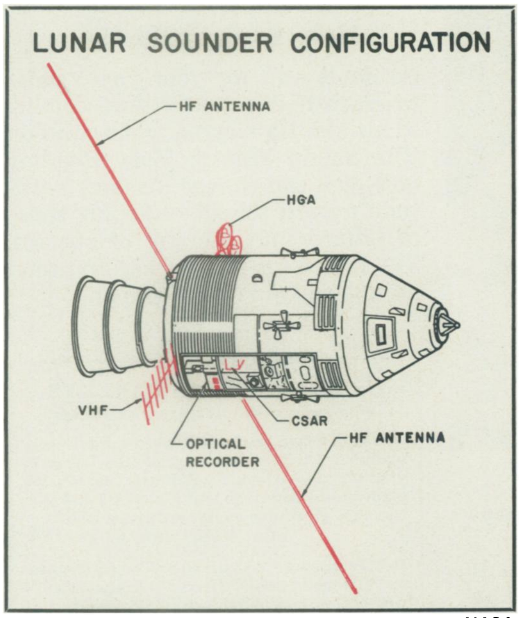
A last fling for science on the moon

The final Apollo mission will carry 13 instruments to the moon, including nine never before used. If all goes well, the results should be interesting.



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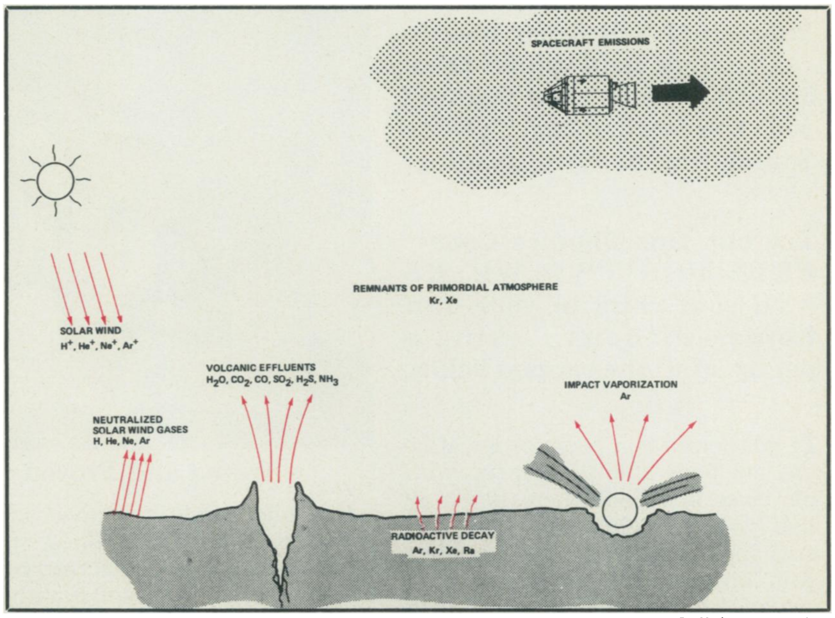

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Sounder: A look beneath the lunar surface. UV instrument: Detection of lunar atmosphere not polluted by spacecraft.

By Everly Driscoll

Science on Apollo has come a long way since those early days in the 1960's when some scientists were beating their brains out to get NASA to carry scientific instruments to the moon. It has come so far that a group of 40 scientists meeting in La Jolla, Calif., for an evaluation of the program recently concluded: "The lunar exploration program is the largest scale, multi-national cooperative effort of interdisciplinary research ever undertaken."

At one time the situation appeared bleak. An engineer reflects: "What were those wild-eyed scientists talking about . . . having astronauts diddling around on the moon setting up instruments? We weren't even sure they could walk on the surface!" It was incredible, but astronauts did land safely on the first try—thanks to those engineers. There was even some science on that first lunar landing. The astronauts collected rocks and set up three simple instruments—a seismometer, a laser reflector, and foil for collecting solar-wind particles.

In the Apollo 11 mission, Neil Armstrong and Edwin (Buzz) Aldrin were on the surface for two hours, 31 minutes and 37 seconds.

On Dec. 6, Apollo 17, carrying Eugene A. Cernan, geologist Harrison (Jack) Schmitt (SN: 9/4/71, p. 137) and Ronald E. Evans, is scheduled to be launched to the moon. Cernan and Schmitt will spend 21 hours out of the lunar module on the moon's surface. Evans will operate a complicated array of orbital instruments housed in the service module.

