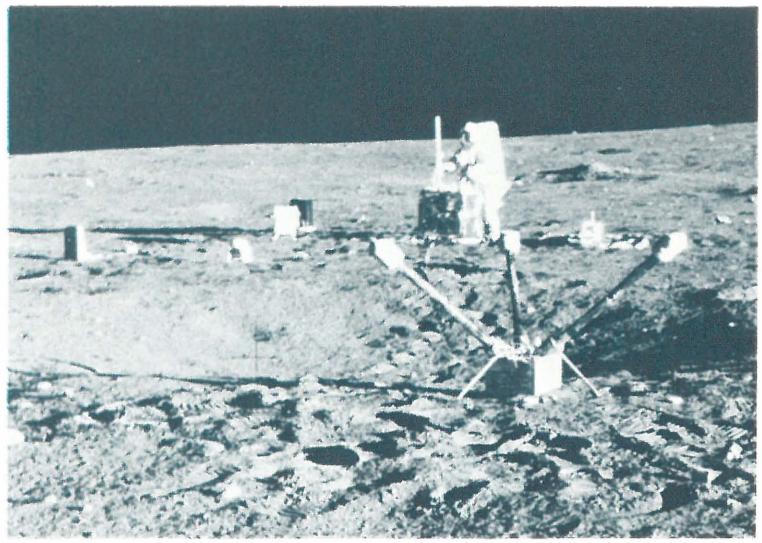
Apollo Lunar Surface Experiments Package (ALSEP)

TWO YEARS OF LUNAR SCIENCE

ALSEP SYSTEM

The Apollo Lunar Surface Experiments Package (ALSEP) is a system of scientific instruments carried to the Moon on the Apollo spacecraft and set up on the lunar surface by the Apollo crew. Using a self-contained power supply and communications equipment, each ALSEP collects and transmits to Earth scientific and engineering data for extended periods following astronaut departure.



