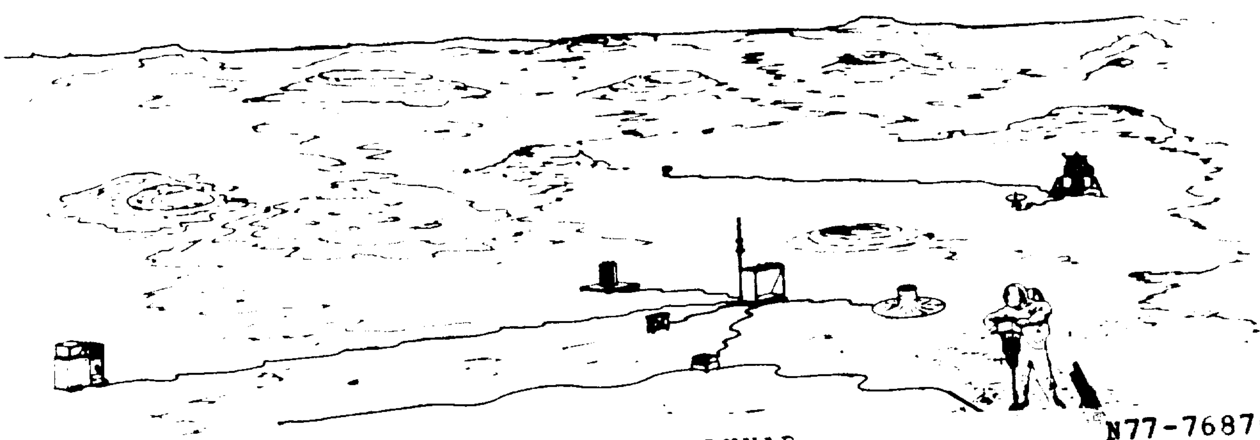
OFFICE OF MANNED SPACE FLIGHT

APOLLO PROGRAM OFFICE

APOLLO 13 LUNAR EXPLORATION EXPERIMENTS AND PHOTOGRAPHY SUMMARY

FEBRUARY 1970



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WASHINGTON, D.C. 20546

APOLLO 13 LUNAR EXPLORATION
EXPERIMENTS AND PHOTOGRAPHY
SUMMARY

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PREFACE

This publication describes the Apollo 13 mission lunar exploration experiments and photographic equipment. The document contains technical and engineering information on all flight equipment to be utilized in the conduct of experiments and photographic tasks assigned to Apollo 13.

Revisions to this publication will be issued on an "as required" basis to maintain it as an accurate and current reference. Correspondence concerning changes should be directed to the appropriate program manager, code MAL, National Aeronautics and Space Administration, Washington, D. C. 20546.

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1.0 INTRODUCTION

The Apollo Lunar Exploration Program is a long-term, multiple-mission undertaking encompassing a large number of scientific experiments and operations for the orderly and progressive achievement of the program goals and objectives.* These goals and objectives are summarized in Table 1-1. Apollo 13 is the third in a series of manned lunar landing missions. The primary mission objectives assigned by the Office of Manned Space Flight to Apollo 13 are:

1) Perform selenological inspection, survey and sampling of materials in a preselected region of the Fra Mauro formation.

2) Deploy and activate the Apollo Lunar Surface Experiments Package.

3) Develop man's capability to work in the lunar environment.

4) Obtain photographs of candidate exploration sites.

The complement of experiments and objectives for a specific mission is dependent not only upon previous accomplishments and future plans but upon the selected landing site as well. For Apollo 13, the prime landing site is the Fra Mauro formation, located at 3°37'S, 17°33'W, about 30 miles north of the crater Fra Mauro. The site is a hilly and undulating upland region on a widespread geological unit covering large portions of the lunar surface around Mare Imbrium. The Fra Mauro formation is interpreted by selenologists to be an ejecta blanket of material thrown out by the event which created the circular Mare Imbrium basin. Thus Fra Mauro samples should allow age dating for time of giant impacts and composition analyses of primitive and deep-seated rocks.

This publication discusses, in summary fashion, all flight experiment hardware and photographic equipment associated with the Apollo 13 mission in support of the primary mission objectives. The subsections on individual experiments contain technical and engineering information and are intended to provide an understanding of what the experiment will accomplish relative to lunar exploration goals and objectives. In addition, flight hardware associated with secondary objectives, dim light photography and television coverage, are discussed herein. One additional experiment assigned to Apollo 13 is the Pilot Describing Function Experiment (T-029). No specific crew task is required to support this experiment which consists of providing certain portions of voice and telemetry data recordings to the Principal Investigator/Ames Research Center. Information regarding medical experiments and operations is not included. The Table of Contents provides a listing of experiments discussed and Section 5.0 contains listings of photographic equipment for Apollo 13.

GOALS

1. Explore the moon and use the moon for the benefit of man.

2. Utilize Apollo equipment effectively in exploration of the moon and in extending our technological and operational space capabilities in support of national interests.

SCIENTIFIC OBJECTIVES

1. Investigate the major lunar surface features and regional relationships.

2. Completely characterize the samples collected at each landing site by detailed analysis on earth.

3. Determine the gross internal structure and processes, ephemeris, and mass distribution by measuring seismic activity, heat flow, and lunar librations with emplaced, long-lived instrumentation.

4. Establish lunar-wide understanding and geodetic control by survey and measurement from orbit about the moon.

5. Investigate the lunar environment, the interaction of the moon with the solar wind, associated magnetic fields, micrometeorite flux and impact effects.

TECHNOLOGICAL OBJECTIVES

1. Extend knowledge of man's biomedical and behavioral performance in space including physiological responses, man-machine relationships and mobility operations on the lunar surface.

2. Extend lunar orbit and surface staytime for increased ability to conduct observations and experiments.

3. Extend explorations to long-range surface traverses with the capability of geophysical investigations, sample collection and deployment of science stations.

4. Extend operational techniques including manned landing capability to specific points over a significant portion of the lunar surface, astronaut surface rendezvous, and deployment of subsatellites in lunar orbit.

5. Evaluate potential utilization of the lunar surface, resources and environment (e.g., astronomy observatory, research laboratory).

TABLE 1-1. GOALS AND OBJECTIVES IN LUNAR EXPLORATION

2.0 SURFACE SCIENCE

2.1 APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE (ARRAY B)

Purpose

The purpose of ALSEP (Array B) is to obtain scientific data on lunar physical and environmental characteristics and transmit the data to earth. Specifically, ALSEP (Array B) has experiments which will furnish data on:

A. The seismic properties of the moon.

B. The conductive heat distribution of the moon.

C. The properties of the solar wind plasma as it exists at the lunar surface.

D. The pressure of the lunar ionosphere.

Description

The ALSEP to be deployed on the lunar surface by the crew of Apollo 13 will consist of the following subsystems:

A. Electrical Power Subsystem

B. Data Subsystem.

C. Five experiment subsystems.

   1. Passive Seismic

   2. Heat Flow

   3. Charged Particle Lunar Environment

   4. Cold Cathode Ionization Gauge

   5. Dust Detector

The experiment and support subsystems of the ALSEP (Array B) system are mounted in two subpackages as shown in Figure 2.1-1 for storage and transportation in the LM. The fuel cask (part of the electrical power subsystem) is attached to the LM as shown in Figure 2.1-1.

Subpackage No. 1 consists of the central station (data subsystem, power conditioning unit, and experiment electronics and antenna), the charged particle lunar environment experiment (CPLEE), the passive seismic experiment (PSE), heat flow experiment (HFE), and cold cathode ionization guage (CCIG) as shown in Figure 2.1-2. Subpackage No. 2 consists of the radioisotope thermoelectric

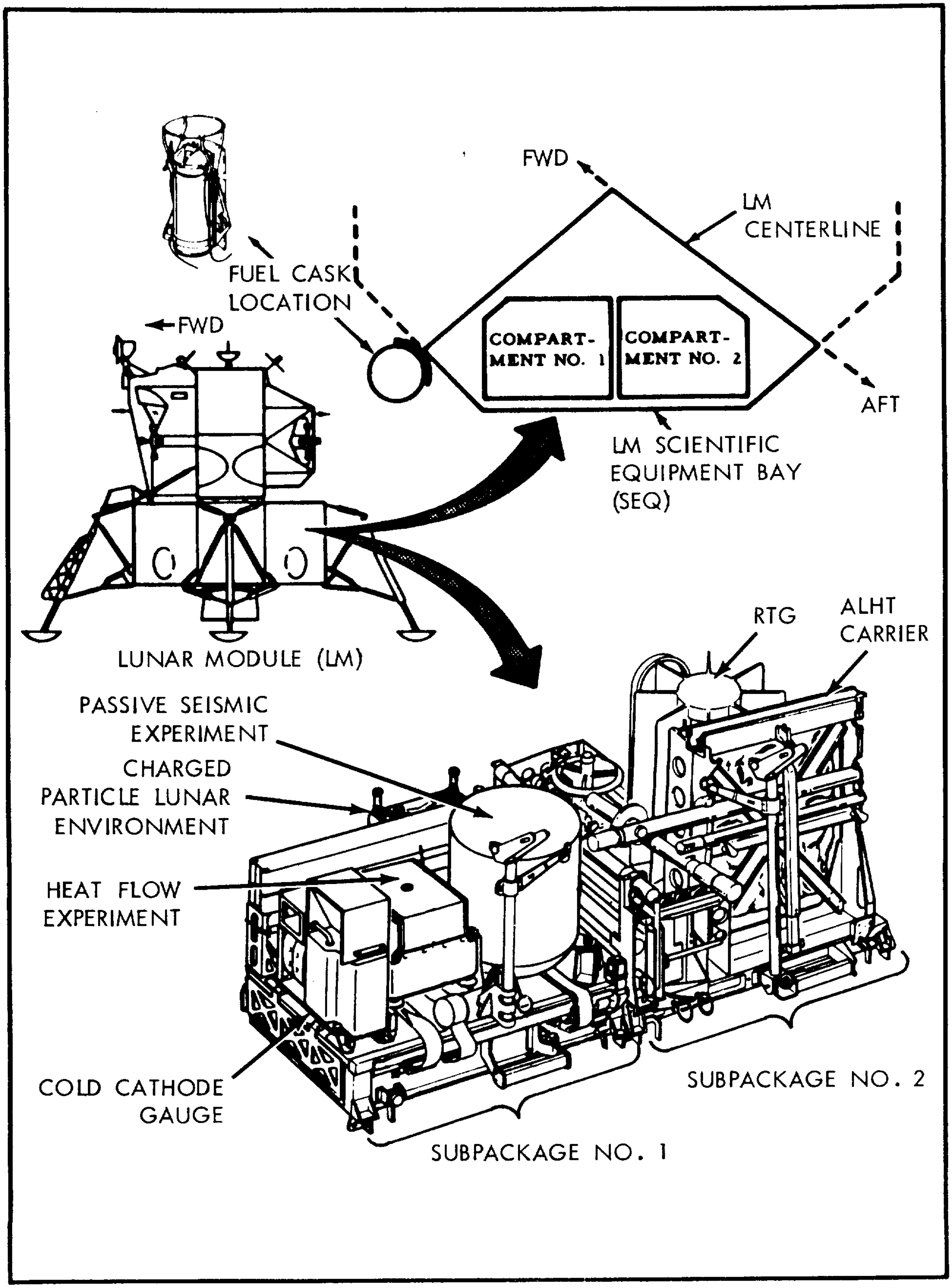


FIGURE 2.1-1 ALSEP STOWED CONFIGURATION

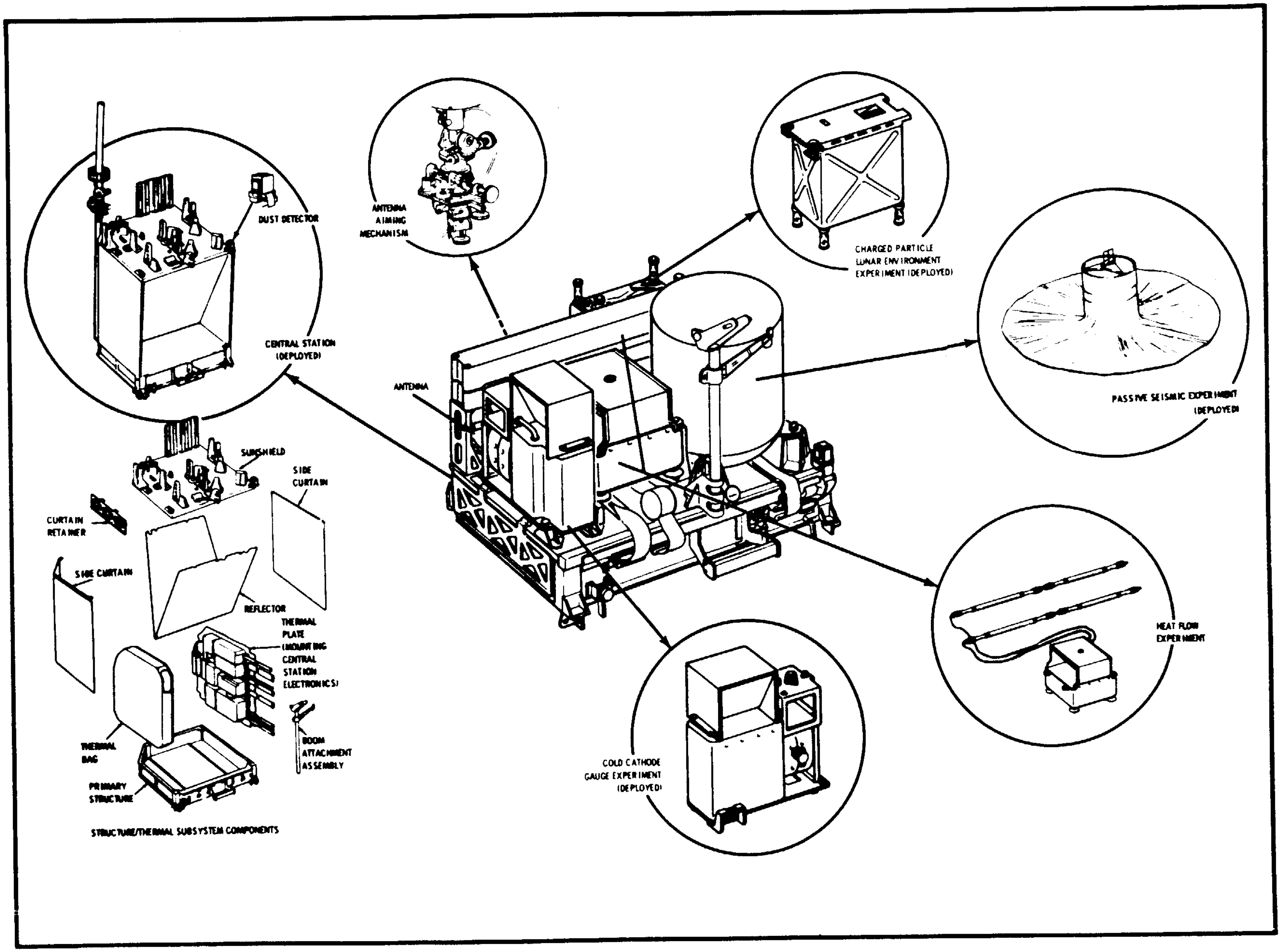


FIGURE 2.1-2 ALSEP SUBPACKAGE NO. 1

generator (RTG), Apollo lunar hand tools (ALHT), Apollo lunar surface drill (ALSD), handling tools, and the antenna mast as shown in Figure 2.1-3.

Obtaining the lunar physical and environmental data is accomplished through the experiments, the supporting subsystems, and the manned space flight network (MSFN) as illustrated in Figure 2.1-4. The mission control center participates in the network for activation of the experiments, initial calibration sequences, and for the duration of the mission. Communications consists of an uplink (earth-moon) for command transmissions to control the ALSEP functions, and a downlink (moon-earth) for scientific experiment and engineering data. Downlink data is recorded by the MSFN stations.

The experiment subsystems perform the scientific measurements of lunar surface and space characterisitcs and supply this information to the central station's data subsystem as digital and analog data for transmittal to earth. The central station also plays a major role in providing control of the ALSEP experiments.

Electrical power for all of the ALSEP subsystems is developed by thermoelectric action with thermal energy supplied by a radioisotope source and is regulated to the required voltage levels for equipment operation.

A structure/thermal subsystem provides structural integrity and thermal protection of the ALSEP equipment and LM in transport and in lunar environment (-300°F to +250°F). This includes packaging, structural support, isolation from heat, cold, shock, and vibration, and the dust detector to monitor lunar dust accumulation.

Figures 2.1-5 through 2.1-7 show the individual subpackages and the barbell carry mode used in deployment of the experiments.

2.1.1 Electrical Power Subsystem

Purpose

The ALSEP electrical power subsystem (EPS) provides the long term, controlled electrical power needed for the operation of the packaged experiments and support subsystems on the lunar surface.

Description

The EPS consists of four principle components as shown in Figure 2.1.1-1; the thermopile, the fuel capsule assembly (FCA), the power conditioning unit and the fuel cask. When assembled together the thermopile and FCA are termed an integrated power unit or radioisotope thermoelectric generator (RTG).

