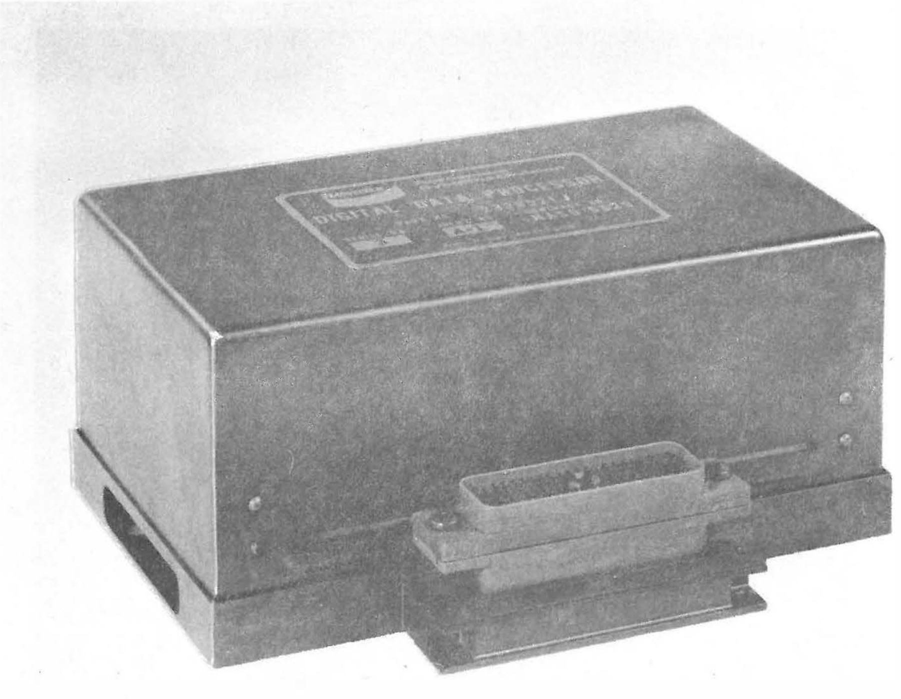


Figure 2-27. Data Subsystem Digital Data Processor

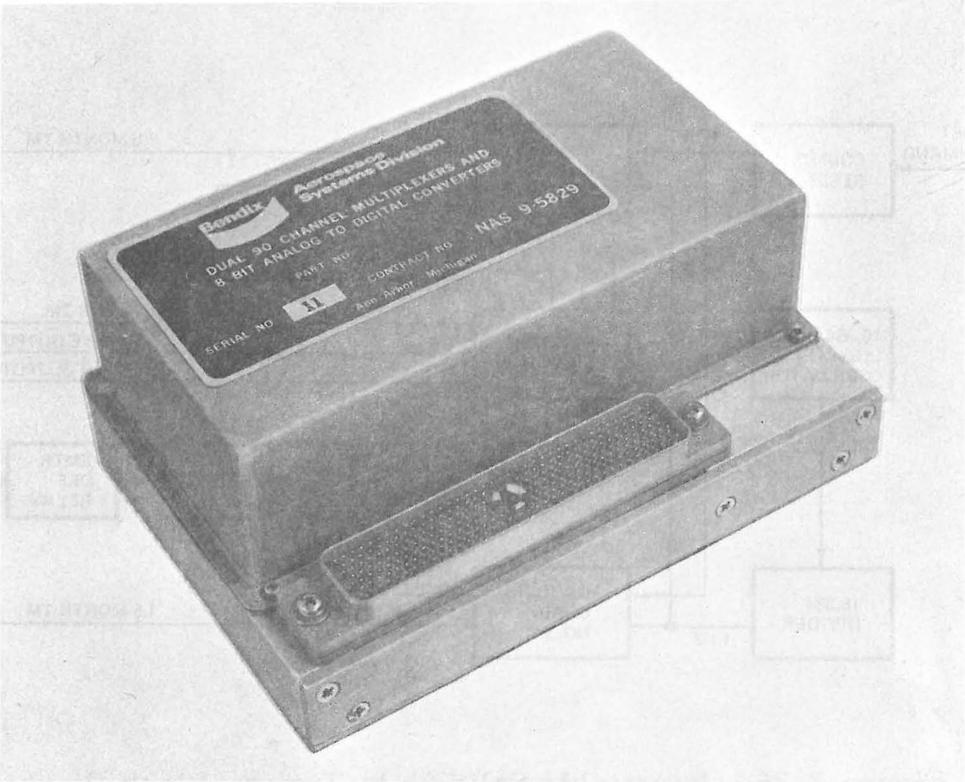


Figure 2-28. Data Subsystem Analog Data Multiplexer/Converter

Table 2-12. Data Subsystem Data Processor Leading Particulars

Characteristic	Value
Digital Data Processor	
Height	2.8 inches
Width	3.94 inches
Length	6.25 inches
Weight	2.60 pounds
Power consumption	Less than 0.5 watts
Analog Multiplexer/Converter	
Height	2.62 inches
Width	4.22 inches
Length	5.92 inches
Weight	1.83 pounds
Power consumption	2.05 watts maximum

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 by command to perform the data processing function.

2-45. Operating Modes - The data processor operates in three modes:

a. Normal mode (1,060 bps)
b. Slow mode (530 bps)
c. Active Seismic mode (10,600 bps).

The normal mode is the standard operating mode which has a data rate of 1,060 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. Characteristics of the timing and control signals are listed in Table 2-13.

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 active seismic mode is provided exclusively for the active seismic experiment. When the active seismic command is received from the command decoder, the signal is stored until the completion of the existing 64-word frame. At the end of the 64th word, the data processor switches into the active seismic mode. This switch may occur in either an odd or even frame, and between any analog words. The switch to active seismic mode gates on serial data from the active

Table 2-13. Data Subsystem Timing and Control Pulse Characteristics in Normal ALSEP Data Mode

Pulse Type	Duration* (μ sec)	Repetition Rate*	Timing Relative to Frame Mark
Frame mark	118	once per ALSEP 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	9,434	once per experiment word in ALSEP frame	occurs asymmetrically as defined in Figure 2-30
Shift pulse	47	640 pulses per frame 1060 pulses per second	a continuous 1,060 pulses per second symmetrical square wave

Amplitude: High or logic "1" — +2.5 to 5.0 volts
Low or logic "0" — 0 to +-.4 volts
Rise and Fall Times: 2 to 10 μ sec 10% to 90% points and 90% to 10% points

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

seismic experiment, gates off all demands to the command decoder and the various experiments, and gates off any incoming serial data from any other data source. The active seismic data rate is 10,600 bps. The data shift signal, frame mark, even frame mark, data gate and 90th frame signals, are sent to the experiments at the normal rate. Operation of the data processor is illustrated in the flow chart, Figure 2-29.

2-46. Data Format - The data processor formats the data collected from the experiments and the data subsystem into a 64-word telemetry frame format as shown in Figure 2-30. The frame rate in the normal mode is 1-21/32 frames/second. A complete frame of data is collected approximately every 0.6 second. Each frame contains 64 words of 10 bits each, giving 640 bits/frame. The basic bit rate is 1,060 bps. In addition to the words assigned to the experiments, the first three 10-bit words are used as a 30-bit control word, and a single 10-bit word is used for command verification purposes. Experiment word and frame assignments are listed in Appendix B.

The bit assignments for the control word are shown in Figure 2-31. A 22-bit word consisting of an 11-bit Barker code, followed by the same code complemented, is used to attain synchronization. The next seven bits provide frame

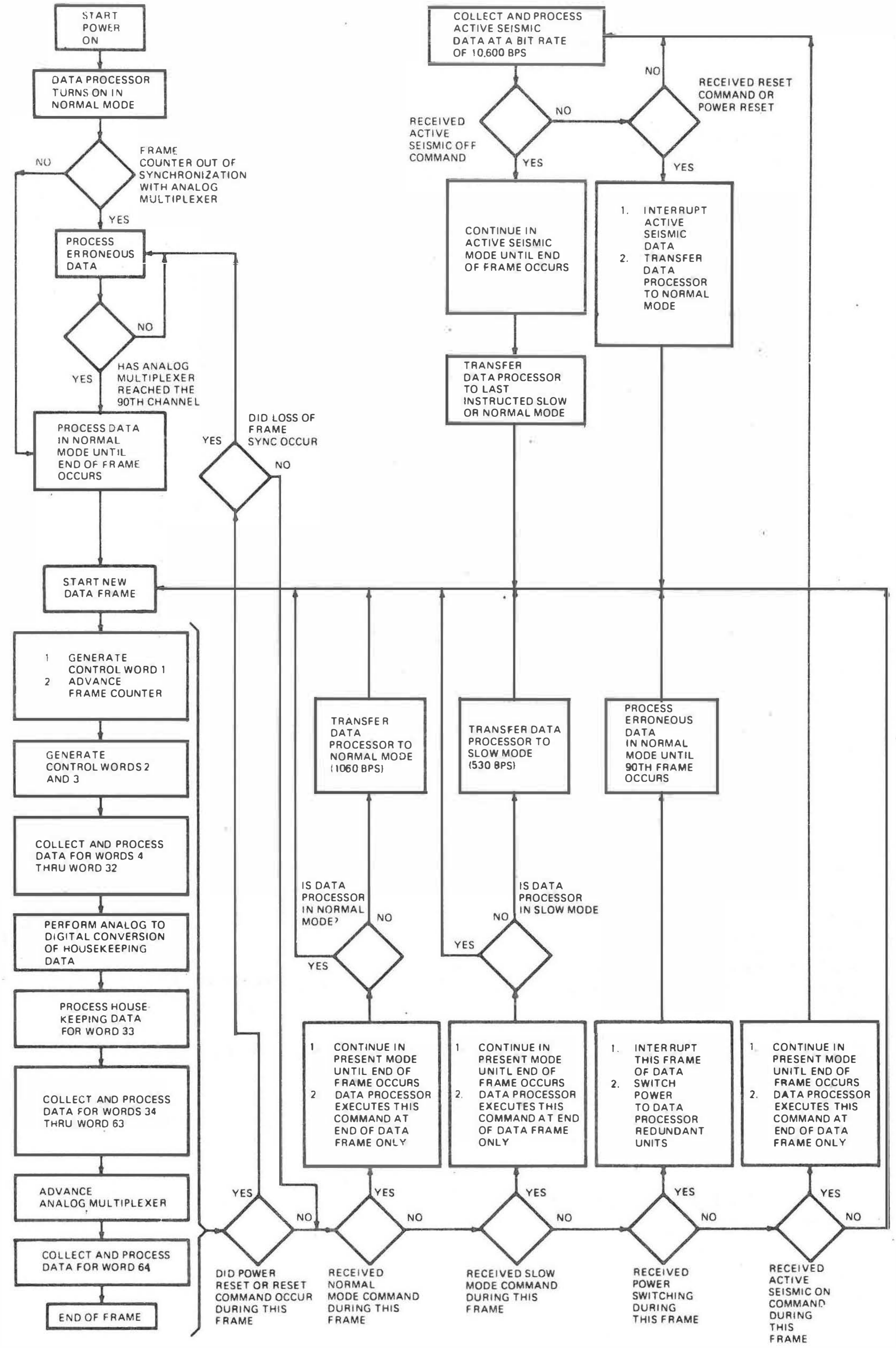


Figure 2-29. Data Subsystem Data Processor Flow Chart

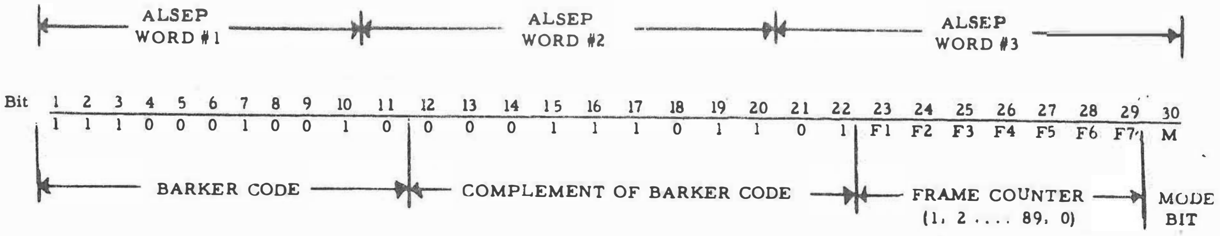
1 x	2 x	3 x	4 X	5 O	6 X	7	8 X
9 -	10 X	11 -	12 X	13 -	14 X	15	16 X
17 O	18 X	19 O	20 X	21 O	22 X	23 HF	24 X
25 -	26 X	27 -	28 X	29 -	30 X	31	32 X
33 H	34 X	35 ●	36 X	37 ●	38 X	39	40 X
41 -	42 X	43 -	44 X	45 -	46 CV	47	48 X
49 O	50 X	51 O	52 X	53 O	54 X	55	56
57 -	58 X	59 -	60 X	61 -	62 X	63	64 X

LEGEND		NUMBER OF WORDS PER FRAME	
x	- CONTROL	3	
X	- PASSIVE SEISMIC - SHORT PERIOD	29	43
-	- PASSIVE SEISMIC - LONG PERIOD SEISMIC	12	
●	- PASSIVE SEISMIC - LONG PERIOD TIDAL AND ONE TEMPERATURE	2	
O	- MAGNETOMETER	7	
HF	- HEAT FLOW	1	
CV	- COMMAND VERIFICATION (UPON COMMAND, OTHERWISE ALL ZEROS)	1	
H	- HOUSEKEEPING	1	
	- NOT USED	8	
	TOTAL	64	

EACH BOX CONTAINS ONE 10 BIT WORD
TOTAL BITS PER FRAME - 10 x 64 = 640 BITS

Figure 2-30. Apollo 16 ALSEP Telemetry Frame Format

CONTROL WORD FORMAT



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

Symbol	Name	ALSEP 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	1-90	7	1.67
DA-3	Mode Bit	Bit 10 of word 3			1.67
DA-4	ALSEP ID	Bit 10 of word 3		3	1/54

DA-3:

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

DA-4:

Frame	Mode Bit	
3	X (MSB)	Data processor Serial number
4	X	
5	X	

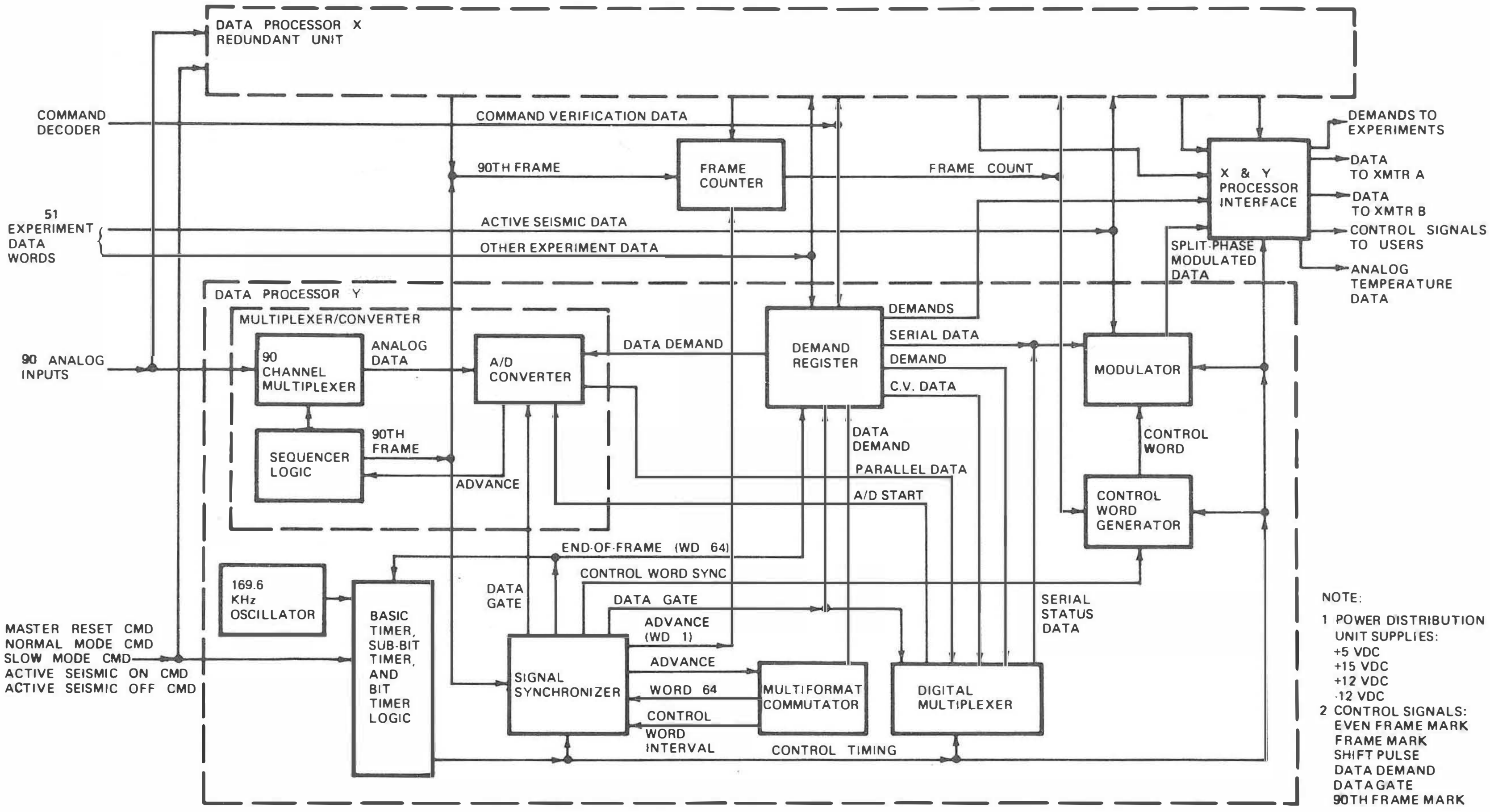
Figure 2-31. ALSEP Telemetry Control Word Bit Assignments

identification for frames 1 through 90 for correlation of the analog multiplexer data. Bit 30 provides normal or slow mode information during the first two frames of the 90-frame sequence, data processor serial number identification during frames 3 through 5, and has no information (reads logic zero) during frames 6 through 90.

2-47. Timing and Control Signals. Timing and control logic circuits provide synchronization signals for use throughout the ALSEP system. (See the data processor functional block diagram, Figure 2-32.)

The basic clock is a 169.6 KHz oscillator. A master flip-flop in the basic timer logic divides the clock frequency down to 84.8 KHz. The 84.8 KHz signal drives a divide-by-eight counter to obtain the 10.6 KHz signal used in the active seismic mode. 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 signal, 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.



NOTE:

1 POWER DISTRIBUTION
UNIT SUPPLIES:
+5 VDC
+15 VDC
+12 VDC
-12 VDC

2 CONTROL SIGNALS:
EVEN FRAME MARK
FRAME MARK
SHIFT PULSE
DATA DEMAND
DATA GATE
90TH FRAME MARK

Figure 2-32. Data Subsytem Data Processor, Functional Block Diagram

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 in multiples of one word length in duration to the demand register 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 multiformat commutator supplies control word interval and end-of-frame (word 64) signals to the signal synchronizer.

The signal synchronizer correlates the bit, word, and frame count to synchronize the control word, analog channel, and digital data measurements in the telemetry frame and sequence format. It provides the data gate to the analog-to-digital (A/D) converter, control word synchronization to the control word generator, and advance pulse to the multiformat commutator.

The frame counter provides frame count data to the control word generator for insertion in the control word. The frame counter is essentially a ripple-through counter. It is advanced by the first word of each frame signal from the signal synchronizer, and is reset by the 90th-frame end-of-sequence signal from the analog multiplexer sequencer logic.

The control word generator generates the synchronization code and provides the information to the modulator 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.

2-48. Data Processing. Ninety channels of analog engineering measurement (housekeeping) data are applied to the multiplexing gates of the analog multiplexer. The multiplexer gates are enabled, one channel per frame, to apply analog measurement data for word 33 to the A/D converter.

The multiplexer gates are controlled by the sequencer logic which is advanced through a 90-step sequence by the advance pulse signal from the A/D converter. The sequencer applies a 90th frame end-of-sequence pulse to the signal synchronizer and to the frame counter.

The A/D converter uses a ramp generation technique to encode the PAM analog signal from the multiplexer into an 8-bit digital word which is applied in parallel to the digital multiplexer. The conversion is controlled by the start pulse from the digital multiplexer, the data demand pulse from the demand register, and the data gate from the signal synchronizer to provide engineering measurement data in word 33 of each telemetry frame.

The demand register applies data demand signals to the A/D converter, to the command decoder, and to the experiments. It gates serial data from the experiments to the modulator, and from the command decoder to the digital multiplexer.

The demand register is controlled by the data demand signal from the multiformat commutator, and by the data gate and the end-of-frame (word 64) pulse from the signal synchronizer.

The digital multiplexer receives 8-bit parallel engineering data words from the A/D converter, and 8-bit serial command decoder data words from the demand register. These inputs are gated into a 10-bit shift register during the appropriate frame word times, and shifted serially as 10-bit words to the modulator. Zeros are inserted into the two most significant bits. The multiplexer is controlled by demand signals from the demand register and data gate signals from the signal synchronizer. It supplies the enable signal to the A/D converter.

The modulator accepts data from the ASE during ASE mode operation, experiment and status data from the demand register or digital multiplexer, and control word data from the control word generator. These data inputs are received by a 2-bit shift register during the appropriate time periods. The register presents the data in serial form to the PCM format converter. The PCM "0" is represented by a "01", and the PCM "1" is represented by a "10". The split phase modulated data signal is applied to the data subsystem transmitter. The data signal phase modulates the transmitter downlink rf carrier signal so that PCM "0" causes a positive phase transition and a PCM "1" causes a negative phase transition.

2-49. DATA SUBSYSTEM TRANSMITTER

The data subsystem transmitter 2345250 is used in the ALSEP flight system to generate a specific S-band carrier frequency within the range of 2275 to 2280 MHz. The signal is phase modulated by the split-phase serial bit stream from the data processor. Two identical transmitters are used in the data subsystem to provide standby redundant operation. Either transmitter can be selected to transmit downlink data.

2-50. Data Subsystem Transmitter Physical Description. The transmitter is comprised of six circuit modules. The X6 multiplier module is superimposed on the power amplifier module to form an integral structural unit with an aluminum base plate. The other four modules are printed circuit boards which are mounted in cavities in the side of the power amplifier module. The operating power and data signal input and telemetry output interface is through a 14-pin connector. The RF carrier output interface is through a coaxial connector. Figure 2-33 shows the structural configuration of the transmitter. Transmitter leading particulars are listed in Table 2-14.

2-51. Data Subsystem Transmitter Functional Description. Figure 2-34 shows a block diagram of the transmitter circuit. Transmitter output frequency is determined by the selection of the oscillator crystal. An oscillator frequency of 38 MHz is used in this discussion.

The crystal-controlled oscillator in the oscillator, buffer, modulator module, A3, generates a 38 MHz signal. The power level of the signal is increased by a buffer amplifier, and applied to a X5 multiplier which consists of a step recovery diode

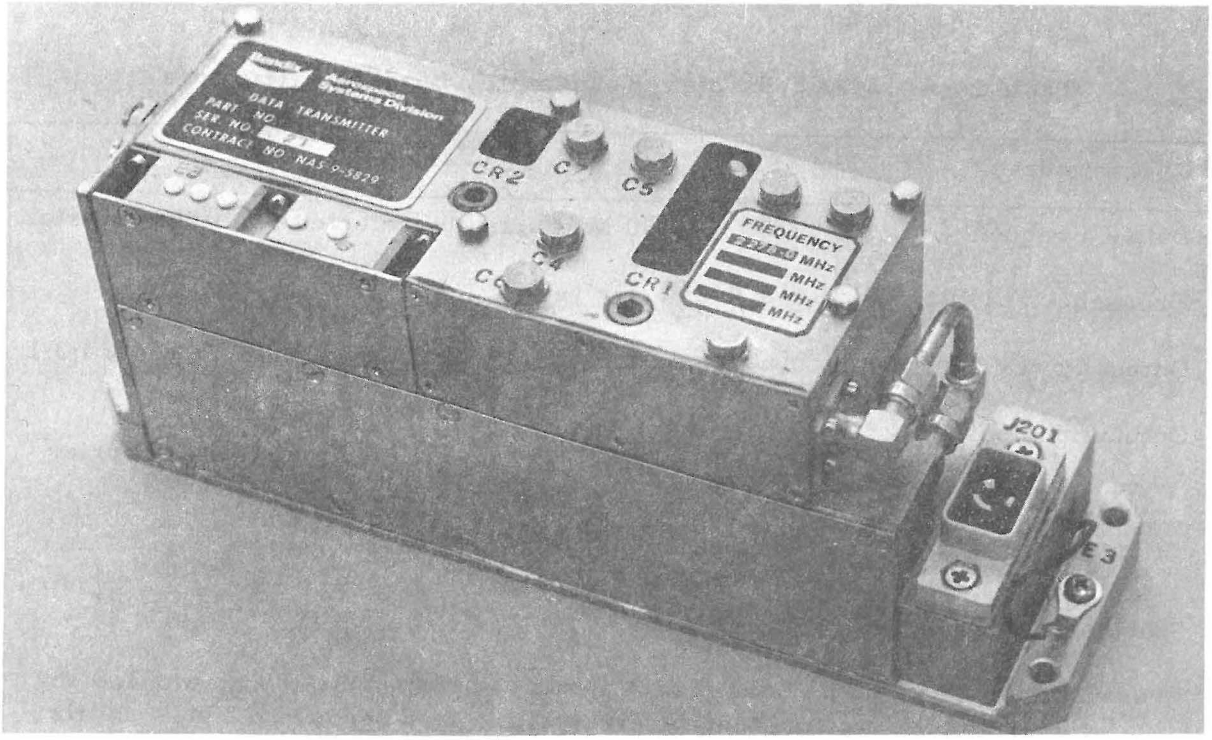


Figure 2-33. Data Subsystem Transmitter

for harmonic generation, and a tuned circuit which passes the fifth harmonic, 190 MHz. A cascode amplifier acts as a buffer between the multiplier and the phase modulator.

The phase modulator module, A4, consists of a modulator and a modulator driver. The modulator receives the 190 MHz carrier signal. Modulation of the signal takes place in a series capacitor and resistor network in which the capacitance is provided by two parallel varactor diodes. The modulator driver receives the 2.5 to 5.5 volt, 265 Hz to 10,600 KHz split-phase modulated binary data signal from the data processor, and develops a back bias across the modulator varactors. The back bias is varied at the data signal frequency to alter the capacitance of the varactors and thus cause a phase shift of the 190 MHz carrier signal. The resultant phase modulated 190 MHz carrier signal is applied through a resistive T-network to the preamplifier.

The preamplifier module, A5, is a three-stage limiting preamplifier which provides a constant drive level over a wide range of temperatures. The output is applied through a resistive T-network which is selected through test to attenuate the phase modulated carrier signal to the correct drive level for the power amplifier.

The power amplifier module, A2, provides a stage of amplification, a X2 multiplier, and two more stages of amplification. The X2 multiplier is a common-base doubler which raises the 190 MHz phase modulated carrier frequency to 380 MHz. The amplifiers raise the power of the phase modulated carrier to three watts. This module also performs 29 VDC power filtering for all modules.

Table 2-14. Data Subsystem Transmitter Leading Particulars

Characteristic	Value
Output Frequency	2275 to 2280 MHz fixed by selected oscillator crystal
Frequency Stability	± 0.0025% per year
Output Power	1 watt min into 50 ohms at a maximum VSWR of 1:3:1
Output Spurious	Frequency: 0 to 2 GHz -30 db below unmodulated carrier 2 to 2.45 GHz -80 db 2.45 to 4.60 GHz -20 db 4.60 to 10.0 GHz -40 db
Spurious A.M.	Less than 3%
Phase Noise	Less than 0.1 rad. RMS measured with a phase coherent receiver with a loop bandwidth 2 B_L = 50 Hz
Carrier Deviation	± 1.25 radians ± 5%
Modulation Drive	Binary signal +2.5 to +5.5 volt p-p
Modulation Frequency	265 Hz to 10.6 KHz binary signal
Modulator Input Impedance	Greater than 10K ohms shunted by less than 100 pf (ac coupled)
Supply Voltage	29 volts ± 2%
Supply Current	Less than 418 ma
Telemetry Outputs	a) Oscillator crystal temperature (-30 to +70°C) b) Heat sink temperature of power output stage (-30 to +70°C) c) R.F. level at power amplifier output (0.63 to 1.58 watts) d) Supply current (250 to 475 ma)
Weight	Less than 2.1 lbs
Form Factor	7.5 x 2.0 inches mounting surface x 2.8 inches high

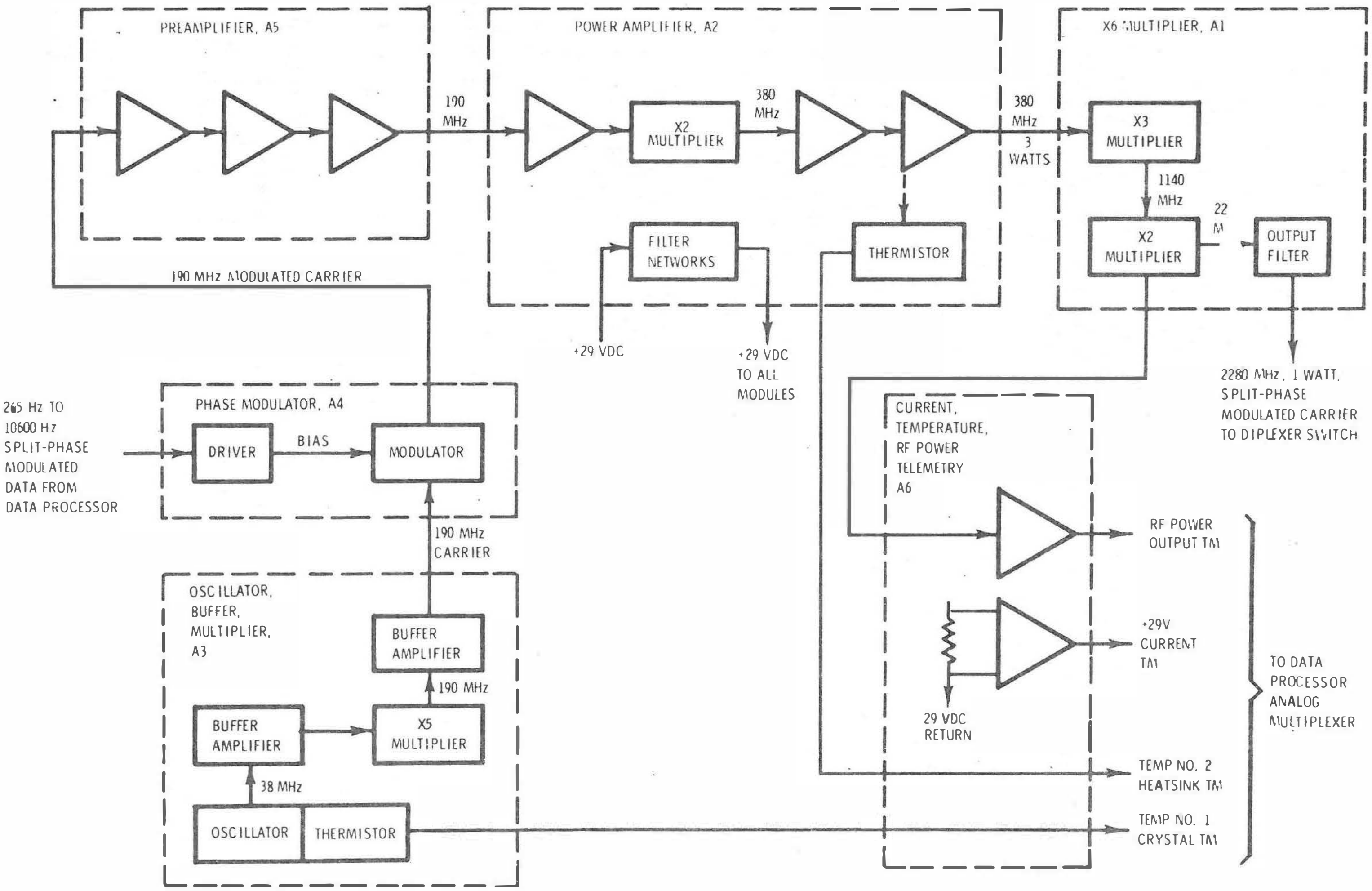


Figure 2-34. Data Subsystem Transmitter, Block Diagram

The X6 multiplier module, A1, increases the frequency of the phase modulated carrier to 2280 MHz in two stages. A coaxial cavity is tuned to the 380 MHz phase modulated carrier input from the power amplifier, and applies it to a varactor multiplier which produces many harmonics. The third harmonic, 1140 MHz, is selected by a tuned coaxial cavity and applied to a second varactor multiplier to produce harmonics. The second harmonic, 2280 MHz, is selected by a tuned coaxial cavity and fed through another tuned coaxial cavity to filter spurious harmonics. The 1-watt, 2280 MHz, split-phase modulated output is applied to the diplexer switch for downlink transmission.

The current, temperature, and RF power telemetry module, A6, circuits provide signals representative of monitored transmitter operational parameters to the analog multiplexer of the data processor for downlink telemetry. The 29 VDC operating current, the output signal power at A1, and the temperature of the crystal in A3 and the output transistor heat sink in A2 are monitored.

2-52. 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 and RTG telemetry monitor signals prior to input to the analog multiplexer for analog-to-digital conversion and subsequent data transmission to earth.

2-53. Data Subsystem Power Distribution Unit Physical Description. A PDU is shown in Figure 2-35. 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.

The amplifier board mounts the RTG temperature 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 four experiments.

The signal conditioning and logic card is comprised of 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 2-15.

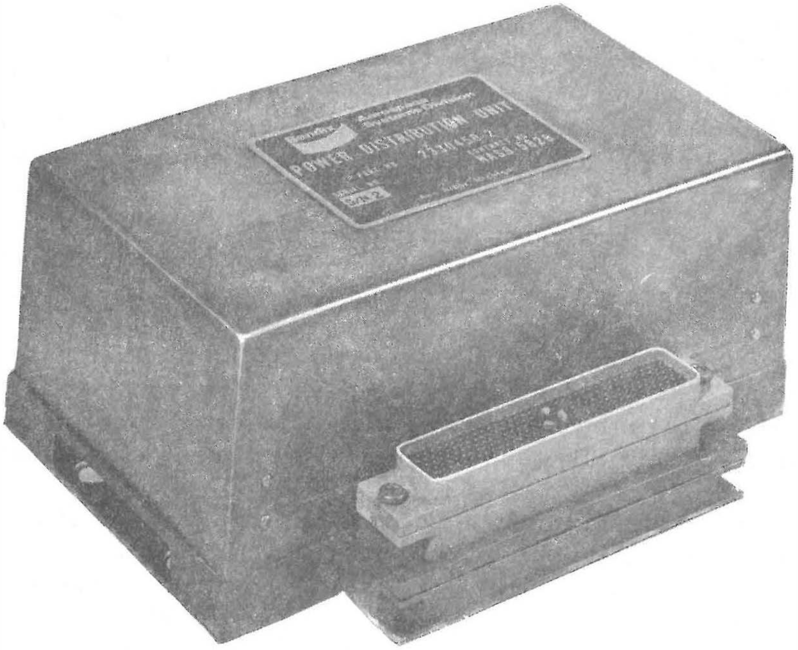


Figure 2-35. Data Subsystem Power Distribution Unit

Table 2-15. 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

2.54. Data Subsystem Power Distribution Unit Functional Description. 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 experiments and central station.

Figure 2-36 shows a block diagram of the PDU.

2-55. 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, and 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.

2-56. Temperature and Voltage Sensor Circuits - Operational amplifiers are used to amplify the resistive bridge outputs for the IPU hot and cold junction temperatures. The temperature sensors located on the RTG are platinum wire sensors. The hot junction sensor resistance is about 2771 ohms at 900°F and 3139 ohms at 1100°F for a resistance change of 368 ohms. The cold junction sensor resistance is about 1785 ohms at 400°F and 2190 ohms at 630°F for a resistance change of 405 ohms. The bridge output amplified by a gain of 14.9 for the hot junction and 10.5 for the cold junction gives a voltage swing of 5 vdc over the temperature range. Bridge excitation is 12 vdc on both the hot and cold junction temperature 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°Fto +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 sunshield temperatures. The circuit is a simple divider consisting of 12 vdc supplied through 5900 ohms and the sensor to ground. The

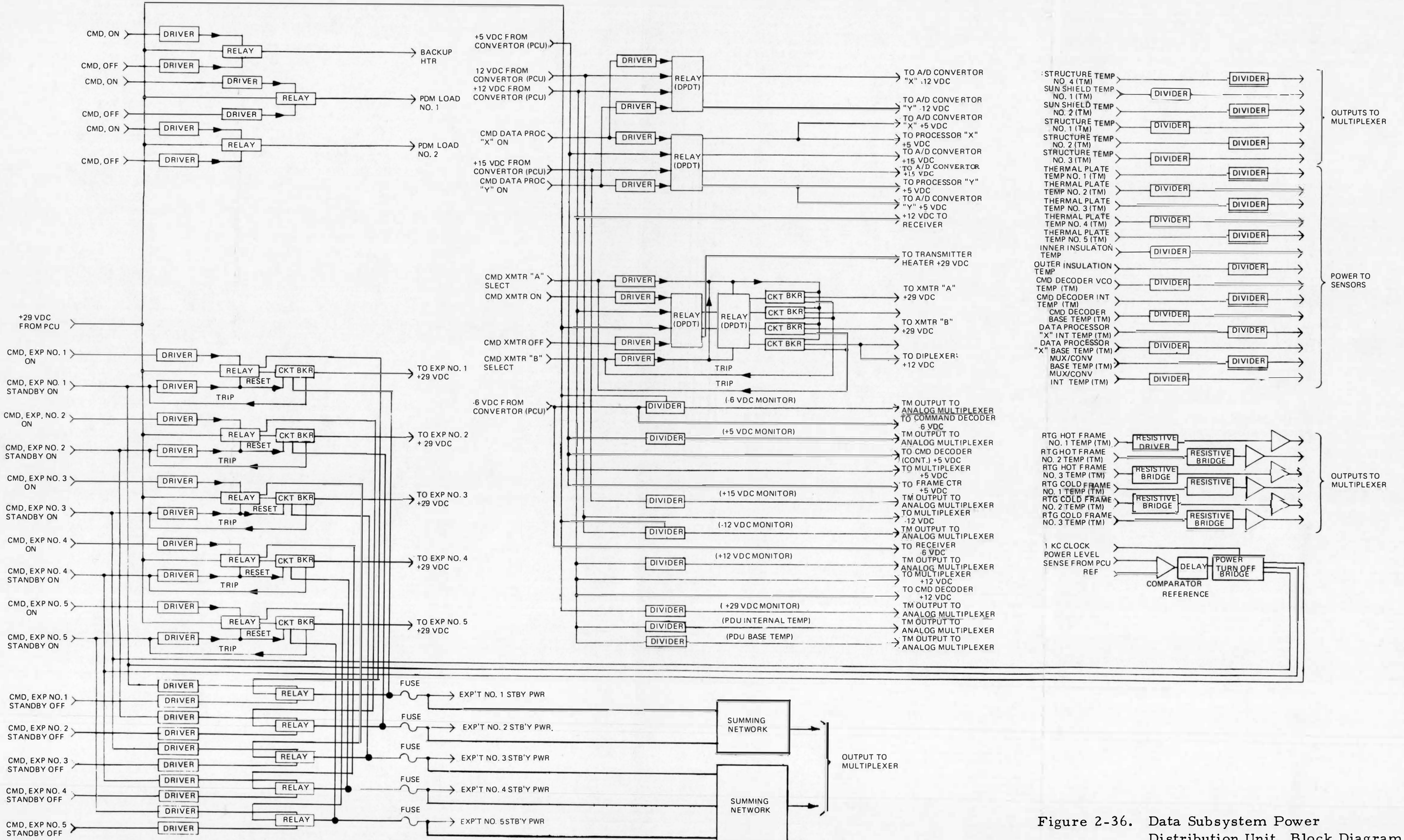


Figure 2-36. Data Subsystem Power Distribution Unit, Block Diagram

output analog signal is taken across the sensor, providing a reasonable 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.

2-57. 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 incorporated. The steering diodes provide isolation between command lines and astronaut control lines 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 2-37 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.

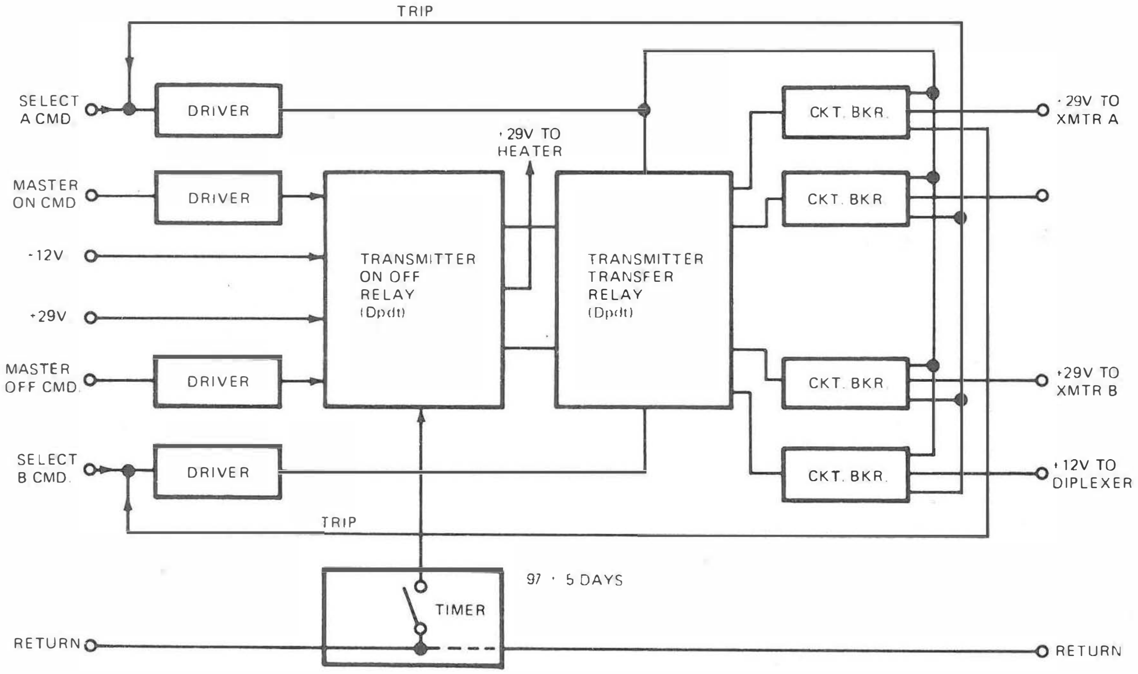


Figure 2-37. Data Subsystem Transmitter Power Control

The transmitter on and off commands operate the double-pole, double-throw relay which switches 29 vdc to the transmitter transfer relay. When the transmitter control relay is off, nominal transmitter operating power is applied to the transmitter heater which maintains thermal balance within the central station. The power line to either of two transmitters is selectable via transmitter A or transmitter B select commands as appropriate. If the 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. The 12 vdc diplexer switching power is applied only when transmitter B is selected.

A transmitter turn-on capability is provided by a manually operated backup switch which is used if an uplink cannot be established following deployment of ALSEP on the lunar surface.

For data processor power control (Figure 2-38), redundant electronics are switched using standard magnetic latching relays. These relays are controlled by standard commands. Overload protection is not provided.

Power dissipation module 1, power dissipation module 2, and the central station backup heaters are switched off and on by ground command only.

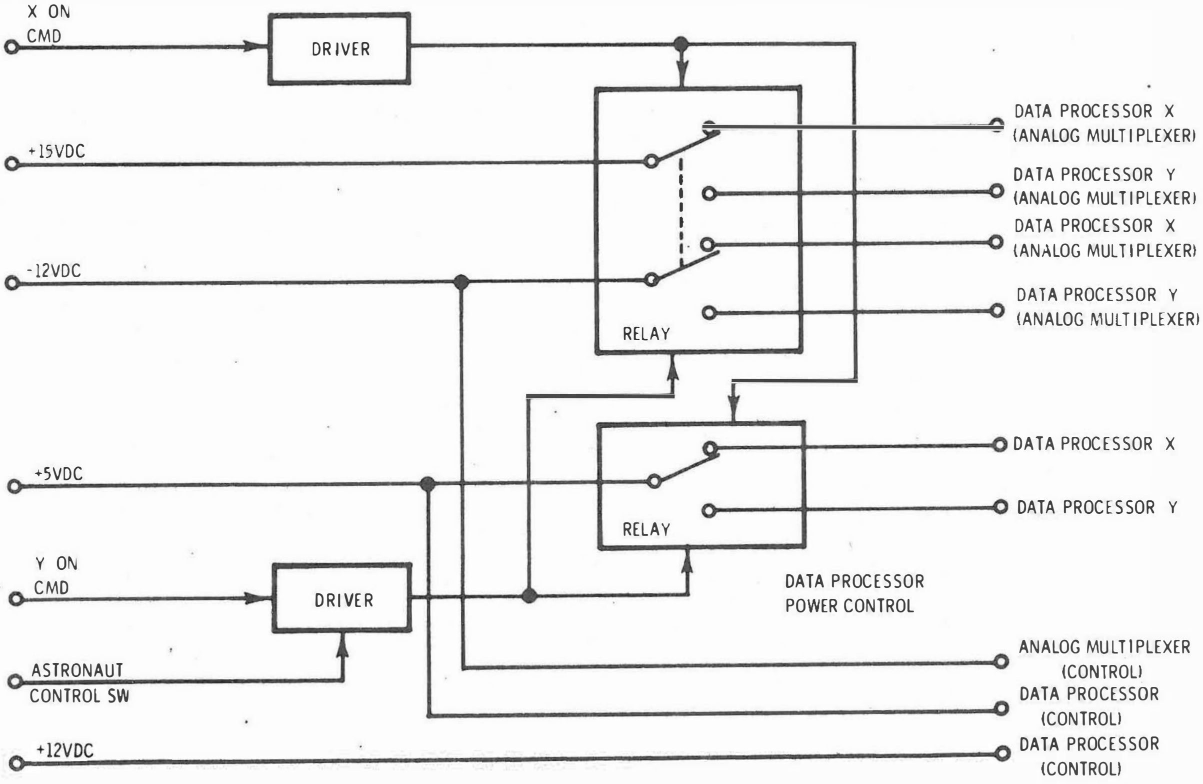


Figure 2-38. Data Processor Power Control

2-58. PASSIVE SEISMIC EXPERIMENT (PSE) SUBSYSTEM

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 changes in the vertical component of gravitational acceleration.

Analyses 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 Hertz) of the PSE seismic signal spectrum, motion of the lunar surface caused by seismic activity will 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 Hertz) of the PSE seismic signal spectrum, vertical motion of the lunar surface caused by seismic activity will 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 amplitude of low frequency seismic motion and is referred to as the seismic output. The secondary output is proportional to the very low frequency accelerations and is referred to as the tidal output. The tidal 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 ALSEP 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 ALSEP 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 ALSEP data subsystem, multiplexed into the ALSEP 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 ALSEP data subsystem.

2-59. PSE PHYSICAL DESCRIPTION

The PSE (Figure 2-39) is composed of four major physical components. The sensor assembly, leveling stool, and thermal shroud are all deployed together by the astronaut on the lunar surface. A separate electronics assembly is located in the ALSEP central station, and provides the electrical interface with the central station.

2-60. 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 base of the cylinder is hemispherical to permit rough leveling of the sensor upon the leveling stool during deployment by the astronaut. 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 seismometers are mounted.

The LP seismometer comprises three orthogonally oriented, capacitance type seismic sensors: two horizontal axes and one vertical axis. Each of the LP horizontal sensors comprises 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 axis 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 to the degree required by leveling the entire assembly.

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 deployment, 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 ALSEP central station. In the sensor, four printed circuit board subassemblies are mounted in the base, surrounding the SP

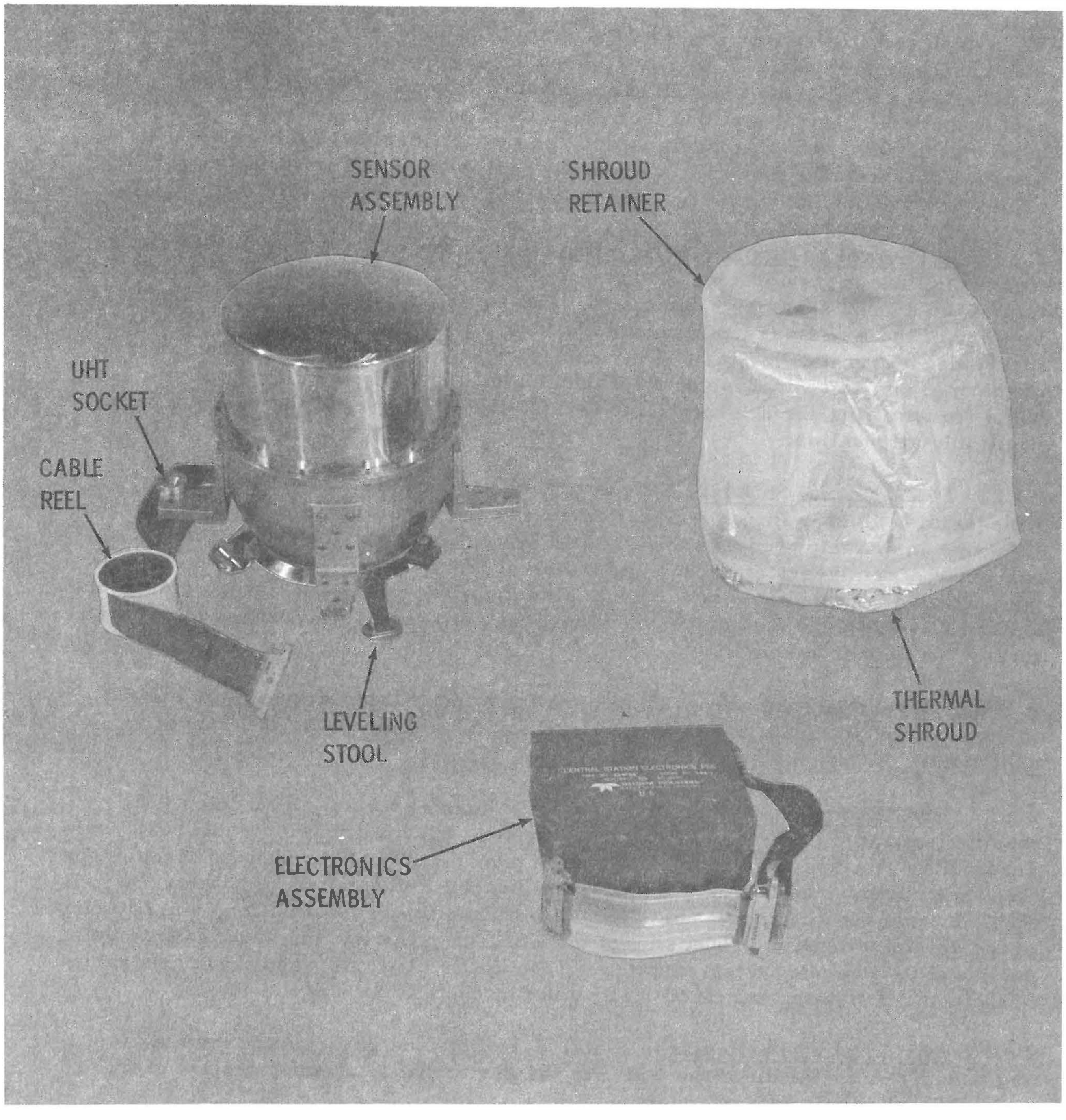


Figure 2-39. Passive Seismic Experiment Subsystem

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.

When deployed, the sensor assembly is seated in the leveling stool and covered with the thermal shroud. A pair of 10-foot, 27-conductor (copper), flat, Kapton-coated, tape cables from the PSE are connected to a pair of 9-inch maganin ribbon cables from the central station electronics (CSE) providing electrical connections between the two units. Manganin is used on the CSE cables to minimize heat losses from the ALSEP central station. A reel mechanism on the 10-foot PSE cables provides compact stowage while on ALSEP subpackage No. 1.

2-61. PSE Leveling Stool. The leveling stool is a short tripod with three thermal insulators on its upper end. These insulators, together with the rounded bottom of the sensor assembly, form a ball and socket joint which permits manual leveling of the sensor assembly to be accomplished by a single astronaut to within five degrees of the vertical. The insulators also provide the required degree of thermal and electrical isolation of the sensor assembly from the lunar surface, while transmitting surface motion up to 26.5 Hz, or more, to the sensors with negligible attenuation.

2-62. PSE Thermal Shroud. The thermal shroud has the shape of a flat-crowned, wide-brimmed hat. The crown portion covers the sensor, while the brim portion (five feet in diameter) covers the adjacent lunar surface. The crown and brim are made of ten layers of aluminized mylar separated by alternate layers of silk cord which are wound on a perforated, aluminum support. The shroud covers the sensor assembly and the adjacent lunar surface, to aid in stabilizing the temperature of the sensor assembly.

A bubble level and a sun compass are provided on the top surface of the shroud for use by the astronaut in leveling and azimuthal alignment of the sensor assembly.

2-63. PSE Electronics Assembly. The PSE central station electronics (CSE) module is located in the ALSEP 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.

2-64. PSE Leading Particulars. Table 2-16 lists the physical characteristics and power requirements of the PSE and the performance characteristics of the eight PSE scientific data channels.

Table 2-16. PSE Leading Particulars

Characteristic	Value	
Physical Data		
Sensor Assembly, including Leveling Stool and Thermal Shroud (stowed configuration):		
Height	15.25 inches	
Diameter	11.75 inches	
Weight	20.9 lbs	
Sensor	18.3 lbs	
Thermal Shroud	2.4 lbs	
Leveling Stool	0.2 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	2.40 watts	
Level System	3.10 watts	
Functional Power and Heater	6.70 watts	
Functional Power and Level	7.20 watts	
Voltage	29.0 ± 0.58 vdc	
Scientific Data Signal Characteristics		
Minimum Detectable Signal:	Max. Requirement	Design Goal
SP and all LP seismic signals	10 mμ	1.0 mμ
LP tidal output signals:		
LPH (Horizontal)	0.4 arc-sec.	0.01 arc-sec.
LPV (Vertical)	320 μgal	8.0 μgal
Sensor assembly temperature	±10°C	±0.02°
Sensitivity at Maximum Gain:		
SP and all LP seismic signals	5.0 v/μ	
LP tidal output signals:		
LPH	0.5 v/arc-sec.	
LPV	0.625 v/mgal	
Sensor assembly temperature	0.25 v/°C	
Frequency Response:		
SP seismic signal	-40 db @0.038 sec.	
(0db = 5 v/μ, maximum gain)	+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	

Table 2-16. PSE Leading Particulars (cont)

Characteristic	Value	
Scientific Data Signal Characteristics		
Dynamic Range:	Analog	Digital
SP and all LP seismic signals	80 db	60 db
All tidal signals	60 db	60 db
Temperature	60 db	60 db
All LP seismic signals (0db = 0.5v/μ, feedback factor = -33.1db, post-amplified gain =1)	-60db @ 0.3 sec. + 48db/oct. 0.3 to 0.7 sec. 0db 0.7 to 15 sec. -12db/oct. 15 to 100 sec. -18db/oct. 150 to 250 sec. -60db @ 250 sec.	
All LP tidal output signals	-74db @ 1.2 sec. + 6db/oct. 1.2 to 15 sec. - 52db @ 15 sec. - 6db/oct. 15 to 150 sec. - 72db @ 150 sec. -12db/oct. 150 to 750 sec. -100db @ 750 sec.	
Sensor assembly temperature	107 - 143°F ± 1%	

μ = micron
mμ = millimicron
v/μ = volts per micron
μgal = microgal
mgal = milligal

The microgal and milligal are subdivisions of the gal, a geophysical unit of measure of acceleration in the cgs system. One gal equals an acceleration of 1 cm/sec/sec.