Whether by forethought or accident, this last Apollo trip to the moon will be scientifically the most risky—and the most dramatic. The landing site, Taurus Littrow (SN: 2/19/72, p. 120), is in a narrow valley between two mountains. Thirteen instruments will be carried (although about 26 experiments and investigative tasks will be done). Of these 13, 9 have never been flown before—a daring but well contemplated step for a cautious NASA. The nine new instruments are a lunar surface gravimeter, a neutron probe, a transmitter and receiver for investigations of surface electrical properties, a lunar ejecta and meteorite detector, a mass spectrometer for measuring atmospheric composition at the surface, a traverse gravimeter, an orbital sounder, an orbital infrared scanning radiometer and an orbital far ultraviolet spectrometer.

Some of the nine new instruments had been scheduled to fly in 1973 on Apollos 18 and 19, now canceled, and several were not initially scheduled to fly at all. At least two are pushing the state of the art. The task of getting these complex instruments qualified and ready in time for Apollo 17 has been largely unheralded.

If the instruments work as designed, and if the scientists in charge can interpret the data, the result should be an extraordinary gain in information.

Although most Apollo experiments are designed to study the moon itself, several, such as the ultraviolet camera and the earlier solar wind composition units, have been used to study the solar system and universe as well. In orbit around the earth, the moon is a reliable spacecraft; free from interferences of earth's atmosphere, oceans, noise and seismic activities, it is a unique physics laboratory. It is therefore an ideal place for the gravimeter designed by Joseph Weber of the University of Maryland.

The gravimeter, a small tungsten mass on a delicate spring, will respond to changes in the surface oscillation amounting to one ten-billionth of lunar gravity. Thus it should be able to monitor changes due to interaction of the earth-moon system (lunar tides) and influences from the sun, free oscillations of the moon, gravitational waves from the universe, and motions of the surface caused by seismic events, meteorite bombardments and astronaut activities at the site.

For more than 12 years now, Weber has been searching for the gravity waves predicted by Einstein. Weber first detected the waves in 1969 coming from the center of the galaxy. This year, in an experiment with Argonne National Laboratory, he saw the waves over a broad band of the spectrum from 1,030 hertz to 1,661 hertz (SN: 7/8/72, p. 30).

"The moon has resonances and overtones," says Weber. According to Einsteinian theory, only certain of these should be excited by gravitational waves. When the signals are broken down into particular frequencies, Weber may be able to determine which of them are excited by things external to the moon.

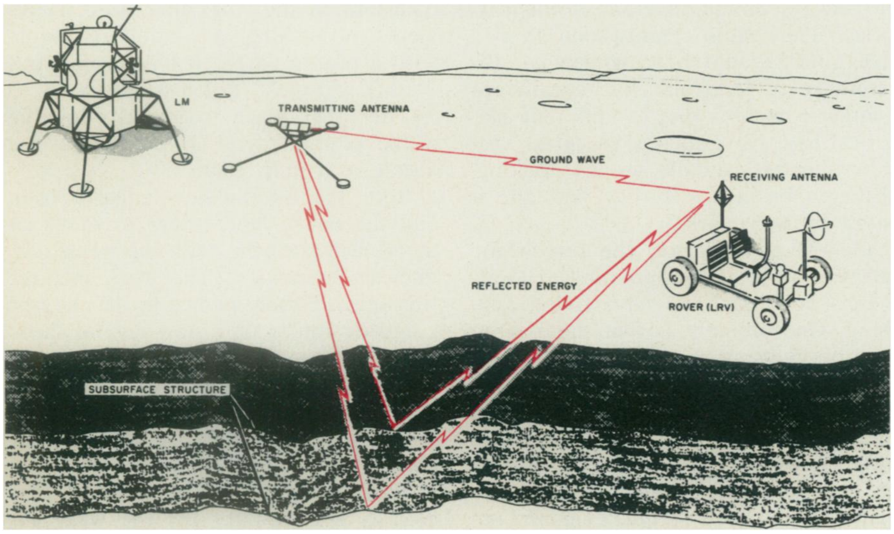
"The experiment can't miss," says an Apollo 17 colleague. "The gravity waves are a long shot, but if Weber sees them he'll probably win a Nobel Prize. The other objective is a cinch. We know oscillations will be there, and this instrument could tell us a lot about the interior of the moon."