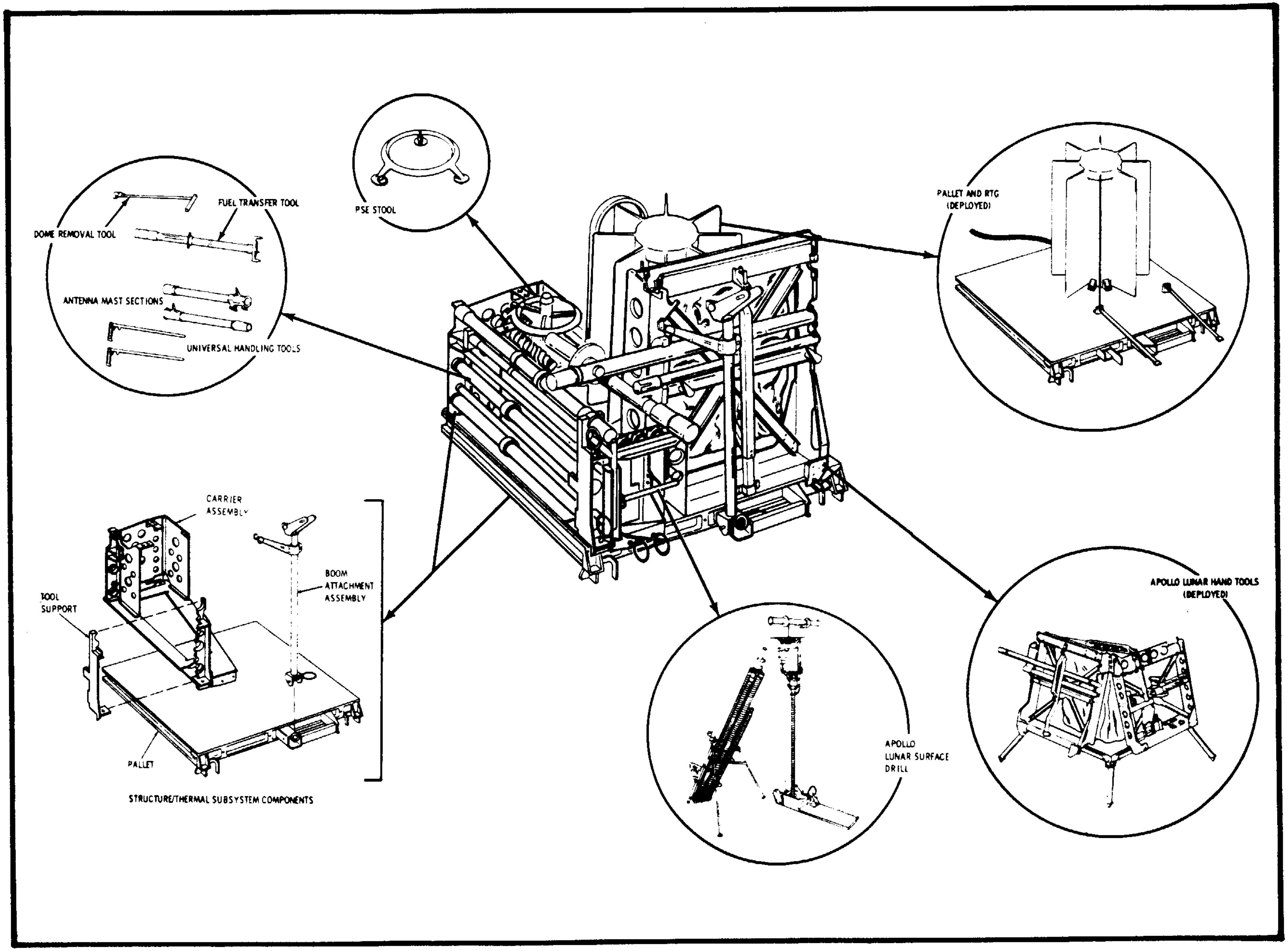


FIGURE 2.1-3 ALSEP SUBPACKAGE NO. 2

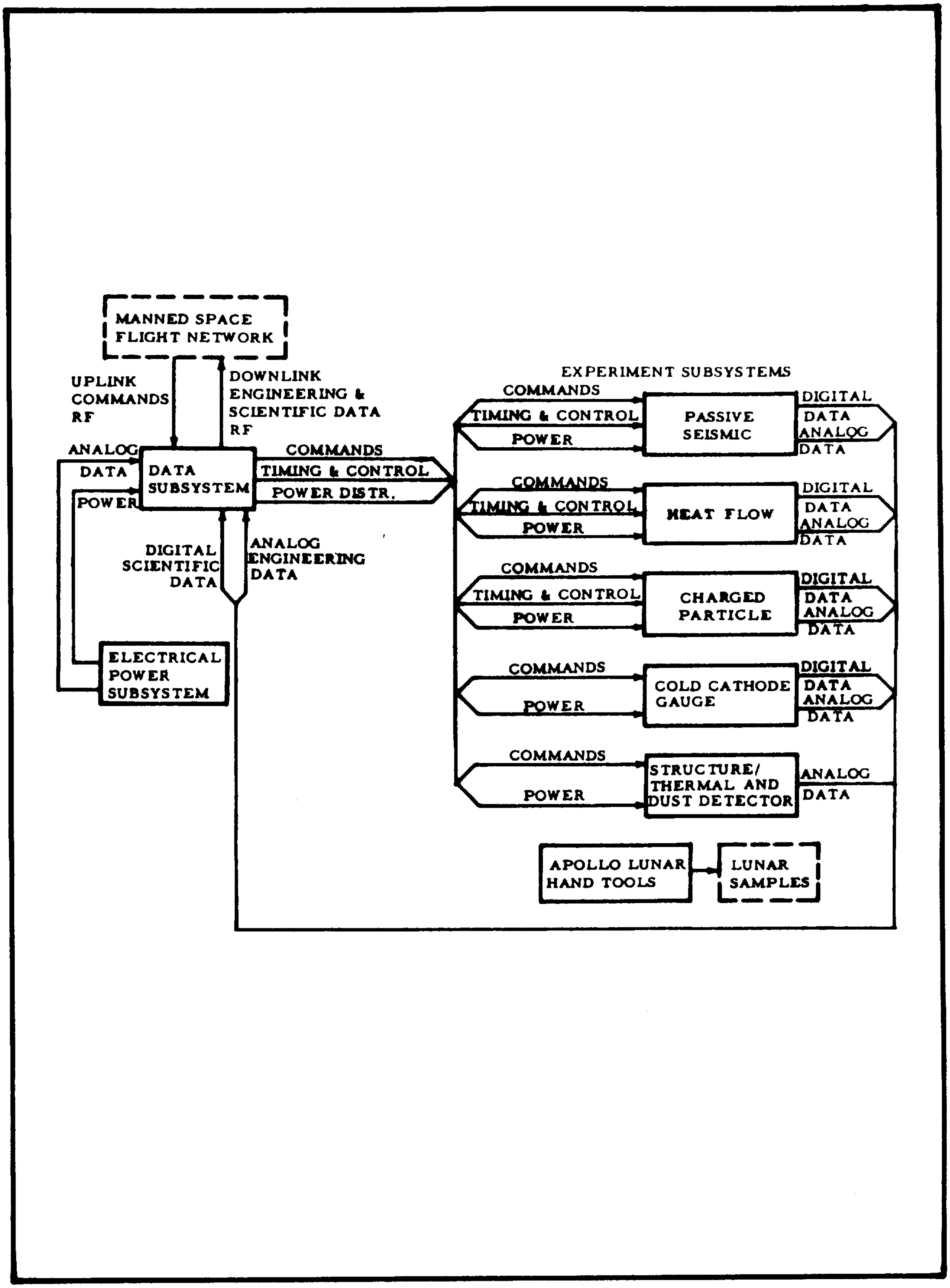


FIGURE 2.1-4 ALSEP (ARRAY B) FUNCTIONAL BLOCK DIAGRAM

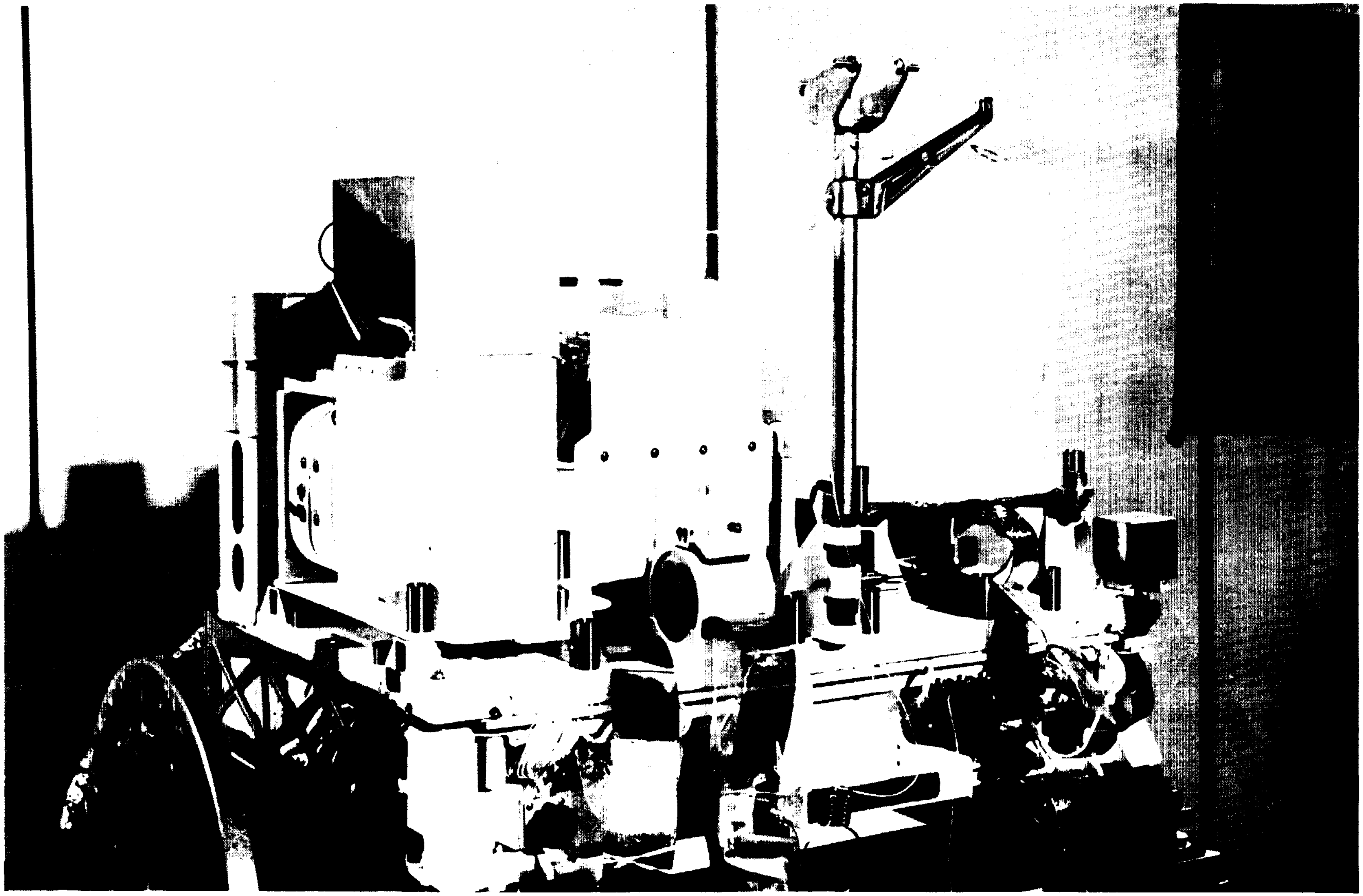


FIGURE 2.1-5 ALSEP (ARRAY B) SUBPACKAGE NO. 1 IN TEST FIXTURE

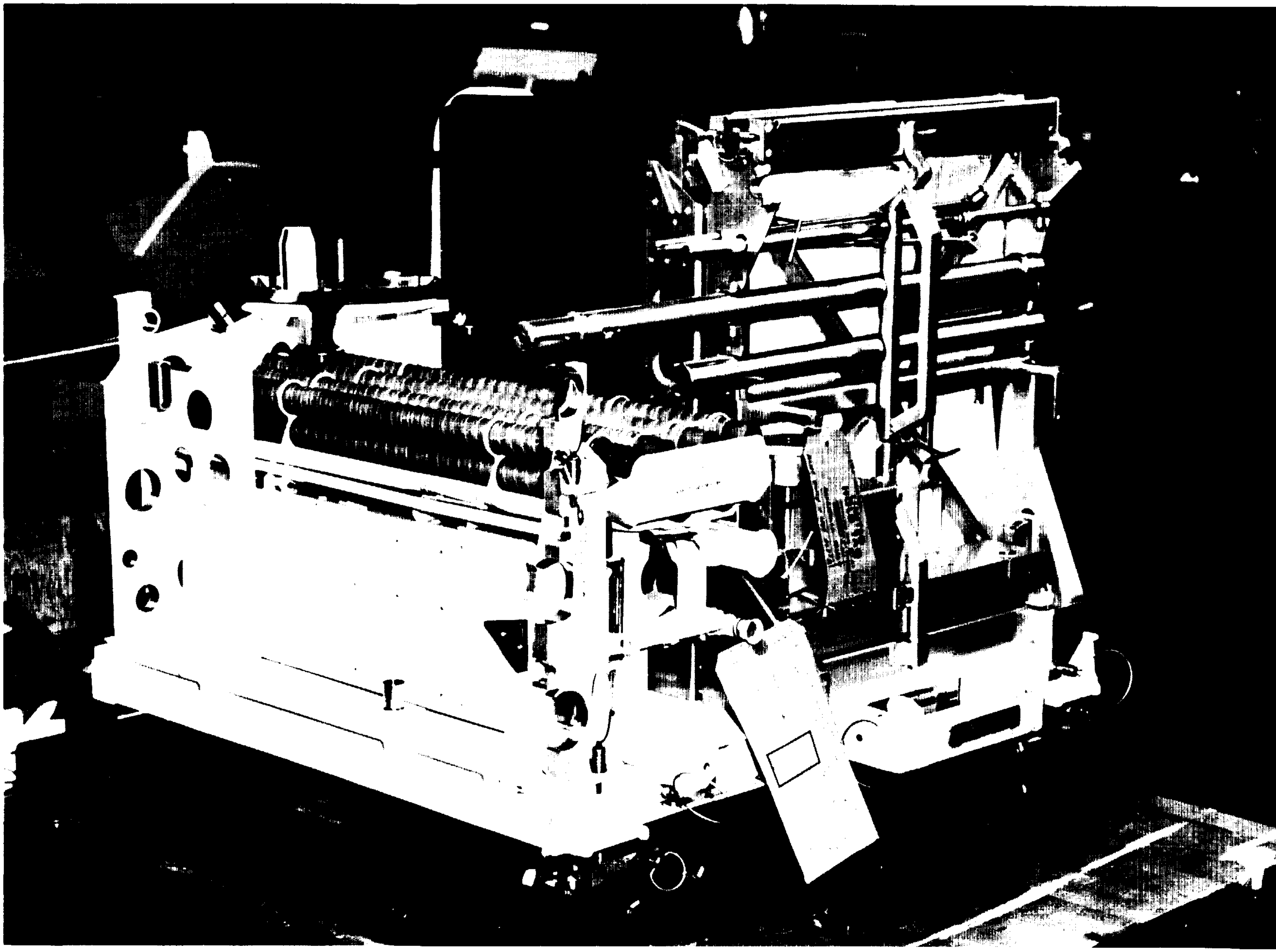


FIGURE 2.1-6 ALSEP (ARRAY B) SUBPACKAGE NO. 2 IN TEST PACKAGE

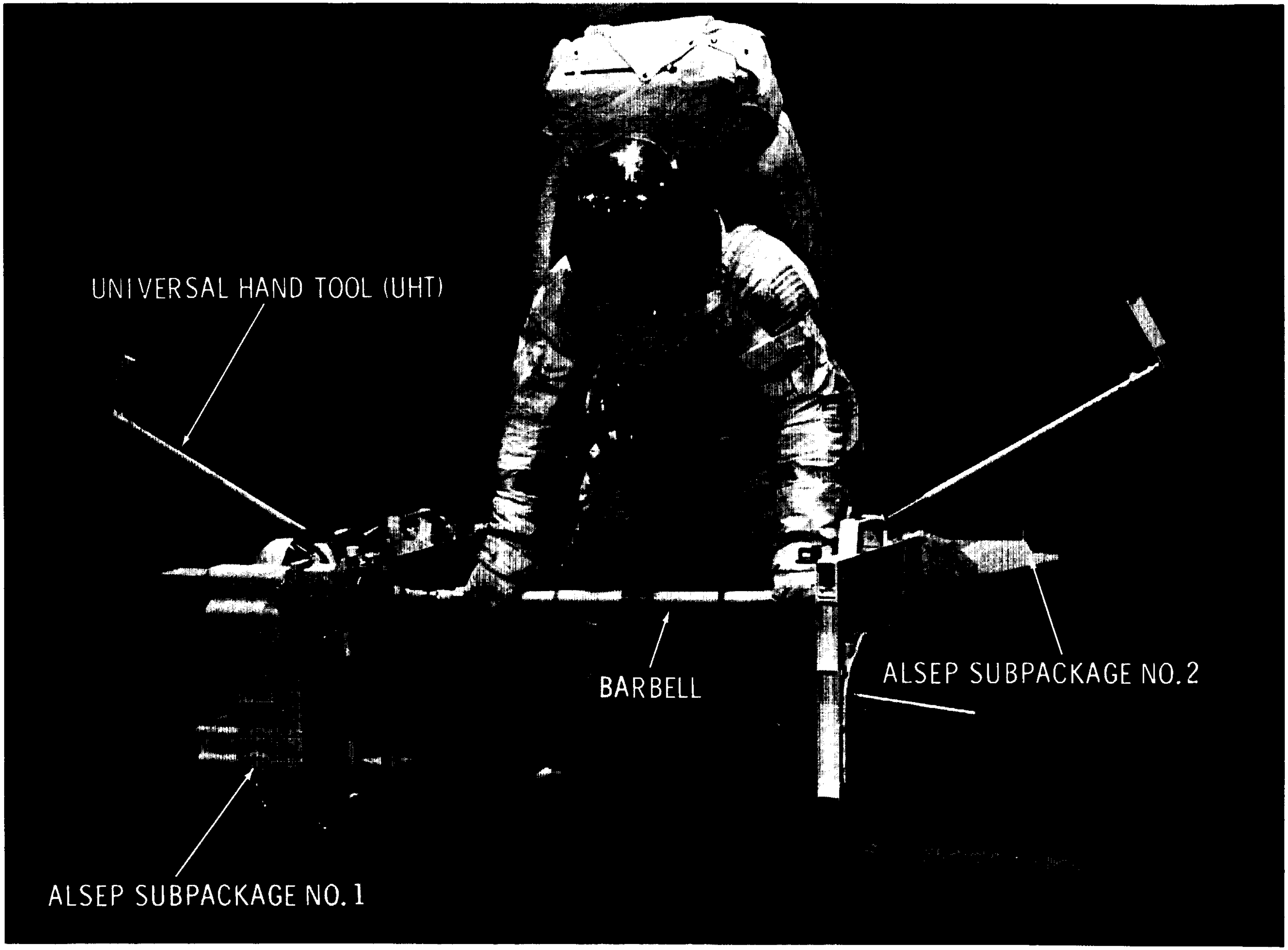


FIGURE 2.1-7 ALSEP ASTRONAUT DEPLOYMENT MODE

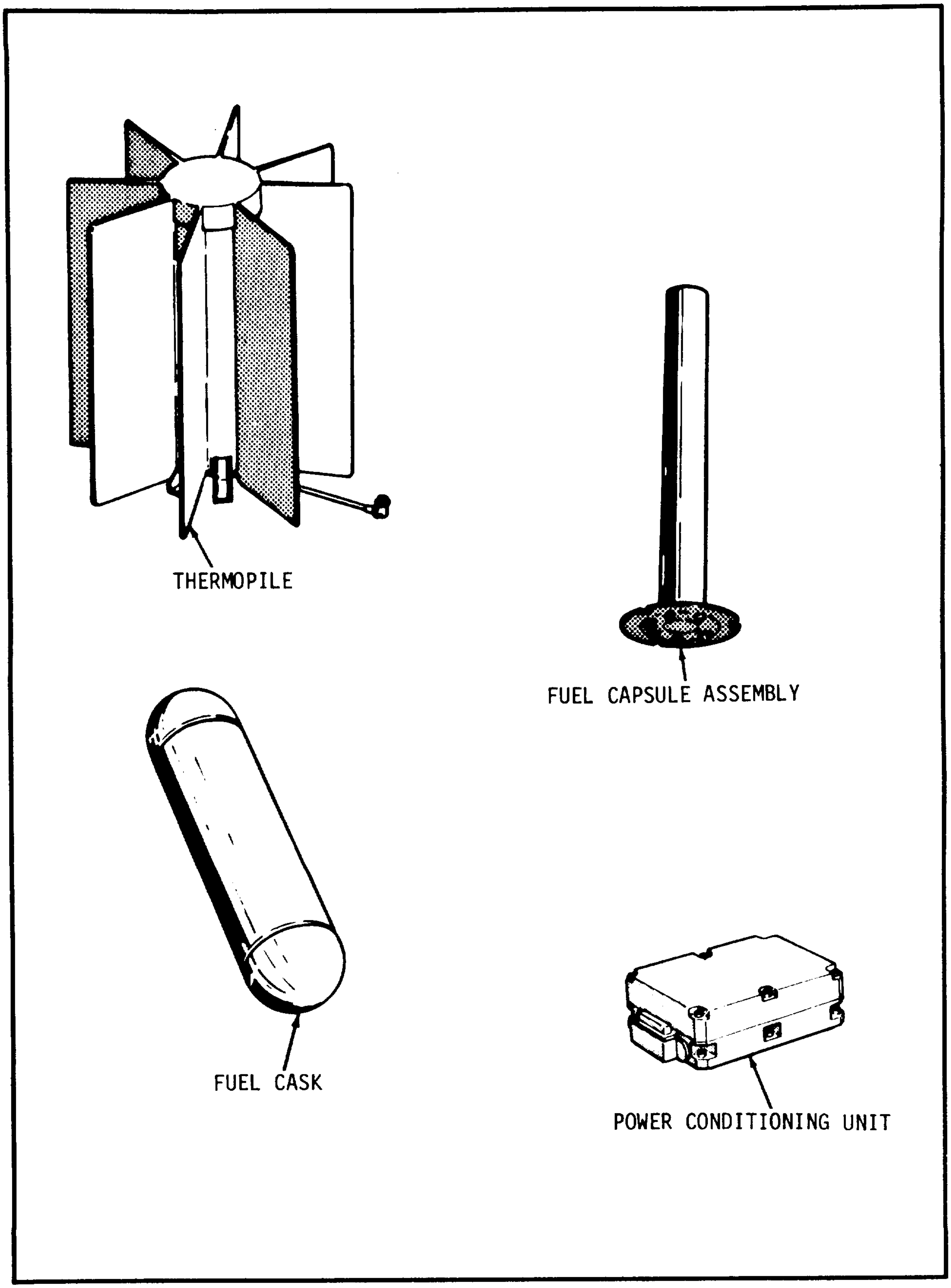


FIGURE 2.1.1-1. ELECTRICAL POWER SUBSYSTEM

The RTG as shown in Figure 2.1.1-2 is a fixed thermopile sandwiched between cylindrical hot and cold junction frames. The hot junction frame surrounds a central cavity which contains the FCA. The cold junction frame butts against a finned, external cylindrical beryllium radiator closed at one end and properly sized to reject uncoverted thermal energy to the environment. The FCA, containing a constant thermal source (Pu 238), incorporates an end plate for RTG closure. Degaussing loops are provided to minimize the magnetic field interference.

The EPS power conditioning unit (PCU) consists of redundant DC voltage converters and shunt regulators, common filters, and two command control amplifiers located in the ALSEP central station.

The fuel cask as shown in Figure 2.1.1-3 is used to transport the fuel capsule assembly from the earth to the moon. The fuel cask is a cylindrical shaped structure with a screw-on end cover at the top end. The cask provides fuel capsule support elements and a free radiation surface for rejection of fuel capsule heat. The fuel cask provides re-entry protection in case of an aborted mission.

EPS handling tools are provided to remove the FCA from the fuel cask and install the FCA in the thermopile-radiator assembly, and deploy the electrical power subsystem. These tools are shown in Figure 2.1-3.

A functional block diagram for the EPS is shown in Figure 2.1.1-4. The radioisotope source developes thermal energy that is applied to the hot frame. The difference in temperature between the hot frame and the cold frame causes the thermopile to develop electrical energy through thermoelectric action. A minimum power of 63 watts at 16 volts is produced for application to the power conditioning unit. The power conditioning unit contains redundant power conditioners. Each power conditioner consists of a dc-to-dc power converter which converts the positive 16 volts input to the six ALSEP required operating voltages, and a shunt voltage regulator which maintains the output voltages within one percent.

Technical Data - Electrical Power Subsystem

	RTG	FCA	PCU	Fuel Cask
Size(in.)	16dia.X18.1	2.6dia. X 16.9	8.3 X 4.1 X 2.9	8.0dia. X23
Weight (lbs.)	28	15.4	4.5	25

Overall Efficiency 4% (approx.)

Fuel Capsule Temperature 1390°F (max.)

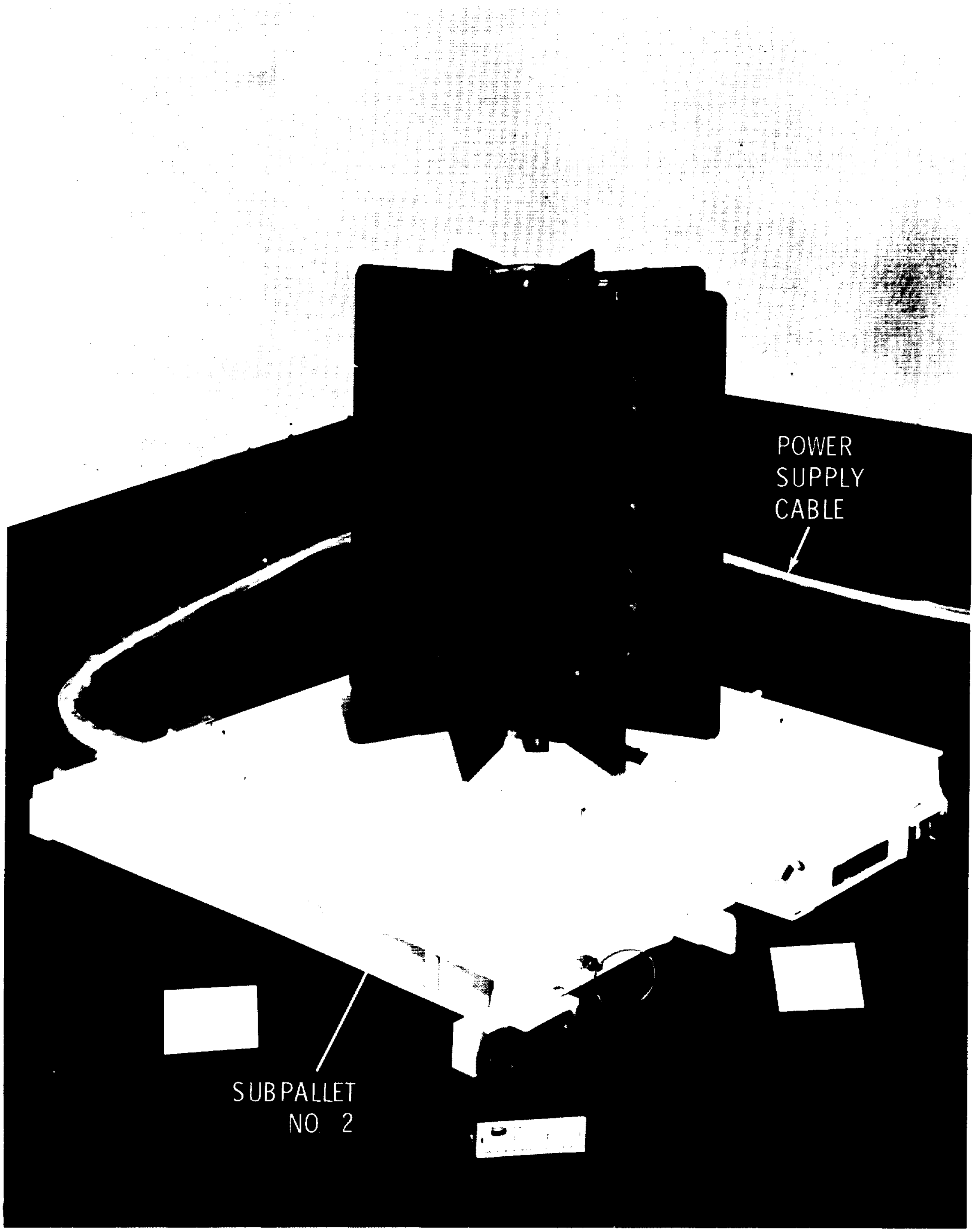


FIGURE 2.1.1-2 APOLLO 13 RTG (UNFUELED)

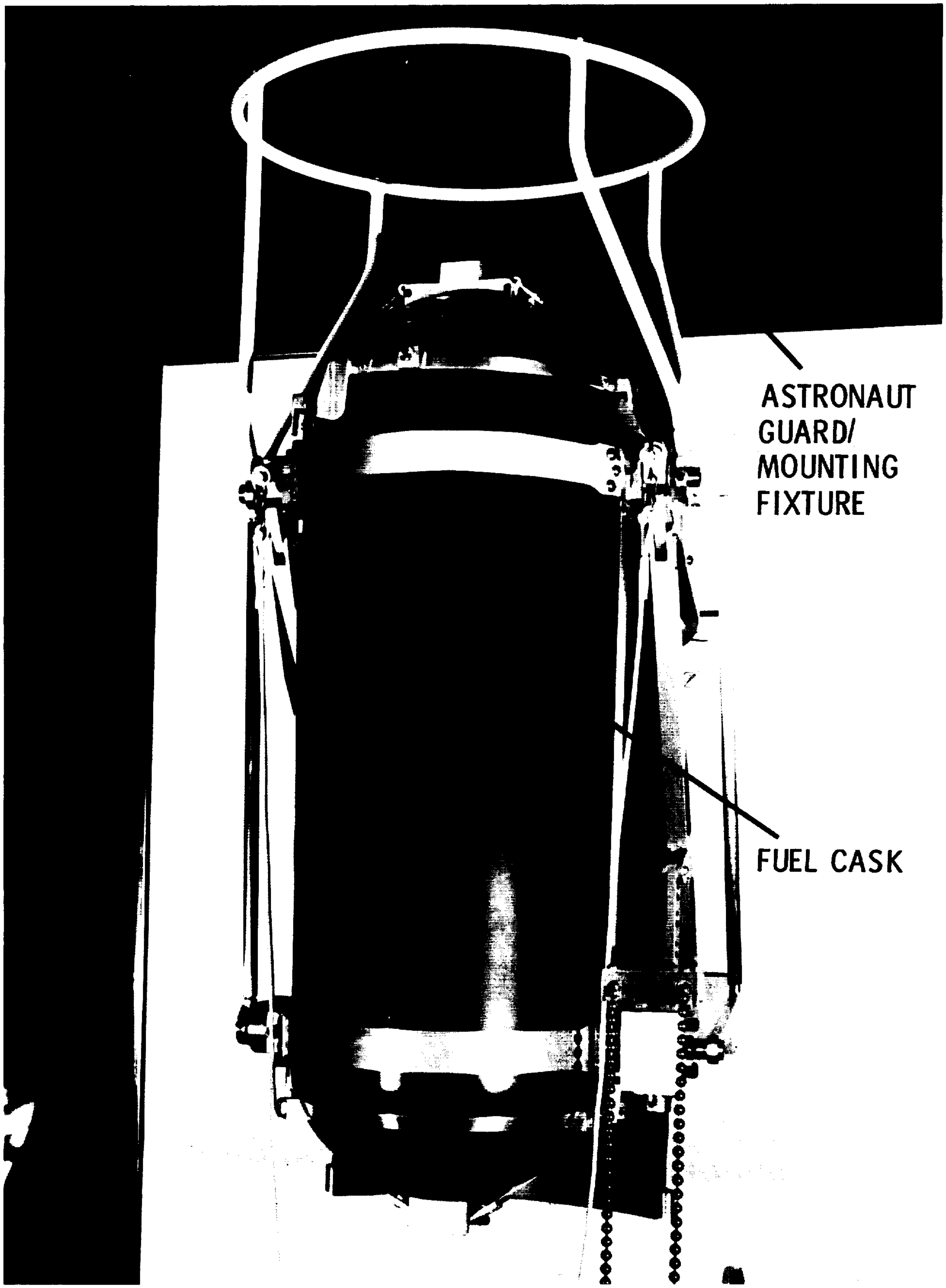


FIGURE 2.1.1-3 APOLLO 13 FUEL CASK AND MOUNTING FIXTURE

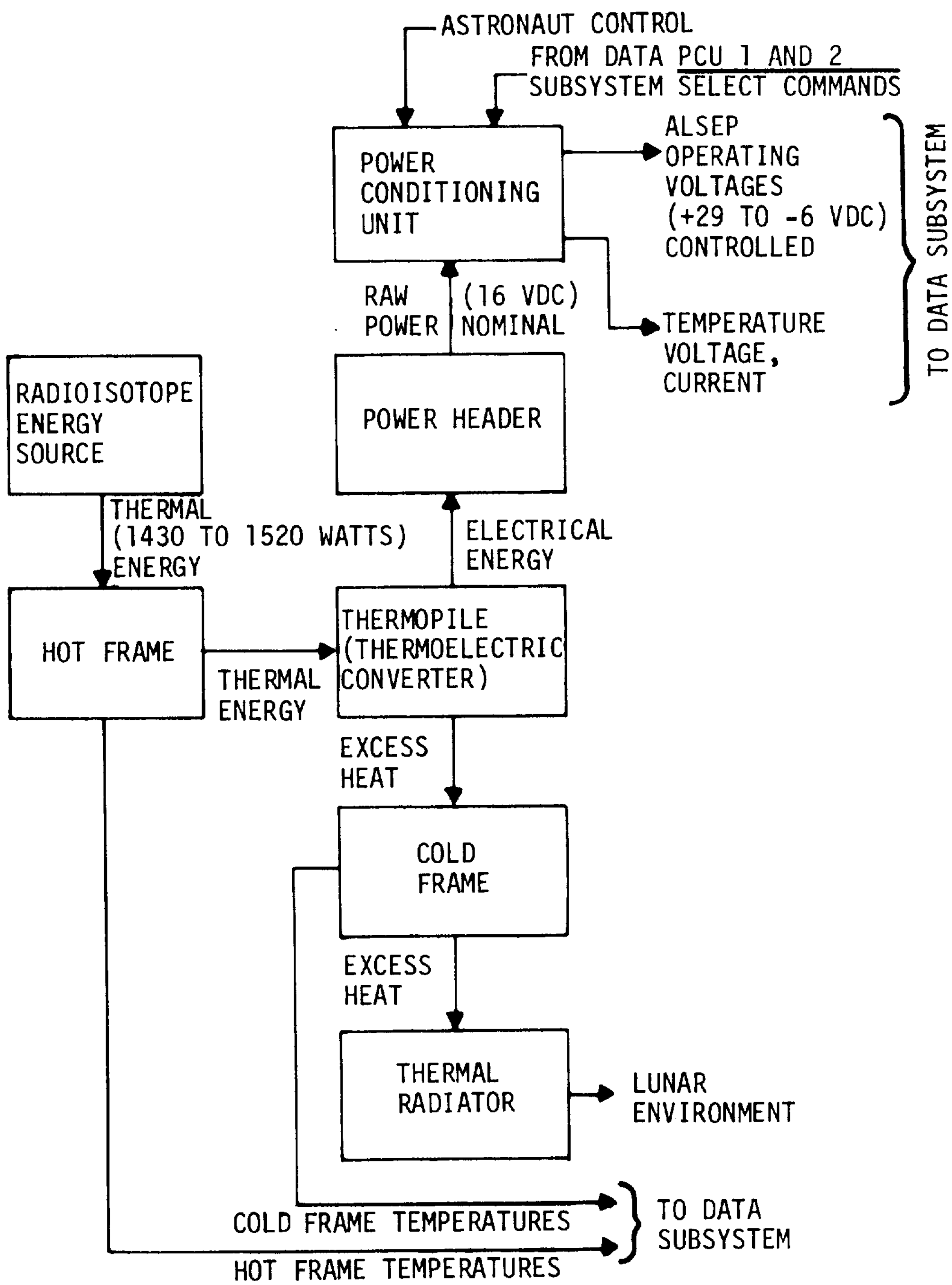


FIGURE 2.1.1-4 EPS-POWER GENERATOR FUNCTIONAL BLOCK DIAGRAM

Technical Data - Electrical Power Subsystem (Continued)

Measurements	Range	Accuracy	Samples per Second
Structural/ Thermal Temperatures	-300°F to +300°F	+15°F	.0185
	-50°F to +200°F	±10°F	.0185
RTG Temperatures			
Hot Frame 1, 2, & 3	950°F to 1150°F	± 5°F	.0185
Cold Frame 1, 2, & 3	400°F to 600°F	± 5°F	.0185

	Subpackage No. 2 Structure
Size (in,)	25.9 X 27.1 X 3.4
Weight (lbs.)	25.2

2.1.2 Data Subsystem

Purpose

The data subsystem is the focal point for control of ALSEP experiments and the collection, processing and transmission of all data (scientific and engineering) to the MSFN. The location of the sybsystem is shown in Figure 2.1.2-1. The data handling system accomplishes three basic functions:

A. Reception and decoding of uplink (earth-to-moon) commands,

B. Timing and control of experiment subsystems,

C. Collection and transmission of downlink (moon-to-earth) scientific and engineering data.

Description

The data subsystem components and their functions are listed below:

Component	Function
Antenna	Provides simultaneous uplink reception and downlink transmission of ALSEP signals.
Diplexer switch	Connects either of two transmitters to the antenna.

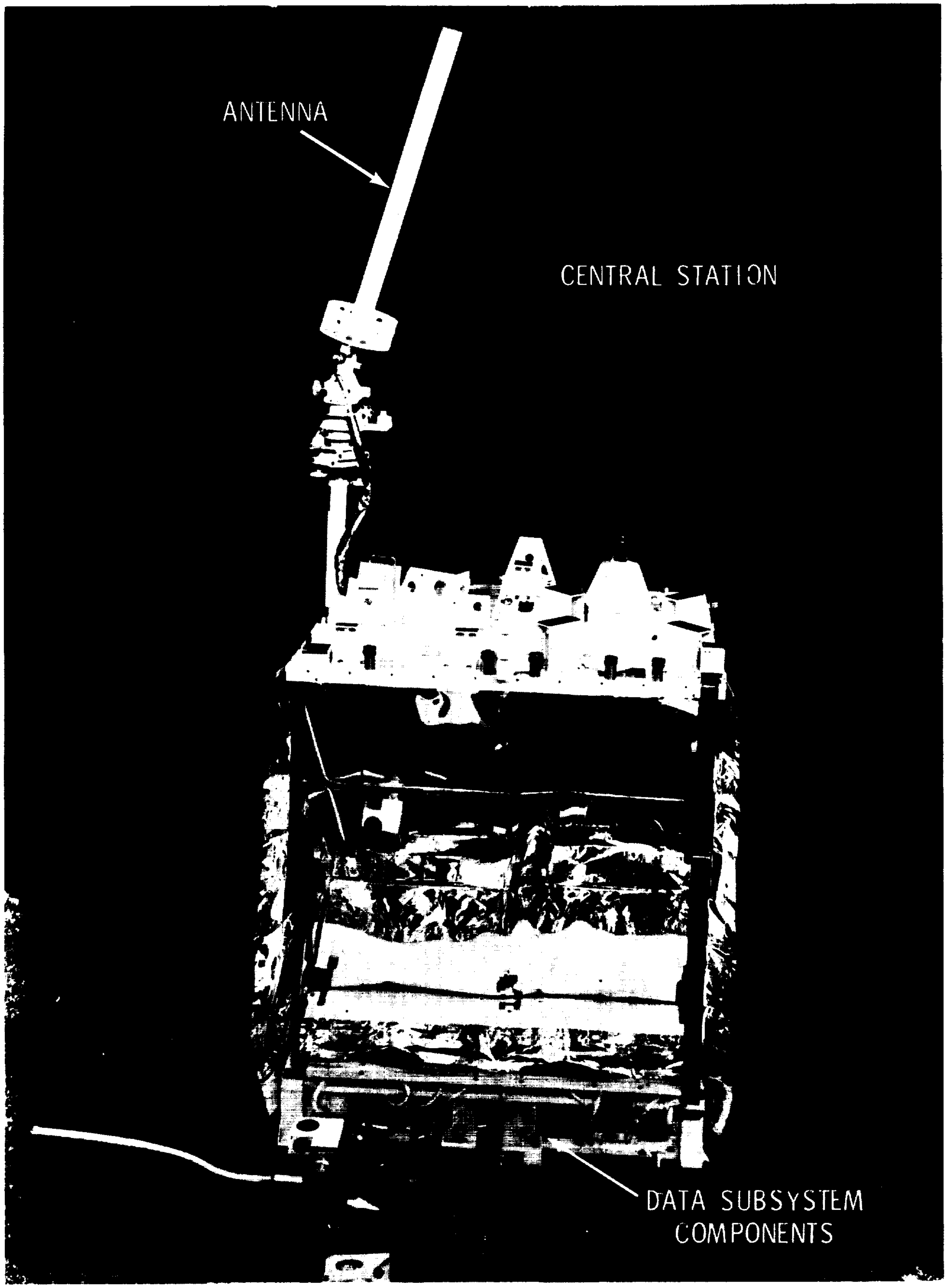


FIGURE 2.1.2-1. DATA SUBSYSTEM LOCATION

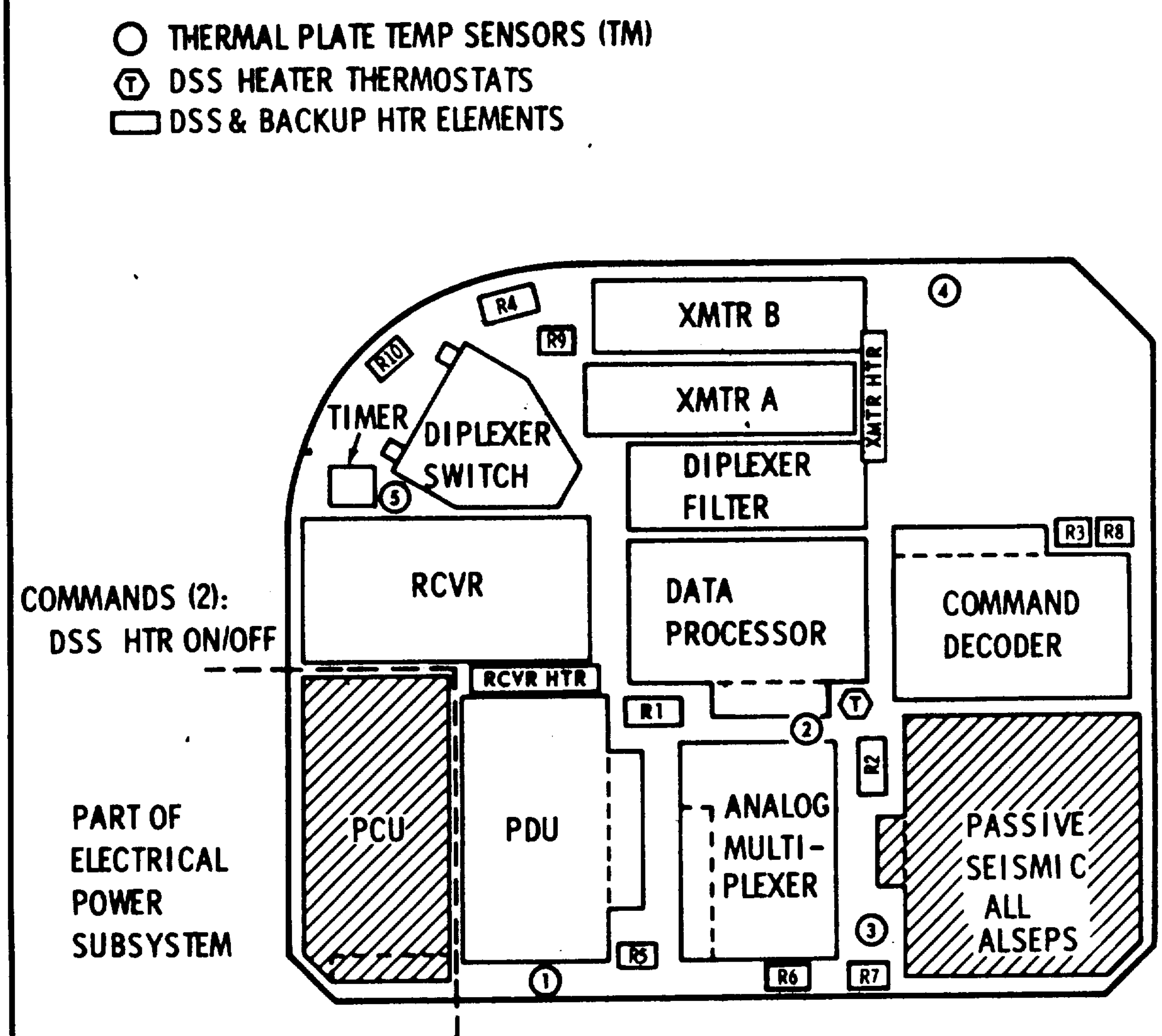
Component	Function
Diplexer filter	Connects receiver input and transmitter output to the antenna.
Transmitter	Transmits moon-to-earth downlink signals.
Command receiver	Accepts earth-to-moon uplink signal.
Command decoder	Decodes received command signals and issues commands to the system.
Central station timer	Provides backup timing signals following departure of astronauts (switch off after 720 $\pm$30 days).
Data processor	Collects and formats digital data inputs from the experiments. Collects and converts analog data into binary form.
Power distribution	Controls power switching and conditions engineering status data.

The data subsystem components are contained in a 23 X 20 X 7 inch package mounted on the central station thermal plate and weigh 25 pounds. The general arrangement, along with the PCU and passive seismic experiment electronics, is shown in Figure 2.1.2-2. A preformed harness electrically connects each component. 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.

As shown in the functional block diagram, Figure 2.1.2-3, the data subsystem is divided into two specific functions, uplink and downlink data transmission.

A. Uplink command data 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 as discrete commands. The discrete commands control experiment operation and initiate command verification functions.

B. 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.



KEY:
RCVR - RECEIVER
PDU - POWER DISTRIBUTION UNIT
PCU - POWER CONDITIONING UNIT
DSS - DATA SUBSYSTEM
HTR - HEATER
XMTR - TRANSMITTER

FIGURE 2.1.2-2 DATA SUBSYSTEM COMPONENTS

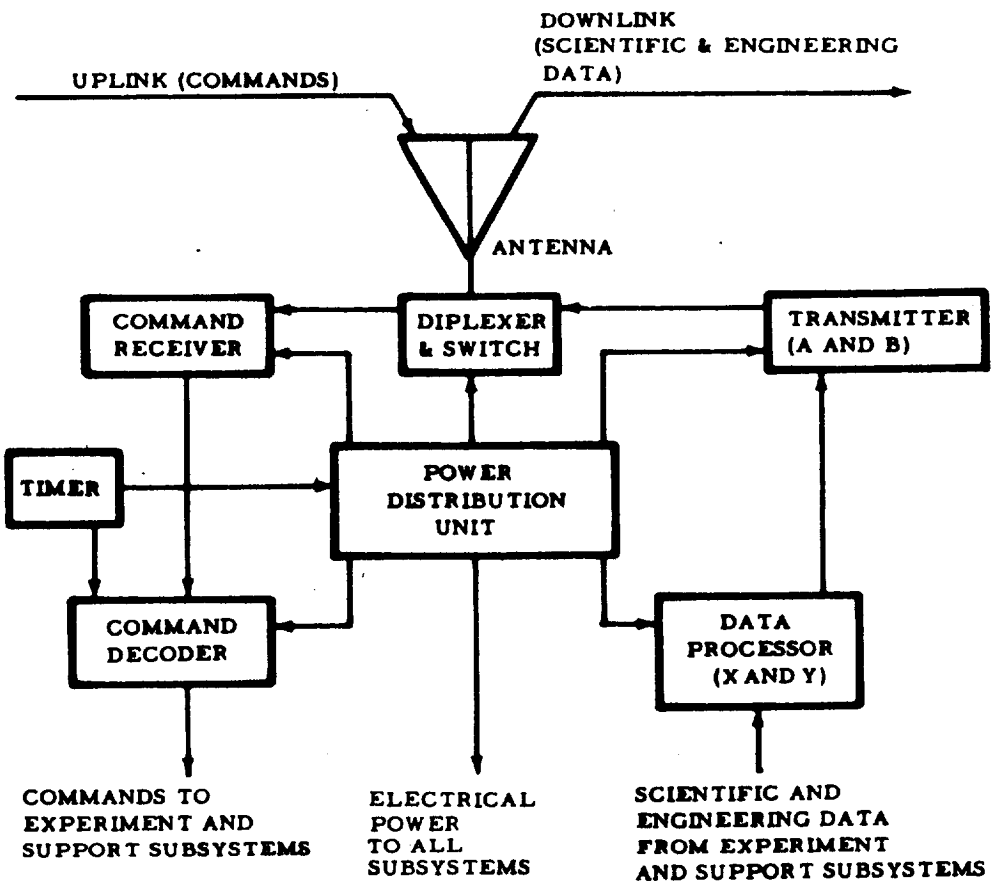


FIGURE 2.1.2-3. DATA SUBSYSTEM FUNCTIONAL BLOCK DIAGRAM

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 temperature and voltages)which reflect operational status and environmental parameters. The data processor accepts binary and analog data from the experiment and support subsystems, 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 the 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.

Technical Data - Data Subsystem

Power Consumption 20 W. (approx.)

Measurements	Range	Accuracy	Samples per Second
Electronic Temperatures	-50 to +200°F	±10°F	.0185
Central Station Electrical			
Converter Input Voltage	0 to 20 VDC	± 2%	.0185
Converter Input Current	0 to 5 ADC	± 2%	.0185
Shunt Reg #1 Current	0 to 3.5 ADC	± 2%	.0185
Shunt Reg #2 Current	0 to 3.5 ADC	± 2%	.0185
PCU Output Voltage #1 (29V)	0 to 35 VDC	± 2%	.0185
PCU Output Voltage #2 (15V)	0 to 18 VDC	± 2%	.0185
PCU Output Voltage #3 (12V)	0 to 15 VDC	± 2%	.0185
PCU Output Voltage #4 (5V)	0 to 6 VDC	± 2%	.0185
PCU Output Valtage #5 (-12V)	0 to -15 VDC	± 2%	.0185

Technical Data - Data Subsystem (Continued)

Measurements	Range	Accuracy	Samples per Second
PCU Output Voltage #6 (-6V)	0 to -7.5 VDC	± 2%	.0185
RCVR., Pre-Limiting Level	-101 to -61 DB	± 1DB	.0185
RCVR., Local OSC Level	0 to 10 DB	± 0.5 DB	.0185
Trans. A., AGC Voltage	0 to 5 V	± 5%	.0185
Trans., B., AGC Voltage	0 to 5 V	± 5%	.0185
Trans. A, DC, Power Doubler	100 to 240 ma	± 5%	.0185
Trans, B, DC, Power Doubler	100 to 240 ma	± 5	.0185

Subpackage No. 1
Structure

Size (in.)	26.8 X 27.4 X 6.9
Weight (lbs.)	24.9

2.1.3 Passive Seismic Experiment (S-031)

Objective

The objective of the Passive Seismic Experiment (PSE) is to monitor seismic activity and detect meteoroid impacts, free oscillations of the moon, surface tilt (tidal deformations) and changes in the vertical component of gravitational acceleration. The Apollo 13 PSE will be the third unit to be deployed as part of a planned network to determine seismic activity on the lunar surface.

Significance

Analysis of the velocity, frequency, amplitude, and attenuation characteristics of the seismic waves will provide data on the number and character of lunar seismic events, the approximate azimuth and distance to their epicenters, the physical properties of subsurface materials, and the general structure of the lunar interior. Measurements of surface tilt and vertical acceleration will provide information on variations in the strength and direction of external gravitational fields acting upon the moon.