2-65. 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, leveling, and power functions (Figure 2-40).

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 of the seismometers
d. Sensor assembly heater
e. Uncaging of the seismometers

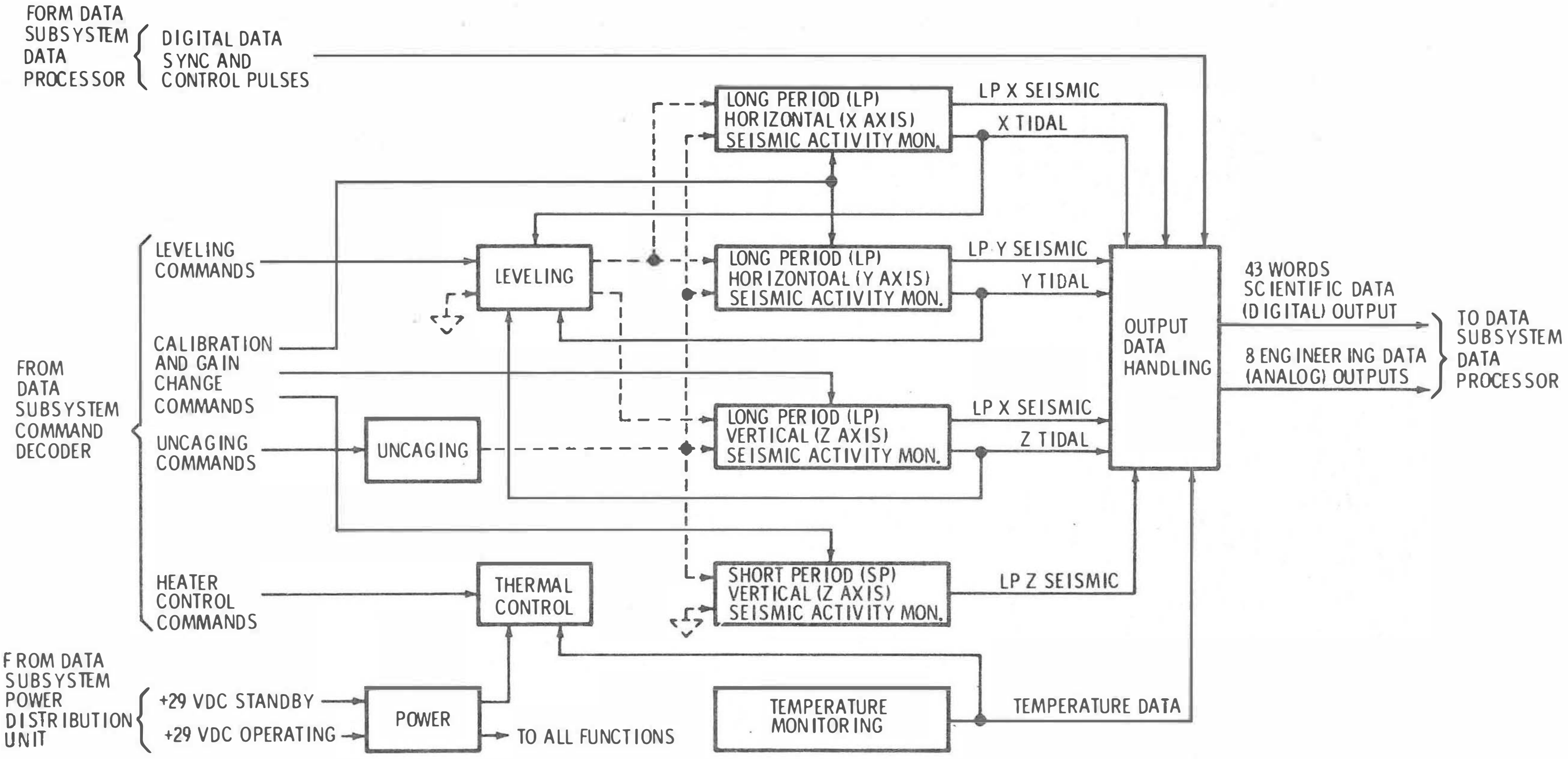


Figure 2-40. Passive Seismic Experiment, Functional Block Diagram

The commands are discrete (on-off or sequential stepping) and are transmitted from MSFN stations on the Earth, through the ALSEP data subsystem. A discussion of these commands and their basic functions is provided in paragraph 2-68.

2-66. 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 to accomplish its primary function of detecting 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 acceleration 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 ALSEP data subsystem as seven of the eight PSE scientific data output signals.

The relative positions of the LP sensors vary 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 ALSEP data subsystem. It is also applied to the sensor assembly heater control circuits.

2-67. 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.

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 ALSEP data processor into the 43 assigned spaces in each of the 64-word ALSEP telemetry word frames. Synchronization and control pulses which control the formatting and readout of the digital data, are received from the ALSEP 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 ALSEP data processor/multiplexer. The data are inserted into housekeeping word number 33 of each of the eight ALSEP telemetry word frames assigned for transmission of this data.

The LP seismometer sensors must be leveled before they can be used to produce useful data. 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 or central station timer commands. Breaking the pressure seal allows the caging system gas to escape, deflating the bellows, releasing the caging pins, and unlocking the inertial masses.

The ALSEP 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 ALSEP +29 vdc operating power into the various voltages required in the PSE circuits, as described in paragraph 2-78.

2-68. PSE Command Functions. 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 leveling motor power (for each axis) during leveling of the LP sensors; control of the sensor assembly heater operating mode; and arming and uncaging the seismometers. A total of 15 commands are used for these purposes. The commands are channeled over 15 separate command lines connecting the ALSEP 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 ALSEP command decoder on the appropriate command line to the PSE. Each of the 15 incoming ALSEP 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 ALSEP 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 insures 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 2-17.

All of the 15 command logic circuits are composed 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 ALSEP operating power.

Table 2-17. 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 2-17. 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

2-69. 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, 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.

2-70. 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.

2-71. PSE Long Period (LP) Channels - Each LP sensor channel (Figure 2-41) 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 (see paragraph 2-76).

Lateral displacement of the horizontal sensor is controlled both by restoring force 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.

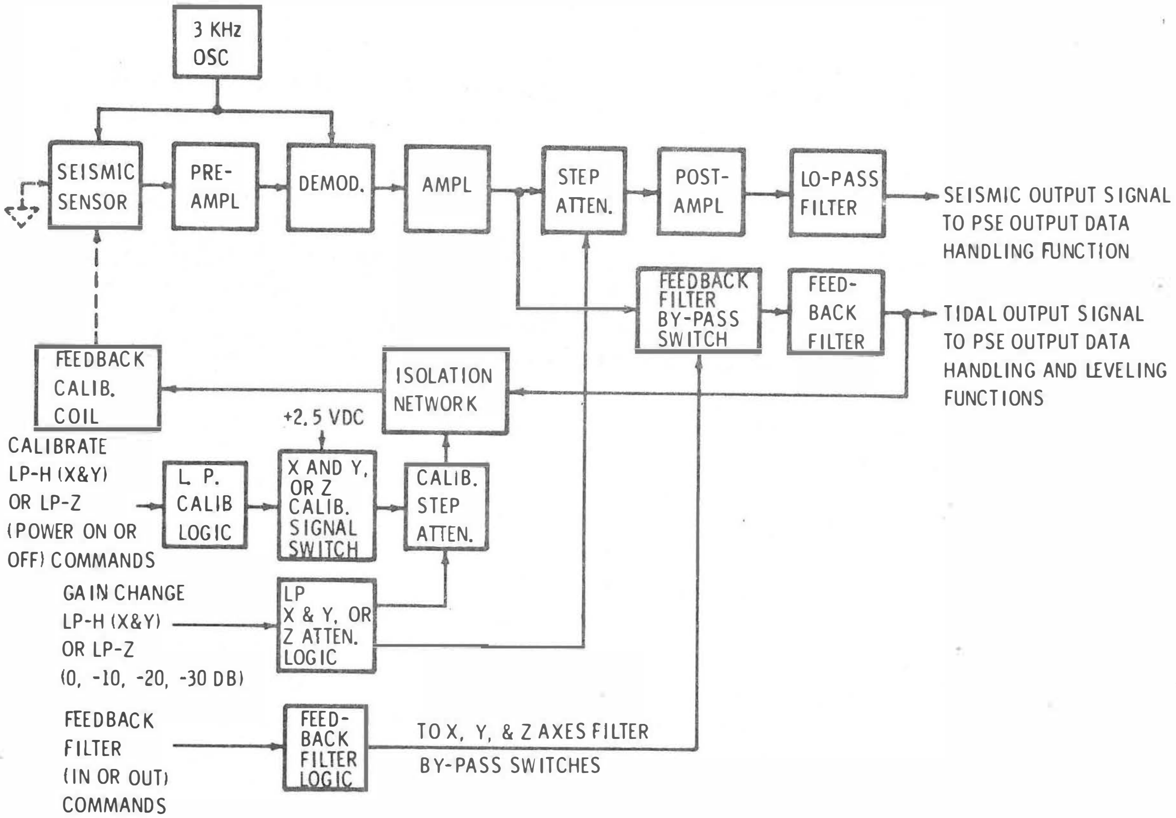


Figure 2-41. PSE Long Period Seismic Activity Monitoring Function, Block Diagram

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 one Hertz. 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 (manual 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

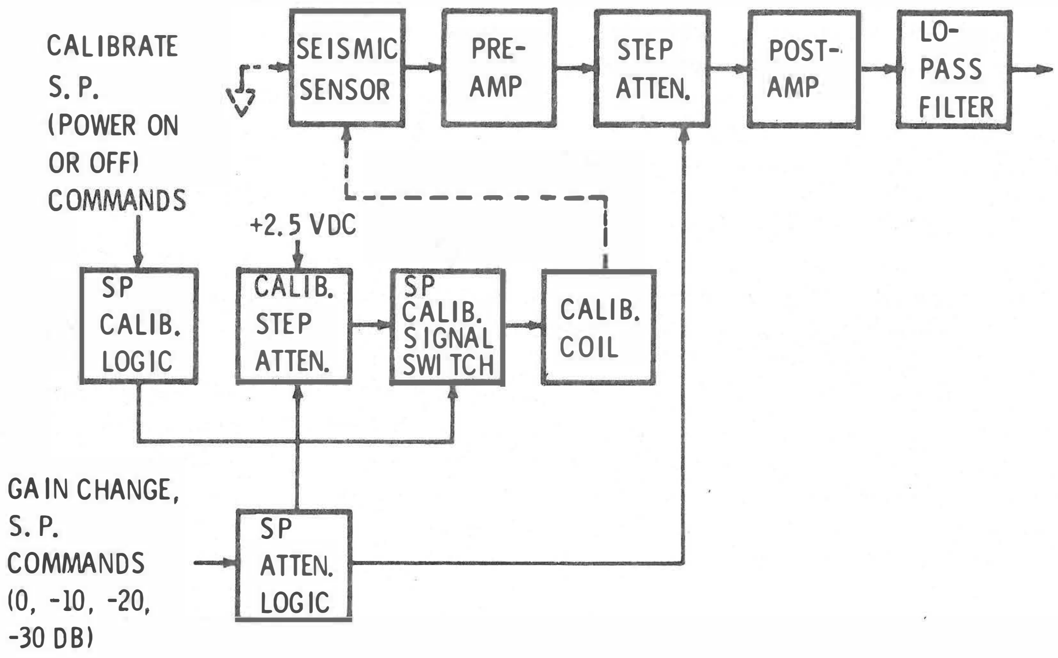


Figure 2-42. PSE Short Period Seismic Activity Monitoring Function, Block Diagram

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.

2-72. PSE Short Period (SP) Channel - The SP channel (Figure 2-42 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.

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 vertically mounted coil mounted 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 ALSEP 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.

2-73. 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. 2°F 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.

2-74. PSE Supporting Functions. The supporting functions comprise data handling, uncaging, leveling, thermal control, and power functions.

2-75 PSE Data Handling - The output data handling function circuits (Figure 2-43) 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 ALSEP telemetry frames in one cycle, and the combining of 11 analog status signals into eight analog channels for insertion into housekeeping word number 33 of each of eight ALSEP 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 provide timing and control pulses to the other subfunctions. It is the interface between the PSE data handling circuits and the ALSEP data subsystem. The buffer amplifiers terminate the input and output lines to and from the ALSEP 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 ALSEP 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 the short period seismic signal a total of 29 word-times in each ALSEP telemetry frame. The three long period seismic signals are each sampled four word-times in each ALSEP 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 ALSEP telemetry frame. Each data word consists of 10 NRZ bits. A listing of PSE telemetry word assignments is given in Table 2-18 and in the Appendix. PSE data word locations in the ALSEP telemetry frame are shown in Figure 2-44. The normal ALSEP bit repetition rate is 1060 bps. Under difficult telemetry communications conditions, the slow ALSEP bit rate, which is half the normal rate, may be used.

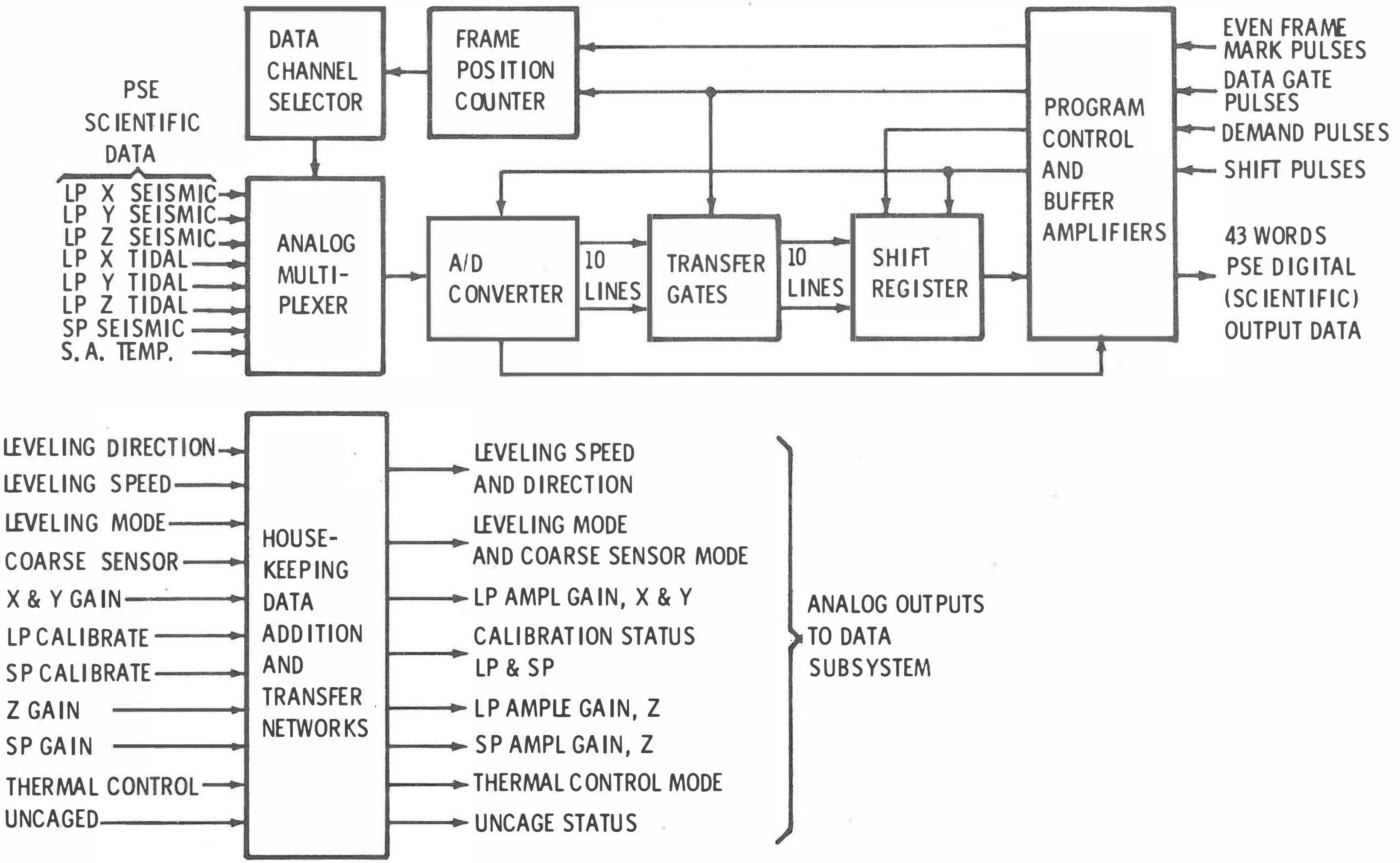


Figure 2-43. PSE Data Handling Function, Block Diagram

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 ALSEP 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 2-44. PSE Data Word Assignments in ALSEP Telemetry Frame

The housekeeping data addition and transfer networks combine 11 status signals into eight channels and transfer these analog data to the ALSEP 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 2-18 along with the telemetry frame in which they are transmitted in housekeeping word number 33.

Table 2-18. PSE Measurements

PSE Measurement Name	Symbol	ALSEP 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 word except 2, 46, and 56 (29 words per frame)	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

Both synchronization and data control pulses are received from the ALSEP data processor for controlling the PSE output data handling functions. Even frame mark, data gate, and shift pulses are provided by the ALSEP data processor to synchronize and control the formatting of the PSE data into 10-bit words compatible with ALSEP 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.

2-76. PSE Uncaging and Leveling - Uncaging and leveling are separate, but related functions (Figure 2-45) which are grouped together in this description for the purpose of discussion. Uncaging must be performed after deployment before 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.

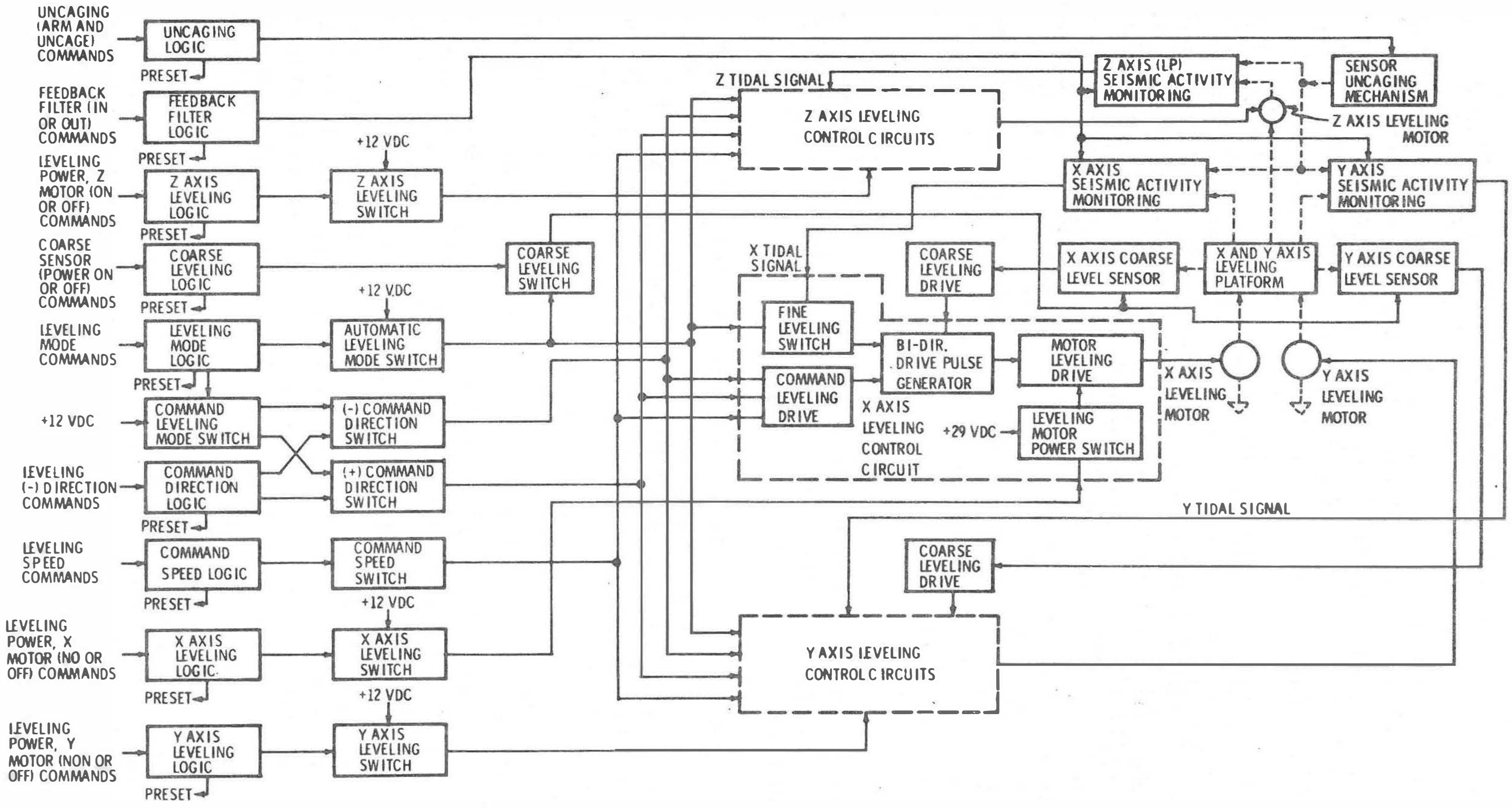


Figure 2-45. PSE Uncaging and Leveling Function, Block Diagram

Both LP and SP 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 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 composed of a capacitive-discharge circuit, piston actuator, 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 "armed", 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 the caging bellows. The bellows are collapsed, withdrawing the locking pins from the 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 a motor drive (Figure 2-45).

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 2-45 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 2-45. These circuits comprise logic circuits controlling the feedback filter bypass switches of each axis, power to the leveling motors of each axis, 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 2-45. 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 2-45 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.

2-77. PSE Thermal Control - The thermal control function circuits (Figure 2-46) 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.

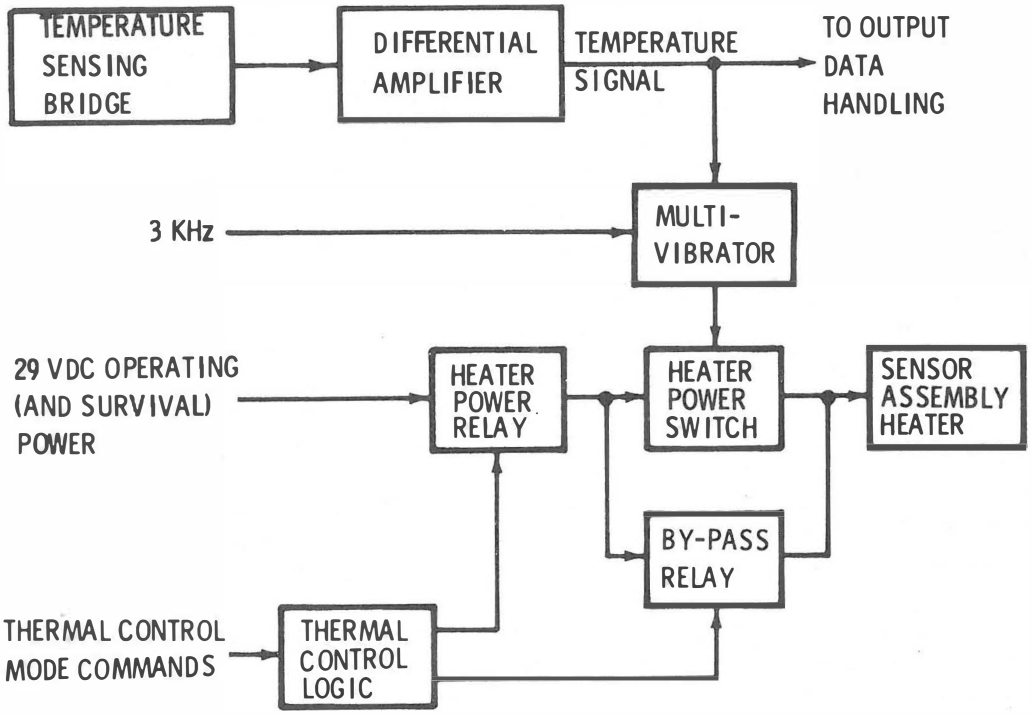


Figure 2-46. PSE Thermal Control Function, Block Diagram

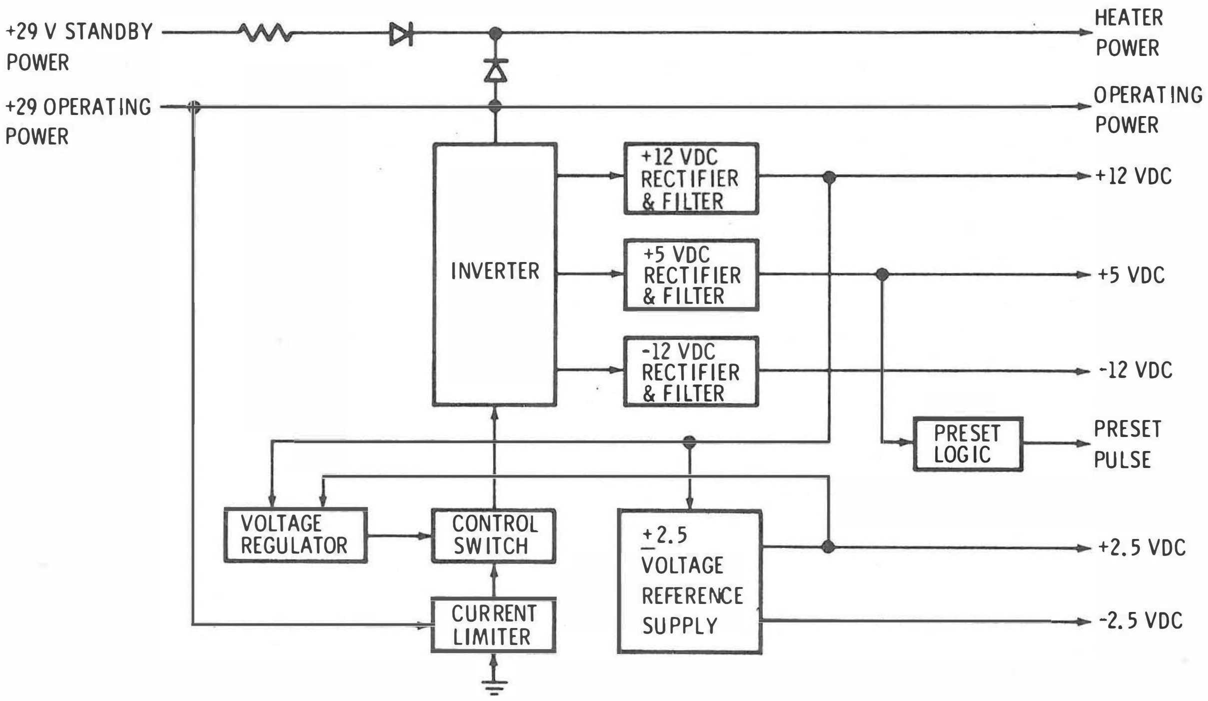


Figure 2-47. PSE Power Converter Function, Block Diagram

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 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.

2-78. PSE Power Converter - The power converter (Figure 2-47) converts ALSEP +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 ALSEP 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.

2-79. ACTIVE SEISMIC EXPERIMENT (ASE) SUBSYSTEM

The primary function of the active seismic experiment (ASE) is to generate and monitor artificial seismic waves in the 3 to 250 Hz range, in the lunar surface and near subsurface. The ASE can also be used to monitor natural seismic waves in the same frequency range. The objective of these functions is to acquire information to enable determination of the physical properties of lunar surface and near subsurface materials.

Seismic waves will be artificially produced by explosive devices, and detected by geophones. The resulting data will be telemetered to Earth for study and interpretation. By varying the location and magnitude of the explosions with respect to the geophones, penetration of the seismic waves to depths of approximately 1, 500 feet can be achieved, and wave velocities through several layers of subsurface materials investigated. The velocities of compressional waves, their frequency spectra, and rate of attenuation are functions of the physical constants of the near surface lunar material. Interpretation of this data permits the type and character of the lunar material to be inferred, as well as the degree of induration and bearing strength of these materials. This information is desirable for understanding the nature and origin of these materials.

Two seismic energy sources will be employed. A thumper device containing 21 explosive initiators will be fired along the geophone lines by the astronaut. The astronaut will also emplace a mortar package containing four high explosive grenades. The grenades will be rocket-launched by Earth command near the end of the ALSEP mission (about one year after deployment) and are designed to impact at four different ranges; approximately 500, 1000, 3000 and 5000 feet, with individual high explosive charges proportional to their range.

The seismic detectors are three identical geophones. The geophones are electromagnetic transducers which translate high frequency seismic energy into electrical signals. The outputs of the three geophones are applied to separate logarithmic compression amplifiers to obtain maximum dynamic range and maximum sensitivity.

The ASE uses seven commands transmitted from the MSFN to arm and fire the grenades and to effect geophone calibration. Other commands are used to effect power distribution to the ASE from the data subsystem and to place the data subsystem in the active seismic mode. The three channels of seismic data generated by the ASE and 13 channels of engineering data will be converted to digital form within the experiment for transmission to Earth. A 20-bit digital word format and a 10, 600 bit/sec data rate will be used in the ASE to ensure accurate encoding and transmission of critical real time event data, and to provide a relatively high frequency seismic data handling capability. The higher bit rate and longer word length are incompatible with the normal ALSEP format and preclude usual data collection from the other experiments during the time the ASE is activated.

There are five significant measurements from the ALSEP electrical power subsystem included in the ASE telemetry format as engineering data. The ASE formats and applies the seismic and engineering data to the data subsystem modulator for modulation and downlink transmission.

2-80. ASE PHYSICAL DESCRIPTION

The ASE comprises the thumper-geophone assembly, mortar package, central electronics assembly, and interconnecting cabling. Figure 2-48 illustrates the ASE components. A mortar package pallet assembly provides deployment alignment and stability as described in Section IV.

2-81. ASE Thumper-Geophone Assembly. The thumper comprises a short handle or staff with an initiator mounting plate and a base plate at the lower end. The upper end contains a pair of switches (ARM/FIRE and ASI Select) and associated electronics. A flat, four-conductor cable connects the thumper to the central station.

The initiator mounting plate contains 21 Apollo standard initiators (ASI) mounted perpendicular to the base plate and a pressure switch to detect the instant of initiation. Two ASIs (nos. 20 and 21) will be test-fired at KSC prior to stowage for flight, leaving 19 ASIs for lunar operation.

The four-conductor cable connecting the thumper and central station electronics is stored on a split spool on the upper end of the thumper handle, above the switches, during the flight phase and is unwound by the astronaut during deployment.

The thumper also stores the three geophones and connecting cables until deployed. The cables are wound on a reel located just above the initiator mounting plate. The geophones are mounted in individual holes in the reel.

2-82. ASE Geophones. The three geophones are electromagnetic devices which translate physical surface or subsurface movement into electrical signals. The amplitude of the output signals is proportional to the rate of physical motion. The geophones are connected to the central station by cables, and will be deployed at specified intervals as described in Section IV. The cables and geophones are stored on the thumper during transport and removed during deployment. The geophones are identical except that geophone no. 1 contains a temperature sensor.

2-83. ASE Mortar Package. The mortar package assembly (MPA) consists of a mortar box assembly, a grenade launch tube assembly (GLA), and interconnecting cables.

The mortar package is deployed at an angle approximately 45° to the lunar surface to provide an optimum launch angle for the grenades. It is attached to a pallet assembly to provide positive stability during rocket launching. The bottom of the thermal insulation bag is fragile and is disintegrated when the rockets are launched to provide open launch tubes which minimize the recoil from the grenade launchings.

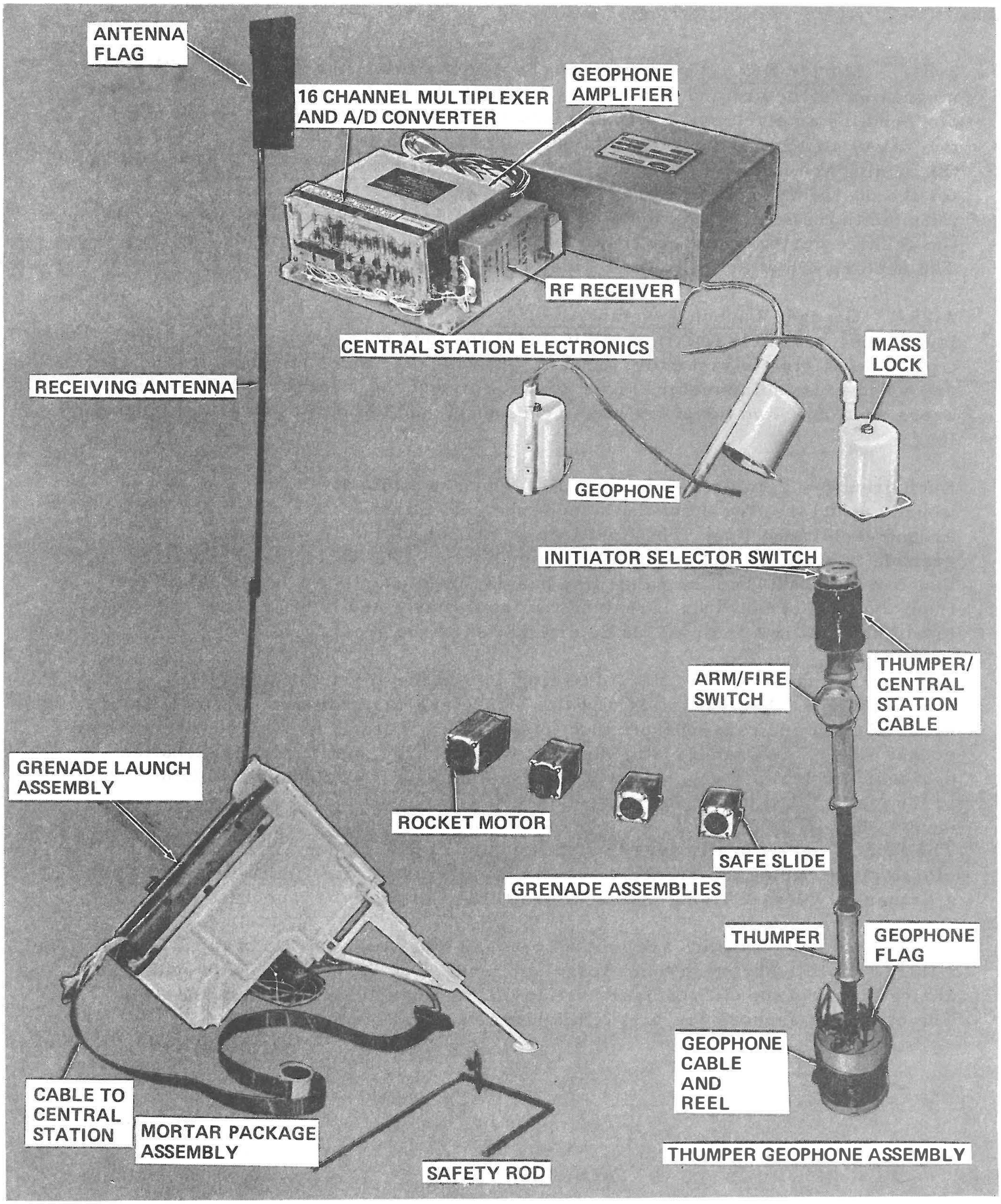


Figure 2-48. Active Seismic Experiment (ASE) Subsystem

2-84. Mortar Box. The mortar box is a rectangular fiberglass box with a magnesium structure and folding legs in which the GLA is mounted. The mortar box contains an electronics printed circuit board assembly, a receiving antenna, two safety switches, and a thermal bag. The electronics contain circuitry for the arming and firing of the rocket motors launching the four grenades, and also for the operation of the heaters. The receiver antenna is a vertical antenna mounted to the side of the mortar box. The antenna is folded along the edge of the package during transport and unfolded by the astronaut during deployment. The heaters are attached to the inside of the thermal bag.

2-85. Grenade Launch Assembly (GLA). The GLA consists of a fiberglass launch tube assembly (LTA) which includes the four rocket-launched grenades, a grenade safety pin assembly, three microswitches, three temperature sensors, and a two-axis inclinometer. Each of the four launch tubes has a three-inch cross section. Two tubes are nine inches long, and the other two are six inches long.

Each grenade is attached to a range line which is a thin stranded cable that is wound around the outside of the launch tube. Two fine copper wires are looped around each range line. The first loop is spaced so that it will break when the grenade is about 16 inches out of the launch tube. The second loop is spaced so that it will break when the range line has deployed exactly an additional 25 feet from the first breakwire. Breaking the loops starts and stops a range gate pulse establishing a time interval for determination of the greande velocity.

The four grenades are similar, differing only in the amount of propellant and high explosive. Each consists of a thin fiberglass casing with a 2.7-inch square cross section and ranging from four to six inches long. The casing contains the rocket motor, safe slide plate, high explosive charge, ignition and detonation devices, thermal battery, and a 30 MHz transmitter. The range line is attached to the transmitter output and serves as a half wave end fed antenna.

The launch tubes for grenades two, three, and four each contain a microswitch closed by launching the grenade. Each switch connects the firing command from a sequential grenade firing circuit to the next grenade to be launched.

Two temperature sensors are located between tubes one and two of the LTA and a third is located between tubes three and four. One of the sensors provides an analog signal of the GLA temperature to the data handling function of the ASE. The other two sensors are part of the heater control circuitry.

The two-axis inclinometer provides pitch and roll angle (deviation from the vertical) information on the mortar package. The analog outputs from the angle transducers are applied to the data handling function of the ASE.

2-86. Interconnecting Cables. A coaxial cable connects the antenna on the mortar box and the central station electronics. A 20-conductor flat tape cable connects the mortar package electronics and the electronics in the central station providing the necessary power and signal paths.

2-87. ASE Central (Station) Electronics. The central electronics assembly is located in the central station and contains circuits for power control, temperature sensing, calibration, signal conditioning and data handling. Included as sub-assemblies are the geophone amplifier, the ASE receiver, and the A/D converter and multiplexer.

2-88. ASE Leading Particulars. Table 2-19 ASE Leading Particulars lists the size, weight, frequency response, and power requirements for the ASE components and assemblies.

Table 2-19. ASE Leading Particulars

Characteristic	Value
Physical Data	
Thumper-Geophone Assembly	
Length (folded)	14.5 inches
Weight	7.59 pounds
Thumper	
Length (deployed)	44.5 inches
Weight (including cables and initiators)	4.64 pounds
Geophones	
Height (including spike)	4.80 inches
Diameter	1.66 inches
Weight (three geophones with cables)	2.95 pounds
Mortar Package	
Dimensions Envelope (Same as mortar box below)	
Weight	14.95 pounds
Mortar Box	
Height	11.5 inches
Width	6.0 inches
Length	15.25 inches
Weight (including antenna and cables)	4.34 pounds

Table 2-19. ASE Leading Particulars (cont)

Characteristics	Value
Physical Data (Cont.)	
Grenade Launch Assembly	
Width	9.0 inches
Length	13.7 inches
Depth	6.23 inches
Weight (including grenades)	10.88 pounds
Grenades	
Cross Section	2.7 inches
Length	4 to 6 inches
Weight (#1=2.67, #2=2.19, #3=1.70, #4=1.52)	8.08 pounds
Central Electronics Assembly	
Height	2.75 inches
Width	6.18 inches
Length	6.77 inches
Weight	3.22 inches
Frequency Response	
Seismic Detection System (to the mean of 10 to 100 Hz response characteristic)	
3.0 to 10 Hz	+1 db, -6 db
10 to 100 Hz	±3 db
100 to 250 Hz	±6 db
250 to 450 Hz	Less than +1 db
450 to 500 Hz	Less than -35 db
Above 500 Hz	Less than -40 db
System Power Requirements	
Voltages	
ASE activated	+29, +15, -12, and +5 vdc
ASE deactivated	+29 vdc
Power	8.0 watts (maximum)
Operational	6.0 watts (nominal)
Thermal control (Standby)	3.00 watts

2-89. ASE FUNCTIONAL DESCRIPTION

The ASE has three basic operating modes related directly to the seismic energy source under investigation: the thumper mode which is activated with the astronaut still on the lunar surface; the passive listening mode which is used to measure natural seismic phenomena during the period of the ALSEP mission on the Moon; and the mortar mode which is activated near the completion of the ALSEP mission.

2-90. ASE Thumper Mode. In the thumper mode, the thumper is used to fire an Apollo Standard Initiator (ASI) at each marked interval as the astronaut returns to the central station along the geophone cable. The instant of ASI initiation is detected and telemetered as a real time event. Compression waves generated in the lunar surface and near surface material are detected by the geophones, and comparison of initiation instant and wave detection times permits determination of the wave velocity.

2-91. ASE Mortar Mode. In the mortar mode, four rocket-grenades are individually launched from the mortar package by commands from Earth. The pitch and roll angles of the mortar package are measured to determine the launch angle of the grenade. Range line breakwire circuits provide launch velocity data. A radio transmitter in the grenade, activated at launch and destroyed on impact, furnishes time of flight and instant of explosion data. Impact point of the grenade and seismic wave velocity may be determined from the above data which are telemetered as real time events.

2-92. ASE Passive Listening Mode. In the passive listening mode, the seismic detection system monitors natural seismic activity generated by tectonic disturbances or meteoroid impacts. The ALSEP data subsystem must be operating in the active seismic mode to accept and process these signals for downlink transmission.

2-93. ASE DETAILED FUNCTIONAL DESCRIPTION

The major functions of the ASE include seismic signal generation, seismic wave detection, timing and control, data handling and power control. Figure 2-49 illustrates the ASE functions. The action and interaction of these functions are discussed in the following paragraphs.

2-94. ASE Seismic Signal Generation. Seismic waves will be artificially generated using two methods. The thumper initiators and the greande high explosives will provide the energy for seismic wave generation. The thumper will be operated by the astronaut while still on the lunar surface. Some time (approximately one year) after the astronauts leave the Moon, the ASE grenades will be launched by commands from Earth. Figure 2-50 illustrates the seismic signal generation function. The astronaut will deploy the ASE in the locations specified in Section IV.

The astronaut will walk in the prescribed geophone deployment direction, unwinding the geophone cable from the thumper, and implant the geophones at the prescribed distances. The thumper power and signal cable will also be unwound as the astronaut deploys the geophones. When the geophones have been implanted, the astronaut will return along the geophone line stopping at marked intervals (approximately every 15 feet) to activate the thumper. The thumper contains 19 Apollo standard initiators (ASI) which are individually selected and fired by activation of the selector switch and the arm/fire switch on the upper portion of the thumper. The indexed selector switch permits the astronaut to select the

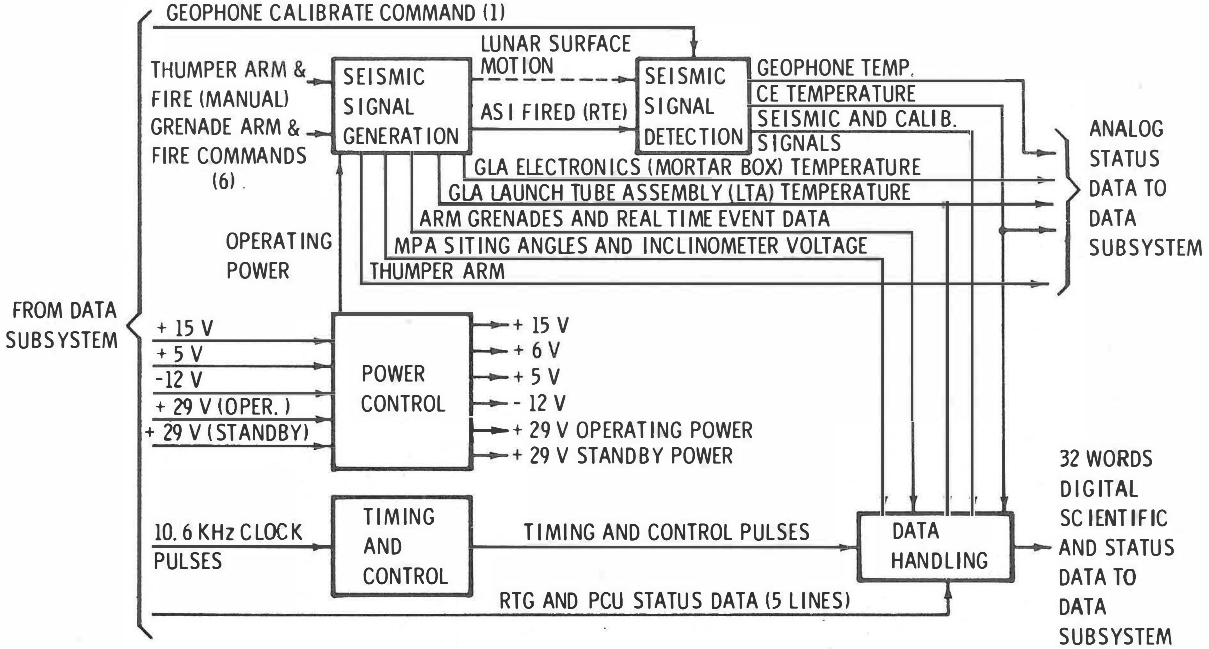


Figure 2-49. Active Seismic Experiment (ASE) Subsystem, Functional Block Diagram

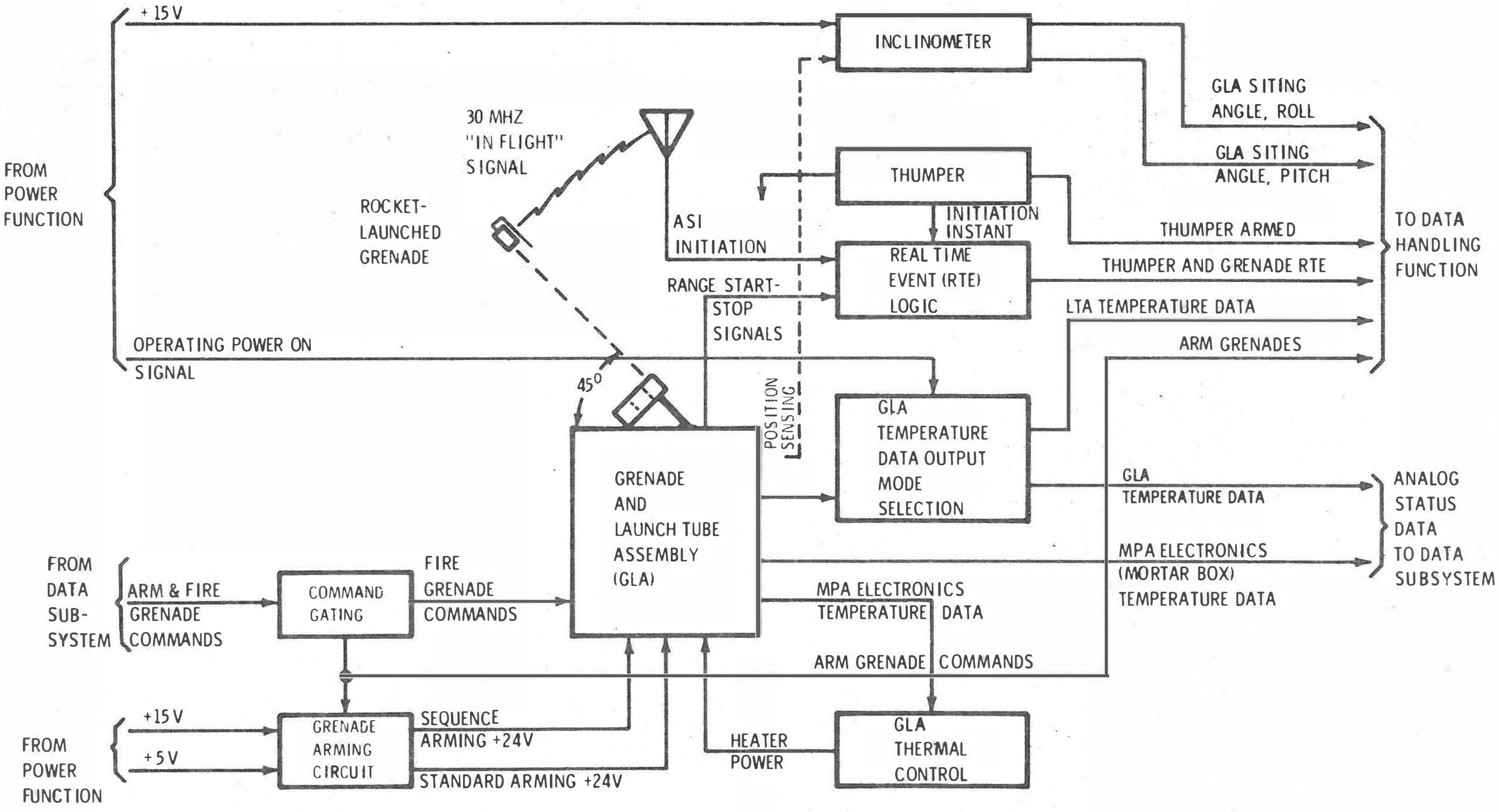


Figure 2-50. ASE Seismic Signal Generation Function, Block Diagram

individual ASI for firing. As a precaution against inadvertent initiation, the arm/fire switch must be rotated and held in that position approximately four seconds before the circuit is armed. Rotating the arm/fire switch charges the firing capacitor and generates a thumper arm signal which is applied to the ASE data handling function. After arming, the thumper is fired by depressing the arm/fire switch, discharging the capacitor and firing the selected ASI. The instant of initiation is monitored by the pressure force momentarily closing a pressure switch on the initiator mounting plate. Closing the pressure switch generates a signal to the real time event logic for application to the ASE data handling function. The real time event logic establishes the event identification for the telemetry format.

Initiation of the ASI creates compressional waves in the lunar surface and near-surface materials. Detection, processing, and analysis of these waves generated with a known force at known distances and times will permit determination of the physical properties of the lunar material.

The astronaut will deploy the mortar package assembly so that no equipment is in the rocket flight path or in the blast effect area. The astronaut will level the mortar package to within 5° of the lunar horizontal with refernces to a bubble level, and will erect the receiver antenna. The actual angle of the mortar package to the horizontal will be monitored by a two-axis inclinometer which will provide analog signals containing this data to the ASE data handling function.

After completion of the deployment process, the astronaut will remove a safety pin assembly and open two shorting (safe/arm) switches. The mortar package will remain in this configuration until activated by commands from Earth. While the experiment is not activated, the mortar package electronics, GLA, and geophone temperatures are monitored and applied as analog signals to the central data subsystem for telemetering to Earth. When the ASE is activated, these temperature signals are included with the data processed by the data handling function of the ASE. Thermal control of the mortar package assembly is effected through multilayer aluminized mylar insulation and two temperature sensors operating in conjunction with a small heater.

The mortar package is activated by the "arm grenade" and "fire grenades" commands from Earth. The arm grenades command is applied to and gated through the command gating to the grenade arming circuit which charges the regular and sequential firing capacitors of the four grenades by applying a 24-volt arming signal. A grenade arm pulse is also applied to the data handling function indicating receipt of the command. After arming, a fire grenade command for each of the grenades is applied to the command gating and gated to the appropriate firing circuit causing the firing capacitor to discharge and ignite the grenade propellant through a single bridgewire Apollo standard initiator (SBASI). As the grenade leaves the launch tube, a safe slide is spring ejected which permits a microswitch in the grenade to close, discharging a capacitor across a thermo-electric match which activates the thermal battery. The thermal battery, when activated, provides internal grenade power to drive the transmitter and to charge the detonator storage capacitors. The first of the two range line breakwires is broken when the grenade is launched, initiating the range gate pulse to the real time event logic. Rocket propellant in the grenade is exhausted before the grenade exits the tube. When the grenade is 25-feet into trajectory, the second range line breakwire is broken terminating the range gate pulse to the real time event logic and providing time/distance data for subsequent determination of grenade velocity. The grenade transmitter, activated at launch, and utilizing the grenade range line as an antenna, transmits until destroyed upon grenade impact. An omnidirectional impact switch in the grenade allows the detonator capacitor to discharge, firing a detonator to set off the grenade high explosive on grenade impact. The 30 MHz signal from the transmitter is received by the antenna mounted on the mortar box and conducted by coaxial cable to the receiver in the central station electronics. The received signal is applied through a level detector to the real time event logic for application to the data handling function. The grenade transmitter signal provides an indication of time of flight and detonation instant thus providing an indication of range. This indication enhances the confidence factor of the range calculations derived from the angle of launch and grenade velocity data generated from the inclinometer and the range line breakwires.

The regular firing order for the grenades will be grenade #2 (3000 feet), grenade #4 (500 feet), grenade #3 (1000 feet) and grenade #1 (5000 feet). The order was selected to provide optimum mortar package firing stability. A redundant arming and firing circuit is provided for sequential firing in the event of failure of one or all of the regular firing circuits. This circuit, designated sequential, is armed by the normal arm grenades command. A series of interlocking switches connect the sequential firing circuit to the grenade firing circuits as the grenades are launched. Initially, the sequential fire command is applied to grenade number two. When grenade number two is launched, it closes a switch to complete the firing circuit to grenade number four, and from number four to number three and then to number one. However, a separate arming command and a separate firing command are required to fire each grenade. If individual firing circuits are intact, individual firing commands may be applied and the sequential switching will provide redundancy.

The seismic energy generated by the initiation of the thumper ASIs and the grenades are transmitted by compressional waves through the lunar material for detection by the geophones of the seismic signal detection function of the ASE.

2-95. ASE Seismic Signal Detection. The active seismic experiment is designed to monitor seismic waves in the 3 Hz to 250 Hz range. Three electromagnetic geophones, three logarithmic compression amplifiers and the interconnecting cabling constitute the major elements of the seismic detection system (Figure 2-51). The detection function is applicable to the three operating modes of the ASE: the thumper mode, the grenade mode, and the passive listening mode. The geophones can be excited mechanically by natural or artificial seismic waves or electrically by a geophone calibrate command.

