Tim White

ALSEP-MT-03

APOLLO LUNAR SURFACE
EXPERIMENTS PACKAGE
(ALSEP)

FLIGHT SYSTEM
FAMILIARIZATION MANUAL
(REVISION B)

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INTRODUCTION

The Apollo Lunar Surface Experiments Package (ALSEP) will be used to obtain long-term scientific measurements of various physical and environmental properties of the Moon consistent with the scientific objectives of the Apollo Program. The ALSEP comprises scientific experiment packages with supporting subsystems. ALSEP will be transported to the lunar surface aboard the Apollo Lunar Module (LM). The ALSEP will remain on the lunar surface after the return of the astronauts and will transmit scientific and engineering data to the Manned Space Flight Network (MSFN).

The purpose of the ALSEP 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 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. ALSEP Flight 2 subpackages have been used in the Early Apollo Scientific Experiments Package (EASEP) Program. Consequently, any reference to Flight 2 in this manual is no longer applicable.

The information contained in this revision of the ALSEP Flight System Familiarization Manual includes formalized data released and available prior to the publication date, 15 April 1969.

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 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 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 on the exterior of the LM as shown in Figure 1-1.

A Saturn V launch vehicle will place the Apollo 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 a preselected landing site on the lunar surface.

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 crewmen will collect samples of the lunar surface using the Apollo lunar hand tools (ALHT) and return to the LM.

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

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

FWD

LM
CENTERLINE

FUEL CASK
LOCATION

FWD

COMPART-
MENT NO. 1

COMPART-
MENT NO. 2

AFT

LM SCIENTIFIC
EQUIPMENT BAY
(SEQ)

LUNAR MODULE (LM)

ALSEP SUBPACKAGES
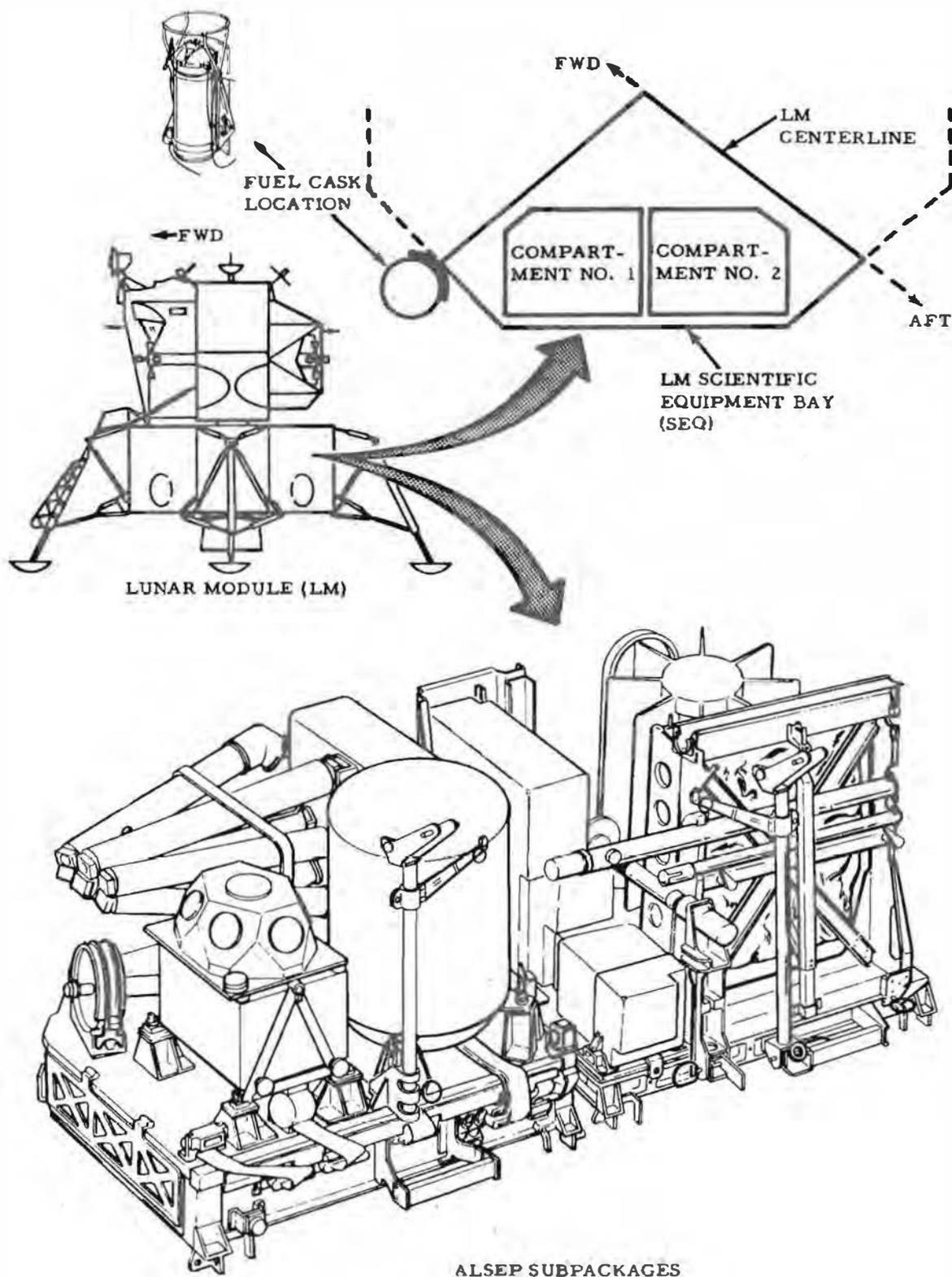
Figure 1-1. ALSEP/LM Interface

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 initiate partial attainment of these objectives the ALSEP includes eight experiments in varying combinations 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.

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. Different configurations of the ALSEP will be used on the different Apollo flights as specified in Table 1-2.

1-5. ALSEP PHYSICAL DESCRIPTION

The ALSEP consists of the following subsystems:
   a. Structure/thermal subsystem
   b. Electrical power subsystem
   c. Data subsystem
   d. Apollo lunar hand tools
   e. Eight experiment subsystems in varying combinations of four each for four separate flights as presented in Table 1-2.

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 LM.

Subpackage No. 1 for Flights 1 and 2 consists of the central station (data subsystem, power conditioning unit, and experiment electronics), the antenna, the passive seismic (PSE), magnetometer (ME), and solar wind (SWE) experiments as shown in Figure 1-2. Subpackage No. 2 for Flights 1, 2, and 4 consists of the radioisotope thermoelectric generator (RTG), suprathermal ion detector experiment (SIDE), Apollo lunar hand tools (ALHT), handling tools, and the antenna mast as shown in Figure 1-3. Similar configurations of the subpackages incorporating different combinations of experiments as shown in Figure 1-4, 1-5, and 1-6 will be employed in Flights 3 and 4. The ALSEP Flight 1 packages, including fuel capsule and cask, weigh approximately 282 pounds and, excluding the fuel capsule and cask, occupy approximately 15 cubic feet.

Table 1-1. 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.
Magnetic field and its temporal variations at the 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.
Interaction of solar wind and Moon (temporal, spectral, and directional characteristics).	Solar Wind Experiment - Detects and monitors particles using exposed collection cups (sensors).
Lunar ionosphere positive ion detection, (flux, energy, and velocity of positive ions). Also pressure of lunar atmosphere and rate loss of contaminants left by astronauts and the LM.	Suprathermal Ion Detector Experiment- Detects positive ions in lunar ionosphere and thermalized solar wind using a curved plate analyzer as detector device. Velocity selector analyzer used to determine particle velocities and energies. Cold cathode ion gauge is used to determine density of lunar atmosphere.
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).
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.

Table 1-1. ALSEP Scientific Objectives (cont)

Measurement Objective	Experiment/Measurement Method
Composition of lunar atmosphere (electron/proton energies)	Charged-Particle Lunar Environment Experiment - Detects and monitors particle energy levels using two sensor assemblies (analyzers).
Pressure of ambient lunar atmosphere including temporal variations either random or associated with lunar local time or solar activity.	Cold Cathode Gauge Experiment - Senses lunar atmospheric density variations using a transducer to effect conversion of particle quantity to direct current.

Table 1-2. ALSEP Experiment Subsystem Flight Assignments

Experiment	Flights 1 and 2	Flight 3	Flight 4
Passive seismic	X	X	X
Magnetometer	X		
Solar wind	X		
Suprathermal ion detector	X		X
Active seismic			X
Heat flow		X	
Charged particle lunar environment		X	X
Cold cathode gauge		X	

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. Mission Control Center (MCC) participates in the network for activation of the experiments, initial calibration sequences, and for the duration of the mission. Communications consist of an uplink (Earth-Moon) for command transmissions to control the ALSEP functions, and a downlink (Moon-Earth) for transmission of scientific experiment and engineering housekeeping data. The MSFN stations will record the downlink data.

As many as three separate ALSEP systems may be operating on the Moon simultaneously. The downlink telemetry of each of these will operate at a different frequency (2278.5 MHz, 2276.5 MHz, 2275.5 MHz, or 2279.5 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 1-7. 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 protection 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. A dust detector monitors accumulation of lunar dust.

1-8. Electrical Power Subsystem. The electrical power subsystem generates 63 to 74 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 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 itself and all the subsystems, and transmits the data to the MSFN receiving stations. The data subsystem also performs the function of switching and distributing operating power to the experiment and support subsystems.

DUST DETECTOR

CENTRAL STATION
(DEPLOYED)

ANTENNA

MAGNETOMETER EXPERIMENT
(DEPLOYED)

SUNSHIELD

SIDE
CURTAIN

CURTAIN
RETAINER

SIDE CURTAIN

REFLECTOR

THERMAL
PLATE
(MOUNTING
CENTRAL
STATION
ELECTRONICS)

THERMAL
BAG

BOOM
ATTACHMENT
ASSEMBLY

PRIMARY
STRUCTURE

STRUCTURE/THERMAL SUBSYSTEM COMPONENTS

SOLAR WIND EXPERIMENT
(DEPLOYED)

PASSIVE SEISMIC EXPERIMENT
(DEPLOYED)
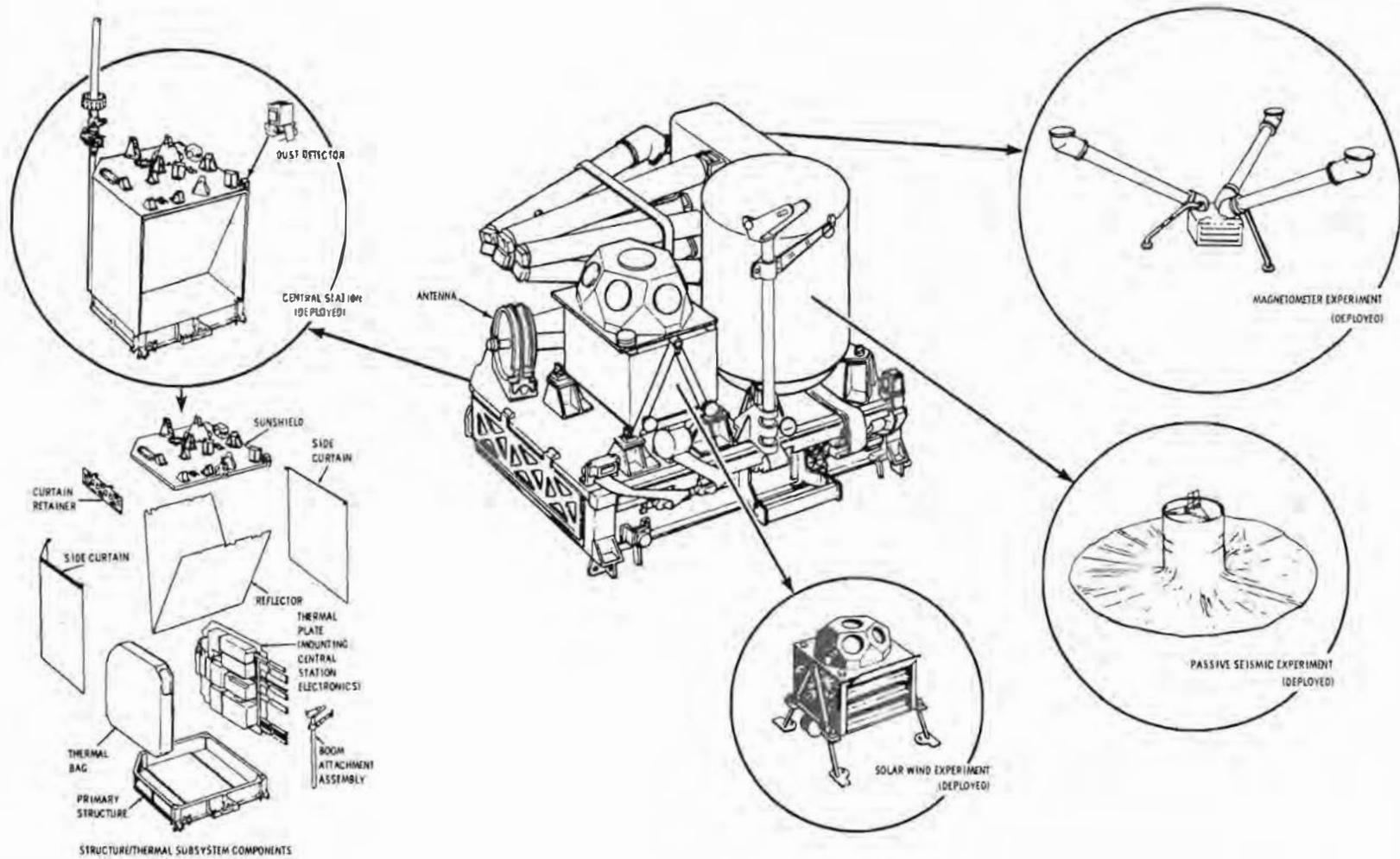
Figure 1-2.   ALSEP Subpackage No. 1 (Flights 1 and 2)

SUPRATHERMAL ION DETECTOR
EXPERIMENT (DEPLOYED)

PSE STOOL

PALLET AND RTG
(DEPLOYED)

SUBPALLET

BOOM
ATTACHMENT
ASSEMBLY

TOOL
SUPPORT

PALLET

STRUCTURE/THERMAL SUBSYSTEM COMPONENTS

ANTENNA
AIMING
MECHANISM

DOME REMOVAL TOOL

FUEL TRANSFER TOOL

ANTENNA MAST SECTIONS

UNIVERSAL HANDLING TOOLS

APOLLO LUNAR HAND TOOLS
(DEPLOYED)
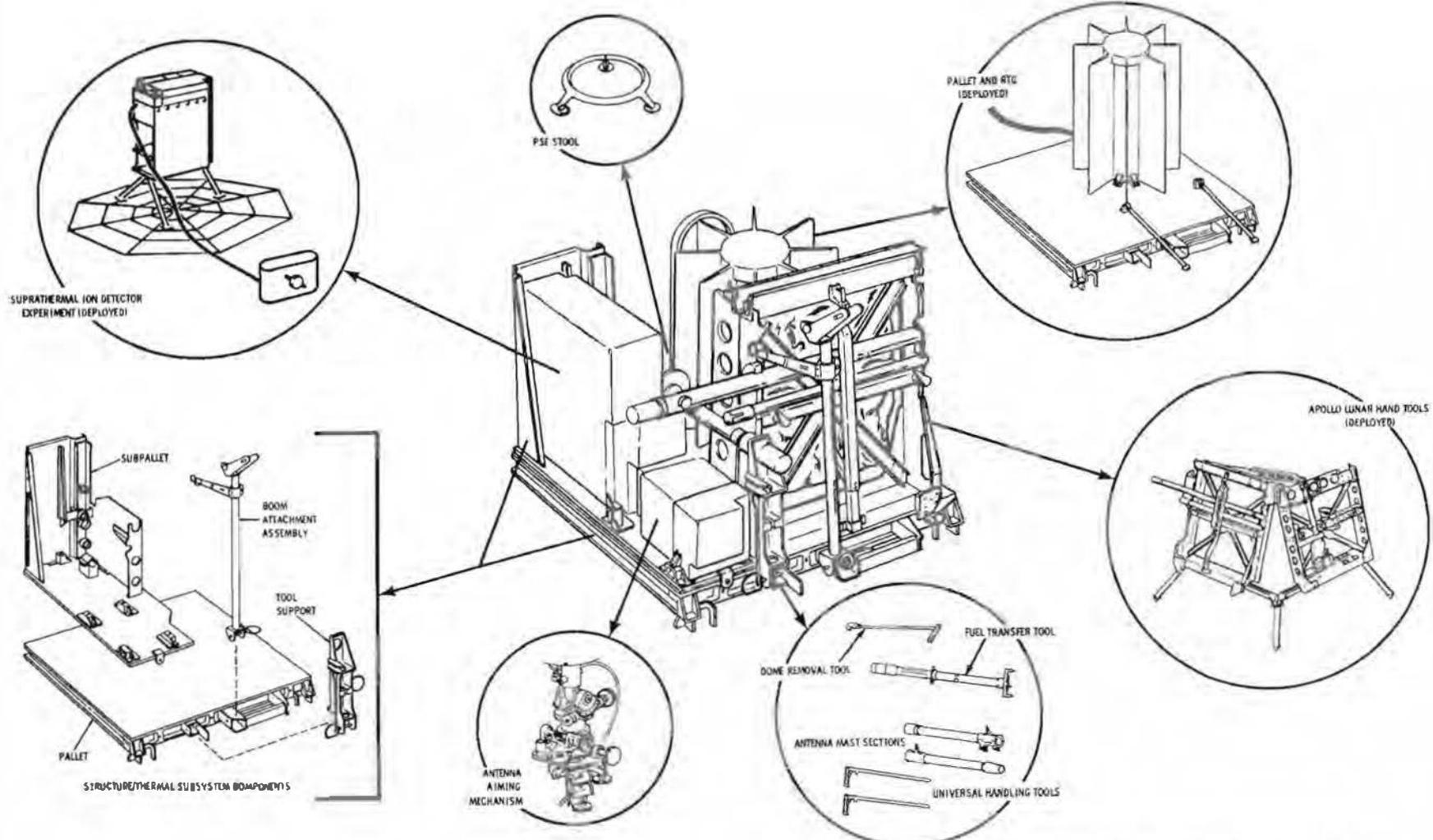
Figure 1-3. ALSEP Subpackage No. 2 (Flights 1, 2, and 4)

DUST DETECTOR

ANTENNA AIMING MECHANISM

CHARGED PARTICLE LUNAR ENVIRONMENT EXPERIMENT (DEPLOYED)

CENTRAL STATION (DEPLOYED)

ANTENNA

PASSIVE SEISMIC EXPERIMENT (DEPLOYED)

SUNSHIELD

SIDE CURTAIN

CURTAIN RETAINER

SIDE CURTAIN

REFLECTOR

THERMAL PLATE (MOUNTING CENTRAL STATION ELECTRONICS)

HEAT FLOW EXPERIMENT

THERMAL BAG

BOOM ATTACHMENT ASSEMBLY

PRIMARY STRUCTURE

COLD CATHODE GAUGE EXPERIMENT (DEPLOYED)

STRUCTURE/THERMAL SUBSYSTEM COMPONENTS

Figure 1-4. ALSEP Subpackage No. 1 (Flight 3)

1-11/1-12

DOME REMOVAL TOOL

FUEL TRANSFER TOOL

ANTENNA MAST SECTIONS

UNIVERSAL HANDLING TOOLS

PSE STOOL

PALLET AND RTG
(DEPLOYED)

CARRIER
ASSEMBLY

BOOM
ATTACHMENT
ASSEMBLY

TOOL
SUPPORT

PALLET

STRUCTURE/THERMAL SUBSYSTEM COMPONENTS

APOLLO
LUNAR SURFACE
DRILL

APOLLO LUNAR HAND TOOLS
(DEPLOYED)
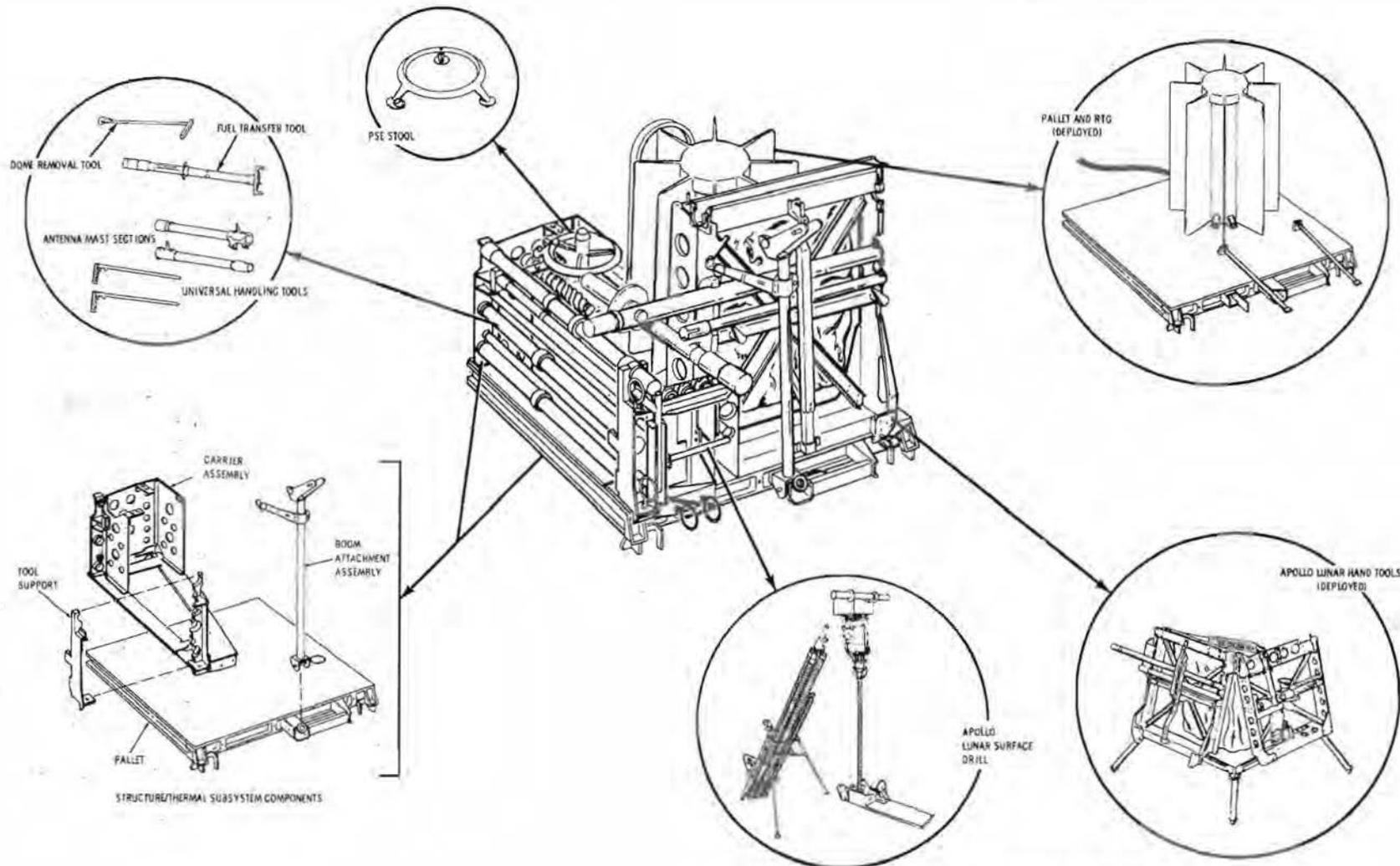
Figure 1-5. ALSEP Subpackage No. 2 (Flight 3)

1-13/1-14

DUST DETECTOR

CENTRAL STATION
(DEPLOYED)

CHARGED PARTICLE
LUNAR ENVIRONMENT
EXPERIMENT (DEPLOYED)

THUMPER
ASSEMBLY
(DEPLOYED)

GEOPHONE
DETECTORS (3)

ANTENNA

SUNSHIELD

SIDE
CURTAIN

CURTAIN
RETAINER

SIDE CURTAIN

REFLECTOR

THERMAL
PLATE
(MOUNTING
CENTRAL
STATION
ELECTRONICS)

BOOM
ATTACHMENT
ASSEMBLY

THERMAL
BAG

PRIMARY
STRUCTURE

STRUCTURE/THERMAL SUBSYSTEM COMPONENTS

MORTAR BOX
ASSEMBLY
(DEPLOYED)

PASSIVE SEISMIC EXPERIMENT
(DEPLOYED)

Figure 1-6. ALSEP Subpackage No. 1 (Flight 4)

1-15/1-16

Figure 1-7. ALSEP System, Simplified Block Diagram

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 expected to be produced in the lunar surface by meteoroid impacts and tectonic disturbances.

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

1-11. Magnetometer Experiment Subsystem. The magnetometer experiment (ME) 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.

1-12. Solar Wind Experiment Subsystem. The solar wind experiment (SWE) will measure energies, densities, incidence angles, and temporal variations of the electron and proton components of the solar wind plasma at the lunar surface. It will use an array of seven modified Faraday cups to measure these properties.

1-13. Suprathermal Ion Detector Experiment Subsystem. The suprathermal ion detector experiment (SIDE) in conjunction with a cold cathode ion gauge (CCIG) will provide data pertaining to the density and temperature of the ionosphere near the lunar surface, and the neutral particle density at the lunar surface. The SIDE counts and measures the velocity and energy of detected ions. The CCIG measures the density of neutral particles at known gauge temperatures to determine the pressure of the ambient lunar atmosphere.

1-14. Active Seismic Experiment Subsystem. The active seismic experiment subsystem (ASE) 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.

The ASE provides a controlled seismic lunar exploration using artificially produced seismic energy of known distances, charge sizes, and timing. It also provides a means of lunar seismic exploration in the event the Moon should be naturally seismically inert and seismic activity cannot be registered by passive seismometers.

1-15. 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, 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 heaters produce a heat pulse at a known distance from a sensor. After an interval of time, the sensor receives the pulse. By determining the time required for the pulse to reach the sensor, the heat conductivity of the lunar subsurface can be calculated.

1-16. Charged Particle Lunar Environment Experiment Subsystem. The charged particle lunar environment experiment (CPLEE) will provide data pertaining to the solar wind, solar cosmic rays and other particle phenomena by measuring the energy distribution and time variations of the proton and electron fluxes at the lunar surface. It employs two particle detectors (analyzers) oriented in different directions for evaluating directional effects.

1-17. Cold Cathode Gauge Experiment. The cold cathode gauge experiment (CCGE) will provide data pertaining to the density of the lunar ambient atmosphere, including temporal variations, and the rate of loss of contamination left in the landing area by the astronauts and the LM.

The CCGE uses a transducer, powered by a 4000-volt power supply, to detect the density of particles of the ambient atmosphere and develop a proportional direct current signal which is converted from analog to digital data for downlink transmission.

1-18. Apollo Lunar Hand Tools Subsystem. The Apollo lunar hand tools (ALHT) will contribute to the overall geophysical exploration of the Moon by facilitating the location, collection, measurement, and removal of representative samples of the lunar surface. The samples collected will be stowed in special containers and transported to Earth for examination and study.

1-19. Apollo Lunar Surface Drill. The Apollo lunar surface drill (ALSD) will provide data on the physical properties of the lunar surface and subsurface materials by extraction of cores obtained while boring emplacement holes for the HFE probes. The ALSD will be used to bore two holes three meters deep with a diameter of 2.54 to 2.86 centimeters. Cores produced from the holes will have a minimum diameter of 1.27 centimeters and a minimum solid length of 2.54 centimeters.

1-20. 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 on Table 1-3.

Table 1-3. ALSEP Principal Investigators

Experiment	GFE or CFE	Principal Investigator and Co-Investigators
Passive seismic	CFE	Dr. Gary Latham - Lamount Geological Observatory Dr. George Sutton - University of Hawaii Dr. Frank Press - Massachusetts Institute of Technology Dr. Maurice Ewing - Columbia University
Magnetometer	GFE	Dr. Charles P. Sonett - NASA-Ames Research Center Dr. Jerry Modisette - Manned Spacecraft Center
Solar wind	GFE	Dr. Conway W. Snyder - Jet Propulsion Laboratory Dr. Douglas Clay - Jet Propulsion Laboratory Mrs. Marcia Neugebauer - Jet Propulsion Laboratory
Suprathermal ion detector Cold cathode ion gauge	GFE	Dr. John Freeman - Rice University Dr. Francis Johnson - Southwest Center for Advanced Studies Mr. Dallas Evans - NASA-Manned Spacecraft Center
Active seismic (Thumper)	CFE	Dr. Robert Kovach - Stanford University 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

Table 1-3. ALSEP Principal Investigators (cont)

Experiment	GFE or CFE	Principal Investigator and Co-Investigators
Charged particle lunar environment	CFE	Dr. Brian J. O'Brien - Rice University
Cold cathode gauge	GFE	Dr. Francis Johnson - Southwest Center for Advanced Studies Mr. Dallas Evans - NASA-Manned Spacecraft Center

SECTION II

ALSEP SUBSYSTEM DESCRIPTION

2-1. ALSEP SUBSYSTEM INTRODUCTION

This section describes the thirteen (eight experiment and five support) subsystems which comprise the total 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. Magnetometer experiment subsystem (ME)
f. Solar wind experiment subsystem (SWE)
g. Suprathermal ion detector experiment subsystem (SIDE)
h. Active seismic experiment subsystem (ASE)
i. Heat flow experiment subsystem (HFE)
j. Charged particle lunar environment experiment subsystem (CPLEE)
k. Cold cathode gauge experiment subsystem (CCGE)
l. Apollo lunar hand tools subsystem (ALHT)
m. Apollo lunar surface drill (ALSD)

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, antenna mast, and a dust detector. Structure/thermal subsystem leading particulars are provided in Table 2-1.

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
Dust Detector	Power Requirements On mode	540 mw maximum, + and -12 vdc.
	Off mode	70 mw maximum, + and -12 vdc.
	Analog Outputs	0 to +5 vdc.
Sensor Package	Size (inches)	1.75 x 1.75 x 1.75
	Weight (pounds)	0.35
Circuit Board	Size (inches)	3.3 x 6.1
	Weight (pounds)	0.26

2-4. 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, 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 station electronics which are mounted on the thermal plate. The sunshield provides tie points for mounting, 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. Fuel Cask Structure Assembly. The fuel cask structure assembly consists of the structure, thermal shield, cask bands, and cask guard as shown in Figure 2-3. 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.

2-8. 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 2-4. 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.

SUNSHIELD

SIDE
CURTAIN

CURTAIN
RETAINER

SIDE CURTAIN

REFLECTOR

THERMAL
PLATE
(MOUNTING
CENTRAL
STATION
ELECTRONICS)

THERMAL
BAG

BOOM
ATTACHMENT
ASSEMBLY

PRIMARY
STRUCTURE
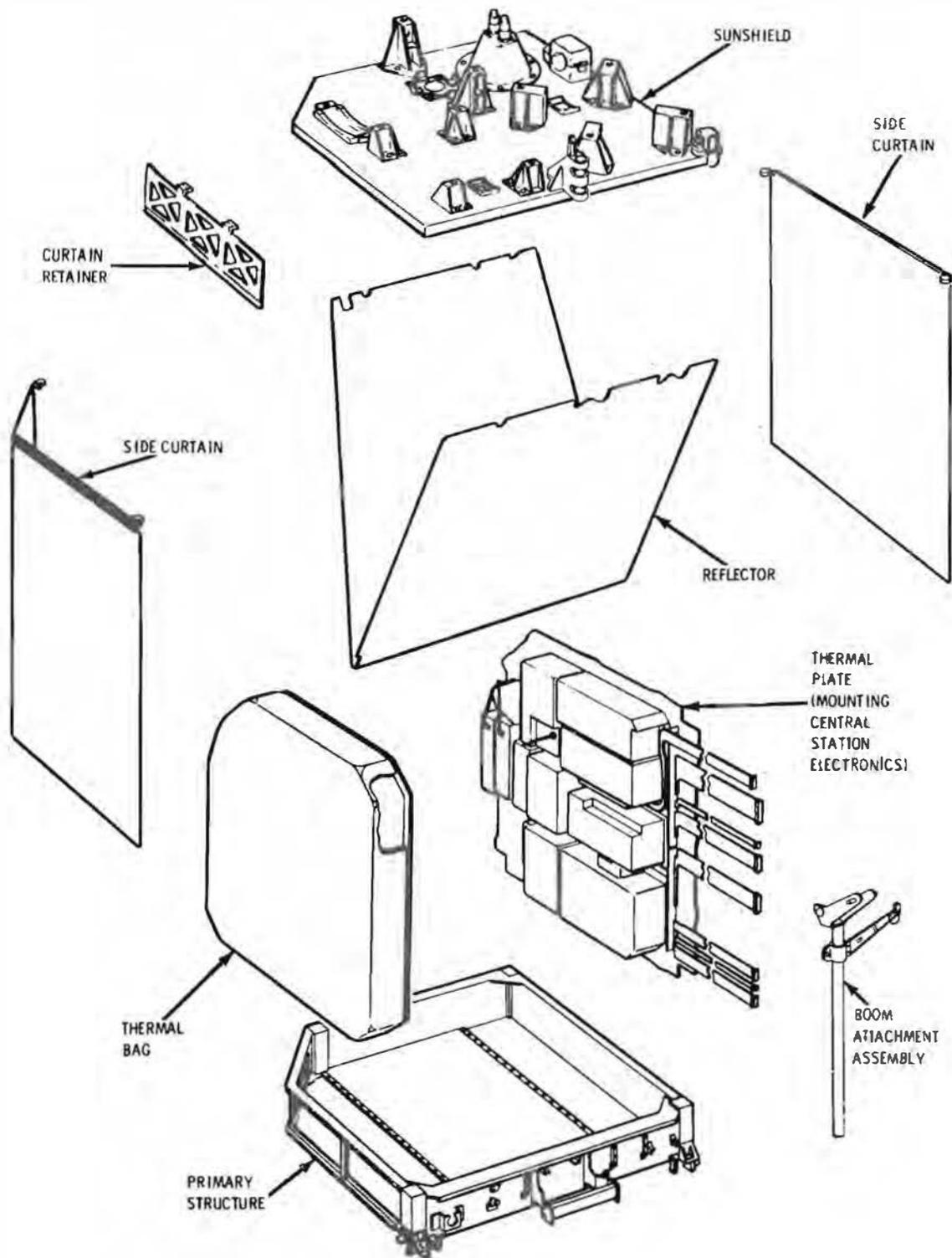
Figure 2-1. Structure, Subpackage No. 1
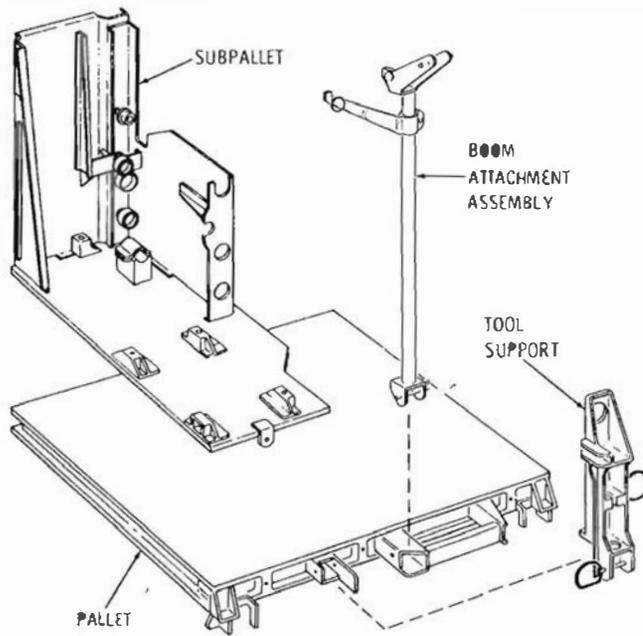
Figure 2-2. Structure, Subpackage No. 2
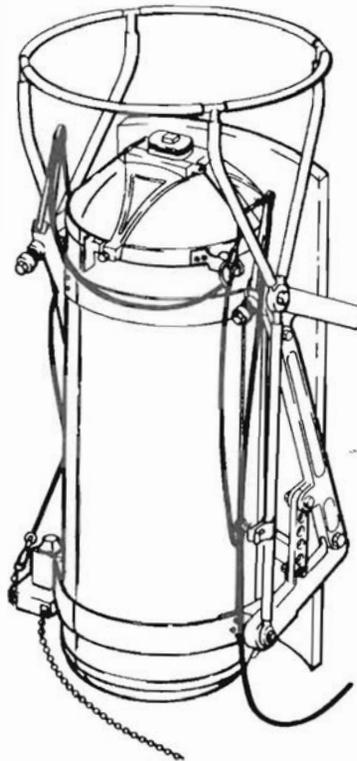
Figure 2-3. Fuel Cask Structure Assembly

FUEL TRANSFER TOOL

UNIVERSAL HANDLING TOOL
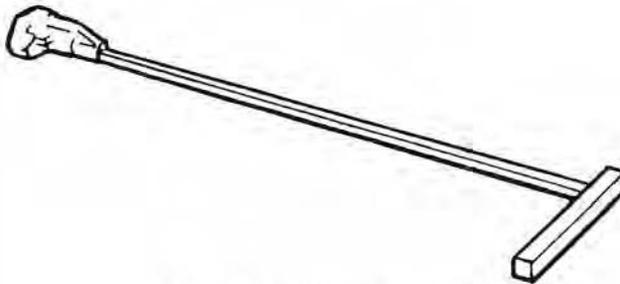
DOME REMOVAL TOOL

Figure 2-4. Handling Tools

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 rota-
ting 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 pro-
vides rigid interface between the tool and a receptacle on the subsystem. Oper-
ation is by a trigger-like lever near the handle.

2-9. Antenna Mast. The antenna mast is provided in two sections as shown in
Figure 2-5. The sections lock together and provide locking devices for attach-
ment 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.

2-10. DUST DETECTOR DESCRIPTION

The dust detector will obtain data for assessment of dust accretion on ALSEP and
provide a measure of thermal degradation of thermal surfaces.

2-11. Dust Detector Physical Description. The dust detector has two com-
ponents; a sensor package (Figure 2-6), and a printed circuit board. The sensor
package is mounted on the subpackage No. 1 sunshield. The sensor has three
photocells orientated on three sides to face the ecliptic path of the sun.
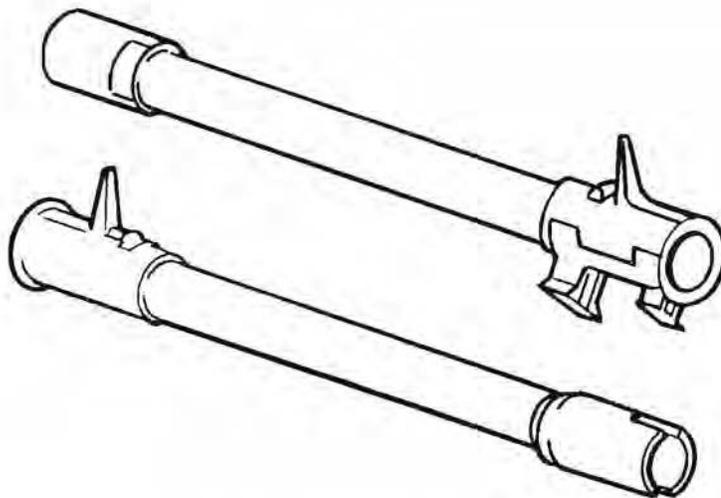
Figure 2-5. Antenna Mast Sections
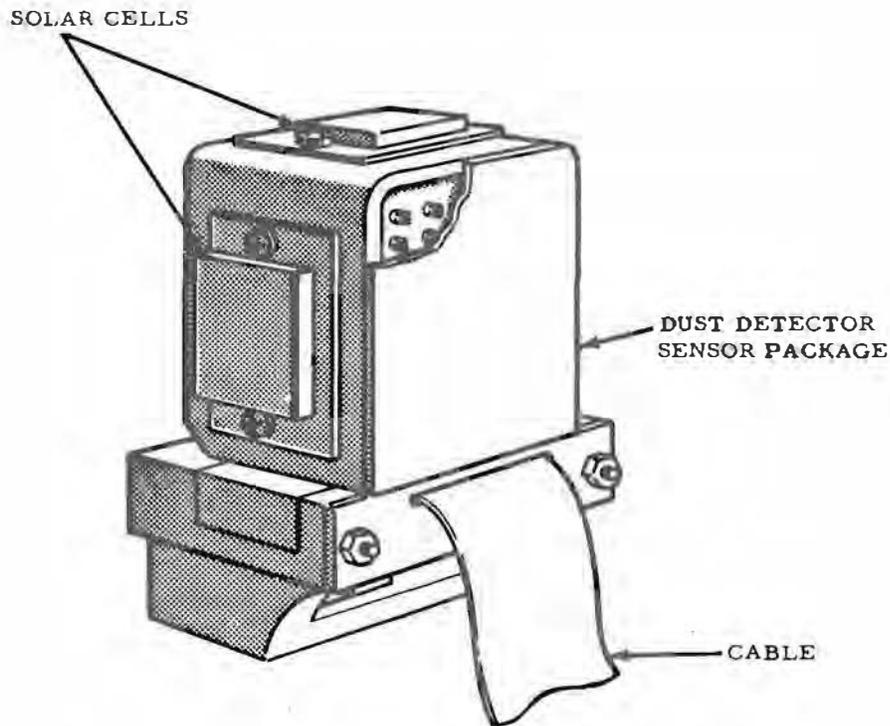
Figure 2-6. Dust Detector

Each cell has a 2 cm by 2 cm active area which is protected by a blue filter to cut off ultraviolet wavelengths below 0.4 micron, and a cover slide for protection against radiation damage. A thermistor is attached to the rear of each photocell to monitor the temperature of the cell. The sensor package is connected through an H-film cable to the printed circuit board which is located in the power distribution unit (PDU) of the data subsystem.

2-12. Dust Detector Functional Description. Dust accumulation on the surfaces of the three solar cells will reduce the solar illumination detected by the cells. The outputs of the solar cells are applied to three amplifiers which condition the signals and apply them to three subcommutated analog data channels of the data subsystem. (See Figure 2-7.) The thermistor outputs are applied to three subcommutated analog data channels of the data subsystem.

Dust detector operation is controlled by on and off commands from the Earth. These commands are applied to the command memory through the data subsystem. The command memory stores the command and controls the operation of the power switches in accordance with the command. The two solid state switches control the application of +12 vdc and -12 vdc operating power from the data subsystem. Individual fusing protection is provided on each of the two voltages.
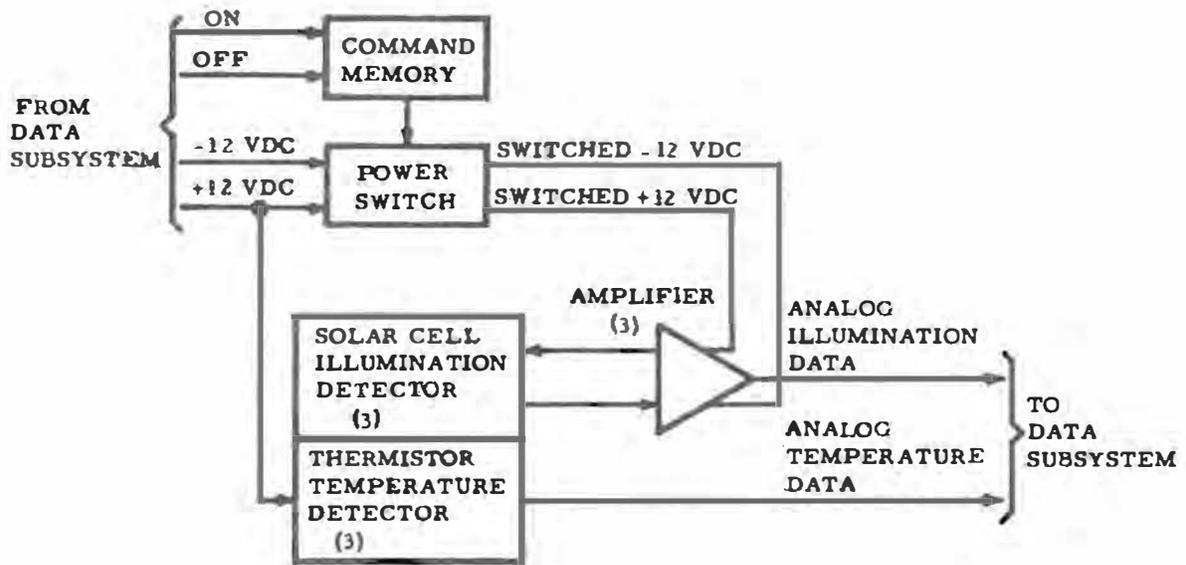
Figure 2-7. Dust Detector, Simplified Block Diagram

2-13. ELECTRICAL POWER SUBSYSTEM

The electrical power subsystem (EPS) provides the electrical power for lunar operation of the ALSEP. Primary electrical power is developed by thermo-electric 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.

2-14. EPS PHYSICAL DESCRIPTION

Major components of the electrical power subsystem are shown in Figure 2-8. The components are a radioisotope thermoelectric generator assembly, a fuel capsule assembly, a power conditioning unit, and a fuel cask.

2-15. EPS Radioisotope Thermoelectric Generator (RTG). The RTG is a cylin-drical 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 lo-cated between the hot frame, which surrounds the cavity, and the cold frame, which interfaces with the outer case and heat rejection fins.

2-16. 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.

2-17. EPS Power Conditioning Unit (PCU). The functional elements of the PCU are redundant dc voltage converters and shunt regulators, filters, and two com-mand control amplifiers. The elements are mounted in cordwood modules that are interconnected by printed circuit boards and attached to the center and lower sec-tions 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.

2-18. 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 pro-vides re-entry protection in case of an aborted mission.

2-19. EPS Leading Particulars. The physical and electrical characteristics of the electrical power subsystem are given in Table 2-2.

2-20. EPS FUNCTIONAL DESCRIPTION

As shown in Figure 2-9, the radioisotope thermoelectric generator (RTG) supplies +16 volts of primary power to the PCU. 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.

Fuel Cask Assembly

Fuel Capsule Assembly

Generator Assembly

Power Conditioning Unit

Figure 2-8. Electrical Power Subsystem

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
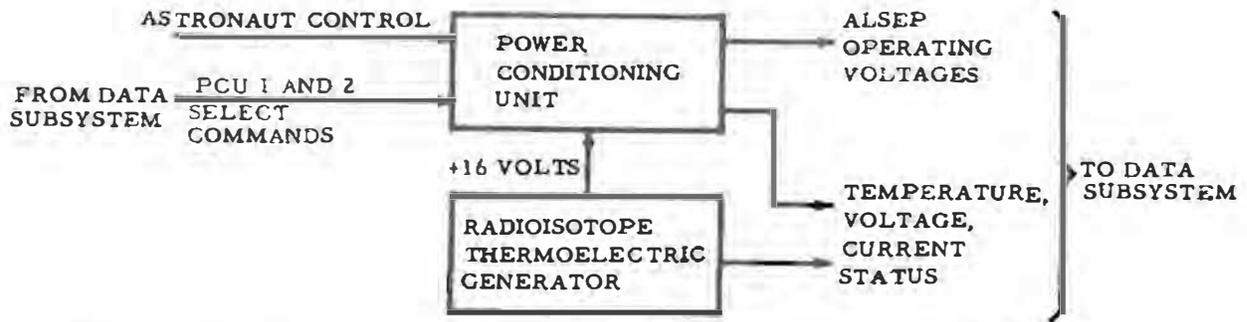
Figure 2-9. Electrical Power Subsystem, Functional Block Diagram

The astronaut control is a back-up signal for starting 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.

2-21. EPS DETAILED FUNCTIONAL DESCRIPTION

2-22. EPS Radioisotope Thermoelectric Generator. The operation of the RTG is illustrated in the block diagram of Figure 2-10. 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.

2-23. 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 2-11, 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. It is necessary to keep a constant load on the generator to prevent generator over-heating.
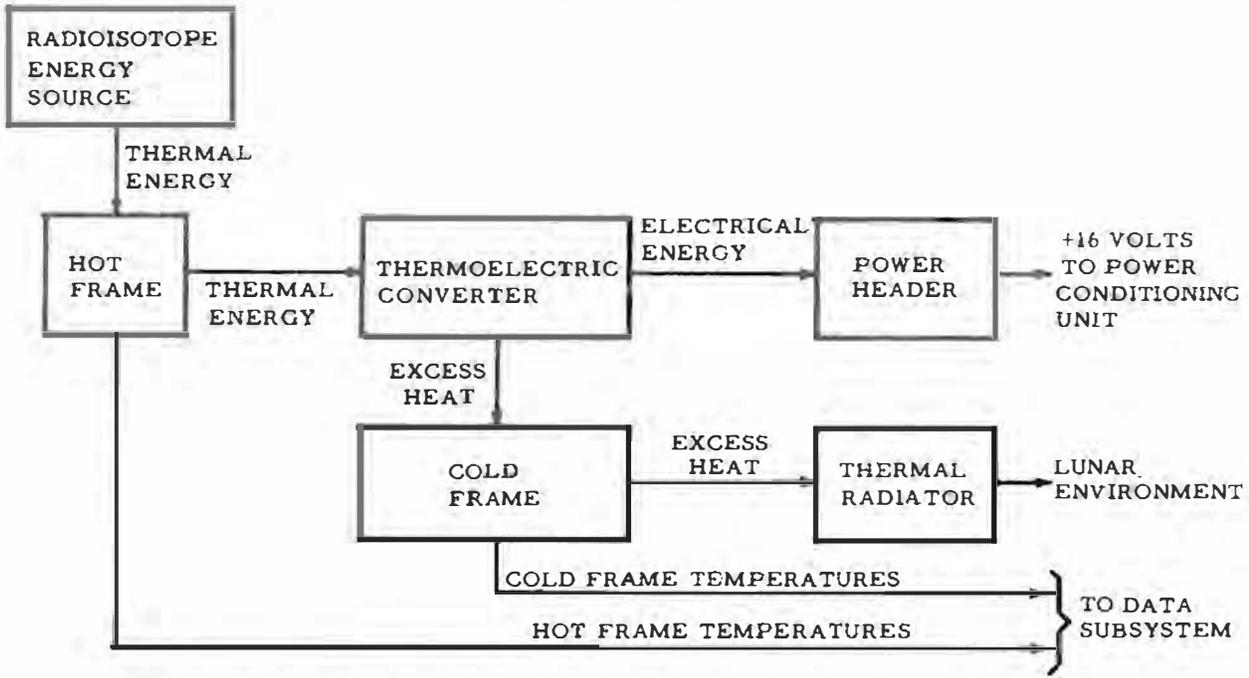
Figure 2-10. EPS Power Generation Function, Block Diagram

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 output voltages are regulated by the 12-volt feedback since they are coupled in the output transformer. The +12 volt is applied to the switching circuit for determining over or under voltage and switching to the redundant inverter and regulator, if necessary.

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.
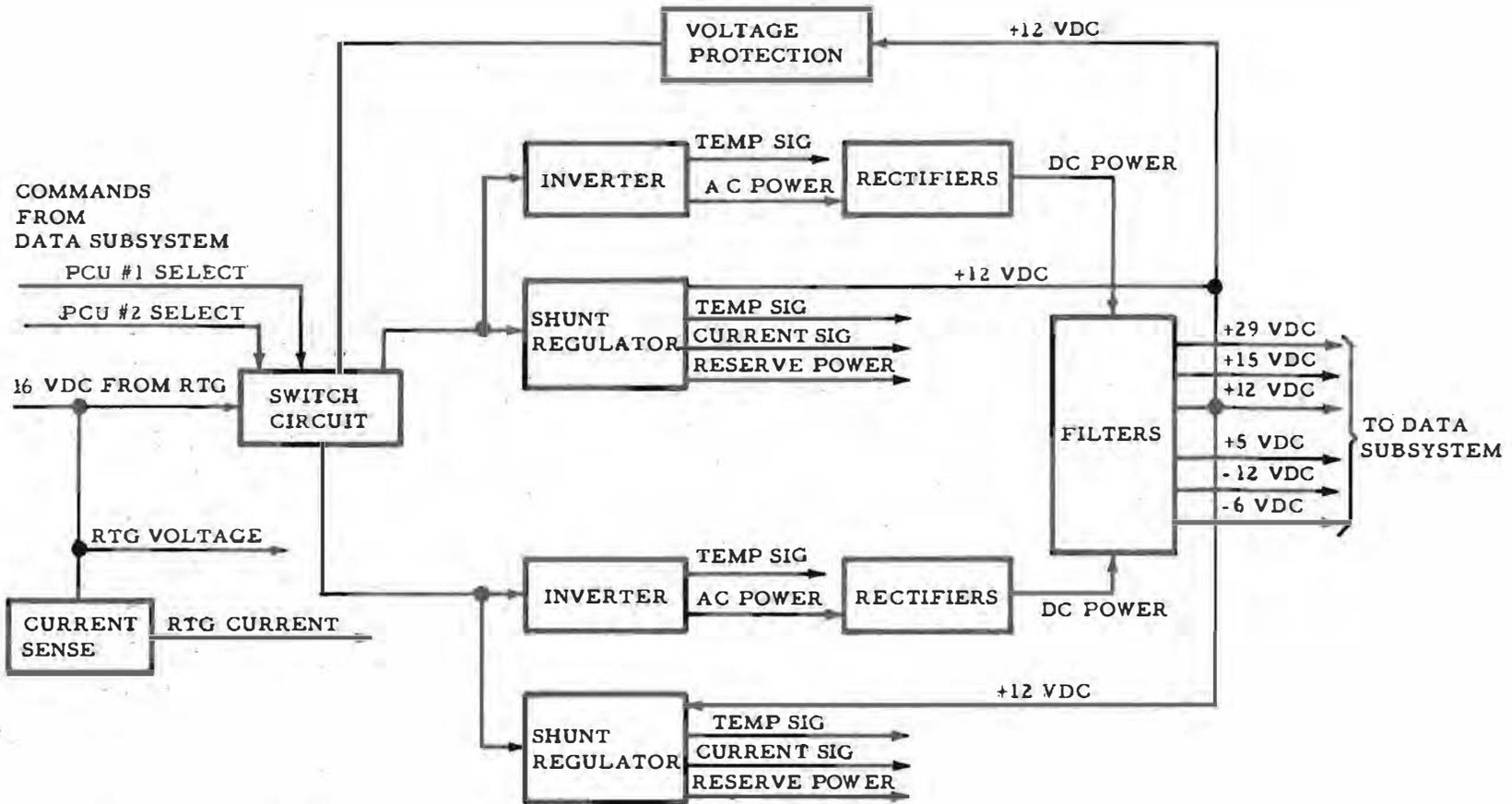
Figure 2-11. EPS Power Regulation Function, Block Diagram

2-24. 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 2-12. The uplink shown in Figure 2-12 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.
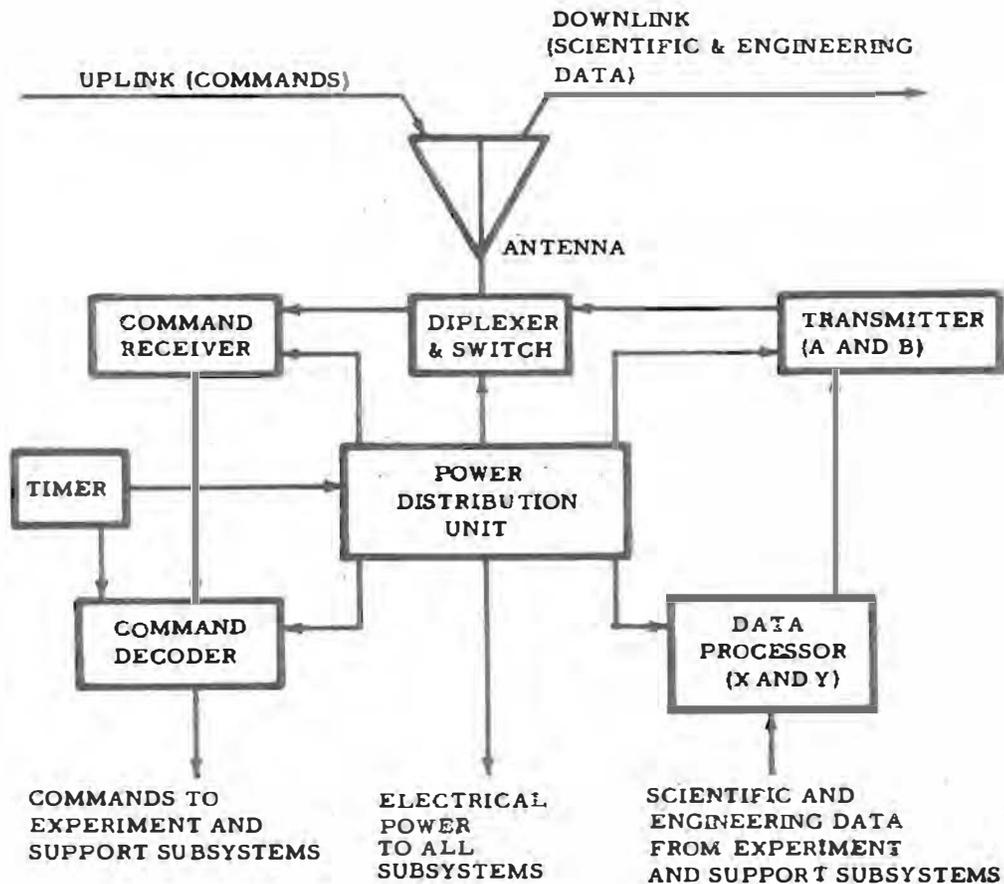
Figure 2-12. Data Subsystem, Simplified Block Diagram

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.
Central station timer	Provides backup timing signals following departure of astronauts Switch off after 720 days ± 30 days
Data processor	Collects and formats scientific data inputs from the experiments. Collects and converts analog housekeeping data into binary form.
Power distribution	Controls power switching and conditions engineering status data.

2-25. 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 2-13 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 multi-pin 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.

The overall weight of the data subsystem is approximately 25 pounds and the power consumption is approximately 20 watts.
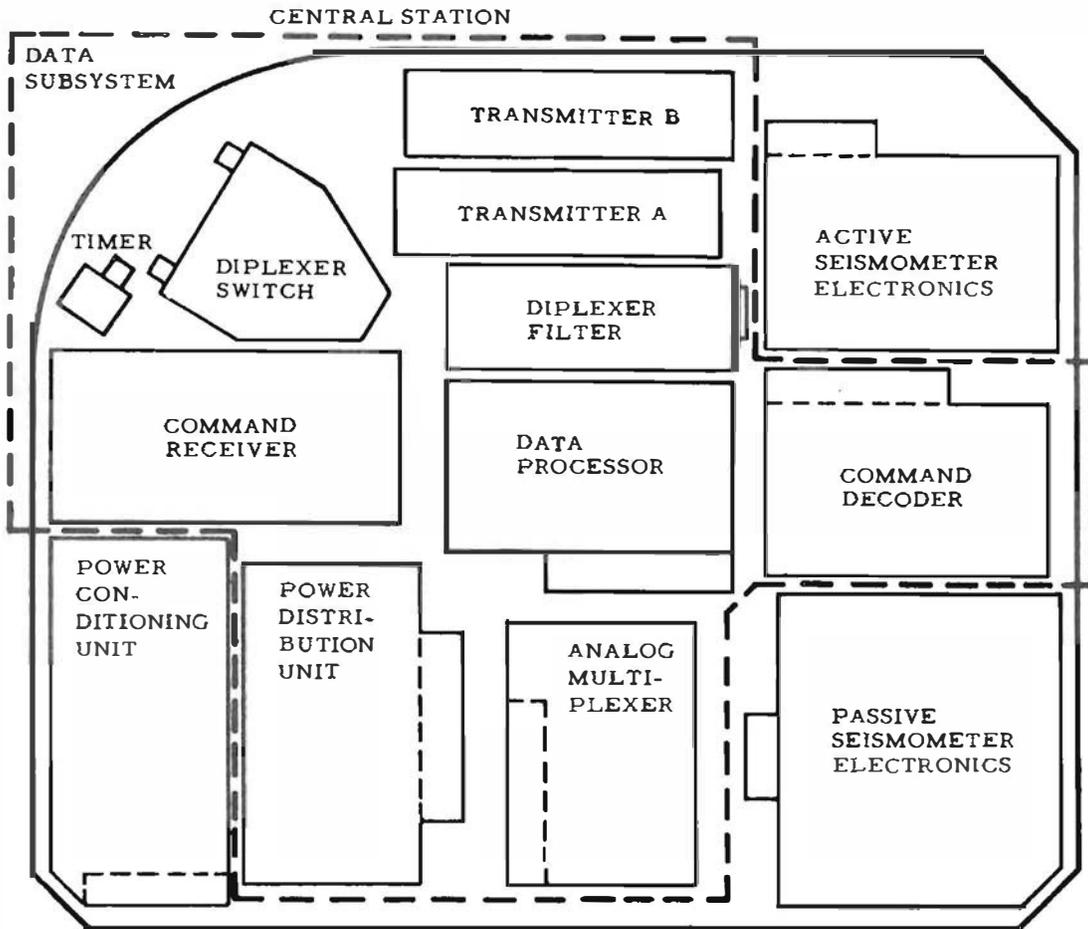
Figure 2-13. Data Subsystem Component Location

2-26. 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.

Table 2-4. ALSEP Commands

Command Usage	Number
Active seismic experiment	7
Passive seismic experiment	15
Heat flow experiment	10
Magnetometer experiment	8
Charged particle experiment	8
Suprathermal ion detector experiment	5
Solar wind experiment	2
Command decoder	2
Data Processor	5
Power distribution unit	29
Power conditioning unit	2

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 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 2-14 shows a functional diagram of the data subsystem and its interfaces with other ALSEP subsystems for Flights 1 and 2. Figures 2-15 and 2-16 show functional block diagrams of the Flight 3 and Flight 4 ALSEP systems. The later flight configurations are similar to the Flight 1 and 2 configuration except for the selection of experiments. Redundant channels are provided for the transmitter and portions of the command decoder and data processor to improve system reliability.

The uplink transmission from MSFN is a 2119 MHz RF carrier with a 2 KHz data subcarrier modulated to a 1 KHz synchronizing subcarrier. The command receive receiver demodulates the carrier and provides the composite 2 KHz and 1 KHz subcarrier to the command decoder. The command decoder demodulator section detects the 2 KHz command data subcarrier and 1 KHz timing signal and applies both to the redundant digital decoder sections (A and B) of the command decoder. The digital decoder sections identify correct address codes, decode the digital
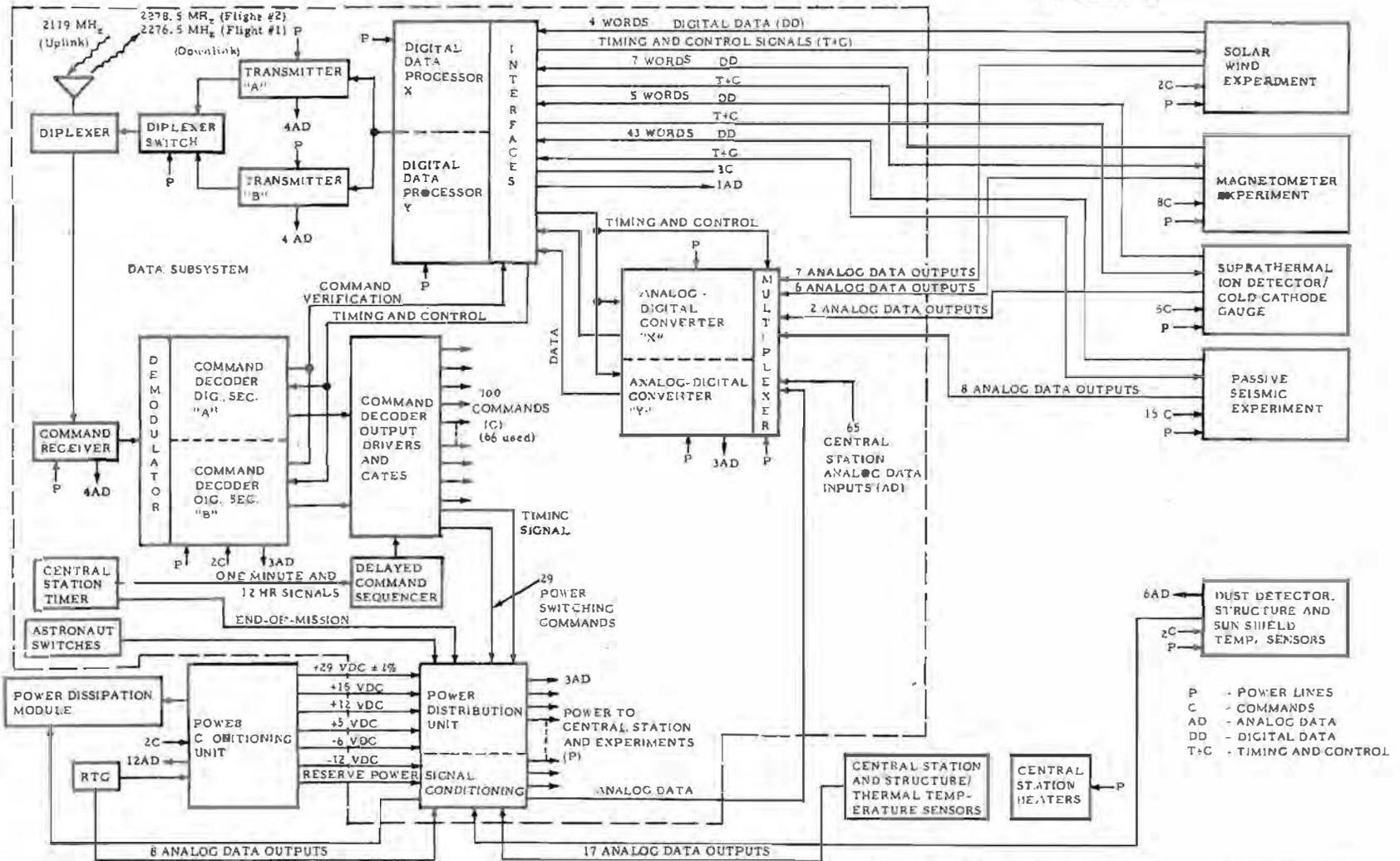
Figure 2-14. Data Subsystem (Flights 1 and 2 Configuration),
Functional Block Diagram

2119 MHz (Uplink) 2275.5 MHz (Downlink)

DIPLEXER

DIPLEXER SWITCH

TRANSMITTER "A"

TRANSMITTER "B"

4AD

4 AD

DATA SUBSYSTEM

DIGITAL DATA PROCESSOR X

DIGITAL DATA PROCESSOR Y

INTERFACES

1 WORDS DIGITAL DATA (DD)

TIMING AND CONTROL SIGNALS (T+C)

6 WORDS DD

T+C

5 WORDS DD

T+C

43 WORDS DD

T+C

3C

1AD

HEAT FLOW EXPERIMENT

10C

P

CHARGED PARTICLE LUNAR ENVIRONMENT EXPERIMENT

8C

P

COMMAND VERIFICATION

TIMING AND CONTROL

TIMING AND CONTROL

DEMODULATOR

COMMAND DECODER DIG. SEC. "A"

COMMAND DECODER DIG. SEC. "B"

COMMAND RECEIVER

P 4AD

COMMAND DECODER OUTPUT DRIVERS AND GATES

100 COMMANDS (C) (74 used)

DATA

ANALOG - DIGITAL CONVERTER "X"

ANALOG-DIGITAL CONVERTER "Y"

P 3AD P

MULTIPLEXER

P

7 ANALOG DATA OUTPUTS

6 ANALOG DATA OUTPUTS

2 ANALOG DATA OUTPUTS

COLD CATHODE GAUGE EXPERIMENT

5C

P

8 ANALOG DATA OUTPUTS

PASSIVE SEISMIC EXPERIMENT

15 C

P

65 CENTRAL STATION ANALOG DATA INPUTS (AD)

TIMING SIGNAL

CENTRAL STATION TIMER

ONE MINUTE AND 12 HR SIGNALS

DELAYED COMMAND SEQUENCER

P 2C 3AD

ASTRONAUT SWITCHES

END-OF-MISSION

29 POWER SWITCHING COMMANDS

POWER DISSIPATION MODULE

POWER CONDITIONING UNIT

2C

RTG

12AD

+29 VDC ±1%

+15 VDC

+12 VDC

+5 VDC

-6 VDC

-12 VDC

RESERVE POWER

POWER DISTRIBUTION UNIT

SIGNAL CONDITIONING

3AD

POWER TO CENTRAL STATION AND EXPERIMENTS (P)

ANALOG DATA

DUST DETECTOR, STRUCTURE AND SUN SHIELD TEMP. SENSORS

6AD

2C

P

P - POWER LINES

C - COMMANDS

AD - ANALOG DATA

DD - DIGITAL DATA

T+C - TIMING AND CONTROL

CENTRAL STATION AND STRUCTURE/ THERMAL TEMPERATURE SENSORS

CENTRAL STATION HEATERS

P

8 ANALOG DATA OUTPUTS

17 ANALOG OUTPUTS

Figure 2-15. Data Subsystem (Flight 3 Configuration). Functional Block Diagram
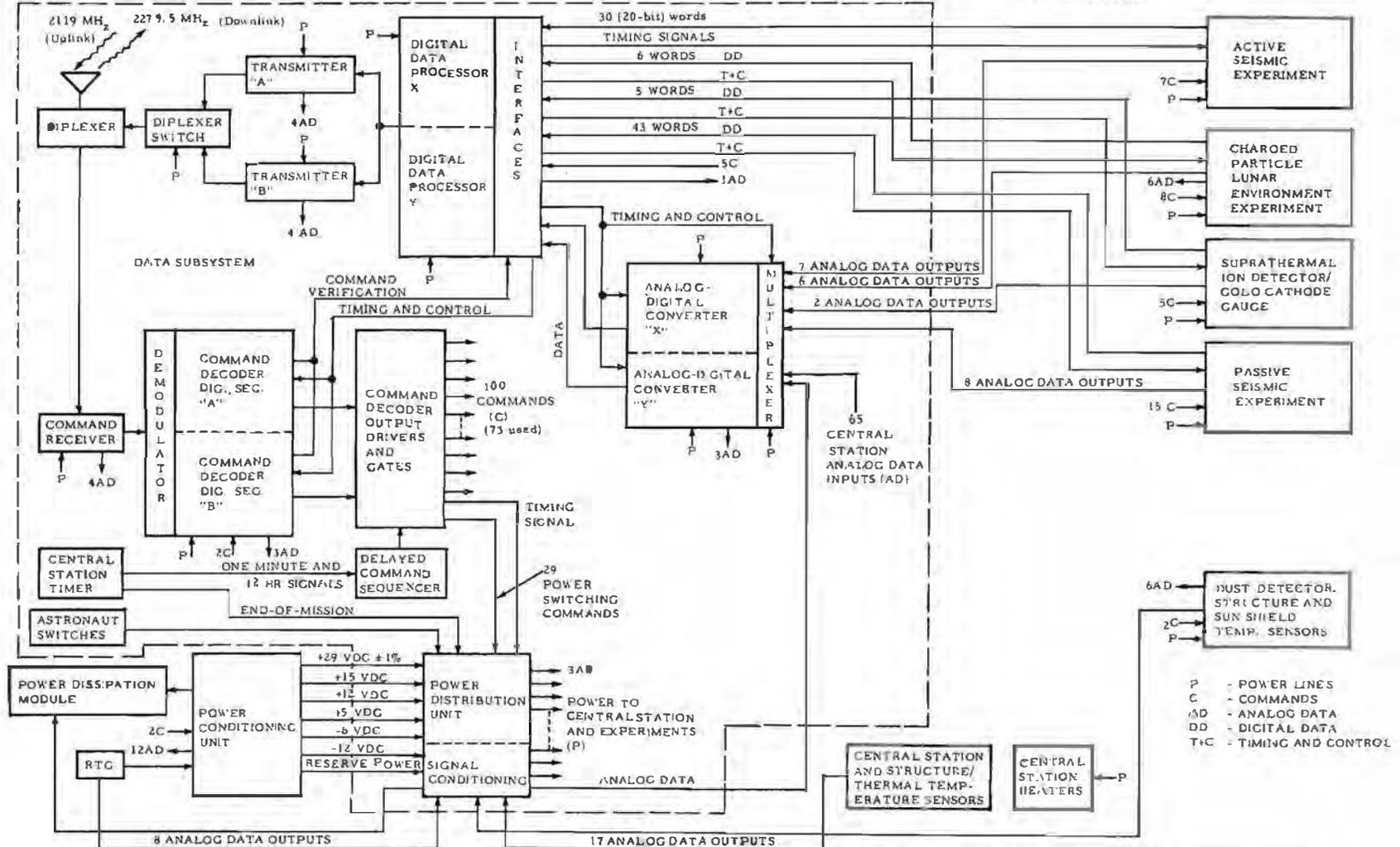
Figure 2-16. Data Subsystem (Flight 4 Configuration),
Functional Block Diagram

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.

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

The digital data processor generates timing and control signals for use throughout the system and formats the scientific and engineering data from the 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.

2-27. 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.

2-28. Antenna Physical Description. The antenna consists of a copper conductor bonded to a fiberglass-epoxy tube for mechanical support. Figure 2-17 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.
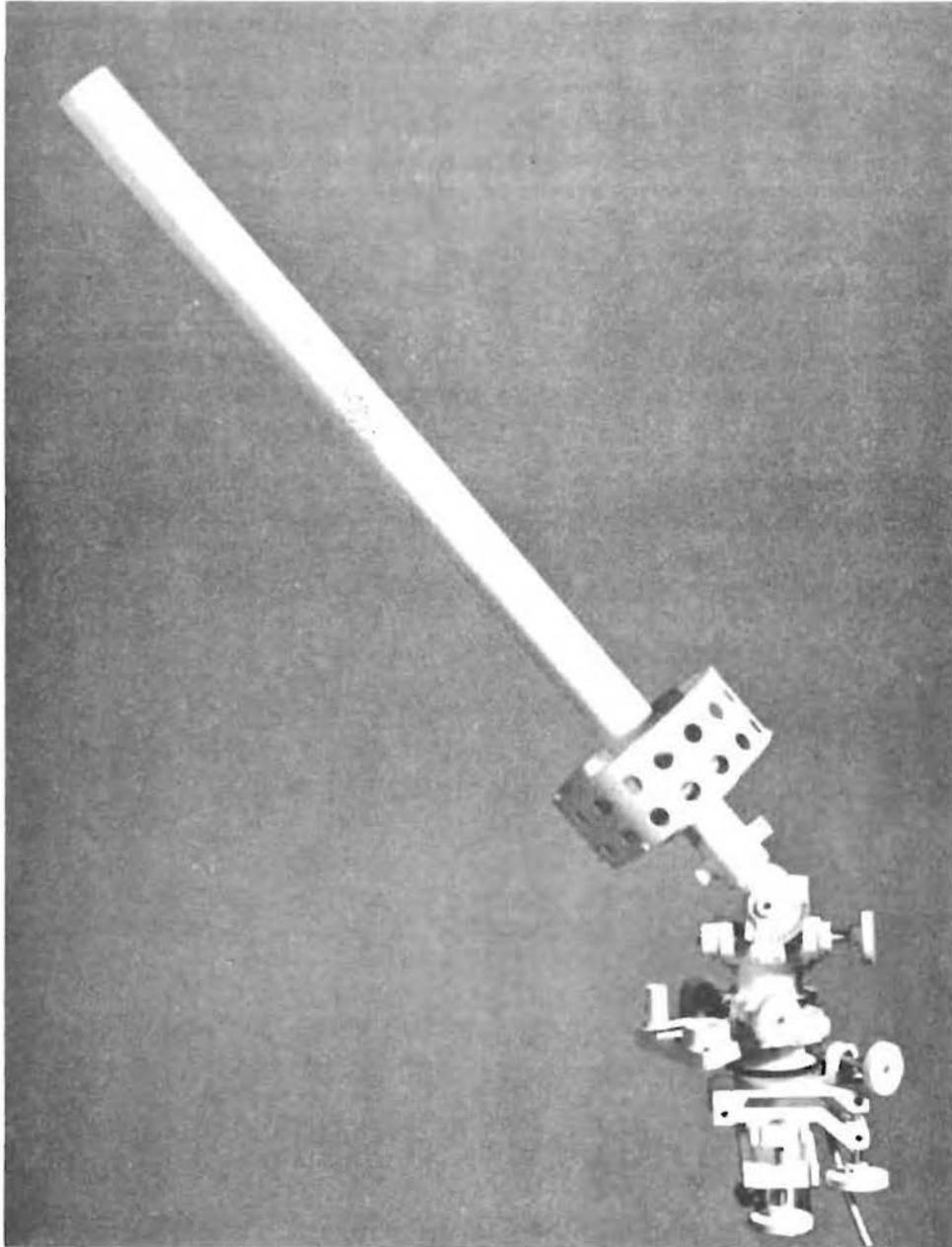
Figure 2-17. Antenna and Aiming Mechanism

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	-11 db	-11.3 db

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

2-29. **Antenna Functional Description**. The antenna receives command signals from Earth on a frequency of 2119 MHz and transmits telemetry data on several frequencies 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.

2-30. 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 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.

2-31. DATA SUBSYSTEM DIPLEXER

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

2-32. Data Subsystem Diplexer Physical Description. The diplexer filter and circulator switch are shown in Figures 2-18 and 2-19, respectively. Figure 2-20 shows a diagram of the circulator switch. The diplexer 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.
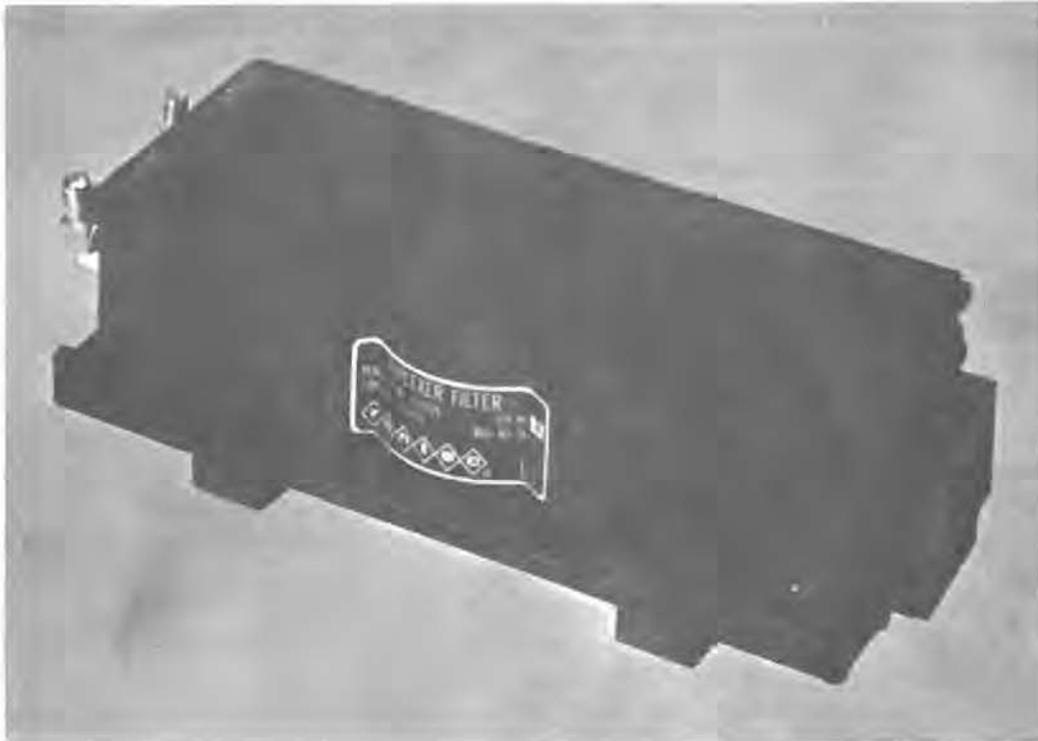
Figure 2-18. Data Subsystem Diplexer Filter

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.

Figure 2-19. Data Subsystem Diplexer Switch
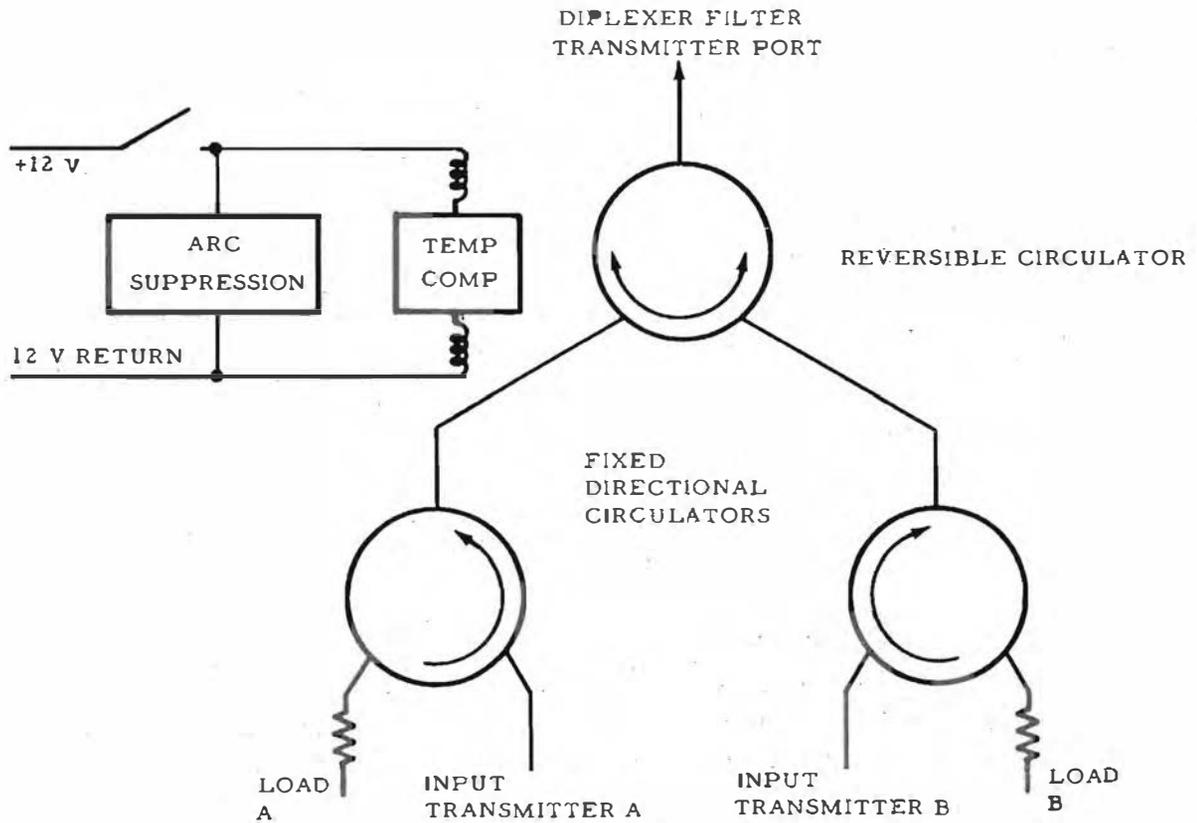
Figure 2-20. Data Subsystem Diplexer Switch Diagram

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

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

2-33. <u>Data Subsystem Diplexer Functional Description.</u> 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 andrequires a +12 vdc signal to switch the back-up transmitter into operation.

2-34. DATA SUBSYSTEM COMMAND RECEIVER

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

2-35. Data Subsystem Command Receiver Physical Description. Figure 2-21 shows the command receiver. The command receiver contains foam-potted individually-shielded circuit modules mounted on a milled magnesium base plate. Module interconnections are routed through channels milled into the base plate. Receiver leading particulars are listed in Table 2-8.
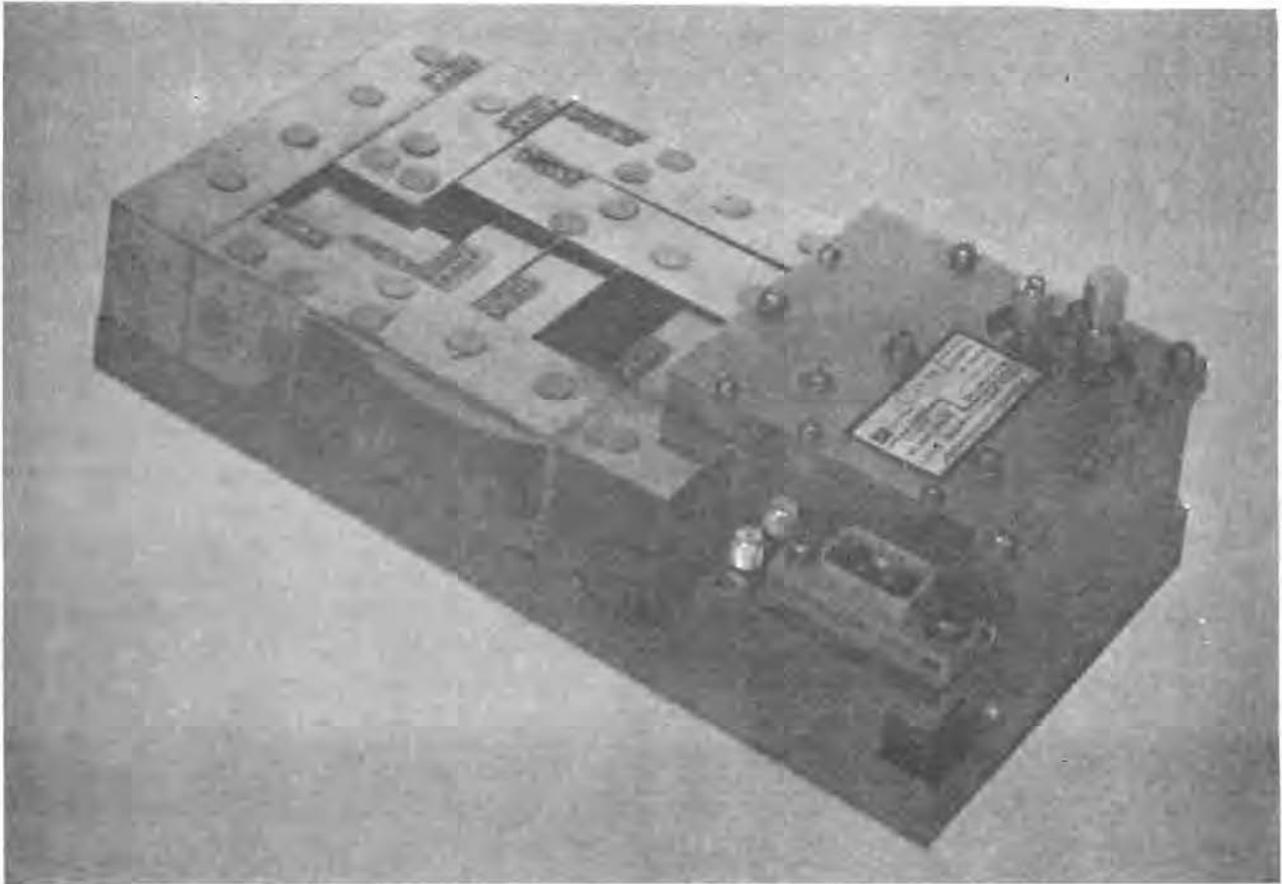
Figure 2-21. Data Subsystem Command Receiver

Table 2-8. Data Subsystem Command Receiver Leading Particulars

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

2-36. <u>Data Subsystem Command Receiver Functional Description</u>. Figure 2-22 shows a detailed block diagram of the command receiver. The 2119 MHz phase-modulated uplink carrier is received by the central station antenna, coupled through the diplexer, and applied to the command receiver mixer. The input signal is mixed with a crystal controlled 2059 MHz local oscillator signal to produce a 60 MHz intermediate frequency signal. Two local oscillator/driver amplifier circuits are used to provide redundant operation. The oscillator/driver amplifier output frequency of 128.7 MHz is increased to 2059 MHz by a multiply-by-16 frequency multiplier. The two 2059 MHz signals from the frequency multipliers are applied to a stripline hybrid which is the redundancy combiner for the redundant local oscillators. From the hybrid, the 2059 MHz local oscillator frequency is applied to the mixer.