APOLLO 12 ALSEP ON THE MOON

Tranquillity to Hadley and Beyond

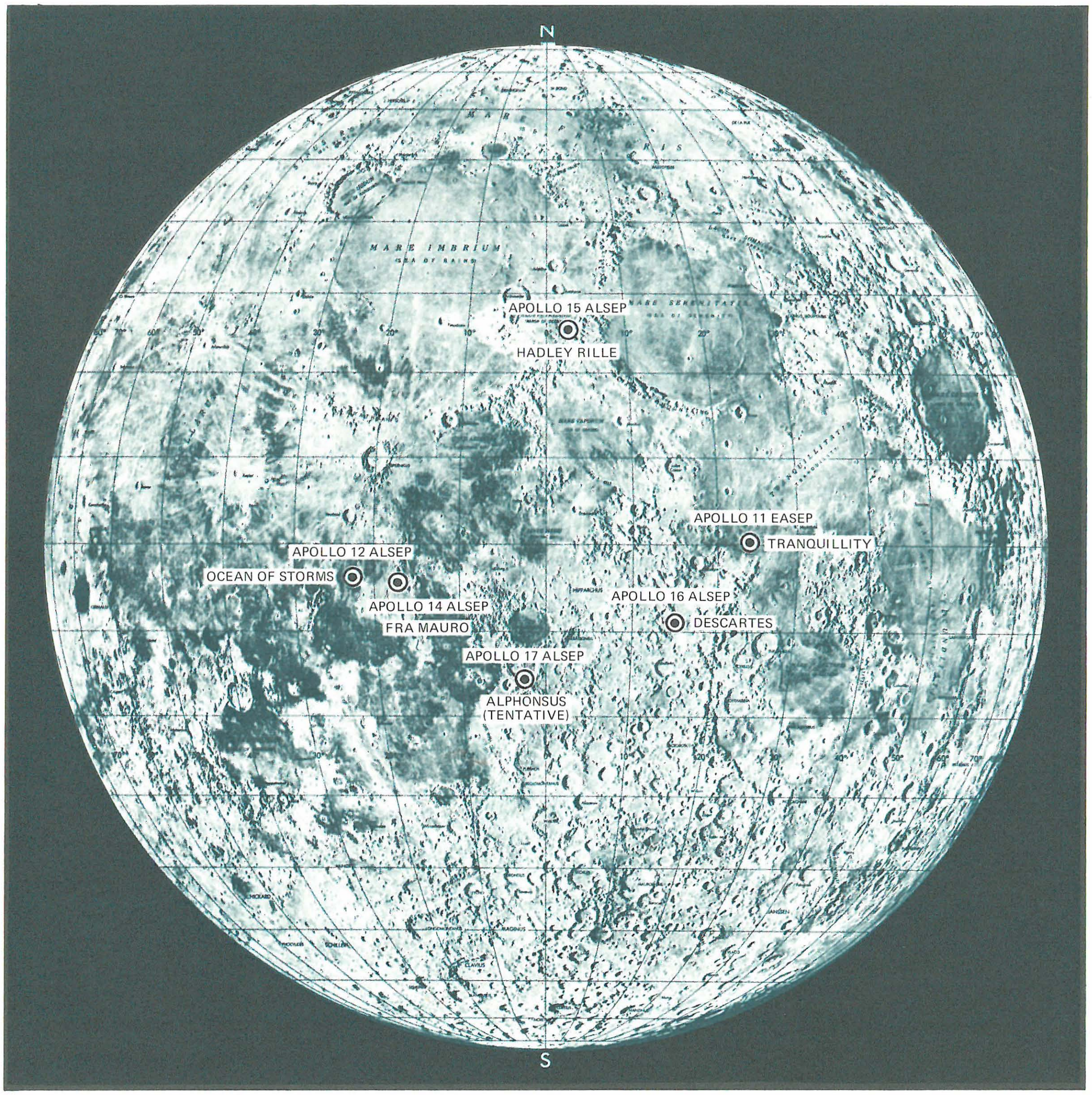
APOLLO MISSION	11	12	14	15
LUNAR LOCATION	TRANQUILLITY	OCEAN OF STORMS	FRA MAURO	HADLEY
DEPLOYMENT DATE	JUL 20, 1969	NOV 19, 1969	FEB 5, 1971	JUL 31, 1971
DESIGN LIFE (DAYS)	14	365	365	365
OPERATING TIME (DAYS)*	71	730	287	111

*As of 19 November 1971

Each ALSEP provides 9 million measurements per day.

Bendix Aerospace Systems Division

LUNAR SCIENCE NETWORK ESTABLISHED



ALSEP SENDS SIGNIFICANT LUNAR SCIENCE DATA

The Apollo 12 Lunar Surface Experiments Package (ALSEP) continues to transmit to Earth scientific and engineering data after more than two years of operation on the lunar surface. Deployment of the Apollo 12 ALSEP on the lunar surface on November 19, 1969 provided man with the first long-term on-site scientific station on another planet. Deployment of the Apollo 14 ALSEP on February 5, 1971 and the Apollo 15 ALSEP on July 31, 1971 established an ALSEP network providing the capability of collecting and transmitting simultaneous scientific data from three remote points on the lunar surface. The ALSEP network has transmitted and continues to transmit a wealth of scientific data for the continuing investigation of the Moon and its relationship to Earth.

The three stations have accepted and executed more than 19,000 commands from Earth and returned ten billion data measurements. The ALSEP experiments investigate the evolution of the Moon and the solar system through instruments such as seismometers, magnetometers, temperature probes, and ion detectors. Establishment of a network of instruments with successive lunar landings enables the definition of the location, velocity, and intensity of lunar events.

MISSION ASSIGNMENTS

Because of power and weight limitations, no single flight can carry all the experiments. A different combination has been assigned to each of the Apollo flights.