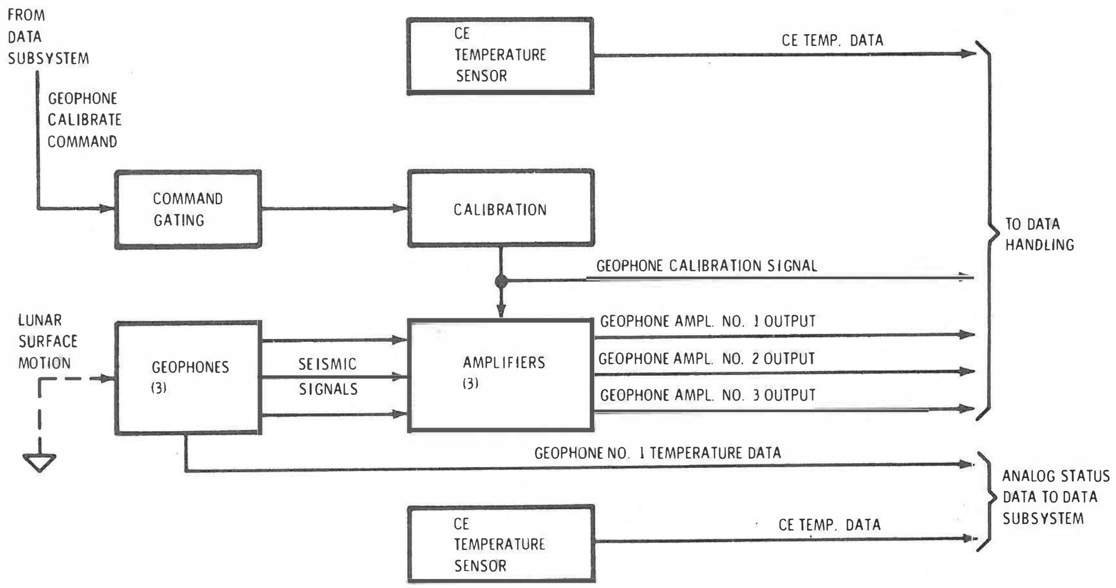


Figure 2-51. ASE Seismic Signal Detection Function, Block Diagram

Induced or natural seismic activity creating motion in the lunar surface or subsurface material will be sensed by the three geophones causing an electrical signal to be generated from the geophones to the respective amplifiers in the central station electronics. The low noise logarithmic compression amplifiers amplify the signal and apply the outputs to the multiplexer and analog-to-digital converter of the data handling function. As the seismic system response may change during the extended storage (one year) in the temperature extremes of the lunar environment, a pulse type calibrator is included with the amplifiers to provide a relative calibration system. The calibration system is activated by a geophone calibrate command applied to the command gating from the central data subsystem. The calibrate command is gated to the calibration circuitry where it is developed into a one second wide pulse and applied to the calibrate driver, electrically exciting the geophones. A geophone calibrate pulse is also applied to the data handling system from the calibrate driver indicating receipt of the calibrate command. Excitation of the geophones permits measurement of the geophones' resonant frequency, generator constant, and damping coefficient relative to the preflight calibration.

A temperature sensor is mounted in the geophone closest to the central station. The output of this temperature sensor is connected directly to the ALSEP central station data processor and is constantly monitored except when the ASE is activated which is for relatively brief periods of time.

2-96. ASE Timing and Control. The timing and control circuitry is basically digital logic which operates the ASE through use of a 10.6 KHz clock signal in conjunction with seven commands received from Earth (Figure 2-52). The data rate of the active seismic logic is 10,600 bits per second. The basic timing is obtained from the 10.6 KHz square wave received from the central data processor. The mod 5, mod 4, and mod 32 sequence counters are used to establish the data frame format. The shift register multiplexing logic selects the data to be loaded into the shift register through analog-to-digital converter, frame, holding, and control gates. A start pulse is applied to the analog-to-digital converter and multiplexer of the data handling function from the decoder of the timing and control function.

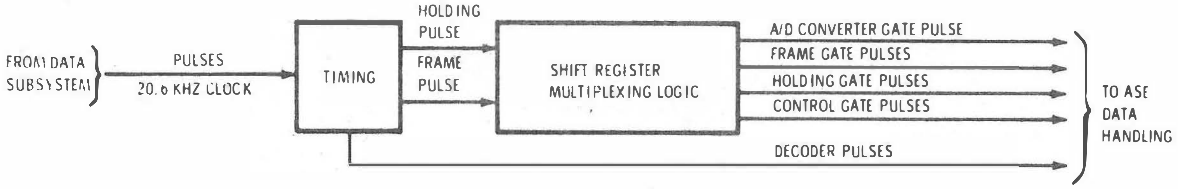


Figure 2-52. ASE Timing and Control Function, Block Diagram

When a real time event occurs, the real time event logic in conjunction with the sequence counters and the holding register provide a mark event signal indicating that a real time event occurred in the prior telemetry frame. The word in which the event occurred and the bit of real time occurrence are also identified. These indications will appear in active seismic words 29, 30, and 31 of the telemetry frame.

2-97. ASE Data Handling Function. Data handling and processing is accomplished through application of 16 channels of analog voltages to the multiplexer and analog-to-digital converter. Figure 2-53 illustrates the ASE data handling function.

Three analog channels are used for geophone outputs, two for GLA angle outputs, three for calibration, three for ASE temperature and power measurements and the other five for ALSEP electrical power subsystem temperature and power measurements. The analog signals are multiplexed, converted to digital signals, and formatted for shifting to the central data subsystem and downlink transmission. Subword, word, and frame signals are derived from the sequence counters through the decoder of the timing and control function.

The ASE data format comprises 32 twenty-bit words per frame with each word consisting of four five-bit subwords. Geophones two and three are sampled and read out in every word of the frame. Geophone one is sampled and read out in all but the first word. In the first word geophone one is sampled and stored, then read out in the first subword of the second word of each frame. The first two subwords of word number one comprise a 10-bit frame synchronizing signal. The first three bits of subword one of word 32 provide a mode identification signal. Data measured and word-subword assignments are listed in Table 2-20.

Table 2-20. ASE Measurements

Symbol	Location/Name	Channel		Range	Sensor Accuracy	Bits/ Sample	Samples/ Sec
	* When the Active Seismic is not operating the following measurements are provided through the 90-channel multiplexer of the Data S/S.						
	Active Seismic Temperatures						
* AS-1	Central Station Package Temp.	29		-40°C to +100°C	±3°C	8	.0185
* AS-2	Mortar Box Temp.	44		-75°C to +100°C	±3°C	8	.0185
* AS-3	Grenade Launcher Assembly Temp.	55		-75°C to +100°C	±3°C	8	.0185
* AS-4	Geophone Temp.	73		-200°C to +130°C	±3°C	8	.0185
	Active Seismic Measurements						
		A/S Word	Subword				
DS-17	Frame Sync	①1	1, 2	N/A	N/A	10	16.56
DS-2	Geophone #2 Data	All	3			5	530
DS-3	Geophone #3 Data	All	4			5	530
DS-1	Geophone #1 Data	2	1			5	530
		2 through 32	2			5	530
AR-4	RTG Cold Frame Temp. #1	②3, 4	1	400°F to 600°F	±5°F	8	16.56
AE-5	Shunt Regulator #1 Current	5, 6	1	0 to 3.5 A DC	±2%	8	16.56
DS-5	+5V Telemetry	7, 8	1	0 to 5.2 VDC	±0.5%	8	16.56
DS-6	Pitch Angle	9, 10	1	±10°	±0.5%	8	16.56
DS-7	Roll Angle	11, 12	1	±10°	±0.5%	8	16.56
AS-3	Grenade Launcher Assembly Temp.	13, 14	1	-75°C to +100°C	±3°C	8	16.56
DS-8	Geophone Calibrate Pulse	15, 16	1	0 to +5V	±1%	8	16.56
DS-11	A/D Calibration 3.75V	17, 18	1	3.5 to 4.0 VDC	±0.5%	8	16.56
DS-10	A/D Calibration 1.25V	19, 20	1	1.0 to 1.5 VDC	±0.5%	8	16.56
AS-1	Central Station Package Temp.	21, 22	1	-40°C to + 100°C	±3°C	8	16.56
AE-3	Converter Input Voltage	23, 24	1	0 to 20 VDC	±2%	8	16.56
AE-4	Input Current	25, 26	1	0 to 5 A DC	±2%	8	16.56
AR-1	RTG Hot Frame Temp. #1	②27, 28	1	950°F to 1150°F	±5°F	8	16.56
DS-18	Mark Event	③29	1	N/A	N/A	5	N/A
DS-19	Word Count	④30	1	N/A	N/A	5	N/A
DS-20	Event Bit Count	⑤31	1	N/A	N/A	5	N/A
DS-13	Mode ID	⑥32	1	N/A	N/A	3	16.56

① In the first 10 bits of the word.

② The first four bits of the measurement are carried in the first four bits of the odd word. The last four bits of the measurement are carried in the first four bits of the even word. In each case the last (or fifth) bit of each subword is spare.

③ Mark code when Real Time Event occurs during prior frame (frame = 32 word sequence)

④ Measures word in prior frame during which Real Time Event occurred.

⑤ Measures bit during which Real Time Event occurred in above word in prior frame.

⑥ In the first 3 bits of the subword - other 2 bits not used.

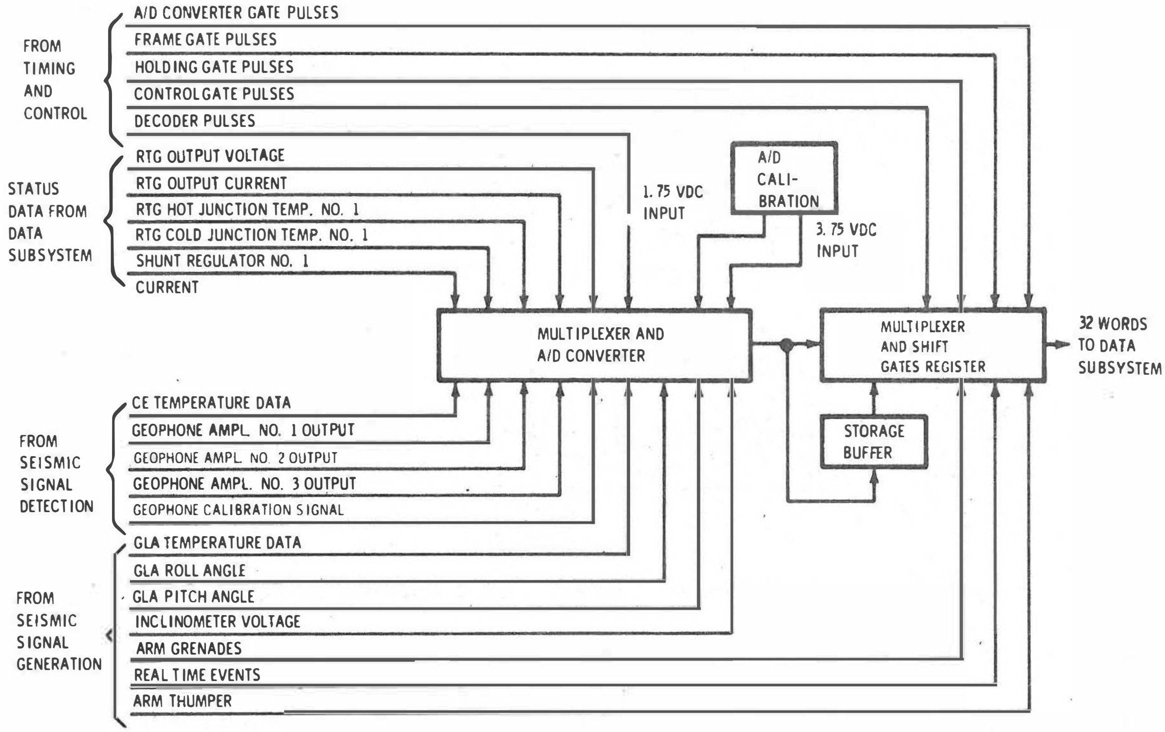


Figure 2-53. ASE Data Handling Function, Block Diagram

The binary signals from the multiplexer converter are applied to the shift register multiplexer gates which are controlled by the shift register multiplexing logic. A storage buffer is provided between the converter multiplexer and the shift register multiplexer gates. The ASE data is shifted out in the 32-word telemetry frame format to the bi-phase modulator of the data subsystem for modulation and downlink transmission.

The analog-to-digital converter calibration circuit provides a two-point check on the multiplexer converter by monitoring resultant output of applying the 1.75 vdc and 3.75 vdc input voltages.

2-98. ASE Power Control Function. Operating and standby (survival) power is supplied from the power distribution unit (PDU) to the ASE at +5, +15, -12, and +29 vdc (Figure 2-54). Current limiters in power circuits prevent over-voltage from damaging the ASE components and conversely the ASE from overloading the PDU in the event of malfunctions. In the ALSEP data subsystem the +29 vdc line is prevented from carrying current greater than 500 ± 50 milliamperes by a current sensor that causes the 29-volt power to be switched from the operational power bus to the standby power line whenever the current exceeds this value for more than 0.5 millisecond. The +15 volt line, the +5 volt line, and the -12 volt line are limited to 150, 500 and 150 milliamperes respectively in the ASE power control circuitry.

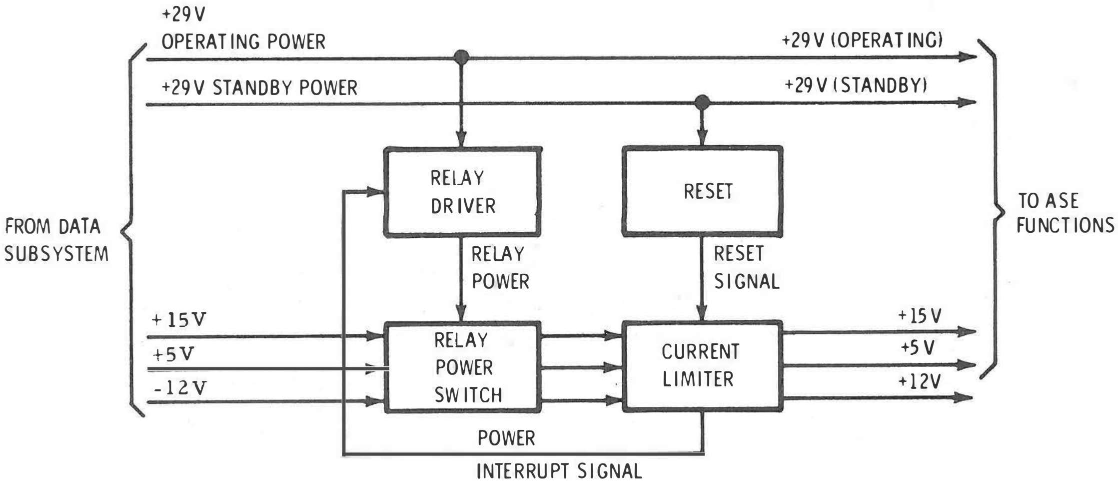


Figure 2-54. ASE Power Control Function, Block Diagram

2-99. SAFETY FEATURES

Both the thumper and mortar package assemblies contain ordnance devices and, therefore, safety has been a major consideration in the designs. A discussion of the electrical and mechanical safety features of each and their use on the lunar surface is given in detail below.

2-100. Thumper-Geophone Assembly. The thumper contains 21 Apollo Standard Initiators (ASIs). The ASIs are rated at one ampere "no fire" and three ampere "all fire". The ASI, as a component, will generate a pressure of approximately 650 psi in a 10 cc volume. In the thumper, the ASIs are discharged directly against a spring loaded impact plate. With the thumper held upright for firing operation, with the impact plate against a surface, the ASI mounting plate confines the ASI discharge pressure primarily to the "chamber" between the mounting plate and the impact plate to deflect any escaping debris downward.

The thumper is designed so that all ASIs are internally shorted by the ASI rotary selector switch when the selector switch is in the "0" position. In any other position (1 through 21) one ASI is connected to the firing circuitry and the remaining 20 ASIs remain shorted out. Rotating this switch from "0" will not in itself fire an ASI even with power applied. A definite two step firing operation with a time delay is required to arm and fire an ASI. After the ASI selector switch is rotated from the "0" position to a numbered position to select an ASI, the thumper is armed by rotating the ARM/FIRE knob approximately 90^o and holding for a minimum of four seconds. The selected ASI is fired by pressing the same knob in, which applies a capacitor charge across the ASI. Should for any reason the firing sequence be stopped after the thumper is armed, the released ARM/FIRE control returns to its normal unactivated position which automatically discharges the arming capacitors in a matter of milliseconds.

The ARM/FIRE control is designed so that the firing switch cannot be actuated until after the arming switch is activated. This switch is also designed to provide a low impedance across the firing capacitors in the normal position to prevent the capacitors from picking up a static charge and to discharge the capacitors if they are charged but have not fired through an ASI.

The end of each ASI mounted in the base of the thumper is covered with a coating of silicone rubber to protect the initiator from the pressure and debris from adjacent initiator firings which otherwise might cause possible sympathetic deflagration. Extensive test firings have demonstrated the adequacy of this design.

2-101. Mortar Package Assembly. The mortar package consists primarily of a mortar box and a GLA. The mortar box is completely inert and contains no ordnance devices. The four grenades in the GLA contain all the ordnance devices in the mortar package assembly. Each grenade contains a SBASI to ignite the rocket motor, up to 45 grams of propellant, a thermal battery containing an enclosed thermoelectric match for ignition, a detonator assembly including a second SBASI and 0.1, 0.3, 0.6 and 1.0 pound of hexanitrostilbene (HNS) type explosive for the #4, #3, #2 and #1 grenades respectively.

As noted the grenades in the GLA contain all the ordnance devices in the mortar package. For safety purposes, the GLA and Mortar Box are never functionally tested together, but are completely checked out separately and mated only just prior to flight. For handling and storage purposes, the GLA is provided with safety release pins which mechanically secure the grenades in the launch tubes. When the GLA is installed in the mortar box, to make up the mortar package assembly, a safety release assembly is used to perform the same function and is only removed by the astronaut prior to leaving the lunar surface. Thus, the grenades are mechanically locked in the launch tubes at all times during earth/lunar operations.

Except for test, all connectors on the GLA are stored with shorting connectors across them. The GLA is completely functionally tested with special test points on the bottom of each grenade. In the test configuration the high explosive SBASI's are not connected to the grenade firing circuits and are shorted out by special test connectors inserted in the bottom of each grenade. Just prior to flight these connectors are removed and flight connectors are installed which connect the SBASI's to the firing circuit leads.

Two SAFE/ARM switches on the mortar package are used to assure a safe mortar package assembly while the astronaut is present on the lunar surface. One switch opens the arming circuit between the ASE central electronic and the mortar package, and shorts out the rocket motor firing capacitors. The second switch disconnects the rocket motor SBASIs from the firing circuits and provides a short circuit across them.

A safe slide in each grenade provides a mechanical block between the detonator and the HNS explosive. The safe slide is held in place at all times when the grenade is in the launch tube and is spring ejected at launch. Thus, while the safe slide is in place, inadvertent detonator ignition will not set off the high explosive charge. In addition, the safe slide maintains a microswitch in a position which prevents the thermal battery output from the high explosive firing circuitry, and provides a low impedance to the firing capacitors to prevent a static charge from charging these capacitors. To insure that the safe slide assemblies are installed each GLA is furnished with X-ray pictures which verify that the safe slide plates were installed when the grenades were installed in the GLA.

The thermal battery in each grenade contains a thermoelectric match which has a "no fire" rating of 0.75 amperes for 10 msec and an "all fire" of 2.0 amperes for 10 msec. The battery can only be activated after the grenade leaves the launch tube and must be activated to provide power to charge the grenade high explosive firing capacitors and operate the associated SCR firing circuitry. If the thermal battery is inadvertently activated and the safe slide plate is in place it will discharge across a short circuit in a short time (less than 10 minutes).

The high explosive firing capacitors are charged through a current limiting resistor which prevents the capacitors from being sufficiently charged to fire the SBASIs until the grenades are safely down range after they are launched. After the thermal battery is activated, it requires approximately eight seconds for the capacitor to charge sufficiently to permit a voltage sufficient to switch on the SCR in the firing circuitry.

The HNS explosive was especially selected for its stability properties. It cannot be set off by impact. It is extremely stable in even a high temperature environment. Auto ignition can only occur in temperatures above 450^{o} centigrade.

The mortar package is designed to be an RFI shield completely enclosing the GLA and grenade. This is primarily provided by the multilayer aluminized mylar thermal bag and cover. The firing circuits are designed with low pass input filters. A pulse of greater than three milliseconds is required to trigger these circuits. In addition, all firing capacitors and SBASIs have resistors connected across them to reduce the effects of electrostatic charge.

The rocket motor and HNS explosive train ignitors are one-amp "no-fire" devices which have been especially designed by NASA for high reliability and optimum safety in ordnance devices.

Power is required to operate the ASE, to arm, and to fire the grenades. At no time while the mortar package is being handled is operational power applied to the mortar package through the ASE central electronics. Operational power to the ASE is switched off by the ALSEP astronaut switch which prevents application of operational power even if a command is inadvertently sent from MSFN to turn the power on.

2-102. LUNAR SURFACE MAGNETOMETER EXPERIMENT SUBSYSTEM

The lunar surface magnetometer experiment (LSM) measures the topology of the interplanetary magnetic field diffused through the Moon to determine boundaries of the electromagnetic diffusivity. The experiment will give some indication of inhomogeneities in the lunar interior.

Data acquisition and processing, both scientific and engineering, proceeds continuously in any of the operational configurations selectable by commands from Earth.

2-103. LSM PHYSICAL DESCRIPTION

The LSM consists of three magnetic sensors, each mounted in a sensor head and located at the ends of three-foot long support arms. (See Figure 2-55.) The mannetic sensors, in conjunction with the sensor electronics, provide signal outputs proportional to the incident magnetic field components parallel to the respective sensor axes. Each magnetic sensor is housed in an outer structural jacket made of fiberglass. The jackets are wrapped with insulation, except for their upper flat surfaces, called thermal control surfaces, that serve as heat radiators. Although the magnetic sensors themselves are positionable, the outer jackets remain stationary throughout LSM operation. The sensors and their jacket housings are supported at equal distances above the lunar surface and apart from each other by the three fiberglass support arms.

The support arms extend from the base structure, called the electronics/gimbal-flip unit (EGFU), which is a rectangular box 9 1/2" x 10 1/2" x 5 1/4" housing the experiment electronics and the gimbal/flip mechanism. The support arms contain the electro-mechanical linkage and the electrical cables that connect the sensors to the EGFU.

The EGFU is divided into a two-section package by an aluminum base plate. The electromechanical gimbal-flip mechanism and the level sensors are mounted to the top side of this base plate and the LSM electronics are mounted on the underside. Electrical power dissipated as heat is conducted to this base plate which in turn radiates heat away from the EGFU via a pair of parabolic reflector arrays (PRA).

The EGFU has parabolic reflectors on two base sides and a multilayered aluminized Kapton blanket for thermal protection. The upper section of the EGFU is enclosed by a fiberglass protective cover underneath the thermal blanket. A thermal shroud is suspended between the support arms to protect the EGFU from direct solar heat.

A flat H-film cable connects the LSM to the ALSEP central station. Prior to deployment, the cable is contained in an enclosed reel which stows under the LSM on subpackage No. 1. The whole LSM assembly sits on the lunar surface on leveling legs that are hinged to the EGFU. Each leg is attached at the base of a

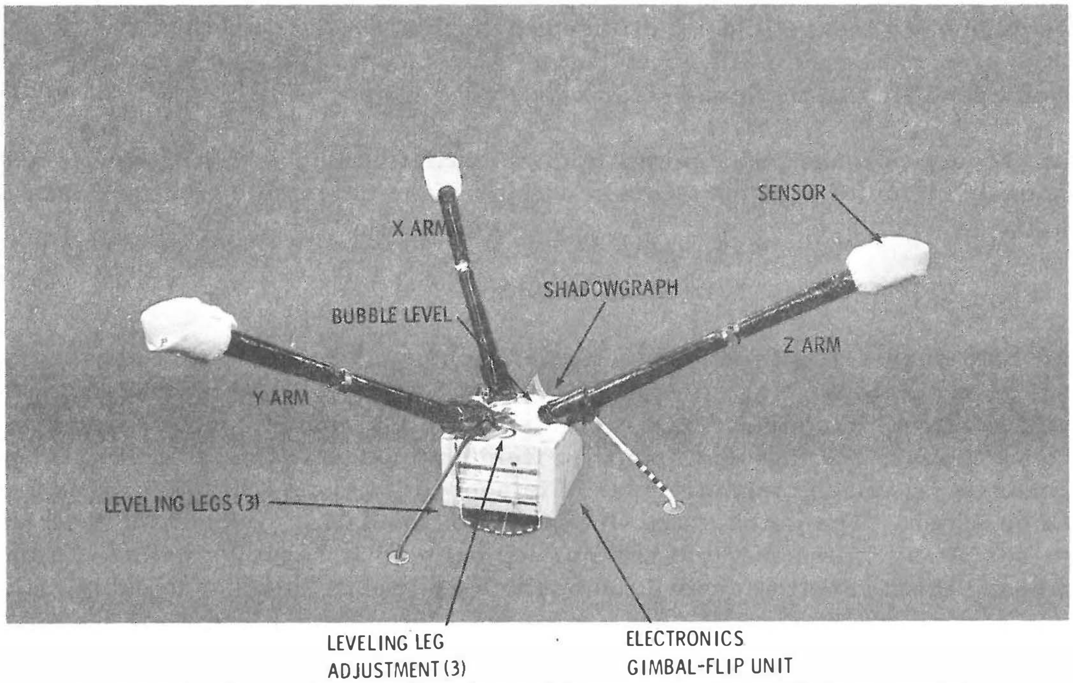


Figure 2-55. Lunar Surface Magnetometer Experiment

sensor support arm through an adjustable joint which permits adjustment of the physical attitude of the LSM. The legs swing to an upright position for stowage within the allowed flight envelope. (See Figure 1-1.) A pad at the bottom of each support leg is sized for LSM weight and lunar bearing strength.

A shadowgraph and a bubble level are mounted on the upper surface of the EGFU. The shadowgraph is used by the astronaut in deployment to align the LSM into an East-West emplacement. The astronaut uses the bubble level to position the LSM parallel to the lunar surface. Calibration marks on both instruments are spaced at 1° increments over at ±3° range.

LSM leading particulars are listed in Table 2-21.

2-104. LSM FUNCTIONAL DESCRIPTION

The LSM has three modes of operation:

a. Site survey mode. This survey is performed once on receipt of Earth command after the LSM is first put into operation. A site survey is performed in each of the three sensing axes. The purpose of the site survey is to identify and locate any magnetic influences permanently inherent in the deployment site so that they will not affect the interpretation of LSM sensing of magnetic flux at the lunar su face.

Table 2-21 LSM Leading Particulars

Characteristics	Value
Size (Inches)	
Stowed	25 x 10 x 11
Deployed	40 high with 60 between sensor heads
Weight (pounds)	19.4
Peak Power Requirements (watts)	
Site Survey Mode	12.25
Scientific Mode	5.8
	10.9 (night)
Calibration Mode	12.0

b. Scientific mode. This is the normal operating mode of magnetic field sensing.

c. Calibration mode. This is performed automatically at 12-hour intervals but can be performed on receipt of Earth command 5 at any time after receipt of Earth command 4. The purpose of the calibration mode is to determine the absolute accuracy of the magnetometer sensors and to correct any drift from their laboratory calibration.

The LSM performs six major functions as shown in Figure 2-56 in accomplishing its purpose of measuring the lunar magnetic field. These functions are as follows:

a. Electromagnetic measurement and housekeeping
b. Calibration and sequencing
c. Sensor orientation
d. Data handling
e. Thermal control
f. Power control

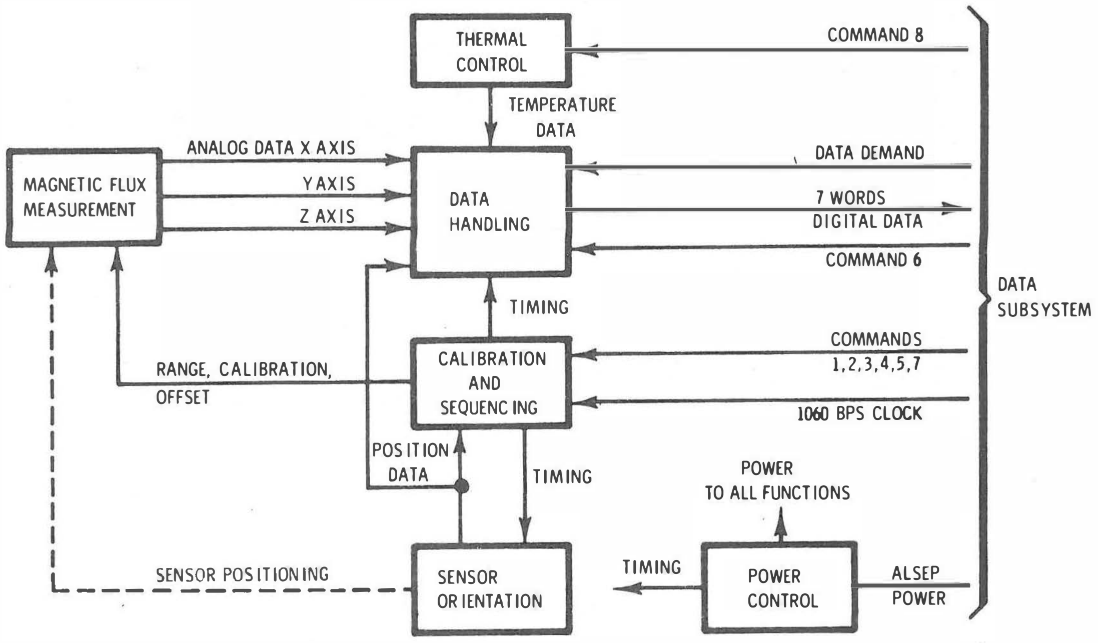


Figure 2-56. LSM Experiment, Functional Block Diagram

The electromagnetic measurement function measures the lunar surface magnetic field by means of three magnetic sensors aligned in three orthogonal sensing axes. These axes are called X, Y, and Z. The three magnetic sensors provide signal outputs proportional to the incidence of magnetic field components parallel to their respective axes. All sensors have the capability to sense over any one of three dynamic ranges:

a.	Range 1	-50 to +50 gamma
b.	Range 2	-100 to +100 gamma
c.	Range 3	-200 to +200 gamma

The range is selected by Earth command during operation.

The housekeeping function provides:

a. Data describing the condition of the LSM subsystem.

b. Status data defining the operational state of the LSM to permit proper interpretation of the scientific data.

c. LSM orientation data to permit referencing the vector magnetic field data to lunar coordinates.

d. Monitoring of LSM temperature by five sensors.

e. Monitoring of the +5V reference supply for magnetic field measurement calibration check.

The sensor orientation function monitors the leveling of the LSM, the position of the magnetic sensors, and performs the electromechanical flip and gimbal of the magnetic sensors under control of Earth command.

The calibration and sequencing function receives and interprets Earth commands to calibrate and sequence the operation of the other LSM functions.

The data handling function receives analog voltages from the electromagnetic measurement and housekeeping function, and processes this analog data into digital format to satisfy ALSEP telemetry requirements. The data handling function then stores this information until the data subsystem requests it.

The thermal control function maintains the required thermal operating environment for the LSM mechanisms and electronics.

The power control function comprises a dc/dc converter and system timer that provide regulated output voltages, as required on a time-shared basis, to the LSM subsystem.

The above functions are performed in response to the eight Earth commands listed in Table 2-22.

2-105. LSM DETAILED FUNCTIONAL DESCRIPTION

The six major functions of the LSM are discussed in the following paragraphs and are illustrated by associated block diagrams.

2-106. Electromagnetic Measurement and Housekeeping Function. Figure 2-57 is a functional block diagram of the LSM electromagnetic measurement and housekeeping function.

Three orthogonally located flux gate magnetic sensors, called X, Y, and Z, are employed in measuring the magnetic flux with three identical signal processing channels. The magnetic sensors, in conjunction with the sensor electronics, provide signal outputs proportional to the incident magnetic field components parallel to their respective axes.

The function of the sensor electronics is to convert the incident magnetic field intensity at the respective sensors into analog voltages. The conversion sensitivity is 25 microvolts/gamma at 10 kHz.

An electrical cable within each sensor support arm connects each magnetic sensor to the sensor electronics in the EGFU.

The sensor electronics assembly provides the fundamental drive power with negligible second harmonic content for exciting the fluxgate sensors. The assembly accepts three sensor output signals, selecting and amplifying only the second harmonic

Table 2-22. LSM Command List

Command Number	Nomenclature	Function
1	Range Select	Selects dynamic range for magnetic sensor operation
2	Steady Field Offset	Introduces known electrical percentage offsets to any of the three magnetic sensors
3	Steady Field Address	Selects sensors to be electronically offset
4	Flip/Cal Inhibits	Inhibits or uninhibits flip/cal cycle
5	Flip/Cal Initiate	Initiates flip/calibration cycle
6	Filter Failure Bypass	Causes major portions of the digital filter to be bypassed in the event of digital filter failure
7	Site Survey	Initiates site survey of each axis. Can only be used after four flip/cal cycles
8	Thermal Control	Selects either X or Y boom sensor temperature detector (or off) for thermal control.

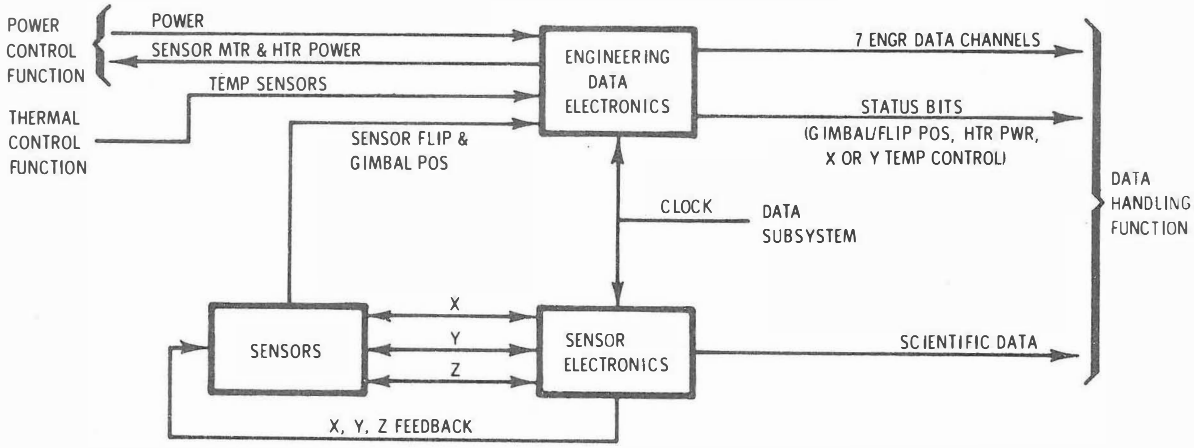


Figure 2-57. LSM Electromagnetic Measurement and Housekeeping Function, Block Diagram

component. It demodulates this to provide the data handling function with analog output voltages proportional to the magnetic field intensity parallel to the axis of each magnetic sensor, with a frequency response of dc to 50 Hz. The sensor electronics also provides feedback current from the analog output to the sensors, and generates fundamental and second harmonic reference square waves at 5.9625 and 11.925 kHz respectively. These are synchronously derived from the 1060 Hz ALSEP clock pulse.

The sensor electronics incorporates provisions for range selection, range offset, and self-calibration. Offset biases and calibration raster data are inserted in the feedback loop of the sensor electronics, and scaling is accomplished by changing the feedback gain. An amplifier in the feedback circuit provides accurate summation of the offset, calibration and feedback voltages at all combinations of signals. It also provides linear drive of the fluxgate sensor feedback winding over wide combinations of dynamic range and range biases.

The engineering data electronics performs the following housekeeping functions:

a. Indicates the nominal flip position (0°, 90°, 180°) of each fluxgate sensor by exciting the flip position sensors and outputting the resultant data in the form of three 2-bit status words.

b. Indicates the gimbal position (pre or post-gimbal) of each fluxgate sensor by exciting the gimbal position switching and outputting the resultant data in the form of three 1-bit status words.

c. Provides the five temperatures monitored within the instrument by exciting the thermistors with a reference voltage and outputting the resultant five analog voltages.

d. Indicates the orientation of the instrument relative to the local lunar vertical by exciting the two-axis gravity level sensor and outputting the resultant two analog voltages.

e. Provides heater power status and temperature control status.

f. Provides +5V reference voltage analog data.

2-107. <u>LSM Calibration and Sequencing Function.</u> The LSM calibration and sequencing functional block diagram is shown in Figure 2-58.

The flip/calibration sequence generator is automatically switched on by the ALSEP central station timer at 18-hour intervals unless inhibited by Earth command 4. Earth command 5 can initiate the flip/calibration sequence at any time after first releasing the flip/cal inhibit by sending Earth command 4 to the site survey sequence generator. Once activated, the flip/cal sequence generator sequentially applies power to the sensor flip motors of the sensor orientation function to drive

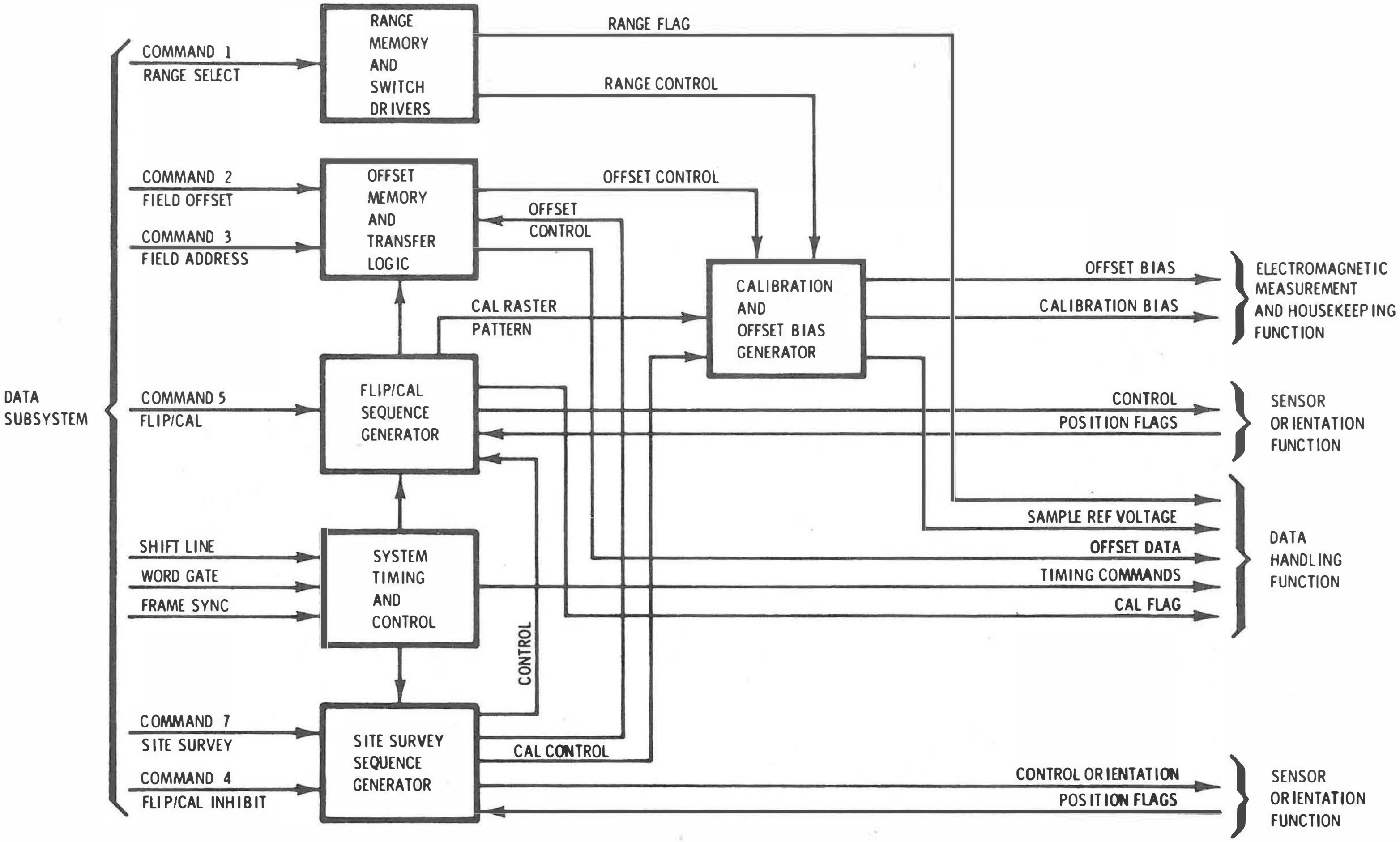


Figure 2-58. LSM Calibration and Sequencing Function, Block Diagram

the sensors to their 180° position. Before and after flips, it triggers the calibration step generator which generates the calibration rasters. There are two rasters applied simultaneously to all three sensors before and after each flip. When the calibration raster generation is completed, a signal is sent back to the flip/calibration sequence generator, which sequences to the next step and generates an X flip power switch on command. After a programmed time limit a signal is generated which steps the sequencer to the next state, which in turn commands the X flip power switch off and the Y flip power switch on. This sequence is continued until all three sensors have been flipped. Then the calibration raster is called again and its completion causes a "calibration complete" signal output which turns off power to the flip/calibration sequence generator.

The flip/calibration sequence generator also receives commands from either the site survey sequence generator during site survey mode, or from the ALSEP central station timer during normal scientific mode. These commands, if not inhibited by a previous Earth command 4, will start the flip/calibration sequence generator operation descirbed in the previous paragraph.

The site survey is performed once at the start of LSM operation. It is initiated on receipt of Earth command 7 which has been preceded by four Earth commands (5) initiated flip/calibrations. These flip/calibrations are required to measure the influence of any residual magnetic perms on the sensors.

Upon receipt of Earth command 7, the site survey sequence generator, in conjunction with internal step commands from the system timing and control generator, generates the following operational sequence employing the flip motors and the flip/gimbal mechanism:

a. Initiate Subsequence 1
b. Initiate Flip/Cal Cycle
c. Flip/Cal Cycle complete
d. Survey X Axis
e. X Axis Survey Complete
f. Return to Scientific Mode
g. Subsequence 1 complete
h. Initiate Subsequence 2
i. Repeat steps b through f for Y axis
j. Subsequence 2 complete
k. Initiate Subsequence 3
l. Repeat steps b through f for Z axis
m. Subsequence 3 complete
n. Site Survey complete

Upon completion of step n, all sensors will be in the scientific orientation with correct offset and offset polarities.

The site survey sequence generator generates the sequence of flip motor, flip-stop motor, and gimbal motor power switching necessary to perform the site survey sequence. The design consists of a binary sequence counter which steps one step at the completion of an operation. The outputs are gated to obtain a coincidence signal which is used to perform their respective functions. These functions include the power switch signals, a calibration mode command signal, and a sequence inhibit signal. Fail-safe features are designed into the sequence; for example, the flip power is applied to each motor, in turn, for 10 seconds each. Should a flip mechanism fail, the sequence is continued with a resulting partial failure at worst.

The offset memory stores, upon Earth command 3, one of seven bias levels for each sensor channel. These bias levels will be sotred in binary form in a flip-flop memory whose output states will drive the offset bias generator. The transfer logic receives sensor position data and derives the switch commands which connect the proper offset bias and polarity to the sensor channels.

The calibration raster generator generates a set of calibration steps in a sequence upon receipt of command. The sequence consists of two identical cycles, each cycle consisting of 8 proportional steps of approximately 10-second duration each. The calibration raster generator receives its command from the flip/cal sequence generator which enables a gate allowing a 1/10 pps clock train from the system clock and timing generator. These pulses set a counter whose states are gated to turn on switches in a ladder network. The output voltages of this ladder are sent out to the sensor electronics calibration input. Both polarities are generated. The process is repeated for two cycles and then the clock gate is disabled and a "cal-step" complete signal is sent back to the flip/cal sequence generator.

The offset bias generator is similar to the calibration raster generator except it contains three separate ladder networks, one for each magnetometer channel. The switch states of the different offset bias generators are determined by the offset memory. In addition, each output will be inverted giving both polarities of each bias voltage. These outputs will be routed to a switch matrix which connects each sensor channel to the proper bias level and polarity as determined by the transfer logic.

The system timing and control generator generates all the timing and synchronization signals necessary to synchronize the data processing and sequencing. It contains a clock which generates periodic internal timing commands for the site survey and calibration sequences.

2-108. <u>LSM Sensor Orientation Function.</u> A functional block diagram of the sensor orientation function is shown in Figure 2-59.

Throughout operation, the physical attitude of the LSM relative to the lunar surface is monitored by an electronic level detector that uses a capacitance pickup to meaure attitude in a range of ±15° of level in the two axes. The detector is mounted on top of the EGFU

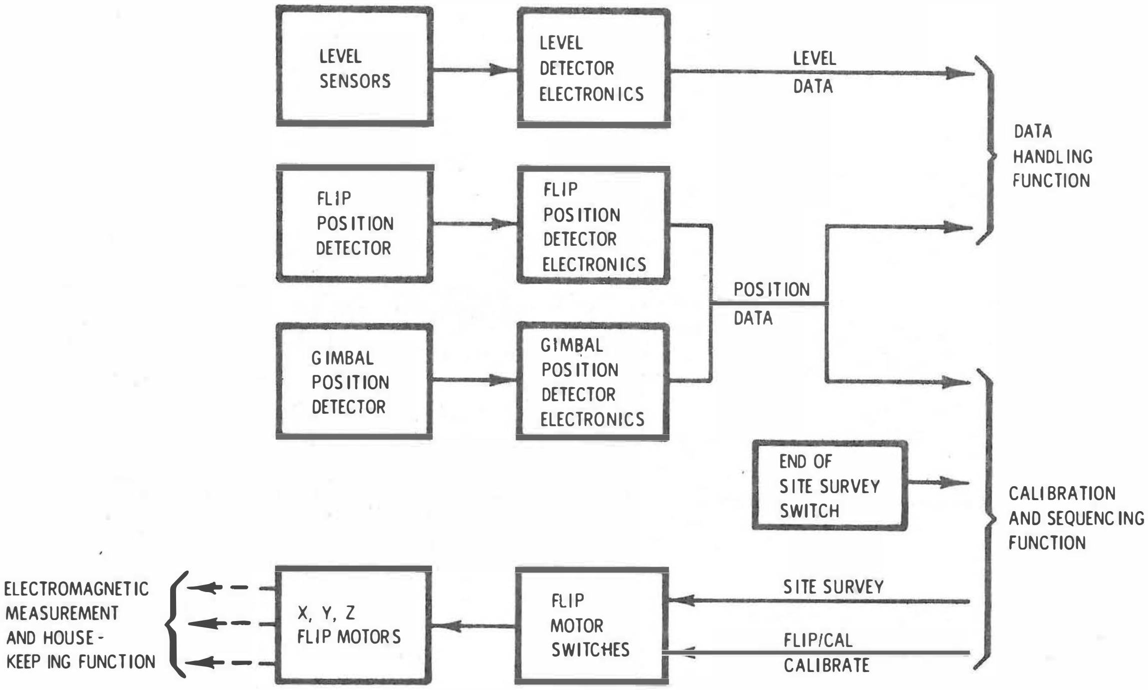


Figure 2-59. LSM Sensor Orientation Function, Block Diagram

and relays level status data to Earth as part of the engineering data. Data on the LSM physical attitude is used in interpreting the scientific data.

In the normal scientific mode, the three sensors have a fixed orientation. Each sensor is pointed along the axis line of its support arm in a direction away from the EGFU. This position is considered the reference or 0° position for sensor orientation in the scientific mode.

In the calibration mode, the three sensors are flipped, in turn, through 180°. In the site survey mode, the three sensors, in turn, are gimbaled 90° and then flipped through 90° and 180°. To accomplish the site survey, all three sensors must be aligned parallel to each of the coordinate axes in turn, as shown in Figure 2-60.

Sensor flipping and gimbaling is best understood by projecting oneself into the same position that the sensor has in the 0° reference position pointed along the axis line of its support arm in a direction away from the EGFU and imaging the sensor's view.

As the sensor looks outward, it has a horizontal plane coincident with the axis line of its support arm. The sensor is capable of movement in this horizontal plane. This movement is called flipping. In the calibration mode the sensors can flip

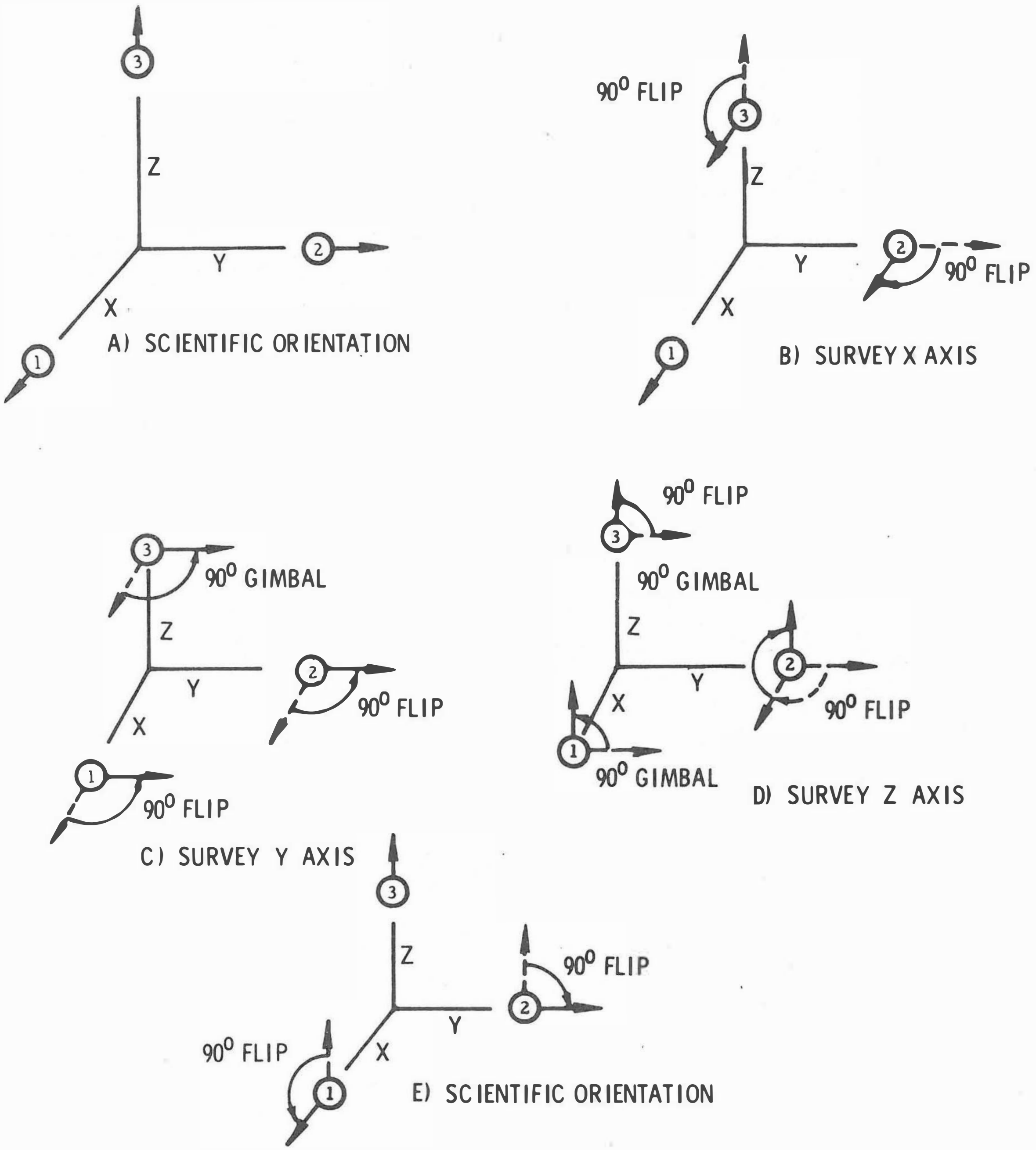


Figure 2-60. LSM Site Survey Sensor Gimbal and Flip Sequence

from 0° to 180° and back. In the site survey mode the sensors can flip 0° to 90° or 180° and back. Sensor flipping is accomplished by three 400-cycle, two-phase ac motors which provide flipping motive power through three flip drive mechanisms to the three sensors. Three position stops incorporated in the support yoke structure of each sensor provide positive control of sensor position during flipping, and guarantee orientation accuracy at each of the three positions, 0, 90, and 180 degrees. The 90-degree stop is necessary during the site survey mode and is permanently retracted after this mode is performed. Control of this retractable stop is provided by a follower assembly located on the drive mechanisms, and is synchronized to the flux measurement sequence. Motive power for stop retraction is provided by the flipper drive motor by means of a drive cable running through the support arm to the sensor head.

Gimbaling is a repositioning of the sensor by physically rotating the sensor and its supporting yoke around the axis that passes through the sensor as an extension of the support arm axis. This rotation is accomplished by a spring released through the mechanical linkage in an inner arm that passes through the outer support arm housing and connects to the gimbal/flip unit. Both flipping and gimbaling are performed internal to the support arm without any visible change to the outside configuration. A sensor can be gimbaled 90°. Once in the new position, the same freedom of movement used for flipping allows the sensor to move through a new plane that is 90° perpendicular to its former movement plane. With this combination of flip and gimbal capabilities, each sensor can be pointed in the direction required for site survey.

In the site survey mode, sensor positions are mechanically programmed by cam action. At the end of this operational mode, the program is stopped by means of a toothless section of the cam. At the same time, the end of site survey switch deactivates the electronic site survey sequence in the sensor orientation function.

Flip and gimbal positions are monitored throughout operation by means of position detectors (3 flip position and 2 gimbal position detectors per axis).

2-109. <u>LSM Data Handling Function.</u> A functional block diagram of the LSM data handling function is shown in Figure 2-61. The data handling function converts scientific and engineering data into a digital format compatible with the ALSEP telemetry interface.

2-110. Scientific Data Processing - The three pre-filtered analog outputs of the sensor electronics are sampled simultaneously (to within 125 microseconds of one another) at the digital filter sampling rate by a sample and hold circuit. The stored (analog) samples are multiplexed into the analog-to-digital converter which sequentially converts each into a 10-bit binary word that is shifted out into a memory unit in the digital filter.

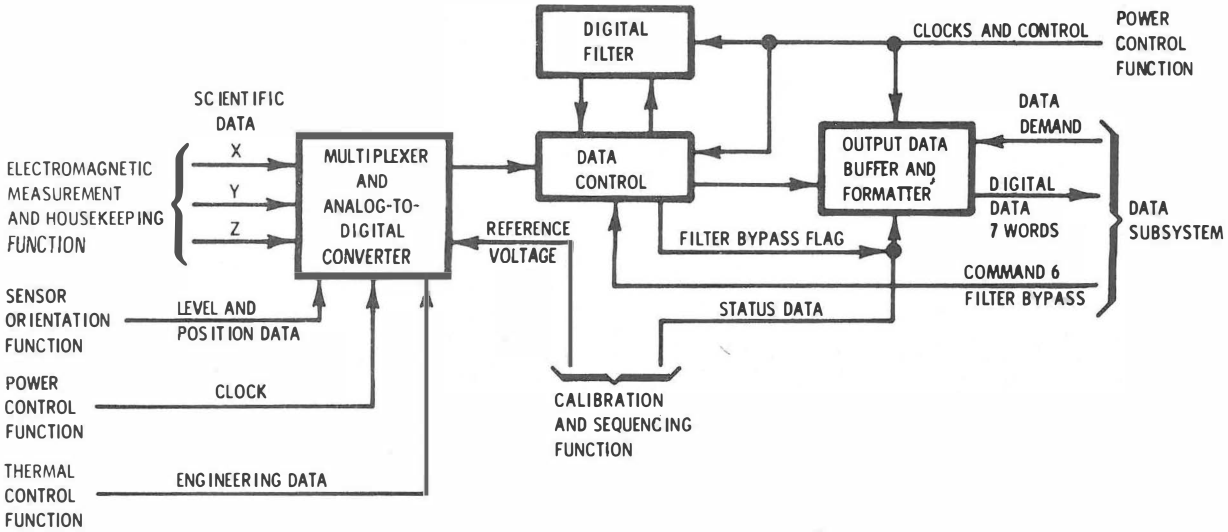


Figure 2-61. LSM Data Handling Function, Block Diagram

The digital filter serves to reduce to an acceptable level the aliasing error introduced into the scientific data by the output data sampling rate. The three channels of scientific data time share the arithmetic unit, the data bus, and the data control in the digital filter. The various state variables are stored in a core memory in the filter when not being used to perform a calculation. The state variable representing the filtered output of each channel at a given (real time) sample instant is shifted out into the output data subsystem upon receipt of a data demand pulse. Therefore, although the readouts ot the data subsystem are staggered in time, they represent approximately simultaneous, periodic samples of the three magnetic field vector components in real time.