Cernan and Schmitt will use another gravimeter called the traverse gravimeter. While Weber's box will principally measure relative gravity, the traverse gravimeter will measure absolute gravity at various stops at the landing site. Manik Talwani of the Lamont-Doherty Geological Observatory, principal investigator (PI) for the instrument, compares the Apollo 17 site to basin and range areas in the West. The Western valleys are full of sediment and mud. The rocks in the hills have a higher density than the valley material. This lower density and mass of the valley decreases the value of the earth's gravitational field. There are two massifs at the lunar site—one to the north and one to the south of the valley. During the geological field trips, the astronauts will measure the gravity at the edges of the valley next to the highland slopes and in the valley itself. Talwani should then be able to determine the density difference between the plains and the highlands and thus find out something about the subsurface material. The gravimeter is accurate to a fraction of a milligal.

The neutron probe will measure the abundances (with depth) of neutrons produced by cosmic rays in the lunar soil. This will give scientists who age-date material by measuring isotope ratios an accurate baseline for determining the ages and mixing history of the material. Don Burnett of the California Institute of Technology is PI.

The surface-electrical-properties experiment is composed of a radio transmitter and a receiver. "The equipment is basically no more complicated than a good quality hi fi FM receiver [except that it's going to the moon]," says Gene Simmons of the Massachusetts Institute of Technology.

The objectives of SEP are similar to those of the lunar radar sounder that will be housed in the service module: to map and measure the depth of the boundary between the regolith and bedrock (or any subsurface material) and to look for subsurface structure (such as boulders) and layers. Simmons should be able to detect layering in the rocks and soils down to a kilometer or so beneath the surface. Any water in the moon will produce a very strong dielectric discontinuity.



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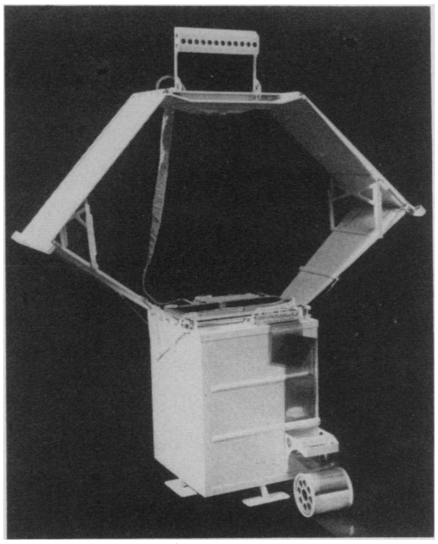
NASA's Don Beattie: "If the SEP sees water, we've really found something."


Bendix/University of Maryland
Weber's gravimeter: "It can't miss."

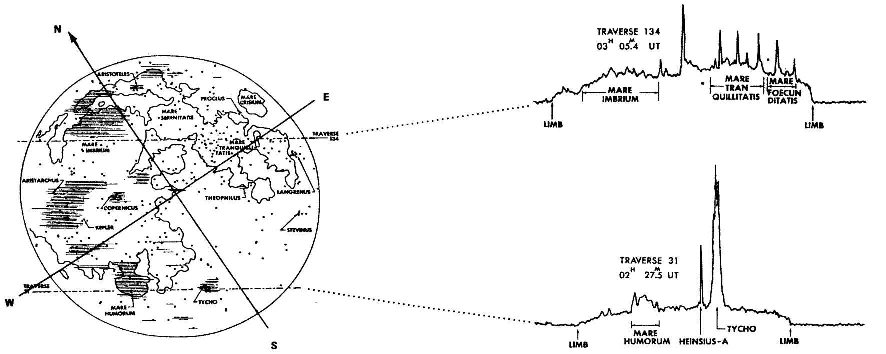
The basic principle involved is interferometry—the interference of two or more waves to produce a beat wave. The transmitter sends out radio waves at six discrete frequencies. These travel above and beneath the surface and down into the moon. At the receiver the waves interfere to produce a beat frequency. By studying the properties of this wave, Simmons and his co-investigator David Strangway of the Manned Spacecraft Center can determine the speed of the waves beneath the surface, the ease of propagation or the extent of attenuation of the waves at various distances from the transmitter.

What SEP allows scientists to detect at the site, the lunar sounder will do for the whole moon (SN: 2/27/71, p. 149). The sounder's radar will penetrate the surface down to 1.2 kilometers all along the ground track of the command module's orbit for 43,000 kilometers. It will use three-frequency radar.

The sounder will measure the range from the spacecraft to the surface (about 110 kilometers) with an accuracy of 5 to 50 centimeters and be able to resolve two targets separated in distance by only 10 radar frequency wavelengths.

