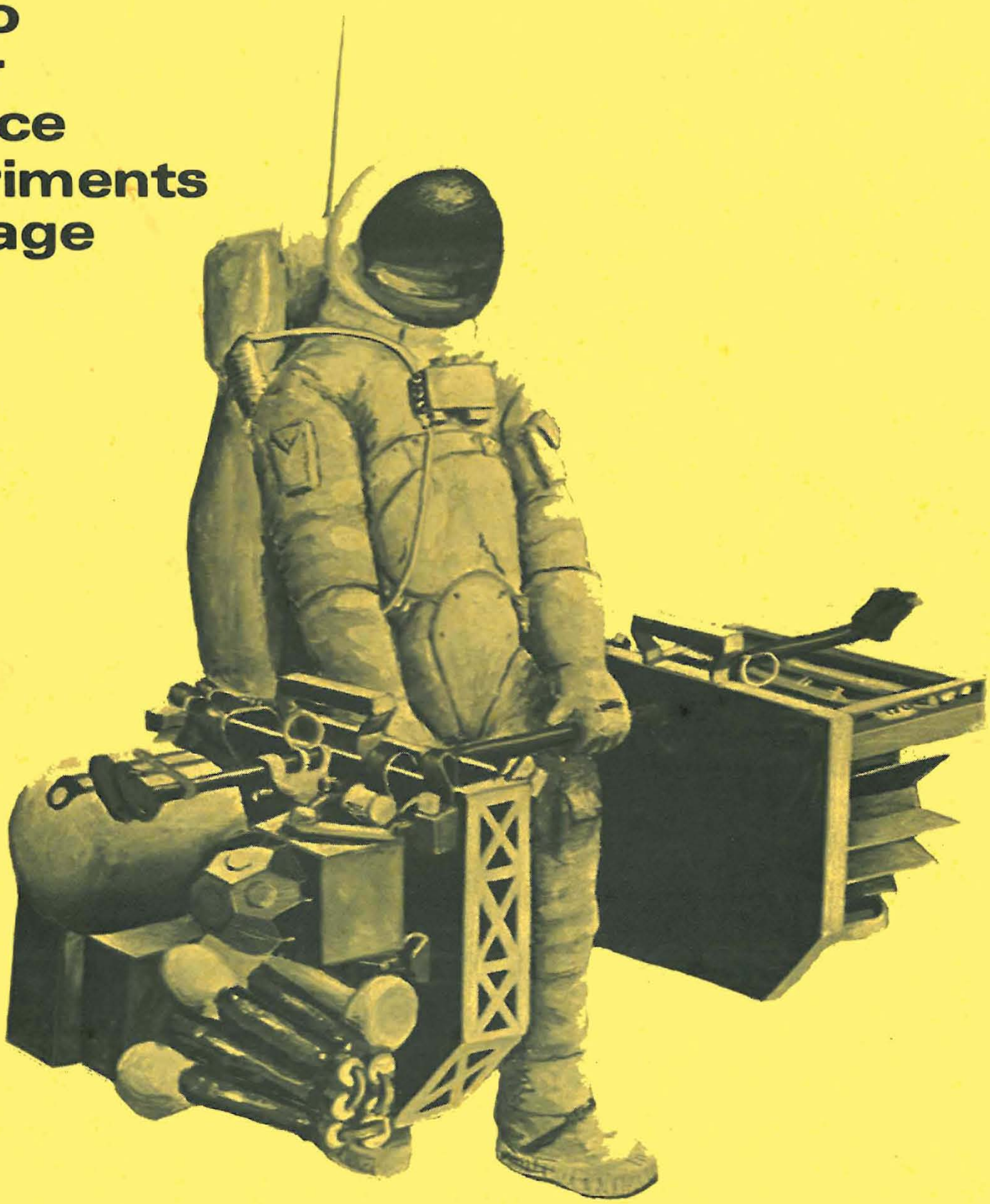
ALSEP Press Backgrounder

Apollo
Lunar
Surface
Experiments
Package



Bendix **Aerospace Systems Division**

The cover painting shows an astronaut carrying the Apollo Lunar Surface Experiments Package (ALSEP) in its "barbell" configuration. The design allows an astronaut to carry ALSEP easily while maintaining his view of the lunar surface.

The frontispiece photograph illustrates a completed deployment of ALSEP as it will be carried on Apollo 12. Ribbon-like conductors link the experiments to the Central Station. ALSEP is deployed beyond 300 feet from the lunar module to assure its safety from the rocket blast of the astronauts' departure.

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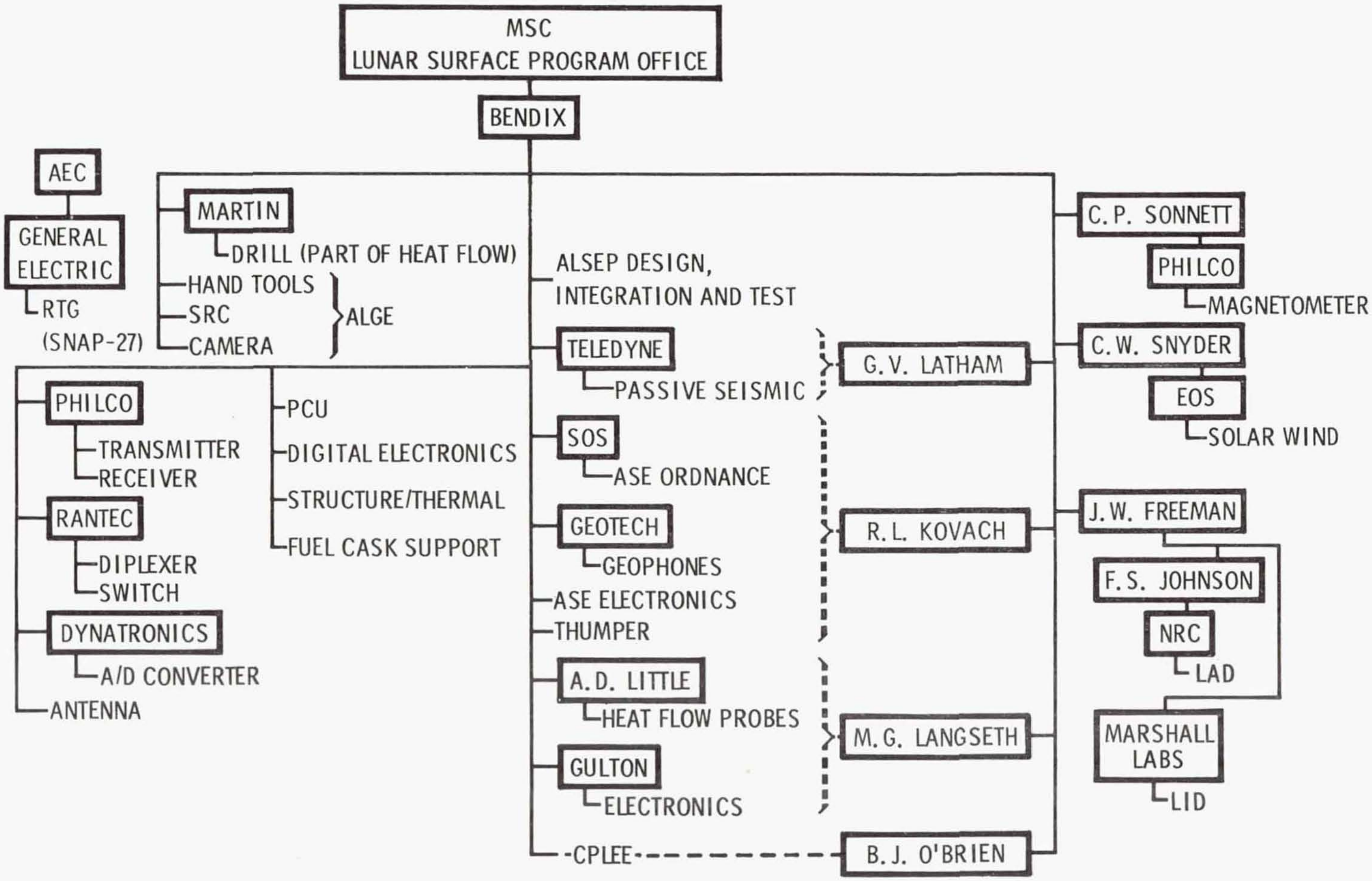
November 1969

ALSEP ORGANIZATION



FOREWORD

ALSEP was to have been flown on Apollo 11. Because of time and distance constraints, astronauts Armstrong and Aldrin were given the Early Apollo Scientific Experiments Package (EASEP), which could be deployed 70 feet from the Lunar Module in about 10 minutes.

To make EASEP, Bendix stripped the proposed Apollo 13 ALSEP (identical to the ALSEP for Apollo 12) and mounted the Passive Seismic Experiment to the top of the Central Station. A laser ranging reflector was installed on the pallet carrying the isotope power supply. Thermal control and antenna pointing designs were traded off in favor of ease of deployment.

EASEP was successfully deployed on the Moon on July 20,1969.

Minutes after its deployment, Earth commands turned on the Passive Seismic Experiment Package (PSEP) and leveled the seismometer, which began sending reports as the astronauts walked on the lunar surface. The seismometer recorded the impact of articles discarded by the astronauts as they prepared to return to the orbiting command module. For the remainder of the first lunar day, it recorded a number of events which appeared to scientists to represent seismic activity and/or rock slides down the sides of nearby craters.

ALSEP will confirm whether or not actual seismic events or meteoroid impacts were recorded by PSEP. Movement of PSEP components may have been great enough to simulate seismic activity; similarly, scientists are unwilling to conclude whether or not there is tectonic activity based on the relatively short period during which PSEP was reporting.

Telemetry indicated that the thermal surfaces of PSEP were degraded 10% by the blast effect of the Lunar Module, but PSEP continued to perform for the first lunar day, reporting average electronics temperatures up to 190°F.

When it was shut down by Earth command on August 2 for the first lunar night, PSEP had achieved 100% mission success.

PSEP survived the lunar night and turned on for the beginning of the second lunar day on August 19. On 25 August, during the second lunar day, PSEP began to refuse commands and the instrument shut down by itself with the darkness of the second lunar night.

The third lunar day began on September 16, and signals were received from PSEP indicating the thermal plate temperature was -52°F in the early lunar dawn. The shadowed (west facing) solar panel reported -242°F. The PSE remained in standby status and the system continued to reject commands.

EASEP is the subject of a separate Press Backgrounder published by Bendix.

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INTRODUCTION

Project Apollo, under the direction of the National Aeronautics and Space Administration, is the program designed to accomplish the national objective of a manned lunar landing in 1969. Project Apollo provides a variety of approaches to lunar exploration: the astronauts will collect samples of the lunar surface for return to Earth; they will emplace a series of scientific experiment instruments on the lunar surface--the Early Apollo Scientific Experiments Package (EASEP) and the Apollo Lunar Surface Experiments Package (ALSEP). Finally, the astronauts will traverse the Moon's surface, observing terrain, taking photographs, collecting lunar samples, and performing other measurements.

The ALSEP System is designed to return lunar scientific data to the Earth for as long as one year after the astronauts' departure. The data to be acquired will, it is anticipated, provide the scientific community with unprecedented knowledge of the lunar environment--especially in the areas of geology, geophysics geochemistry, particles and fields.

This Backgrounder is published to familiarize the reader with the principal scientific objectives of ALSEP, the equipment, its operation and its deployment on the lunar surface by the Apollo astronauts.

LUNAR EXPLORATION

The broad goals of lunar exploration are to (1) obtain information from the Moon to determine its environment, composition and gross body properties, (2) utilize the unique characteristics of the Moon to establish observatories and laboratories for long-term scientific investigations, and (3) determine if lunar resources could be used for extended lunar operations, future interplanetary exploration, and terrestrial purposes. The knowledge gained from these goals will allow not only an understanding of the Moon, but will also provide insight into the history and evolutionary sequence of events in the formation of our solar system. The Moon's proximity to Earth, its environment which provides unobstructed observation of our solar system, and the geological process of its evolution make it the logical first step for manned exploration of the solar system.