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

The 60 MHz IF signal from the mixer is amplified in the IF preamplifier and filter module and in the IF amplifier module before being applied to the amplifier and discriminator module. The discriminator is a double tuned diode discriminator which provides FM detection. The integrator circuit in the output amplifier and integrator module provides phase detection of the FM detected signal. The output signal from the command receiver is a combined 2 KHz data subcarrier and a 1 KHz synchronization subcarrier which is applied to the command decoder. Receiver output characteristics are shown in Figure 2-23.

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

2-37. 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.

2-38. <u>Data Subsystem Command Decoder Physical Description</u>. Figure 2-24 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 particular of the command decoder are listed in Table 2-9.
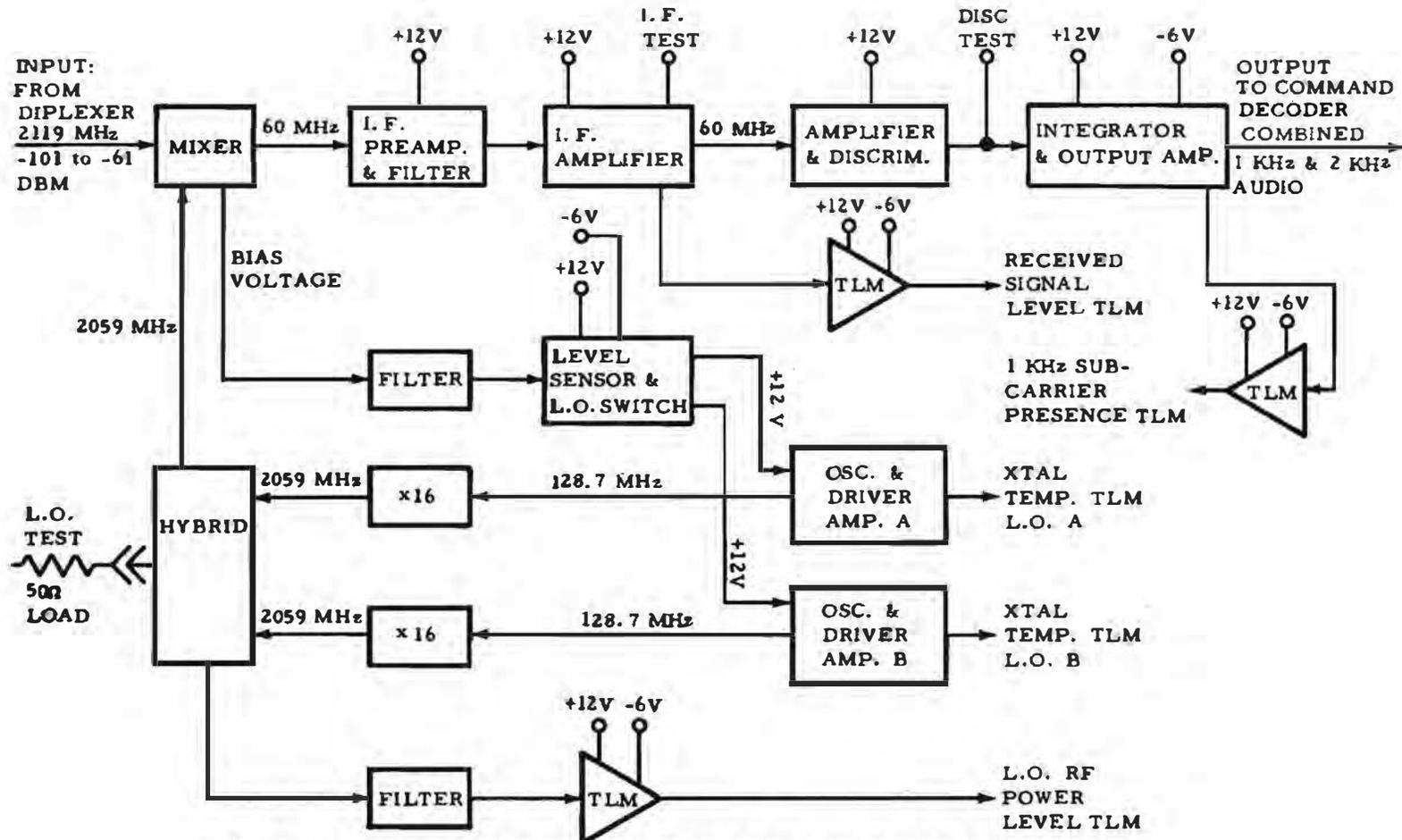
Figure 2-22.   Data Subsystem Command Receiver Block Diagram
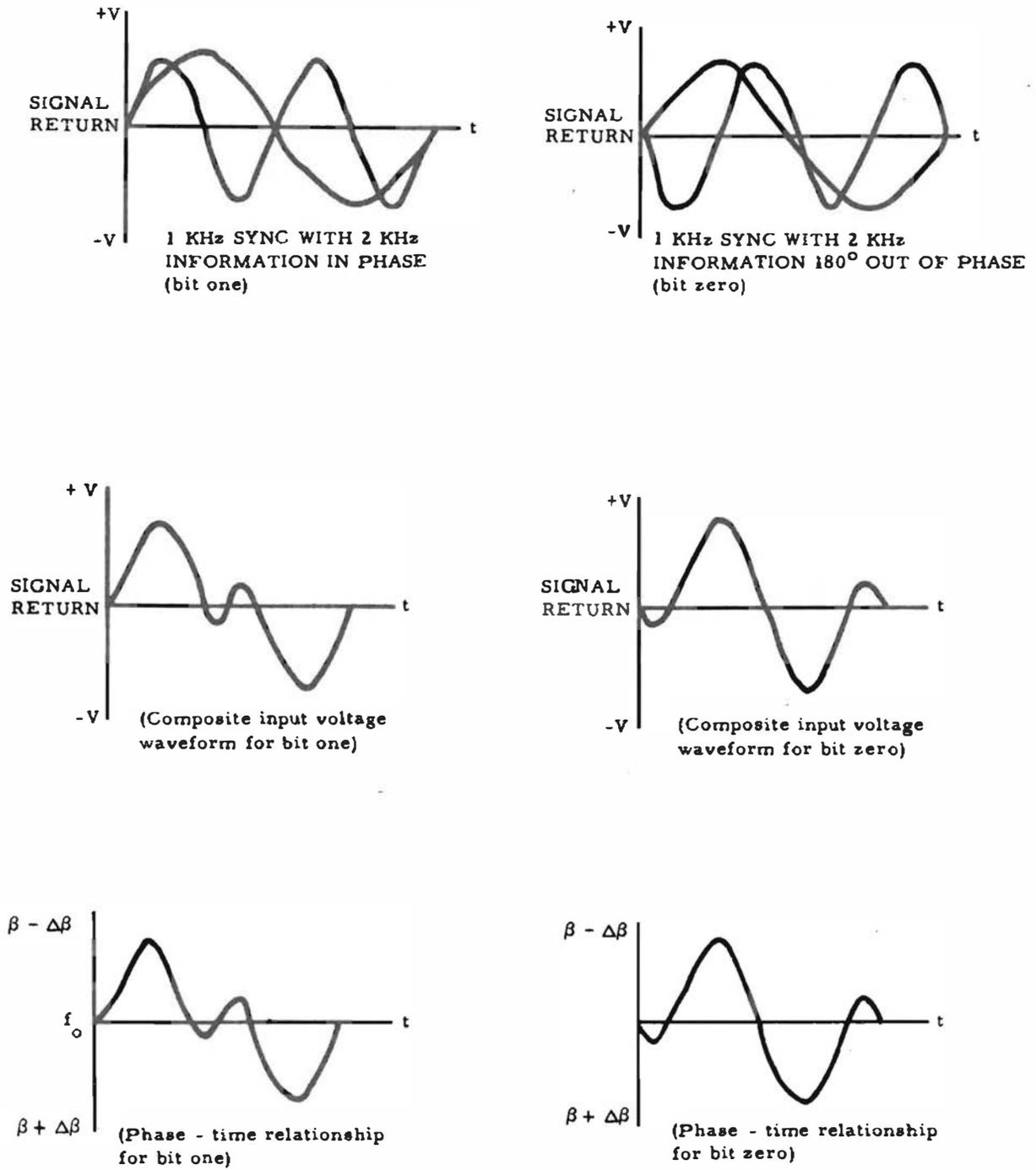
Figure 2-23. Data Subsystem Command Receiver
Output Signal Characteristics

Figure 2-24. 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

2-39. Data Subsystem Command Decoder Functional Description. The command decoder consists of a demodulator section and digital decoder sections. Figure 2-25 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.
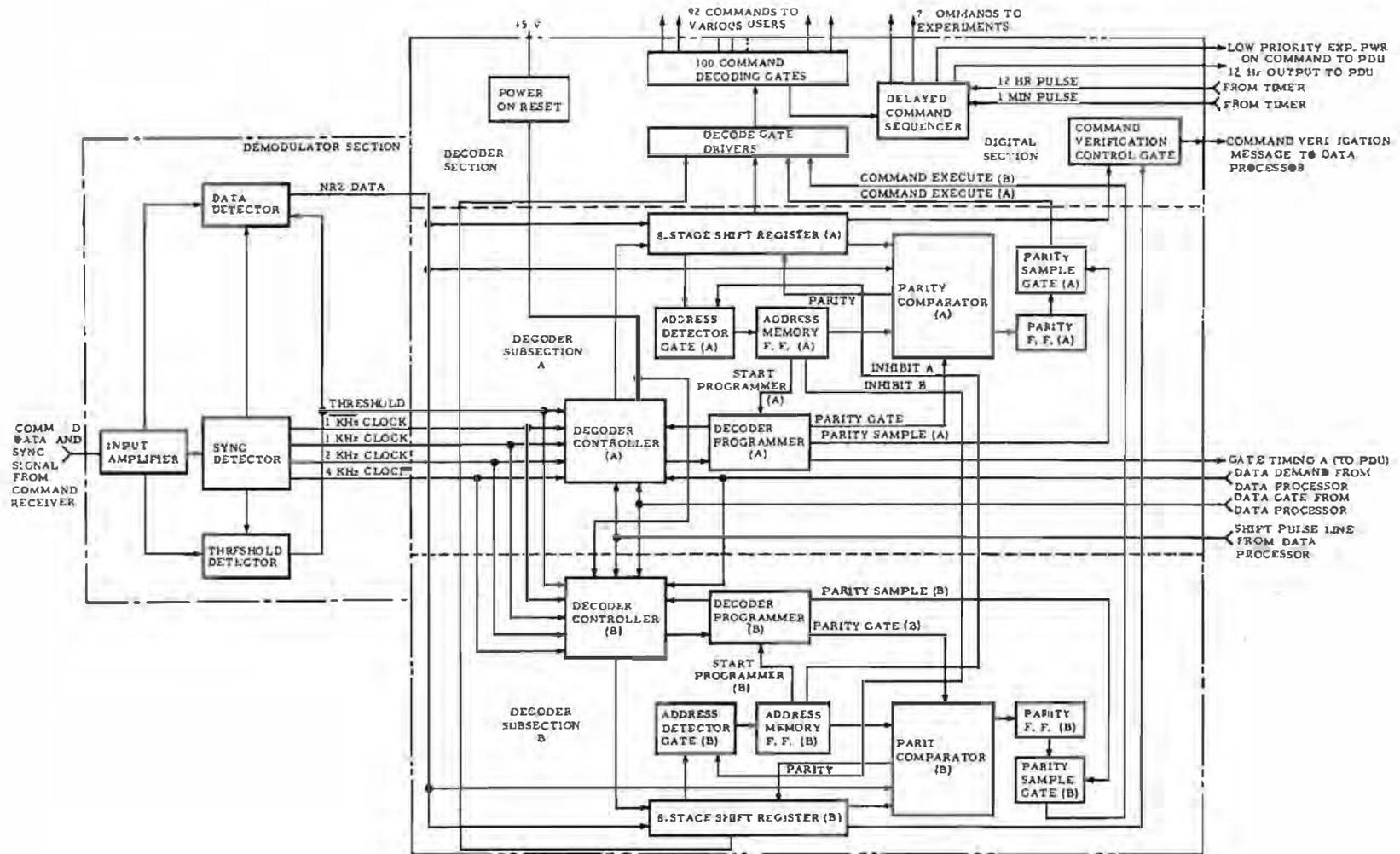
Figure 2-25. Data Subsystem Command Decoder,
Functional Block Diagram

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 2-26 illustrates the functional flow chart of the command decoder and depicts the complete routines and subroutines from initiation through reset cycle.

In the normal (non-active seismic) mode, the serial data enters shift registers A and B, and continually shifts through these registers. The decoder remains in this search mode until a valid address has been detected by either one of the address gates. For example, if address gate A detects a valid address code in shift register A, it immediately sets address memory flip-flop A which simultaneously starts decoder programmer A and inhibits address gate B from responding. After seven timing periods, programmer A activates parity comparator A which performs a bit-by-bit comparison of the seven command and seven command complement bits. At the end of this comparison, a parity check takes place. If correct, the appropriate command decode gate is activated for 20 milliseconds and a command execute pulse sets the first stage of shift register A to a one. This signifies that a proper command has been received. If parity does not check, the command is inhibited and the first stage of shift register A is set to a zero.

POWER RESET CIRCUIT ACTIVATED

IS THRESHOLD ACTIVATED — NO

ENTER SEARCH MODE — YES

PROPER ADDRESS DETECTED — NO

YES

ADDRESS A — NO

ADDRESS B — NO

ACTIVATE RESET A

HAVE 2 SECONDS ELAPSED — YES

NO

DATA DEMAND ACTIVATED — YES

SHIFT COMMAND VERIFICATION MESSAGE TO DATA PROCESSOR @ DATA PROCESSOR SHIFT PULSE RATE

ACTIVE SEISMIC MODE — ON / OFF

START PROGRAMMER A INHIBIT B — YES

ALLOW 7 COMMAND COMPLEMENT BITS TO ENTER SHIFT REGISTER A

1. ALLOW 7 COMMAND BITS TO ENTER SHIFT REGISTER AND PARITY COMPARATOR.
2. ALLOW 7 COMMAND COMPLEMENT BITS TO ENTER PARITY COMPARATOR.
3. GENERATE PARITY GATE PULSE.

GENERATE PARITY SAMPLE PULSE A

PARITY CHECKS — YES / NO

1. DECODE CONTENTS OF SHIFT REGISTER A AND EXECUTE COMMAND FOR 20 MILLISECONDS.
2. ENTER "1" IN FIRST STAGE OF SHIFT REGISTER A

1. INHIBIT COMMAND EXECUTE A
2. ENTER ZERO IN FIRST STAGE OF SHIFT REGISTER A

START PROGRAMMER B INHIBIT A — YES

ALLOW 7 COMMAND COMPLEMENT BITS TO ENTER SHIFT REGISTER B

1. ALLOW 7 COMMAND BITS TO ENTER SHIFT REGISTER AN PARITY COMPARATOR.
2. ALLOW 7 COMMAND COMPLEMENT BITS TO ENTER PARITY COMPARATOR.
3. GENERATE PARITY GATE PULSE.

GENERATE PARITY SAMPLE PULSE B

PARITY CHECKS — YES / NO

1. DECODE CONTENTS OF SHIFT REGISTER B AND EXECUTE COMMAND FOR 20 MILLISECONDS
2. ENTER "1" IN FIRST STAGE OF SHIFT REGISTER B

1. INHIBIT COMMAND EXECUTE B
2. ENTER ZERO ON FIRST STAGE OF SHIFT REGISTER B

ACTIVATE RESET B

HAVE 2 SECONDS ELAPSED — YES

NO

DATA DEMAND ACTIVATED — YES

SHIFT COMMAND VERIFICATION MESSAGE TO DATA PROCESSOR @ DATA PROCESSOR SHIFT PULSE RATE

ACTIVE SEISMIC MODE — ON / OFF

LEGEND:

◇ DECISION POINT

▭ ACTION TO BE TAKEN

Figure 2-26. Data Subsystem Command Decoder Flow Diagram

2-43/2-44

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.

2-40. 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 three ALSEP assemblies. Each command decoder shall respond to two address codes; one for section A and another for section B. Address codes have been selected as follows:

ALSEP No.	Address Code No.	Binary Weighted Code Pattern	Command Decoder No.
1	88	1011000	1A
1	24	0011000	1B
2	78	1001110	2A
2	14	0001110	2B

ALSEP No.	Address Code No.	Binary Weighted Code Pattern	Command Decoder No.
3	105	1101001	3A
3	41	0101001	3B
4	21	0010101	4A
4	53	0110101	4B

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, 29, 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 114 discrete commands which have been allotted as follows:

a. Experiments   62
b. Power distribution   29
c. Power conditioning unit   2
d. Data processor   5
e. Command decoder   2
f. Available for test purposes 14

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

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

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

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

The command decoder automatically generates seven one-time commands after a 96-hour delay. The delayed command functions and time of execution are listed in Table 2-10. A flow chart of delayed command sequences is shown in Figure 2-27.

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

Table 2-10. Data Subsystem Delayed Command Functions

Command	Function	Time of Execution
75	Blow CPLEE dust cover	96 hours + 2 minutes
69	Set CCIG seal break	"
59	Uncage PSE	"
72	Execute CCIG seal break	96 hours + 3 minutes
82	Blow SWE dust cover	96 hours + 4 minutes
71	Set SIDE blow dust cover	"
72	Execute SIDE blow dust cover	96 hours + 5 minutes
89	Magnetometer flip calibrate	108 hours + 1 minute, then every 12 hours
42	Restore power to lowest priority experiment	108 hours + 7 minutes, then every 12 hours

2-41. DATA SUBSYSTEM CENTRAL STATION TIMER

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

2-42. Data Subsystem Central Station Timer Physical Description. The central station timer consists of a Bulova model TE-12 Accutron clock and a long life mercury cell battery.

The timer is housed in a black anodized aluminum case approximately 2.6 inches long and 1.3 inches in diameter. Weight of the unit is slightly more than 0.25 pounds. Solder terminals provide electrical connection. Figure 2-28 shows the central station timer.

2-43. Data Subsystem Central Station Timer Functional Description. Figure 2-29 shows a block diagram of the timer. The central station timer starts to provide back-up timing pulses when the IPU cable is mated to the central station. A tuning fork controls the frequency of a transistorized 360 Hz oscillator which provides the basic timing frequency. This timing frequency drives the electromechanical arrangement used to provide three back-up timing switch closures. The switch closures are at one minute, 12-hour, and 720-day intervals. The one-minute and 12-hour closures are continuously repetitive and are applied to the
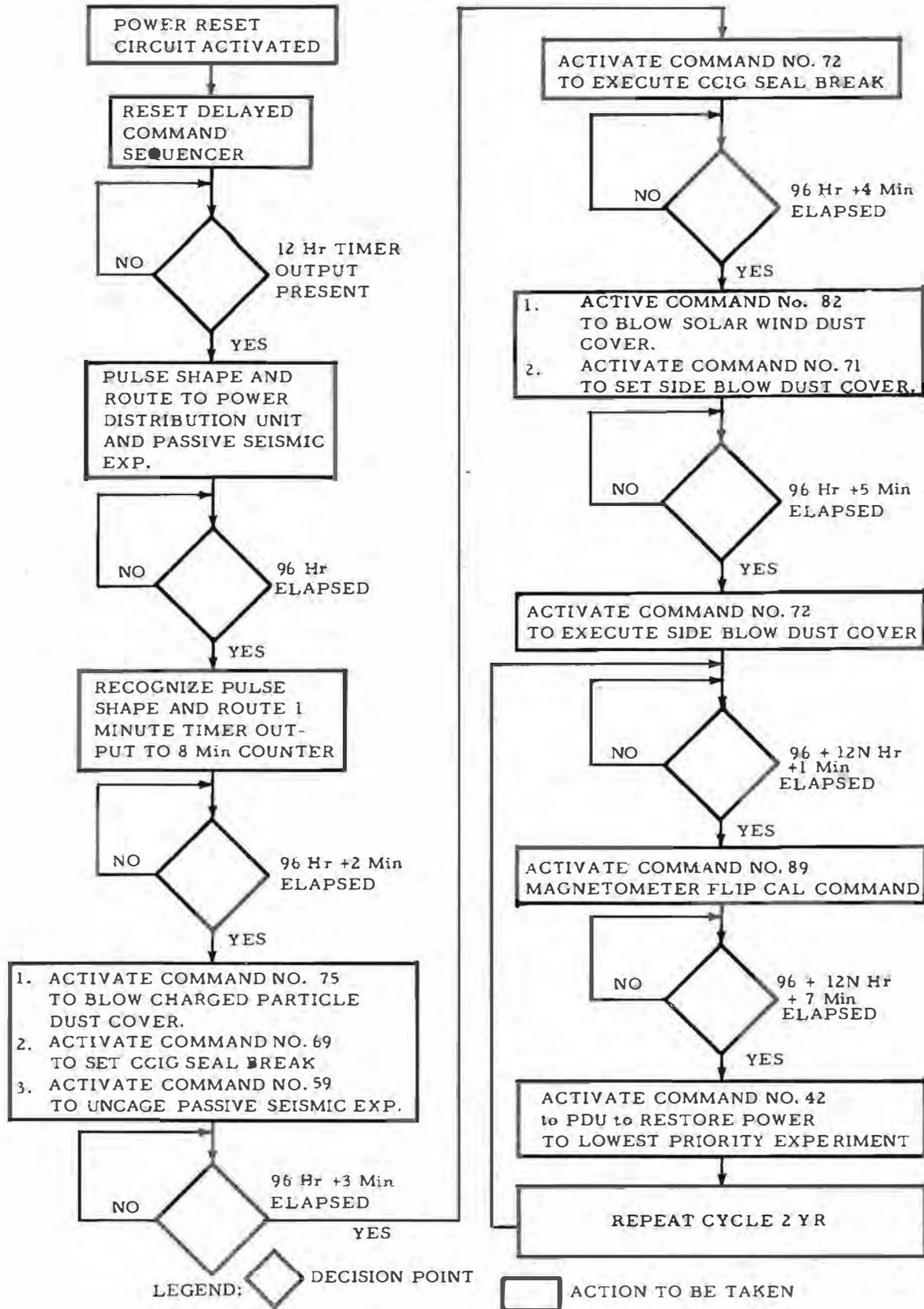
Figure 2-27. Data Subsystem Delayed Command Sequence, Functional Flow Chart
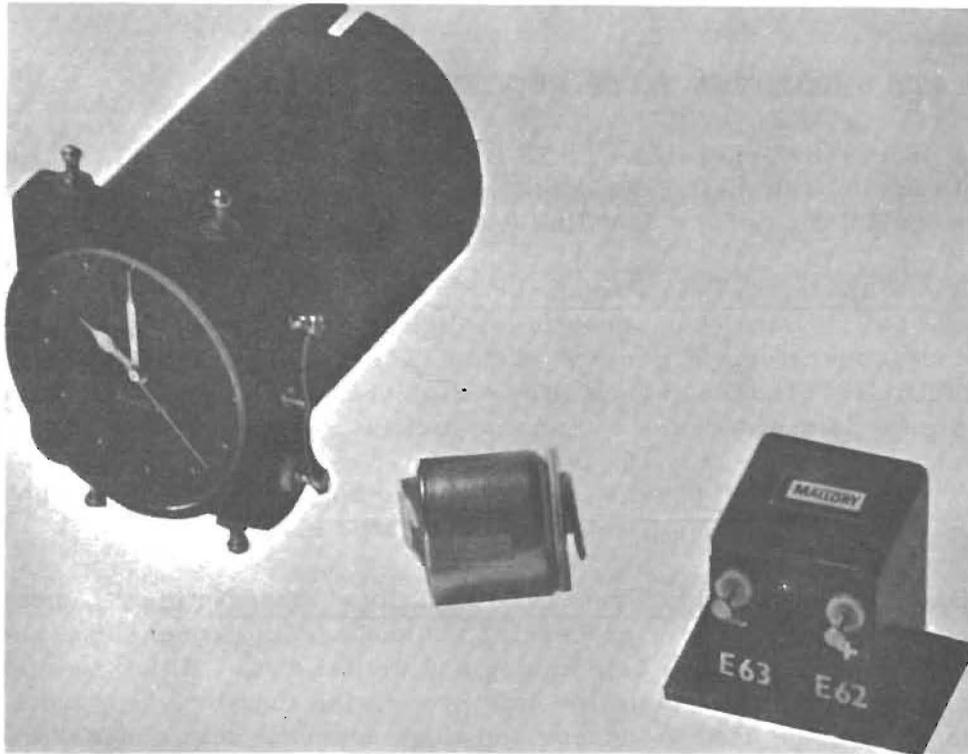
Figure 2-28.   Data Subsystem Central Station Timer
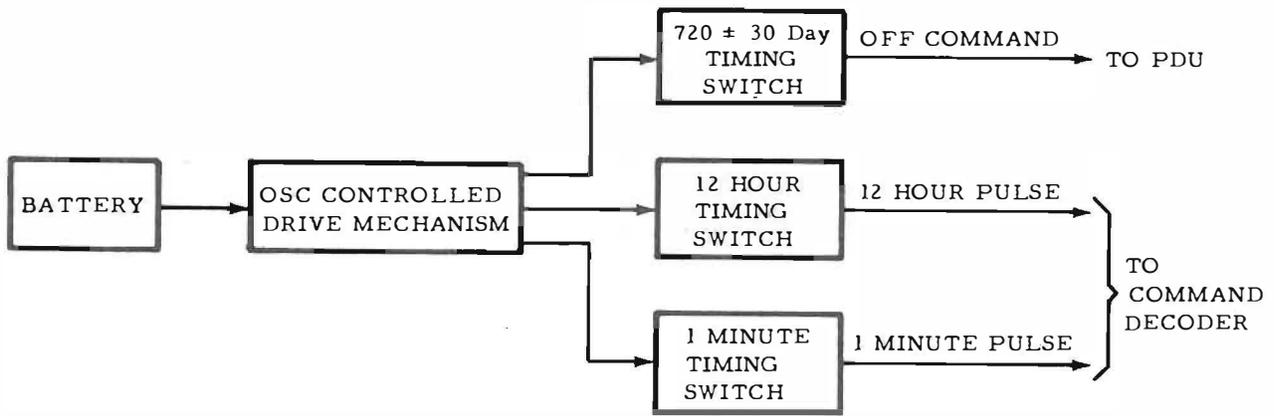
Figure 2-29.   Data Subsystem Central Station Timer, Block Diagram

delayed command sequencer in the command decoder.   The 720-day closure oc-
curs only once and initiates a permanent off command to the ALSEP transmitter.
The commands activated by the command decoder delayed command sequencer
are listed in Table 2-10.

2-44. DATA SUBSYSTEM DATA PROCESSOR

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

2-45. Data Subsystem Data Processor Physical Description. The data processor
consists of two physical components: (a) digital data processor, (b) analog
multiplexer/converter. Figures 2-30 and 2-31 show the digital processor and
analog multiplexer/converter. Multilayer printed circuit boards are used through-
out the digital data processor and analog multiplexer/converter. The analog
multiplexer/converter uses 15, two-layer boards. The digital data processor
uses seven twelve-layer boards, one six-layer board and one three-layer discrete
component board. Leading particulars are listed in Table 2-11.

2-46. 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 chan-
nel may be selected to perform the data processing function. Figure 2-32 is a
block diagram of the data processor showing redundant data processor channels
X and Y. Digital data is applied directly to the processor channels. Analog engi-
neering (housekeeping) data is applied to the 90-channel analog multiplexer. Fig-
ure 2-33 shows a block diagram of the analog multiplexer/converter. Multiplexer
channels 1-15 are considered high reliability channels because of the redundant
gating provided. Channels 16-90 are normal channels without redundant gating.
An advance pulse from the timing and control circuits of the X and Y processor
channels is applied to the multiplexer sequencer logic. The sequencer logic ap-
plies timing signals to the multiplexing circuitry, and an end-of-frame signal to
the frame counter when the frame advance reaches ninety. Multiplexed analog
outputs from the multiplexing circuitry are applied through two parallel buffer
stages to the analog-to-digital converters in data processors X and Y. The chan-
nel assignments of the analog multiplexer/converter are listed in the Appendix.

Analog data inputs from the analog multiplexer are received by the analog-to-
digital converter. (See Figure 2-32.) The analog-to-digital converter digitizes
the PAM output signal from the analog multiplexer. The analog-to-digital con-
verters use a ramp generation technique to encode the analog signal into an eight-
bit digital word. A single eight-bit conversion is made every telemetry frame.
Processor timing and control circuits provide signals which assure that the con-
versions are made at the appropriate time. The digitized output data is applied to
the digital multiplexer in parallel data form.

The digital multiplexer consists of a ten-bit shift register which accepts eight
parallel bits from the analog-to-digital converter or eight serial bits from the
command decoder and serially shifts them as a ten-bit word with zeros inserted
in the two most significant figures. The bits are shifted high order first. Gates
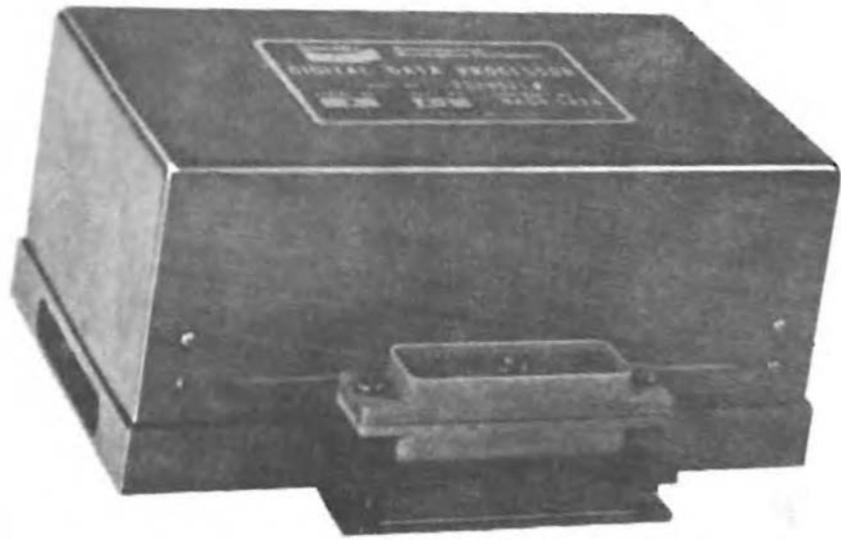
Figure 2-30. Data Subsystem Digital Data Processor
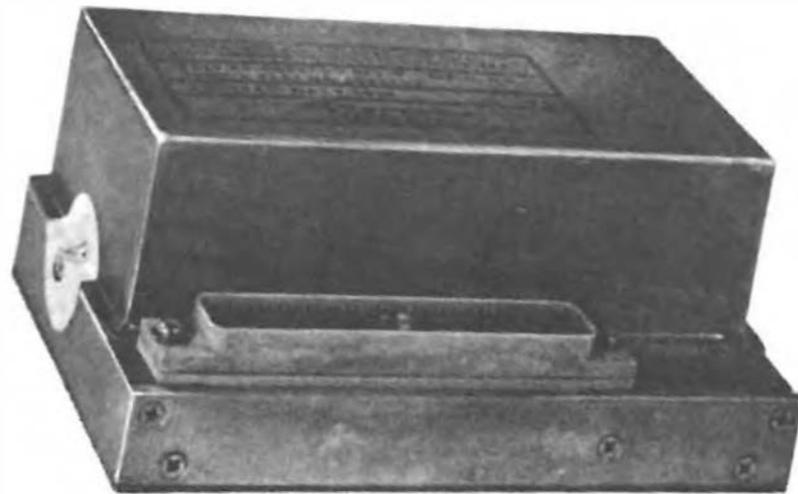
Figure 2-31. Data Subsystem Analog Data Multiplexer/Converter
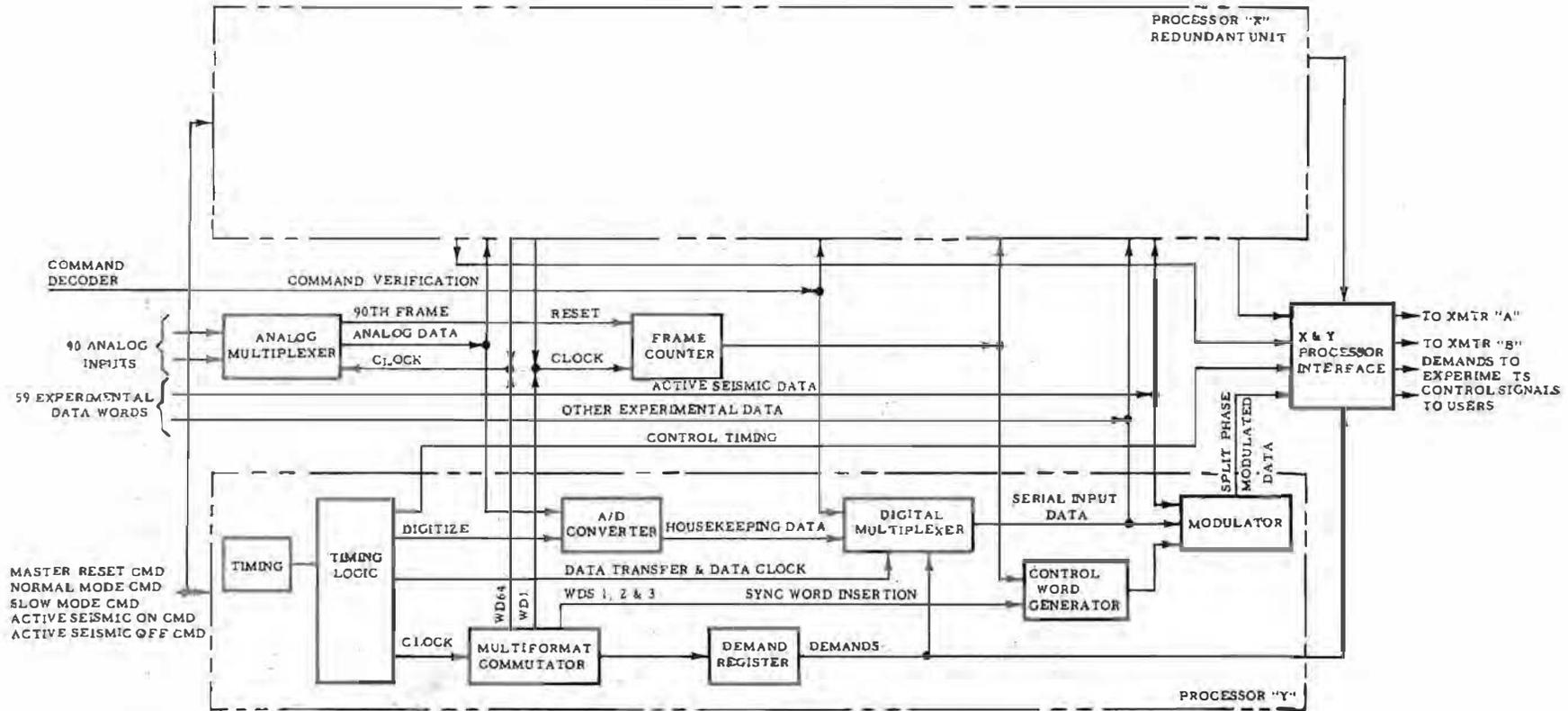
Figure 2-32. Data Subsystem Data Processor,
Functional Block Diagram

Table 2-11. 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. 2 inches
Length	5. 9 inches
Weight	1.86 pounds
Power consumption	Approx. 1.44 watts
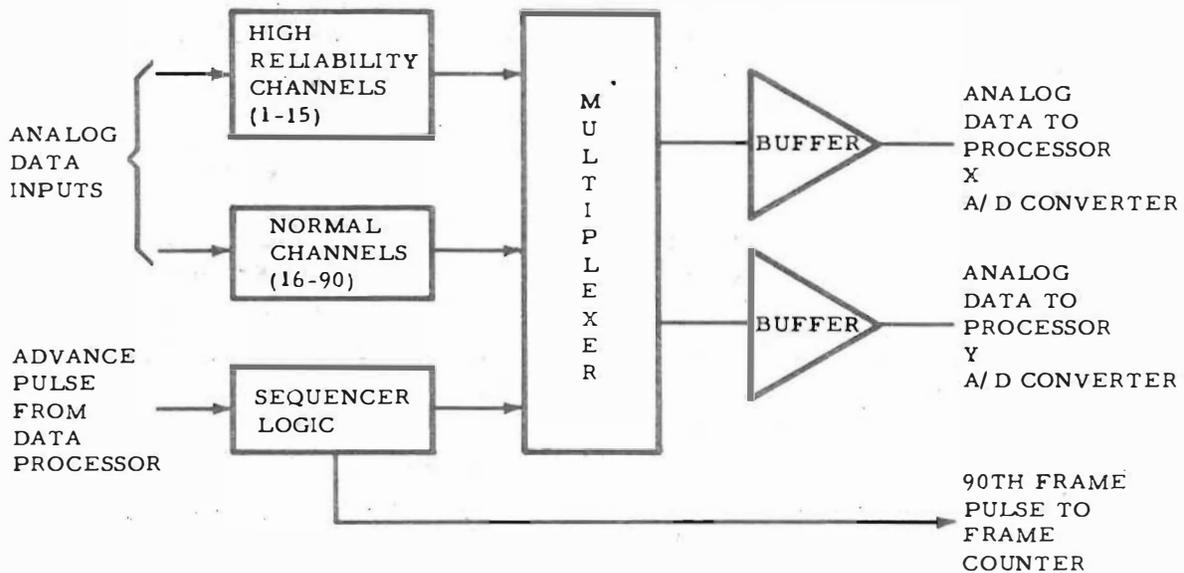
Figure 2-33. Data Subsystem Analog Multiplexer/Converter,
Block Diagram

are included in the digital multiplexer circuitry which gate serial input data directly from the experiments. The gate outputs and the ten-bit shift register outputs are "OR'd" and presented to a two-bit shift register which accepts either serial data from experiments or parallel control word coding.

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

Table 2-12 lists the characteristics of ALSEP timing and control signals.

Table 2-12. Data Subsystem Timing and Control Pulse
Characteristics in Normal ALSEP Data Mode

Pulse Type	Duration* (μsec)	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	9434	once per experiment word in ALSEP frame	occurs asymmetrically as defined in Figure 2-33
Shift pulse	47	640 pulses per frame 1060 pulses per second	a continuous 1060 pulses per second symmetrical square wave

Amplitude: High "or" logic "1" — +2.5 to 5.0 volts
            Low "or" logic "0" — 0 to +0.4 volts
Rise and Fall Times: 2 to 10 μsec 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.

2-47. Operating Modes - The data processor operates in three modes:

   a. Normal mode (1060 bps)
   b. Slow mode (530 bps)
   c. Active Seismic mode (10600 bps).

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

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

The 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 on either the odd or even frame, and between any analog words. The switch to active seismic mode gates on serial data from the active 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 signals, and 90th frames are sent to the experiments at the normal rate.

The data processor formats the data collected from the experiments into a telemetry format as shown in Figure 2-34. The frame rate in the normal mode is 1 and 21/32 frames/second. A complete frame of data is collected approximately every 0.6 second. Each frame contains 64 words of ten bits each giving 640 bits/frame. The basic bit rate is 1060 bps. In addition to the words assigned to the experiments, the first three ten-bit words are used as a 30-bit control word and a single ten-bit word is used for command verification purposes. Experiment word and frame assignments are listed in the Appendix.

The bit assignments for the control word are shown in Figure 2-35. 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 identification for one through 90 frames for correlation of the analog multiplexer data. The 30th bit provides normal or slow mode information during the first two frames of the 90-frame sequence, and data processor serial number identification during the third through fifth frames of the 90-frame sequence. For the sixth through 90th frames the 30th bit has no information and reads logic zero.

2-48. Timing and Control Signals - Timing and control logic circuits provide synchronization signals for use throughout the ALSEP system.

The basic clock is a 169.6 KHz oscillator. A master flip-flop divides the clock frequency down to 84.8 KHz. The 84.8 KHz signal drives a divide-by-eight

FLIGHTS 1 & 2

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

WORD TOTALS	LEGEND
3	x = Control
29	X = Passive Seismic - Short Period
12	- = Passive Seismic - Long Period
2	● = Passive Seismic - Long Period Tidal and one Temperature
7	o = Magnetometer
4	S = Solar Wind
5	I = Suprathermal Ion Detector
1	CV = Command Verification
1	H = Housekeeping

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

Figure 2-34. ALSEP Telemetry Frame Format (Sheet 1 of 3)

FLIGHT 3

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

WORD TOTALS	LEGEND
3	x = Control
30	X = Passive Seismic - Short Period
12	- = Passive Seismic - Long Period
2	● = Passive Seismic - Long Period Tidal and one Temperature
1	HF = Heat Flow
5	CG = Cold Cathode Gauge Experiment (MSC)
6	CP = Charged Particle Lunar Environment
1	CV = Command Verification
1	H = Housekeeping
3	NA = Not Assigned (all zeros shall be transmitted)

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

Figure 2-34.   ALSEP Telemetry Frame Format (Sheet 2 of 3)

FLIGHT 4

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

WORD TOTALS   LEGEND

3	x	= Control
30	X	= Passive Seismic - Short Period
12	-	= Passive Seismic - Long Period
2	●	= Passive Seismic - Long Period Tidal and one Temperature
5	I	= Suprathermal Ion Detector/Cold Cathode Gauge Experiment
6	CP	= Charged Particle Lunar Environment
1	CV	= Command Verification
1	H	= Housekeeping
4	NA	= Not Assigned (all zeros shall be transmitted)

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

Figure 2-34.   ALSEP Telemetry Frame Format (Sheet 3 of 3)

CONTROL WORD FORMAT
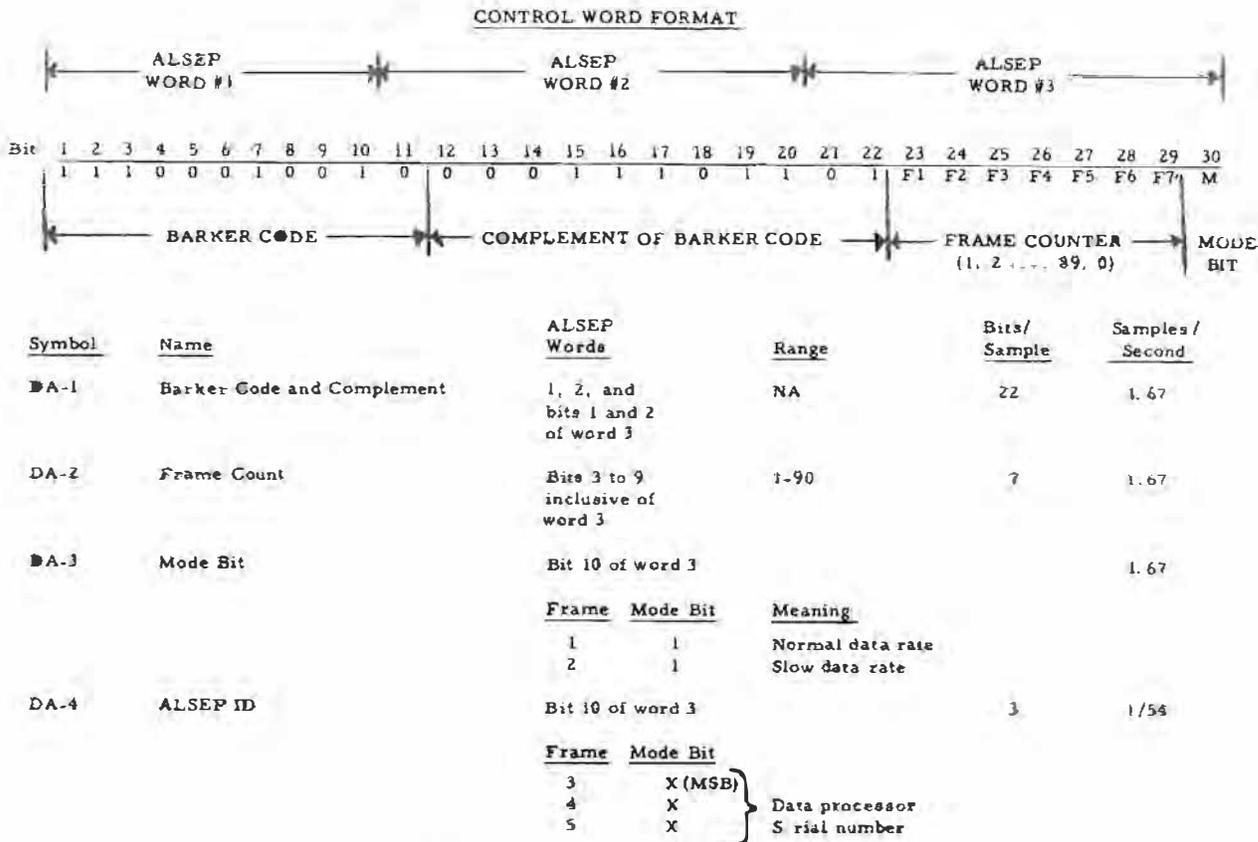
Figure 2-35. ALSEP Telemetry Control Word Bit Assignments

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

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

Symbol	Name	ALSEP Words	Bits/ Sample	Samples / Second
DA-4	ALSEP ID	Bit 10 of word 3	3	1/56

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

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 also drives a divide-by-ten counter. The outputs from this counter are used to drive the sub-bit counter and the timing logic. The sub-bit counter is a divide-by-eight counter with output frequencies of 1060 Hz or 530 Hz depending upon the operational mode. This output establishes the bit rate, drives a bit time counter, and provides timing signals for the timing logic.

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

The multiformat commutator determines the specific assignments of each word within the 64 word telemetry format. The commutator provides signals (demand pulses) of one word length and multiples of one word length in duration so that

data may be gated from the experiments and command decoder through the split-phase modulator and into the transmitter in a predetermined sequence. The output of the multiformat commutator is applied to the demand register and the control word generator.

The demand register performs the following functions:

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

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

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

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

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

A flow chart of the data processor is presented in Figure 2-36.

2-49. DATA SUBSYSTEM TRANSMITTER

The data subsystem transmitter generates an S-band carrier frequency between 2275 and 2280 MHz which is phase modulated by the split-phase serial bit stream from the data processor.

2-50. Data Subsystem Transmitter Physical Description. Two identical transmitters are used in each data subsystem to provide standby redundant operation. Either transmitter can be selected to transmit downlink data. A transmitter is shown in Figure 2-37. Most circuit modules are mounted on a milled out magnesium base plate. Some modules and other components are located inside the base plate. Transmitter leading particulars are listed in Table 2-13.

2-51. Data Subsystem Transmitter Functional Description. Figure 2-38 shows a block diagram of the transmitter circuit. Transmitter output frequency is a function of the oscillator crystal and tuning. Transmitter frequencies will vary between individual ALSEP systems. An oscillator frequency of 142 MHz is used as an example in this discussion. The crystal-controlled oscillator in the oscillator-buffer-phase modulator generates a 142 MHz frequency which is phase modulated by the binary data from the data processor. A buffer amplifier between
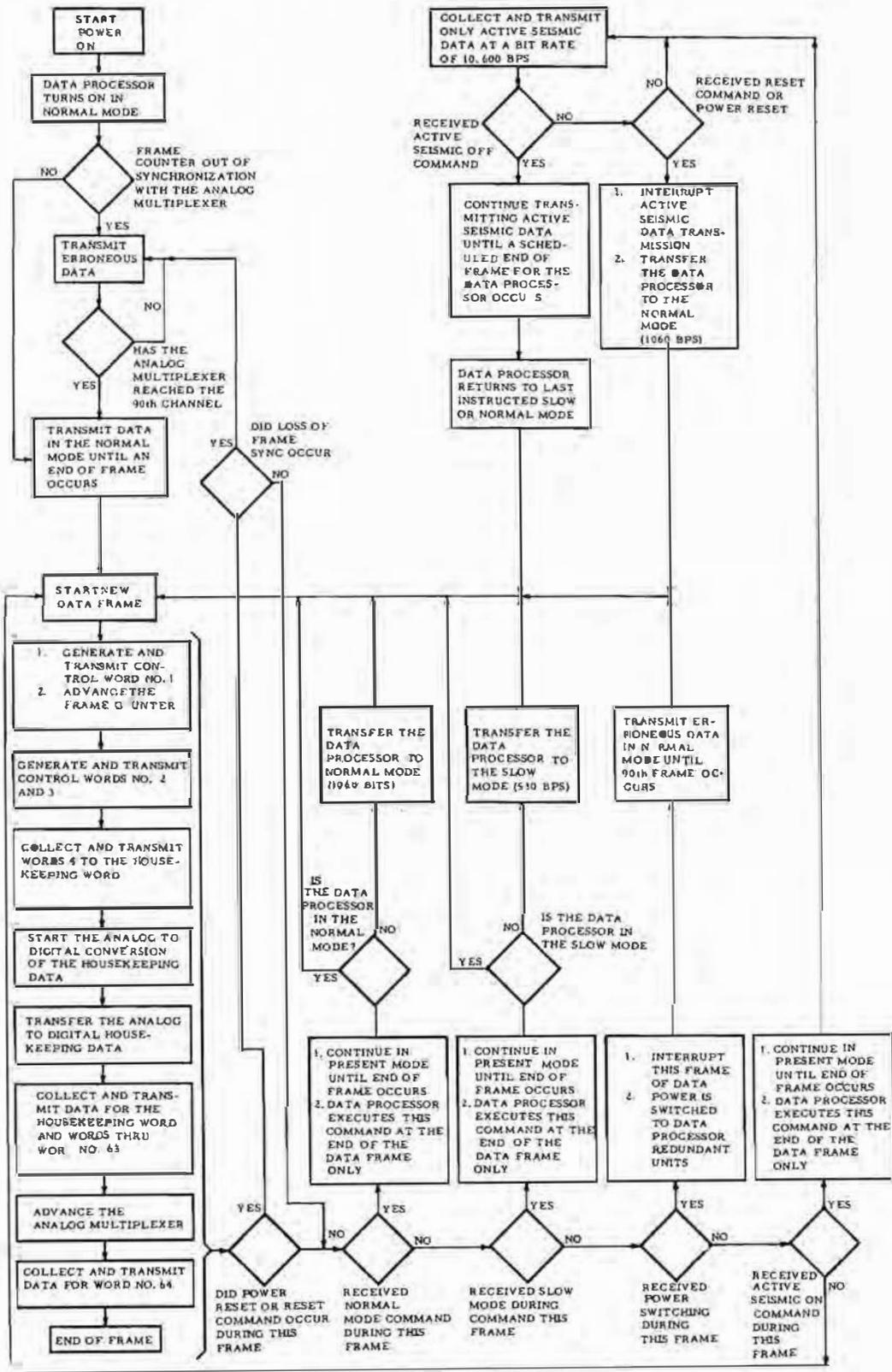
Figure 2-36. Data Subsystem Data Processor Flow Chart
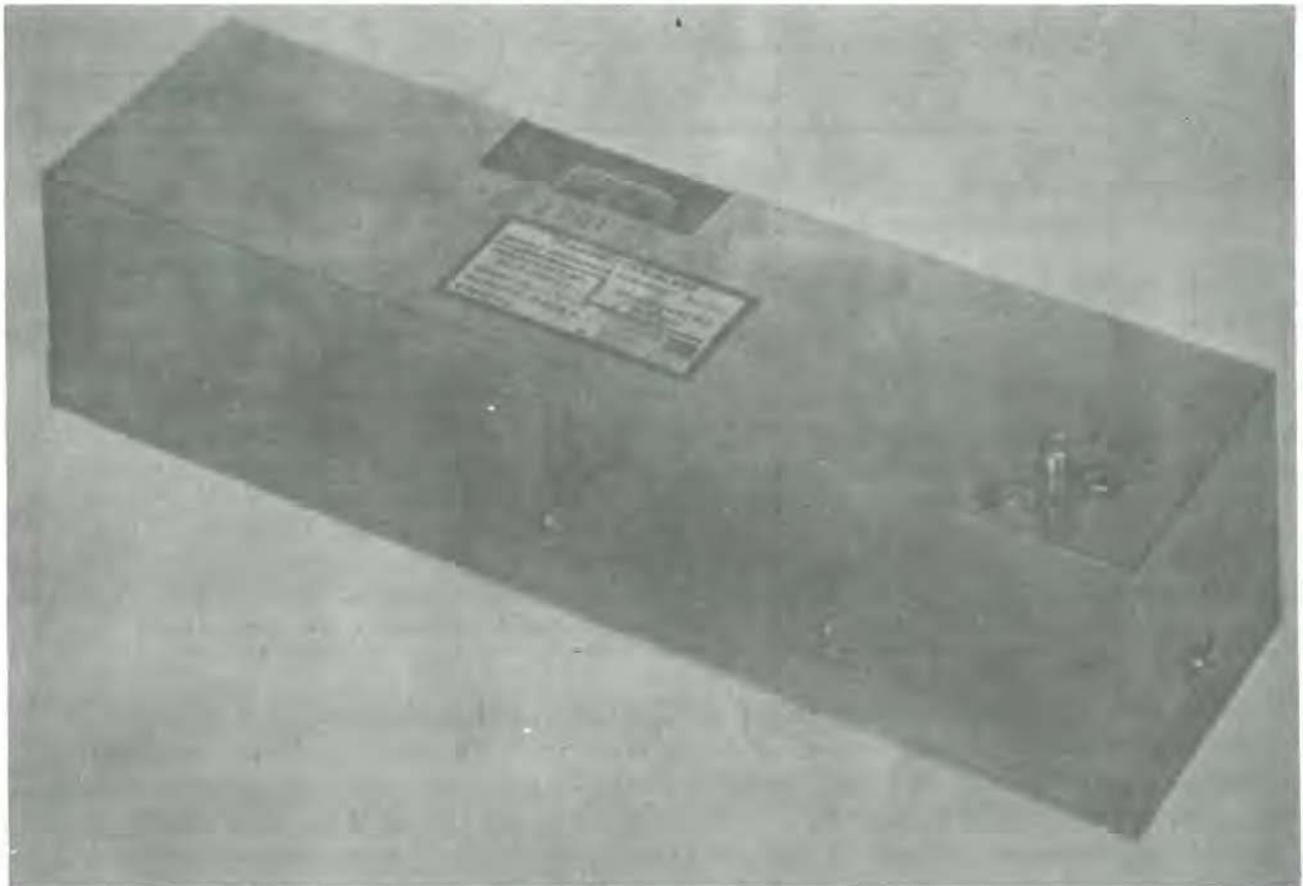
Figure 2-37. Data Subsystem Transmitter

Table 2-13. Data Subsystem Transmitter Leading Particulars

Characteristic	Value
Output frequency	Channel 1 = 2276. 5 MHz
	Channel 2 = 2278. 5 MHz
	Channel 3 = 2275. 5 MHz
Frequency stability	(a) ±.0025%/year (long term)
	(b) 2. 2 x 10^{-10} parts/second (short term)
Output power	1 watt minimum into 50 ohm load with maximum VSWR of 1. 3:1
Output spurious	(a) Harmonically related: 0 dbm, 2-7 GHz
	(b) Other: -50 dbm above 2-GHz - 10 dbm, 7-10 GHz
	(c) All: 0 dbm below 2 GHz
Incidental AM	Less than 3% (0. 25 db power ratio)
Phase noise	Less than 4. 5° rms as measured with a phase coherent receiver having a loop bandwidth 2 B_L = 50 cps
Carrier deviation	Fixed at ±1. 25 radians ±5%
Modulation drive	+2. 5 to +5. 5 volt peak-to-peak (binary voltage only)

Table 2-13. Data Subsystem Transmitter Leading Particulars (cont)

Characteristic	Value
Modulation polarity	+ phase shift for + modulation voltage
Modulation frequency	200 Hz to 12 KHz/binary voltage
Modulation input impedance	22K ohm minimum shunted by less than 100 pf (ac coupled)
Supply voltages	+29 vdc ± 1% +12 vdc ± 1%
Supply power	9. 5 watts maximum (9. 2 watts nominal = 8. 7 w @ +29 v + 0. 5 watts @ +12v)
Telemetry outputs	(a) Oscillator crystal temperature
	(b) Heat sink temperature at highest power stage
	(c) RF level at output (AGC voltage)
	(d) Supply current to power doubler
Weight	1. 13 pounds
Form factor	7. 5 x 2. 0 inches mounting surface x 1. 50 inches in height exclusive of connectors

the 142 MHz oscillator and the phase modulator provides impedance matching and circuit isolation which enhance modulator stability. The analog phase modulator contains a pair of back-to-back varactor diodes which vary the capacitance of a parallel resonant tank circuit by varying the diode back bias at the modulating frequency. A modulator driver maintains the proper diode bias voltages for binary modulation voltage variations from 2. 5 volts to 5. 5 volts peak-to-peak.

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

The 284 MHz output from the frequency multiplier is amplified by the power amplifier, and doubled in frequency by the power doubler. A times four varactor frequency multiplier then quadruples the carrier frequency. The output frequency is between 2275 and 2280 MHz, depending on the selection of the crystal-controlled oscillator. A stripline filter reduces spurious harmonics of the output signal to 30 db below the carrier. Additional spurious rejection is provided by the interfacing diplexer. A directional coupler built into the filter provides an RF output to the AGC circuit.

Monitor circuits provide analog signals to the data processor indicating the status of current supply, AGC voltage and the temperatures at the oscillator crystal and the power heat sink.
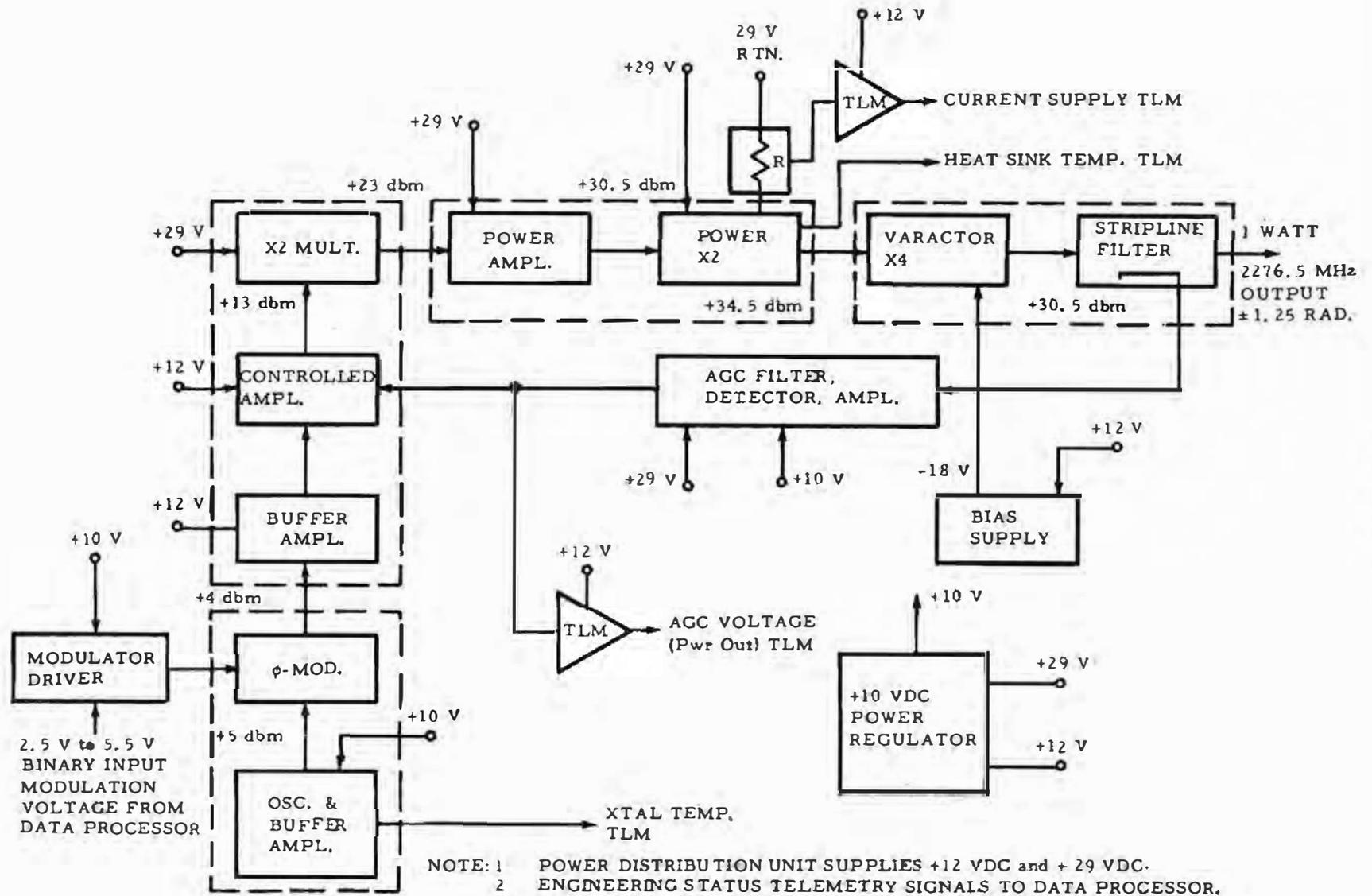
Figure 2-38. Data Subsystem Transmitter, Block Diagram

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 2-39. The power distribution unit is comprised of five printed circuit cards, a mother board to provide interconnection between the individual boards, the component connector, a case, and a cover. All electrical inputs are made through a rectangular, screw-lock, 244-pin connector.

Figure 2-39. Data Subsystem Power Distribution Unit

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 2-14.

Table 2-14. 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 2-40 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.
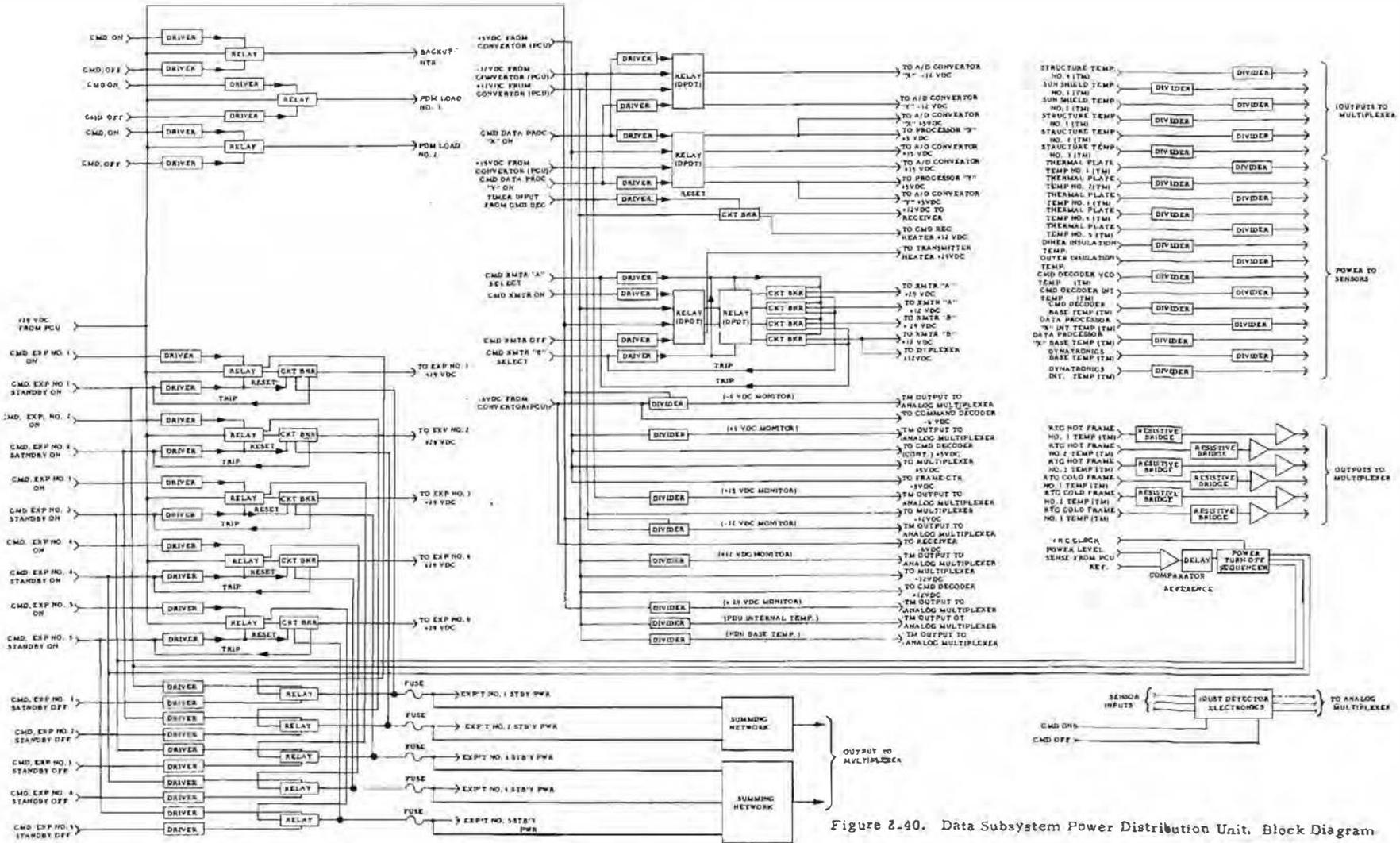
Figure 2-40. Data Subsystem Power Distribution Unit, Block Diagram

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

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

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°F to +200°F temperature span of measurement, provides an output measurement with very low dissipation of power. The maximum sensor current is less than 2 milliamperes.

The nickel wire temperature sensors (2000 ohms at the ice point) are used in dividers to monitor exposed structural temperature, multilayer bag insulation temperatures, and sunshield temperatures. The circuit is a simple divider consisting of 12 vdc supplied through 5900 ohms and the sensor to ground. The output analog signal is taken across the sensor, providing a 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 2-41 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.
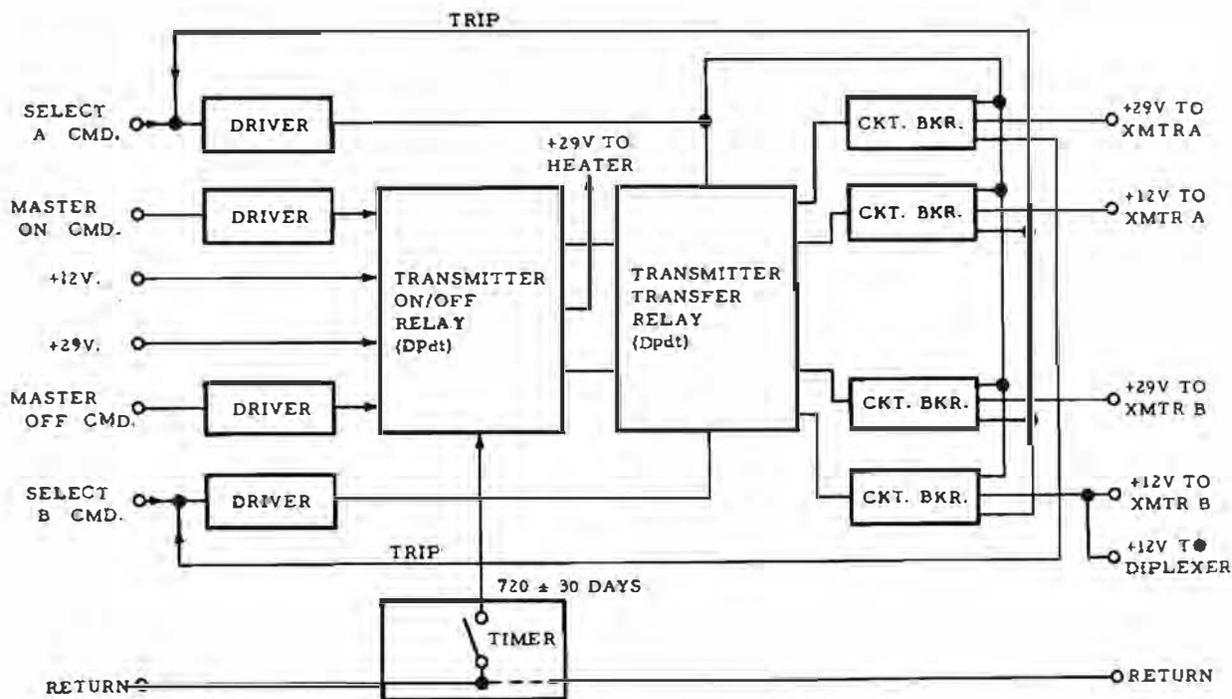
Figure 2-41. Data Subsystem Transmitter Power Control

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

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.

The command receiver requires both 12 vdc and -6 vdc for operation (Figure 2-41). The -6 vdc line is not provided with circuit protection because of the high reliability of the -6 volt line load. The 12 vdc line is provided with overload protection which uses a magnetic latching circuit breaker relay. The sensing coil of this device will interrupt the 12 vdc of the receiver when current is excessive. Since no redundancy of receivers exists, a 12-hour reset pulse is supplied to the breaker every 12 hours. If the receiver is tripped off, a receiver heater load is energized by the transfer of the circuit breaker contacts to maintain thermal balance.

For data processor power control (Figure 2-42), 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.

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

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

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

The operational amplifier consists of an integrated circuit differential amplifier with added circuitry to establish a closed loop fixed gain configuration. Its functional purpose is to condition the output of the photocell detectors, which act as

variable current sources of a 0 to +5 vdc varying dc level for telemetry informa-
tion. Temperature measurement is accomplished with a thermistor attached to
the photocell and a series resistor, located on the card to optimize thermistor
sensitivity and provide a 0 to +5 vdc telemetry signal.
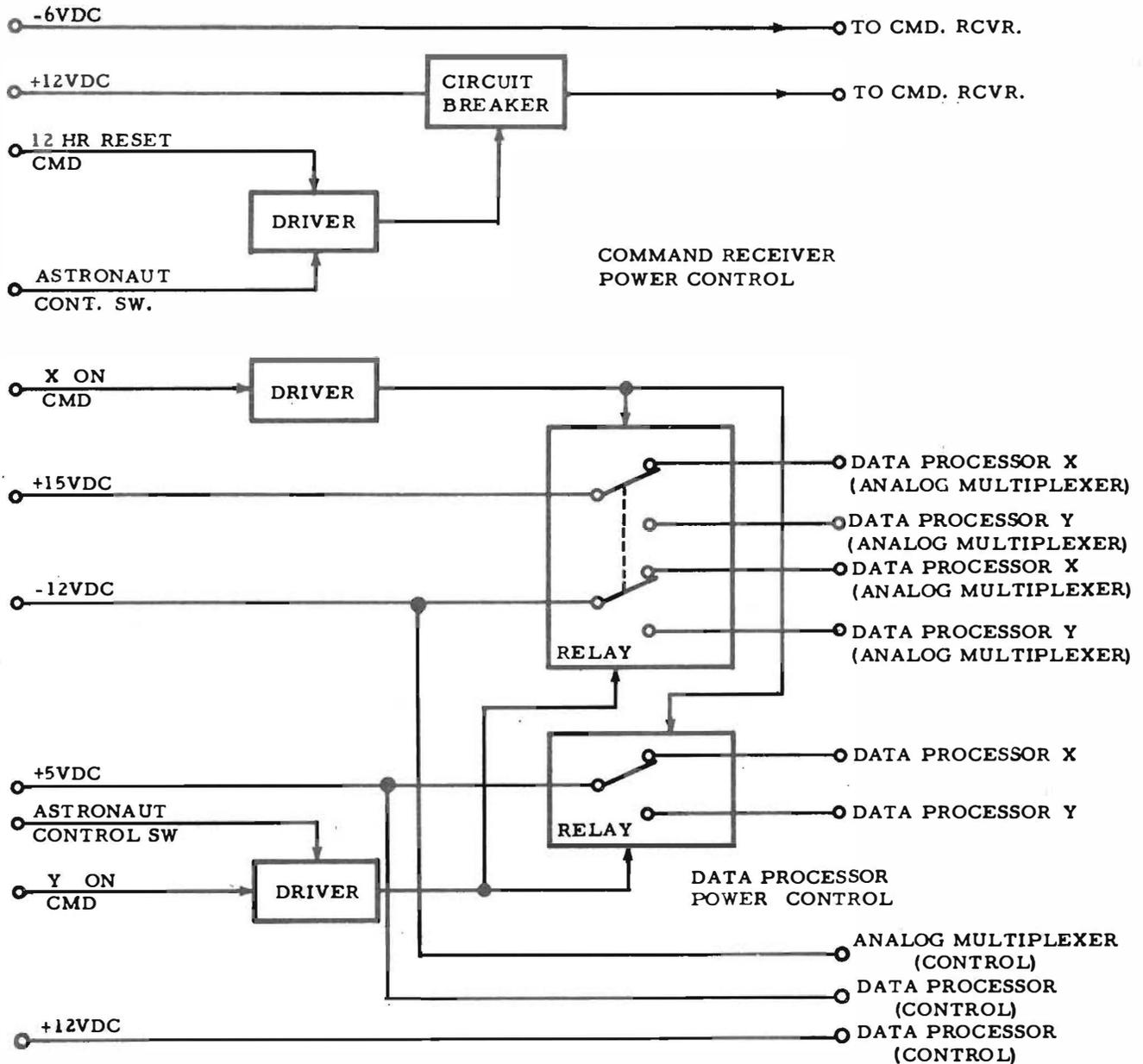
Figure 2-42. Command Receiver and Data Processor Power Control

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 gravita-
tional fields acting upon the Moon and changes in the vertical component of gravi-
tational acceleration.

Analyses of the velocity, frequency, amplitude, and attenuation characteristics of
the seismic waves should provide data on the number and character of lunar seis-
mic events, the approximate azimuth and distance to their epicenters, the physi-
cal properties of subsurface materials, and the general structure of the lunar in-
terior.

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 elec-
tronics 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 pro-
portional 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 sub-
system 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 2-43) 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 level-ing of the sensor upon the leveling stool during deployment by the astronaut. The long period (LP) and short period (SP) seismometers, the sensor leveling plat-form, 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. The LP horizontal sensors comprise 1.65 pound masses mounted on the ends of horizontal booms. The boom and mass assemblies are suspended from the sensor frame so that they are free to rotate through a very limited portion of their horizontal planes in the manner of a swinging gate. Inertia of the masses causes them 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 transducers attached to the inertial masses produce an output proportional to the amount of displacement of the frame with respect to the masses. The LP vertical axis differs from the horizontal axes 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 suspen-sion 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 as-sembly. 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 siesmometer 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 seis-mometer. These subassemblies provide circuitry associated with amplification,
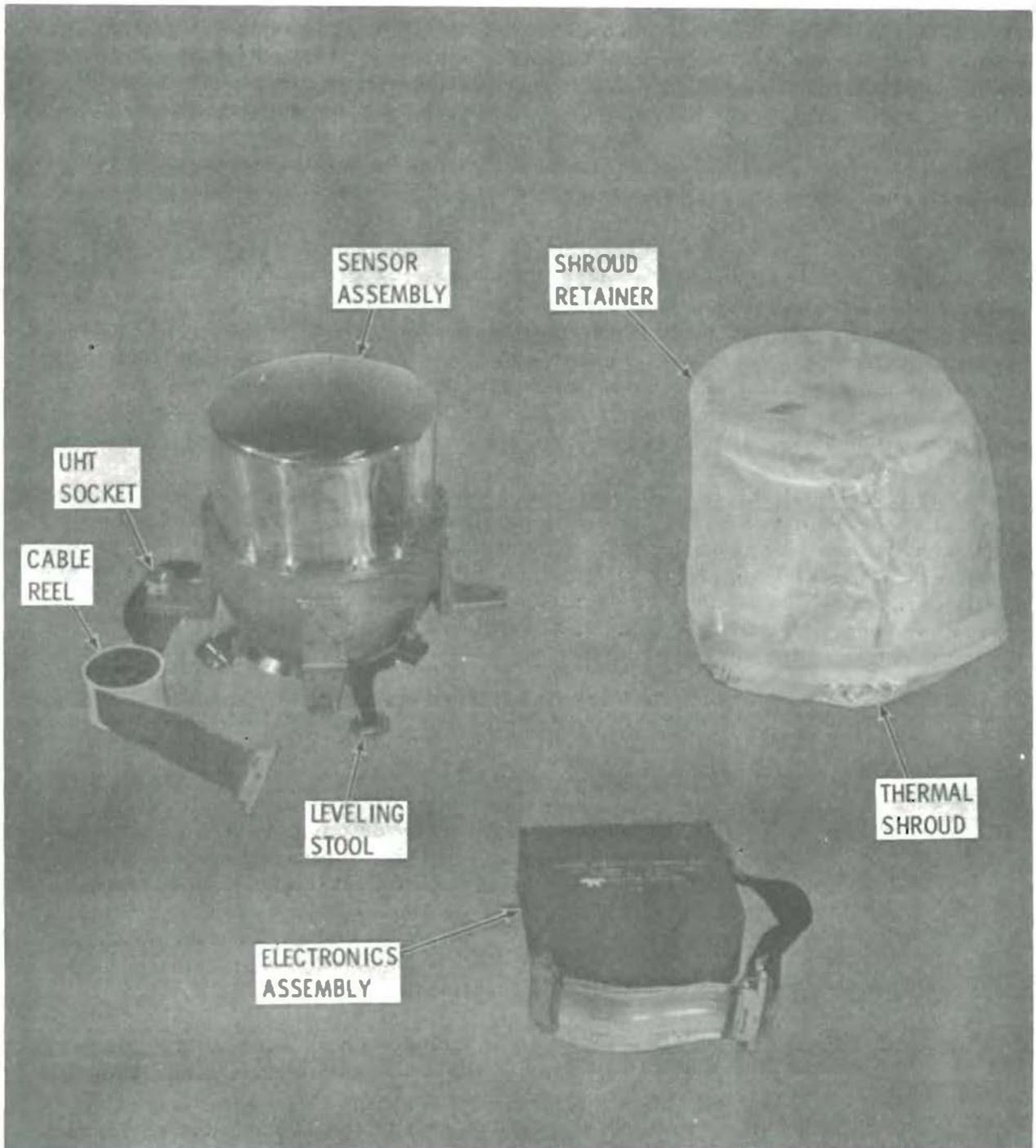
Figure 2-43.   Passive Seismic Experiment Subsystem

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 manganin 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.

On top of the thermal shroud are located the ball level assembly, used by the astronaut to level the sensor to within plus or minus five degrees of horizontal, and the gnomon/compass rose assembly, used by the astronaut to orientate the sensor.

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. The PSE is included on all scheduled ALSEP flights. The sensor, thermal shroud, and CSE are all contained in subpackage number one. The leveling stool is mounted in subpackage two. Table 2-15 lists the physical characteristics and power requirements of the PSE and the performance characteristics of the eight PSE scientific data channels.

Table 2-15. 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.	.01 arc-sec.
LPV (Vertical)	320 μgal	8. 0 μgal
Sensor assembly temperature	±10°C	±.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.	
(Odb = 5v/μ, maximum gain)	+ 42db/oct. 0. 038 to 0. 1 sec.	
	+ 20db @ 0. 1 sec.	
	- 6db/oct. 0. 1 to 1. 0 sec.	
	- 18db/oct. 1. 0 to 20 sec.	
	- 78db @ 20 sec.	

Table 2-15. 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 instrumentation employed to achieve the objectives of the PSE 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 2-44).

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

FROM DATA SUBSYSTEM DATA PROCESSOR { DIGITAL DATA SYNC AND CONTROL PULSES

LONG PERIOD (LP) HORIZONTAL (X AXIS) SEISMIC ACTIVITY MON.

LP X SEISMIC

X TIDAL

LEVELING COMMANDS

LEVELING

LONG PERIOD (LP) HORIZONTAL (Y AXIS) SEISMIC ACTIVITY MON.

LP Y SEISMIC

Y TIDAL

FROM DATA SUBSYSTEM COMMAND DECODER

CALIBRATION AND GAIN CHANGE COMMANDS

UNCAGING COMMANDS

UNCAGING

LONG PERIOD (LP) VERTICAL (Z AXIS) SEISMIC ACTIVITY MON.

LP Z SEISMIC

Z TIDAL

OUTPUT DATA HANDLING

43 WORDS SCIENTIFIC DATA (DIGITAL) OUTPUT

8 ENGINEERING DATA (ANALOG) OUTPUTS

TO DATA SUBSYSTEM DATA PROCESSOR

HEATER CONTROL COMMANDS

THERMAL CONTROL

SHORT PERIOD (SP) VERTICAL (Z AXIS) SEISMIC ACTIVITY MON.

SP Z SEISMIC

FROM DATA SUBSYSTEM POWER DISTRIBUTION UNIT {

+29 VDC STANDBY

+29 VDC OPERATING

POWER

TO ALL FUNCTIONS

TEMPERATURE MONITORING

TEMPERATURE DATA

Figure 2-44. Passive Seismic Experiment, Functional Block Diagram

ALSEP-MT-03

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 $\pm 0.02°C$. 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 tele-
metry word frames. Synchronization and control pulses which control the for-
matting 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
produce useful data. Leveling is accomplished through automatic and/or com-
mand (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; how-
ever, power to the leveling motor of each servo is controlled by separate com-
mands. The ability to activate leveling motors separately provides for independ-
ent 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 com-
mand 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, re-
leasing the caging pins, and unlocking the inertial masses.

The ALSEP power distribution unit furnishes 29 vdc operating and standby (sur-
vival) 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 seis-
mometers. 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 2-16.