The digital filter may be bypassed if so ordered by ground command 6 in the event of filter failure. In this case, the scientific data undergoes only analog filtering with a resultant increase in aliasing error. Re-execution of the filter command 6 removes the bypass.

2-111. Engineering and Status Data Processing - The engineering data processing unit converts 8 channels of analog engineering data into binary form in addition to processing binary status data.

The engineering data is multiplexed with the scientific data, thus permitting the use of a single multiplexer and A/D converter. The analog engineering data is converted to 10-bit binary words by the converter but is subsequently truncated to 7 bits, yielding a resolution of approximately ± 0.5 percent. The converted engineering data bypasses the digital filter routine and is sent to the output data buffer and formatter where it is subcommutated with the binary status data and shifted out to the data subsystem for downlink transmission as word 5 in 16 consecutive ALSEP frames.

2-112. LSM Thermal Control Function - The LSM is designed to operate over the temperature range of -50°C to +65°C. This range applies to the interior of the base package and each sensor head. Maintenance of interior temperatures within the above range in the severe lunar thermal environment is accomplished by a combination of insulation, control surfaces, parabolic reflectors, sunshades, and heaters. Figure 2-62 is a block diagram of the active thermal control function.

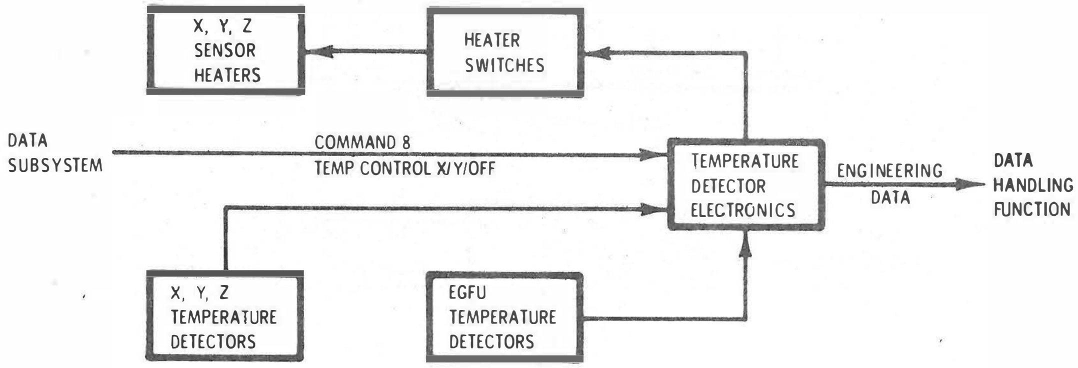


Figure 2-62. LSM Thermal Control Function, Block Diagram

Heaters dissipating one watt are required in each sensor head to maintain a minimum of +35°C during the lunar night. The heaters are automatically switched on and off as required by a thermistor network which is controlled by a sensor head temperature detector. Maximum temperature during the day is expected to be limited to +50°C. Earth command 8 switches from the X sensor thermistor to the Y sensor thermistor, to heaters off, and back to X. Two additional detectors monitor the temperature within the electronics base package. All temperature data is processed and transmitted to Earth as engineering data.

2-113. LSM Power Control and Timing Function - The LSM power control and timing function provides: conditioning of the 29 vdc ALSEP power for use by LSM subsystems; time-sharing high-power loads of the sensor motors and heaters; time-sharing electronics power during interval sequences so that peak and average power demands on the ALSEP are greatly reduced; internally-generated clocks synchronized to the 1060 Hz ALSEP clock. Figure 2-63 shows LSM loads that couple directly to the ALSEP 29-volt line, as well as internal power distribution requirements. The power conditioning function is performed by the DC/DC converter. Internal power-sharing is controlled by the system timer.

Ten switched power outputs are driven by internal timing divider circuits. System synchronization is maintained since clocks and switched power outputs are derived from the same divider chain. A system power-on reset pulse is generated to initialize subsystems as required.

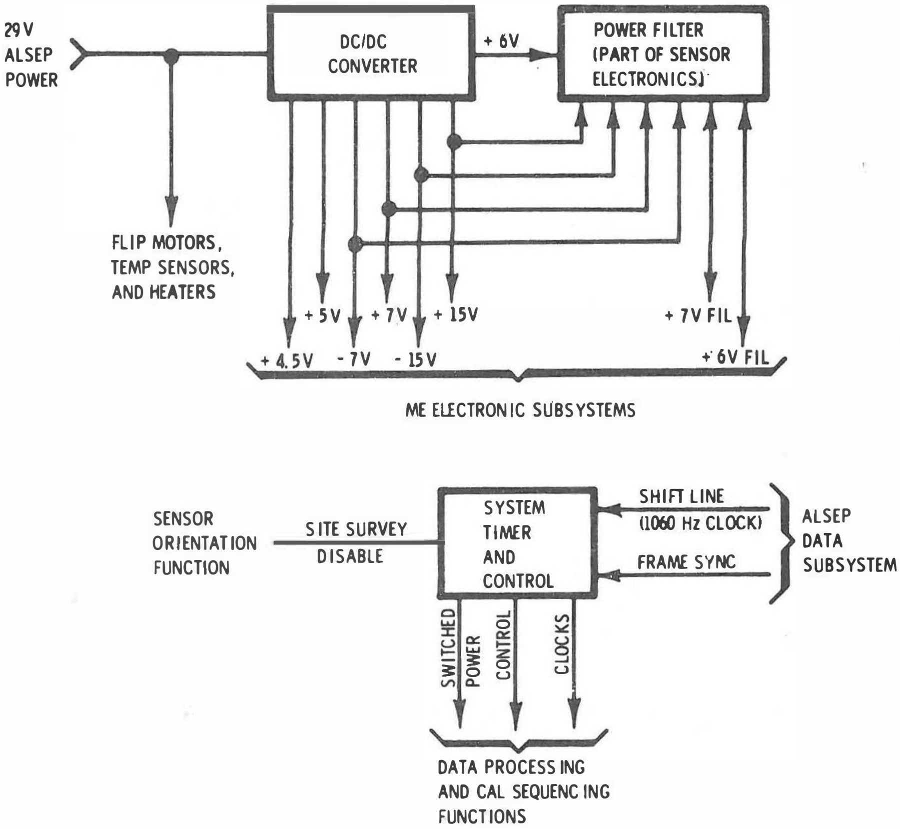


Figure 2-63. LSM Power Control and Timing Function, Block Diagram

2-114. LSM Data Subsystem Interface. The data subsystem supplies the LSM with the eight Earth commands listed in Table 2-22. In addition the data subsystem supplies the following timing pulses to the LSM to ensure proper sequencing of output data:

a. Data Clock
b. Frame Mark
c. Data Demand

The LSM sends back to the data subsystem two kinds of data:

a. Scientific
b. Engineering

Both the scientific and engineering data are supplied to the data subsystem data processor over a single digital output data line. (See Figure 2-56.) The magnetometer data is contained in ALSEP words 5, 17, 19, 21, 49, 51, and 53. (See Figure 2-30.)

Word 5 of each ALSEP data frame contains LSM engineering data and status information and words 17, 19, 21, 49, 51, and 53 contain LSM scientific data. Words 17 and 49 represent two successive X-axis values, words 19 and 51 represent two successive Y-axis values, and words 21 and 53 represent two successive Z-axis values. Each 10-bit scientific X, Y, and Z word has the format depicted in Table 5, Appendix B.

The engineering data and instrument status information is contained in 16 subcommutated frames using the format depicted in Tables 5 and 6, Appendix B.

The engineering status bit structure is described in Table 7, Appendix B.

2-115. HEAT FLOW EXPERIMENT (HFE) SUBSYSTEM

The heat flow experiment (HFE) measures the temperature gradient and the thermal conductivity in the near surface layers of the moon. From these measurements the lunar heat flow can be calculated. The measurements obtained from the experiment enable the average value as well as the direction of the net heat flux to be determined. The knowledge of the lunar heat flux will provide additional information on:

a. A comparison of the radioactive content of the Moon's interior and the Earth's mantle.
b. A thermal history of the Moon
c. A lunar temperature versus depth profile
d. The value of thermal parameters in the first three meters of the moon's crust.

When compared with seismic measurements, data from the HFE experiment will provide information on the composition and physical state of the Moon's interior.

The HFE is deployed with the two sensor probles emplanted in the lunar surface in three-meter boreholes. These holes are drilled by the astronaut with the Apollo lunar surface drill (ALSD). (Refer to Section IV for a description of HFE deployment.) The two probes are connected by two multiple-lead cables to the HFE electronics package which is deployed separately from the ALSEP central station.

Ten Earth commands control the operation of the HFE. The HFE responds to the data subsystem with scientific datums and six engineering status datums. One word of the first 16 frames of each 90-frame ALSEP telemetry cycle is used to transmit the HFE scientific datums downlink to Earth. The HFE engineering status datums are subcommutated with other ALSEP engineering and housekeeping datums in word 33 of the ALSEP telemetry frame. Refer to the Command List, Appendix A, and the Measurement Requirements, Appendix B, for command and data definition.

2-116. HFE PHYSICAL DESCRIPTION

The major components of the HFE are two sensor probes and an electronics package as shown in Figure 2-64. The probes are epoxy-fiberglass tubular structures which support and house temperature sensors, heaters, and the associated electrical wiring. Each probe has two sections, each 55 cm long, spaced 2 cm apart and mechanically connected by a flexible spring. The flexible spring allows the probe assembly to be bent into a U-shape to facilitate packing, stowage, and carrying.

There is a gradient heat sensor surrounded by a heater coil at each end of each probe section. Each of these two gradient sensors consists of two resistance

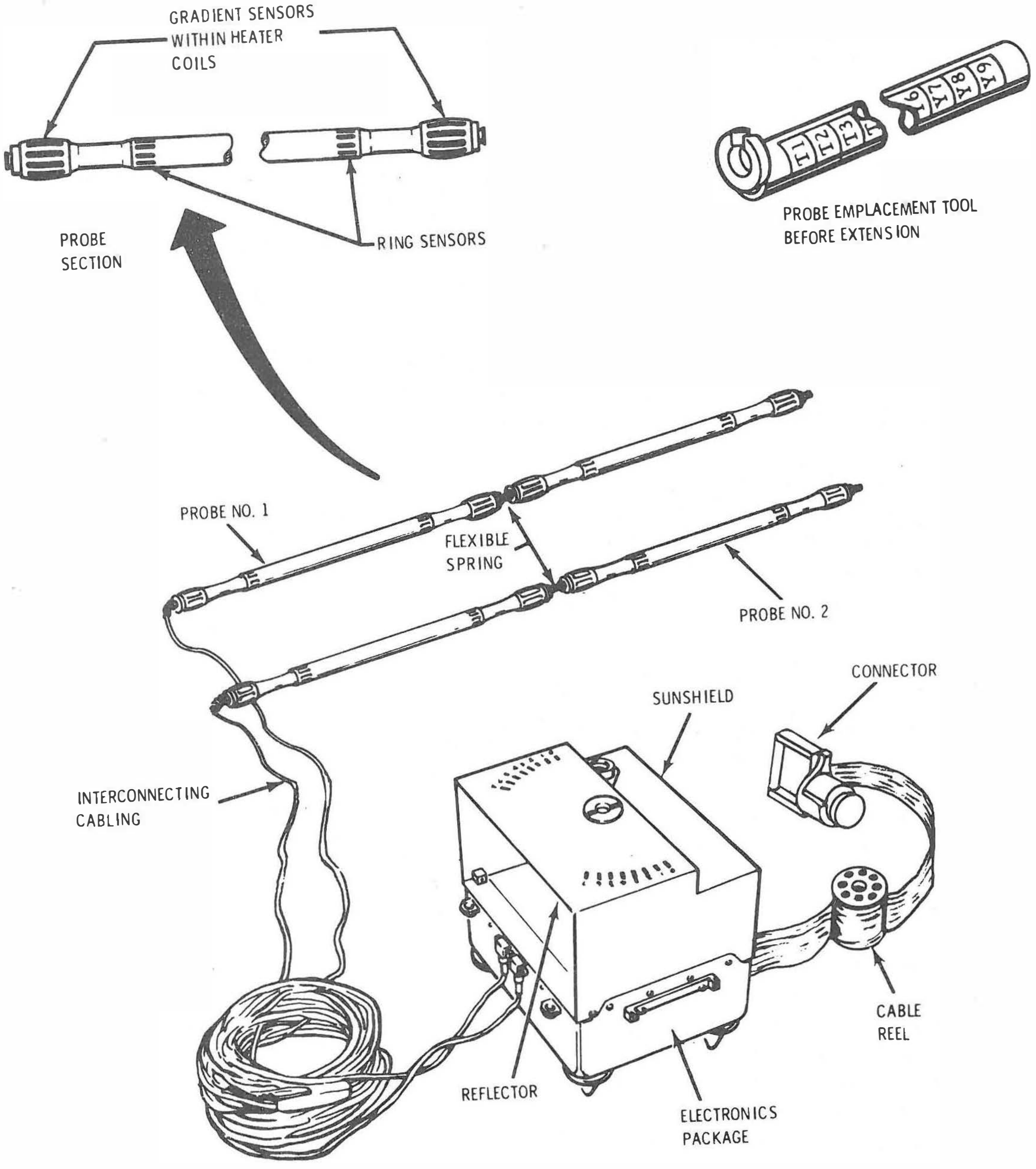


Figure 2-64. Heat Flow Experiment (HFE) Subsystem

elements. These four resistance elements are connected in an electrical bridge circuit. Ring sensors are located 10 cm from each end of each probe section. Each of these two ring sensors has two resistance elements. These four resistance elements are connected into an electrical bridge circuit. Four thermocouples are located in the cable of each probe.

The heat flow electronics package contains six printed circuit boards which mount the electronic circuits of the experiment. An external cable reel houses the HFE central station cable and facilitates deployment. A sunshield thermally protects the electronics package from externally generated heat. A reflector built into the open end of this sunshield aid in the radiation of internally generated heat that otherwise might be entrapped under the sunshield. The electronics package is thermally protected by multilayer insulation and thermal control paint. The leading particulars of the HFE are listed in Table 2-23.

Table 2-23. HFE Leading Particulars

Characteristic	Value
Size of probes (excluding handles - both packaged for flight) in inches	25.5 x 4.5 x 3.5
Size of electronics unit in inches	10 x 11 x 9.55
Weight of probes (both packaged for flight) in pounds	3.6
Weight of electronics unit in pounds	7.1
Power Requirements	
Mode 1	3.7 watts (day) 9.3 watts (night)
Mode 2	4.2 watts (day) 9.6 watts (night)
Mode 3	5.4 watts (day) 10.3 watts (night)

2-177. HFE FUNCTIONAL DESCRIPTION

The operation of the HFE electronics instrumentation when measuring the lunar material temperatures may be classified into six functions as shown in Figure 2-65. These functions are command processing, timing and control, temperature measurement, conductivity heater, data handling, and power and electronics thermal control.

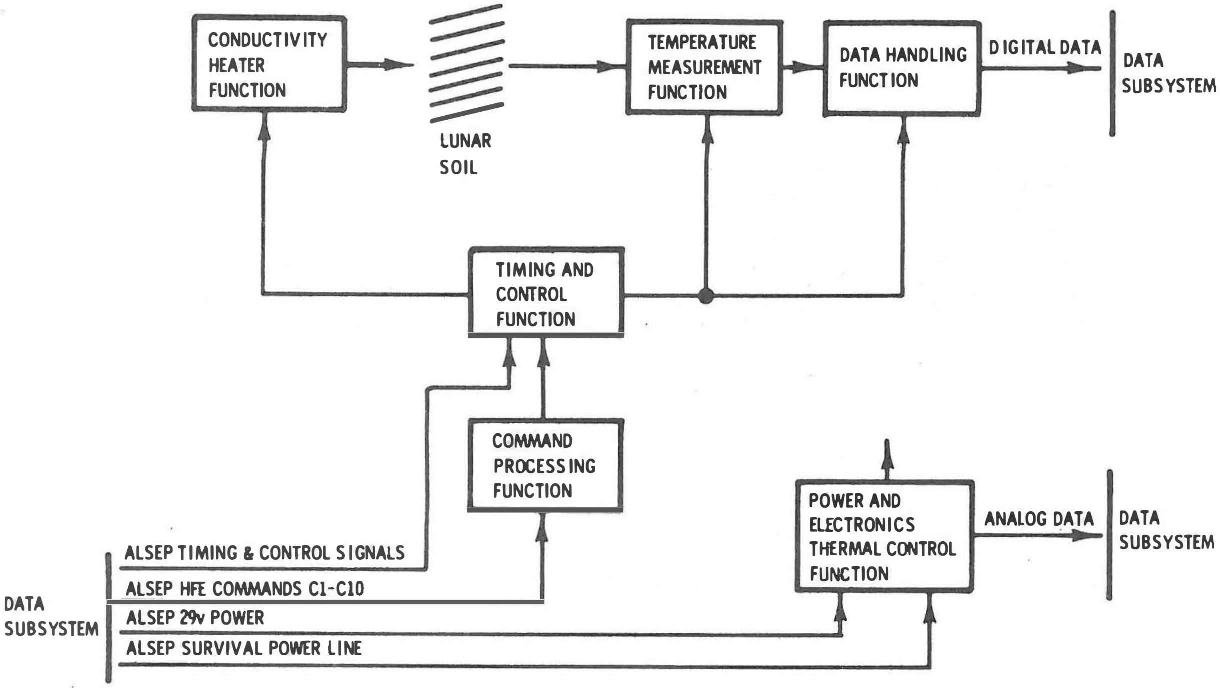


Figure 2-65. Heat Flow Experiment, Functional Block Diagram

The command processing function receives 10 different Earth commands (listed in Table 2-24) and translates these commands to allow ground control of the various optional operations of the HFE.

The timing and control function receives basic ALSEP timing signal inputs from the central station and translated command select signals from command processing and distributes logic control signals to all other major functions. The timing and control function actively sequences the operation of the HFE through measurement routines in accordance with signals received from command processing.

The temperature measurement function receives sensor excitation signals from timing and control and provides analog temperature measurement data to the data handling function. The conductivity heater function receives heater select stepping signals for discrete operation of all eight heaters and generates the drive current necessary to energize the lunar soil with a predetermined amount of heat.

The data handling function converts the analog measurement science data to digital data. In addition, it receives mode, sequence, subsequence, and heater status data. It formats and supplies this data to the data subsystem in response to the data demand and data shift pulses for insertion in the ALSEP telemetry data stream.

The power and electronics thermal control function distributes supply voltages to all functions and maintains the proper operating temperature for the HFE electronics package.

2-118. HFE DETAILED FUNCTIONAL DESCRIPTION

2-119. HFE Command Processing Function. The command processing function consists of the input buffer, mode select register, measurement select register, probe select register, and the heater and remote bridge sensor (ring sensors) select register as shown in Figure 2-66. Command processing includes the reception of Earth commands, command decoding, and subsequent generation of mode control signals that establish the logic routines for heater, probe, measurement, and mode operations.

The input buffer accepts and stores all ten Earth commands (C1 through C10, Table 2-24). They are gated to appropriate inputs of the respective select registers by the 90th frame mark.

Table 2-24. HFE Command List

Command Number		Command Nomenclature
Symbol	Octal	
CH-1	135	Normal (Gradient) Mode Select (HFE MODE/G SEL)
CH-2	136	Low Conductivity Mode Select (Ring Source) (HFE MODE/LK SEL)
CH-3	140	High Conductivity Mode Select (Heat Pulse) (HFE MODE/HK SEL)
CH-4	141	HF Full Sequence Select (HFE SEQ/FUL SEL)
CH-5	142	HF Probe #1 Sequence Select (HFE SEQ/P1 SEL)
CH-6	143	HF Probe #2 Sequence Select (HFE SEQ/P2 SEL)
CH-7	144	HF Subsequence #1 (HFE LOAD 1)
CH-8	145	HF Subsequence #2 (HFE LOAD 2)
CH-9	146	HF Subsequence #3 (HFE LOAD 3)
CH-10	152	HF Heater Advance (HFE HTR STEPS) (Steps through following 16-step sequence, one step per command)

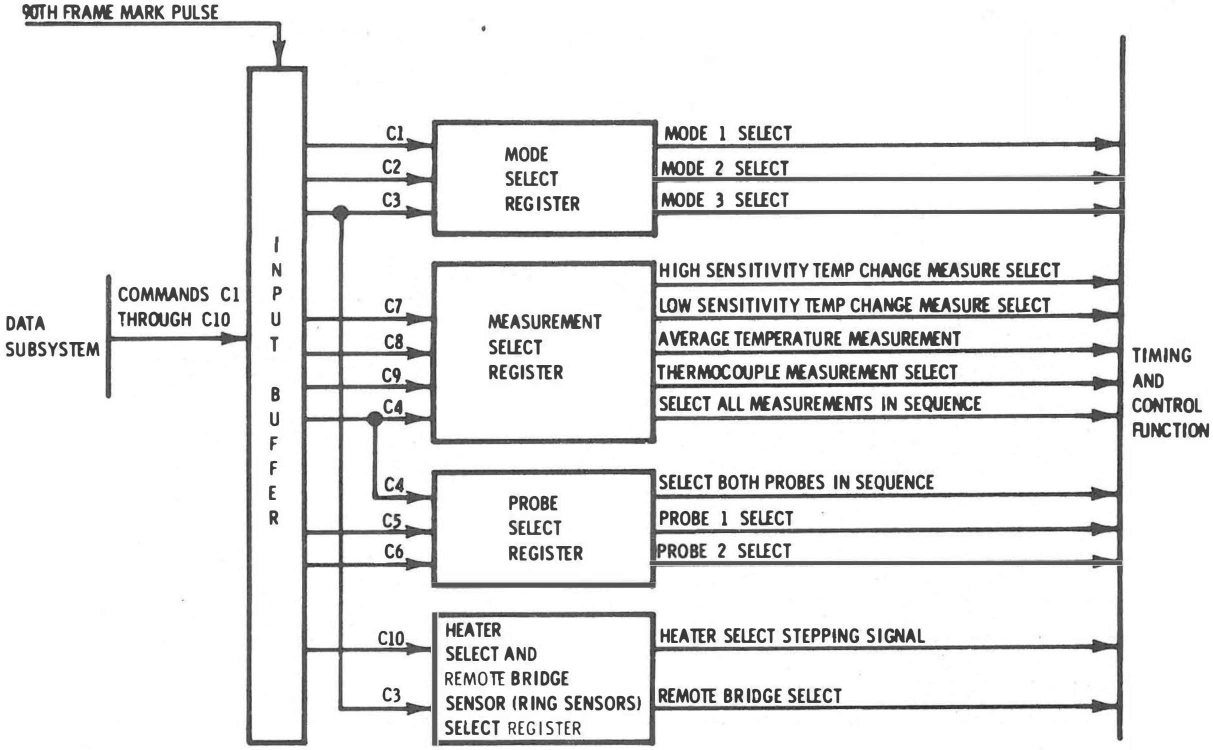


Figure 2-66. HFE Command Processing Function, Block Diagram

The mode select register receives commands C1 through C3 and operates as a mutually exclusive logic circuit providing only one signal output for one command input. The output of the mode select register places the HFE in one of three basic modes of operation for performing temperature measurements. The notation assigned to these three basic modes are mode 1 (normal, or gradient mode), mode 2 (low conductivity mode), and mode 3 (high conductivity mode).

Operation of the HFE in performing measurements in modes 1 and 2 are identical; but in mode 2, the probe heater constant current supply is turned on and any one of the four heaters on either probe can be selected by command 10 to measure lunar material heat conductivity.

Operation of the HFE in performing measurements in mode 3 is controlled by the heater select and remote bridge sensor (ring sensors) select register. Mode 3 operation utilizes the ring sensors in conjunction with the heaters. Mode 2 operation utilizes the gradient bridge sensors in conjunction with the heaters, while mode 1 operation utilizes only the gradient bridge sensors with the heaters turned off. In addition, the HFE is preset to mode 1 and full measurement sequence employing the gradient bridge sensors upon turn-on.

The measurement select register is a logic circuit that senses various combinations of commands C4 and C7 through C9. It determines the measurement routine for modes 1 and 2. In addition, the measurement select register acts as a mutually exclusive circuit when sensing command 4 thus setting up subsequent circuitry for a full sequence of temperature measurements as described in Table 2-25.

The probe select register is a mutually exclusive logic circuit that allows the option of selecting probe 1 or probe 2 independently during any temperature measurement format in mode 1 or mode 2. When C4 is applied to the probe select register, the register will select both probes in sequence.

The heater select and remote bridge sensor select register is a mutually exclusive and conditional logic circuit that selects both the heaters and remote bridge sensors (ring sensors). During mode 1 the register has no effect on operation. Command C10 is gated into the register to allow for heater selection from Earth In mode 2 the register serves as a heater select register only. In mode 3, the register serves as both a heater select register and remote bridge select register.

2-120. HFE Timing and Control Function. The timing and control function is shown in Figure 2-67 and consists of the measurement sequence programmer, 400 KHz clock, and the measurement sequence decoder. Timing and control receives command and timing signals from the command processor function and data subsystem, respectively. It provides the basic timing and control required for acquisition of data from the sensors and for formatting that data through the data handling function.

The measurement sequence programmer controls HFE measurement sequencing in modes 1 and 2 in response to measurement select signals. Sequence status is applied through the sequence decoder to control measurements and sensor excitation. The full sequence of measurements is listed in Table 2-25. A 90th frame mark occurs once every 54. 4 seconds. The time required to make a complete cycle of readings (full sequence) is 7. 25 minutes. In addition, the respective probe selection is handled by the measurement sequence programmer during modes 1 or 2.

The subsequence programmer, driven by a 400 KHz clock, allows any one of four possible measurement types (N_1 through N_4) to be taken. (See Table 2-24.) It provides a data control gate and digital subsequence status data through the decoder to the data handling function.

Signals received from the measurement sequence programmer and the subsequence programmer are compared and decoded by the measurement sequence decoder and sent to the conductivity heater, temperature measurement, and data handling functions for program control during HFE operation.

2-121. HFE Temperature Measurement Function. The HFE temperature measurement function block diagram is shown in Figure 2-68 and consists of the pulse power supply, sensor excitation switching circuit, gradient bridge sensors,

Table 2-25. HFE Measurements

Sequential Order	Symbol	Measurement and Location	Heater Status
		Modes 1 and 2 Sequence (Gradient and Low Conductivity)	
		<u>High Sensitivity</u>	Off in Mode 1, as selected in Mode 2
1	DH-01	Temperature difference, upper gradient bridge probe 1 ($\Delta T_{11}H$)	
2	DH-02	Temperature difference, lower gradient bridge probe 1 ($\Delta T_{12}H$)	
3	DH-03	Temperature difference, upper gradient bridge probe 2 ($\Delta T_{21}H$)	
4	DH-04	Temperature difference, lower gradient bridge probe 2 ($\Delta T_{22}H$)	
		<u>Low Sensitivity</u>	
5	DH-05	Temperature difference, upper gradient bridge probe 1 ($\Delta T_{11}L$)	
6	DH-06	Temperature difference, lower gradient bridge probe 1 ($\Delta T_{12}L$)	
7	DH-07	Temperature difference, upper gradient bridge probe 2 ($\Delta T_{21}L$)	
8	DH-08	Temperature difference, lower gradient bridge probe 2 ($\Delta T_{22}L$)	
		<u>Ambient Temperature</u>	
9	DH-09	Upper gradient bridge probe 1 (T_{11})	
10	DH-10	Lower gradient bridge probe 1 (T_{12})	
11	DH-11	Upper gradient bridge probe 2 (T_{21})	
12	DH-12	Lower gradient bridge probe 2 (T_{22})	

Table 2-25. HFE Measurements (cont)

Sequential Order	Symbol	Measurements and Location	Heater Status
Modes 1 and 2 Sequence (Gradient and Low Conductivity) (cont)			
		<u>Thermocouple</u>	Off in Mode 1 as selected in Mode 2
13	DH-13	Thermocouple reference junction thermometer (T ref)	
14		Four thermocouples in probe 1 cable (four readings) (TC group 1)	
	DH-14	Reference thermocouple - thermocouple 4 (Ref. TC-TC_1(4))	
	DH-24	Thermocouple 4 - thermocouple 1 (TC_1(4) - TC_1(1))	
	DH-34	Thermocouple 4 - thermocouple 2 (TC_1 (4) - TC_1 (2))	
	DH-44	Thermocouple 4 - thermocouple 3 (TC_1 (4) - TC_1 (3))	
15	DH-15	Thermocouple reference junction thermometer (T ref)	
16		Four thermocouples in probe 2 cable (four readings) (TC group 2)	
	DH-16	Reference thermocouple - thermocouple 4 (Ref. TC - TC_2 (4))	
	DH-26	Thermocouple 4 - thermocouple 1 (TC_2 (4) - TC_2 (1))	
	DH-36	Thermocouple 4 - thermocouple 2 (TC_2 (4) - TC_2 (2))	
	DH-46	Thermocouple 4 - thermocouple 3 (TC_2 (4) - TC_2 (3))	
Mode 3 (High Conductivity)			
	DH-50	Differential temp. probe 1 - bridge 1	OFF
	DH-51	Ambient temp. probe 1 - bridge 1	OFF
	DH-52	Differential temp. probe 1 - bridge 1	H_{12} ON
	DH-53	Ambient temp. probe 1 - bridge 1	H_{12} ON
	DH-60	Differential temp. probe 1 - bridge 2	OFF
	DH-61	Ambient temp. probe 1 - bridge 2	OFF
	DH-62	Differential temp. probe 1 - bridge 2	H_{14} ON
	DH-63	Ambient temp. probe 1 - bridge 2	H_{14} ON

Table 2-25. HFE Measurements (cont)

Sequential Order	Symbol	Measurement and Location	Heater Status
		Mode 3 (High Conductivity) (cont)	
	DH-56	Differential temp. probe 1 - bridge 1	OFF
	DH-57	Ambient temp. probe 1 - bridge 1	OFF
	DH-58	Differential temp. probe 1 - bridge 1	H_{11} ON
	DH-59	Ambient temp. probe 1 - bridge 1	H_{11} ON
	DH-66	Differential temp. probe 1 - bridge 2	OFF
	DH-67	Ambient temp. probe 1 - bridge 2	OFF
	DH-68	Differential temp. probe 1 - bridge 2	H_{13} ON
	DH-69	Ambient temp. probe 1 - bridge 2	H_{13} ON
	DH-70	Differential temp. probe 2 - bridge 1	OFF
	DH-71	Ambient temp. probe 2 - bridge 1	OFF
	DH-72	Differential temp. probe 2 - bridge 1	H_{22} ON
	DH-73	Ambient temp. probe 2 - bridge 1	H_{22} ON
	DH-80	Differential temp. probe 2 - bridge 2	OFF
	DH-81	Ambient temp. probe 2 - bridge 2	OFF
	DH-82	Differential temp. probe 2 - bridge 2	H_{24} ON
	DH-83	Ambient temp. probe 2 - bridge 2	H_{24} ON
	DH-76	Differential temp. probe 2- bridge 1	OFF
	DH-77	Ambient temp. probe 2 - bridge 1	OFF
	DH-78	Differential temp. probe 2 - bridge 1	H_{21} ON
	DH-79	Ambient temp. probe 2 - bridge 1	H_{21} ON
	DH-86	Differential temp. probe 2 - bridge 2	OFF
	DH-87	Ambient temp. probd 2 - bridge 2	OFF
	DH-88	Differential temp. probe 2- bridge 2	H_{23} ON
	DH-89	Ambient temp. probe 2 - bridge 2	H_{23} ON

Table 2-25. HFE Measurements (cont)

Note 1 Each of the HFE measurements (except thermocouples) consists of four voltage samples as follows:

High Sensitivity and T_{ref}	Low Sensitivity	Ambient
+ Excitation Volts	+ Current*	+ Excitation Volts
+ Bridge Output Volts	+ Bridge Output Volts	+ Current*
- Excitation Volts	- Current*	- Excitation Volts
- Bridge Output Volts	- Bridge Output Volts	- Current*

*Voltage across a current measuring resistor.

Note 2 Each pair of Mode 3 measurements is selected by execution of heater advance command 10.

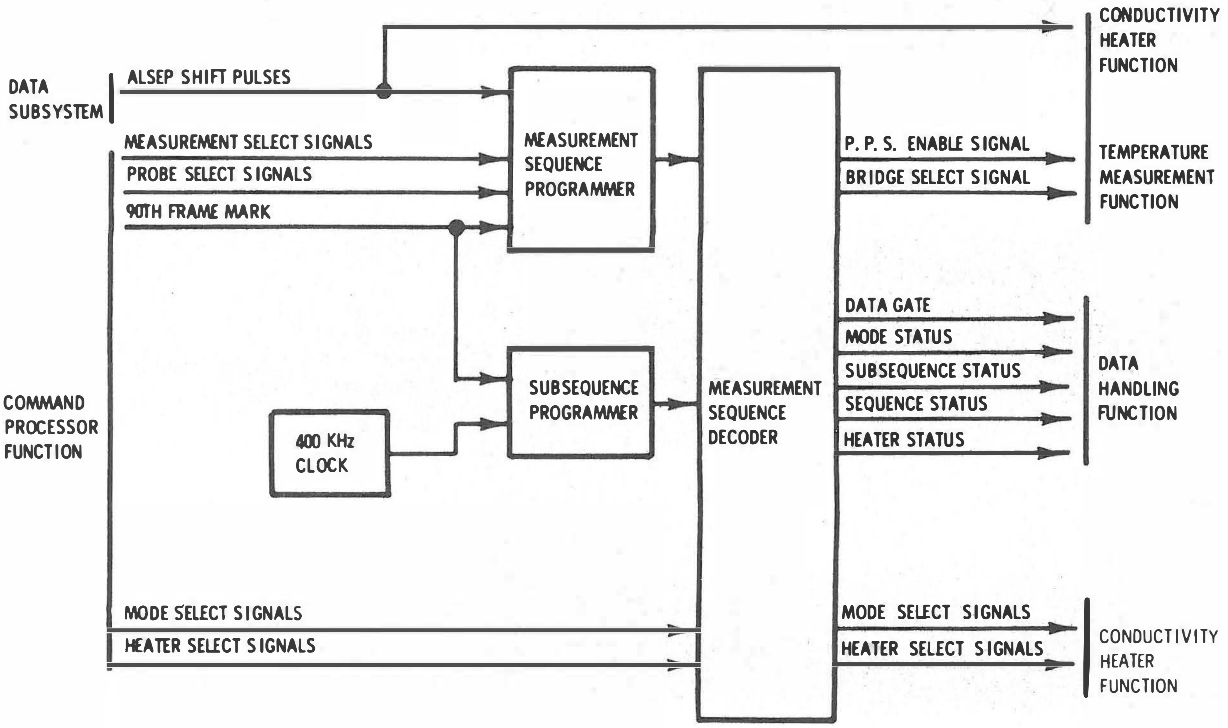


Figure 2-67. HFE Timing and Control Function, Block Diagram

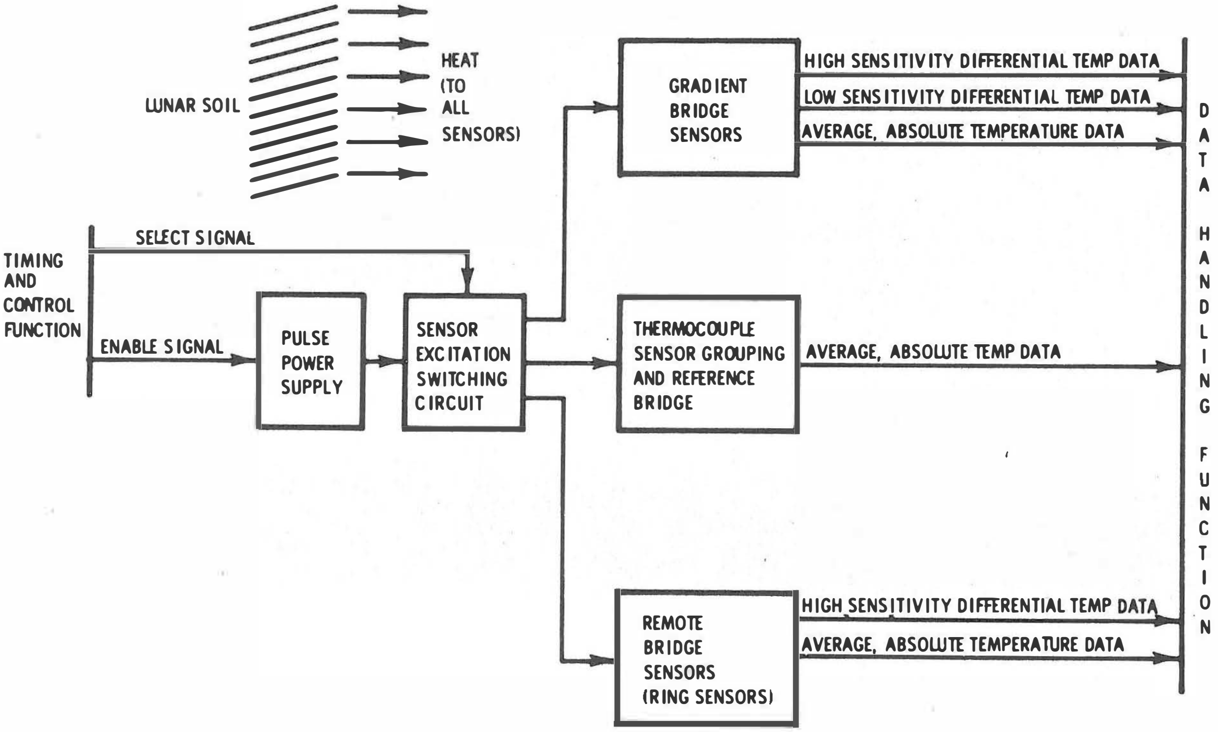


Figure 2-68. HFE Temperature Measurement Function, Block Diagram

thermocouple sensor grouping and reference bridge, and the remote bridge sensors (ring sensors). The gradient bridges and ring bridges receive excitation in accordance with the mode and sequence selected by command, and are energized by the pulse power supply. Selection is controlled by the sensor excitation switching circuit. The sensors and thermocouples are sampled to obtain analog temperature measurement information which is supplied to the data handling function.

Five types of measurements are performed in the three basic modes of operation as follows:

a. High sensitivity bridge measurement of probe temperature difference (gradient). These measurements are performed in a ±2°C range with a probable error of 0.003°C. The gradient sensors are used for these measurements in modes 1 and 2. The ring sensors are used in mode 3 operation.

b. Low sensitivity bridge measurement of probe temperature difference (gradient). These measurements are performed in a ±20°C range with a probable error of 0.03°C. The gradient sensors are used for these measurements in modes 1 and 2 operation.

c. Total bridge resistance measurement of probe ambient temperature. These measurements are performed in a 200 to 250°K range with a probable error of 0.1°C. The gradient bridges are measured in modes 1 and 2. The ring bridges are measured in mode 3 operation.

d. Bridge measurement of the thermocouple reference junction temperature. These measurements are performed in a 0° to 60° C range with a probable error of 0.1°C. These measurements are performed in modes 1 and 2 operation.

e. Thermocouple measurements of probe cable ambient temperature. These measurements are performed in a 90 to 350°K range with a probable error of 0.3°C. These measurements are performed only in modes 1 and 2 operation.

2-122. The normal gradient mode is used to monitor the heat flow in and out of the lunar surface crust. Heat from solar radiation flows into the Moon during the lunar day and out of the Moon during lunar night. This larger heat gradient in the near subsurface of the Moon will be monitored and measured in order to differentiate it from the more steady but smaller heat flow outward from the interior of the Moon.

The temperature gradients and average-absolute temperatures are measured with the gradient sensors and with the thermocouples spaced along the two cables connecting the probes to the electronics package.

In each deployed probe, the temperature difference between the ends of each of the two sections is measured by the gradient bridge consisting of the gradient sensors positioned at the ends of the probe section. Gradient temperatures are measured in both the high sensitivity and low sensitivity ranges.

Average-absolute temperature measurements are made by all gradient bridges and by any one of the thermocouples spaced at four points along each probe cable. In each probe cable, the thermocouples are placed at the top gradient sensor and at distance increments of 65, 115, and 165 cm above the top gradient sensor. The reference junction for the thermocouples is mounted on the HFE electronics package thermal plate. Gradient bridges and thermocouple locations are identified by a number system. Gradient bridges are identified by probe number (1 or 2), and probe section (1 for upper, 2 for lower). Thermocouples are identified by probe number, and by position in the cable (1, 2, 3, or 4, with 4 at the upper end of the probe).

2-123. Thermal conductivity of the lunar material is measured with the principal of creating a known quantity of heat at a known location by exciting one of the eight probe heaters, and measuring the resultant probe temperature change for a period of time. Because it is not known whether the surrounding material will have a low conductivity (loosely consolidated material) or a high conductivity (solid rock), the capability to measure over a wide range using two modes of operation are incorporated into the HFE design.

In low conductivity operation, the thermal conductivity of the lunar material is determined by measuring the temperature rise of the end of the probe in which the selected heater is located. The temperature which the heater must reach to dissipate the power input is a measure of thermal conductivity of the surrounding material. The low conductivity measurements are performed in the sequence (Table 2-25) selected by Earth command (Table 2-24). The probe heater selected by Earth command receives low power excitation, and dissipates two milliwatts of power.

In high conductivity operation, the thermal conductivity of the lunar material is determined by measuring the temperature rise at the ring bridge nearest the selected heater. The temperature rise per unit of time at the known distance is a measure of thermal conductivity of the surrounding material. The high conductivity (mode 3) measurements are temperature gradient in the high sensitivity range, and probe average-absolute temperature (Table 2-25) on a single remote bridge. The bridge used in performing a measurement is determined by the heater selected by Earth Command 10. The heater receives high power excitation, and dissipates 500 milliwatts of power. Because of the higher power consumption, this mode, if selected, will operate only during lunar day.

Ring bridge locations are identified in the same manner as the gradient bridges. Heater locations are identified by probe number (1 or 2), and by position on the probe (1, 2, 3, or 4, with 1 at the top and 4 at the bottom of the probe).

2-124. HFE Conductivity Heater Function. The conductivity heater function block diagram is shown in Figure 2-69 and consists of a constant current supply, heater select switching circuit, and eight heaters arranged on the top and bottom of upper and lower sections of probe 1 and 2. The conductivity heaters are used to apply a known amount of heat energy to the lunar soil.

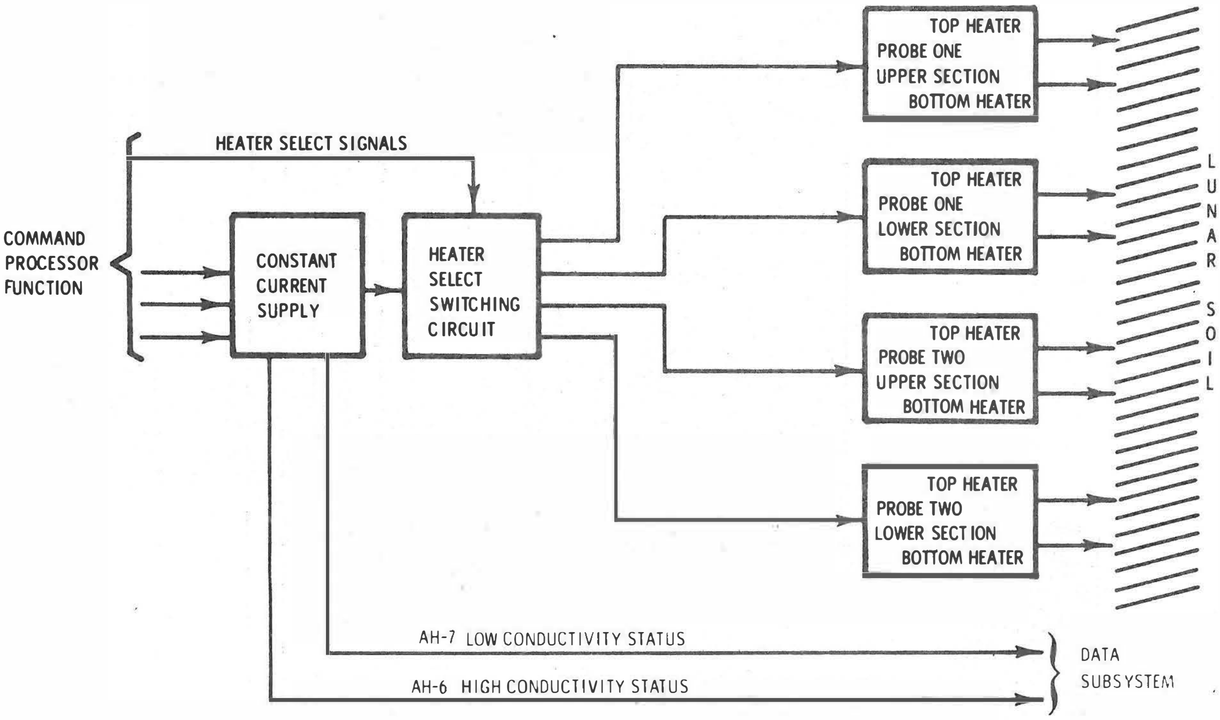


Figure 2-69. HFE Conductivity Heater Function, Block Diagram

The constant current supply provides the drive current for the heaters while the heater select switching circuit gates the drive current to the selected heater. Ground commands 1 through 3 are received from the command processor by the constant current supply. Command 1 inhibits the operation of the constant current supply. Commands 2 and 3 turn the constant current supply on and select the low or high constant current, respectively. The heater select signal (command 10) advances the heater select switching circuit sequentially to select the heater to be activated.

Analog housekeeping data and digital heater status data is supplied to the data handling function for insertion in the data output.

2-125. <u>HFE Data Handling Function</u>. The data handling function block diagram is shown in Figure 2-70 and consists of the multiplexer, data amplifier, analog-to-digital converter, and output shift register. Data handling includes the compiling and digitizing of analog temperature measurement science data for subsequent insertion into the data subsystem telemetry format.

The multiplexer compiles analog temperature data received from the temperature measurement function and distributes this data to the data amplifier in accordance with data gates received from timing and control.

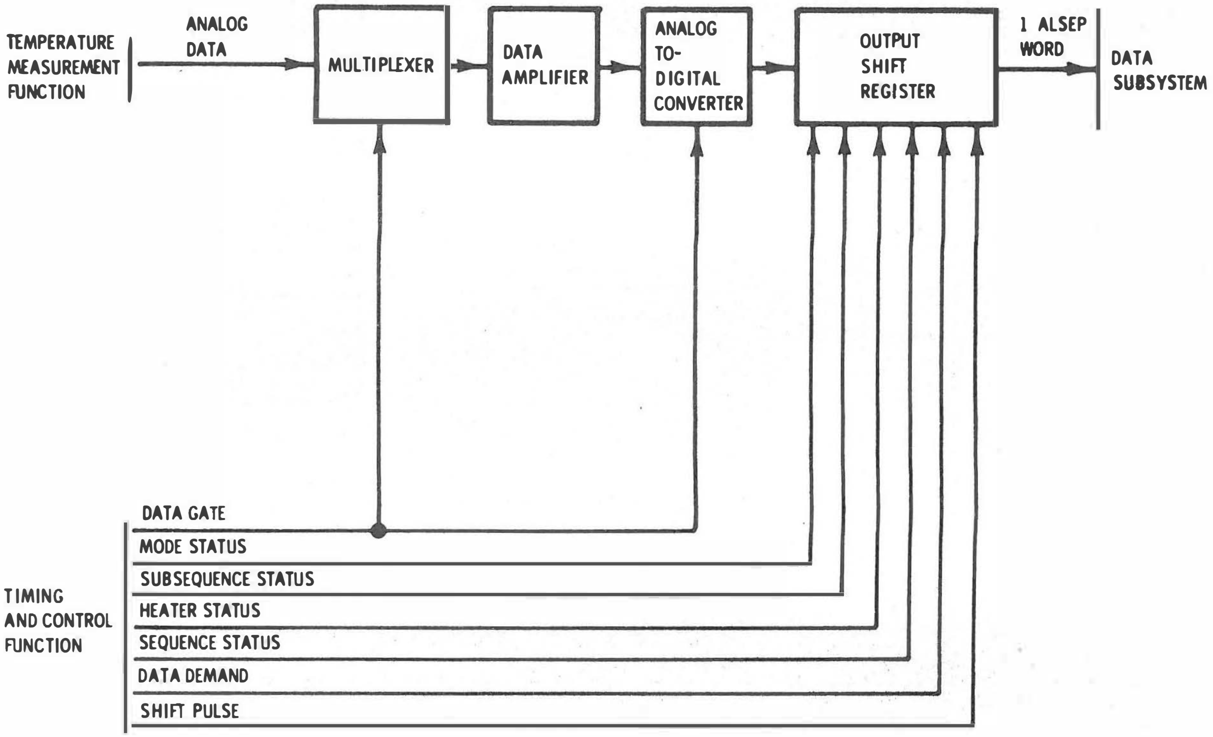


Figure 2-70. HFE Data Handling Function, Block Diagram

The data amplifier conditions the bridge and thermocouple voltages to the dynamic range required by the analog-to-digital-converter. A successive approximation technique is employed to digitize the data for storage in the output shift register. Mode, sequence, subsequence, and heater status data is also stored in the output shift register in alloted positions as shown in Figure 2-70. The data demand from the ALSEP data subsystem then allows the scientific data along with an identification code to be shifted out to the central station for insertion in the ALSEP telemetry frame and downlink transmission to Earth.

2-126. HFE Power and Electronics Thermal Control Function. The HFE power and electronics thermal control function block diagram is shown in Figure 2-71. and consists of the DC power converter, electronics temperature control circuit, electronics package heater, and the power gating control circuit.

The DC power converter receives the primary 29 VDC power and develops the required operating power levels for distribution to all HFE electronic circuitry through the power gating control circuit located electrically on the secondary side of the DC power converter. The power gating control circuit does the actual distribution of power and operates in conjunction with a thermostatic switch. When the HFE package temperature reaches 30°C, the thermostatic switch signals the power gating control circuit and power distribution is limited during periods between measurements.

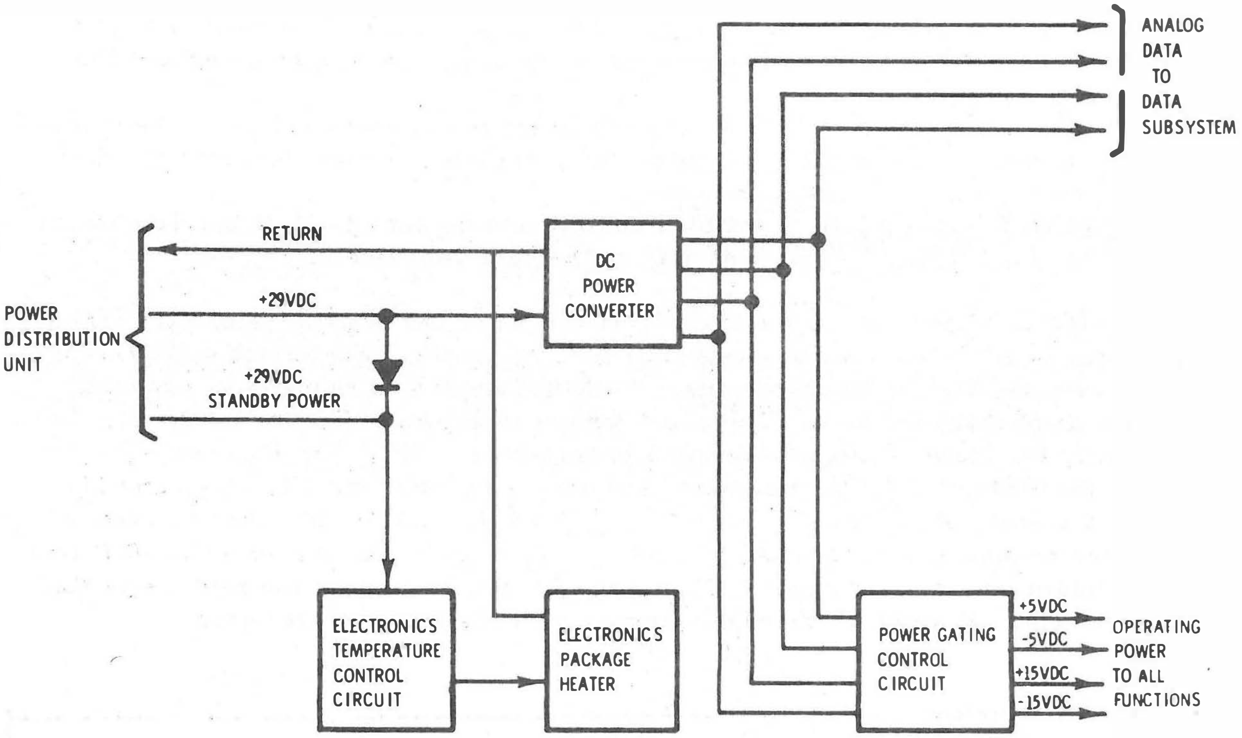


Figure 2-71. HFE Power and Electronics Thermal Control Function, Block Diagram

Active thermal control of the HFE electronics package is provided by the electronics temperature control circuit and the electronics package heater. The heater is mounted on the thermal plate and aids in maintaining the temperature of the HFE electronics within its operational temperature range of 0° to 60°C. The active component in the electronic temperature control circuit is a thermostatic switch which is sensitive to the effective operating temperature range of the HFE electronics package.

In addition, the heater is connected to a standby heater power line in order to provide thermal control during periods when operational power to the HFE is turned off. At these times the heater dissipates a maximum of 4. 5 watts for thermal control.

2-127. <u>HFE/Data Subsystem Interface</u> - In addition to the ten Earth commands listed in Table 2-24, the HFE receives the following four timing and control signals from the ALSEP data subsystem:

a. 90-frame mark which is the time base for the HFE operation. It is received by the measurement sequence programmer and releases commands from the command receiver.

b. Frame mark which is the time base for synchronizing data outputs to the data subsystem. It is used by the measurement sequence programmer and the subsequence programmer.

c. Data demand which is a dc level maintained for one word time on the demand line during the readout of the HFE output shift register, which receives the data demand from the ALSEP data subsystem.

d. Data shift pulse which is enabled during data demand to shift the data to the data subsystem at the 1060 BPS bit rate of the data subsystem.

2-128. The HFE has been allocated one 10-bit word per ALSEP telemetry frame for temperature data transmission. The HFE transmits data during the first 16 frames of each ALSEP 90-frame cycle. Eight frames are required to transmit one data point measurement. The word format is shown in Figure 2-72. R_1 and R_2 identify the state of the subsequence programmer. P_1, P_2, P_3, and P_4 identify the state of the measurement sequence programmer. M_1, M_2, and M_3 identify the state of the mode register. H_1, H_2, H_3, and H_4 identify the state of the heater sequence programmer. Frames 1 through 8 starting with the 90 frame mark contain one measurement. Frames 9 through 16 contain the next sequential measurement. Frames 17 through 90 contain words that are all zeros.