Operational Concept

The PSE consists of a sensor assembly in a cylindrical housing and associated electronics which are located in the central station. The sensor assembly is made up of three long period (LP) seismometers in an orthogonal arrangement and one vertical component short period (SP) seismometer. Figure 2.1.3-1 shows details of the instrument: spring, mass and boom system for the long period vertical and two horizontal seismometers. The seismometer measures by recording relative motion between two points. The body of the instrument encloses a weight suspended on a very flexible hinge. The seismometer will move with the ground while the suspended weight inside tends to remain immobile. The sensors in the horizontal plane 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 serving its primary function of detecting displacement in the vertical axis.

Functional Description

As shown in the functional block diagram, Figure 2.1.3-2, the Passive Seismic Experiment instrumentation is functionally divided into three LP seismic data channels, three tidal data channels, one SP seismic data channel, and a temperature monitoring channel.

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

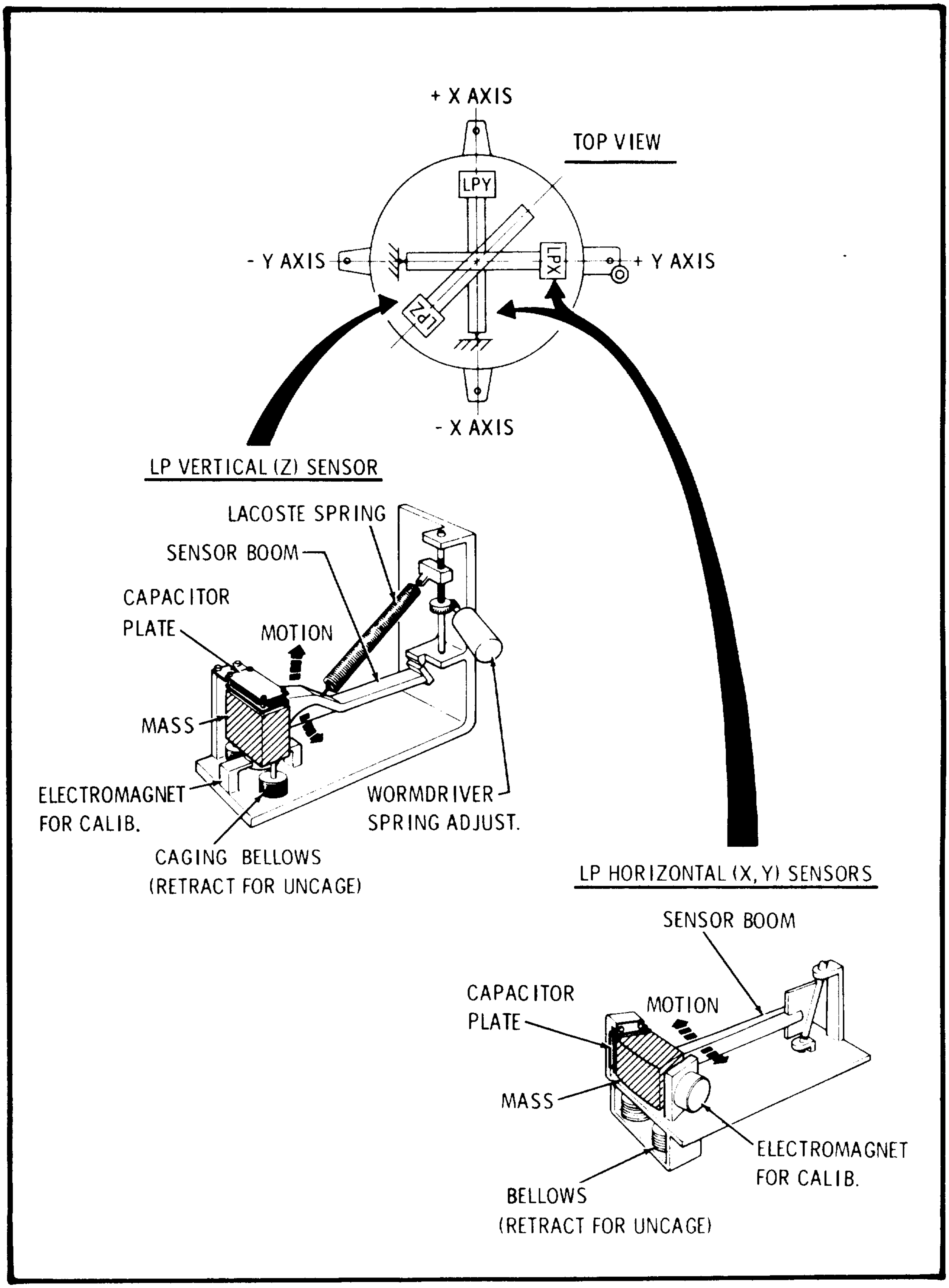


FIGURE 2.1.3-1 PASSIVE SEISMIC MEASUREMENT CONCEPT

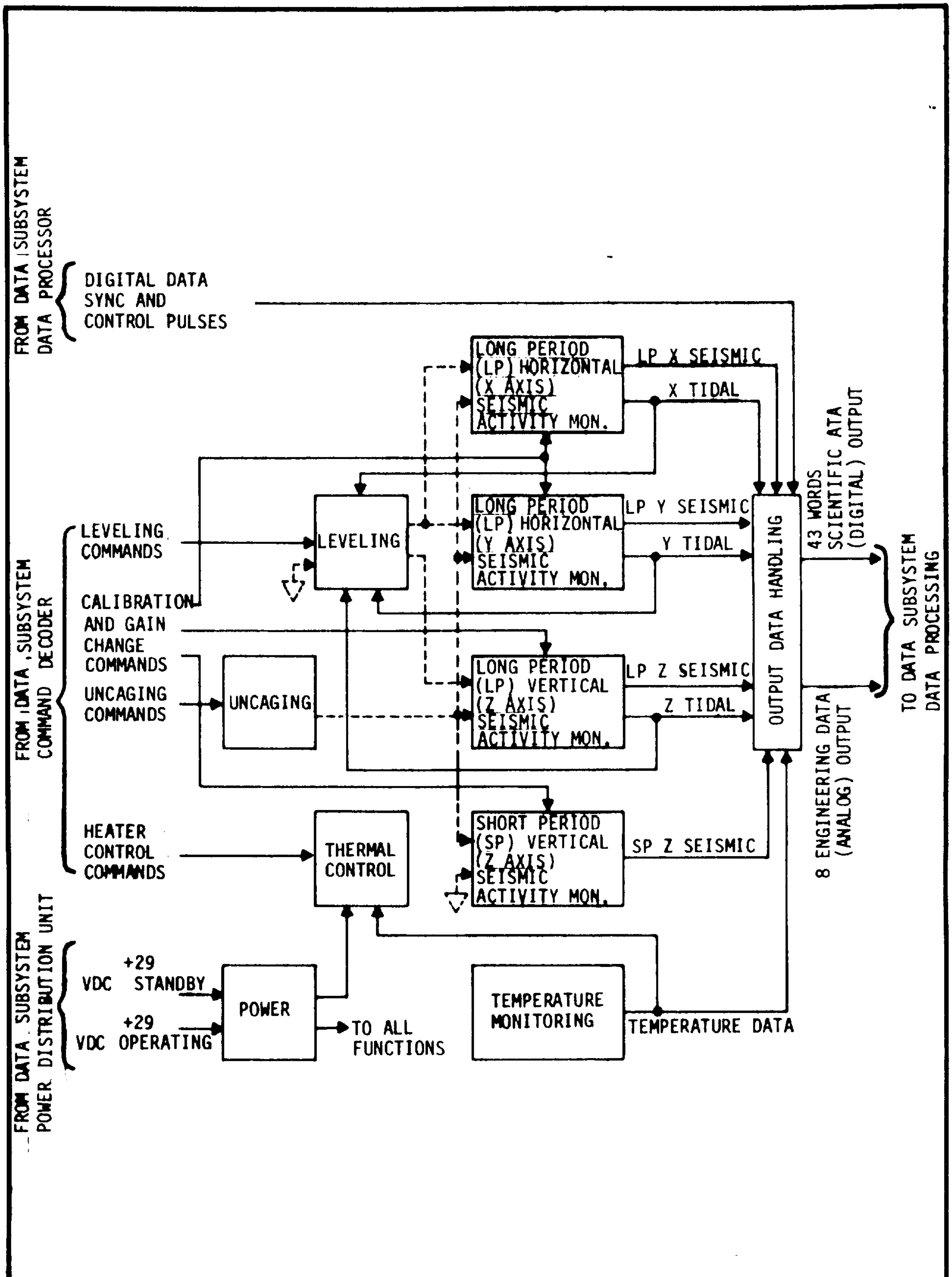


FIGURE 2.1.3-2 PSE FUNCTIONAL BLOCK DIAGRAM

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. The tidal output in the LP vertical axis is proportional to the change in the lunar gravitional acceleration as determined by that axis. The SP seismometer yields a seismic output proportional to velocity motion in the vertical axis of the instrument. The LP seismic outputs are produced by amplifying and filtering the phase referenced output signals of the capacitance type sensors. Very low frequency filtering of these signals produces the tidal components. The SP seismic output is produced similarly except that a coil-magnet type sensor is used.

The response of the LP sensors varies with temperature making thermal control important, particularly for tidal data outputs. The PSE has an active thermal control system capable of applying heat as required to maintain a nominal temperature of 125° F. The temperature monitoring channel output signal is obtained from a thermistor bridge circuit balanced at 125° F and sensitive to changes as small as 0.2° F. A thermal shroud encases the PSE and extends to a diameter of 5 feet around the experiment to aid in thermal stabilization of the sensor assembly. The passive seismic experiment and its components are shown in Figures 2.1.3-3 and 2.1.3-4.

Technical Data - Passive Seismic Experiment

Principal Investigator: Dr. Gary Latham, Lamont Geological Observatory

	Short Period Instrument	Long Period Instrument
Minimum Detectable Amplitude	0.3 millimicron	0.3 millimicron
Natural Period	0.5 to 1.0 sec.	15 seconds
Band Pass	0.05 to 20 Hz	0.004 to 3 Hz
Acceleration		8 microgals
Dynamic Range	80 db	80 db

Weight: 25 lbs.

Size : 11.75" dia. X 15.25" (sensor + stool)

Power : 7.0 W.max. oper., 12.3 W. peak

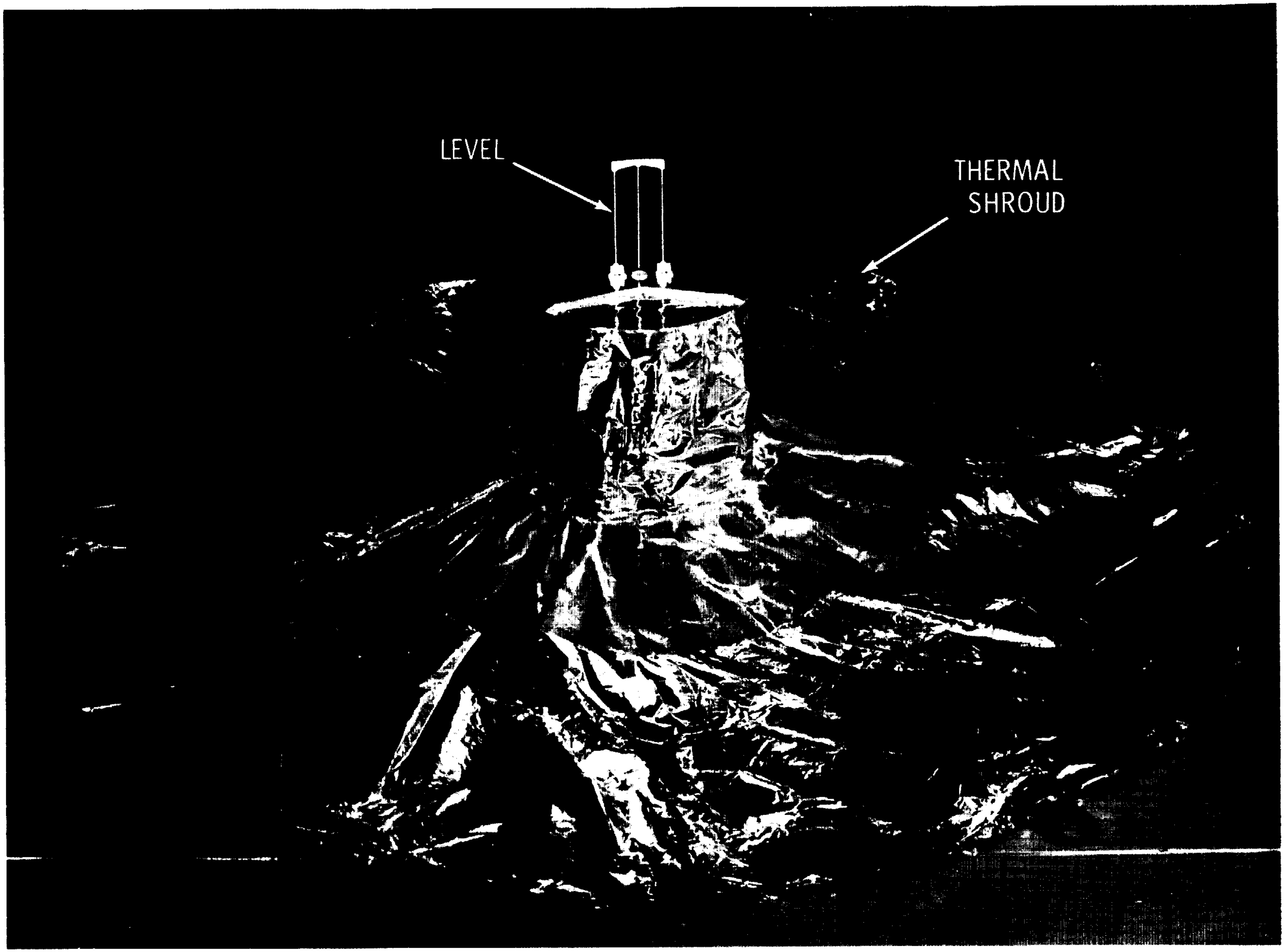


FIGURE 2.1.3-3 APOLLO 13 PASSIVE SEISMIC EXPERIMENT DEPLOYED

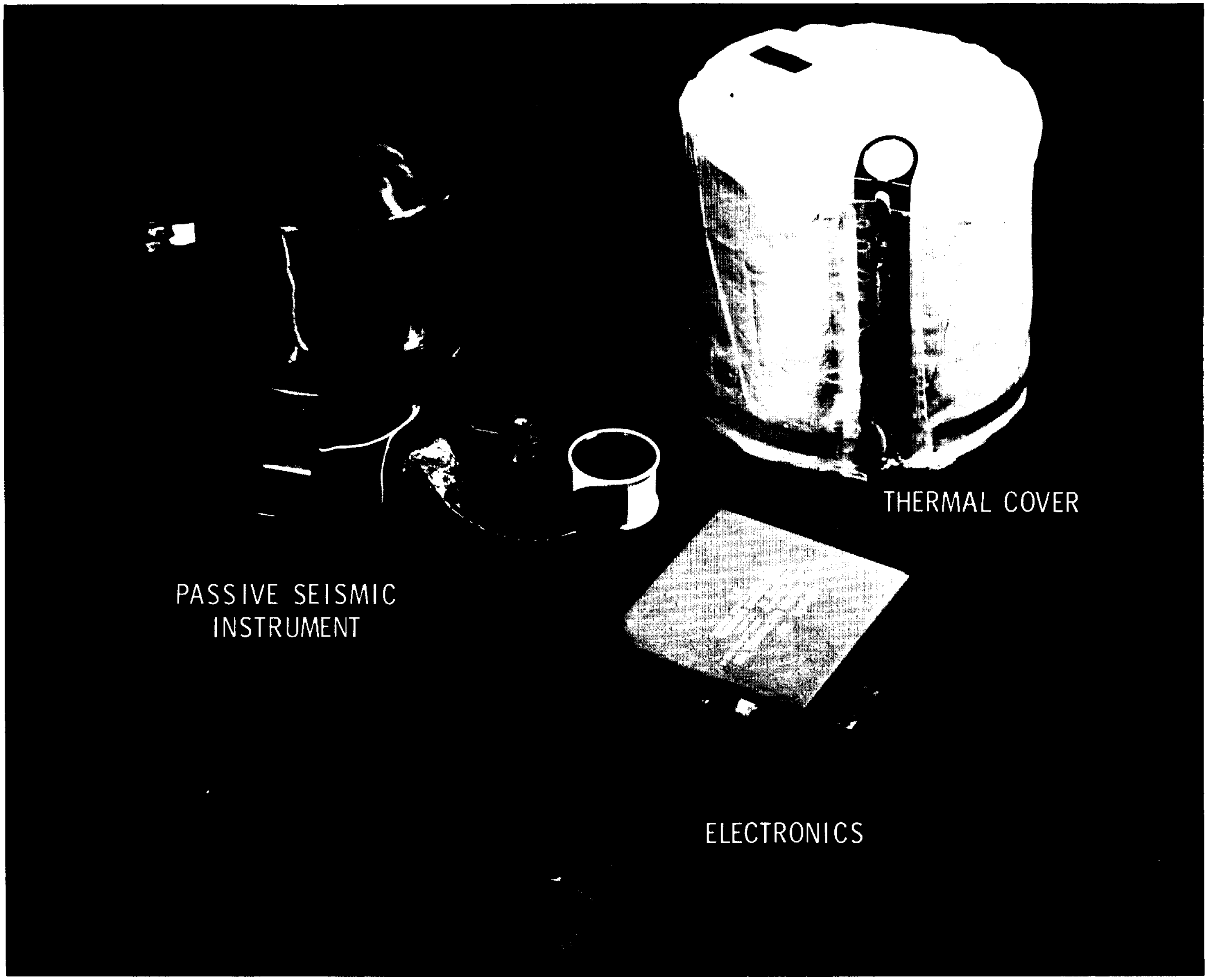


FIGURE 2.1.3-4 APOLLO 13 PASSIVE SEISMIC EXPERIMENT COMPONENTS

Technical Data - Passive Seismic Experiment (Continued)

Scientific Measurements:

	Sensor Range	Sensor Accuracy	Sample per Second
Short Period Seismic Z	0.3mμ to 10μ	5%	48.0
Long Period Seismic X	0.3mμ to 10μ	5%	6.625
Long Period Seismic Y	0.3mμ to 10μ	5%	6.625
Long Period Seismic Z	0.3mμ to 10μ	5%	6.625
Tidal X	.01 to 10"(arc)	5%	0.85
Tidal Y	.01 to 10"(arc)	5%	0.85
Tidal Z	8μgal to 8mgal	5%	0.85
Sensor Unit Temperature	107 - 143°F	±1%	0.85

2.1.4 Heat Flow Experiment (S-037)

Objective

The objective of the Heat Flow Experiment (HFE) is to gain knowledge of the lunar heat flux to provide information on:

1. A lunar temperature versus depth profile.
2. A comparison of the radioactive content of the moon's interior and the earth's mantle.
3. A thermal history of the moon.
4. The value of thermal parameters in the first three meters of the moon's crust.

This will represent the first use of the Heat Flow Experiment on an Apollo Mission.

Significance

This experiment measures the lunar temperature profile and moon's thermal conductivity. This will provide information regarding the net outward flux of heat from the moon's interior and the radioactive content of the moon's interior when compared to that of the earth's mantle. It will also provide data from which it will be possible to reconstruct the temperature profile of the subsurface layers of the moon and to determine whether the melting point may be approached toward its interior. A similarity between earth and moon heat flow measurements would provide strong evidence for concluding that a compositional similarity exists between the moon and the earth.

Operational Concept

The Heat Flow Experiment utilizes two-section probes with heat sensors and a heater at each end of each section which are used in conjunction with an electronics package to measure absolute and differential temperatures and thermal conductivity of the lunar materials. The heaters produce heat pulses at known distances from the sensors. By determining the interval of time required for the heat pulses to reach the sensors, which are located at a known distances from the heaters, the heat conductivity of the lunar subsurface can be calculated. The heat flow probe operates as shown in Figure 2.1.4-1.

The Apollo lunar surface drill (ALSD) is provided as a means for the astronaut to emplace the Heat Flow Experiment probes below the lunar surface and secondly, to collect subsurface cores. The ALSD is battery operated and a separate piece of experiment hardware. Emplacement Of the HFE probes requires the boring of two subsurface holes to a maximum depth of three meters. The bore

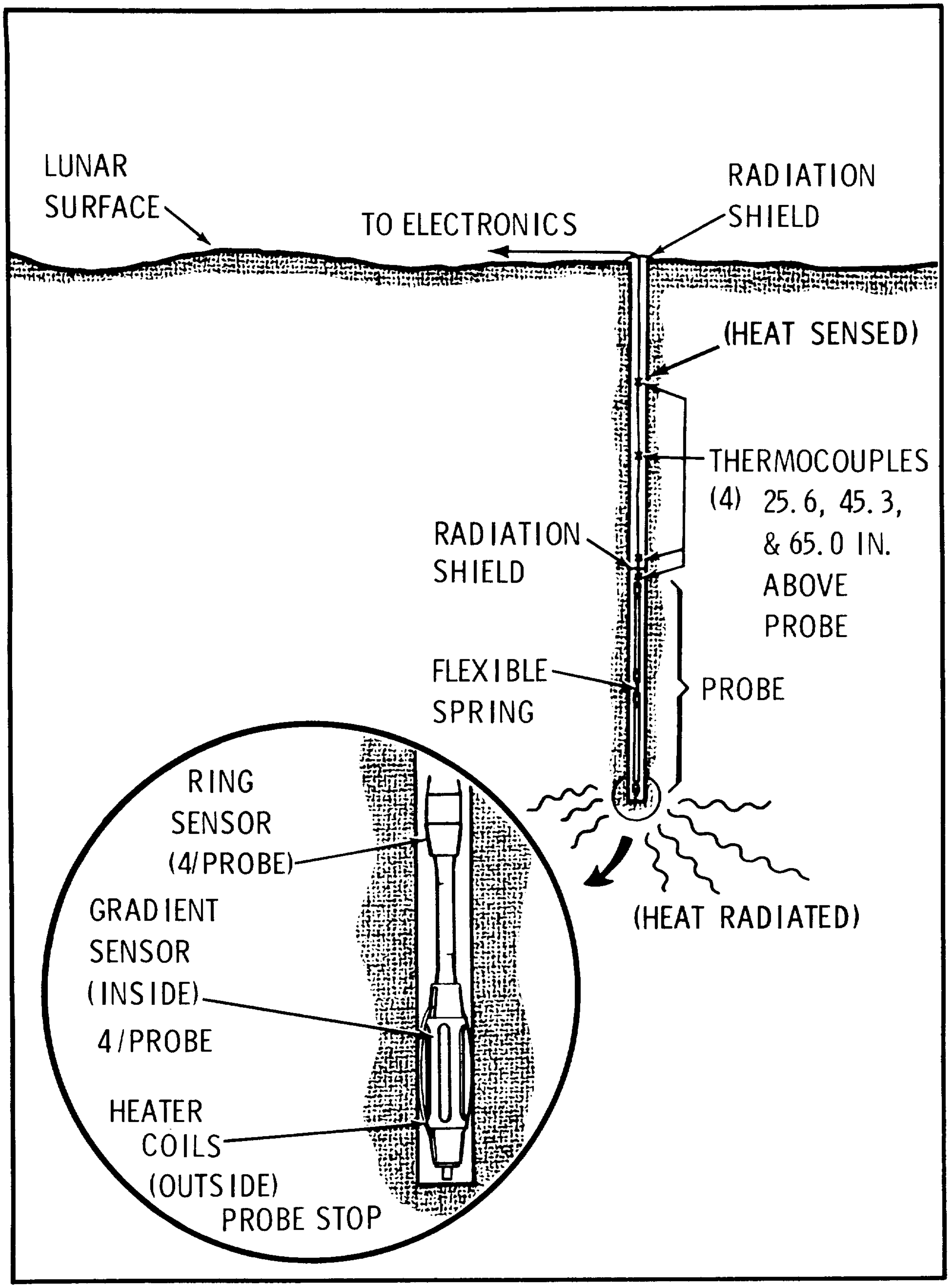


FIGURE 2.1.4-1. HEAT FLOW MEASUREMENT CONCEPT

stems remain in position in the lunar soil and function as an encasement to preclude cave-in of lunar material and for easy probe insertion. A subsurface core is to be obtained by powering six core stems into the lunar surface, removing and capping the stems for return to earth. This is a separate and distinct activity from the HFE probe emplacement task.

Functional Description

The operation of the HFE instrumentation when measuring the lunar material temperatures may be classified into the six functions shown in Figure 2.1.4-2. Earth commands are received by the command processing function which decodes the commands and generates the mode control signals that establish logic routines for heater, probe, measurement and mode operations.

There are five types of measurements performed in three basic modes of operation as follows:

1. High sensitivity measurement of probe temperature difference (gradient).

2. Low sensitivity measurement of probe temperature difference (gradient).

3. Measurement of probe ambient temperature.

4. Measurement of probe reference junction temperature.

5. Measurement of probe cable ambient temperature.

The normal or gradient mode, is used to monitor the heat flow in and out of the lunar crust. Heat from solar radiation flows into the moon during the lunar day and out of the moon during lunar night. Gradient temperatures are obtained from the temperature difference between the ends of the two sections of each probe as sensed by the gradient sensors with all heaters off.

Average-absolute temperature measurements are made by all gradient sensors or ring sensors and by any one of the thermocouples spaces at four points along each probe cable. The reference junction for the thermocouples is mounted on the HFE electronics package thermal plate.

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 lunar material surrounding the probe will have a low conductivity (loosely consolidated material) or high conductivity (solid rock), there are two modes of operation for the capability to measure over a wide range. In the low conductivity mode of operation the temperature rise is measured

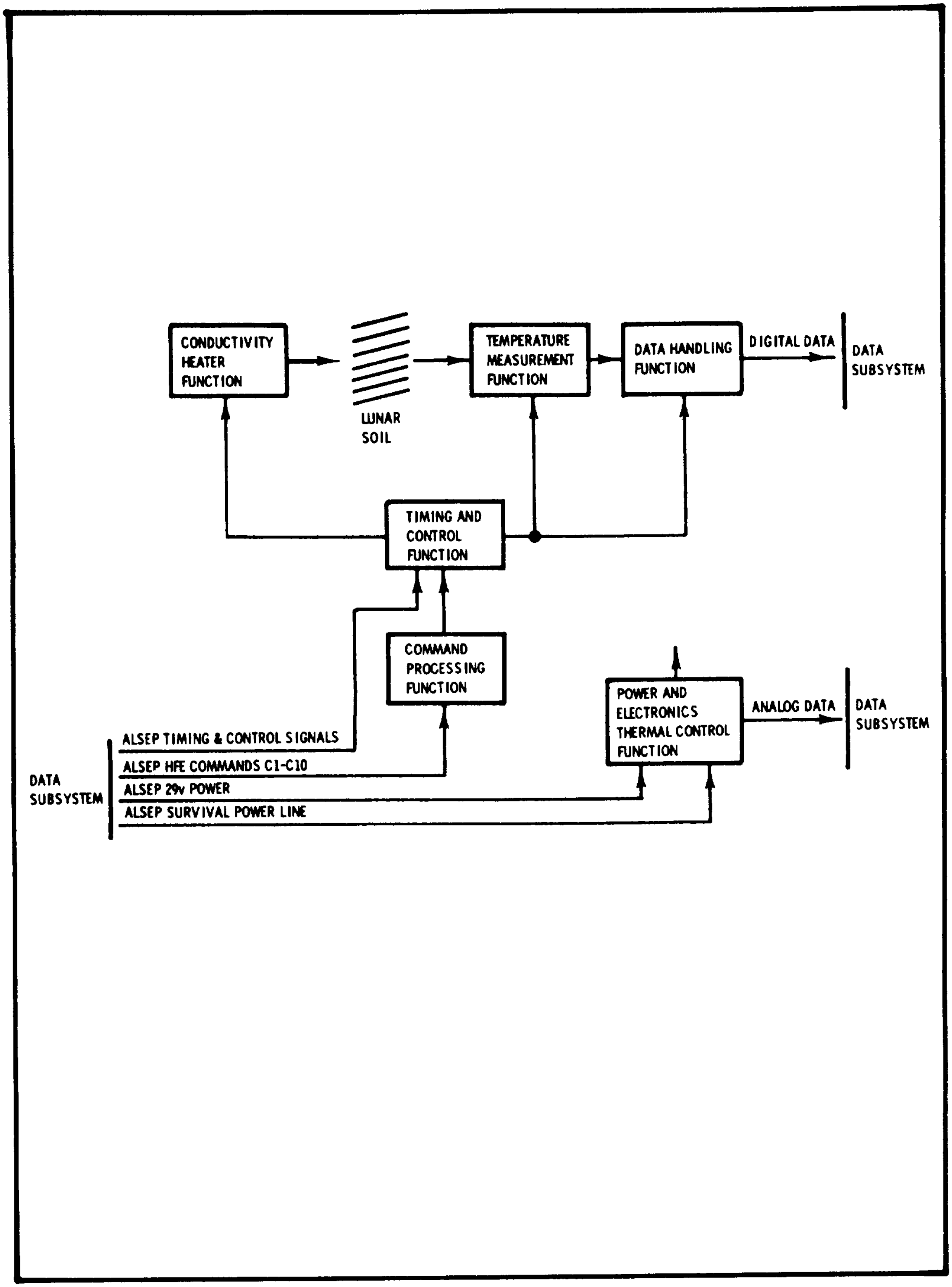


FIGURE 2.1.4-2. HEAT FLOW EXPERIMENT FUNCTIONAL BLOCK DIAGRAM

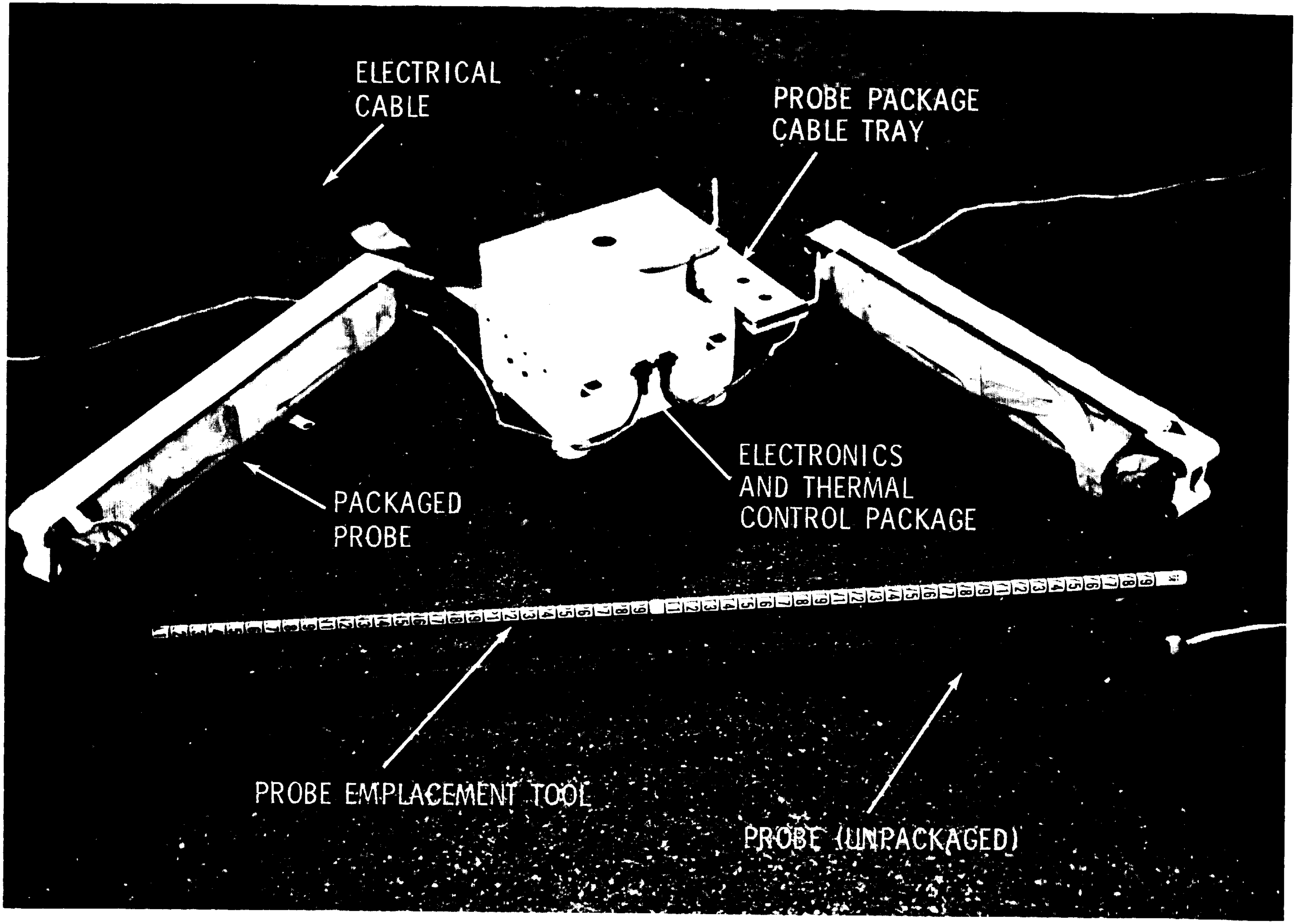


FIGURE 2.1.4-3 HEAT FLOW EQUIPMENT

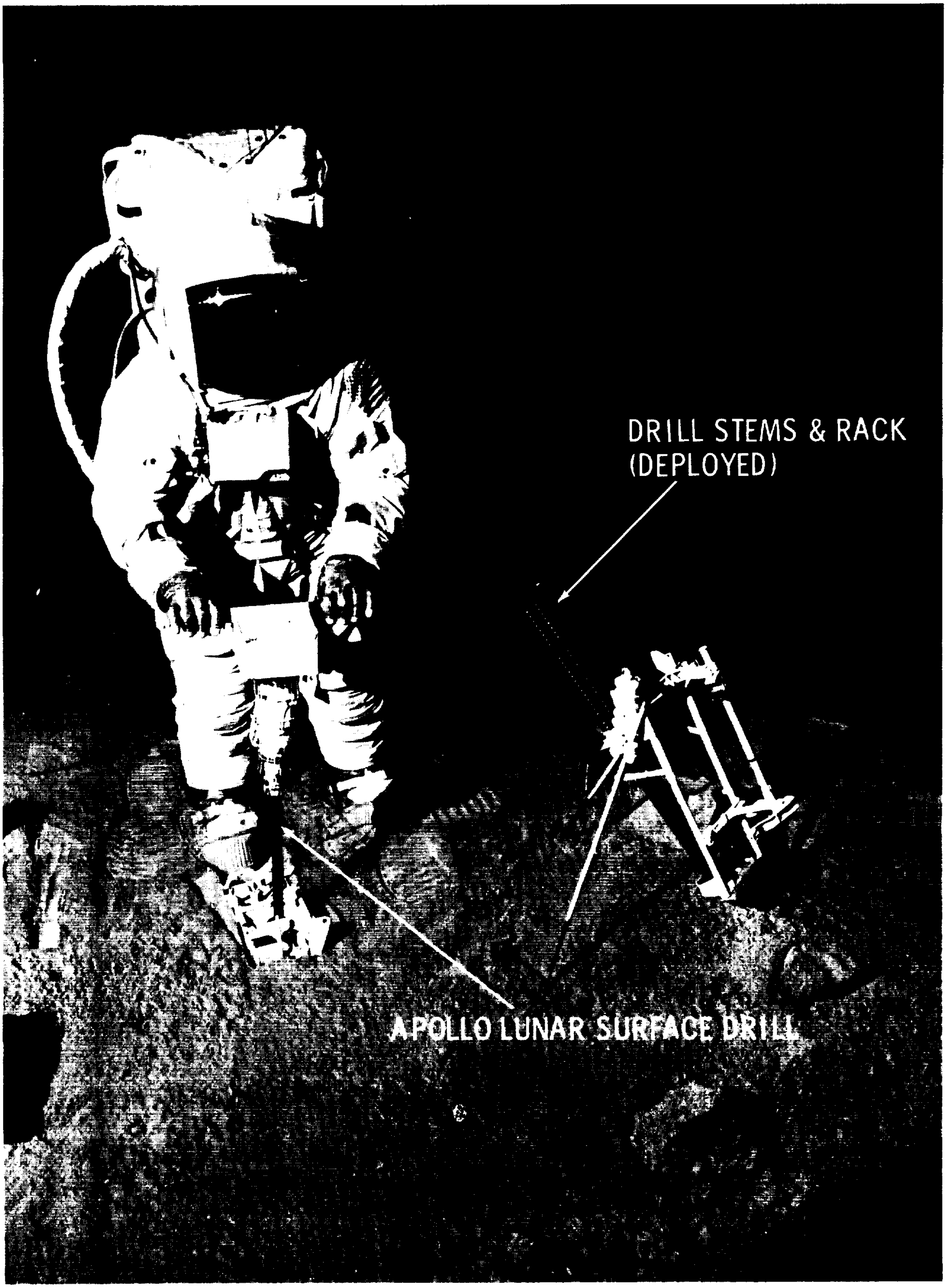


FIGURE 2.1.4-4, APOLLO LUNAR SURFACE DRILL

at the end of the probe in which the selected heater is located. In the high conductivity mode of operation the temperature rise is measured at the ring sensor nearest the selected heater. The HFE and ALSD are shown in Figures 2.1.4-3 and 2.1.4-4.