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 2-16. PSE Command Functions

Commands	Functions	Preset State
1. Uncaging (arm and execute)	The simultaneous uncaging of all four seismic sensors. Requires separate arm and execute commands.	Caged
2. Feedback filter (in or out)	Switches the feedback (tidal) filters in all three LP channels in or out simultaneously.	Out
3. Leveling Mode (Automatic or Command)	Switches leveling mode of operations from automatic to command, or the reverse, in all three LP axes.	Automatic
4. Leveling Speed (Low or high)	Switches leveling speed in all three LP axes from low to high, or the reverse, while leveling in the command mode.	Low
5. Leveling Direction (+ or -)	Switches leveling direction in all three LP axes to -, or the reverse, while leveling in the command mode.	+

Table 2-16. PSE Command Functions (cont)

Commands	Functions	Preset State
6. Coarse Sensor (in or out)	Switches power on or off to coarse leveling sensors.	Out
7. Leveling Power, X Motor (on or off)	Switches power on or off to leveling motor in LP X horizontal axis.	Off
8. Leveling Power, Y Motor (on or off)	Switches power on or off to leveling motor in LP Y horizontal axis.	Off
9. Leveling Power, Z Motor (on or off)	Switches power on or off to leveling motor in LP Z vertical axis.	Off
10. Gain Change, LP-H (X, Y)	Progressively cycles the (two) attenuators in the X & Y axes signal channels through 0, -10, -20, & -30 db steps, and the (two) attenuators in the X & Y axes calibration circuits through -30, -20, -10, & 0 db steps at the same time. Requires one command per step, or a total of four for a complete cycle.	-30 db
11. Gain Change, LP-Z	Same as 10, except that only two attenuators, one in the signal, and one in the calibration circuit, are involved.	-30 db
12. Gain Change, SP (Z)	Same as 10	-30 db
13. Calibration, LP on or off	Switches power on or off to the step attenuators in the calibration circuits of all three LP axes.	Off
14. Calibration, SP on or off	Switches power on or off to the step attenuator in the SP calibration circuit.	Off
15. Thermal Mode Control	Progressively steps the heater control circuits through four steps, automatic mode on or off, and thermostat bypass mode on or off.	Automatic

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 2-45) 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.
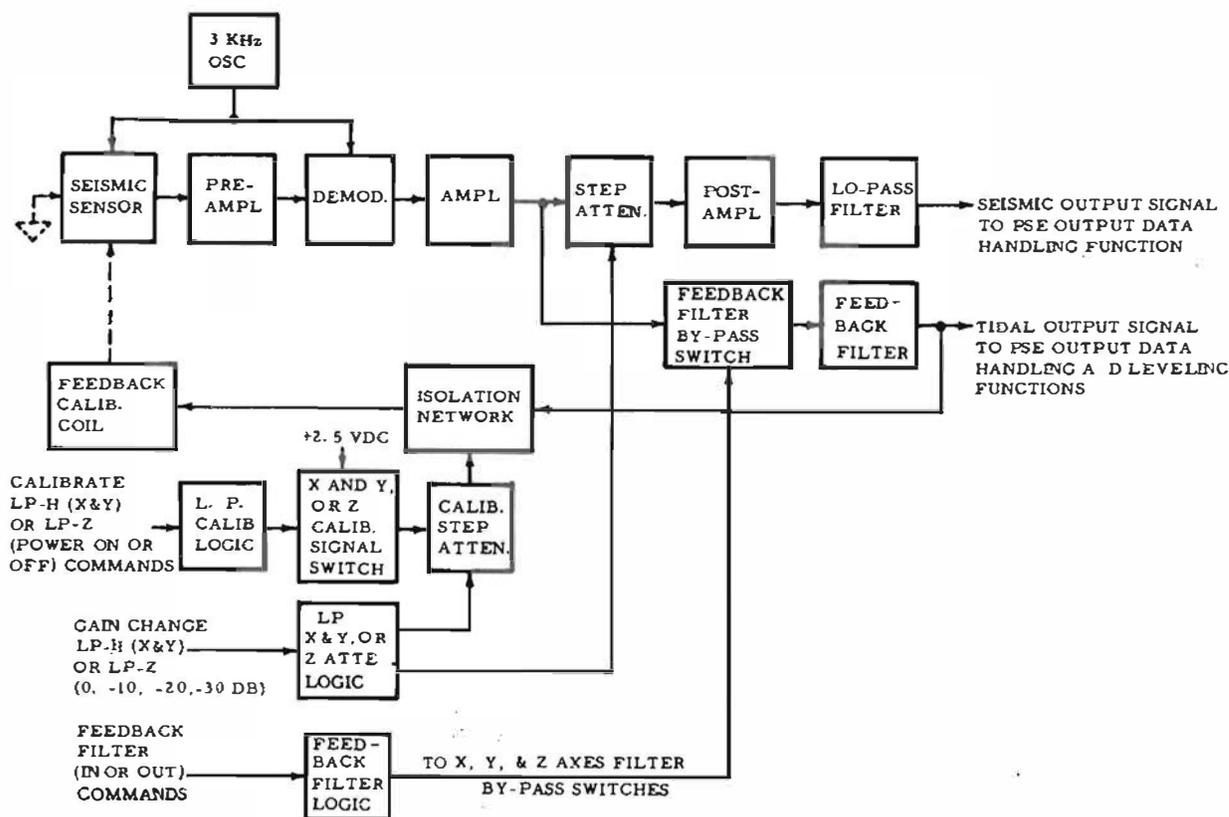
Figure 2-45. PSE Long Period Seismic Activity Monitoring Function, Block Diagram

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
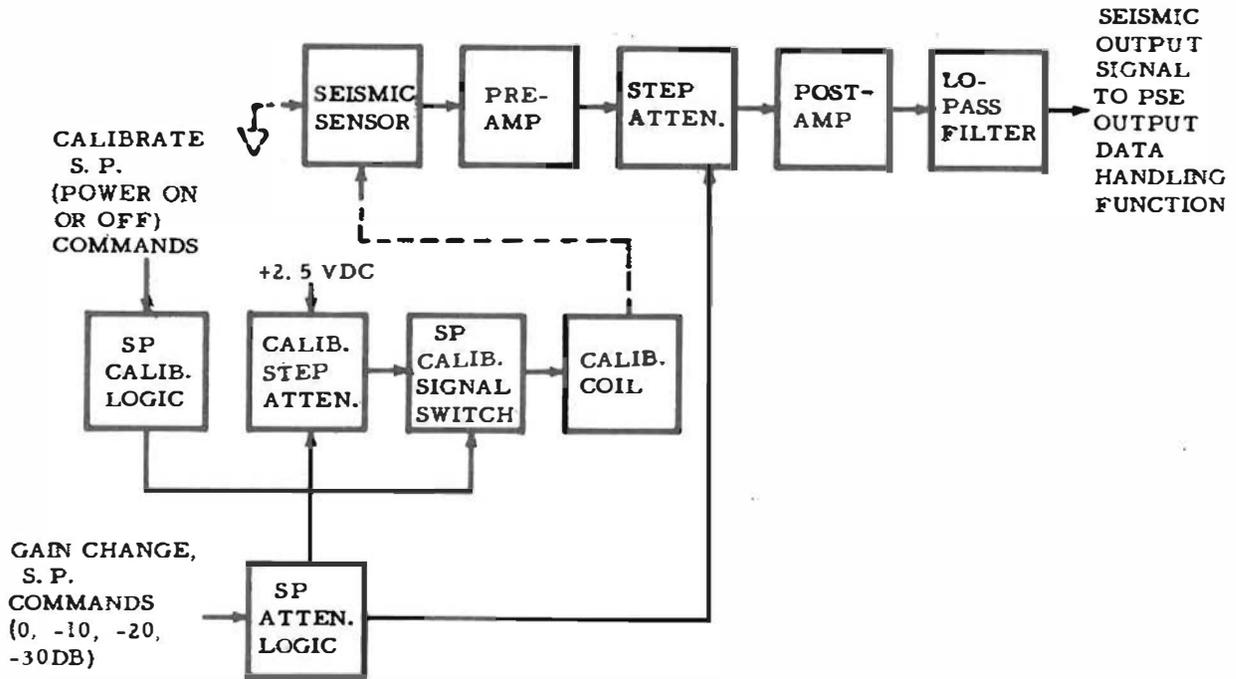
Figure 2-46.   PSE Short Period Seismic Activity Monitoring Function,
Block Diagram

the seismic signal path.   However, when the dc voltages are applied to the feed-
back 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 2-46) 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 ($\pm 5^{\circ}$ 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.
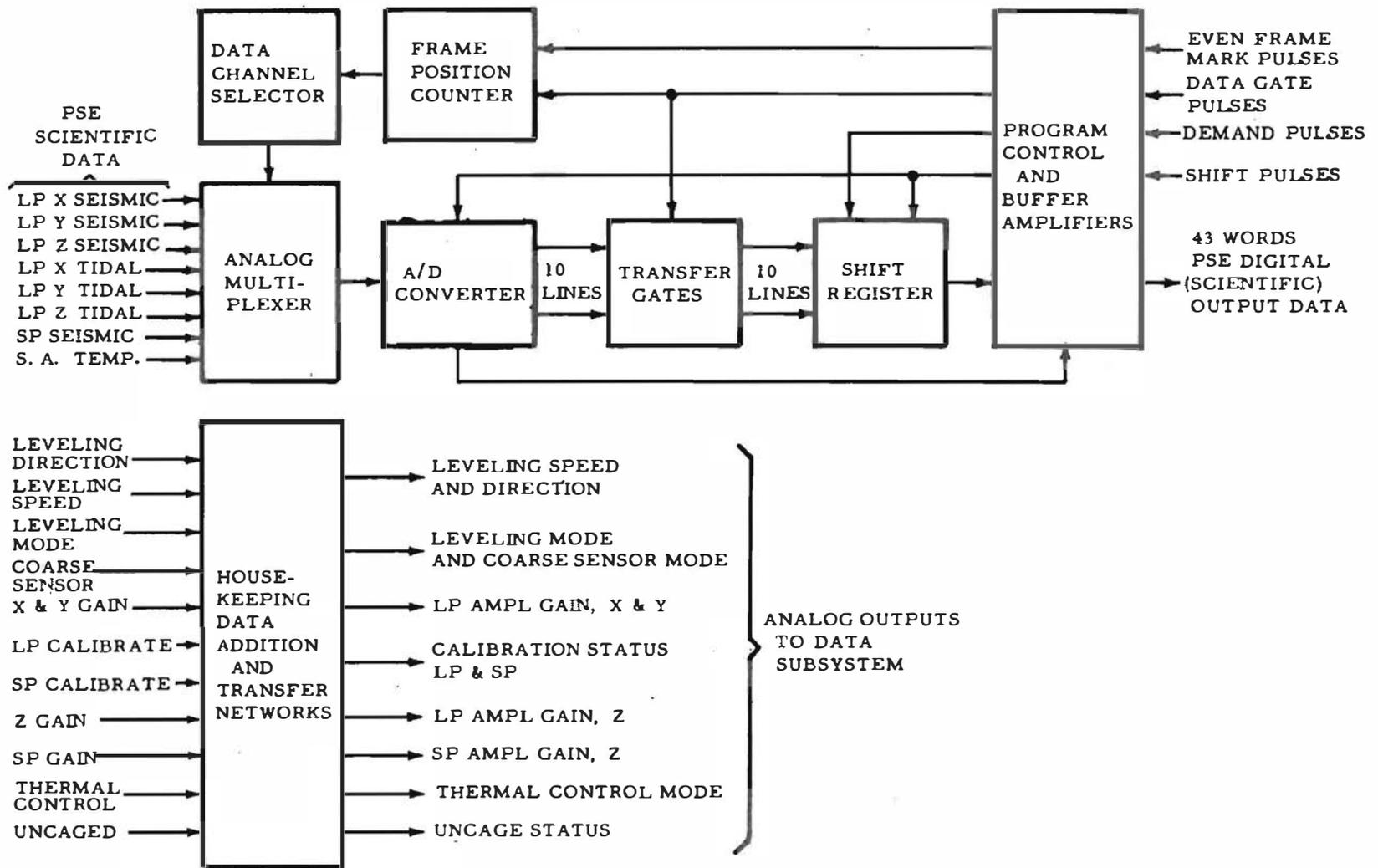
Figure 2-47. PSE Data Handling Function, Block Diagram

2-75. PSE Data Handling - The output data handling function circuits (Figure 2-47)
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 provides 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 in-
put 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 accord-
ing 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 tele-
metry frame. Each data word consists of 10 NRZ bits. A listing of PSE tele-
metry word assignments is given in Table 2-17 and in the Appendix. PSE data
word locations in the ALSEP telemetry frame are shown in Figure 2-48. The
normal ALSEP bit repetition rate is 1060 bps. Under difficult telemetry commun-
ications conditions, the slow ALSEP bit rate, which is half the normal rate may
be used.

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 2-48. 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 2-17 along with the telemetry frame in which they are transmitted in housekeeping word number 33.

Table 2-17. 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 except 2*, 46, and 56	Every
Engineering Data			
LP Ampl. Gain, X and Y	AL-1	33	23
LP Ampl. Gain, Z	AL-2	33	38
Leveling Direction and Speed	AL-3	33	53
SP Ampl. Gain, Z	AL-4	33	68
Leveling Mode and Coarse Sensor Mode	AL-5	33	24
Thermal Control Mode	AL-6	33	39
Calibration Status, LP & SP	AL-7	33	54
Uncage Status	AL-8	33	69

* In Flights 1 and 2

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 2-49) 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.
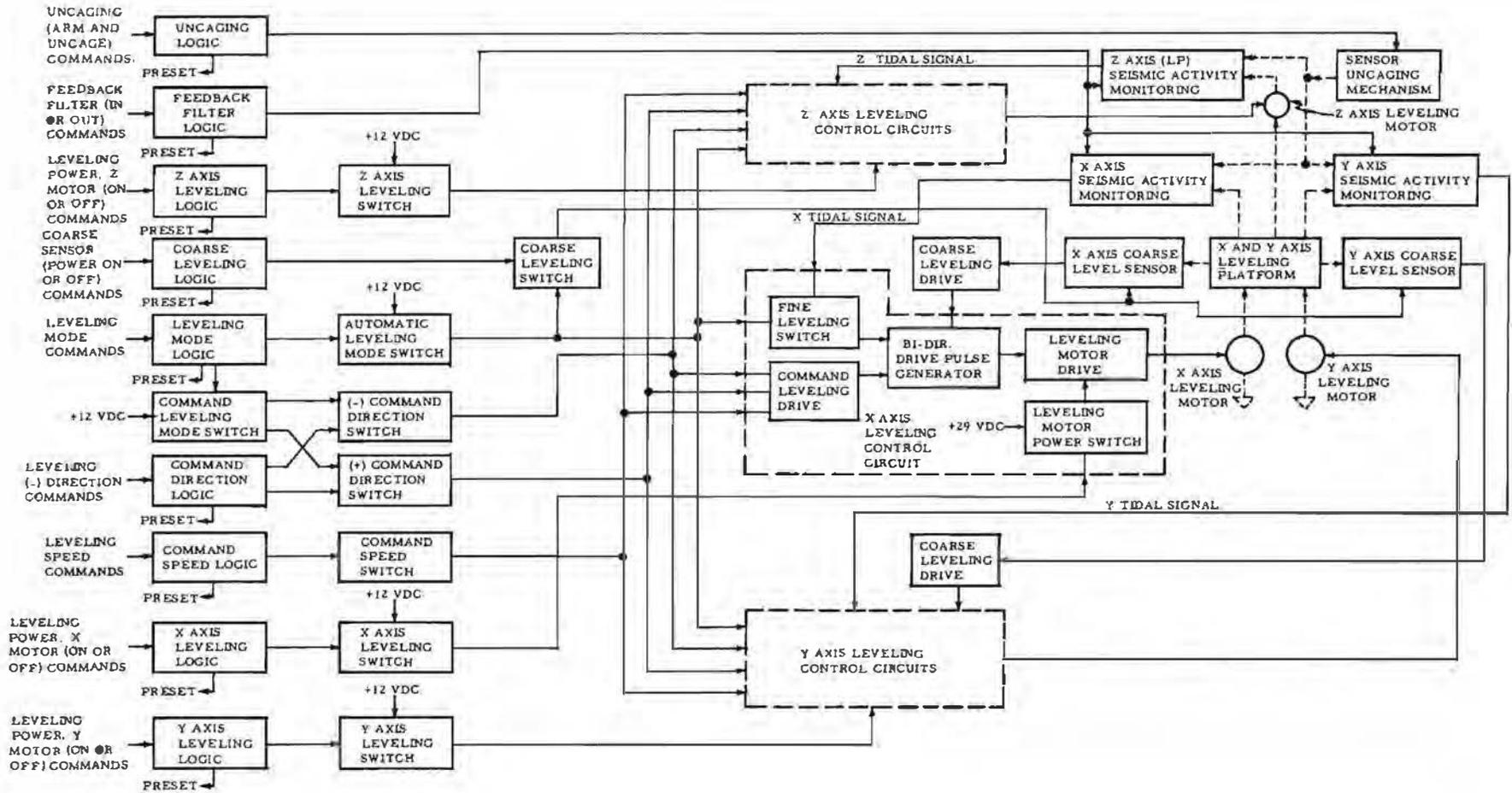
Figure 2-49. PSE Uncaging and Leveling Function, Block Diagram

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 2-49).

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 ($\pm$ 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 2-49 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 2-49. These circuits comprise logic circuits controlling the feedback filter bypass switches of each axis, power to the leveling motors of each axes, leveling mode, and command leveling speed and direction. The feedback filter logic circuit is used to switch the feedback filter out of the feedback loop (simultaneously in all three axes) during the automatic-coarse and command-high speed leveling modes. This is done to decrease the sensitivity of the seismometers during leveling. The leveling logic and switching circuits control application of operating power to the leveling motor drive circuits of their respective axes. The leveling mode, command leveling speed and direction logic, and switching circuits control these functions in all three axes.

Details of the leveling control circuits of the X axis are shown in a block in the center of Figure 2-49. 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 2-49 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 b - 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 2-50) 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.
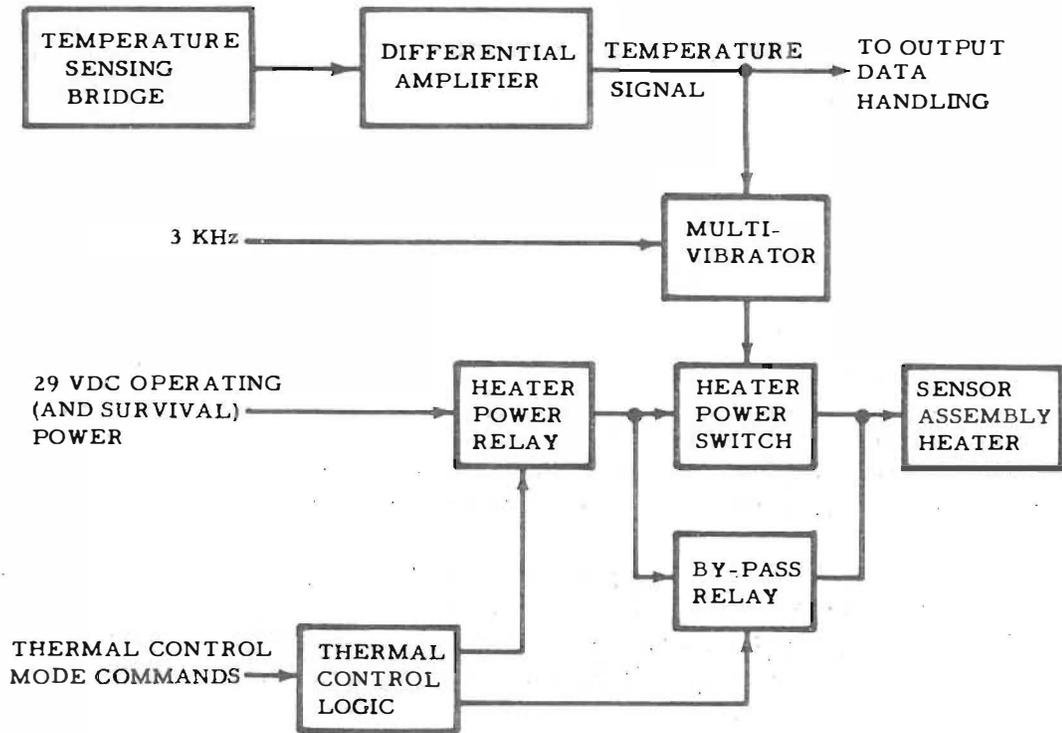
Figure 2-50. PSE Thermal Control Function, Block Diagram
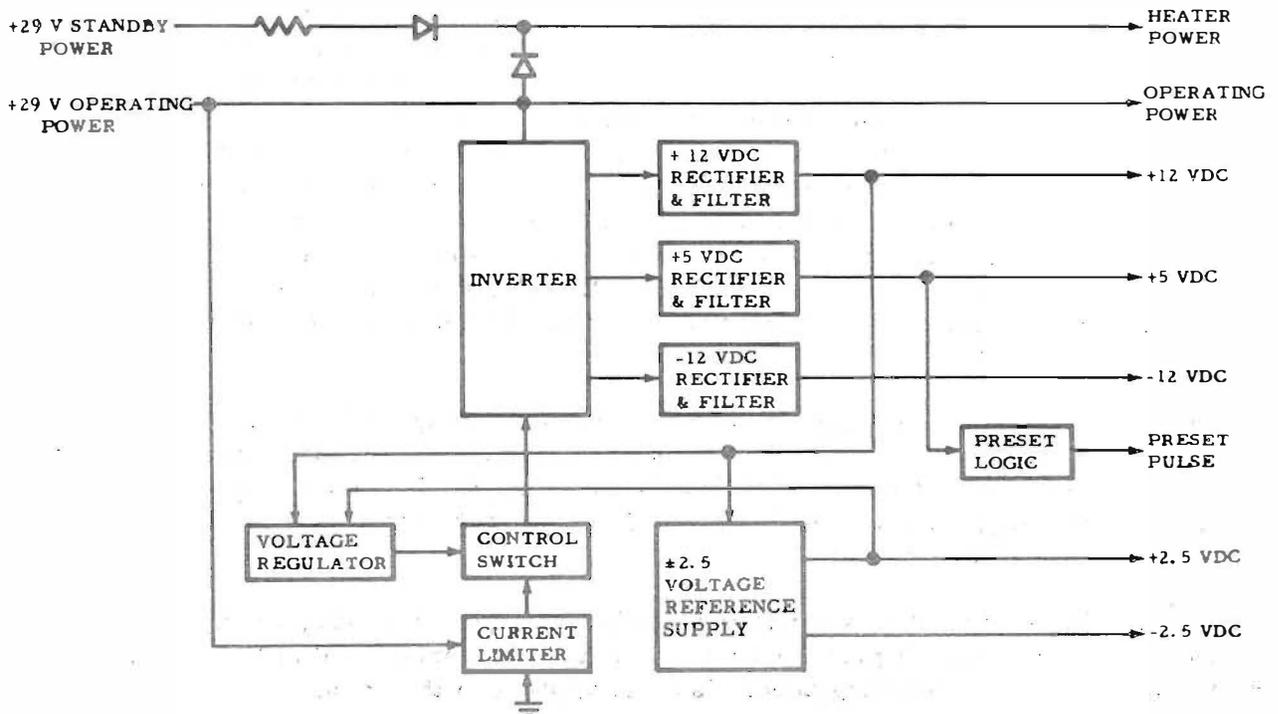
Figure 2-51. PSE Power Converter Function, Block Diagram

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 2-51) 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. MAGNETOMETER EXPERIMENT (ME) SUBSYSTEM

The magnetometer experiment (ME) 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.

2-80. ME PHYSICAL DESCRIPTION

The ME consists of three magnetic sensors, each mounted in a sensor head and located at the ends of three-foot long support arms (see Figure 2-52).   The magnetic 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 ME 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, labeled X, Y, and Z in Figure 2-52, extend from a 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 ME 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 flat H-film cable connects the ME to the ALSEP central station.   Prior to deployment, the cable is contained in an enclosed reel which stows under the ME on subpackageNo. 1.   The whole ME assembly sits on the lunar surface on leveling legs that are fastened to the EGFU.   Each leg is attached at the base of a sensor
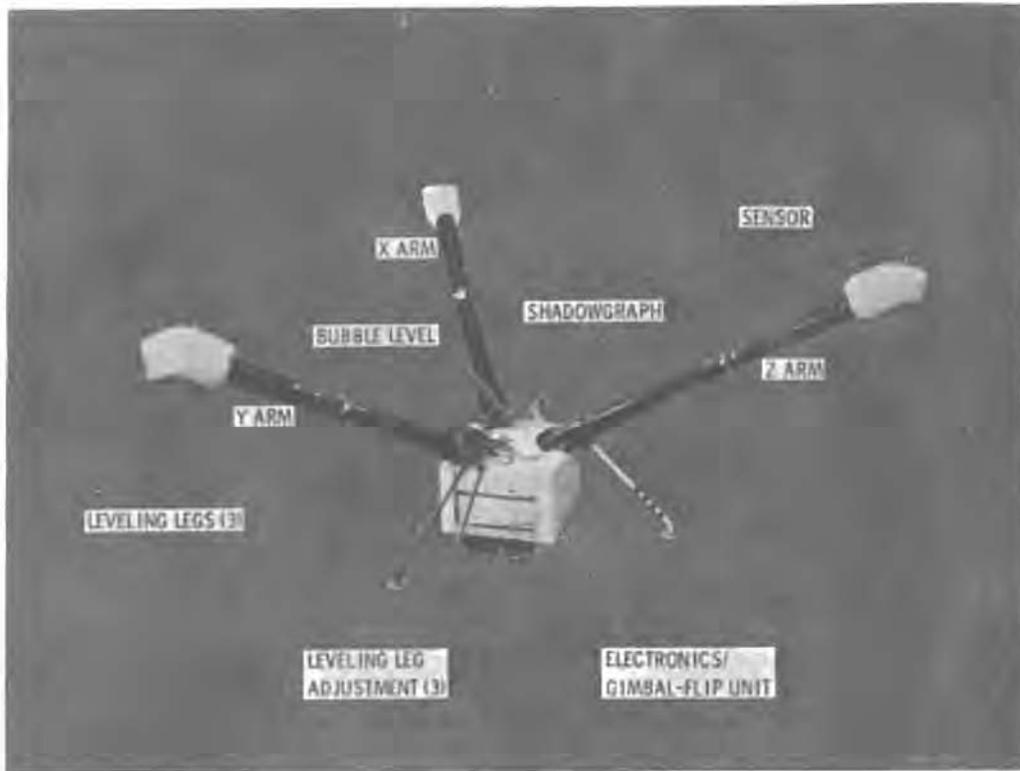
Figure 2-52. Magnetometer Experiment

support arm through an adjustable joint which permits adjustment of the physical attitude of the ME.   The legs swing to an upright position for stowage within the al-lowed flight envelope (See Figure 1-1).   A pad at the bottom of each support leg is sized for ME 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 ME deployment to align the ME into an East-West emplacement.   The astronaut uses the bubble level to position the ME parallel to the lunar surface.   Calibration marks on both instruments are spaced at 1° increments over at $\pm 3^{\circ}$ range.

ME leading particulars are listed in Table 2-18.

2-81. ME FUNCTIONAL DESCRIPTION

The ME has three modes of operation:

   a. Site survey mode.   This survey is performed once on receipt of Earth com-mand after the ME 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 ME sensing of magnetic flux at the lunar sur-face.

Table 2-18. ME 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 ME performs six major functions as shown in Figure 2-53 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
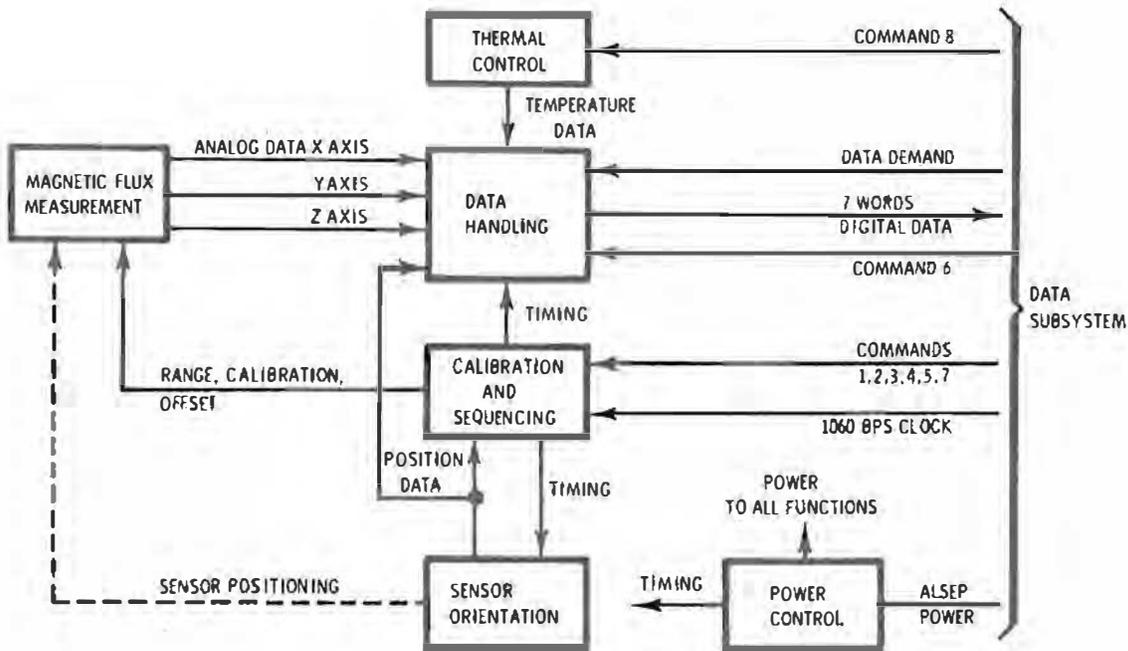
Figure 2-53. Magnetometer Experiment, Functional Block Diagram

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   -100 to +100 gamma
b. Range 2   -200 to +200 gamma
c. Range 3   -400 to +400 gamma

The range is selected by Earth command during ME operation.

The housekeeping function provides:

a. Data describing the condition of the ME subsystem.

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

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

d. Monitoring of ME temperature by five sensors.

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

The sensor orientation function monitors both the leveling of the ME and the position of the magnetic sensors and performs the electromechanical flip and gimbal of the magnetic sensors controlled by Earth command during ME operation.

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

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 ME subsystem.

The above functions are performed in response to the eight Earth commands listed in Table 2-19.

2-82. ME DETAILED FUNCTIONAL DESCRIPTION

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

2-83. Electromagnetic Measurement and Housekeeping Function. Figure 2-54 is a functional block diagram of the ME 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.

Table 2-19. ME Command List

Command Number	Nomenclature	Function
1	Range Select	Selects dynamic range for magnetic sensor operation
2	Steady Field Off-set	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.
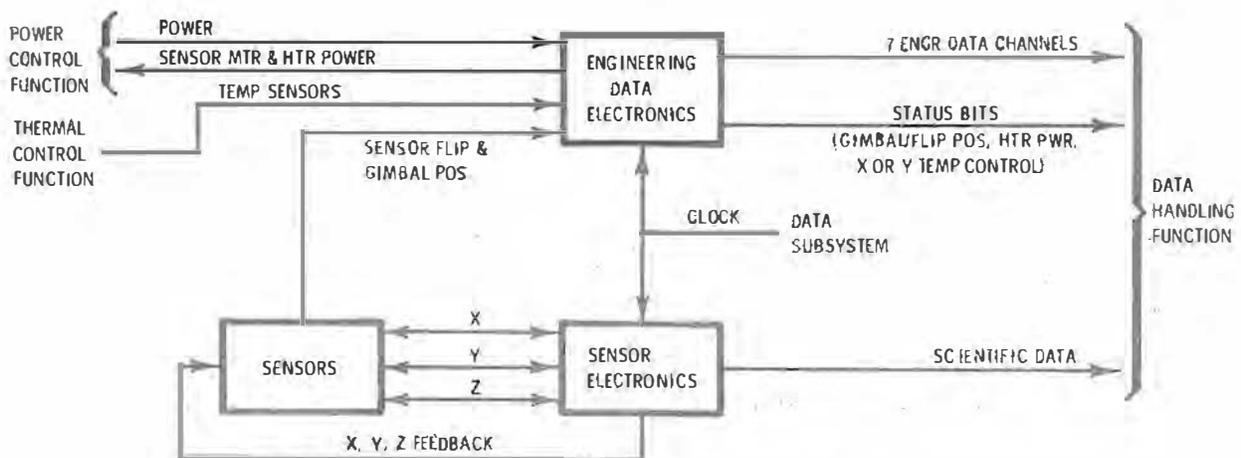
Figure 2-54. Electromagnetic Measurement and Housekeeping Function, Block Diagram

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 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.

2-84. ME Calibration and Sequencing Function. The ME calibration and sequencing functional block diagram is shown in Figure 2-55.
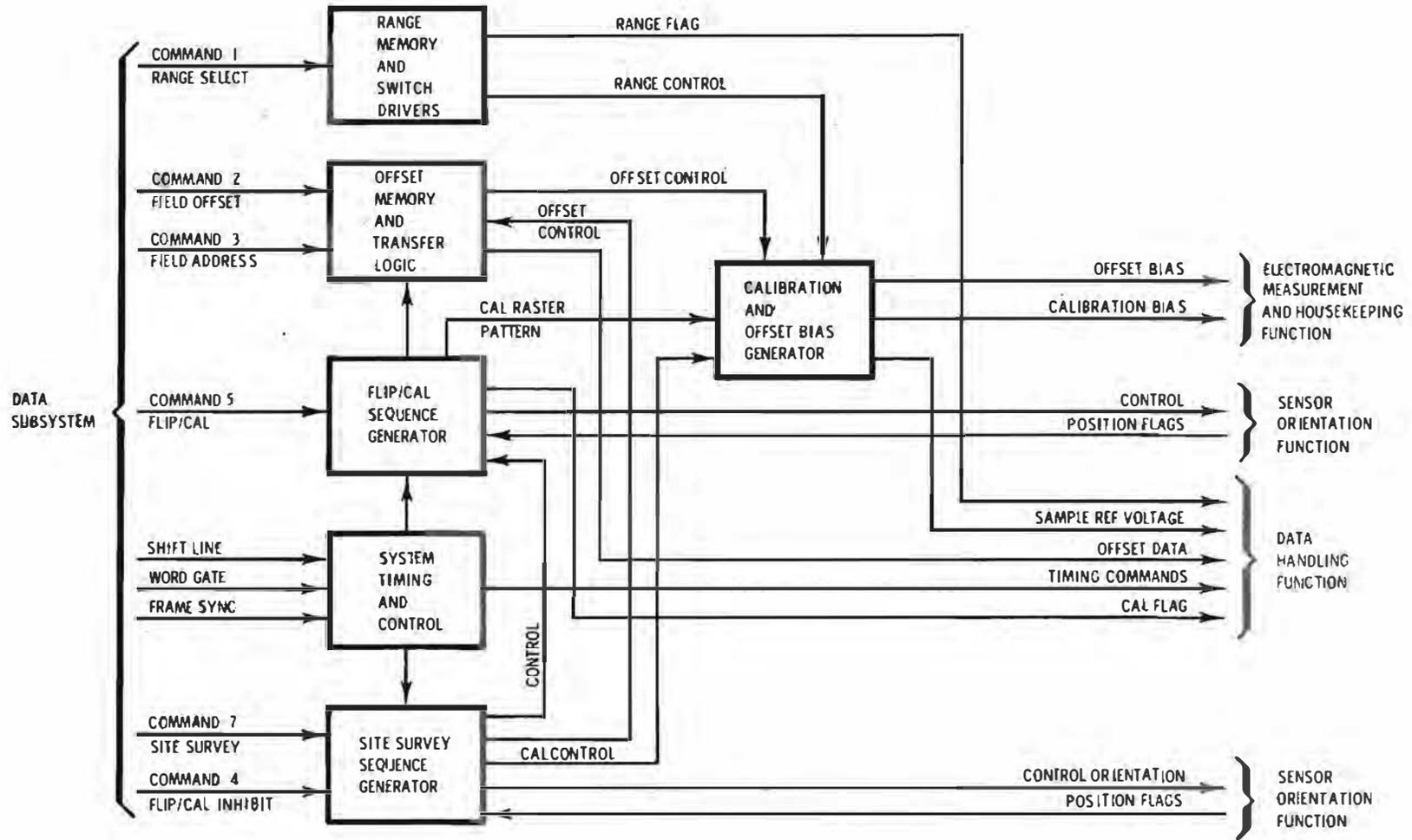
Figure 2-55. ME Calibration and Sequencing Function, Block Diagram

The flip/calibration sequence generator is automatically switched on by the ALSEP central station timer at 12-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 ME sensor flippers in the ME positioning function to flip them 180 degrees. 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 flipper 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 flipper power switch off and the Y flipper 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 described in the previous paragraph.

The site survey is performed once at the start of ME 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 flipper 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 above for Y axis
j. Subsequence 2 Complete
k. Initiate Subsequence 3
l. Repeat steps b through f above 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 flipper 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 stored 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.

2-85. ME Sensor Orientation Function. A functional block diagram of the sensor orientation function is shown in Figure 2-56.
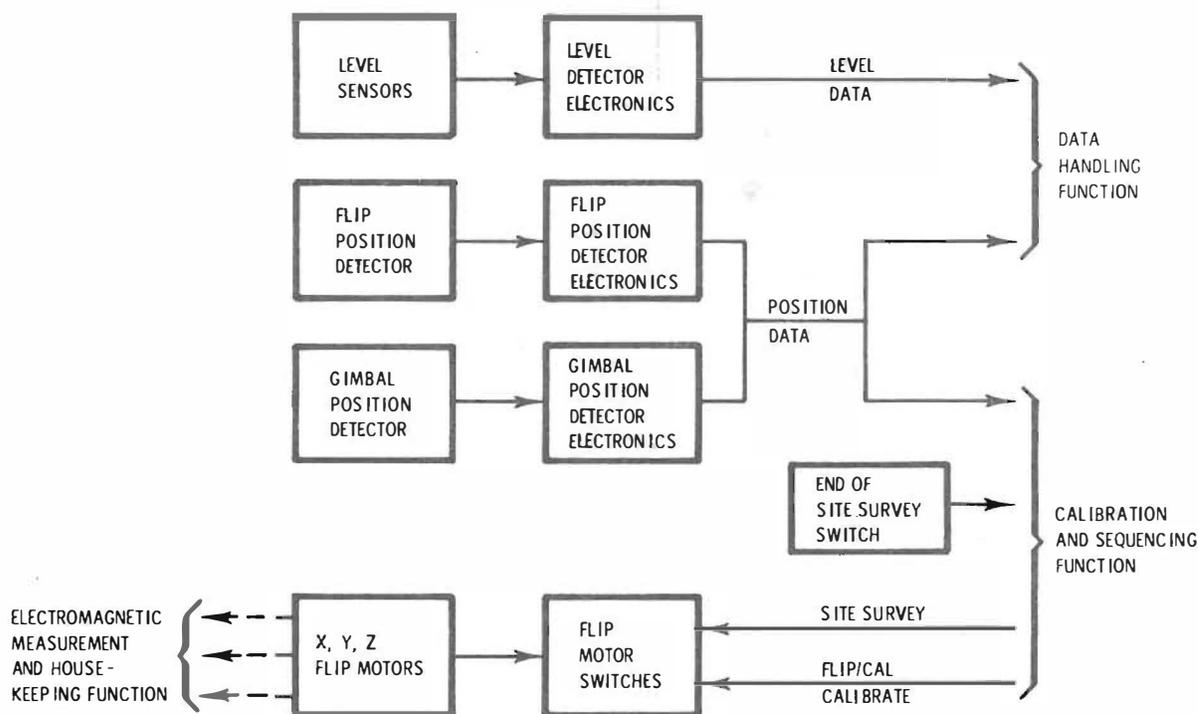
Figure 2-56. ME Sensor Orientation Function, Block Diagram

Throughout operation, the physical attitude of the ME relative to the lunar surface is monitored by an electronic level detector that uses a capacitance pickup and measures attitude $\pm 15^{\circ}$ in two axes. The detector is mounted on top of the EGFU and relays level status data to Earth as part of the ME engineering data. Data on the ME physical attitude is used in interpreting the ME 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 2-57.

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.
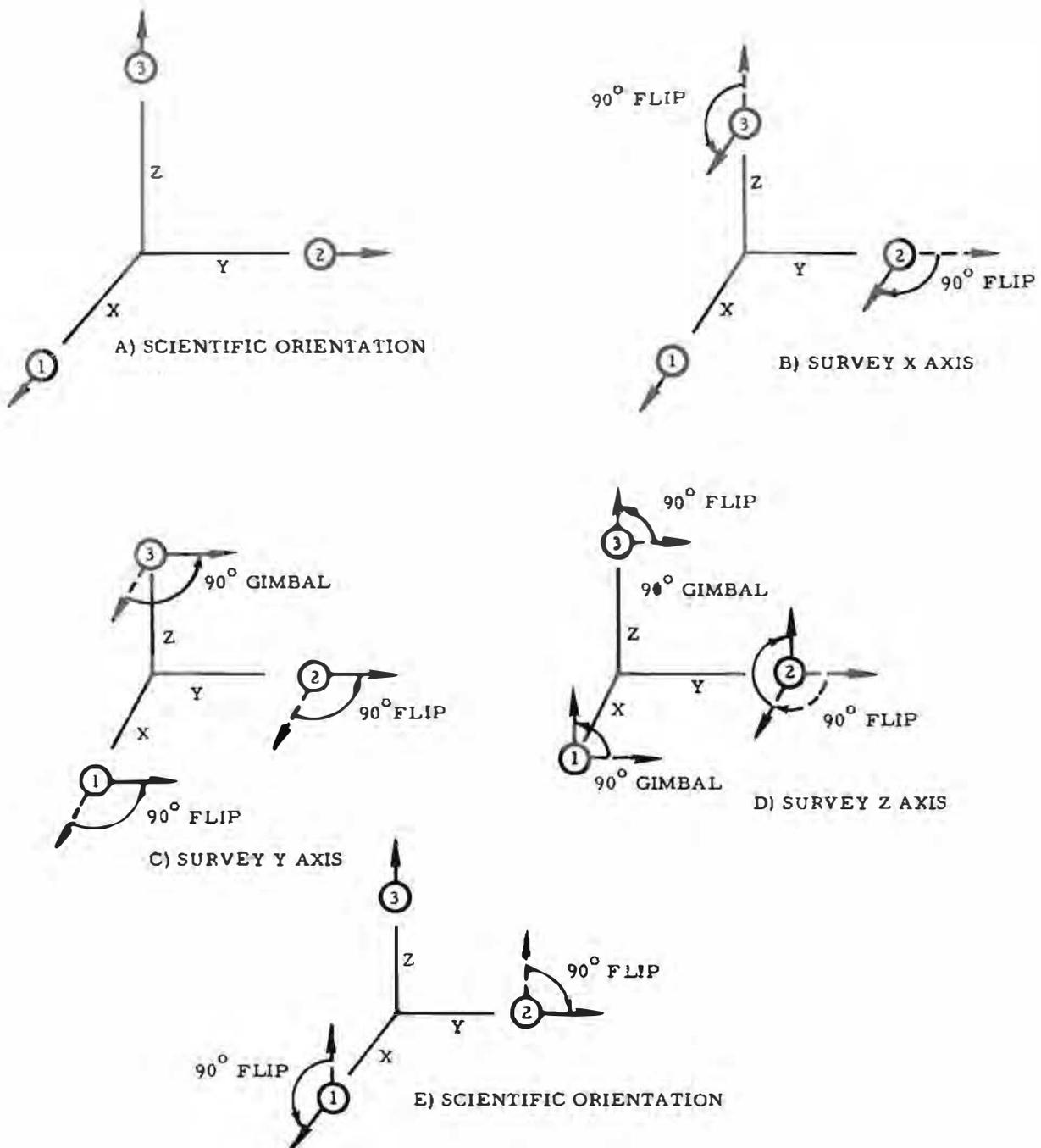
Figure 2-57.   ME Site Survey Sensor Gimbal and Flip Sequence

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 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).

2-86. ME Data Handling Function. A functional block diagram of the ME data handling function is shown in Figure 2-58. The data handling function converts scientific and engineering data into a digital format compatible with the ALSEP telemetry interface.

2-87. 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.
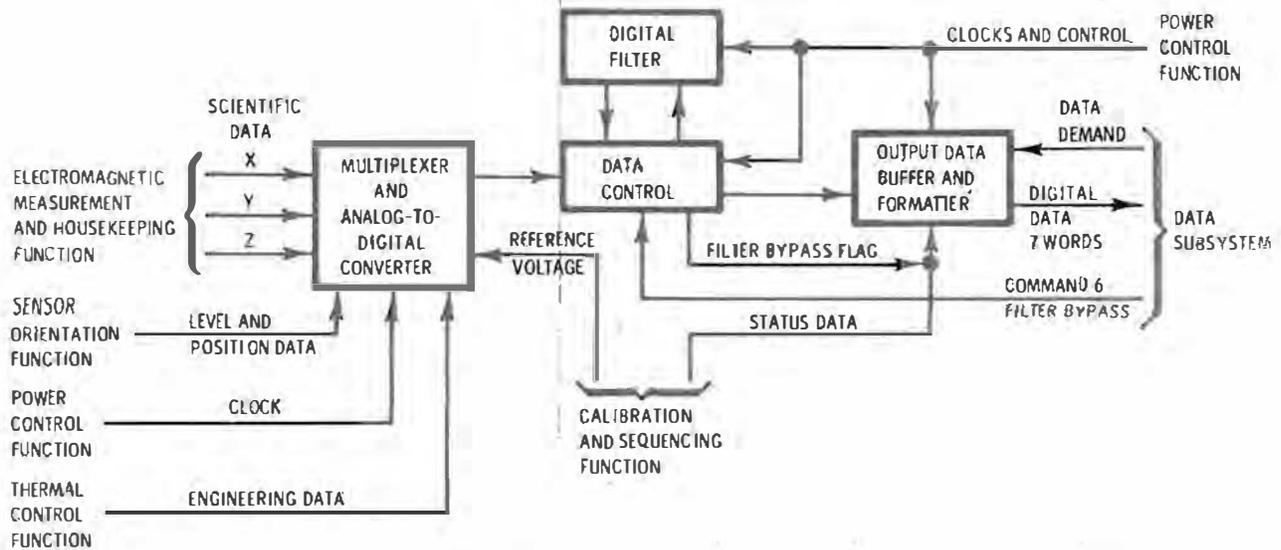
Figure 2-58.   ME Data Handling Function, Block Diagram

The digital filter serves to reduce to an acceptable level the aliasing error intro-
duced 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 repre-
senting 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 to 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.

2-88.   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 engi-
neering 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.

2-89. ME Thermal Control Function - The ME 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 ME 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 2-59 is a block diagram of the active thermal control function.
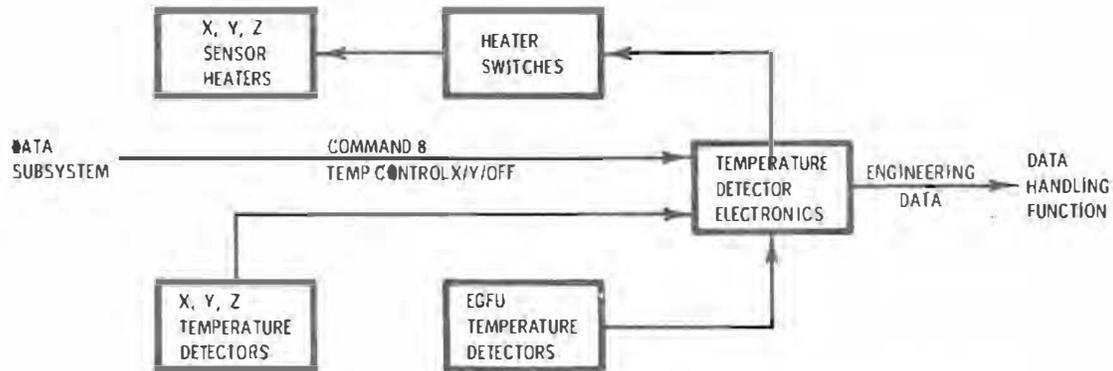
Figure 2-59. ME Thermal Control Function, Block Diagram

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.

2-90. ME Power Control and Timing Function - The ME power control and timing function provides: conditioning of the 29 vdc ALSEP power for use by ME 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 ME clocks synchronized to the 1060 Hz ALSEP clock. Figure 2-60 shows ME loads that couple directly to the ALSEP 29 v 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.
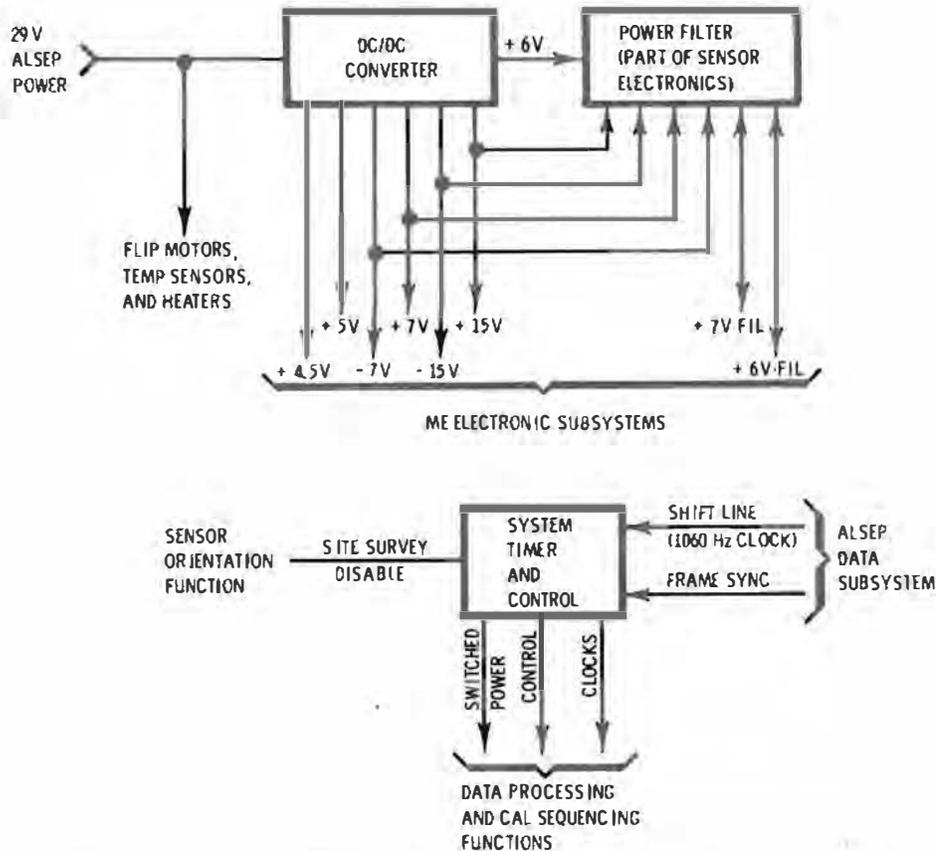
Figure 2-60. ME Power Control and Timing Function, Block Diagram

2-91. ME Data Subsystem Interface. The data subsystem supplies the ME with the eight Earth commands listed in Table 2-19. In addition the data subsystem supplies the following timing pulses to the ME to ensure proper sequencing of output data:

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

The ME 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 2-52). The magnetometer data is contained in ALSEP words 5, 17, 19, 21, 49, 51, and 53 (see Figure 2-34).

Each ALSEP word contains 10 bits and the normal transmission rate is 1060 bits per second. Word 5 contains engineering data and status information and words 17, 19, 21, 49, 51, and 53 contain 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 following format:

2^9	$2^8\ 2^7\ 2^6\ 2^5\ 2^4\ 2^3\ 2^2\ 2^1\ 2^0$
POLARITY BIT	SCIENTIFIC DATA (ALSEP Words 17, 19, 21, 49, 51, and 53)

The polarity bit 0 is plus and 1 is minus and the convertion factors for the three ranges are: (a) 0.1959 γ/bit on 100γ range, (b) 0.3908 γ/bit on 200γ range and 0.7816 γ/bit on the 400γ range.

2^9	$2^8\ 2^7\ 2^6\ 2^5\ 2^4\ 2^3\ 2^2\ 2^1\ 2^0$	
SUBFRAME MARK BIT	ENGINEERING DATA (ALSEP Word 5)	STATUS BITS

This engineering data and instrument status information is contained in 16 sub-commutated frames using the format depicted in Table 4, Appendix B.

The status bit information is listed in Table 5, Appendix B.

2-92. SOLAR WIND EXPERIMENT (SWE) SUBSYSTEM

The Solar Wind Experiment (SWE) subsystem will measure energies, densities, incidence angles, and temporal variations of the electron and proton components of the solar wind plasma that strikes the surface of the Moon.

The experiment will yield data that will be utilized to expand knowledge in the following scientific areas:

    a.   The existence of solar wind at the lunar surface.
    b.   The general properties of the solar wind.
    c.   The properties of the magnetospheric tail of the Earth.

Operating with high gain modulation, the SWE measures electrons having energies between 10 and 1400 electron volts and protons having energies between 75 and 9600 electron volts with a minimum flux density of approximately 10^6 particles per square centimeter per second. The SWE has a field of view of approximately 6.0 steradians and is capable of determining the direction of a collimated plasma flux to within 15 degrees. The accuracy of SWE electronic measurements averages about three percent over a four decade dynamic range.

Seven Faraday cups, designed specifically for the ALSEP Program, collect and detect the solar wind electrons and protons. The cups open toward different but slightly overlapping portions of the lunar sky. Data from each cup individually and from all seven cups combined are processed and fed to the ALSEP data subsystem for Moon-to-Earth transmission. Therefore, with a knowledge of the positioning of the SWE on the lunar surface, the direction of the bulk of charged particle motion can be deduced. Voltages on modulation grids of the cups are changed in sign and varied so that the cups will differentiate between electrons and protons and between particles having different energies.

Accuracy of SWE measurement data is checked by the readout of internally generated calibration signals. The signals are processed through the measurement and data handling sections of the SWE to check their operation.

The SWE output signal is a serial, non-return-to-zero digital train that is accepted by the data subsystem at the rate of four words per ALSEP telemetry frame. A complete SWE measurement cycle is organized into 16 sequences of 186 ten-bit words. Each word of each sequence contains a specific element of data. The words are identified within the sequence by the first two bits of the word and the sequence is identified by the least significant bits of the 185th word of the sequence. Of the 186 words in each sequence, 112 words contain positive particle measurement data, 56 words contain negative particle measurement data, 16 words contain SWE calibration and operation data, and two words contain sequence and cycle identification data.

2-93. SWE PHYSICAL DESCRIPTION

The SWE is shown in Figure 2-61. Physical and electrical characteristics of the SWE are shown in Table 2-20. The SWE consists of a sensor assembly, electronic assembly, thermal control assembly, and leg assembly. A 20-conductor flat cable provides electrical connection between the SWE and the ALSEP data subsystem and allows the subsystems to be separated by as much as 14 feet. The cable is housed in a reel stowed beneath the SWE.
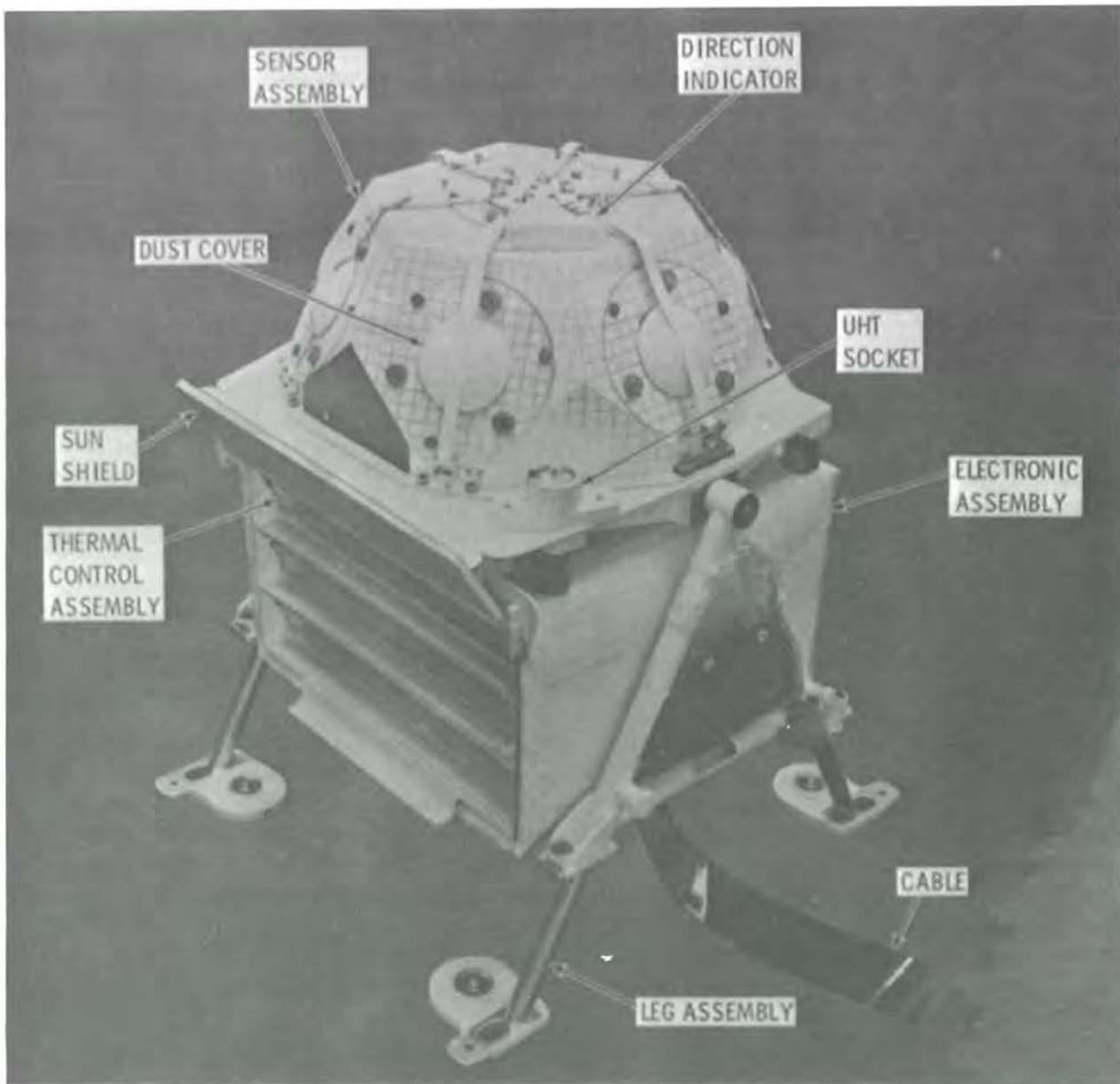
Figure 2-61. Solar Wind Experiment Subsystem

Table 2-20. SWE Leading Particulars

Characteristic	Value
Dimensions	
Stowed	9.0 x 11.1 x 10.6 inches
Deployed	12.0 x 11.1 x 13.6 inches
Weight on Earth	12.5 pounds
Input voltage	28.25 to 29.30 volts
Input power	3.2 watts average. No more than 6.5 watts except briefly for starting transients, dust cover removal, and high voltage gain change command.
Measurement ranges	
Electrons	
High gain modulation	10.5 to 1376 electron volts
Low gain modulation	6.2 to 817 electron volts
Protons	
High gain modulation	75 to 9600 electron volts
Low gain modulation	45 to 5700 electron volts
Field of view	6.0 steradians
Angular resolution	15 degrees (approximately)

2-94. <u>SWE Sensor Assembly.</u> The sensor assembly consists of seven Faraday cups arranged in a hexagonal cupola configuration. One cup is mounted on each of the six sides of the cupola and one cup is mounted on the top of the cupola so that it faces upward after deployment on the lunar surface.

Thin, spring-loaded covers protect the cups from contamination by dust during handling, lunar deployment, and LM takeoff. After LM takeoff, in response to a command initiated on Earth, the covers are released and ejected.

A sun sensor device, consisting of a slit on the top of the sensor housing through which sunlight can enter and a photoelectric cell circuit, will indicate leveling of the SWE after lunar deployment.

2-95. <u>SWE Electronic Assembly.</u> The electronic assembly contains all the circuits required to modulate the plasma flux entering the Faraday cups and to convert cup output signals, calibration data, and operation data into appropriate digital format for the ALSEP data subsystem. The assembly consists of the following modules:

    a.   Module 100 - Signal Chain
    b.   Module 200 - Programmer
    c.   Module 300 - Power Supply and HV Modulator

Heaters in the assembly keep the electronics warm enough for proper operation during lunar nights.

2-96. <u>SWE Thermal Control Assembly.</u> The thermal control assembly includes a set of three radiators on one vertical face and insulation covering the other five faces of the electronic assembly. A sunshield prevents direct sunlight from reaching the radiators. The thermal control assembly, together with the heaters, will maintain the temperature of the electronics within the range for proper operation through all variations in lunar surface temperature.

2-97. <u>SWE Leg Assembly.</u> The leg assembly consists of two tubular A-frames containing telescoping legs. The legs will be extended manually during SWE deployment on the Moon. A button on each A-frame locks the legs automatically during deployment.

2-98. <u>SWE Leading Particulars.</u> SWE physical and electrical characteristics are shown in Table 2-20.

2-99. SWE FUNCTIONAL DESCRIPTION

The SWE is a highly sophisticated scientific instrument that will be used to detect the type, quantity, and directional characteristics of solar wind plasma and to supply this information, in the required digital format, to the data subsystem on demand.

The SWE uses a modified Faraday cup as the basic detector. The cup measures the current produced by the charged particle flux entering it. The energy (more accurately, the energy per unit charge, E/Q, associated with the component of velocity normal to the grid plane) and polarity of the particles are determined by placing a retarding potential, V, upon a modulator grid near the cup entrance and measuring the change in current, Δi, with a known change in retarding potential, ΔV. The change in current, Δi, is, then, a result of the flux of particles that possess the proper polarity and energy to be within the portion of the energy spectrum associated with voltages V and $V + \Delta V$. Using a series of ΔV's, the entire range of voltage (both positive and negative) can be swept out to give a complete energy spectrum of the charged particles.

The basic principle of plasma detection in the SWE is to apply to the modulator grid of a Faraday cup a square wave retarding potential, having both ac and dc components, which modulates the flow of charged particles within a particular energy range and then to synchronously demodulate the ac current resulting from the collection of these particles. This scheme makes it possible to discriminate against the constant flux of photoelectrons produced in the instrument by electromagnetic waves (primarily solar ultraviolet light).

To be sensitive to solar wind plasma from any direction above the horizon of the Moon and to ascertain angular distribution of plasma flux, the SWE has an array of seven cups. Since the cups are identical, an isotropic flux of particles produces equal currents in each cup. For an anisotropic flux, analysis of the relative amounts of current in the seven collectors determines the variation in plasma flow with direction.

The electronics of the SWE supplies the modulating voltage, identifies the currents caused by flux in each Faraday cup, and conditions this information so that it can be sent to the ALSEP data subsystem, telemetered to Earth, and analyzed. A sequence of measurements whose conditions are known by a prior knowledge of the sequence and by a calibration of voltage and current response is produced to provide the data necessary for interpretation.

The following particle parameters will be deduced:

   a. flux intensity – Deduced from knowledge of the magnitude of the collected currents and the effective aperture size. The number of particles detected per second is equal to the current measured by a sensor, divided by 1.6×10^{-19} coulombs, the charge of an electron or proton.
   b. direction of mean velocity – Deduced from knowledge of the sensor geometry, orientation of the SWE on the lunar surface, and relative current readings from the seven cups. The direction will be able to be deduced to within fifteen degrees or less, depending on plasma temperature.
   c. energy of the particles – Deduced from the direction of mean velocity and the relative responses to the various modulating potentials applied to the repelling grid of the cup. (Assumptions are made regarding the mass and charge of the

particles.) For paraxial particles, the particle energy in electron volts is between the upper and lower limits of the modulating grid potential.

d.   type of particles - Deduced from the polarity of the voltage on the modulating grid and from the energy spectrum.   A positive grid voltage corresponds to measurement of positive ions and a negative grid voltage corresponds to measurement of electrons. Protons, electrons, and α particles are known to comprise the vast majority of solar wind particles.

e.   density of particles - Deduced from the velocity and flux intensity of the solar wind.

f.   particle temperature - Deduced from the energy spectrum of the particles and a detailed knowledge of the SWE response to particles. The higher the temperature is, the broader the peak in the energy spectrum will be.

The SWE requires only power and synchronizing signals to provide a continuous train of digital data on the solar plasma impinging on it.

Operation of the SWE may be classified into the functional activities shown in Figure 2-62. These activities are measurement, modulation, sequencing, data handling, power supply, dust cover release, and heaters.
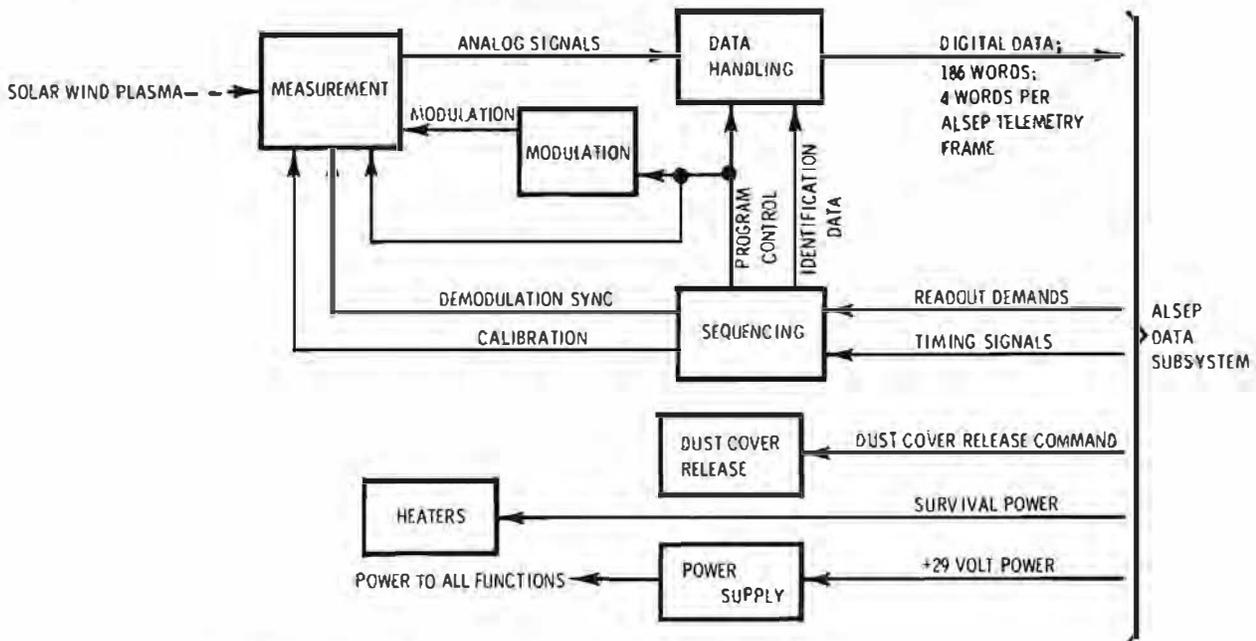
Figure 2-62. SWE, Functional Block Diagram

The measurement function detects the solar wind plasma entering seven Faraday cups and produces a dc voltage proportional to the plasma flux.

The modulation function generates modulation voltages that are applied to grids of the Faraday cups.

The sequencing function provides signals to control various operations of the SWE in conformance with the sequence of the ALSEP data subsystem telemetry format, provides phasing signals to a synchronous demodulator in the measurement function, and provides calibration voltages for the measurement function.

The data handling function converts the analog signals from the measurement function and from several operational sampling transducers to digital signals and combines the digital signals with identification data provided by the sequencing function so that the data are compatible with the requirements of the ALSEP data subsystem for transmission to the Earth and for subsequent analysis.

The dust cover release function permits protective dust covers, held by springs over the seven Faraday cups, to eject from the SWE on receipt of a command signal. The command signal will be initiated on Earth after the LM has left the lunar surface.

The heater function maintains the temperature within the electronics assembly at proper operating temperatures.

2-100. SWE DETAILED FUNCTIONAL DESCRIPTION

2-101. SWE Measurement Function. The measurement function, under the control of the sequencing function, performs measurement of the solar wind plasma, SWE temperatures, and SWE leveling with respect to the Sun.

The basic functional parts of the SWE measurement function are shown in the block diagram of Figure 2-63. The parts are:

a. seven Faraday cup sensors that transform solar wind particles to measurable currents.
b. a sun sensor that indicates SWE leveling.
c. four temperature sensors that provide SWE temperature data and a temperature sensor commutator that sequentially switches data from each of the temperature sensors to the data handling function.
d. seven preamplifiers that amplify the small collector currents of the Faraday cups, and
e. preamplifier switches, a bandpass amplifier, a synchronous demodulator, and a dc amplifier that condition the signals for presentation to the data handling function.

2-102. SWE Faraday Cups. An array of seven Faraday cups detects the solar wind plasma. One cup faces the vertical and the remaining six cups surround the vertical cup so that the angle between the normals of any two adjacent cups is approximately 51 degrees. The acceptance angle of all cups combined is approximately six steradians. Each cup has a circular opening, several grids, and a collector. By successively placing different voltages on the modulation grids and measuring the corresponding collector currents, the flux of charged particles having polarities
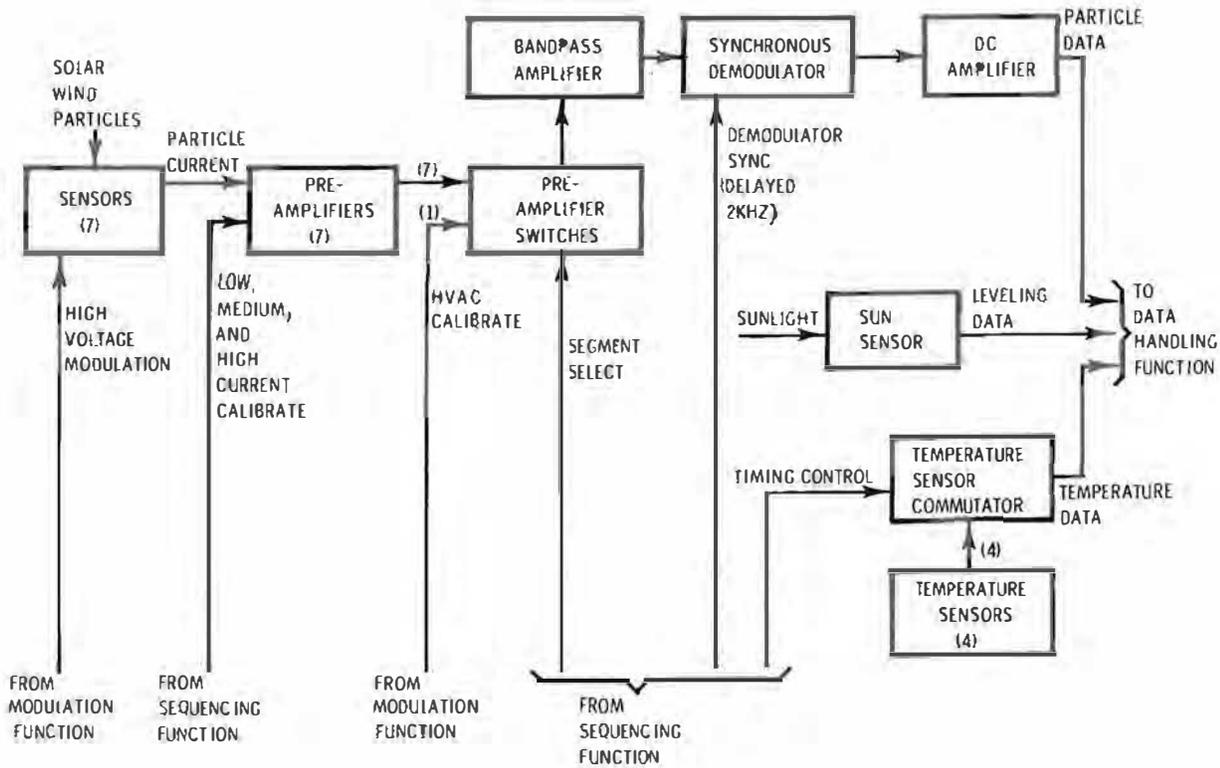
Figure 2-63. SWE Measurement Function, Block Diagram

and energies per unit charge corresponding to each voltage can be determined.
Using a number of negative and positive grid voltages, a complete energy spectrum
of both negative and positive particles can be obtained. Since the cups are identi-
cal, if particle flux is equal in each direction, equal current will be produced in
each cup. If the flux is not equal in each direction, analysis of the relative
amounts of current in the seven collectors will determine the variation of particle
flow with direction.

A diagram of a Faraday cup is shown in Figure 2-64. The functions of the Fara-
day cup grid structures are:

 a. modulator grid - To modulate the incoming particle flux.
 b. entrance grid and screen grids - To terminate the electric field from the
modulator grid and prevent capacitive coupling from the modulator grid to the col-
lector.
 c. suppressor grid - To prevent the escape of secondary electrons or photoelec-
trons from the collector.

The Faraday cup collector plate generates a fluctuating current from the electric
charge brought in by the solar wind particles. The ac signal from each collector
plate is fed to a separate preamplifier.
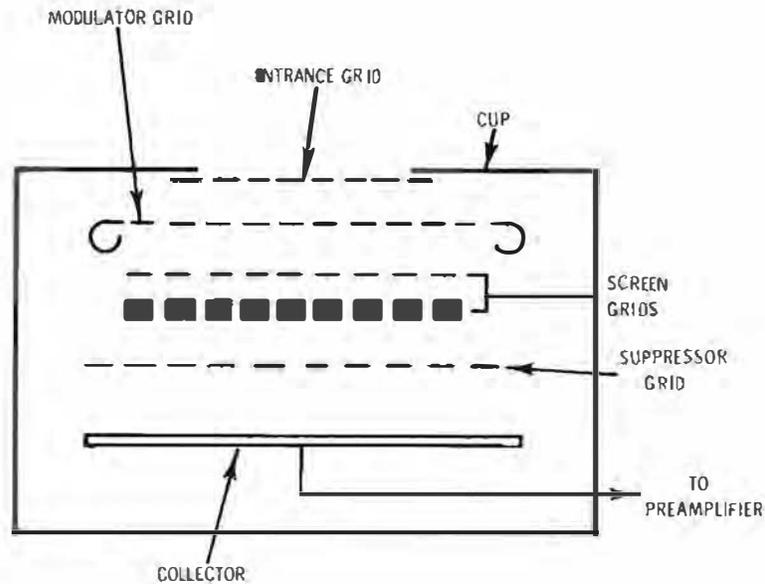
Figure 2-64. SWE Faraday Cup Diagram

2-103. SWE Preamplifiers - Each of the seven preamplifiers consists of an integrated circuit operational amplifier with a discrete FET at the input. The preamplifier input currents are from 6×10^{-13} to 6×10^{-9} ampere and the output voltages are from 6×10^{-5} to 6×10^{-1} volt.

A known 2 KHz square wave current signal from a current calibrate generator of the sequencing function is applied to the input of each preamplifier during calibrate periods to check the measurement capability of the SWE.

2-104. SWE Preamplifier Switches - Under the control of a segment driver and a sequence counter of the sequencing function, the preamplifier switches connect the output of each preamplifier or the outputs of all preamplifiers combined to the bandpass amplifier. A high voltage modulator ac calibrate signal is also periodically connected through the switches to the bandpass amplifier. Each switch consists of a two-transistor, series-shunt configuration. The analog signal is transferred through the switch when a gate is applied to the input transistor from the segment driver and sequence counter in the sequencing function. The signal is shunted to ground when the control gate is turned off.

2-105. SWE Bandpass Amplifier - The bandpass amplifier amplifies the desired ac signal and suppresses noise. The amplifier consists of an operational amplifier with a bridged T-network in the feedback loop. The amplifier bandwidth is

approximately 400 Hz centered on the 2 KHz carrier frequency. The gain from the preamplifier output to the bandpass amplifier output is ten. The maximum output signal from the bandpass amplifier is about 6. 5 volts peak-to-peak. By suppressing all frequencies except the first harmonic, the square wave input signal is converted into a sine wave output signal.

2-106. SWE Synchronous Demodulator - The synchronous demodulator converts the modulated signal into a half wave rectified signal that is synchronized to the ac voltage applied to the Faraday cup modulator grid. The synchronous demodulator is a one-transistor switch controlled by a delayed 2 KHz demodulator reference signal obtained from a frequency divider in the sequencing function. The half wave demodulated output is fed to a dc amplifier.

2-107. SWE DC Amplifier - the dc amplifier is an operational amplifier with a dc gain of approximately five and a three db frequency bandwidth of about eight Hz. This bandwidth reduces ripple and produces an output signal rise time of about 60 milliseconds. The maximum dc amplifier output signal amplitude is 10 vdc. This signal is applied to the data handling function.

2-108. SWE Sun Sensor - A photoelectric cell, mounted at the bottom of the sensor assembly housing, will detect sunlight when it enters a slit at the top of the housing at an angle of 30 degrees with respect to the vertical axis of the housing. Knowing when this occurs will permit determining the leveling of the SWE after deployment. The circuit for the sun sensor consists of a photosensitive cell in parallel with a resistor. When the sun is at that angle relative to the SWE at which the cell is fully illuminated, maximum voltage will be produced. The output of the cell is fed to the data handling function for insertion into the data stream. The resistor reduces the noise level by keeping the cell output voltage low when little or no light is reaching the cell.

2-109. SWE Temperature Sensors - Four thermistors are used for monitoring the temperatures of SWE assemblies. One thermistor is mounted on the sensor assembly and the other three thermistors are mounted on the electronics assembly. The range of temperature monitored on the sensor assembly is from -200 to +200 degrees C; the range of temperature monitored on the electronics assembly is from -50 to +150 degrees C. Temperature data on the sensors are monitored sequentially (subcommutated) under the control of a calibration driver of the sequencing function and applied to an output commutator of the data handling function.

2-110. SWE Modulation Function. The modulation function generates positive and negative voltages that are superimposed on a 2 KHz square wave and applied to the modulator grids of the Faraday cups. The positive voltages are applied for proton measurements and the negative voltages are applied for electron measurements. The voltages are applied in a sequence of increasing levels ranging from a few volts to kilovolts. The level and polarity are controlled by signals from the sequencing function. Figure 2-65 is a functional block diagram of the modulation function.
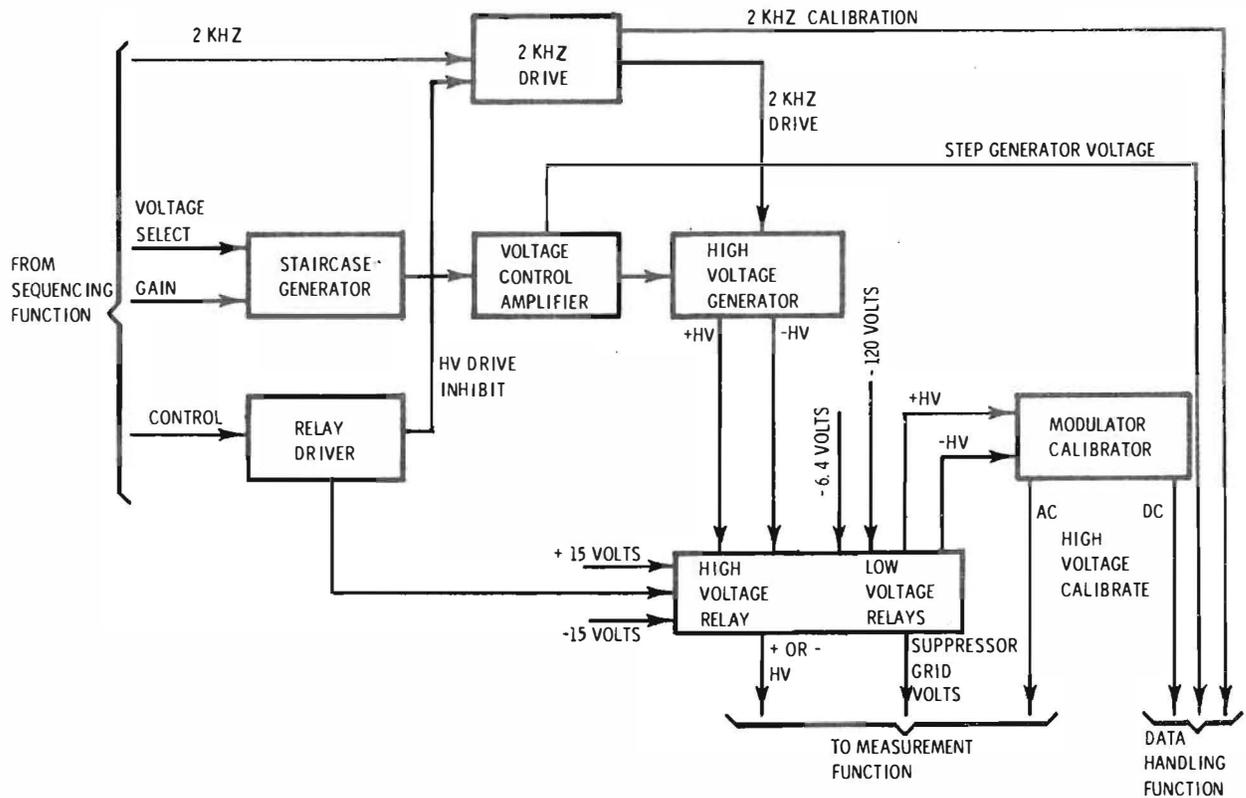
Figure 2-65. SWE Modulation Function, Block Diagram

2-111. SWE Staircase Generator - The staircase or step generator produces 14 voltage steps for the measurements of protons and seven voltage steps for the measurements of electrons. The generator consists of a precision current source that feeds one of two current levels to seven precision resistors. The inputs to this circuit are various logic levels which program the required output voltage magnitude. The output is a precise voltage equal to the current source times the parallel combination of any or all of the seven precision resistors. The maximum output voltage is +10 volts. The voltage is fed to the voltage control amplifier.

2-112. SWE Voltage Control Amplifier - The voltage control amplifier feeds both the +HV and -HV chopping circuits. The amplifier multiples the input signal by a factor of three and provides sufficient power to operate the HV generator circuits. The accuracy of the generated HV is determined by the accuracy of the output of the voltage control amplifier.

To protect the SWE from high voltage arcing during its initial outgassing period on the lunar surface, the gain of the voltage control amplifier is kept somewhat lower than its final value until a command signal is received from Earth. The command signal, consisting of dust cover release commands repeated at close intervals, is received by the data subsystem and fed through the input of the SWE

dust cover release circuitry to a control circuit. The circuit decreases resistance in the voltage control amplifier, thereby increasing the gain of the amplifier and, consequently, the high voltage applied to the modulator grids of the Faraday cups.

2-113. SWE 2 KHz Drive - The 2 KHz drive generates the 2 KHz chopping signal used to drive HV transformers in the HV generator. The inputs to the 2 KHz drive are positive and negative high voltage inhibit signals from the relay driver, a high voltage inhibit signal from the dust cover release circuit, and a 2 KHz signal from a frequency divider of the sequencing function. There are two sets of outputs (four outputs total) each consisting of two out-of-phase, symmetrical, square wave signals. One set drives the +HV circuits and the other the -HV circuits. The logic inputs are such that only one set of outputs operates at any one time. Thus either +HV or -HV output is produced but never both.

2-114. SWE High Voltage Generator - The +HV generator consists of a chopper, step-up transformer, and three voltage doublers. The incoming 2 KHz drive signals cause the voltage control amplifier output to be chopped to ground. The transformer steps up this voltage by a factor of approximately 50. The voltage doublers increase the dc voltage by a factor of six. The ac component, however, remains essentially at the transformer output magnitude. Thus, a three to one ratio between dc and ac is achieved. The +HV output is routed through the HV relay to the modulator grids of the Faraday cups.

The operation of the -HV generator is similar to that of the +HV generator except that the -HV generator transformer has a lower turns ratio. Two voltage doublers are used in this element and the dc-to-ac ratio is held at 1.5. The -HV is routed through the HV relay to the modulator grids of the Faraday cups.

2-115. SWE Modulator Calibrator - The modulator calibrator monitors the high voltage output to provide ac calibration signals to the measurement function and dc calibration signals to the data handling function. The calibrator consists of two sections; one that monitors the ac portion of the HV being generated and the other that monitors the dc portion. Each section consists of a resistor divider network and a relay for selecting a small sample of the high voltage output and an integrated circuit amplifier. The relays are slaved to the HV relay. The outputs of the amplifiers represent the magnitude of the HV being generated. Separate samples of the dc and ac components of the sensor modulating voltage are applied to the measurement and data handling functions for insertion in the data streams.

2-116. SWE Relay Driver - The relay driver accepts logic signals from a main counter and a sweep driver of the sequencing function to control the HV select relays. During -HV measurements, the relays are energized by a 30 volt potential established by +15 and -15 volt supply voltages. After a period of 50 milliseconds, the -15 volt supply is removed, leaving a holding potential of +15 volts. When the logic input calls for +HV measurements, the relays are released.

2-117. SWE Relays - Three relays are employed. One relay is a high voltage relay that selects positive or negative high voltage for application to the modulator grids of the Faraday cups. The other two relays are signal switching relays that select the high voltage sample for application to the modulator calibrator and that apply negative voltages to the Faraday cup suppressor grids.

2-118. SWE Sequencing Function. The sequencing function controls and times the SWE so that measurements are performed in a fixed sequence and data are supplied to the data subsystem in the desired digital format. The SWE is asynchronous with respect to the data subsystem, so the SWE may transmit data from any point in its sequence when first interrogated by the data subsystem.

To compress the data to be telemetered to Earth, a fixed but rather complex data format is used. An understanding of this format will aid in understanding the operation of the sequence function.

To measure positive particles, the SWE places positive voltages on the modulation grids of the Faraday cups. In the high gain modulation mode of operation, dc voltages on the grids rise from 75 to 9,600 volts in 14 steps. For each grid voltage, a set of eight measurements are taken. The first measurement is the sum of all cup outputs. The remaining seven measurements are sequential measurements of individual cup outputs. For any single measurement, a ten-bit word is sent to Earth receiving stations. Thus, 112 words (words 0 through 111) are used to transmit positive ion data.

The next 16 words (words 112 through 127) contain SWE calibration and operation data. These data are subcommutated.

The next 56 words (words 128 through 183) are used to measure negative particles. In the high gain modulation mode of operation, dc voltages on the Faraday cup modulation grids descend from -10 to -1,300 volts in seven steps. For each grid voltage, a measurement of the sum of all cup outputs and sequential measurements of individual cup outputs are made and converted into ten-bit words for transmission to Earth.

Words 184 and 185 (actually the 185th and 186th words since there is a word 0) contain the count of each group of 186 words (one sequence). The eight least significant bits of the sequence counter are in word 184 and the eight most significant bits are in word 185.

All data, including all calibration and operation data, are included within 16 sequences (one cycle). To ensure word identification, the two most significant bits of every word are used to indicate whether the word contains Faraday cup measurement data, calibration or operation data, or sequence count data.

Using the format described, unique data interpretation will be possible, even if only one sequence of words is intelligible.

Operating in the normal mode of 1060 bits per second, a sequence lasts 28.1 seconds and a cycle lasts 7.49 minutes. Operating in the slow mode of 530 bits per second, a sequence lasts 56.2 seconds and a cycle lasts 14.98 minutes. Mode selection is determined by the ALSEP data subsystem.

Timing control of SWE operation is provided by a 1024 KHz master clock oscillator as shown in the sequencing function block diagram, Figure 2-66.

2-119. SWE Frequency Divider - The frequency divider is an eleven stage ripple counter that counts down the 1024 KHz master clock frequency to provide the frequencies needed to control SWE operation. These frequencies are 256 KHz, 500 Hz, 2 KHz, and a delayed 2 KHz demodulator reference signal.

2-120. SWE Level Inhibit and Miscellaneous Sync - The level inhibit and miscellaneous sync provides:

   a. pulses to control the step generator,
   b. pulses to reset the main counter after every 186 words, and
   c. pulses to control the read-in gates of the data handling function.

2-121. SWE Input Decoder - The input decoder receives demand pulse and shiftclock signals from the data subsystem and develops the shift register clock which causes data to be transferred to the data subsystem in the desired timing. The decoder develops timing and control signals which are used to clear the conversion counter of the data handling function prior to making a new conversion, to trigger the analog-to-pulse-width converter of the data handling function and to define the time during which a conversion will be made, and to advance the main counter so that the next measurement can be made.

2-122. SWE Main Counter - The timing and control signals developed by the main counter provide direct or indirect control of all SWE functions. The counter is an eight-stage counter which defines the 186 words that make up the basic sequence. The most significant five bits of the eight-bit counter are decoded by the sweep driver to define measurement energy level word groups. The least significant three bits are decoded by the segment driver to define words within the energy level word groups.

2-123. SWE Sequence Counter - The sequence counter is a 16-bit counter that is triggered each time the main counter is reset to zero. It is read out as the last two words in each data sequence. The four least significant bits of the counter provide timing and control signals for calibrations that are not made every sequence (that are subcommutated). This count is supplied to the shift read-in gates of the data handling function.

The sequence count is gated with timing signals from the main counter and with energy level period signals from the converter and temperature calibration driver to provide calibration and sequence control signals. These signals are applied as follows:

2-138
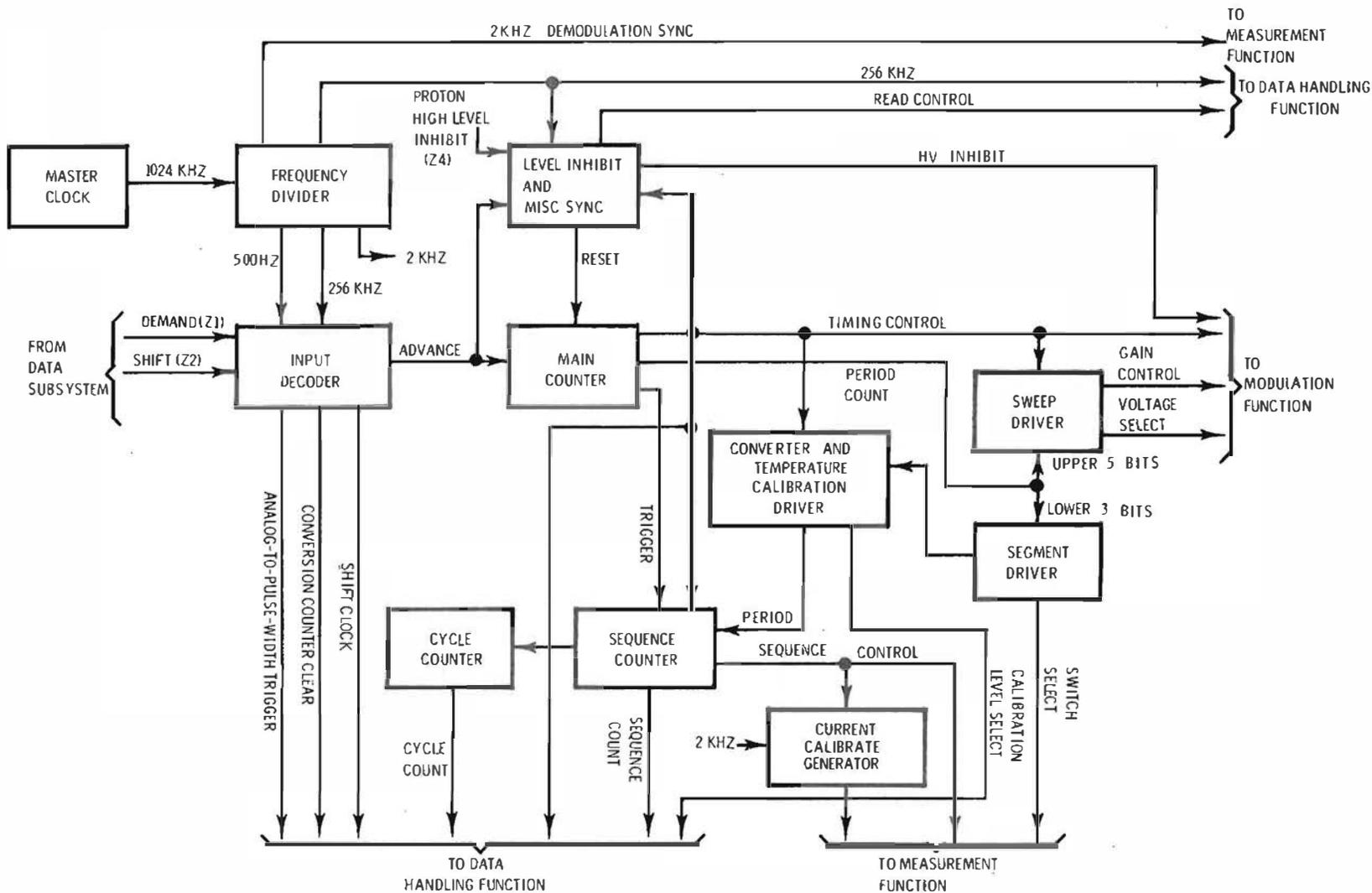
Figure 2-66. SWE Sequencing Function, Block Diagram

a. to the current calibrate generator to control the calibration current level.

b. to the segment driver and the preamplifier switches to control high voltage ac and dc calibration words during sequences 14 and 15 of each cycle.

c. to the commutator driver of the data handling function to determine when various data signals are fed to an analog-to-pulse-width converter.

d. to the shift register of the data handling function to inhibit the "all collector" measurement during sequences 14 and 15 of each cycle. The dc calibrate measurement is substituted during sequence 14 and the ac calibrate measurement is substituted during sequence 15.