EXPLORATION OBJECTIVES

The Space Science Board of the National Academy of Sciences met at Woods Hole, Massachusetts in the summer of 1965 to study the goals of lunar exploration. At this meeting 15 major questions associated with exploration of the Moon were established. These questions provide a detailed elucidation of the scientific interests:

1. What is the internal structure of the Moon?

2. What is the geometric shape of the Moon?

3. What is the present internal energy regime of the Moon?

4. What is the composition of the lunar surface?

5. What principal processes are responsible for the present structure of the lunar surface?

6. What is the present pattern and distribution of tectonic activity on the Moon?

7. What are the dominant processes of erosion, transport and deposition of material on the lunar surface?

8. What volatile substances are present on or near the lunar surface?

9. Are there organic and/or proto-organic molecules on the Moon?

10. What is the age of the Moon and the age of stratigraphic units on the lunar surface?

11. What is the history of dynamical interaction between the Earth and the Moon?

12. What is the thermal, the tectonic, and possible volcanic history of the Moon?

13. What has been the rate of solid objects striking the Moon and how has that flux varied with time?

14. What is the history of cosmic and solar radiation flux acting on the Moon?

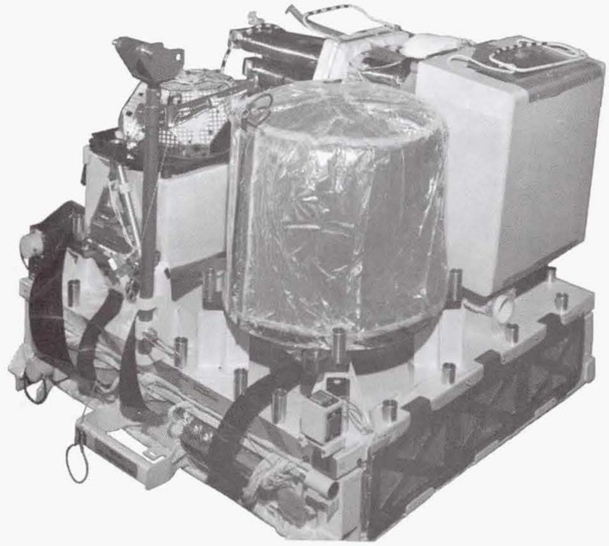
15. What magnetic fields are retained in rocks on the lunar surface?

A number of scientific disciplines contribute to the operational techniques necessary for lunar exploration. Aside from the obvious contributions of the geosciences (geodesy, geology, geochemistry and geophysics), other contributing disciplines include biology, particles and fields, lunar atmospheres and astronomy. Following the National Academy of Sciences meeting, the National Aeronautics and Space Administration conducted a Lunar Exploration and Science Conference at Falmouth, Massachusetts to consider the specific approaches to be taken in each of the disciplinary areas pertinent to lunar exploration.

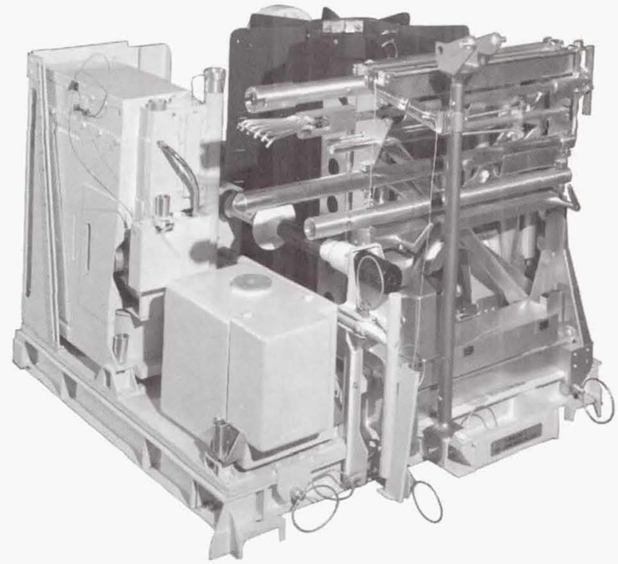
ALSEP SYSTEM SELECTED

Of the lunar exploration system concepts investigated, the most noteworthy is the Apollo Lunar Surface Experiments Package (ALSEP) which was developed under the direction of the National Aeronautics and Space Administration (NASA), Manned Spacecraft Center. NASA selected the Bendix Aerospace Systems Division as the prime contractor for the design, integration, test and systems management of this scientific exploration package.

The ALSEP system (Figures 1 and 2) is a set of scientific instruments which will remain on the lunar surface after the astronauts' departure, and will provide important data on the structure, composition and characteristics of the Moon as well as providing



SUBPACKAGE 1



SUBPACKAGE 2

Figure 1 ALSEP Stowed Configuration

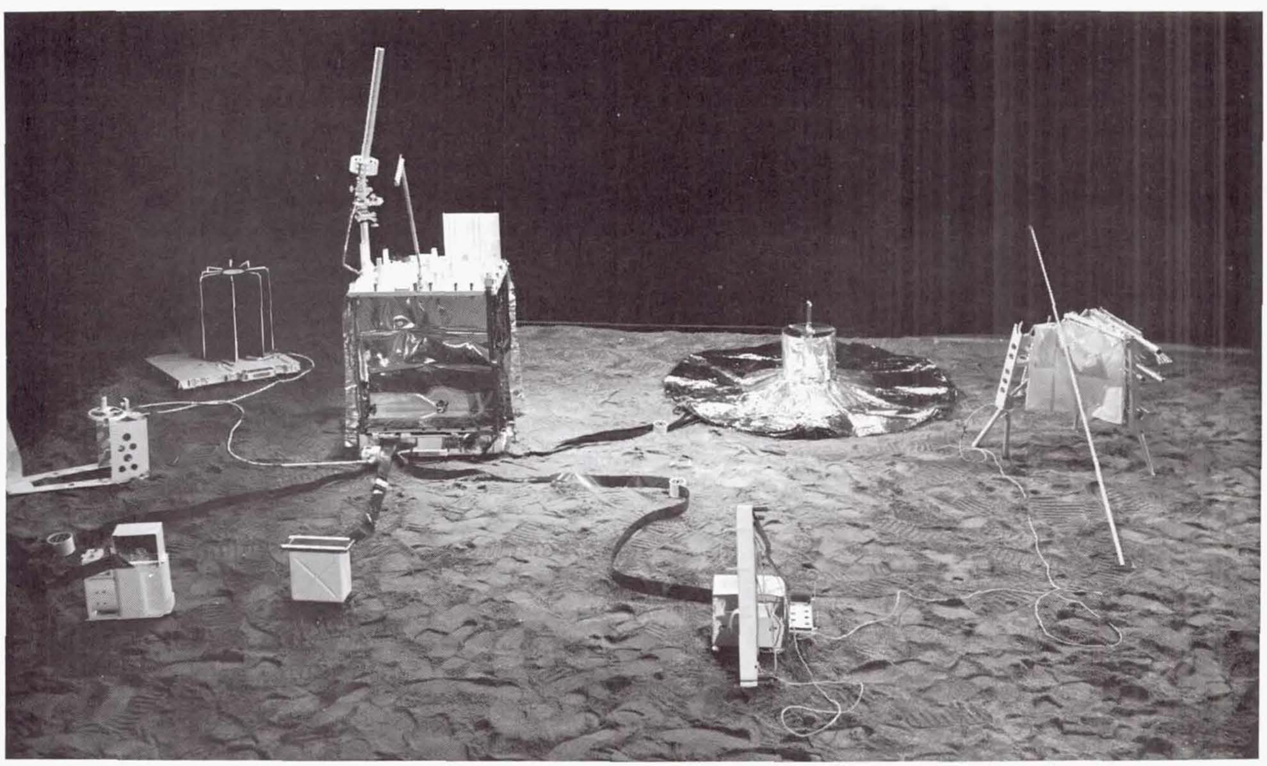


Figure 2 ALSEP Deployed Configuration
(Apollo 13)

advanced scientific study in areas of the solar wind, lunar atmosphere and magnetic fields.

ALSEP INSTRUMENT OBJECTIVES

Lunar studies will lead to a better understanding of the geology and geophysics of the Earth and will have a major impact on the evaluation of contemporary theories of lunar and Earth evolution. Measurements of physical properties of the lunar surface and interior are not ends in themselves; they are important also in that they reveal the structure, composition, and state of the Moon's interior and will help to explain its surface features.

In a broader sense, studies of the Moon gain significance when viewed in the context of an evolving program of planetary exploration directed toward information related to the origin and development of the solar system.

One of the most interesting questions to be explored with the ALSEP instruments will be whether or not the Moon evolved in the same pattern as is now believed for the Earth. On the Earth, rock formations include granite and basalt - both with an almost bewildering variety of mineral combinations. The lunar geophysical information we have thus far does not permit scientists to determine whether similar lunar differentiation exists. ALSEP instruments and extensive exploration of the lunar surface will provide information which may permit scientific answers to this important question.

The extent of layer exposure that exists on the Moon is also of scientific interest. On the Earth, this exposure results from erosion or man's excavation. Exposure may occur on the Moon in regions of faulting and may provide scientists an opportunity to study the layering of the rock as it occurs in depth. It is only with this exposure and the use of the ALSEP instruments (particularly the seismic instruments) that scientists will be able to determine lunar subsurface characteristics.

The ALSEP seismic instruments will allow a definitive study of the structure and tectonic activity of the Moon. Two expected sources of lunar seismic energy, moonquakes and meteroid impacts, were not definitely detected by EASEP. Thus there is still no clear evidence to prove whether the moon is seismically active or inactive.

Supposing that there are moonquakes; as the number of recorded seismic events increases, the compressional and shear velocity structure of the Moon may be revealed with a precision dependent upon the number, type, and distribution of quakes. Scientists may then be able to answer such basic questions as: (1) Is the internal structure of the Moon radially symmetrical as the Earth, and, if so, is it differentiated? (2) Does the Moon have a core and a crust? and (3) Is the Moon's core fluid or solid?

If the Moon turns out to be seismically inactive, we will have to rely upon meteoroid impacts and pyrotechnics to provide seismic energy. The ALSEP active seismic instrument will provide valuable lunar data resulting from artifically produced sources of seismic energy. Recordings of meteoroid impacts by an ALSEP passive seismometer will provide a clear measure of meteoroid flux density in the lunar environment. Recorded meteoroid impacts should range from the continuous rain of small particles very near the seismic instrument to the occasional meteoroid of such great size that its impact may be measurable at any point on the lunar surface.

Is the Moon's core a remnant of a molten body formed during the same period as the Earth? If the core does exist, and is still hot, it may be sustained by insulating layers of mantle or supplemented by heat from radioactive decay. The ALSEP heat flow experiment will determine the net flow of heat outward from the Moon's interior, and it may reveal the existence of a hot core. Precise measurements of the flow of the interplanetary magnetic field through the Moon by an ALSEP magnetometer instrument will tell if the Moon attracts or repels this interplanetary field. The data obtained from this experiment will aid scientists in interpreting the internal composition of the Moon.

Determining the amount, composition, and variation of the lunar atmosphere will greatly contribute to lunar geophysical information. It is possible that the lunar atmosphere is dominated by volcanism or other outgassing processes. The atmospheric measurements by ALSEP instruments are, therefore, directly relevant to a study of the structure of the Moon.

The occasional violent outbursts of protons from the Sun (related to the solar flares) can be studied from the Moon in ways not possible from the Earth. On the Earth, the solar wind cannot be studied because the Earth's magnetic field repels it. On the Moon, where the magnetic field gradient is significantly less, scientific measurement of solar wind particles with ALSEP instruments will be possible. Also, particles sent out by the Sun set up currents through the Moon which can be monitored by the ALSEP solar wind spectrometer. The characteristics of these currents will aid in determining the conductivity of the Moon. Data on the Moon's conductivity and its magnetic properties will give additional insight to the composition of the Moon.

Finally, the role of the unexpected must not be underrated. A series of scientific experiment instruments successfully deployed and operating on the lunar surface may reveal heretofore unexpected and perhaps inexplicable information. Indeed, the course of extraterrestrial exploration and our understanding of the forces in the universe may change dramatically as the ALSEP experiments report their data.