ALSEP EXPERIMENT / APOLLO / LOCATION	11	12	13	14	15	16	17
LOCATION	23.4°E 0.7°N	23.5°W 3.0°S		17.5°W 3.7°S	3.7°E 26.1°N	15.5°E 8.9°S	*4.1°W 13.9°S
PASSIVE SEISMIC EXPERIMENT	●	●	●	●	●	●	SECOND GENERATION
ACTIVE SEISMIC EXPERIMENT				●		●	
SUPRATHERMAL ION DETECTOR		●		●	●		
COLD-CATHODE ION GAGE		●	●	●	●		
SOLAR WIND SPECTROMETER		●			●		
CHARGED-PARTICLE EXPERIMENT			●	●			
LUNAR SURFACE MAGNETOMETER		●			●	●	
HEAT FLOW EXPERIMENT			●		●	●	
LASER-RANGING RETRO-REFLECTOR	●			●	●		

*TENTATIVE

MOONQUAKES DEEPER THAN EARTHQUAKES

PASSIVE SEISMIC EXPERIMENT

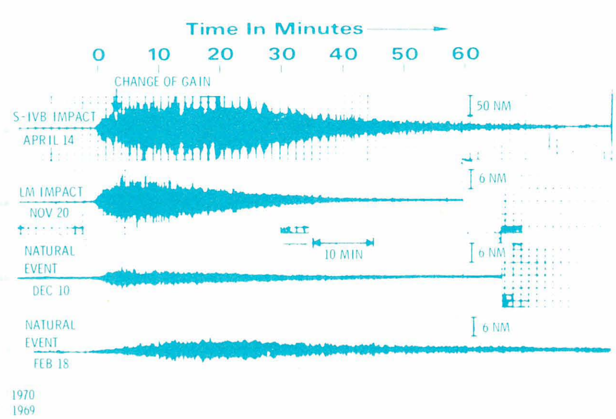
The three ALSEP Passive Seismic Experiments (PSE) provide information on the internal composition of the Moon by monitoring natural and man-made seismic events. The three stations, separated by as much as 1100 kilometers, make it possible to determine the location of seismic events, such as the moonquakes that occur with regularity when the Moon is at apogee and perigee of the orbit. It has been determined that the epicenter of the majority of these moonquakes is approximately 600 kilometers sout-southwest of the Apollo 12 ALSEP and the depth of focus appears to be nearly 800 kilometers which is deeper than any known earthquake.

In addition to the periodic moonquakes, episodes of frequent small moonquakes have been observed. The source of these moonquake "swarms" has yet to be determined but they may well result from continuing minor adjustments to stresses in the Moon's outer crust.

Seismic evidence of a lunar crust and mantle has been discovered. The crust in the region of the Apollo 12 and 14 stations appears to be between 25 and 70 kilometers thick and may consist of two layers.

ACTIVE SEISMIC EXPERIMENT

In addition to the PSE an Active Seismic Experiment (ASE) was deployed at the Apollo 14 ALSEP site. The ASE measures seismic sources such as the astronauts' movements or the detonation of small explosive devices. The data obtained thus far indicate that the ASE measurements are in agreement with predictions obtained from PSE data. A major phase of the ASE investigations, using ground-activated grenades, will be performed after data collection from other Apollo 14 ALSEP experiments is virtually complete.



TYPICAL SEISMIC DATA

MAGNETISM ON THE MOON

LUNAR SURFACE MAGNETOMETER

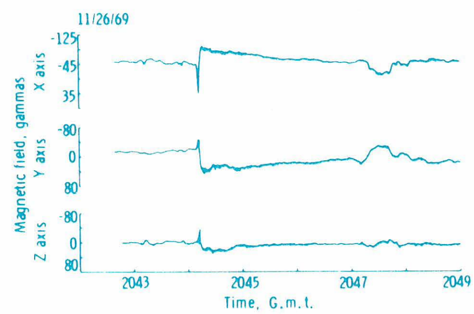
The ALSEP Lunar Surface Magnetometer (LSM) and the Lunar Portable Magnetometer (LPM) have been deployed on the lunar surface to study intrinsic remanent lunar magnetic fields and the global magnetic response of the Moon to large-scale solar and terrestrial magnetic fields.