2-124. SWE Converter and Temperature Calibration Driver - The converter and temperature calibration driver receives logic signals from the segment driver and from the main counter that define the "all collector" step of each energy level and that define the periods of energy levels 14 and 15 of each sequence. These signals are gated to the sequence counter where they are gated into the sequence count.

The level 14 signal is also gated with the switch select inputs from the segment driver to control the operation of subcommutator A, subcommutator B, and the temperature subcommutator, all three of which are part of the data handling function. Subcommutator A is enabled during energy level 14 of even sequences and the temperature subcommutator and subcommutator B are enabled sequentially during level 14 of odd sequences.

2-125. SWE Current Calibrate Generator - The current calibrate generator feeds known levels of 2 KHz square wave current signal to the input of each preamplifier during the calibrate period. The calibration control signal from the sequence counter controls addition of successive resistance attenuators to determine which current level (off, low, medium, or high) will be performed during a given sequence. The off-level provides a means of determining background noise of the preamplifiers.

2-126. SWE Sweep Driver - The sweep driver decodes the most significant bits of the main counter to establish the high voltage select control signals supplied to the step generator. It also develops signals that control the gain of the step generator and inhibits high voltage generation during energy levels 14, 15, and 23.

2-127. SWE Segment Driver - The segment driver controls the preamplifier switches to select the cup collector to be sampled during the eight words of an energy level. During the first word of an energy level, all seven cup signals are turned on at once to get a total measurement of the current from all cups. During the next seven steps, the signals are turned on one at a time in numerical sequence.

2-128. SWE Data Handling Function. The data handling function processes the data so that it can be presented to the data subsystem in the desired digital format. Figure 2-67 is a block diagram of the data handling function.
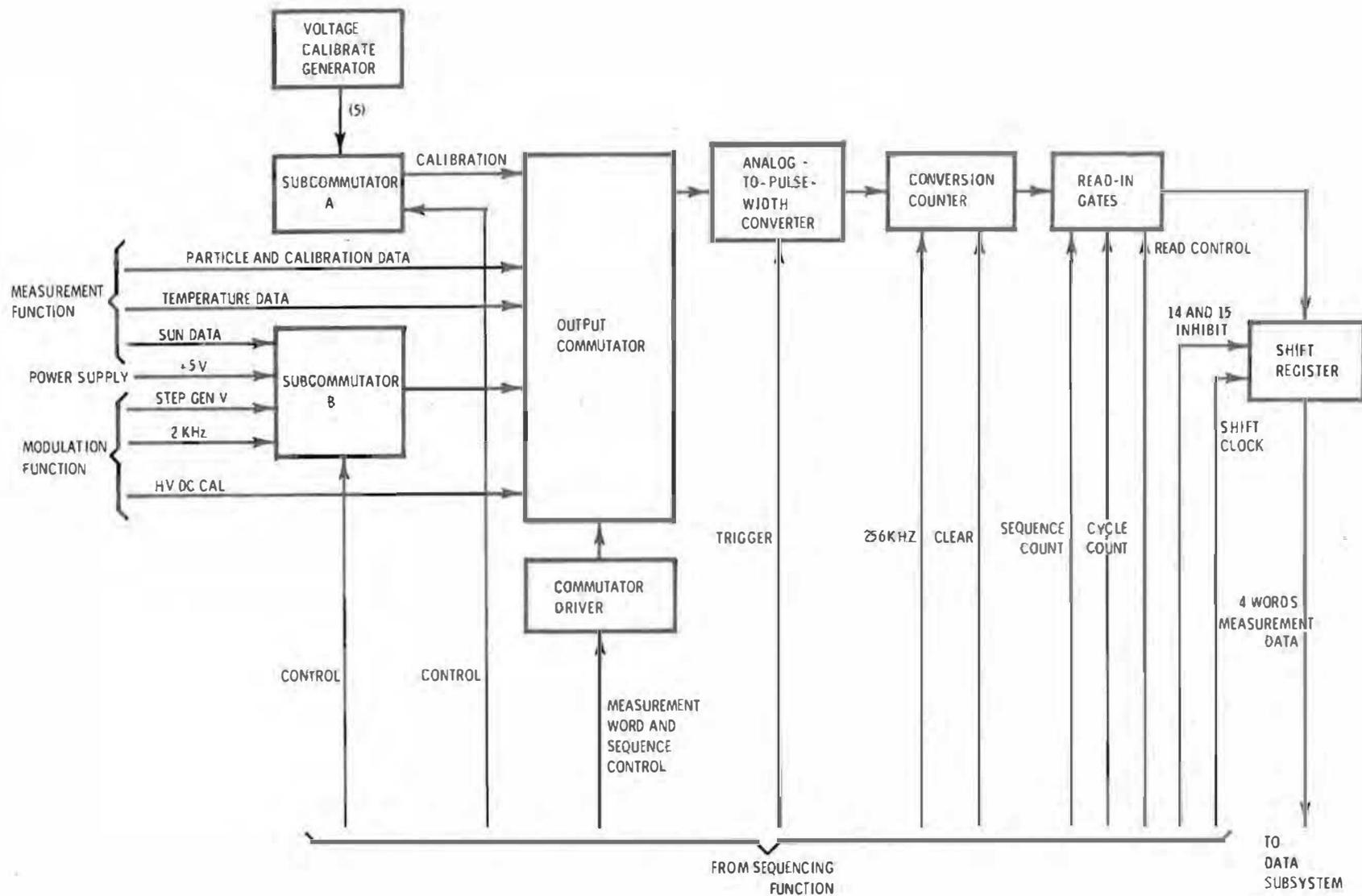
Figure 2-67. SWE Data Handling Function, Block Diagram

2-129. SWE Output Commutator - Under control of the main counter and sequence counter of the sequencing function, the output commutator connects Faraday cup data, calibration data, and engineering status data to the analog-to-pulse-width converter. Each of the five input channels of the output commutator consists of two transistors which drive a series FET switch. Measurements which the output commutator organizes into the data word stream are:

    a.   particle measurements and high voltage ac calibration signals,
    b.   five subcommutated analog-to-pulse-width calibrate signals,
    c.   four subcommutated temperature measurements,
    d.   high voltage dc calibration signals, and
    e.   four subcommutated engineering status measurements.

2-130. SWE Subcommutator A - Under control of the converter and temperature calibration driver, subcommutator A sequentially connects five analog-to-pulse-width calibration signals from the voltage calibrate generator to one channel of the output commutator.

2-131. SWE Subcommutator B - Under control of the converter and temperature calibration driver, subcommutator B sequentially connects four engineering status measurements to one channel of the output commutator. The four status measurements are:

    a.   sun sensor output signal,
    b.   power supply +5 vdc output,
    c.   step generator voltage sample, and
    d.   a summed sample of the 2 KHz output of the frequency divider.

2-132. SWE Analog-to-Pulse-Width Converter - The analog-to-pulse-width converter transforms dc voltage levels into precisely controlled pulse widths. The transformation results in logarithmic data compression and enables the conversion counter to convert analog signals into digital format compatible with requirements of the ALSEP data subsystem. Analog-to-pulse-width conversion is accomplished by timing the discharge of a capacitor that has been charged to the data voltage level. Signal potentials ranging from one millivolt to 10 volts are converted into pulse widths ranging from four microseconds to two milliseconds.

2-133. SWE Conversion Counter - The conversion counter is a nine-stage ripple counter that performs the analog-to-digital conversions required to transfer the SWE data to the data subsystem. These conversions are accomplished by counting at a 256 KHz rate while a pulse is present at the output of the analog-to-pulse-width converter. The most significant eight bits of this counter are read out into the shift register through the read-in gates.

2-134. SWE Read-in Gates - The read-in gates consist of eight OR gates. Each OR gate consists of three NAND gates controlled by signals from the level inhibit and miscellaneous sync of the sequencing function. When the read control signal applied to the NAND gates is ZERO, outputs from the conversion, sequence, or cycle

counters are transferred in parallel through the gates into the least significant eight bits of the shift register. During the first 184 words of a sequence, the contents of the conversion counter are read into the shift register. During the 185th word, the eight low order bits of the sequence counter are read into the shift register. During the 186th and last word of a sequence, the most significant eight bits of the sequence counter are read into the shift register.

2-135. SWE Shift Register - The shift register is a ten-stage register that is loaded in parallel with data. These data are shifted out serially, most significant bit first, to the data subsystem when a demand pulse is received. The least significant eight bits of this register get their inputs from the read-in gates. The ninth bit of the shift register is a calibration tag bit. This position contains a logic ONE for all calibration measurements and a logic ZERO for all other measurements. The tenth bit of the shift register is set to ONE only during the 185th and 186th words of a sequence. This provides a unique index for the data sequence and provides a way of identifying all data.

2-136. SWE Voltage Calibrate Generator - The voltage calibrate generator applies known voltages of 9000, 3000, 900, 90, and 9 millivolts through subcommutator A and the output commutator to the analog-to-pulse-width converter. The voltages check operation of the converter and calibrate it.

2-137. SWE Power Supply Function. The data subsystem supplies power at +29 volts to the SWE power supply function. The power supply transforms this power to the various voltage levels required by the SWE and isolates the individual levels from the data subsystem ground. The power supply provides:

    a. +15 v at 50 ma
    b. -15 v at 50 ma
    c. -6.4 v at 1.0 ma
    d. +5 v at 225 ma
    e. +35 v at 100 ma
    f. -120 v at 1.0 ma

A block diagram of the power supply function is shown in Figure 2-68.

2-138. SWE Inverter - The inverter transforms input direct current power to alternating current power with which to drive the primary of the output transformer.

2-139. SWE Output Transformer, Rectifiers, and Filters - The output transformer has four secondaries. Three of the secondaries are connected to full wave rectifiers that produce voltages of +15 volts, -15 volts, +5.0 volts, and +35 volts. The -6.4 volt power is obtained from a zener diode connected to the -15 volt line. The -120 volt power is obtained from a voltage doubler circuit connected to the same secondary as the +35 volt rectifiers. Each output is adequately filtered.
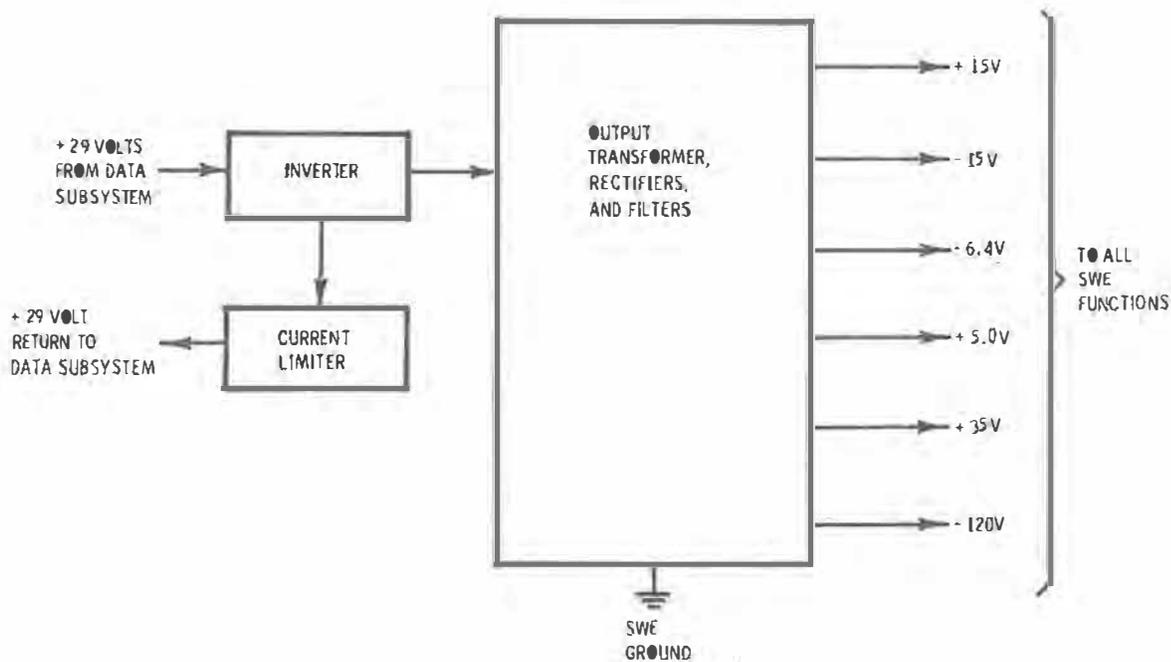
Figure 2-68. SWE Power Supply, Block Diagram

2-140. SWE Current Surge Suppressor - An RC circuit in the +35 volt line stores electrical energy to minimize voltage variation during mode or energy level changes.

2-141. SWE Spike Suppressor Circuits - Three spike suppressor circuits reduce transient voltages fed back to the data subsystem to less than 100 mv peak-to-peak.

2-142. SWE Current Limiter - The current limiter contains a transistor in series with a low value resistance. The transistor and resistance are connected in series with the +29 volt return to the data subsystem. Normally, the transistor and resistor have little resistance; however, if excessive power is drawn by the inverter, current through the resistor causes an increase in transistor emitter voltage, thereby increasing transistor resistance and limiting the current. Limiting becomes effective at twice normal load. If, for any reason, inverter oscillation amplitude should decrease, diodes in the limiter circuit rectify less current. This causes resistance of the series transistor to decrease so that inverter oscillation amplitude returns to approximately its original value.

2-143. SWE Dust Cover Release Function. After the LM has left the lunar surface, a dust cover release command signal will be initiated on Earth. The data subsystem will receive the signal and send a pulse through the interconnecting cable to SWE dust cover removal circuitry. The circuitry heats a fusible cord that holds spring-loaded protective covers over the Faraday cup apertures. When the cord melts, the covers spring away from the SWE. High voltage is inhibited during the pulse so that any tendency for the SWE to arc while cord vapor may exist near the SWE is prevented.

2-144. <u>SWE Heaters Function</u>. If the temperature of the electronics assembly falls below a certain value, a thermistor mounted on the assembly causes resistors in the assembly to dissipate heat. In this manner, the temperature within the assembly is maintained within the range for proper operation during lunar nights. Whenever the SWE is not operating, the ALSEP data subsystem supplies power to resistors mounted on the SWE electronics assemblies. This is done to prevent mechanical and electrical stresses caused by the extreme cold of the lunar enivronment.

2-145. SUPRATHERMAL ION DETECTOR EXPERIMENT (SIDE) SUBSYSTEM

The suprathermal ion detector experiment (SIDE) comprises the suprathermal ion detector and the cold cathode ion gauge (CCIG) (Figure 2-69). The purpose of the SIDE is to measure the ionic environment of the Moon by detecting the ions resulting from the ultra-violet ionization of the lunar atmosphere and the free streaming and thermalized solar wind. The suprathermal ion detector will measure the flux, number density, velocity, and energy per unit charge of positive ions in the vicinity of the lunar surface. The cold cathode ion gauge will determine the density of any lunar ambient atmosphere, including any temporal variations either of a random character or associated with lunar local time or solar activity. In addition, the rate of loss of contaminants left in the landing area by the astronauts and lunar module (LM) will be measured.

The SIDE uses two curved plate analyzers to detect and count ions. The low-energy analyzer has a velocity filter of crossed electric and magnetic fields. The velocity filter passes ions with discrete velocities and the curved plate analyzer passes ions with discrete energy, permitting determination of mass as well as number density. The second curved plate analyzer, without a velocity filter, detects higher energy particles, as in the solar wind. The SIDE is emplaced on a wire mesh ground screen on the lunar surface and a voltage is applied between the electronics and ground plane to overcome any electrical field effects.

The SIDE will count the number of low-energy ions in selected velocity and energy intervals over a velocity range of 4×10^4 cm/sec up to 9.35×10^6 cm/sec and an energy range of 0.2 ev to 48.6 ev. The distribution of ion masses up to 120 AMU can be determined from this data. In addition, the electric potential between the SIDE and the local lunar surface will be controlled by applying a known voltage between the instrument and a ground plane beneath it. If local electric fields exist, they will be offset at one of the ground plane voltage steps. By accumulating ion count data at different ground plate potentials, an estimate of local electric fields and their effects on ion characteristics can be made.

In addition to low-energy ions, the SIDE will also measure the number of particles of higher energies, primarily solar wind protons. A separate detector counts the number of particles in selected energy intervals between 10 ev and 3500 ev. The mass of these particles cannot be determined because the detector does not have a velocity selector.

The CCIG will determine the pressure of the ambient lunar atmosphere by measuring the density of neutral atoms and the temperature of the gauge at the time of measurement. The CCIG measurements will also provide an indication of the effects of contaminants left by the LM and the astronauts on the lunar atmosphere and the rate of decay of these contaminants. The CCIG will measure pressures over the range of 10^{-6} torr to 10^{-12} torr.
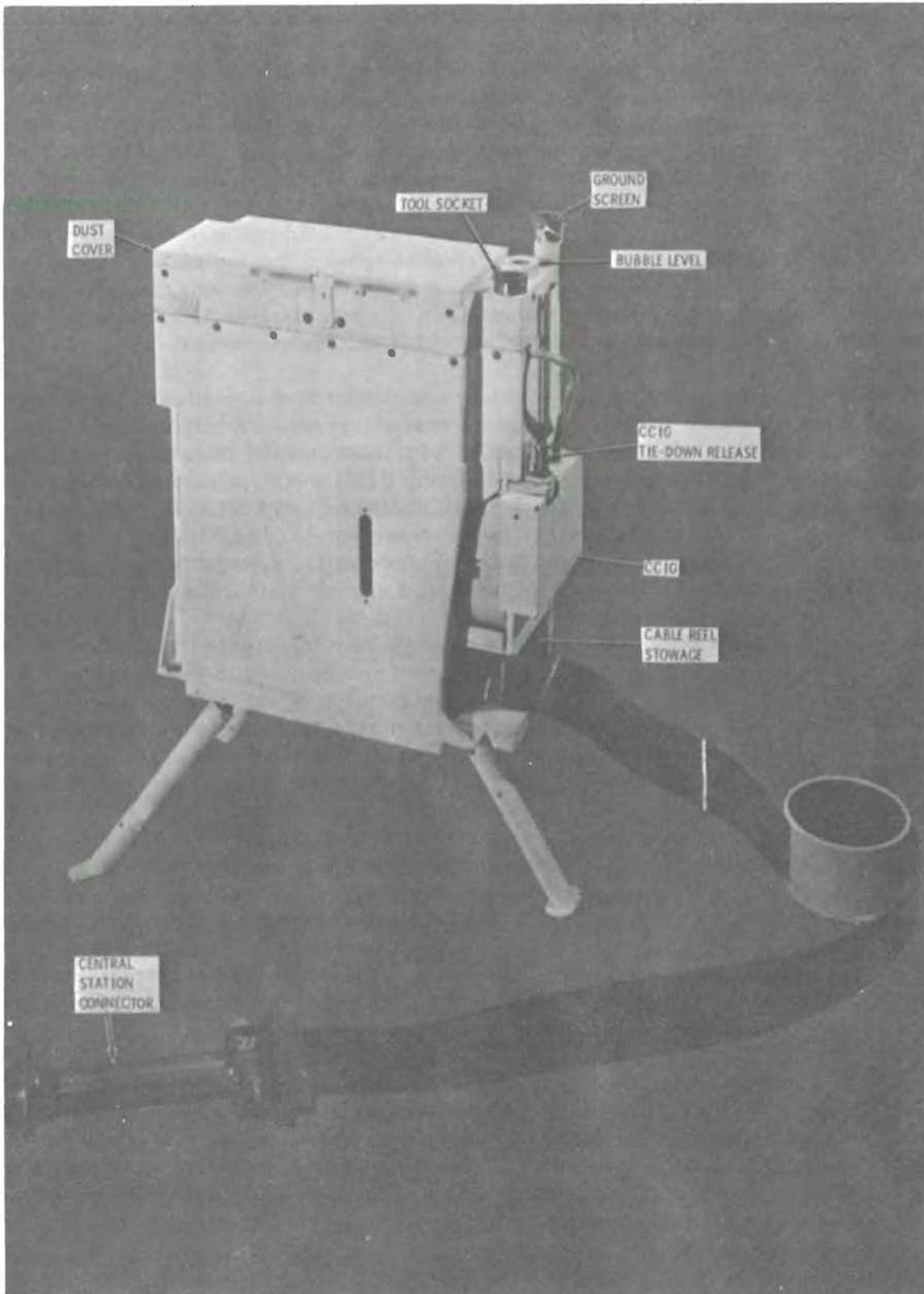
Figure 2-69. Suprathermal Ion Detector Experiment Subsystem

Five command lines are provided from the ALSEP data subsystem to the SIDE/CCIG. Four of these lines are used to encode up to 15 different command functions; the fifth line provides an execute command to carry out the command encoded into the other four lines. The experiment also has the capability to carry out two, one-time commands. For example, the first time a pulse is placed on command line No. 2, it also goes to a one-time command register. When the command is executed, the corresponding one-time command is also executed. Subsequent pulses on that line do not affect the one-time command register.

Two analog data lines from the SIDE/CCIG to the ALSEP data subsystem provide the high energy curved plate analyzer (CPA) count rate and the low energy CPA count rate to the data subsystem for incorporation into ALSEP housekeeping word 33. These count rates are used as backup measurements in the event of digital counting electronics failure.

The digital scientific data from the SIDE/CCIG consists of five 10-bit words in each ALSEP telemetry frame (words 15, 31, 47, 56, and 63). A total of 10 words are used to make up the basic unit of data, which is called a SIDE frame. The experiment programmer goes through 128 steps in completing its program; this is called a cycle. The ground plane stepper steps once per cycle. The 24 cycles, which constitute the number of ground plane voltage steps, are called a field.

2-146. SIDE PHYSICAL DESCRIPTION

The suprathermal ion detector experiment consists of a velocity filter, a low energy curved plate analyzer ion detector, a high energy curved plate analyzer ion detector, a cold cathode ion gauge, a wire mesh ground plane, and associated electronics.

The package structure consists of an internal chassis which mounts the electronics and ion detectors. The inner chassis is held under tension to the outer case by four tie-down points to the base, and is supported at the top by four nylon buffers in the thermal spacer. The thermal spacer reduces the solar heat input to the electronics by reflection at the second surface mirrors on its top surface and by isolating the inner chassis from the outer case. The thermal spacer also allows heat from the electronics to be radiated to space. A conductive grid network on the upper surface of the top plate provides an equipotential reference surface around the apertures to the ion detectors.

The ion detector apertures are protected during transit and LM departure by a single dust cover released, on ground command, by a solenoid operated catch. The outer case, legs, and dust covers are painted with white thermal paint which contributes to the thermal control of the experiment. Further thermal control is obtained through use of electric heaters. A bullseye leveling gauge is mounted on top of the SIDE to enable the astronaut to level the package within $5°$ of level during deployment. Three folding legs on the base of the chassis are extended during deployment to form a low tripod supporting the package.

The outer case houses the cold cathode ion gauge (CCIG) which is removed by the astronaut during deployment of the SIDE. The gauge is connected to the experiment by a short cable. The CCIG aperture is sealed against ingress of dirt and moisture. The seal is removed, on ground-command, by an explosive actuated piston releasing a spring.

The ground plane is housed in a tube attached to the SIDE and is removed by the astronaut during deployment. The ground plane is a conductive wire mesh network placed on the lunar surface beneath the experiment to provide an equipotential reference surface for control of local electric fields between the two SIDE ion detectors and the lunar surface.

The flat tape cable connecting the experiment to the ALSEP central station is housed in a reel which is stowed at the base of the SIDE. The reel is removed and the cable deployed when deploying the experiment. Table 2-21 lists the leading particulars of the SIDE/CCIG.

Table 2-21. SIDE Leading Particulars

Characteristic	Value
Height	15.25 inches
Width	4.5 inches
Depth	13 inches
Weight	19.6 pounds
Instrument operational power	6.0 watts
Heater power: operating	4.0 watts (night)
survival	6.0 watts (night)
	2.0 watts (day)
Input voltage	+29 vdc

2-147. SIDE FUNCTIONAL DESCRIPTION

The SIDE/CCIG is divided into four major functional elements; command function, programmer function, ion detection function, and data handling function (Figure 2-70). In addition, a power supply function provides system power to all operational circuits and a thermal control function maintains thermal equilibrium of the experiment on the lunar surface.

The command function accepts command and execute pulses from the central station data subsystem, decodes the commands, and applies them to the programmer function or the ion detection functions as appropriate.
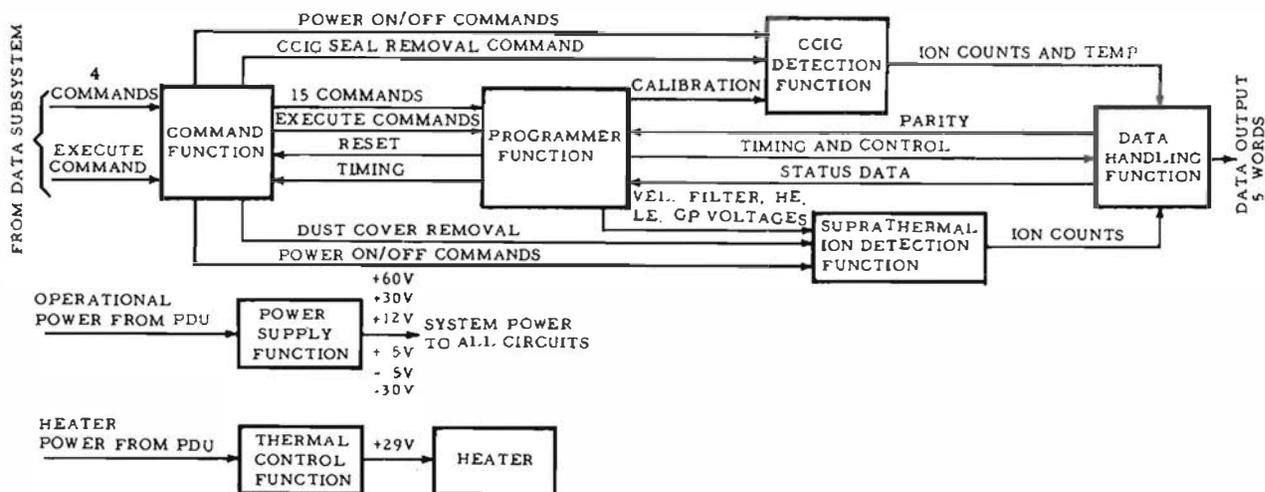
Figure 2-70. Suprathermal Ion Detector Experiment, Functional Block Diagram

The programmer function provides timing and control to the ion detection function and the data handling function. The voltage stepping of the high energy curved plate analyzer, low energy curved plate analyzer, velocity filter, and ground plane are controlled by the programmer function. The programmer also supplies calibration timing to the CCIG.

The ion detection function is accomplished by the low energy curved plate analyzer, the high energy curved plate analyzer, the crossed field velocity filter, the low energy channeltron, and the high energy channeltron. Ions detected at the various voltage steps are counted and the data is provided to the data handling function.

The data handling function accepts digital and analog data from the other functional elements of the experiment, converts as necessary, commutates, and gates out the scientific and engineering data to the central data subsystem. A parity check is also generated in the data handling function.

2-148. SIDE DETAILED FUNCTIONAL DESCRIPTION.

The four major functions of the SIDE/CCIG are discussed in detail in the following paragraphs in data flow sequence; command function, programmer function, ion detection function, and data handling function.

2-149. SIDE Command Function. Five command lines are provided from the ALSEP data subsystem to the SIDE/CCIG (Figure 2-71). Four of these lines are used to encode up to 15 different command functions; the fifth line provides an execute command to carry out whatever command is coded into the other four lines. Commands are received from the MSFN ground stations through the ALSEP data subsystem, decoded, and applied to the SIDE/CCIG command function.
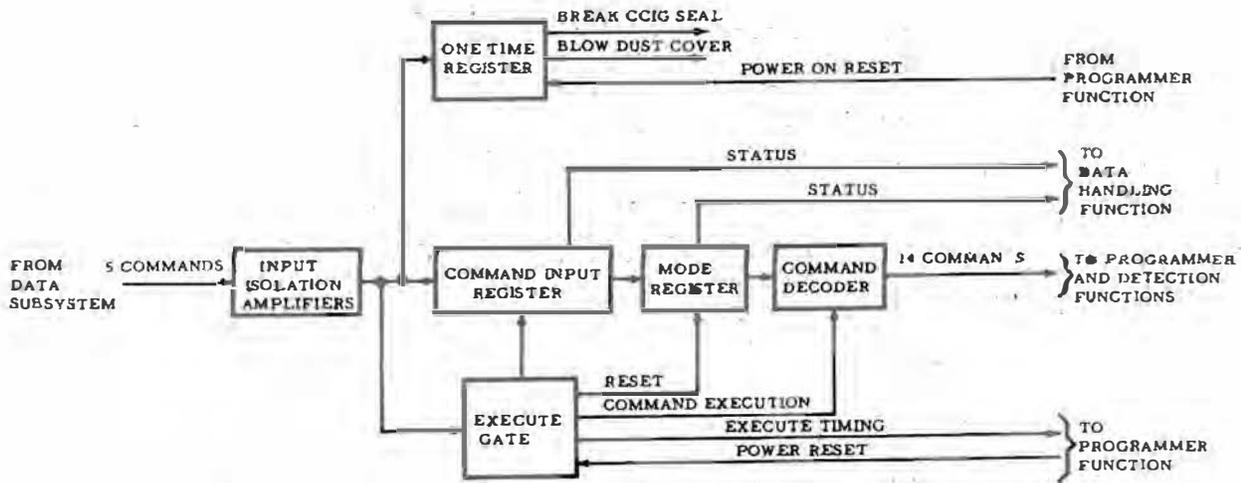
Figure 2-71. SIDE Command Function, Block Diagram

The command function receives and further decodes the functional commands and routes them to the appropriate programmer function timing and control circuits for implementation. The coding of the commands and their functions are listed in Table 2-22. All commands are pulses. The SIDE/CCIG uses these pulsed commands by encoding. Two encoded commands are used for one time only operations as well as routine operation. Four of the five incoming command lines are encoded in a four bit command input buffer which is then strobed into a second (mode) buffer when an execution command is received via the fifth line. On receipt of the execute command, the commands are decoded and applied to the appropriate timing and control circuits of the programmer function.

Two one-time commands are incorporated to permit activation of the CCIG Seal Break and Dust Cover Blow circuits. The first time octal command 105 appears, it is routed to the one time command register as well as the command input register. When the execute command is received in the execute gate, the command in the one-time register is executed causing CCIG seal removal. Subsequent octal 105 commands are routed to the command input register only and have no effect on the one-time register. The same is true of octal command 107 as a one-time command causing dust cover blow. The status of the command input and mode registers is monitored and status signals are supplied to the data handling function.

2-150. SIDE Programmer Function. The programmer function provides timing and control signals to the two curved plate analyzers, the CCIG, ground plane, and the data handling function (Figure 2-72). Basic timing is received from the ALSEP data subsystem in the form of shift, data demand, frame mark, and even frame mark pulses to the logic timing of the programmer. Command pulses from the command function and a parity pulse from the data handling function are the other inputs to the programmer function.

Table 2-22. SIDE/CCIG Commands

SYMBOL	FUNCTION	OCTAL COMMAND SEQUENCE				
		104	105	106	107	110
One-time commands						
CI-1	Break CCIG seal		X			X
CI-2	Blow dust cover				X	X
Operational commands						
CI-6	Ground plane step programmer on/off	X				X
CI-7	Reset SIDE frame counter at 10		X			X
CI-8	Reset SIDE frame counter at 39	X	X			X
CI-9	Reset velocity filter counter at 9			X		X
CI-10	Reset SIDE frame counter at 79	X		X		X
CI-11	Reset SIDE frame counter at 79 and velocity counter at 9		X	X		X
CI-12	X 10 accumulation interval on/off	X	X	X		X
CI-13	Master reset				X	X
CI-14	Velocity filter voltage on/off	X			X	X
CI-15	Low energy CPA high voltage on/off		X		X	X
CI-16	High energy CPA high voltage on/off	X	X		X	X
CI-17	Force continuous calibration (cycles 120 to 127)			X	X	X
CI-18	CCIG high voltage on/off	X		X	X	X
CI-19	Channeltron high voltage on/off		X	X	X	X
CI-20	Reset command input register	X	X	X	X	X

The SIDE frame counter is the primary time reference. It is a N/128 counter capable of controlling the experiments 128 states. Synchronization and advance pulses are applied to the high energy, low energy, velocity filter, and ground plane counters that control the voltage stepping in the ion detection function and also are applied to the accumulators and gates in the data handling function. In addition, the programmer function enables gates for a series of calibration signals through the ion detectors at the end of each counting period.
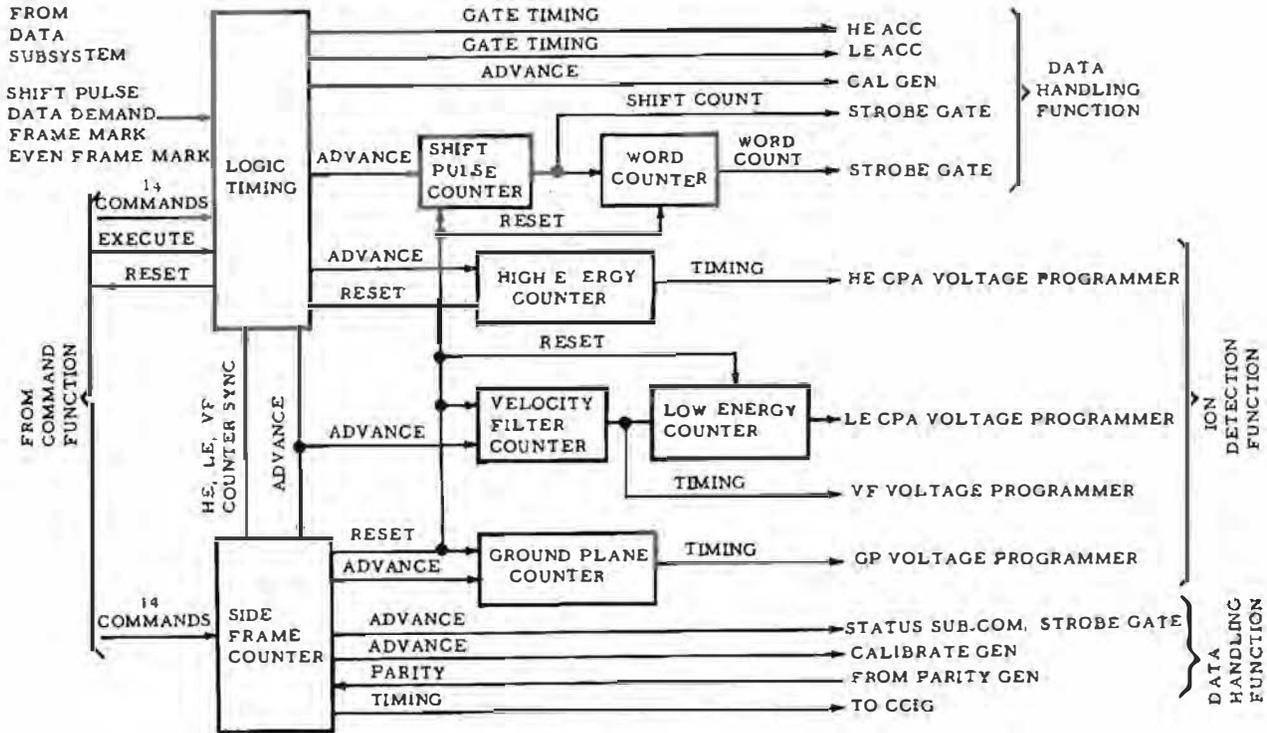
Figure 2-72. SIDE Programmer Function, Block Diagram

2-151. **SIDE Ion Detection Function.** The low and high energy ion detectors count the positive ions within certain velocity and/or electron volt energy bands that enter the detectors within a specific time interval (Figure 2-73). The CCIG counts neutral atoms entering the CCIG sensor within a specific time interval and also monitors the temperature of the sensor to provide the data required for calculation of the lunar atmospheric pressure. The ground plane voltage control circuits control the electrostatic potential between the lunar surface and the SIDE ion detectors.

The low energy ion detector measures the differential energy spectrum of positive ions having energies between 0.2 and 48.6 electron volts per unit charge and masses between one and 120 AMU. The low energy ion detector consists of a Wein velocity filter (crossed magnetic and electric fields), curved plate analyzer, electron multiplier, detector amplifier, and stepping voltage supplies for the velocity filter and the curved plate analyzer. Positive ions enter an aperture in the SIDE top plate and enter the velocity filter, which passes only those ions in a narrow velocity range. The range is determined by the voltage applied by the velocity filter stepping voltage supply. This voltage supply is sequenced by the counter in the programmer function through a series of 120 different voltage steps; 20 steps for each of six voltages of the low energy curved plate analyzer into which the ions passed by the velocity filter are directed. The curved plate analyzer passes only those ions with a mass per unit charge that will permit the ions to follow the curvature of an electrostatic field developed between the two curved parallel plates of the CPA. Ions with mass per unit charge ratios outside
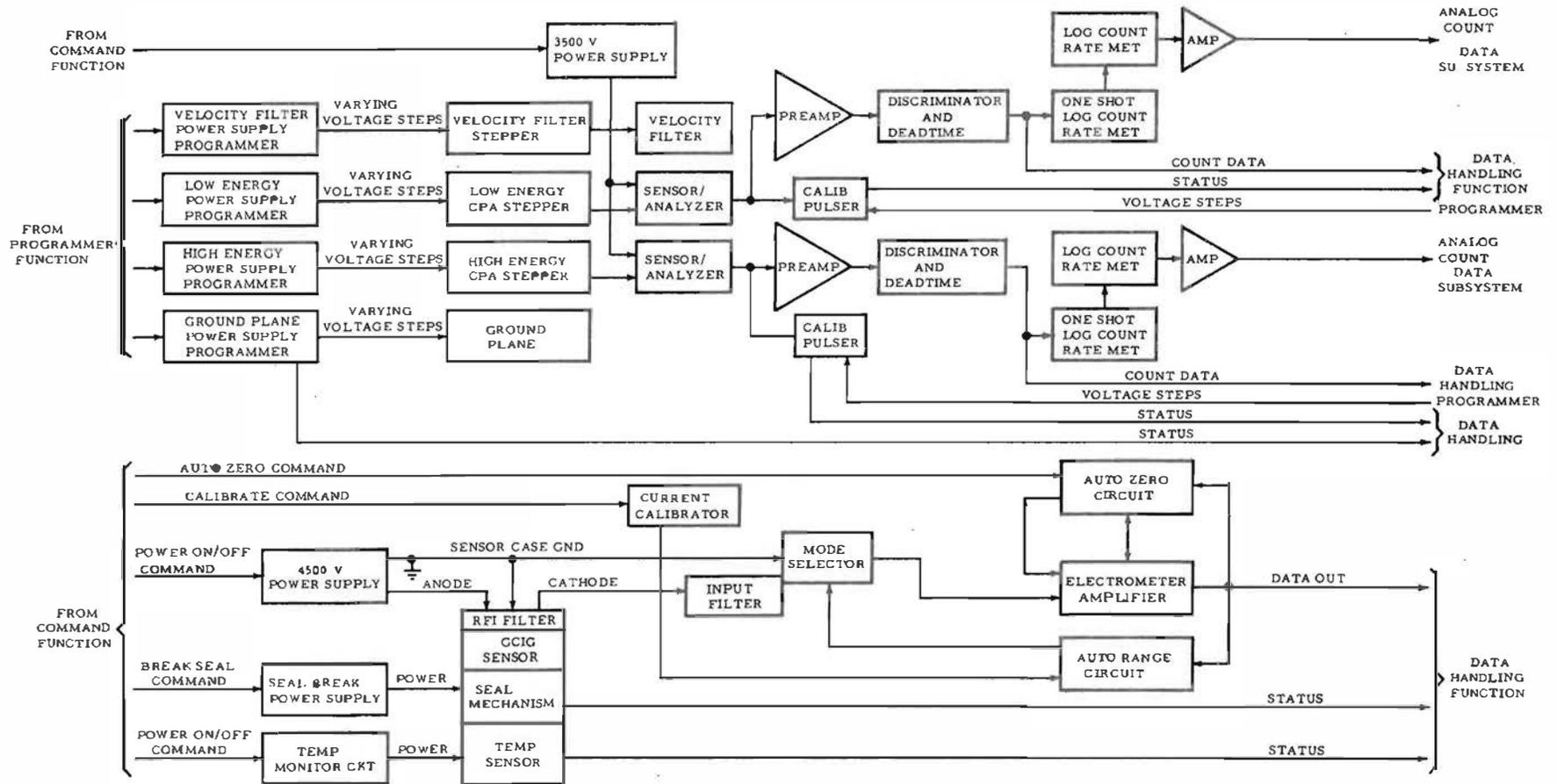
Figure 2-73. SIDE Ion Detection Function, Block Diagram

those which can follow the curved field are absorbed by the CPA plates. The mass per unit charge ratio at the center of the band passed by the CPA is controlled by the voltage applied to the curved plates by the CPA stepping voltage supply. This voltage supply is sequenced by the low energy counter in the programmer function through a series of six different steps or passbands ranging from +0. 1 to +24. 3 vdc. These steps together with the voltage ranges of the velocity filter, permit a total of 120 mass per unit charge resolution steps.

The high energy ion detector measures the differential energy spectrum of positive ions having energies between 10 and 3500 electron volts per unit charge regardless of mass. The high energy ion detector does not employ a velocity filter, but is otherwise similar to the low energy detector. Positive ions entering the high energy ion detector aperture pass directly into the high energy curved plate analyzer. Because no velocity filter is used, all positive ions having mass/ velocity product per unit charge ratios within a certain band are passed dependent on the voltage applied to the curved plate analyzer plates. This voltage is supplied by the high energy curved plate analyzer stepping voltage supply and is sequenced by the high energy counter in the programmer function through a series of 20 different voltage steps ranging from 2. 5 to 875 vdc.

The ions passed by both the low energy and high energy curved plate analyzers enter separate Channeltron® electron multipliers which multiply, up to 1000 times, the pulse effect of the individual ion inputs. The Channeltrons® are operated at -3500 vdc.

The output pulses are applied to separate detector amplifiers. The detector amplifiers discriminate between the output pulses and circuit noise, as well as amplifying the output pulses. In addition, pulses from the Channeltron ^{R} are limited to approximately one per microsecond. The detector amplifier outputs are applied to the data accumulators in the data handling function and to the logarithmic count rate meters.

Calibration signals at 0 Hz, 136. 72 Hz, 17. 5 KHz, and 560 KHz are gated in sequence through the amplifiers of the ion detectors at approximately 2. 5 minute intervals to verify the functioning of the amplifiers and associated counting electronics. During calibration the CPA stepping voltage supplies are programmed to zero and the velocity filter voltage to maximum positive preventing ion counts.

The CCIG detector measures neutron atom densities corresponding to atmospheric pressures of 10^{-6} torr to approximately 10^{-12} torr. The CCIG detector consists of the CCIG sensor, +4500 vdc power supply, RFI filter, electrometer amplifier, range control and calibration circuits, and CCIG sensor temperature monitor circuits. Charged particles entering the CCIG sensor are deflected into elongated spiral paths by a combination of magnetic and electrostatic fields enhancing the probability of collision with the more numerous neutral atoms entering the sensor. Ions produced by these collisions and free ions are collected by the sensor electrodes which create the electrostatic field. A +4500 volts dc is maintained on the

electrodes by the +4500 vdc power supply. The ions resulting from collisions within the CCIG greatly outnumber the free ions and result in a minute current flow through the sensor connecting cable, RFI filter, and input circuits of the electrometer amplifier. The electrometer amplifier amplifies input currents between 0. 1 and 10^6 micro-microamperes, and applies them to the data handling function. The electrometer amplifier has three operating ranges which are automatically selected by the range control and calibration circuits. These circuits also automatically correct the no-ion count output of the electrometer to zero, and on command from the programmer, gate a series of precisely regulated currents through the electrometer amplifier input circuits for calibration and measurement accuracy checks. The temperature monitoring circuit monitor the temperature of the CCIG sensor during the counting periods to provide temperature data for calculation of the lunar atmospheric pressure.

The ground plane and voltage control circuits apply a series of dc voltages in steps to the wire mesh ground plane. (The CCIG sensor, a neutral particle detector, is not placed on the ground plane in the deployment process.) The voltages applied to the ground plane are controlled by the ground plane stepping voltage supply. This supply is sequenced by the ground plane counter in the programmer function through a series of 24 different voltage steps, ranging from +27. 6 to -27. 6 vdc. The voltage is stepped each time the SIDE frame counter resets to zero.

2-152. SIDE Data Handling Function. The major elements of the data handling function (Figure 2-74) are the status sub-commutator, analog-to-digital converter commutator, and the high and low energy count accumulators; all applying data to the strobe gate for transfer to the central data subsystem and subsequent downlink transmission to the MSFN. In addition, a parity generator provides a parity bit for each SIDE frame.

Status signals from the ion detection function, command function, and programmer function are provided to the status sub-commutator of the data handling function for commutation into one output. The following status signals are supplied to the status-subcommutator: ground plane step, calibration rate, electrometer range, dust cover and CCIG seal, mode register, command register and a programmer advance pulse. A parity bit from the parity generator is also supplied. After commutation, these signals are supplied to the data handling strobe gate as a single input.

Voltages from the ion detectors and other engineering housekeeping data is supplied to the analog-to-digital converter commutator in analog form. The analog signals are converted to digital signals, commutated and applied to the data handling strobe gate for transfer to the central data subsystem.
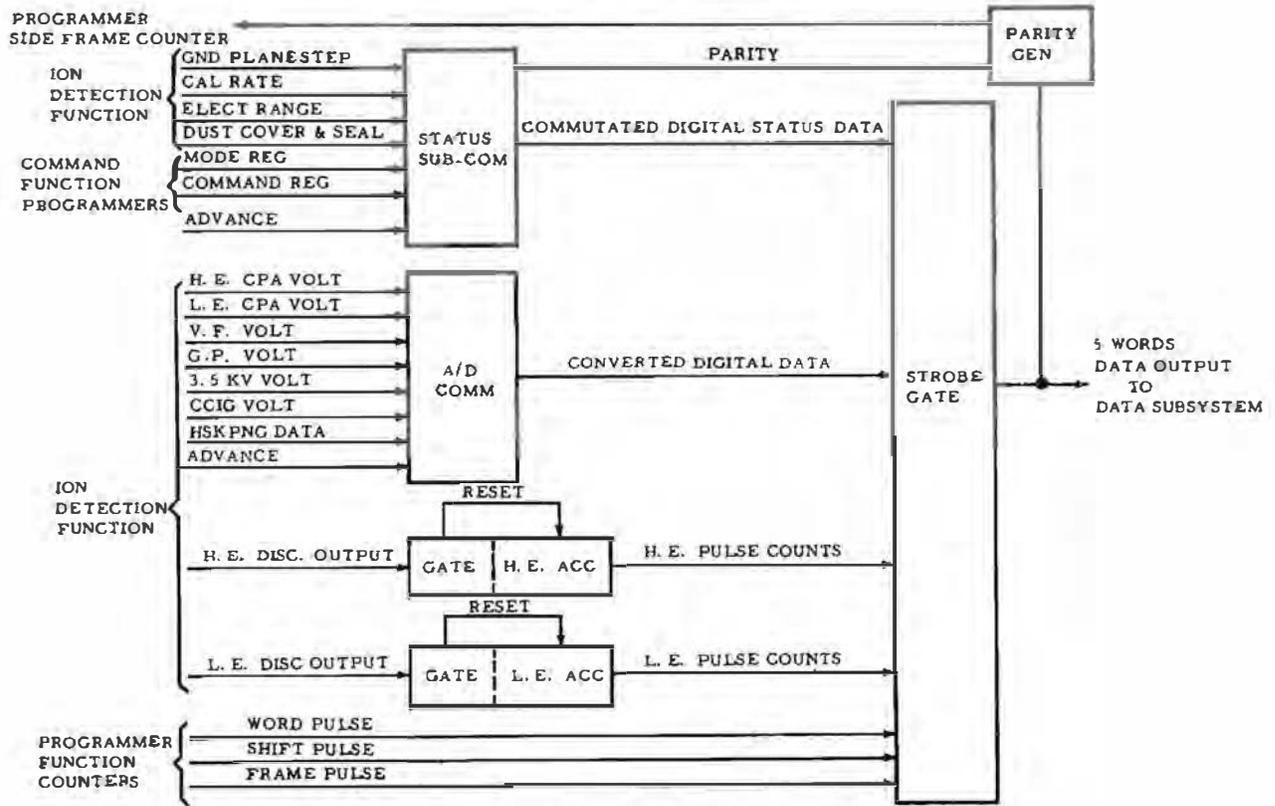
Figure 2-74. SIDE Data Handling Function, Block Diagram

The high and low energy accumulators are 20-bit counters which accumulate the number of output pulses from the high and low energy discriminators and gate them out to the data handling strobe gate.

Word, shift, and even frame pulses are supplied to the data handling strobe gate from the programmer function to control the operation of the strobe gate.

A parity generator looks at the strobe gate outputs and counts the number of ones in each frame. If the number is odd, one is inserted for the parity bit of the next frame. If the number is even, zero is inserted for the parity bit of the next frame. This provides a parity check for each SIDE frame.

2-153.   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 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 sub-system included in the ASE telemetry format as engineering data. The ASE formats and applies the seismic and engineering data to the data subsystem mod-ulator for modulation and downlink transmission.

2-154.   ASE PHYSICAL DESCRIPTION

The ASE comprises the thumper-geophone assembly, mortar package, central electronics assembly, and interconnecting cabling. Figure 2-75 illustrates the ASE components.

2-155.   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 (arming firing, and ASI selection) 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.

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 deploy-ment.

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.

2-156.   ASE Geophones. The three identical 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 physi-cal motion. The geophones will be deployed at 10, 160, and 310 foot intervals from the central station and are connected to it by cables. The cables and geo-phones are stored on the thumper during transport and removed during deploy-ment.

2-157.   ASE Mortar Package. The mortar package assembly (MPA) consists of a mortar box assembly, a grenade launch tube assembly (GLA), and interconnect-ing cables.

The mortar package is deployed at an angle approximately 45° to the lunar sur-face to provide an optimum launch angle for the grenades. Two legs spread from the upper end of the package to form a triangular base with a beveled lower end for stability. The stability of the mortar package is enhanced by the effect-
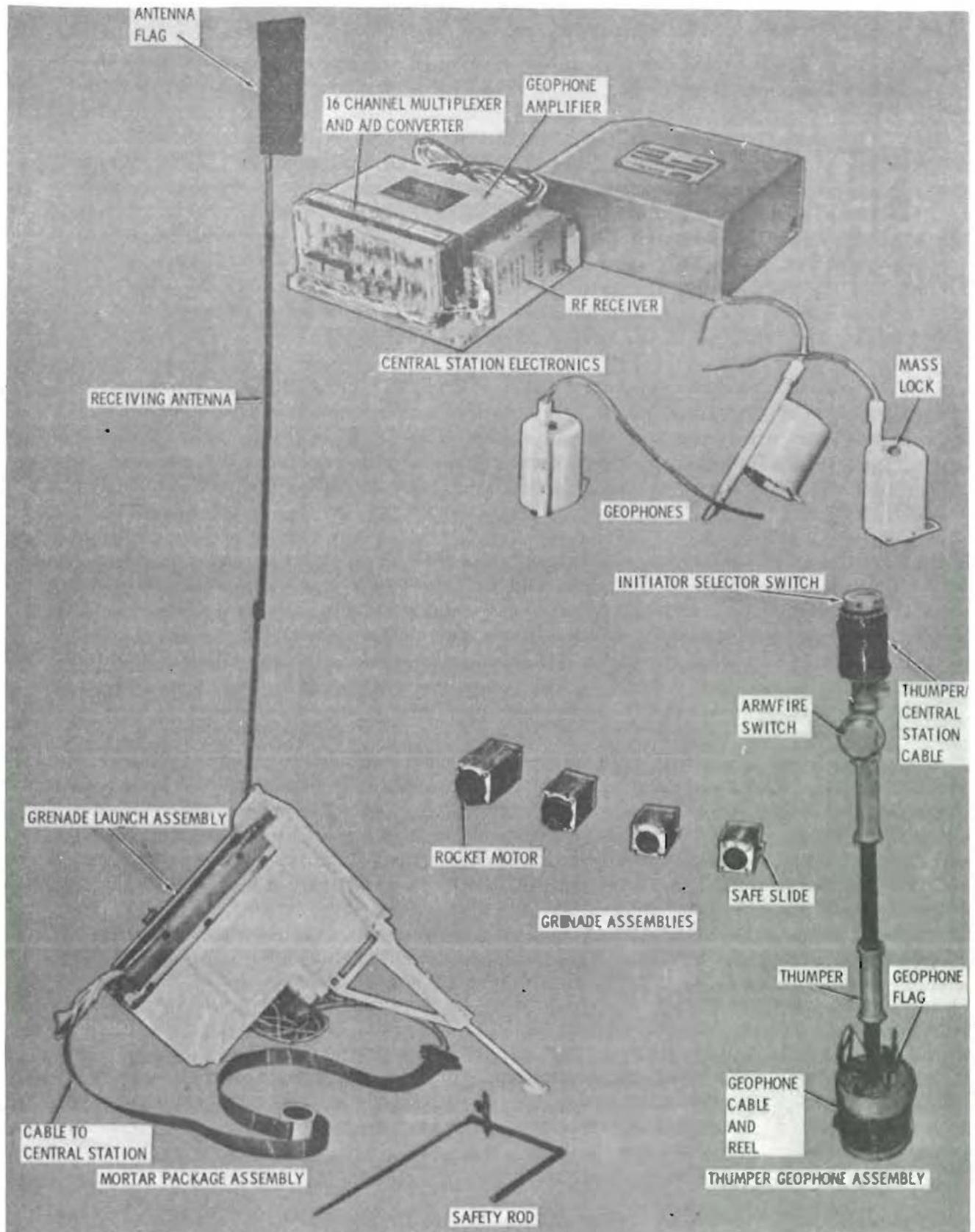
Figure 2-75. Active Seismic Experiment (ASE) Subsystem

ively open launch tubes which minimize the recoil from the grenade launchings. The bottom of the thermal insulation bag is fragile and is disintegrated when the rockets are launched.

2-158.   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.

2-159.   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 start and stop a range gate pulse establishing a time interval for determination of the grenade 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 feed 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.

2-160. 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.

2-161. 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.

2-162. ASE Leading Particulars. Table 2-23 ASE Leading Particulars list the size, weight, and power requirements for the ASE components and assemblies.

Table 2-23. ASE Leading Particulars

Characteristic	Value
Physical Data	
Thumper-Geophone Assembly	
Length (folded)	14.5 inches
Weight	6.96 pounds
Thumper	
Length (deployed)	44.5 inches
Weight (including cables and initiators)	4.01 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	14.69 pounds
Mortar Box	
Height	9.5 inches
Width	4.0 inches
Length	15.6 inches
Weight (including antenna and cables)	4.08 pounds

Table 2-23. ASE Leading Particulars (cont)

Characteristic	Value
Frequency Response	
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	3.07 pounds
Seismic Detection System (To the mean of ten 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	
Operational	8.0 watts
Thermal control (Standby)	1.75 watts

2-163. 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.

2-164.   ASE Thumper Mode.   In the thumper mode, the thumper is used to fire an Apollo Standard Initiator (ASI) at each 15 foot 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 permit determination of the wave velocity.

2-165.   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 seimic wave velocity may be determined from the above data which are telemetered as real time events.

2-166.   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.

2-167.   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 2-76 illustrates the ASE functions.   The action and interaction of these functions are discussed in the following paragraphs.
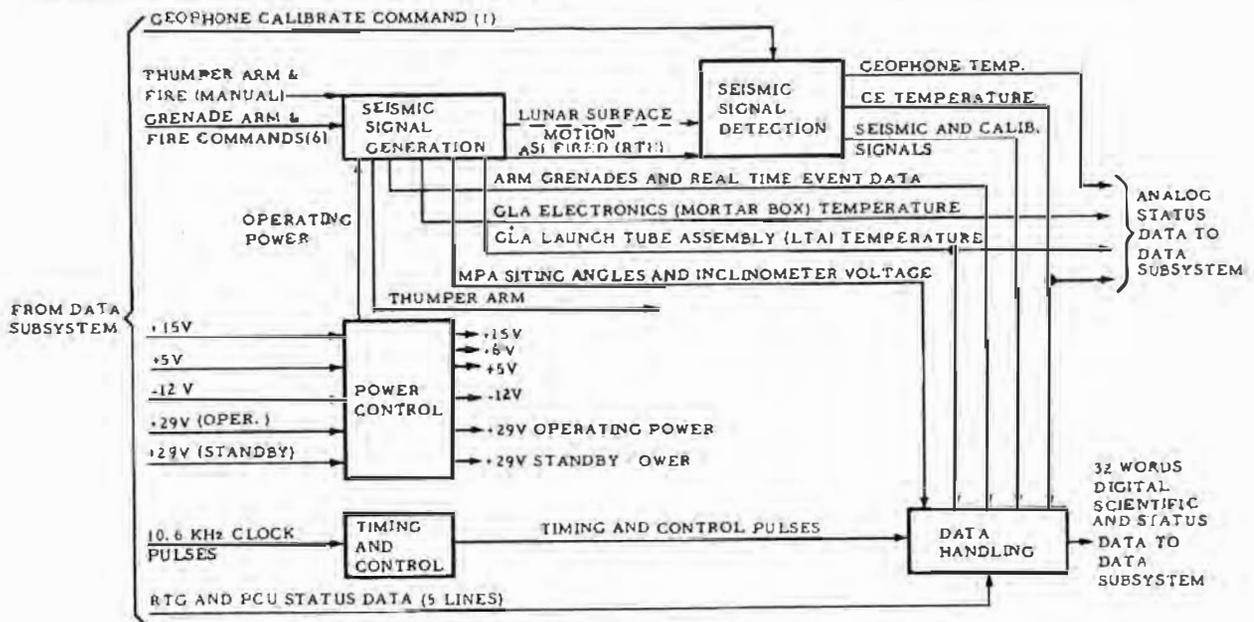
Figure 2-76.   Active Seismic Experiment (ASE) Subsystem, Functional Block Diagram

2-168.   ASE Seismic Signal Generation.   Seismic waves will be artificially gen-
erated using two methods.   The thumper initiators and the grenade high explosives
will provide the energy for sismic 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 2-77 illustrates the seismic signal generation
function.

The astronaut will remove the thumper from the subpackage and place it in a tem-
porary location.   The mortar package assembly will be deployed 10 feet from the
central station in a direction opposite to that selected for geophone emplacement.
(See Flight 4 deployment diagram in Section IV.)   The astronaut will coarse level
the mortar package as it is sited and erect the receiver antenna including the flag
for use in visual alignment of the geophones.   Actual angle of the mortar package
from the vertical will be sensed by the two-axis inclinometer and its transducers
will provide analog signals containing this data to the ASE data handling function.
The +15 vdc transducer operating power is also monitored and an analog signal
indicating status is applied to the data handling function.

The astronaut will retrieve the thumper and unwind the geophone cable from the
thumper as the geophones are emplanted at the prescribed 10, 160, and 310 foot
distances from the central station.   The thumper power and signal cable will also
be unwound as the astronaut deploys the geophones.   When the geophones have
been emplanted, the astronaut will return along the geophone line stopping at
marked intervals (approximately every 15 feet) to activate the thumper.   The
thumper contains 21 Apollo standard initiators (ASI) which are individually se-
lected 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 individual ASI for firing.   As a precaution against inadvertent initia-
tion, 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 in-
stant of initiation is monitored by the pressure force momentarily closing a pres-
sure 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 func-
tion.   The real time event logic establishes the event identification for the tele-
metry 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.

After completion of the thumping process, the astronaut will return to the mortar
package.   The astronaut will remove a safety pin assembly and open two shorting
(safe/arm) switches.   The mortar package will remain in this configuration until
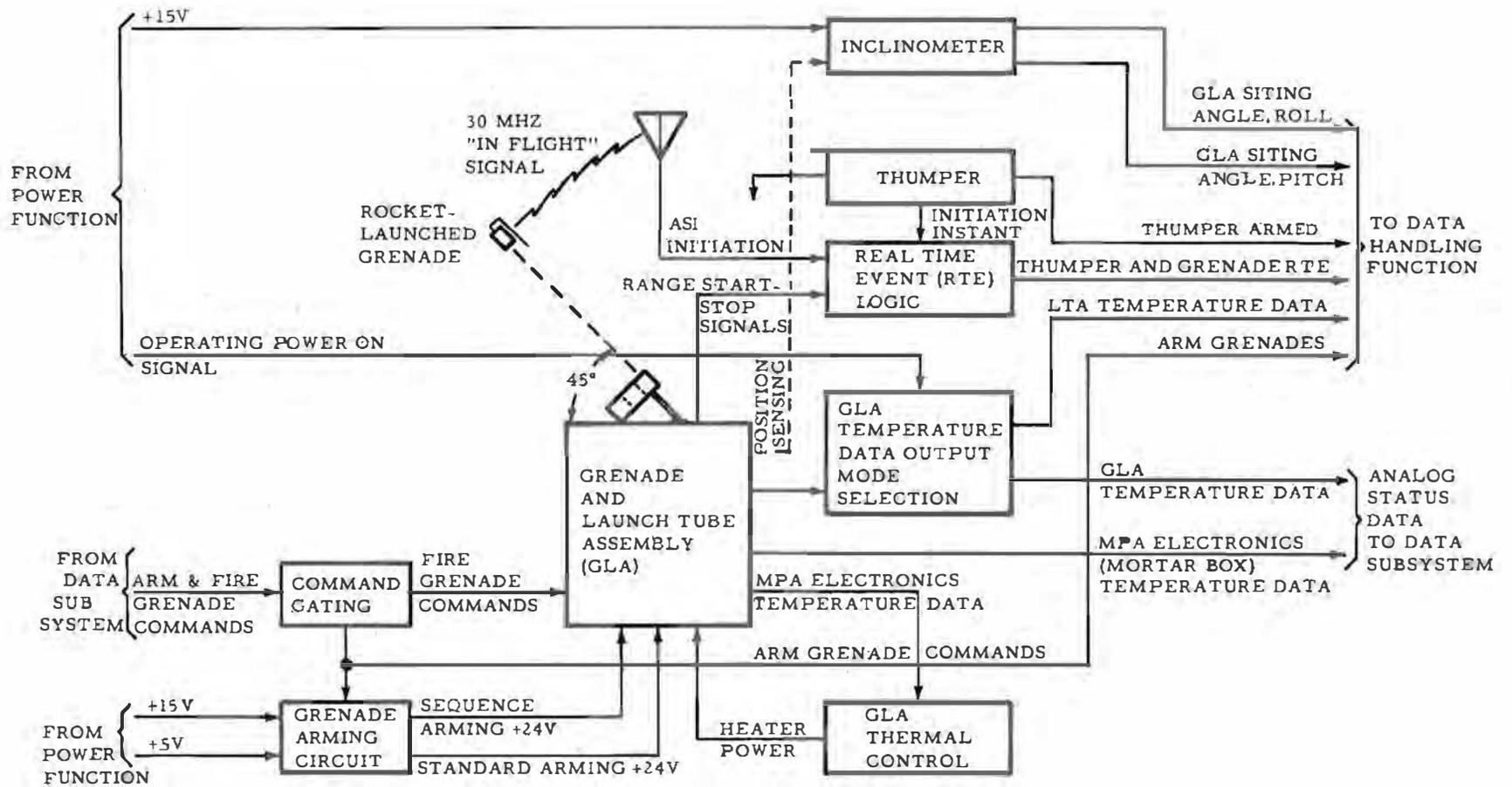
Figure 2-77. ASE Seismic Signal Generation Function, Block Diagram

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 grenades" 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 thermoelectric 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 providing an indication of range thus enhancing 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 ASI's 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.

2-169. ASE Seismic Signal Detection. The active seismic experiment is designed to monitor seismic waves in the 3Hz 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 2-78). 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.
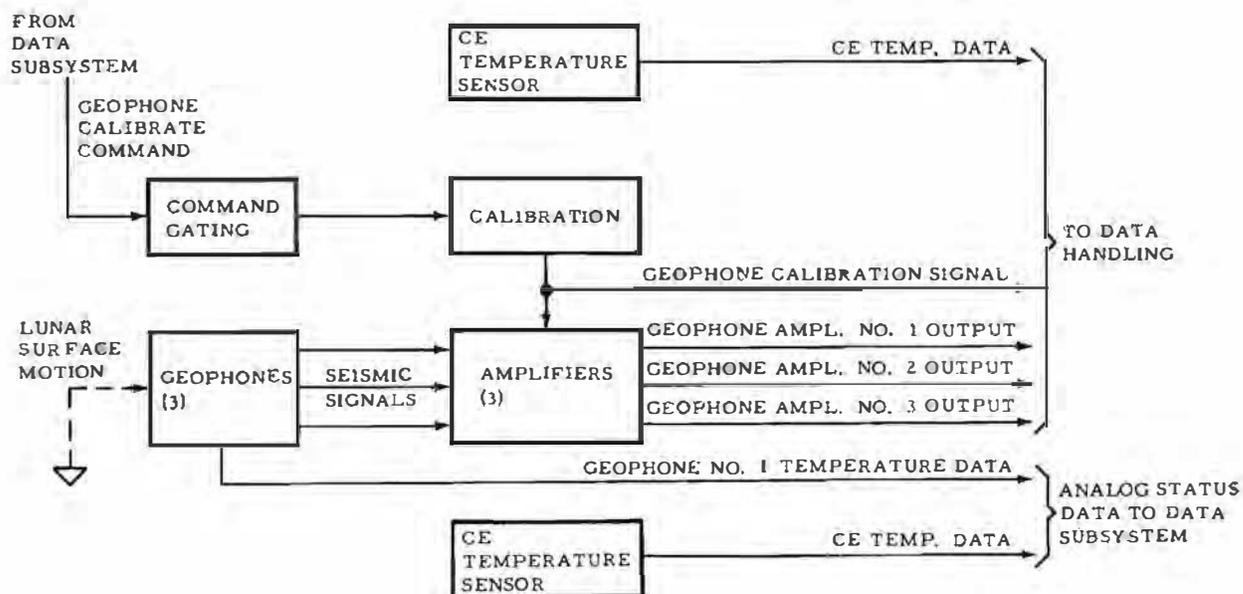
Figure 2-78. ASE Seismic Signal Detection Function, Block Diagram

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.

2-170. 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 2-79). 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.
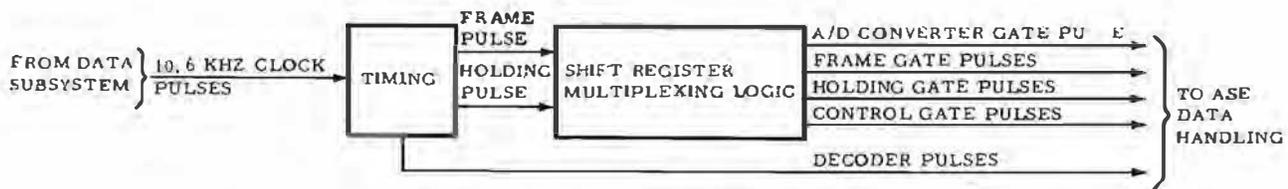
Figure 2-79. ASE Timing and Control Function, Block Diagram

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.

2-171. 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 2-80 illustrates the ASE data handling function.
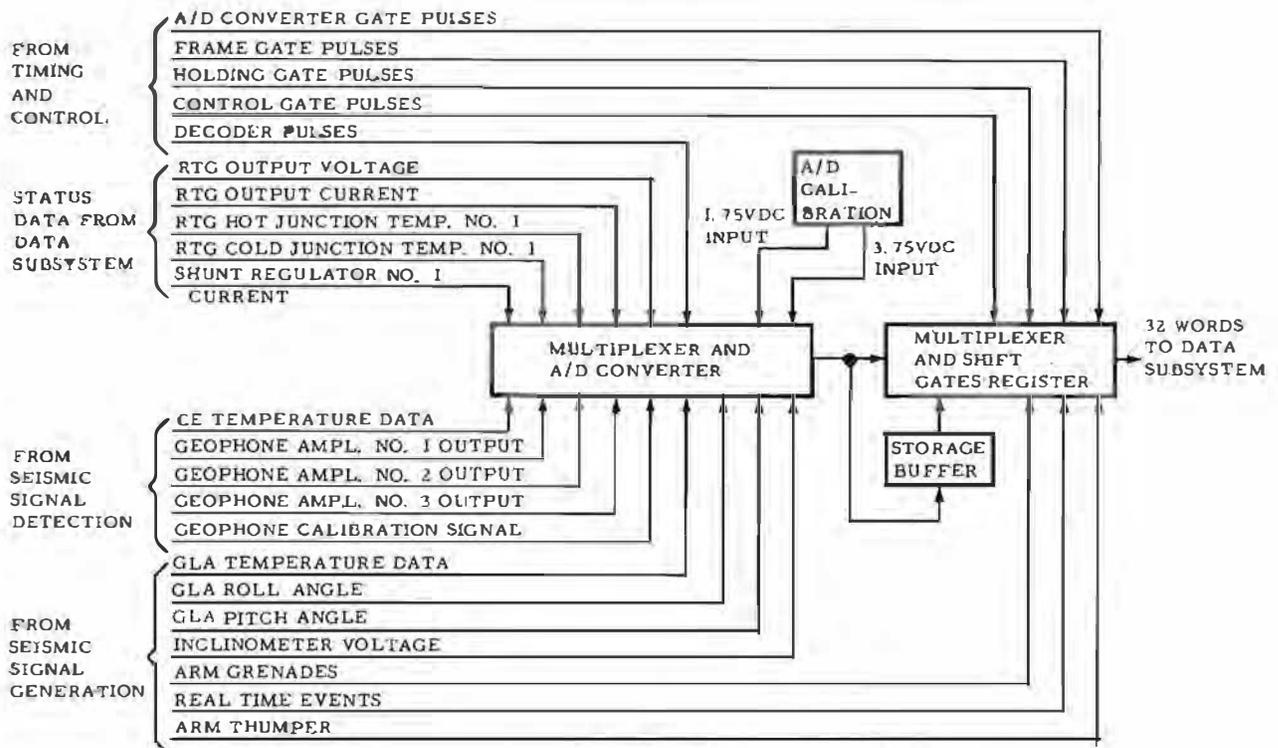
Figure 2-80. ASE Data Handling Function Block Diagram

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 2-24.

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

Table 2-24. 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 [From Table 1]

Symbol	Location/Name	Channel	Range	Sensor Accuracy	Bits/ Sample	Samples/ Sec
AS-1	Central Station Package Temp.	29	$-40^{\circ}C$ to $+100^{\circ}C$	$\pm 3^{\circ}C$	8	.0185
AS-2	Mortar Box Temp.	44	$-75^{\circ}C$ to $+100^{\circ}C$	$\pm 3^{\circ}C$	8	.0185
AS-3	Grenade Launcher Assembly Temp	55	$-75^{\circ}C$ to $+100^{\circ}C$	$\pm 3^{\circ}C$	8	.0185
AS-4	Geophone Temp.	73	$-100^{\circ}C$ to $+130^{\circ}C$	$\pm 3^{\circ}C$	8	.0185

Active Seismic Measurements

Symbol	Location/Name	A/S Word	Subword	Range	Sensor Accuracy	Bits/ Sample	Samples/ Sec
DS-17	Frame Sync	①1	1,2	N/A	N/A	10	26.56
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	$400^{\circ}F$ to $600^{\circ}F$	$\pm 5^{\circ}F$	8	16.56
AE-5	Shunt Regulator #1 Current	5, 6	1	0 to 3.5 A DC	$\pm 2\%$	8	16.56
DS-9	+5V Telemetry	7, 8	1	0 to 5.2 VDC	$\pm 0.5\%$	8	16.56
DS-6	Pitch Angle	9,10	1	$\pm 10^{\circ}$	$\pm 0.5\%$	8	16.56
DS-7	Roll Angle	11,12	1	$\pm 10^{\circ}$	$\pm 0.5\%$	8	16.56
AS-3	Grenade Launcher Assembly Temp.	13, 14	1	$-75^{\circ}C$ to $+100^{\circ}C$	$\pm 3^{\circ}C$	8	16.56
DS-8	Geophone Calibrate Pulse	15,16	1	0 to +5V	$\pm 1\%$	8	16.56
DS-11	A/D Calibration 3.75V	17, 18	1	3.5 to 4.0 VDC	$\pm 0.5\%$	8	16.56
DS-10	A/D Calibration 1.25V	19,20	1	1.0 to 1.5 VDC	$\pm 0.5\%$	8	16.56
AS-1	Central Station Package Temp	21,22	1	$-40^{\circ}C$ to $+100^{\circ}C$	$\pm 3^{\circ}C$	8	16.56
AE-1	Converter Input Voltage	23, 24	1	0 to 20 VDC	$\pm 2\%$	8	16.56
AE-4	Input Current	25, 26	1	0 to 5 A DC	$\pm 2\%$	8	16.56
AR-1	RTG Hot Frame Temp. #1	②27,28	1	$950^{\circ}F$ to $1150^{\circ}F$	$\pm 50^{\circ}F$	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.

format to the bi-phase modulator of the data subsystem for modulation and down-link 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.

2-172. 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 2-81). 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.
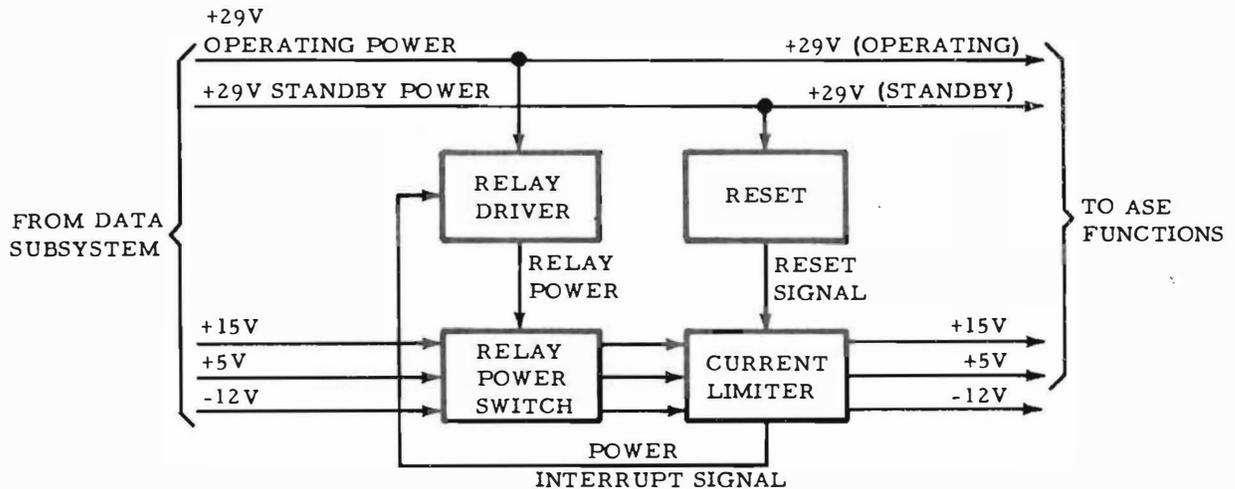
Figure 2-81. ASE Power Control Function, Block Diagram

2-173. 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.

2-174. Thumper-Geophone Assembly. The thumper contains 21 Apollo Standard Initiators (ASI's). The ASI's 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 ASI's 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 ASI's 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 ASI's 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° and holding for a minimum of four seconds. The selected ASI is fired by pressing the same switch 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.

2-175. 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 SBASI's 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° centigrade.

The mortar package is designed to be a 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 SBASI's 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 and 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.

2-176. 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.

2-177. HFE PHYSICAL DESCRIPTION

The major components of the HFE are two sensor probes and an electronics package as shown in Figure 2-82. 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
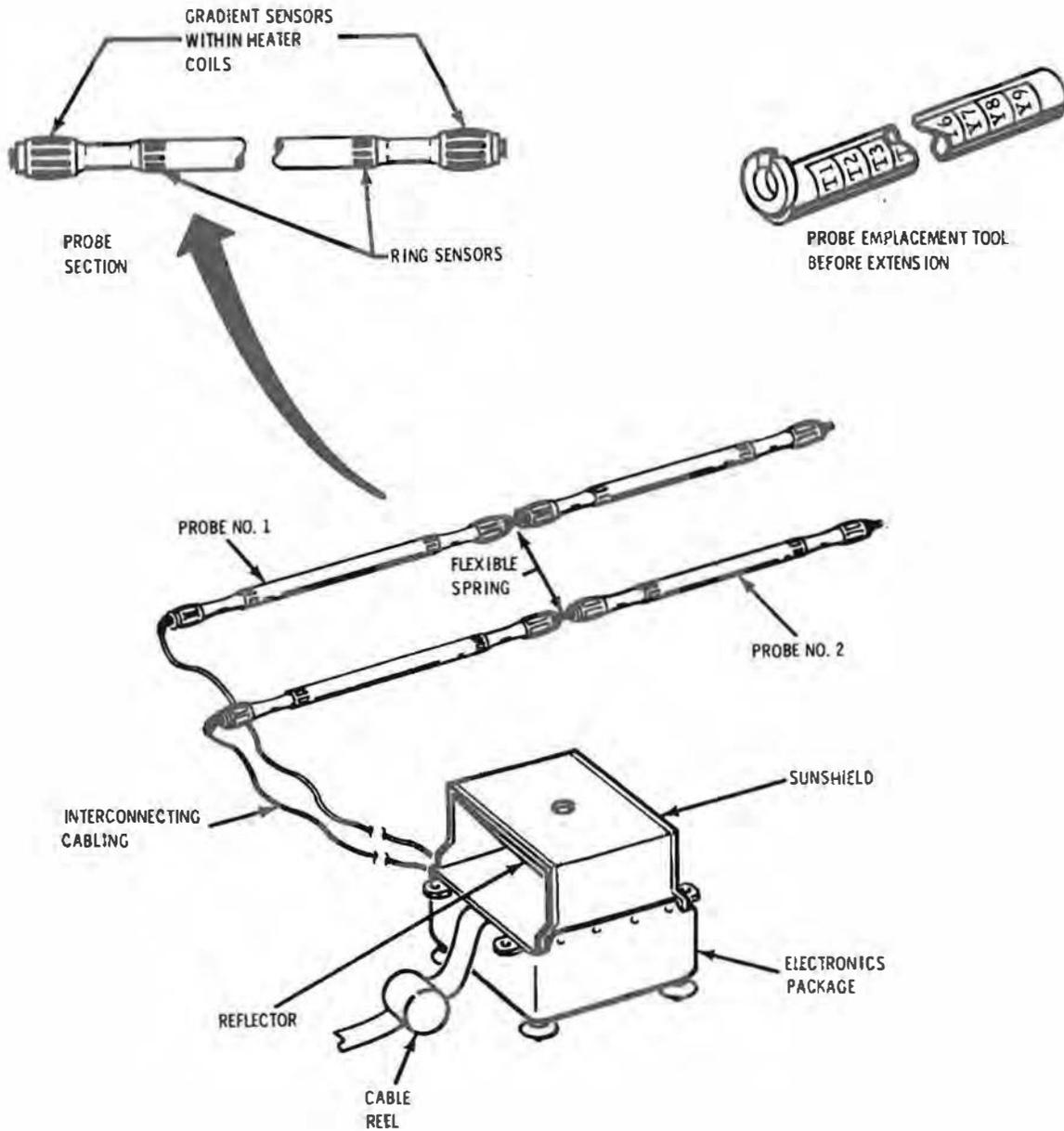
Figure 2-82. Heat Flow Experiment (HFE) Subsystem

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. Two reflectors built into the open ends 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 2-25.

Table 2-25. HFE Leading Particulars

Characteristic	Value
Size of probes (both packaged for flight) in inches	25.5 x 4.5 x 3.5
Size of electronics units in inches	13 x 9 x 8
Weight of probes (both packaged for flight) in pounds	3.50
Weight of electronics unit in pounds	6.20
Power Requirements	
Mode 1	6.0 watts (day) 9.5 watts (night)
Mode 2	11.0 watts (day or night)
Mode 3	9.0 watts (day only)

2-178. 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 2-83. These functions are command processing, timing and control, temperature measurement, conductivity heater, data handling, and power and electronics thermal control.
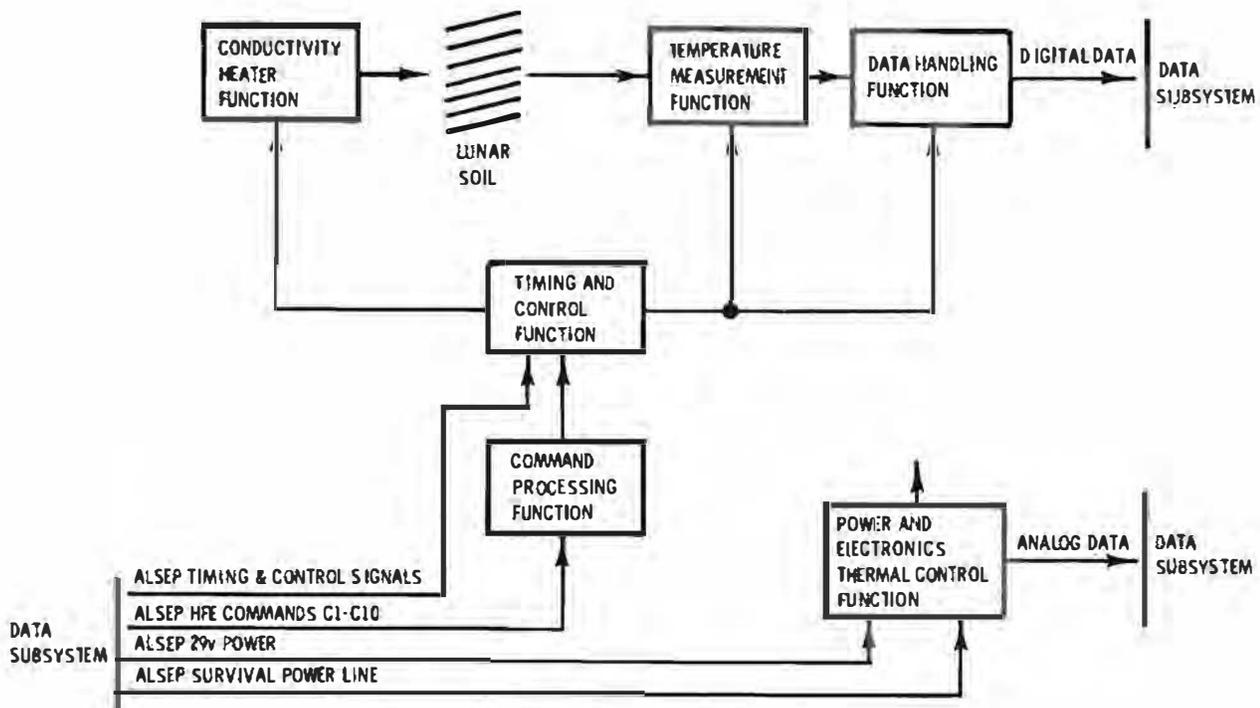
Figure 2-83. Heat Flow Experiment, Functional Block Diagram

The command processing function receives 10 different Earth commands (listed in Table 2-26) 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.

2-179. HFE DETAILED FUNCTIONAL DESCRIPTION

2-180. HFE Command Processing Function. The command processing function block diagram is shown in figure 2-84 and 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. 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 (Cl through C10, table 2-26). They are gated to appropriate inputs of the respective select registers by the 90 FM.

Table 2-26. HFE Command List

Command Number		Command Nomenclature
Symbol	Octal	
CH-1	135	Normal (Gradient) Mode Select[1] (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[1] (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[2] (HFE LOAD 1)
CH-8	145	HF Subsequence #2[2] (HFE LOAD 2)
CH-9	146	HF Subsequence #3[2] (HFE LOAD 3)
CH-10	152	HF Heater Advance (HFE HTR STEPS) (Steps through following 16-step sequence, one step per command)
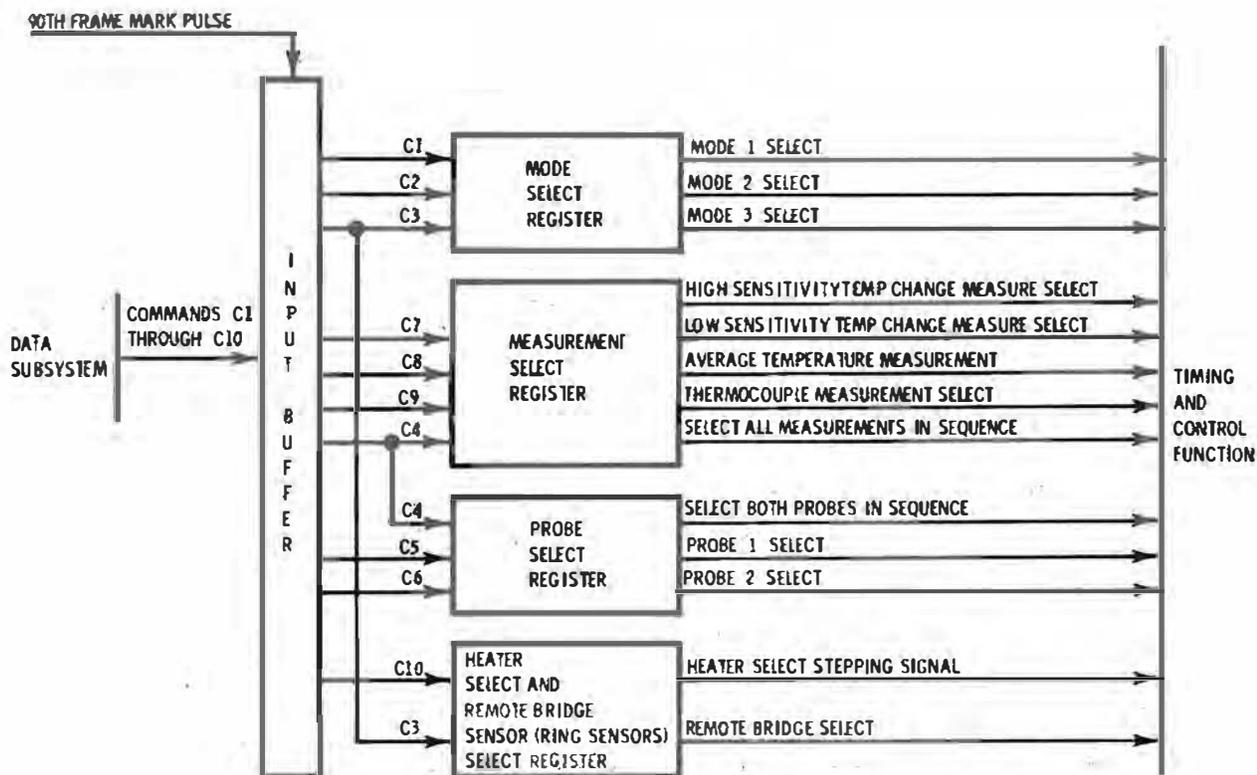
Figure 2-84. HFE Command Processing Function, Block Diagram

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 2-27.