The ALSEP objectives listed in Table 1 are accomplished by eight experiment subsystems selected by the National Aeronautics and Space Administration to be included as part of the ALSEP System. Weight and volume restrictions and the achievement of optimum

TABLE 1
ALSEP SYSTEM OBJECTIVES

	Measurement	Experiment/Method Used
	GEOPHYSICS	
1.	Natural Seismology (meteroid impacts and tectonic disturbances)	Passive Seismic Experiment/long-and short-period seismometers which detect by displacing an inertial mass relative to a fixed transducer
2.	Properties of lunar interior (existence of core, mantle, etc.)	Passive Seismic Experiment/tidal interpretation of long-period seismic measurement
3.	Properties at shallow depths (elastic properties of lunar near-surface materials)	Active Seismic Experiment/artificial seismic energy sources (grenade launcher assembly and thumper device) and detection equipment (geophones)
4.	Chemical sorting of mantle material (rate of heat flow outward from the Moon's interior)	Heat Flow Experiment/two heat flow probe assemblies. Probes (temperature sensors and heating elements) placed in 10-ft holes
5.	Insulating properties of lunar surface (conductive heat flow through lunar surface)	Heat Flow Experiment
6.	Lunar dust (dust accretion effects on thermal equilibrium of instruments)	Dust Detector/rate of dust accretion and its effects on three solar cells oriented in ecliptic plane of Sun. Solar cell outputs and their temperatures, as monitored by thermistors, provide data for evaluating dust effect on instruments
	PARTICLES AND FIELDS	
7.	Interaction of solar wind and Moon (temporal, spectral, and directional characteristics)	Solar Wind Experiment/monitoring of particles using exposed collection cups (sensors) having electrically charged grids
8.	Magnetic field and its temporal variations at the lunar surface	Magnetometer Experiment/tri-axis flux-gate magnetometer instrument. Three booms, each with flux-gate sensors, separated to form a rectangular coordinate system and gimballed to allow alignment in parallel or orthogonal configurations. Parallel orientation measures local field gradient. Flipper device provides for 180-degree sensor rotation
9.	Composition of lunar atmosphere (electron/proton energies)	Charged-Particle Lunar Environment Experiment/detection and monitoring of particle energy levels using two sensor assemblies (analyzers)
10.	Lunar ionosphere positive ion detection, (flux, energy, and velocity of positive ions). Also loss rate of contaminants left by astronauts and the LM	Lunar Ionosphere Detector/detection of positive ions in lunar ionosphere and thermalized solar wind using a curved plate analyzer as detector device. Velocity selector analyzer used to determine particle velocities and energies
11.	Lunar atmospheric pressure	Lunar Atmosphere Detector/measures the presence of particles for an interpretation of the density of the lunar atmosphere

efficiency in over-all system operation requires a division of the experiment subsystems into separate flight systems, each containing four experiments distributed as shown in Table 2.

TABLE 2

ALSEP DEPLOYMENT CONFIGURATIONS

Experiment Subsystems	APOLLO 12 AND 15	APOLLO 13	APOLLO 14
Passive Seismic	X	X	X
Active Seismic			X
Magnetometer	X		
Solar Wind	X		
Lunar Ionosphere Detector	X		X
Heat Flow		X	
Charged-Particle Lunar Environment		X	X
Lunar Atmosphere Detector		X	

ALSEP SYSTEM OPERATION

ALSEP is currently scheduled to be included on the second through fifth Apollo manned lunar landings. The ALSEP system objectives listed in Table 1 will be achieved through the use of eight scientific experiment instruments and their supporting subsystems. The Apollo astronauts will place the experiment instruments and related subsystems on the lunar surface. While in operation on the Moon, the ALSEP system will be self-sufficient and use a Radioisotope Thermoelectric Generator (RTG) for electrical power. It will collect, format, and transmit scientific data to Earth for a period of approximately one year after the astronauts leave the lunar surface. Communications will be maintained through the Manned Space Flight Network (MSFN). ALSEP commands will originate within the Mission Control Center (MCC), Houston, Texas, and will be forwarded to the remote sites of the MSFN. At these same sites, telemetry data received from ALSEP will be forwarded to the MCC.

The ALSEP telemetry system (Figure 3) consists of two distinct links. The Earth-to-Moon link (the up-link) provides for remote control of ALSEP command functions such as experiment mode selection, transmitter selection, change of subsystem data rates and subsystem operation flexibilities (turn-on, turn-off, etc.). The Moon-to-Earth link (the down-link) provides for the transmission of scientific and engineering data from the ALSEP subsystems to Earth receiving stations. Four different data transmission frequencies will be used to permit simultaneous operation of four separate ALSEP systems.

ALSEP will be deployed by the Apollo astronauts in a prescribed arrangement. Each instrument will be connected to the Central Station by flat, ribbon-like conductor cabling. The Central Station consists of the transmitters and receivers, the Data Subsystem, electronics for the seismic instruments, and a switch panel for system activation by the astronaut.

ALSEP SUPPORTING SUBSYSTEMS

The ALSEP system consists of two subpackages and a fuel cask assembly (Figure 4). One subpackage contains three of the experiment subsystems, the Data Subsystem, and a portion of the

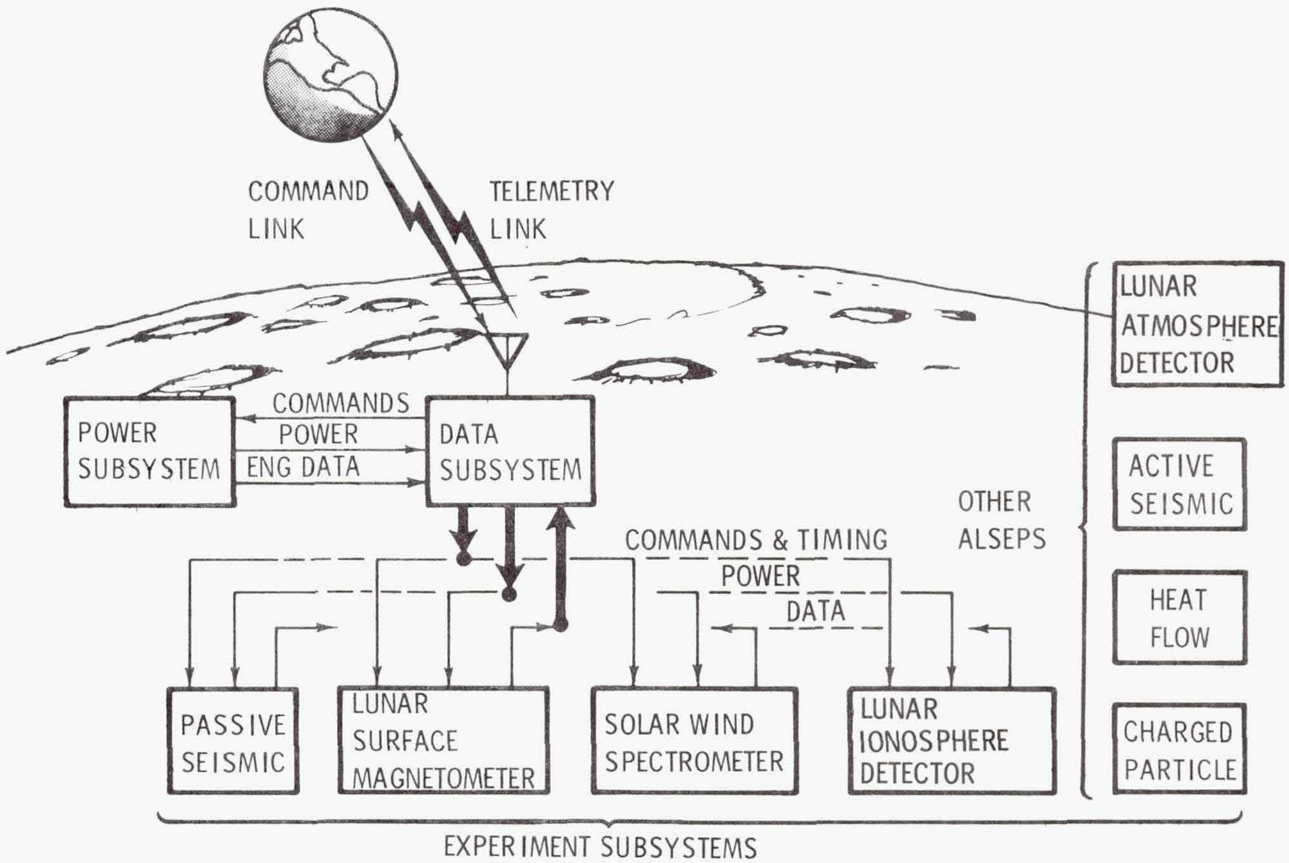


Figure 3 ALSEP Data Flow

Electrical Power Subsystem. The other subpackage contains the astronaut hand tools used for geological sampling, one of the experiment subsystems and the remainder of the Electrical Power Subsystem. The fuel cask assembly is the transportation container for the radioactive fuel capsule.

The two ALSEP subpackages will be mounted within the Scientific Equipment (SEQ) bay of the Lunar Module (LM) for transit to the Moon. The SEQ bay is located in the LM descent stage and is divided into compartments which accept the two ALSEP subpackages. The two ALSEP subpackages occupy a volume of approximately 15 cubic feet and, together with the fuel cask assembly and lunar hand tools, weigh approximately 280 pounds. Quick-disconnect fasteners are provided for locking the ALSEP subpackages in place in the SEQ bay during Earth-to-Moon transit and for easy removal by the astronaut during the lunar surface deployment of ALSEP.

ELECTRICAL POWER SUBSYSTEM

The fuel cask assembly is part of the Electrical Power Subsystem. It is mounted externally to the LM on the left side of the SEQ bay, adjacent to ALSEP subpackage 1. When fueled with the radioactive fuel capsule, the fuel

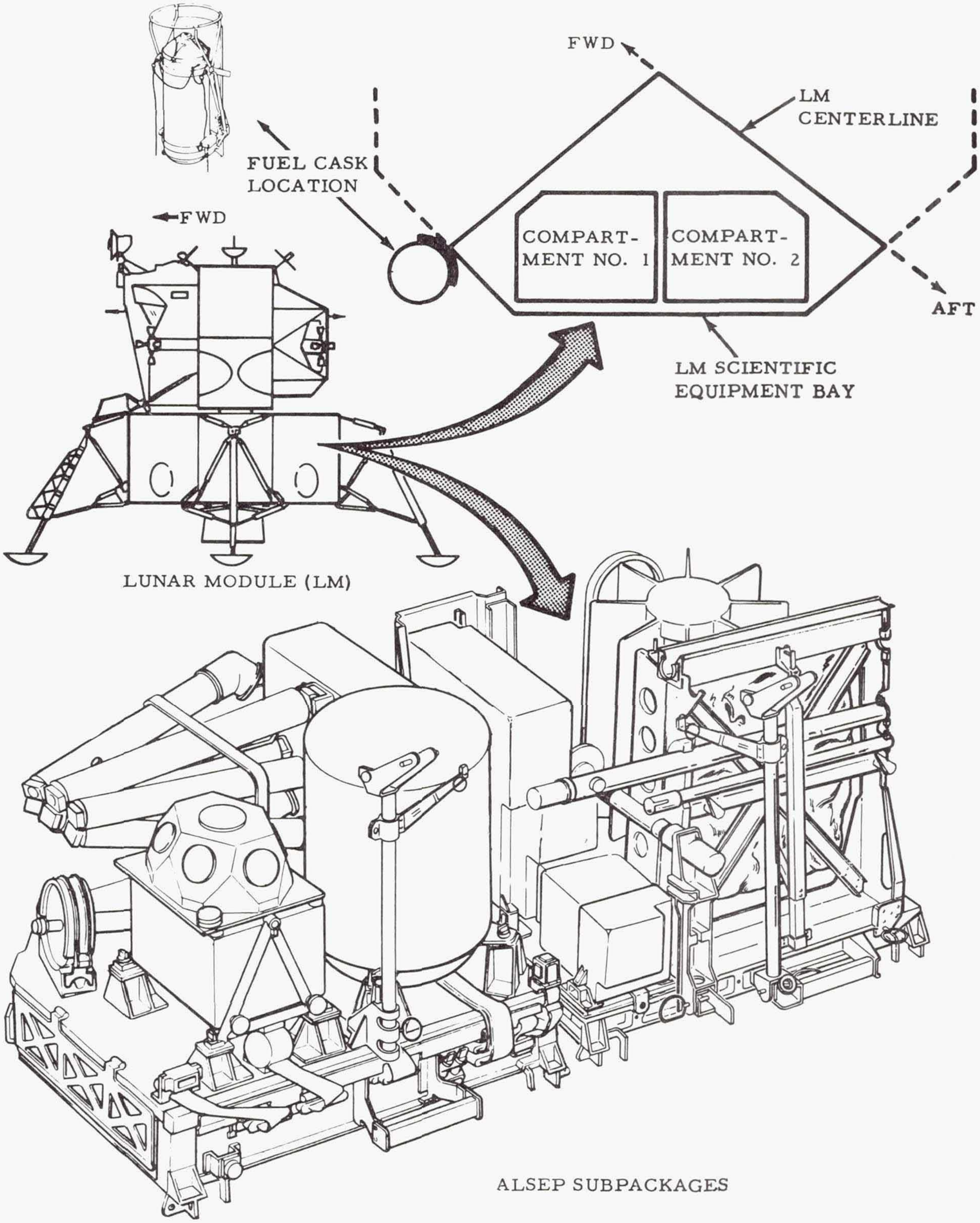


Figure 4 Location of ALSEP Within the LM

cask assembly weighs approximately 22 pounds. The location of the fuel cask assembly allows for in-flight radiative heat transfer from the fuel capsule to space. A guard and shield plus special tools provide astronaut thermal protection during deployment.