A study of the interaction between the magnetic field of a planet and the hot ionized gas emanating from the sun permits one to determine the accretion of an atmosphere, radiation belts, and absorbed gases during the evolutionary phase of that planet.

Using the magnetometer experiments on Apollo 12, 14, and 15, local steady fields have been calculated at a total of four lunar sites. The steady fields were 38±3 gammas at the Apollo 12 LSM site, 103±5 and 43±6 gammas at the two Apollo 14 LPM sites, and 6±4 gammas at the Apollo 15 LSM site.

By comparison, the field at the Earth's equator is approximately 35,000 gammas. These fields are all atrributed to remanent magnetization in the nearby subsurface material. The remanent fields could be due to a variety of types of sources, including possible nearby platelike regions that were originally uniformly magnetized but have subsequently been changed by some mechanism such as meteoroid shock impact. The fact the remanent magnetic fields could be extended over two orders of magnitude indicates that the lunar surface steady field varies widely with location on the Moon; magnetic concentrations (magcons) evidently exist at widely separated regions of the Moon. The large differences in magnetic remanence properties of the Apollo 15 and Apollo 12-14 regions suggest the possibility that they were formed at different times under different ambient field conditions or that the magnetic properties of the materials in the two regions differ substantially.

The electrical conductivity of the lunar interior has been determined from magnetic field step-transient measurements. The data fit a spherically symmetric three-layer lunar model having a thin outer crust of very low electrical conductivity. For the case of an olivine Moon, the temperatures of the three layers are approximately as follows: crust 440^{o}K, intermediate layer 810^{o}K, and core 1240^{o}K.



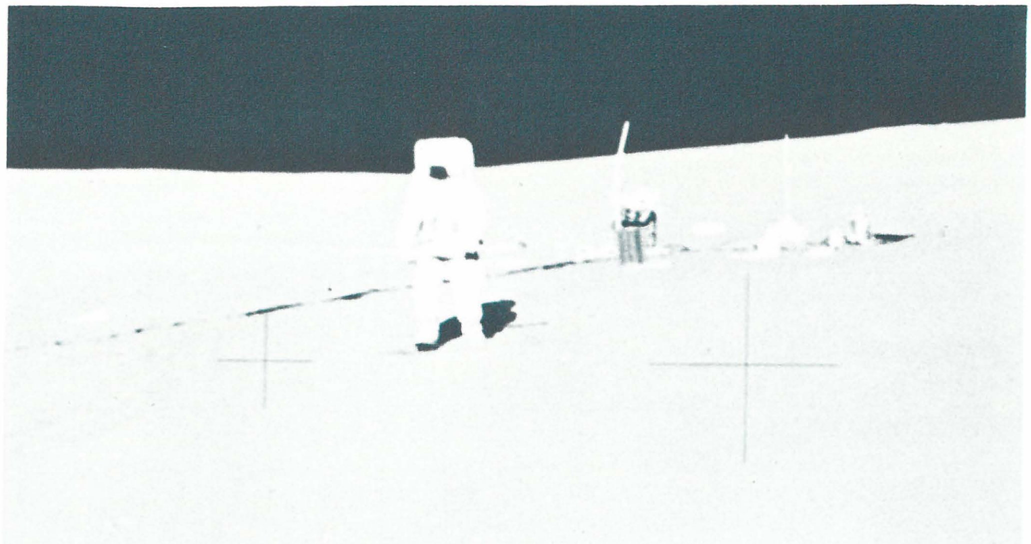
MAGNETOMETER DATA CROSSING BOW SHOCK

PRECISE DISTANCE: EARTH-TO-MOON

LASER RANGING RETRO-REFLECTOR

The Laser Ranging Retro-Reflectors (LRRR) deployed on the lunar surface on the Apollo 11, 14, and 15 missions serve as reference points in measuring precise ranges between the array and points on Earth using the technique of short pulse laser ranging.

