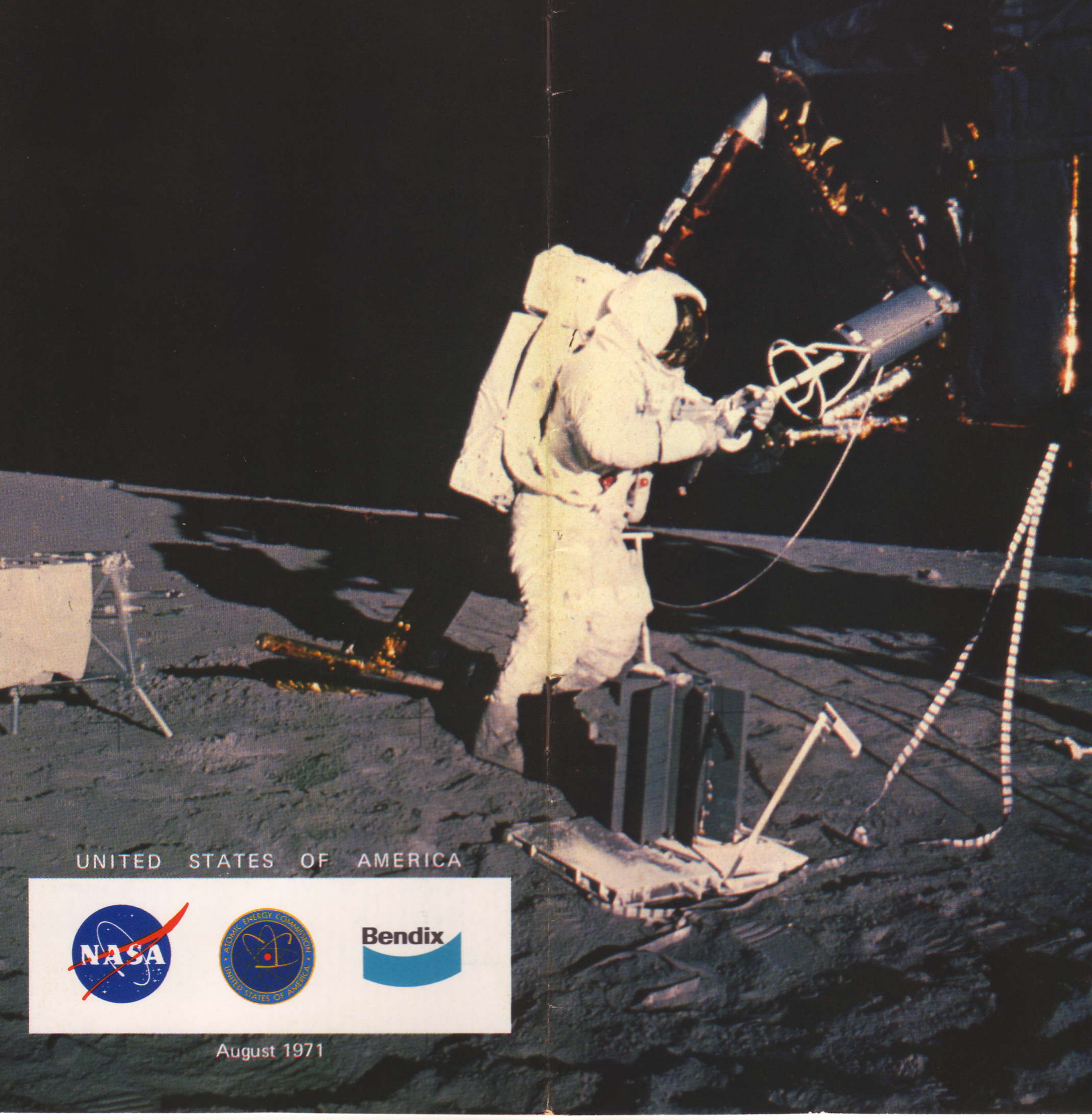
The cover shows Apollo 12 astronaut Alan Bean removing the radioisotopic fuel capsule from its transportation cask on the lunar module in preparation for the fueling of the SNAP-27 generator seen in the foreground.