The Electrical Power Subsystem provides DC power to the data and experiment subsystems. It contains a SNAP 27 Radioisotope Thermoelectric Generator (RTG), a power conditioning unit (PCU) and interconnecting cabling. The two components provide all DC voltage for ALSEP operation. Selected DC electrical outputs of the PCU are supplied to the power distribution and signal conditioning components in the Data Subsystem which distribute (via command data processed by the command decoder circuits) DC power to: (1) heater circuits of the data, experiment, and electrical power subsystems' thermal control elements, (2) experiment subsystem electronic packages, and (3) the Data Subsystem electronics package.

DATA SUBSYSTEM

The Data Subsystem is the "nerve center" of the ALSEP system. It accepts the experiment subsystem scientific and engineering data and encodes the data for phase modulated RF signal transmission to Earth. The Data Subsystem also receives command data from the Earth and decodes and distributes the commands to the ALSEP subsystems. The Data Subsystem is capable of the simultaneous reception of commands and the transmission of data. As a backup measure to help ensure one year operation, redundant transmitters and data processor components are included in such a way that, by MSFN command, the output of either data processor may be connected to either transmitter.

The experiment subsystems receive decoded command data from the command decoder, perform their respective lunar environmental detection and measuring activities, and provide scientific and engineering data to the data processor for encoding and ultimate transmission to the MSFN.

The functional operation of the ALSEP system is illustrated in Figure 5.

PASSIVE SEISMIC EXPERIMENT

The Passive Seismic Experiment (Figure 6) is designed to determine the natural seismicity of the Moon. Seismic energy is expected to be produced on the Moon by tectonic disturbances and meteoroid impacts. Knowledge of moonquakes is essential for definition of the strain regime of the Moon. It is also important to know the location of quake epicenters, thus permitting correlation of seismic events with surface features. In this way, insight into the origin of visible features on the Moon may be achieved. Analysis of the form and characteristics of seismic waves themselves will provide data on the physical properties of the lunar interior. Subsurface materials will differ in compressibility, rigidity, and temperature. These differences will cause variation in seismic wave velocities and character, from which the material characteristics may be inferred. Finally, this experiment will permit study of

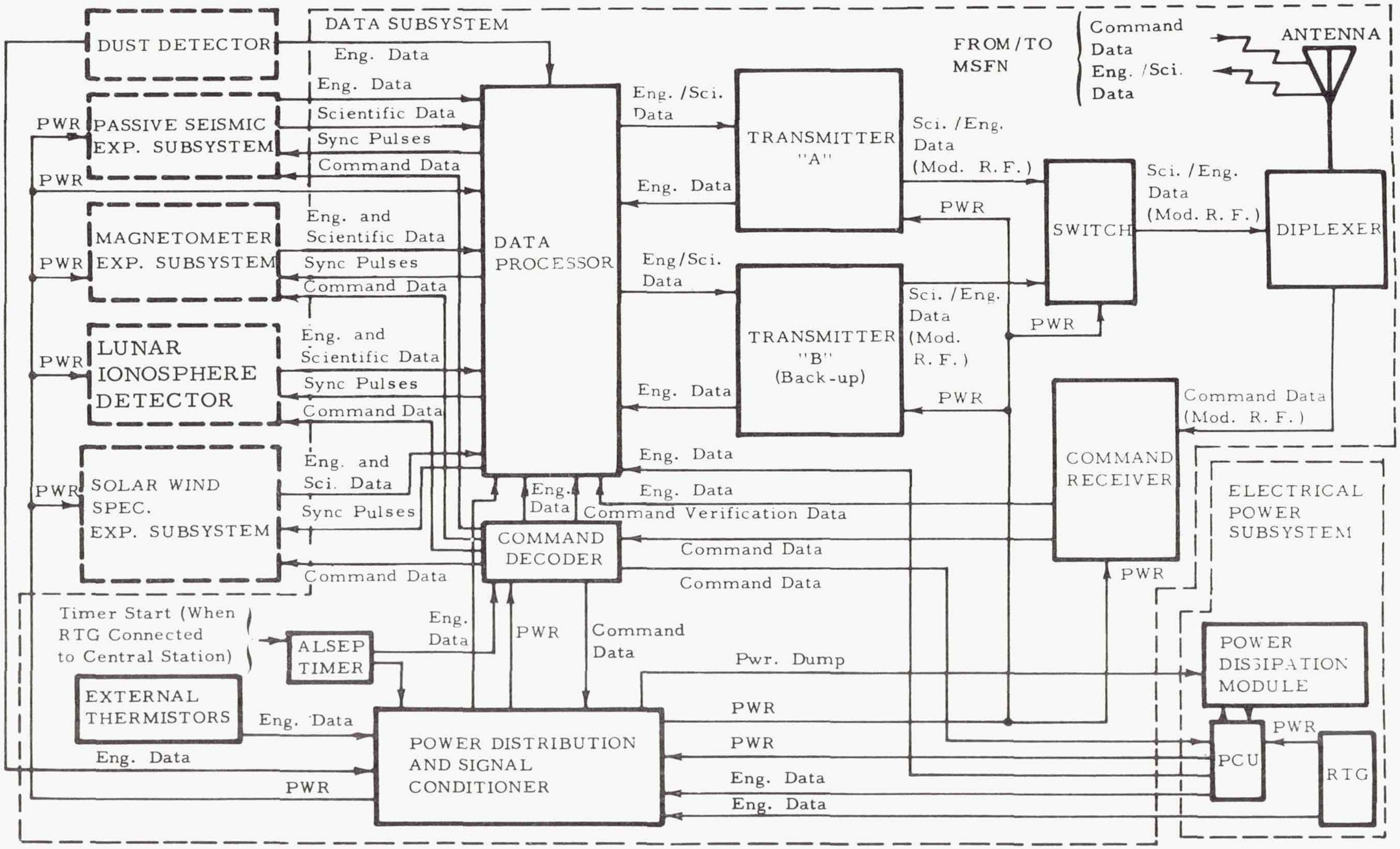


Figure 5 ALSEP System Functional Block Diagram

Figure 6 Passive Seismic Experiment

the free oscillations and tidal deformation of the Moon to provide data on the gross physical properties of the Moon.

The Passive Seismic Experiment functions by monitoring the displacement of inertial masses from their zero positions relative to sensitive transducers. It contains four sensors mounted in a single package. Three of these sensors comprise a 10- to 15-second, three-axis, orthogonal seismometer which monitors long-period, low-frequency seismic energy. Therefore, this instrument measures approximate azimuth and distance to seismic epicenters as well as monitoring lunar tidal deformations. A short-period (one-half- to one-second) sensor is used to monitor the high-frequency signal spectrum. It also serves as a backup for the long-period instrument.

The Passive Seismic Experiment is a portable 20-pound package which has a shape similar to a drum rounded on one end. It is approximately 11 inches in diameter and 15 inches high. The instrument will require approximately 7.5 w of power for normal operation with a small additional amount of power required for the heaters during the lunar night.

The astronaut will place the instrument on a small leveling stool ten feet from the Central Station, coarse level the instrument manually and deploy its thermal shroud. The shroud (or radiation shield) minimizes temperature fluctuations within the instrument.

The principal investigator for the Passive Seismic Experiment is Dr. Gary Latham of Lamont Geological Observatory. Dr. George

Sutton of the University of Hawaii, Dr. Frank Press of Massachusetts Institute of Technology, and Dr. Maurice Ewing of Columbia University are the co-investigators for the experiment.

ACTIVE SEISMIC EXPERIMENT

Artificially produced seismic events (explosions) are a certain way of exploring the structure of the moon, and will complement whatever findings are made by the Passive Seismic Experiments.

An active seismic survey will provide information for determining the structure, thickness, physical properties, and elasticity of surface and shallow-depth materials of the Moon. The Active Seismic Experiment (Figure 7) uses explosive devices detonated at various distances to measure the elastic properties of lunar subsurface material to a depth of approximately 500 feet. Seismic energy will be transmitted through lunar subsurface material and detected by a geophone array.

The Active Seismic Experiment contains the seismic energy sources and the detection system. Two energy sources will be employed: a mortar box assembly, from which four explosive grenades will be launched to detonate at various distances up to 5000 feet from the geophone detectors, and a "thumper" assembly containing 21 explosive Apollo Standard Initiator (ASI) cartridges which will be activated by the astronaut at specified locations along the geophone line. The detection system is a linear array of three geophones together with amplifier systems and electronics.

The thumper assembly is used for investigation of material characteristics within a 75-foot depth of the lunar surface. It is about three feet long, and will be folded for transportation. The upper section contains electronics for the firing mechanism, the cartridge barrel, and contact points. The lower section is a hollow cylinder containing a plate which couples the energy source to the lunar surface and imparts seismic waves to surface materials for detection by the geophones.

The mortar box contains four explosive grenades to be activated by Earth command near the end of the one-year operation on the lunar surface. About 15 inches long, it contains electronics and grenade launching rockets and is designed to minimize the effects of recoil. Since it is necessary to know the distance from the geophone array at which the grenade is detonated as well as the time of detonation, the design provides for measurement of grenade launch angle, grenade launch velocity, and time of flight.

Refraction velocity surveys by the active seismic instrument will be used to study the subsurface relations between the maria and the highlands, possible internal layering within the maria, and the existence and nature of isostatic lunar topographic features. On a smaller scale, data on the thickness, strength and the variation of physical properties with depth in a possible surface fragmental layer is pertinent to a full interpretation of the fine structure of the lunar surface. It is also possible that

Figure 7 Active Seismic Experiment

surface bearing strength and the degree of hardened subsurface materials may be inferred from active seismic refraction data. A controlled active seismic survey will also be of particular importance in the search for water on the Moon. Local concentrations of ice may be present on the lunar surface - beneath the depth of penetration of the diurnal heat wave. A seismic velocity survey could be used to detect the presence or absence of buried ice layers on the Moon.

The principal investigator for The Active Seismic Experiment is Dr. Robert Kovach of Stanford University. The design approach for the thumper assembly is that of Dr. Joel Watkins of the Massachusetts Institute of Technology.

LUNAR SURFACE MAGNETOMETER EXPERIMENT

The Lunar Surface Magnetometer (Figure 8) will measure the magnitude and direction of the surface magnetic field of the Moon and changes in the field direction up to a frequency of about one cycle per second. The placement of this ALSEP instrument on the Moon is such that the equatorial magnetic field will be determined. Magnetic fields connected with interplanetary space should show periodic variations; fields associated with the Moon will be stationary during the lunar rotation.

As the solar wind sweeps the interplanetary magnetic field against the Moon, some of this field should diffuse into the interior in a manner roughly analogous to heat flow. By studying the surface manifestations of this interior field during lunar day and night, it may be possible to infer the electrical conductivity and magnetic permeability of the lunar interior. These quantities must depend upon the composition of the Moon and its internal temperature, and therefore are related to the origin and thermal history of that body. If the Moon has a small core of iron-like material, magnetic field lines diffusing in from the solar wind should "hang up" on the core and impede the diffusion. It is possible, then, to imagine a lunar magnetic field streaming out through the Moon on its dark side, raising the possibility of utilizing the magnetometer for determining deep structure in the Moon. Other approaches to the problem of the interior composition are found by examining the propagation of electromagnetic disturbances which originate in the solar wind and are carried through the Moon. The response of the Moon should be that of a negative-gain conductor.