Technical Data - Heat Flow Experiment

Principal Investigator: Dr. Marcus Langseth, Lamont Geological Observatory

Scientific Measurements:

	Range	Error	Seconds per sample
Probe Gradient Temperatures			
High Sensitivity	±2°C	0.003°C	433
Low Sensitivity	±20°C	0.03°C	433
Probe Ambient Temperatures	200to250°K	0.1°C	433
Reference Junction Temperatures	-20to+60°C	0.1°C	433
Probe Cable Temperatures	90to350°K	0.3°C	433

Weight:

HFE	9.7 lbs.
Drill	24.0 lbs.

Size:

Electronics	10 X 8 X 7.5"
Probe Package	25.5 X 3.5 X 5"
Drill	7.0 X 9.6 X 22.7" (Stowed)

Power: 10.6 W. max. oper.

2.1.5 Charged Particle Lunar Environment Experiment (S-038)

Objective

The objective of the Charged Particle Lunar Environment Experiment (CPLEE), which is to be used for the first time on Apollo 13, is to provide data on the energy distribution, time variations, and the direction of proton and electron fluxes at the lunar surface.

Significance

Results of the electron and proton measurements at the lunar surface will permit a more detailed study of the processes which cause auroras and Van Allen radiation. Because the moon is sufficiently large to be an obstacle to the flow of the solar wind, there may, at times, be a standing front. If so, the CPLEE will detect the disordered or thermalized fluxes of electrons and protons which share energy on the downstream side of the front. The physical processes that occur at such fronts are of fundamental interest in plasma research.

Operational Concept

The instrumentation used to perform the measurement of solar wind electrons and protons, thermalized solar wind electrons and protons, magnetospheric tail particles and low-energy solar cosmic rays consists of two detector packages oriented in different directions for minimum exposure to the ecliptic path of the sun. Each detector package contains six particle detectors, five of which provide information about particle energy distribution, 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, as shown in Figure 2.1.5-1. The recording of the particle count and the transmittal of the data to the data subsystem is performed by the electronics package.

Functional description

The Charged Particle Lunar Environment Experiment is a self-contined unit consisting of sensing and signal processing electronics housed in an insulated case. 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 polarity and energy content of the charged particles, measured in a programmed sequence, are translated to pulses by each detector and sent to separate amplifiers where the pulses are amplified, wave-shaped and sent to the multiplexer in the data handling function. In this function the measured data is converted by means of a programmed sequence to a digital format compatible with the ALSEP telemetry frame and stored until

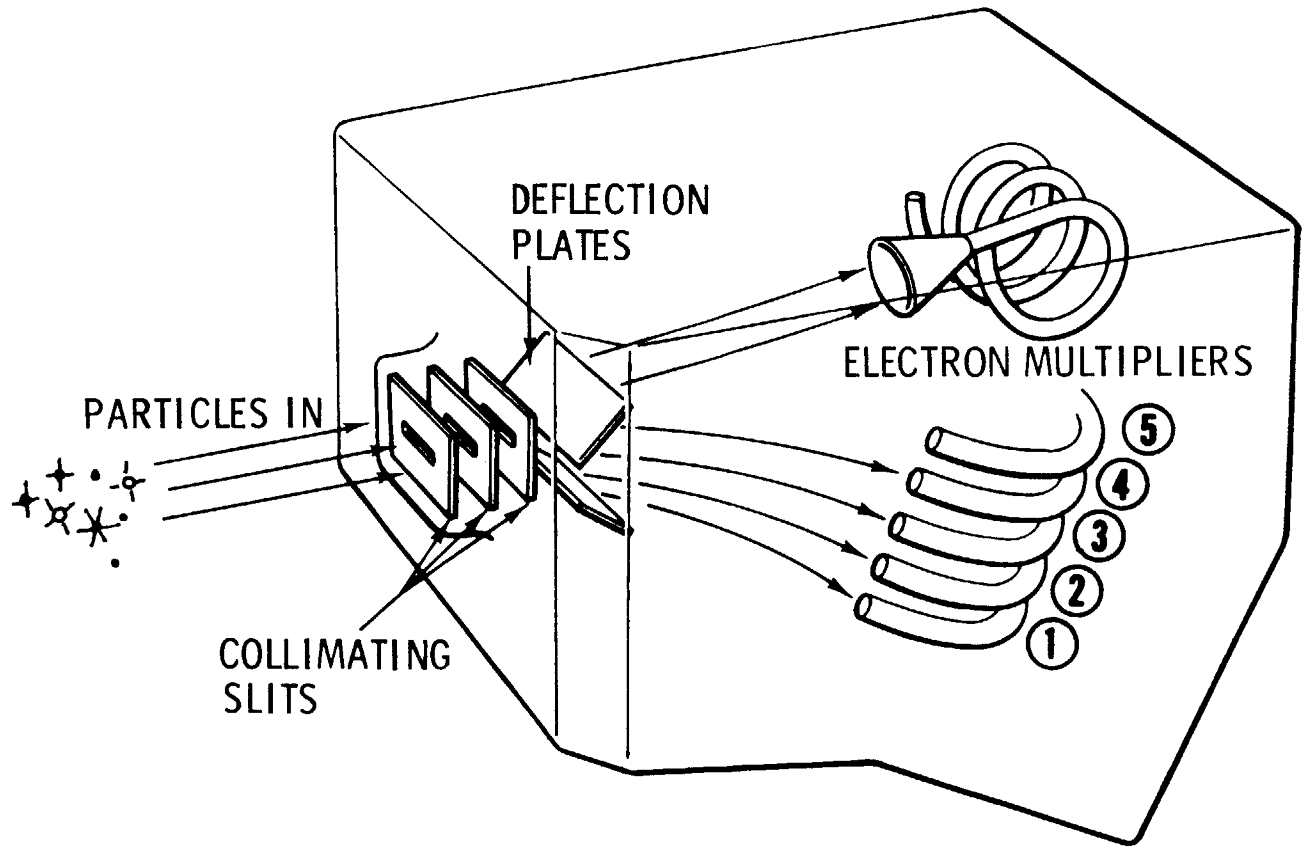


FIGURE 2.1.5-1. CPLEE MEASUREMENT CONCEPT

requested by the data subsystem for transmission to earth. A functional block diagram is shown in Figure 2.1.5-2. The CPLEE is shown in Figure 2.1.5-3.

Technical Data - Charged Particle Lunar Environment Experiment

Principal Investigator: Dr. Brian J. O'Brien, University of Sydney, Australia

Differential Energy Spectra	50ev to 15 kev
Range	10^2 to 10^{10} particles/cm^2-sec-str.
Geometric Factors	10^{-3} cm^2 for funnel channeltron
	10^{-5} cm^2 for other 5 channeltrons

Weight: 5.1 lbs.

Size : 10.3 X 4.5 X 10.0"

Power : 6.5 W. max. oper.

Scientific Measurements:

	Particle Counter Range	Samples per Sec.
Detectors 1-4, A&B at +3500V, ∓ 350V, ∓ 35V	0 to 524,287 for each voltage level	0.05 per detector for each voltage level
Detectors 5&6, A&B at +3500V, ∓ 350V, ∓ 35V	0 to 1,048,575 for each voltage level	0.05 per detector for each voltage level
Detectors 1-6, A&B at +OV	$<$100	0.05
-OV	420,000±10%	0.05

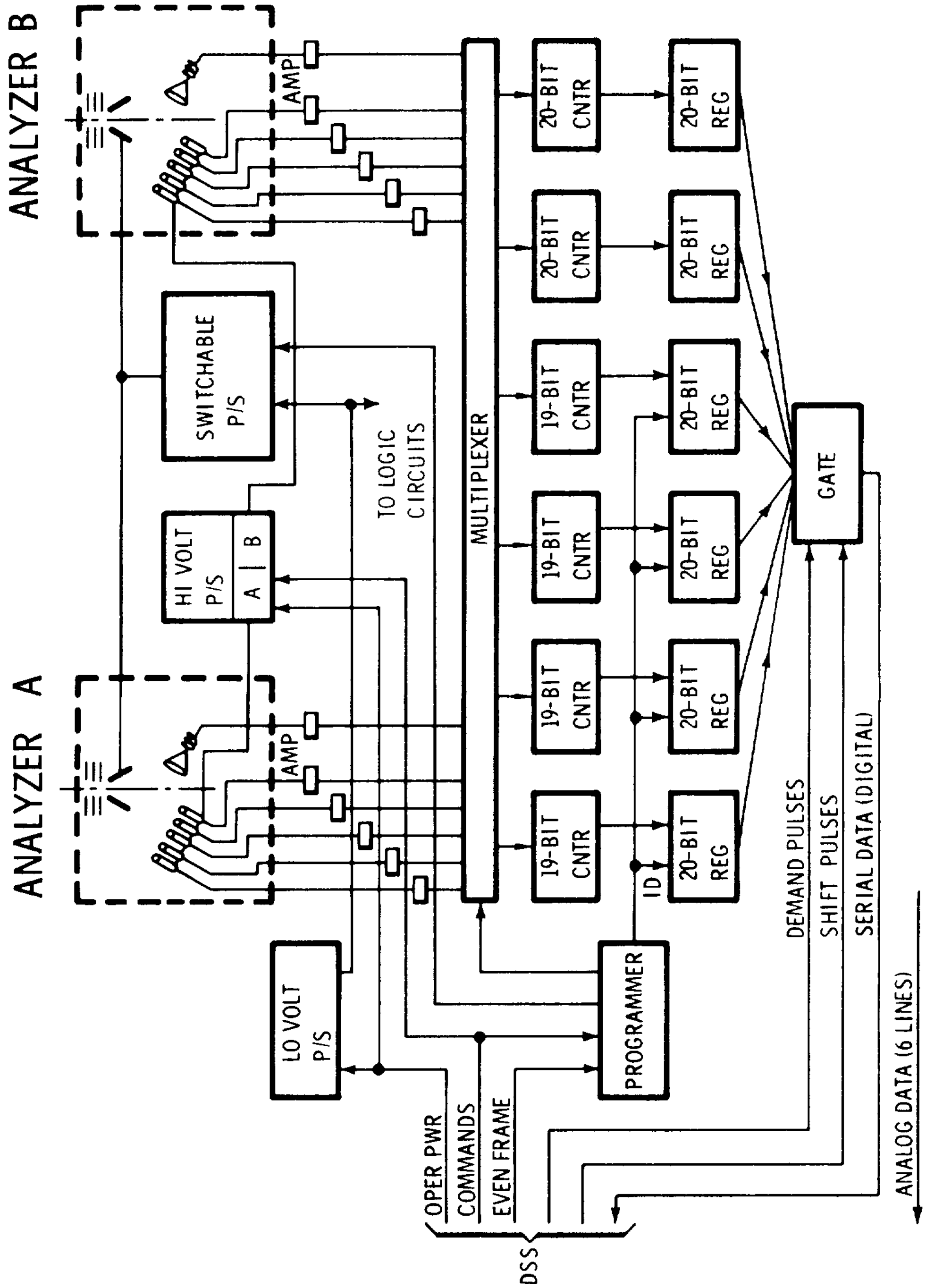


FIGURE 2.1.5-2. CPLEE FUNCTIONAL BLOCK DIAGRAM

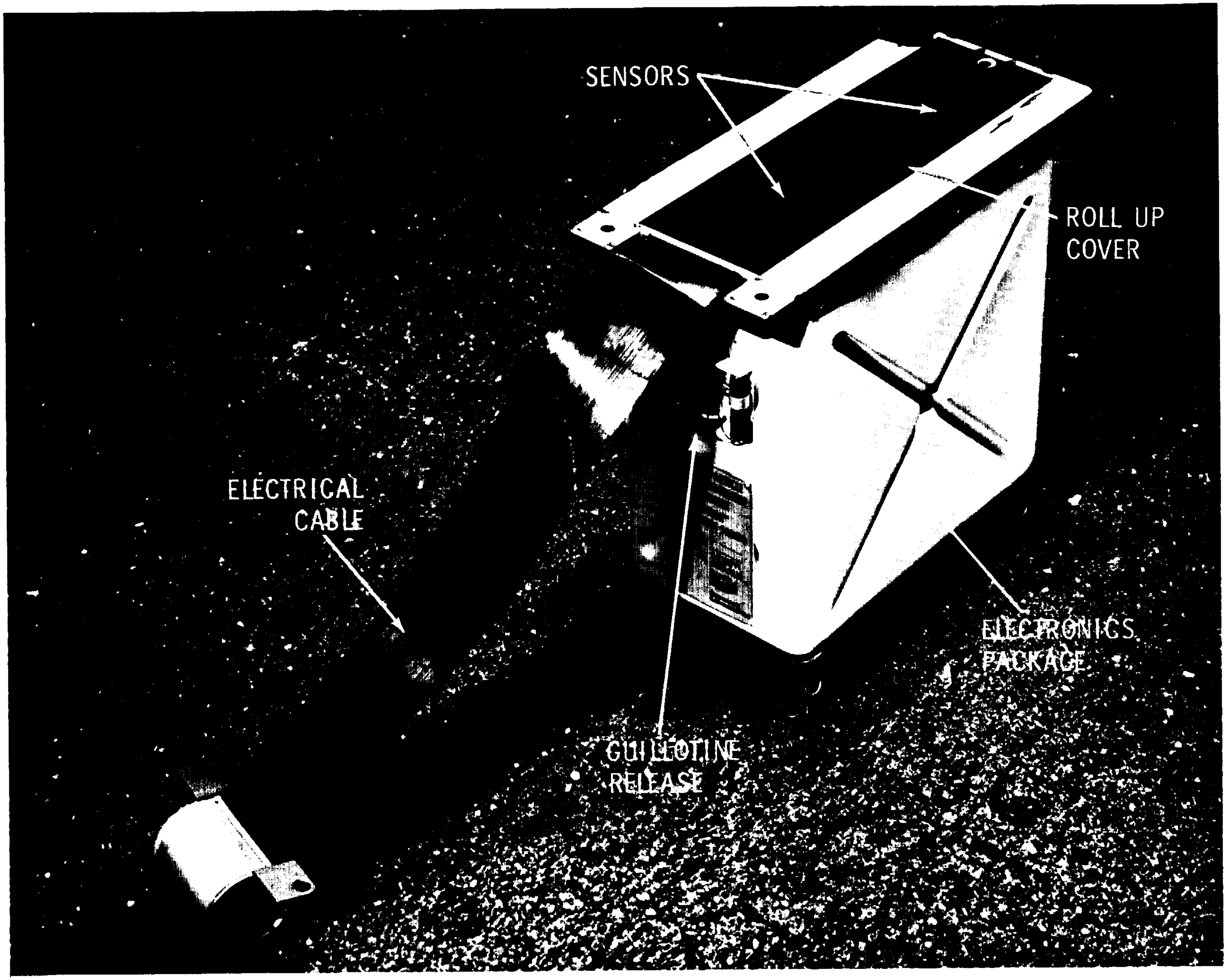


FIGURE 2.1.5-3 CHARGED PARTICLE LUNAR ENVIROMENT EXPERIMENT

2.1.6 Cold Cathode Ionization Gauge Experiment (S-058)

Objective

The objective of the Cold Cathode Ionization Gauge (CCIG) is to detect the density of neutral particles and the variations in density associated with the lunar phases or with possible solar activity.

Significance

Knowledge of the lunar atmosphere will contribute to the understanding of the chemical action on the lunar surface, the gases escaping from the lunar subsurface and the remnant of any original lunar atmosphere. Secondly, the instrument will provide data on the rate of loss of contamination left in the landing area.

Operational Concept

The ionization gauge (Figure 2.1.6-1) is basically a crossed electro-magnetic field device. Electrons in the gauge are accelerated by the combined magnetic and electric fields producing a collision with the neutral particles entering the gauge. Ions produced by these collisions are collected by the cathode where they form a flow of positive ions. The current of the positive ions is proportional to the density of the gas molecules entering the gauge. In addition, the detector's temperature is measured directly. From the density and temperature data the pressure of the ambient lunar atmosphere can be calculated. The pressure gauge has been calibrated for each gas it is expected to encounter on the lunar surface. Any one of seven different dynamic ranges may be selected permitting detection of neutral particles from 10^{-6} torr (highest pressure predicted) to 10^{-12} torr (maximum sensitivity of gauge). The torr is defined as 1/760 of a standard atmosphere.

Functional Description

The CCIG is divided into four major functional elements; measurement function, timing and control function, command function, and data handling function (Figure 2.1.6-2). 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 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 also provides calibration timing

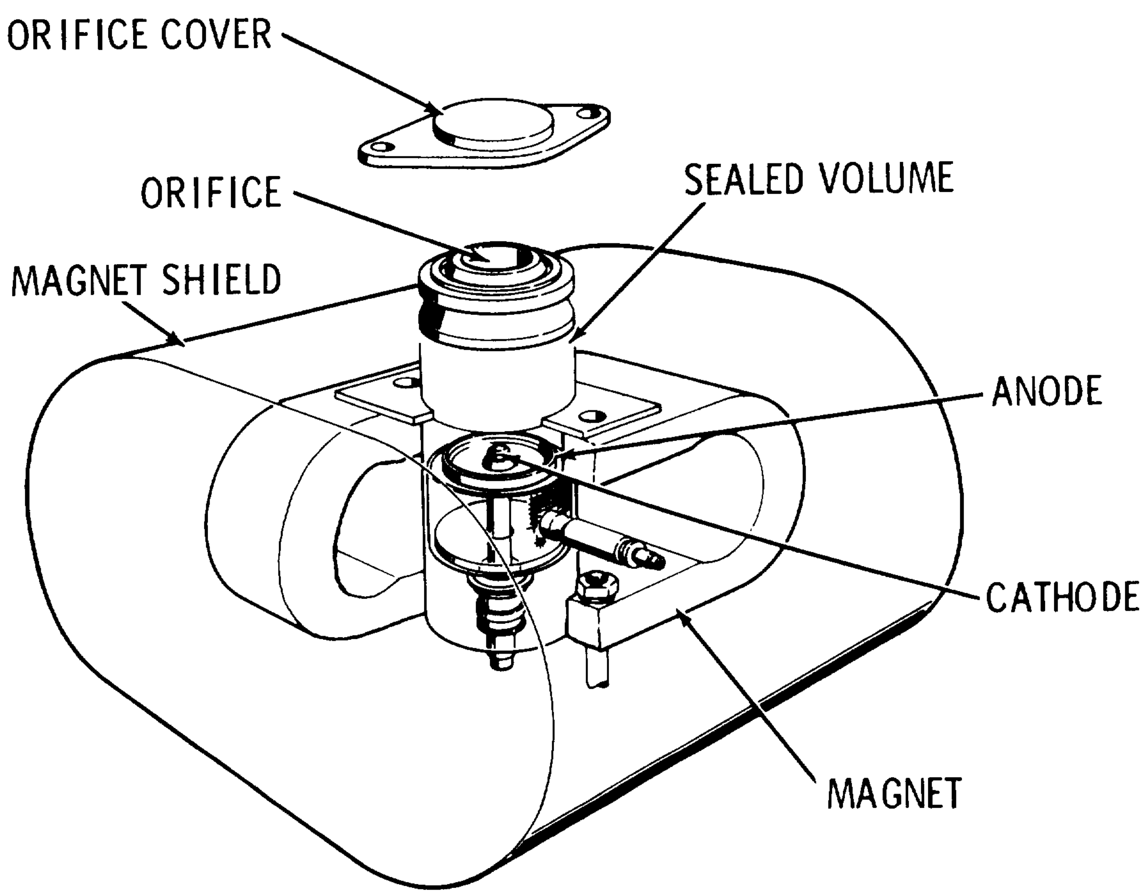


FIGURE 2.1.6-1. COLD CATHODE IONIZATION GAUGE

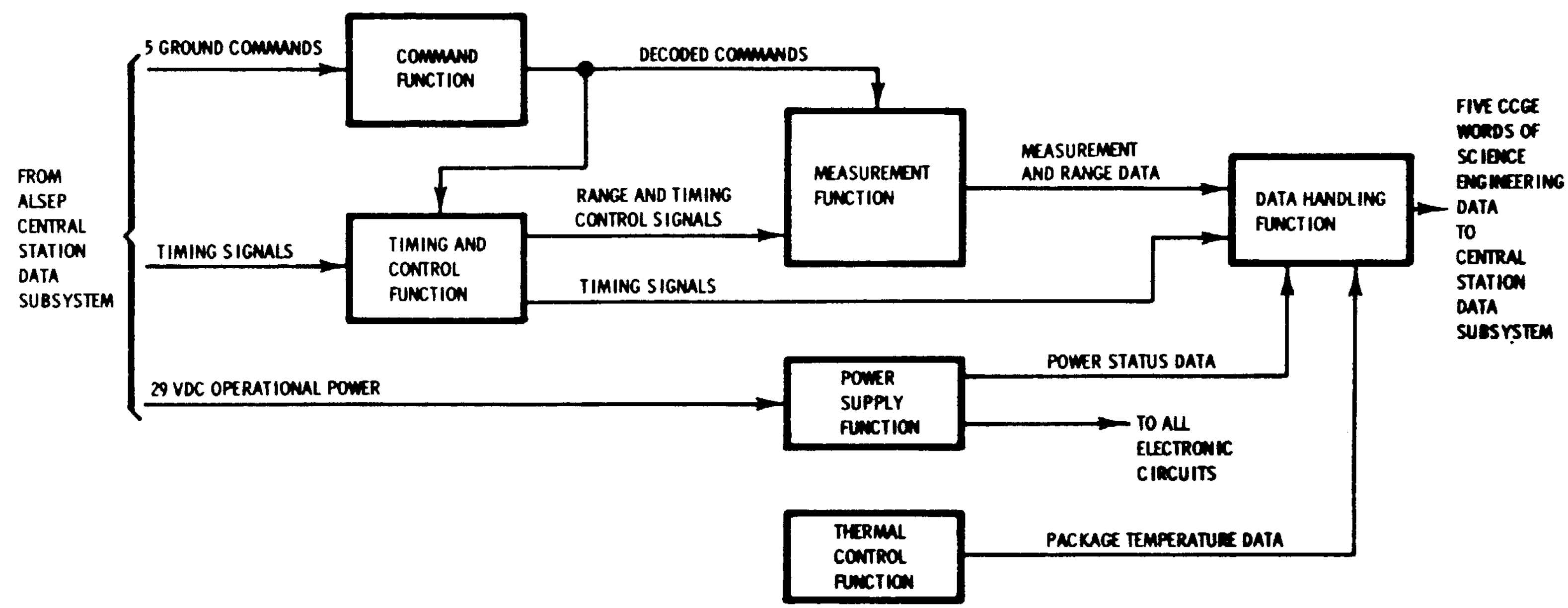


FIGURE 2.1.6-2. COLD CATHODE GAUGE EXPERIMENT, FUNCTIONAL BLOCK DIAGRAM

to the measurement function. The function uses shift, frame mark, and data demand pulses from the data subsystem to control its internal timing.

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. The CCIG experiment, also referred to as the Cold Cathode Gauge Experiment (CCGE) is shown in Figure 2.1.6-3.

Technical Data - Cold Cathode Ionization Gauge Experiment

Principal Inventigator: Dr. Francis Johnson, University of Texas/Dallas

Range 10^{-6} Torr to 10^{-12} Torr

Accuracy

Above 10^{-10} Torr $\pm 30\%$

Below 10^{-10} Torr $\pm 50\%$

Oper. Voltage +4500V

Weight: 12.5 lbs.

Size : 13.4 X 4.6 X 12.0"

Power : 6.5 W. max. oper.

Sample per second 1.66

Measurements:

	Range	Accuracy	Samples per Second
Gauge Temperature	-90 to 125°C 100 to 400°K	$\pm$5°C $\pm$10°K	1.66 1.66
High Voltage Supply	3.72 to 5.45KV		.415

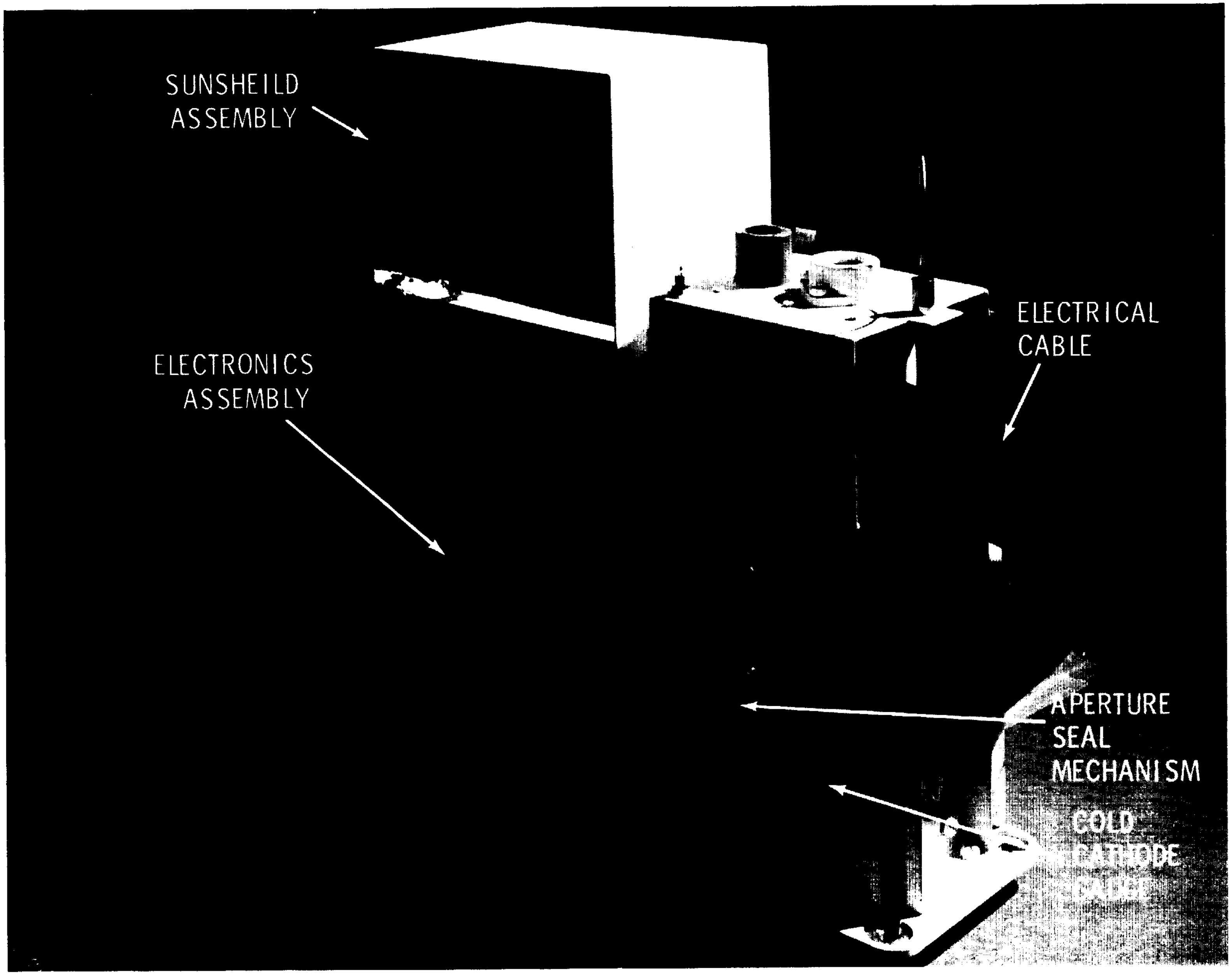


FIGURE 2.1.6-3 COLD CATHODE GAUGE EXPERIMENT (CCGE)

2.1.7 Dust Detector Experiment (M-515)

Objective

The objective of the lunar surface dust detector is to obtain data on dust accretion rates.

Significance

An assessment of dust accretion rates will provide a measure on the degradation of thermal surfaces of the ALSEP.

Operational Concept

The dust detector (Figure 2.1.7-1) is mounted on the central station sunshield with photocells facing the ecliptic path of the sun. Attached to the rear of each photo cell is a thermistor to monitor the individual cell's temperature. The temperature and output, compared to the anticipated values for exposure at a given solar angle, is a measure of dust accretion and insulating values.

Functional Description

The dust detector sensors are three photocells oriented on three sides of the sensor package to face toward the ecliptic. Each 2cm x 2cm photo cell has a blue filter to cut off ultra-violet wavelengths below 0.4 microns and a 0.060 inch fused silica lens for protection against radiation damage. Dust accumulation on the surfaces will reduce the solar radiation detected. The outputs of the photocells are amplified and electrically conditioned for application to commutated channels of the ALSEP data systems.

Technical Data - Dust Detector Experiment

Principal Investigator: Brian J. O'Brien, University of Sydney, Australia

Measurements:

	Range	Sensor Accuracy	Seconds per Sample
#1 Cell Temperature	+80°F to +300°F	± 15°F	54
#2 Cell Temperature	+80°F to +320°F	± 15°F	54
#3 Cell Temperature	+80°F to +320°F	± 15°F	54
#1 Cell Output	0-150 mv	1%	54
#2 Cell Output	0-150 mv	1%	54
#3 Cell Output	0-150 mv	1%	54

Weight: 0.66 lbs.

Size: 2.1 x 1.6 x 1.1"

Power: 0.54 W. max. oper.

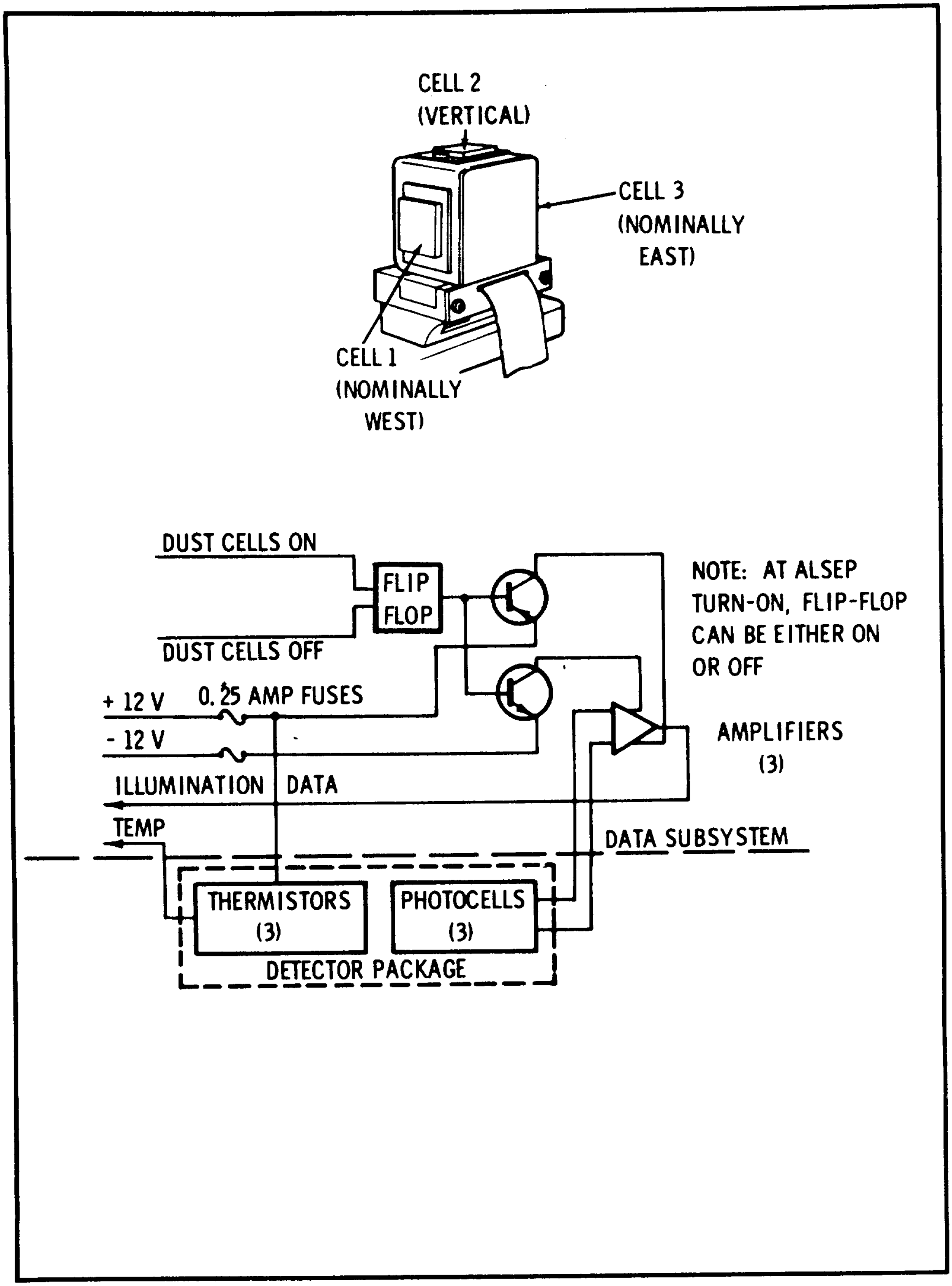


FIGURE 2.1.7-1. DUST DETECTOR FUNCTIONAL BLOCK DIAGRAM

2.2 FIELD GEOLOGY EXPERIMENT (S-059)

Objective

The Apollo 13 Mission will provide the third opportunity for direct collection of lunar surface material and other scientific information. The primary geological questions to be answered by early Apollo lunar landing missions are: 1) the nature and origin of the material underlying the maria floors and other lunar plains, and 2) the nature and rates of the processes that have taken place on the lunar surface.