The Apollo 11 and 14 retro-reflectors are both near the equator, but are well separated; and the retro-reflector deployed by the Apollo 15 crew completes a triangular network for precision ranging by Earth-based lasers. The Apollo 15 LRRR has 300 retro-reflectors, compared to 100 reflectors on the Apollo 11 and 14 arrays. These reflectors have made possible the measurement of the Earth-Moon separation (240,000 miles) with an uncertainty of 6 inches. The better signal-to-noise ratio available with the larger retro-reflector permits more frequent ranging measurements and the use of telescopes of smaller aperture than used with the smaller arrays. The third array provides the important long north-south baseline separation with the Apollo 11 and the Apollo 14 retro-reflectors. Accumulation of data necessary to the planned astronomical, geophysical, and general relativity experiments will require ranging measurements over a period of years.



APOLLO 14 ON THE MOON

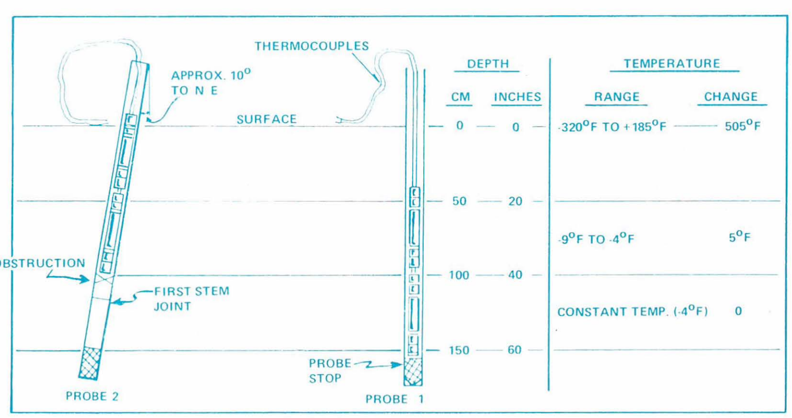
HEAT FLOW FROM MOON HALF THAT OF EARTH

LUNAR HEAT FLOW EXPERIMENT

The temperature of the moon is being monitored by the Lunar Heat Flow Experiment which was deployed on the lunar surface by the crew of Apollo 15. The heat flow experiment is designed to make temperature and thermal property measurements within the lunar subsurface to determine the rate at which heat is flowing out of the Moon. This loss of heat is directly related to the rate of internal heat production and to the internal temperature profile.

Initial measurements with this instrument show a subsurface temperature one meter below the surface of 252.4^{o}K at one probe site and 250.7^{o}K at the other, temperatures which are about 35^{o}K above the mean surface temperature. From a depth of 1 meter down to 1.5 meters, the temperature increases at the rate of 1.75^{o}K/meter $\pm 2\%$. Conductivity measurements of values between 1.4×10^{-4} and 2.5×10^{-4} W/cm^{o}K were determined at depth and are a factor of 7 to 10 above the conductivity of the surface layer, thus indicating that conductivity increases with depth.

Preliminary analysis indicates that the heat flow from beneath the Apollo 15 site is 3.3×10^{-6} W/cm^2 $\pm 15\%$. This value is approximately half the average of heat flow from the Earth. With the assumption that this figure is an accurate representation of the heat flow at the Apollo 15 site (data accumulation from a number of lunations will be required for accuracy), and with the further assumption that this figure represents the Moon-wide value, then consideration of the Moon as a sphere with uniform internal heat generation yields a picture of the Moon with far more radioactivity than has been previously expected, and far more radioactive than suggested by the ordinary chrondites and the carbonaceous chrondites which have formed the bases of standard models of the Earth and Moon to date.



APOLLO 15 ALSEP HEAT FLOW EXPERIMENT

LUNAR ATMOSPHERE

Gas Clouds - Water Vapor

The ALSEP Suprathermal Ion Detector Experiment (SIDE), the associated Cold Cathode Gage Experiment (CCGE), and the Charged–Particle Lunar Environment Experiment (CPLEE) are measuring the dynamics of the lunar ion atmosphere.