An additional purpose of this experiment is to monitor the passage of the Moon through the magnetic tail of the Earth. It will also obtain specific information on the interaction of the solar wind with the lunar surface and whether the process results in the generation of plasma waves and produces some compression of the interplanetary field during the impacting of the solar plasma. Lastly, the site-surveying property of the magnetometer instrument allows detection of plasma currents and the presence of subsurface magnetic material such as meteorites.

Figure 8 Lunar Surface Magnetometer Experiment

The scientific measurements are performed using a three-axis, flux-gate magnetometer which consists of three sensors mounted at mutual right-angles on the ends of three-foot booms. The booms are joined to an electronics package which is placed on the lunar surface. Sensor rotations within the housing on the end of each boom are automatically programmed and driven by small electronic motors to provide both the scientific measurements and site-survey gradient measurements. The range of the magnetometer is adjustable with the maximum value being 400 gamma. (The equatorial magnetic field of the Earth is approximately 35,000 gamma.) Digital filtering techniques are employed to reduce the noise in the output signal. The Magnetometer Experiment has a total Earth weight of about 20 pounds and will use about 10 watts of electrical power. The instrument is to be deployed by the astronaut about 50 feet from the Central Station.

The principal investigator for this experiment is Dr. Charles P. Sonett of the Space Sciencės Division, NASA-Ames Research Center, Moffett Field, California. The co-investigator is Mr. Jerry Modisette of the Space Sciences Division, NASA-Manned Spacecraft Center, Houston, Texas.

SOLAR WIND EXPERIMENT

The Solar Wind Experiment (Figure 9) will measure medium energy ranges of the solar wind particles. The solar wind is a flow of electrons, protons, and other charged particles from the Sun. The nature of the interaction of the solar wind with the Moon is an

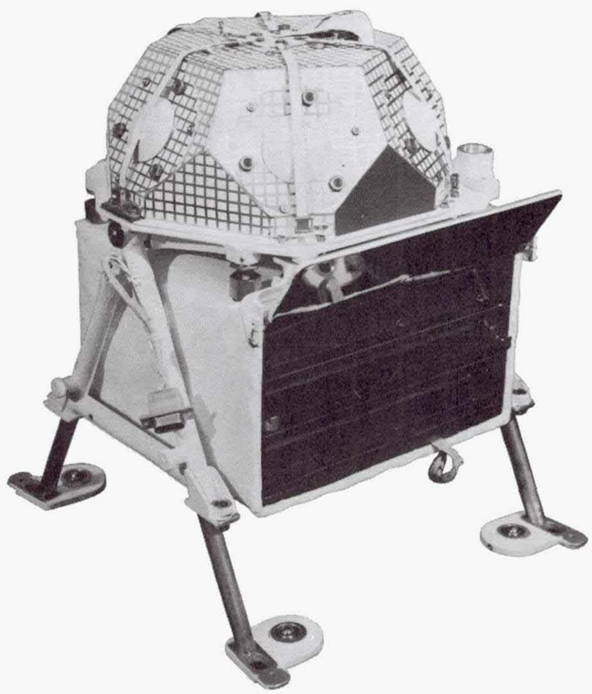


Figure 9 Solar Wind Experiment

intriguing problem in basic plasma physics. This interaction is different from that with the Earth's magnetic field, and cannot be predicted theoretically with any certainty. Because of these uncertainties, the solar wind instrument is equipped to accept fluxes from all directions above the lunar horizon and has a wide range of sensitivities down to fluxes much smaller than an undisturbed interplanetary solar wind.

Information obtained by the Solar Wind Experiment may contribute to an understanding of the history and physical properties of the lunar mass in the following areas: (1) gross electrical conductivity, (2) possibility of retaining an atmosphere, and (3) the possible effects on the lunar surface from sputtering or electrical charging caused by solar corpuscular radiation.

The structure and propagation velocity of the solar wind can be studied by measuring the time intervals between the observations of sudden changes in solar wind properties at the Moon and at the Earth. The time intervals are expected to be as long as 15 minutes, depending on the relative positions of the Sun, Moon, and Earth. The measurements of the Solar Wind Experiment will permit knowledge to be gained about the length, breadth, and structure of the magnetic turbulent wake of the Earth.

The Solar Wind Experiment will measure the number of charged particles impinging on it, and their energy up to 1330 electron volts for electrons and to 9780 electron volts for protons. The direction of these particles will be obtained by observing which of seven sensors (each sensitive to an overlapping portion of the lunar sky) indicates their flow.

The solar wind instrument is about 17 inches high, 11 inches long, and 9 inches wide. It will weigh approximately 12 pounds (Earth weight) and requires a maximum of 6.5 w operating power.

The principal investigator for the Solar Wind Experiment is Dr. Conway W. Snyder; assisting as co-investigators are Dr. Douglas Clay and Mrs. Marcia Neugebauer - all of the Jet Propulsion Laboratory.

LUNAR IONOSPHERE DETECTOR

The Lunar Ionosphere Detector (LID), Figure 10, will measure the flux, number density,

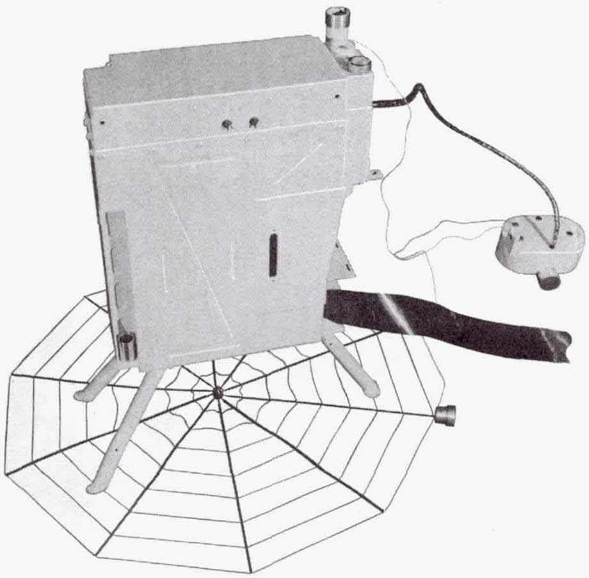


Figure 10 Lunar Ionosphere Detector

velocity, and energy per unit charge of positive ions in the vicinity of the lunar surface.

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

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

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

The principal investigator for the LID is Dr. John Freeman of Rice University.

LUNAR ATMOSPHERE DETECTOR

The Lunar Atmosphere Detector (LAD) will provide data pertaining to the density of the lunar ambient atmosphere. Of particular interest will be any variations of the particle density associated with lunar phase or solar activity. This instrument will also study the effects of foreign material left by the LM and the astronauts, and rate of loss of contaminants.

The instrument used for these measurements is a cold cathode gauge which is mounted with the LID on Apollo 12,14 and 15 but is a separate unit on Apollo 13. The gauge produces an electrical current which is proportional to the measured atmosphere density. This current is amplified and read out as the instrument's scientific data. The LAD is deployed from its own subassembly on Apollo 13.

When the astronaut deploys the LID package, he removes the LAD and emplaces it three to five feet away from the LID. An electrical cable connects the cold cathode gauge instrument to the LID.

The LAD package has an Earth weight of 12.5 pounds and requires 6.5 watts of operating power, including power for temperature control during the lunar night.

The principal investigator for the LAD is Dr. Francis Johnson of Southwest Center for Advanced Studies. Mr. Dallas Evans of the Manned Spacecraft Center/ NASA is the co-investigator.

HEAT FLOW EXPERIMENT

The Heat Flow Experiment (HFE) measures the lunar temperature profile at depths up to 10 feet and the value of the Moon's thermal conductivity over the same depth. From these measurements, information may be deduced regarding the net outward flux of heat from the Moon's interior and the radioactive content of the Moon's interior compared to that of the Earth's mantle. It will also provide data from which it is 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.

Earth heat flow measurements and measurements of the radioactive content of mantle-type rocks indicate that between 10^{-14} and 5×10^{-14} watts are now being produced by radioactive decay in each gram of mantle material. If measurements indicate that a similar rate of heat production exists on the Moon, there would be strong evidence for concluding a compositional similarity between the Moon and the Earth.

The HFE, shown in Figure 11, consists of two sensor probes and a common electronics package. Two one-inch diameter, 10-foot holes will be drilled into the lunar surface by the Apollo astronaut. This will be accomplished by a specially designed heat flow drill. A two-section probe approximately 45 inches long will be lowered into each of the two holes. The probes contain sensors to measure absolute temperature and temperature difference. Thermal conductivity is investigated by measuring absolute and differential temperatures while actuating small electric heaters in the probes.

The Apollo Lunar Surface Drill (ALSD), Figure 12, allows the astronaut to implant heat flow temperature probes below the lunar surface and to collect subsurface core material.

The ALSD is designed as a system which can be removed as a single

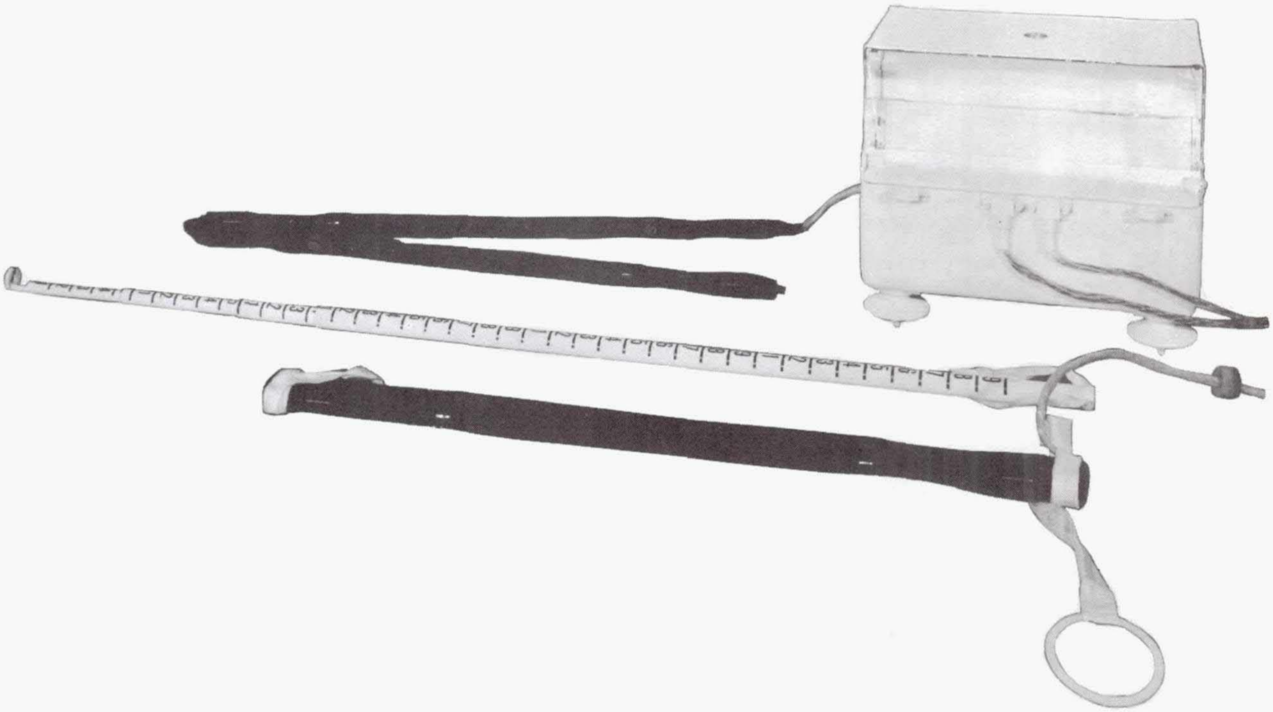


Figure 11 Heat Flow Experiment

package from the ALSEP pallet and carried to the drilling site. There it will be used to drill two holes.