Apollo Lunar Surface Experiments Package (ALSEP)



UNITED STATES OF AMERICA

NASA

ATOMIC ENERGY COMMISSION · UNITED STATES OF AMERICA

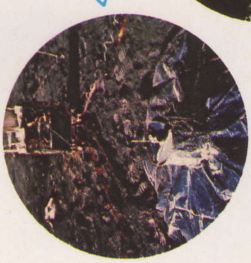
Bendix

August 1971

Mission Assignments

ALSEP EXPERIMENT \ APOLLO	11	12	13	14	15	16	17
LOCATION	23.5°E 0.6°N	23.4°W 3.0°S		17.5°W 3.6°S	3.6°E 26.1°N	15.5°E 8.9°S	*4.1°W 13.9°S
PASSIVE SEISMIC EXPERIMENT	•	•	•	•	•	•	SEE PAGE 13
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



The 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.

Because of power and weight limitations, no single flight can carry all the experiments. A different combination has been assigned to each of Apollo flights 11 through 17 (see table on facing page).

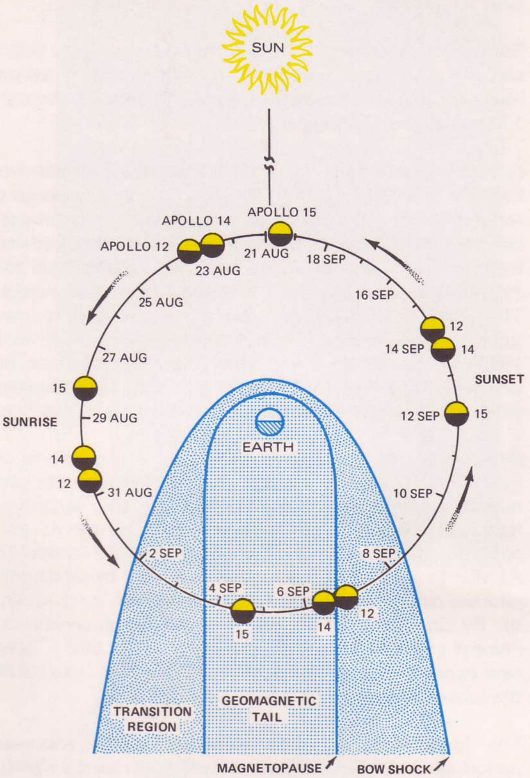
Apollo 11 carried the Early Apollo Surface Experiments Package (EASEP), which consisted of a laser-ranging retro-reflector and a passive seismic experiment; powered by solar cells, the seismometer operated during lunar day to provide pioneering lunar seismic data for 4½ months, well beyond its design life of two weeks. The Apollo 12 ALSEP, with a radioisotopic power supply, has operated continuously since November 1969, far longer than the mission life specification of one year. The Apollo 13 ALSEP mission was aborted when a spacecraft malfunction prevented lunar landing.

Deployment of the Apollo 14 ALSEP at Fra Mauro in February 1971 made possible for the first time the correlation of measurements taken at two widely separated locations on the lunar surface; its experiments still continue to transmit data. Deployment of the Apollo 15 ALSEP in July 1971 has further extended this data correlation capability, as will Apollo 16, which is scheduled to fly in April 1972, carrying similar experiments. Present planning calls for the Apollo 17 ALSEP — four new experiments and one carried previously — to reach the lunar surface in January 1973.

The lunar scientific data collected in the two-year period since Apollo 11 have already contributed significantly to man's understanding of the lunar environment. Some early theories have been validated and others revised in the light of the new information. The continuing long-term measurement of lunar exosphere, surface, and subsurface properties will greatly enhance our knowledge of the moon and should provide answers to basic questions concerning the origin of the earth, earth/moon relationships, and interactions with the solar system.

Moon Position Relative to Earth/Sun Line

One lunar day/night cycle spans 29½ earth days as the moon circles the earth at a distance of 240,000 miles. This orbit takes the ALSEP systems through the undisturbed region of free space and through the wake in the solar wind produced by the earth and the geomagnetic field.