SUPRATHERMAL ION DETECTOR

The network of ALSEP Suprathermal Ion Detectors are continuing to provide information on the energy and mass spectra of positive ions close to the lunar surface. These ions can be grouped into two classifications; those resulting from ionization of gases generated at the Moon by natural and man-made sources and those which arrive from sources beyond the near-Moon environment.

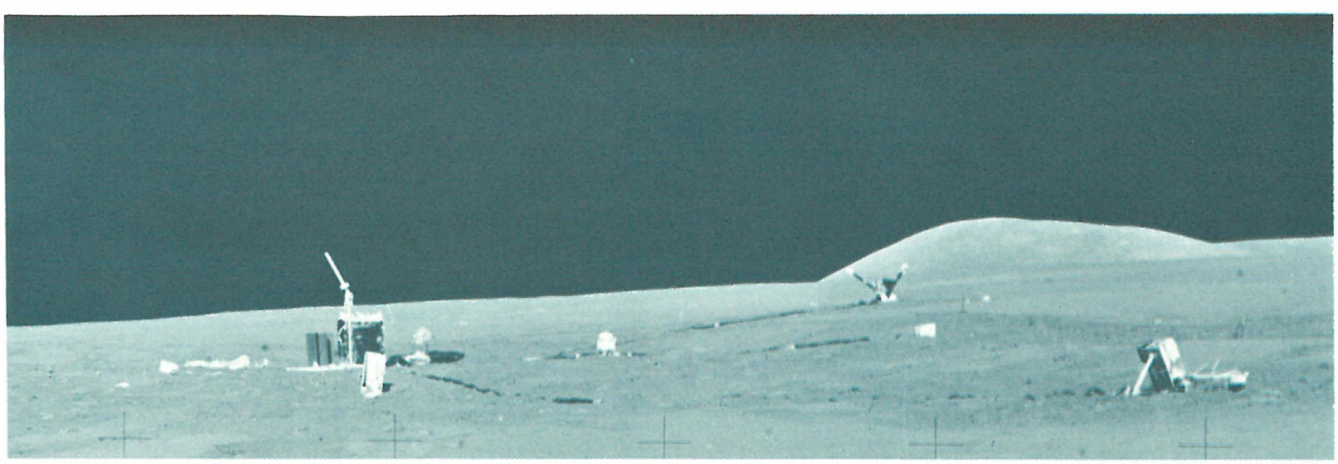
Evidence of the operation of a prompt ionization and acceleration mechanism operating in the lunar exosphere has been discovered based on the data from the Apollo 12 and 14 instruments. Electric and magnetic fields near the lunar surface can be studied by observing their effects on the motions and energies of the ions after they are generated. The network of three SIDE instruments (Apollo 12, 14, and 15) now operating on the Moon allows a more precise determination of dimensions and motions of ion clouds moving across the lunar surface.

An example of the significant results of the SIDE experiments is the detection of water vapor in the lunar exosphere by the Apollo 14 SIDE. Water from some unknown depth below the surface is believed to be liberated by seismic activity, and vaporized instantly upon exposure to the lunar atmosphere. The vapor is then dispersed over a wide area; some fraction of it becomes ionized and is subsequently dedected by the SIDE.

COLD CATHODE GAGE EXPERIMENT

The ALSEP Cold Cathode Gage Experiment (CCGE) measures the density of the tenuous lunar atmosphere at the lunar surface. This thin concentration of gases is supplied by the solar wind, by the possible continued release of molecules from the Moon's interior through the lunar crust, and venting and outgassing from the lunar module and other space gear.

The data from the Apollo 12, 14, and 15 CCGE instruments have shown that the gas concentrations observed during the lunar days appear to be due overwhelmingly to contaminants released by the lunar module and its associated equipment. However, the concentrations observed during the lunar nights, typically less than 2×10^5 particles/cm^3, are lower even than those expected from just the neon component of the solar wind alone. This suggests that the contaminant gases from spacecraft equipment remain adsorbed at the low night-time temperatures, and that the lunar surface itself is not saturated with neon, but that the rate of neon release from the surface is much slower than the rate of neon implantation.