Significance

The moon offers a unique opportunity to study a planetary surface that is nearly primordial in terms of geologic evolution. Because of the lack of a lunar atmosphere, the external processes which modify the lunar surface must predominantly comprise meteorite bombardment, solar radiation, and diurnal temperature changes. Thus many of the first-order features on the moon's surface, such as the highlands and mare basins and many of the major structures, may be representative of features formed in the early stages of planetary development; features long since destroyed or altered beyond recognition on earth. Comparison of these features with processes that operate on earth is critical to the understanding of the evolutionary development of earth.

Operational Concept

To systematically explore the lunar surface, the astronauts will conduct planned operations which are combined to form a series of stops or stations that constitute geologic traverses. Upon determination of the LM landing location, real time evaluation of the traverses planned in advance is performed. This is accomplished by visual assessments of the landing site, use of photomaps and geology maps provided in a flight data package and communication with geology team personnel on earth. Within the operating radius from the LM, the astronauts then play the central role in the acquisition of scientific data through careful selective sampling and surface observations for the field geology experiment. The gathering of this data will be made through use of the Apollo lunar hand tools (ALHT), real time television and astronaut observations, and sequence, still and stereoscopic camera photography. Voice communication between the astronauts and the geology team members on earth will be utilized to ensure maximum return of geotechnical information from each facet of the planned operations.

Functional Description

The camera is a prime geologic tool which will gather quantitative geometric, photometric, polarimetric and colorimetric information to which astronaut observations and sampling data can be applied.

The photography equipment utilized in conjunction with the field geology experiment consists of the following:

Lunar Surface Color TV Camera

Lunar Surface Black & White TV Camera

16MM Lunar Surface Data Acquisition Camera
Lunar Surface Electric Hasselblad Camera

Closeup Stereo Camera

The camera descriptions and technical data are presented in Section 5.2 (Section 2.4 for the closeup stereo camera). Brief descriptions and functions of the Apollo 13 lunar hand tools are presented in Table 2.2-1 and illustrated in Figures 2.2-1 through 2.2-3.

The portions of the Field Geology Experiment (S-059) assigned to Apollo 13 (Mission H-2) and operational requirements for sampling are summarized below:

1) Drill stem samples will be collected utilizing the Apollo lunar surface drill. The six drill stem sections will be placed in sample return container number 1.

2) Three samples will be collected in the core tubes and placed in sample return container number 2.

3) A lunar environment soil sample of lunar surface material will be collected, sealed in the lunar environment sample container and placed in the sample return container.

4) A gas analysis rock sample of lunar surface material will be collected, sealed in the gas analysis sample container and placed in the sample return container.

5) One or two lunar surface rock samples will be collected, placed in the magnetic sample container and stored in the sample return container. These rocks should fill the container as nearly as possible.

6) Samples will be collected using the lunar hand tools and carrier and will be documented by photographs. A limited number of specially selected samples will be placed individually in prenumbered bags and the bags placed in the sample return container weigh bag.

   Additional samples judged by the crew to be of particular interest will be loose stowed in the weigh bag. If the weigh bag is filled with samples, then at the discretion of the crew and

Tool Nomenclature	Description and Function
Extension Handle	This tool is of aluminum alloy tubing with a stainless steel cap used as an anvil surface. The handle is used as an extension for other tools permitting their use without requiring the astronaut to kneel or bend down. The handle is approximately 32 inches long and one inch in diameter. The tool contains a sliding T handle and the female half of a quick-disconnect fitting for tool attachment.
Core Tubes	These stainless steel tubes are designed to be driven or augered into loose gravel, sandy material, or soft rock. They are about 15 inches in length and one inch in diameter. 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 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.
Large Scoop	The scoop is primarily aluminum and has a hardened-steel cutting edge and a nine-inch handle. A stainless steel anvil is on the end of the handle. The scoop is either used by itself or with the extension handle and incorporates a one cm mesh screen (not illustrated) to permit discarding fine material.
Sampling Hammer	This tool is used as a sampling hammer, a pick or mattock, and a hammer to drive the core tubes or scoop. The head has a small hammer face on one end, a broad blade on the other, and large hammering flats on the sides. The handle is 14" long and is made of tubular aluminum.
Tool Carrier	The carrier is the stowage container for some tools during the lunar flight. For field use, the carrier opens into a triangular configuration and is used to transport most tools required and samples obtained on traverses. The carrier is constructed of formed sheet aluminum and approximates a truss structure. The carrier may also be used as a work table at a stop along a traverse.

TABLE 2.2-1 APOLLO LUNAR HAND TOOLS

Tool Nomenclature	Description and Function
Field Sample Bags	There are Teflon bags of two sizes included in the ALHT for the packaging of samples.
Collection Bag	This is a large bag attached to the astronaut's side of the tool carrier and is used for general storage or to hold items temporarily.
Tongs	A pair of tongs allow the astronauts 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" in overall length.
Brush/Scriber/ Hand Lens	A composite tool (1) <u>Brush</u> - To clean samples as required. (2) <u>Scriber</u> - To put identifying marks on samples. (3) <u>Hand Lens</u> - Magnifying glass to aid in the study and identification of samples.
Weighing Scale	To weigh lunar material samples to maintain the weight budget for return to Earth.
Trenching Tool	This is a two position tool which allows the astronaut to dig a trench for subsurface sampling and photography. The overall length in the shovel position is approximately 70". In the trenching or hoe position, with the blade at the right angle to the handle, the length is 60 inches.
Gnomon	The gnomon is a stadia rod mounted on a tripod and provides an accurate vertical reference and calibrated length for determining the size and position of objects in near field photographs. A color scale is painted on the rod.
Color Patch	The color patch is a 6 1/2 inch square with one half painted in shades of gray and the other half a color scale of blue, red and green. The patch is used as a color reference for photography.

TABLE 2.2-1 APOLLO LUNAR HAND TOOLS (CONTINUED)

Tool Nomenclature	Description and Function
Small Scoop	The small scoop is an aluminum tool with a steel alloy cutting edge. It is used to retrieve granular samples or other samples too small for the tongs.
Instrument Staff	The staff measures 43 1/2 inches with both sections assembled and is used as a camera mount for photography. The staff is mounted on the tool carrier and can be rotated to allow panoramic photography.
Sample Return Container	While not actually a part of the hand tools, two sample return containers play an important role in sample collection and are included in this list for convenience. The containers are portable, aluminum and provide a sealed enclosure for transport of lunar samples back to earth. The container is commonly referred to as the rock box or SRC.
Special Containers	These are small can-like containers with self-sealing capability for the return of special gas analysis, magnetic and environment samples.

TABLE 2.2-1 APOLLO LUNAR HAND TOOLS (CONTINUED)

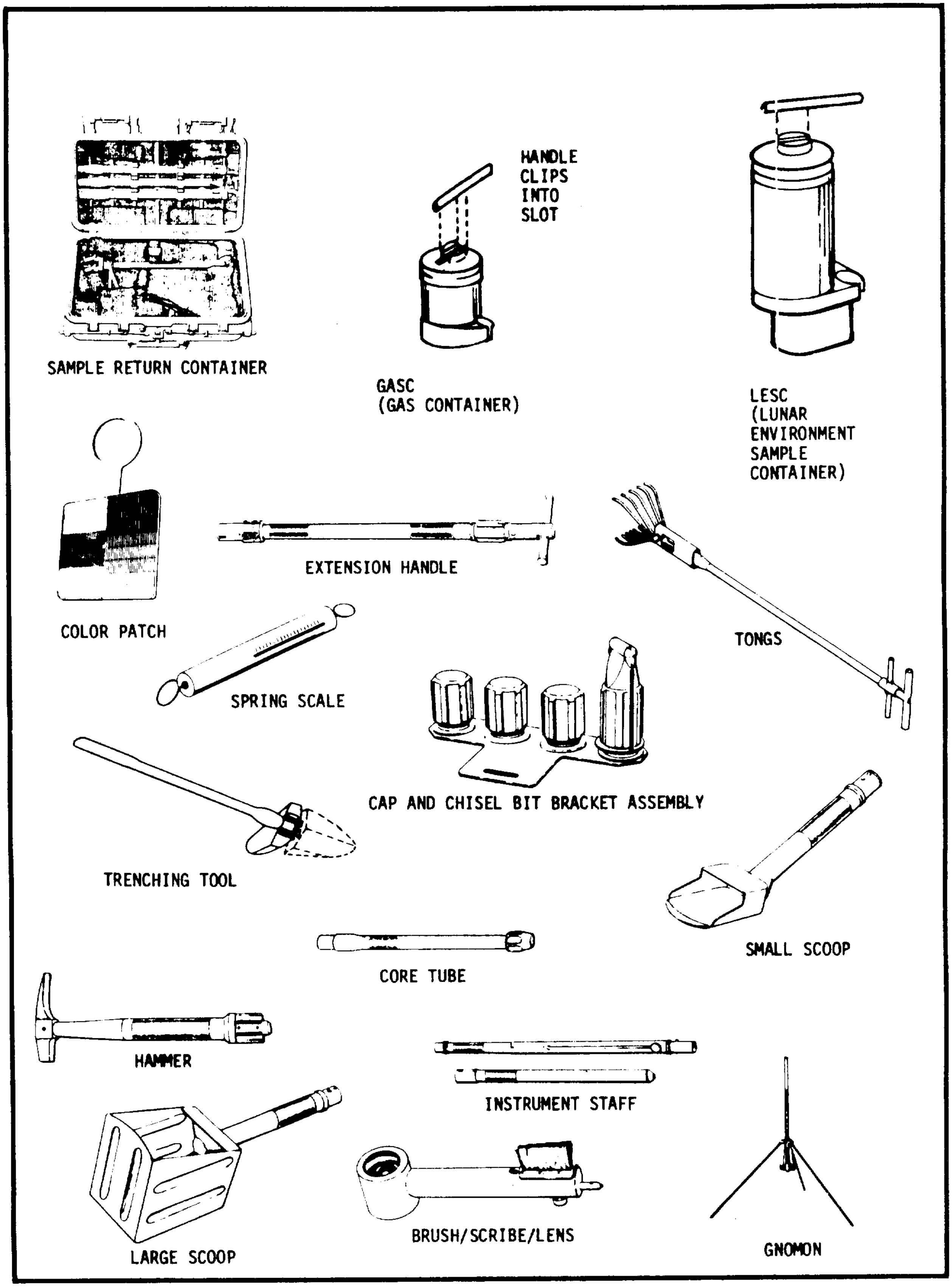


FIGURE 2.2-1 APOLLO LUNAR HAND TOOLS

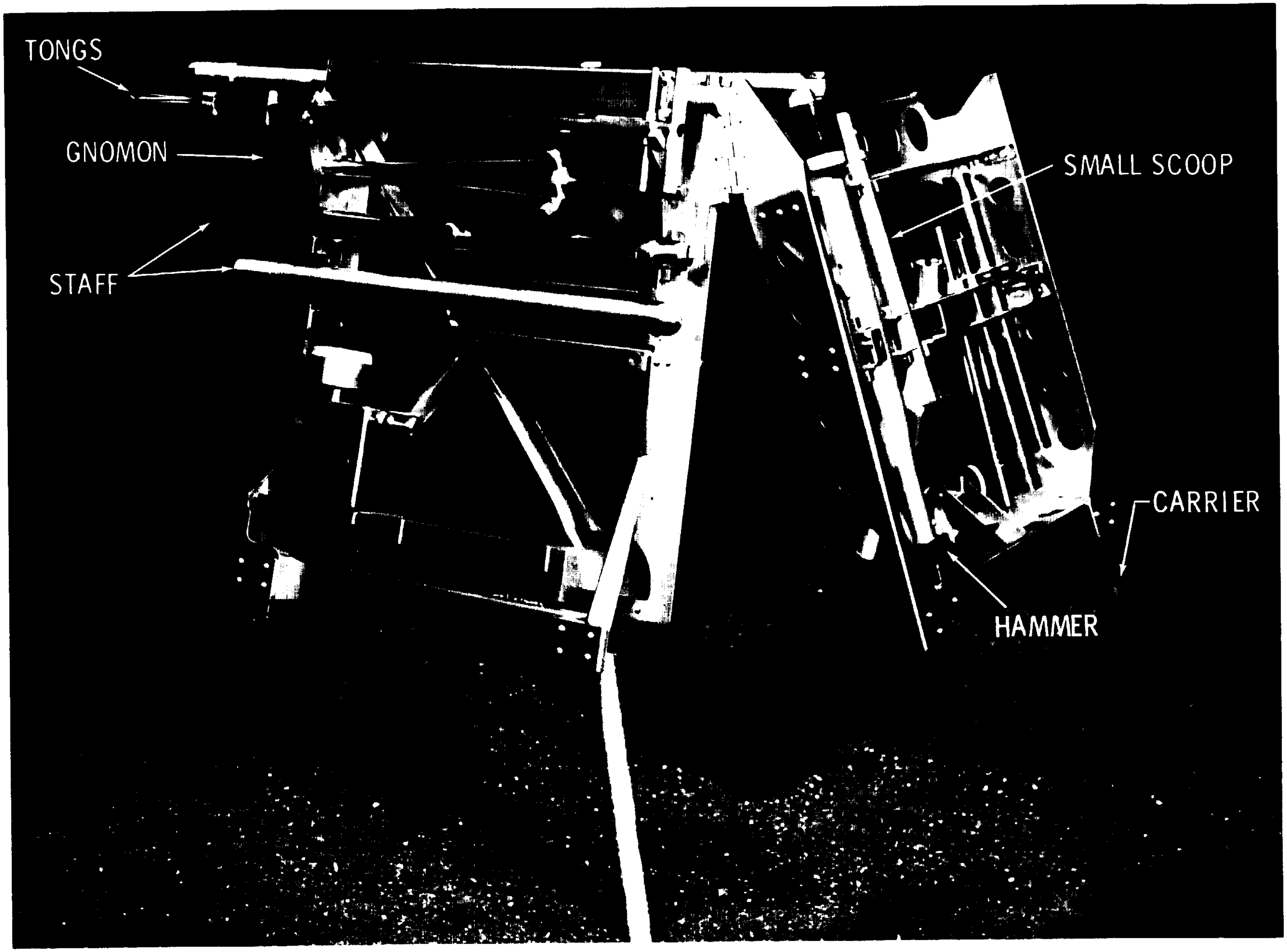


FIGURE 2.2-2, APOLLO LUNAR HAND TOOLS

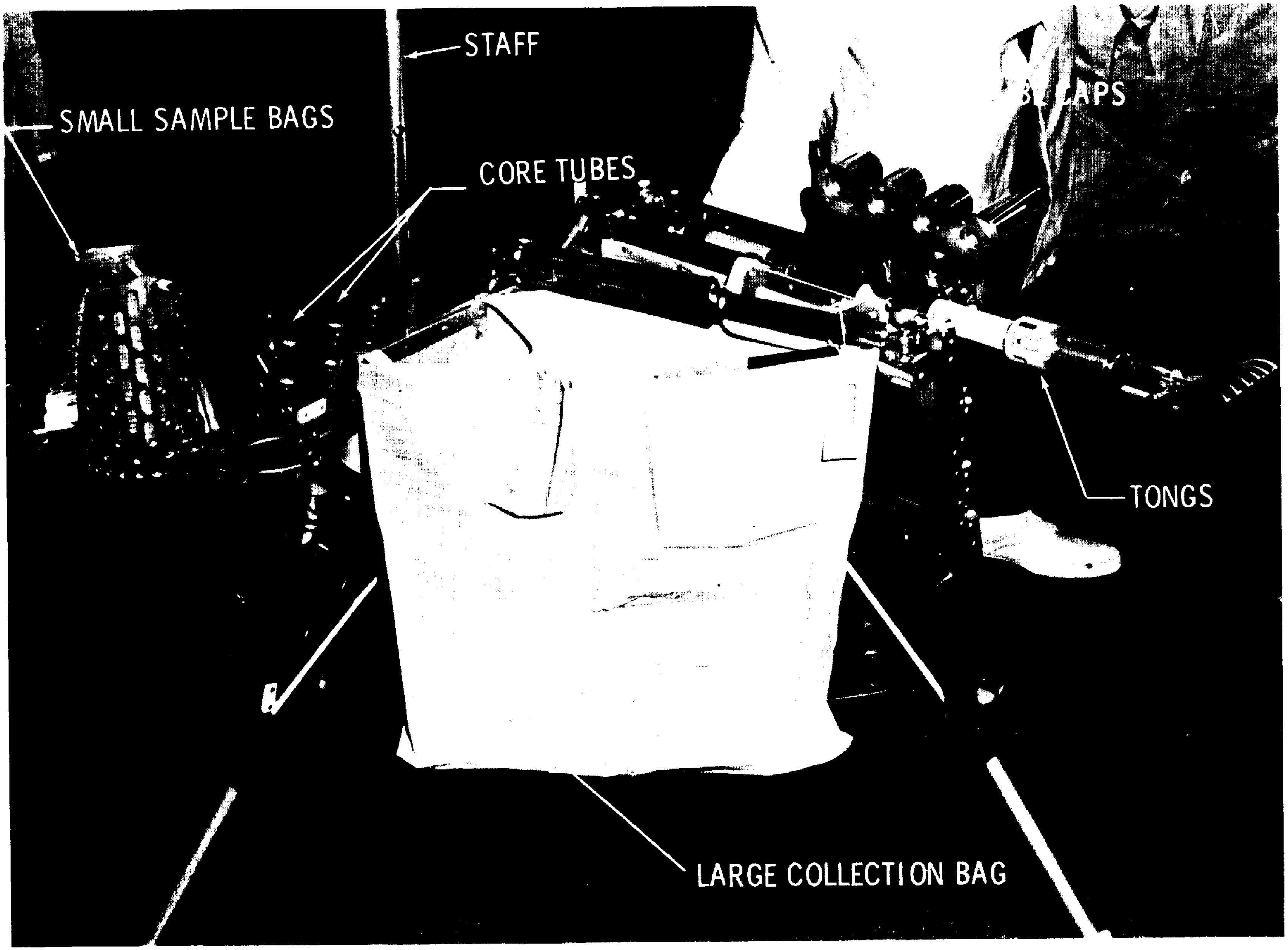


FIGURE 2.2-3, APOLLO LUNAR HAND TOOLS

within the timeline constraints, additional loose samples may be placed in the remaining volume of the SRC available for samples.

Near field polarimetric measurements will be obtained to provide local calibration data. The film data will provide new "in situ" measurements of the photometric properties of the fine-grain material and rock fragments, including the undersides of rocks, disturbed and compressed fine-grained material, and stereo-coverage of the sample area.

Far field polarimetric measurements will be obtained of a rock strewn area by taking a picture of such an area at least 40 feet from the crewman through each filter position at phase angles of about 90 and 130 degrees.

Photometric chart measurements will be obtained by leaning the photometric chart (stowed on the tool carrier) against a representative rock with the chart facing the sun and the gnomon close to the rock.

Additional photographs of lunar surface sample areas and of the samples will be obtained without use of the polarizing filter or photometric charts.

7) Lunar surface features and field relationships will be described and photographed. Several sets of panoramic photographs will be taken. Each set will consist of at least 12 photographs, over-lapped to provide 360-degree coverage. The far-field detent will be used for all panoramic photographs. The astronaut will aim the Hasselblad so that the horizon will appear near the top of each photograph.

Three sets of panoramic photographs will be taken in immediate proximity to the LM. At least five more sets of panoramic photographs will be taken at strategic points along the geologic traverse, chosen by the crewmen at approximately 200-foot intervals.

The Principal Investigator, Dr. E. Shoemaker, California Institute of Technology, and investigation team will evaluate and study the samples and data returned to earth. The investigations will be conducted in the Lunar Receiving Laboratory (LRL).

2.2.1 Lunar Soil Mechanics

Objective

The objective of the lunar soil mechanics investigation is to obtain data on the lunar soil mechanical behavior and on the surface and subsurface characteristics.

Significance

The mechanical behavior and characteristics of the lunar surface are required for design and operation of lunar surface exploration equipment, such as roving vehicles, and to establish the criteria and standards for possible future construction of a scientific station either on or within the lunar surface.

Operational Concept

The lunar soil mechanics investigations are performed by obtaining data available in the course of performing other activities including LM landing, ALSEP deployment and the conduct of the Field Geology Experiment. The data will be in the form of spacecraft telemetry, biomedical data, crew observations, photographs and lunar samples.

Functional Description

The mechanical behavior of the lunar surface material will be assessed through analyses of the LM footpad-lunar soil interactions, soil accumulation on the LM vertical surfaces, soil mechanics data obtained during EVA, and the returned lunar surface samples. The footpad-soil interaction will be determined from photographs and from analysis of the landing gear stroking and touchdown conditions as determined from lunar trajectory data, descent engine thrust and vehicle mass properties. The investigation team will analyze the soil samples returned to the LRL.

Lunar surface characteristics (i.e., slopes, boulders, ridges, rills and craters) as they effect the mobility of men and roving vehicles on the lunar surface will be evaluated. The effects of lunar surface characteristics on crew mobility while traversing the lunar terrain carrying various weights will be evaluated through crew comments correlated with the metabolic rates during the traverses.

Lunar surface activities will include excavating a hole or trench using the trenching tool, recording crew observations and biomedical data, and obtaining photographs. The excavation will be made as deep as possible within the constraints of the timeline, crew capability, or until an impenetrable stratum is encountered. An excavation at least two feet deep is desired. The excavated material will be piled in one heap to determine the natural slope of the material. An astronaut will step on the pile and record observed differences in firmness between the excavated soil and virgin soil.

Lunar subsurface characteristics will be evaluated through analysis of the core samples, and analysis of the crew comments and photographs of the excavation and material excavated. The excavation and excavated material will provide data on sub-surface strata, sidewall crumbling, density, and natural slope of the subsurface material. An estimation of the work required to excavate the lunar surface will be made through analysis of the astronaut metabolic rates while the excavation is in progress. These data will be used to determine the types of construction that would be possible either on or under the lunar surface.

2.3 SOLAR WIND COMPOSITION EXPERIMENT (S-080)

Objective

The objective of the Solar Wind Composition Experiment is to determine the elemental abundances and isotopic composition of the noble gases in the solar wind.

Significance

By comparing the experiment results with the noble gas elemental and isotopic abundances in the earth's atmosphere, in meteorites, and in lunar surface dust, knowledge will be gained on the history of the lunar surface, on the origin of the earth's atmosphere, and on the origin and history of the solar system in general.

Operational Concept

The solar wind includes ionized elements streaming away from the sun at high velocities (approximately 200 miles/second). These ion species cannot reach the earth because of the magnetic field of the planet. They do, however, reach the moon since the moon's magnetic field is negligible - the moon behaving as a passive obstacle to the solar wind.

The physical properties of the solar wind have been successfully studied although little about it's composition is known. The solar wind foil (Reference Figure 2.3-1) will be exposed on the lunar surface, returned to earth and the foil melted to release and analyze any trapped gases. In particular, isotopes of the noble gases will be determined using mass spectrometers.

Functional Description

The solar wind foil, shown in Figure 2.3-2, will be deployed approximately 100 meters from the lunar module in an area free of "disturbed" solar dust. The foil is to be unrolled at the point of deployment and exposed to solar wind flux. Ions incident on the foil are decelerated by collisions with the aluminum atoms until the energy remaining is sufficient to permit escape of the particle and it becomes entrapped in the foil. A spectrometric analysis of the returned trapped particles allows determination of the quantitative composition of the solar wind for helium, neon, argon, krypton and zenon. The foil is reeled up during the second EVA, placed in a bag, sealed and stowed in a sample return container for return to earth.

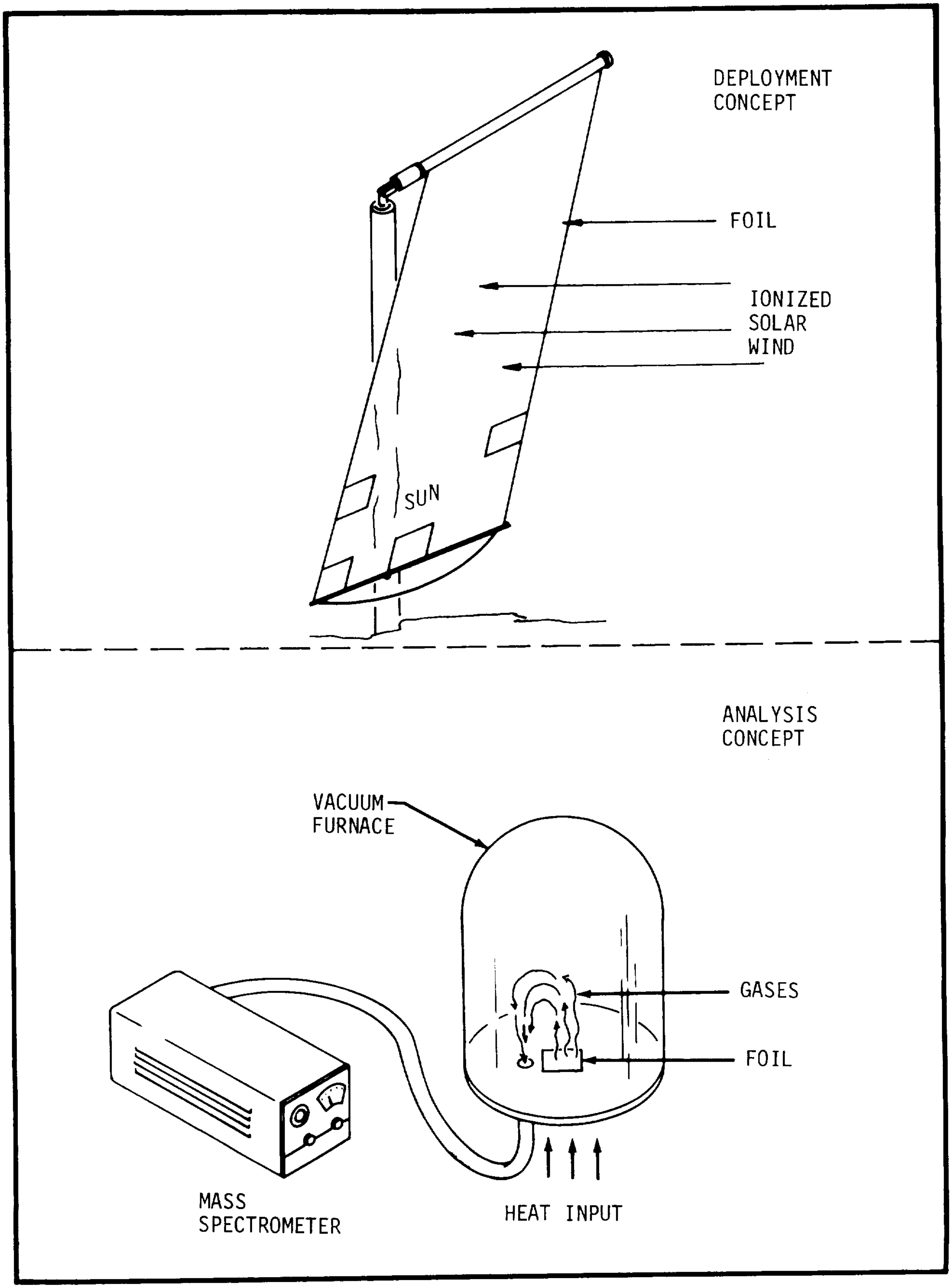


FIGURE 2.3.1. SOLAR WIND COMPOSITION MEASUREMENT CONCEPT

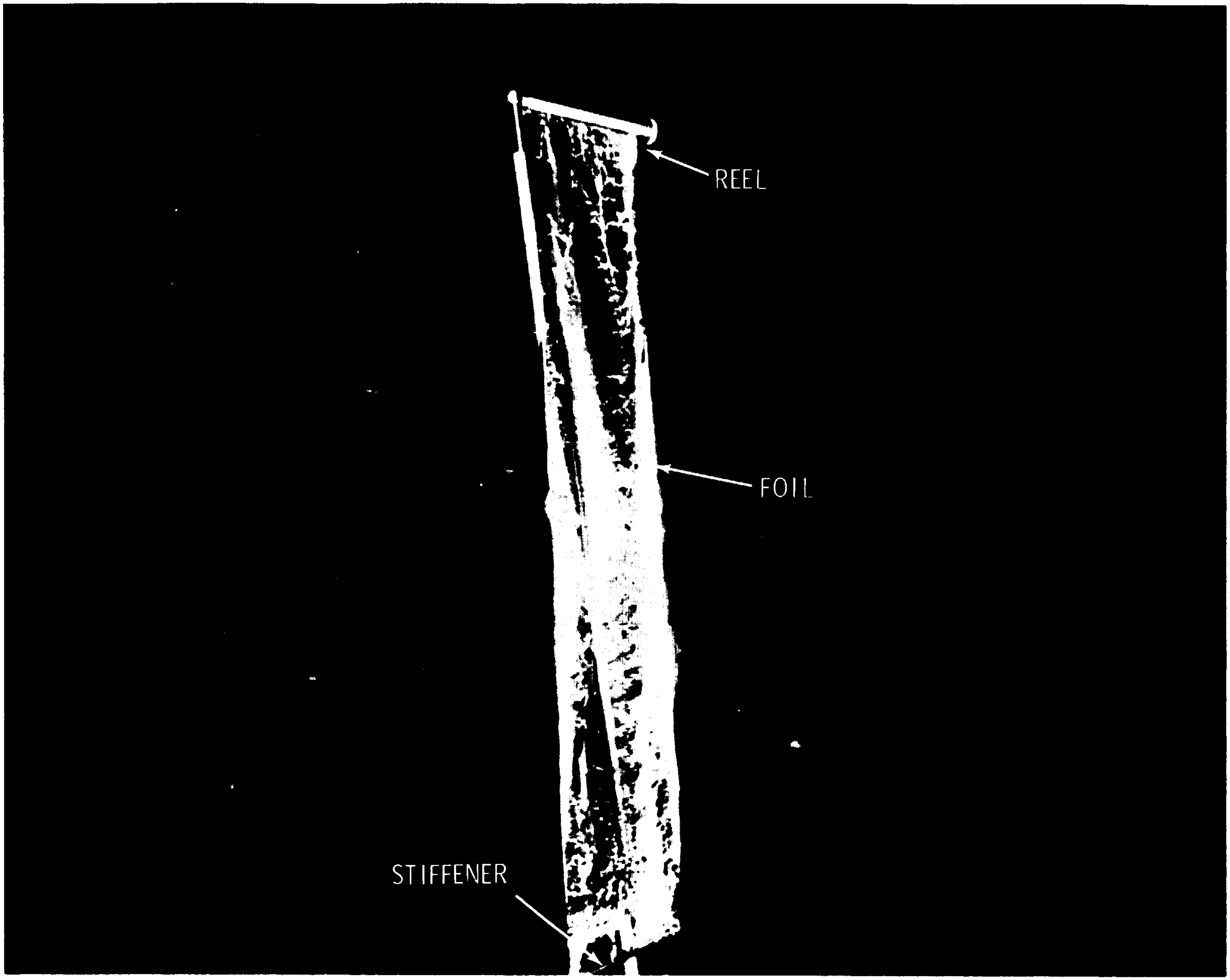


FIGURE 2.3-2. SOLAR WIND COMPOSITION

Technical Data - Solar Wind Composition Experiment

Principal Investigator: Dr. J. Geiss, Berne University, Switzerland

Equipment:

Aluminum foilscreen of 4 square feet area approximately 5 MIL thickness.

Staff which consists of a five-section telescopic pole and reel attach fitting.

Reel on which the foil is rolled.

Weight: 0.95 lb.

Size:

Deployed: 4 ft^2
Stowed: 1.34" dia. x 14.8"

2.4 LUNAR SURFACE CLOSEUP PHOTOGRAPHY EXPERIMENT (S-184)

Objective

The objective of the Lunar Surface Closeup Photography Experiment is to obtain high resolution stereoscopic photographs of the lunar surface to allow examination, in their natural structure and environment, of small scale (between micro and macro) features on the lunar surface.

Significance

Closeup stereo photography of small scale features on the lunar surface will aid in understanding the derivation and deposition processes that were responsible for the blanket of rock powder that seems to cover the moon. It will also aid in understanding the evolution of the lunar surface by detection of changes in the distribution of masses on the moon that may have taken place to account for the small height of the rims of old craters, compared with the height of younger craters of the same diameter.

Operational Concept

A series of close-up stereo photographs of significant surface structure phenomena will be taken by a specially developed stereo close-up camera shown in Figure 2.4-1 which will be operated by an astronaut on the lunar surface. The photographs will be analyzed after return to earth for information concerning the lunar soil and rock structure. A schematic of the camera optical system is shown in Figure 2.4-2.

Functional Description

The Apollo Lunar Surface Closeup Camera is designed with optimum operational simplicity. The camera has a film magazine capacity of 100 stereo pairs and is an automatic, self-powered, twin-lens stereoscopic camera with a fixed focus and flash exposure. Photographs of the lunar surface are obtained by the astronaut setting the camera over the material and depressing the trigger located on the camera handle. After the film exposure has been completed, the film is automatically advanced to the next frame and the electronic flash recharged.

A standoff, extending forward to the object plane, provides the proper object distance and a handle grip allows the suited astronaut to trigger the camera from a standing position.