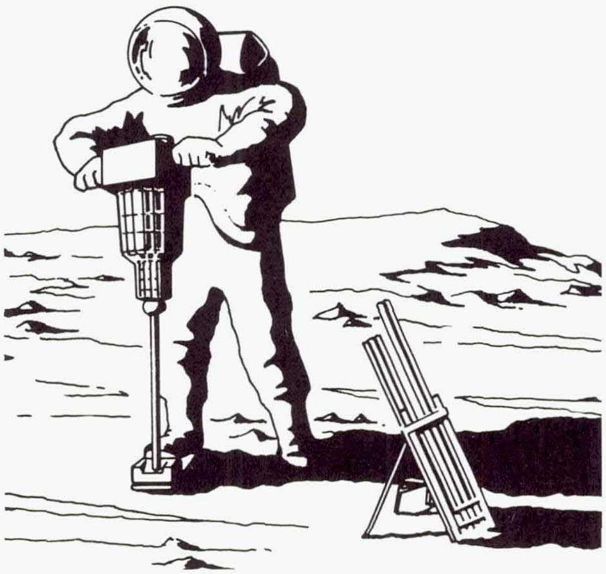


Figure 12 Apollo Lunar Surface Drill

The holes are cased to prevent cave-in and to facilitate insertion of the probes of the Heat Flow Experiment. The subsurface core material from the second hole will be retained in the drill string and returned to Earth in a sample return container.

The drill is a hand held, battery powered rotary percussion unit which is designed to operate with minimum torque reaction. When being used, the drill will maintain low temperatures at the drill bit so no coolant such as air or water will be needed.

The principal investigator for the HFE is Dr. Marcus G. Langseth of Columbia University. Assisting as co-principal investigators are Dr. Sidney Clarke of

Yale University and R.M. Eugene Simmons of Massachusetts Institute of Technology.

CHARGED-PARTICLE LUNAR ENVIRONMENT EXPERIMENT

The Charged-Particle Lunar Environment Experiment (CPLEE), Figure 13, will study the energy distribution and time variations of proton and electron fluxes in 18 energy intervals over the range of about 50 to 150,000 electron volts.

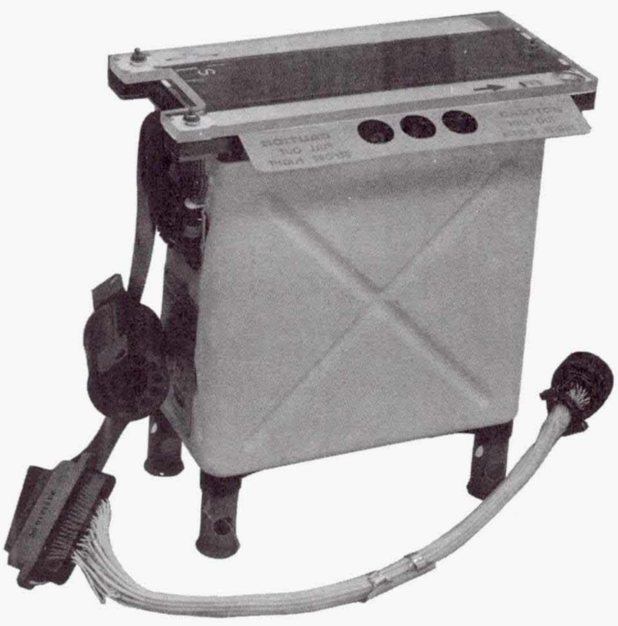


Figure 13 Charged-Particle Lunar Environment Experiment

The lunar surface may be bombarded by electrons and protons of the solar wind. This wind is caused by the expansion of the outer gaseous envelope of the Sun into interplanetary space. Because the solar wind is supersonic and the Moon is a large body, it is possible that, at times, there may be a standing shock front of the solar wind between the Moon and the Sun. The detailed physical processes occurring at such a shock front are largely not understood, and they are of considerable interest in fundamental plasma research. If there is such a shock front near the moon, the CPLEE will detect the disordered or thermalized fluxes of electrons and protons on the downstream side of the shock front.

At times of the full Moon, when the Moon is in the "magnetic tail" of the Earth, the CPLEE will detect the accelerated electrons and protons that cause auroras when they plunge into the terrestrial atmosphere. These acceleration procresses are not understood, and their simultaneous observation near Earth and the Moon is essential for detailed study.

The CPLEE will also measure the lower-energy solar cosmic rays occasionally produced in solar eruptions or flares. The Moon is an excellent platform for such studies, since both its atmosphere and magnetic field are relatively negligible.

The CPLEE consists of two detector packages (analyzers); one oriented vertically and the other 60° from the vertical. Each detector package has six particle detectors. Five of these detectors provide information about the particle's energy distribution, while the sixth detector provides high sensitivity at low particle fluxes. The particles are deflected by an electrical field inside the instrument into one of the six detectors, depending on the energy and polarity of the particles. The instrument also includes electronics for recording the particle counts and providing data to the Data Subsystem.

The CPLEE weighs approximately four and one-half pounds (Earth weight) and requires 4.78 watts of operating power, including power to maintain temperature control during lunar night.

The principal investigator for the CPLEE is Dr. Brian J. O'Brien of Rice University.

DUST DETECTOR

The Dust Detector (Figure 14) will measure the accumulation and effect of lunar dust accretion over the ALSEP Central Station. It is a 1.75- x 1.75- x 2.63-inch sensor unit, weighs approximately 0.15 pound and contains three photocells and thermistors. The package is mounted on top of the Central Station sunshield with the photocells facing the ecliptic path of the Sun. Each cell is protected by a blue filter to cut off ultraviolet wavelengths below 0.4 micron and a cover slide for protection against radiation damage. Attached to the rear of each photocell is a thermistor to monitor the individual cell's temperature. The temperature of each photocell, compared to the anticipated value for exposure at a given solar angle, is a measure of dust accretion and insulating values. The electronics for the Dust Detector weigh approximately 0.10 pound, and are mounted within the thermally-controlled Central Station electronics assembly.

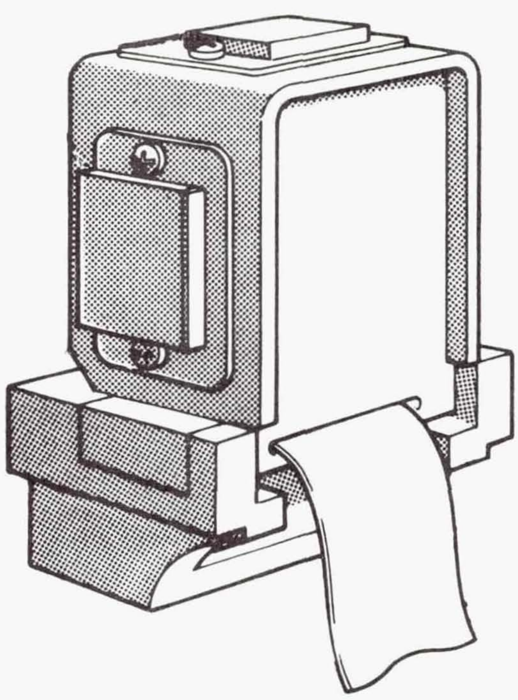


Figure 14 Dust Detector

DATA SUBSYSTEM

ALSEP communications are through an helical antenna attached to the Central Station. This type of antenna obtains high gain over a moderately narrow beam width. When deployed on the lunar surface, the antenna will be aimed at the Earth using a sun compass and adjustment knobs. The Data Subsystem is located in the base of the Central Station (Figures 15 and 16).

The diplexer and switch component of the Data Subsystem provides interference protection between the transmitter and receiver components at the ALSEP antenna. It also permits alternate connection of either of two transmitters to the antenna. Command data (uplink) are received by the helical antenna and go to the command receiver which demodulates the input

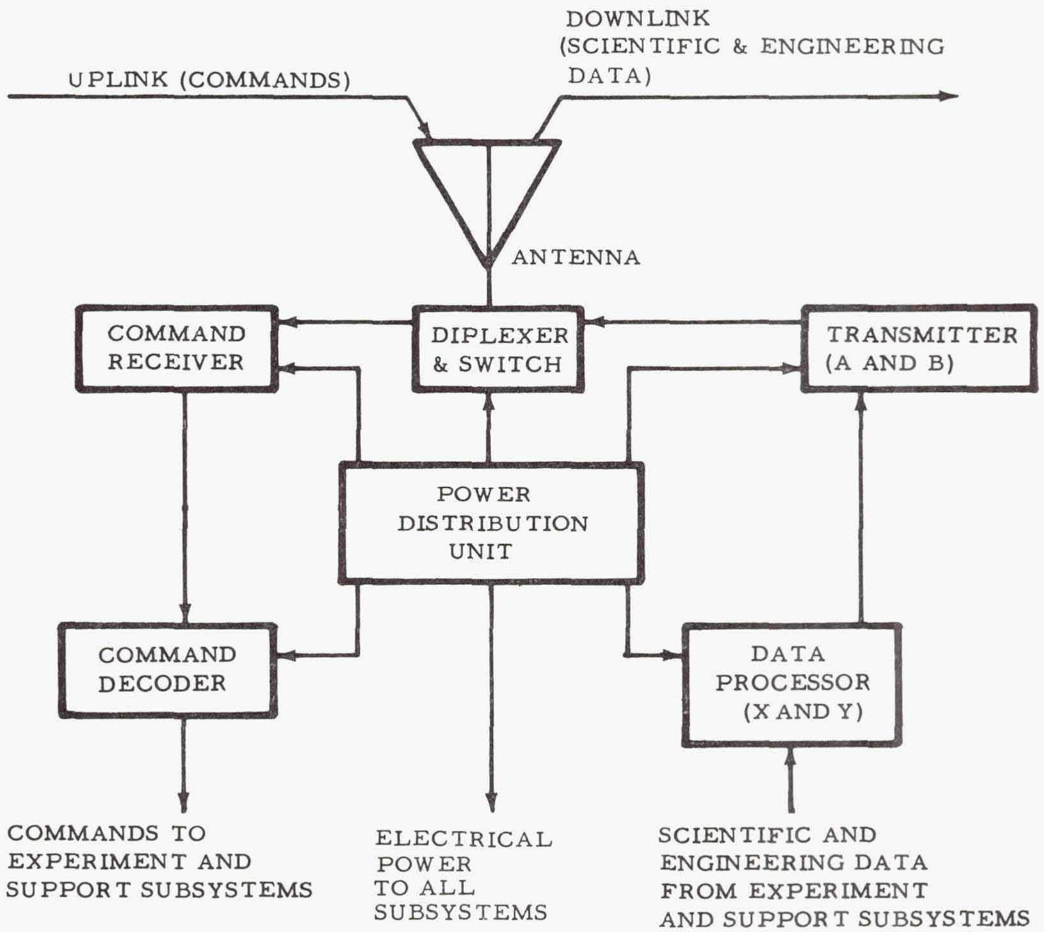


Figure 15 Data Subsystem Simplified Block Diagram

carrier signal and provides a modulated subcarrier output to the command decoder. The command decoder processes the output, converts the command information into digital format and decodes the digital information into discrete ALSEP subsystem commands. Conversely, data from ALSEP subsystems are routed to the data processor. In addition to scientific data from the experiments there are engineering (housekeeping) data inputs from the experiments and supporting subsystems. Although most ALSEP data are in digital form, there are some analog data collected. The analog data are converted into eight-bit digital words and combined with other digital data into a prescribed telemetry format. The formatted data are phase-modulated and routed to the transmitter, which amplifies, multiplies the subcarrier signals and, ultimately, sends a 1.0-watt, S-band signal output to the helical antenna.