ALSEP Temperatures

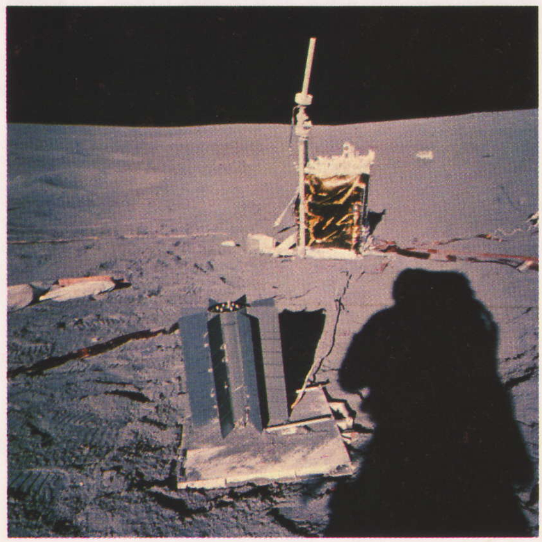
Upward-facing surfaces of the ALSEP equipment record temperatures as high as 180°F (compared to lunar surface temperatures of 250°F) during lunar day and as low as -295°F during lunar night. It has been established that a yearly cycle of daytime temperatures (a summer/winter effect) exists, caused by the eccentricity of the earth's orbit around the sun. During three lunar eclipses, ALSEP surface temperatures showed a rapid decrease – as much as 320°F in two hours – followed by a less rapid return to original temperatures.

ALSEP Power Supplies

Power for the Apollo 11 EASEP was provided by an array of solar cells. The power supply for the Apollo 12 ALSEP and subsequent experiments packages is the SNAP-27 radioisotopic thermoelectric generator (RTG), fueled by plutonium 238. Each generator has a thermopile consisting of 442 thermocouples, which convert thermal energy to electric power with an efficiency of approximately 4 percent. The nuclear radiation levels external to the RTG are not high enough to constitute a hazard for the Apollo crew.

The power output of the Apollo 12 ALSEP generator was 74.2 watts at start-up on the moon; it decreased slowly to 72.5 watts and since June 1970 has remained at that level. The Apollo 14 RTG output has been a constant 72.5 watts since start-up.

Time-dependent factors that affect generator performance, other than the 87.8-year halflife of plutonium 238, include the mechanical contacts at the ends of the thermocouples and the internal resistances of the thermocouples. The lunar day/night temperature variation also has a minor effect, output during the cold lunar night being approximately 0.2 watt higher than that during the warm lunar day.



Apollo 14 Power Supply and Communications Equipment

ALSEP Communications

Nine million measurements are transmitted from each ALSEP on the moon in a 24-hour period. On the earth, the downlink signal from each ALSEP is received and recorded continuously by one of the twelve worldwide tracking stations of the Manned Space Flight Network (MSFN) of the National Aeronautics and Space Administration (NASA). The measurements are subsequently extracted from these recordings for engineering evaluation and scientific analysis.

In addition to recording data continuously, MSFN stations periodically relay live ALSEP data — via the NASA Goddard Space Flight Center (GSFC) in Greenbelt, Maryland — to the NASA Manned Spacecraft Center (MSC) in Houston, Texas, which is responsible for the overall operation and control of ALSEP. At MSC, the data are processed through a computer and presented on various display devices for real-time monitoring and evaluation of system performance.

Each ALSEP can receive, decode, and distribute up to 100 different radio commands from the earth. These commands, sent from MSC, are used to adjust the experiments, activate heaters, and make other functional changes in the equipment. More than 10,000 commands have been sent to the Apollo 12 ALSEP and some 3000 to the Apollo 14 ALSEP.

The transmission of live ALSEP data to MSC — and to Geneva, Switzerland, during the Fourth International Conference on the Peaceful Uses of Atomic Energy — is accomplished in the following steps (see map opposite):

1. Downlink signals are received and processed at one of the MSFN stations. The station then transmits two data messages on two different network links to GSFC. One message contains the total ALSEP data; the other contains only housekeeping data — voltages, currents, and temperatures.