F. J. Low of the University of Arizona is PI for the orbital infrared scanning radiometer. Thermal anomalies on the lunar frontside have been mapped from earth during eclipses. Ground-based surface resolution is about 15 kilometers. But from orbit the resolution should be two kilometers. The radiometer will allow Low to measure and map the surface temperature of the unilluminated portions of the moon to an accuracy of two degrees C. Many of these "hot" spots are located near bright-rayed craters, and scientists believe the hot spots are due to heat retention by ejected boulders from the craters. But some of these hot spots are not located near craters. They may be related to natural heat sources within the moon. Low should be able to differentiate debris from hard rock. He might even be able to differentiate crystalline rocks from breccias—but that's a long shot, admits NASA's Noel Hinners.

The ultraviolet spectrometer will measure the atomic composition of the very tenuous lunar atmosphere by observing reradiation of absorbed solar ultraviolet between 1,175 and 1,675 angstroms wavelength. William E. Fastie of Johns Hopkins University hopes to determine the height of the constituents as well as measure the far ultraviolet albedo and how it varies geographically.



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Lunar hot spots: Surface material or internal heat? Radiometer may answer.

He will also use the instrument to look at far UV galactic emissions and study distribution of atomic hydrogen between earth and the moon.

The panoramic and metric cameras are also in the orbital package again as on Apollos 15 and 16.

All this plus about 200 pounds of rocks and soil (Apollo 16 returned 208), plus the astronauts' observations, should keep scientists busy for a while. Although this is the last Apollo, Evans said in a press conference this month that the crew feels that the flight "is just the beginning" of man's exploration of the universe. With all this data, Project Apollo will certainly have given scientists a running start. □

Next: "A geologist goes to the moon"

The 'lost' particles of physics

Where, oh where are the quarks, the heavy leptons, and the intermediate vector boson?

by Dietrick E. Thomsen

Physicists have discovered more than 100 subatomic particles. Many were unexpected, and some of the particles seem superfluous. But in the midst of finding things they don't want, physicists are having a difficult time finding some things they do want. There are a number of predicted particles whose existence is important to one theory or another that physicists so far have not been able to find. Primarily these are the quarks, the intermediate vector boson and heavy leptons.

Reports of searches for these particles were summarized at the 16th International Conference on High Energy Physics by Robert Adair of Yale, who said he was chosen because "my colleagues and myself are the only ones to have mounted massive searches for all of them. In some circles that is held to indicate a weakness of character."

The most fundamental of these unfound particles is the quark. Quarks were invented simultaneously by Murray Gell-Mann and George Zweig both of California Institute of Technology. They found that the properties of particles belonging to the classes called mesons and baryons could be explained if the particles were regarded as being made up of two or three constituents called quarks. Only three different quarks are required to build up the known mesons and baryons.

As soon as the theory was out, experimenters began to look for quarks in spite of Gell-Mann's insistence that they are not real. The theory is perfectly good if the quarks are never free but always bound together inside particles. Gell-Mann points out that a free quark would be a somewhat different particle from his constituent quark; it would obey a different statistical law. Nevertheless he agrees that experimenters should go on looking, although he says, "If they find one it won't be my quark."

Gell-Mann's or not, the search for quarks has been disappointing. The attempts don't seem to have found anything. One problem is that there is no way of guessing the mass of a quark. One thing that should help is that quarks would have only a fraction of the electric charge that other particles have, one-third or two-thirds. But if the lowest possible quark state happened to contain two quarks bound together, it could have unit charge and appear electrically like any particle.

Most physicists who have looked for quarks have supposed that the reason they couldn't find any was that quarks are too massive to be produced in the most energetic collisions available up to now. If that is so, the Intersecting Storage Rings at the CERN laboratory in Geneva ought to be able to find heavier quarks than any previous experiment. But proton-proton collisions in the rings that were equivalent to striking a stationary target with a proton of 1,250 billion electron-volts 1,250 GeV) failed to find any.

The other place to look for quarks is the cosmic rays. These observations also give a null result.

Both the intermediate vector boson and the heavy leptons are products of theoretical struggles with the weak subnuclear interaction. The weak interaction seems closely related to the electromagnetic interaction, and several theories that unite the two are now a focus of experimental attention. All these unifying theories require either heavy leptons or an intermediate vector boson or both.

The IVB would be the particle that acts as intermediary for the weak interaction, carrying its effect from one particle to another, as the photon does for electromagnetism and various me-