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.

2-181. HFE Timing and Control Function. The timing and control function is shown in Figure 2-85 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 2-27. 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 2-26). 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.

2-182. HFE Temperature Measurement Function. The HFE temperature measurement function block diagram is shown in Figure 2-86 and consists of the pulse power supply, sensor excitation switching circuit, gradient bridge sensors,

Table 2-27. HFE Measurements

Sequential Order	Symbol	Measurement and Location	Heater Status
		Modes 1 and 2 Sequence (Gradient and Low Conductivity)	
		High Sensitivity	
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 $(\Delta T_{22}H)$	
		Low Sensitivity	Off in Mode 1, as selected in Mode 2
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 $(\Delta T_{22}L)$	
		Ambient Temperature	
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 2-27. HFE Measurements (cont)

Sequential Order	Symbol	Measurements and Location	Heater Status
		Modes 1 and 2 Sequence (Gradient and Low Conductivity) (cont)	
		Thermocouple	
13	DH-13	Thermocouple reference junction thermometer (T ref)	
14		Four thermocouples in probe 1 cable (four readings) (TC group 1)	Off in
	DH-14	Reference thermocouple - thermocouple 4 (Ref. $TC-TC_1(4)$)	Mode 1
	DH-24	Thermocouple 4 - thermocouple 1 ($TC_1(4) - TC_1(1)$)	as
	DH-34	Thermocouple 4 - thermocouple 2 ($TC_1(4) - TC_1(2)$)	selected
	DH-44	Thermocouple 4 - thermocouple 3 ($TC_1(4) - TC_1(3)$)	in Mode 2
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 2-27. 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 2-27. 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.
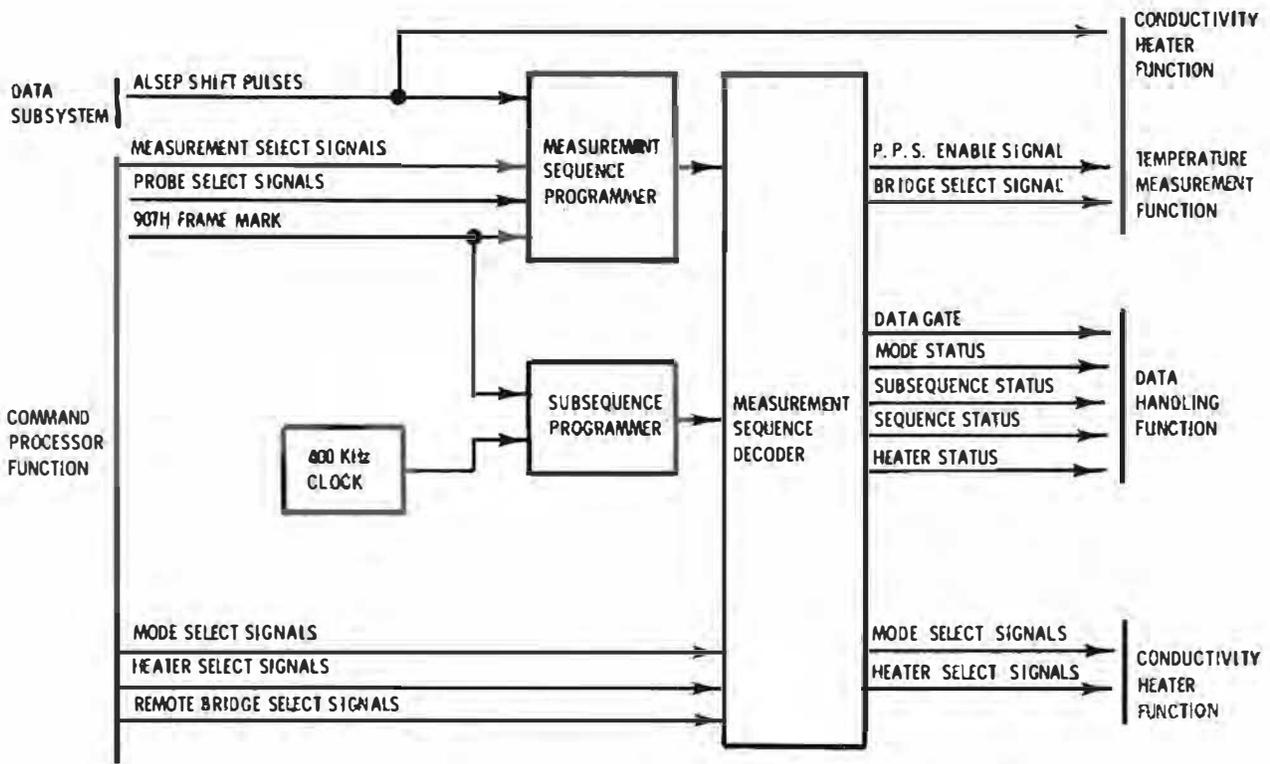
Figure 2-85. HFE Timing and Control Function, Block Diagram
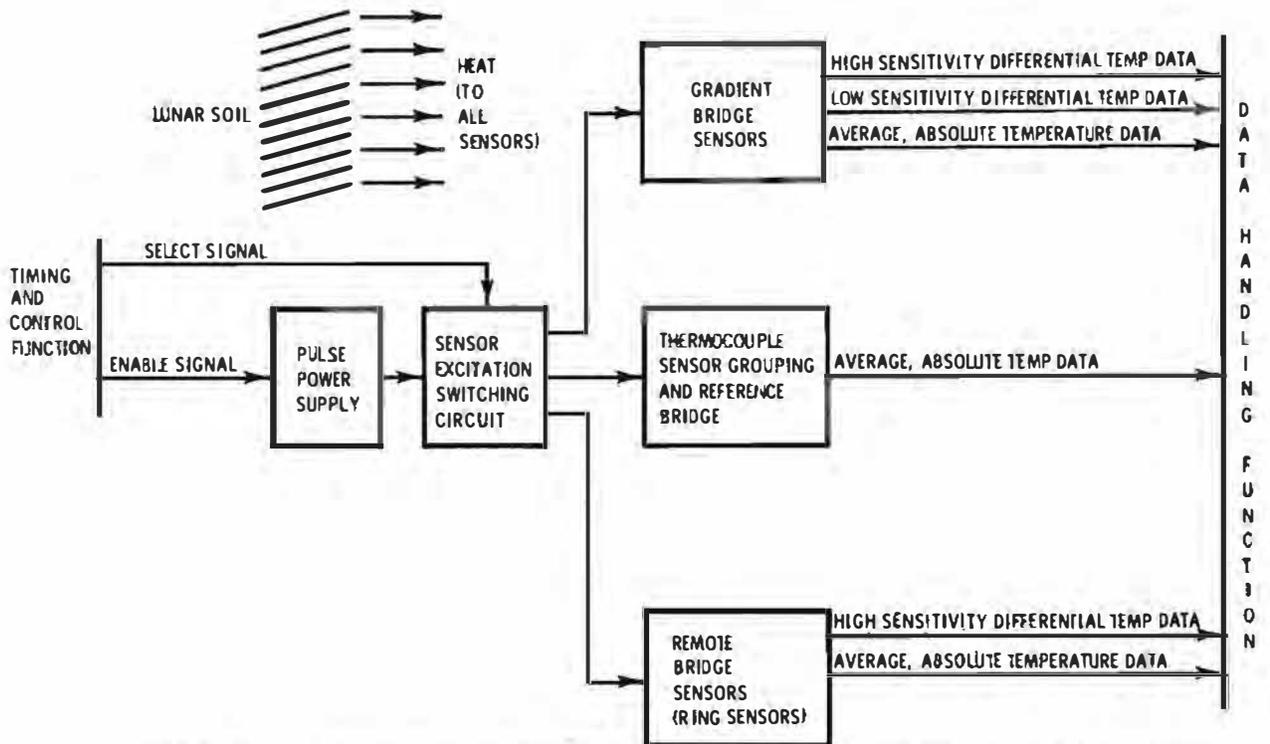
Figure 2-86. HFE Temperature Measurement Function, Block Diagram

thermocouple sensor grouping and reference bridge, and the remote bridge sensors (ring sensors). The gradient bridges, ring bridges, and thermocouples 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 -20 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.

2-183. 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).

2-184. 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 2-27) selected by Earth command (Table 2-26). 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 2-27) 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).

2-185. HFE Conductivity Heater Function. The conductivity heater function block diagram is shown in figure 2-87 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.
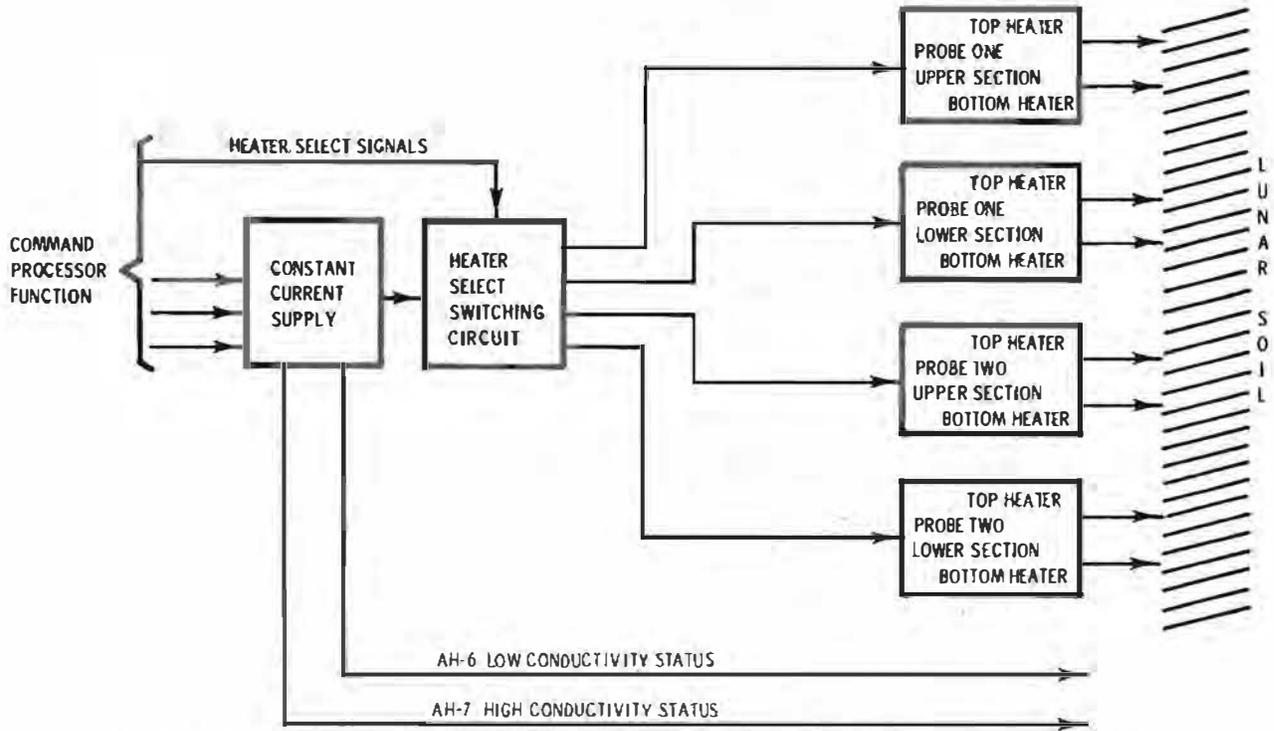
Figure 2-87. HFE Conductivity Heater Function, Block Diagram

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.

2-186. HFE Data Handling Function. The data handling function block diagram is shown in Figure 2-88 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.
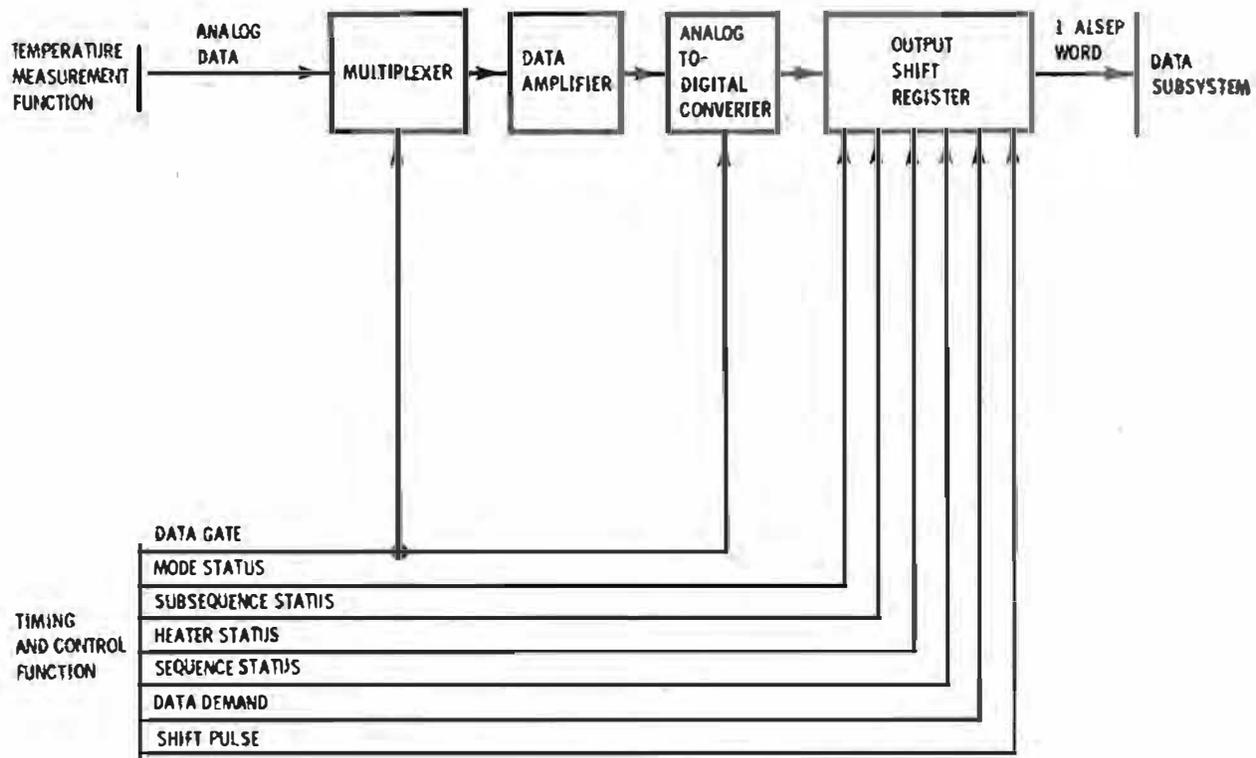
Figure 2-88. HFE Data Handling Function, Block Diagram

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 2-83. 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.

2-187. HFE Power and Electronics Thermal Control Function. The HFE power and electronics thermal control function block diagram is shown in figure 2-89. 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.
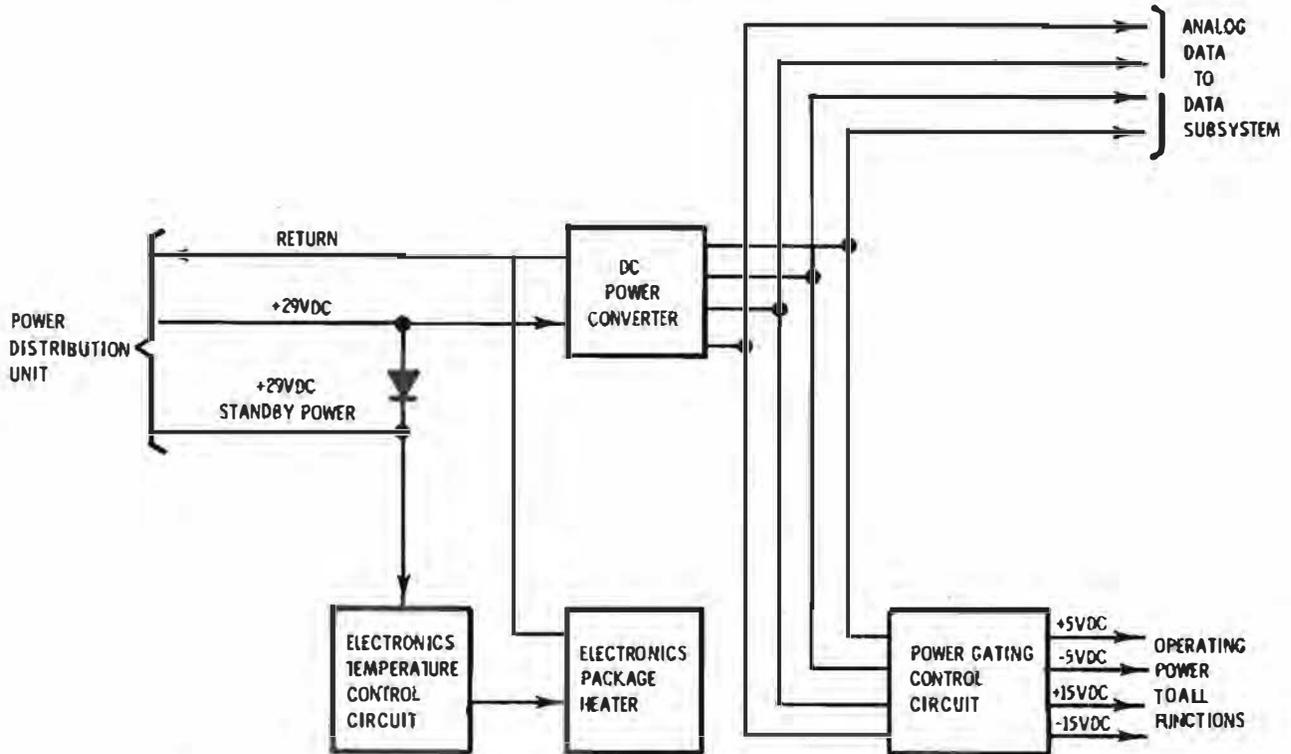
Figure 2-89. HFE Power and Electronics Thermal Control Function,
Block Diagram

Active thermal control of the HFE electronics package is provided by the elec-
tronics 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 10° 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 ther-
mal control.

2-188. HFE/Data Subsystem Interface - In addition to the ten Earth commands
listed in Table 2-26, the HFE receives the following four timing and control sig-
nals 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 com-
mand 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.

2-189. 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 2-89A. 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.
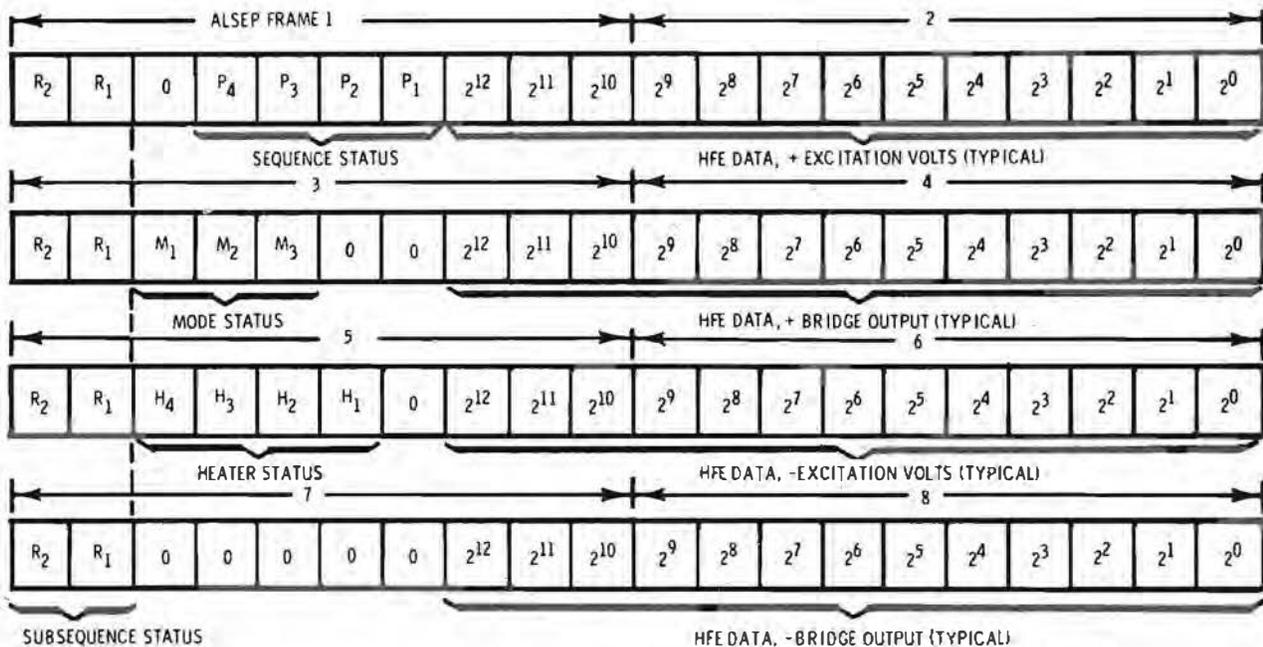
Figure 2-89A. HFE Measurement Digital Data Format

2-190. 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 2-28.

Table 2-28. 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	Low Conductivity Heater	57	ON/OFF
AH-7	High Conductivity Heater	75	ON/OFF

2-191. CHARGED PARTICLE LUNAR ENVIRONMENT EXPERIMENT (CPLEE)
SUBSYSTEM

The charged particle lunar environment experiment (CPLEE) measures the energy
distribution, time variations, and direction of proton and electron fluxes at the
lunar surface. The results of these measurements will provide information on a
variety of particle phenomena.

The lunar surface may be bombarded by electrons and protons caused by several
phenomena that are as yet not understood. For example, occasionally the solar
wind may hit the surface. This wind is caused by the expansion into interplane-
tary space of the very hot outer gaseous envelope of the Sun. The resulting flow
stream apparently carries energy and perturbations from the Sun to the Earth-
Moon system. During times of the full Moon, this solar wind stream also sweeps
the magnetospheric tail of the Earth toward the Moon. It appears that here the
electrons and protons that cause auroras and Van Allen radiation are accelerated
when they plunge into the terrestrial atmosphere. These acceleration processes
are not understood and simultaneous observations of them near the Earth and
Moon will permit more detailed study of their extent and other characteristics.

Because the Moon is sufficiently large to prove an obstacle to the flow of the solar
wind, it is possible that, at times, there is a standing front. The detailed physi-
cal processes that occur at such fronts are not fully understood, and they are of
considerable fundamental interest in plasma research. If there is such a front
near the Moon, the CPLEE will detect the disordered or thermalized fluxes of
electrons and protons which share energy on the downstream side of the front.

To study these phenomena, the CPLEE measures the energy of protons and elec-
trons separately, and measures each in 18 different energy intervals. The
CPLEE is capable of measuring particles with energies ranging from 40 ev to ap-
proximately 70 kev with flux levels of about 10^5 to 10^{10} particles per square
centimeter/second/steradian. The CPLEE measures particles and, therefore,
characteristics of the following solar radiation phenomena:

    a. Solar wind electrons and protons (50 kev to 5 kev)
    b. Thermalized solar wind electrons and protons (50 ev to 10 kev)
    c. Magnetospheric tail particles (50 ev to 70 kev)
    d. Low-energy solar cosmic rays (10 ev to 70 kev).

The basic instrument of the CPLEE used to perform these measurements consists
of two detector packages (analyzers) oriented in different directions for minimum
exposure to the ecliptic path of the Sun. Each detector package has six particle
detectors. Five of these detectors provide information about particle energy dis-
tribution, while the sixth detector provides high sensitivity at low particle fluxes.
Particles entering the detector package are deflected by an electrical field into

one of the six detectors, depending on the energy and polarity of the particles. The CPLEE also includes electronics for recording the particle counts and providing data to the data subsystem.

The CPLEE reports scientific data to the data subsystem in six words of the 64-word ALSEP telemetry frame. The CPLEE also reports six housekeeping signals to the data subsystem.

2-192. CPLEE PHYSICAL DESCRIPTION

The CPLEE is a self-contained unit consisting of sensing and signal processing electronics housed in an insulated case. The CPLEE is supported by four legs in a rectangular arrangement (see Figure 2-90). Leading particulars of the CPLEE are shown in Table 2-29. Figure 2-91 shows the three major components of the CPLEE:

  a. Two physical analyzers
  b. Electronics.

Each physical analyzer consists of entrance slits, deflection plates, and six detectors.
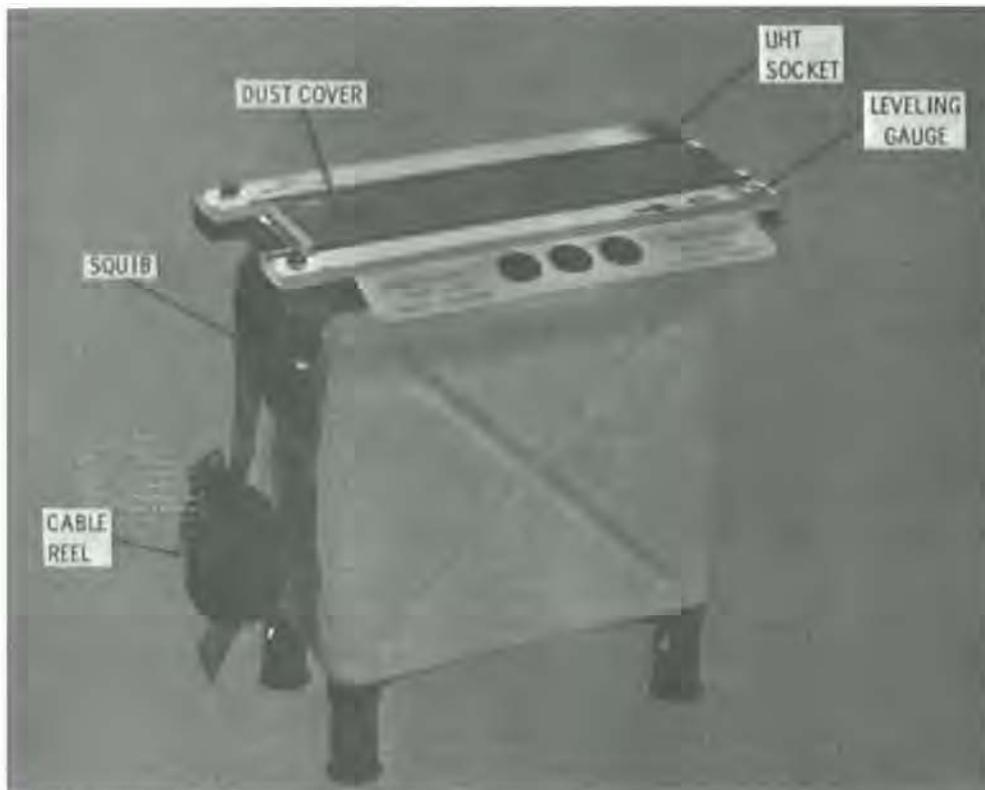
Figure 2-90. Charged Particle Lunar Environment Experiment Subsystem

Table 2-29. CPLEE Leading Particulars

Characteristic	Value
Size	10. 3 x 4. 5 x 10. 0 inches
Weight on Earth Power Requirements	5. 08 pounds No more than 6. 5 watts for operation and heaters

CPLEE electronics consist of the following major subassemblies:

    a.   Switchable power supply (deflection plate voltages)
    b.   Power supply for Analyzer A
    c.   Power supply for Analyzer B
    d.   Low voltage power supply
    e.   Logic module
    f.   Amplifiers module
    g.   Ancillary module.
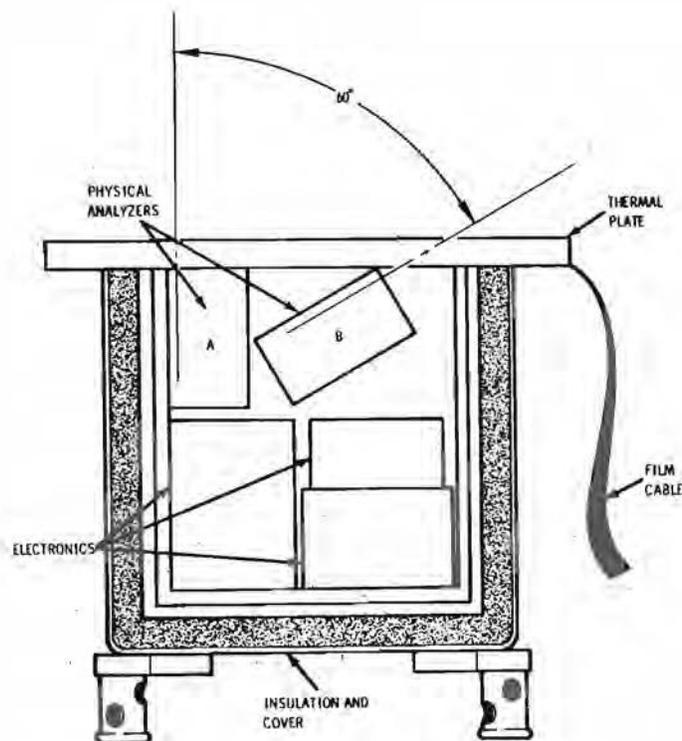
Figure 2-91. CPLEE Major Components

The upper thermal support plate is the primary structural component of CPLEE. The support plate provides a mounting base for all internal and external components, and is a tie point for mounting the experiment to ALSEP subpackage No. 1. Two apertures in the support plate provide particle access to the detectors. A mylar sheet, attached to a spring retention device, covers the apertures until a dust cover removal command is received.

An external shell of insulation provides thermal protection for the inner components and isolates the support plate from the outer case.

The CPLEE is connected to the central station by a tape cable which is contained in an enclosed reel prior to deployment.

2-193. CPLEE FUNCTIONAL DESCRIPTION

The CPLEE has six major functions:

    a. Charged particle detection
    b. Particle discrimination and programming
    c. Data handling
    d. Power supply
    e. Self-test
    f. Environmental control.

Figure 2-92 is a functional block diagram showing the relationship of these CPLEE functions.
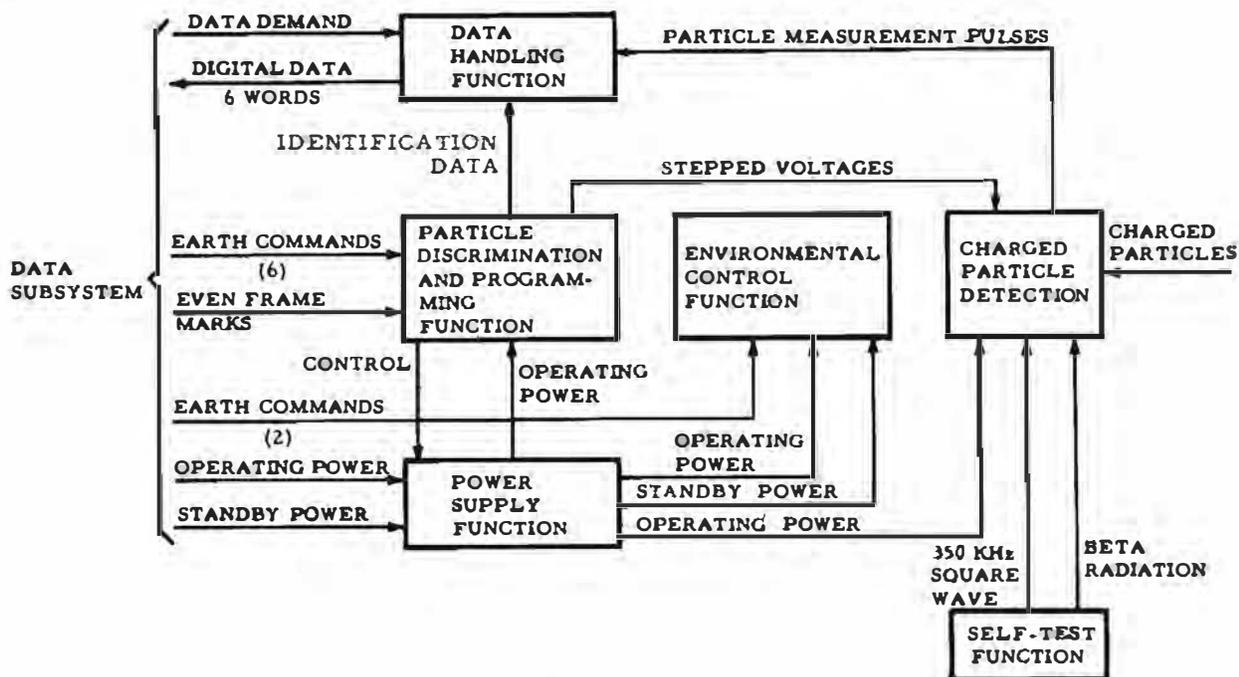
Figure 2-92. CPLEE, Functional Block Diagram

The polarity and energy content of charged particles are measured in a programmed sequence. These data are reported to data handling which converts them in a programmed sequence to digital format compatible with the ALSEP telemetry frame. These digital data are stored until requested by the data subsystem for down-link transmission to Earth.

The power supply provides high voltage to the deflection plates in the sensing function as programmed, high voltage to the twelve detectors in both physical analyzers, and low voltage to all the CPLEE electronic circuits.

The CPLEE contains two provisions to self-test its own operation:

a. Beta radiation source for end-to-end testing before dust cover removal
b. Test oscillator for checking amplifiers and data processing electronics.

Environment control features include a dust cover, dust cover removal, and thermal control.

In its operation, the CPLEE is responsive to Earth commands as listed in Table 2-30. Only one of these eight Earth commands (command 3 - dust cover removal) is essential for the operation of the CPLEE. The ALSEP central station timer provides an automatic back-up command for this operation. The other seven commands are included to extend the versatility of the experiment.

Table 2-30. CPLEE Command List

Command Number	Nomenclature
1	Operational heater ON
2	Operational heater OFF
3	Dust cover removal
4	Automatic voltage sequence ON
5	Step voltage level
6	Automatic voltage sequence OFF
7	Channeltron ® voltage increase ON
8	Channeltron ® voltage increase OFF

When operating power is applied to CPLEE, the thermal control circuitry is preset in an automatic mode. Automatic control consists of the thermostat and heaters controlling the temperature. Command 1 overrides the automatic mode by removing the thermostat from the active thermal control circuits and applying +28 volts to the heaters continuously.

Command 2 turns off the heater. In this mode the experiment operates without any active thermal control. The thermal control is returned to the automatic mode by momentarily interrupting the prime 29 vdc power to the CPLEE.

Command 3 detonates the two squibs that remove the dust cover.

Command 4 returns the CPLEE to automatic deflection plate voltage sequencing after interruption by command 6.

If automatic deflection voltage sequencing has been interrupted by command 6, command 5 will permit the deflection voltage to be manually stepped to any of the operating positions (± 3500, ± 350, ± 35, background, or test oscillator).

Command 6 may be used to interrupt the automatic deflection voltage switching sequence. The deflection voltage will remain at the operating position coincident with receipt of this command and will continue to be automatically switched between physical analyzers A and B.

Command 7 may be used to increase the operating voltage applied to the detector from 2800 to 3200 volts. This capability is included so that the operating voltage can be increased in the event that the electron gain characteristics of the detector degrade during the life of the experiment.

Command 8 returns the CPLEE detector voltages to an operating voltage of 2800 volts.

2-194. CPLEE DETAILED FUNCTIONAL DESCRIPTION

The following paragraphs describe in detail the six major CPLEE functions.

2-195. CPLEE Detecting Function. The CPLEE detecting functional block diagram is shown in Figure 2-93.

The basic detector element in the CPLEE is the Bendix Channeltron ® electron multiplier. This detector is sensitive to both protons and electrons over the energy range required for this experiment and operates at a counting rate of up to one megahertz.

The detector is a glass capillary tube having an inside diameter of about one millimeter and a length of 10 centimeters. A layer of special conducting material that has secondary electron emission characteristics is deposited over the interior surface of the tube. When a potential difference is applied between the ends of the tube, an electric field is established down its length. Any electron ejected from the inside surface by photoelectric or secondary emission will be accelerated down the tube and will simultaneously drift across the tube with whatever lateral velocity was acquired by the ejection process. Electron multiplication occurs when the potential difference is such that these free electrons gain enough energy

PARTICLE DISCRIMINATION
AND PROGRAMMING FUNCTION

STEPPED   TEST OSCILLATOR
DEFLECTION   SELF TEST FUNCTION
PLATE
VOLTAGES
                 350 KH$_z$
                 SQUARE
CHARGED   WAVE   AMPLIFIED AND
PARTICLES   PHYSICAL   SHAPED PULSES
             ANALYZER   AMPLIFIERS
             A   (SIX)
                       PARTICLE
                       MEASUREMENT
2800 OR   PULSES
3200 VOLTS

POWER   POWER   DATA
SUPPLY   HANDLING
FUNCTION   POWER   FUNCTION
2800 OR 3200 VOLTS

                    PARTICLE
CHARGED   MEASUREMENT   AMPLIFIED AND
PARTICLES   PHYSICAL   PULSES   SHAPED PULSES
             ANALYZER   AMPLIFIERS
             B   (SIX)
                   350 KH$_z$
             STEPPED   SQUARE
             DEFLECTION WAVE
             P ATE
             VOLTAGES TEST OSCILLATOR
                      SELF-TEST FUNCTION

PARTICLE DISCRIMINATION
AND PROGRAMMING FUNCTION

Figure 2-93. CPLEE Charged Particle Detection Function, Block Diagram

from the electric field between encounters with the surface that more than one
secondary electron is generated at each encounter. A single electron ejected at
the low potential end of the detector can result in an electron gain of about 10^8 at
the high potential end. Figure 2-94 illustrates the typical electron gain character-
istics of a Bendix Channeltron ® detector. Note that the knee of the gain curve
occurs at about 2700 volts. Between the knee of the curve and the saturation re-
gion, the amplitude and shape of the output pulses tend to be uniform and indepen-
dent of the type or energy level of the radiation.

Energy measurements are translated to pulses by each detector and sent to sepa-
rate amplifiers where the pulses are amplified, wave-shaped, and sent to the
multiplexer in the data handling function.

Since the detector is sensitive to electrons, protons, x-rays, and ultraviolet radi-
ation, the output pulses from the detector contain no information concerning the
type or energy of the primary radiation. Therefore, information concerning these
parameters is obtained by electrostatic analysis of the charged particles prior to
their entering the detector.

Figure 2-95 illustrates the major components in the physical analyzer used in the
CPLEE. Each physical analyzer consists of a set of entrance slits, deflection
plates, and six detectors.
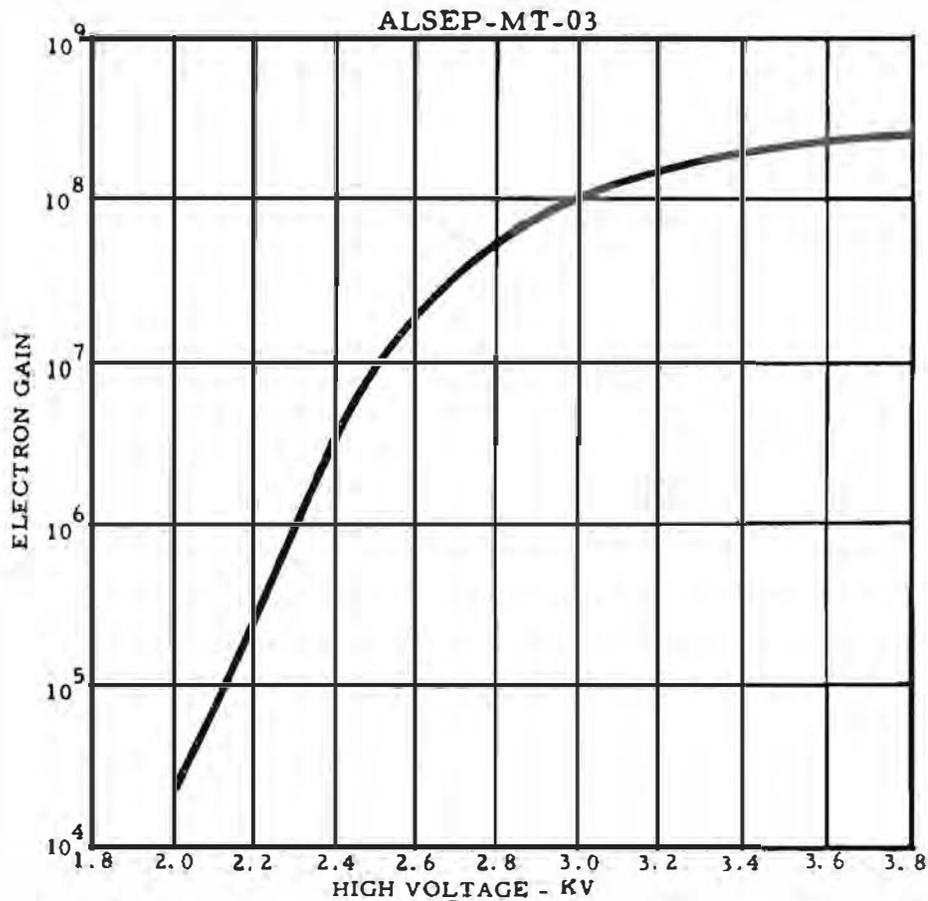
Figure 2-94. Channeltron ® Detector Typical Electron Gain

Charged particles entering the deflection plate region will be deflected along curved paths which are a function of their energy-to-charge ratio. Particles of one sign will be detected in five discrete energy levels by the five C-type detectors which are positioned below the center line of the deflection plates as defined by the entrance slits. Particles of the opposite sign are detected simultaneously by the helical detector in one broad energy spectrum.

The switchable power supply in the particle discrimination and programming function provides voltage at three levels and in each polarity to the deflector plates. This voltage applied to the deflection plates is automatically cycled through seven levels: three positive, three negative, and a nominal zero so that the background flux can be measured. Particles having a particular energy level are measured by each detector in the physical analyzer as the deflection plate voltage is automatically programmed through ±35, ±350, and ±3500 volts.

A timing sequence is used to automatically switch the deflection plate voltage. This timing sequence uses the even frame marks from the data subsystem as the basic timing clock. The even frame marks are received by the particle, discrimination and programming function which translates them into deflection plate voltage commands to the switchable power supply. Since each ALSEP telemetry frame requires 0.604 second, the even frame marks occur every 1.21 seconds.
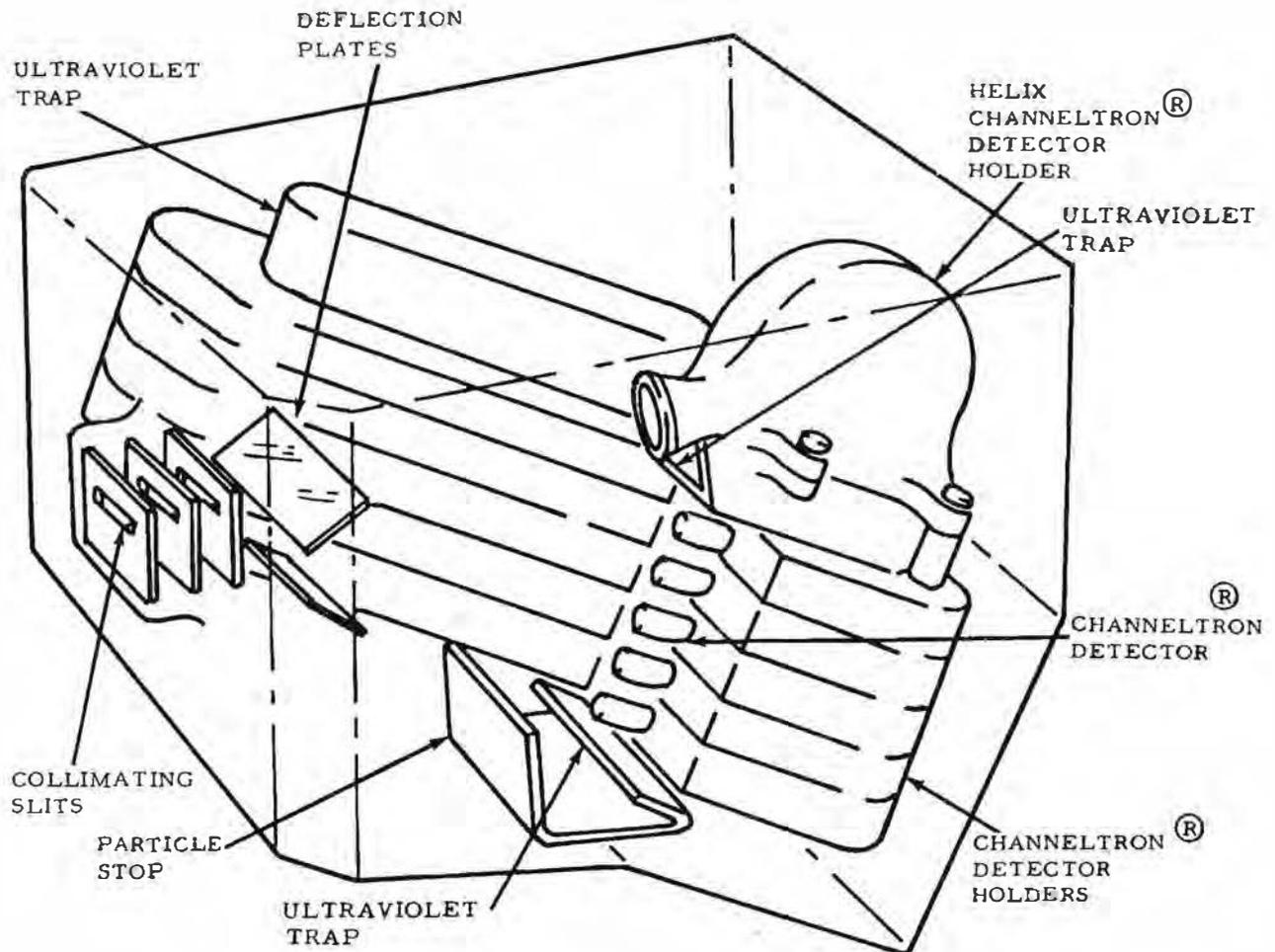
Figure 2-95. CPLEE Physical Analyzer Major Components

When the experiment is turned on, the timing sequence may start at any point. Assuming that the operation starts when +3500 volts is applied to the deflection plates, analyzer A measures the charged-particle flux for a period of 1.21 seconds. Then analyzer B measures the incident radiation for 1.21 seconds, after which the deflection voltage is automatically switched to +350 volts and the measurement sequence by analyzers A and B is repeated. Since the measurement period at each deflection voltage level is 2.42 seconds and a complete cycle of operation includes eight steps, the complete sequence requires 19.4 seconds. During the time period that one physical analyzer is measuring the flux level, the last measurement made by the second analyzer is being read out by the ALSEP data subsystem.

2-196. CPLEE Particle Discrimination and Programming Function. The CPLEE particle discrimination and programming functional block diagram is shown in Figure 2-96.
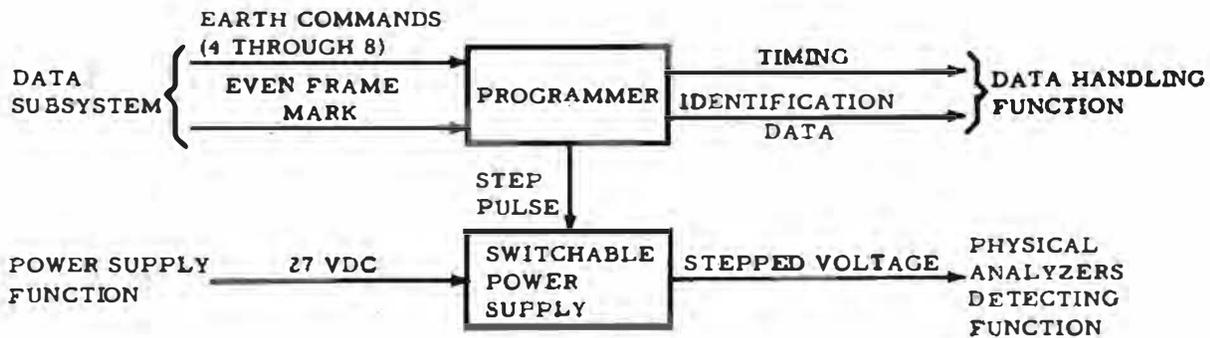
Figure 2-96. CPLEE Discrimination and Programming Function,
Block Diagram

The programmer receives even frame marks from the data subsystem and uses them as the basic timing clock to synchronize the switchable power supply which provides stepped voltages to the physical analyzer deflection plates in the detecting function.

The switchable power supply on command from the programmer provides the following stepped voltages:

a. ± 35 vdc
b. ± 350 vdc
c. ± 3500 vdc
d. 0 vdc.

These voltages are stepped as commanded by the programmer.

The outputs from the two physical analyzers in the detecting function are gated by the programmer to the multiplexer and counters of the data handling function. The two physical analyzers are gated into the counters as follows:

The pulses from physical analyzer A are gated to the counters and information is collected for a specific deflection voltage level. On receipt of an even frame mark from the data subsystem, all counter inputs are inhibited and identification data bits are stored in the shift registers. The first shift pulse, following in time, transfers the count data into the shift registers. At the falling edge of this pulse, the programmer directs the switchable power supply to its next voltage level. Approximately 30 milliseconds later, the counters are all reset to zero. About 60 milliseconds after the original even frame mark pulse, the counter inputs are enabled and physical analyzer B couples into the counters.

The output from each counter is transferred to a shift register in the data handling function upon command from the programmer. Then the count data from the shift registers are read out as serial digital data to the ALSEP data subsystem upon receipt of a data demand from the data subsystem.

2-197. <u>CPLEE Data Handling Function.</u> The CPLEE data handling function is shown in Figure 2-97.
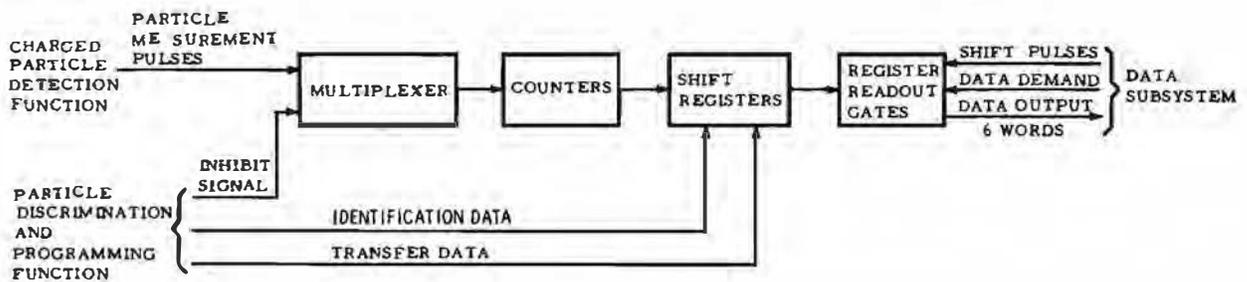
Figure 2-97. CPLEE Data Handling Function,
Block Diagram

The outputs from the detecting function are received by the multiplexer. The multiplexer contains 12 input gates, one for each detector. The multiplexer routes these outputs to the pertinent counters. The high energy and helix detectors (detectors 5 and 6) in each physical analyzer have 20-bit counters and detectors 1 through 4 have 19-bit counters. The output from each counter is transferred to a shift register upon command from the particle discrimination and programming function. The outputs from detectors 1 through 4 have only 19 bits at this point but in the shift register the identification data, ID, sent by the particle discrimination and programming function is added to each word. ID bit number 1 is added to the count data from detector 1 to indicate whether analyzer A or B is being read out. ID bit number 2 indicates the polarity (positive or negative) of the deflection voltage, and ID bit numbers 3 and 4 indicate the magnitude of the deflection voltage (3500, 350, 35, or zero). Only four bits out of 120 are used for identification data; all of the remaining digital data contain scientific information. Analyzer count data are transferred from the shift registers to the register readout gates on demand from the data subsystem. The data subsystem sends a data demand pulse to the register readout gates and the count data are read out on a digital data line.

2-198. <u>CPLEE Power Supply Function.</u> The CPLEE power supply functional block diagram is shown in Figure 2-98.

The data subsystem power distribution unit supplies primary power to the CPLEE low voltage power supply which, in turn, provides operating power to the two detector power supplies and to the switchable power supply in the particle discrimination and programming function. The switchable power supply supplies deflection plate voltages to the physical analyzers in the detecting function and its operation is discussed in the preceding particle discrimination and programming paragraphs.
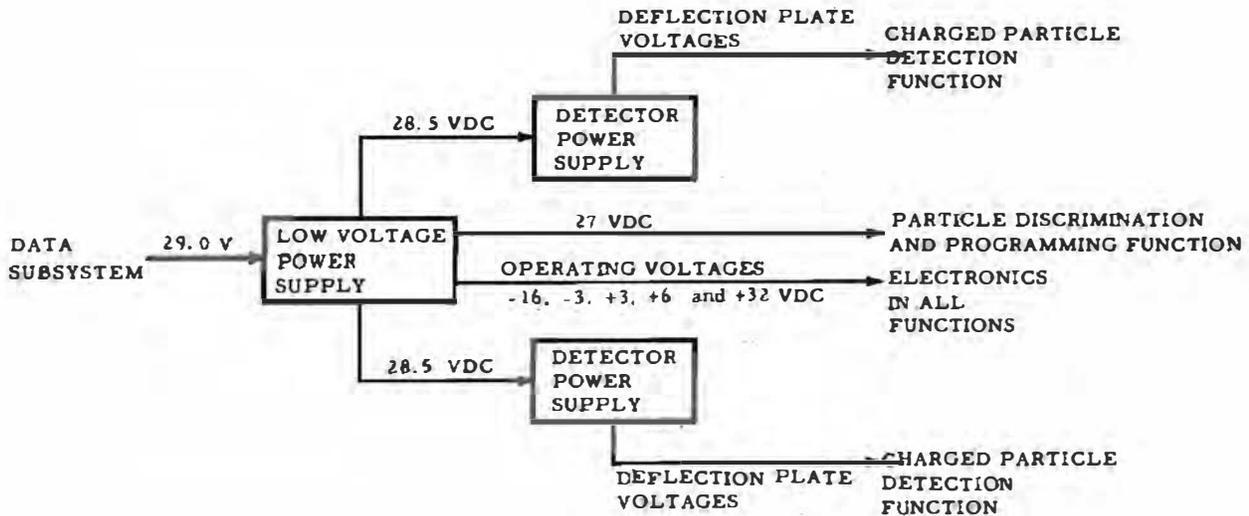
Figure 2-98. CPLEE Power Supply Function, Block Diagram

The low voltage power supply also provides ±3, +6, -16, +27, and +32 vdc for the operating voltages to all of the CPLEE electronics.

2-199. CPLEE Self-Test Function. A self-test of the preamplifiers, amplifiers, counters, and shift registers is provided by the test oscillator. The test oscillator is energized every other time the switchable power supply in the particle discrimination and programming function switches to zero volts. Therefore, a self-test is made of all the signal processing in the CPLEE during each complete cycle of operation.

The output of the test oscillator is connected to the input of the preamplifiers in parallel. The oscillator output is a near square wave continuous signal at a frequency of 350 KHz ± 10%. The oscillator pulse data are read out by the data subsystem in the same manner as detector pulses.

Another self-test of the CPLEE operation is provided by a beta-ray source located on the dust cover. This radiation is detected by the physical analyzers and the output pulses are processed as described for other charged particles. This allows a complete check of the detectors and signal processing electronics during preflight testing and prior to dust cover removal during lunar operation.

When the dust cover is removed, the effect of the beta-ray source is reduced to less than 0.1 count per second on any one detection channel.

2-200. CPLEE Environmental Control Function. The CPLEE is designed to operate over a temperature range of -50 to +150 degrees F and to survive a nonoperational temperature range of -60 to +160 degrees F.

For passive thermal control, the CPLEE is surrounded on five sides by thermal insulation of alternate layers of aluminized mylar and fiberglass with spaces between the layers. The top of the CPLEE is a thermal plate to which all of the CPLEE electronics are mounted. This thermal plate functions as a heat sink and radiates excess operation-generated heat into the lunar atmosphere.

For active thermal control, the CPLEE has heaters and a thermostat mounted to the underside of this thermal plate to maintain operating temperature levels during the lunar night. Earth command 1 bypasses the automatic thermal control employing the thermostat, and turns the heater on. Earth command 2 bypasses the thermostat and turns the heater off. Automatic control is reinstated by switching the operating power off and then on.

The CPLEE has a dust cover that protects the sensor apertures and thermal control surfaces from dust until after LM ascent. The dust cover is removed by Earth command 3 which detonates two squibs that release a spring retention device. The dust cover rolls up on one end of the thermal plate and exposes both apertures. In the event of failure of Earth command 3, a backup timer in the ALSEP data subsystem will initiate removal of the dust cover.

2-201. <u>CPLEE/ALSEP Data Subsystem Interface.</u> The scientific data from CPLEE are read out on a digital data line. Each ALSEP telemetry frame consists of 64 digital words which have ten bits each. Six words in each ALSEP telemetry frame are assigned to the CPLEE. However, the output from each of the six detectors in one physical analyzer consists of twenty bits. Therefore two ALSEP telemetry frames are required to read out one step of CPLEE operation for each physical analyzer. Word assignment is as follows:

<u>Initial T/M Frame</u>

Words 7 and 17	Detector 1
Words 19 and 23	Detector 2
Words 39 and 55	Detector 3

<u>Second T/M Frame</u>

Words 7 and 17	Detector 4
Words 19 and 23	Detector 5
Words 39 and 55	Detector 6

In addition to the digital data output signal, the CPLEE provides six analog signals for engineering data. Four of the analog signals monitor the four power supplies and the other two signals monitor the temperature of analyzer A and the switchable power supply. The ALSEP data subsystem converts these analog data to an eight-bit digital signal and each of the six signals is sampled by the data subsystem at least once every 90 frames or 54.45 seconds.

2-202. COLD CATHODE GAUGE EXPERIMENT (CCGE) SUBSYSTEM.

The cold cathode gauge experiment (CCGE) comprises the cold cathode ion gauge (CCIG) and associated electronics (Figure 2-99). The purpose of the experiment is to measure the density of the lunar atmosphere. The CCGE will determine the density of any lunar ambient atmosphere, including any temporal variations either of a random character or associated with lunar local time or solar activity. In addition, the rate of loss of contaminants left in the landing area by the astronauts and lunar module (LM) will be measured.

The cold cathode ion gauge (CCIG) and the electronics make up the two basic sub-assemblies of the CCGE. The CCIG performs the required sensing while the electronics develops the scientific and engineering data measurements which are routed to the ALSEP central station data subsystem. The CCIG detects densities corresponding to pressures of 10^{-6} torr to approximately 10^{-12} torr. All numerical parameters are contingent upon known temperatures, anode voltages, and related magnetic/electrostatic field strengths. The normal gauge accuracy (including reproducibility) is $\pm 30\%$ above 10^{-10} torr and $\pm 50\%$ below 10^{-10} torr. At 10^{-10} torr, the starting time for the gauge does not exceed 45 minutes at 23°C in total darkness and while operating at rated voltages and related magnetic/electrostatic field strengths. Above 5×10^{-9} torr, the starting time will be instantaneous.

The cold cathode gauge experiment (CCGE) is designed to sense the particle density of the lunar atmosphere immediately surrounding its deployed position. An electrical current is produced in the gauge, proportional to particle density. This current is amplified and converted into a 10 bit digital word and transmitted to ALSEP at a prescribed time in the ALSEP telemetry format.

2-203. CCGE PHYSICAL DESCRIPTION.

The cold cathode gauge experiment consists of a cold cathode ion gauge assembly (CCIG), electronics package, and structural and thermal housings. Table 2-31 lists the leading particulars of the CCGE.

2-204. Cold Cathode Ion Gauge. The CCIG structural location is identified in figure 2-99 and is made of type 304 stainless steel. The gauge is connected to the electronics package by a short cable. All feedthrough insulators are high alumina ceramic designed for ultra-high vacuum use. The CCIG aperture is sealed against ingress of dirt and moisture. The seal is removed, on ground command, by an explosive actuated piston releasing a spring.

2-205. CCGE Electronics Package. The electronics package contains the power supplies, electrometer amplifier assembly, temperature, squib, and logic circuitry. The logic circuitry of the electronics package consists of nine modules using integrated circuits. The integrated circuits are supported by two strips of mylar with interconnect leads welded externally to the support mylar.. The modular package is mounted to a 23-pin header coated with silicone and potted. The nine modules are soldered to the printed circuit mother board of the electronics package assembly.
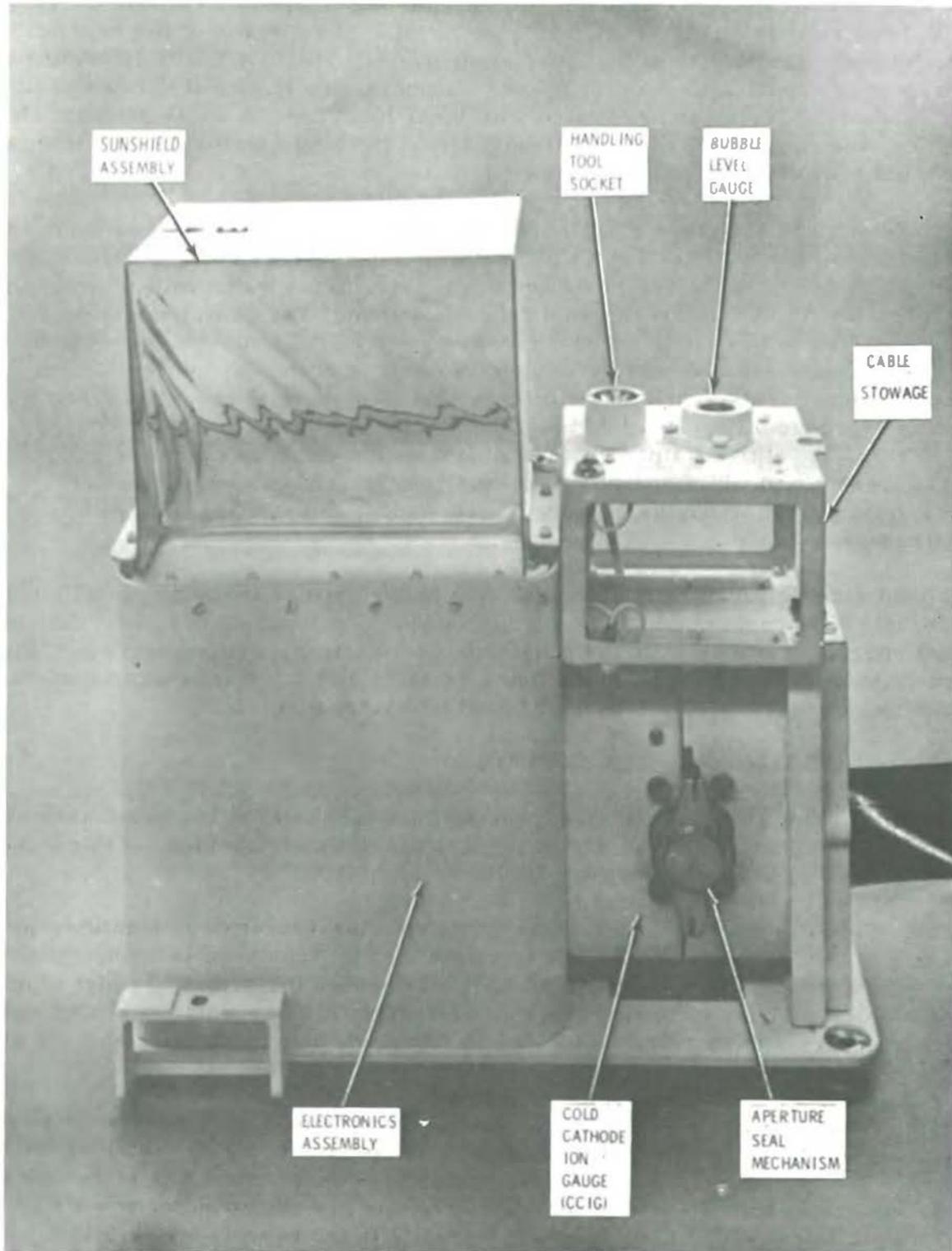
Figure 2-99. Cold Cathode Gauge Experiment (CCGE) Subsystem

Table 2-31. CCGE Leading Particulars

Characteristic	Value
Height	13.38 inches
Width	4.625 inches
Depth	12 inches
Weight	13.0 pounds
Instrument operational power	2.0 watts
Heater power	4.5 watts
Input voltage	+29 vdc

2-206. Structural Housing. The structural housing consists of a base and a fiber-glass housing for the electronic circuits and the gauge sensor. The top plate serves as a support for the electronic modules and as a heat sink. The tool socket and the bullseye bubble are mounted on top of the housing to permit the astronaut to deploy and level the experiment. Leveling will be within five degrees.

2-207. Thermal Control. The structural housing is covered with a thermal coating to aid in maintaining the internal (electronics) temperature between -20 degrees C and +80 degrees C during normal operation when exposed to the anticipated lunar environment. A sunshield is used with a reflector to shade the thermal plate from direct sunlight and to allow it to view deep space. The reflector also reduces heat input from the lunar surface. An auxiliary electric heater is provided to maintain the internal temperature during non-operating periods and to assist in the thermal control during normal operation.

2-208. CCGE FUNCTIONAL DESCRIPTION.

The CCGE is divided into four major functional elements; measurement function, timing and control function, command function, and data handling function (Figure 2-100). In addition, a power supply function provides system power to all operational circuits and a thermal control function maintains thermal equilibrium of the experiment on the lunar surface.

The measurement function is accomplished by the cold cathode ion gauge (CCIG), the electrometer amplifier, and the gauge temperature sensor. The lunar atmospheric particles are detected by the gauge and amplified by the electrometer. In the automatic mode, the sensitivity of the electrometer is automatically controlled by the timing and control function. Seven ranges of sensitivity are available.

The timing and control function provides range control signals to the measurement function and timing signals to the data handling function. The range sensitivity stepping of the electrometer amplifier is controlled by the timing and control function when the CCGE is in the automatic ranging mode of operation. The timing and control function also provides calibration timing to the measurement function. The function uses, shift, frame mark, and data demand pulses from ALSEP to control its internal timing.
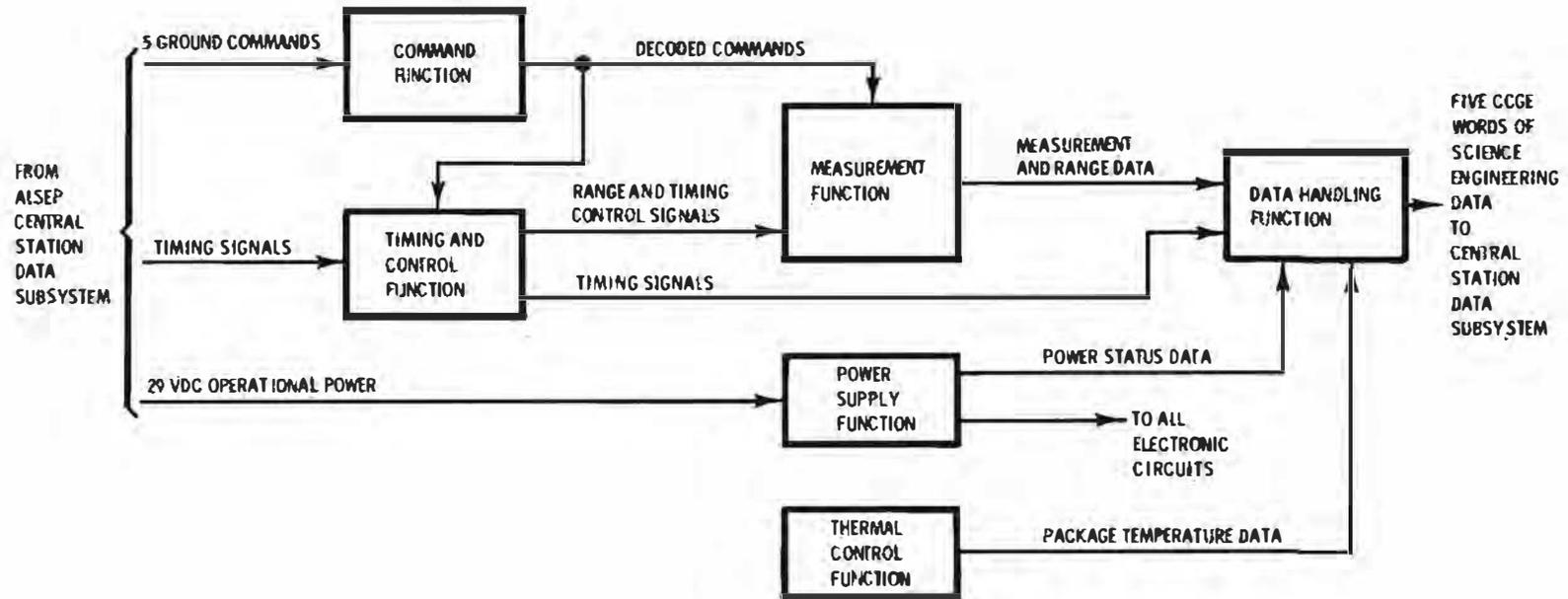
Figure 2-100. Cold Cathode Gauge Experiment, Functional Block Diagram

The command function accepts ground command pulses from the central station data subsystem, decodes the commands, and applies them to the timing and control function or the measurement function as appropriate.

The data handling function accepts digital and analog data from the other functional elements of the experiment, converts as necessary, commutates, and gates out the scientific and engineering data to the central station data subsystem at word times required by the telemetry format of ALSEP central station.

2-209.   CCGE DETAILED FUNCTIONAL DESCRIPTION.

The four major functions and the two additional functions of the CCGE are discussed in detail in the following data flow sequence: measurement function, timing and control function, command function, data handling function, power function, and thermal control function.

2-210.   <u>CCGE Measurement Function.</u> The measurement function (figure 2-101) measures neutral atom densities corresponding to atmospheric pressures of 10^{-6} torr to approximately 10^{-12} torr. The measurement function consists of the cold cathode ion gauge (CCIG) sensor, electrometer, current calibrator, zero mode calibrator, range position analyzer, range selector network, CCIG temperature sensor and monitor, and aperture seal mechanism.

Electronics in the CCIG sensor are deflected into elongated spiral paths by a combination of magnetic and electrostatic fields enhancing the probability of collision with the more numerous neutral atoms entering the sensor. Ion produced by these collisions are collected by the cathode of a pair of sensor electrodes which maintain the electrostatic field. A +4500 volt dc potential is applied to the anode to create the electrostatic field. The flow of positive ion current is found to be proportional to the number density of the gas molecules within the gauge. Therefore, a minute current flows to the input of the electrometer amplifier.

The electrometer consists of an input amplifier, seven position sensitivity ranging network, offset compensation network, and a buffer amplifier output. The input amplifier measures and converts the gauge input current to an analog voltage and applies this to the buffer amplifier output which provides the data handling function with the gauge analog voltage representing the primary scientific data output. The sensitivity of the measurement is determined by one of the seven possible ranges available from the seven-position sensitivity ranging network. The network operates in conjunction with the input amplifier to provide measurement sensitivity in increments of one tenth of an ampere within the micro and micro-micro ampere range. Measurement sensitivity range one represents the lowest sensitivity (one microampere input current) and range seven represents the highest sensitivity (one micro-microampere input current). Selection of sensitivity ranges one through seven is determined either by external command signals, or by electrometer output voltages, and precision stepping signals. The offset compensation network is a special function of the electrometer that memorizes signal drift and operates in conjunction with the zero mode calibrator to correct (compensate) for this drifting.
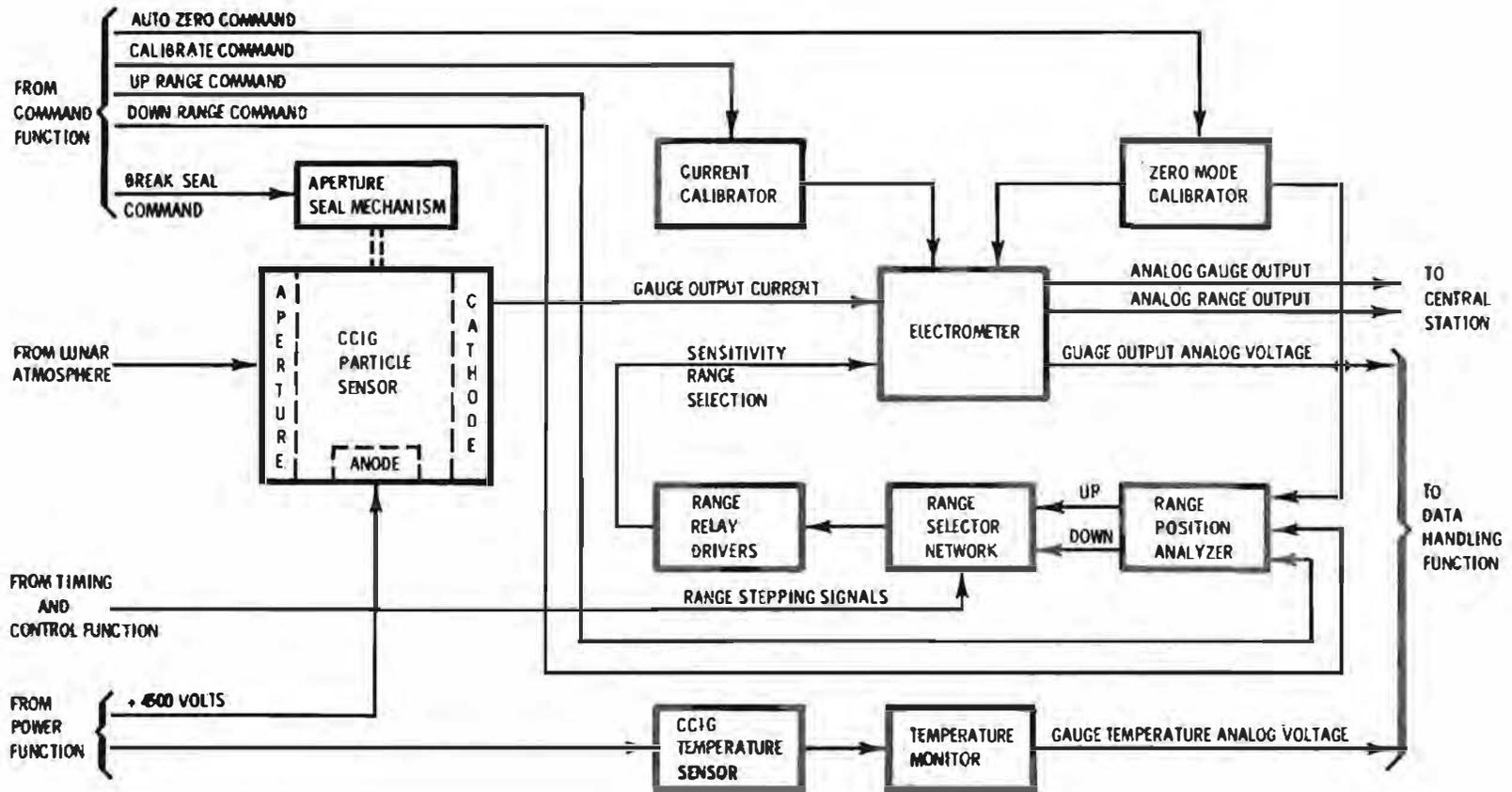
Figure 2-101. CCGE Measurement Function, Block Diagram

The current calibrator provides the electrometer with a precision current source for calibrating purposes. The current calibrator is operative on receipt of a calibrate command from the command function and automatically after an auto-zero function. In the auto mode, range stepping signals cause the electrometer to step through the seven sensitivity ranges allowing each range to be calibrated with respect to the precision current source.

The zero mode calibrator provides the electrometer with the correction signal necessary to compensate for signal drift. The zero mode calibrator operates every 30 minutes and 55 seconds as determined by the timing and control function. The memorized amount of signal drift is received from the offset compensation network within the electrometer. During this period the gauge input current relay is disconnected from the electrometer and after zeroing compensation remains disconnected until the automatic calibration completes the function described in the current calibrator paragraph above.

The range position analyzer consists of a command and control subfunction and an up-down comparator. The command and control subfunction handles the uprange and downrange commands from the command function. When the uprange command is present as an input signal to the range position analyzer command and control subfunction the range position analyzer produces an output-signal that steps the range sensitivity network up one position within the range selector network. The opposite occurs when the downrange signal is present. The up-down comparator operates in a similar manner. When the electrometer output voltage reaches a value that is either to high or too low a different range is automatically selected by the action of the up-down comparator. The up-down comparator produces and upper-trip-point signal or a lower-trip-point signal that results in an up-signal or down-signal to the range selector network and eventually producing a corresponding sensitivity range change.

The range selector network consists of a series of counting registers which track the seven sensitivity ranges and generate the step pulse that changes the electro-meter measurement sensitivity range either one step up or one step down. The output signal of the range selector network is applied to the range relay drivers. The range relay drivers produce the required current magnitude to actuate the appropriate range relay within the electrometer and effect the sensitivity range change.

The CCIG temperature sensor operates in conjunction with the temperature monitor function to produce the gauge temperature analog voltage which is sent to the data handling function for data processing. The signal developed across the transducer is applied to the temperature monitor for signal conditioning and subsequent application to the data handling function.

Two science data analog voltage lines go directly to the central station data subsystem via the data handling function to insure receipt of electrometer gauge output data and range data in case of digital electronic logic circuit failure.

A break seal command from the command function operates the aperture seal mechanism to remove the seal from the CCIG orifice and expose the CCIG to the lunar atmosphere. The seal is removed by an explosive actuated piston releasing a spring which normally holds the seal over the aperture.

2-211. CCGE Timing and Control Function. The timing and control function (Figure 2-102) provides timing and control signals to the measurement, command, and data handling functions. Basic timing is received from the ALSEP data subsystem in the form of shift, data demand, and frame mark, pulses to the logic timing of the multiplexer controller. Command pulses from the command function are the other inputs to the timing and control function. The timing and control function. The timing and control function consists of the frame mark counter, shift pulse counter, multiplexer controller, data transfer sequencer, housekeeping submultiplexer, CCGE word counter, zero mode timer, and range calibration stepping timer.

The frame mark counter and shift pulse counter track the basic timing from the central station data subsystem. The output of the frame mark counter operates in conjunction with the data demand pulse to establish the origin point for subsequent CCGE word events. The output pulses of the shift pulse counter operate during the data demand pulse period to establish the origin point of CCGE bit events.

The multiplexer controller is the primary time reference distribution and status reporting function. The multiplexer controller establishes timing control signals within each data frame to perform analog-to-digital conversion and data formatting for ALSEP telemetry frame correspondence. Frame mark, data demand, and shift pulses are distributed to the appropriate circuits to accomplish these functions. Commands that are received and decoded by the command function are applied to the multiplexer controller to control the operating modes. The state of all the timing and control functions is recorded by registers and reported as control data to the data handling function for incorporation into CCGE word one.

The data transfer sequencer tracks the ALSEP shift pulses and applies the signal conditioned shift pulses to the data transfer register for synchronized storing, converting, transferring, and clearing of binary data.

The housekeeping submultiplexer in conjunction with the CCGE word counter operate to control the subcommutation of four different types of engineering data into CCGE word five. The CCGE counter generates a pulse after accumulating a total of five data demand pulses. This enables the housekeeping submultiplexer to identify the fifth CCGE word. By counting frame mark pulses, the housekeeping submultiplexer can relate the appropriate type of engineering data to each reoccurring CCGE word five and therefore account for all four types of engineering data at the required time. The housekeeping submultiplexer gating and status signal are sent to the data handling function for implementation and identification of engineering data subcommutation events related to CCGE word five.
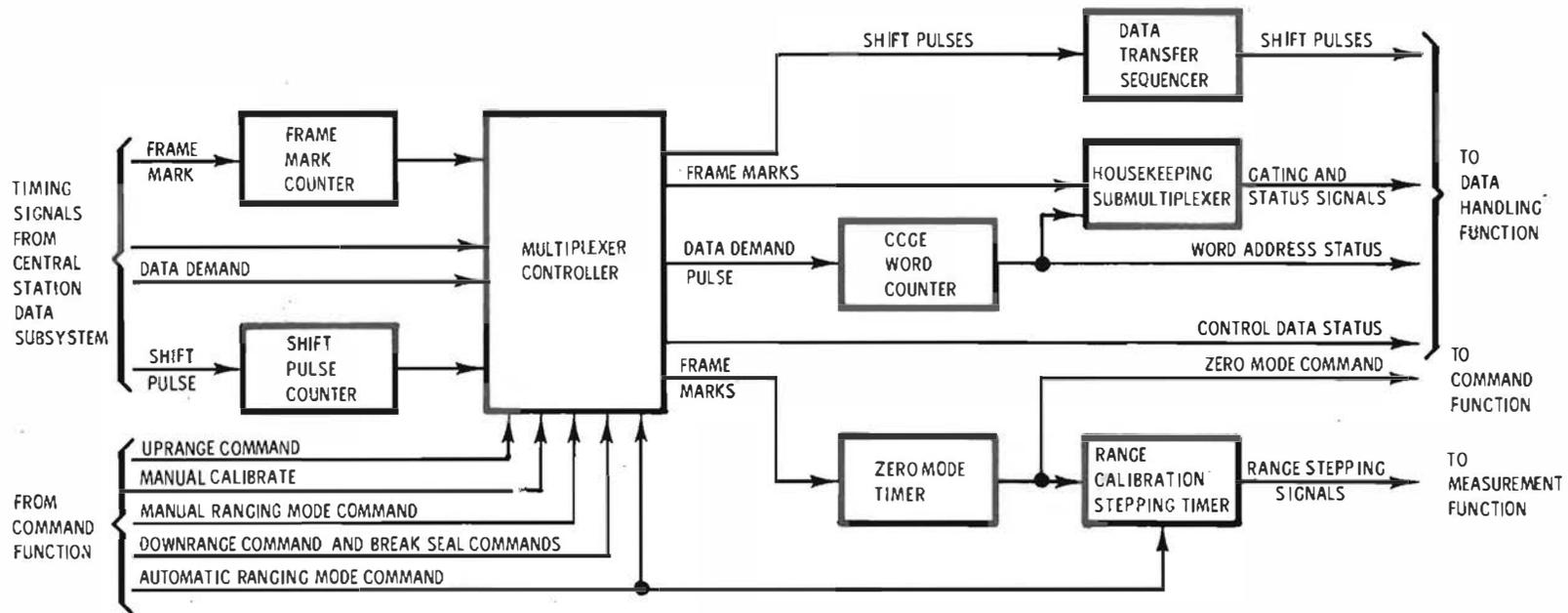
Figure 2-102. CCGE Timing and Control Function, Block Diagram

The zero mode timer accumulates the ALSEP frame mark count. When a 3072 ALSEP frame mark count is obtained (corresponding to 30 min and 55 sec of ALSEP operation), the zero mode command signal is generated to initiate the zeroing and automatic calibration of the electrometer operating in the measurement function. The command inhibits the gauge current entering the electrometer amplifying circuit so that calibration currents can be inserted in lieu of the gauge current. The zero mode command takes precedence over all other commands. In addition, the zero mode command initially inhibits the range calibration stepping timer, and after 10 seconds, provides an enable pulse. The range calibration stepping timer then operates to provide precision timing pulses in the form of range stepping signals to allow calibration of the electrometer in all seven measurement sensitivity ranges. The range calibration can also be activated by the manual ranging mode command, allowing extended calibration in any desired range. The down range command has a secondary function which is to activate the squib which pleases the gauge dust cover. This is a "one time" event. An uprange command prior to the downrange command may be required after experiment turn on to set the circuitry into the correct state.

2-212. CCGE Command Function. Five command lines are provided from the ALSEP data subsystem to the CCGE (Figure 2-103). The uprange, calibration mode set, manual mode, downrange, and automatic, operate mode commands are received from the MSFN ground stations through the ALSEP data subsystem, decoded, and applied to the CCGE command function. The command function establishes the operating modes in conjunction with the timing and control function to perform range changing, calibration, and data measurement.

The range changing mode is selected by the Uprange or Downrange commands in the manual mode of operation. The manual mode can be selected for either science or calibration data. The manual mode command also provides the clock pulse to the range counter for either up or down range operation, changing the range by one step in the required direction upon command transmission. There are seven sensitivity ranges available for selection by the uprange and downrange commands.

The calibration mode of operation is initiated by the calibration mode set command or by the zero mode command in the auto mode of operation. The calibrate command sets the logic to the manual mode of operation. The zero mode command signal takes precedence over all other commands, and through the command mode inhibitor, locks out the functioning of the command mode decoder while allowing the automatic calibration cycle to occur within the electrometer.