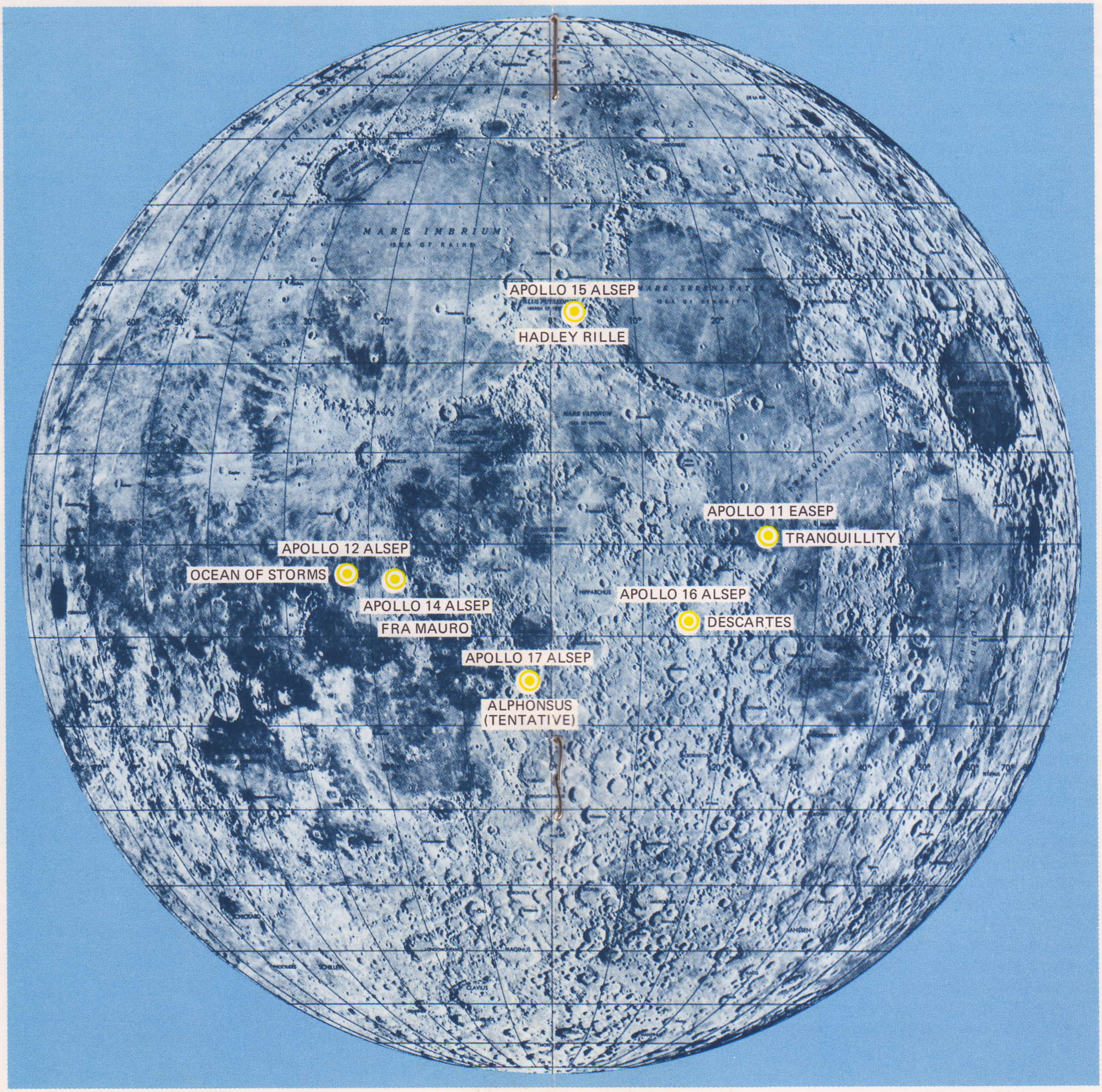
2. At GSFC, the two data messages are switched to appropriate network circuits for routing. Both the total ALSEP data message and the housekeeping message are routed to MSC.

3. The housekeeping message only is routed from GSFC to the MSFN station at Madrid, Spain.

4. At Madrid, the message is converted to a suitable signal for transmission on commercial telephone lines to Geneva, Switzerland.

Data Flow from the Moon to Geneva

ALSEP on the Moon



Experiment Descriptions and Results

THE PASSIVE SEISMIC EXPERIMENT

Principal Investigator: Gary Latham
Lamont Doherty Geological Observatory

The passive seismic experiment detects seismic and tidal movements of the moon to locate seismic epicenters and to refine our understanding of the moon's structure. It measures the frequency and amplitude of both natural and man-induced seismic events, as well as of the slow surface deformations caused by tidal forces. The instrument contains one short-period sensor mounted vertically and three long-period sensors mounted orthogonally.

It appears that the outer structure of the moon is not stratified, as is that of the earth, but is a collection of rock clumps. Signals from the man-induced impacts of the Apollo 13 and Apollo 14 S-IVB booster stages exhibited extremely large peak amplitudes and persisted for several hours — much longer than would have been the case on earth. Meteoroid impact signals are recorded almost daily. Moonquake signals are recorded several times each month, most often when the moon is nearest the earth, at perigee; the high tidal stresses near perigee are believed to trigger the release of internal strains of unknown origin, causing the moonquakes.