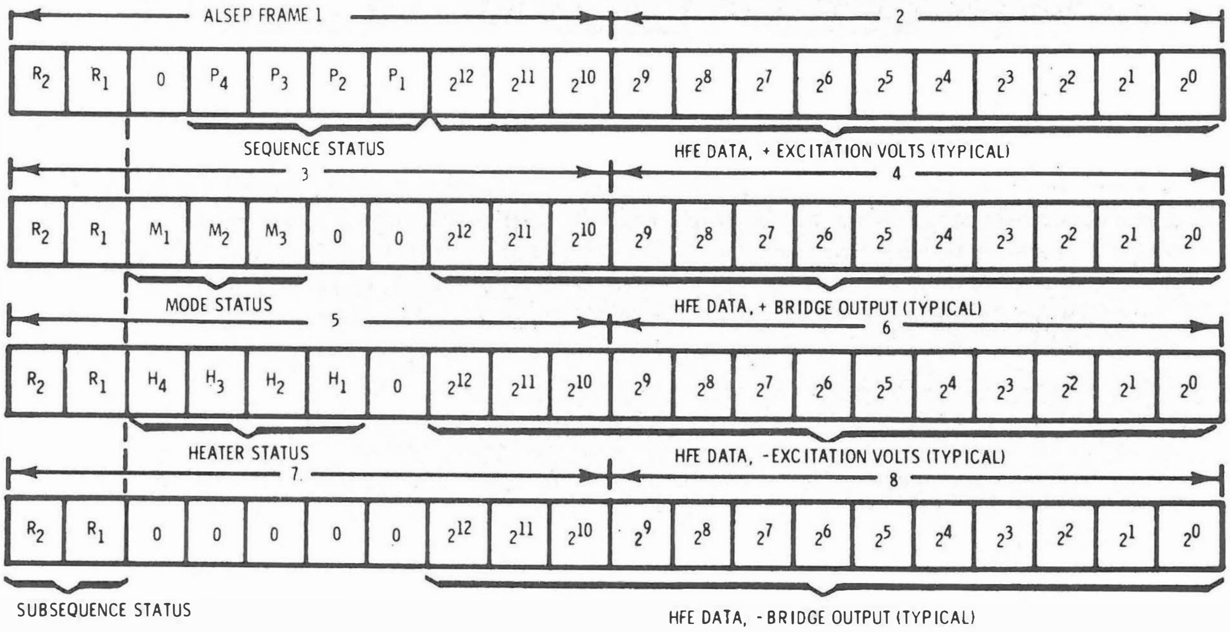


Figure 2-72. HFE Measurement Digital Data Format

2-129. Seven analog data lines are allocated to the HFE. They are used to monitor the HFE power supply and probe heater current supply as listed in Table 2-26.

Table 2-26. HFE Analog Housekeeping Datums

Symbol	Name	Frame	Range
AH-1	Supply Voltage #1	30	0 to +5 volts
AH-2	Supply Voltage #2	45	0 to -5 volts
AH-3	Supply Voltage #3	56	0 to +15 volts
AH-4	Supply Voltage #4	74	0 to -15 volts
AH-5	(not used)	86	
AH-6	High Conductivity Heater	57	ON/OFF
AH-7	Low Conductivity Heater	75	ON/OFF

SECTION III

MAINTENANCE

3-1. MAINTENANCE CONCEPT

The ALSEP system equipment for which maintenance planning is defined is as follows:

a. The ALSEP Flight Article - Consists of ALSEP lunar surface equipment; experiment subsystems, the data subsystem, electrical power subsystem, and structure/thermal subsystem.

b. Ground Support Equipment - Consists of all equipment required to support the maintenance events of the flight article after NASA acceptance of ALSEP, through ALSEP installation in LM.

c. ALSEP Support Manuals - Consists of seven manuals as described in para. 3-13.

ALSEP flight hardware enters a maintenance situation when it has been accepted by NASA through DD-250 sign-off. Maintenance planning is provided for the period from acceptance through installation in LM. ALSEP hardware categories for maintenance purposes are defined in Table 3-1.

Table 3-1. ALSEP Hardware Categories

Nomenclature	Definition
System	A complete, self-contained, operating device (ALSEP).
Subsystem	Major identifiable support device having a unique, defined function (PSE, ASE, HFE). In the ALSEP, each experiment is designated a subsystem.
Component	An identifiable replaceable assembly within a subsystem (receiver, mortar). Also defined as a combination of parts, subassemblies, or assemblies, usually self-contained, which performs a distinctive function in the operation of the overall equipment (black box).
Part	Lowest level of equipment, singular item (resistor, screw). Also defined as one piece, or two or more **pieces** joined together which are not normally subject to disassembly without destruction.

Two basic levels of maintenance, system (level A) and specialized (level B), have been established to provide a total maintenance capability for support of the ALSEP system. The maintenance flow for the ALSEP flight system is illustrated in Figure 3-1.

Level A maintenance consists of those actions required to ascertain flight-readiness of the ALSEP flight system. It is limited to inspection, functional test, corrective maintenance, and removal and installation of subsystems and components.

Level B maintenance consists of factory repair and calibration. It will include detailed repair, component/part removal and replacement, adjustment, calibration, and testing.

3-2 MAINTENANCE LEVEL A (SYSTEM).

Level A maintenance is performed at Bendix Aerospace Systems Division (BxA) and at Kennedy Space Center (KSC) as illustrated in the maintenance flow diagram, Figure 3-2.

The ALSEP subpackages and equipment, in addition to the flight article spares listed in Table 3-2 will be maintained in bonded storage until called for by KSC. The spare grenade launch assembly, because it contains live ordnance, is stored at the KSC ordnance facility. Those spares designated Government Furnished Equipment (GFE) in Table 3-2 are stored at the facilities at which they were manufactured or at Government facilities. The remaining spares are stored in BxA.

3-3 Level A Maintenance at BxA. Level A maintenance at BxA consists of those actions required to maintain the ALSEP flight system, and ready it for delivery to KSC. It includes storage, inspection, testing, replacement of subsystems or components, and shipment in the sequence illustrated in Figure 3-2.

Subsystems or components which have exceeded their calibration periods, or which were found defective in inspection or test, are replaced with a flight article spare. Spare subsystems or components are subjected to pre-integration acceptance tests prior to integration into the system. Replaced subsystems or components are shipped to their respective level B maintenance facility.

The functional capability of the flight system is tested by the system test set in an integrated system test. The flight system can be delivered to KSC upon satisfactory completion of this test.

This maintenance facility receives repaired and/or calibrated components and subsystems from maintenance level B. Subpackages found defective at KSC are received at BxA for malfunction isolation and corrective action.

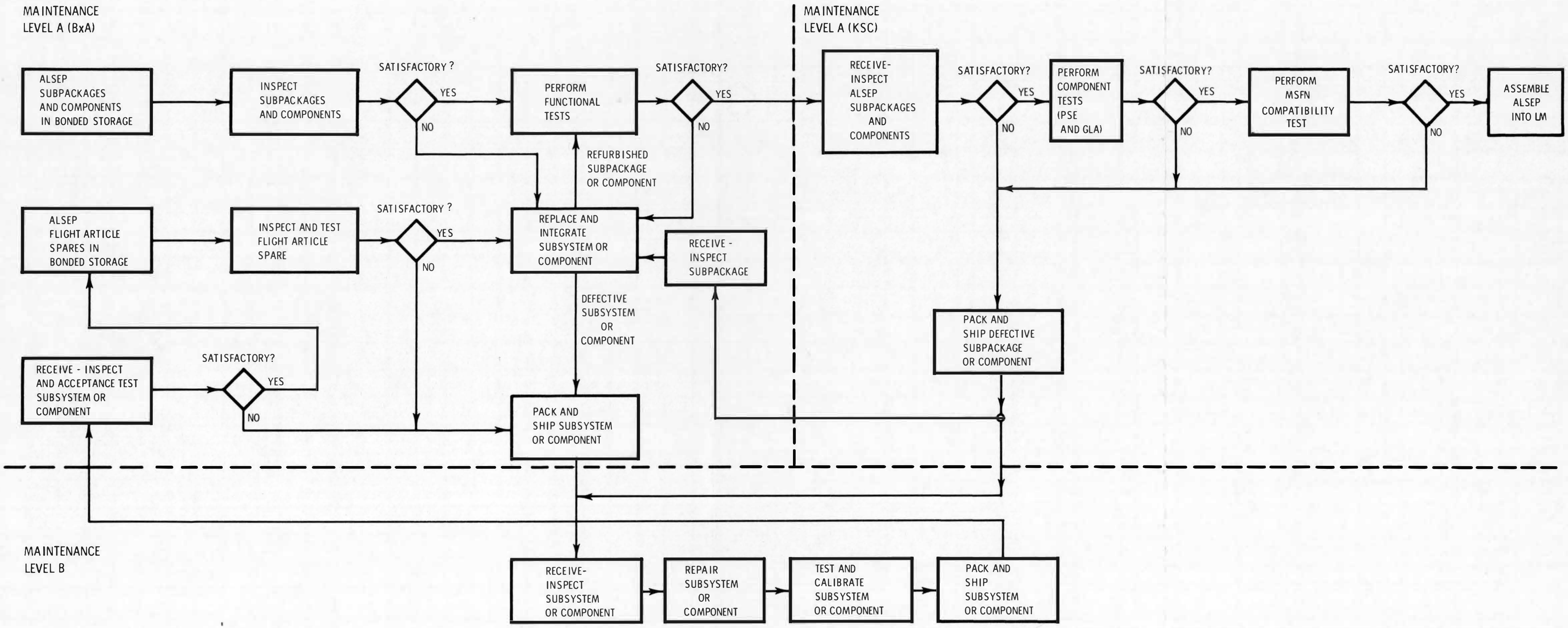


Figure 3-1. ALSEP Flight System Maintenance Flow Diagram

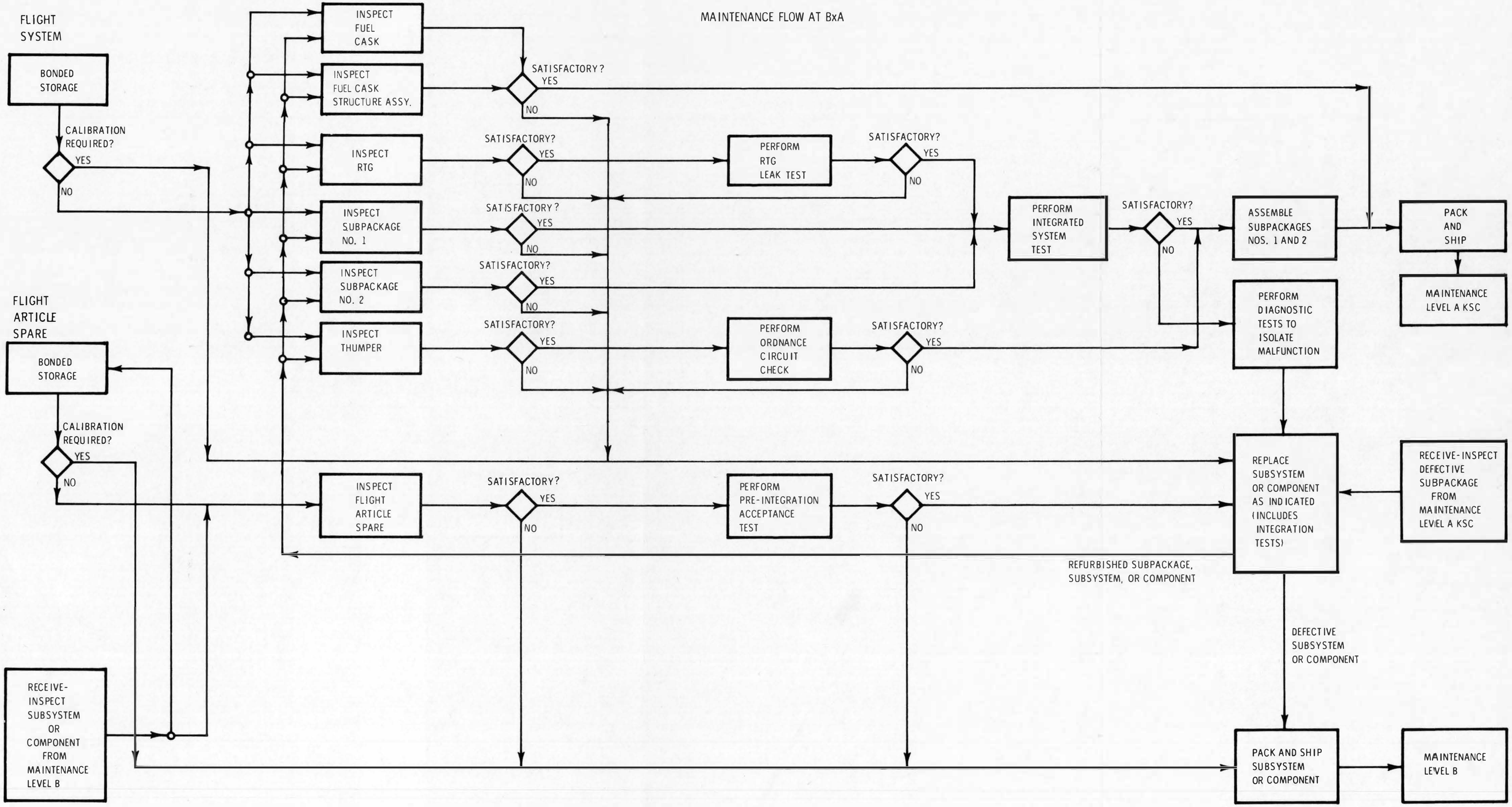


Figure 3-2. Level A Maintenance Flow Diagram (Sheet 1 of 2)

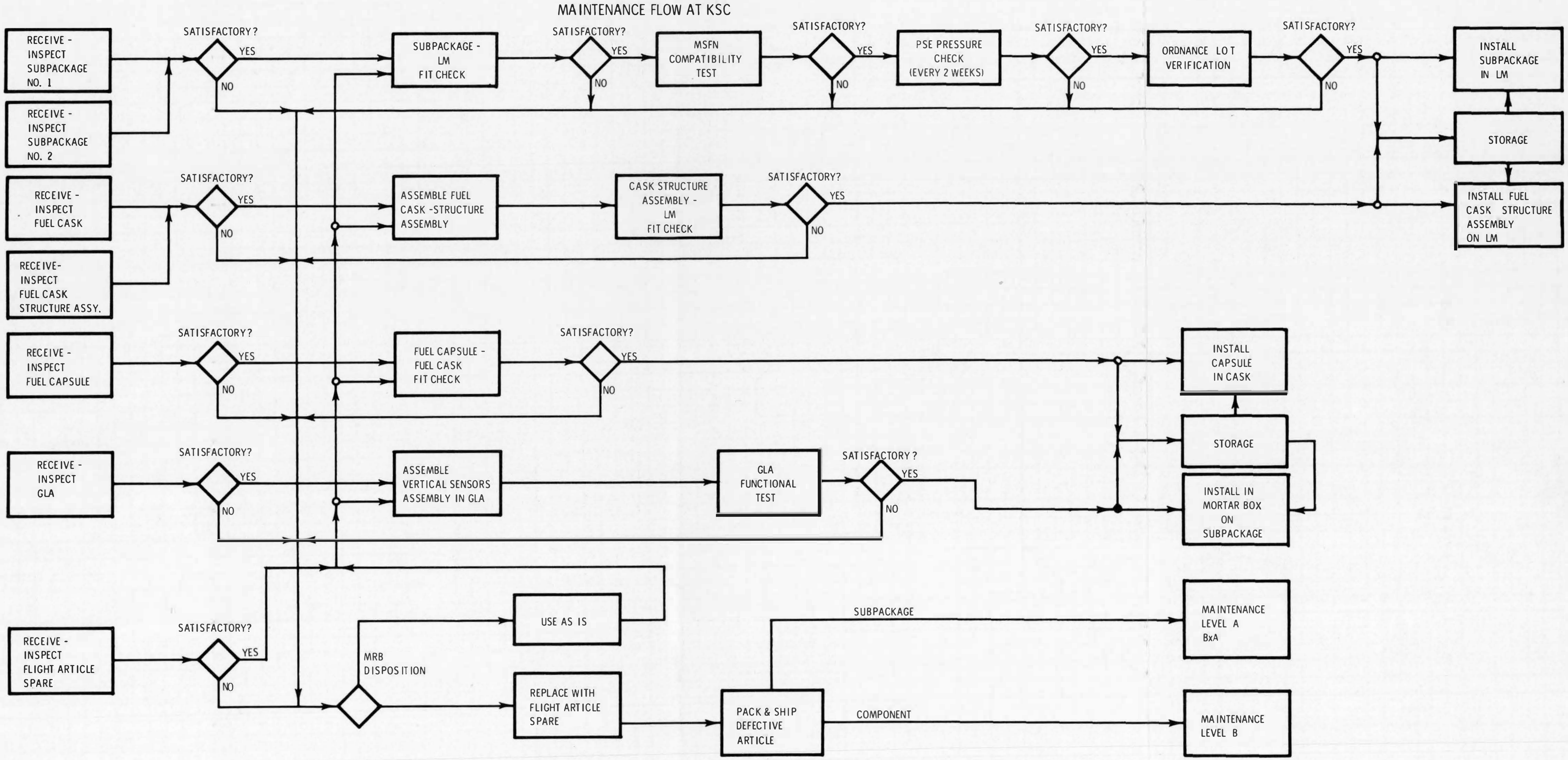


Figure 3-2. Level A Maintenance Flow Diagram (Sheet 2 of 2)

TABLE 3-2. ALSEP Flight Article Spares

Nomenclature	Quantity	Part Number	Note
Passive seismic experiment sensor/shroud	1	2338460-5	
PSE Central electronics	1	2334670	
PSE leveling stool	0	2344723	
Active seismic experiment electronics	1	2334468	
Grenade launch assembly	1	2338507-2	KSC
Mortar box assembly	1	2334499-4	
Thumper and geophone assembly	1	2334772-4	
Magnetometer experiment	1	2330657	GFE
Heat flow experiment	1	2345430-102	GFE
Radioisotope thermoelectric generator	0	47E300779	GFE
Fuel cask	0	47E301134	GFE
Fuel capsule	0	47D300400	GFE
Universal handling tool	1	2338102	
Dome removal tool	0	2338002	
Helical antenna	0	2330307	
Antenna cable assembly	0	2334522	
Antenna aiming mechanism	0	2339175	
Diplexer switch	0	2330526	
Diplexer filter	0	2330525	
Command receiver	1	2345147	
Command decoder	1	2330509	
Analog to digital converter-multiplexer	1	2338900	
Data processor	1	2330521	
Transmitter A& B	2	2345250	
Power distribution unit	1	2330450-2	
Timer	1	2338511	
Power conditioning unit	0	2330000-3	
Specular reflector	3	2330264C	
Curtain hinge spring	2	2335628	
Curtain hinge spring	2	2335629	
Curtain hinge spring	2	2335630	
RF cable assembly	1	2345632	
RF cable assembly	1	2330671-2	
RF cable assembly	1	2330671-3	
RF cable assembly	2	2344607	
Diplexer switch cable assembly	2	2344698-1	
Diplexer switch cable assembly	2	2344698-2	
Ammeter shorting plug	1	2338017	
Sensor strap	2	2338039	
Screw	5	2338047	
Fuel cask mounting assembly	0	2338770	

Table 3-2. ALSEP Flight Article Spares (cont)

Nomenclature	Quantity	Part Number	Note
Lever and wire assembly	2	2338681-1	
Lever and wire assembly	2	2338681-2	
Body release mechanism	2	2338687-1	
Body release mechanism	2	2338687-2	
Shear pin stop bracket (left hand)	2	2338685	
Shear pin stop bracket (right hand)	2	2338686	
Tab lock	4	2338689	
Special washer, release mechanism	4	2338693	
Shear pin	2	2338668	
Tension stud	2	2338692	
Square shear pin cutter	14	2338671-3	
Belleville washer	16	BO500-025	
Shear wire	25	2338043	
Shear wire	26	2338054	
Setscrew	4	2338665	
Screw 4-40 x .25 inch	15	MS35275-213	
Lanyard assembly	1	2338128	
Switch, barometric	1	2203114	
RTG cable spring clip	4	2335516	
Thermistor, platinum	2	5001-32	
Outboard support pin	3	2335126	
Outboard quick release pin	2	2334525-3	
Guide fastener	31	2335931-1	
Guide fastener	4	2335931-2	
Guide fastener	2	2335931-4	
Guide fastener	2	2335931-6	
Guide fastener	6	2335931-7C	
Guide fastener	2	23344998	
Guide fastener cap	150	2334675-1D	
Guide fastener cap	23	2334675-3D	
Washer, special	20	2341477	
Dust cover	2	2344999	
Quick release pin	3	51706-2	
Quick release pin	3	51706-4	
Strain gage	2	WK05-125BS120	
Screw	5	MS51957-30	
Screw, socket hd	5	MS16995-10	
Screw, socket hd	5	MS16995-13	
Screw, Hex hd	5	MS20033-1	
Screw pan hd	5	NAS 1216-3C-8	

Table 3-2. ALSEP Flight Article Spares (cont)

Nomenclature	Quantity	Part Number	Note
Quick release pin	1	2335577-1	
Dust cover connector	1	2334528-6	
Dust Cover	1	2339418	
Bolt, special	6	2335067	
Bolt, special	12	2338041	
Boyd bolt	8	CA2773-2-1	
Boyd bolt	23	CA2773-4-1	
Boyd bolt	16	CA2773-6-1	
Boyd bolt	15	CA2773-8-1	
Boyd bolt	8	CA2773-10-1	
Boyd bolt	26	CA2773-14-1	
Boyd bolt	11	CA2773-20-1	
Boyd bolt	6	CA2773-24-1	
Boyd bolt spring	65	CS1014	
Boyd bolt nut	60	SP1015B	
Accordion rivet	100	PC47290	
Accordion rivet	100	PC47289	
Boom attachment	0	2335500-3	
Screw, self lock	5	NAS 1189C02P3	
Nut	5	MS19068-003	
Nut, self lock	10	MS21043-3	
Nut, self lock	23	MS21043-4	
Nut, self lock	10	MS21043-06	
Nut, self lock	5	MAS1291C02M	
Nut plate	7	CA 2774D	
Washer, flat	5	MS15795-707	
Washer	5	MS15795-802	
Washer, flat	5	MS15795-803	
Washer, flat	10	MS20995-808	
Rivet, blind	5	MS20604AD3-2	
Lug, terminal	5	MS35436-6	
Lug, terminal	5	MS35446-2	
Wire, lock	15 ft.	MS20995-N-20	
Wire, lock	15 ft.	MS20995-N-32	

3-4. Level A Maintenance at KSC. Level A maintenance at KSC consists of those actions required to receive the flight system from BxA, and install it in the LM. It includes receiving-inspection, fit checks, and functional checks in the sequence illustrated in Figure 3-2. Any discrepancy requires a Material Review Board disposition. If an article cannot be used as is, it is replaced with a flight article spare which is requested from Level A BxA.

3-5. MAINTENANCE LEVEL B (SPECIALIZED)

Maintenance level B consists of factory repair and overhaul of ALSEP flight equipment. It will consist of detailed repair, overhaul, and component/part removal and replacement as well as required adjustments and calibration necessary to achieve the high level of ALSEP performance.

3-6. GROUND SUPPORT EQUIPMENT (GSE)

ALSEP GSE includes test sets, exciters, simulators, handling equipment, and selected standard tools and test equipment. Corrective maintenance for the STS includes self-test diagnostic programs (in conjunction with the "ALSEP System Test Equipment Maintenance Manual") to fault-isolate to the black box, panel, component, part, or to a functional circuit group of logic cards in the programmer/processor.

Maintenance beyond the level A capability will be accomplished at specialized repair (level B maintenance) levels, or by vendor services. ALSEP peculiar deliverable GSE will be directed to Bendix (or Bendix subcontractor), for repair as required.

3-7. GSE ELECTRICAL

Electrical GSE used in level A maintenance for testing of the ALSEP system is listed in Table 3-3. The system test set is the prime ALSEP maintenance tool and all other equipment listed in Table 3-3 is considered peripheral test equipment that complements the system test set. Figures 3-3 through 3-15 illustrate these equipments.

3-8. GSE MECHANICAL

Mechanical GSE used in handling, test, installation, and maintenance of the ALSEP system is listed in Tables 3-4 through 3-7, and illustrated in Figures 3-16 through 3-22.

3-9. TOOLS AND TEST EQUIPMENT

Standard tools and test equipment, facilities, and supplies required for maintenance are listed in Table 3-8.

Table 3-3. Electrical Ground Support Equipment

Figure No.	Nomenclature	Part Number	CFE or GFE
3-3	ALSEP system test set	2331700	CFE
3-4	Magnetometer flux tank assembly	WDL-29-173299 (Philco)	GFE
3-5	Gamma control console	WDL-99-173301 (Philco)	GFE
3-6	Integrated power unit test set	47E300467G1 (GE-MSD)	GFE
3-7	Environmental test chamber	PD452971 (3M)	GFE
3-8	IPU breakout box	BSX 7482	CFE
3-9	RTG simulator	BSX 6997	CFE
3-10	Grenade launch assembly test set	2331657	CFE
3-11	Active seismic sensor simulator	2331601	CFE
3-12	Passive seismic sensor exciter	CBE 2250 (Teledyne)	CFE
3-13	Heat flow sensor simulator	2332375	CFE
3-14	Electric fuel capsule simulator	47D300261 (GE-MSD)	GFE
3-15	Antenna cap fixture	2333830	CFE
-	Thumper--AIRME adapter	2345477	CFE

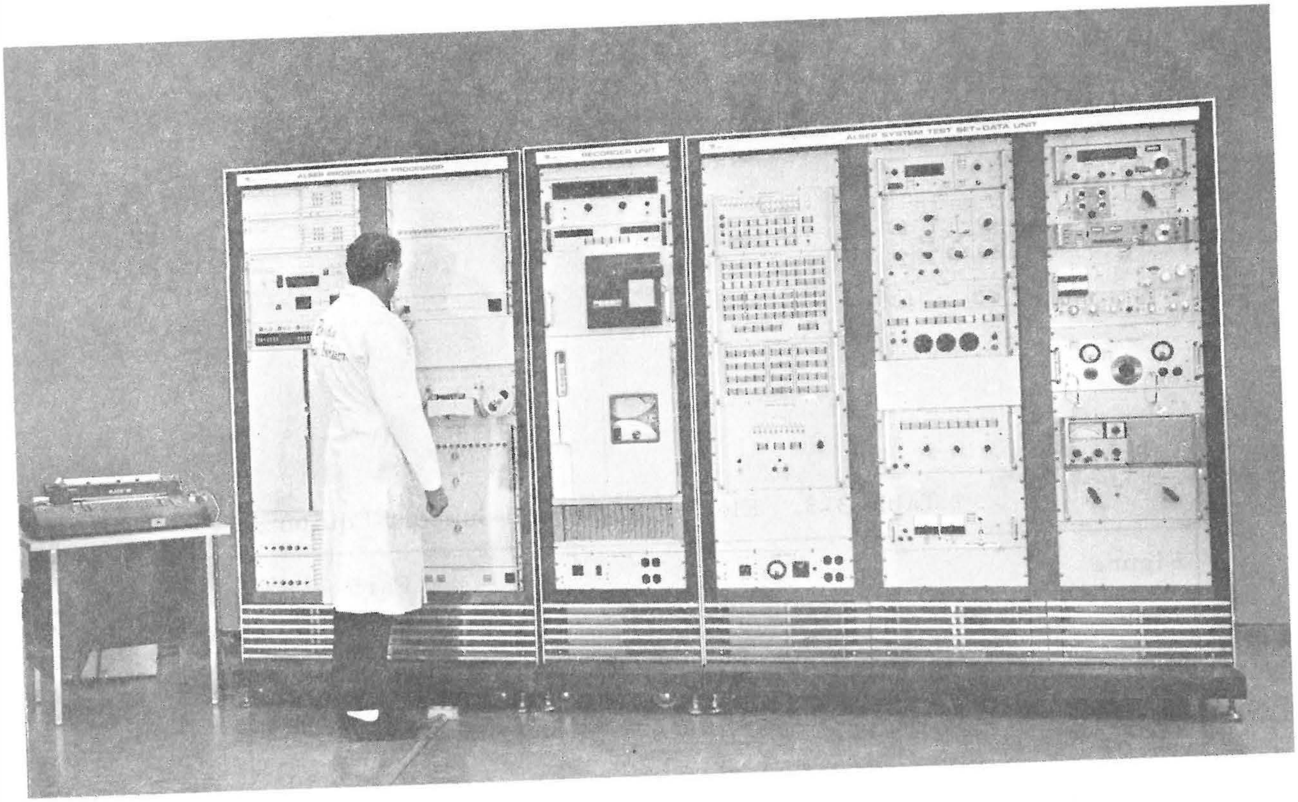


Figure 3-3. ALSEP System Test Set

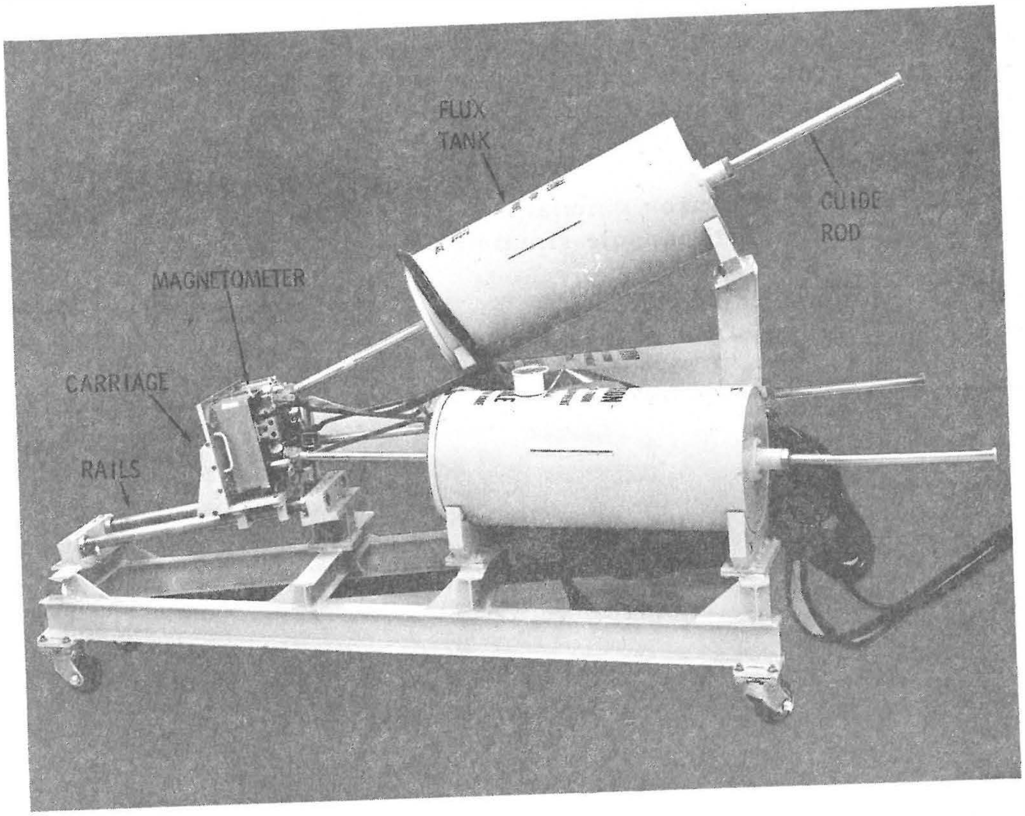


Figure 3-4. Magnetometer Flux Tanks (Configuration B)

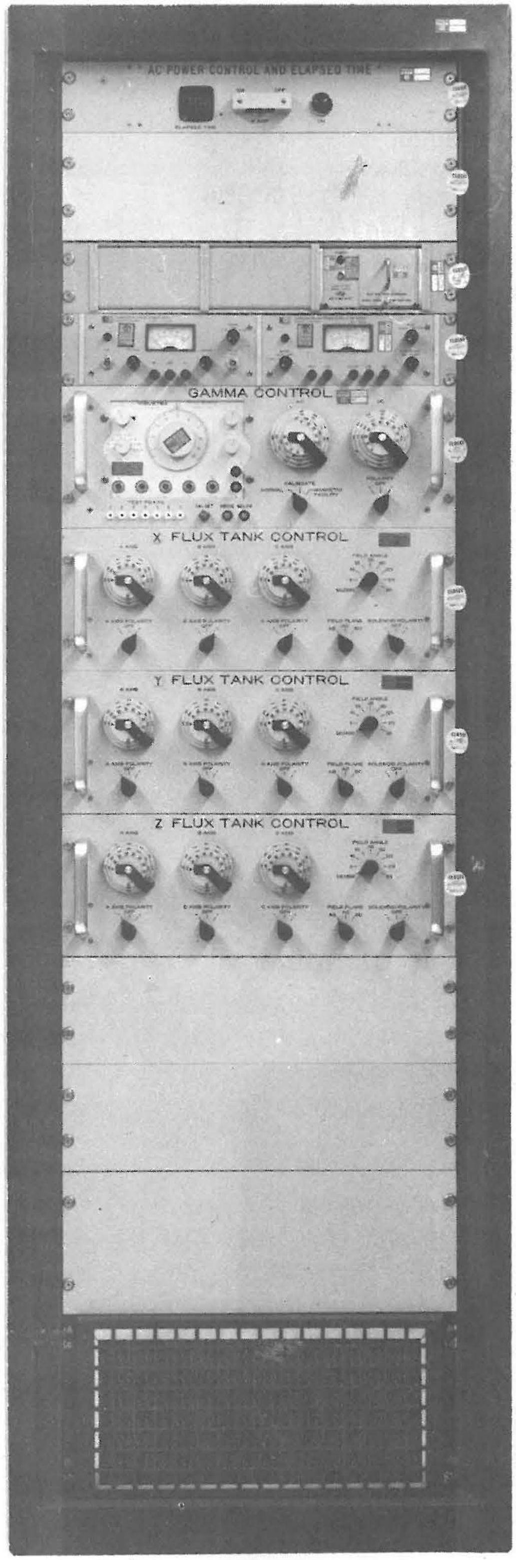


Figure 3-5. Gamma Control Console

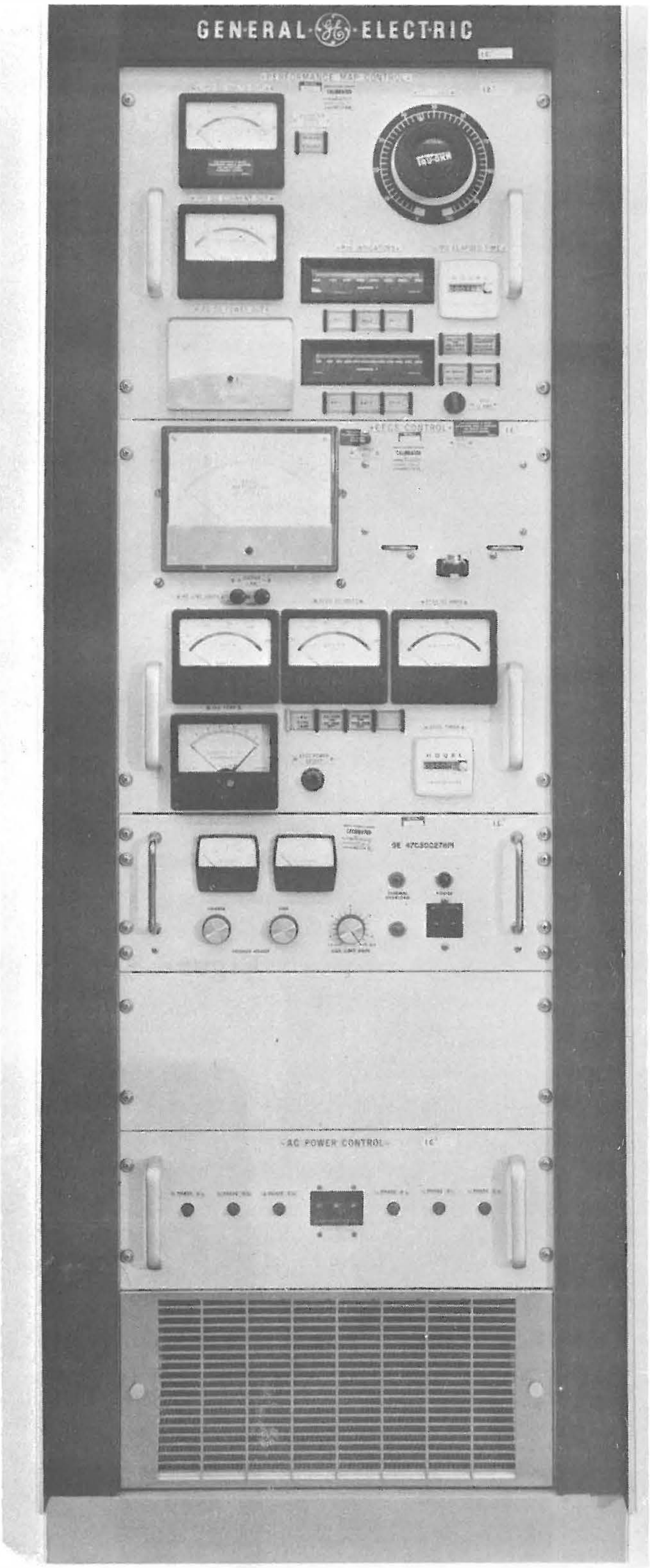


Figure 3-6. Integrated Power Unit Test Set

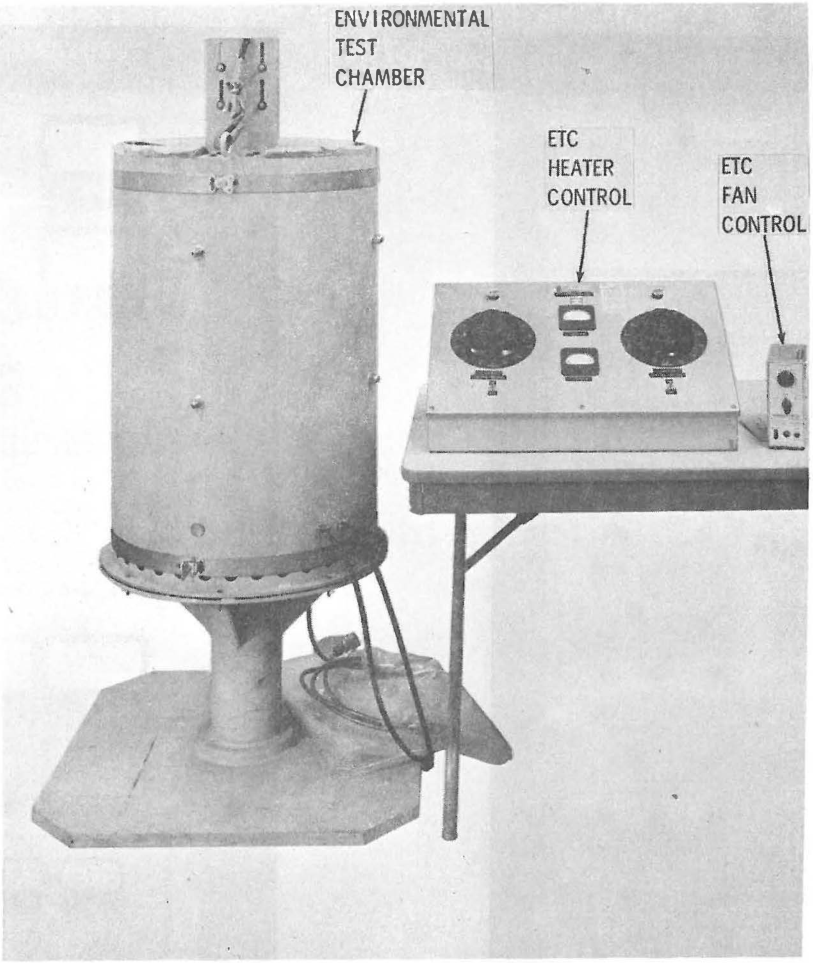


Figure 3-7. Environmental Test Chamber

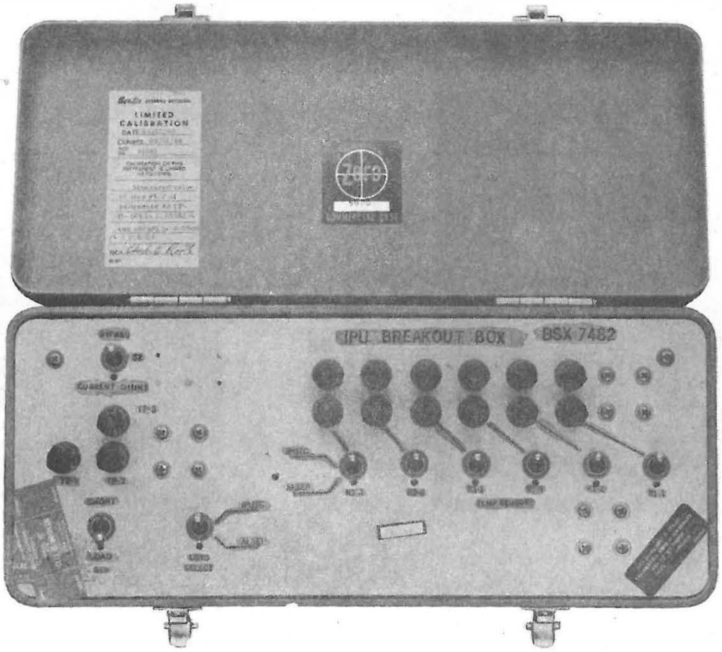


Figure 3-8. IPU Breakout Box

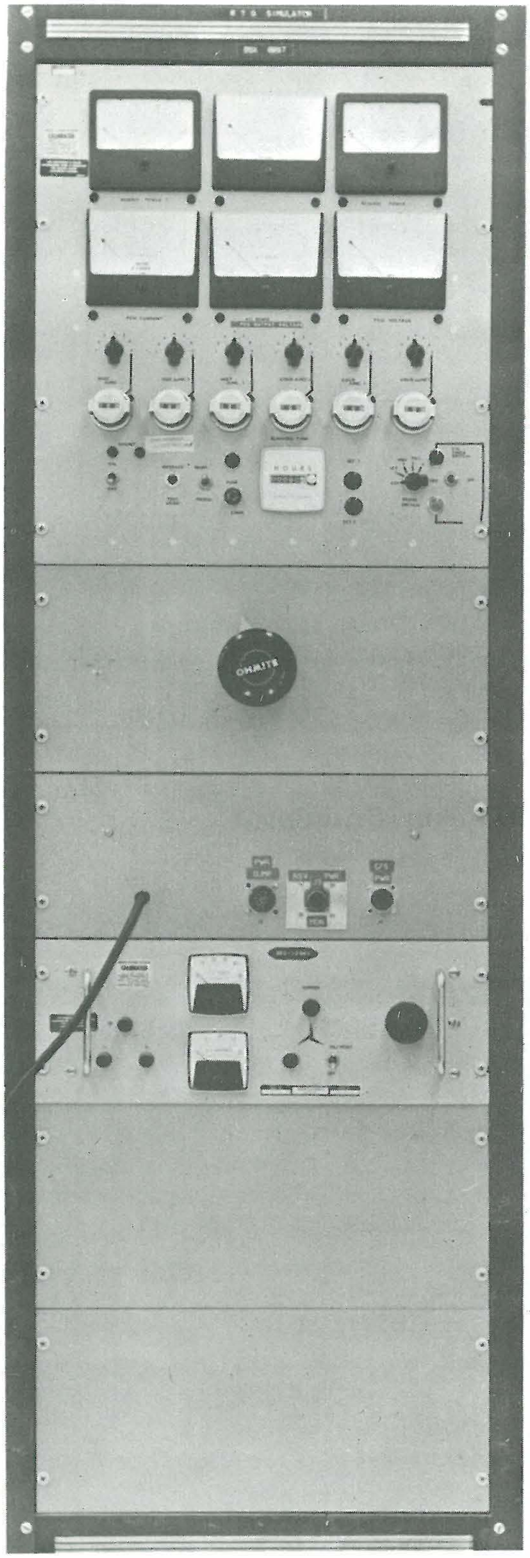


Figure 3-9. RTG Simulator

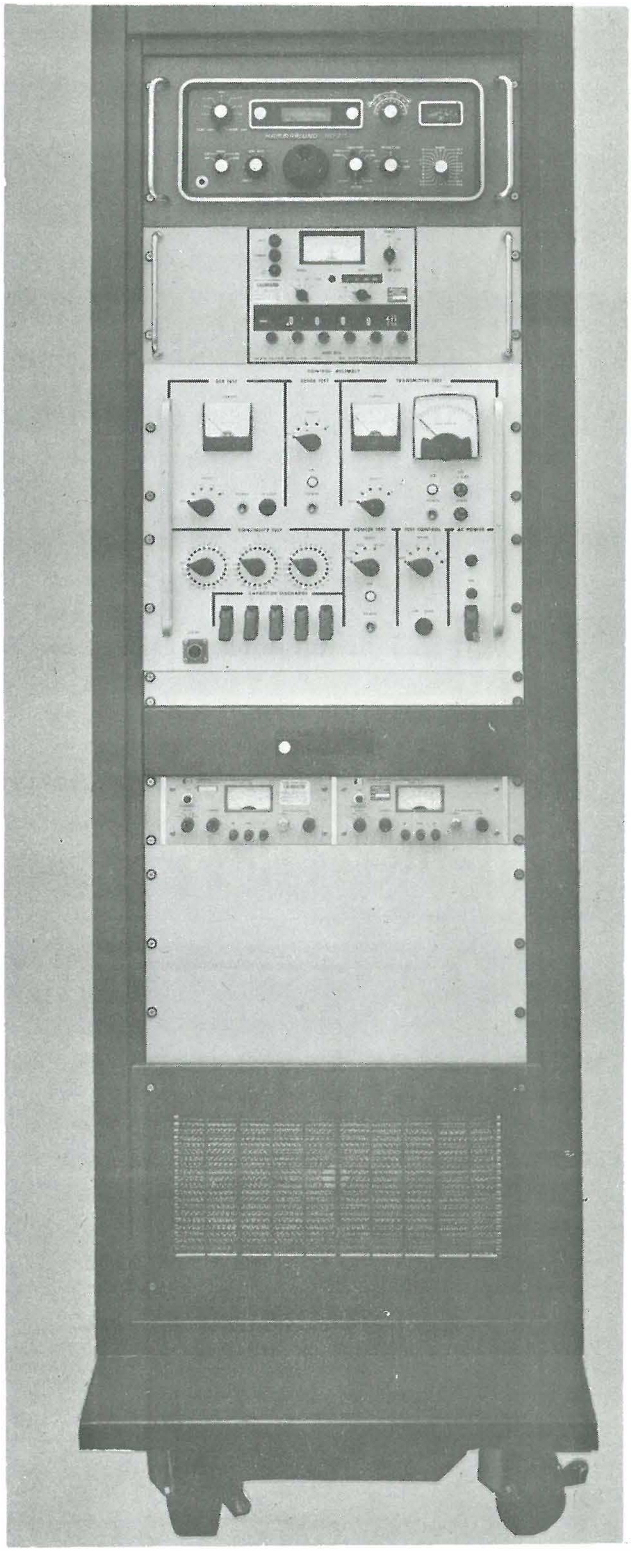


Figure 3-10. Grenade Launch Assembly Test Set

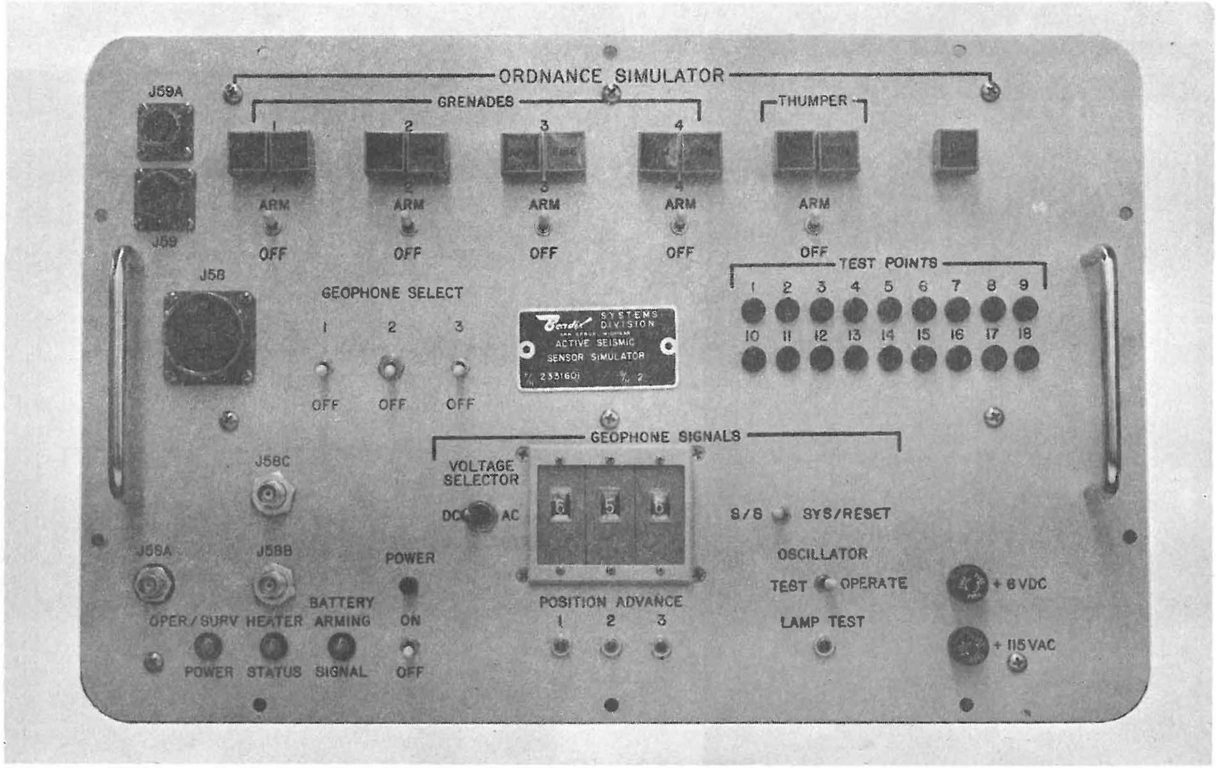


Figure 3-11. Active Seismic Sensor Simulator

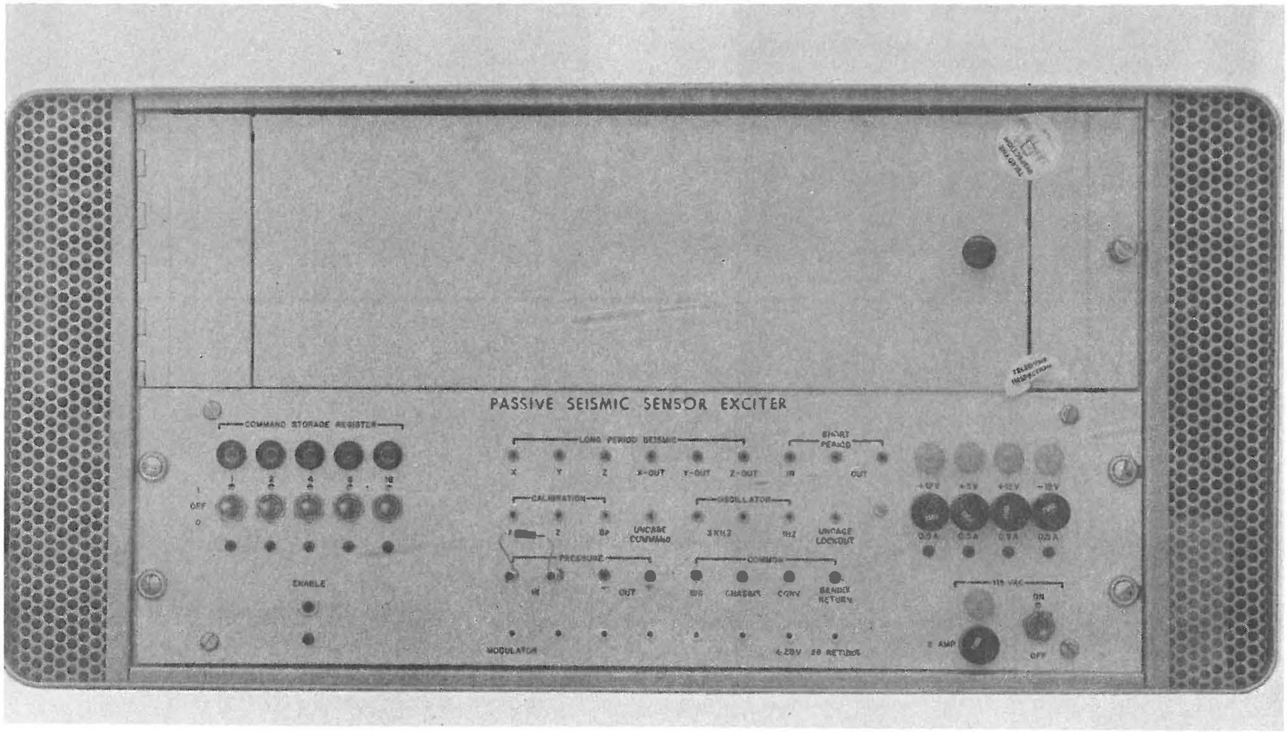


Figure 3-12. Passive Seismic Sensor Exciter

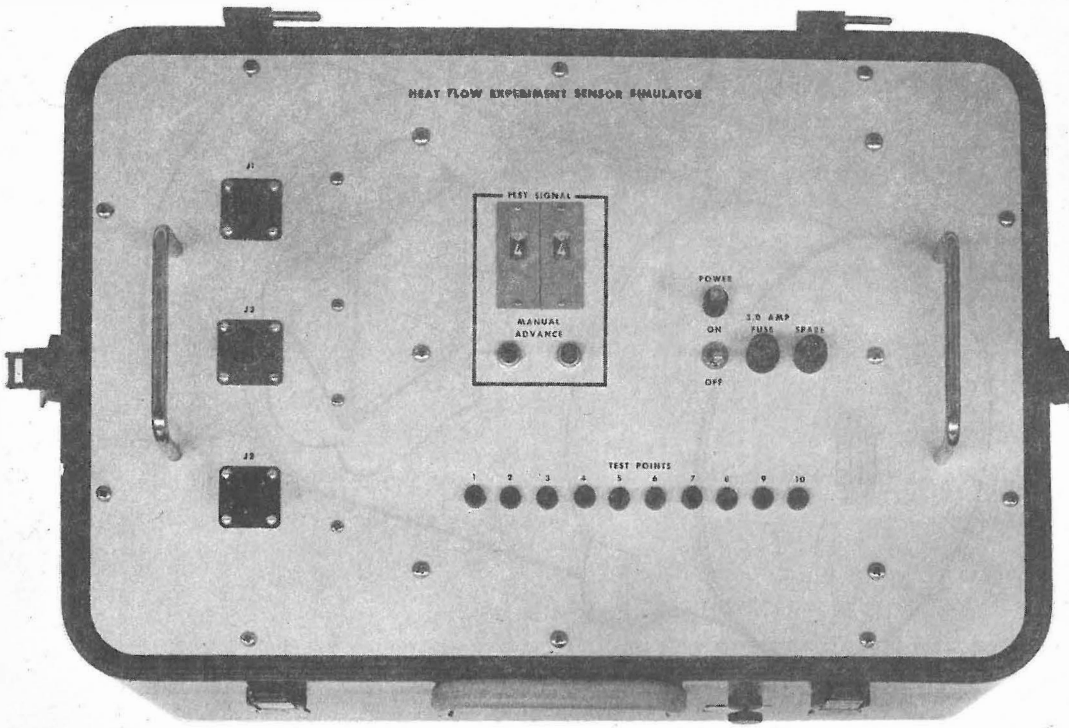


Figure 3-13. Heat Flow Sensor Simulator

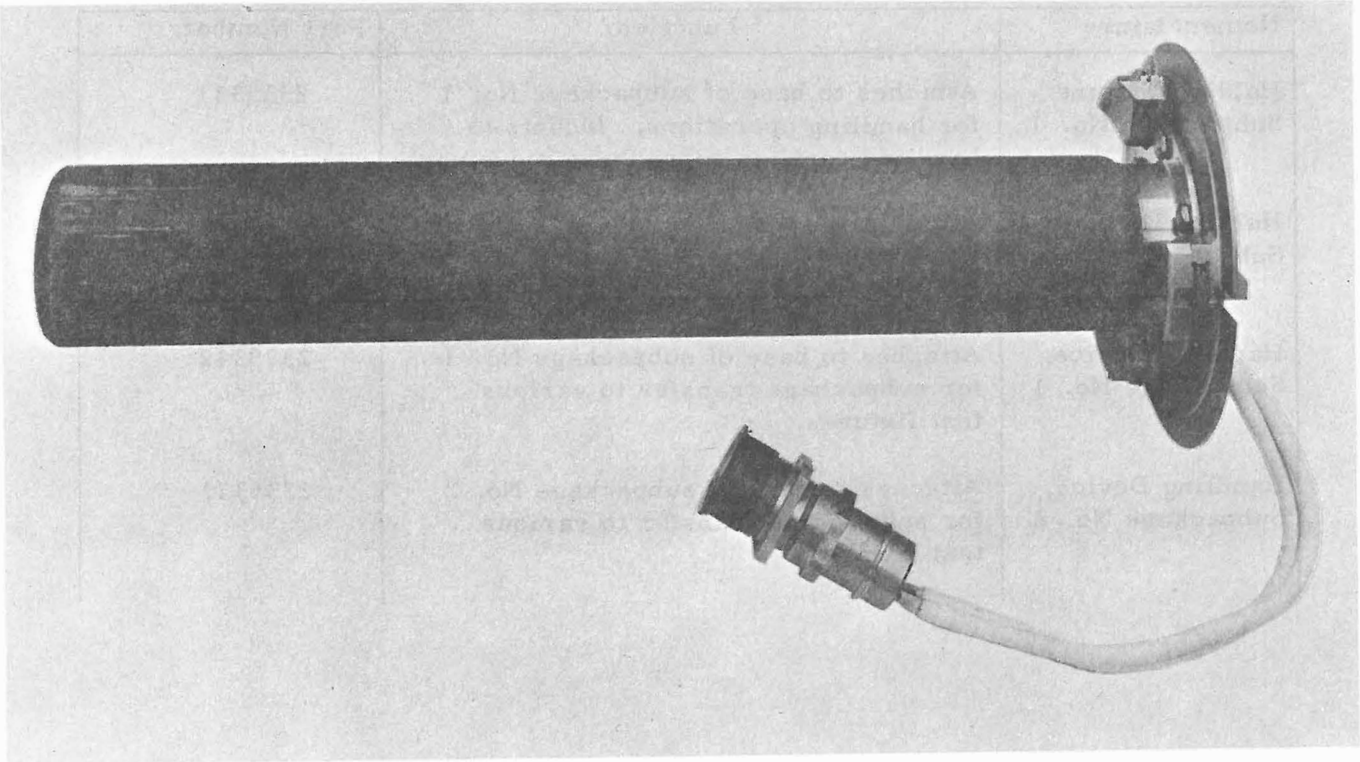


Figure 3-14. Electric Fuel Capsule Simulator

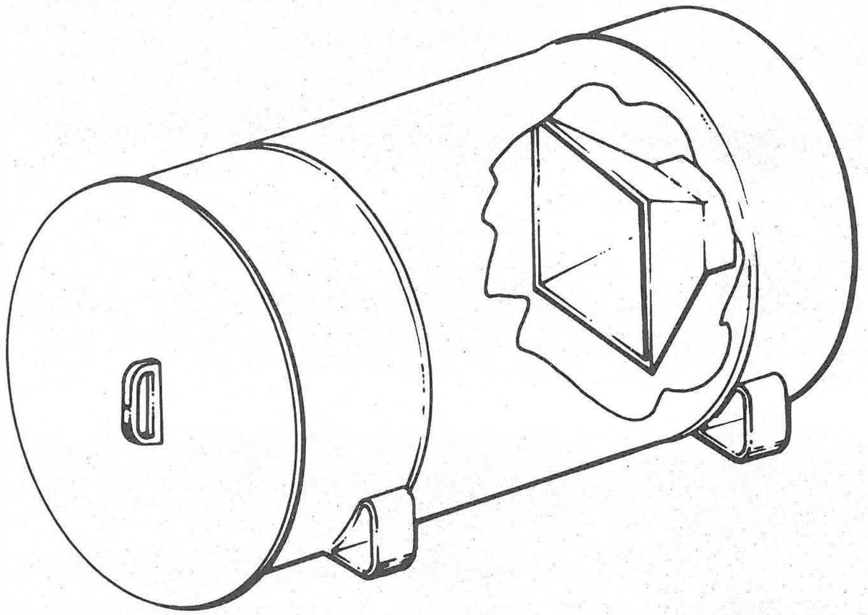


Figure 3-15. Antenna Cap Fixture

Table 3-4. Mechanical Ground Support Equipment

Nomenclature	Function	Part Number
Holding Fixture Subpackage No. 1	Attaches to base of subpackage No. 1 for handling operations. Mounts to handling cart for subpackage movement.	2335311
Holding Fixture, Subpackage No. 2	Attaches to base of subpackage No. 2 for handling operations. Mounts to handling cart for subpackage movement.	2335338
Handling Device, Subpackage No. 1	Attaches to base of subpackage No. 1 for subpackage transfer to various test fixtures.	2335312
Handling Device, Subpackage No. 2	Attaches to base of subpackage No. 2 for subpackage transfer to various test fixtures.	2335313