The data measurement modes of operation occur either in the automatic operate mode or the manual mode. In the automatic operate mode the range counter steps between ranges as determined by the Up-Down comparator in conjunction with the Range counter. The stepping between ranges occur at 10 second intervals when a change of more than one range occur, eg during the calibration cycle after zeroing in the manual mode the range is determined by ground command.
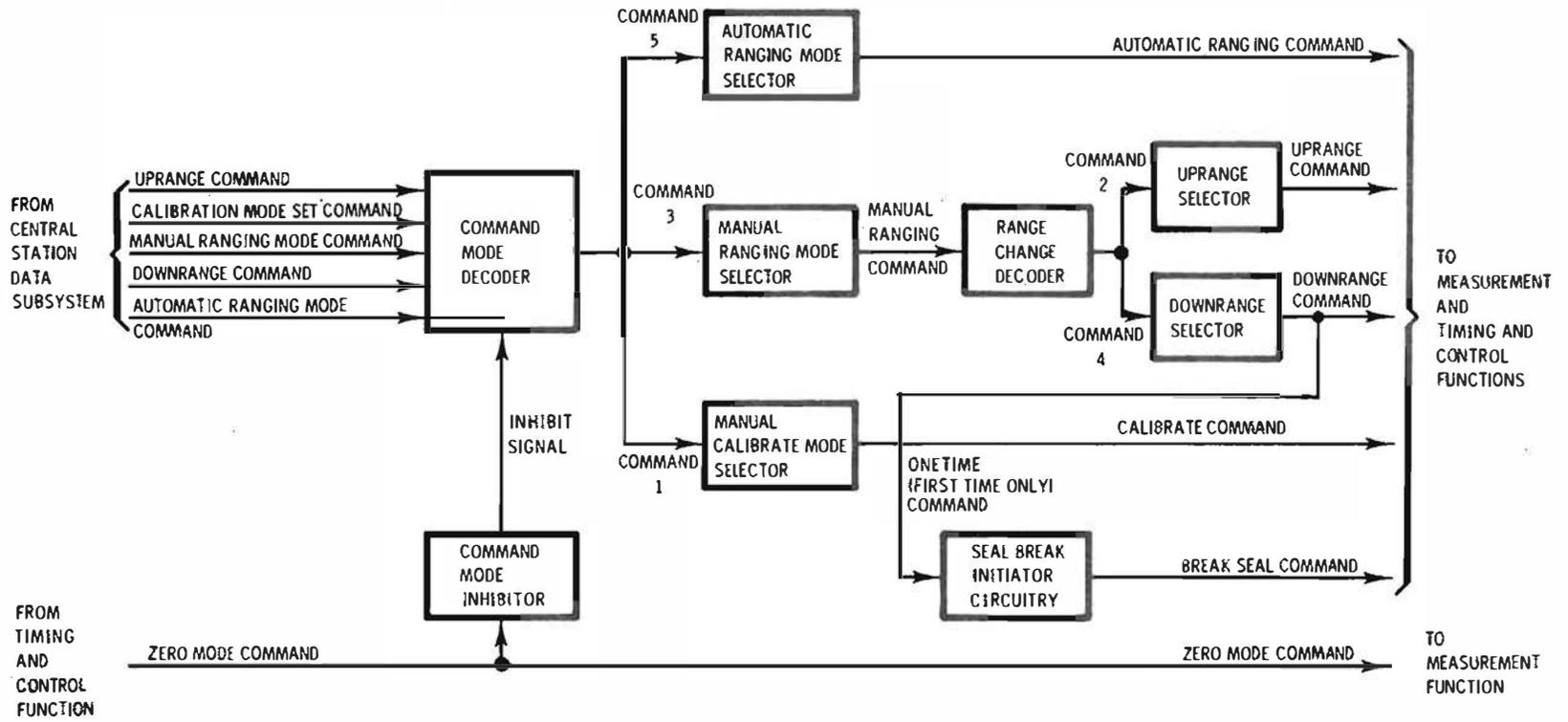
Figure 2-103. CCGE Command Function, Block Diagram

2-213. CCGE Data Handling Function. - The major elements of the data handling function (Figure 2-104) are the analog multiplexer, analog-to-digital converter, and the data transfer register. All of the data handling functional elements operate to apply science and engineering digital data to the data transfer register for transmittal to the central station data subsystem and subsequent downlink transmission to the MSFN in a digital word format.

Science data, engineering data, mode data, range data, and control status data from all other CCGE functions are applied to the analog multiplexer for subsequent commutation. The sequence of commutation is determined by the multiplexer controller operating in the timing and control function.

Using the analog voltage from the analog reference source and the analog voltage from the analog multiplexer, the analog-to-digital converter performs a bit by bit successive approximation conversion of the analog data from the multiplexer and applies the resultant digital data to the data transfer register. The conversion time requires ten shift pulses or one data demand period prior to being shifted out to the central station. The eight bit data measurement is shifted out with the most significant bit first, followed by two bits of data identification and control data information from the multiplexer controller located in the timing and control function.

The data transfer register provides data storage during analog-to-digital conversion and data transfer during the ALSEP data demand period. The digital data output is composed of 10 bits that are serially transferred at the shift pulse bit rate during the appropriate ALSEP demand period.

There are five CCGE words alloted for every ALSEP telemetry frame. CCGE words one through five correspond to ALSEP words 15, 31, 47, 56, and 63, respectively. This relationship exists for every ALSEP frame. Each word is composed of ten bits. CCGE word one will occur in all ALSEP frames as a control word containing six parameters. These are: two bits of CCGE word identification, one bit identifying zero mode, one bit identifying calibrate or operate mode, two bits identifying the submultiplexing status, one bit identifying the automatic or manual mode, and three bits identifying the sensitivity range of the electrometer measurement. Gauge output scientific data (Eight bits to CCGE word 2), Gauge temperature engineering data (Eight bits of CCGE word 3), and Package temperature engineering data (Eight bits of CCGE word 4), will occur in every ALSEP frame with two bits assigned to each word for word identification. The +4500 volts dc engineering data, +15 volts dc engineering data, -15 volts dc engineering data, and the +10 volts dc engineering data will be subcommutated into CCGE word five (eight bits each) during five successive ALSEP frames. Since CCGE word 5 will occur every ALSEP frame, the housekeeping submultiplexer in conjunction with the CCGE word counter will keep track of this timing relationship and insert two identifying bits in CCGE word. The housekeeping submultiplexer will count ALSEP frames and relate this to CCGE word counts to identify the correct subcommutation time for the corresponding one-of-four CCGE housekeeping engineering data measurement times. This subcommutation cycle will repeat itself after four completed ALSEP frames.
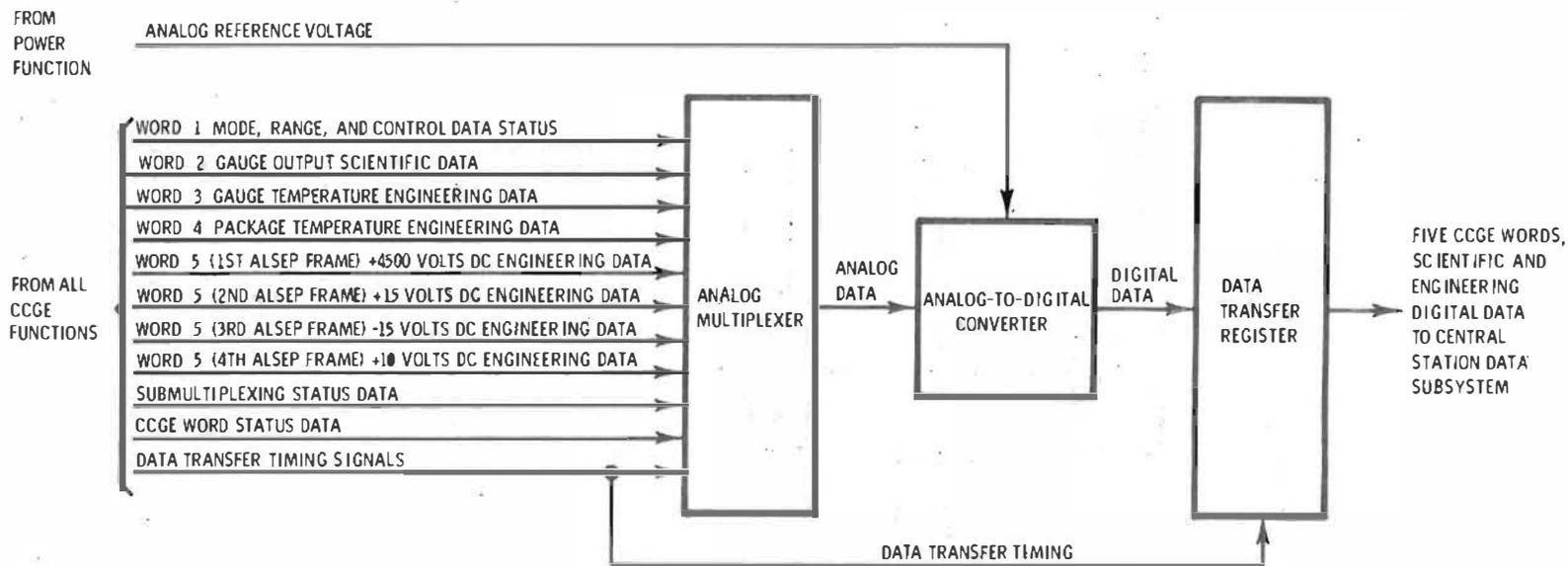
Figure 2-104. CCGE Data Handling Function, Block Diagram

2-214. CCGE Power Function - The central station power distribution unit pro-
vides the 29 volts dc basic operational power for the CCGE. In addition, a sur-
vival line is applied to the CCGE to maintain heater power in the event that the
CCGE internal electronics is turned off. The power requirements of the CCGE do
not exceed a power consumption of two watts for normal operation and do not ex-
ceed five watts power consumption when the thermal control function is operating
during the lunar night. The major components of the power function consists of
the low voltage supply, high voltage supply, and the voltage regulator (Fig-
ure 2-105). All three major components apply status data to the data handling
function.
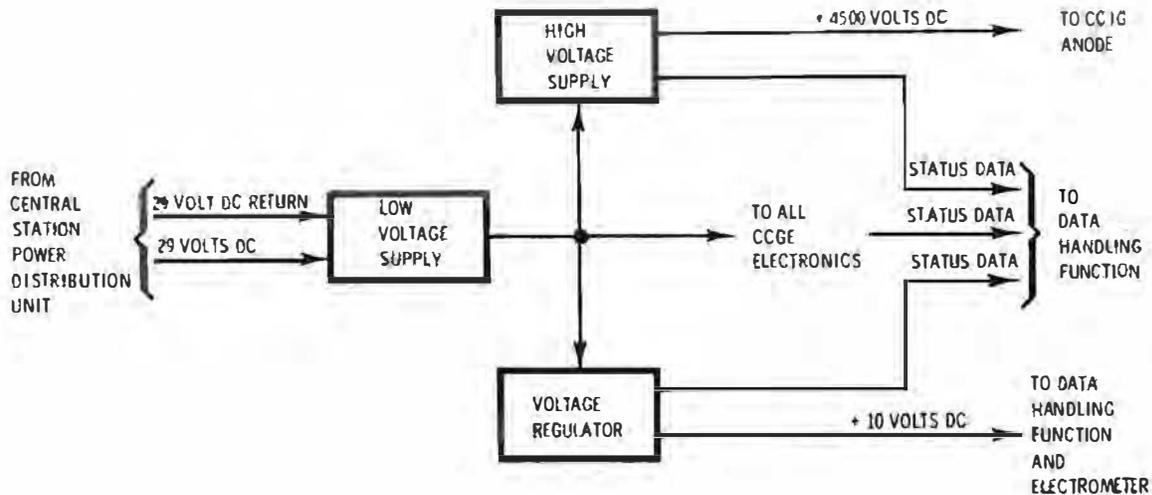
Figure 2-105. CCGE Power Function, Block Diagram

The main power supply is a low voltage power supply that derives its input power
(29 volts dc +2% and -5%) from the central station power distribution unit and dis-
tributes CCGE operational power to the high voltage supply, voltage regulator, and
all other functional logic electronic circuits in the CCGE.

The high voltage supply develops a +4500 volts dc and applies this potential to the
anode of the cold cathode ion gauge sensor in order that the electrostatic/magnetic
field be maintained across the CCIG sensor electrodes for particle measurement.

The voltage regulator develops a constant plus 10 volts dc and applies this poten-
tial to the data handling function as a reference voltage for analog-to-digital con-
version and the same potential applied to the electrometer is used as a source
calibration voltage.

2-215. CCGE Thermal Control Function. The major functional elements of the
thermal control function (Figure 2-106) are the heater, heater control circuit,
package temperature sensor, and electronic monitor.
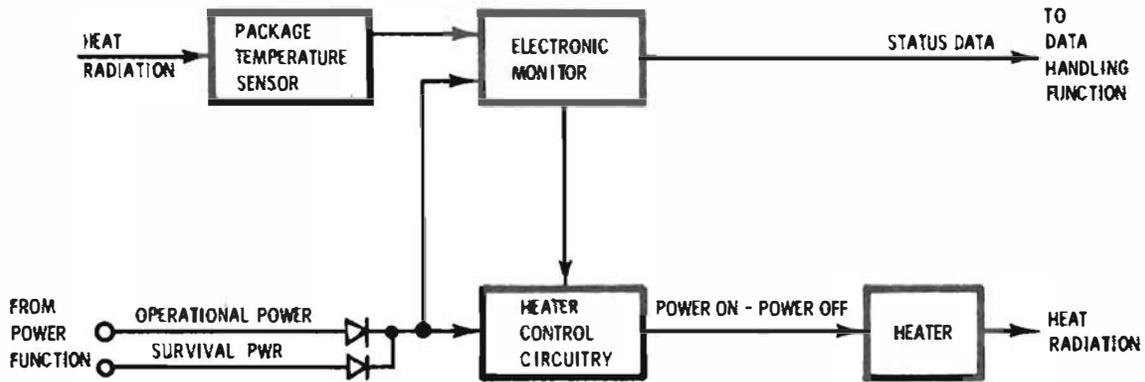
Figure 2-106. CCGE Thermal Control Function, Block Diagram

The heater functional elements are the heater and heater control circuit. The heater comprises two wire mesh heater strips controlled by a circuit with an input signal from a temperature sensing element. The heater control provides an on/off signal to the heater elements.

The package temperature monitoring function comprises a package temperature sensor and electronic monitor. The sensor is a thermistor used to measure the CCGE internal temperature and apply a proportional electrical signal to the electronic monitor. The sensor signal is conditioned by an operational amplifier and applied to the data handling function for status reporting and to the heater control circuit for initiation of heater-on and heater-off events.

2-216. APOLLO LUNAR HAND TOOLS (ALHT) SUBSYSTEM

The ALHT subsystem is a collection of equipments which will be used by the astronaut to perform lunar surface observations and to collect lunar material samples.

2-217. ALHT DESCRIPTION

The ALHT Subsystem consists of a carrier and various tools, instruments, and other specialized equipment. The carrier is a metal framework designed to hold the equipment. During the flight from the Earth to the Moon, the carrier is mounted on subpackage No. 2 and contains a scoop, a brush/scriber/hand lens, and a staff. The carrier and mounted items are about 16 inches long, 18 inches high, and six inches wide. The remainder of the subsystem equipment is stowed elsewhere in the lunar module during the flight. On reaching the Moon, an astronaut will descend from the lunar module, open the lunar module scientific equipment bay, release the ALHT Subsystem carrier from the subpackage, transport the carrier some distance from the lunar module, unfold the carrier, and set the carrier on the lunar surface. The equipment can then easily be removed from or replaced on the carrier as required.

The ALHT equipment can be classified into three categories according to function as follows:

   (a) Geologic sampling tools
   (b) Surveying and photographic instruments
   (c) Support and auxiliary equipment.

The ALHT equipment is listed and described in Table 2-32 and illustrated in Figures 2-107, 2-108, and 2-109.

Where possible, the tools are anodized to minimize heat absorption from solar radiation. Individual tools which are made up of several parts or which mate with other tools are coded to facilitate assembly.

Table 2-32. Apollo Lunar Hand Tools

Tool Nomenclature	Description and Function
Geologic Sampling Tools	
Aseptic collection device	This tool is designed to take a small sample of granular material or material of low structural strength from six inches below the lunar surface without exposing the sample to contamination.
Extension handle	This tool is of aluminum alloy tubing with a malleable, stainless steel cap designed to be

Table 2-32. Apollo Lunar Hand Tools (cont)

Tool Nomenclature	Description and Function
Extension handle (cont.)	used as an anvil surface. The handle is designed to be used as an extension for several other tools and to permit their use without requiring the astronaut to kneel or bend down. The handle is approximately 24 inches long and one inch in diameter. The handle contains the female half of a quick-disconnect fitting designed to resist compression, tension, torsion, or a combination of these loads. Also incorporated are a sliding T handle at the top and an internal mechanism operated by a rotating sleeve which is used with the aseptic collection device.
Three core tubes	These tubes are designed to be driven or augured into loose gravel, sandy material, or into soft rock such as feather rock or pumice. They are about 15 inches in length and one inch in diameter and are made of aluminum. Each tube is supplied with a removable, non-serrated cutting edge and a screw-on cap which replaces the cutting edge. The upper end of each tube is sealed and designed to be used with the extension handle or as an anvil. Incorporated into each tube is a device to retain loose materials in the tube.
Scoop	The scoop is fabricated primarily of aluminum and has a riveted-on, hardened-steel cutting edge and a nine-inch handle. A malleable stainless steel anvil is on the end of the handle. The scoop is either by itself or with the extension handle.
Sampling hammer	This tool serves three functions; as a sampling hammer, as a pick or mattock, and as a hammer to drive the core tubes or scoop. The head has a small hammer face on one end, a broad horizontal blade on the other, and large hammering flats on the sides. The handle is fourteen inches long and is made of formed tubular aluminum. On its lower end, the hammer has a quick-disconnect to allow attachment to the extension handle for use as a hoe.

Table 2-32. Apollo Lunar Hand Tools (cont)

Tool Nomenclature	Description and function
Tongs	The tongs are designed to allow the astronaut to retrieve small samples from the lunar surface while in a standing position. The tines are of such angles, length, and number to allow samples from 3/8-inch diameter to 2 1/2-inch diameter to be picked up. This tool is 26 1/2-inches in overall length.
Brush/Scriber/Hand Lens	A composite tool (1) Brush - To clean samples prior to selection (2) Scriber - To scratch samples for selection and to mark for identification (3) Hand lens - Magnifying glass to facilitate sample selection
Spring scale	To weigh lunar material samples to maintain weight budget for return to Earth.
Surveying and Photographic Instruments	
Instrument staff	The staff provides steady support for photography. The staff breaks down into two sections. The upper section telescopes to allow generation of a vertical stereoscopic base of one foot for photography. Positive stops are provided at the extreme of travel. The bottom section is available in two lengths to suit the staff to astronauts of varying sizes. The device is fabricated from tubular aluminum.
Gnomon	This tool consists of a weighted staff suspended on a two-ring gimbal and supported by a tripod. The staff extends twelve inches above the gimbal and is painted with a gray scale. The gnomon is used as a photographic reference to indicate vertical sun angle and scale. The gnomon has a required accuracy of vertical indication of 20 minutes of arc. Damping is incorporated to reduce oscillations.
Color chart	The color chart is painted with three primary colors and a gray scale. It is used as a calibration for lunar photography. The scale is mounted on the tool carrier but may easily be removed and returned to Earth for reference. The color chart is six inches in size.

Table 2-32. Apollo Lunar Hand Tools (cont)

Tool Nomenclature	Description and Function
Support and Auxilliary Equipment	
Tool carrier	The carrier is the stowage container for some tools during the lunar flight. After the landing, the carrier serves as support for the sample bags and samples and as a tripod base for the instrument staff. The carrier folds flat for stowage. For field use, it opens into a triangular configuration. The carrier is constructed of formed sheet aluminum and approximates a truss structure. Six-inch legs extend from the carrier to elevate the carrying handle sufficiently to be easily grasped by the astronaut.
Field sample bags	Approximately 70 four inch by five inch bags are included in the ALHT for the packaging of samples. These bags are fabricated from Teflon.
Collection bag	This is a large bag attached to the astronaut's side of the tool carrier. Field sample bags are stowed in this bag after they have been filled. It can also be used for general storage or to hold items temporarily.
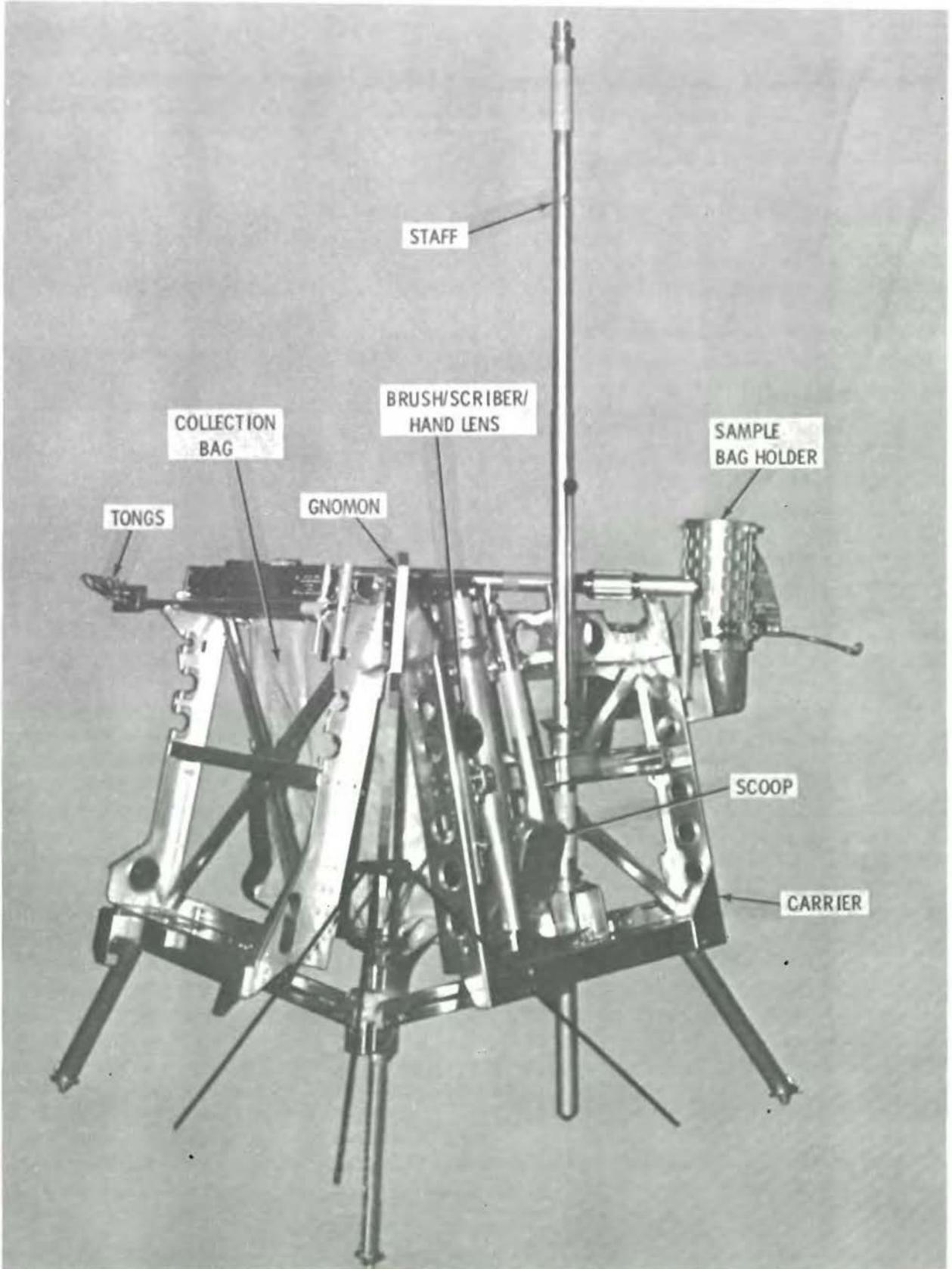
Figure 2-107. Apollo Lunar Hand Tools Subsystem Deployed
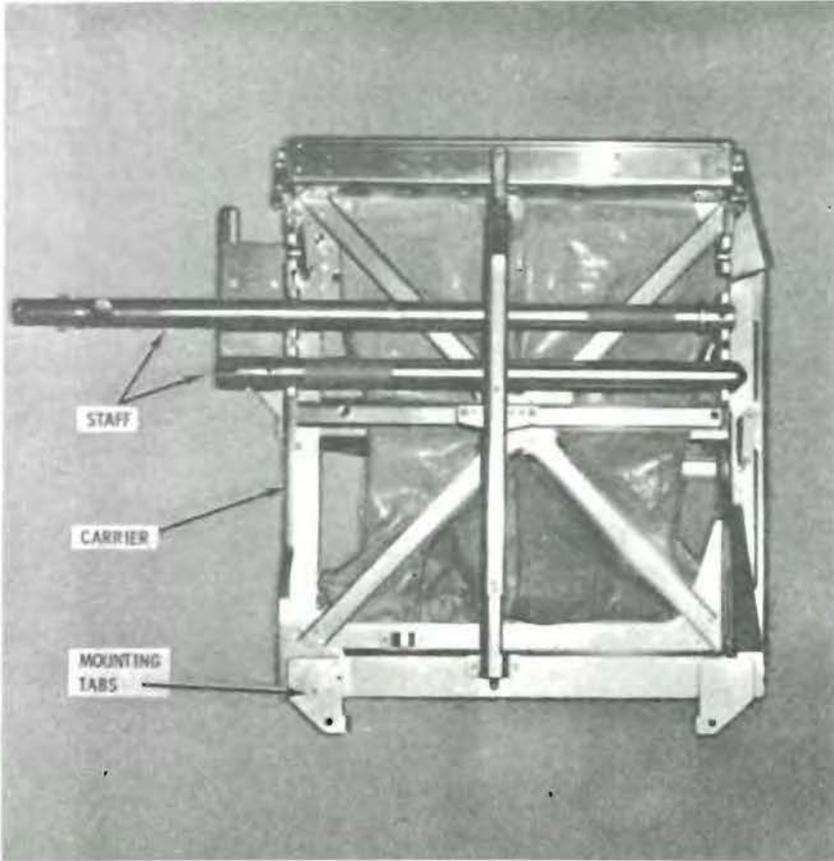
Front
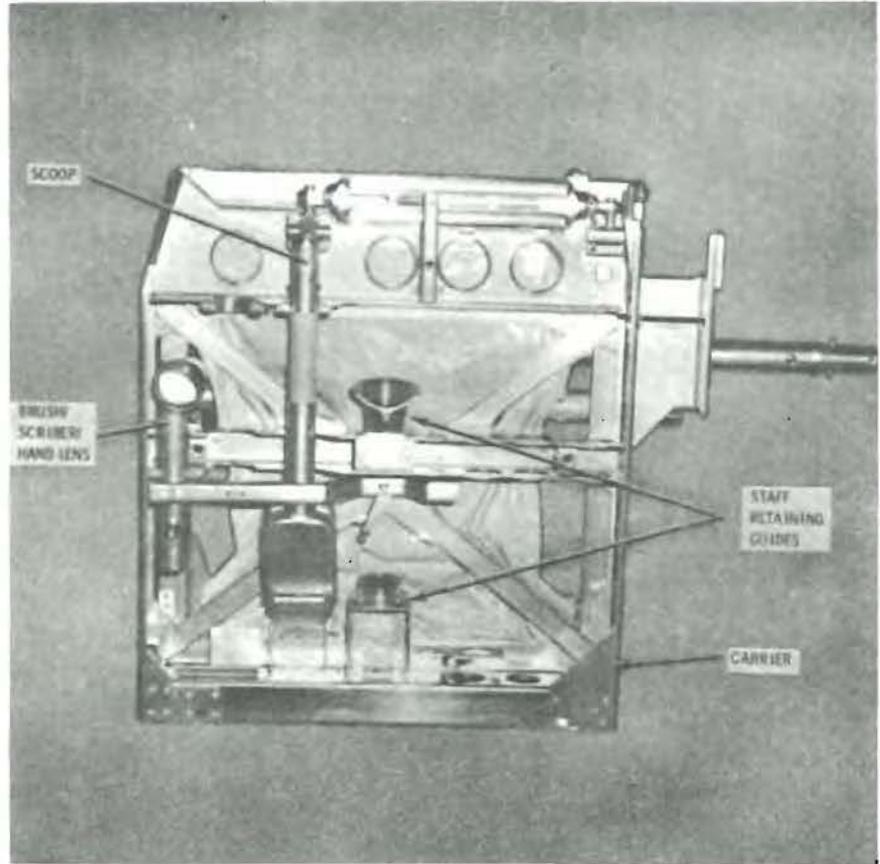
Rear

Figure 2-108. ALHT Subsystem Front and Rear Views of Flight Configuration
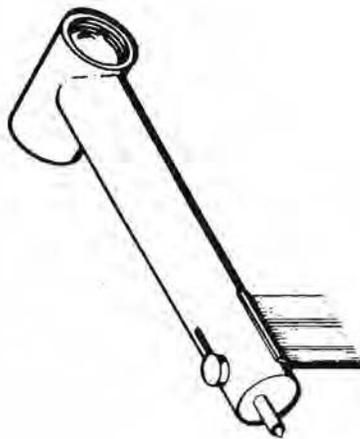
BRUSH/SCRIBER/HAND LENS
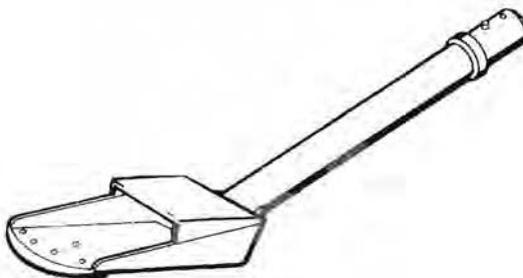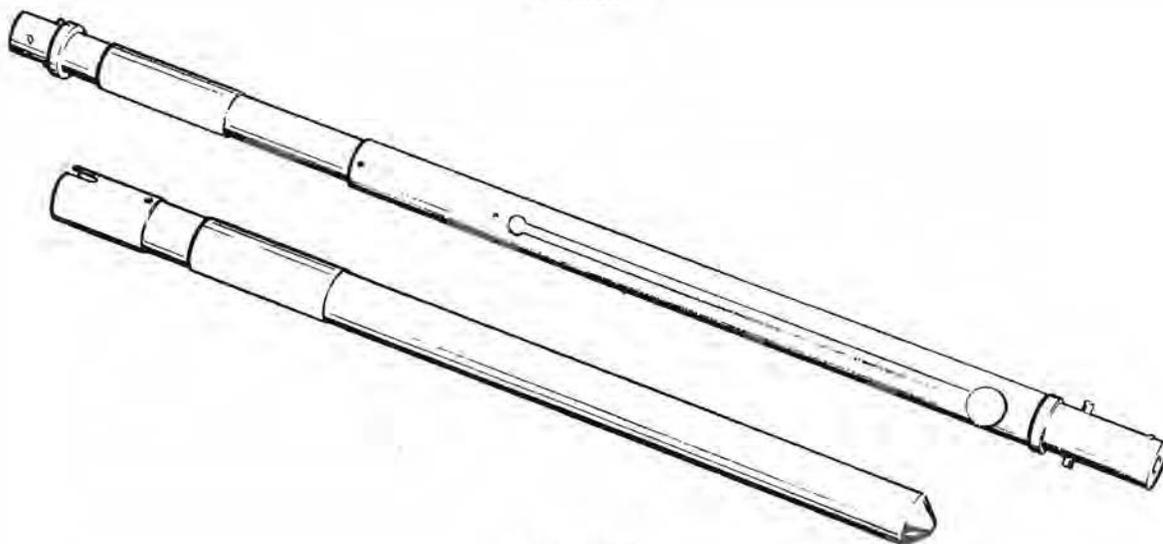
SCOOP

SHAFT

Figure 2-109. ALHT Subsystem Brush/Scriber/Hand Lens, Scoop, and Staff

2-218. APOLLO LUNAR SURFACE DRILL (ALSD)

The Apollo lunar surface drill (ALSD) is used to provide a means for an astronaut to implant heat flow temperature probes below the lunar surface and to collect sub-surface core material. (Figure 2-110).

The ALSD is designed as a totally integrated system which interfaces with the ALSEP pallet located in the LM during transit from earth to the moon's surface. The drill and associated assemblies can be removed as a single package from the ALSEP pallet and transported by the astronaut to the selected drilling site for subsequent assembly and operation. The ALSD possesses the capability of drilling in lunar surface materials ranging from low density, fragmental material, to dense basalt.

Implanting the temperature probes requires drilling two holes to a maximum depth of three meters. The holes are cased to prevent cave-in and to facilitate insertion of the probes. Subsurface core material resulting from the drilling operation of the first hole will be removed from the drill string and discarded. The subsurface core material resulting from the second hole will be retained in the drill string and returned to earth in the sample return container.

2-219. ALSD PHYSICAL DESCRIPTION

The ALSD is a hand-held battery-powered, rotary percussion drill consisting of four major elements; a battery pack, power head, drill string, and accessory group (Figure 2-111). Table 2-33 provides leading particulars of the Apollo lunar surface drill.

2-220. ALSD Battery Pack. The battery pack provides the power necessary for the lunar surface drilling mission. The battery pack comprises a battery case, battery cells, power switch, thermal shroud, and handle assembly.

The battery case is a magnesium alloy enclosure with a pressure relief valve, electrical receptacle, and power switch. Integral with the case are brackets for securing the case to the power head and the portable handle assembly. The external surface of the case is coated for a high ratio of thermal emissivity-to-absorptivity to control the battery temperature profile during lunar surface operation. The case material shields the active circuit elements and conductors to contain potential electromagnetic interference.

The battery has 16 individual cells and operates at a nominal output of 23 ± 1 volts dc at 18.75 amperes for 40 minutes. Each cell is constructed with a silver oxide primary, zinc secondary, and encased in a high temperature plastic. The battery cells are activated by filling each cell with an electrolyte during the pre-launch operations.

The power switch is a single-pole, single-throw, heavy-duty, microswitch with a push-to-activate mechanism. The switch portion of the assembly is contained by the battery case with the push-to-activate mechanism protruding through the case for external operation.
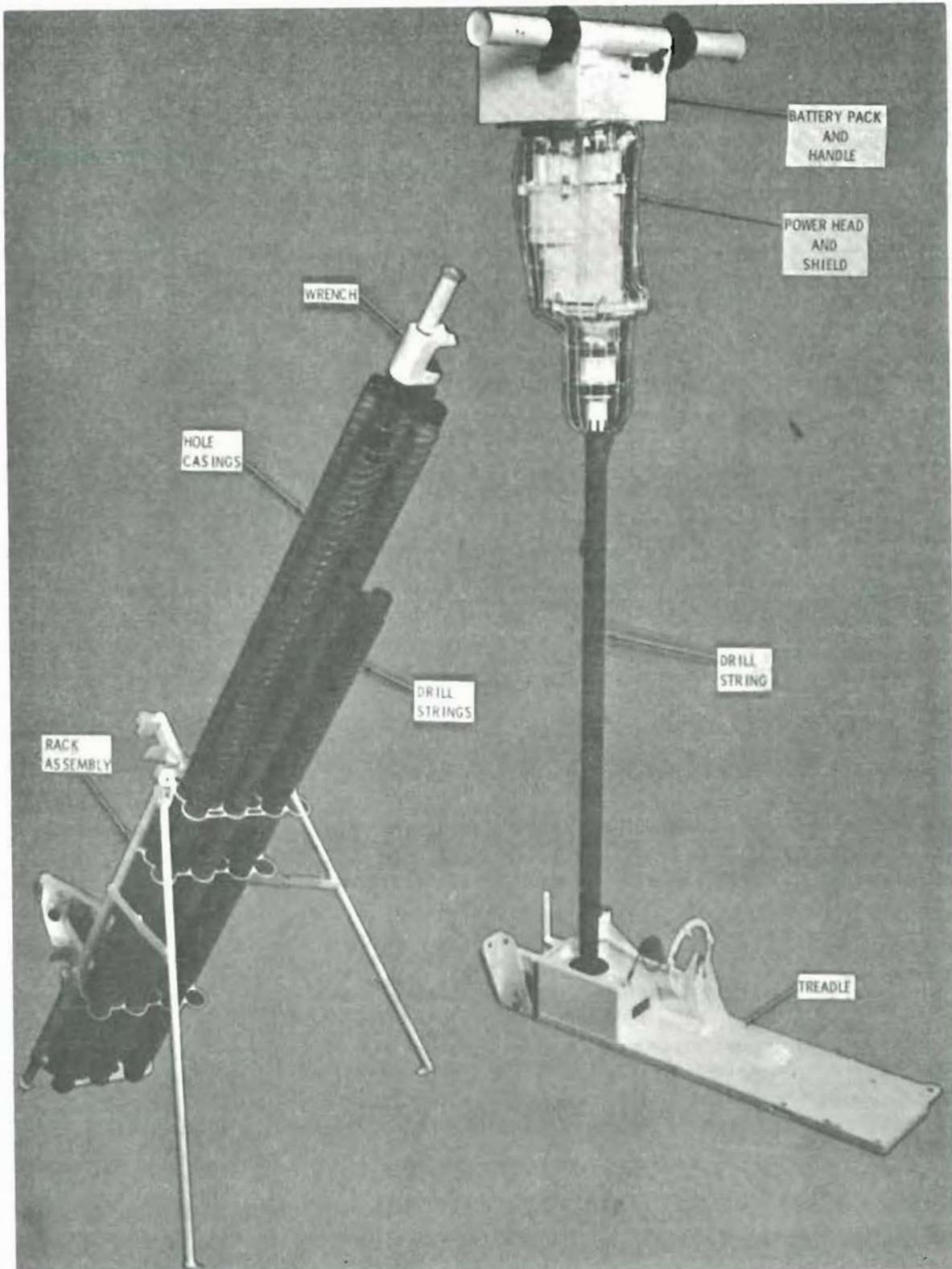
Figure 2-110. Apollo Lunar Surface Drill (ALSD)

BATTERY
POWER HEAD
& THERMAL GUARD ASSY

THERMAL SHROUD

BATTERY, POWER HEAD,
THERMAL GUARD &
THERMAL SHROUD ASSY

DRILL STRING, BIT & CAPS

HANDLE &
SWITCH ASSY

ALSD ASSY

ALSEP STOWAGE
MODE

LUNAR SURFACE
TRANSPORT MODE

LUNAR SURFACE
OPERATIONAL MODE

WRENCH

TREADLE ASSY

RACK ASSY

CASINGS
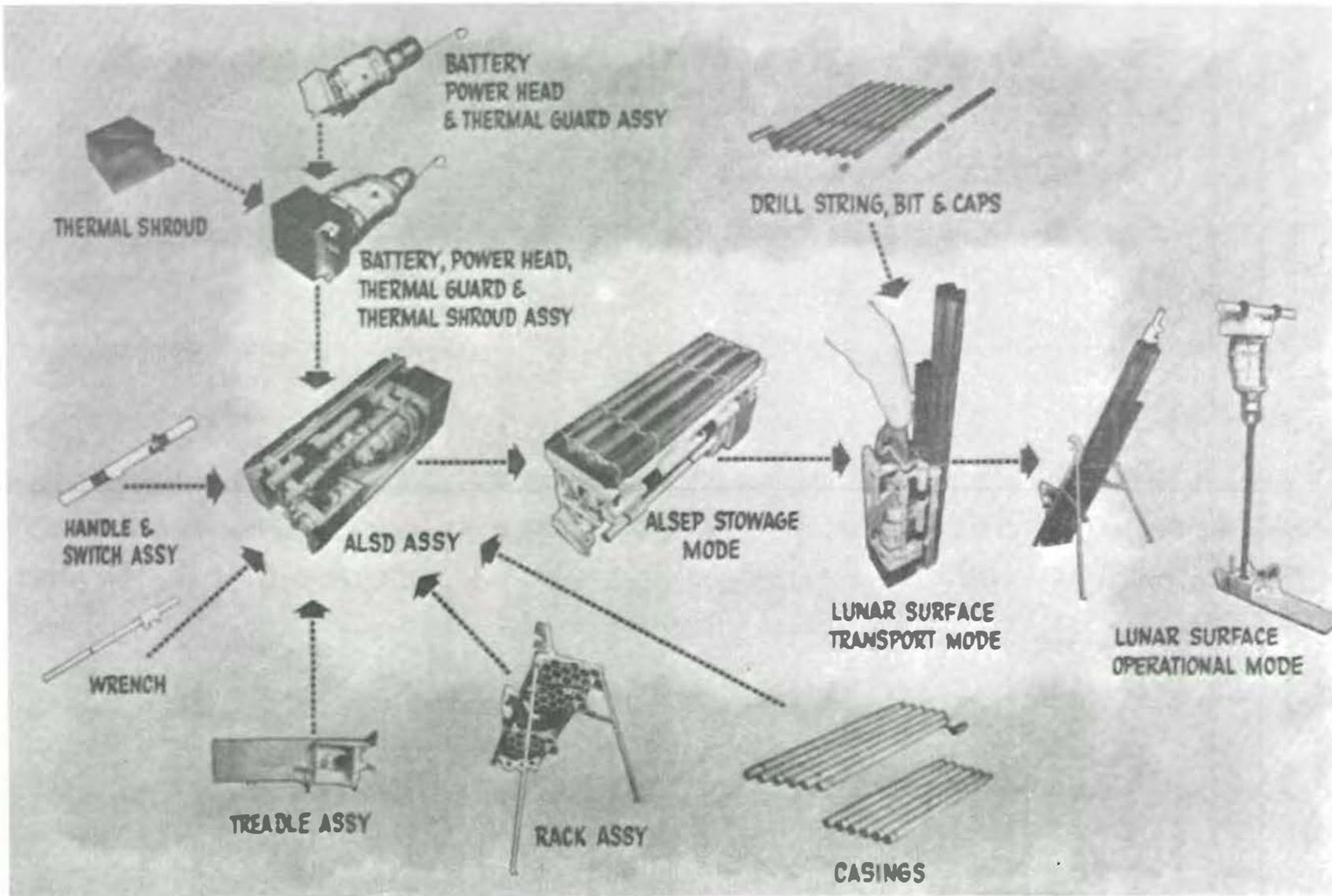
Figure 2-111. ALSD, Partially Exploded View

Table 2-33. ALSD Leading Particulars

Characteristic	Value
Battery Assembly	
Silver-zinc cells	16
Open circuit voltage	29.6 ± 0.5 vdc
Operating voltage	23.0 ± 1 vdc
Nominal operating current	18.75 amperes
Nominal power capacity	300 watt-hours
Activated storage life	30 days
Recharge capability	3 cycles
Dry storage life	2 years
Electrolyte	40% potassium hydroxide
Cell pressure	8 ± 3 psig
ECS (case) pressure	5 ± 0.5 psig
Weight	7.24 pounds
Power Head	
Motor	
Operating voltage	23.0 ± 1 vdc
Load speed	9300 rpm
Load current	18.75 amperes
Efficiency	70%
Percussor	
Blow rate	2270 bpm
Energy per blow	39 inch-pounds
Spring energy	240 pounds/inch
Effective hammer weight	0.661 pounds
Hammer velocity	213 inches/second
Power Train	
Motor-to-cam ratio	4.1
Motor-to-drive shaft ratio	33.1
Drive shaft speed	280 rpm
Blows per bit revolution	8.1
Weight	8.37 pounds
Drill String Assembly	
Integrated length	126 inches
Extension tube length	16.75 inches
Drill bit	
Cutting diameter	1.032 inch
Body outside diameter	1.00 inch
Body inside diameter	0.802 inch
Length	2.5 inches
Number of carbide cutters	5
Inside cutting (core) diameter	0.752 inch
Weight	3.49 pounds
Hole Casing Sleeve (12)	
Wall Thickness	0.025 inch
Length	22 inches
Nominal diameter	1.0 inch

The thermal shroud, fabricated predominately from aluminum alloy sheeting, provides battery temperature compensation during temporary lunar stowage under the combined effects of minimum temperature (20 degrees F) and low sun angles (7 to 22 degrees) above the lunar horizon. The shroud will be removed from the ALSD at sun angles higher than 22 degrees above the horizon. Under all sun angle conditions, the shroud will be removed when the ALSD is used to perform the drilling mission. Removal is performed by pulling a release lanyard. The thermal shroud will always be installed on the battery case during the trans-lunar portion of the mission and at specified sun angles when the ALSD is undergoing temporary lunar stowage.

The handle assembly provides the astronaut with a means of manual restraint and ALSD motor control. The handle assembly comprises the handle and the switch actuator assembly. The handle enables the astronaut to provide the rotary restraint and axial force required for drilling. The switch actuator assembly contains the fail-safe controls for operating the power head motor. The handle assembly is attached to the battery case by fixed and spring-loaded lock pins.

2-221. ALSD Power Head. The power head is self-contained within a housing which interfaces with the battery and drill string. The power head comprises a housing, motor armature, power train, clutch assembly, percussor, shock absorber, output spindle, pressurization system, and a thermal guard shield.

The housing consists predominantly of three magnesium alloy castings mated together by externally sealed flanges threaded for socket head screws. The internal surfaces of the castings are impregnated with a polyester resin sealant to prevent leakage through the walls.

The motor armature is a nominal 0.4 horsepower, brush-commutated, direct-current, device employing as its field a permanent magnet. The armature is wound with copper wire protected by high temperature insulation. The motor possesses a peak efficiency of approximately 70 percent when operating at its nominal 9,300 rpm at an input voltage and current of 23 volts dc and 18.75 amperes, respectively. A reduction gear couples the output shaft of the motor armature to the power train.

The power train consists of reduction gears which provide the proper rotational speeds for the percussor cam gear and output drive spindle of 2270 blows per minute and 280 revolutions per minute, respectively.

The clutch assembly consists of a metal disc emplaced between two bronze discs. Friction between the discs is maintained by a preloaded spring. The clutch assembly is in series with the power train behind the final output drive gear. The clutch assembly limits the reactive torque load to a level which can be safely controlled by the astronaut.

The percussor converts the uniform rotary output motion of the power train into pulsating, high energy, short duration, linear impact, blows which are delivered to the output spindle. This action is accomplished by a rotating cam riding against a spring-loaded cam follower which is an integral part of the percussor.

The shock absorber consists of a telescoping, titanium, tube element (internal to and concentric with the percussor spring) restrained by the center housing. When the end of the shock absorber is impacted by the percussor hammer, the titanium tube elements extend under tension thus dissipating the percussor energy into heat.

The output spindle contains a female double lead thread, one revolution per inch pitch, which mates interchangeably with any drill string extension tube and hole casing adapter. Visual rotation indicators are painted on the output spindle to serve as a positive means of determining drill string rotation.

The pressurization system maintains pressure integrity within the power head housing through the use of eight static seals, one linear bellows dynamic seal, and two rotary dynamic seals. The static seals are employed between the three housing sections, front end section, and the various components such as the connector, pressure relief valve, and lubrication ports. The lubricated dynamic seals are employed with the output spindle. Internal pressure of the power head is controlled by a 10 (± 1 psi) relief valve.

The thermal guard shield consists of a wire cage mounted to the external surface of the power head. The shield is used to prevent damage to the astronaut's suit when accidentally brushing against the power head which may have a temperature exceeding +250 degrees F.

2-222. **ALSD Drill String.** The drill string provides the cutting capability required for coring the hole in any lunar surface material which may be encountered ranging in hardness from dense basalt to unconsolidated conglomerate. The drill string is comprised of a core bit and eight extension tubes.

The core bit is composed of five tungsten-carbide tips which are brazed into a steel body and functions to provide the rock cutting capability of the drill string. Four helical flutes are machined into the outer diameter of the bit body. The flutes, or ramps, transport the rock cuttings from the face of the cutting tips upward to the double flute system of the extension tubes and subsequently to the surface. Coupling of the core bit to the extension tubes is accomplished by double acme-type male threads machined into the extension tubes and core bit.

The eight extension tubes provide the mechanical coupling to transmit the rotary-percussive energy from the power head output spindle to the core bit. During normal drilling operations, the extension tubes are added in groups of two as the depth of the hole increases until the full depth of three meters is attained.

2-223. **ALSD Accessory Group.** The accessory group comprises extension tube caps, hole casings, hole casing adapter, rack assembly, treadle assembly, and a wrench.

The extension tube caps are fabricated from teflon and are installed on each end of the extension tubes after completion of second hole drilling. The caps prevent loss of core material from within the extensions during stowage in the sample return container (SRC) for the earth return flight.

Hole casings are employed by the astronaut on the lunar surface when the hole is drilled in unconsolidated material which tends to cave-in after retraction of the drill string. Twelve hole casing sections are required for the two, 3-meter holes. The casings are fabricated from continuous filament, glass fabric, epoxy laminated tubes. The casings are assembled in groups of two and power driven into the pre-drilled hole with the power head. The first casing of each assembly incorporates a closed tip on its forward end which prevents entry of core material during the emplacement process. The continuous 0.875 inch inside diameter of the emplaced hole casing permits rapid insertion of the HFE probe.

The hole casing adapter, made of titanium with one end that mates with the hole casings and the other end mating with the power head, is used to sequentially couple the double sections to the power head during the casing emplacement process.

The rack assembly is made of magnesium alloy and provides basic restraint for the twelve hole casings, wrench, and handle assembly within the ALSD assembly stowage mode during the outbound translunar phase of the mission. On the lunar surface, the rack is deployed into a tripod configuration which provides vertical stowage for the core bit, extension tubes, and hole casings.

The treadle assembly is primarily aluminum alloy sheeting and provides structural restraint for the rack assembly and battery power head assembly during outbound mission stowage on the ALSEP subpackage. On the lunar surface, the treadle assembly drill string locking feature is used in conjunction with the wrench for uncoupling extension tube joints during phases of the drilling operation.

The wrench is a multi-purpose tool employed to perform four functions: (1) decouple emplaced extension tubes in conjunction with the treadle assembly, (2) aid in retracting the emplaced drill string after completion of hole drilling, (3) assist in removing core material from the extension tubes, and (4) aid in retrieving objects from surface level, e.g., extension tubes, treadle assembly.

2-224. ALSD FUNCTIONAL DESCRIPTION

The ALSD is a battery-powered, rotary-percussion drill. The rotary-percussion drilling principle is used in this application because: the axial bit pressure and rotary torque requirements for efficient drilling are considerably less than for rotary drilling; drill bit operating temperatures are sufficiently low to preclude a requirement for bit coolant; and the tungsten-carbide cutters will drill with reasonable efficiency in the presence of a small dust layer in the bottom of the hole which is inherent with a mechanical cuttings transport system.

2-225. ALSD DETAILED FUNCTIONAL DESCRIPTION

Power is supplied from the 16-cell silver oxide-zinc battery to the power head motor (Figure 2-112) at 23 vdc. The nominal speed of the motor armature is 9300 rpm. A reduction gear couples the output shaft of the motor to the power train which consists of the necessary reduction gears to provide the desired rotary motion and percussive action; 280 rpm at 2,270 blows per minute at the output shaft.

CAM GEAR

MOTOR ARMATURE

SHIELD

CLUTCH

RECIPROCATING SEAL
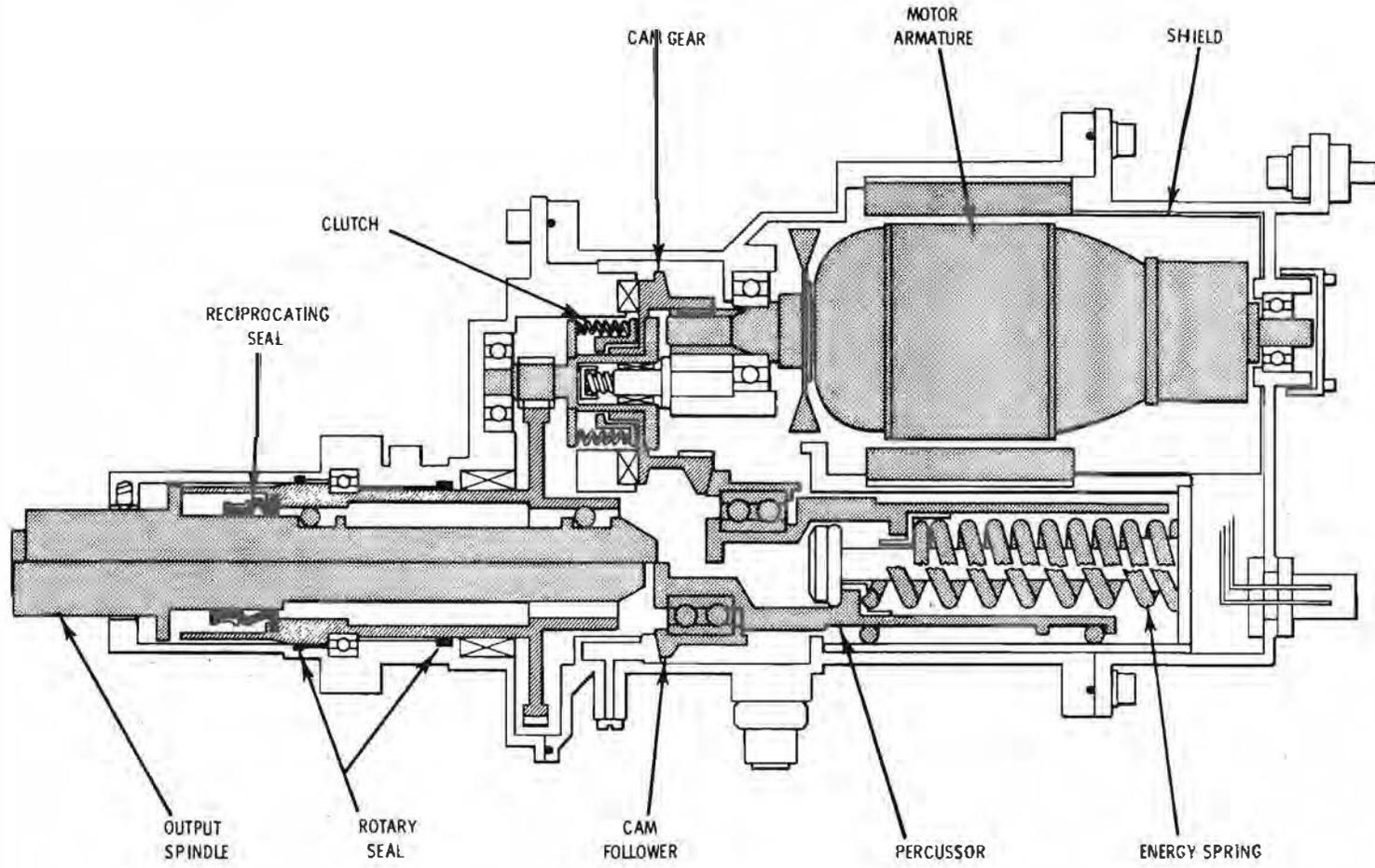
NOTE: Percussor & Spindle Shown in Both Fully Retracted and Fully Extended Positions.

OUTPUT SPINDLE

ROTARY SEAL

CAM FOLLOWER

PERCUSSOR

ENERGY SPRING

Figure 2-112. ALSD, Power Head, Simplified Cutaway View

The interface between the power train and the percussor is provided by the clutch. The clutch limits the torque load to a level which can be safely controlled by the astronaut. (The clutch is designed for a nominal slip value of 20 foot-pounds.)

The percussor converts the uniform rotary output motion of the power train into pulsating, high-energy, short-duration, linear-impact blows to the output shaft of the power head. The impact action is accomplished by a rotating cam against a cam follower, which also serves as the hammer. As the cam rotates, the follower raises, cocking a spring. The spring, by virtue of the cam shape, releases its kinetic energy rapidly thereby accelerating the hammer toward a transition section. This transition section, or power head shaft, serves as the anvil for the hammer and as the receiver for the rotary motion output of the power train.

The rotary-percussive energy at the output of the power head is coupled to the core bit by the drill string. The drill string operates through the treadle assembly which employs a locking mechanism insuring positive energy coupling to the core bit. The core bit delivers the rotary-percussive energy to the rock. The percussive element of the input energy fractures the rock by exceeding its compressive strength under each cutting tip. The rotary element of the input energy repositions the cutting tips for subsequent rock fracturing and provides the means for transporting the rock cuttings upward to the surface via the helical transport flutes.

The drill string stores the core material cuttings. After the second hole is completed, the drill string is dissassembled, capped, and installed into the sample return container (SRC) for eventual return to Earth of lunar core material samples.

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 six manuals as listed in Table 3-8.

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, de-fined function (PSE, ASE, SIDE). 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 at BxA in Michigan.

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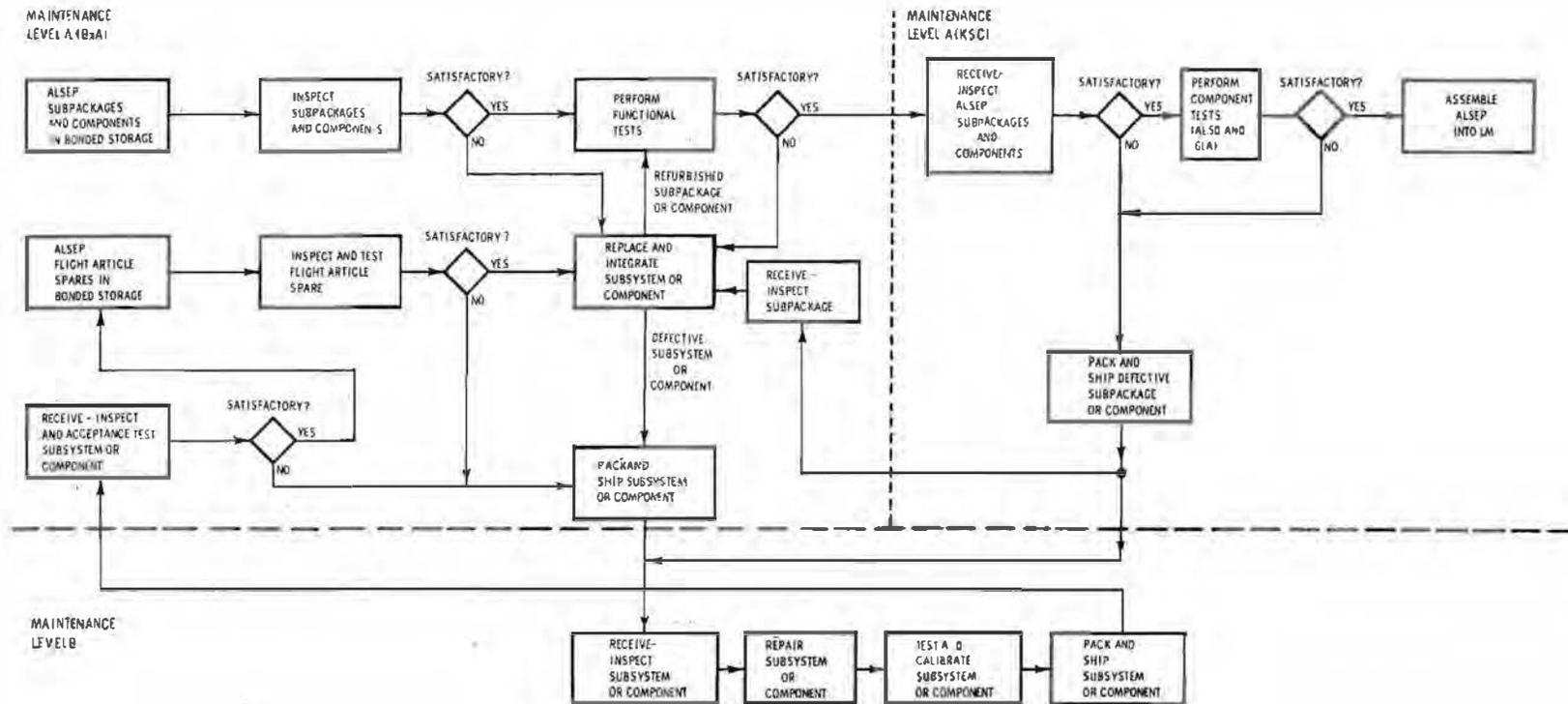
Figure 3-1. ALSEP Flight System Maintenance Flow Diagram
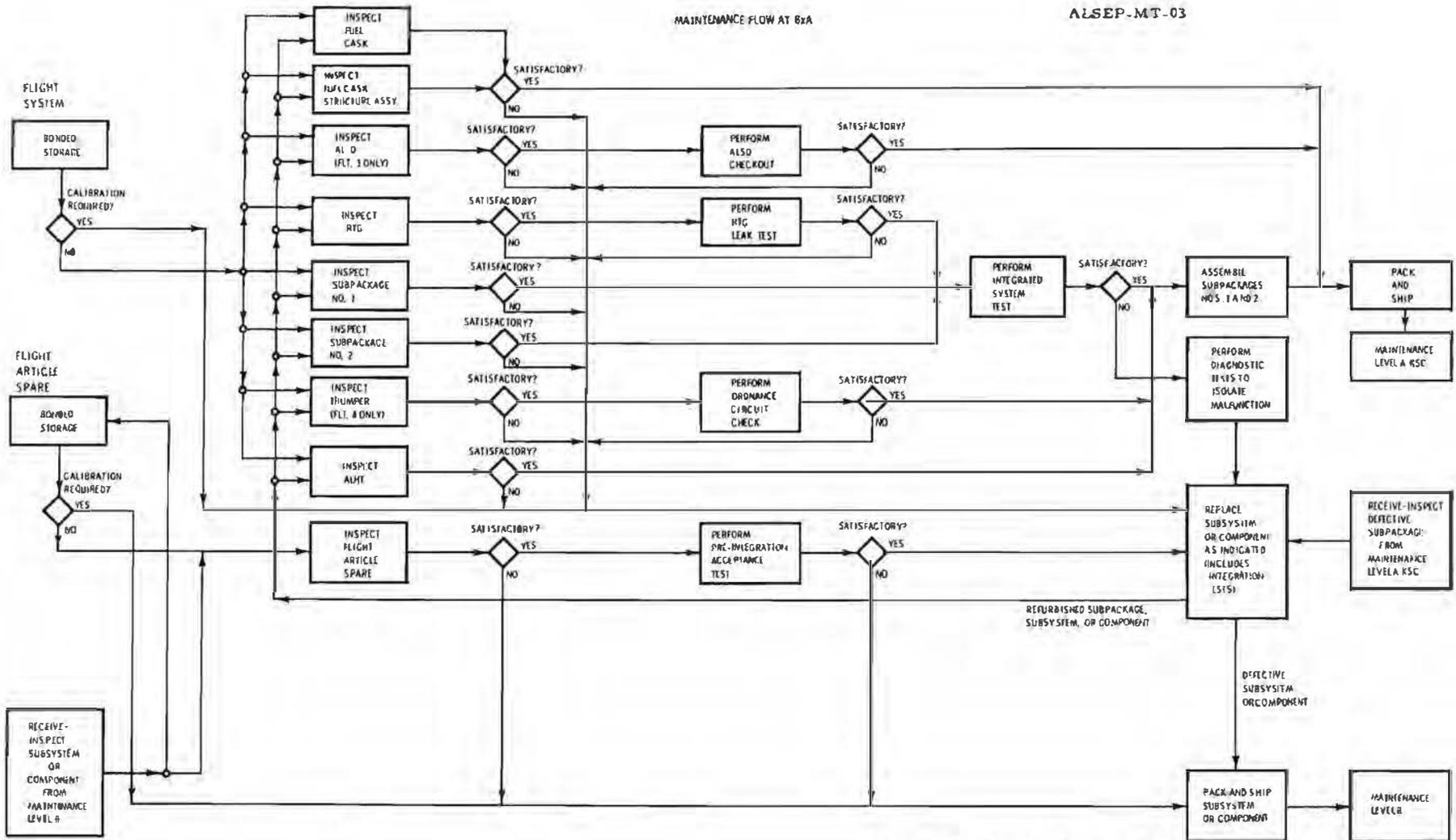
Figure 3-2. Level A Maintenance Flow Diagram (Sheet 1 of 2)

MAINTENANCE FLOW AT KSC
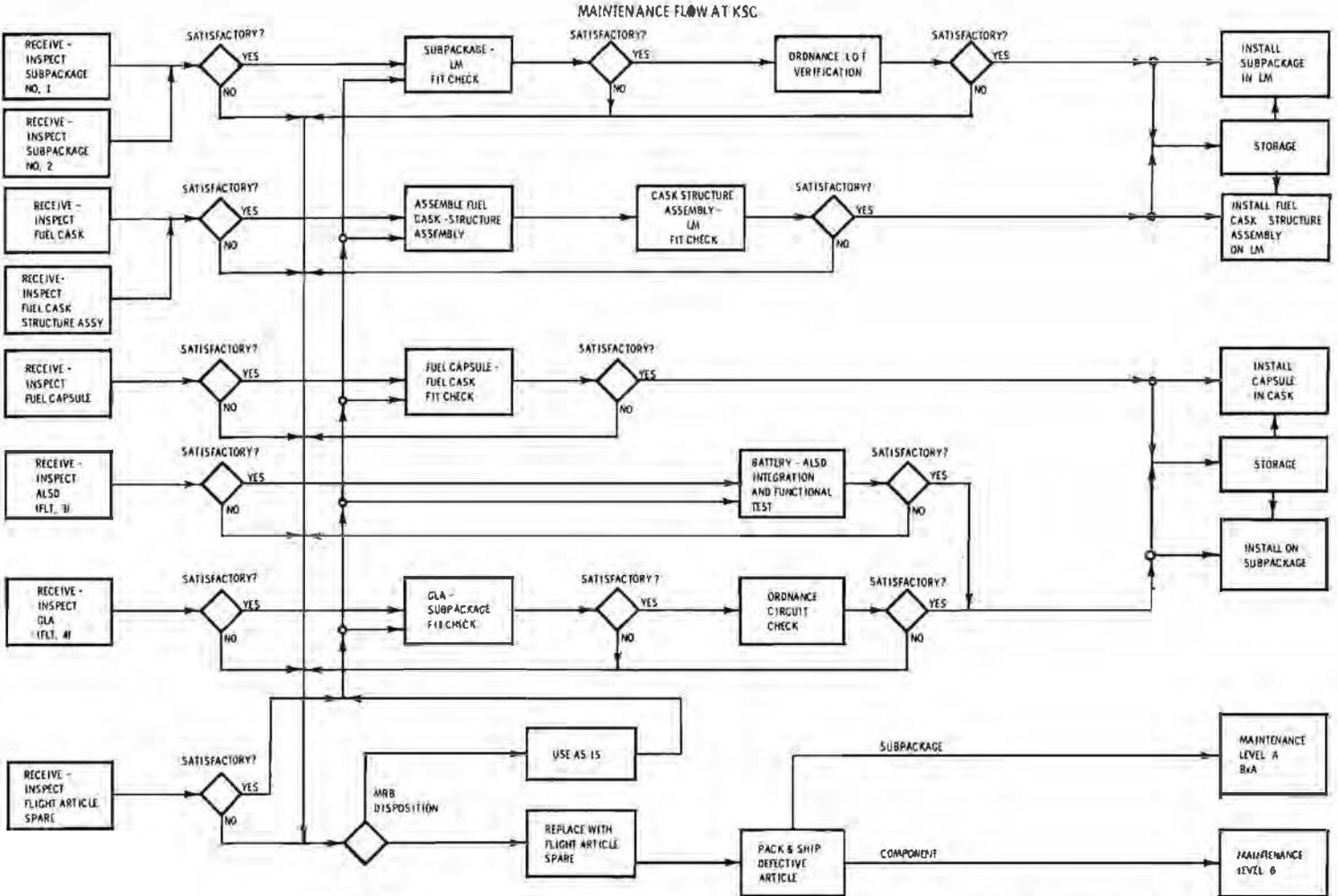
Figure 3-2. Level A Maintenance Flow Diagram (Sheet 2 of 2)

Table 3-2. ALSEP Flight Article Spares

Nomenclature	Quantity	Part Number	Note
Passive seismic experiment	1	2330659	
Heat flow experiment	2	2330661	
Charged particle lunar environment experiment	1	2330662	
Active seismic experiment electronics	2	2334468	
Grenade launch assembly	2	2338507-2	KSC
Mortar box assembly	2	2334499-4	
Thumper and geophone assembly	2	2334772-4	
Magnetometer experiment	2	2330657	GFE
Solar wind experiment	2	2330658	GFE
Suprathermal ion detector experiment	2	2330660	GFE
Dust detector	2	2330370-2	
Radioisotope thermoelectric generator	2	47E300779	GFE
Apollo lunar surface drill	1	467A805000	GFE
Apollo lunar hand tools	1	SGB39101165	GFE
Fuel cask	1	47E301134	GFE
Fuel capsule	1	47D300400	GFE
Universal handling tool	1	2338102	
Helical antenna	1	2330307	
Antenna cable assembly	1	2334522	
Antenna aiming mechanism	1	2330309	
Diplexer switch	2	2330526	
Diplexer filter	2	2330525	
Command receiver	2	2330523	
Command decoder	2	2330509	
Analog to digital converter-multiplexer	2	2330524	
Data processor (flights 1 and 2)	1	2330521-A4	
Data processor (flights 3 and 4)	1	2330521-B7	
Transmitter (2276.5 mc)	1	2330527	
Transmitter (2278.5 mc)	1	2330527	
Power distribution unit	1	2330450-2	
Timer	1	2330626	
Timer battery	2	2334476	
Power conditioning unit	1	2330000-3	
RF cable assembly	2	2330528-4	
RF cable assembly	2	2330528-5	
RF cable assembly	2	2330528-6	
RF cable assembly	2	2330670-3	
RF cable assembly	2	2330670-4	
RF cable assembly	2	2330671-2	
RF cable assembly	2	2330671-3	
Ammeter shorting plug	1	2335520	
Ammeter shorting plug	1	2338017	

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

Nomenclature	Quantity	Part Number	Note
PSE stool quick release pin	1	2335565	
SIDE connector quick release pin	1	2335574	
Fuel cask mounting assembly	1	2338660	
Lever and wire assembly	2	2338681-1	
Lever and wire assembly	1	2338681-2	
Body release mechanism	1	2338687-1	
Body release mechanism	1	2338687-2	
Shear pin stop bracket (left hand)	1	2338685	
Shear pin stop bracket (right hand)	1	2338686	
Tab lock	2	2338689	
Special washer	2	2338693	
Shear pin	2	2338668	
Tension stud	2	2338692	
Square shear pin cutter	2	2338671-3	
Self-locking nut	4	MS21043-4	
Belleville washer	8	BO500-025	
Shear wire	4	2338043	
Setscrew	2	2338665	
Screw 4-40x.25 inch	4	MS35275-213	
Lanyard assembly	1	2338128	
Tool support quick release pin	1	2335575	
RTG cable spring clip	4	2335516	
Boom quick release pin	1	2335262	
Outboard support pin	2	2335126	
Outboard quick release pin	2	2334525-3	
Guide fastener	20	2335931-1	
Guide fastener	2	2335931-2	
Guide fastener	2	2335931-4	
Guide fastener	3	2335931-5	
Guide fastener	2	2335931-6	
Guide fastener	2	2335931-7	
Guide fastener cap	100	2334675-1	
Guide fastener cap	8	2334675-2	
Guide fastener cap	10	2334675-3	
Guide fastener cap	4	2334675-4	
Quick release pin	1	2335577-5	
Quick release pin	1	2335577-4	
Dust cover connector	1	2334528-2	
Dust cover connector	1	2334528-6	
Dust cover connector	1	2334528-8	
Boyd bolt	4	CA2773-2-1	
Boyd bolt	4	CA2773-4-1	
Boyd bolt	4	CA2773-6-1	

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

Nomenclature	Quantity	Part Number	Note
Boyd bolt	2	CA2773-8-1	
Boyd bolt	4	CA2773-10-1	
Boyd bolt	8	CA2773-14-1	
Boyd bolt	4	CA2773-18-1	
Boyd bolt	4	CA2773-20-1	
Boyd bolt	4	CA2773-24-1	
Boyd bolt spring	25	CS1014	
Boyd bolt nut	25	SP1015	
Accordion rivet	50	PC47290	
Accordion rivet	50	PC47289	
Boom attachment release assembly	3	2335501-1	
Boom attachment release assembly	3	2335501-2	

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 Field 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 3-17 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 3-6, and illustrated in Figures 3-18
through 3-22.

3-9. TOOLS AND TEST EQUIPMENT

Standard tools and test equipment, facilities, and supplies required for mainte-
nance are listed in Table 3-7.

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	ALSD pressurization unit	467A8090000 (Martin-Marietta)	GFE
3-15	ALSD battery charging unit	467A808000 (Martin-Marietta)	GFE
	ALSD battery filling kit		GFE
3-16	Electric fuel capsule simulator	47D300261 (GE-MSD)	GFE
3-17	Antenna cap fixture	2333830	CFE
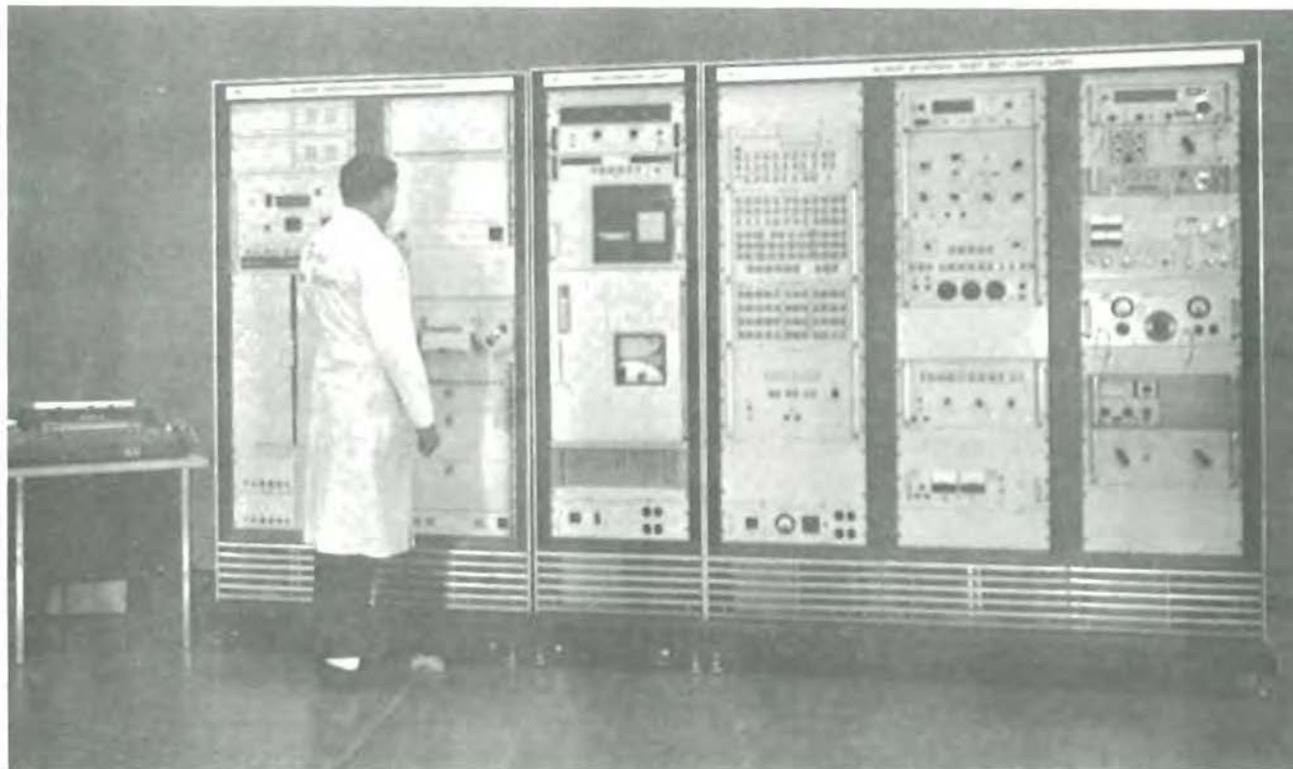
Figure 3-3. ALSEP System Test Set
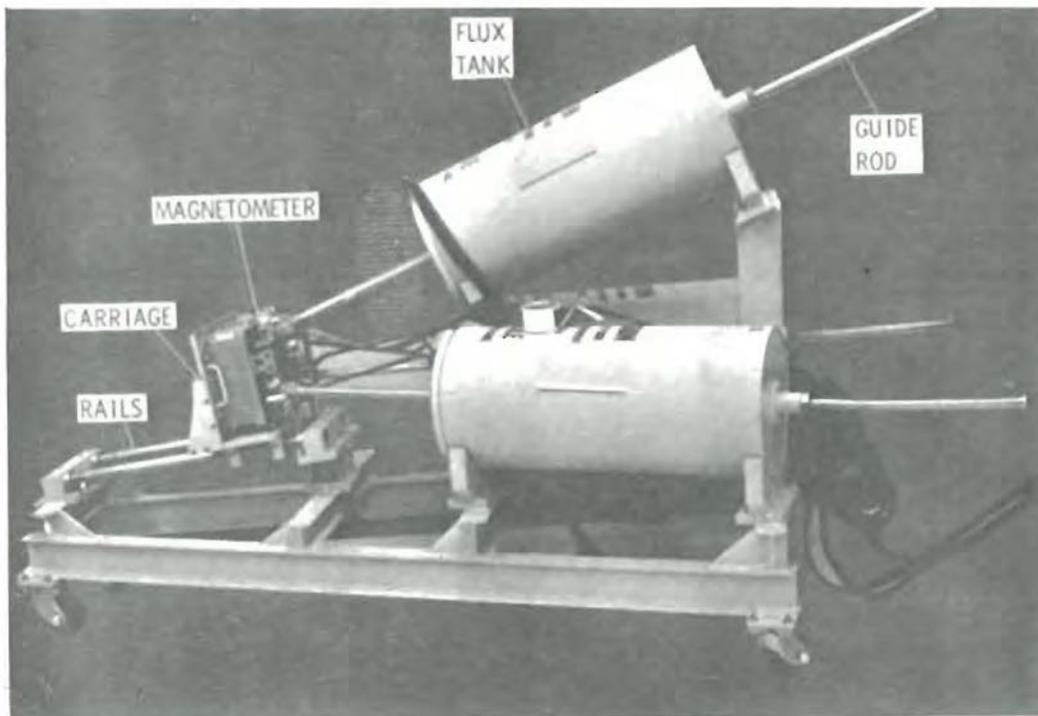
Figure 3-4. Magnetometer Flux Tanks (Configuration B)
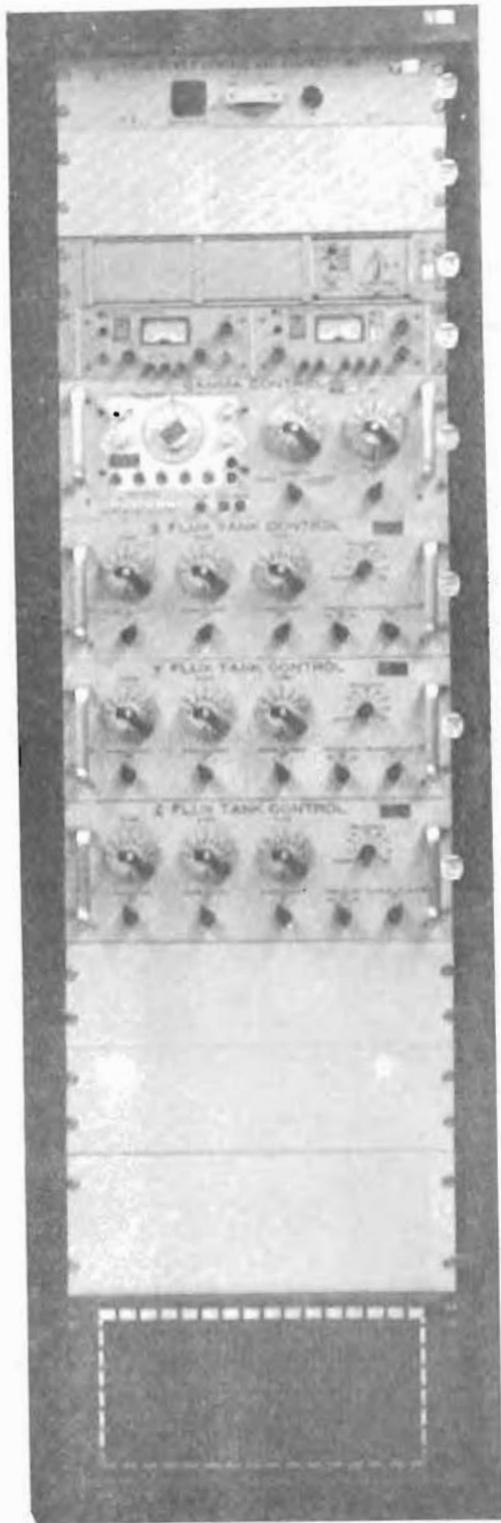
Figure 3-5. Gamma
Control Console
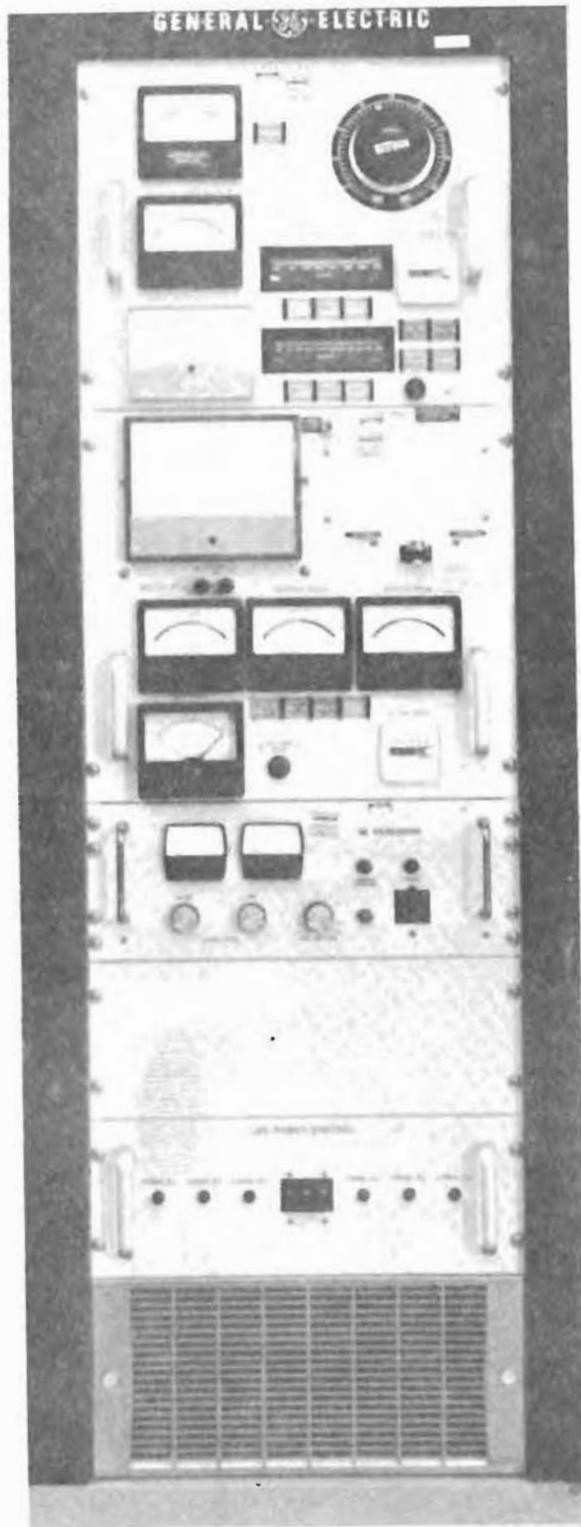
Figure 3-6. Integrated Power
Unit Test Set
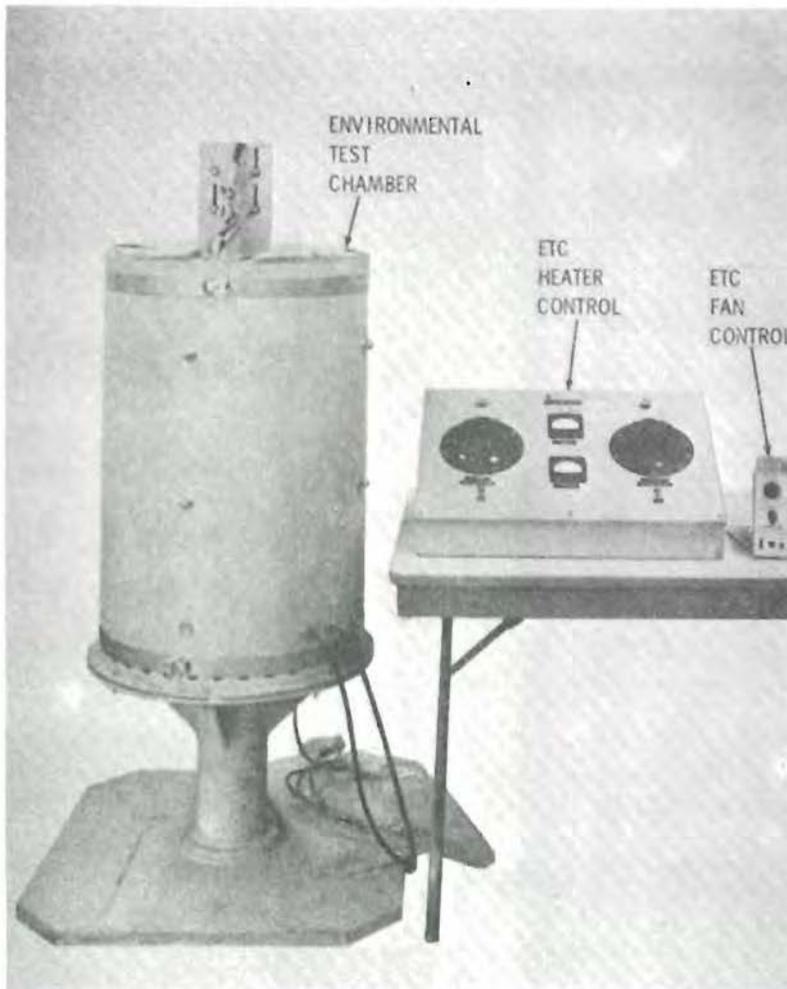
Figure 3-7. Environmental Test Chamber
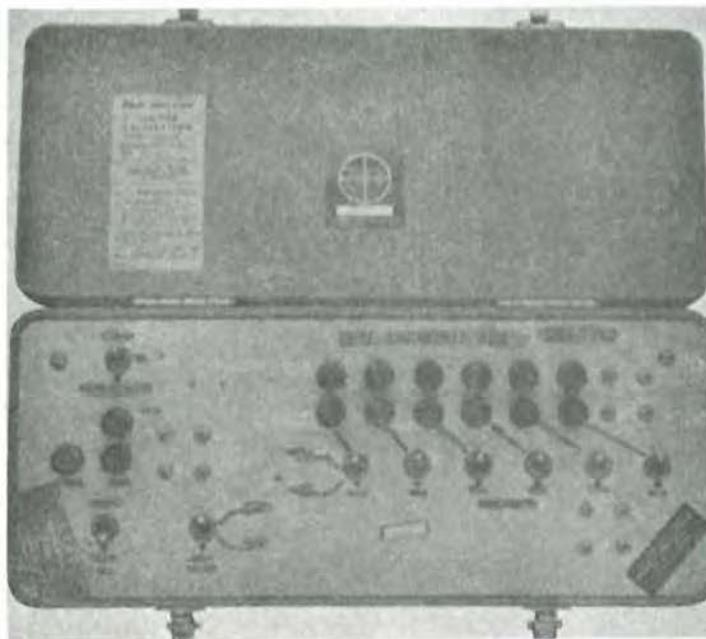
Figure 3-8. IPU Breakout Box
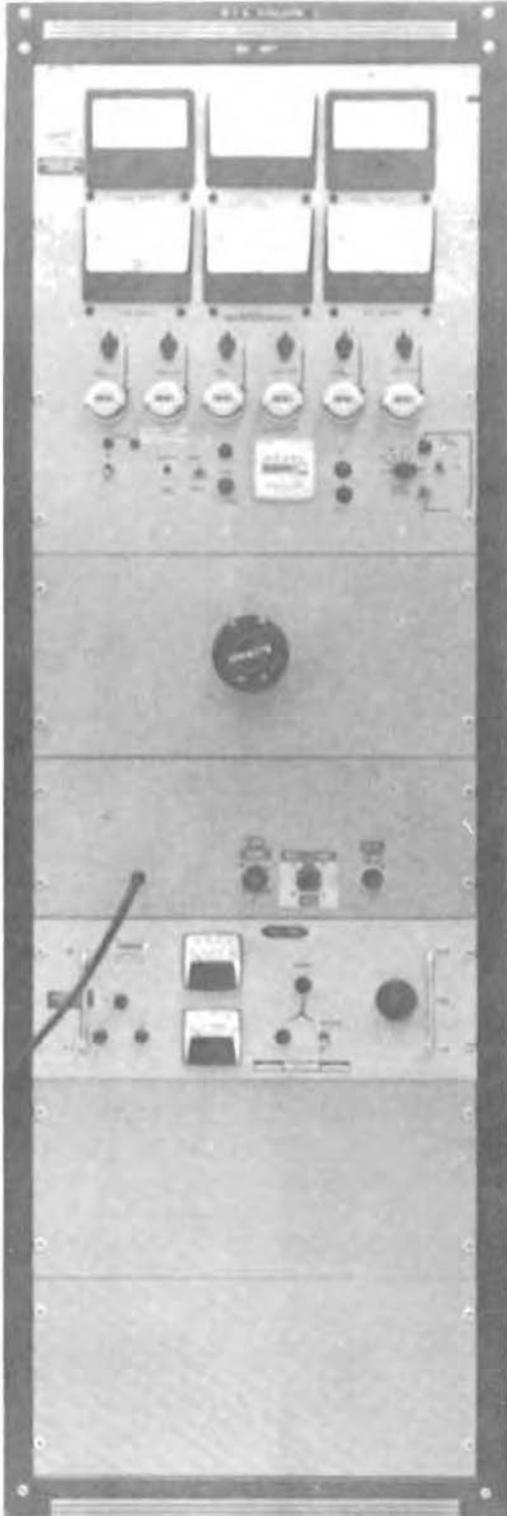
Figure 3-9.   RTG Simulator
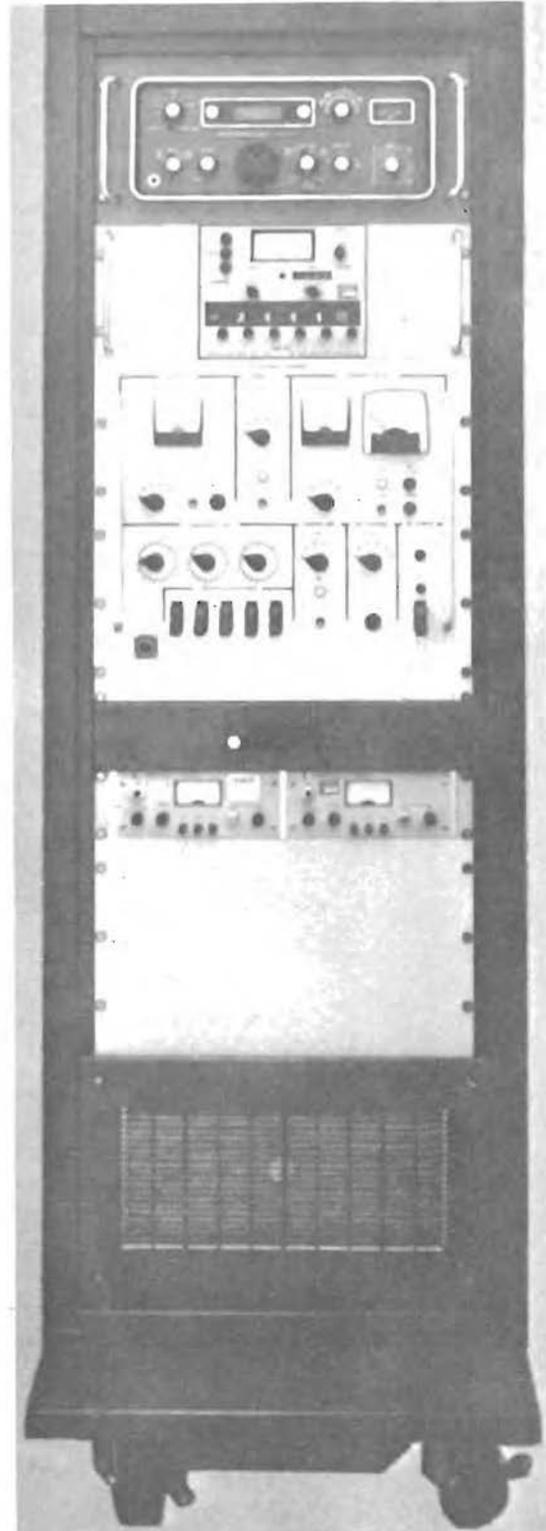
Figure 3-10.   Grenade Launch
Assembly Test Set
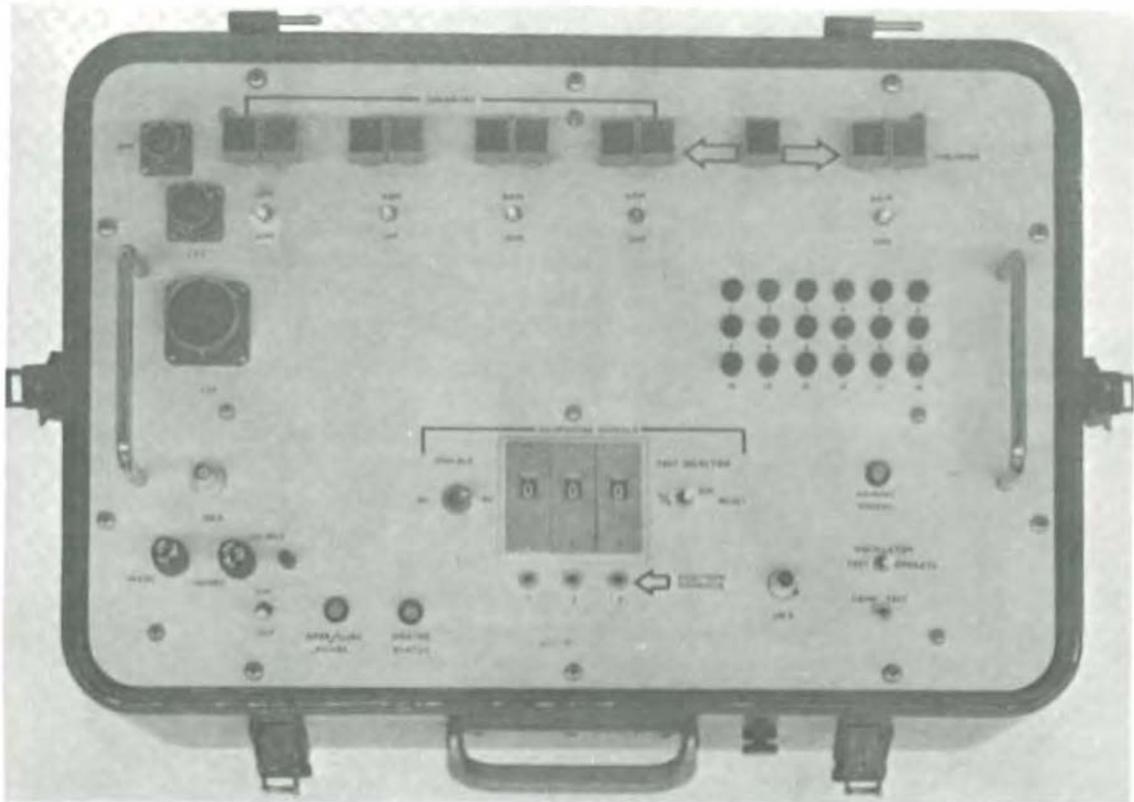
Figure 3-11. Active Seismic Sensor Simulator
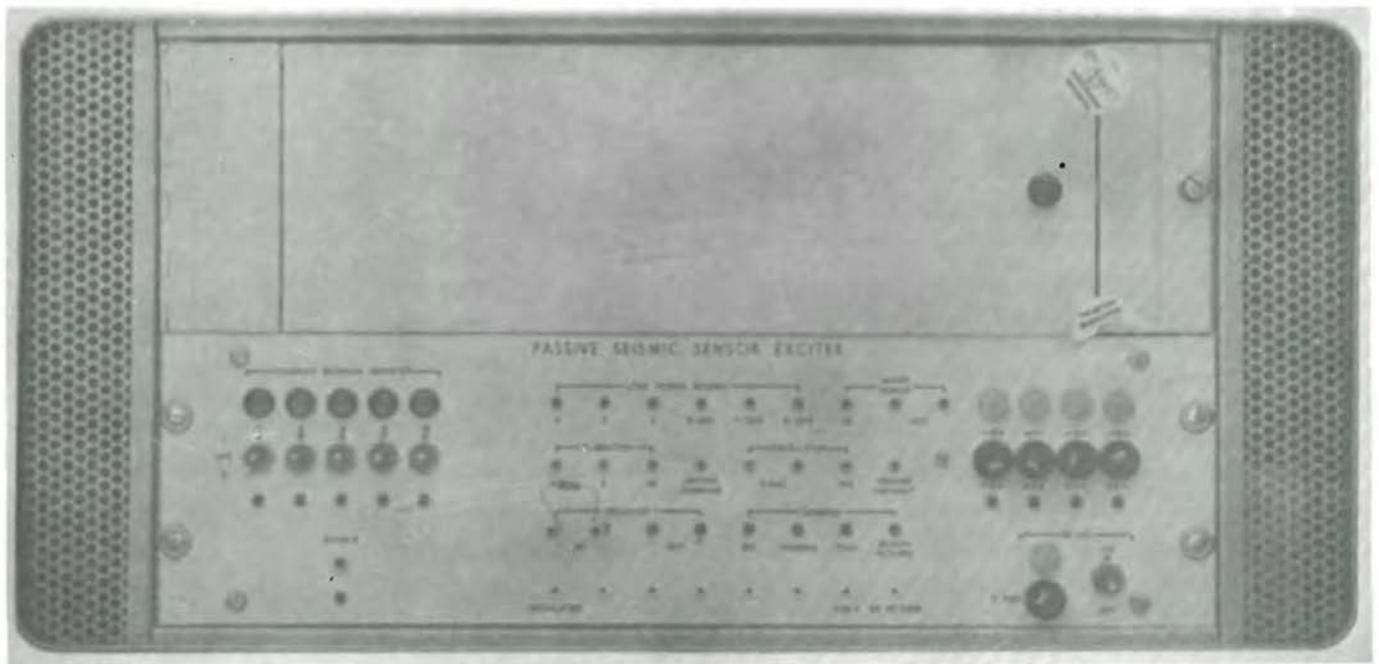
Figure 3-12. Passive Seismic Sensor Exciter
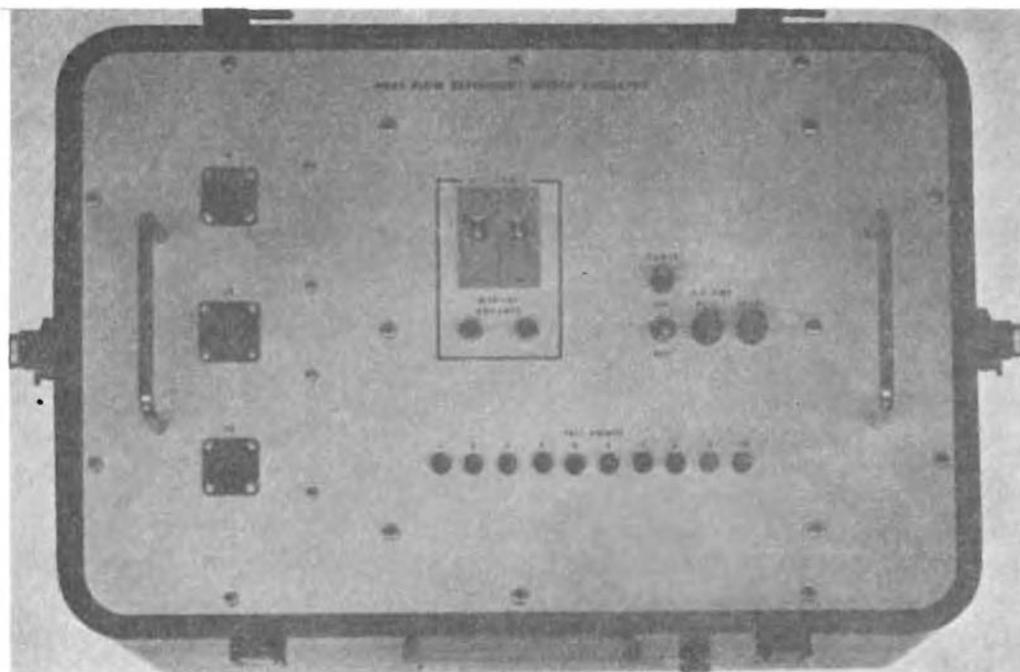
Figure 3-13. Heat Flow Sensor Simulator