THE ACTIVE SEISMIC EXPERIMENT

Principal Investigator: Robert Kovach
Stanford University

The active seismic experiment measures the elastic properties of the lunar subsurface, using a string of geophone sensors to detect seismic signals generated by a thumper device or by rocket grenades. The thumper contains a number of small-explosive initiators, which are fired by the astronaut near the emplaced geophones. The grenades are to be ground-activated after data collection from the other ALSEP experiments is virtually complete.

Data obtained at the Apollo 14 station indicate the lunar surface layer (regolith) at that site to be 8.5 meters thick. The seismic propagation velocity of 104 meters per second observed in the surface layer agrees with predictions based on passive seismometer data.

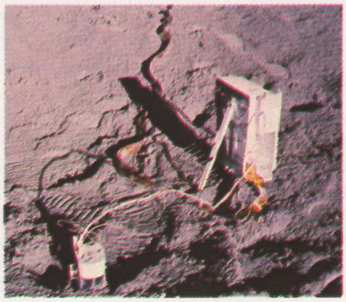
THE SUPRATHERMAL ION DETECTOR EXPERIMENT

Principal Investigator: John Freeman
Rice University

The suprathermal ion detector experiment and the cold-cathode ion gage experiment (described below) share a single instrument package. The detector consists of two curved-plate ion analyzers, one containing a velocity filter, which measure the energy and mass spectra of the positive ions (ionosphere) close to the lunar surface.

Clouds of low-energy ions are seen regularly near lunar sunrise and sunset. Positive ions of high energy are detected within one to seven days following each lunar sunset. Ions having complex energy spectra, with rapid time-variations in intensity, are found during each passage through the geomagnetic transition region. The effects of booster-stage impacts, lunar eclipses, and solar storms have also been recorded. With the two ionosphere detectors deployed on Apollo missions 12 and 14, it is possible to differentiate moving ion clouds from temporal fluctuations in overall ion distribution.

Suprathermal Ion Detector



Cold-Cathode Ion Gage

THE COLD-CATHODE ION GAGE EXPERIMENT

Principal Investigator: Francis Johnson
University of Texas

The cold-cathode ion gage measures by ionization the concentration of neutral atoms at the lunar surface to define the normal lunar atmosphere and to detect the passage of gas clouds.

Neutral-particle concentrations of 2×10^5 atoms per cubic centimeter are observed during lunar night. At dawn the concentration increases over a period of two minutes to 2×10^7 and then decays over approximately fifty hours to a daytime level of less than 1×10^7. Transient increases in concentration are frequently observed during both lunar day and lunar night.

THE SOLAR WIND SPECTROMETER EXPERIMENT

Principal Investigator: Conway Snyder
Jet Propulsion Laboratory

The solar wind spectrometer uses seven Faraday-cup sensors to measure the flux, particle energy, and direction of the solar wind – a stream of ionized gas, or plasma, emanating from the sun and impinging on the lunar surface.

No plasma is detected during lunar night, when the moon is between the sun and the spectrometer, nor during a 4½-day period when the moon is in the geomagnetic tail of the earth. Plasma that is less strongly perturbed by the earth's field is measured for about three days on either side of the geomagnetic tail (in the transition region). During the remaining five days of each lunar cycle, the plasma parameters measured are typical of those for free space.

Contrary to expectation, gas clouds resulting from the lunar impact of the Apollo 13 S-IVB booster stage were detected by the Apollo 12 spectrometer.

THE CHARGED-PARTICLE LUNAR ENVIRONMENT EXPERIMENT

Acting Principal Investigator: David Reasoner
Rice University

The charged-particle lunar environment experiment determines the number and energies of the positively and negatively charged particles impinging on the lunar surface, using two identical physical analyzers.

Rapid changes in solar wind flux are observed, both when the moon is in interplanetary space and when it is in the earth's magnetospheric tail. The detection in the magnetospheric tail of electrons having energy spectra similar to those found above terrestrial aurorae has important topological implications. Low-energy electrons are detected whenever the site is illuminated by the sun; these may be photoelectrons liberated from the lunar surface.

Charged-Particle Lunar Environment Experiment

THE LUNAR SURFACE MAGNETOMETER EXPERIMENT

Principal Investigator: Palmer Dyal
Ames Research Center

The lunar surface magnetometer measures the magnitude, gradient, and direction of the magnetic field at the lunar surface, using three flux-gate sensors.