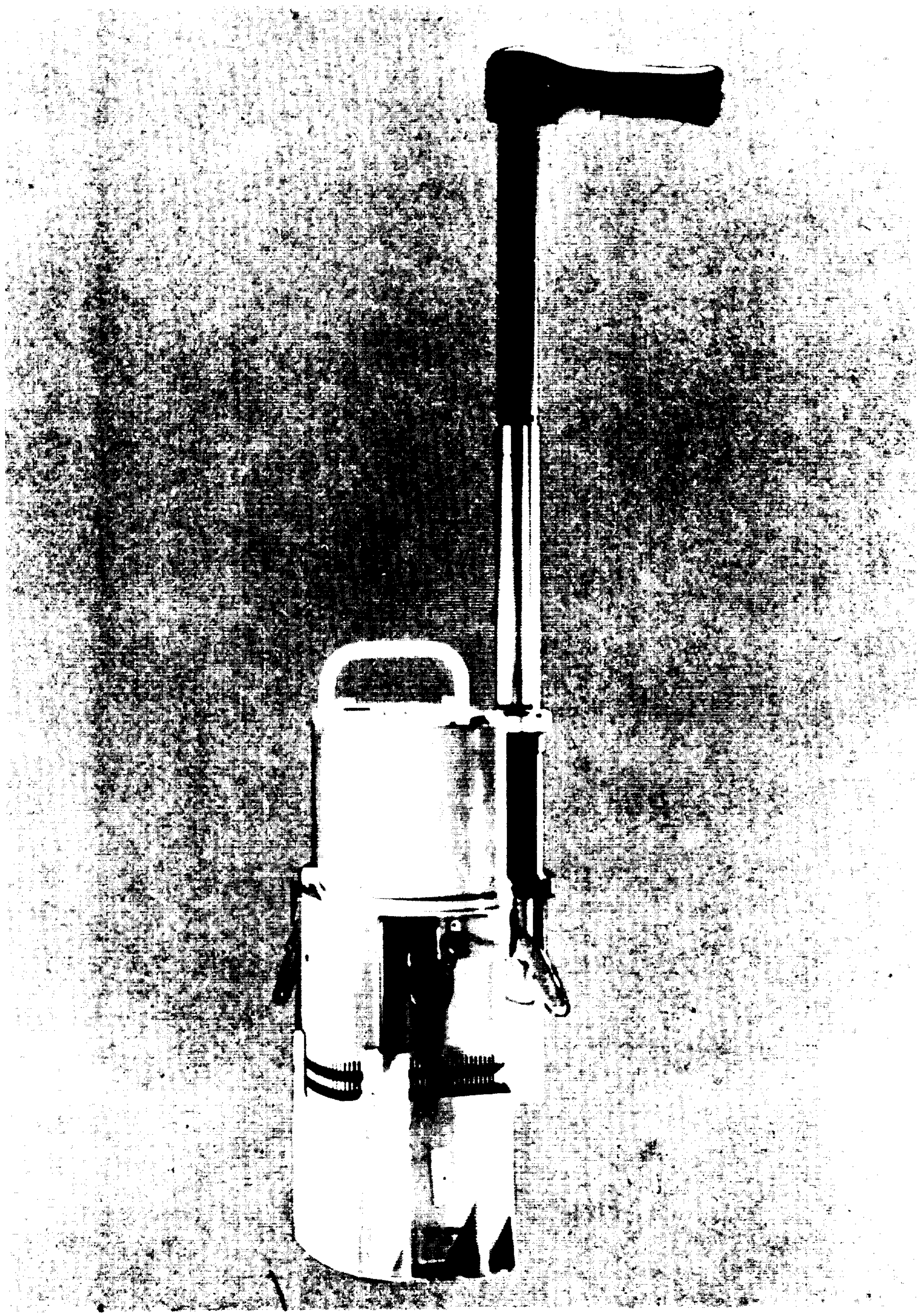


FIGURE 2.4-1 CLOSE-UP STEREO CAMERA

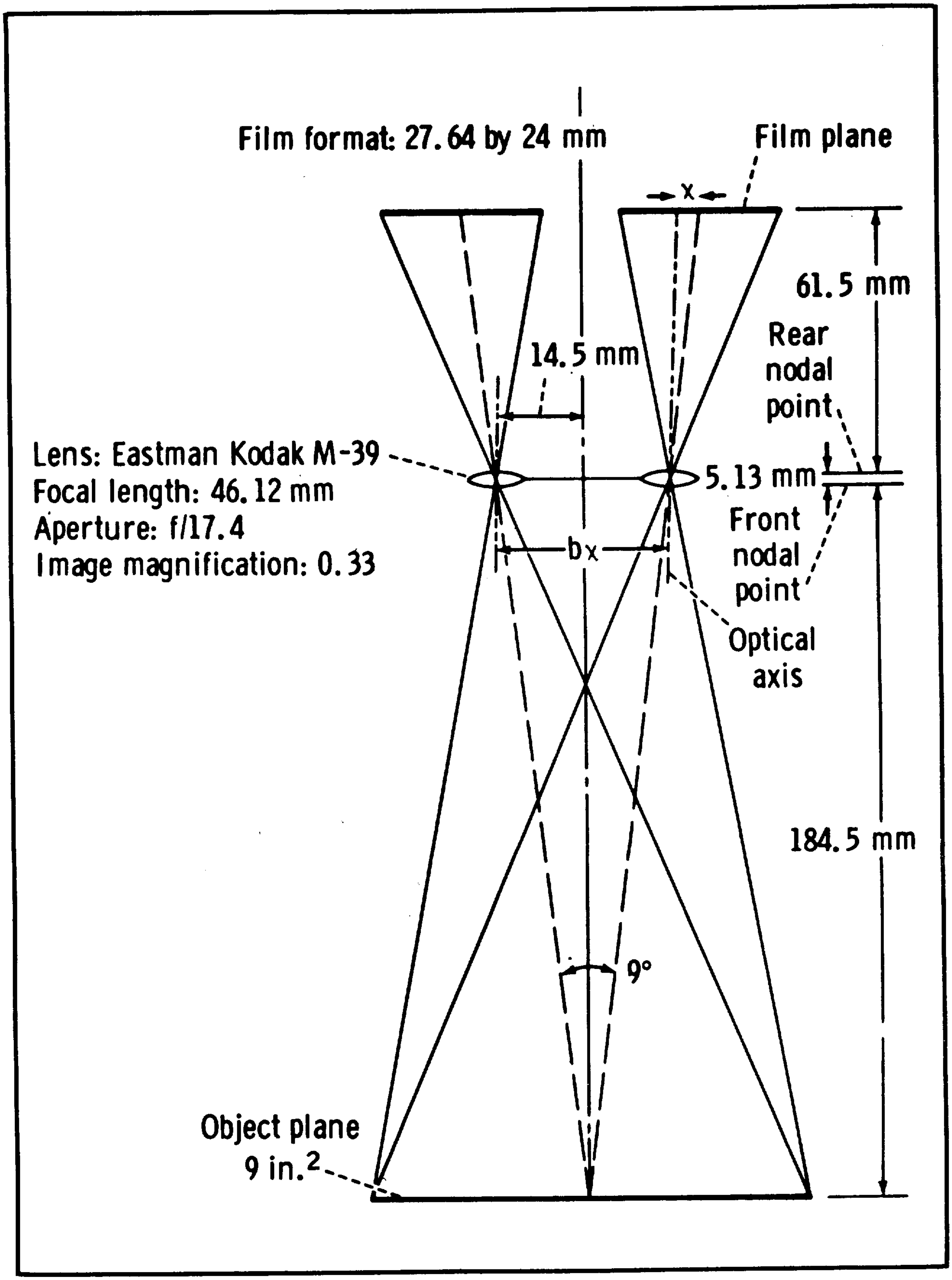


FIGURE 2.4-2 LUNAR CLOSE-UP CAMERA OPTICS

Technical Data - Closeup Stereo Photography Experiment

Principal Investigator: Thomas Gold, Cornell University

Manufacturer:	Eastman Kodak P/N 2501-120
Shutter Speed:	1/1000 sec.
Lens:	M-39
Focus Range:	Fixed
Aperture:	f/22.6
Film Magazine:	
Capacity	100 stereo pairs
Type	35mm SO 368 Ektachrome MS Color reversal ASA 64 2.5 mil Estar polyestor base
Weight:	10 lbs.

3.0 ORBITAL SCIENCE

3.1 GEGENSCHEIN IN LUNAR ORBIT (S-178)

Objective

The objective of the experiment is to obtain photographs of the Gegenschein and Moulton point regions to determine their spatial distribution. From these results, a detemination will be made of the extent of the contribution of dust particles, if any, at the Moulton point to the Gegenschein phonomenon.

Significance

Gegenschein is a light-source located on the earth's anti-solar axis. The Moulton point is one of the five gravity-null points in the sun-earth system and is also located on the earth's anti-solar axis at a distance of about 940,000 statute miles from the earth. It has long been thought that interplanetary dust particles might collect at the Moulton point and produce a light due to the normal scattering of sunlight. This experiment may determine whether a relationship exists between the gegenschein and the Moulton point, and will provide the first conclusive observational test of the phenomenon. Figure 3.1-1 shows the spatial relationship of the earth, the moon and the Moulton point during the conduct of S-178.

Operational Concept

From the vantage point of the quarter moon, the Moulton point has an angular separation from the extended anti-solar axis of nearly 15 degrees. Six photographs will be made using the 16mm data acquisition camera (DAC), w/18mm lens, EK 2485 or 2484 film and an aperture setting of f/0.90. Two photographs will be taken in each of three directions to span the region between the anti-solar direction and the Moulton point. Time per exposure will be 90 seconds or less depending on the film used.

Camera aiming directions will be provided by the Mission Control Center. Photographs will be taken after sunset and earthset. The spacecraft outside lights will be turned off and interior lighting will be reduced to a minimum. Window shades will be in place, with the bracket-mounted camera sighted through a suitable opening in the window shade. The spacecraft will be in inertial attitude hold with minimum attitude rates.

Analysis of the returned film will be by isodensitometry. Other data required to support the analysis include time and gimbal angles for each photograph.

Functional Description

The camera description and technical data are presented in Section 5.1.

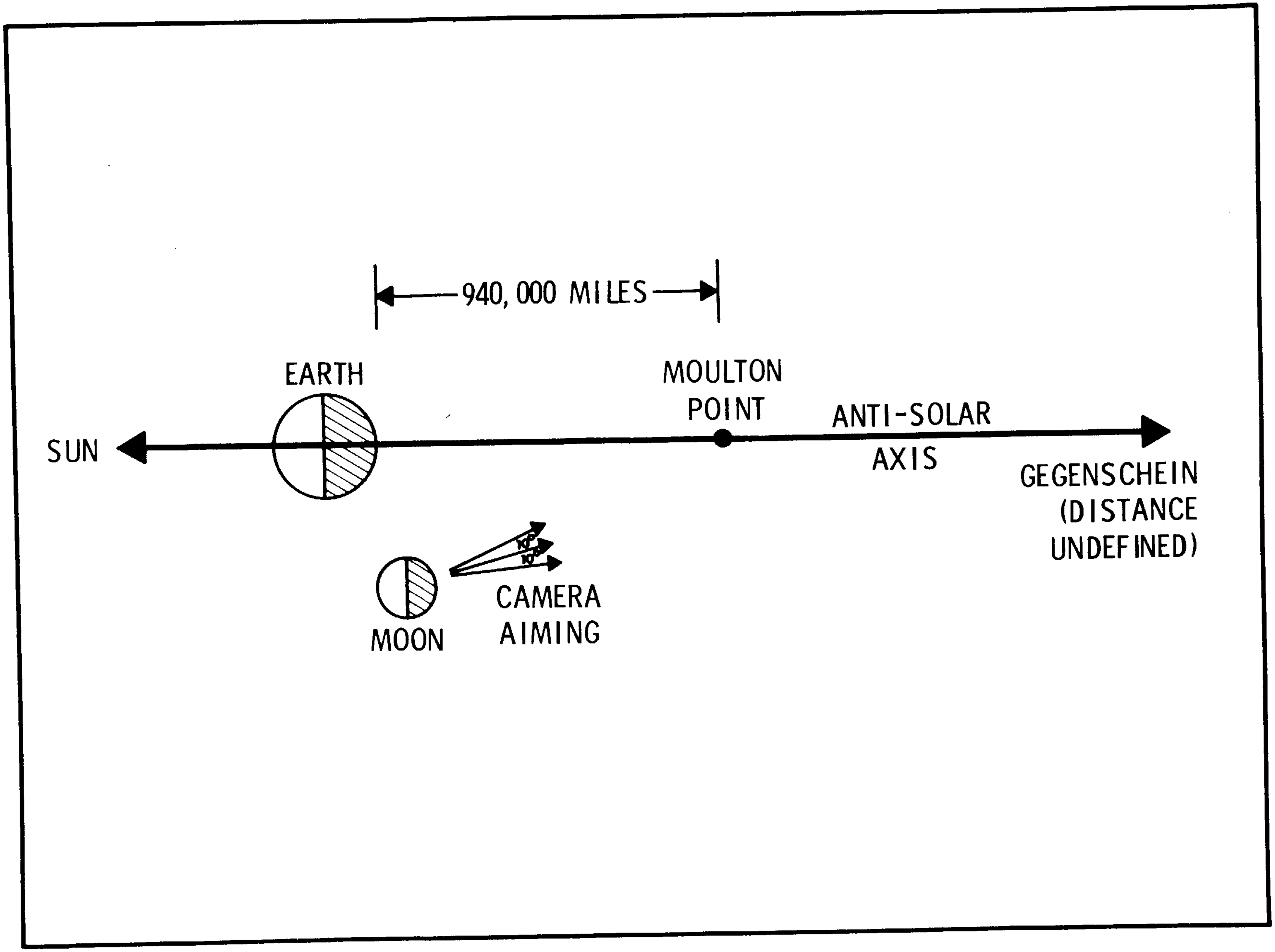


FIGURE 3.1-1. GEGENSCHEIN EXPERIMENT SPATIAL RELATIONSHIPS

3.2 LOW LEVEL LIGHT PHOTOGRAPHY

Objective

The objective of the low light level photography is to acquire photographs of various astronomical phenomena in the absence of the earth's atmosphere and to evaluate the ability to perform astronomical observations from a manned spacecraft.

Significance

A spacecraft in lunar orbit and transearth environments provides a unique opportunity for astronomical observations and photography because of the absence of the masking and distorting effects of an atmosphere. This is especially true in observations of phenomena such as solar corona, zodiacal light, lunar limb brightening and the gegenschein, in which the level of illumination is very low. The space environment also provides an opportunity to learn more about the contamination cloud that is believed to accompany manned spacecraft as well as the ice particles caused by water dumps.

a. Solar Corona

The solar corona is visible as a whitish halo surrounding the sun's disk and extending out for millions of miles. It is an irregular shaped envelope of high temperature, highly ionized gases which produce little visible light because of the extemely low density of the region. Because the moon has no atmosphere, it projects a sharp edge for coronal photography after sunset and before sunrise. Photographs will be taken just after the spacecraft enters the lunar umbra and will be compared with those taken later in the mission to reveal large scale coronal motions.

b. Zodiacal Light

Zodiacal light as viewed from the earth is a domeshaped (or pyramidal) region of faint luminosity which is believed to be sunlight scattered by particles suspended between the sun and the earth, and presumably orbiting throughout the solar system. Photographs will be taken in lunar orbit using the moon's horizon as an occulting edge which will provide a measure of the intensity of zodiacal light at much greater elongation than is possible from earth. An analysis of the intensity versus elongation will provide detailed information as to the spatial distribution of interplanetary particles and assist in the studies of micrometeoroid distribution in the solar system.

c. Lunar Limb Brightening

Photographs by Surveyor spacecraft and reports from astronauts indicate that a bright rim appears above the lunar horizon just after lunar sunset. If a good series of photographs of the phenomena can be obtained from lunar orbit it may be possible to determine if the effect is produced by sunlight scattered from lunar secondary ejecta as has been postulated. A study of the intensity of this light should indicate the particle size and distribution. These quantities will be helpful in evaluating the micrometeoroid environment in the lunar region.

d. Contamination

A contamination cloud has been found to be associated with manned spacecraft due to cryogenic outgassing, liquid dumps, etc. Photographs of selected star fields will be taken in lunar orbit and analysis of these photographs should determine the degree to which visual observations of stars are obscured by the contamination cloud. Apollo Applications Program experiments T025 and T027 will provide detailed contamination investigations to complement the advance information provided by these photographs.

e. Ice Particles

Ice particles are formed following a spacecraft water dump. The movement and collection points of these particles must be known to ensure clear observation during star sightings. Photographs of a star field of known brilliance will be taken during the transearth mission phase immediately following a water dump. This sould allow analysis of the visual degradation caused by ice particles.

Operational Concept

The condition for each of the functional test objectives follows:

FTO 1) Photographs of the solar corona, using the moon as an occulting disc, will be taken at both lunar sunset and lunar sunrise. These photographs will be taken as early as feasible and as late as feasible in lunar orbit. The Hasselblad camera, W/80mm lens will be used.

FTO 2) Photographs of the zodiacal light will be taken at both lunar sunrise and lunar sunset. Line-of-sight of the 16 mm DAC, W/18 mm lens will be 6 degrees above the lunar horizon.

FTO 3) Photographs of a selected star field will be taken in lunar orbit with the CSM in sunlight and with the CSM in lunar darkness to determine presence of contamination cloud surrounding the spacecraft. Line-of-sight of the Hasselblad, W/80 mm lens will be at angles of 45 degrees and 90 degrees from the sun.

FTO 4) Photographs will be taken in sunlight (during the trans-earth phase) of a water dump against a background of a star field of known brilliance. The 16mm DAC, W/18 mm lens will be used.

FTO 5) Photographs will be taken of the lunar limb just after lunar sunset. Line-of-sight of the 16mm DAC, W/18 mm lens will be on the lunar horizon.

Data requirements are as follows:

a) Astronaut Logs or Voice Records:

Record of G.E.T., magazine number, frame number, exposure time and any pertinent visual observations regarding the photographs obtained.

b) Photographs:

Photographs of the various dim light phenomena.

c) Trajectory Data:

Best estimate of trajectory (BET) for the CSM during the period when the dim light photographs are obtained.

Functional Description

Camera equipment is described in Section 5.1.

3.3 COMMAND MODULE PHOTOGRAPHY OF THE LUNAR SURFACE

Four major objectives are assigned to CM photography of the lunar surface. Each of the objectives are covered under separate subsections. Description of the cameras used in photography of the lunar surface are in Section 5.1.

3.3.1 Photography of Surface Areas of Prime Scientific Interest

Objective

The objective is to obtain photographs from orbit of areas and features of the lunar surface which are of interest to the scientific community and which will aid in the total exploration of the moon.

Significance

Very little of the moon's surface will be physically explored through manned landings and surface traverses. It is, therefore, important to the total exploration of the moon to utilize every means to accumulate data to add to our overall knowledge of the moon. Although prior programs such as Ranger, Surveyor and Lunar Orbiter provided large area coverage with low resolution photography, the area of high resolution photography coverage was extremely limited. From the CM in lunar orbit, high illumination angles and zero phase photography of high scientific and operational value can be obtained. Hence, this photography will guide future mission planning, generate questions as new phenomena are revealed, and allow for extrapolation of data collected at landing sites to larger segments of the lunar surface.

Operational Concept

A list of target areas of scientific interest is included in the Mission Requirements Document, H-2 Type Mission. The conditions for each functional test objective follows:

FTO 1) High resolution black and white photographs of areas of prime scientific interest will be obtained from the CSM using the Hycon KA-74 camera with image motion compensation (IMC) and 18 inch lens. This camera will be used both before rendezvous and after LM jettison to obtain photographs of scientific areas. Camera frame cycling will be set to provide 60 percent forward overlap. The number of frames per sequence are defined in the Photographic and Television Procedures Plan. The Hycon KA-74 will be attached to the hatch window for this FTO.

FTO 2) Low resolution black and white photographs of particular areas of the lunar surface will be obtained utilizing the Hasselblad reseau camera with the 80 mm lens. Camera frame cycling will be set to provide 60 percent forward overlap. This mode will also be utilized in obtaining terminator-to-terminator stereo strips at both low and high inclinations with respect to the lunar equatorial plane. One of these terminator-to-terminator strips may be the same data obtained in support of FTO 2) of objective Photographs of Candidate Exploration Sites (Section 3.3.2).

FTO 3) Medium resolution photographs of particular regions of the moon's surface will be obtained using the Hasselblad camera with the 250 mm lens. Camera frame cycling will be set to provide 60 percent forward overlap. The medium resolution photographs will be black and white except where specified otherwise.

FTO 4) Black and white photographs of particular areas in earthshine will be obtained using the 16 mm DAC camera. Camera frame cycling will be one frame per second. The number of frames per sequence will be as defined in the Photographic and Television Procedures Plan.

Data requirements include telemetry of 70 mm Hasselblad camera shutter opening and Hycon KA-74 camera sutter opening as indicated above for FTO 1, 2 and 4. Since shutter telemetry data can be obtained from only one of the two cameras at any specific time, first priority will be given to the use of the Hasselblad reseau camera as defined in FTO 2) while taking terminator-to-terminator strips. Second priority for shutter telemetry data will be given to the use of Hycon KA-74 camera. Shutter telemetry data are not required whenever the Hasselblad camera is used in support of FTO 3).

Other data required for all FTO's include astronaut logs or voice records to provide a record of G.E.T., magazine number, frame number, exposure times and any pertinent visual observations.

3.3.2 Photographs of Candidate Exploration Sites

Objective

The objective is to obtain photographs of candidate exploration sites for future Apollo missions.

Significance

Several of the future Apollo missions have as their prime objective the scientific exploration of lunar sites outside the original Apollo zone. In order to accomplish this, sufficient photographic data of the candidate sites must be obtained. These data will supplement the data obtained during unmanned missions and during

Apollo 8, 10, 11 and 12.

Operational Concept

The conditions for each functional test objective follows:

FTO 1) Photographs of the Censorinus site wll be obtained from the CSM at low altitude after the DOI maneuver but prior to the initial separation of the CSM and LM. The Hycon KA-74 camera, with image motion compensation (IMC), will be used with the camera axis normal to the local horizontal. Camera frame cycling will be set to provide 60 percent forward overlap. The photographic sequence will begin approximately 120 NM uprange of th Censorinus site and terminate approximately 30 NM downrange.

FTO 2) Photographs of candidate lunar sites will be obtained using a Hasselblad reseau camera with an 80 mm lens. Photographs of the ground track will be obtained from terminator to terminator for one pass over the two sites. Photographs will be taken every 20 seconds or less in order to achieve a 60 percent forward overlap thereby providing stereoscopic data.

The field of view of the above pass will include at least four landmarks spaced to bracket the candidate exploration sites and to control each end of the strip photographs. During the above pass, photographs will also be obtained at one frame per second through the sextant with the 16 mm DAC camera operating from terminator to terminator.

FTO 3) High resolution photographs will be taken of the selected sites with the Hycon KA-74 camera. Camera frame cycling will be set to provide 60 percent forward overlap. On either the preceding or succeeding revolution, a second strip of high resolution photographs will be taken with the camera optical axis aligned approximately 30 degrees forward of the local vertical. The high resolution photographic sequence will extend from at least 120 NM uprange to 30 NM downrange from each site.

Data requirements include the 70 mm Hasselblad shutter open and the Hycon KA-74 shutter open telemetry. Other data include records of magazine number, pertinent visual observations of each sequence, and trajectory data.

3.3.3 Selenodetic Reference Point Update

Objective

The objective is to obtain lunar landmark tracking data for selected sites for use in updating selenodetic reference points.

Significance

Lunar surface photographs and navigation data obtained from various spacecraft in lunar orbit have resulted in the preparation of detailed photomaps of a relatively small portion of the lunar surface. Inconsistencies exist in the coordinates for lunar features identified by both lunar aeronautical charts (LAC) and the photomaps. Therefore, in order to adequately update the coordinate system used in constructing LAC, it is necessary to accurately determine the location of a set of defined lunar reference points.

Operational Concept

While in lunar orbit the CM will track preselected lunar landmarks.

The CSM scanning telescope will be used to track a small feature as close as possible to the center of the specified lunar landmarks. Tracking will start at approximately one and one-half minutes prior to passing over each landmark and will continue for approximately one and one-half minutes after passing each landmark.

During each pass that landmark tracking is accomplished, photographs will be obtained at one frame per second through the sextant with the 16 mm DAC camera. During the photography, the optics will be in either the low or medium rate drive mode.

As soon as possible after the final mark on each landmark is completed, 16 mm sequence photographs at one frame per second will be obtained of the area surrounding the landmark. This will be accomplished by moving the scanning telescope such that the sextant field of view traverses the target across the width and along the length of the landmark to include the edges of the landmark.

3.3.4 Transearth Lunar Photography

Objective

The objective is to obtain photographs yielding large area coverage of the lunar farside and eastern limb for extension of selenodetic control and improved mapping.

Significance

The area covered by orbital Apollo photographs of the moon is limited by the altitude of the orbit, the focal length of the cameras used and the fact that all orbits have been near equatorial. Observations from earth are limited to the near side of the moon. As a result, our knowledge of the features on the limbs, the far side and at high latitude is quite limited. Accomplishment of this objective will increase the knowledge of the size, shape and mass distribution of the moon and result in improved charts of the lunar surface.

Operational Concept

The planned photography consists of a number of sequences, each of which will provide full coverage of the visible disc of the moon by either one photograph or a series of overlapping photographs. All photographs will be taken through the hatch window since the required full disc coverage cannot always be obtained through the other windows without attitude maneuvers.

After TEI, photographs of the lunar surface will be obtained using the Hasselblad camera with 80 mm and 250 mm lens and using the Hycon KA-74 camera.

All photographs will be obtained with the spacecraft in attitude hold and oriented with the hatch window pointed toward the center of the visible surface of the moon. The photographs will be taken through the hatch window. All photographs will be taken on Type 3400 black and white film.

4.0 MISSION OPERATIONS

4.1 LANDING SITES

The primary landing site for Apollo 13 is the Fra Mauro formation. The backup site is the Flamsteed region. The location of the sites and other landmarks are shown in Figure 4.1-1.

4.2 LAUNCH WINDOWS

The launch windows for both Fra Mauro and Flamsteed are shown below:

LAUNCH DATE	LAUNCH WINDOW OPEN	CLOSE	SITE	TRAJECTORY	SUN ANGLE
April 11, 1970	14:13 EST	17:37 EST	Fra Mauro	Hybrid	9.9°
May 10, 1970	13:35 EDT	16:44 EDT	Fra Mauro	Hybrid	7.75°
May 12, 1970	13:42 EDT	16:40 EDT	Flamsteed	Hybrid	8.0°

4.3 LUNAR SURFACE OPERATIONS

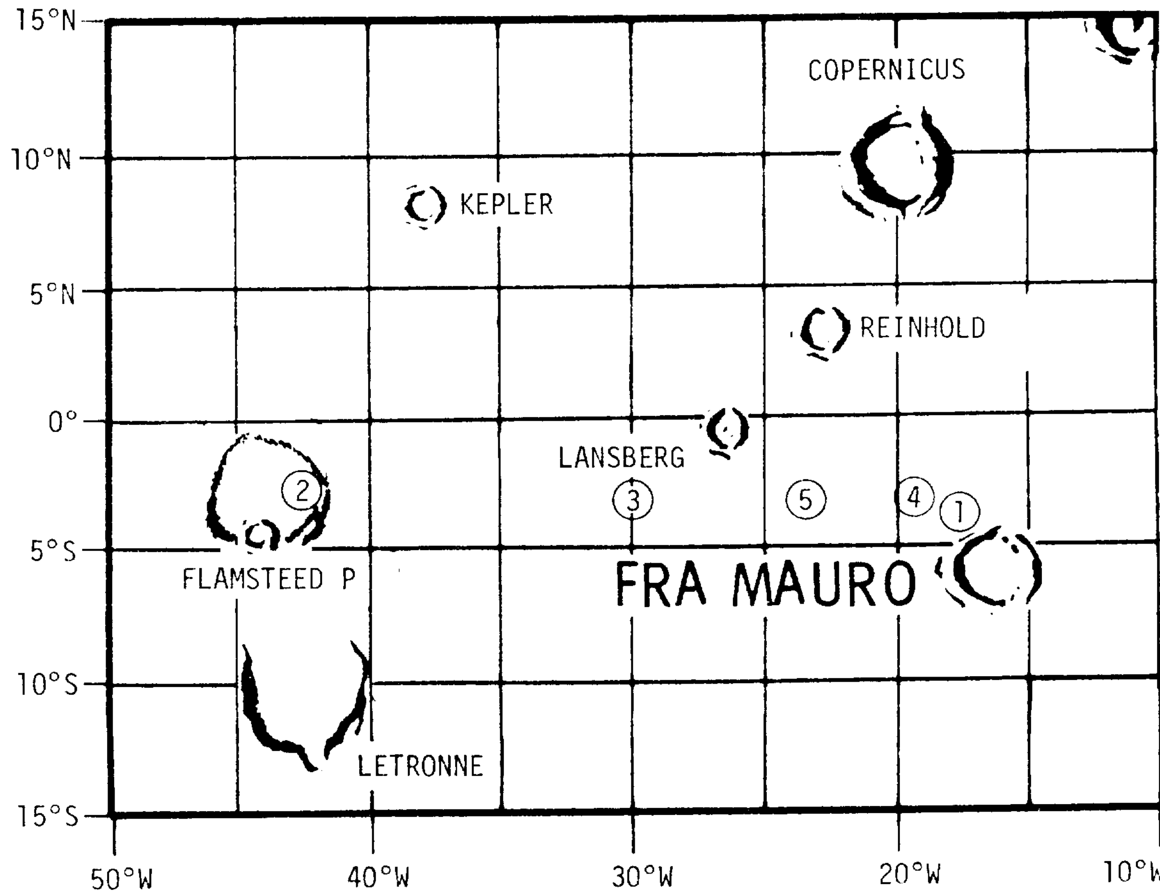
EVA-1

The first lunar surface excursion commences with depressurization of the LM ascent stage cabin. The Commander (CDR) will move through the hatch, deploy the lunar equipment conveyor (LEC) and the modularized equipment stowage assembly (MESA) and then descend to the lunar surface. The Lunar Module Pilot (LMP) will monitor and photograph the CDR using a 70mm and a sequence camera (16 mm Data Acquisition Camera). A summary of EVA-1 activities is shown in Figure 4.3-1.

Environmental Familiarization/Contingency Sample Collection - After stepping to the surface and checking his mobility, stability, and the extravehicular mobility unit (EMU), the CDR will collect a contingency sample which would make it possible to assess the differences in the lunar surface material in the event the EVA were terminated at this point. The sample will be collected by quickly scooping up a loose sample of the lunar material (approximately 2 pounds) and sealing it in a contingency sample container which is later transferred in the equipment transfer bag (ETB) into the LM using the LEC.

The LMP will lower the Hasselblad 70mm camera on the LEC to the CDR. The CDR performs preliminary photography of the lunar surface. The LMP will then descend to the surface.

1. APOLLO 13 PRIMARY SITE
2. APOLLO 13 BACKUP SITE
3. APOLLO 13 S-IVB IMPACT
4. APOLLO 13 ASCENT STAGE IMPACT
5. APOLLO 12



SITE	LATITUDE	LONGTITUDE	SOURCE DATA
Primary - FRA MAURO	3°37'S.	17°33'W.	Lat. and Long. from Lunar Orbiter IV Triangulation
Backup - FLAMSTEED	2°46'S.	42°41'W.	MSC Triangulation.

FIGURE 4.1-1. LANDING SITES

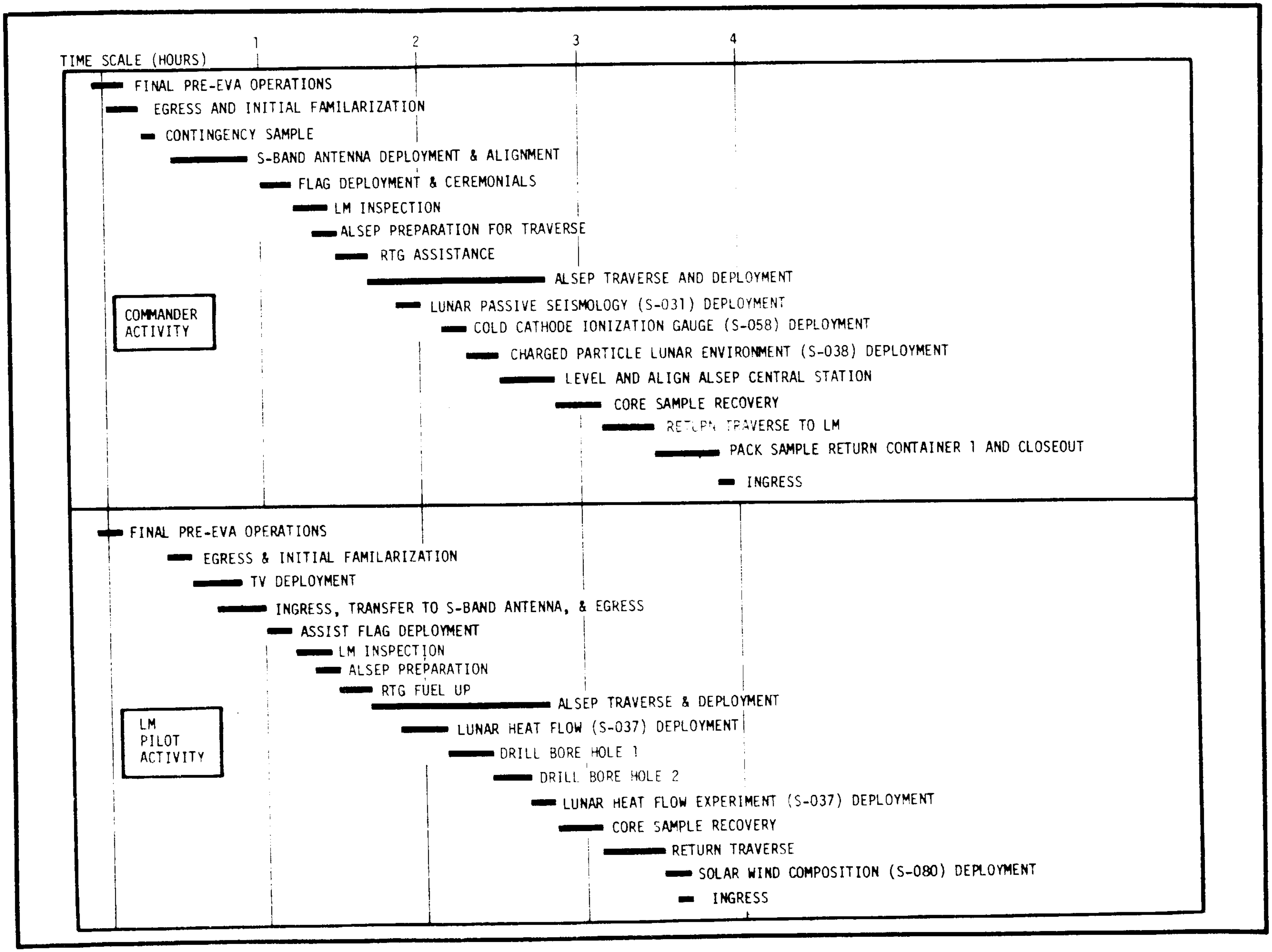


FIGURE 4.3-1 APOLLO 13 EVA-1 SURFACE ACTIVITIES

S-Band Antenna Deployment - The S-band antenna will be removed from the LM by the CDR who will erect it, connect the antenna cable, and perform the required alignment. The activity will be photographed by the LMP.