Figure 3-14. ALSD Pressurization Unit
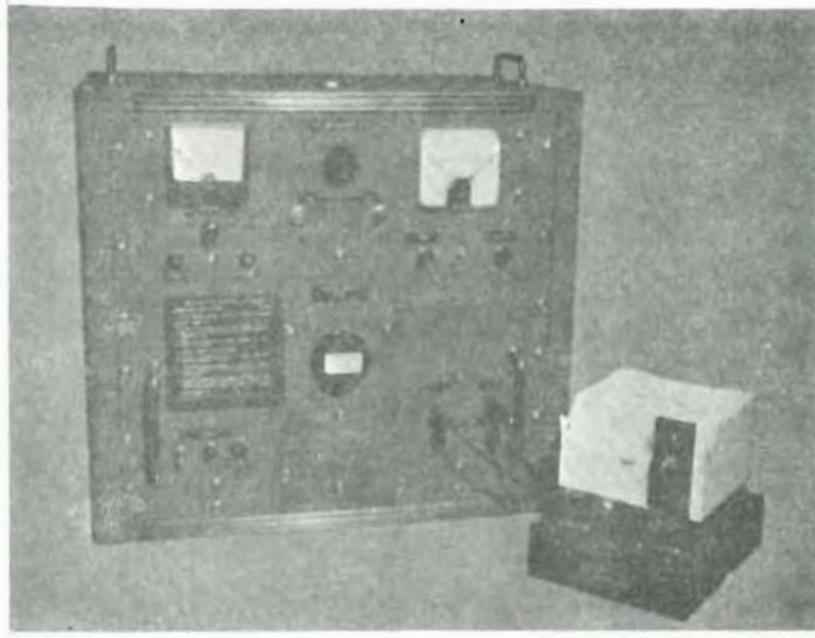
Figure 3-15. ALSD Battery Charging Unit
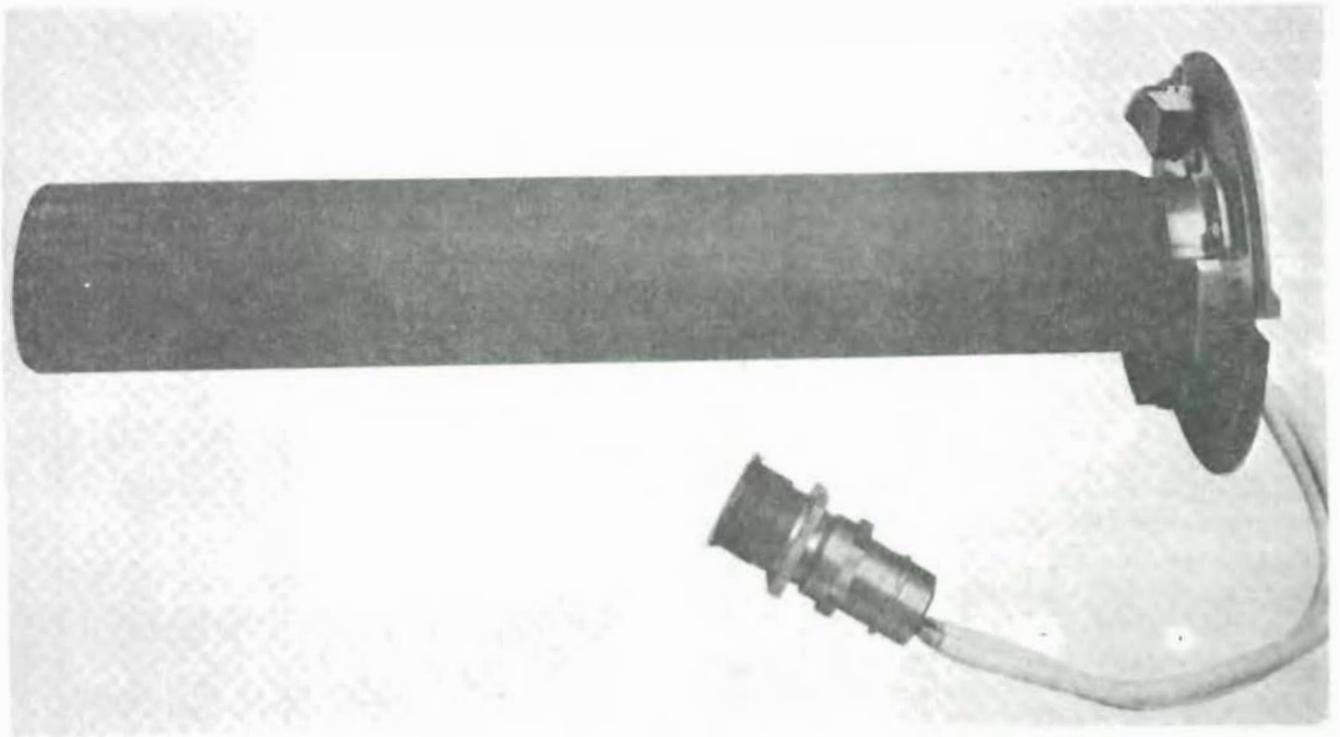
Figure 3-16. Electric Fuel Capsule Simulator
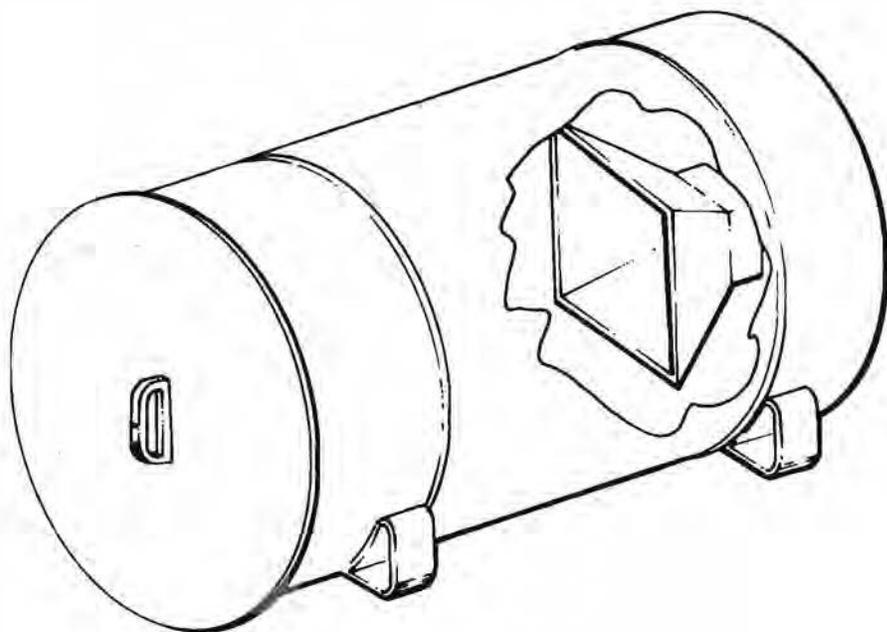
Figure 3-17. Antenna Cap Fixture

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

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

Nomenclature	Function	Part Number
Handling Device, Subpackage No. 2	Attaches to base of subpackage No. 2 for subpackage transfer to various test fixtures.	2335313
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.	2338215
Boyd Bolt Spindle Force Measuring Tool	Used to measure force required to depress Boyd bolt spindle.	2338213
Boyd Bolt Spindle Position Measuring Tool	Used to measure position of spindle relative to Boyd bolt body.	2338651
Boyd Bolt Release Tool	Used to release Boyd bolt.	2335910
GLA Test Fixture (also called a Mechanical Attitude Reference Positioning Device or MARPD)	GLA alignment sensor checkout.	2331455
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

HOISTING DEVICE

HANDLING DEVICE
(TYPICAL)

HOLDING FIXTURE
(TYPICAL)

HANDLING CART
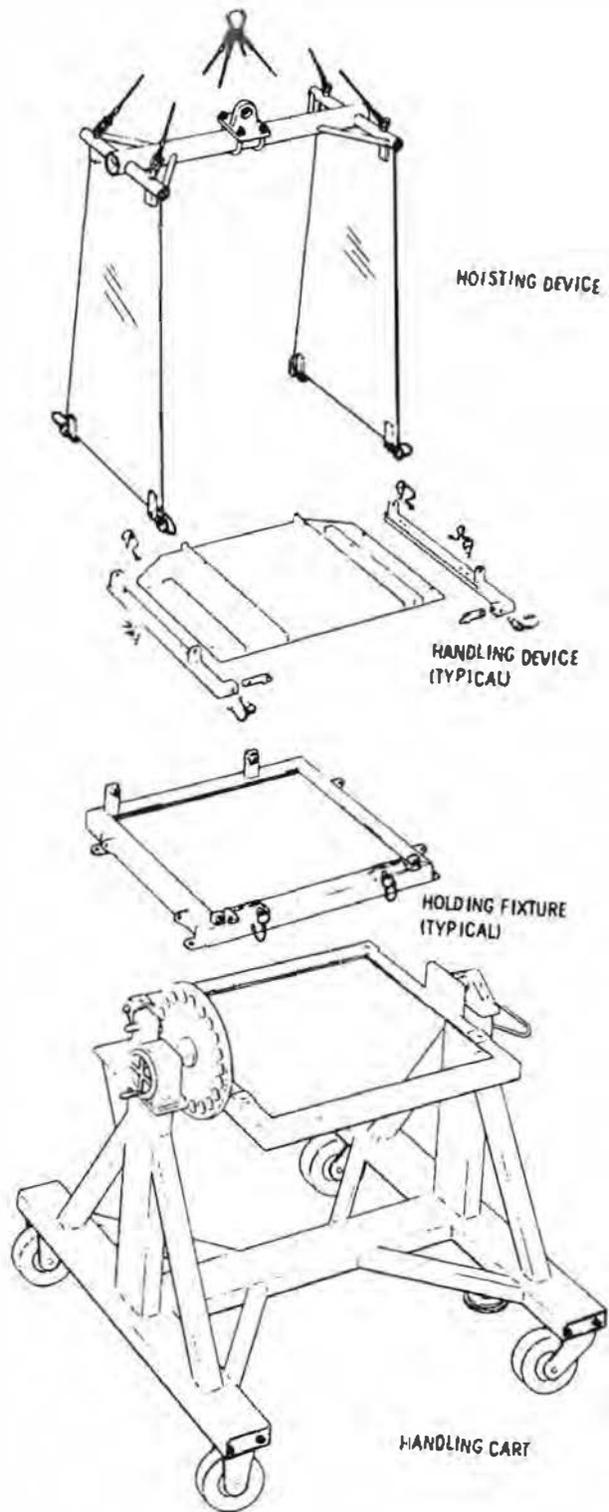
Figure 3-18. Subpackage Handling GSE

Figure 3-19.   Boyd Bolt Tools
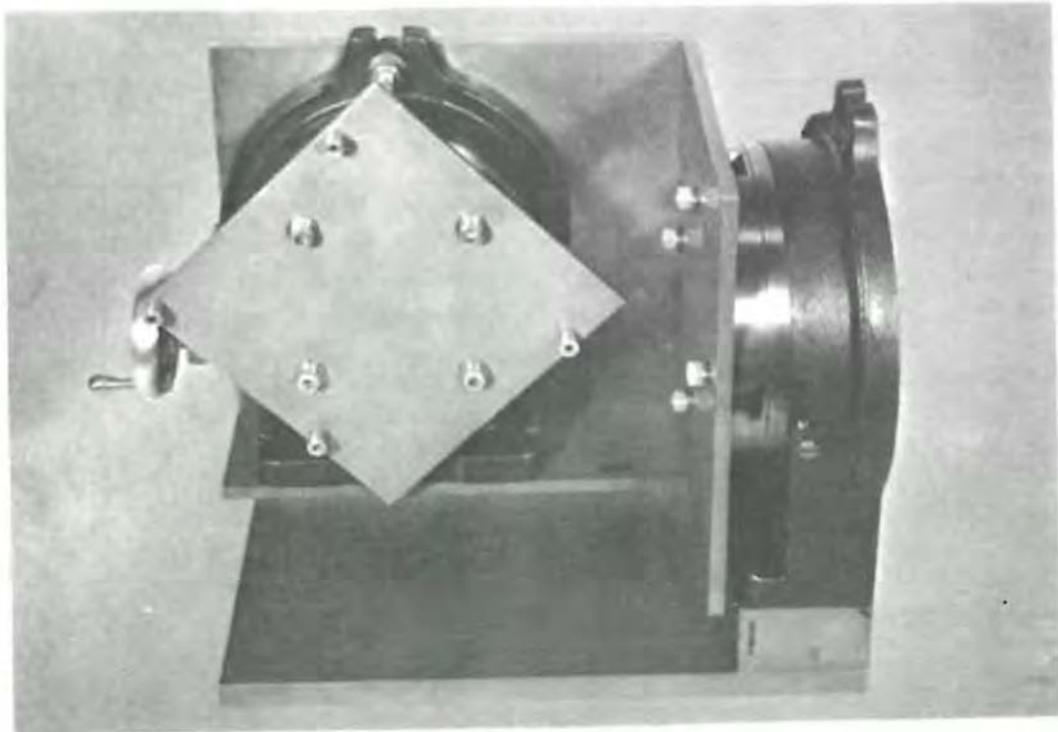
Figure 3-20.   GLA Test Fixture

Table 3-5. 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 3-6. 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)

FUEL CASK/BAND
ASSEMBLY
HANDLING DEVICE

CASK/STRUCTURE
HANDLING DEVICE

STRAIN GAGE
READOUT DEVICE

TRUNNION
ALIGNMENT/BAND
CALIBRATION
HOLDING FIXTURE

DOME
REMOVAL TOOL

BAND
TENSIONING
TOOL

CG
DETERMINATION
FIXTURE

FUEL CASK
HANDLING CART

DOME/TOOL
RECEPTACLE
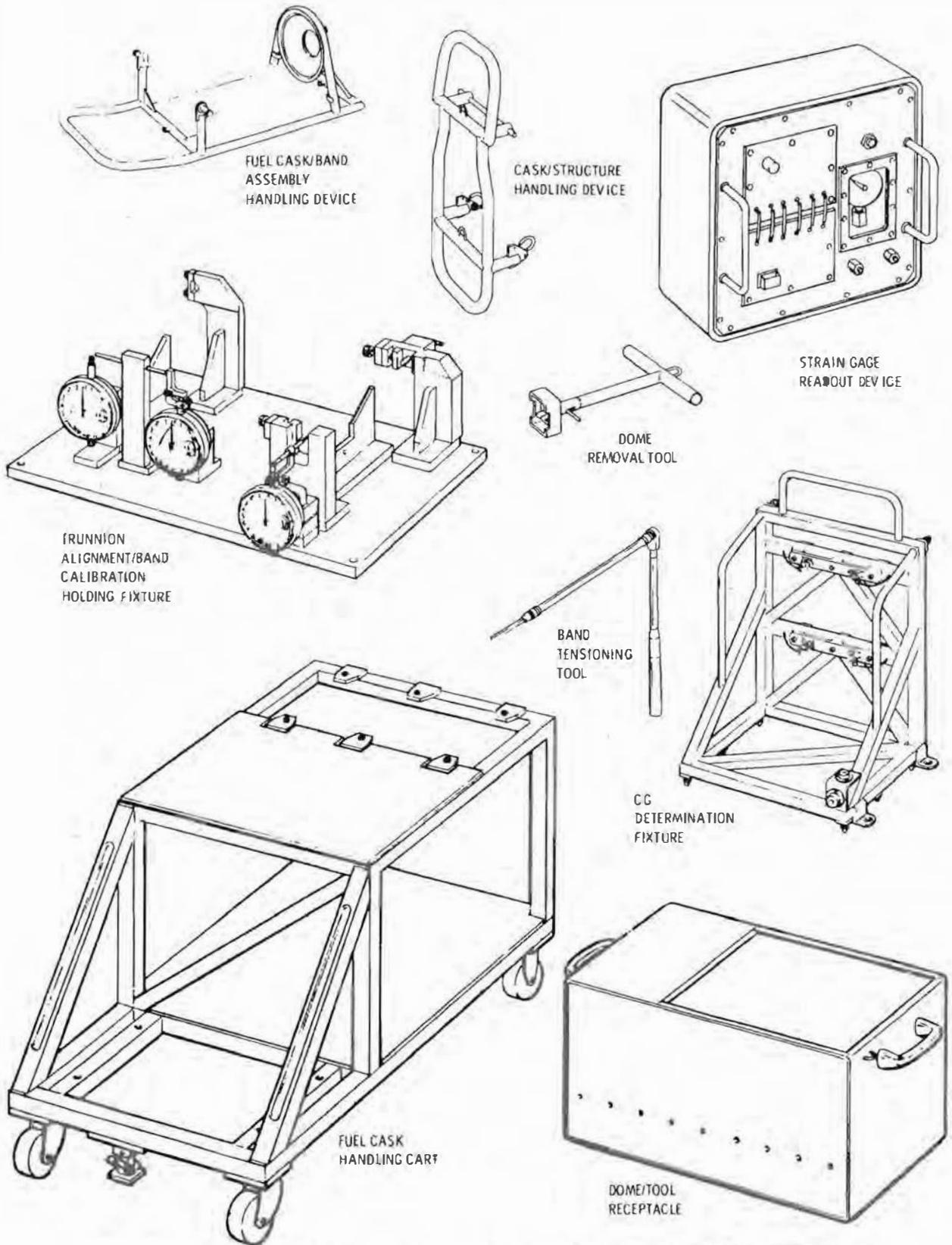
Figure 3-21. Fuel Cask/Structure Assembly Handling Equipment
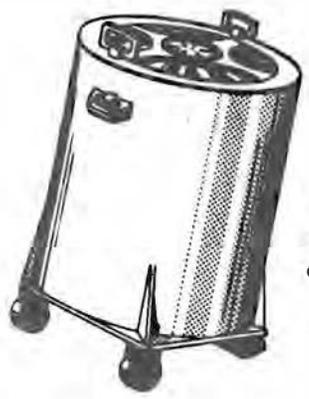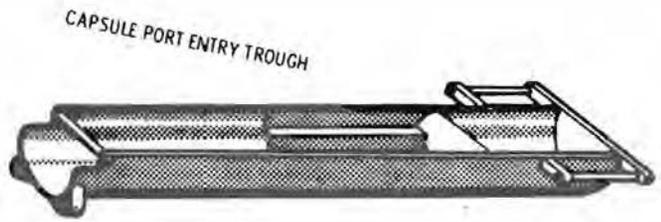
CAPSULE PORT ENTRY TROUGH

CAPSULE
TRANSFER
CASK
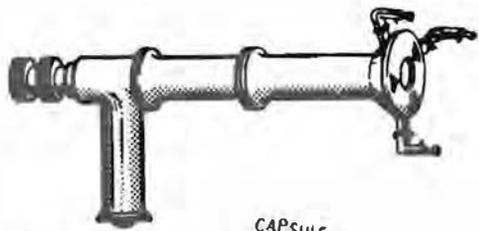
CAPSULE
SLA HANDLING
TOOL
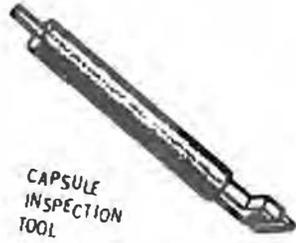
CAPSULE
INSPECTION
TOOL

Figure 3-22. Fuel Capsule Handling Equipment

Table 3-7. 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-SPS2000 (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 (regulated at 150 psig (max.)	Calibration and checkout of ALSD.
	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. <u>ALSEP Containers.</u> Special containers are provided for each ALSEP sub-package assembly, and separately shipped subsystem component. Figure 3-23 illustrates typical ALSEP containers.

The ALSEP containers are constructed for an outer metal housing specifically shaped 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, Flights 1 and 2, incorporates a GFE flux recorder for checking magnetic field exposure during shipment.

3-12. <u>Commercial Packages.</u> 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 six ALSEP support manuals used as an integrated documentation system to support the ALSEP hardware system. These manuals are listed in Table 3-8.

Table 3-8. 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

SUBPACKAGE CONTAINER
(TYPICAL)

FUELCAPSULE
GROUND SHIPPING
CASK
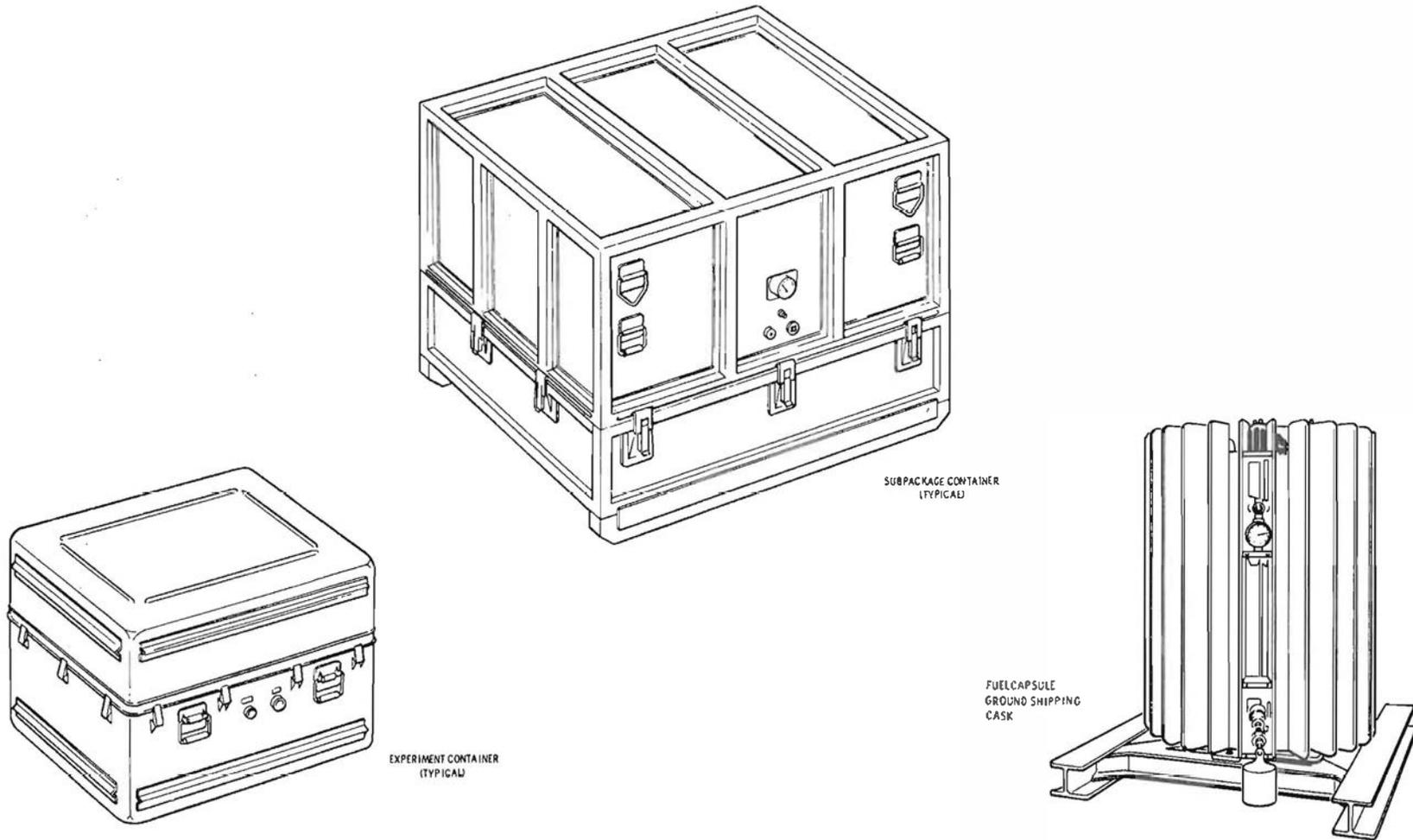
EXPERIMENT CONTAINER
(TYPICAL)

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	Postdeployment
ALSEP inspection	In-flight configuration	MSFN operation
	Post-landing operations	MCC operation
Fit checks	Carry mode	PI activities
Ordnance verification		
ALSD activation	Deployment:	
	(a) Support subsystems	
ALSEP installation	(b) Experiment subsystems	
ALSD installation		
Grenade and thumper 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. Parachute building, M7-657 (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 Hypergolic Test Cell No. 2, Building M7-1210 which is located south of the manned spacecraft operation building (MSOB). 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 actuate CCIG and CPLEE dust covers and 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 Hypergolic Test Cell No. 2, Building M7-1210.

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 recorders will be monitored for maximum excursions, if applicable. Excursions will be recorded on the logistic traveler or the quality assurance inspection report (QAIR).

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. The ALSEP system is delivered to the ordnance laboratory after all ordnance tests are complete. The ALSEP system is stored in the ordnance laboratory storage facility between ordnance installation activities. Ordnance items are installed as follows:

Table 4-2. KSC Inspection

Item	Sub-item (if applicable)
GLA Test Set (GLATS)	(Received at ordnance facility and trans-ferred to Building M7-1210 for inspection)
CPLEE CCIG, 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 (RTG)
Apollo Lunar Hand Tools	
Apollo Lunar Surface Drill (ALSD)	Battery pack
	Power head
	Casing
ALSD GSE	Transport/storage case
	Battery charger
	Pressurization unit
Flight Fuel Cask	
Fuel Cask Structure Assembly	
RTG 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
Flight Fuel Capsule Handling Tool	
ALSEP/LM Installation and Handling Equipment	Sub-package hoist equipment
	ALSEP/LM Insertion handling fixtures
	Handling equipment support platform
	(ALSEP installation equipment is stored in the MSOB after inspection.)

a. Dust cover squibs are installed on particle experiments and the connections are soldered.

b. The thumper assembly is installed on subpackage no. 2.

c. The GLA is installed in the mortar box to make up the mortar package asse assembly which is mounted on subpackage No. 1 after ALSEP has been installed in the LM and moved to the pad.

Table 4-3. KSC GSE Calibration

Item	Task
GLA Test Set	Calibrate in accordance with "GLA Test Set Instructions Manual."
ALSD (GSE)	Check the battery charger for rate, voltage, and charge termination using spare set of silver oxide zinc cells. Calibrate low and high pressure relief valve settings.
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 while the LM is in the landing gear fixture just prior to mating with the spacecraft LM adapter (SLA). A special platform is erected to the SEQ bay level to facilitate ALSEP installation.

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).
ALSD	Verify the ALSD battery and power head have correct internal pressure settings on the relief valve and that the power head functions satisfactorily.
ALSD GSE	Verify correct operation of ALSD battery charger and pressurization unit by verifying the output of the battery charger and leak testing the pressurization unit.

4-11. KSC ALSD Installation. Included in the ALSD installation are battery activation, pressure checks, and functional tests, which are performed as follows:

a. The ALSD battery is activated and charged prior to installation in the ALSD. If rescheduling at this point delays the activity by more than 6 days, the batteries are replaced.

b. The pressurization unit is connected to a supply of regulated nitrogen. The pressure required to actuate the relief valve is checked. A soak test is conducted to check for leaks from the battery box. A check is then made of the battery power switch operation and the off load voltage at the output connector.

c. The ALSD power head and battery pack are assembled and locked together. The power head is operated for ten seconds to verify proper operation.

d. The ALSD is transported to the SLA at Complex 39 where it is mounted on ALSEP subpackage No. 2 which is already installed in the SEQ bay. After completion of the ALSD installation the SEQ bay door is closed and secured.

Table 4-5. KSC Fit Checks

Item	Fit Checked with:
CPLEE ordnance (2 "reefing Line Cutters")	CPLEE (at ordnance test facility)
Thumper Assembly	Subpackage No. 2 (at ordnance test facility)
GLA	Mortar Box (at ordnance test facility)
ALSD	Subpackage No. 2
Fuel Capsule	Ground handling tool
	SLA handling tool (from cask to port entry through and back to cask)
	Flight handling tool
Fuel Capsule	Fuel cask
Fuel Capsule	RTG
Fuel Cask	Mounting hardware and heat shield
Fuel Cask, heat shield, structure assembly	LM
ALHT	Subpackage No. 2
ALSEP (Subpackages and ALSD)	LM

4-12. KSC Fuel Cask and Fuel Capsule Installation. The fuel 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.

4-13. 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.

4-14. 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 for Flights 1 and 2 are listed in Table 4-6. On Flight 3 the magnetometer and solar wind experiments are replaced by charged particle, cold cathode gauge, and heat flow experiments on subpackage No. 1 and the Apollo lunar surface drill replaces the suprathermal ion detector experiment on subpackage No. 2. On Flight 4 subpackage No. 2 is identical with subpackage No. 2 of Flights 1 and 2. Flight 4 subpackage No. 1 will mount the passive seismic and charged particle experiments, the mortar box assembly and the thumper of the active seismic experiment. In addition, the active seismic electronics package will be incorporated in the central station.

Table 4-6. Subpackage Configuration, Flights 1 and 2

Subpackage No. 1 (SEQ Compartment No. 1)	Subpackage No. 2 (SEQ Compartment No. 2)
Magnetometer experiment	Suprathermal ion detector experiment
Passive seismic experiment	Radioisotope thermoelectric generator
Solar wind experiment	Passive seismic stool
Dust detector*	Apollo lunar hand tools
Data subsystem antenna*	Fuel transfer tool
Data subsystem*	Universal handling tool (2)
Power conditioning unit*	Dome removal tool
	Antenna aiming mechanism
	Antenna mast/carry bar sections (2)
*Part of central station	

4-15. 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 approximately -50 to -60 degrees F. At a sun angle of 22 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.

The ALSEP related events that take place after the LM has descended on the Moon are presented here in the order in which they will be accomplished by the crewmen:

    a. Perform survey functions and enter the data on the antenna aiming table which is used in deploying the data subsystem.

    b. Proceed to the SEQ bay and begin ALSEP equipment removal and deployment procedures.

4-16. 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
Apollo Lunar Hand Tools (ALHT)	See Section II

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.

4-17. 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	Descent to lunar surface
2	Walk to descent stage stowage compartment (SEQ)
3	Unload ALSEP
	(a) Gain access to stowage compartment
	(b) Remove subpackage No. 1
	(c) Remove subpackage No. 2
4	Fuel RTG
5	Prepare subpackages for barbell carry
6	Locate correct traverse bearing
7	Walk 300 feet at selected bearing carrying packages

4-18. Descent to Lunar Surface. The predeployment phase begins with the crewman descending from the LM to the lunar surface.

4-19. 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, pulls deployment lanyard to release subpackage No. 2, pull boom with subpackage No. 1 out of the SEQ bay, lower 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.

4-20. 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.

4-21. Transport ALSEP to Emplacement Area. The crewman places the sub-packages in the carrying position and connects the antenna mast between the sub-packages. 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 300 feet from the LM on the Z axis. The Z axis is predicted on deployment being conducted in full view of the crewman remaining in the LM. The representative direction of the Z axis is affected by the suitability of the surrounding terrain. For purposes of this description, it is assumed that a southwesterly direction from LM is satisfactory for the emplacement of the ALSEP. While carrying the subpackages lateral balance is shifted by changing the hand position on the carry bar.

. The 300-foot distance to the emplacement area is the result of a trade-off in comparing the necessity of ALSEP deployment out of the LM ascent blast area with the constraints of keeping the crewman within the time and distance limitations dictated by the PLSS oxygen curve to assure a safe return to the LM. The walk to the deployment area is timed to prevent excess RTG warmup and thereby avoid potential thermal problems for the crewman.

4-22. DEPLOYMENT

To aid the astronaut in proper deployment of the experiments, decals, similar to those shown in Figure 4-1A, are attached to the subpackages and experiments.

The following describes the events that occur from the time the crewman arrives at the ALSEP emplacement area (300 feet from the LM) until he has deployed all ALSEP equipment and returned to the LM. It is assumed that the ALHT was removed from the ALSEP No. 2 subpackage on the initial excursion. Deployment activities are discussed in the procedural sequence performed by the crewman. Figures 4-2 through 4-4 illustrate the layout of the ALSEP equipment and experiments after deployment. The immediately following steps are applicable to Flights 1 and 2. Flights 3 and 4 are discussed in paragraphs 4-23 through 4-25.

Figure 4-1. Barbell Carry Mode
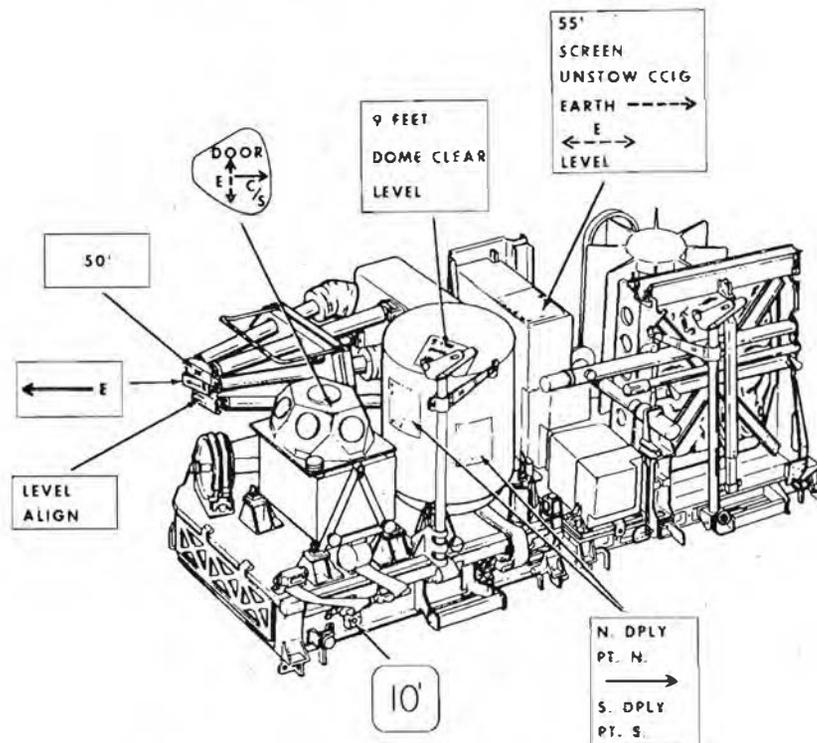
Figure 4-1A. Deployment Decals
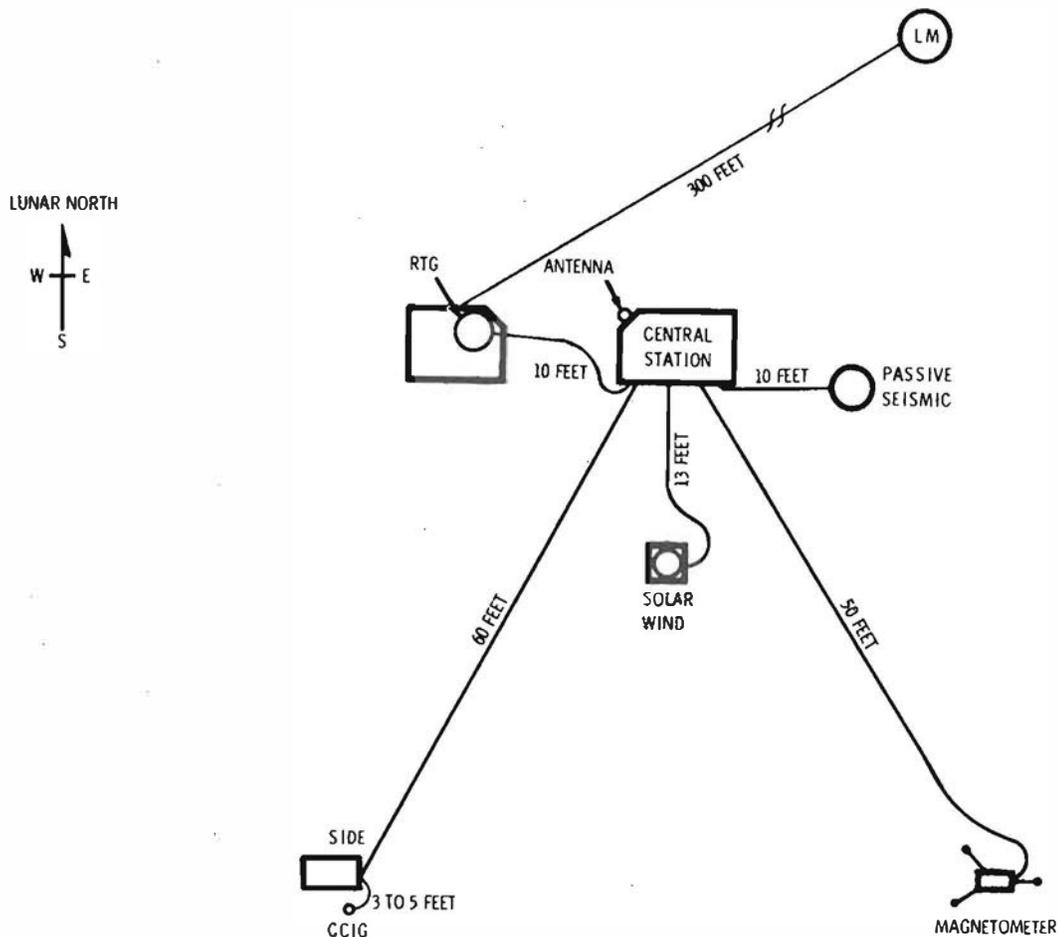
Figure 4-2.   Deployment Arrangement Flights 1 and 2, Typical

Step	Event
1	Emplace ALSEP on lunar surface on a N/S axis with subpackage No. 1 on the South side.
2	Remove subpackage No. 1 and carry to emplacement site 10 feet East of subpackage No. 2.
3	Return to subpackage No. 2, rotate it upright and align subpackage on E/W axis with RTG on East side. Remove subpallet and carry to subpackage No. 1.
4	Return to subpackage No. 2, remove cable reel, and return to subpackage No. 1 deploying cable enroute. Make power connection to subpackage No. 1.
5	Remove SIDE from subpallet, unfold legs, place SIDE on lunar surface approximately 5 feet South of subpackage No. 1, and complete cable connection.
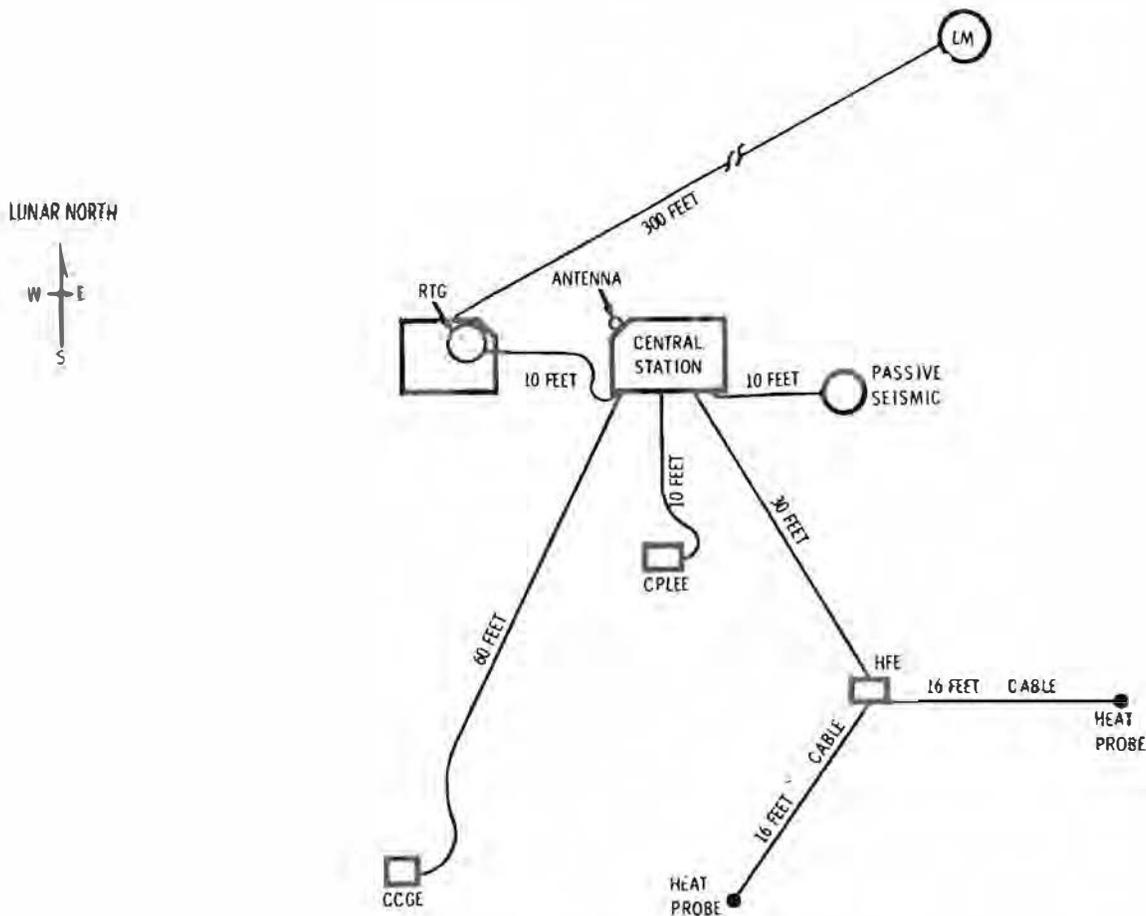
Figure 4-3. Deployment Arrangement Flight 3, Typical

Step	Event
6	Return to subpackage No. 1, remove carry bar and install on subpallet taper fitting.
7	Using handle of UHT, release PSE leveling stool pull pin, and remove stool from subpallet, carry stool to a point 10 feet East of subpackage No. 1 and emplace. Return to subpackage No. 1.
8	Set subpackage upright and align on E/W axis.
9	Release SWE, remove SWE from central station, carry 13 feet South, and emplace on lunar surface. Align by observing shadow cast by sensor head.
10	Release PSE, remove PSE from subpackage No. 1, carry with UHT to emplacement site, release thermal shroud restraint, emplace and align PSE, deploy thermal shroud, and level PSE. (See Figure 4-5.)
11	Release ME sensor arm fasteners, remove horse collar/brace assembly, release ME from subpackage No. 1, and place ME on lunar surface about 5 feet from subpackage No. 1 in the direction of deployment.
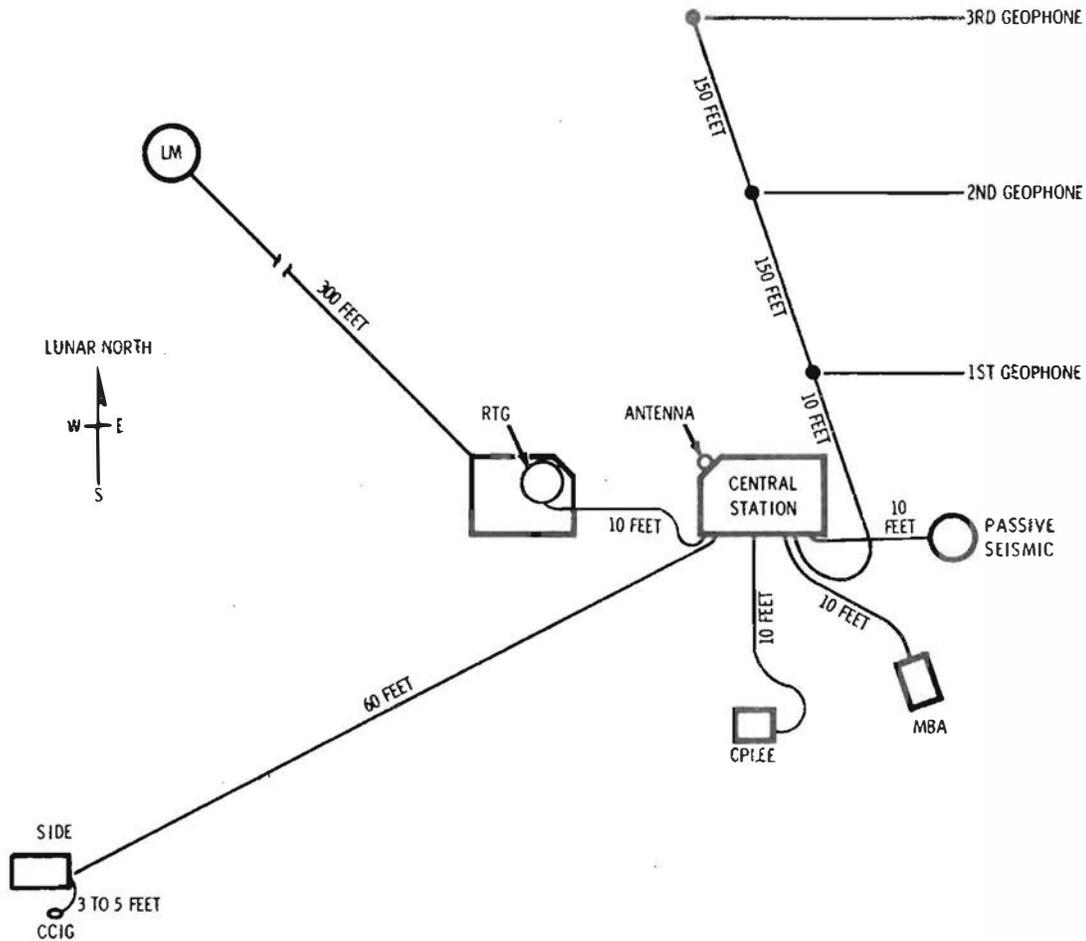
Figure 4-4. Deployment Arrangement Flight 4, Typical

Step   Event

12   Return to central station, release SIDE connector, release and deploy
            RF cable, release antenna tie-downs, release and raise sunshield, re-
            move antenna mast and antenna aiming mechanism housing from sub-
            pallet, assemble to central station, retrieve antenna and install on aim-
            ing mechanism. (See Figure 4-6.)

13   Align central station antenna by: entering azimuth and elevation offsets,
            leveling and aligning the antenna subsystem. (See Figure 4-7.)

14   Walk to ME, grasp carry handle, carry ME in predetermined direction
            50 feet, deploy legs, align ME and place on lunar surface, extend sen-
            sors, deploy parabolic reflector assemblies, level and align ME. (See
            Figure 4-8.)

Figure 4-5. PSE Shroud Deployment and Experiment Leveling
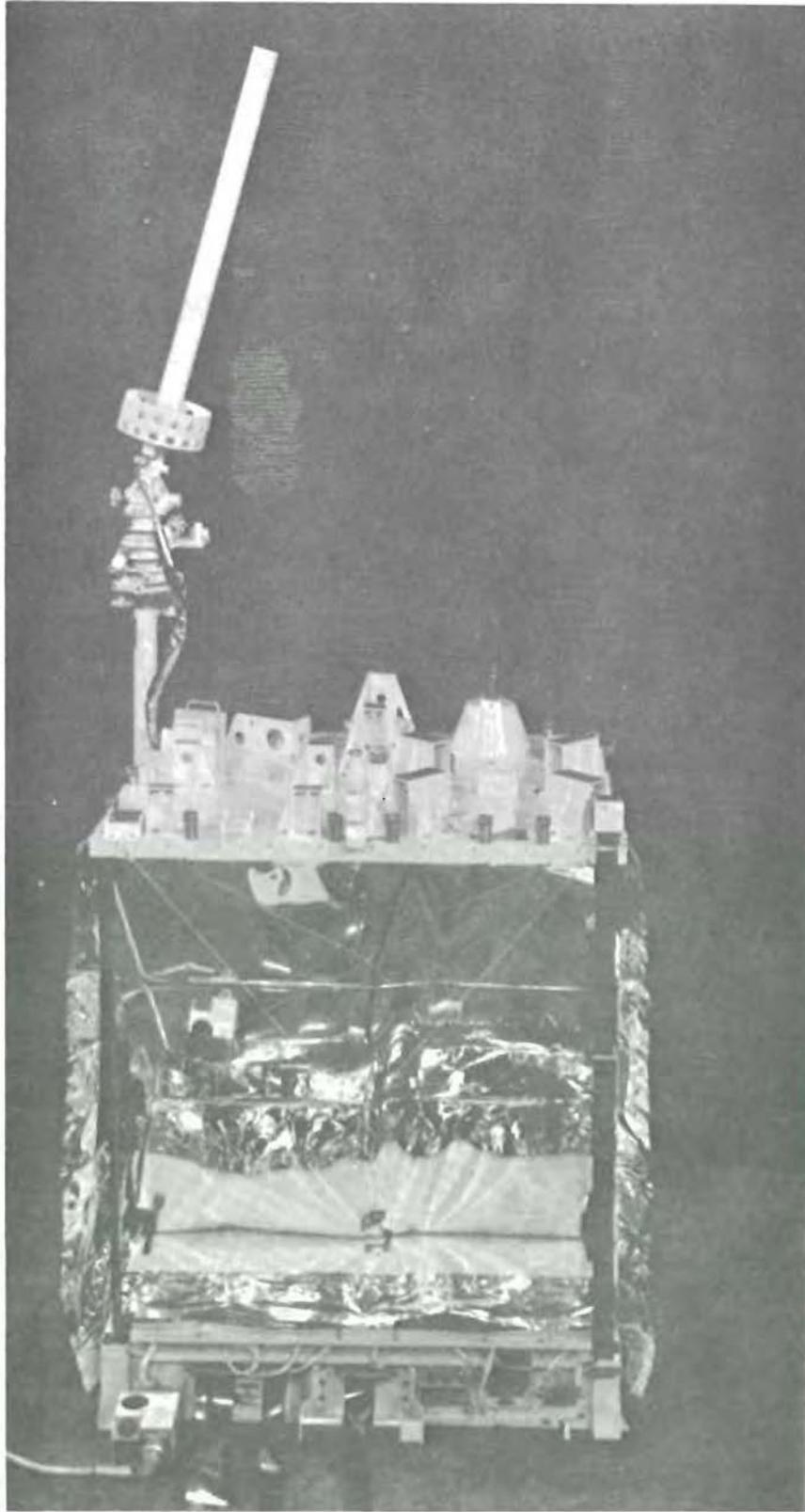
Figure 4-6. Central Station Erected

Figure 4-7. Antenna Aiming Mechanism Alignment

Figure 4-8.   ME Deployment

Step	Event

15   Walk to SIDE, insert UHT, carry SIDE 55 ± 5 feet in predetermined direction deploying cable, emplace SIDE on lunar surface, deploy ground screen on level surface, lift SIDE, remove CCIG and hold, emplace SIDE on ground screen, emplace CCIG maximum distance from SIDE with seal side of CCIG away from SIDE, central station, and LM, and level and align SIDE.

16   Return to central station, turn on Astronaut switch No. 1 using UHT, request transmitter turn-on, check antenna orientation, receive confirmation of receipt of RF signal and useful data.

4-23. Deployment (Flights 3 and 4). Flights three and four will carry different combinations of experiments which also differ from the combination of experiments carried on Flights one and two. Deployment of those experiments not carried on Flights one and two are discussed in the following paragraphs.

4-24. Flight Three - Flight three will carry the heat flow experiment (HFE), the passive seismic experiment (PSE), the charged particle lunar environment experiment (CPLEE), and the cold cathode gauge experiment (CCGE). Deployment of the PSE has been discussed in paragraph 4-22, and therefore, the following steps cover deployment of the CPLEE, CCGE, and HFE only, (Figure 4-3).

Step	Event

1   Remove CCGE from subpackage No. 1 and place CCGE on lunar surface approximately 5 feet South of subpackage No. 1.

2   Remove HFE electronic package, with probe box attached, from subpackage No. 1 and place on lunar surface approximately 5 feet South of subpackage No. 1.

3   Remove and carry the CPLEE, deploying the cable, to approximately 10 feet South of the central station.

4   Emplace the CPLEE parallel to the central station. Level and align the CPLEE and return to the central station.

5   Insert UHT and carry CCGE 55 ±5 feet in predetermined direction, deploying cable. Emplace CCGE on lunar surface, level and align. Return to central station.

6   Insert UHT and carry HFE assembly 30 feet South, deposit package, and return to package No. 2 for ALHT and ALSD. After retrieving ALHT and ALSD and returning to HFE assembly, walk an additional 16 feet to site for probe No. 1 emplacement.

7   Drill probe hold (Figure 4-9) and insert sheathing.

8   Return to electronics package, detach probe box and separate two halves of probe box; carry half probe box with attached emplacement tool to probe emplacement site deploying cable enroute. Insert HFE probe (Figure 4-10) and proceed to second emplacement area with ALHT, ALSD, and emplacement tool.

9   Return to electronics package, pick up remaining half of probe box, return to second probe emplacement site and emplace probe as in steps 7 and 8. Return to and align the HFE electronics package.

Figure 4-9.   ALSD Use in HFE

Figure 4-10. HFE Probe Emplacement

4-25. Flight Four - Flight four will carry the suprathermal ion detector experiment (SIDE), the PSE, the CPLEE, and the active seismic experiment (ASE). All but the ASE deployment have been discussed in previous paragraphs; therefore the following steps cover deployment of the ASE only. (Figure 4-4).

Step   Event

1   Remove thumper-geophone assembly and mortar package from experiment package, assemble thumper, and partially deploy mortar package.
2   Using UHT turn central station ASE safe/enable switch to enable.
3   Emplace goephones at 10, 160, and 310 foot points along a Northwest line, deploying geophone and thumper cables enroute.
4   Return along the geophone cables activating the thumper at the marked intervals; approximately every 15 feet. Return to central station after final thumper activation.
5   Using UHT turn central station ASE safe/enable switch to safe.
6   Remove safety rods from mortar package, turn on mortar package safe/ arm switches, return to the central station and enable the ASE.

The mortar package and grenades will be activated by commands from MSFN on Earth some time (approximately one year) after the astronauts and LM have left the Moon.

4-26. Antenna Aiming - The final step in all deployment sequences before returning to the LM 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 4-11 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 ± 90 degrees
c. Elevation angle ± 50 degrees
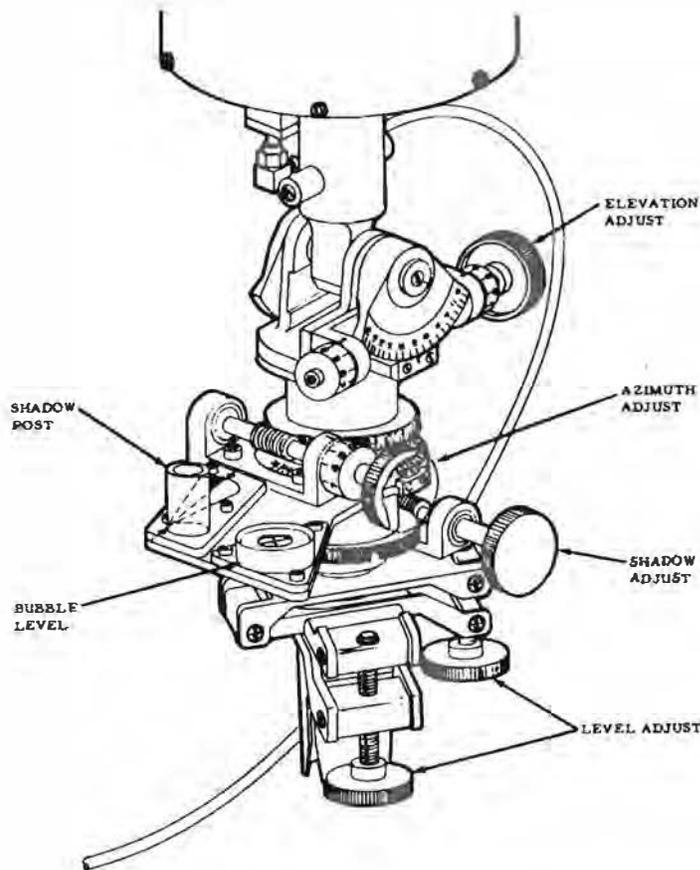
Figure 4-11. Antenna Aiming Mechanism

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 4-12) 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.

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.

4-27. POST-DEPLOYMENT OPERATIONS

Communication between MCC and ALSEP is established with the activation of 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 establish remote sites around the Earth. Remote sites for ALSEP will include the following:

   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 end of one year when the grenades are launched (this is in addition to intermittent monitoring periods).

Longitude 22° 12'

Latitude	Upper Gimbal +East	-West	N.E. Quad	Sun Compass S.E. Quad	S.W. Quad	N.W. Quad
0°0'	22.0	0.0	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 4-12. Antenna Aiming Table (Sample)

There may be three separate ALSEP systems operating simultaneously on the Moon. Communication with the three systems would be provided by MSFN through integrated time frames. For instance, the 45-day monitoring and command period for ALSEP No. 1 would be complete by the time ALSEP No. 2 is emplaced. Within this time frame continuous monitoring of two ALSEP systems would not be required. The present MSFN capabilities permit continuous monitoring of one ALSEP and at the same time monitoring the other two on a time sharing basis.

An MSFN station tapes each ALSEP telemetry (downlink) continuously. A maximum of two ALSEP's are monitored at MCC, and controlled from MCC. Thus, operation of three ALSEP's simultaneously will require time-sharing of MCC monitoring and control (but all three will be taped continuously). When ALSEP is in the active seismic mode, the transmission of its high data rate to MCC precludes monitoring a second ALSEP during that interval.

4-28. 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.

4-29. <u>Downlink Transmission.</u> Figure 4-13 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 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.
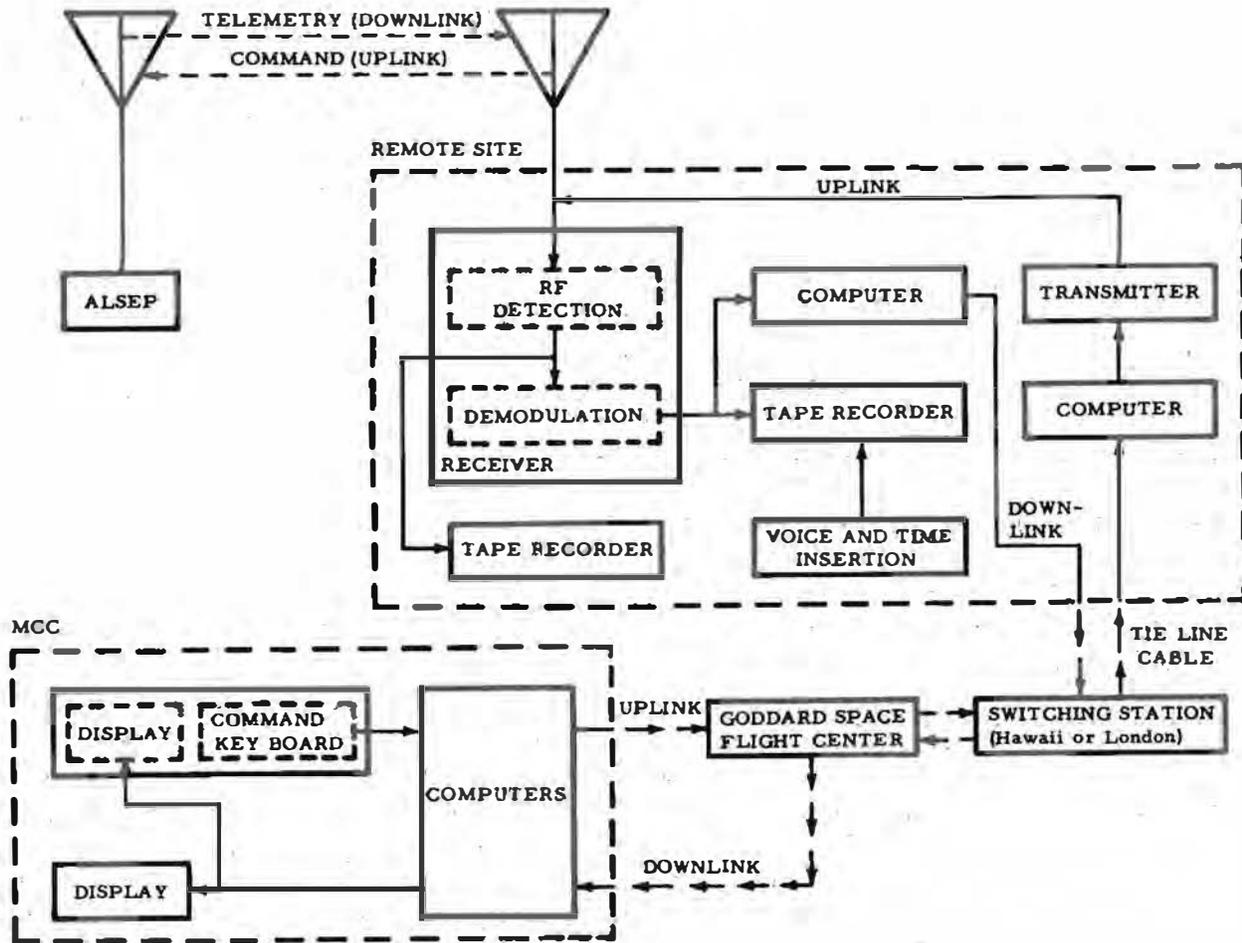
Figure 4-13. MSFN Functional Block Diagram

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 telemetry data are routed to MCC. At MCC the telemetry data are decoded and processed by computer for display.

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.

4-30. 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 to modulate the remote site transmitter and the command is transmitted to ALSEP.

4-31. <u>MCC Operation.</u> 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
ALHT	Apollo Lunar Hand Tools
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
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)

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
LSRL	Lunar Sample Receiving Laboratory
LTA	Launch Tube Assembly
MCC-H	Mission Control Center -Houston
ME	Magnetometer Experiment
MSC	Manned Spacecraft Center
MSFN	Manned Space Flight Network
MSOB	Manned Spacecraft Operation Building
NASA	National Aeronautics and Space Administration
NRZ	Non Return to Zero
PAM	Pulse Amplitude Modulation
PCM	Pulse Coded Modulation
PCU	Power Conditioning Unit
PDU	Power Distribution Unit
PI	Principal Investigator
PSE	Passive Seismic Experiment
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)

SM	Service Module
SP	Short Period
SWE	Solar Wind 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 four ALSEP flight systems.
Table 1 lists the commands by symbol, flight, nomenclature, number, and
termination point. Table 2 provides a summary of command allocation.
Table 3 cross-references command numbers and command functions.

TABLE 1

Symbol	Flight Systems	Command Nomenclature	Octal Command	Decimal Command	Termination Point		
CD-31	4	ASE High Bit Rate ON[3]	003	3	Data Processor		
CD-32	4	ASE High Bit Rate OFF[1]	005	5	"	"	
CD-33	All	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	021	17	"	"	"
CD-7	"	PDR #2 ON	022	18	"	"	"
CD-8	"	PDR #2 OFF	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	036	30	"	"	"
CD-14	"	Experiment 1 Standby Power[2]	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, 5]	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 executed.

[4] Changes bit rate upon command execution.

[5] For Flight systems 1 and 2, Experiment 2 is effectively OFF in this mode.

TABLE 1 (CONT.)

Symbol	Flight Systems	Command Nomenclature	Octal Command	Decimal Command	Termination Point
CD-18	All	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]	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.

TABLE A-1 (CONT.)

Symbol	Flight System	Command Nomenclature		Octal Command	Decimal Command	Termination Point		
CL-5	All	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	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[4]	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	"	"	"
CT-1	1, 2, 4	SIDE Load Cmd #1	Command	104	68	Suprathermal Ion Det.		
CT-2	"	SIDE Load Cmd #2	Functions	105	69	"	"	"
CT-3	"	SIDE Load Cmd #3	As shown	106	70	"	"	"
CT-4	"	SIDE Load Cmd #4	in Note 1	107	71	"	"	"
CT-5	"	SIDE Execute Command	on Page 15	110	72	"	"	"
CC-1	3, 4	CPLEE Operational Heater	ON[5]	111	73	Charged Particle Exp.		
CC-2	"	CPLEE Operational Heater	OFF	112	74	"	"	"
CC-3	"	CPLEE Dust Cover Removal		113	75	"	"	"
CC-4	"	CPLEE Automatic Voltage Sequence - ON[1]		114	76	"	"	"
CC-5	"	CPLEE Step Voltage Level[3] (Steps voltage through following steps one step per command)		115	77	"	"	"

    3500
    350
    35
    0
    -35
    -350
    -3500
    0 and repeat

[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] Command sequence is to send CC-6 and then send CC-5 to step voltage levels. CPLEE stops at level it is on at time of command execution.

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

[5] There are three CPLEE heater modes. On initial turn on the CPLEE thermostat controls the heaters. CC-1 over rides thermostat and turns heaters on, CC-2 turns heaters off. CPLEE is placed back on thermostat by experiment power turn off and back on.

TABLE 1 (CONT.)

Symbol	Flight System	Command Nomenclature	Octal Command	Decimal Command	Termination Point
CC-6	1,4	CPLEE Automatic Voltage Sequence - OFF[1]	117	79	Charged Particle Exp.
CC-7	"	CPLEE Channeltron Voltage Increase - ON (One step increase in voltage)	120	80	" " "
CC-8	"	CPLEE Channeltron Voltage Increase - OFF[2]	121	81	" " "
CW-1	1,2	SWS Dust Cover Removal[5,7]	122	82	Solar Wind Experiment
CM-1	"	LSM Range Select (Steps through three ranges, one step per command) 400 gammas full scale[2] 100 " " " 200 " " " repeat	123	83	LSM Experiment
CM-2	"	Steady Field Offset[3] (Step through seven values, one step per command) 0 percent of full scale[2] +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 0 percent of full scale and repeat } 6	124	84	" "
CM-3	"	Steady Field Address (Steps through following step X axis to Y axis to Z axis to neutral[2])	125	85	" "
CM-4	"	Flip/Cal Inhibit In[2]/Out	127	87	" "
CM-5	"	Flip/Cal[4] Initiate (Returns to Science mode after Flip/Cal sequence)	131	89	" "

[1]CPLEE remains in voltage level activated at time of CC-6 command execution and then can be stepped to the next step in sequence by CC-5 or returned to automatic mode by CC-4.

[2]Preset turn-on operating mode.

[3]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.

[4]Also activated every 12 hours after hour 108 by delayed command sequencer.

[5]Also executed at hour 96 by delayed command sequencer.

[6]For 0o flip position; reverse for 180o flip position.

[7]Repetition of CW-1 three times within ten seconds results in High Voltage Gain Change.

TABLE 1 (CONT.)

Symbol	Flight System	Command Nomenclature	Octal	Decimal	Termination Point
CM-6	1, 2	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	3	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	144	100	" " "
CH-8	"	HF Subsequence #2 } as shown In Note 2	145	101	" " "
CH-9	"	HF Subsequence #3 } on page 16	166	102	" " "
CH-10	"	HF Heater Advance (Steps through following 16 step-sequence one step per command)	152	106	" " "

CH-10 (continued):
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.

TABLE 1 (CONT.)

Symbol	Flight System	Command Nomenclature	Octal Command	Decimal Command	Termination Point
CS-1	4	Geophone Calibrate	156	110	Active Seismic Expt.
CS-3	4	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	4	ASE Grenade #1 Fire	163	115	" " "
CS-5	4	ASE Grenade #2 Fire	164	116	" " "
CS-6	4	ASE Grenade #3 Fire	165	117	" " "
CS-7	4	ASE Grenade #4 Fire	166	118	" " "
CS-8	4	Arm Grenades	170	120	" " "
CX-1	All	Dust Detector - ON [4]	027	023	Power Dist. Unit
CX-2	All	Dust Detector - OFF	031	025	" " "
CG-1	3	Cal Mode Set	104	068	Cold Cathode Gauge Expt.
CG-2	3	Uprange [1]	105	069	" " " "
CG-3	3	Manual Ranging Mode (Steps through seven ranges)	106	070	" " " "
CG-4	3	Downrange [1,2]	107	071	" " " "
CG-5	3	Automatic Ranging Mode [3]	110	072	" " " "

[1] Command sequence for manually changing range is CG-3 after either CG-2 or CG-4 to set up or downrange respectively.

[2] Command CG-4 breaks CCGE seal on first execution, may require prior execution of CG-2 to set.

[3] Preset turn-on operating mode.

[4] Lunar surface initial conditions programmed in during final system checkout.

TABLE 2

COMMAND SUMMARY

Termination Point	Number of Commands		
	Flight Systems # 1 & 2	Flight System #3	Flight System #4
Data Processor	3	3	5
Power Distribution Unit (Power Switching)	29	29	29
Power Conditioning Unit	2	2	2
Command Decoder	2	2	2
Passive Seismic	15	15	15
Suprathermal Ion Detector/CCGE	5	-	5
Charged Particle	-	8	8
Solar Wind	1	-	-
Magnetometer	8	-	-
Heat Flow	-	10	-
Active Seismic	-	-	7
CCGE (MSC)	-	5	-
Total	65	74	73

Special Commands - Not Assignable

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

Commands Assigned	93
Commands Not Assignable	28
Commands Not Presently Assigned (150, 153, 154, 155, 160, 171, 172, 174)	8
Total Commands	129

*Addresses for Flight System #4 are 25, 65.

**Address complements for Flight System #4 are 152, 112
    (See ATM-696 for details.)

TABLE 3

CROSS REFERENCE OF COMMAND NUMBER TO COMMAND FUNCTION

| Decimal Command | Octal Command | Command Symbol | Usage | | | Test Cmds. | Address | Address Complement | No Command | Not Presently Assigned |
			Flt. Sys. 1 & 2	Flt. Sys. 3	Flt. Sys. 4					
1	1					X				
2	2					X				
3	3	CD-31			X					
4	4					X				
5	5	CD-32			X					
6	6	CD-33	X	X	X					
7	7	CD-34	X	X	X					
8	10					X				
9	11	CD-35	X	X	X					
10	12	CD-1	X	X	X					
11	13	CD-2	X	X	X					
12	14	CD-3	X	X	X					
13	15	CD-4	X	X	X					
14	16						X			
15	17	CD-5	X	X	X					
16	20						X			
17	21	CD-6	X	X	X					
18	22	CD-7	X	X	X					
19	23	CD-8	X	X	X					
20	24	CD-9	X	X	X					
21	25	CD-10	X	X	X (X)		(X)			
22	26								X	

TABLE 3 (CONT.)

Decimal Command	Octal Command	Command Symbol	Usage			Test Cmds.	Address	Address Complement	No Command	Not Presently Assigned
			Flt. Sys. 1 & 2	Flt. Sys. 3	Flt. Sys. 4					
23	27	CX-1	X	X	X					
24	30						X			
25	31	CX-2	X	X	X					
26	32	CD-36	X	X	X					
27	33	CD-37	X	X	X					
28	34	CD-11	X	X	X					
29	35	CD-12	X	X	X					
30	36	CD-13	X	X	X					
31	37	CD-14	X	X	X					
32	40					X				
33	41	CD-15	X	X	X					
34	42	CD-16	X	X	X					
35	43	CD-17	X	X	X					
36	44	CD-18	X	X	X					
37	45	CD-19	X	X	X					
38	46	CD-20	X	X	X					
39	47							X		
40	50	CD-21	X	X	X					
41	51						X			
42	52	CD-22	X	X	X					
43	53	CD-23	X	X	X					
44	54	CD-24	X	X	X					
45	55	CD-25	X	X	X					
46	56	CD-26	X	X	X					

TABLE 3 (CONT.)

Decimal Command	Octal Command	Command Symbol	Usage Flt. Sys. 1 & 2	Flt. Sys. 3	Flt. Sys. 4	Test Cmds.	Address	Address Complement	No Command	Not Presently Assigned
47	57	CD-27	X	X	X					
48	60	CU-1	X	X	X					
49	61							X		
50	62	CU-2	X	X	X					
51	63	CL-1	X	X	X					
52	64	CL-2	X	X	X					
53	65	CL-3	X	X	X (X)		(X)			
54	66	CL-4	X	X	X					
55	67	CL-5	X	X	X					
56	70	CL-6	X	X	X					
57	71	CL-7	X	X	X					
58	72	CL-8	X	X	X					
59	73	CL-9	X	X	X					
60	74	CL-10	X	X	X					
61	75	CL-11	X	X	X					
62	76	CL-12	X	X	X					
63	77					X				
64	100					X				
65	101	CL-13	X	X	X					
66	102	CL-14	X	X	X					
67	103	CL-15	X	X	X					
68	104	CT-1	X	CG-1 X	X					

TABLE 3 (CONT.)

Decimal Command	Octal Command	Command Symbol	Usage			Test Cmds.	Address	Address Complement	No Command	Not Presently Assigned
			Flt. Sys. 1 & 2	Flt. Sys. 3	Flt. Sys. 4					
69	105	CT-2	X	CG-2 X	X					
70	106	CT-3	X	CG-3 X	X					
71	107	CT-4	X	CG-4 X	X					
72	110	CT-5	X	CG-5 X	X					
73	111	CC-1		X	X					
74	112	CC-2		X	X (X)			(X)		
75	113	CC-3		X	X					
76	114	CC-4		X	X					
77	115	CC-5		X	X					
78	116						X			
79	117	CC-6		X	X					
80	120	CC-7		X	X					
81	121	CC-8		X	X					
82	122	CW-1	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 (CONT.)

Decimal Command	Octal Command	Command Symbol	Usage			Test Cmds.	Address	Address Complement	No Command	Not Presently Assigned
			Flt. Sys. 1 & 2	Flt. Sys. 3	Flt. Sys. 4					
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						
101	145	CH-8		X						
102	146	CH-9		X						
103	147							X		
104	150									X
105	151						X			
106	152	CH-10		X	(X)			(X)		
107	153									X
108	154									X
109	155									X
110	156	CS-1			X					
111.	157					X				
112	160									X

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TABLE 3 (CONT.)

Decimal Command	Octal Command	Command Symbol	Usage			Test Cmds.	Address	Address Complement	No Command	Not Presently Assigned
			Flt. Sys. 1 & 2	Flt. Sys. 3	Flt. Sys. 4					
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	65	74	73	14	6	6	2	8

Note 1

Suprathermal Ion Detector Command Structure

All commands are pulses. The SIDE uses these pulsed commands by encoding. Two encoded commands are used for one time only operations as well as routine operation. Four of the five incoming command lines are encoded in a four bit command buffer which is then strobed into a second (mode) buffer where it is held for decoding and execution. This latter buffer might be thought of as an execute buffer. The commands are as follows:

SYMBOL	FUNCTION	OCTAL COMMAND SEQUENCE				
		104	105	106	107	110
CI-1	Break CCIG Seal[2]		X			X
CI-2	Blow Dust Cover[2]				X	X
CI-5	Not Used					X
CI-6	Ground Plane Step Programmer ON[1]/OFF	X				X
CI-7	Reset SIDE Frame Counter at 10		X			X
CI-8	Reset SIDE Frame Counter at 39	X	X			X
CI-9	Reset Velocity Filter at 9			X		X
CI-10	Reset SIDE Frame Counter at 79	X		X		X
CI-11	Reset SIDE Frame Counter at 79 and Velocity Filter Counter at 9		X	X		X
CI-12	X 10 accumulation interval ON/OFF[1]	X	X	X		X
CI-13	Master Reset				X	X
CI-14	Velocity Filter Voltage ON[1]/OFF	X			X	X
CI-15	Low Energy CPA high voltage ON[1]/OFF		X		X	X
CI-16	High Energy CPA high voltage ON[1]/OFF	X	X		X	X
CI-17	Force Continuous Calibration (Reset to 120)			X	X	X
CI-18	Cold Cathode Ion Gauge HiV ON[1]/OFF	X		X	X	X
CI-19	Channeltron high voltage ON[1]/OFF		X	X	X	X
CI-20	Reset Command Register	X	X	X	X	X

One Time Commands (CI-1, CI-2, CI-5)

Operational Commands (CI-6 through CI-20)

Commands CI-1 and CI-2 have been incorporated into the design of the SIDE as one time CCIG Seal Break and one time Dust Cover Blow. These are identical to CI-7 and CI-13 respectively, thus the first time CI-7 is executed, so is CI-1 but not thereafter. A similar statement holds for CI-13 and CI-2.