APOLLO 15 ALSEP ON THE MOON

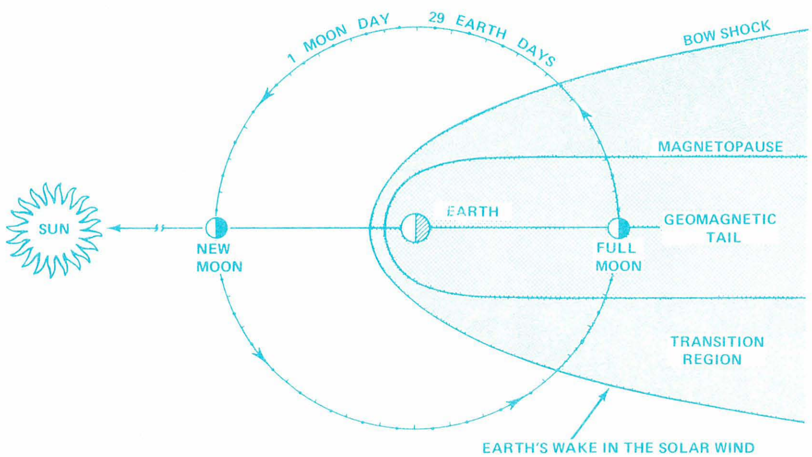
LUNAR ATMOSPHERE

Gas Clouds - Water Vapor

CHARGED-PARTICLE LUNAR ENVIRONMENT EXPERIMENT

The ALSEP Charged-Particle Lunar Environment Experiment (CPLEE) which was deployed by the crew of Apollo 14 measures the ambient fluxes of charged particles, both electrons and ions, with energies in the range of 50 to 50,000 eV. One of the most stable features observed is the presence of low-energy electrons whenever the landing site is illuminated by the Sun. The variation in the low-energy-electron flux during the lunar eclipse of February 10, 1971 provided strong evidence that the electrons are photoelectrons liberated frrom the lunar surface. The solar-wind flux observed by the CPLEE has exhibited rapid time variations (periods of approximately 10 sec), both when the Moon is in interplanetary space and when it is immersed in the magnetospheric tail of the Earth. Passage of the Moon through the magnetopause and magnetospheric tail has produced some particularly interesting data, including rapidly fluctuating low energy (50- to 200-eV) electrons, fluxes of medium-energy electrons lasting from a few minutes to tens of minutes, and electrons that have energy spectra remarkably similar to those observed above terrestrial auroras. Thus, auroral particles appear to penetrate far into the magnetospheric tail, an observation that, if confirmed, contains important implications concerning the general topology of the magnetosphere.

After the Apollo 14 LM ascent-stage impact, two plasma clouds, which were separated in time by a few seconds, passed the CPLEE. The clouds were traveling at approximately 1 km/sec and had diameters of 14 and 7 km.