Lunar TV Camera (Color) Deployment - While the CDR deploys the S-band antenna, the LMP will unstow the TV camera and deploy it on the tripod approximately 50 feet from the LM.

As soon as the S-band antenna and TV camera are deployed, the LMP ingresses the LM. The LMP activates and verifies TV transmission with the mission control center. The contingency sample and other equipment is transferred into the LM and the 16mm lunar surface data acquisition camera is transferred to the surface. The LMP egresses again, leaves the hatch slightly ajar, and descends to the surface. Following this, the American flag is deployed and the deployment ceremony is completed by the CDR.

LM Inspection - After repositioning the TV to view the scientific equipment bay area, the LMP will inspect and photograph the LM footpads and quadrants I, II, II and IV with an EMU-mounted 70mm camera. Concurrently the CDR will obtain panorama and close-up photographs.

ALSEP Deployment - After offloading ALSEP from the LM, the radioisotope thermoelectric generator (RTG) will be fueled, the ALSEP packages will be attached to a one-man carry bar for traverse in a barbell mode, and the TV will be positioned to view the ALSEP site. The hand tools are loaded on the hand tool carrier and the CDR and LMP will then carry the ALSEP packages, hand tool carrier, and Apollo lunar surface drill to the deployment site approximately 300 feet from the LM. The crew will survey the site and determine the desired location for the experiments. The following individual experiment packages will then be separated, assembled, and deployed to respective sites in the arrangement shown in Figure 4.3-2.

Lunar Heat Flow (S-037) - The LMP will assist the CDR with the RTG electrical cable deployment after which the heat flow experiment will be deposited on the surface. The battery powered drill will be assembled by the LMP; and he will drill two three-meter deep holes using hollow-center bore stems. Each bore stem will be left in place as an encasement into which the heat flow probes are inserted.

Passive Seismic (S-031) - The CDR will, concurrently with the LMP's deployment of the heat flow experiment, deploy the stool and set up the passive seismic package with its thermal cover.

Cold Cathode Ionization Gauge (S-058) - The CDR will then deploy and orient the cold cathode ionization guage.

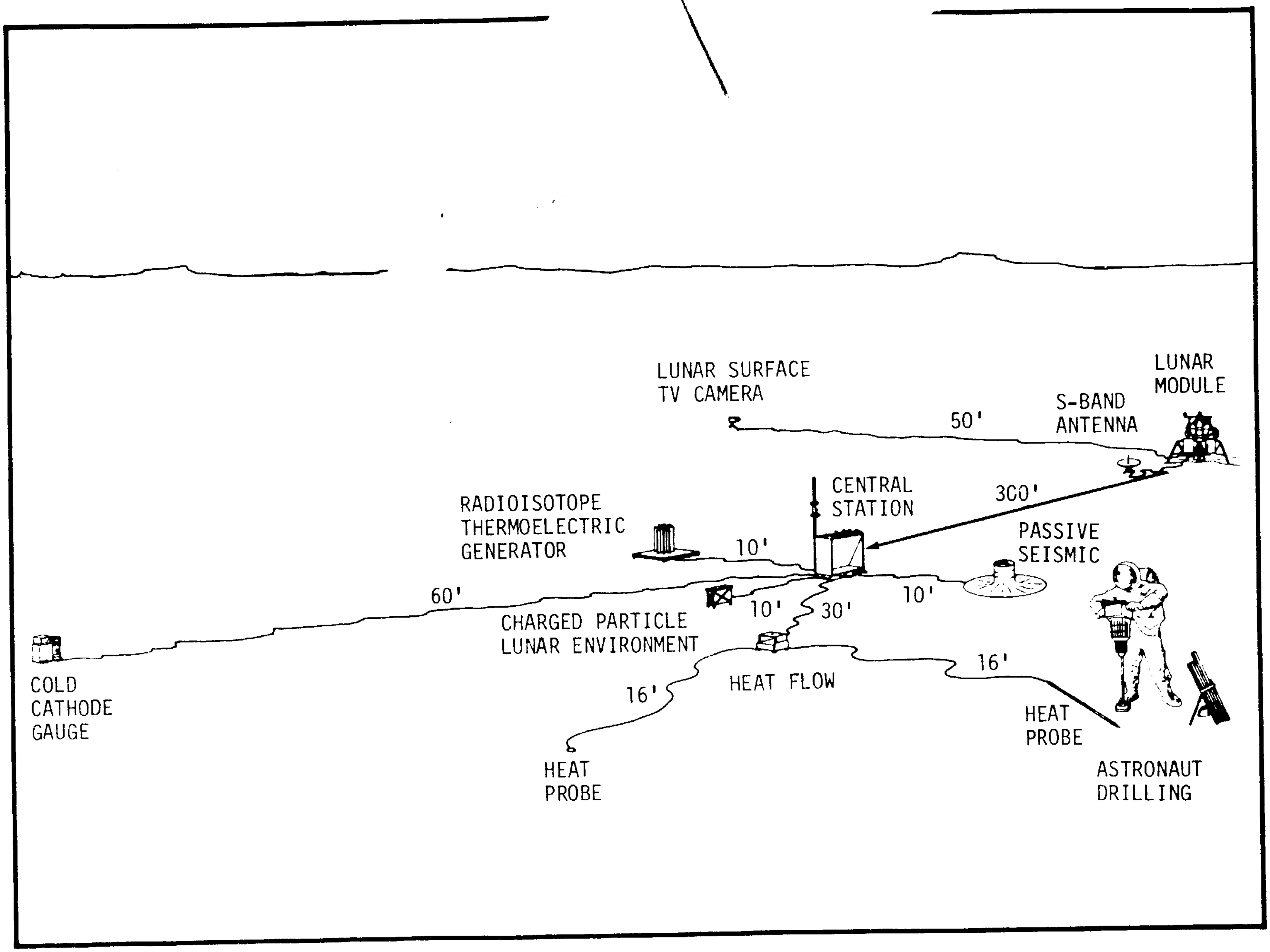


FIGURE 4.3-2 DEPLOYMENT GEOMETRY FOR ALSEP III (ARRAY B)

Charged Particle Lunar Environment (S-038) - The CDR will deploy and orient the Charged Particle Lunar Environment Experiment while the LMP is drilling hole number one for the HFE.

ALSEP Central Station - The CDR will level and align the central station which includes delopyment of the sun shield. At this time the LMP will be drilling hole number two for the HFE.

Core Sampling - The CDR will assist the LMP to complete deployment of the lunar heat flow experiment as required. The crew will modify the lunar surface drill for core sampling. After this operation is completed, the CDR will take final photographs of the ALSEP layout while the LMP conducts debris cleanup.

Selected Sample Collection - The crew will begin the return traverse and initiate collection of the selected samples. At the return to the LM samples are weighed and, with the core stems, stowed in the sample return container (SRC) and the SRC sealed.

Solar Wind Composition (S-080) - The four square feet panel of aluminum foil will be deployed by the LMP.

EMU cleaning and ingress into the LM will be accomplished by the LMP and the CDR will transfer SRC 1 into the LM assisted by the LMP. The CDR will clean his EMU and ingress. The LM cabin will be repressurized and EVA-1 terminated.

EVA-2

The LM will be configured for EVA activities and the CDR will egress. The LMP will again monitor and photograph the CDR and then transfer camera equipment in the ETB to the CDR with the LEC. The LMP will descend to the lunar surface leaving the LM hatch slightly ajar. A summary of EVA-2 activities is shown in Figure 4.3-3.

Contaminated Sample Collection and Close-Up Stereo Photos - While the CDR is retrieving SRC 2 and collecting a contaminated sample under the LM, the LMP will obtain lunar surface close-up stereo photos near the LM and the contaminated sample area. The LMP will then position the TV camera for the field geology traverse.

Lunar Field Geology (S-059) Traverse - Both crewmen will participate in the conduct of the field geology traverse. The field geology traverse is planned in detail prior to launch. Additional support and real-time planning will be provided from the ground based on features of the landing site obtained from crew descriptions and TV. Traversing outbound from the LM, the crew will obtain close-up stereo camera (CSC) photos of selected areas. They will dig trenches, as suggested by features of surface panoramas, obtain subsurface samples, core samples, and surface samples. Special gas analysis and magnetic lunar surface samples will be collected. Approximately 1/2 mile from the LM the CDR will dig a

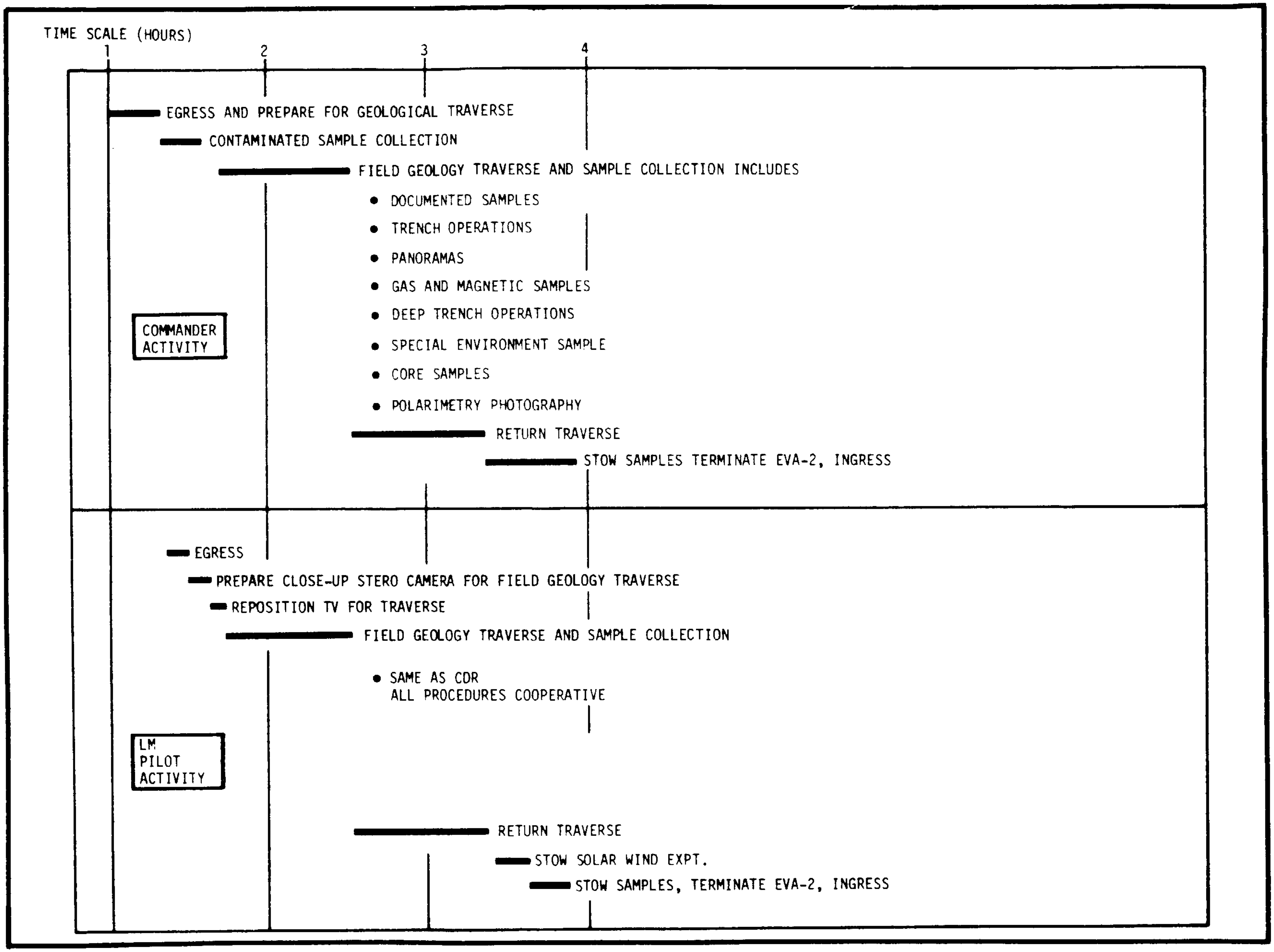


FIGURE 4.3-3 APOLLO 13 EVA-2 SURFACE ACTIVITIES

deep trench for lunar soil mechanics evaluation. The LMP will collect a core sample and a special environmental sample from the trench and obtain photographic data of the boot prints in the trench material.

The crew will begin traversing inbound to the LM by a different route to obtain additional documented samples as performed on the outbound traverse. A typical documented sample procedure will include locating the gnomon up sun of the sample site, photography of the site and the sample, description of the sample, and stowage of the lunar surface material in a sample bag. The typical core sampling will consist of placing the gnomon up sun and photography of the sample site cross sun, driving the core tube into the surface, recovery and capping the sample within the tube.

Upon return of the crew to the LM, the CDR will offload the samples into SRC 2. The LMP takes down and rolls up the solar wind experiment and places it in the SRC, which is then closed and sealed. The LMP will clean his EMU, ingress into the LM, and hook up the LEC. The CDR and LMP will utilize the LEC to transfer samples and equipment into the LM. The CDR will clean his EMU, ascend into the LM, jettison the LEC and ingress. The LM will be repressurized, terminating EVA-2. Equipment and samples will be stowed and preparations made for equipment jettison. The LM will be depressurized, equipment jettisoned, and the LM repressurized.

4.4 ORBITAL OPERATIONS

Initial Lunar Orbits

The LOI maneuver will result in a 60 by 170 nm elliptical orbit. During the two revolutions in this orbit the crew will observe the lunar surface, eat, conduct housekeeping chores, monitor earthrise through the optics, conduct lunar landmark tracking, realign the IMU, accept numerous updates from the ground, conduct sextant star checks, and prepare for the DOI (LOI-2) maneuver.

Low Lunar Orbits

After two revolutions in the 60 by 170 nm orbit DOI will be performed with the SPS to place the spacecraft in an initial 8 by 60 nm lunar orbit. The main activities in this orbit include LM housekeeping acitivites, intervehicular transfer (IVT) to the LM for checkout, photography of Censorinus, guidance updates, IMU realignments, an 8 1/2 hour rest period, and undocking and separation.

CSM Solo

Undocking and separation will occur during the twelfth lunar orbit. While the LMP and CDR land on the lunar surface and conduct lunar surface operations the Command Module pilot (CMP) will conduct CSM solo operations. After one revolution the CSM performs a circularization maneuver which changes the CSM orbit to a 60 by 60 nm orbit. During CSM solo operations the CMP will align the IMU, conduct housekeeping activities, engage in lunar landmark tracking, track the LM, receive updates from the ground each revolution, obtain spacecraft contamination field photographs, obtain photographs of the solar corona and limb brightening, conduct orbital science photograph, execute a CSM orbital plane change of 2°, obtain photographs of the zodiacal light and gegenschein, and set up cameras to photograph docking and rendezvous. The CMP will dock with the LM on revolution 33.

Post-Ascent CSM Activities

After CSM/LM docking, equipment will be transferred; decontamination accomplished and the LM jettisoned. The LM ascent stage will be deorbited to impact on the lunar surface. High resolution photographs of sites near Davy Rille and northwest of Censorinus will be taken with the Lunar Topographic Camera. One pass will be be made with the camera axis aligned 30 degrees forward of the local vertical. As a backup high resolution photographs using the 500mm lens will be taken of Descartes and Censorinus. A second CSM plane change of 11° will be executed to gain additional photographic coverage of selected prime sites for future landing missions. Stereo strip photography will be obtained from terminator to terminator. The crew will sleep for 8 hours, engage in housekeeping activities, realign the IMU, receive numerous updates and tracking pads from the ground, eat, track lunar landmarks, obtain photographs of the solar corona and limb brightening, and prepare for and execute the TEI maneuver during revolution 46.

5.0 PHOTOGRAPHIC EQUIPMENT

5.1 COMMAND MODULE

Equipment List

Three types of operational and/or orbital science cameras are provided for Apollo 13 photography. In addition a color television camera system is included. Functional descriptions of camera use in orbital science experiments are provided in Section 3.0. Typical operational uses of cameras are LM docking and crew operations. Table 5.1-1 lists camera equipment to be carried and used in the command module (CM).

Camera Systems	Part Number	Units
16mm Data Acquisition Camera	SEB 33100100-204	1
16mm magazine	SEB 33100125-203	5
5mm lens	SEB 33100056-208	1
18mm lens	SEB 33100018-301	1
75mm lens	SEB 33100019-302	1
Miscellaneous Accessories		
70mm Electric Hasselblad w/Reseau Grid	SEB 33100040-304	1
70mm Electric Hasselblad	SEB 33100102-206	1
70mm magazine	SEB 33100082-213	2
80mm lens	SEB 33100261-301	1
250mm lens	SEB 33100032-201	1
500mm lens	SEB 33100284-301	1
Miscellaneous Accessories		
Hycon KA-74 w/18mm Lens	SEB 33100306-301	1
magazines	SEB 33100307-301	2
Miscellaneous Accessories		
Color TV Camera System	SEB 16101081-301	1
Miscellaneous Accessories		

TABLE 5.1-1 CM PHOTOGRAPHIC EQUIPMENT LIST

16mm Data Acquisition Camera

Purpose

The Data Acquisition Camera (DAC) will be used for obtaining sequential photographic data, for documentary photography of crew activity within the CM, and for the orbital science photography.

Description

The DAC is a modified movie camera which is an improved version of the earlier Gemini-type 16mm sequence camera equipped with upgraded external film magazines which greatly enhance the photographic capabilities of the camera. Camera operation is manually controlled by an on-off switch located on the front of the camera. Camera accessories include a power cable, film magazines, lenses, right angle mirror, and a ring sight. Film for each mission is supplied in pre-loaded film magazines that may be easily installed and/or removed from the camera by a gloved crew member. Magazine run time versus frame rate varies from 87 minutes at one frame per second to 3.6 minutes at 24 frames per second. The camera is shown in Figure 5.1-1.

Technical data on the 16mm DAC camera and major accessories are presented in Table 5.1-2.

70mm Hasselblad Electric Camera and Accessories

Purpose

The 70mm camera is primarily used for high resolution still photography, and is hand-held or bracket mounted and manually operated.

Description

Camera features include interchangeable lenses and film magazines. The standard lens is an 80mm f/2.8; a 250mm f/4 lens and a 500mm f/8 telephoto lens are provided for photography of distant objects. Two types of 70mm film magazines are provided, one for standard-base films, the other for thin-base films. On Apollo 13, the 500mm lens is being provided as a backup to the Hycon KA-74 camera. Some specific uses of the camera are as follows:

- Verify landmark tracking
- Lunar landmark and mapping
- Record Saturn IVB separation

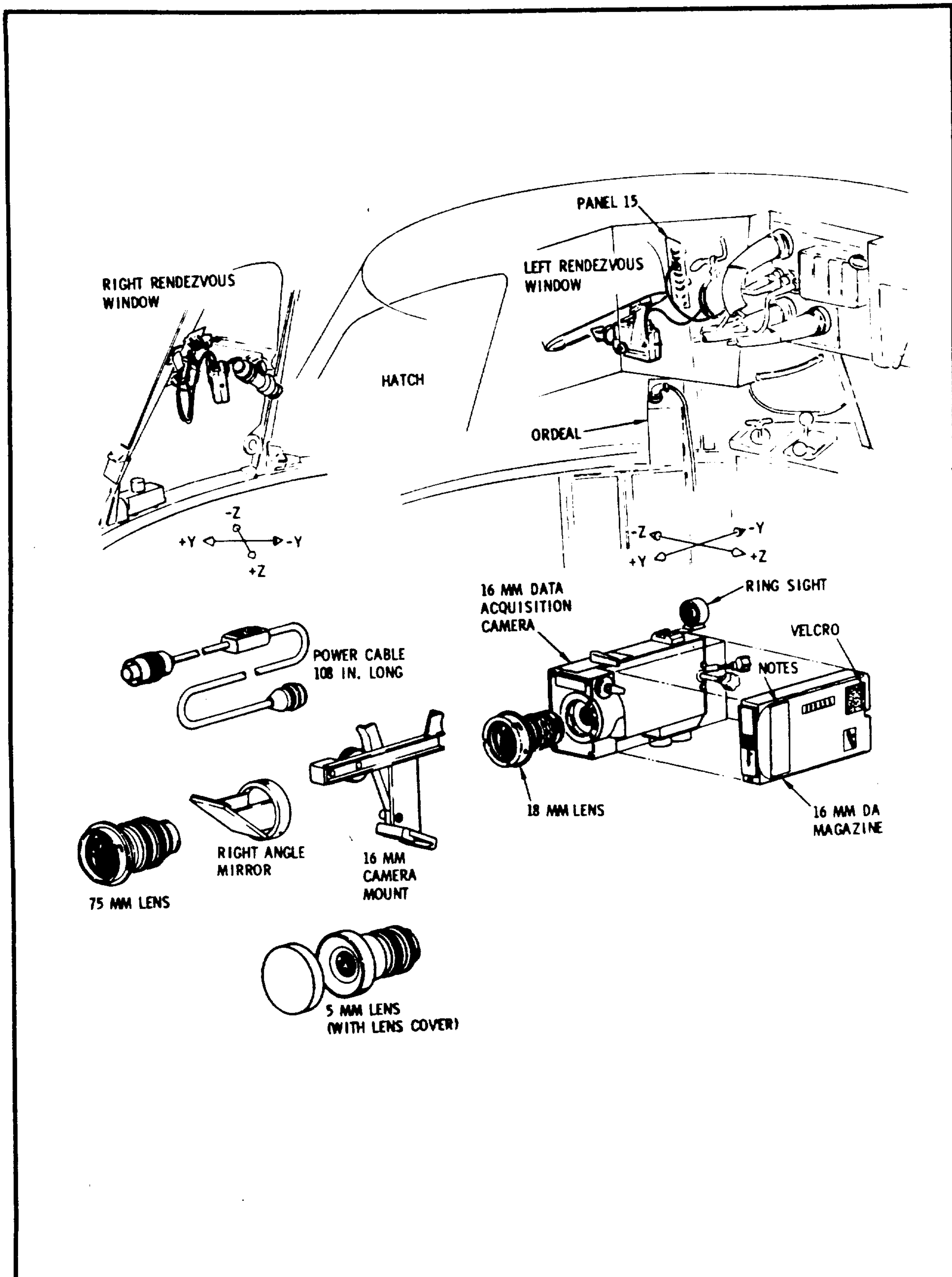


FIGURE 5.1-1. 16MM DATA ACQUISITION CAMERA

	CAMERA	MAGAZINE	5mm LENS	18mm LENS	75mm LENS
P/N SEB	33100100 - 204	33100125 - 203	33100056 - 208	3310018 - 301	33100019 - 302
MFR.	MAURER	MAURER	FAIRCHILD	KERN	KERN
SIZE (Inches)	6 x 3.75 x 2.4	3.5 x 5.6 x .8			
WEIGHT (Lbs.)	1.8	1	0.7	0.71	0.8
POWER	BATTERY OR S/C 28 vdc				
SHUTTER SPEED (Sec.)	1/60, 1/125, 1/250 1/500, 1/1000				
FRAME RATES (Time)	1, 6, 12, 24, TIME				
APERTURE			f/2.0-f/16	T/1-T/22	T/2.8-T22
FOCUS RANGE			LENS FACE TO INFINITY	1 FT. TO INFINITY	5 FT. TO INFINITY
FIELD OF VIEW (Degrees)			117.5 x 80.2 160 DIAG.	32 x 24 39 DIAG.	7.9 x 5.7 10 DIAG.
MAGAZINE CAPACITY		130 FT. THIN BASE FILM			

TABLE 5.1-2 16MM DAC EQUIPMENT DATA

- Photography disturbed weather regions (hurricanes, typhoons, etc.) debris collection on the spacecraft windows, SLA separation, LM during rendezvous and docking, and terrain of geological and oceanographic interests, and other space equipment in orbit

- Act as a backup to the 16mm sequence camera

- Record crew activities (s/c interior)

The 70mm Hasselblad camera is electrically operated. A built-in 6.25-vdc battery-powered, electric-motor-driven mechanism advances the film and cocks the shutter whenever the actuation button is pressed. An accessory connector permits remote camera operation and shutter operation indication for time correlation. The 70mm Hasselblad camera may be equipped with a reseau grid. The camera is shown in Figure 5.1-2.

The reseau grid (Figure 5.1-3) is used to improve the photogrammetric data thereby facilitating scientific evaluation and mapping of the lunar surface. As used in the modified 70mm Hasselblad, a precision glass-plate reseau grid is installed on the camera body immediately in front of the image plane. Three lenses have been designed or modified for use with the 70mm Hasselblad w/reseau grid: the Planar f3.5/100mm lens; the Planar f2.8/80mm lens; and the Biogen f5.6/60mm lens.

The intervalometer is a remote control device used for taking sequential pictures. It is extremely useful for strip map photography (vertical stereo strip from rendezvous window, oblique stereo strip from side windows, etc.). The intervalometer can be set over an interval range of 6 to 35 seconds and is powered from the Hasselblad Electric Camera battery pack.

Technical data on the 70mm Hasselblad cameras and major accessories are presented in Table 5.1-3.

Hycon KA-74 Camera

Purpose

The Hycon KA-74 camera (w/18 inch focal length lens) is used primarily for high resolution photography of the lunar surface.

Description

The camera is mounted to the command module hatch window. Lunar surface area coverage from an altitude of 60 nautical miles (nm) is 15nm by 15nm for a single frame of film. Total coverage provided by one magazine is 15nm x 2840nm with minimum overlap. Object size resolution from a 60 nm lunar orbit is approximately 12 feet. Interfaces with the spacecraft are the mounting bracketry,

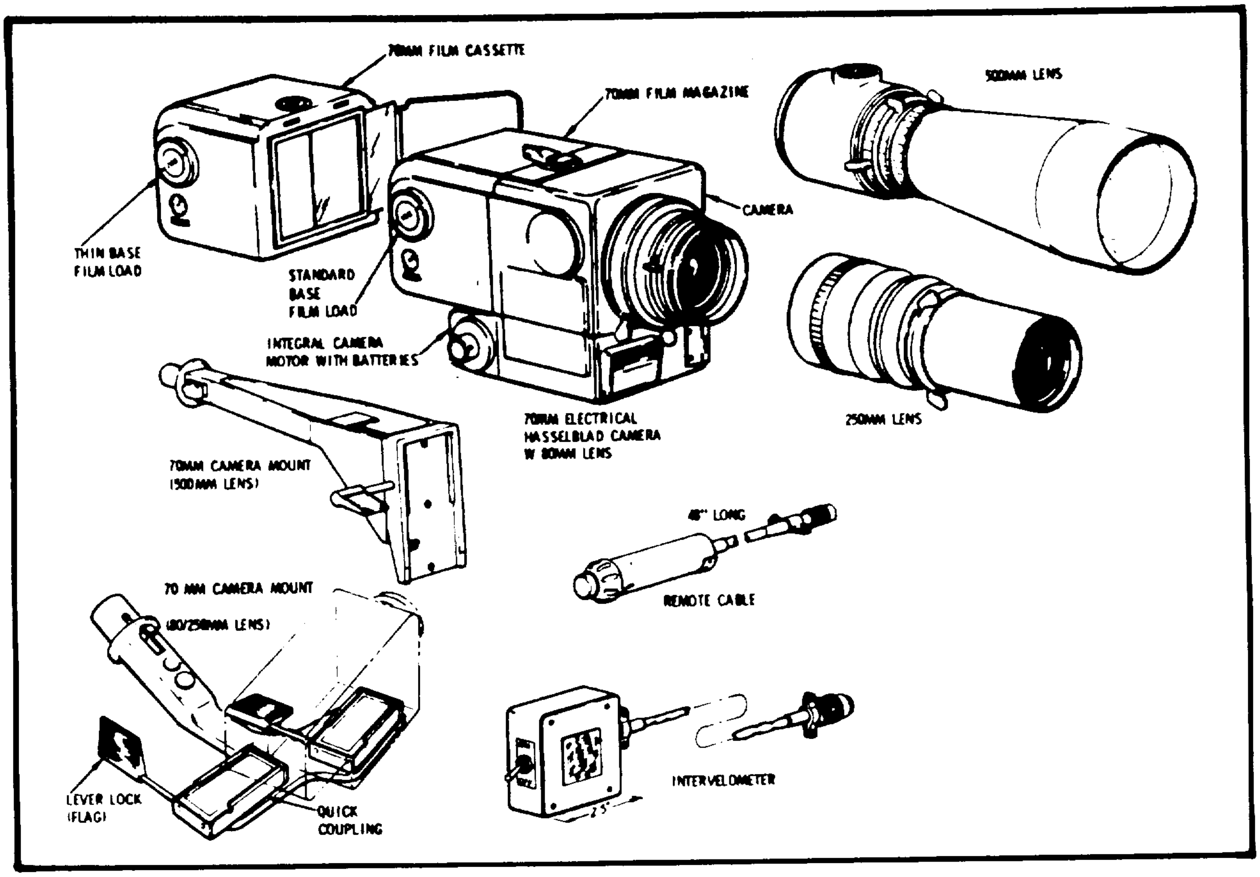


FIGURE 5.1-2. 70MM HASSELBLAD CAMERA

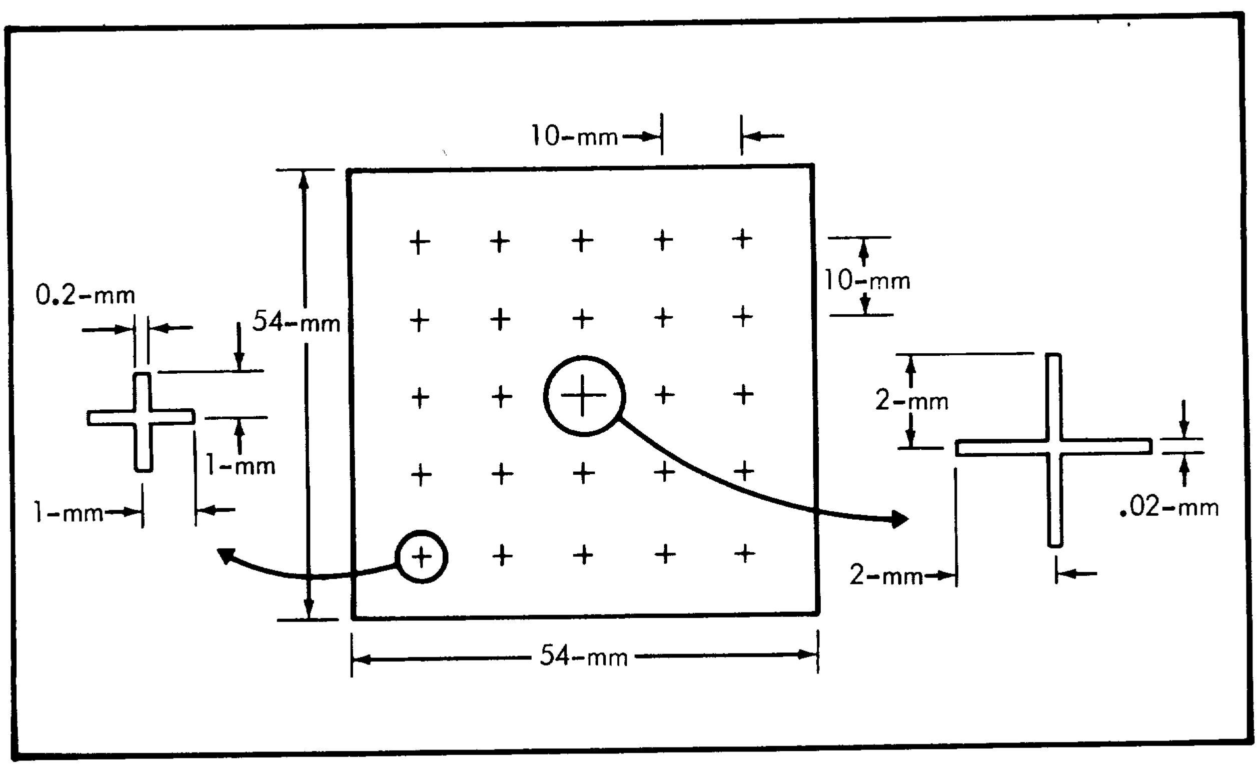


FIGURE 5.1-3. RESEAU GRID

	CAMERA	MAGAZINE	80mm LENS	250mm LENS	500mm LENS
P/N SEB	33100040-304(1) 33100102-206	33100261 -213	33100261 - 301	33100032 - 201	33100284 - 301
MFR.	HASSELBLAD	HASSELBLAD	ZEISS	ZEISS	ZEISS
SIZE (Inches)	4.7 x 4.2 x 5.8	3.5 x 3.5 x 3.25	2.0 x 4.2 diam.		12.13 x 3.54 diam.
WEIGHT (Lbs.)	3.0	1.75	1.0	2.06	5
POWER	(2)6.25v Ni-Cd BATTERIES				
SHUTTER SPEED (Sec.)			1 TO 1/500	TIME 1 TO 1/500	1 TO 1/500
FRAME RATES (Time)	TIME ONLY				
APERTURE			f/2.8 - f/22	f/5.6 - f/45	f/8 - f64
FOCUS RANGE			3 FT. TO INFINITY	8.5 FT. TO INFINITY	28 FT. TO INFINITY
FIELD OF VIEW (Degrees)			37.9 x 37.9 51.8 DIAG.	12.5 x 12.5 17.6 DIAG.	APPROX. 7
MAGAZINE CAPACITY		200 THIN BASE B&W OR 160 THIN BASE COLOR			

(1) P/N 33100040 -304 HAS RESEAU GRID. P/N 33100102 - 206 HAS NO RESEAU GRID.

TABLE 5.1-3 70MM HASSELBLAD EQUIPMENT DATA the power supply and connection to the auxiliary urine dump on the hatch (to provide a vacuum to the film platen). A feature of the camera which facilitates spacecraft operations is the image motion compensation which provides overlapping photographs when making strip photography. The camera is shown in Figure 5.1-4.