[1]Preset turn-on operating mode.

[2]Also activated at hour 96 by delayed command sequences.

Note 2

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.

Note 3

Experiment Designations by Flight System

Experiment No.	Flights 1 & 2	Flight 3	Flight 4
1	PSE	HFE	PSE
2	ME	PSE	ASE
3	SWE	CPLEE	SIDE/CCGE
4	SIDE/CCGE	CCGE	CPLEE

APPENDIX B

MEASUREMENT REQUIREMENTS DOCUMENT

INTRODUCTION

This document tabulates the measurements to be telemetered from the 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 is capable of encoding analog housekeeping and science signals to 8-bit accuracy. The encoded word occupies 10 bit positions to fill word 33 in the 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 has an output consistent with the frame format section of the ALSEP Data Subsystem. The high data rate required by the Active Seismic Experiment (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 (a)   – Channel Assignments for the Analog Multiplexer (ALSEP Word 33)

Table 1 (b)   – Analog Housekeeping Channel Usage

Table 1 (c)   – Summary of Analog Channel Usage, Flights 1 to 4

Table 2   – Passive Seismic Experiment

Tables 3, 4, 5   – Magnetometer Experiment

Table 6   – Suprathermal Ion Detector and Cold Cathode Gauge Experiment

Flight Systems 1 & 2

1 x	2 x	3 x	4 X	5 O	6 X	7 S	8 X
9 -	10 X	11 -	12 X	13 -	14 X	15 I	16 X
17 O	18 X	19 O	20 X	21 O	22 X	23 S	24 X
25 -	26 X	27 -	28 X	29 -	30 X	31 I	32 X
33 H	34 X	35 ●	36 X	37 ●	38 X	39 S	40 X
41 -	42 X	43 -	44 X	45 -	46 CV	47 I	48 X
49 O	50 X	51 O	52 X	53 O	54 X	55 S	56 I
57 -	58 X	59 -	60 X	61 -	62 X	63 I	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
S	-	Solar Wind	4
I	-	Suprathermal Ion Detector	5
CV	-	Command Verification (upon command, otherwise all zeros)	1
H	-	Housekeeping	1

TOTAL 64

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

Figure 1. ALSEP Channel Assignment for Flight Systems 1 and 2

Flight System 3

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

Legend

			Number of Words Per Frame	
x	-	Control	3	
X	-	Passive Seismic - Short Period	30	
-	-	Passive Seismic - Long Period Seismic	12	44
●	-	Passive Seismic - Long Period Tidal and One Temperature	2	
HF	-	Heat Flow	1	
CP	-	Charged Particle	6	
CV	-	Command Verification (upon command, otherwise all zeros)	1	
H	-	Housekeeping	1	
NA	-	Not Assigned (all zeros shall be transmitted)	3	
CG	-	Cold Cathode Gauge Experiment (MSC)	5	
		TOTAL	64	

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

Figure 2 ALSEP Channel Assignment for Flight System 3

Flight System 4

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

Legend

			Number of Words Per Frame	
x	-	Control	3	
X	-	Passive Seismic - Short Period	30	
-	-	Passive Seismic - Long Period Seismic	12	44
●	-	Passive Seismic - Long Period Tidal and One Temperature	2	
I	-	Suprathermal Ion Detector/CCGE	5	
CP	-	Charged Particle	6	
CV	-	Command Verification (upon command, otherwise all zeros)	1	
H	-	Housekeeping	1	
NA	-	Not Assigned (all zeros shall be transmitted)	4	
		TOTAL	64	

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

Figure 3. ALSEP Channel Assignment for Flight System 4

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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 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 (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	0-89	7	1.67
DA-3	Bit Rate ID	Bit 10 of word 3		1	1/54

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

Symbol	Name	ALSEP Words		Bits/ Sample	Samples/Second
DA-4	ALSEP ID	Bit 10 of word 3		3	1/54

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

Figure 4. Control Word Format

TABLE 1 (a)

CHANNEL ASSIGNMENTS FOR ANALOG MULTIPLEXER
(ALSEP WORD 33)

FLIGHT SYSTEMS 1, 2, 3 and 4

Channel Number	Flight Systems 1 and 2	Flight System 3	Flight System 4
1.	AE-3		
2.	AE-1		
3.	AE-2		
4.	AT-3		
5.	AE-4	Same on all Flight Systems	
6.	AR-1		
7.	AR-4		
8.	AE-5		
9.	AB-1		
10.	BLANK	AC-4	AC-4
11.	BLANK	AC-5	AC-5
12.	AB-4		
13.	AE-6		
14.	AB-5		
15.	AT-10		
16.	AT-21		
17.	AT-22	Same on all Flight Systems	
18.	AT-23		
19.	AT-24		
20.	AE-7		
21.	AE-13		
22.	AE-18		
23.	AL-1		
24.	AL-5		
25.	BLANK	AC-1	AC-1
26.	AX-5		
27.	AT-1	Same on all Flight Systems	
28.	AT-4		
29.	BLANK	AH-1	AS-1
30.	AX-2		
31.	AT-25		
32.	AT-26		
33.	AT-27		
34.	AT-28		
35.	AE-8	Same on all Flight Systems	
36.	AE-14		
37.	BLANK	AR-2	AR-2
38.	AL-2	Same on all Flight Systems	
39.	AL-6		
40.	BLANK	AC-3	AC-3
41.	AX-6		
42.	AT-2	Same on all Flight Systems	
43.	AT-5		

NOTE: Channels 1-15 are "High Reliability" channels.

TABLE 1 (a) (CONT.)
CHANNEL ASSIGNMENTS FOR ANALOG MULTIPLEXER
(ALSEP WORD 33)

Channel Number	Flight Systems 1 and 2	Flight System 3	Flight System 4
44.	BLANK	BLANK	AS-2
45.	BLANK	AH-2	BLANK
46.	AT-29		
47.	AT-30		
48.	AT-31		
49.	AT-32	Same on all Flight Systems	
50.	AE-9		
51.	AE-15		
52.	AR-3		
53.	AL-3		
54.	AL-7		
55.	BLANK	AH-3	AS-3
56.	AX-3	AX-3	AX-3
57.	BLANK	AH-6	BLANK
58.	AT-6		
59.	AT-8		
60.	AT-12		
61.	AT-33		
62.	AT-34		
63.	AT-35	Same on all Flight Systems	
64.	AT-36		
65.	AE-10		
66.	AE-16		
67.	AR-5		
68.	AL-4		
69.	AL-8		
70.	AI-1	AG-1	AI-1
71.	AT-7	Same on all Flight Systems	
72.	AT-13	Same on all Flight Systems	
73.	BLANK	BLANK	AS-4
74.	BLANK	AH-4	BLANK
75.	BLANK	AH-7	BLANK
76.	AT-37		
77.	AT-38		
78.	AT-39		
79.	AE-11		
80.	AE-12	Same on all Flight Systems	
81.	AF-17		
82.	AR-6		
83.	AX-1		
84.	AX-4		
85.	AI-2	AG-2	AI-2
86.	BLANK	Same on all Flight Systems	
87.	AT-9	Same on all Flight Systems	
88.	AT-11	Same on all Flight Systems	
89.	BLANK	AC-2	AC-2
90.	BLANK	AC-6	AC-6

TABLE 1 (b)

ANALOG HOUSEKEEPING CHANNEL USAGE

Symbol	Location/Name	Flight	Channel	Range	Sensor Accuracy	Bits/ Sample	Sample/ Sec.
	Structural/Thermal Temperatures						
AT-1	Sunshield #1	All	27	-300°F to +300°F	±15°F	8	.0185
AT-2	" #2	"	42	" "	"	"	"
AT-3	Thermal Plate #1	"	4	-50°F to +200°F	±10°F	"	"
AT-4	" " #2	"	28	" "	"	"	"
AT-5	" " #3	"	43	" "	"	"	"
AT-6	" " #4	"	58	" "	"	"	"
AT-7	" " #5	"	71	" "	"	"	"
AT-8	Left Side Structure #1	"	59	-300°F to +300°F	±15°F	8	.0185
AT-9	Right Side Structure #2	"	87	" "	"	"	"
AT-10	Bottom Structure #3	"	15	" "	"	"	"
AT-11	Back Structure #4	"	88	" "	"	"	"
AT-12	Inner Multilayer Insulation	"	60	-50°F to +200°F	±10°F	"	"
AT-13	Outer Multilayer Insulation	"	72	-300°F to +300°F	±15°F	"	"
	Electronic Temperatures						
AT-21	Local OSC. Crystal A	"	16	-50°F to +200°F	±10°F	8	.0185
AT-22	Local OSC. Crystal B	"	17	" "	"	"	"
AT-23	Transmitter A Crystal	"	18	" "	"	"	"
AT-24	Transmitter A Heat Sink	"	19	" "	"	"	"
AT-25	Transmitter B Crystal	"	31	" "	"	"	"
AT-26	Transmitter B Heat Sink	"	32	" "	"	"	"
AT-27	Analog Data Processor, Base	"	33	" "	"	"	"
AT-28	Analog Data Processor, Internal	"	34	" "	"	"	"
AT-29	Digital Data Processor, Base	"	46	" "	"	"	"
AT-30	Digital Data Processor, Internal	"	47	" "	"	"	"
AT-31	Command Decoder, Base	"	48	" "	"	"	"
AT-32	Command Decoder, Internal	"	49	" "	"	"	"
AT-33	Command Demodulator VCO	"	61	" "	"	"	"
AT-34	PDU, Base	"	62	" "	"	"	"
AT-35	PDU, Internal	"	63	" "	"	"	"
AT-36	PCU, Power OSC #1	"	64	" "	"	"	"
AT-37	PCU, Power OSC #2	"	76	" "	"	"	"
AT-38	PCU, Regulator #1	"	77	" +210°F	"	"	"
AT-39	PCU, Regulator #2	"	78	" "	"	"	"

Total of 32 Central Station Temperatures

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

Symbol	Location/Name	Flight	Channel	Range			Sensor Accuracy	Bits/ Sample	Sample/ Sec.
	Central Station Electrical								
AE-1	ADC Calibration 0.25V	All	2	Octal Count 015 ± 1			0.5%	8	.0185
AE-2	ADC Calibration 4.75 V	"	3	Octal Count 361 ±1			"	"	"
AE-3	Converter Input Voltage	"	1	0 to 20 VDC			+2%	"	"
AE-4	Converter Input Current	"	5	0 to 5 ADC			"	"	"
AE-5	Shunt Reg #1 Current	"	8	0 to 1.5 ADC			"	"	"
AE-6	Shunt Reg #2 Current	"	13	0 to 3.5 ADC			"	"	"
AE-7	PCU Output Voltage #1 (29V)	"	20	0 to 35 VDC			"	"	"
AE-8	PCU Output Voltage #2 (15V)	"	35	0 to 18 VDC			"	"	"
AE-9	PCU Output Voltage #3 (12V)	"	50	0 to 15 VD			"	"	"
AE-10	PCU Output Voltage #4 (5V)	"	65	0 to 6 VDC			"	"	"
AE-11	PCU Output Voltage #5 (-12V)	"	79	0 to -15 VDC			"	"	"
AE-12	PCU Output Voltage #6 (-6V)	"	80	0 to -7.5 VDC			"	"	"
AE-13	RCVR., Pre-Limiting Level	"	21	-101 to -61 DBM			+1 DB	"	"
AE-14	RCVR., Local OSC Level	"	36	0 to 10 DBM			+0.5 DB	"	"
AE-15	Trans. A, AGC Voltage	"	51	0 to 5V			+5%	"	"
AE-16	Trans. B, AGC Voltage	"	66	0 to 5V			"	"	"
AE-17	Trans. A, DC, Power Doubler	"	81	100 to 240 ma			"	"	"
AE-18	Trans. B, DC, Power Doubler	"	22	100 to 240 ma			"	"	"
	Central Station Bistatic								
AB-1	Receiver, 1 KHz Subcarrier Present	"	9	No modulation Octal 057				8	.0185
				Modulation Octal 275					
AB-4 *	Power Distribution, Experiments #1 and #2	"	12	Exper. #1	Exper. #2	Octal Count		8	.0185
				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, 4, and DSS Heater #2	"	14	Exper. #3	Exper. #4	Heater #2 / Octal Count		8	.0185
				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 / 262-304			
				Standby on	Standby on	On / 314-340			

* Experiments numbered as shown below:

FLIGHT SYSTEMS

Exp. No.	1 & 2	3	4
1	PSE	HFE	PSE
2	ME	PSE	ASE
3	SWE	CCGE	SIDE/CCGE
4	SIDE/CCGE	CPLEE	CPLEE

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

Symbol	Location/Name	Flight	Channel	Range	Sensor Accuracy	Bits/ Sample	Samples/ Sec.
	RTG Temperatures						
AR-1	Hot Frame #1	All	6	950°F to 1150°F	+5°F	8	.0185
AR-2	Hot Frame #2	"	37	* 950°F to 1150°F	"	"	"
AR-3	Hot Frame #3	"	52	950°F to 1150°F	"	"	"
AR-4	Cold Frame #1	"	7	400°F to 600°F	"	"	"
AR-5	Cold Frame #2	"	67	400°F to 600°F	"	"	"
AR-6	Cold Frame #3	"	82	* 400°F to 600°F	"	"	"
	Dust Accretion						
AX-1	#1 Cell Temperature	"	83	+80°F to +300°F	+15°F	8	.0185
AX-2	#2 Cell Temperature	"	30	+80°F to +320°F	"	"	"
AX-3	#3 Cell Temperature	"	56	+80°F to +320°F	"	"	"
AX-4	#1 Cell Output	"	84	0-150 mV	+1%	"	"
AX-5	#2 Cell Output	"	26	0-150 mV	"	"	"
AX-6	#3 Cell Output	"	41	0-150 mV	"	"	"
	Passive Seismic						
AL-1	L.P. Ampl. Gain (X & Y)	"	23	Discrete		8	.0185
AL-2	L.P. Ampl. Gain (Z)	"	38	"		"	"
AL-3	Level Direction and Speed	"	53	"		"	"
AL-4	S.P. Ampl. Gain (Z)	"	68	"		"	"
AL-5	Leveling Mode & Coarse Sensor Mode	"	24	"	See Table 2	"	"
AL-6	Thermal Control Status	"	39	"		"	"
AL-7	Calibration Status L.P. & S.P.	"	54	"		"	"
AL-8	Uncage Status	"	69	"		"	"
	Active Seismic						
AS-1	Central Station Package Temp.	4	29	-40°C to +100°C	+3°C	8	.0185
AS-2	Mortar Box Temperature	4	44	-75°C to +100°C	"	"	"
AS-3	Grenade Launcher Assembly Temp.	4	55	-75°C to +100°C	"	"	"
AS-4	Geophone Temperature	4	73	-200°C to +130°C	"	"	"
	Heat Flow						
AH-1	Supply Voltage #1	3	29	0 to +5 volts	5% full scale	8	.0185
AH-2	Supply Voltage #2	3	45	0 to -5 volts	"	"	"
AH-3	Supply Voltage #3	3	55	0 to +15 volts	"	"	"
AH-4	Supply Voltage #4	3	74	0 to -15 volts	"	"	"
AH-5	Not Assigned						
AH-6	Supply Voltage #6	3	57	Discrete	"	"	"
AH-7	Supply Voltage #7	3	75	"	"	"	"

In Flight Models 1 and 2, these channels monitor fixed resistors, giving, typically, octal readings of 151-171 for channel 37 and 215-223 for channel 82.

TABLE 1 (b) (CONT.)

ANALOG HOUSEKEEPING CHANNEL USAGE

Symbol	Location/Name	Flight	Channel	Range	Sensor Accuracy	Bits/ Sample	Samples/ Sec.
Charged Particle							
AC-1	Switchable P. S. Voltage	3, 4	25	0-4. 5V	+5%	8	.0185
AC-2	Channeltron P. S. #1	"	89	0-4.5V	"	"	"
AC-3	Channeltron P. S. #2	"	40	0-4.5V	"	"	"
AC-4	DC-DC Converter Voltage	"	10	0-4.5V	"	"	"
AC-5	Temperature of Physical Analyzer	"	11	-30° to $+80^\circ$C	"	"	"
AC-6	Temperature of Switchable P. S.	"	90	-39° to $+80^\circ$C	"	"	"
SIDE/CCGE							
AI-1	Low Energy Detector Count Rate	1, 2, 4	70	$10-10^6$ counts/sec	+10%	8	.0185
AI-2	High Energy Detector Count Rate	1, 2, 4	85	$10-10^6$ counts/sec	"	"	"
CCGE							
AG-1	Gauge Output	3	70	0-5.0V		8	.0185
AG-2	Gauge Range	"	85	0-5.0V		"	"

TABLE 1 (c)

SUMMARY OF ANALOG CHANNEL
USAGE FLIGHTS 1 TO 4

	Flights 1 & 2	Flight 3	Flight 4
Central Station			
Data and Power Subsystems	38	38	38
Experiment On-Off Status	2	2	2
Structural/Thermal	13	13	13
RTG Temperatures	4	6	6
TOTAL	57	59	59
Experiments			
Passive Seismic	8	8	8
Solar Wind	—	—	—
Magnetometer	—	—	—
SIDE	2	—	2
Heat Flow	—	6	—
CPLEE	—	6	6
Active Seismic	—	—	4
CCGE (MSC)	—	2	—
Dust Detector	6	6	6
TOTAL	16	28	26
Not Assigned	17	3	5
TOTAL	90	90	90

TABLE 2

PASSIVE SEISMIC MEASUREMENT, FLIGHTS 1, 2, 3, AND 4

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 or 30**

Housekeeping Measurements

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

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

* The exception of three ALSEP words occurs in Flight Systems 1 & 2. In Flight Systems 3 & 4, word 46 is used for Short Period.
** 29 in Flight Systems 1 & 2, 30 in Flight Systems 3 & 4
*** +0.05°C resolution.
**** Uncage locked-out on all ground tests.

TABLE 3

MAGNETOMETER MEASUREMENTS

Scientific Measurements

Symbol	Location/Measurement	ALSEP Word	Frame	Range	Sensor Accuracy	Frequency Response	Bits/ Sample	Sample/ Sec.	Sample/ Frame
DM-25	X-Axis Field	17, 49	Every	±100, ±200, ±400 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 are in Words 17, 19, 21, 49, 51, 53 and 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 1/4, 1/2 and 3/4 of saturation level, or PCM counts of 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 Engineering	A2 Data	A3	A4	A5	A6	A7	B1	B2

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 3 (CONT.)
MAGNETOMETER MEASUREMENTS

Engineering Measurements (Cont.)

Symbol	Location/Measurement	ALSEP Word	Frame	Range	Sensor Accuracy	Bits/ Sample	Sample/ Sec	Sample/ Frame
DM-1	Temperature #1 (X Sensor)	5	1, 9,	-30°C to +65°C	+3%	7	.207	1/8
DM-2	Temperature #2 (Y Sensor)	"	2, 10,	" "	"	"	"	"
DM-3	Temperature #3 (Z Sensor)	"	3, 11,	" "	"	"	"	"
DM-4	Temperature #4 (Base)	"	4, 12,	" "	"	"	"	"
DM-5	Temperature #5 (Internal)	"	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		2 status bits	.104	1/16
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	Temperature Control Select	"	5	"		1 " "	"	"
DM-16	Measurement Range	"	7	"		2 " "	"	"
DM-17	X Offset Field	"	See Table 4	"		3 " "	"	"
DM-18	Y Offset Field	"	See Table 4	"	See Table 5	3 " "	"	"
DM-19	Z Offset Field	"	See Table 4	"		3 " "	"	"
DM-20	Mode State	"	13	"		1 " "	"	"
DM-21	Offset Address	"	14	"		2 " "	"	"
DM-22	Filter In/Out	"	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	"	6,8	"		2 " "	"	"
DM-30	LSM Frame ID	"	(Derived from F in Frame #1)					

Detail of the status-bit usage is shown in Table 4 and the status bit structure is shown in Table 5.

TABLE 4

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 Bit - 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 Address 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 5

MAGNETOMETER ENGINEERING STATUS BIT STRUCTURE

Status Flag	Commutator Point	B_1	B_2	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
Heater Power Status	6	1	1	Heater ON
	6	1	0	Heater OFF
Measurement Range	7	0	0	100γ Range
" " "	7	1	0	200 γ Range
" " "	7	1	1	400 γ Range
" " "	7	0	1	Error
Filler Bits	8	1	1	Not used
X-axis Field Offset	9	0	1	0% offset
" " "	10	1		0% offset
" " "	9	1	0	-25% offset
" " "	10	0		-25% offset
" " "	9	1	0	-50% offset
" " "	10	1		-50% offset
" " "	9	1	1	-75% offset
" " "	10	0		-75% offset
" " "	9	0	0	+75% offset
" " "	10	0		+75% offset
" " "	9	0	0	+50% offset
" " "	10	1		+50% offset
" " "	9	0	1	+25% offset
" " "	10	0		+25% offset
Y-axis Field Offset	10		0	0% offset
" " "	11	1	1	0% offset
" " "	10		1	-25% offset
" " "	11	0	0	-25% offset
" " "	10		1	-50% offset
" " "	11	0	1	-50% offset
" " "	10		1	-75% offset
" " "	11	1	0	-75% offset
" " "	10		0	+75% offset
" " "	11	0	0	+75% offset
" " "	10		0	+50% offset
" " "	11	0	1	+50% offset
" " "	10		0	+25% offset
" " "	11	1	0	+25% offset
Z-axis Field Offset	12	0	1	0% offset
" " "	13	1		0% offset
" " "	12	1	0	-25% offset
" " "	13	0		-25% offset
" " "	12	1	0	-50% offset
" " "	13	1		-50% offset
" " "	12	1	1	-75% offset
" " "	13	0		-75% offset
" " "	12	0	0	+75% offset
" " "	13	0		+75% offset
" " "	12	0	0	+50% offset
" " "	13	1		+50% offset
" " "	12	0	1	+25% offset
" " "	13	0		+25% offset
Mode State	13		0	Calibrate ON
" "	13		1	Calibrate OFF (Science)
Offset Address 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

TABLE 6
SUPRATHERMAL ION DETECTOR AND COLD CATHODE
GAUGE EXPERIMENT MEASUREMENTS

Flight Systems 1, 2, and 4   (SIDE)

Symbol	Location/Name	SIDE Frame	Range**	Accuracy	Bit/ample	Sample/Sec.
Following measurements carried in ALSEP Word 15 even, SIDE Word 1 and in indicated SIDE Frames.						
DI-1	*SIDE Frame Number	All	0 - 127	NA	7 bit 4 to 10* inclusive	
Following measurements carried in ALSEP Word 31 even, SIDE Word 2 and in indicated SIDE Frames.						
DI-2	+5 volts analog	0,32,64,96	5V +0.15V		8	
DI-3	CCGE Output	1,3,5,7,9,41,73,105,121-127			"	
DI-4	Temp. #1	2,34,66,98	100 to 400°K	+ 10°K	"	
DI-5	Temp. #2	1,36,68,100	-90 to +125°C	+5°C	"	
DI-6	Temp. #3	6,38,70,102	-90 to +125°C	+5°C	"	
DI-7	4.5 KV	8,40,72,104	3.72 to 5.45KV		"	
DI-8	CCGE Range	10,24,42,56,74,88,106,120	Range #1 6.9 to 9.0V Range #2 4.2 to 5.7V Range #3 2.2 to 3.2V		"	
DI-9	Temp. #4	11,43,75,107	-50 to +90°C		"	
DI-10	Temp. #5	12,44,76,108	-50 to +90°C		"	
DI-11	GND Plane Voltage	13,15,29,31,45,47,61,63,69 77,79,93,95,109,111			"	
DI-12	Solar Cell	14,78	15 mV to 600 mV	± 3%	"	
DI-13	+60 volts	16,48,80,112	.15 to 150V		"	
DI-14	+30 volts	17,49,81,113	.15 to 150V		"	
DI-15	+5 volts digital	18,50,82,114	15 mV to 15V		"	
DI-16	Ground	19,51,83,115	0 to 18 mV		"	
DI-17	-5 volts	20,52,84,116	-15 mV to -15V		"	
DI-18	-30 volts	21,53,85,117	-.15 to -150V		"	
DI-19	Temp. #6	22,54,86,118	-50 to +90°C		"	
DI-20	-3.5 KV	23,55,87,119	-2.9 to -4.25 KV		"	
DI-21	+1.0 volt cal.	27,59,91	153 - 157 Count		"	
DI-22	+30 mV cal.	25,57,89	20 - 34 Count		"	
DI-23	+ A/D Ref. voltage	26,58,90	15 mV to 15V		"	
DI-24	Dust Cover and Seal	67,71	Preset 3.125 to 5.5V Seal only 1.875 to 3.125V Dust cover only .625 to 1.875V Cover and seal 0 to .625V		"	
DI-25	+A/D Ref. volt	30,62,94	-15 mV to -15V		"	
DI-26	-1.0 volt cal.	37,101	153 - 157 Count		"	
DI-27	-12 volt cal.	39,103	244 - 248 Count		"	
DI-28	+12 volt cal.	28,60,92	244 - 248 Count		"	
DI-29	Pre Reg Duty Fact.	65	68% to 100%		"	
DI-30	+30 mV cal.	46,110	12 - 34 Count		"	

*See note on Page 21 for measurement content.

**Range of sensor output

TABLE 6 (CONT.)

SUPRATHERMAL ION DETECTOR AND COLD CATHODE GAUGE EXPERIMENT MEASUREMENTS

SIDE

Symbol	Location/Name	SIDE Frame	Nominal Value	Tolerance	Bit/ Sample	Sample/ Sec.
DF-29	One Time Command Register Status	33, 35, 97, 99	Preset 0 to .625V		8	
			Seal only .625 to 1.875V		"	
			Dust cover 1.875 to 3.125V		"	
			Dust cover and Seal 3.125 to 5.5V		"	

Following measurements carried in ALSEP Word 47 even, SIDE Word 3 and in indicated SIDE Frames.

Energy Filter Voltage

Symbol	Location/Name	SIDE Frame	Nominal Value	Tolerance	Bit/ Sample	Sample/ Sec.
DI-40	HECPA Stepper Voltage	1, 21, 41, 61, 81, 101	+437.5V		8	
DI-41	"	2, 22, 42, 62, 82, 102	406.25V		"	
DI-42	"	3, 23, 43, 63, 83, 103	375.0V		"	
DI-43	"	4, 24, 44, 64, 84, 104	343.75V		"	
DI-44	"	5, 25, 45, 65, 85, 105	312.5V		"	
DI-45	"	6, 26, 46, 66, 86, 106	281.25V		"	
DI-46	"	7, 27, 47, 67, 87, 107	250.0V		"	
DI-47	"	8, 28, 48, 68, 88, 108	218.75V		"	
DI-48	"	9, 29, 49, 69, 89, 109	187.5V		"	
DI-49	"	10, 30, 50, 70, 90, 110	156.25V		"	
DI-50	"	11, 31, 51, 71, 91, 111	93.75V		"	
DI-51	"	12, 32, 52, 72, 92, 112	93.75V		"	
DI-52	"	13, 33, 53, 73, 93, 113	62.5V		"	
DI-53	"	14, 34, 54, 74, 94, 114	31.25V		"	
DI-54	"	15, 35, 55, 75, 95, 115	12.5V		"	
DI-55	"	16, 36, 56, 76, 96, 116	8.75V		"	
DI-56	"	17, 37, 57, 77, 97, 117	6.25V		"	
DI-57	"	18, 38, 58, 78, 98, 118	3.75V		"	
DI-58	"	19, 39, 59, 79, 99, 119	2.5V		"	
DI-59	"	20, 40, 60, 80, 100, 120	1.25V		"	
DI-60	"	0, 121, 122, 123, 124, 125 126, 127	0V		"	

Following measurements carried in ALSEP Word 56 even, SIDE Word 4 and in indicated SIDE Frames.

Symbol	Location/Name	SIDE Frame	Nominal Value	Tolerance	Bit/ Sample	Sample/ Sec.
DI-61***	HE Data - MSD*	All	0 to 999 decimal		10	

Following measurements carried in ALSEP Word 63 even, SIDE Word 5 and in indicated SIDE Frames.

Symbol	Location/Name	SIDE Frame	Nominal Value	Tolerance	Bit/ Sample	Sample/ Sec.
DI-62***	HE Data - LSD**	All	0 to 999 decimal		10	

*MSD - Most significant data

**LSD - Least significant data

*** For Calibration values, see end of table.

SIDE

Symbol	Location/Name	SIDE Frame	Range	Accuracy	Bits/ Sample	Sample/ Sec.
(follow\n nHH urllmt'Hts Citrn't:d in ALSEP Word 15 udd SIDE Word b,and in ihdicated SJDE Frames, bits 4 to 10 inclusive. *						
DI-63	Ground Plane Sttp un,btr	0,2,4,6,8,10,12,14,16, 18,20,22,24,26,28,30, 32,34,36,38,40,42,44,46,48 50,52,54,56,58,60,62,64, 66,68,70,72,74,76,78,80, 82,84,86,88,90,92,94,96, 98,100,102,104,10b,108,110, 112,114,116,118	24 step 0-11, 16-27	NA	7	
DI-64	Command Register	1,5,13,17,21,29,33,37,45,49, 53,61,65,69,77,81,85,93,97, 101,109,113,117,125	0 to 15	NA	7	
DI-65	Mode Register	3,11,15,19,23,27,31,35,43,47, 51,55,59,63,67,75,79,83,87, 91,95,99,107,111,115,119	0 to 14	NA	7	
DI-66	Ouot Cover and Seal	7,39,71,103	Oust covera d seal blown - 0 Seal only - 1 Duot cover only - Z Re•et - 3		7	
DI-67	£leClrometer Range	9,25,41,57,73,89,105	Range #1 - 0 Ral\ge #2 - 2 Range #3 - 3		7	
DI-68	Cal Rate I 1 Status	120,124	0		7	
DI-69	Cal Rate #2 Status	121	1			
DI-70	Cal R.te #3 Status	122,126	2			
DI-71	Col Rate #4 Stat\U	123,127	3			

"m .J, DI-63 through DI-71 measurem<nt content shown below:

2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
P	F_1	F_2	A_J	A_2	$A_)$	A_4	A_5	A_6	A_7

P P&dty check bit
F f'rame ID
A Data (LS£ in A_7)

| DF-7 | Parity | Same aa DI-63 th.ough DI-71 and DI-1 | "1" odd number o(ones in previou• ALSEP frame.

"0" even number ol ones in previoue ALSEP frame. | | (| |
| DF-8 | Frar « JO | Same as DI-63 through DI-?1 and OI-1 | 00 even ALSEP frah'e. 11 odd ALSEP frame. | | | 2 |

TABLE 6 (CONT.)

SUPRATHERMAL ION DETECTOR AND COLD CATHODE
GAUGE EXPERIMENT MEASUREMENTS

SIDE

Symbol	Location/Name	SIDE Frame	Nomin l Value	Tolerance	Bits/ Sample	Sample/ Sec.

Following measurements carried in ALSEP Word 31 odd. SIDE Word 7 and in indicated SIDE Frames.

Symbol	Location/Name	Normal Mode	Reset @9	Voltage	Bits/Sample
DI-72	Velocity Filter Voltage	0	0,60	29.0V	8
DI-73	" " "	1	1,61	26.3	"
DI-74	" " "	2	2,62	23.8	"
DI-75	" " "	3	3,63	21.4	"
DI-76	" " "	4	4,64	19.2	"
DI-77	" " "	5	5,65	17.1	"
DI-78	" " "	6	6,66	14.5	"
DI-79	" " "	7	7,67	13.3	"
DI-80	" " "	8	8,68	11.6	"
DI-81	" " "	9	9,69	10.0	"
DI-82	" " "	10		8.59	"
DI-83	" " "	11		7.30	"
DI-84	" " "	12		6.40	"
DI-85	" " "	13		5.13	"
DI-86	" " "	14		4.25	"
DI-87	" " "	15		3.50	"
DI-88	" " "	16		2.89	"
DI-89	" " "	17		2.41	"
DI-90	" " "	18		2.07	"
DI-91	" " "	19		1.87	"
DI-92	" " "	20	10,70	16.7	"
DI-93	" " "	21	11,71	15.2	"
DI-94	" " "	22	12,72	13.7	"
DI-95	" " "	23	13,73	12.4	"
DI-96	" " "	24	14,74	11.1	"
DI-97	" " "	25	15,75	9.86	"
DI-98	" " "	26	16,76	8.36	"
DI-99	" " "	27	17,77	7.66	"
DJ-0	" " "	28	18,78	6.68	"
DJ-1	" " "	29	19,79	5.78	"
DJ-2	" " "	30		4.96	"
DJ-3	" " "	31		4.21	"
DJ-4	" " "	32		3.69	"
DJ-5	" " "	33		2.96	"
DJ-6	" " "	34		2.45	"
DJ-7	" " "	35		2.02	"
DJ-8	" " "	36		1.67	"
DJ-9	" " "	37		1.39	"
DJ-10	" " "	38		1.20	"

TABLE 6 (CONT.)

SUPRATHERMAL ION DETECTOR AND COLD CATHODE
GAUGE EXPERIMENT MEASUREMENTS

SIDE

Symbol	Location/Name	SIDE Frame		Nominal Value	Tolerance	Bits/ Sample	Sample/ Sec.
		Normal Mode	Reset @ 9	Voltage			
DJ-11	Velocity Filter Voltage	39		1.08V		8	
DJ-12	" " "	40	20,80	9.65		"	
DJ-13	" " "	41	21,81	8.77		"	
DJ-14	" " "	42	22,82	7.93		"	
DJ-15	" " "	43	23,83	7.14		"	
DJ-16	" " "	44	24,84	6.39		"	
DJ-17	" " "	45	25,85	5.69		"	
DJ-18	" " "	46	26,86	4.83		"	
DJ-19	" " "	47	27,87	4.42		"	
DJ-20	" " "	48	28,88	3.86		"	
DJ-21	" " "	49	29,89	3.34		"	
DJ-22	" " "	50		2.86		"	
DJ-23	" " "	51		2.43		"	
DJ-24	" " "	52		2.13		"	
DJ-25	" " "	53		1.71		"	
DJ-26	" " "	54		1.42		"	
DJ-27	" " "	55		1.17		"	
DJ-28	" " "	56		.963		"	
DJ-29	" " "	57		.805		"	
DJ-30	" " "	58		.691		"	
DJ-31	" " "	59		.624		"	
DJ-32	" " "	60	30,90	5.57		"	
DJ-33	" " "	61	31,91	5.06		"	
DJ-34	" " "	62	32,92	4.58		"	
DJ-35	" " "	63	33,93	4.12		"	
DJ-36	" " "	64	34,94	3.69		"	
DJ-37	" " "	65	35,95	3.29		"	
DJ-38	" " "	66	36,96	2.79		"	
DJ-39	" " "	67	37,97	2.55		"	
DJ-40	" " "	68	38,98	2.23		"	
DJ-41	" " "	69	39,99	1.93		"	
DJ-42	" " "	70		1.65		"	
DJ-43	" " "	71		1.40		"	
DJ-44	" " "	72		1.23		"	
DJ-45	" " "	73		.987		"	
DJ-46	" " "	74		.817		"	
DJ-47	" " "	75		.673		"	
DJ-48	" " "	76		.556		"	
DJ-49	" " "	77		.464		"	
DJ-50	" " "	78		.399		"	

TABLE 6 (CONT.)

SUPRATHERMAL ION DETECTOR AND COLD CATHODE GAUGE EXPERIMENT MEASUREMENTS

SIDE

Symbol	Location/Name	SIDE Frame		Nominal Value	Tolerance	Bits/ Sample	Sample/ Sec.
		Normal Mode	Reset @ 9	Voltage			
DJ-51	Velocity Filter Voltage	79		.360v		8	
DJ-52	" " "	80	40, 100	3.22		"	
DJ-53	" " "	81	41, 101	2.92		"	
DJ-54	" " "	82	42,102	2.64		"	
DJ-55	" " "	83	43, 103	2.38		"	
DJ-56	" " "	84	44,104	2.13		"	
DJ-57	" " "	85	45, 105	1.90		"	
DJ-58	" " "	86	46, 106	1.61		"	
DJ-59	" " "	87	47, 107	1.47		"	
DJ-60	" " "	88	48,108	1.29		"	
DJ-61	" " "	89	49,109	1.11		"	
DJ-62	" " "	90		.954		"	
DJ-63	" " "	91		.811		"	
DJ-64	" " "	92		.710		"	
DJ-65	" " "	93		.570		"	
DJ-66	" " "	94		.472		"	
DJ-67	" " "	95		.389		"	
DJ-68	" " "	96		.321		"	
DJ-69	" " "	97		.268		"	
DJ-70	" " "	98		.230		"	
DJ-71	" " "	99		.208		"	
DJ-72	" " "	100	50,110	1.86		"	
DJ-73	" " "	101	51, 111	1.69		"	
DJ-74	" " "	102	52,112	1.53		"	
DJ-75	" " "	103	53, 113	1.37		"	
DJ-76	" " "	104	54, 114	1.23		"	
DJ-77	" " "	105	55, 115	1.10		"	
DJ-78	" " "	106	56,116	.930		"	
DJ-79	" " "	107	57, 117	.851		"	
DJ-80	" " "	108	58,118	.743		"	
DJ-81	" " "	109	59, 119	.642		"	
DJ-82	" " "	110		.551		"	
DJ-83	" " "	111		.468		"	
DJ-84	" " "	112		.409		"	
DJ-85	" " "	113		.329		"	
DJ-86	" " "	114		.272		"	
DJ-87	" " "	115		.224		"	
DJ-88	" " "	116		.185		"	
DJ-89	" " "	117		.155		"	
DJ-90	" " "	118		.133		"	
DJ-91	" " "	119		.120		"	

TABLE 6 (CONT.)

SUPRATHERMAL ION DETECTOR AND COLD CATHODE
GAUGE EXPERIMENT MEASUREMENTS

SIDE

Symbol	Location/Name	SIDE Frame		Nominal Value	Tolerance	Bits/ Sample	Samples/ Sec.
		Normal Mode	Reset @ 9	Voltage			
DJ-92	Velocity Filter Voltage	120	120	29.0		8	
DJ-93	" " "	121	121	26.3		"	
DJ-94	" " "	122	122	23.8		"	
DJ-95	" " "	123	123	21.4		"	
DJ-96	" " "	124	124	19.2		"	
DJ-97	" " "	125, 126, 127	125, 126, 127	>29.0		"	

Following measurements carried in ALSEP Word 47 odd, SIDE Word 8 and in indicated SIDE Frames.

Symbol	Location/Name	SIDE Frame		Energy Filter Voltage		Bits/ Sample	
		Normal Mode	Reset Vel. Filter @ 9				
DJ-98	LECPA Stepper Voltage	0-19	0-9, 60-69	12..15 V		8	
DJ-99	"	20-39	10-19,70-79	4.050		"	
DF-0	"	40-59	20-29,80-89	1.35		"	
DF-1	"	60-79	30-39,90-99	.450		"	
DF-2	"	80-99	40-49,100-109	.150		"	
DF-3	"	100-119	50-59,110-119	.050		"	
DF-4	"	120-127	120-127	0 V		"	

Symbol	Location/Name	SIDE Frame	Range	Accuracy	Bits/ Sample	Sample/ Sec.

Following measurements carried in ALSEP Word 56 odd, SIDE Word 9 and in indicated SIDE Frames.

DF-5	LE Data - MSD	All	0 to 999 decimal		10	

Following measurements carried in ALSEP Word 63 odd, SIDE Word 10 and in indicated SIDE Frames.

DF-6	LE Data - LSD	All	0 to 999 decimal		10	

Two SIDE measurements are included in ALSEP Housekeeping Word 33 (Table 1)

AI-1	Low Energy Detector Count Rate	70	$10 - 10^6$ counts/sec		8	.0185
A1-2	High Energy Detector Count Rate	85	$10 - 10^6$ counts/sec		8	.0185

SCIENCE CAL. DATA (NORMAL MODE)

Symbol	Location/Name	SIDE Frame	PCM Count Range
DI-61, 62	HE Data	120, 124	618,800 to 646,800
		121, 125	0 to 4
		122, 126	150 to 158
		123, 127	19,375 to 20,175
DF-5, 6	LE Data	120, 124	0 to 4
		121, 125	150 to 158
		122, 126	19,375 to 20,175
		123, 127	618,800 to 646,800

TABLE 7

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)					
AS-1	Central Station Package Temp.	20	$-40^{\circ}C$ to $+100^{\circ}C$	$\pm 1^{\circ}C$	8	0185
AS-2	Mortar Box Temp.	44	$-75^{\circ}C$ to $+100^{\circ}C$	$\pm 1^{\circ}C$	8	0185
AS-3	Grenade Launcher Assembly Temp.	55	$-75^{\circ}C$ to $+100^{\circ}C$	$\pm 1^{\circ}C$	8	0185
AS-4	Geophone Temp.	71	$-200^{\circ}C$ to $+150^{\circ}C$	$\pm 1^{\circ}C$	8	0185
	Active Seismic Measurements					

Symbol	Location/Name	A/S Word	Subword	Range	Sensor Accuracy	Bits/ Sample	Samples/ Sec
DS-17	Frame Sync	①1	1,2	N/A	N/A	10	16.56
DS-2	Geophone #2 Data	All	3			5	530
DS-4	Geophone #4 Data	All	4			5	530
DS-1	Geophone #1 Data	2	1			5	530
		2 through 32				5	530
AR-4	RTG Cold Frame Temp. #1	②3,4	1	$400^{\circ}F$ to $600^{\circ}F$	$\pm 5^{\circ}F$	8	16.56
AR-5	Shunt Regulator #1 Current	5,6	1	0 to 3.5 A DC	$\pm 2\%$	8	16.56
DS-5	+5V Telemetry	7,8	1	0 to 5.2 VDC	$\pm 0.5\%$	8	16.56
DS-6	Pitch Angle	9,10	1	$\pm 10^{\circ}$	$\pm 0.5\%$	8	16.56
DS-7	Roll Angle	11,12	1	$\pm 10^{\circ}$	$\pm 0.5\%$	8	16.56
AS-3	Grenade Launcher Assembly Temp.	13,14	1	$-75^{\circ}C$ to $+100^{\circ}C$	$\pm 1^{\circ}C$	8	16.56
DS-8	Geophone Calibrate Pulse	15,16	1	0 to 15V	$\pm 1\%$	8	16.56
DS-11	A/D Calibration 1, 75V	17,18	1	372 to 376 (Octal)	$\pm 0.5\%$	8	16.56
DS-10	A/D Calibration 1, 25V	19,20	1	76 to 104 (Octal)	$\pm 0.5\%$	8	16.56
AS-1	Central Station Package Temp.	21,22	1	$-40^{\circ}C$ to $+100^{\circ}C$	$\pm 1^{\circ}C$	8	16.56
AR-1	Converter Input Voltage	23,24	1	0 to 20 VDC	$\pm 2\%$	8	16.56
AR-4	Input Current	25,26	1	0 to 5 A DC	$\pm 2\%$	8	16.56
AR-3	RTG Hot Frame Temp. #1	②27,28	1	$950^{\circ}F$ to $1150^{\circ}F$	$\pm 5^{\circ}F$	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-11	Mode ID	⑥32	1	N/A	N/A	1	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); mark code is 00100 (all zeros if no event.

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

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

● In the first 1 bits of the subword - other 4 bits not used.

TABLE 8

CHARGED PARTICLE EXPERIMENT SCIENTIFIC MEASUREMENTS

Flight Systems 3 & 4

Symbol	Measurement	ALSEP Words	* CPLEE Frame	Range (Counts)	Accuracy	T/M Bits Per Sample	Samples Per Second	Samples Per Frame
DC-1	DET. 1-A +3500V	7, 17	1	0-524, 287	••	19	1/19.3	1/32
DC-2	DET. 2-A +3500 V	19, 23	1	"	"	19	"	"
DC-3	DET. 3-A +3500 V	39, 55	1	"	"	19	"	"
DC-4	DET. 4-A +3500 V	7, 17	2	0-1048, 575	"	19	"	"
DC-5	DET. 5-A +3500 V	19, 23	2	"	"	20	"	"
DC-6	DET. 6-A +3500 V	39, 55	2	"	"	20	"	"
DC-7	DET. 1-B +3500 V	7, 17	3	0-524, 287	"	19	"	"
DC-8	DET. 2-B +3500 V	19, 23	3	"	"	19	"	"
DC-9	DET. 3-B +3500 V	39, 55	3	"	"	19	"	"
DC-10	DET. 4-B +3500 V	7, 17	4	"	"	19	"	"
DC-11	DET. 5-B +3500 V	19, 23	4	0-1048, 575	"	20	"	"
DC-12	DET. 6-B +3500 V	39, 55	4	"	"	20	"	"
DC-13	DET. 1-A +350 V	7, 17	5	0-524, 287	"	19	"	"
DC-14	DET. 2-A +350 V	19, 23	5	"	"	19	"	"
DC-15	DET. 3-A +350 V	39, 55	5	"	"	19	"	"
DC-16	DET. 4-A +350 V	7, 17	6	"	"	19	"	"
DC-17	DET. 5-A +350 V	19, 23	6	0-1048, 575	"	20	"	"
DC-18	DET. 6-A +350 V	39, 55	6	"	"	20	"	"
DC-19	DET. 1-B +350V	7, 17	7	0-524, 287	"	19	"	"
DC-20	DET. 2-B +350V	19, 23	7	"	"	19	"	"
DC-21	DET. 3-B +350V	39, 55	7	"	"	19	"	"
DC-22	DET. 4-B +350V	7, 17	8	"	"	19	"	"
DC-23	DET. 5-B +350V	19, 23	8	0-1048, 575	"	20	"	"
DC-24	DET. 6-B +350V	39, 55	8	"	"	20	"	"
DC-25	DET. 1-A +35 V	7, 17	9	0-524, 287	"	19	"	"
DC-26	DET. 2-A +35V	19, 23	9	"	"	19	"	"
DC-27	DET. 3-A +35V	39, 55	9	"	"	19	"	"
DC-28	DET. 4-A +35V	7, 17	10	"	"	19	"	"
DC-29	DET. 5-A +35V	19, 23	10	0-1048, 575	"	20	"	"
DC-30	DET. 6-A +35V	39, 55	10	"	"	20	"	"

*CPLEE sampling may initialize at any step voltage but always starts with analyzer A. Detector 1 on an even ALSEP frame. "CPLEE Frame Numbers" are arbitrarily assigned to designate a position in the sequence.

•• Error is stochastically related to count magnitude.

TABLE 8 (CONT.)

CHARGED PARTICLE EXPERIMENT SCIENTIFIC MEASUREMENTS

Symbol	Measurement	ALSEP Words	*CPLEE Frame	Range (Counts)	Accuracy	T/M Bits Per Sample	Samples Per Second	Samples Per Frame
DC-31	DET. 1-B +35V	7, 17	11	0-524, 287	**	19	1/19.3	1/32
DC-32	DET. 2-B +35V	19,23	11	"	"	19	"	"
DC-33	DET. 3-B +35V	39,55	11	"	"	19	"	"
DC-34	DET. 4-B +35V	7, 17	12	"	"	19	"	"
DC-35	DET. 5-B +35V	19,23	12	0-1048, 575	"	20	"	"
DC-36	DET. 6-B +35V	39,55	12	"	"	20	"	"
DC-37	DET. 1-A-40V	7, 17	13	< 100	"	19	"	"
DC-38	DET. 2-A-40V	19,23	13	"	"	19	"	"
DC-39	DET. 3-A-40V	39,55	13	"	"	19	"	"
DC-40	DET. 4-A-40V	7, 17	14	"	"	19	"	"
DC-41	DET. 5-A-40V	19,23	14	"	"	20	"	"
DC-42	DET. 6-A-40V	39,55	14	"	"	20	"	"
DC-43	DET. 1-B-40V	7, 17	15	"	"	19	"	"
DC-44	DET. 2-B-40V	19,23	15	"	"	19	"	"
DC-45	DET. 3-B-40V	39,55	15	"	"	19	"	"
DC-46	DET. 4-B-40V	7, 17	16	"	"	19	"	"
DC-47	DET. 5-B-40V	19,23	16	"	"	20	"	"
DC-48	DET. 6-B-40V	39,55	16	"	"	20	"	"
DC-49	DET. 1-A -3500V	7, 17	17	0-524, 287	"	19	"	"
DC-50	DET. 2-A -3500 V	19,23	17	"	"	19	"	"
DC-51	DET. 3-A -3500 V	39,55	17	"	"	19	"	"
DC-52	DET. 4-A -3500 V	7, 17	18	"	"	19	"	"
DC-53	DET. 5-A -3500 V	19,23	18	0-1048, 575	"	20	"	"
DC-54	DET. 6-A -3500 V	39,55	18	"	"	20	"	"
DC-55	DET. 1-B -3500V	7, 17	19	0-524, 287	"	19	"	"
DC-56	DET. 2-B -3500V	19,23	19	"	"	19	"	"
DC-57	DET. 3-B -3500V	39,55	19	"	"	19	"	"
DC-58	DET. 4-B -3500V	7, 17	20	"	"	19	"	"
DC-59	DET. 5-B -3500V	19, 23	20	0-1048, 575	"	20	"	"
DC-60	DET. 6-B -3500V	39,55	20	"	"	20	"	"

*CPLEE sampling may initialize at any step voltage but always starts with analyzer A, Detector 1 on an even ALSEP frame. "CPLEE Frame Numbers" are arbitrarily assigned to designate a position in the sequence.

** Error is stochastically related to count magnitude.

TABLE 8 (CONT.)

CHARGED PARTICLE EXPERIMENT SCIENTIFIC MEASUREMENTS

Symbol	Measurement	ALSEP Words	°CPLEE Frame	Range (Counts)	Accuracy	T/M Bits Per Sample	Samples Per Second	Samples Per Frame
DC-61	DET. 1-A-350	7, 17	21	0-524, 287	**	19	1/19.3	1/32
DC-62	DET. 2-A-350	19, 23	21	"	"	19	"	"
DC-63	DET. 3-A-350	39,55	21	"	"	19	"	"
DC-64	DET. 4-A-350	7, 17	22	"	"	19	"	"
DC-65	DET. 5-A-350	19,23	22	0-1048, 575	"	20	"	"
DC-66	DET. 6-A-350	39,55	22	"	"	20	"	"
DC-67	DET. 1-B-350	7, 17	23	0-524, 287	"	19	"	"
DC-68	DET. 2-B-350	19,23	23	"	"	19	"	"
DC-69	DET. 3-B-350	39, 55	23	"	"	19	"	"
DC-70	DET. 4-B-350	7, 17	24	"	"	19	"	"
DC-71	DET. 5-B-350	19,23	24	0-1048, 575	"	20	"	"
DC-72	DET. 6-B-350	39,55	24	"	"	20	"	"
DC-73	DET. 1-A-35	7,17	25	0-524, 287	"	19	"	"
DC-74	DET. 2-A-35	19,23	25	"	"	19	"	"
DC-75	DET. 3-A-35	39,55	25	"	"	19	"	"
DC-76	DET. 4-A-35	7, 17	26	"	"	19	"	"
DC-77	DET. 5-A-35	19, 23	26	0-1048, 575	"	20	"	"
DC-78	DET. 6-A-35	39,55	26	"	"	20	"	"
DC-79	DET. 1-B-35	7, 17	27	0-524, 287	"	19	"	"
DC-80	DET. 2-B-35	19,23	27	"	"	19	"	"
DC-81	DET. 3-B-35	39,55	27	"	"	19	"	"
DC-82	DET. 4-B-35	7, 17	28	"	"	19	"	"
DC-83	DET. 5-B-35	19,23	28	0-1048, 575	"	20	"	"
DC-84	DET. 6-B-35	39,55	28	"	"	20	"	"
DC-85	DET. 1-A-0	7, 17	29	420, 000+10%	10 counts	19	"	"
DC-86	DET. 2-A-0	19,23	29	"	"	19	"	"
DC-87	DET. 3-A-0	39,55	29	"	"	19	"	"
DC-88	DET. 4-A-0	7, 17	30	"	"	19	"	"
DC-89	DET. 5-A-0	19,23	30	"	"	20	"	"
DC-90	DET. 6-A-0	39,55	30	"	"	20	"	"

*CPLEE sampling may initialize at any step voltage but always starts with analyzer A, Detector 1 on an even ALSEP frame. "CPLEE Frame Numbers" are arbitrarily assigned to designate a position in the sequence.

** Error is stochastically related to count magnitude.

TABLE 8 (CONT.)

CHARGED PARTICLE EXPERIMENT SCIENTIFIC MEASUREMENTS

Symbol	Measurement	ALSEP Words	*CPLEE Frame	Range (Counts)	Accuracy	T/M Bits Per Sample	Samples Per Second	Samples Per Frame
DC-91	DET. 1-B-0	7, 17	31	420,000 +10%	10 counts	19	1/19.3	1/32
DC-92	DET. 2-B-0	19,23	31	"	"	19	"	"
DC-93	DET. 3-B-0	39,55	31	"	"	19	"	"
DC-94	DET. 4-B-0	7, 17	32	"	"	19	"	"
DC-95	DET. 5-B-0	19,23	32	"	"	20	"	"
DC-96	DET. 6-B-0	39,55	32	"	"	20	"	"
DC-97	Physical Analyzer ID	7	1. *	N.A.	N.A.	1	1/1,208	1/2
DC-98	Polarity of Deflection Voltage ID	19	1. *	N.A.	N.A.	1	"	"
DC-99	Deflection Voltage Level ID	{ 39 / 7	1. * / 2. *	N.A. / N.A.	N.A. / N.A.	1 / 1	" / "	" / "

*Measurement DC-97 is the first bit of word 7, even ALSEP frames; one bit of DC-99 is the first bit of word 7, odd ALSEP frames. DC-98 is the first bit of word 19, even frames. The remaining bit of DC-99 is the first bit of word 39, even frames.

CPLEE ANALOG HOUSEKEEPING DATA

(ALSEP Word 33)

Symbol	Housekeeping Parameter	Channel	Range	Accuracy	Bits Per Sample	Sample Per Second	Samples Per Frame
AC-1	Switchable P.S. Voltage	25	0-4.5V	+5%	8	.0185	1/90
AC-2	Channeltron P.S. #1	89	0-4.5V	"	"	"	"
AC-3	Channeltron P.S. #2	40	0-4.5V	"	"	"	"
AC-4	DC-DC Converter Voltage	10	0-4.5V	"	"	"	"
AC-5	Temperature of Physical Analyzer	11	-30° to +80°C	"	"	"	"
AC-6	Temperature of Switchable P.S.	90	-30° to +80°C	"	"	"	"

TABLE 9 (a)

WORD FORMAT FOR HEAT FLOW EXPERIMENT
(FLIGHT SYSTEM 3)

Each Heat Flow data point employs eight 10-bit words (ALSEP Word 21 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 9(b).

DH-92 R_2, R_1 are binary equivalent of Heat Flow Word.

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 9(b)

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)

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

$\Delta T_{ij}L$ = 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 10(a)

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 Meas	.00231
DH-2	$\Delta T_{12}H$	Temp. Grad. High Sens.	8-15	± 2°C	0.003°C	1/720	4	13 Meas	.00231
DH-3	$\Delta T_{21}H$	Temp. Grad. High Sens.	90-97	± 2°C	0.003°C	1/720	4	13 Meas	.00231
DH-4	$\Delta T_{22}H$	Temp. Grad. High Sens.	98-105	± 2°C	0.003°C	1/720	4	13 Meas	.00231
DH-5	$\Delta T_{11}L$	Temp. Grad. Low Sens.	180-187	± 20°C	0.03°C	1/720	4	13 Meas	.00231
DH-6	$\Delta T_{12}L$	Temp. Grad. Low Sens.	188-195	± 20°C	0.03°C	1/720	4	13 Meas	.00231
DH-7	$\Delta T_{21}L$	Temp. Grad. Low Sens.	270-277	± 20°C	0.03°C	1/720	4	13 Meas	.00231
DH-8	$\Delta T_{22}L$	Temp. Grad. Low Sens.	278-285	± 20°C	0.03°C	1/720	4	13 Meas	.00231
DH-9	T_{11}	Probe Ambient Temp.	360-367	200 to 250°K	0.1°C	1/720	4	13 Meas	.00231
DH-10	T_{12}	Probe Ambient Temp.	368-375	200 to 250°K	0.1°C	1/720	4	13 Meas	.00231
DH-11	T_{21}	Probe Ambient Temp.	450-457	200 to 250°K	0.1°C	1/720	4	13 Meas	.00231
DH-12	T_{22}	Probe Ambient Temp.	458-465	200 to 250°K	0.1°C	1/720	4	13 Meas	.00231
**DH-13	Ref. T_1	Temp. Ref. Junction	540-547	-20 to +60°C	0.1°C	1/720	4	13 Meas	.00231
***DH-14, 24, 34, 44	TC1 group	Probe Cable Temp.	548-555	90 to 350°K	0.3°C	4/720	1	13 Meas	.00231
**DH-15	Ref. T2	Temp. Ref. Junction	630-637	-20 to +60°C	0.1°C	1/720	4	13 Meas	.00231
***DH-16, 26, 36, 46	TC2 group	Probe Cable Temp.	638-645	90 to 350°K	0.3°C	4/720	1	13 Meas	.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 10(b).

TABLE 10(b)

HEAT FLOW THERMOCOUPLE GROUP MEASUREMENTS

	Symbol	Data	R-Bits R_2	R_1
	DH-14	Ref. TC - $TC_1(4)$	0	0
TC_1	DH-24	$TC_1 (4) - TC_1 (1)$	0	1
Group	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	DH-26	$TC_2 (4) - TC_2 (1)$	0	1
Group	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 10(c)

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 10(a) is thus increased by subsequencing.

TABLE II

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 12

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	Low Conductivity Heater Power Status	57	2.0-2.5 volts ON Otherwise OFF		8	.0185
AH-7	High Conductivity Heater Power Status	75	2.0-2.5 volts ON Otherwise OFF		8	.0185

TABLE 13

SOLAR WIND SPECTROMETER (SWS) MEASUREMENTS

Flight Systems #1 and #2

Note: The SWS uses ALSEP Words 7, 23, 39 and 55 (in that order) to convey experiment data. The data is organized into 16 sequences of 186 words per sequence. Since the position of any element of data (Word) is indeterminate with respect to ALSEP Frames and Words, the channel designation is determined internally from information carried in the data. Therefore, in the following data, channel designation is not used but the data is identified by the SWS Word and by the first two bits (FB) which have been provided for Word identification within the sequence; and the sequence is identified by the Least Significant Bits (LSB) of Word 184 lying in the sequence being identified.

Basic Sequence, Repeated 16 times per cycle

Typical Data Word   Cycle - Sequence Count Words

TABLE 13 (CONT.)

SOLAR WIND SPECTROMETER (SWS) MEASUREMENTS

Symbol	Location/Name	Flag Bit (FB)	SWS Word	Range	Sensor Accuracy	Bits/ Sample	Sample/ Sec
Science Data							
	Plasma Magnitude (Positive Ions)						
	Subcommutated as follows: a reading is made of the sum of the outputs of the 7 Faraday cups and then there are 7 consecutive readings of the individual Faraday cups. This set of 8 is repeated for 14 different settings of the analyzer plate voltage.						
DY-1	Pos. Ions - Sum - Lev 1	00	0	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-2	Pos. Ions - Cup 1 - Lev 1	00	1	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-3	Pos. Ions - Cup 2 - Lev 1	00	2	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-4	Pos. Ions - Cup 3 - Lev 1	00	3	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-5	Pos. Ions - Cup 4 - Lev 1	00	4	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-6	Pos. Ions - Cup 5 - Lev 1	00	5	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-7	Pos. Ions - Cup 6 - Lev 1	00	6	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-8	Pos. Ions - Cup 7 - Lev 1	00	7	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-9	Pos. Ions - Sum - Lev 2	00	8	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-10	Pos. Ions - Cup 1 - Lev 2	00	9	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-11	Pos. Ions - Cup 2 - Lev 2	00	10	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-12	Pos. Ions - Cup 3 - Lev 2	00	11	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-13	Pos. Ions - Cup 4 - Lev 2	00	12	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-14	Pos. Ions - Cup 5 - Lev 2	00	13	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-15	Pos. Ions - Cup 6 - Lev 2	00	14	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-16	Pos. Ions - Cup 7 - Lev 2	00	15	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1

TABLE 13 (CONT.)

SOLAR WIND SPECTROMETER (SWS) MEASUREMENTS

Symbol	Location/Name	Flag Bit (FB)	SWS Word	Range	Sensor Accuracy	Bits/ Sample	Sample/ Sec
DY-17	Pos. Ions - Sum - Lev 3	00	16	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-18	Pos. Ions - Cup 1 - Lev 3	00	17	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-19	Pos. Ions - Cup 2 - Lev 3	00	18	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-20	Pos. Ions - Cup 3 - Lev 3	00	19	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-21	Pos. Ions - Cup 4 - Lev 3	00	20	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-22	Pos. Ions - Cup 5 - Lev 3	00	21	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-23	Pos. Ions - Cup 6 - Lev 3	00	22	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-24	Pos. Ions - Cup 7 - Lev 3	00	23	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-25	Pos. Ions - Sum - Lev 4	00	24	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-26	Pos. Ions - Cup 1 - Lev 4	00	25	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-27	Pos. Ions - Cup 2 - Lev 4	00	26	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-28	Pos. Ions - Cup 3 - Lev 4	00	27	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-29	Pos. Ions - Cup 4 - Lev 4	00	28	Log 0.4 to 6290 pA	±(2% + 1pA)	8	1/28.1
DY-30	Pos. Ions - Cup 5 - Lev 4	00	29	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-31	Pos. Ions - Cup 6 - Lev 4	00	30	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-32	Pos. Ions - Cup 7 - Lev 4	00	31	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-33	Pos. Ions - Sum - Lev 5	00	32	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-34	Pos. Ions - Cup 1 - Lev 5	00	33	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-35	Pos. Ions - Cup 2 - Lev 5	00	34	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-36	Pos. Ions - Cup 3 - Lev 5	00	35	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-37	Pos. Ions - Cup 4 - Lev 5	00	36	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-38	Pos. Ions - Cup 5 - Lev 5	00	37	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-39	Pos. Ions - Cup 6 - Lev 5	00	38	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-40	Pos. Ions - Cup 7 - Lev 5	00	39	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-41	Pos. Ions - Sum - Lev 6	00	40	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-42	Pos. Ions - Cup 1 - Lev 6	00	41	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-43	Pos. Ions - Cup 2 - Lev 6	00	42	Log 0.4 to 6200 pA	±(2% + 1 pA)	8	1/28.1
DY-44	Pos. Ions - Cup 3 - Lev 6	00	43	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-45	Pos. Ions - Cup 4 - Lev 6	00	44	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-46	Pos. Ions - Cup 5 - Lev 6	00	45	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-47	Pos. Ions - Cup 6 - Lev 6	00	46	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-48	Pos. Ions - Cup 7 - Lev 6	00	47	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-49	Pos. Ions - Sum - Lev 7	00	48	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-50	Pos. Ions - Cup 1 - Lev 7	00	49	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-51	Pos. Ions - Cup 2 - Lev 7	00	50	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-52	Pos. Ions - Cup 3 - Lev 7	00	51	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-53	Pos. Ions - Cup 4 - Lev 7	00	52	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-54	Pos. Ions - Cup 5 - Lev 7	00	53	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-55	Pos. Ions - Cup 6 - Lev 7	00	54	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-56	Pos. Ions - Cup 7 - Lev 7	00	55	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1

TABLE 13 (CONT.)

SOLAR WIND SPECTROMETER (SWS) MEASUREMENTS

Symbol	Location/Name	Flag Bit (FB)	SWS Word	Range	Sensor Accuracy	Bits/ Sample	Sample/ Sec
DY-57	Pos. Ions - Sum - Lev 8	00	56	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-58	Pos. Ions - Cup 1 - Lev 8	00	57	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-59	Pos. Ions - Cup 2 - Lev 8	00	58	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-60	Pos. Ions - Cup 3 - Lev 8	00	59	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-61	Pos. Ions - Cup 4 - Lev 8	00	60	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-62	Pos. Ions - Cup 5 - Lev 8	00	61	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-63	Pos. Ions - Cup 6 - Lev 8	00	62	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-64	Pos. Ions - Cup 7 - Lev 8	00	63	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-65	Pos. Ions - Sum - Lev 9	00	64	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-66	Pos. Ions - Cup 1 - Lev 9	00	65	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-67	Pos. Ions - Cup 2 - Lev 9	00	66	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-68	Pos. Ions - Cup 3 - Lev 9	00	67	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-69	Pos. Ions - Cup 4 - Lev 9	00	68	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-70	Pos. Ions - Cup 5 - Lev 9	00	69	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-71	Pos. Ions - Cup 6 - Lev 9	00	70	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-72	Pos. Ions - Cup 7 - Lev 9	00	71	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-73	Pos. Ions - Sum - Lev 10	00	72	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-74	Pos. Ions - Cup 1 - Lev 10	00	73	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-75	Pos. Ions - Cup 2 - Lev 10	00	74	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-76	Pos. Ions - Cup 3 - Lev 10	00	75	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-77	Pos. Ions - Cup 4 - Lev 10	00	76	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-78	Pos. Ions - Cup 5 - Lev 10	00	77	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-79	Pos. Ions - Cup 6 - Lev 10	00	78	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-80	Pos. Ions - Cup 7 - Lev 10	00	79	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-81	Pos. Ions - Sum - Lev 11	00	80	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-82	Pos. Ions - Cup 1 - Lev 11	00	81	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-83	Pos. Ions - Cup 2 - Lev 11	00	82	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-84	Pos. Ions - Cup 3 - Lev 11	00	83	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-85	Pos. Ions - Cup 4 - Lev 11	00	84	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-86	Pos. Ions - Cup 5 - Lev 11	00	85	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-87	Pos. Ions - Cup 6 - Lev 11	00	86	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-88	Pos. Ions - Cup 7 - Lev 11	00	87	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-89	Pos. Ions - Sum - Lev 12	00	88	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-90	Pos. Ions - Cup 1 - Lev 12	00	89	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-91	Pos. Ions - Cup 2 - Lev 12	00	90	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-92	Pos. Ions - Cup 3 - Lev 12	00	91	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-93	Pos. Ions - Cup 4 - Lev 12	00	92	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-94	Pos. Ions - Cup 5 - Lev 12	00	93	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-95	Pos. Ions - Cup 6 - Lev 12	00	94	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DY-96	Pos. Ions - Cup 7 - Lev 12	00	95	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1

TABLE 13 (CONT.)

SOLAR WIND SPECTROMETER (SWS) MEASUREMENTS

Symbol	Location/Name	Flag Bit (FB)	SWS Word	Range	Sensor Accuracy	Bits/ Sample	Sample/ Sec
DZ-1	Pos. Ions - Sum - Lev 13	00	96	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-2	Pos. Ions - Cup 1 - Lev 13	00	97	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-3	Pos. Ions - Cup 2 - Lev 13	00	98	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-4	Pos. Ions - Cup 3 - Lev 13	00	99	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-5	Pos. Ions - Cup 4 - Lev 13	00	100	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-6	Pos. Ions - Cup 5 - Lev 13	00	101	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-7	Pos. Ions - Cup 6 - Lev 13	00	102	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-8	Pos. Ions - Cup 7 - Lev 13	00	103	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-9	Pos. Ions - Sum - Lev 14	00	104	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-10	Pos. Ions - Cup 1 - Lev 14	00	105	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-11	Pos. Ions - Cup 2 - Lev 14	00	106	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-12	Pos. Ions - Cup 3 - Lev 14	00	107	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-13	Pos. Ions - Cup 4 - Lev 14	00	108	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-14	Pos. Ions - Cup 5 - Lev 14	00	109	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-15	Pos. Ions - Cup 6 - Lev 14	00	110	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-16	Pos. Ions - Cup 7 - Lev 14	00	111 *	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
	Plasma Magnitude (Electrons)		128-183	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1

Subcommutated in a manner similar to above except that here the set of θ is repeated for 7 different settings of the analyzer plate voltage.

Symbol	Location/Name	Flag Bit (FB)	SWS Word	Range	Sensor Accuracy	Bits/ Sample	Sample/ Sec
DZ-17	Elec - Sum - Lev 15	00	128	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-18	Elec - Cup 1 - Lev 15	00	129	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-19	Elec - Cup 2 - Lev 15	00	130	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-20	Elec - Cup 3 - Lev 15	00	131	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-21	Elec - Cup 4 - Lev 15	00	132	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-22	Elec - Cup 5 - Lev 15	00	133	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-23	Elec - Cup 6 - Lev 15	00	134	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-24	Elec - Cup 7 - Lev 15	00	135	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-25	Elec - Sum - Lev 16	00	136	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-26	Elec - Cup 1 - Lev 16	00	137	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-27	Elec - Cup 2 - Lev 16	00	138	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-28	Elec - Cup 3 - Lev 16	00	139	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-29	Elec - Cup 4 - Lev 16	00	140	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-30	Elec - Cup 5 - Lev 16	00	141	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-31	Elec - Cup 6 - Lev 16	00	142	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-32	Elec - Cup 7 - Lev 16	00	143	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1

*Word 112 to 127 are engineering data covered later in table.

TABLE 13(CONT.)

SOLAR WIND SPECTROMETER (SWS) MEASUREMENTS

Symbol	Location/Name	Flag Bit (FB)	SWS Word	Range	Sensor Accuracy	Bits/ Sample	Sample/ Sec
DZ-33	Elec - Sum - Lev 17	00	144	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-34	Elec - Cup 1 - Lev 17	00	145	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-35	Elec - Cup 2 - Lev 17	00	146	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-36	Elec - Cup 3 - Lev 17	00	147	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-37	Elec - Cup 4 - Lev 17	00	148	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-38	Elec - Cup 5 - Lev 17	00	149	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-39	Elec - Cup 6 - Lev 17	00	150	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-40	Elec - Cup 7 - Lev-17	00	151	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-41	Elec - Sum - Lev 18	00	152	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-42	Elec - Cup 1 - Lev 18	00	153	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-43	Elec - Cup 2 - Lev 18	00	154	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-44	Elec - Cup 3 - Lev 18	00	155	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-45	Elec - Cup 4 - Lev 18	00	156	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-46	Elec - Cup 5 - Lev 18	00	157	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-47	Elec - Cup 6 - Lev 18	00	158	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-48	Elec - Cup 7 - Lev 18	00	159	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-49	Elec - Sum - Lev 19	00	160	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-50	Elec - Cup 1 - Lev 19	00	161	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-51	Elec - Cup 2 - Lev 19	00	162	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-52	Elec - Cup 3 - Lev 19	00	163	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-53	Elec - Cup 4 - Lev 19	00	164	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-54	Elec - Cup 5 - Lev 19	00	165	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-55	Elec - Cup 6 - Lev 19	00	166	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-56	Elec - Cup 7 - Lev 19	00	167	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-57	Elec - Sum - Lev 20	00	168	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-58	Elec - Cup 1 - Lev 20	00	169	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-59	Elec - Cup 2 - Lev 20	00	170	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-60	Elec - Cup 3 - Lev 20	00	171	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-61	Elec - Cup 4 - Lev 20	00	172	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-62	Elec - Cup 5 - Lev 20	00	173	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-63	Elec - Cup 6 - Lev 20	00	174	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-64	Elec - Cup 7 - Lev 20	00	175	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-65	Elec - Sum - Lev 21	00	176	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-66	Elec - Cup 1 - Lev 21	00	177	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-67	Elec - Cup 2 - Lev 21	00	178	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-68	Elec - Cup 3 - Lev 21	00	179	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-69	Elec - Cup 4 - Lev 21	00	180	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-70	Elec - Cup 5 - Lev 21	00	181	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-71	Elec - Cup 6 - Lev 21	00	182	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1
DZ-72	Elec - Cup 7 - Lev 21	00	183	Log 0.4 to 6200 pA	±(2% + 1pA)	8	1/28.1

TABLE 13 (CONT.)

SOLAR WIND SPECTROMETER (SWS) MEASUREMENTS

Symbol	Location/Name	Flag Bit FB	SWS Word	LSB	Range	Sensor Accuracy	Bits/ Sample	Sample/ Sec
Engineering Data								
	Sequence Counter							
DW-1	1 bit per sequence	10	184	All	0-255		8	.035
DW-2	1 bit per 256 sequences	10	185	All	0-255		8	.035
	A/D Converter Calibration, Repeated Every Other SWS Sequence							
DW-3	9mv ± 2%	01	112, 117	0	(log) 0.6 to 10,000 mV	± 25%	8	0.018
DW-4	90mv ± 2%	01	113	0	(log) 0.6 to 10,000 mV	± 3.3%	8	0.018
DW-5	900mv ± 2%	01	114, 118	0	(log) 0.6 to 10,000 mV	± 2.2%	8	0.018
DW-6	3000mv ± 2%	01	115	0	(log) 0.6 to 10,000 mV	± 2.1%	8	0.018
DW-7	9000mv ± 2%	01	116, 119	0	(log) 0.6 to 10,000 mV	± 2.1%	8	0.018
DW-11	Temperature Mod 100	01	112	1	-50 to +150°C	±5°C	8	0.018
DW-12	Temperature Mod 200	01	113	1	-50 to +150°C	±5°C	8	0.018
DW-13	Temperature Mod 300	01	114	1	-50 to +150°C	±5°C	8	0.018
DW-14	Temperature Sensor Cup Assem	01	115	1	-185 to +150°C	± 10°C	8	0.018
DW-15	Sun Angle Sensor	01	116	1	One Value		8	0.018
DW-16	Programmer Voltage	01	117	1	0 to 9V	5%	8	0.018
DW-17	Step Generator Voltage	01	118	1	0 to 9V	5%	8	0.018
DW-18	Modulatio Monitor	01	119	1	236 ± 4 (OCT)	± 3 counts	8	0.018
	Current Calibrate, Repeated Every Fourth SWS Sequence							
DW-19	0 Ampere	01	120	00	(log) 0.4 to 6200 pA	±(2% + 1pA)	8	.0088
DW-20	0 Ampere Cup 1	01	121	00	(log) 0.4 to 6200 pA	±(2% + 1pA)	8	.0088
DW-21	0 Ampere Cup 2	01	122	00	(log) 0.4 to 6200 pA	±(2% + 1pA)	8	.0088

TABLE 13 (CONT.)
SOLAR WIND SPECTROMETER (SWS) MEASUREMENTS

Symbol	Location/Name	Flag Bit FB	SWS Word	LSB	Range	Sensor Accuracy	Bits/ Sample	Sample/ Sec
Engineering Data (Cont.)								
Current Calibrate (Cont.)								
DW-22	0 Ampere Cup 3	01	123	00	(log) 0.4 to 6200 pA	±(2% + 1 pA)	8	.0088
DW-23	0 Ampere Cup 4	01	124	00	(log) 0.4 to 6200 pA	±(2% + 1 pA)	8	.0088
DW-24	0 Ampere Cup 5	01	125	00	(log) 0.4 to 6200 pA	±(2% + 1 pA)		.0088
DW-25	0 Ampere Cup 6	01	126	00	(log) 0.4 to 6200 pA	±(2% + 1 pA)	8	.0088
DW-26	0 Ampere Cup 7	01	127	00	(log) 0.4 to 6200 pA	±(2% + 1 pA)	8	.0088
DW-27	$7 \times 5.76 \times 10^{-12}$ Ampere	01	120	01	(log) 0.4 to 6200 pA	±3.8%	8	.0088
DW-28	5.76×10^{-12} Ampere Cup 1	01	121	01	(log) 0.4 to 6200 pA	13.%	8	.0088
DW-29	5.76×10^{-12} Ampere Cup 2	01	122	01	(log) 0.4 to 6200 pA	13.%	8	.0088
DW-30	5.76×10^{-12} Ampere Cup 3	01	123	01	(log) 0.4 to 6200 pA	13.%	8	.0088
DW-31	5.76×10^{-12} Ampere Cup 4	01	124	01	(log) 0.4 to 6200 pA	13.%	8	.0088
DW-32	5.76×10^{-12} Ampere Cup 5	01	125	01	(log) 0.4 to 6200 pA	13.%	8	.0088
DW-33	5.76×10^{-12} Ampere Cup 6	01	126	01	(log) 0.4 to 6200 pA	13.%	8	.0088
DW-34	5.76×10^{-12} Ampere Cup 7	01	127	01	(log) 0.4 to 6200 pA	13.%	8	.0088
DW-35	$7 \times 5.76 \times 10^{-11}$ Ampere	01	120	10	(log) 0.4 to 6200 pA	2.3%	8	.0088
DW-36	5.76×10^{-11} Ampere Cup 1	01	121	10	(log) 0.4 to 6200 pA	3.2%	8	.0088
DW-37	5.76×10^{-11} Ampere Cup 2	01	122	10	(log) 0.4 to 6200 pA	3.2%	8	.0088
DW-38	5.76×10^{-11} Ampere Cup 3	01	123	10	(log) 0.4 to 6200 pA	3.2%	8	.0088
DW-39	5.76×10^{-11} Ampere Cup 4	01	124	10	(log) 0.4 to 6200 pA	3.2%	8	.0088
DW-40	5.76×10^{-11} Ampere Cup 5	01	125	10	(log) 0.4 to 6200 pA	3.2%	8	.0088
DW-41	5.76×10^{-11} Ampere Cup 6	01	126	10	(log) 0.4 to 6200 pA	3.2%	8	.0088
DW-42	5.76×10^{-11} Ampere Cup 7	01	127	10	(log) 0.4 to 6200 pA	3.2%	8	.0088
DW-43	$7 \times 5.76 \times 10^{-9}$ Ampere	01	120	11	(log) 0.4 to 6200 pA	Saturated	8	.0088
DW-44	5.76×10^{-9} Ampere Cup 1	01	121	11	(log) 0.4 to 6200 pA	2.2%	8	.0088
DW-45	5.76×10^{-9} Ampere Cup 2	01	122	11	(log) 0.4 to 6200 pA	2.2%	8	.0088
DW-46	5.76×10^{-9} Ampere Cup 3	01	123	11	(log) 0.4 to 6200 pA	2.2%	8	.0088
DW-47	5.76×10^{-9} Ampere Cup 4	01	124	11	(log) 0.4 to 6200 pA	2.2%	8	.0088
DW-48	5.76×10^{-9} Ampere Cup 5	01	125	11	(log) 0.4 to 6200 pA	2.2%	8	.0086
DW-49	5.76×10^{-9} Ampere Cup 6	01	126	11	(log) 0.4 to 6200 pA	2.2%	8	.0088
DW-50	5.76×10^{-9} Ampere Cup 7	01	127	11	(log) 0.4 to 6200 pA	2.2%	8	.0088

TABLE 13 (CONT.)

SOLAR WIND SPECTROMETER (SWS) MEASUREMENTS

Symbol	Location/Name	Flag Bit FB	SWS Word	LSB	Range	Sensor Accuracy	Bits/ Sample	Sample/ Sec
Engineering Data (Cont.)								
DC High Voltage, Repeated Once Every 16 SWS Sequences								
DW-51	Level #1 (Proton)	01	0	1110	~0 to 8200V (log)	2.6%	8	.0022
DW-52	Level #2	01	8	1110	~0 to 8200V (log)	2.5	8	.0022
DW-53	Level #3	01	16	1110	~0 to 8200V (log)	2.4	8	.0022
DW-54	Level #4	01	24	1110	~0 to 8200V (log)	2.3	8	.0022
DW-55	Level #5	01	32	1110	~0 to 8200V (log)	2.3	8	.0022
DW-56	Level #6	01	40	1110	~0 to 8200V (log)	2.2	8	.0022
DW-57	Level #7	01	48	1110	~0 to 8200V (log)	2.2	8	.0022
DW-58	Level #8	01	56	1110	~0 to 8200V (log)	2.1	8	.0022
DW-59	Level #9	01	64	1110	~0 to 8200V (log)	2.1	8	.0022
DW-60	Level #10	01	72	1110	~0 to 8200V (log)	2.1	8	.0022
DW-61	Level #11	01	80	1110	~0 to 8200V (log)	2.1	8	.0022
DW-62	Level #12	01	88	1110	~0 to 8200V (log)	2.1	8	.0022
DW-63	Level #13	01	96	1110	~0 to 8200V (log)	2.1	8	.0022
DW-64	Level #14	01	104	1110	~0 to 8200V (log)	2.1	8	.0022
DW-65	Level #15 (Electron)	01	128	1110	~0 to 1200V (log)	3.0%	8	.0022
DW-66	Level #16	01	136	1110	~0 to 1200V (log)	2.4	8	.0022
DW-67	Level #17	01	144	1110	~0 to 1200V (log)	2.3	8	.0022
DW-68	Level #18	01	152	1110	~0 to 1200V (log)	2.2	8	.0022
DW-69	Level #19	01	160	1110	~0 to 1200V (log)	2.1	8	.0022
DW-70	Level #20	01	168	1110	~0 to 1200V (log)	2.1	8	.0022
DW-71	Level #21	01	176	1110	~0 to 1200V (log)	2.1	8	.0022
AC High Voltage, Repeated Once Every 16 SWS Sequences								
DW-72	Level #1 (Proton)	01	0	1111	~0 to 1500V (log)	9.0%	8	.0022
DW-73	Level #2	01	8	1111	~0 to 1500V (log)	4.3	8	.0022
DW-74	Level #3	01	16	1111	~0 to 1500V (log)	3.0	8	.0022
DW-75	Level #4	01	24	1111	~0 to 1500V (log)	2.6	8	.0022
DW-76	Level #5	01	32	1111	~0 to 1500V (log)	2.4	8	.0022
DW-77	Level #6	01	40	1111	~0 to 1500V (log)	2.3	8	.0022
DW-78	Level #7	01	48	1111	~0 to 1500V (log)	2.2	8	.0022
DW-79	Level #8	01	56	1111	~0 to 1500V (log)	2.2	8	.0022
DW-80	Level #9	01	64	1111	~0 to 1500V (log)	2.1	8	.0022
DW-81	Level #10	01	72	1111	~0 to 1500V (log)	2.1	8	.0022

TABLE 13 (CONT.)

SOLAR WIND SPECTROMETER (SWS) MEASUREMENTS

Symbol	Location/Name	Flag Bit FB	SWS Word	LSB	Range	Sensor Accuracy	Bits/ Sample	Sample/ Sec
Engineering Data (Cont.)								
DW-82	Level #11	01	80	1111	~0 to 1500V	2.1%	8	.0022
DW-83	Level #12	01	88	1111	~0 to 1500V	2.1	8	.0022
DW-84	Level #13	01	96	1111	~0 to 1500V	2.1	8	.0022
DW-85	level #14	01	104	1111	~0 to 1500V	2.1	8	.0022
DW-86	Level #15 (Electron)	01	128	1111	~0 to 350V	2.7%	8	.0022
DW-87	Level #16	01	136	1111	~0 to 350V	2.4	8	.0022
DW-88	Level #17	01	144	1111	~0 to 350V	2.3	8	.0022
DW-89	Level #18	01	152	1111	~0 to 350V	2.2	8	.0022
DW-90	Level #19	01	160	1111	~0 to 350V	2.1	8	.0022
DW-91	Level #20	01	168	1111	~0 to 350V	2.1	8	.0022
DW-92	Level #21	01	176	1111	~0 to 350V	2.1	8	.0022

TABLE 14

COLD CATHODE GAUGE EXPERIMENT (MSC)

Science Measurements

Symbol	Measurement	CCGE Word	ALSEP Words	ALSEP Frame	Range	Sensor Accuracy	Bit/ Sample	Sample/ Sec.	Sample/ Frame
DG-1	Multiplexer State	All bits 10,9	15, 31, 47 56,63	All	0-3	NA	2	8.3	5
DG-2	Automatic Zero State	1 bit 8	15	All	"0" - Operate "1" - Zeroing	NA	1	1.66	1
DG-3	Calibrate State	1 bit 7	15	All	"0" - Operate "1" - Calibrate	NA	1	1.66	1
DG-4	Housekeeping Word ID	1 bits 6 & 5	15	All	0 - DG-10 1 - DG-11 2 - DG-12 3 - DG-13	NA	2	1.66	1
DG-5	Ranging Mode	1 bit 4	15	All	"1" - Automatic "0" - Manual	NA	1	1.66	1
DG-6	Range	1 bits 3,2,1	15	All	10^{-6} - 10^{-12} torr in 7 steps	NA		1.66	1
DG-7	Gauge Output	2	31	All	0-255	±50%	8	1.66	1
	Engineering Measurements								
DG-8	Gauge Temperature	3	47	All			8	1.66	1
DG-9	Electronics Package Temperature	4	56	All			8	1.66	1
DG-10	4.5 K volt Monitor	5	63	DG-4 = 0			8	.415	.25
DG-11	+15 volts	5	63	DG-4 = 1			8	.415	.25
DG-12	-15 volts	5	63	DG-4 = 2			8	.415	.25
DG-13	-10 volts	5	63	DG-4 = 3			8	.415	.25
	Analog Outputs								
AG-1	Gauge Output	NA	33(channel 70)		0-5V		8	.0185	1/90
AG-2	Gauge Range	NA	33(channel 85)		0-5V		8	.0185	1/90

TABLE 14 (CONT.)

COLD CATHODE GAUGE EXPERIMENT (MSC)

Flight 3 Only

The CCGE (MSC) interface is designed to replace the SIDE/CCGE without change to the ALSEP system. The experiment uses ALSEP words 15, 31, 47, 56, and 63. The first CCGE (MSC) word contains six experiment state indications; the second CCGE (MSC) words, the cold cathode gauge output; the third, the gauge temperature; the fourth, the CCGE electronics temperature, and the fifth is a subcommutated housekeeping engineering data word. The basic format is shown below:

CCGE/MSC Word	ALSEP Word	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	Remarks
1	15	R_1	R_2	R_3	RM	HKID	HKID	CAL	Zero	ID 1	ID 1	Identification Information
2	31	X	X	X	X	X	X	X	X	0	0	Gauge Output
3	47	X	X	X	X	X	X	X	X	0	1	Gauge Temperature
4	56	X	X	X	X	X	X	X	X	1	0	Electronics Package Temperature
5	63	X	X	X	X	X	X	X	X	1	1	Housekeeping Engineering Data

R - Range
RM - Range Mode
HKID - Housekeeping ID

CAL - Calibration State
Zero - Automatic Zero State
ID - Multiplexer State

Gauge output (word 2), in CAL mode, is PCM count (decimal) in range 96-160.