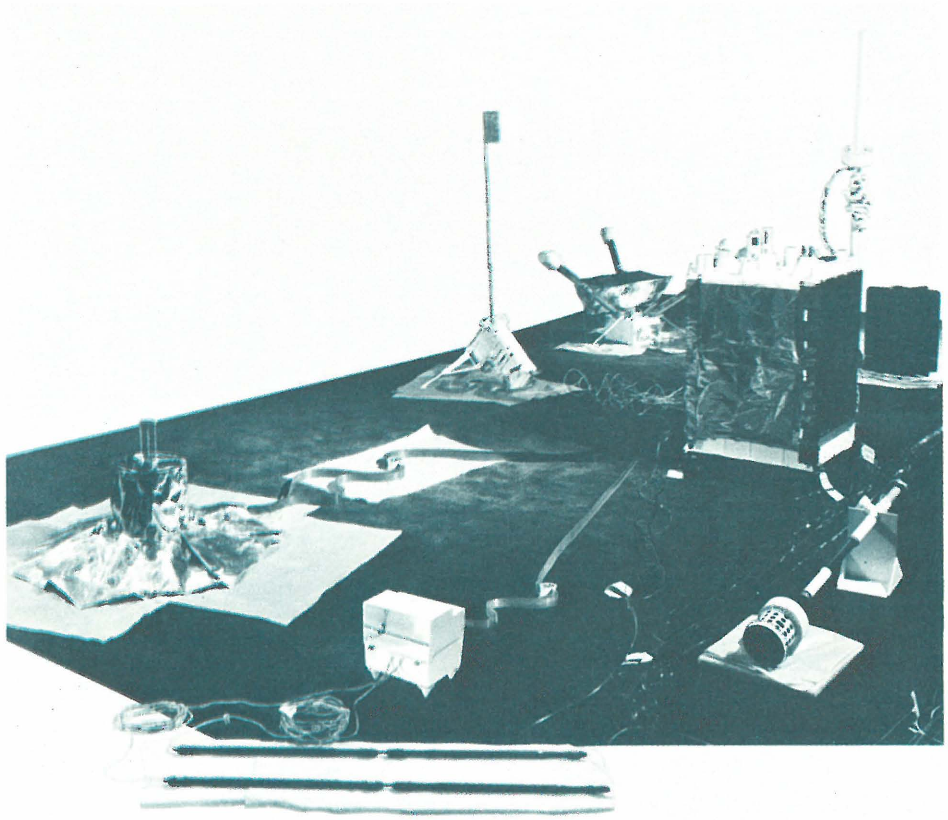
ALSEP LUNAR LABORATORY SURVEYS EARTH'S ENVIRONMENT

SOLAR WIND SPECTROMETER

The two Solar Wind Spectrometer Experiments (SWS) deployed on Apollo 12 and 15 missions are designed to determine the interaction of the Moon and the solar wind. The solar wind, or plasma, is the top layer of the atmosphere of the Sun (often called the corona), which is completely ionized and is expanding into space at hypersonic velocity in all directions.

The Solar Wind Spectrometer Experiments are operating 1100 km apart at the Apollo 12 and the Apollo 15 sites. Solar wind plasma, magnetosphere plasma, and magnetopause crossings have been observed by both instruments which show good agreement between these observations; for example, simultaneous (within 15 seconds) changes in proton densities and velocities are detected at both sites. As first measured with the Apollo 12 instrument the solar plasma right at the lunar surface is indistinguishable from the solar plasma some distance out from the surface (monitored by orbiting instruments), both when the Moon is ahead of and when the Moon is behind the magnetic bow shock of the Earth.

SCIENTIFIC EXPLORATION GOES FORWARD



APOLLO 16 ALSEP PREPARED FOR 1972 FLIGHT TO THE MOON

Future Lunar Exploration

The two remaining Apollo missions, Apollo 16 and Apollo 17, will also carry ALSEP systems to further the scientific investigation of the Moon. The subsequent ALSEP's will consist of varying experiment arrays to supplement and complement those scientific experiments already operating on the lunar surface. For example, an additional seismometer will be deployed to complement the seismic sensing network. Further particle and field measurements will be made with magnetometers, gravimeters, and ion detectors. Thermal characteristics of the lunar surface will be explored with a second heat flow experiment.

The ALSEP to be carried on Apollo 17, presently the last planned Apollo mission, is designed for a two-year operational life. Each of the earlier ALSEP's will be operational for a minimum of one year. The continuing long-term scientific measurement and data collection of lunar exosphere, surface mantle, and whole body properties are essential to the understanding of the Earth-Moon relationship and the solar system. The two-year anniversary of the first ALSEP marks a major milestone in systematic scientific lunar exploration.

Apollo Lunar Surface Experiments Packages are developed by the Aerospace Systems Division of The Bendix Corporation under the direction of the National Aeronautics and Space Administration Manned Spacecraft Center.

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