Table 3-4. Mechanical Ground Support Equipment (cont)

Nomenclature	Function	Part Number
Handling Cart	Provides mounting tie-down for ALSEP subpackages during handling and transportation during maintenance.	2332899
Hoisting Device	Attaches to ALSEP holding fixture or handling device for subpackage hoisting operations.	2335310
Boyd Bolt Installation Tool	Attaches to Boyd bolt for insertion into ALSEP structure.	2338343
Boyd Bolt Torque Tool (Long)	Used to tighten Boyd bolt to required tension.	2338212
Boyd Bolt Torque Tool (short)	Used to tighten Boyd bolt to required tension.	2338315
Boyd Bolt Spindle Force Measuring Tool	Used to measure force required to depress Boyd bolt spindle.	2338313
Boyd Bolt Spindle Position Measuring Tool (long & short)	Used to measure position of spindle relative to Boyd bolt body.	2338651-1 2338651-2
Boyd Bolt Release Tool	Used to release Boyd bolt.	2335910
GLA Test Fixture	GLA alignment sensor checkout.	2331455
Cask Assembly Protective Cover	Protects fuel cask assembly on LM in SLA until fuel capsule loading.	2345612
Central Station Handling Cart	Provides mounting tie-down for central station during handling and transportation.	2333431
Center of Gravity Fixture	Provides mounting tie-down during subpackage No. 1 or No. 2 center of gravity testing.	2335309
Pressure Regulator Assembly	Lowers pressure of gas from gas cylinders to purge or pressurize containers.	2338476

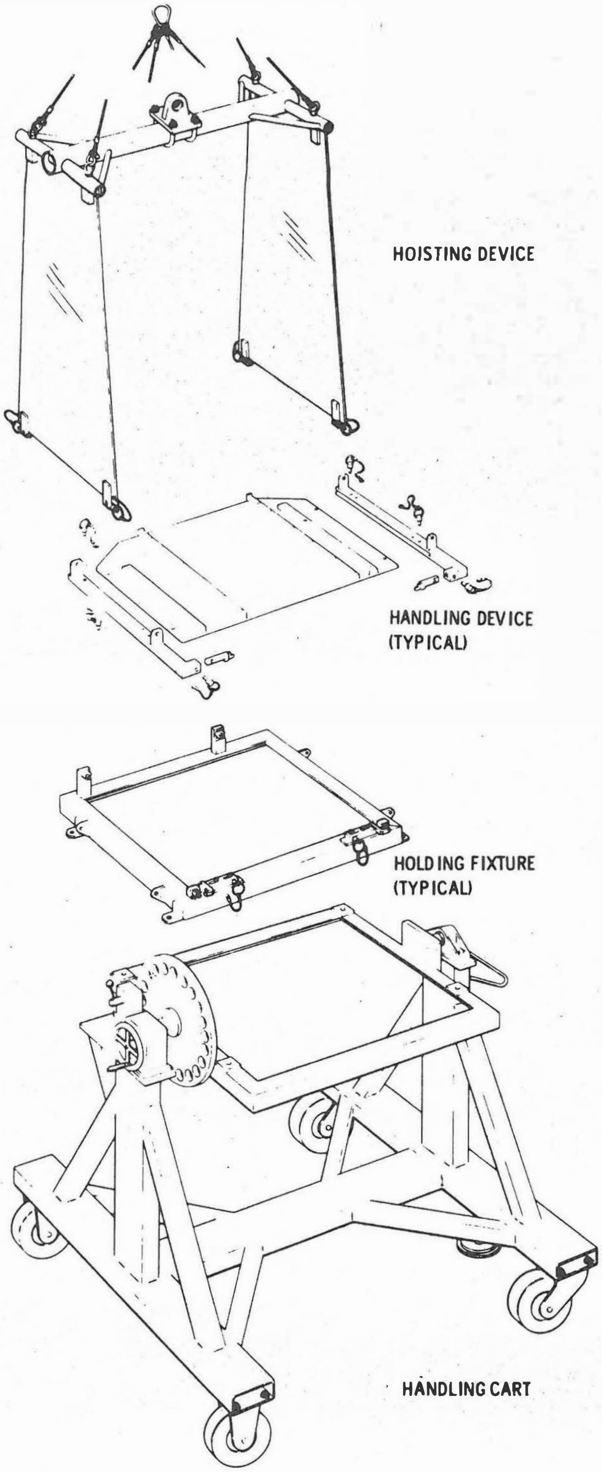


Figure 3-16. Subpackage Handling GSE

Figure 3-17. Boyd Bolt Tools

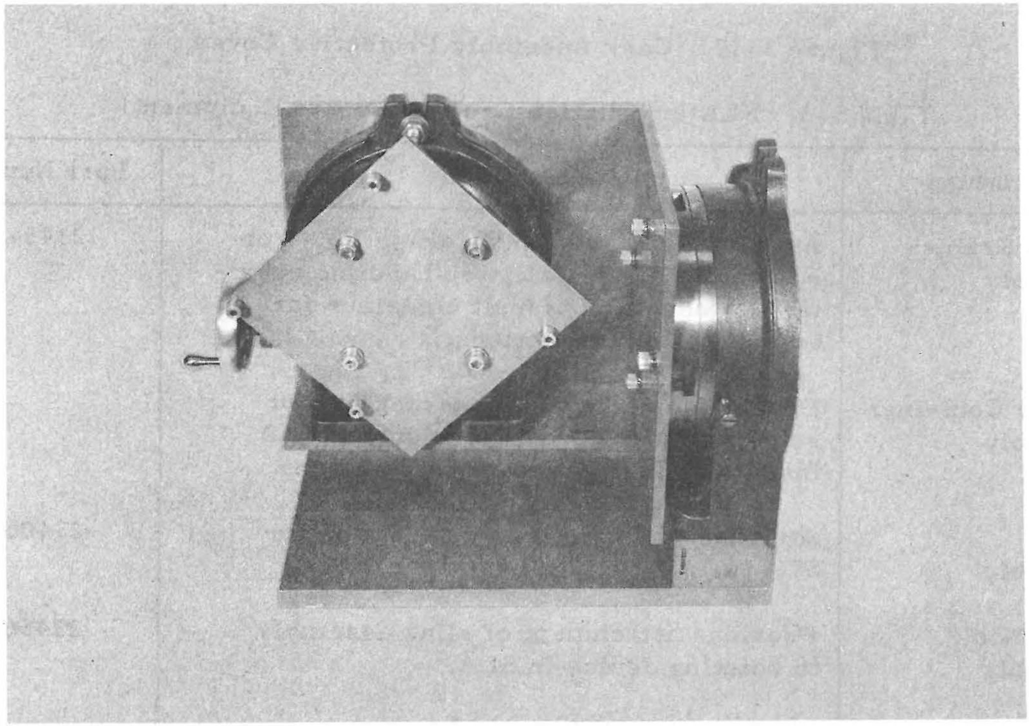


Figure 3-18. GLA Test Fixture

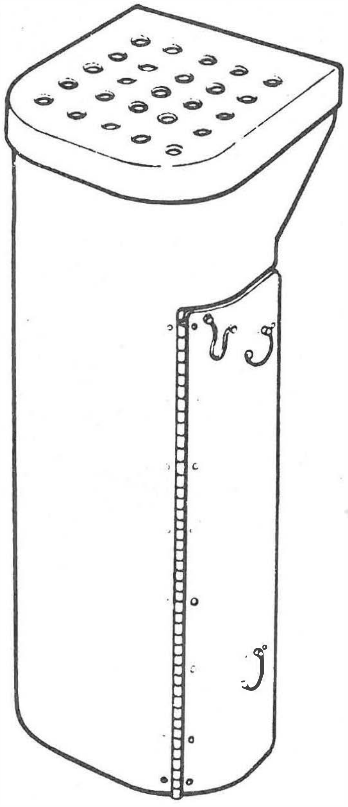


Figure 3-19. Cask Assembly Protective Cover

Table 3-5. SLA Installation Ground Support Equipment

Nomenclature	Function	Part Number
Lifting Frame Assembly	Attaches to base of subpackage No. 1 or No. 2 for SLA installation handling operations. Mounts in transit container for transportation operations.	2345480
Transit Container Assembly	Provides environmental protection for subpackage No. 1 or No. 2 during SLA installation transportation operations.	
Sling Assembly	Attaches to lifting frame assembly for SLA installation hoisting operations.	2340585
Safety Hook Assembly	Provides attachment of sling assembly to hoisting device in SLA.	2345600

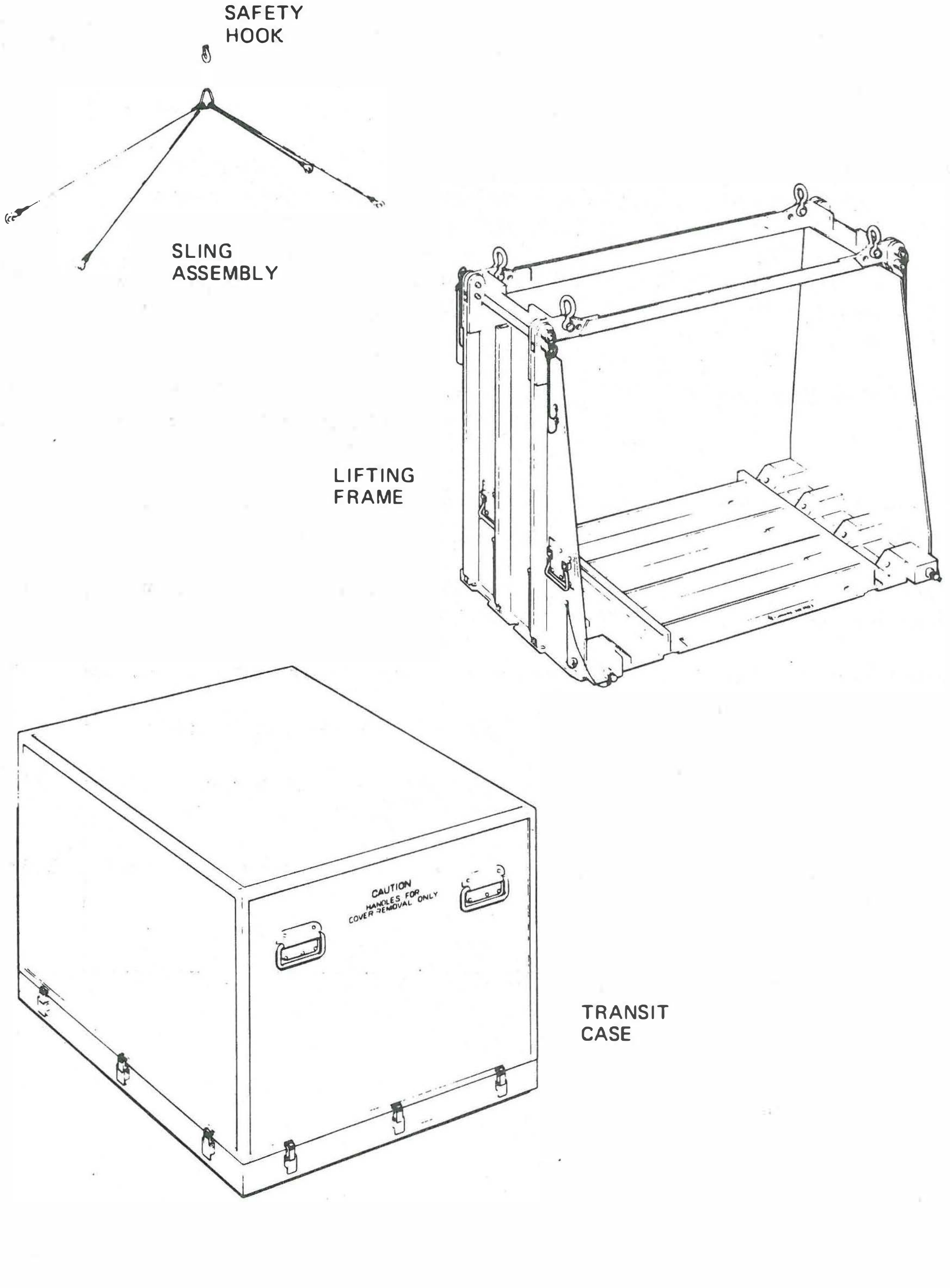


Figure 3-20. SLA Installation GSE

Table 3-6. Fuel Cask/Structure Assembly Handling Equipment

Nomenclature	Function	Part Number
Cask/Structure Handling Device	Fuel cask structure assembly handling during fuel cask fit checks and LM fit checks.	2335319
Fuel Cask/Band Assembly Handling Device	Fuel cask/band assembly handling during fit checks to fuel cask structure assembly and installation on LM.	2335318
Trunnion Alignment/ Band Calibration Fixture	Fixture for cask/band assembly trunnion alignment and band tensioning procedures.	2335316
Dome Handling Tool	Fuel cask dome removal and handling during fuel capsule insertion/removal operations.	2335908
Strain Gage Readout Device	Provides tensioning readout during cask band tensioning procedures.	2332320
Fuel Cask Handling Cart	Provides transportation accommodations for fuel cask movement.	2335315
Dome Removal Tool	Remove dome from fuel cask during buildup.	2335317
Band Tensioning Tool	Used to tighten or loosen cask bands.	2338044
Dome/Tool Receptacle	Provides storage for fuel cask dome with dome handling tool attached.	2337950
CG Determination Fixture	Holding, CG, and fit check fixture for fuel cask and structure assembly.	2335314

Table 3-7. Fuel Capsule Handling Equipment

Nomenclature	Function	Part Number
Capsule SLA handling tool	Used at the launch area for insertion and removal of the fuel capsule assembly.	(GFE)
Capsule transfer cask	Used to transport fuel capsule assembly from a van on the launch pad to the SLA platform area of the Apollo spacecraft.	(GFE)
Capsule port entry trough	Used to transfer the fuel capsule assembly, with the SLA handling tool attached through a ten-inch access port in the spacecraft structure at the level of LM/ fuel cask attachment.	(GFE)
Capsule inspection tool	Used to verify proper engagement of fuel capsule assembly in the LM fuel cask.	(GFE)

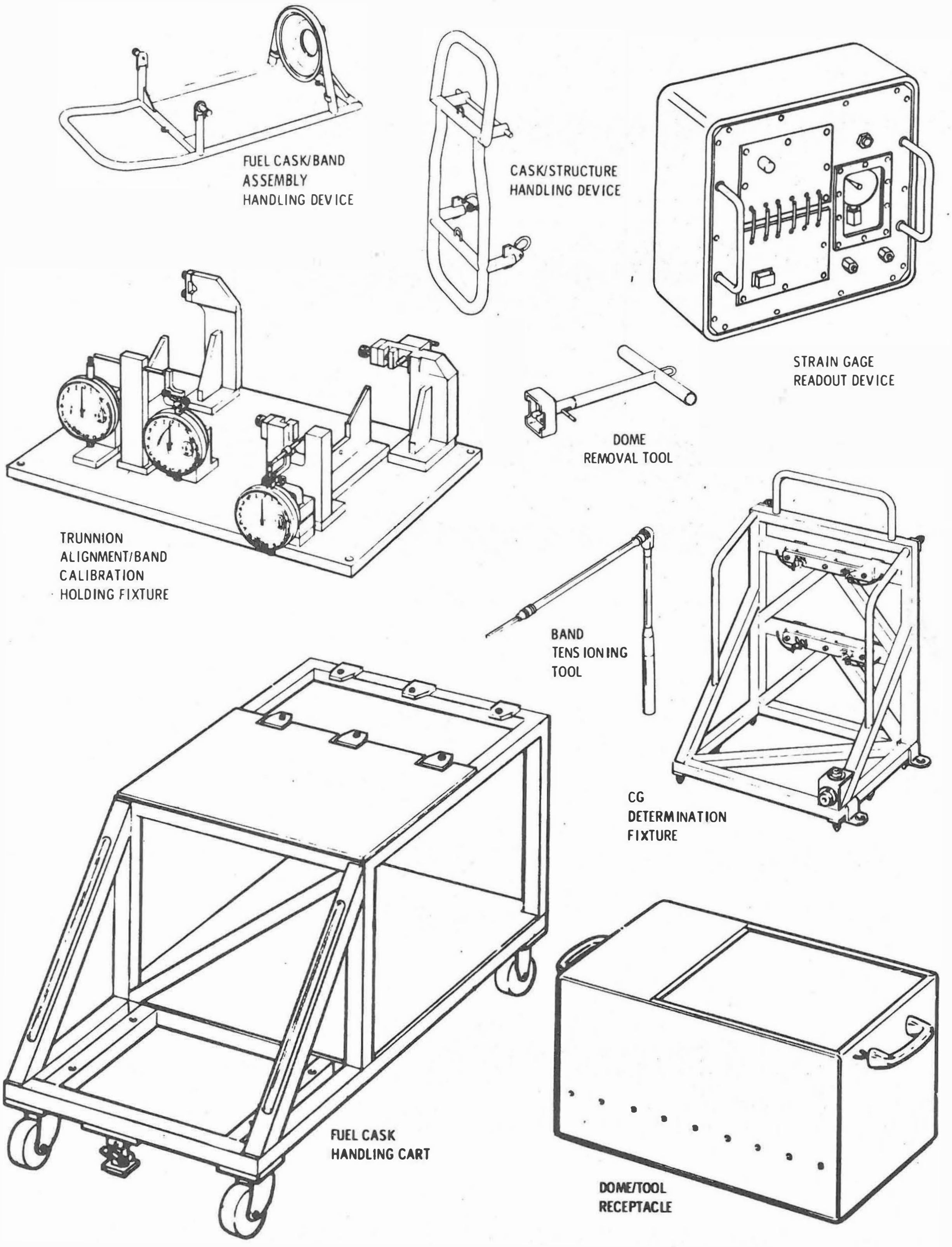


Figure 3-21. Fuel Cask/Structure Assembly Handling Equipment

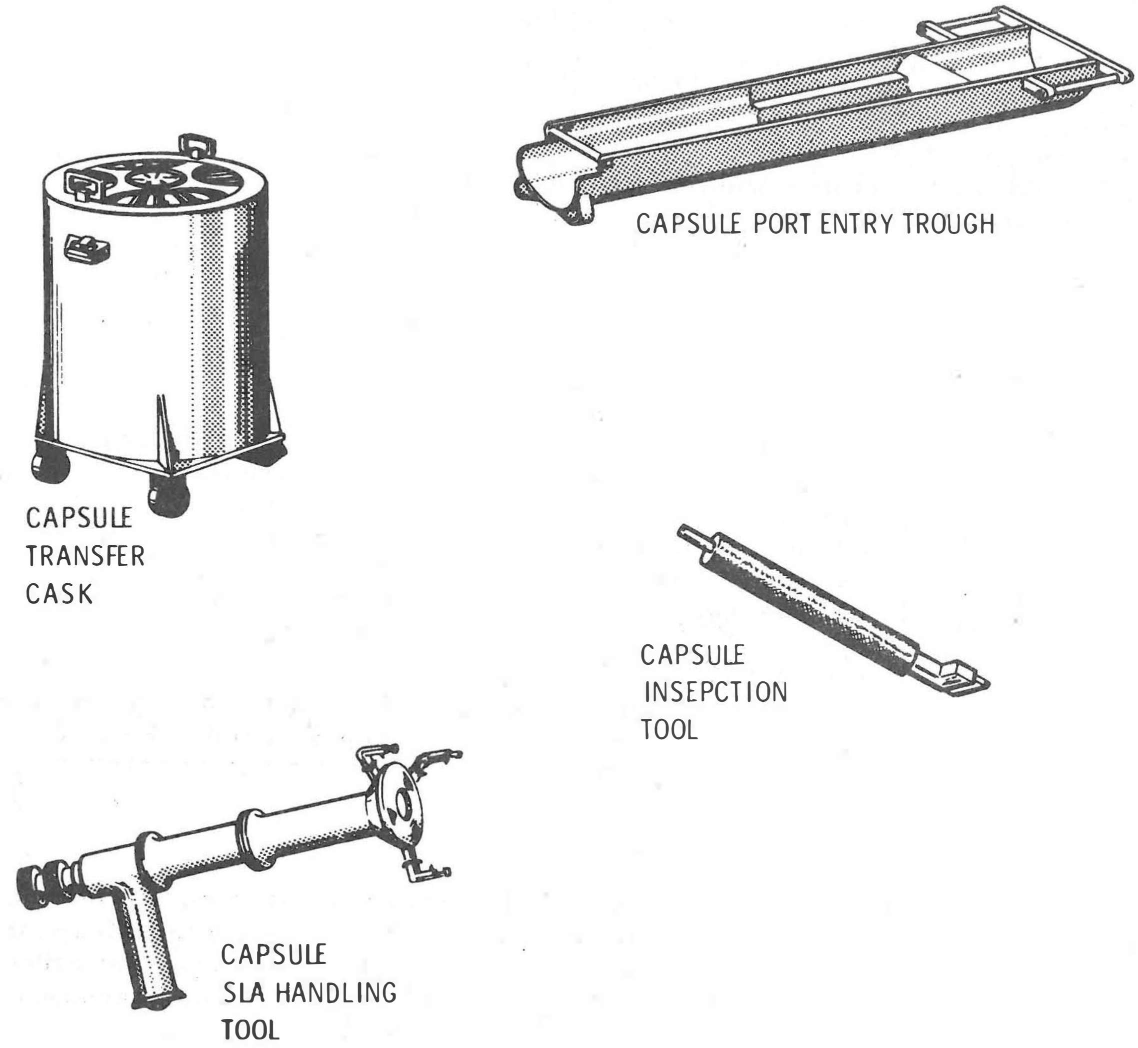


Figure 3-22. Fuel Capsule Handling Equipment

Table 3-8. Standard Tools, Test Equipment, Facilities, and Supplies

Part Number	Nomenclature	Function
Tektronix 546	Oscilloscope (2)	
Tektronix CA	Vertical plug-in unit (2)	
HP 805 C	Slotted line (1)	
HP 415 B	VSWR meter (1)	
HP 211 A	Square wave generator (1)	
HP 616 B	Signal generator (1)	
HP 851-8551	Spectrum analyzer (1)	
Empire AT30-10	Attenuator pad (2)	
BPD-SP2000 (or equivalent)	Stored program simulator (1)	
HP 410 B	VTVM (2)	
Simpson 206-5M	VOM (2)	
HP 721 A	Power Supply (1)	
HP 405	Digital Voltmeter (1)	
	Set miscellaneous cables	
(GFE)	Apollo Initiator Resistance Measuring Equipment (AIRME)	Thumper assembly and GLA circuit checks.
(GFE)	ALINCO squib tester	CPLEE ordnance circuit checks
	Vacuum enclosure	RTG leak test.
	Vacuum pump	RTG leak test.
(GFE)	Spectrometer type leak detector	RTG leak test.
	Gaseous nitrogen supply	Pressurize ALSEP containers.
	Gaseous argon supply	Repressurizing RTG container.

3-10 TRANSPORTATION EQUIPMENT

Transportation equipment consists of ALSEP containers that provide protection for the flight article subsystems and components during delivery to KSC and movement between facilities at KSC during maintenance activities. Transportation equipment for the ground support equipment consists of commercial packages that provide protection for the GSE components during shipment to KSC.

The shipping containers used for transportation of the ALSEP flight article and associated GSE include two types, ALSEP containers and commercial packages. The following paragraphs briefly describe each type of container.

3-11. ALSEP Containers. Special containers are provided for each ALSEP subpackage assembly, and separately shipped subsystem component. Figure 3-23 illustrates typical ALSEP containers.

The ALSEP containers are constructed for an outer metal housing specifically shpaed to enclose the associated assembly which is mounted on a shock isolation plate. The containers are instrumented to provide a real-time history of shock on three axes, and temperature for at least seven days. A humidity indicator, visible from outside the container, provides an indication of the humidity within the container. The container for subpackage No. 1 incorporates a GFE flux recorder for checking magnetic field exposure during shipment.

3-12. Commercial Packages. Commercial packaging is primarily used for shipment of GSE. The packages consist of components wrapped or packaged in a carton, box, bag, or similar container that conforms to commercial shipping practice. Commercial packaging methods are as follows:

a. Component mounted on a pallet, wrapped in plastic, and metal-banded to pallet.

b. Component mounted in a plywood box on mating hardpoints and box packed with dunnage.

c. Component wrapped in plastic, placed in a plywood box, and packed with dunnage.

d. Component sealed in plastic, wrapped in cellulose or aircap, and placed in corrugated paper box.

e. Component packed in foam, molded to fit component contour, and packed in wood, metal, or plastic box.

3-13. ALSEP SUPPORT MANUALS

There are seven ALSEP support manuals used as an integrated documentation system to support the ALSEP hardware system. These manuals are listed in Table 3-9.

Table 3-9. ALSEP Support Manuals

Title	Document Number
ALSEP General Familiarization Manual	ALSEP-MA-24
ALSEP Flight System Familiarization Manual	ALSEP-MT-03
ALSEP Flight System Maintenance Manual	ALSEP-LS-04
ALSEP System Test Equipment Maintenance Manual	ALSEP-LS-06
ALSEP Transportation and Handling Manual	ALSEP-LS-03
Grenade Launch Assembly Test Set Instructions Manual	ALSEP-LS-07
Apollo 16 ALSEP, Array D Flight System Familiarization Manual	ALSEP-MT-06

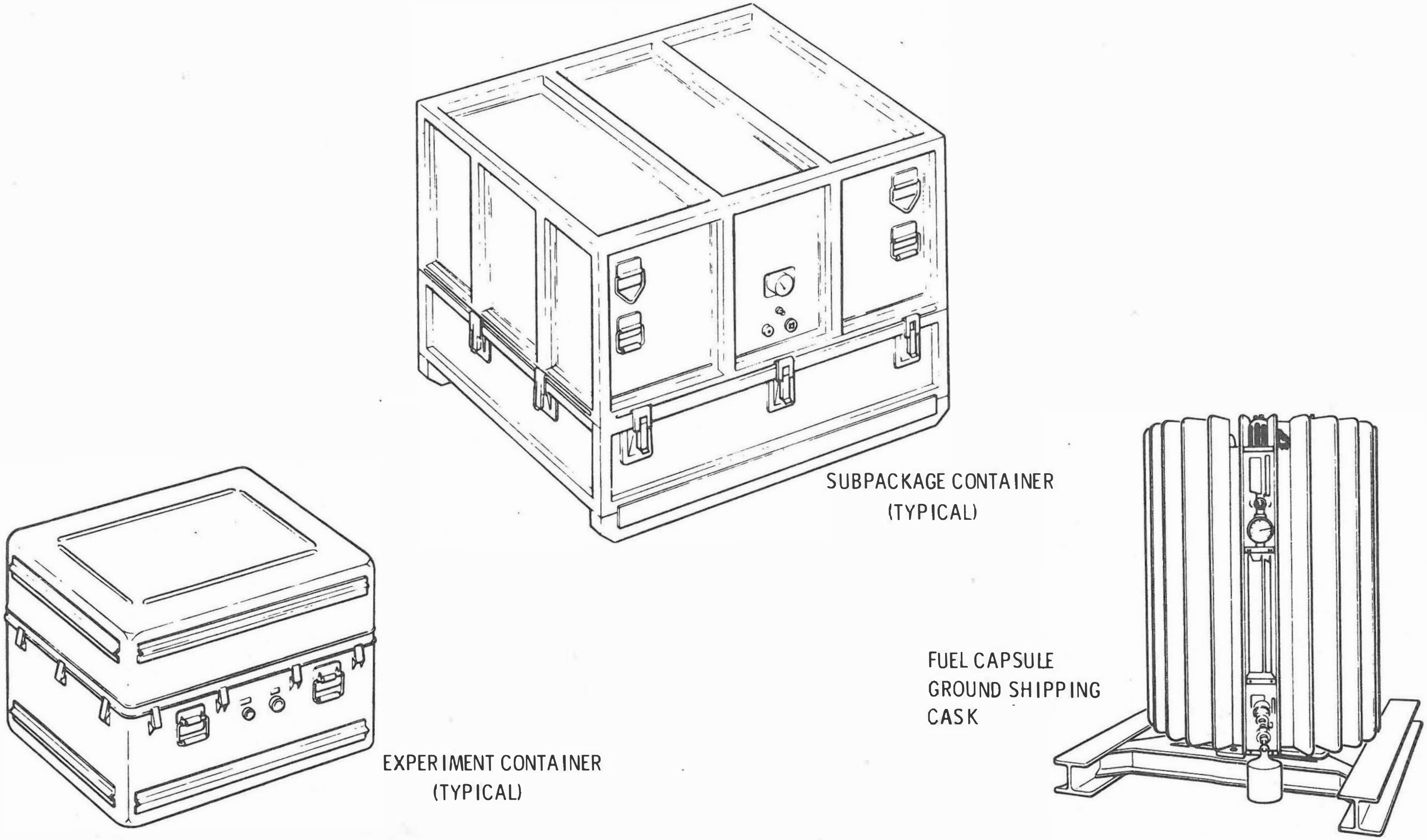


Figure 3-23. ALSEP Containers

SECTION IV

OPERATIONS

4-1. OPERATIONS, GENERAL

This section presents a description of the operational ALSEP flight hardware operations. The description encompasses events occurring between equipment receipt at Kennedy Space Center (KSC) and the programmed shutdown of ALSEP lunar operation. Table 4-1 contains a location index of ALSEP operations.

Table 4-1. ALSEP Operations Locations

KSC	Lunar Surface	Post deployment
ALSEP inspection	In-flight configuration	MSFN operation
	Post-landing operations	MCC operation
Fit checks	Carry mode	PI activities
Ordnance verification		
MSFN compatibility tests	Deployment: (a) Support subsystems (b) Experiment subsystems	
GLA installation		
ALSEP installation		

4-2. KSC PRELAUNCH CHECKOUT AND INSTALLATION

Activity at KSC includes inspection, fit checks, ordnance verification, assembly, test, and ALSEP installation. Figure 3-2, Sheet 2 shows the sequence of events necessary to receive, check out, and install ALSEP equipment in the LM. Note that Class A ordnance and radioactive items are received and checked in a location separate from the rest of the ALSEP equipment. KSC ALSEP facilities consist of:

a. Bunker facility - used for checkout of the GLA

b. Ordnance laboratory building, M7-1417- Used in conjunction with the bunker facility to test the GLA, thumper, and ordnance

c. ALSEP launch preparation site (ALPS) - Used for receipt, inspection assembly, and bonded stores operations.

d. AEC fuel capsule storage.

4-3. KSC INSPECTION AND CHECKOUT

ALSEP activities are centered in the ALPS (Hangar S, Cape Kennedy Air Force Station). All ALSEP subsystems except the GLA and thumper are received and tested here.

Ordnance items are stored in the ordnance test storage facility (LC-39) where ordnance circuit tests, lot verification and installation are accomplished. Ordnance items include the following:

a. Squib devices - used to uncage the PSE after experiment deployment.
b. Thumper initiators - used in thumper firing operations.
c. Four rocket grenades - used in the active seismic experiment. (Class A ordnance)

4-4. KSC Inspection. Ordnance items, as noted in paragraph 4-3, will be received, inspected, and stored at the KSC ordnance test storage facility. The remaining ALSEP equipment will be received, inspected, and stored at the ALPS.

The ALSEP equipment listed in Table 4-2 will be inspected upon receipt for possible shipping damage that may have occurred in transit. Temperature, humidity, magnetic flux and shock recorder records will be monitored for maximum excursions, then inserted into the test and inspection record (TAIR) book. An out-of-tolerance record will be documented on a discrepancy report (DR) for further action.

4-5. KSC Equipment Calibration. Equipment calibration conducted at KSC is listed in Table 4-3 with an explanation of the task to be performed. All calibration data will be entered in the GSE calibration log.

4-6. KSC Equipment Checkout. Table 4-4 lists the ALSEP equipment and ALSEP GSE requiring checkout. Appropriate checks for each item are referenced.

4-7. KSC Fit Checks. Fit checks of ALSEP hardware, tools, packages, and the LM are required to verify tolerances and effective operation and installation. Table 4-5 lists the fit checks required.

4-8. KSC ALSEP INSTALLATION

4-9. KSC Ordnance Installation. After completion of GLA tests at the ordnance laboratory, the GLA is installed in the mortar box to make up the mortar package assembly which is mounted on subpackage No. 1.

Table 4-2. KSC Inspection

Item	Sub-item (if applicable)
GLA Test Set (GLATS)	(Received at ordnance facility and transferred to Building M7-1210 for inspection)
PSE Ordnance	Lot verification ordnance
Thumper Geophone Cable Assembly	Thumper 21 Apollo Standard Initiators (ASI) Three geophones and cables
Grenade Launcher Assembly (GLA)	Launcher assembly Four rocket grenades
ALSEP Subpackage No. 1	Experiment subsystems Data subsystem
ALSEP Subpackage No. 2	Experiment subsystems Radioisotope Thermoelectric Generator Handling Tools
Flight Fuel Cask	
Fuel Cask Structure Assembly	
Fuel Capsule	(The fuel capsule will not be removed from the shipping cask for inspection and will be stored in the AEC storage facility)
Fuel Capsule Handling Tools	Capsule ground handling tool Capsule spacecraft LM adapter (SLA) handling tool Capsule transfer cask Capsule port transfer trough
ALSEP/LM Installation and Handling Equipment	Sub-package hoist equipment ALSEP/LM Insertion handling fixtures Handling equipment support platform

Table 4-3. KSC GSE Calibration

Item	Task
GLA Test Set	Calibrate in accordance with "GLA Test Set Instructions Manual."
Trunnion Alignment/Band Calibration Fixture	Adjust per top assembly drawing.

4-10. KSC ALSEP Installation in LM. The ALSEP subpackages are installed in the SEQ bay of the LM in the SLA at Launch Complex 39. The special GSE listed in Table 3-5 is used to facilitate this operation.

Table 4-4. KSC ALSEP Equipment Checkout

Item	Checks
GLA test set	Check satisfactory operation in accordance with "GLA Test Set Instructions Manual."
Thumper assembly circuit check	Verify circuit continuity of Apollo standard initiators installed in thumper using squib tester at ordnance test facility.
GLA	Verify circuit continuity of squibs and cable using AIRME squib tester and ordnance voltmeter (Simpson 260 with batteries removed).

Table 4-5. KSC Fit Checks

Item	Fit Checked with:
Fuel Capsule	SLA handling tool (from cask to port entry trough and back to cask) Fuel Transfer tool Fuel cask RTG
Fuel Cask	Fuel cask structure assembly
Fuel Cask structure assy	LM
ALSEP (Subpackages 1 and 2)	LM

4-11. KSC Fuel Cask and Fuel Capsule Installation. The fule cask and mounting structure assembly is transported to the work platform at SLA and is mounted on the LM structure after the LM has been fueled.

The radioactive and hot (1200 °F) fuel capsule is transported to the SLA work platform, inserted into the fuel cask in the upright position, and locked in place using the SLA handling tool.

4-12. LUNAR SURFACE OPERATIONS

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

a. Flight mode - the in-flight configuration of ALSEP equipment.
b. Post-landing operations - The events that occur between lunar landing and the beginning of ALSEP deployment procedures.
c. Carry mode - The activity performed by the crewmen in removing the ALSEP equipment from the LM and transporting it to the emplacement area.
d. Deployment and activation - The events performed by the crewmen in emplacing and activating the experiments.

4-13. FLIGHT MODE

During flight, the ALSEP system is inert except for the structure/thermal subsystem function of providing thermal protection to the LM. The location of the fuel cask assembly, external to the LM, provides a heat rejection system for the fuel capsule and for crew safety during deployment. The cask support structure incorporates a thermal shield to reflect cask thermal radiation away from the LM. In addition, insulators are incorporated in the structure to reduce conductive heat transfer to the LM.

ALSEP subsystems and experiments are mounted on subpackage pallets which are secured in the LM SEQ bay. The SEQ bay is located in LM descent stage behind a thermal door. The subpackages occupy a volume of approximately 15 cubic feet and are locked in place by retaining pins. Contents of the two subpackages are listed in Table 4-6. The Apollo lunar surface drill is mounted elsewhere on the LM.

Table 4-6. Subpackage Configuration

Subpackage No. 1 (SEQ Compartment No. 1)	Subpackage No. 2 (SEQ Compartment No. 2)
Passive seismic experiment Active seismic experiment Lunar Surface magnetometer Data subsystem antenna	Heat Flow experiment Radioisotope thermoelectric generator Passive seismic stool Fuel Transfer tool Universal handling tool (2) Dome removal tool Antenna aiming mechanism Antenna mast/carry bar sections (2) Mortar package pallet

4-14. POST-LANDING OPERATIONS

Lunar environmental conditions impose constraints on ALSEP hardware and its deployment by the Apollo crewmen. ALSEP 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 +80 to +100 degrees F. ALSEP design allows deployment at a maximum sun angle of 45 degrees and a relative lunar surface temperature of approximately +165 degrees F.

4-15. Tools Used in Deployment. Table 4-7 lists the tools used by the crewmen during deployment. The universal handling tool (UHT) is used to release the tie-down fasteners, and to transport and emplace the experiment subsystems. The insertion end of the UHT is a positive locking device that provides a rigid interface between the tool and a receptacle on the experiment for transport and emplacement of the experiment. A trigger on the tool handle must be depressed to engage or release the tool from the experiment receptacle. An Allen wrench fitting, extending from the insertion end of the tool, engages the hexagon socket in the head of Boyd bolt tie-down fasteners to rotate and release the bolt.

Table 4-7. Deployment Tools

Nomenclature	Function
Universal Handling Tool (UHT) (2)	Used to release tie down fasteners and to carry experiments
Dome Removal Tool (DRT)	Used to remove and handle the dome of the fuel cask
Fuel Transfer Tool (FTT)	Used to transfer fuel capsule from cask to RTG
Probe Emplacement Tool	Used to emplace heat flow probes
Apollo Lunar Surface Drill (ALSD)	Used to drill holes for heat flow probe emplacement

The dome removal tool (DRT) is used to remove and handle the dome of the fuel cask. The tool engages, is locked in place, and unlocks a nut on the fuel cask dome. Rotation of the nut releases the dome.

The fuel transfer tool (FTT) is used to transfer the fuel capsule assembly from the fuel cask to the radiosotope thermoelectric generator. Three prongs on the end of the tool engage the fuel capsule and are locked in place by rotating the knurled handle of the tool. This engagement releases the fuel capsule retaining latches to free the capsule from the cask.

4-16. PREDEPLOYMENT

The predeployment phase encompasses the task of removing ALSEP equipment from the LM SEQ bay, assembling subpackages No. 1 and No. 2 in the transportation configuration, and traversing to the emplacement area.

Table 4-8 presents the basic predeployment events in chronological sequence. Subsequent paragraphs describe each event in the order in which they appear in the table.

Table 4-8. Predeployment Events

Event No.	Operation
1	Walk to descent stage stowage compartment (SEQ)
2	Unload ALSEP (a) Gain access to stowage compartment (b) Remove subpackage No. 1 (c) Remove subpackage No. 2
3	Fuel RTG
4	Prepare subpackages for barbell carry
5	Locate correct traverse bearing
6	Walk 300 feet at selected bearing carrying packages

4-17. Remove ALSEP Equipment from the LM. The crewman walks to the LM SEQ bay, releases, and raises the thermal door. The crewman retrieves subpackage No. 1 deployment lanyard, walks 10 feet from the LM, and pulls deployment lanyard to release subpackage No. 1 and pull boom with subpackage No. 1 out of the SEQ bay. He lowers subpackage No. 1 to the lunar surface, releases deployment lanyard quick-release catch, pulls pin to separate subpackage No. 1 from the boom attachment assembly, and restows the boom. Subpackage No. 2 is removed in a similar manner and is placed near subpackage No. 1 on the lunar surface.

4-18. Fuel the RTG. The fuel cask must be rotated to an attitude consistent with the LM tilt angle to provide a good view and crewman reach attitude. The crewman, using the cask lanyard, rotates cam levers to shear trunnion pins, pulls spline to partially free the cask dome, and operates the rotation mechanism to rotate the cask to a proper unloading angle. Using the dome removal tool, the crewman removes the cask dome and discards the cask dome and the DRT.

The crewman removes the fuel capsule from the fuel cask by inserting the FTT into the fuel capsule head, rotating the tool handle to achieve engagement and capsule release, and withdrawing the tool and capsule from the cask. The crewman then moves with the tool and attached fuel capsule to the RTG and lowers the capsule into the generator cavity. Once the fuel capsule has been placed in the RTG, release is accomplished by reversing the rotation of the tool handle. Releasing the tool from the fuel capsule head automatically locks the fuel capsule in the RTG. The tool provides positive connection with the fuel capsule, separation from the hot element, and control of the transfer by the crewman. The FTT is discarded.

4-19. Transport ALSEP to Emplacement Area. The crewman places the subpackages in the carrying position and connects the antenna mast between the subpackages. The connectors are simple keyhole slip-fit. The crewman lifts the subpackages to the carrying position in "barbell" fashion as shown in Figure 4-1, and carries them to the selected deployment location. While carrying the subpackages, lateral balance is shifted by changing the hand position on the carry bar.

4-20. DEPLOYMENT

To aid the astronaut in proper deployment of the experiments, decals, similar to those shown in Figure 4-2, are attached to the subpackages and experiments. The deployment alignment and level indicating devices of the central station and experiments are illustrated in Figure 4-3.

The following paragraphs describe the events that occur from the time the crewmen arrive at the ALSEP emplacement area until they have deployed all ALSEP equipment. Deployment activities are discussed in the procedural sequence performed by the crewmen. Figure 4-4 illustrates the layout of the ALSEP equipment and experiments after deployment.

4-21. Deployment Sequence. The Apollo 16 ALSEP will be deployed by both crewmen, and will be accomplished as described in the following steps.

1. Remove subpackages from LM SEQ bay
2. Remove handling tools from subpackage #1
3. Remove fuel capsule from cask, and fuel the RTG
4. Assemble antenna mast sections for carry bar, and attach to subpackages
5. Carry ALSEP to the deployment site
6. Position subpackages at deployment site
7. Remove carry bar from subpackages
8. Remove HFE subpallet from subpackage #2
9. Remove subpallet from subpackage #2
10. Remove MPA pallet from subpallet
11. Connect RTG cable to central station
12. Deploy PSE (See Figure 4-5.)
13. Connect HFE cable to central station
14. Assemble ALSD
15. Drill bore holes for HFE probes (See Figure 4-6.)

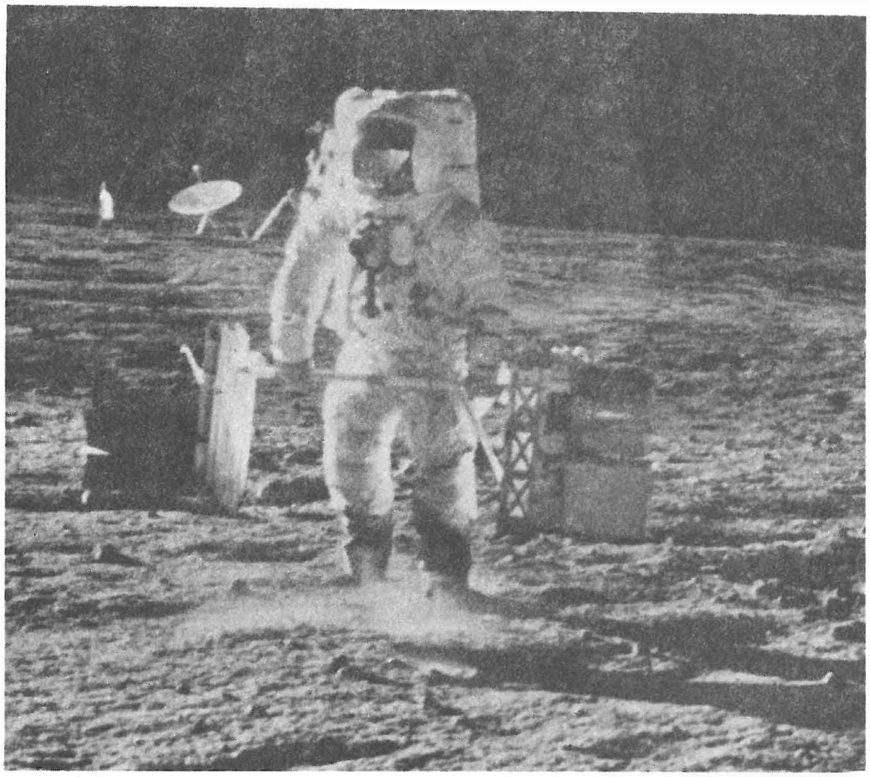


Figure 4-1. Barbell Carry Mode (Apollo 12 Photo)

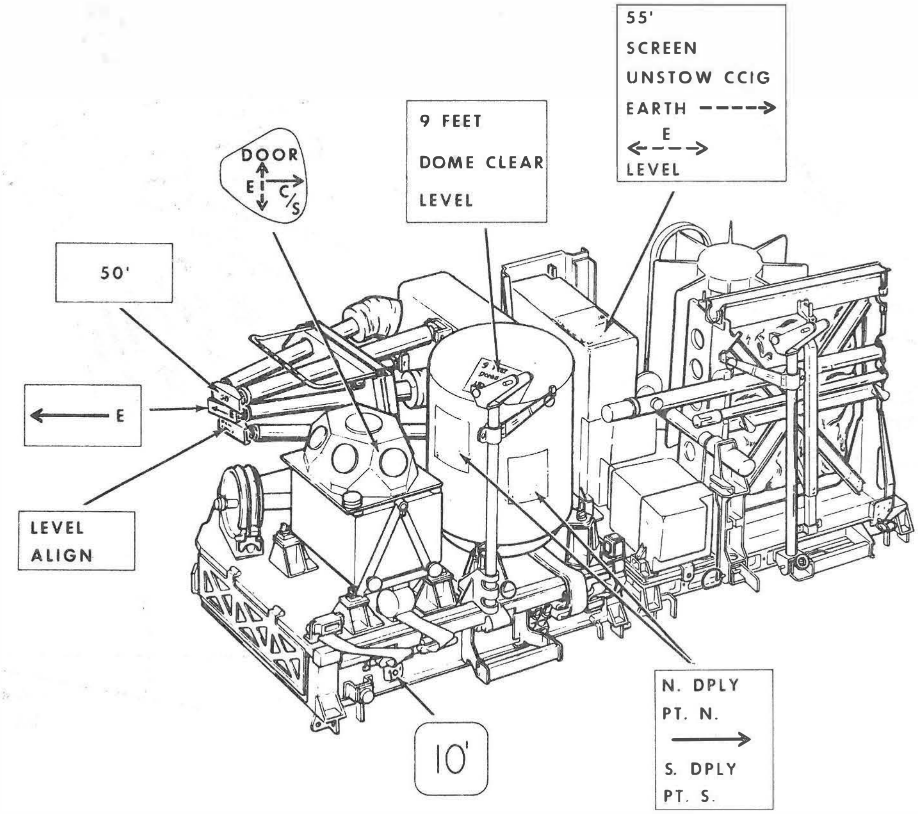


Figure 4-2. Deployment Decals (Typical)

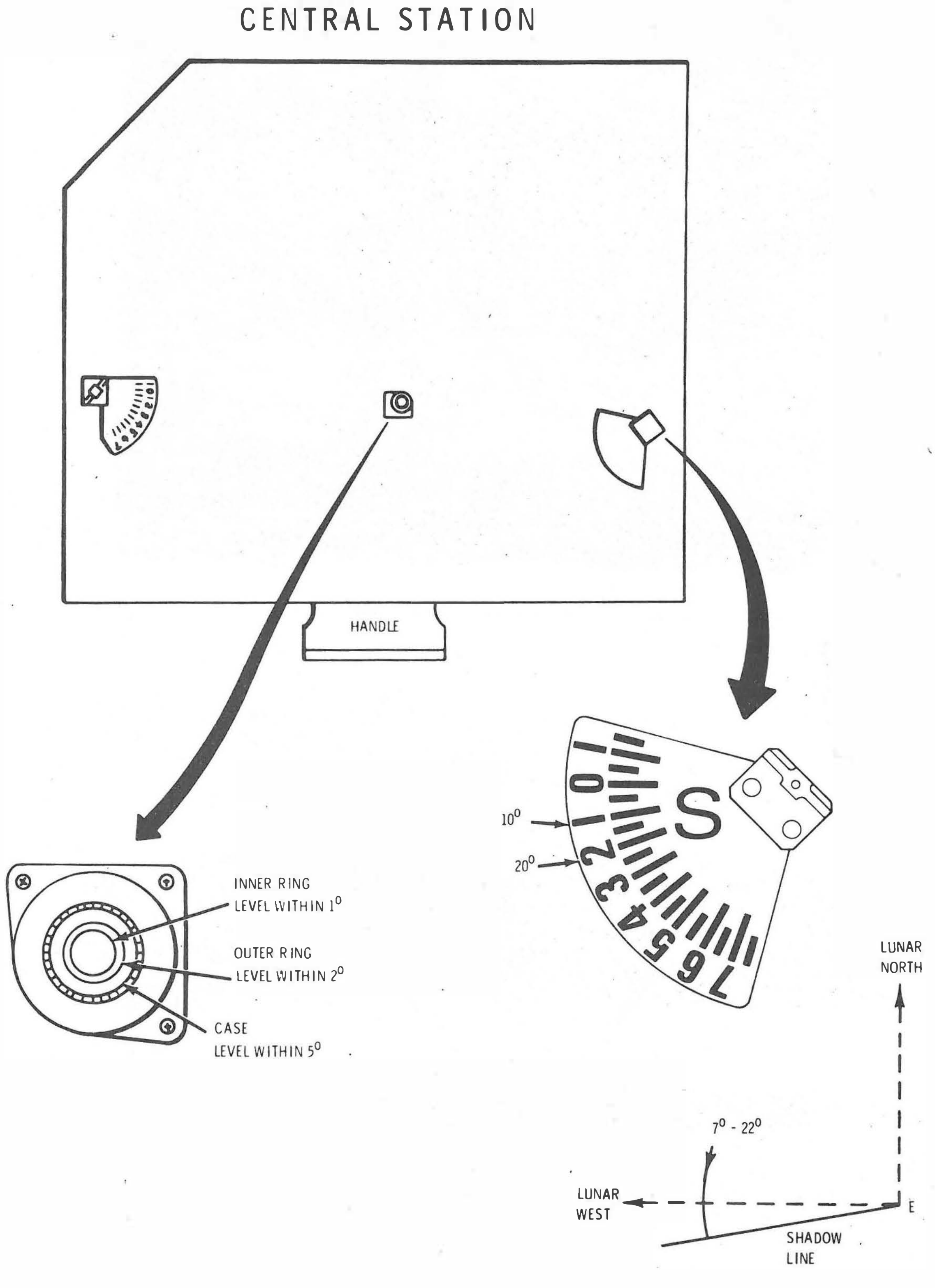


Figure 4-3. Alignment and Leveling Devices (Sheet 1 of 6)