A steady 36-gamma field at the magnetometer location, combined with magnetic-gradient measurements, suggests the presence of an extensive fossil remanent of a larger field, frozen in cooling lava. Superimposed on the steady field are time-dependent field changes. Correlation of these changes with simultaneous measurements from Explorer 35 orbiting the moon indicates that large electric currents may be generated deep in the interior of the moon and that the lunar temperature profile has an average value of 800°K down to about half the radius of the moon and reaches 1200°K in the inner core.

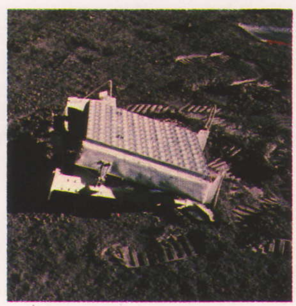
THE LASER-RANGING RETRO-REFLECTOR

Principal Investigator: J. E. Faller
Wesleyan University

The laser-ranging retro-reflector is a passive array of precision optical reflectors aimed at the earth to provide a target for special earth-based laser-ranging equipment. The arrays carried on Apollo flights 12 and 14 had 100 retro-reflectors each. The array carried on Apollo 15 has 300 retro-reflectors; it completes a triangular network and provides a return signal strong enough to permit smaller observatories to conduct ranging experiments.

Measurements of the earth/moon separation (240,000 miles) with an accuracy of 6 inches are being made on a scheduled basis to detect lunar motions, earth wobble, and continental drift. Full scientific utilization of the experiment will require measurements over a period of several years; results to date indicate that this lifetime will be achieved.

Laser-Ranging Retro-Reflector



The Apollo 17 ALSEP

As currently planned, four new experiments and one previously flown will make up the Apollo 17 ALSEP.

THE HEAT FLOW EXPERIMENT

Principal Investigator: Mark Langseth
Lamont Doherty Geological Observatory

The heat flow experiment measures the thermal conductivity of near-surface materials and the rate at which the interior is losing energy to outer space. Precision bridge thermometers placed in two specially drilled 10-foot-deep holes permit determination of the temperature and radioactivity of the core and whether it is molten. The heat flow experiment was flown on Apollo missions 13 and 15 and will be flown on Apollo 16.

THE LUNAR SURFACE PROFILING EXPERIMENT

Principal Investigator: Robert Kovach
Stanford University

The lunar surface profiling experiment will measure surface and near-surface response to artificially induced seismic energy in the form of relatively large explosive charges placed on the surface by the crew and detonated from earth. From this response, lunar physical characteristics to substantial depths can be inferred.

THE LUNAR MASS SPECTROMETER

Principal Investigator: John H. Hoffman
University of Texas

The lunar mass spectrometer will determine the mass spectra of constituents of the lunar atmosphere to identify them and determine their densities. A magnetic-sector mass spectrometer with a thermionic emission source will be used.

THE LUNAR EJECTA AND METEORITES EXPERIMENT

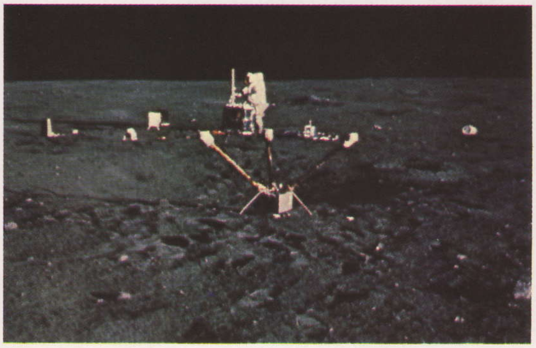
Principal Investigator: Otto Berg
Goddard Space Flight Center

The lunar ejecta and meteorites experiment will measure long-term variations in cosmic dust influx rates, the extent and nature of the lunar ejecta, and the radiant, flux density, and speed of particles in the meteorite streams.

THE LUNAR SURFACE GRAVIMETER

Principal Investigator: Joseph Weber
University of Maryland

The lunar surface gravimeter will measure the vertical component of gravity in the frequency ranges characteristic of tidal, seismic, and lunar free-mode oscillations. The free-mode data will be examined for evidence of gravitational waves from cosmic sources, which, if observed, will verify the general theory of relativity.



Apollo 12 ALSEP on the Moon

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. For additional information, please contact:

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