Technical Data - Hycon KA-74 Camera

Part Number	SEB 33100306-301
Mfr.	Hycon
Size (w/lens)	11" x 12" x 28"
Weight (w/lens)	47 lbs.
Power	115 vac, 400 Hz
18 Inch Lens	
Mfr.	Perkins-Elmer
Size	11" x 6.1" diameter
Weight	18.6 lbs.
Aperture	f/4
Focus	Infinity
Shutter speeds	1/50, 1/100, 1/200 (sec.)
Magazine	P/N SEB 33100307-301
Mfr.	Hycon
Size	10.3" x 8.2" x 6.4"
Weight	11 lbs.
Capacity	430 frames
Format	4.5" x 4.5"
Special Camera System Features	
Data Recording	time, shutter speed, magazine no.
Photogrammetric	reseau grid on format edge
Image Motion Compensation	
Vacuum Platen	film flattening

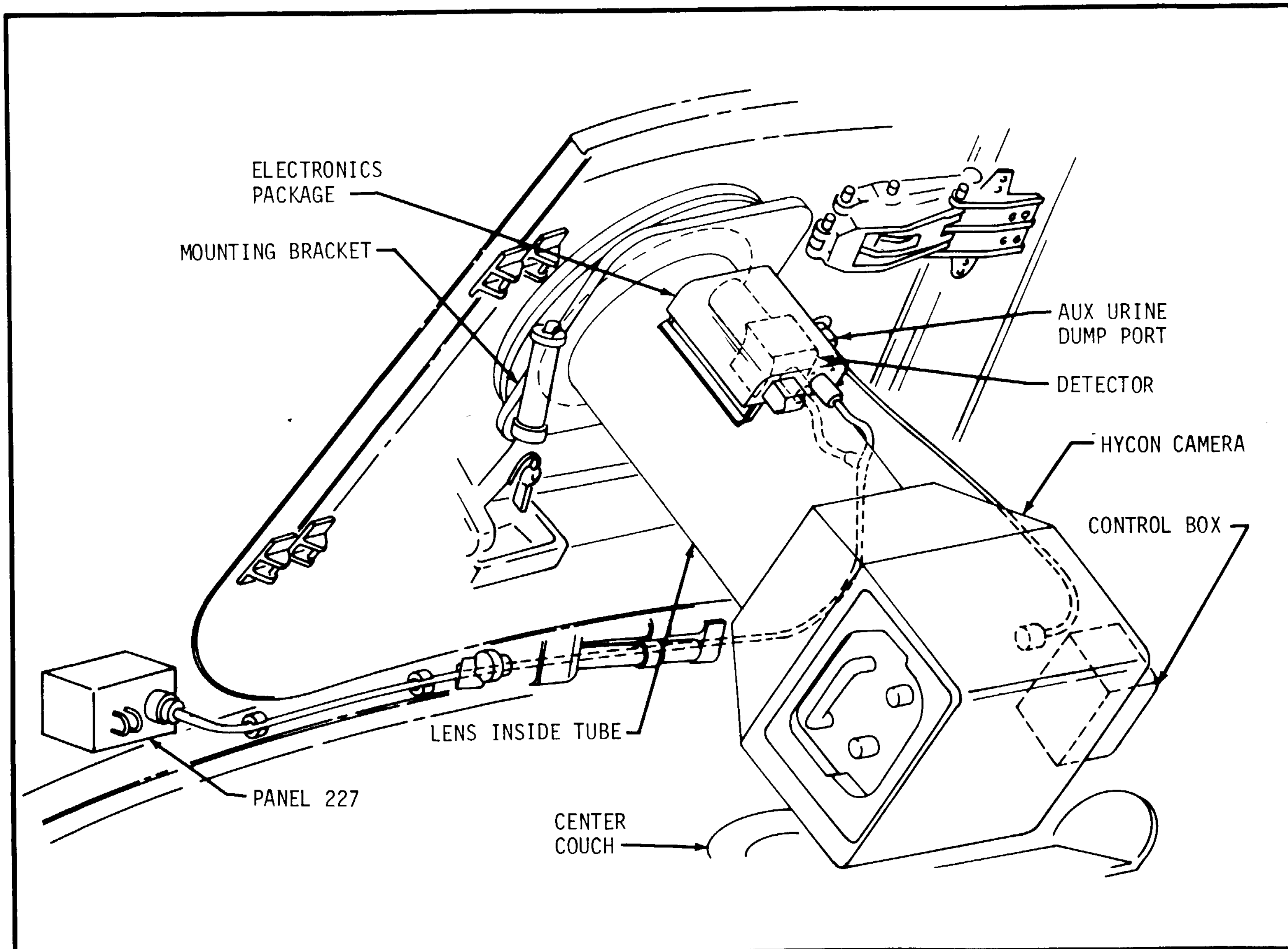


FIGURE 5.1-4. HYCON KA-74 CAMERA INSTALLED

Color TV System (Figure 5.1-5)

Purpose

The color TV system is used to acquire real-time color video information for transmission to MSFN. The primary function is to provide converage during rendezvous and docking.

Description

The system consists of a small portable color television camera that can be hand-held, or bracket mounted. A TV monitor is provided to allow astronaut viewing of TV operations. A zoom lens and a 12 foot cable are provided. Camera operation is controlled by an on/off switch on the camera handle.

Technical Data - Color TV Camera

Part Number	SEB 16101081-701
Mfr.	Westinghouse
Size (w/zoom lens)	17" x 4.5" x 6.5"
Weight	13 lbs.
Power	28vdc/20 watts
Lens	P/N SEB 16101081-703
T-number	T/5.1 - T/51
Zoom Ratio	6:1
Focal Length	25mm - 150mm
Field of View	
Wide Angle	43° horizontal
Narrow Angle	7° horizontal

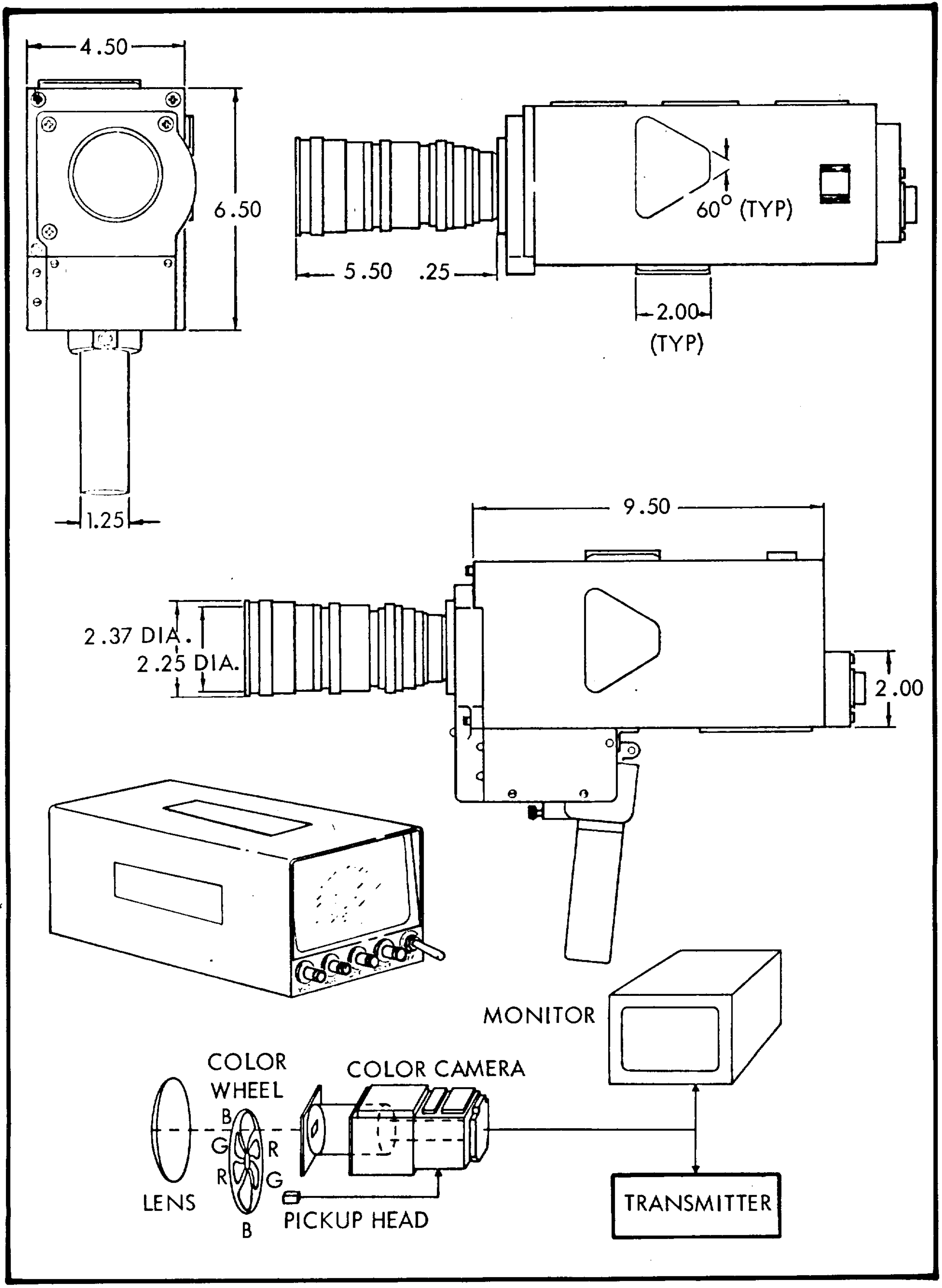


FIGURE 5.1-5. CM COLOR TV CAMERA AND MONITOR

5.2 LUNAR MODULE

Equipment List

Three types of operational and/or surface science cameras are furnished on Apollo 13 for lunar surface photography. In addition, both color and black and white television camera systems are included. Functional descriptions of employment in surface science experiments are provided in Section 2.0. Typical operational uses of the cameras are LM descent and ascent, crew EVA operations, and lunar surface photography. Table 5.2-1 lists camera equipment used in the LM and on the lunar surface.

Camera Systems	Part Number	Units
Color TV Camera System	SEB 16101147-303	1
Miscellaneous Accessories		
Black and White TV Camera	SEB 16100823-303	1
Miscellaneous Accessories		
16mm Data Acquisition Camera	SEB 33100100-205	1
16mm magazine	SEB 33100125-204	6
10mm lens	SEB 33100010-302	1
Cables and Mounting Bracket		
16mm Lunar Surface Data Acquisition Camera		1
Lens, Magazine, Accessories		
Lunar Surface Electric Hasselblad	SEB 33100040-304	2
w/Reseau Grid		
70mm magazine	SEB 33100082-213	5
60mm lens	SEB 33100048-303	2
Closeup Stereo Camera	2501-122-K	1
Cassette	2501-120	1

TABLE 5.2-1 LM PHOTOGRAPHIC EQUIPMENT LIST

Color TV Camera

Purpose

The lunar surface color television camera provides real-time color viewing of the lunar surface during the astronauts stay on the moon. Scenes will include views of astronauts leaving and entering the LM and on the lunar surface, and the LM on the lunar surface.

Description

The camera is a portable self contained unit which, initially mounted in the Lunar Module modularized equipment stowage assembly, can be hand-held or tripod mounted on the lunar surface. A zoom lens and a 100 foot cable are provided for flexibility and camera operation is controlled by a switch in the Lunar Module.

The camera contains a secondary electron conduction imaging tube and utilizes a field sequential technique which consists of rotating a color wheel at 600 rpm in front of the imaging tube and producing a series of red, blue, and green pictures. The color images are then combined and converted into a signal compatible with commercial TV by the MSFN. The camera is similar to the one shown in Figure 5.2-1.

Technical Data - Color TV Camera

Part Number	SEB 16101147-701
Mfr.	Westinghouse
Size (w/zoom lens)	17" X 4.5" X 6.5"
Weight (w/zoom lens)	13 lbs.
Power	28vdc/20 watts
Lens	P/N SEB 16101147-703
Aperture	T/5
Zoom Ratio	6:1
Focal Length	25mm - 150mm
Field of View	
Wide Angle	43° horizontal
Narrow Angle	7° horizontal

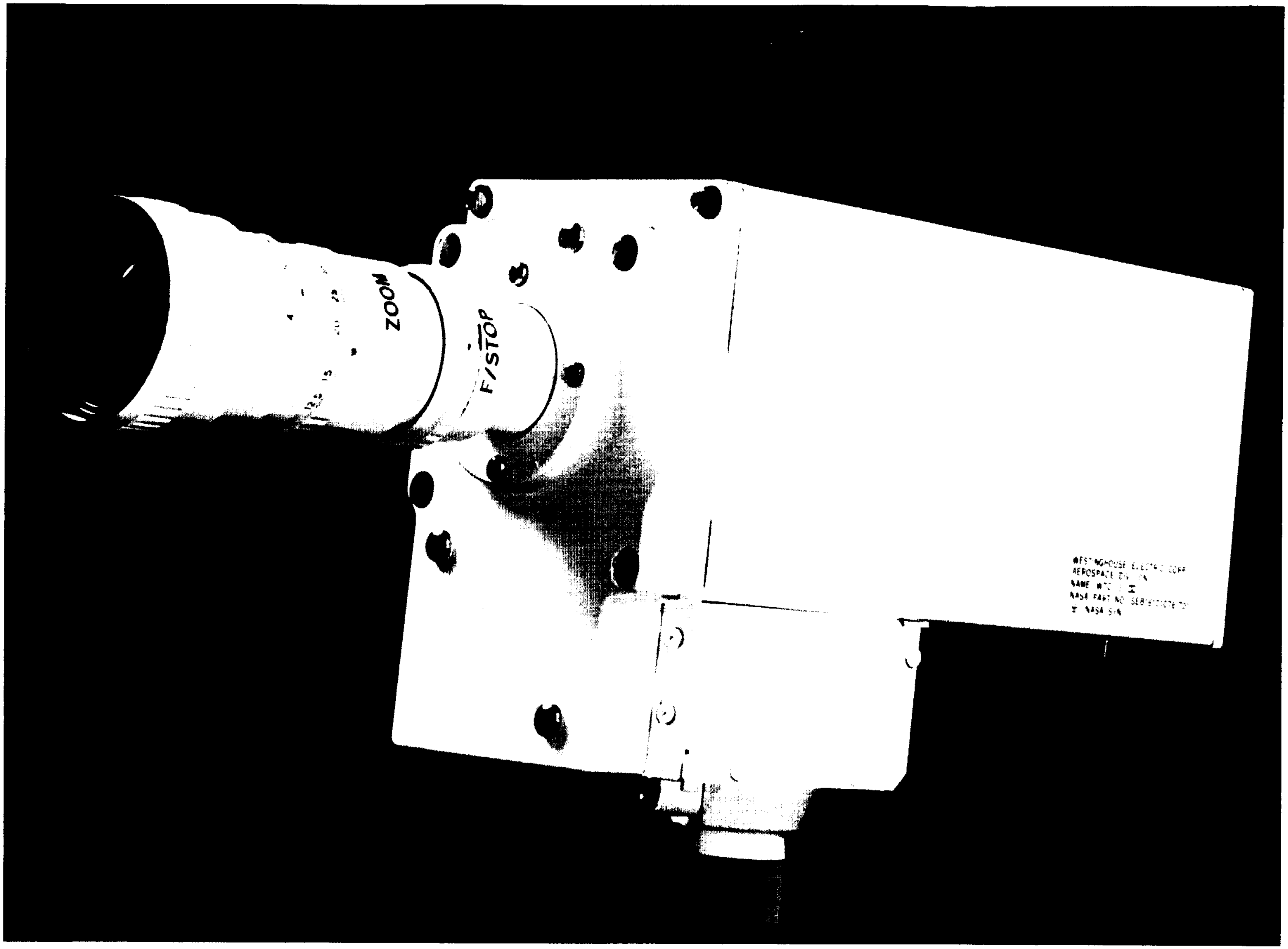


FIGURE 5.2-1, LUNAR SURFACE COLOR TV CAMERA

Black and White TV Camera

Purpose

The Black and White TV Camera is included aboard the Lunar Module for the purpose of providing television backup capability in the event that the Color TV Camera fails during lunar surface operations.

Description

The camera, identical to one used on Apollo 11, is a portable unit which may be either hand held or tripod mounted. It operates on 28VDC and employs two fixed focus lenses and a secondary electron conduction imaging tube that allows operation under both low and high light levels encountered on the lunar surface. The camera is shown in Figure 5.2-2.

Technical Data - Black and White TV Camera

Part Number	607R962	
Manufacturer	Westinghouse	
Power	6.5 watts, 24-32 vdc input	
Weight	7.25 lbs.	
Video Band Width	2 Hz to 500 kHz	
Scene Illumination	0.007 to 12,600 ft. lamberts	
Automatic Control Range	1000:1	
Aspect Ratio	4:3	
Resolution	500 TV lines	
Fixed Focus Lenses	Wide Angle	General Purpose
Part Number	618R377-G01	618R376-G01
Field of View	80 degrees	30 degrees

16 MM Data Acquisition Camera

Purpose

The 16mm Data Acquisition camera is used to obtain sequential photographic data of LM descent and ascent and initial sequences of the Commander on the lunar surface.

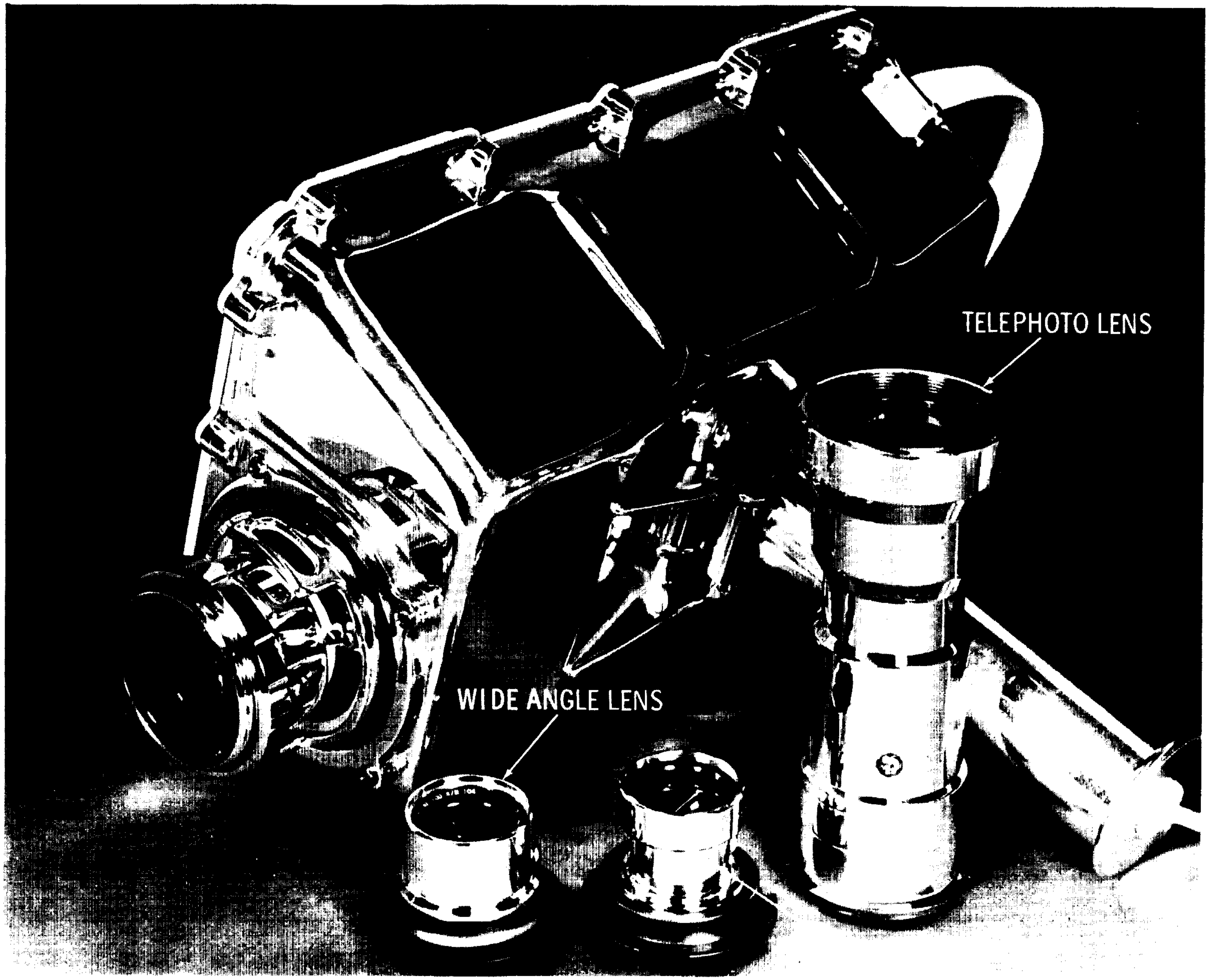


FIGURE 5.2-2, LUNAR TV CAMERA (BLACK & WHITE)

Description

The camera shown in Figure 5.2-3 is a modified movie camera and is an improved version of the earlier Gemini-type 16mm sequence camera equipped with new-type external film magazines which greatly enhance the photographic capabilities. The camera, operated from Lunar Module DC Power, is equipped with a 10mm lens and may be hand held or bracket mounted. Film is supplied in pre-loaded film magazines that may be easily installed and/or removed from the camera by a gloved crew member. Magazine run time versus frame rate varies from 87 minutes at one frame per second to 3.6 minutes at 24 frames per second.

Technical Data - 16mm Data Acquisition Camera

Part Number	SEB 33100100-205
Film Magazine P/N	SEB 33100125-204
10mm Lens	
Part Number	SEB 33100010-302
Manufacturer	Kern and Co.
Focal Length	10mm
Field of View	54.9° X 41.1°, 65.2° diagonal
Focus Range	6" to infinity
erture	T/1.8 to T/22
ght	0.6 lb.

'ee Table 5.1-2 for additional data.

16MM Surface Data Acquisition Camera

Purpose

The 16mm lunar surface data acquisition camera is used to obtain sequential photographic data during astronaut extra vehicular activities on the lunar surface.

Description

The camera shown in Figure 5.2-4 is a modified movie camera and is an improved version of the earlier Gemini-type 16mm sequence camera equipped with new-type external film magazines which greatly enhance the photographic capabilities. The camera, equipped with a 10mm lens, operates from a power pack attached to the camera, and may be hand held or bracket mounted to the remote control unit of the portable life support system. Film is

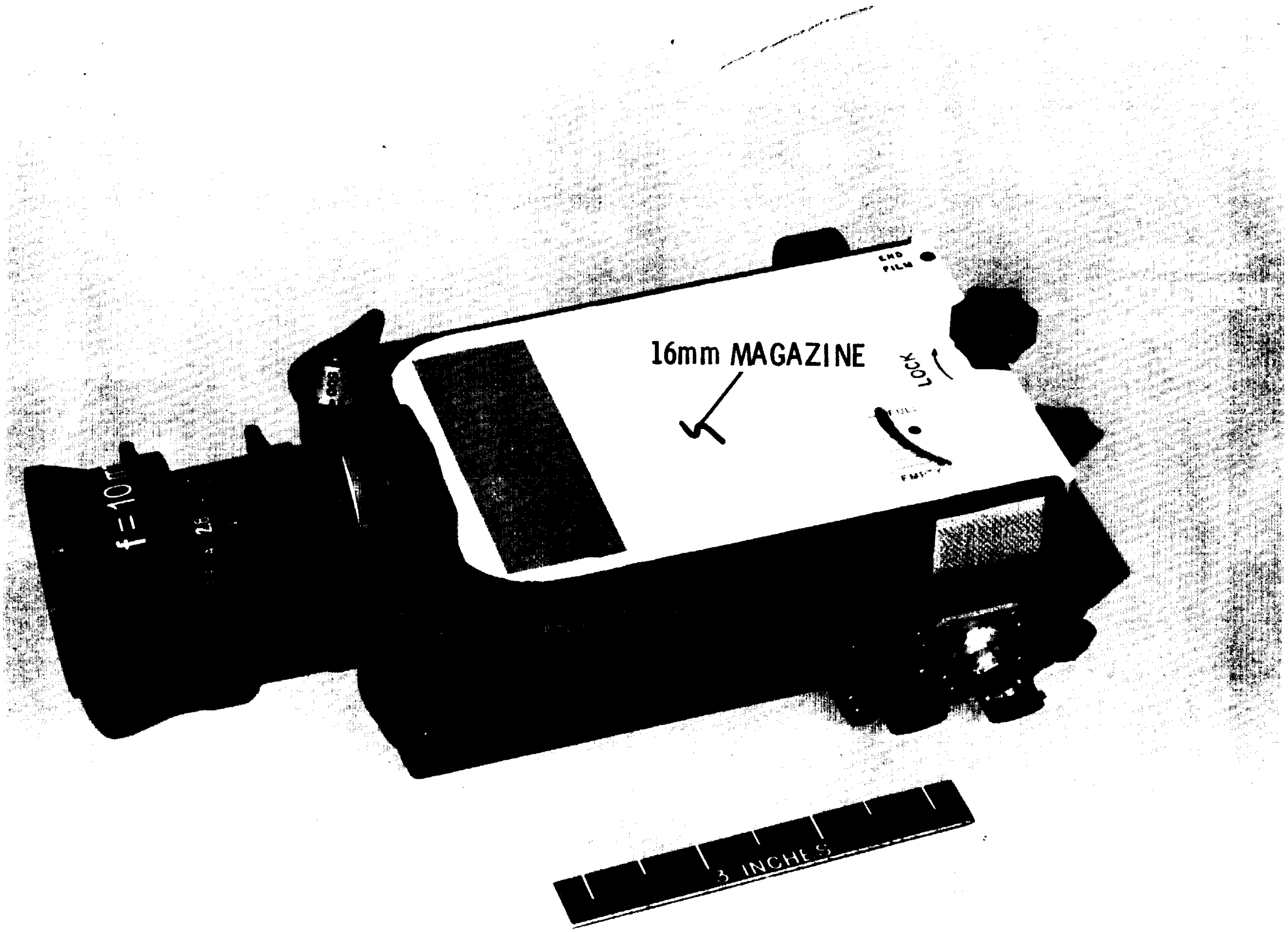


FIGURE 5.2-3, 16 MM DATA ACQUISITION CAMERA

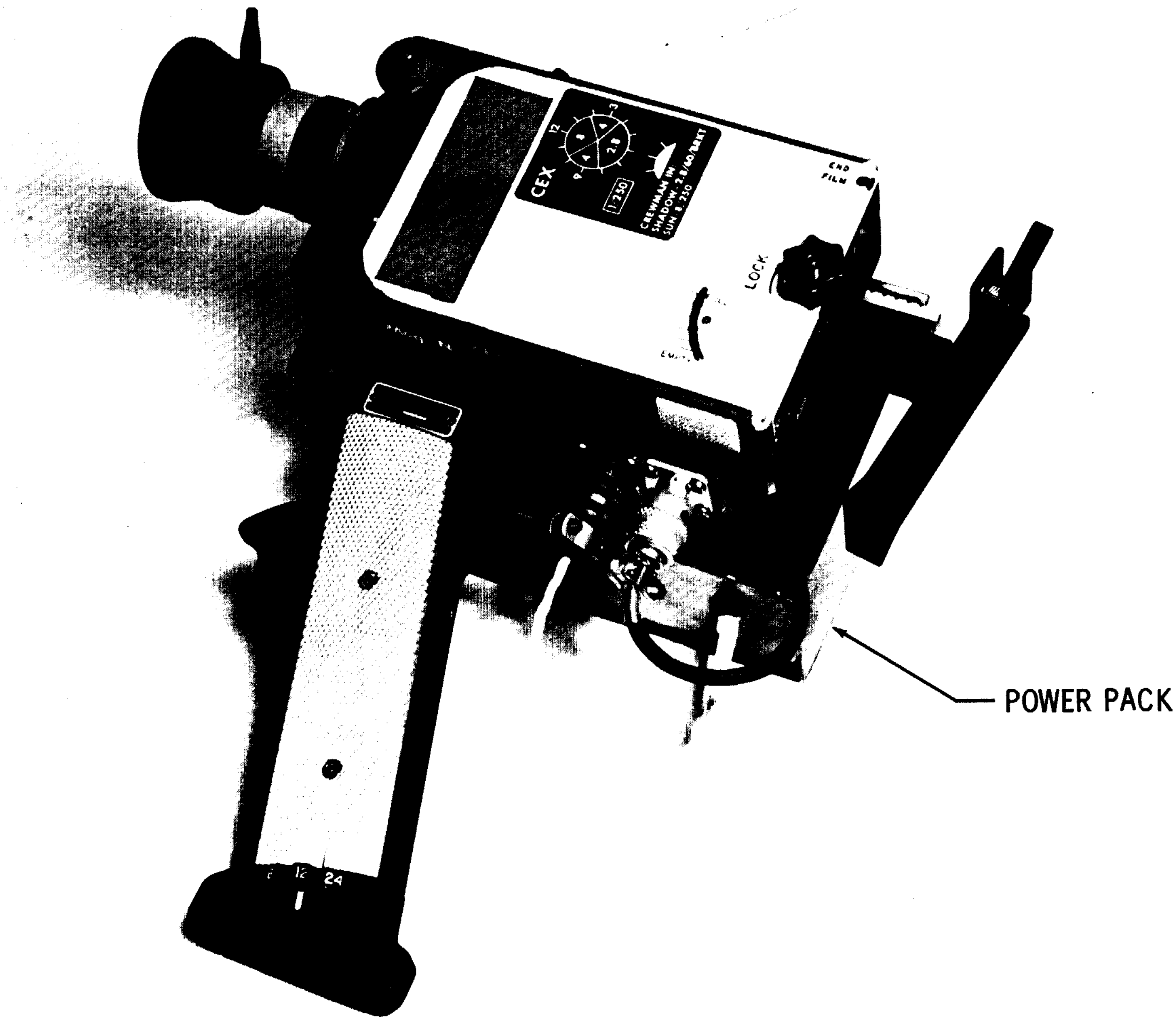


FIGURE 5.2-4, 16MM LUNAR SURFACE DATA AQUISITION CAMERA

supplied in pre-loaded film magazines that may be easily installed and/or removed from the camera by a gloved crew member. Magazine run time versus frame rate varies from 87 minutes at one frame per second to 3.6 minutes at 24 frames per second.

Technical Data - 16mm Lunar Surface Data Acquisition Camera

Part Number	
Film Magazine P/N	SEB 33100125-204
10mm Lens	
Part Number	SEB 33100010-302
Mfr.	Kern and Co.
Focal Length	10mm
Field of View	54.9° X 41.1°, 65.2° diagonal
Focus Range	6" to infinity
Aperture	T/1.8 to T/22
Weight	0.6 lb.

NOTE: See Table 5.1-2 for additional data.

Lunar Surface Electric Hasselblad Camera

Purpose

The purpose of the Lunar Surface Electric Hasselblad Camera is to provide still photographic data of lunar excursions.

Description

The camera is basically a 70mm Hasselblad data-camera incorporating modifications for ease of operation by a suited astronaut as shown in Figure 5.2-5. A 60mm lens is used to provide maximum field of view, minimum distortion and maximum aperture. The camera system incorporates a rigidly installed glass-plate Reseau grid immediately in front of the image plane. The grid consists of a square of 25 crosses 10mm apart and is used to provide a visible reference scale utilized in the photogrammetric analysis.

The camera's film magazine is a modification of the commercial Hasselblad 70mm magazine.

Two nickel-cadmium batteries power a motor drive mechanism to advance the film and cock the shutter whenever the camera button is actuated.

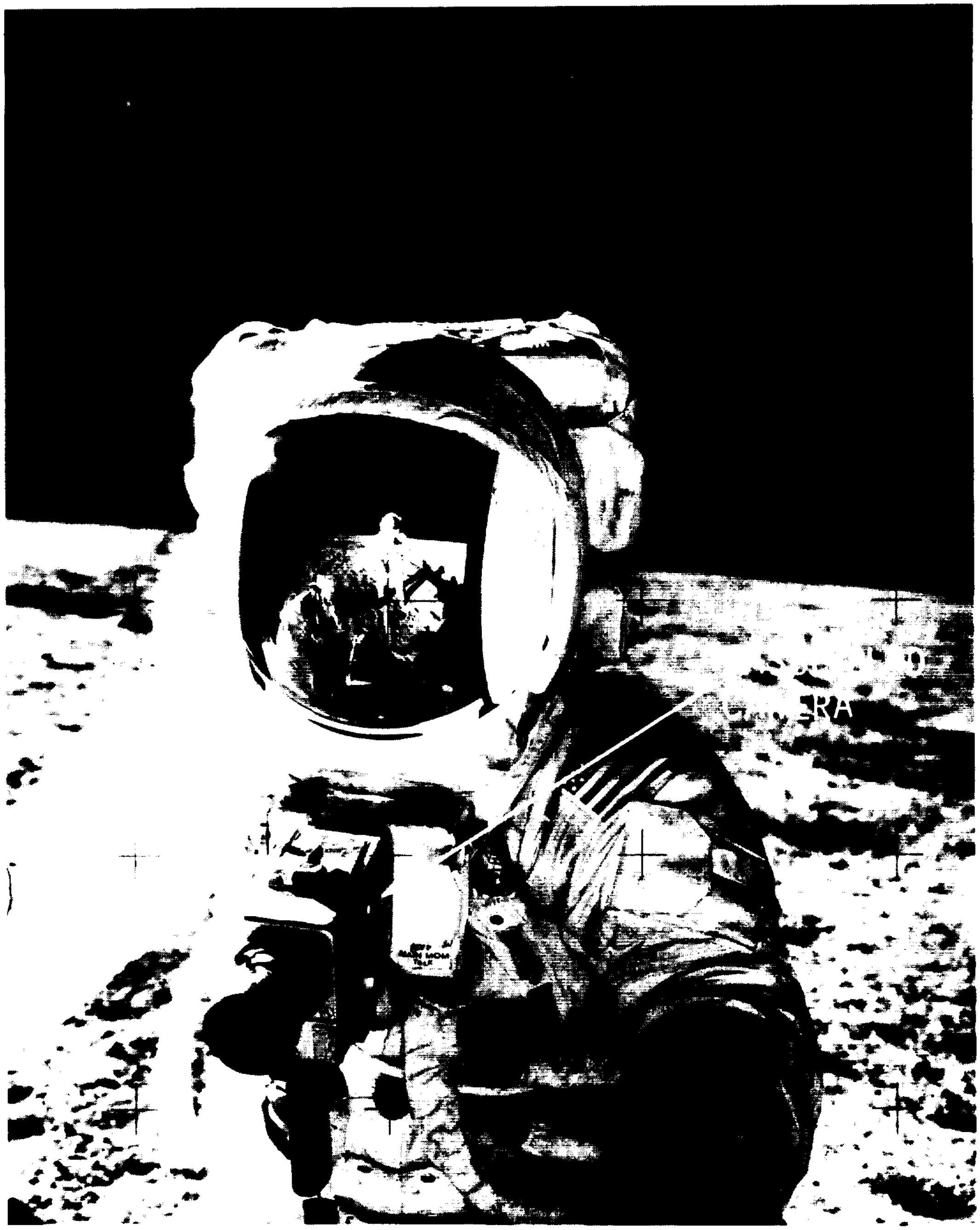


FIGURE 5.2-5 LUNAR SURFACE HASSELBLAD CAMERA

Technical Data - Lunar Surface Electric Hasselblad Camera

Part Number	SEB 33100040-304
60mm Lens	P/N SEB 33100048-303
Manufacturer	
Lens	Carl Zeiss
Shutter	Compur-Werk
Size	5.3" X 4.2" diameter
Weight	1.7 lbs.
Aperture Range	f/5.6 to 45
Focus Range	3 ft. to infinity

NOTE: See Table 5.1-3 for additional data.

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