CENTRAL STATION ANTENNA

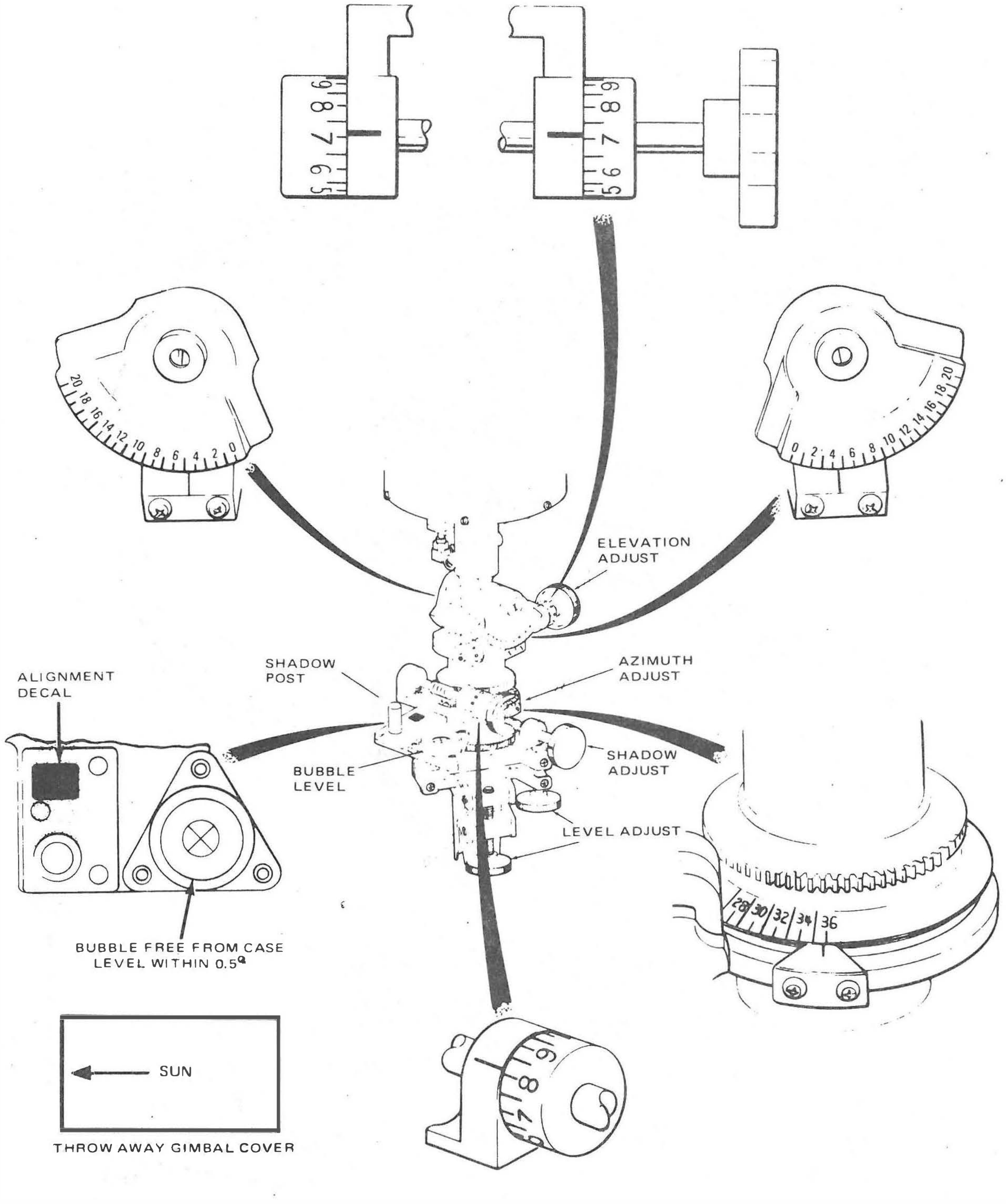


Figure 4-3. Alignment and Leveling Devices (Sheet 2 of 6)

PSE

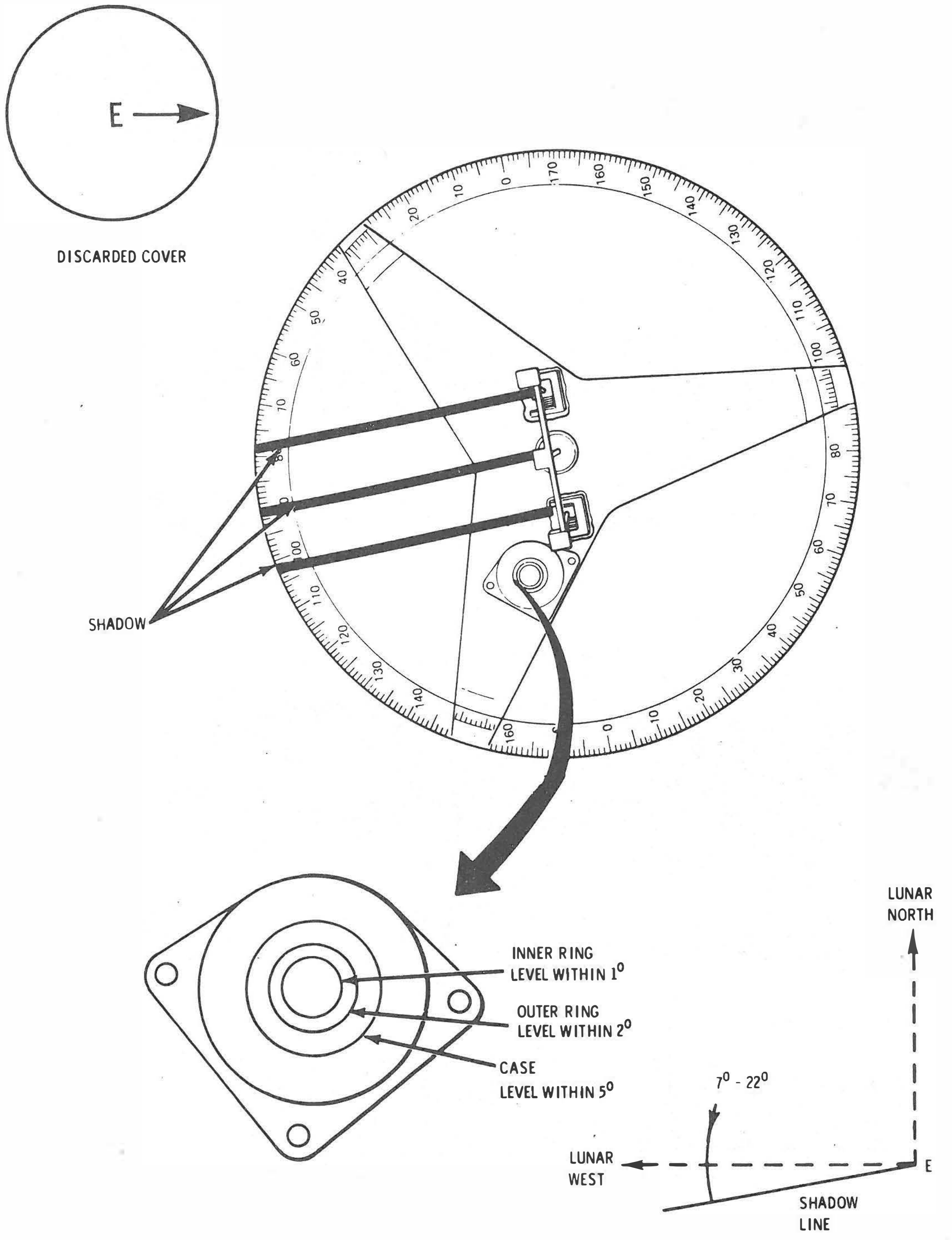


Figure 4-3. Alignment and Leveling Devices (Sheet 3 of 6)

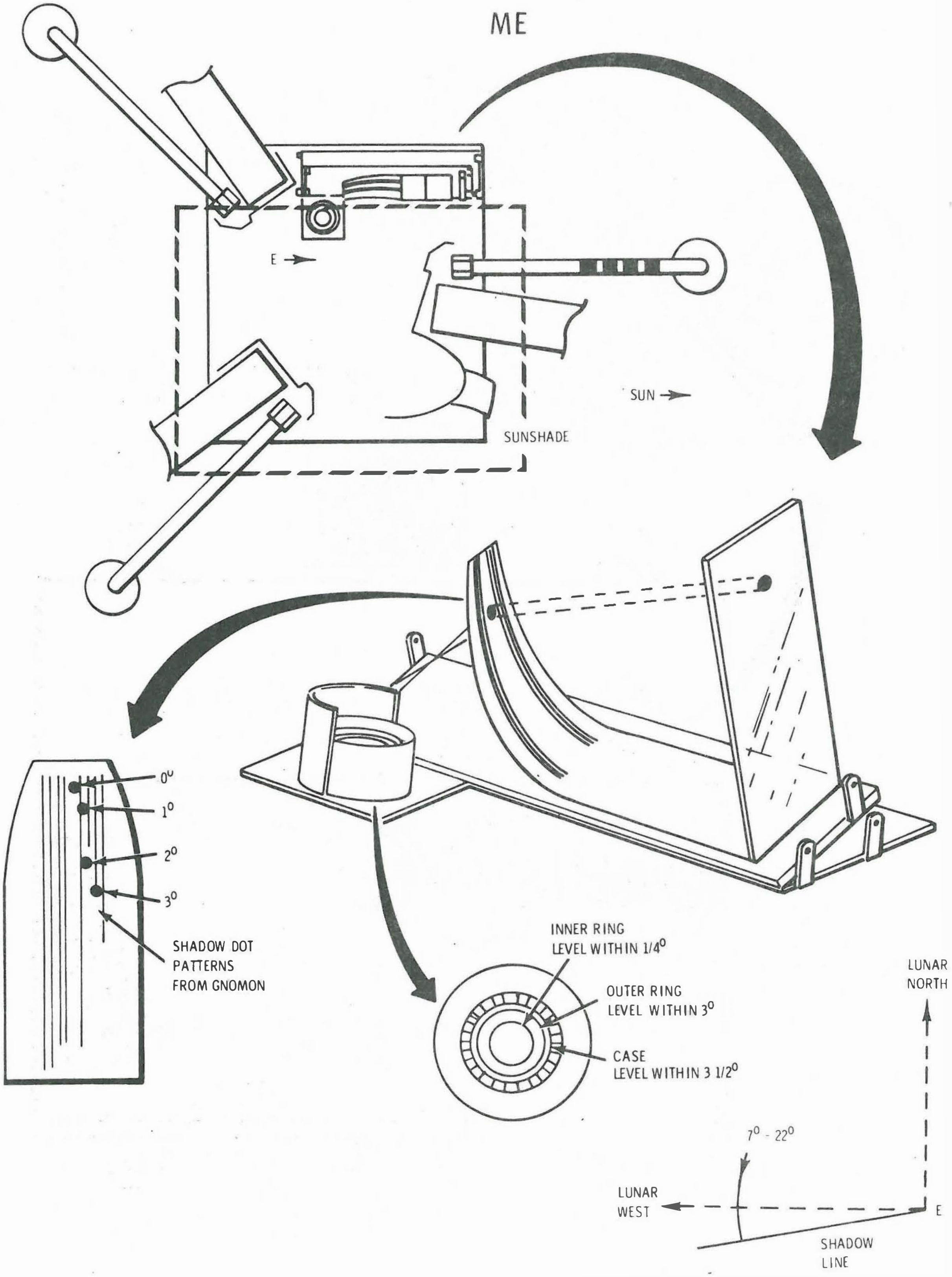


Figure 4-3. Alignment and Leveling Devices (Sheet 4 of 6)

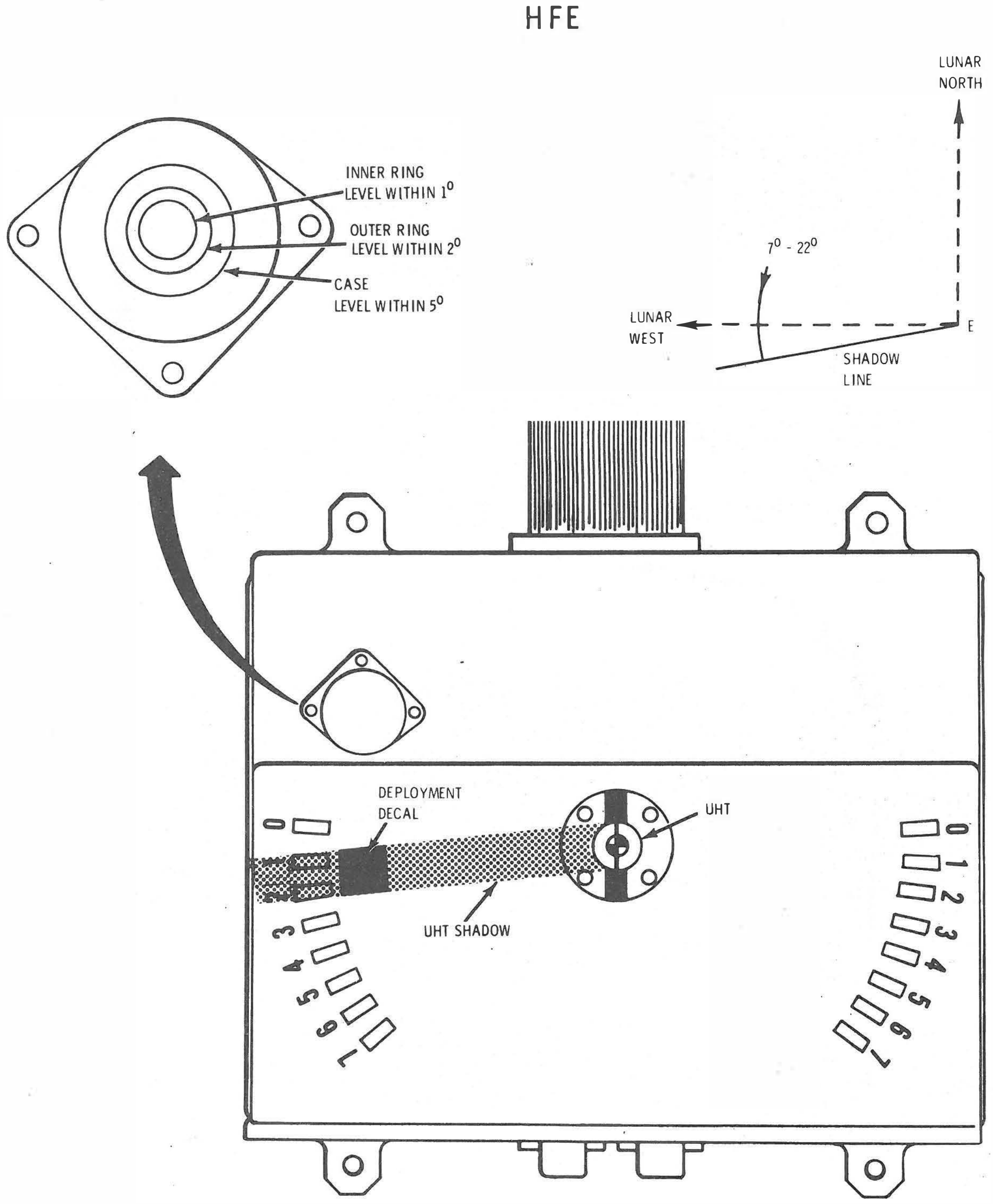


Figure 4-3. Alignment and Leveling Devices (Sheet 5 of 6)

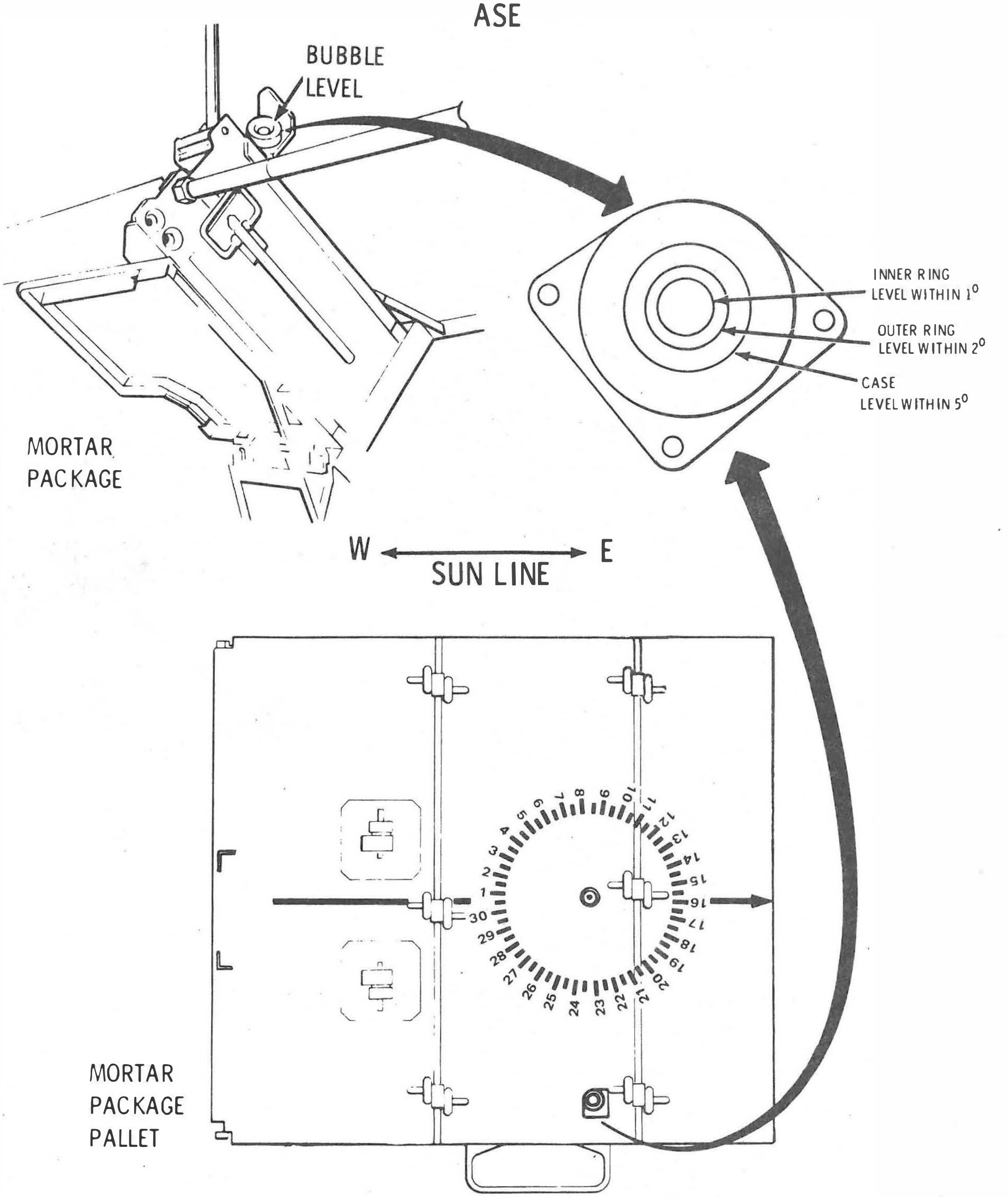


Figure 4-3. Alignment and Leveling Devices (Sheet 6 of 6)

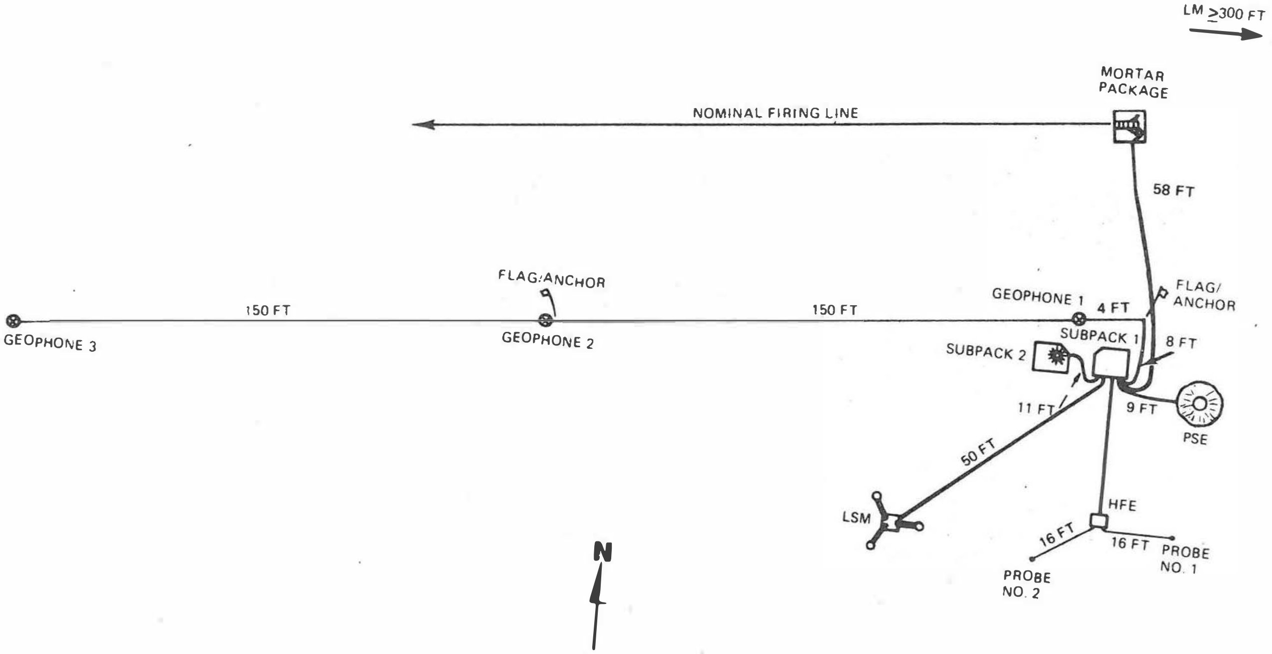


Figure 4-4. Deployment Arrangement

Figure 4-5. PSE Shroud Deployment and Experiment Leveling

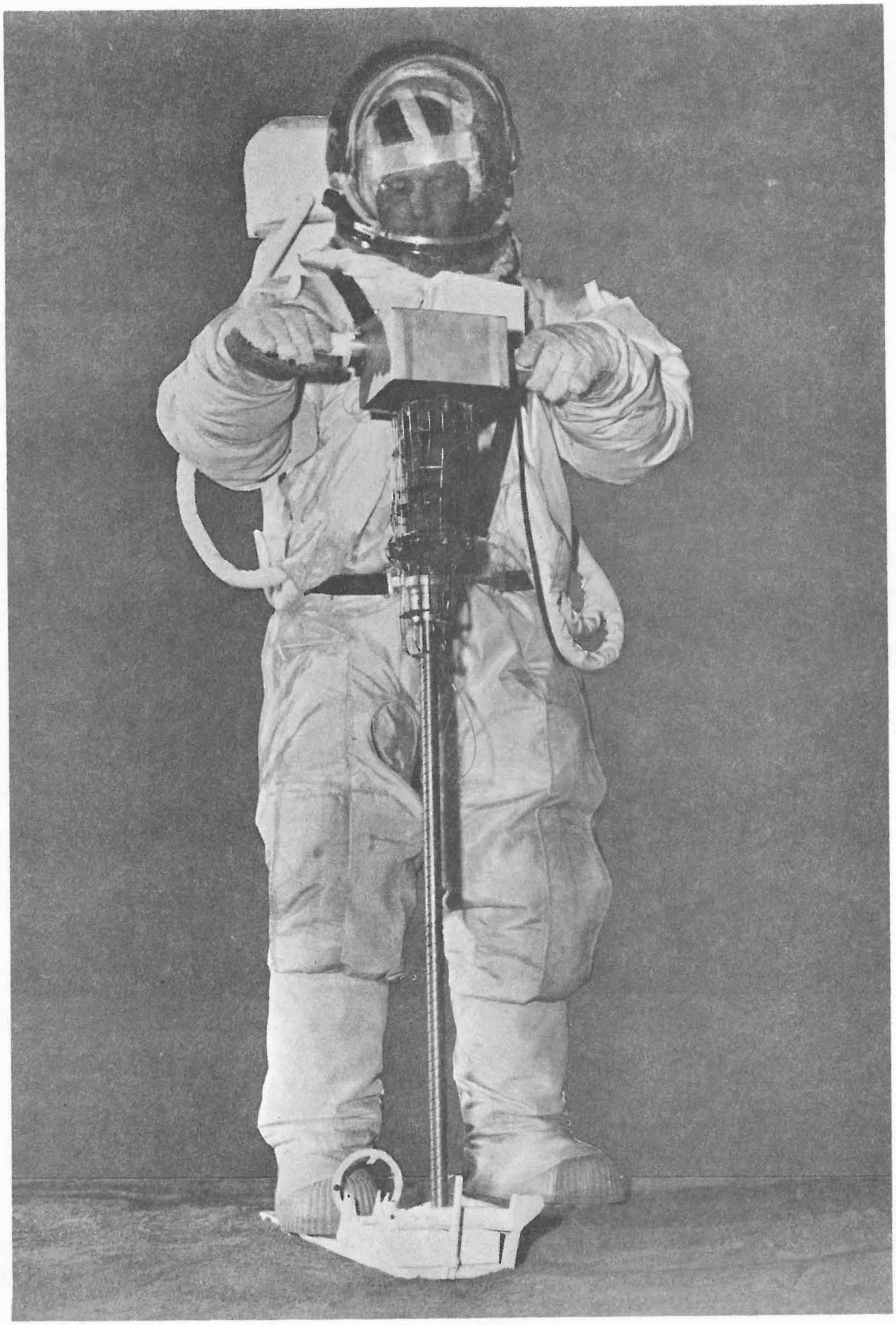


Figure 4-6. ALSD Use in HFE

16. Deploy HFE (See Figure 4-7.)
17. Remove thumper/geophone assembly from subpackage #1
18. Remove mortar package from subpackage #1
19. Remove LSM from subpackage #1
20. Align and level the central station, and deploy sunshield (See Figure 4-8.)
21. Assemble and orient antenna (See Figure 4-9.)
22. Deploy LSM (See Figure 4-10.)
23. Activate central station
24. Deploy geophones (See Figure 4-11.)
25. Conduct thumper activity (See Figure 4-12.)
26. Deploy mortar package (See Figure 4-13.).

4-22. Antenna Aiming. The final step in the deployment sequence is to verify, and correct if necessary, the alignment and leveling of the central station antenna. The following operations, performed in the sequence shown, effect antenna aiming:

a. Set the antenna in elevation.
b. Set the antenna in azimuth.
c. Level the mechanism.
d. Align the shadow with the marked null line.

On completion of antenna aiming, all four settings are checked and readjusted as necessary. Any readjustment in leveling may require further adjustment of the shadow null setting. Refer to Figure 4-14 for location of adjustments and position readouts.

The ALSEP antenna is pointed to the mean position of Earth by means of the elevation, azimuth, and shadow adjustments. The three gimbal mechanisms provide null and angular adjustments through worm and wheel gears at a 72:1 ratio. Correction range for each adjustment is as follows:

a. Sun shadow null ± 15 degrees
b. Azimuth angle ± 15 degrees
c. Elevation angle ± 50 degrees

Elevation and azimuth adjustments are made by rotating the applicable knobs. The elevation and azimuth angles will each be measured by two scales, a coarse scale measuring increments of 5 degrees and set on the respective elevation and azimuth axis, and a fine scale measuring increments of 1/20 of each 5 degree resolution and set on the respective worm drive axis. Data for these settings are derived from aiming tables (Figure 4-15) and relayed via the voice link between astronaut and MCC.

From these two fixed data the mechanism sets the antenna at a predetermined angle in elevation and in azimuth. The azimuth and sunshadow null adjustments are on a common axis. Therefore, the azimuth adjustment is relative to the shadow null position. The elevation angle is measured relative to the local vertical set of the bubble level.

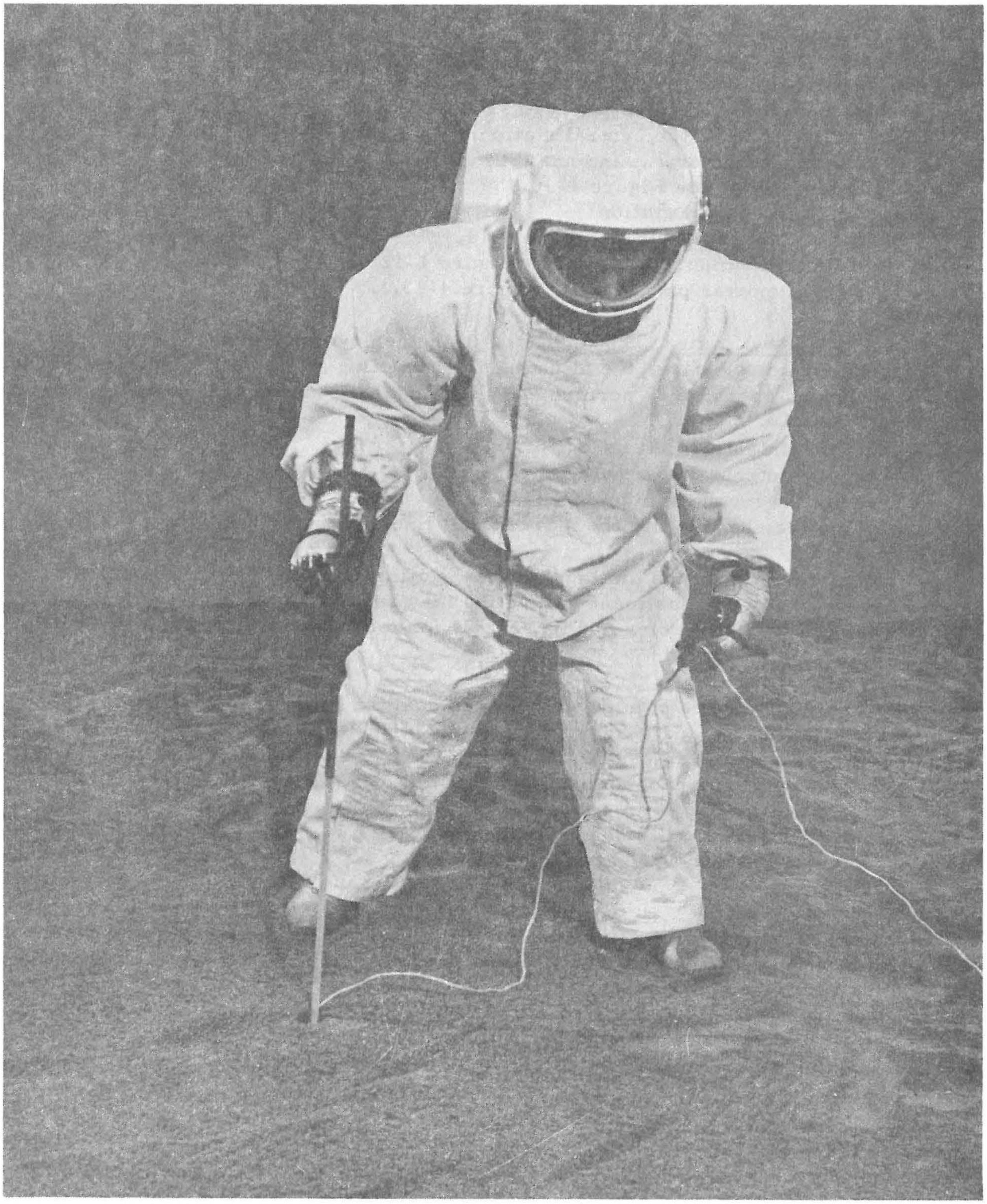


Figure 4-7. HFE Probe Emplacement

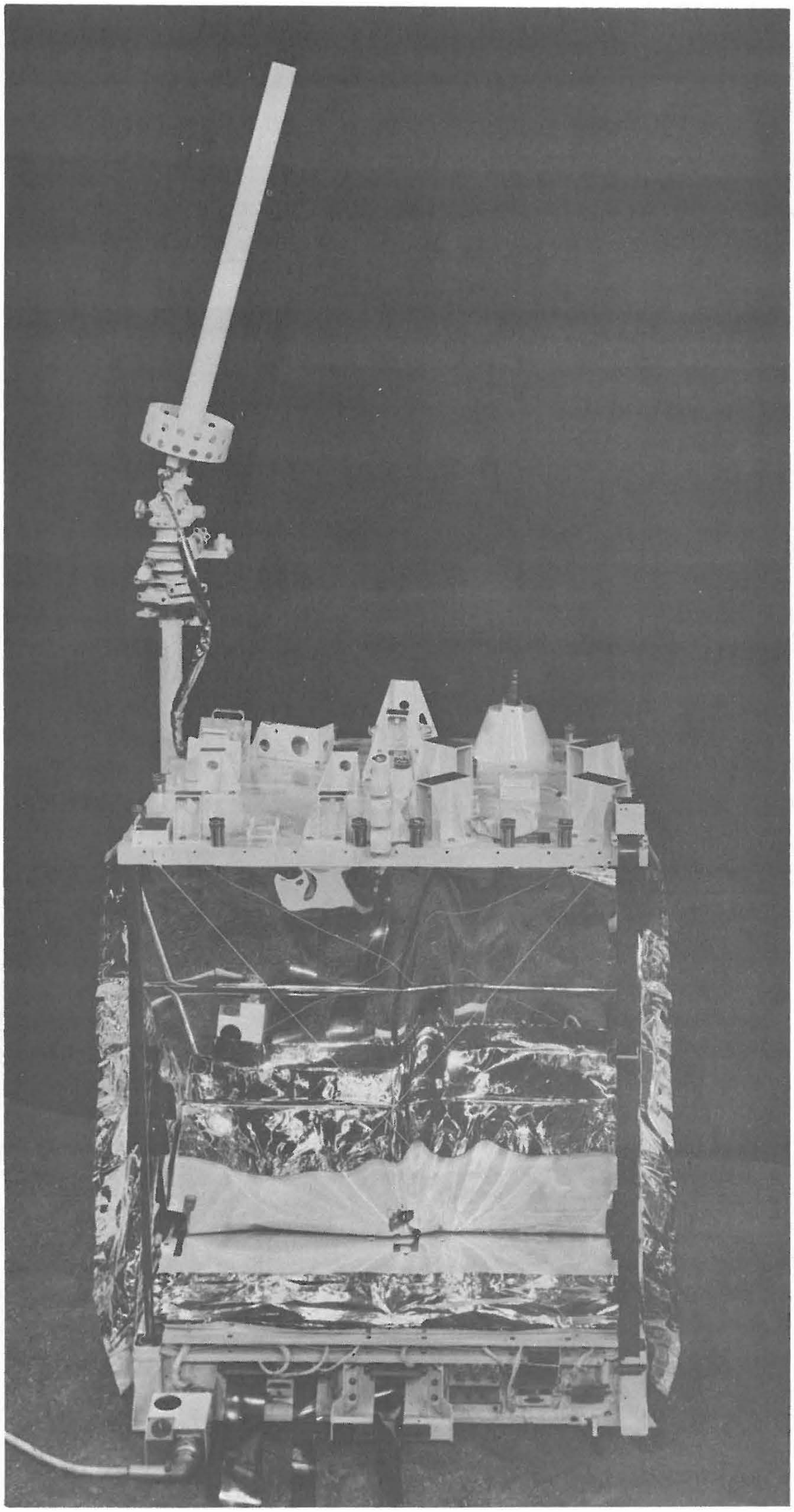


Figure 4-8. Central Station Erected

Figure 4-9. Antenna Aiming Mechanism Alignment

Figure 4-10. ME Deployment

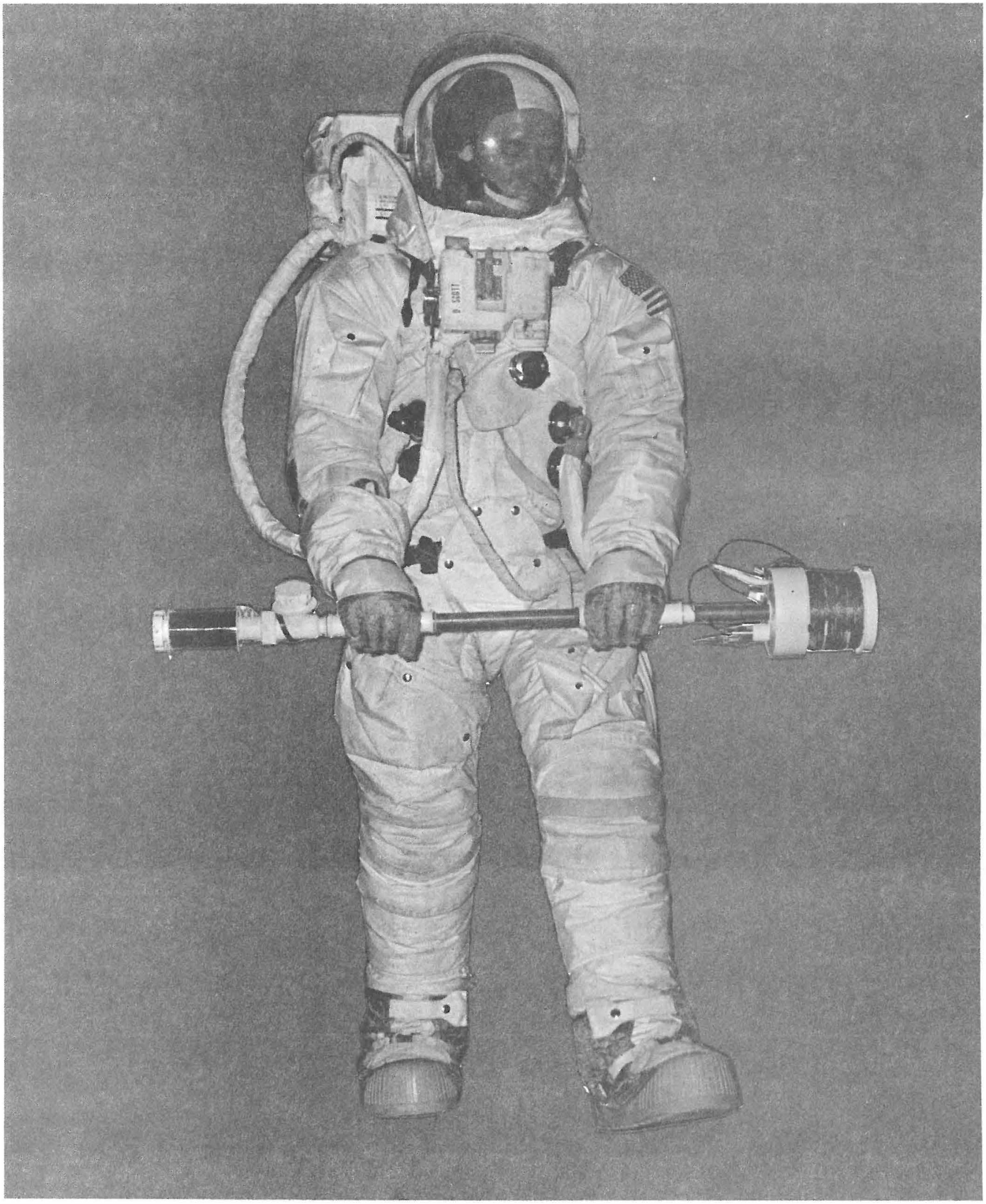


Figure 4-11. Geophone Deployment

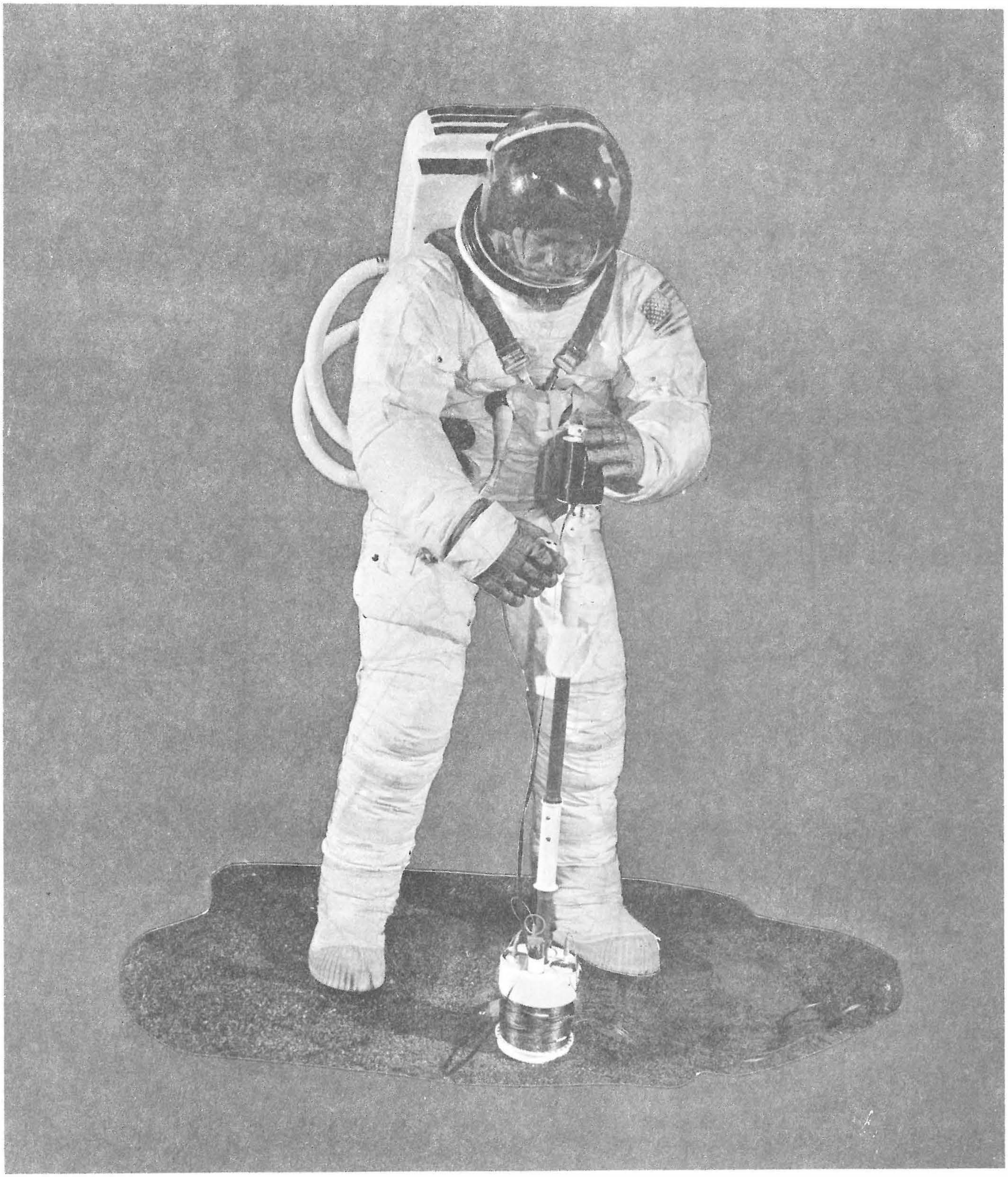


Figure 4-12. Thumper Operation

Figure 4-13. Mortar Package Deployment

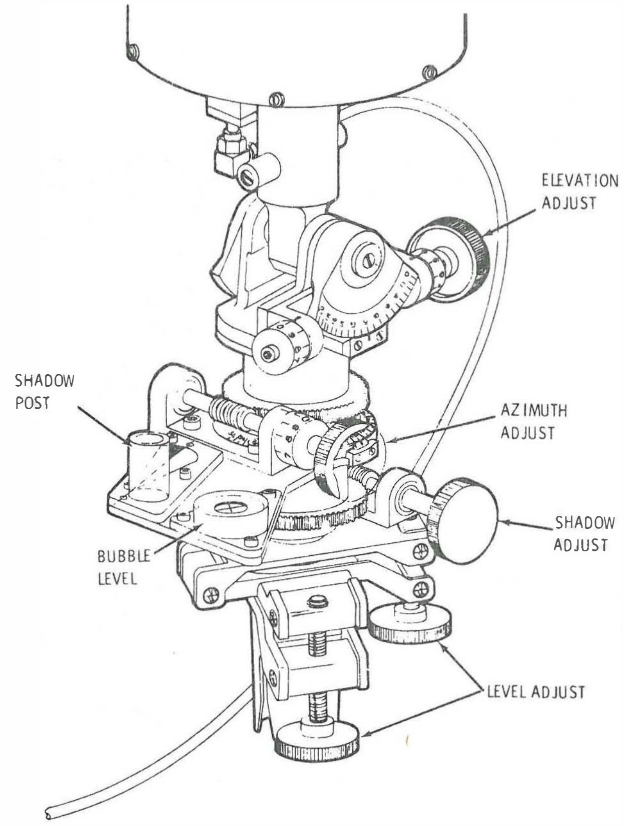


Figure 4-14. Antenna Aiming Mechanism

The antenna is leveled to ± 0.5 degrees by adjusting the two knobs located on the lower side of the aiming mechanism. Sensitivity of the leveling adjustments is 1 degree per revolution of the knob. The adjustment mechanism will correct up to ±6 degrees from the horizontal plane. As the knobs are rotated observe the bubble level to determine when leveling is accomplished.

Upon satisfying the leveling requirements, the shadow knob is rotated (which rotates the mechanism in azimuth) until a specified (null) setting is positioned directly under the shadow from the antenna mounted sun compass. With this accomplished, the antenna is pointed toward the mean position of Earth within ±0.7 degrees, and provides a reference direction between LM and a subsolar point from which fine antenna aiming is made.

To check all adjustments after the mechanism has been set, the bubble level is positioned 3-1/2 inches out from the center of the mechanism and the elevation coarse and fine scales are set at each end of their respective axis.

Longitude 22° 12'

	Upper Gimbal	Sun Compass			
Latitude	+East -West	N.E. Quad	S.E. Quad	S.W. Quad	N.W. Quad
0°0'	22.0	0.0	0.0	0.0	0.0
0°4'	22.0	0.3	-0.4	0.1	-0.2
0°8'	22.0	0.6	-0.8	0.2	-0.3
0°12'	22.0	0.9	-0.2	0.3	-0.5
'	'	'	'	'	'
'	'	'	'	'	'
'	'	'	'	'	'
4°48'	22.5	16.4	-1.82	6.6	-9.4
4°52'	22.5	16.7	-18.6	6.7	-9.5
4°56'	22.5	17.0	-19.0	6.9	-9.7
5°0'	22.5	17.2	-19.4	7.0	-9.8

(Main Table)

Latitude 4°40'
Sun Elevation

0°	-1.5
5°	-1.1
10°	-0.8
15°	-0.4
20°	-0.1
25°	+0.3
30°	+0.7
35°	+1.0
40°	+1.2
45°	+1.6

(Correction Table)

NOTE: Table entries are not correct and are given for illustration only.

Figure 4-15. Antenna Aiming Table (Sample)

4-23. POST-DEPLOYMENT OPERATIONS

Communication between MCC and ALSEP is established with the activation of the central station during deployment operations. For 45 days ALSEP operation is monitored continuously. Commands which initiate specific actions required for normal operation are sent to ALSEP during this period. Commands are also sent to change or request status of ALSEP subsystems or experiments.

After the initial 45-day period, MCC monitors and controls ALSEP at least two hours out of each 24-hour day and 48 to 60 hours during lunar sunrise and sunset. For the active seismic experiment, high data rate is used either 15 minutes once a week or 30 minutes every two weeks.

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

Because of the Earth's rotation, it is necessary to schedule remote sites around the Earth. The following MSFN remote sites are typical of those which may be scheduled for ALSEP operations:

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

The stations selected will provide transmitters/receivers in latitude about the equator ranging from approximately 34 degrees north to 37 degrees south.

The 30-foot dish antennas can be used for normal operations, but the 85-foot dish antennas will be used when ALSEP is in the active seismic mode. ALSEP will be in the active seismic mode approximately one hour during deployment when the astronaut activates the thumper, and another hour at the time that the grenades are launched (this is in addition to intermittent monitoring periods).

The initial operation of each ALSEP system has been monitored in real time at the MCC for 45 days following deployment. At present there are three ALSEP systems operating at different lunar locations. A single MSFN site can receive, segregate, and record this many ALSEP downlink data streams simultaneously. These tape recordings are mailed to MSC routinely for cataloging. Transmission line constraints limit the real-time transfer to MCC of this received data to any two of the three ALSEP downlinks. The data processing and display facilities in MCC are capable of presenting all the data from two ALSEPs in near-real time to the system control personnel.

4-24. MANNED SPACE FLIGHT NETWORK (MSFN)

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

4-25. Downlink Transmission. Figure 4-16 provides a block diagram illustrating the ALSEP functions of MSFN. Telemetry data (engineering status and scientific data) are transmitted by ALSEP 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 the 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 ALSEP data are recorded on this tape recorder for the full year regardless of whether MCC 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 ALSEP).

The 14-channel tape recorder is operated at 3-3/4 ips. When the recorder reel 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 may terminate 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 telemety data are routed to MCC. At MCC the telemetry data are decoded and processed by computer for display.

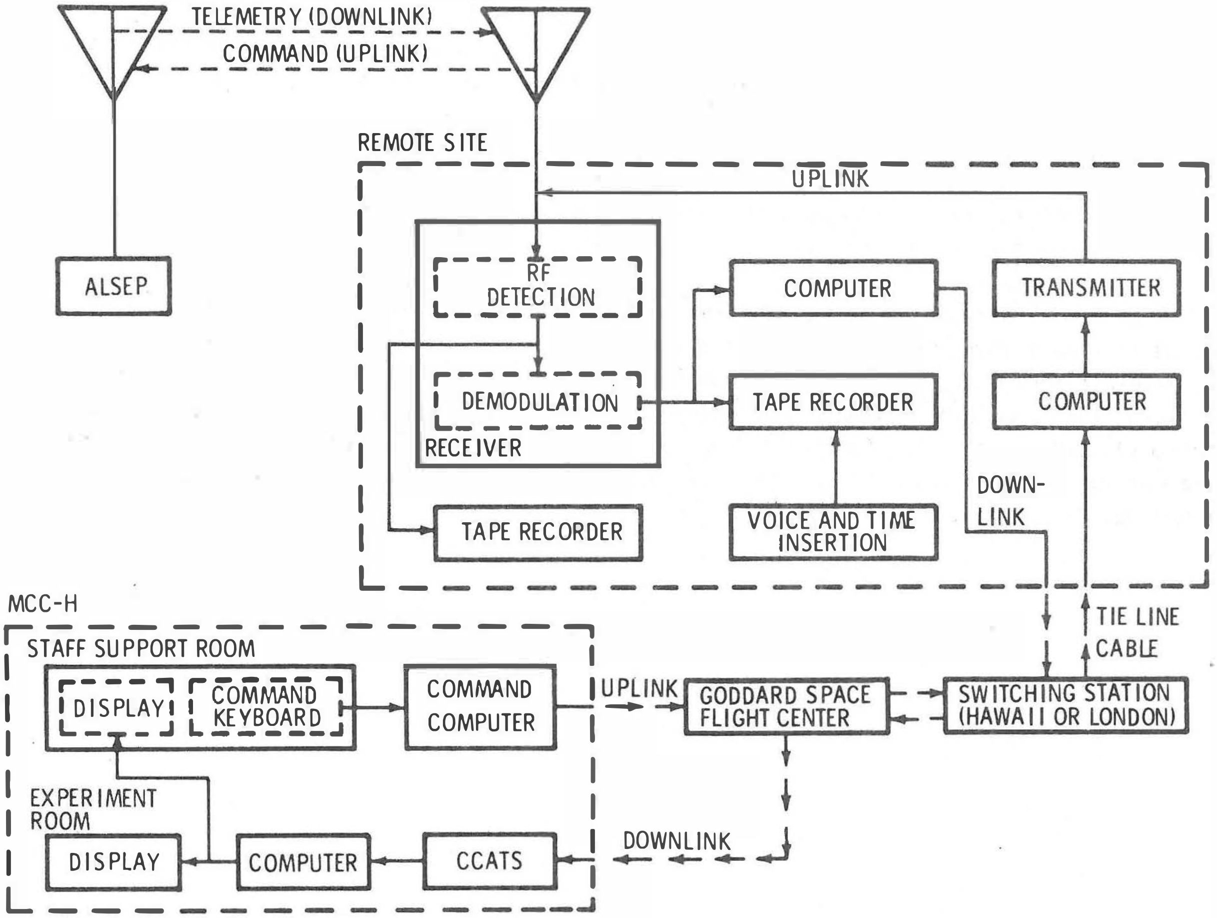


Figure 4-16. MSFN Functional Block Diagram

Principal investigators (PI) observe the display and make preliminary evaluations. The PI may advise the ALSEP 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.

4-26. Uplink Transmission. Commands are generated by the console controller at the ALSEP console command keyboard. The generated signal is routed in teletype code to the applicable remote site. At the remote site, the command transmission is fed into a computer for formatting. The output of the computer serves the modulate the remote site transmitter and the command is transmitted to ALSEP.

4-27. MCC Operation. The ALSEP console controller initiates commands to ALSEP using the command keyboard. Telemetry data received from ALSEP are displayed on the console. As data are received, the controller evaluates the status of ALSEP and generates corrective commands as required. For example, ALSEP may stop transmitting modulation on the carrier in which case the console controller would probably issue a command for ALSEP to switch data processors.

The ALSEP console controller also inserts commands required for the normal operation of ALSEP. These include: mode selection, experiment switching, GLA activation, and dust cover deployment (refer to Appendix for a complete list of the normal commands).

As ALSEP transmits engineering and scientific data back to Earth, the controller must evaluate the status of ALSEP 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
ALSD	Apollo Lunar Surface Drill
ALSEP	Apollo Lunar Surface Experiments Package
AMU	Atomic Mass Unit
ASE	Active Seismic Experiment
ASI	Apollo Standard Initiator
BxA	Bendix Aerospace Systems Division
CCGE	Cold Cathode Gauge Experiment
CCIG	Cold Cathode Ion Gauge
CFE	Contractor Furnished Equipment
CM	Command Module
CPA	Curved Plate Analyzer
CPLEE	Charged Particle Lunar Environment Experiment
CS	Central Station
DRT	Dome Removal Tool
DS/S	Data Subsystem
DTREM	Dust, Thermal, and Radiation Engineering Measurements Package
EASEP	Early Apollo Scientific Experiment Package
EGFU	Electronics/Gimbal-Flip Unit
EMU	Extravehicular Mobility Unit
EPS	Electrical Power Subsystem
FCA	Fuel Capsule Assembly
FET	Field Effect Transistor
FTT	Fuel Transfer Tool
GFE	Government Furnished Equipment
GHz	Gigahertz
GLA	Grenade Launch Assembly
GSE	Ground Support Equipment
HFE	Heat Flow Experiment

GLOSSARY (Cont.)

Abbreviation	Definition
Hz	Hertz; Cycles per Second
IPU	Integrated Power Unit
IST	Integrated Systems Test
KHz	Kilohertz
KSC	Kennedy Space Center
LM	Lunar Module
LP	Long Period
LSM	Lunar Surface Magnetometer Experiment
LRRR	Laser Ranging Retro-Reflector
LTA	Launch Tube Assembly
MCC-H	Mission Control Center-Houston
MSC	Manned Spacecraft Center
MSFN	Manned Space Flight Network
MSOB	Manned Spacecraft Operations Building
NASA	National Aeronautics and Space Administration
NRZ	Non-Return-to-Zero
PAM	Pulse Amplitude Modulation
PCM	Pulse Code Modulation
PCU	Power Conditioning Unit
PDU	Power Distribution Unit
PI	Principle Investigator
PSE	Passive Seismic Experiment
PSEP	Passive Seismic Experiment Package
RF	Radio Frequency
RFI	Radio Frequency Interference
RTG	Radioisotope Thermoelectric Generator
SBASI	Single Bridgewire Apollo Standard Initiator
SEQ	Scientific Equipment Bay in LM
SIDE	Suprathermal Ion Detector Experiment
SIDE/CCIG	Suprathermal Ion Detector Experiment with Cold Cathode Ion Gauge

GLOSSARY (Cont.)