ELECTRICAL POWER SUBSYSTEM

The Electrical Power Subsystem provides all the electrical power for ALSEP system operation on the lunar surface for a period of at

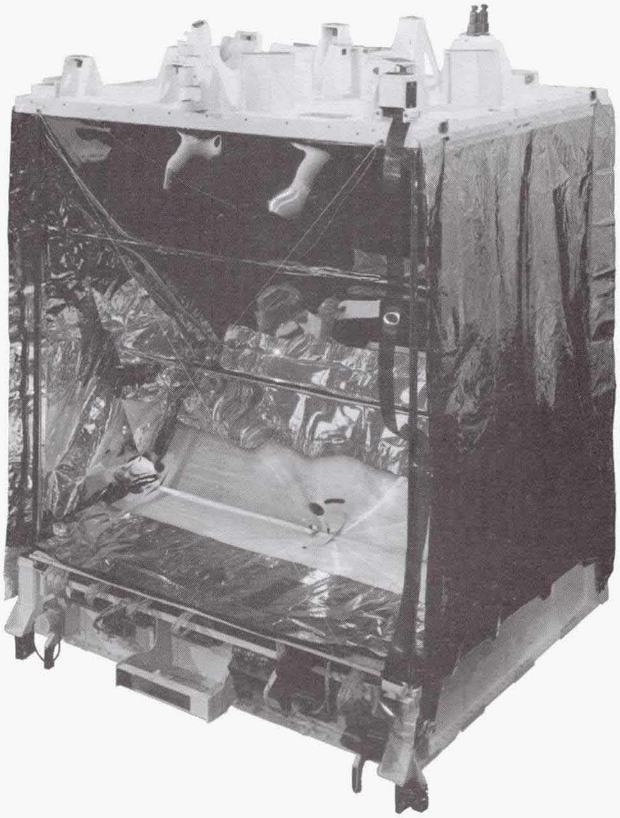


Figure 16 Central Station

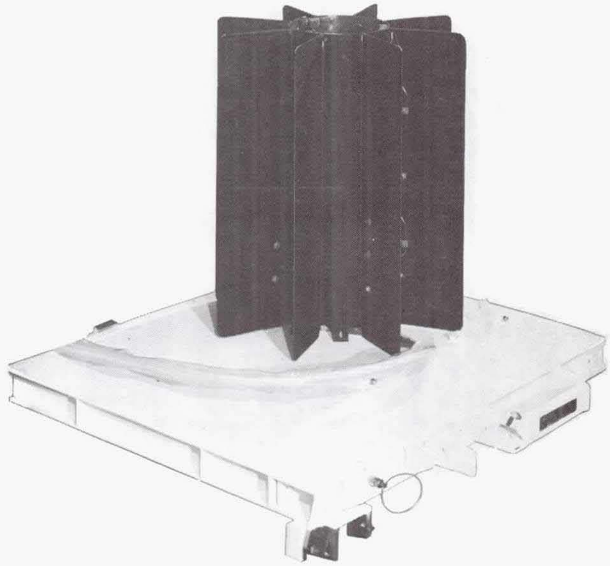


Figure 17 Electrical Power Subsystem Generator Assembly

least one year. The major components include the generator assembly (Figure 17), the fuel capsule assembly, and the power conditioning unit (PCU) which is located in the Central Station. The supporting components include the graphite LM fuel cask (Figure 18), the fuel cask mounting assembly, and the fuel transfer tool.

The fuel capsule assembly (or fuel "source") uses the nuclear fuel Plutonium-238 and produces 1500 watts of thermal energy. When the fuel capsule assembly is combined with the generator assembly to form the SNAP-27 Radioisotope Thermoelectric Generator (RTG), at least 63 watts are converted by thermocouples from thermal energy to electrical energy and supplied (at + 16 VDC nominal) to the PCU.

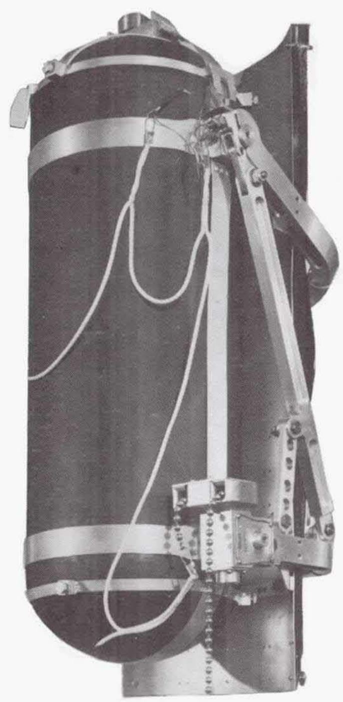


Figure 18 Fuel Cask Assembly

Thermocouples, which are normally used individually to sense temperature by converting heat to electricity, are grouped in such numbers that a useful amount of electrical power is generated. The PCU accepts the primary + 16 VDC source voltage from the RTG and performs conversion and regulation functions to produce six output voltages: -12 VDC, -6 VDC, -5 VDC, +12 VDC, +15 VDC and +29 VDC. The six output voltages are supplied to the PCU of the Data Subsystem where all switching and distribution functions are performed.

Engineering data on PCU "housekeeping" functions, and six key temperatures of the RTG, are provided to the Data Subsystem for transmission in the ALSEP telemetry to the MSFN Earth receiving stations.

The graphite LM fuel cask is designed to carry the fuel capsule assembly during Earth-to-Moon transit. It provides for intact re-entry of the fuel capsule in the event of mission abort.

As one of the initial ALSEP deployment tasks, the astronaut transfers the fuel capsule from the cask to the generator (Figure 19). The fuel cask mounting assembly is tilted for access to the cask and the fuel transfer tool is used to effect a transfer. Thermal equilibrium (i.e., full power) of the RTG is reached in approximately 1.5 hours.

Figure 19 Astronaut Inserting Fuel Capsule into RTG

STRUCTURE/THERMAL SUBSYSTEM

The Structure/Thermal Subsystem consists of the support structure and thermal control components of ALSEP subsystem equipment. The function of this Subsystem is to provide structural confinement of the ALSEP subpackages within the predetermined space allocation and weight restrictions of the LM, and to ensure structural and thermal protection of ALSEP equipment in the lunar environment (-300°F to +250°F).

Since each experiment has its own structure and, in general, it own thermal control, the primary components of the ALSEP Structure/Thermal Subsystem support the Data Subsystem and the Electrical Power Subsystem. Additional components serve to secure the experiments to supporting structure (and thus to the LM) during the severe loads of launch and landing.

Subpackage 1, as stowed for flight to the Moon, carries three experiments and the antenna on a honeycomb pallet which is used as a sunshield during lunar operations. The sunshield is fastened to the primary structure, a shallow box having a forged-aluminum outer frame, which houses the Data Subsystem.

Subpackage 2 has an aluminum pallet as the main structural member. The unfueled RTG (generator assembly) is permanently attached to the pallet. Temporarily attached, in the stowed configuration, is a subpallet carrying the antenna aiming mechanism, the Lunar Ionosphere Detector Experiment, and ALSEP astronaut tools. Also attached, with quick release fasteners, are the Apollo Lunar Hand Tools (ALHT) in their carrier - ready for astronaut use during lunar geological explorations.

Thermal control for the RTG is assured by removing all other equipment from the pallet (during ALSEP deployment) and locating the RTG at least 10 feet from other ALSEP equipment.

After removal of the sunshield-mounted experiments, the sunshield is raised approximately two feet above its stowed position to prepare subpackage 1 for operation under lunar thermal conditions. Spring-loaded tubular extenders facilitate raising the sunshield. Thermal curtains and reflectors automatically unfold as the sunshield is raised.

The fully deployed configuration of subpackage 1, called the Central Station (see Figure 16), has its electronics packages mounted on the underside of a thermal radiator plate and surrounded (bottom and four sides) by an insulating thermal blanket. The blanket prevents heat losses from the electronics compartment at night or gains during lunar day through any side except the radiator plate. The plate serves as the main heat path, allowing radiative losses from the plate to space. The radiator plate (and attached electronics packages) are further isolated from the lunar surface day/night thermal cycles by the reflectors mounted between the plate and the sunshield. Finally, the sunshield and curtains prevent direct solar energy from striking the thermal radiator plate and adding to the lunar-day heat loads.

ALSEP DEPLOYMENT

The conditions of the lunar environment during ALSEP deployment by the Apollo astronauts (temperature extremes, vacuum, a one-sixth gravitational pull, and extreme light intensity) are moderated by the Extravehicular Mobility Unit (EMU) consisting of a pressure suit, thermal overgarment, a helmet with multiple visors, and a Portable Life Support System. Development of the EMU is independent of ALSEP but EMU characteristics influenced the design of ALSEP handling features.

REMOVE PACKAGES

ALSEP is inoperative during its trip to the Moon. After landing, it is deployed and activated by a series of astronaut tasks together with a series of Earth commands to the Data Subsystem from the Manned Space Flight Network. The sequence of deployment events is outlined in Figure 20. Deployment begins when ALSEP subpackages 1 and 2 are separately removed from the SEQ bay and lowered to the lunar surface. The astronaut opens the SEQ bay door on the Lunar Module, removes the package restraints, and grasps a deployment lanyard which is attached to a boom and one subpackage. Pulling the lanyard extends the boom and allows the package to be withdrawn from the SEQ bay and lowered to the Moon in a continuous motion. The other subpackage is similarly unloaded.

TRANSFER FUEL

The radioisotope fuel capsule is next transferred from the fuel cask (mounted on the LM exterior) to the generator mounted on subpackage 2. This includes rotating the fuel cask to a horizontal position, removing its dome and withdrawing the fuel capsule with the fuel transfer tool (FTT). Using the FTT as a handle, the astronaut inserts the capsule into the generator (refer to Figure 19), locking it in place with a twisting motion which also frees the FTT.

The Apollo astronauts next carry ALSEP from 300 to 1000 feet to the final deployment site. The primary transport mode uses the antenna mast attached to the two subpackages to form a "barbell" (Figure 21). A simple, slip-fit, trigger-actuated lock secures the mast to the subpackages. The alternate "suitcase" carry mode makes use of individual handles on the subpackages.

During the traverse the astronauts will determine the most desirable, site, beyond 300 feet from the LM, to locate ALSEP. They will be looking for a smooth area, large enough to accommodate the planned 100-foot separation between the magnetometer and the LID; a level site, free from rubble.

The specified distance assures that there are no destructive LM ascent blast effects on ALSEP and also reflects the need to keep the astronaut at all times within a safe distance for return to the LM in case of failure in his oxygen supply.

DEPLOY RTG

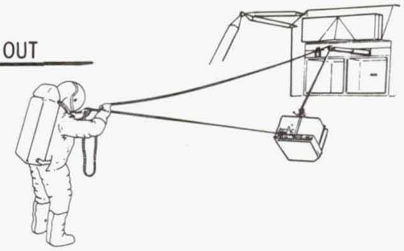
At the end of the traverse, the astronaut deploys the RTG by removing all other equipment from subpackage 2 and placing it in its upright position. The RTG-to-Central Station interconnecting cable is connected to a receptacle located on subpackage 1.

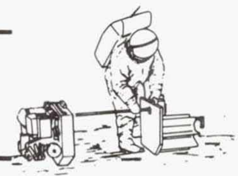
DEPLOY CENTRAL STATION

Subpackage 1, which contains the Central Station, is deployed by placing it in an upright position 10 feet from subpackage 2, removing the experiments from the sunshield, raising the sunshield, and installing the antenna.

Experiments are removed from the sunshield by using a Universal Handling Tool (UHT) to release the tie-down fasteners and to lift the experiments to other locations.

MIN : SEC	COMMANDER ACTIVITY	LM PILOT ACTIVITY
00:00 – 00:54	REMOVE PKG #1 (54 SEC)	MONITOR FOR SAFETY REPORT: PKG #1 OUT
00:55 – 02:02	RELOCATE PKG #1 (15 SEC) MONITOR FOR SAFETY REPORT: PKG #2 OUT	REMOVE PKG #2 (53 SEC)
02:03 – 04:26 TENTATIVE	MONITOR FOR SAFETY CLOSE SEQ BAY DOOR (01 MIN) OBTAIN & STOW GEOLOGICAL TOOLS (42 SEC) REPORT: READY FOR FUEL TRANSFER	RELOCATE PKG #2 (11 SEC) REMOVE ALHT (42 SEC) REMOVE & DEPLOY ALSEP TOOLS (01 MIN 30 SEC)
04:27 – 07:24 TENTATIVE	CONTINUE STOWING GEOLOGICAL TOOLS MONITOR FOR SAFETY & SUPPLY TOOLS REPORT: RTG FUELED	ROTATE PKG #2 UPRIGHT & REMOVE SUBPALLET (40 SEC) ROTATE FUEL CASK (43 SEC) REMOVE CASK DOME (26 SEC) TRANSFER FUEL CAPSULE (01 MIN 08 SEC)
07:25 – 07:52	RETRIEVE SUBPALLET (16 SEC) REPORT: START OF TRAVERSE	ASSEMBLE BARBELL CONFIGURATION (27 SEC)
07:53 – 13:45	CARRY SUBPALLET & ALHT LEAD TRAVERSE PICK ROUTE REST AS NECESSARY (5 MIN 52 SEC) REPORT: TRAVERSE COMPLETE	CARRY BARBELL REST AS NECESSARY (5 MIN 52 SEC)





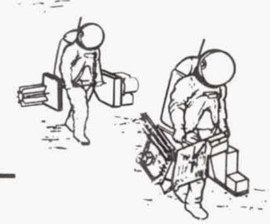
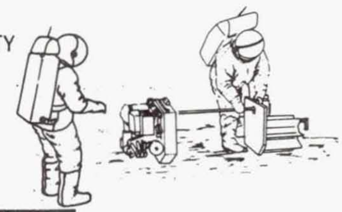