Abbreviation	Definition
SM	Service Module
SP	Short Period
SWS	Solar Wind Spectrometer Experiment
UHT	Universal Handling Tool
VAB	Vehicle Assembly Building

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APPENDIX A

COMMAND LIST

INTRODUCTION

This document tabulates the commands used in the Apollo 16 ALSEP flight system (Array D). 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 function.

TABLE 1

Symbol	Command Nomenclature	Octal Command	Decimal Command	Termination Point		
CD-31	ASE High Bit Rate ON[3]	003	3	Data Processor		
CD-32	ASE High Bit Rate OFF[1]	005	5	"	"	
CD-33	Normal Bit Rate[1,3]	006	6	"	"	
CD-34	Slow Bit Rate	007	7	"	"	
CD-35	Normal Bit Rate Reset[4]	011	9	"	"	
CD-1	Transmitter "A" Select[2]	012	10	Power	Dist.	Unit
CD-2	Transmitter ON	013	11	"	"	"
CD-3	Transmitter OFF[2]	014	12	"	"	"
CD-4	Transmitter "B" Select	015	13	"	"	"
CD-5	PDR #1 ON	017	15	"	"	"
CD-6	PDR #1 OFF[2]	021	17	"	"	"
CD-7	PDR #2 ON	022	18	"	"	"
CD-8	PDR #2 OFF[2]	023	19	"	"	"
CD-9	DSS HTR 3 ON[2]	024	20	"	"	"
CD-10	DSS HTR 3 OFF	025	21	"	"	"
CD-11	Data Processor "X" Select[2]	034	28	"	"	"
CD-12	Data Processor "Y" Select	035	29	"	"	"
CD-13	Experiment 1 Operational Power ON[6]	036	30	"	"	"
CD-14	Experiment 1 Standby Power[2,5]	037	31	"	"	"
CD-15	Experiment 1 Standby OFF	041	33	"	"	"
CD-16	Experiment 2 Operational Power ON	042	34	"	"	"
CD-17	Experiment 2 Standby Power[2]	043	35	"	"	"

[1] Preset turn-on operating mode.
[2] Lunar surface initial conditions programmed in during final system checkout.
[3] Changes bit rate at end of ALSEP frame during which command 15 is executed.
[4] Changes bit rate upon command execution.
[5] Experiment 1 is effectively OFF in this mode.
[6] Experiments are numbered as follows: 1 PSE, 2 ASE, 3 LSM, and 4 HFE.

TABLE 1 (CONT.)

Symbol	Command Nomenclature	Octal Command	Decimal Command	Termination Point
CD-18	Experiment 2 Standby OFF	044	36	Power Dist. Unit
CD-19	Experiment 3 Operational Power ON	045	37	" " "
CD-20	Experiment 3 Standby Power[2]	046	38	" " "
CD-21	Experiment 3 Standby OFF	050	40	" " "
CD-22	Experiment 4 Operational Power ON	052	42	" " "
CD-23	Experiment 4 Standby Power[2]	053	43	" " "
CD-24	Experiment 4 Standby OFF	054	44	" " "
CD-25	DSS HTR 1 Select (10w)	055	45	" " "
CD-26	DSS HTR 2 Select (5w)	056	46	" " "
CD-27	DSS HTR 2 OFF[2,3]	057	47	" " "
CD-36	Timer Output Accept[1]	032	26	Command Decoder
CD-37	Timer Output Inhibit	033	27	" "
CU-1	PCU #1 Select[1]	060	48	Power Cond. Unit
CU-2	PCU #2 Select	062	50	" " "
CL-1	Gain Change LPX, LPY (Steps through following sequence one step per command) -30dB[1] 0dB -10dB -20dB	063	51	Passive Seismic Exp.
CL-2	Gain Change LPZ (Steps through same sequence as CL-1)	064	52	" " "
CL-3	Calibration SP ON/OFF[1,4]	065	53	" " "
CL-4	Calibration LP ON/OFF[1]	066	54	" " "

[1] Preset turn-on operating mode.

[2] Lunar surface initial conditions programmed in during final system check out.

[3] Command CD-27 must be preceded by CD-26.

[4] Calibration is initiated automatically at 18-hour intervals by the delayed command sequencer unless this feature has been inhibited by execution of CD-37.

TABLE 1 (CONT.)

Symbol	Command Nomenclature	Octal Command	Decimal Command	Termination Point
CL-5	Gain Change SPZ (Steps through same sequence as CL-1)	067	55	Passive Seismic Exp.
CL-6	Leveling Power X Motor[2] ON/OFF[1]	070	56	" " "
CL-7	Leveling Power Y Motor[2] ON/OFF[1]	071	57	" " "
CL-8	Leveling Power Z Motor[2] ON/OFF[1]	072	58	" " "
CL-9	Uncage[4] Arm/Fire	073	59	" " "
CL-10	Leveling Direction[2] Plus[1]/Minus	074	60	" " "
CL-11	Leveling Speed[2] Low[1]/High	075	61	" " "
CL-12	Thermal Control Mode Auto[1]/Manual[3]	076	62	" " "
CL-13	Feedback Filter IN/OUT[1]	101	65	" " "
CL-14	Coarse Level Sensor IN/OUT[1]	102	66	" " "
CL-15	Leveling Mode[2] Auto[1]/Manual	103	67	" " "

[1] Preset turn-on operating mode.

[2] Manual leveling sequence is as follows: Send CL-15 to change from auto to manual leveling mode, change direction, and speed by CL-10 and CL-11 as necessary, and then execute leveling operation 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.

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

[4] The uncage sequence of Arm and Fire is executed automatically by the delayed command sequencer at 144 hours and 162 hours, respectively, in the event that uncaging has not been previously accomplished by ground command.

TABLE 1 (CONT.)

Symbol	Command Nomenclature	Octal Command	Decimal Command	Termination Point
CM-1	LSM Range Select (Steps through three ranges, one step per command)[5] 200 gammas full scale[1] 50 gammas full scale 100 gammas full scale repeat	123	83	LSM Experiment
CM-2	Steady Field Offset[2] (Step through seven values, one step per command) 0 percent of full scale[1] +25 percent of full scale +50 percent of full scale +75 percent of full scale -75 percent of full scale -50 percent of full scale -25 percent of full scale[4] 0 percent of full scale and repeat	124	84	" "
CM-3	Steady Field Address (Steps through following X axis to Y axis to Z axis to neutral[1])	125	85	" "
CM-4	Flip/Cal Inhibit In[1]/Out	127	87	" "
CM-5	Flip/Cal Initiate (Returns to Science mode after Flip/Cal sequence)[3]	131	89	" "

[1] Preset turn-on operating mode.

[2] Field offset sequence is as follows: Select proper axis with CM-3, then execute CM-2 the proper number of times to step from present value to desired value.

[3] Also activated every 18 hours after hour 162 by delayed command sequencer.

[4] For 0° flip position; reverse polarity for 180° flip position.

[5] **Expected** ranges shown

TABLE 1 (CONT.)

Symbol	Command Nomenclature	Octal Command	Decimal Command	Termination Point
CM-6	LSM Filter Failure (In[1]/Out) Bypass	132	90	LSM Experiment
CM-7	Site Survey[2]	133	91	" "
CM-8	Temperature Control X[1]/Y/OFF Repeat (Changes from X-axis sensor[1] to Y-axis sensor to OFF)	134	92	" "
CH-1	Normal (Gradient) Mode Select[1]	135	93	Heat Flow Experiment
CH-2	Low Conductivity Mode Select (Ring Source)	136	94	" " "
CH-3	High Conductivity Mode Select (Heat Pulse)	140	96	" " "
CH-4	HF Full Sequence Select[1]	141	97	" " "
CH-5	HF Probe #1 Sequence Select	142	98	" " "
CH-6	HF Probe #2 Sequence Select	143	99	" " "
CH-7	HF Subsequence #1 } Command Functions as shown in Note 1, page A-8	144	100	" " "
CH-8	HF Subsequence #2	145	101	" " "
CH-9	HF Subsequence #3	146	102	" " "
CH-10	HF Heater Advance (Steps through following 16-step sequence, one step per command)	152	106	" " "

All heaters off
Probe #1 heater #2 ON
All heaters off
Probe #1 heater #4 ON
All heaters off
Probe #1 heater #1 ON
All heaters off
Probe #1 heater #3 ON
All heaters off
Probe #2 heater #2 ON
All heaters off
Probe #2 heater #4 ON
All heaters off
Probe #2 heater #1 ON
All heaters off
Probe #2 heater #3 ON
repeat

---

[1] Preset turn-on operating mode.

[2] First execution of CM-7 performs X-axis survey, second execution Y-axis survey, and third execution Z-axis survey. The associated command line is then disabled and cannot be further used

TABLE 1 (CONT.)

Symbol	Command Nomenclature	Octal Command	Decimal Command	Termination Point
CS-1	Geophone Calibrate	156	110	Active Seismic Expt.
CS-3	ASE Grenade Sequential Single Fire (Fires single grenades in sequence 2, 4, 3, 1. Previous grenade must fire before next grenade will fire. Four executions required.)	162	114	" " "
CS-4	ASE Grenade #1 Fire	163	115	" " "
CS-5	ASE Grenade #2 Fire	164	116	" " "
CS-6	ASE Grenade #3 Fire	165	117	" " "
CS-7	ASE Grenade #4 Fire	166	118	" " "
CS-8	Arm Grenades[1]	170	120	" " "
CR-1	Timer Reset	150	104	Timer

[1] Command CS-8 is required to arm grenades before each "Fire" Command.

NOTE 1

Heat Flow Command Structure

Octal commands 144 through 146 are used to select subsets of the full heat flow measurement sequence as follows:

> Command 144 selects a subset consisting of the four high sensitivity gradient measurements only.
>
> Command 144 followed by command 145 selects a subset consisting of the four low sensitivity gradient measurements only.
>
> Command 144 followed by command 146 selects a subset consisting of probe ambient temperature measurements only.
>
> Command 145 followed by command 146 selects a subset consisting of thermocouple measurements only.

TABLE 2
COMMAND SUMMARY

Termination Point	Number of Commands
Data Processor	5
Power Distribution Unit (Power Switching)	27
Power Conditioning Unit	2
Command Decoder	2
Timer	1
Passive Seismic	15
Magnetometer	8
Heat Flow	10
Active Seismic	7
Total	77

Function	Octal Code	Number
Test Command	1, 2, 4, 10, 20, 40, 100, 77, 137, 157, 167, 173, 175, 176	14
ALSEP Addresses	130, 30, 116, 16, 151, 51, 25, 65, 62, 144*	10
Address Complements	47, 147, 61, 161, 26, 126, 152, 112, 115, 33**	10
No Command	0, 177	2

Commands Assigned to Array D	77
Commands Exclusively Reserved for Other Usage	30
Available Commands Not Assigned in Array D	21
Total Commands	128

*Addresses for Array D are 62, 144

**Address complements for Array D are 115, 33

TABLE 3

CROSS REFERENCE OF COMMAND NUMBER TO COMMAND FUNCTION

Decimal Command	Octal Command	Command Symbol	Array D Usage	Test Cmds.	Address	Address Complement	No Command	Not Assigned
1	1			X				
2	2			X				
3	3	CD-31	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	X					
21	25	CD-10	* (X)		(X)			
22	26					X		

* X in parentheses indicates dual usage.

TABLE 3

CROSS REFERENCE OF COMMAND NUMBER TO COMMAND FUNCTION

Decimal Command	Octal Command	Command Symbol	Array D Usage	Test Cmds.	Address	Address Complement	No Command	Not Assigned
23	27							X
24	30				X			
25	31							X
26	32	CD-36	X					
27	33	CD-37	(X)			(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	X					
35	43	CD-17	X					
36	44	CD-18	X					
37	45	CD-19	X					
38	46	CD-20	X					
39	47					X		
40	50	CD-21	X					
41	51				X			
42	52	CD-22	X					
43	53	CD-23	X					
44	54	CD-24	X					
45	55	CD-25	X					
46	56	CD-26	X					

TABLE 3

CROSS REFERENCE OF COMMAND NUMBER TO COMMAND FUNCTION

Decimal Command	Octal Command	Command Symbol	Array D Usage	Test Cmds.	Address	Address Complement	No Command	Not Assigned
47	57	CD-27	X					
48	60	CU-1	X					
49	61					X		
50	62	CU-2	(X)		(X)			
51	63	CL-1	X					
52	64	CL-2	X					
53	65	CL-3	(X)		(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

CROSS REFERENCE OF COMMAND NUMBER TO COMMAND FUNCTION

Decimal Command	Octal Command	Command Symbol	Array D Usage	Tests Cmds.	Address	Address Complement	No Command	Not 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	CM-1	X					
84	124	CM-2	X					
85	125	CM-3	X					
86	126					X		
87	127	CM-4	X					
88	130				X			
89	131	CM-5	X					
90	132	CM-6	X					

TABLE 3

CROSS REFERENCE OF COMMAND NUMBER TO COMMAND FUNCTION

Decimal Command	Octal Command	Command Symbol	Array D Usage	Test Cmds.	Address	Address Complement	No Command	Not Assigned
91	133	CM-7	X					
92	134	CM-8	X					
93	135	CH-1	X					
94	136	CH-2	X					
95	137			X				
96	140	CH-3	X					
97	141	CH-4	X					
98	142	CH-5	X					
99	143	CH-6	X					
100	144	CH-7	(X)		(X)			
101	145	CH-8	X					
102	146	CH-9	X					
103	147					X		
104	150	CR-1	X					
105	151				X			
106	152	CH-10	(X)			(X)		
107	153							X
108	154							X
109	155							X
110	156	CS-1	X					
111	157			X				
112	160							X

TABLE 3

CROSS REFERENCE OF COMMAND NUMBER TO COMMAND FUNCTION

Decimal Command	Octal Command	Command Symbol	Array D Usage	Test Cmds.	Address	Address Complement	No Command	Not Assigned
113	161					X		
114	162	CS-3	X					
115	163	CS-4	X					
116	164	CS-5	X					
117	165	CS-6	X					
118	166	CS-7	X					
119	167			X				
120	170	CS-8	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	77	14	10	10	2	21

APPENDIX B

MEASUREMENT REQUIREMENTS DOCUMENT

INTRODUCTION

This document tabulates the measurements to be telemetered from the Array D (Flight Model 5) ALSEP 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 encodes each analog housekeeping and science signal to 8-bit accuracy. The encoded word occupies word 33 in the ALSEP 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 experiments are consistent with the frame format section of the ALSEP Data Subsystem shown in Figure 1. Control and Command Verification Word Formats are shown in Figure 2. The high data rate required by the Active Seismic (ASE) necessitates inhibiting other signals for the operation period of the ASE, except for selected critical items which are incorporated in the ASE format.

The following tables categorize the telemetered measurements:

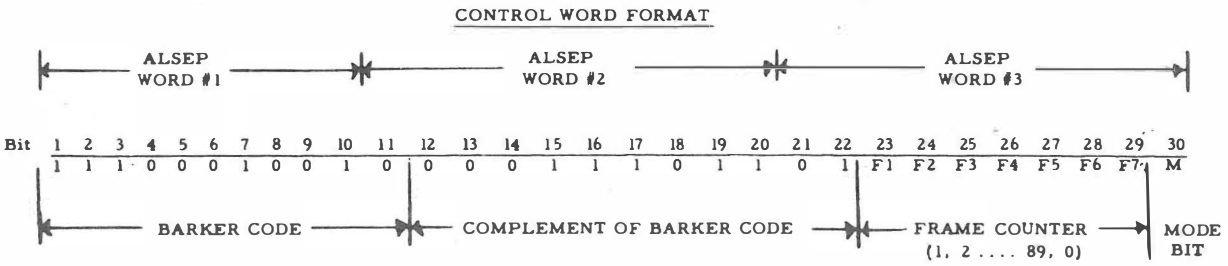
Table 1	- Channel Assignments for the Analog Multiplexer (ALSEP Word 33)
Table 2	- Analog Housekeeping Channel Usage
Table 3	- Summary of Analog Channel Usage
Table 4	- Passive Seismic Experiment
Tables 5, 6, 7	- Magnetometer Experiment
Table 8	- Active Seismic Experiment
Tables 9-15	- Heat Flow Experiment

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

Legend			**Number of Words Per Frame**	
x	-	**Control**	3	
X	-	**Passive Seismic - Short Period**	29	
-	-	**Passive Seismic - Long Period Seismic**	12	43
●	-	**Passive Seismic - Long Period Tidal and One Temperature**	2	
O	-	**Magnetometer**	7	
HF	-	Heat Flow	1	
CV	-	Command Verification (upon command, otherwise all zeros)	1	
H	-	Housekeeping	1	
	-	Not Used	8	
		Total	64	

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

Figure 1. ALSEP Word Assignment



Symbol	Name	ALSEP Words	Range	Bits / Sample	Samples / Second (at normal data rate)
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	1-90	7	1.67
DA-3	Mode Bit	Bit 10 of word 3			1.67
		Frame · **Mode Bit** 1 · 1 2 · 1	**Meaning** Normal data rate Slow data rate		
DA-4	ALSEP ID	Bit 10 of word 3		3	1/54
		Frame · **Mode Bit** 3 · X (MSB) 4 · X 5 · X	Data processor Serial number		
*DA-5	Received Command Message	Bits 3 to 9 inclusive of word 46	1 to 128	7	**
DA-6	Command MAP	Bit 10 of word 46	"0" no parity "1" parity	1	**

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

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

Figure 2. Control and Command Verification Words Format

TABLE 1

CHANNEL ASSIGNMENTS FOR ANALOG MULTIPLEXER (ALSEP WORD 33)

Channel Number		Mnemonic and Service
1.	AE-3	Input Voltage
2.	AE-1	0.25V Calibration
3.	AE-2	4.75V Calibration
4.	AT-3	Thermal Plate #1 Temp.
5.	AE-4	Input Current
6.	AR-1	Hot Frame #1 Temp.
7.	AR-4	Cold Frame #1 Temp.
8.	AE-5	Shunt Regulator Current PC 1
9.	AB-8	Rec. A Command Subcarrier Status
10.	AZ-1	18-Hour Bistatic
11.	AZ-2	1-1/2 Month #1
12.	AB-4	Exp. 1 & 2 Status
13.	AE-6	Shunt Regulator Current PCU 2.
14.	AB-5	Exp. 3, 4 & Heater 2 Status
15.	AT-10	Bottom Structure Temp.
16.	AT-40	Rec. CASE Temperature
17.	AB-9	Rec. B Command Subcarrier Status
18.	AT-23	TX A Xtal Temperature
19.	AT-24	TX A Heat Sink Temperature
20.	AE-7	29 Volts
21.	AE-19	Receiver A Input Signal Level
22.	AE-18	TX B Current
23.	AL-1	LP Gain XY
24.	AL-5	Level & Coarse Sensor Mode (PSE)
25.	AS-1	Central Station Electronics Temp. (ASE)
26.	AB-6	Rec. A Power Status
27.	AT-1	Sunshield Top Temperature
28.	AT-4	Thermal Plate #2 Temperature
29.	AH-1	HFE Supply Voltage #1
30.	AB-7	Rec. B Power Status
31.	AT-25	TX B Xtal Temperature
32.	AT-26	TX B Heat Sink Temperature
33.	AT-27	A. D. P. Base Temperature
34.	AT-28	A. D. P. Internal Temperature
35.	AE-8	15 Volts
36.	AE-20	Rec. B Input Signal Level
37.	AR-2	Hot Frame #2
38.	AL-2	LP Gain Z
39.	AL-6	PSE Thermal Control Status
40.	AS-2	Mortar Box Temperature
41.	AE-6*	Shunt Regulator Current PC 2
42.	AT-2	Sunshield Underside Temperature
43.	AT-5	Thermal Plate #3 Temperature
44.	AS-3	GLA Temperature
45.	AH-2	HFE Supply Voltage #2

*HK-41 and 56 repeat measurement of HK-8 - HK-13

TABLE 1 (CONTINUED)

CHANNEL ASSIGNMENTS FOR ANALOG MULTIPLEXER (ALSEP WORD 33)

Channel Number		Mnemonic and Service
46.	AT-29	DDP Base Temperature
47.	AT-30	DDP Internal Temperature
48.	AT-31	Decoder Base Temperature
49.	AT-32	Decoder Internal Temperature
50.	AE-9	12 Volts
51.	AE-15	TX A Output Power
52.	AR-3	Hot Frame #3 Temperature
53.	AL-3	PSE Level Direction and Speed
54.	AL-7	Calibration Status LP & SP
55.	AH-3	HFE Supply Voltage #3
56.	AE-5*	Shunt Regulator Current PC 1
57.	AH-6	HFE High Conductivity Heater Power Status
58.	AT-6	Thermal Plate #4 Temperature
59.	AT-8	Left Structure Temperature
60.	AT-12	Inner Bag Temperature
61.	AT-33	VCO Temperature
62.	AT-34	PDU Base Temperature
63.	AT-35	PDU Internal Temperature
64.	AT-36	PCU Osc. #1 Temperature
65.	AE-10	5 Volts
66.	AE-16	TX B Output Power
67.	AR-5	Cold Frame #2 Temperature
68.	AL-4	SP Gain
69.	AL-8	Uncage Status
70.	AB-10	Data Processor Status
71.	AT-7	Thermal Plate #5 Temperature
72.	AT-13	Outer Bag Temperature
73.	AS-4	Geophone Temperature
74.	AH-4	HFE Supply Voltage #4
75.	AH-7	HFE Low Conductivity Heater Power Status
76.	AT-37	PCU Osc. #2 Temperature
77.	AT-38	PCU Reg. #1 Temperature
78.	AT-39	PCU Reg. #2 Temperature
79.	AE-11	-12 Volts
80.	AE-12	-6 Volts
81.	AE-17	TX A Current
82.	AR-6	Cold Frame #3 Temperature
83.	BLANK	
84.	BLANK	
85.	BLANK	
86.	AZ-3	1-1/2 Month Output #2
87.	AT-9	Right Structure Temperature
88.	AT-11	PDM Temperature
89.	BLANK	
90.	BLANK	

TABLE 2

ANALOG HOUSEKEEPING CHANNEL USAGE

Symbol		Channel	Range	Sensor Accuracy
	Structural/Thermal Temperatures			
AT-1	Sunshield #1	27	-300°F to +300°F	±15°F
AT-2	Sunshield #2	42	-300°F to +300°F	±15°F
AT-3	Thermal Plate #1	4	-50°F to +210°F	±10°F
AT-4	Thermal Plate #2	28	-50°F to +210°F	±10°F
AT-5	Thermal Plate #3	43	-50°F to +210°F	±10°F
AT-6	Thermal Plate #4	58	-50°F to +210°F	±10°F
AT-7	Thermal Plate #5	71	-50°F to +210°F	±10°F
AT-8	Vertical Structure #1 (Left)	59	-300°F to +300°F	±15°F
AT-9	Vertical Structure #2 (Right)	87	-300°F to +300°F	±15°F
AT-10	Bottom Structure	15	-300°F to +300°F	±15°F
AT-11	Power Dump Module	88	-300°F to +300°F	±15°F
AT-12	Inner Multilayer Insulation	60	-50°F to +210°F	±10°F
AT-13	Outer Multilayer Insulation	72	-300°F to +300°F	±15°F
	Electronic Temperatures			
AT-23	Transmitter A Crystal	18	-25°F to +175°F	±10°F
AT-24	Transmitter A Heat Sink	19	-25°F to +175°F	±10°F
AT-25	Transmitter B Crystal	31	-25°F to +175°F	±10°F
AT-26	Transmitter B Heat Sink	32	-25°F to +175°F	±10°F
AT-27	Analog Data Processor, Base	33	-50°F to 210°F	±10°F
AT-28	Analog Data Processor, Internal	34	-50°F to 210°F	±10°F
AT-29	Digital Data Processor, Base	46	-50°F to 210°F	±10°F
AT-30	Digital Data Processor, Internal	47	-50°F to 210°F	±10°F
AT-31	Command Decoder, Base	48	-50°F to 210°F	±10°F
AT-32	Command Decoder, Internal	49	-50°F to 210°F	±10°F
AT-33	Command Demodulator VCO	61	-50°F to 210°F	±10°F
AT-34	Power Distribution Unit, Base	62	-50°F to 210°F	±10°F
AT-35	Power Distribution Unit, Internal	63	-50°F to 210°F	±10°F
AT-36	PCU, Power OSC #1	64	-50°F to +210°F	±10°F
AT-37	PCU, Power OSC #2	76	-50°F to +210°F	±10°F
AT-38	PCU, Regulator #1	77	-50°F to +210°F	±10°F
AT-39	PCU, Regulator #2	78	-50°F to +210°F	±10°F
AT-40	Rec. Case	16	-50°F to +200°F	±5% absolute

Total of 31 Central Station Temperatures

TABLE 2 (CONT.)

ANALOG HOUSEKEEPING CHANNEL USAGE

Symbol	Location/Name	Channel	Range			Sensor Accuracy
	Central Station Electrical					
AE-1	ADC Calibration 0.25V	2	Digital Count 015 ± 1			0.5%
AE-2	ADC Calibration 4.75V	3	Digital Count 361 ± 1			0.5%
AE-3	Converter Input Voltage	1	0 to 20 VDC			± 2%
AE-4	Converter Input Current	5	0 to 5 ADC			± 2%
AE-5	Shunt Reg #1 Current	8, 56	0 to 2.5 ADC			± 2%
AE-6	Shunt Reg #2 Current	13, 41	0 to 2.5 ADC			± 2%
AE-7	PCU Output Voltage #1 (29V)	20	0 to 35 VDC			± 2%
AE-8	PCU Output Voltage #2 (15V)	35	0 to 18 VDC			± 2%
AE-9	PCU Output Voltage #3 (12V)	50	0 to 15 VDC			± 2%
AE-10	PCU Output Voltage #4 (5V)	65	0 to 6 VDC			± 2%
AE-11	PCU Output Voltage #5 (-12V)	79	0 to -15 VDC			± 2%
AE-12	PCU Output Voltage #6 (-6V)	80	0 to -7.5 VDC			± 2%
AE-15	Trans. A, RF Power	51	27 to 32 dBm			± 0.1 DB
AE-16	Trans. B, RF Power	66	27 to 32 dBm			± 0.1 DB
AE-17	Trans. A, Current	81	0 to 500 ma			± 5 ma
AE-18	Trans. B, Current	22	0 to 500 ma			± 5 ma
AE-19	RCVR. A, Input Signal (AGC) Level	21	-100 dBm to -60 dBm			varies with
AE-20	RCVR. B, Input Signal (AGC) Level	36	-100 dBm to -60 dBm			signal level
	Central Station Bistatic					
AB-4*	Power Distribution, Experiments #1 and #2	12	Exper. #1	Exper. #2	Octal Count	
			Standby off	Standby off	000-002	
			Standby on	Standby off	076-122	
			Standby off	Standby on	171-215	
			Standby on	Standby on	264-314	
AB-5*	Power Distribution, Experiments 3 and 4 and DSS Heater #1 (10W)	14	Exper. #3	Exper. #4	Heater #1	Octal Count
			Standby off	Standby off	Off	000-002
			Standby off	Standby off	On	031-055
			Standby off	Standby on	Off	073-117
			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 follows: Exp. No. (1) PSE, (2) ASE, (3) LSM, (4) HFE.

TABLE 2 (CONT.)

ANALOG HOUSEKEEPING CHANNEL USAGE

Symbol	Location/Name	G. E. Nos.	Channel	Range	Sensor Accuracy
AB-6	RCVR. A Power Status		26	OFF: 000-002;* ON: 221-241*	
AB-7	RCVR. B Power Status		30	OFF: 000-002;* ON: 221-241*	
AB-8	Receiver A Command Subcarrier Status		9	No modulation 025-064;* Modulation 242-364*	
AB-9	Receiver B Command Subcarrier Status		17	No modulation 025-064;* Modulation 242-364*	
AB-10	Data Processor Status		70	X Selected 160-220*; Y Selected 000-100*	
	RTG Temperatures	G. E. Nos.			
AR-1	Hot Frame #1	R1-1	6	950° F to 1150 F	±5 F
AR-2	Hot Frame #2	R1-2	37	950° F to 1150° F	±5° F
AR-3	Hot Frame #3	R1-3	52	950° F to 1150° F	±5° F
AR-4	Cold Frame #1	R3-1	7	400° F to 600° F	±5° F
AR-5	Cold Frame #2	R3-2	67	400° F to 600° F	±5° F
AR-6	Cold Frame #3	R3-3	82	400° F to 600° F	±5° F
	Passive Seismic				
AL-1	L. P. Ampl. Gain (X & Y)		23	Discrete	
AL-2	L. P. Ampl. Gain (Z)		38	Discrete	
AL-3	Level Direction and Speed		53	Discrete	
AL-4	S. P. Ampl. Gain (Z)		68	Discrete	
AL-5	Leveling Mode & Coarse Sensor Mode		24	Discrete	See Table 4
AL-6	Thermal Control Status		39	Discrete	
AL-7	Calibration Status L. P. & S. P.		54	Discrete	
AL-8	Uncage Status		69	Discrete	
	Active Seismic				
AS-1	Central Station Package Temp.		25	-40° C to +100° C	±3° C
AS-2	Mortar Box Temperature		40	-75° C to +100° C	±3° C
AS-3	Grenade Launcher Assembly Temp		44	-75° C to +100° C	±3° C
AS-4	Geophone Temperature		73	-200° C to +130° C	±3° C

*Octal

TABLE 2 (CONT.)

ANALOG HOUSEKEEPING CHANNEL USAGE

Symbol	Location/Name	Channel	Range	Sensor Accuracy
	Heat Flow			
AH-1	Supply Voltage #1	29	0 to +5 volts	5% full scale
AH-2	Supply Voltage #2	45	0 to -5 volts	5% full scale
AH-3	Supply Voltage #3	55	0 to +15 volts	5% full scale
AH-4	Supply Voltage #4	74	0 to -15 volts	5% full scale
AH-5	Not Assigned			
AH-6	High Conductivity Heater Power Status	57	Discrete	See Table 15
AH-7	Low Conductivity Heater Power Status	75	Discrete	
	Timer			
AZ-1	Timer 18-hour bistatic	10	Alternately Hi-Lo*	
AZ-2	Timer 1 1/2 month bistatic #1	11	Hi after 1 1/2 months*	
AZ-3	Timer 1 1/2 month bistatic #2	86	Hi after 1 1/2 months*	

*Hi > 200_8, Lo < 40_8

TABLE 3

SUMMARY OF ANALOG CHANNEL USAGE

Central Station		
Data and Power Subsystems	46	
Experiment On-Off Status	2	
Structural/Thermal	13	
RTG Temperatures	6	
TOTAL		67
Experiments		
Passive Seismic	8	
Magnetometer	0	
Heat Flow	6	
Active Seismic	4	
TOTAL		18
Not Assigned		5
TOTAL		90

TABLE 4

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.

		Channel				
AL-1	L. P. Amp. Gain X, Y	23	0db -10db -20db -30db	0-0.4V 0.6-1.4 1.6-2.4 2.6-4.0	8	.0185
AL-2	L. P. Amp. Gain Z	38	0db -10db -20db -30db	0-0.4V 0.6-1.4 1.6-2.4 2.6-4.0	8	.0185
AL-3	Level Direction and Speed	53	+low -low +high -high	0-0.4V 0.6-1.4 1.6-2.4 2.6-4.0	8	.0185
AL-4	S.P. Amp. Gain Z	68	0db -10db -20db -30db	0-0.4V 0.6-1.4 1.6-2.4 2.6-4.0	8	.0185
AL-5	Leveling Mode and Coarse Sensor Mode	24	Automatic, coarse level out Manual, coarse level out Automatic, coarse level in Manual, coarse level in	0-0.4V 0.6-1.4 1.6-2.4 2.6-4.0	8	.0185
AL-6	Thermal Control Status	39	Automatic Mode ON Automatic Mode OFF Manual Mode ON Manual Mode OFF	0-0.4V 0.6-1.4 1.6-2.4 2.6-4.0	8	.0185
AL-7	Calibration Status LP & SP	54	All On LP-ON SP-OFF LP-OFF SP-ON All Off	0-0.4V 0.6-1.4 1.6-2.4 2.6-4.0	8	.0185
AL-8	Uncage Status	69	Preset Arm Uncage Uncage lockout	0-0.4V 0.6-1.4 1.6-2.4 0-0.4**	8	.0185

*± 0.05°C resolution.

**Uncage locked-out on all ground tests.

TABLE 5

MAGNETOMETER MEASUREMENTS

Scientific Measurements

Symbol	Location/Measurement	ALSEP Word	Frame	Expected Range	Sensor Accuracy	Frequency Response	Bits/ Sample	Sample/ Sec.	Sample/ Frame
DM-25	X-Axis Field	17, 49	Every	± 50, ± 100, ± 200 gamma	*	~1.5 cycle/sec.	10	3.3	2
DM-26	Y-Axis Field	19, 51	"	" " " "	*	~ " " "	"	"	"
DM-27	Z-Axis Field	21, 53	"	" " " "	*	~ " " "	"	"	"

These data have the following format:

2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Polarity Bit**	Science Data ***								

*** Resolution - 0.2% Full Scale**
Accuracy - 0.5% Full Scale

**** 0 = Plus, 1 = Minus**

***Calibrate levels of Science Data are 0 and plus and minus 1/4, 1/2 and 3/4 of full scale (or PCM counts of 0 and ± 128, ± 256 and ± 384.

Engineering Measurements

Housekeeping is located in ALSEP Word 5 which is sub- commutated over 16 frames as follows:

Bit in Word 5	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Meaning	**F**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**B1**	**B2**
		Engineering Data								

Where B1, B2 are bistable status data
A1, ..., A7 are bits derived from analog measurements
F locates the subcommutation start, F = 1 is frame 1 of the subcommutation and F = 0 elsewhere.

TABLE 5 (CONT.)

MAGNETOMETER MEASUREMENTS

Engineering Measurements in ALSEP Word #5

	Symbol	Location/Measurement	Subcom-mutation	Range		Sensor Accuracy	Bits/ Sample
*	DM-1	Temperature #1	1, 9	-30°C to +65°C		±3%	7
	DM-2	Temperature #2	2, 10	" "		"	"
	DM-3	Temperature #3	3, 11	" "		"	"
	DM-4	Temperature #4	4, 12	" "		"	"
	DM-5	Temperature #5	5, 13	" "		"	"
	DM-6	Level Sensor #1	6, 14	-15° to +15°			"
	DM-7	Level Sensor #2	7, 15	" "			"
	DM-8	Supply Voltage	8, 16	0 to +6.25V		±0.1%	"
**	DM-9	X Flip Position	1,	Discrete	See Table 7		2 status bits
	DM-10	Y Flip Position	2	"			2 " "
	DM-11	Z Flip Position	3	"			2 " "
	DM-12	X Gimbal Position	4	"			1 " "
	DM-13	Y Gimbal Position	4	"			1 " "
	DM-14	Z Gimbal Position	5	"			1 " "
	DM-15	Thermal Control State	5	"			1 " "
	DM-16	Measurement Range	7	"			2 " "
	DM-17	X Offset Field	9, 10	"			3 " "
	DM-18	Y Offset Field	10, 11	"			3 " "
	DM-19	Z Offset Field	12, 13	"			3 " "
	DM-20	Mode State	13	"			1 " "
	DM-21	Offset Ratchet State	14	"			2 " "
	DM-22	Filter Status	15	"			1 " "
	DM-23	Flip/Cal Inhibit Status	15	"			1 " "
	DM-24	Filler Bits	16	"			2 " "
	DM-28	Heater Power Status	6	"			2 " "
	DM-29	Filler Bits	8	"			2 " "
	DM-30	LSM Frame No.	(Derived from F in Frame #1)				

Details of the status-bit usage are shown in Table 6 and the status bit structure is shown in Table 7.

* Repeated every eight frames for a sample rate of 0.207 per second.
** Repeated every 16 frames for a sample rate of 0.103 per second.

TABLE 6

MAGNETOMETER 16 POINT ENGINEERING SUBCOMMUTATION FORMAT

Magnetometer Subcommutation Frame	Frame Mark Bit	Data	Status Bits (bits 9 and 10 in word 5)	
1	1	Temp #1	X-axis Flip Position - B_1 B_2	
2	0	Temp #2	Y-axis Flip Position - B_1 B_2	
3	0	Temp #3	Z-axis Flip Position - B_1 B_2	
4	0	Temp #4	X-axis Gimbal Position - B_1 Y-axis Gimbal Position - B_2	
5	0	Temp #5	Z-axis Gimbal Position - B_1 Thermal Control Select - B_2	
6	0	Level #1	Spare - B_1 Heater Power Status B_2	
7	0	Level #2	Measurement Range - B_1 B_2	
8	0	Voltage #1	Filler Bits - B_1 B_2	
9	0	Temp #1	X-axis Field Offset - B_1 B_2	3 bit word
10	0	Temp #2	X-axis Field Offset - B_1 Y-axis Field Offset - B_2	3 bit word
11	0	Temp #3	Y-axis Field Offset - B_1 B_2	
12	0	Temp #4	Z-axis Field Offset - B_1 B_2	3 bit word
13	0	Temp #5	Z-axis Field Offset - B_1 Mode State - B_2	
14	0	Level #1	Offset Ratchet State - B_1 B_2	
15	0	Level #2	Filter Status - B_1 Flip/Cal inhibit status - B_2	
16	0	Voltage #1	Filler bits - B_1 B_2	

TABLE 7

MAGNETOMETER ENGINEERING STATUS BIT STRUCTURE

	Commutator Point	B1	B2	Status
X-axis Flip Position	1	0	0	Not at 0°, 90°, or 180° position
" " "	1	0	1	0° position
" " "	1	1	0	90° position
" " "	1	1	1	180° position
Y-axis Flip Position	2	0	0	Not at 0°, 90°, or 180° position
" " "	2	0	1	0° position
" " "	2	1	0	90° position
" " "	2	1	1	180° position
Z-axis Flip Position	3	0	0	Not at 0°, 90°, or 180° position
" " "	3	0	1	0° position
" " "	3	1	0	90° position
" " "	3	1	1	180° position
X-axis Gimbal Position	4	1		Pre Site Survey Position
" " "	4	0		Post Site Survey Position
Y-axis Gimbal Position	4		1	Pre Site Survey Position
" " "	4		0	Post Site Survey Position
Z-axis Gimbal Position	5	1		Pre Site Survey Position
" " "	5	0		Post Site Survey Position
Temp Control State	5		1	X-axis Control
" " "	5		0	Y-axis Control/OFF
Filler Bit	6	1		Not Used
Heater Power Status	6		1	Heater ON
" " "	6		0	Heater OFF
Measurement Range	7	0	0	50 γ Range *
" " "	7	1	0	100 γ Range
" " "	7	1	1	200 γ Range
" " "	7	0	1	Error
Filler Bits	8	1	1	Not used
X-axis Field Offset	9	0	1	0% offset
" " "	10	1		
" " "	9	1	0	-25% offset
" " "	10	0		
" " "	9	1	0	-50% offset
" " "	10	1		
" " "	9	1	1	-75% offset
" " "	10	0		
" " "	9	0	0	+75% offset
" " "	10	0		
" " "	9	0	0	+50% offset
" " "	10	1		
" " "	9	0	1	+25% offset
" " "	10	0		
Y-axis Field Offset	10		0	0% offset
" " "	11	1	1	
" " "	10		1	-25% offset
" " "	11	0	0	
" " "	10		1	-50% offset
" " "	11	0	1	
" " "	10		1	75% offset
" " "	11	1	0	
" " "	10		0	+75% offset
" " "	11	0	0	
" " "	10		0	+50% offset
" " "	11	0	1	
" " "	10		0	+25% offset
" " "	11	1	0	
Z-axis Field Offset	12	0	1	0% offset
" " "	13	1		
" " "	12	1	0	-25% offset
" " "	13	0		
" " "	12	1	0	-50% offset
" " "	13	1		
" " "	12	1	1	-75% offset
" " "	13	0		
" " "	12	0	0	+75% offset
" " "	13	0		
" " "	12	0	0	+50% offset
" " "	13	1		
" " "	12	0	1	+25% offset
" " "	13	0		
Mode State	13		0	Calibrate ON
" "	13		1	Calibrate OFF
Offset Ratchet State	14	0	0	Not at X, Y, or Z
" " "	14	1	0	X-axis position
" " "	14	0	1	Y-axis position
" " "	14	1	1	Z-axis position
Filter Status	15	1		Filter bypassed
" "	15	0		Filter not bypassed
Flip/Cal. Inhibit Status	15		1	Calibration Inhibited
" " "	15		0	Calibration not inhibited
Filler Bits	16	0	0	Not used

* Expected ranges

TABLE 8

ACTIVE SEISMIC MEASUREMENTS

Symbol	Location/Name	Channel	Range	Sensor Accuracy	Bits/ Sample	Samples/ Sec

When the Active Seismic is not operating the following measurements are provided through the 90-channel multiplexer of the Data S/S.

Active Seismic Temperatures (From Table 1)

Symbol	Location/Name	Channel	Range	Sensor Accuracy	Bits/ Sample	Samples/ Sec
AS-1	Central Station Package Temp.	25	-40 °C to +100°C	±3°C	8	.0185
AS-2	Mortar Box Temp.	40	-75°C to +100°C	±3°C	8	.0185
AS-3	Grenade Launcher Assembly Temp.	44	-75°C to +100°C	±3°C	8	.0185
AS-4	Geophone Temp.	73	-200°C to +130°C	±3°C	8	.0185

Active Seismic Measurements

Active Seismic Type B Logic (32 20-bit words each consisting of four 5-bit subwords)

		A/S Word	Subword				
DS-17	Frame Sync	①1	1, 2	N/A	N/A	10	16.56
DS-2	Geophone #2	All	3		±10% Referred to Input	5	530
DS-3	Geophone #3	All	4	⑦	±10% Referred to Input	5	530
DS-1	Geophone #1	2	1		±10% Referred to Input	5	530
		2 through 32	2		±10% Referred to Input	5	530
AR-4	RTG Cold Frame Temp. #1	②3, 4	1	400 °F to 600°F	±5°F	8	16.56
DS-7	Pitch Angle	5, 6	1	±10°	±20'	8	16.56
DS-5	Mortar Box Ground Monitor	7, 8	1	0 to 400 MV	±16.5MV	8	16.56
DS-6	Roll Angle	9, 10	1	±10°	±20'	8	16.56
	Not Used	11, 12	1			8	16.56
AS-3	Grenade Launcher Assembly Temp.	13, 14	1	-75°C to +100°C	±3°C	8	16.56
DS-8	Geophone Calibrate Pulse	15, 16	1	0 to +5V	±1%	8	16.56
DS-11	A/D Calibration 3.75V	17, 18	1	272 to 316 (Octal)	±0.5%	8	16.56
DS-10	A/D Calibration 1.25V	19, 20	1	76 to 104 (Octal)	±0.5%	8	16.56
AS-1	Central Station Package Temp.	21, 22	1	-40°C to +100°C	±3°C	8	16.56
AE-3	Converter Input Voltage	23, 24	1	0 to 20 VDC	±2%	8	16.56
AE-4	Input Current	25, 26	1	0 to 5 ADC	±2%	8	16.56
AR-1	RTG Hot Frame Temp. #1	②27, 28	1	950°F to 1150°F	±5°	8	16.56
DS-18	Mark Event	③29	1	N/A	N/A	5	N/A
DS-19	Word Count	④30	1	N/A	N/A	5	N/A
DS-20	Event Bit Count	⑤31	1	N/A	N/A	5	N/A
DS-13	Mode ID	⑥32	1	N/A	N/A	3	16.56

[1] In the first 10 bits of the word.

[2] The first four bits of the measurement are carried in the first four bits of the odd word. The last four bits of the measurement are carried in the first four bits of the even word. In each case the last (or fifth) bit of each subword is spare.

[3] Mark code when Real Time Event occurs during prior frame (frame = 32 word sequence)

[4] Measures word in prior frame during which Real Time Event occurred.

[5] Measures bit during which Real Time Event occurred in above word in prior frame.

[6] In the first 3 bits of the subword - other 2 bits not used.

[7] Calibrated data in milli microns of ground motion (log compressed, 80 db dynamic range).

TABLE 9

WORD FORMAT FOR HEAT FLOW EXPERIMENT

Each Heat Flow data point employs eight 10-bit words (ALSEP Word 23 in eight consecutive frames), arranged as follows:

Heat Flow Word	**Bit Position**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	R_2	R_1	0	P_4	P_3	P_2	P_1	2^{12}	2^{11}	2^{10}
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
1	R_2	R_1	M_1	M_2	M_3	0	0	2^{12}	2^{11}	2^{10}
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
2	R_2	R_1	H_4	H_3	H_2	H_1	0	2^{12}	2^{11}	2^{10}
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
3	R_2	R_1	0	0	0	0	0	2^{12}	2^{11}	2^{10}
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

Where:

DH-90	M_1, M_2, M_3 are mode registers, (100) Gradient Mode, (010) Low Conductivity Mode, and (001) High Conductivity Mode, respectively.
DH-91	P_4, P_3, P_2, P_1 are measurement identification as described in Table 10.
DH-92	R_2, R_1 are binary equivalent of Heat Flow Word number.
DH-93	H_4, H_3, H_2, H_1 are conductivity heater registers (8 heaters).
DH-94	HFE filler bits (shown as zeros in above chart).

TABLE 10

HEAT FLOW P-BIT MEASUREMENT DESIGNATIONS

P Identification Bits				Measurement	P Identification Bits				Measurement
P_4	P_3	P_2	P_1		P_4	P_3	P_2	P_1	
0	0	0	0	$\Delta T_{11}H$	1	0	0	0	T_{11}
0	0	0	1	$\Delta T_{12}H$	1	0	0	1	T_{12}
0	0	1	0	$\Delta T_{21}H$	1	0	1	0	T_{21}
0	0	1	1	$\Delta T_{22}H$	1	0	1	1	T_{22}
0	1	0	0	$\Delta T_{11}L$	1	1	0	0	T_{ref}
0	1	0	1	$\Delta T_{12}L$	1	1	0	1	TC group, Probe 1
0	1	1	0	$\Delta T_{21}L$	1	1	1	0	T_{ref}
0	1	1	1	$\Delta T_{22}L$	1	1	1	1	TC group, Probe 2

Key to Measurement Name

The first subscript refers to the probe (probe 1 or probe 2), the second refers to the probe section (upper or lower, respectively).

$T_{ij}H$ = Bridge measurement of probe temperature gradient, high sensitivity.

$T_{ij}L$ = Bridge measurement of probe temperature gradient, low sensitivity.

T_{ij} = Total bridge resistance measurement of ambient temperature.

TC group = Thermocouple measurements of probe cable ambient temperature, 4 measurements per probe.

T ref = Bridge measurement of the temperature of the thermocouple reference junction.

TABLE 11

HEAT FLOW MEASUREMENTS FOR GRADIENT AND LOW CONDUCTIVITY MODES (1 AND 2)

Symbol	Location/Name		*Frame	Range	Probable Error	Data Points/ Frame	Samples/ Data Point	Bits/ Sample	Samples/ Sec.
DH-1	$\Delta T_{11}H$	Temp. Grad. High Sens.	0-7	±2°C	0.003°C	1/720	4	13	.00231
DH-2	$\Delta T_{12}H$	Temp. Grad. High Sens.	8-15	±2°C	0.003°C	1/720	4	13	.00231
DH-3	$\Delta T_{21}H$	Temp. Grad. High Sens.	90-97	±2°C	0.003°C	1/720	4	13	.00231
DH-4	$\Delta T_{22}H$	Temp. Grad. High Sens.	98-105	±2°C	0.003°C	1/720	4	13	.00231
DH-5	$\Delta T_{11}L$	Temp. Grad. Low Sens.	180-187	±20°C	0.03°C	1/720	4	13	.00231
DH-6	$\Delta T_{12}L$	Temp. Grad. Low Sens.	188-195	±20°C	0.03°C	1/720	4	13	.00231
DH-7	$\Delta T_{21}L$	Temp. Grad. Low Sens.	270-277	±20°C	0.03°C	1/720	4	13	.00231
DH-8	$\Delta T_{22}L$	Temp. Grad. Low Sens.	278-285	±20°C	0.03°C	1/720	4	13	.00231
DH-9	T_{11}	Probe Ambient Temp.	360-367	200 to 250°K	0.1°C	1/720	4	13	.00231
DH-10	T_{12}	Probe Ambient Temp.	368-375	200 to 250°K	0.1°C	1/720	4	13	.00231
DH-11	T_{21}	Probe Ambient Temp.	450-457	200 to 250°K	0.1°C	1/720	4	13	.00231
DH-12	T_{22}	Probe Ambient Temp.	458-465	200 to 250°K	0.1°C	1/720	4	13	.00231
**DH-13	Ref. T_1	Temp. Ref. Junction	540-547	-20 to +60°C	0.1°C	1/720	4	13	.00231
***DH-14, 24, 34, 44	TC1 group	Probe Cable Temp.	548-555	90 to 350°K	0.3°C	4/720	1	13	.00231
**DH-15	Ref. T_2	Temp. Ref. Junction	630-637	-20 to +60°C	0.1°C	1/720	4	13	.00231
***DH-16, 26, 36, 46	TC2 group	Probe Cable Temp.	638-645	90 to 350°K	0.3°C	4/720	1	13	.00231

*Two Heat Flow data points are carried in the first 16 frames following each ALSEP 90-frame mark. Initial 90-frame mark is arbitrary.

**DH-13 and DH-15 are identical physical measurements separated in time by approximately 54 seconds.

***Each group comprises the measurements indicated in Table 12.

TABLE 12

HEAT FLOW THERMOCOUPLE GROUP MEASUREMENTS

	Symbol	Data	R-Bits	
			R_2	R_1
	DH-14	Ref. $TC-TC_1$ (4)	0	0
TC_1 Group	DH-24	TC_1 (4) - TC_1 (1)	0	1
	DH-34	TC_1 (4) - TC_1 (2)	1	0
	DH-44	TC_1 (4) - TC_1 (3)	1	1
	DH-16	Ref. $TC-TC_2$ (4)	0	0
TC_2 Group	DH-26	TC_2 (4) - TC_2 (1)	0	1
	DH-36	TC_2 (4) - TC_2 (2)	1	0
	DH-46	TC_2 (4) - TC_2 (3)	1	1

Note: Subscript refers to probe (1 or 2) while designator in parentheses refers to thermocouple location, with (1) at top position and (4) at cable/probe interface.

OTHER DATA POINTS

High Sensitivity and T_{ref}	Low Sensitivity	Ambient	R-Bits	
			R_2	R_1
+ Excitation Volts	+ Current	+ Excitation Volts	0	0
+ Bridge Output	+ Bridge Output	+ Current	0	1
- Excitation Volts	- Current	- Excitation Volts	1	0
- Bridge Output	- Bridge Output	- Current	1	1

TABLE 13

SELECTABLE SUBSEQUENCES, MODES 1 AND 2

Measurement Type	Probe 1	Probe 2	Both Probes
High Sensitivity Gradient	DH-1, -2	DH-3, -4	DH-1 to DH-4
Low Sensitivity Gradient	DH-5, -6	DH-7, -8	DH-5 to DH-8
Ambient Temperature	DH-9, -10	DH-11, -12	DH-9 to DH-12
Thermocouple Temperature	DH-13, -14, -24, -34, -44	DH-15, -16, -26, -36, -46	DH-13, -14, -24, -34, -44, -15, -16, -26, -36, -46
All four of the above	DH-1, -2, -5, -6, -9, -10, -13, -14, -24, -34, -44	DH-3, -4, -7, -8, -11, -12, -15, -16, -26, -36, -46	DH-1 to DH-14 DH-24, -34, -44 DH-15, -16, -26, -36, -46

NOTE: Selected subsequence cycles continuously in first 16 frames after each ALSEP 90-frame mark. Sampling rate of Table 11 is thus increased by subsequencing.

TABLE 14

HEAT FLOW MEASUREMENTS, MODE 3 (HIGH CONDUCTIVITY)

Symbol	Measurement	Probe	Bridge	H-Bits	Heater Status	Frame	Samples/ Sec.
DH-50	Differential Temp.	1	1	0000	OFF	0-7	.0185
DH-51	Ambient Temp.	1	1	0000	OFF	8-15	.0185
DH-52	Differential Temp.	1	1	0001	H_{12} ON	0-7	.0185
DH-53	Ambient Temp.	1	1	0001	H_{12} ON	8-15	.0185
DH-60	Differential	1	2	0010	OFF	0-7	.0185
DH-61	Ambient	1	2	0010	OFF	8-15	.0185
DH-62	Differential	1	2	0011	H_{14} ON	0-7	"
DH-63	Ambient	1	2	0011	H_{14} ON	8-15	"
DH-56	Differential	1	1	0100	OFF	0-7	"
DH-57	Ambient	1	1	0100	OFF	8-15	"
DH-58	Differential	1	1	0101	H_{11} ON	0-7	"
DH-59	Ambient	1	1	0101	H_{11} ON	8-15	"
DH-66	Differential	1	2	0110	OFF	0-7	"
DH-67	Ambient	1	2	0110	OFF	8-15	"
DH-68	Differential	1	2	0111	H_{13} ON	0-7	"
DH-69	Ambient	1	2	0111	H_{13} ON	8-15	"
DH-70	Differential	2	1	1000	OFF	0-7	"
DH-71	Ambient	2	1	1000	OFF	8-15	"
DH-72	Differential	2	1	1001	H_{22} ON	0-7	"
DH-73	Ambient	2	1	1001	H_{22} ON	8-15	"
DH-80	Differential	2	2	1010	OFF	0-7	"
DH-81	Ambient	2	2	1010	OFF	8-15	"
DH-82	Differential	2	2	1011	H_{24} ON	0-7	"
DH-83	Ambient	2	2	1011	H_{24} ON	8-15	"
DH-76	Differential	2	1	1100	OFF	0-7	"
DH-77	Ambient	2	1	1100	OFF	8-15	"
DH-78	Differential	2	1	1101	H_{21} ON	0-7	"
DH-79	Ambient	2	1	1101	H_{21} ON	8-15	"
DH-86	Differential	2	2	1110	OFF	0-7	"
DH-87	Ambient	2	2	1110	OFF	8-15	"
DH-88	Differential	2	2	1111	H_{23} ON	0-7	"
DH-89	Ambient	2	2	1111	H_{23} ON	8-15	"

NOTES: (1) First Heater (H) subscript is probe number and second subscript denotes position of heater, with 1 on top and 4 on bottom of probe.

(2) Each pair of the above measurements is selected, in turn, by execution of the HFE Heater Steps Command.

TABLE 15

HFE ANALOG (ENGINEERING) MEASUREMENTS (ALSEP Word 33)

Symbol	Data	Frame	Range	Accuracy	Bits/ Sample	Samples/ Sec.
AH-1	Supply Voltage #1	29	0-160 (octal)	5% full scale	8	.0185
AH-2	Supply Voltage #2	45	0-160 (octal)	5% full scale	8	.0185
AH-3	Supply Voltage #3	55	0-160 (octal)	5% full scale	8	.0185
AH-4	Supply Voltage #4	74	0-160 (octal)	5% full scale	8	.0185
AH-5	Spare				8	.0185
AH-6	High Conductivity Heater Power Status	57	1.5-2.5 volts ON 0-0.4 OFF		8	.0185
AH-7	Low Conductivity Heater Power Status	75	1.5-2.5 volts ON 0-0.4 OFF		8	.0185