Figure 20 ALSEP Deployment Timeline

MIN : SEC	COMMANDER ACTIVITY	LM PILOT ACTIVITY
13:46	TEMPORARILY EMPLACE SUBPALLET & ALHT (14 SEC)	DEPLOY MAST/PKG #1 (22 SEC)
TENTATIVE	DEPLOY PKG #2 (01 MIN 10 SEC)	MONITOR FOR SAFETY
	CONNECT RTG TO CENT STA (02 SEC)	
15:12	REPORT: RTG PLUG IN	
15:13	DISCONNECT & STOW MAST (01 MIN)	REMOVE LID/LAD & CONNECT CABLE (41 SEC)
		ACTIVATE RTG SW (2 SEC)
16:13		REPORT: RTG SW ON
16:14	ROTATE PKG #1 (14 SEC)	DEPLOY PSE STOOL (18 SEC)
	RELEASE SWS (32 SEC)	
	RELEASE PSE (32 SEC)	DEPLOY SWS (01 MIN 22 SEC)
	REMOVE LSM (54 SEC)	REPORT: ALIGNMENT COMPLETE
		DEPLOY PSE (01 MIN 05 SEC)
TENTATIVE	RELEASE SUNSHIELD (03 MIN)	REPORT: ALIGNMENT VALUES
		DEPLOY LSM (02 MIN 34 SEC)
	DEPLOY SUNSHIELD (53 SEC)	REPORT: ALIGNMENT VALUES
	ASSEMBLE ANTENNA (02 MIN 06 SEC)	DEPLOY LID (03 MIN 42 SEC)
	CONFIRM: AZ/EL SETTING (02 MIN 07 SEC)	
	ACTUATE SW-1 REQUEST: XMTR ON IF ALSEP DOES NOT RESPOND ACTUATE SW-2 AND SW-3	OBTAIN METRIC PHOTOGRAPHS OF DEPLOYED ALSEP
28:00	REPORT: SW POSITIONS	
	RETURN TO LM	RETURN TO LM



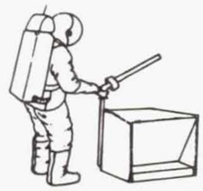


Figure 20 (Continued)

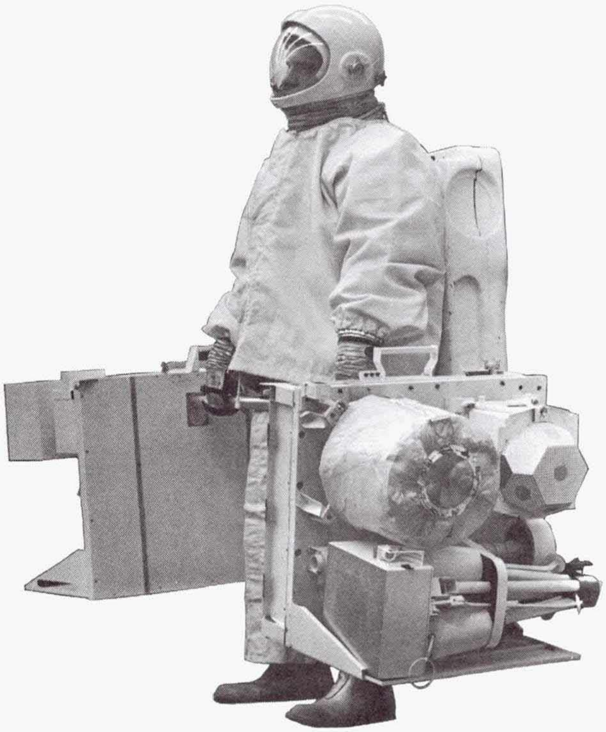


Figure 21 Barbell Carry Mode

After the experiments are removed, additional tie-down fasteners holding the sunshield are released using the UHT. Spring-loaded tubular extenders raise the sunshield and the thermal curtains unfold automatically along with the reflectors.

Antenna installation involves attaching the assembled mast to the Central Station, mounting the aiming mechanism on the mast, and installing the antenna on the aiming mechanism. Antenna alignment is accomplished in four steps:

1. Leveling the base of the antenna aiming mechanism using thumb screws and an integral bubble level

2. Aligning the antenna aiming mechanism with respect to a shadow; i.e., establishing an East-West reference. This alignment uses an adjusting knob, shadow post, and paint pattern

3. Entering coarse and fine elevation settings in the aiming mechanism using an adjustment knob with two scales

4. Entering coarse and fine azimuth settings in the same manner.

Values for these settings are obtained from pointing tables which depend on lunar latitude and longitude and may be relayed to the astronaut from the Earth. The astronauts report completion of alignment and request Earth commands for ALSEP activation.

DEPLOY EXPERIMENTS

Figure 22 shows ALSEP as it will be deployed for Apollo 12.

The Passive Seismic Experiment is emplaced ten feet East (or West) of the Central Station, directly opposite the RTG. The astronaut places the sensor assembly on a small stool, deploys the thermal shroud, levels the sensor on the stool (within 5°), reports the shadow alignment, and returns to the Central Station.

The Solar Wind Experiment is placed 14 feet South of the Central Station. The astronaut

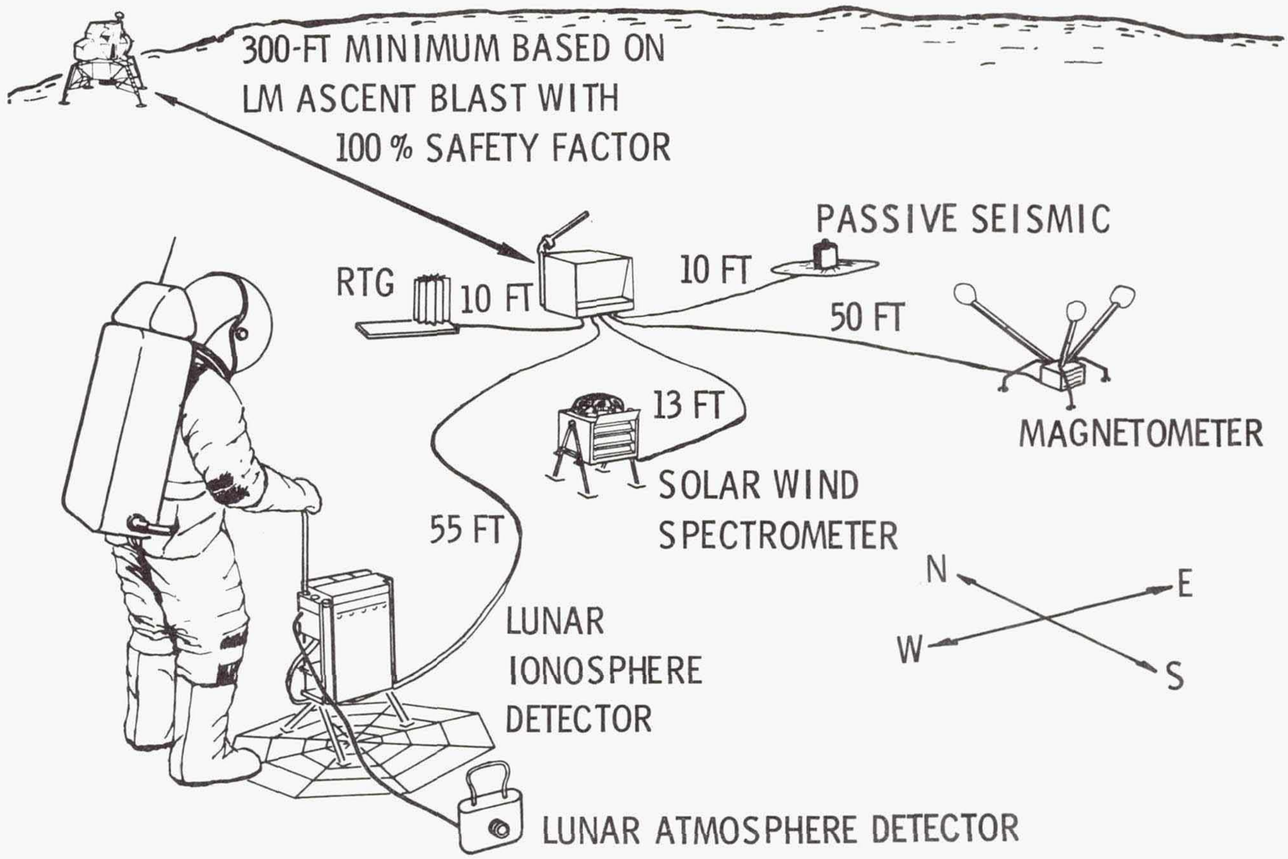


Figure 22 ALSEP Deployment

extends its legs, sets the instrument on the lunar surface, and aligns it relative to a shadow pattern.

The Lunar Surface Magnetometer is placed 55 feet from the Central Station in a direction away from the LM. Its interconnecting cable is deployed during the 55-foot traverse. Upon arrival at the magnetometer location, the astronaut unfolds the legs, places the instrument on the surface in approximately the proper East-West alignment, unfolds the booms which carry the sensors, and makes final leveling and alignment adjustments. The astronaut will then report the alignment and return to the Central Station.

The astronaut next carries the Lunar Ionosphere Detector 55 feet, simultaneously deploying the interconnecting cable, to a position at least 80 feet from the Magnetometer. Before emplacing the LID, the astronaut removes a wire mesh "ground plane" and places it on the lunar surface. Next, the astronaut removes the Lunar Atmosphere Detector from the LID and places it off the edge of the ground plane in a direction away from the Central Station and the LM. Finally, he lowers the instrument to the surface, in the center of the screen, and levels and aligns it. A bubble level and shadows are used for establishing alignment.

The second and third flights of ALSEP contain different experiments as shown in Table 2.

If the Active Seismic Experiment is included, the mortar box assembly is deployed first. It is placed 10 feet from the Central Station, pointing away from the anticipated geophone line. The thumper/geophone assembly is then carried along the preselected line. The geophone cable has three geophone detectors wired to it in such a way that the astronaut can insert the geophones in the lunar surface at distances of 10 feet, 160 feet, and 310 feet from the Central Station. When the astronaut returns along the geophone cable he fires the cartridge-actuated thumper at 15-foot intervals (21 cartridges).

Deployment of the Heat Flow Experiment requires the drilling of holes for the heat flow probes. Using the Apollo Lunar Surface Drill, two holes are drilled approximately one-inch diameter and 10 feet deep. The 45-inch-long probes are placed in the bottoms of the drilled holes by means of a special tool. The probes are connected by cables to an electronics package which is, in turn, cable-connected to the Central Station. The astronaut places the electronics package on the surface with a prescribed alignment which satisfies thermal (sunshield) requirements.

The Charged-Particle Lunar Environment Experiment is emplaced ten feet from the Central Station. The astronaut will set it on the lunar surface, level the instrument to within ±5 degrees of vertical, and align it to within ±2 degrees with respect to shadow lines on the instrument.

With the ALSEP deployed and activated, the astronauts may return to the LM or continue other lunar surface mission tasks such as geological surveys.

ABBREVIATIONS

Abbreviation	Definition
A/D	Analog to Digital
AEC	Atomic Energy Commission
ALGE	Apollo Lunar Geological Equipment
ALHT	Apollo Lunar Hand Tools
ALSD	Apollo Lunar Surface Drill
ALSEP	Apollo Lunar Surface Experiments Package
AMU	Atomic Mass Unit
ASE	Active Seismic Experiment
ASI	Apollo Standard Initiator
CCGE	Cold Cathode Gauge Experiment
CCIG	Cold Cathode Ion Gauge
CPLEE	Charged-Particle Lunar Environment Experiment
EMU	Extravehicular Mobility Unit
Eng.	Engineering
HFE	Heat Flow Experiment
LM	Lunar Module
LSM	Lunar Surface Magnetometer
MCC	Mission Control Center
Mod	Modulated
MSFN	Manned Space Flight Network
NASA	National Aeronautics and Space Administration
PCU	Power Conditioning Unit
PWR	Power
R.F.	Radio Frequency
RTG	Radioisotope Thermoelectric Generator

Abbreviation	Definition
Sci	Science
SEQ bay	Scientific Equipment Bay
SIDE	Suprathermal Ion Detector Experiment
SRC	Sample Return Containers
SWS	Solar Wind Spectrometer
UHT	Universal Handling Tool