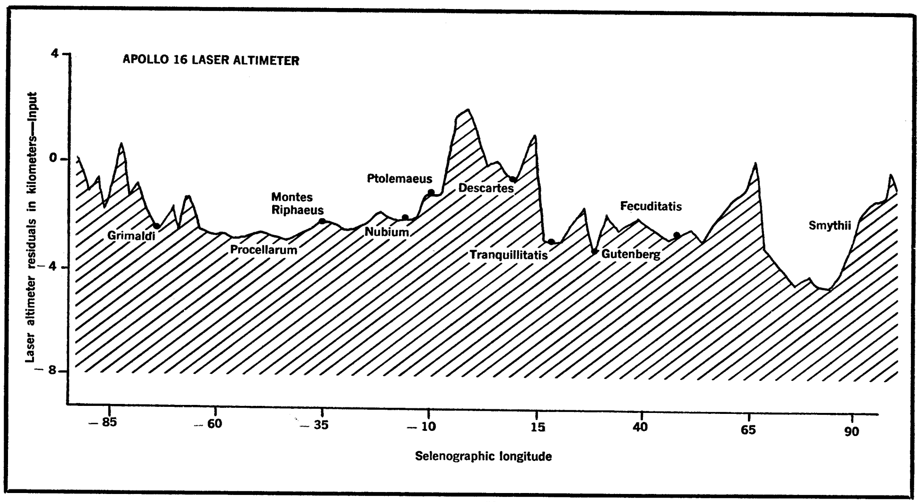
science news
OF THE WEEK

Monitoring the moon from orbit



E. Cherry Doyle from Sjogren and Wollenhaupt

Apollo 16's orbiting laser altimeter provided a topographic profile of moon.

"There is nothing so far removed from us as to be beyond our reach, or so hidden that we cannot discover it."—René Descartes (1596-1650), quoted by John W. Young from space.

One year ago the Descartes highlands landing site seemed far removed —"just a gleam in our eye," reflected Rocco Petrone, Apollo program director, after the successful splashdown of Apollo 16 last week in the Pacific.

This week, the fifth manned landing on the moon is history, and the detailed work of uncovering those mysteries of Descartes was under way at the Manned Spacecraft Center in Houston as scientists got their first glimpse of the estimated 212 pounds of lunar material returned by Astronauts John W. Young, Charles Moss Duke and Thomas Ken Mattingly.

But even last week while the crew was still on the moon, data about the moon's surface composition from remote sensing instruments operated by Mattingly in lunar orbit began pouring in to scientists on earth. What the astronauts sample on the surface provides "ground truth" for the orbital data, which can then be extrapolated to other areas of the moon. "It is very important to be able to say that what [the crews] are actually picking up at these selected areas, is in fact characteristic of a large part of the feature that is being explored," says Isadore Adler of NASA's Goddard Space Flight Center.

The Descartes site is perhaps one of the most significant yet explored in this respect. It is the first flight to explore the moon's highlands or terrae, which make up about 80 percent of the moon's surface. Orbital data from Apollo 15 had shown that the eastern limb and the farside highlands had high aluminum to silicon ratios and that the amount of aluminum dropped off sharply as the spacecraft passed over the nearside maria. The ratios supported a theory that the highlands were indeed what was left of the moon's original crust and that they probably would be made of anorthosites or anorthositic gabbros. Apollo 16 passed over a large portion of the nearside highlands, including Descartes, and one of the first questions that the crew asked while still on the moon was the results of the X-ray spectrometer instrument. "What we're observing from Apollo 16 is very much like that from Apollo 15," said Adler, principal investigator of the instrument. "There is a distinct difference between the highlands and the maria. The aluminum is very high at the Descartes site—approximately 1.45 on a scale where the farside highlands are about 1.56. I would be astonished, in fact, if we didn't find large amounts of the important feldspar mineral in the samples that we brought back." Adler's results also verify that very little if any horizontal or lateral mixing is taking place on the lunar surface. In other words, no large amounts of the highland material are being mixed with the mare basalt material.

The gamma-ray spectrometer revealed very high amounts of radioactivity in the regions of the western maria. On Apollo 15 the instruments found high ratios of potassium, uranium and thorium over the northern part of Oceanus Procellarum, particularly around the area of Aristarchus, where some scientists have reported seeing volcano-like transient events. Apollo 16 data show a high spot in radioactivity just south of the crater Fra Mauro, the region explored by Apollo 14. The ratios dropped substantially over the highlands. "I have been advertising to my friends that I am going to tell them how radioactive the soil in the rock boxes will be that they will bring back from Apollo 16," says James R. Arnold of the University of California at San Diego. "It will be as little as one to two parts per million of thorium."

The magnetic fields on the moon follow geographic features, says Paul Coleman of the University of California at Los Angeles, one of the principal investigators for the orbital magnetometer. The highlands are substantially rougher magnetically than the maria, says Coleman.

Feature	Al/Si
Mare Smythii	0.94 ± 0.05
Mare Fecunditatis	0.98 ± 0.03
East rim of Smythii	1.12 ± 0.05
West edge of Fecunditatis	1.16 ± 0.14
West edge of Tranquillitatis	1.16 ±
East of Fecunditatis (Langrenus area)	1.20 ± 0.12
Highlands west of Smythii	1.32 ± 0.05
Isidorus and Capella (area)	1.37 ± 0.09
Highlands west of landing site	1.43 ± 0.08
Descartes-highland area	1.45 ± 0.12
Eastern Highlands (105-115E)	1.48 ± 0.05
Highlands east of Smythii	1.51 ± 0.17
Farside Highlands (west of Mendeleev)	1.56 ± 0.11

Isadore Adler

High aluminum in lunar highlands.

The analysis of the lunar gravity data shows an unusually large negative anomaly at the Descartes site.

The laser altimeter data plotted by William Sjogren of the Jet Propulsion Laboratory and W. R. Wollenhaupt of MSC found a very large depression in the center of the moon's far side. "It's beginning to look like there is a very large basin which might be just like a mare basin except not filled, and it extends from—the Russians estimate—about 30 degrees south all the way to the south pole," says Coleman.

The mass spectrometer recorded almost no residual neon in the lunar atmosphere. "We are able to set an upper limit—approximately 2,000 atoms of neon per cubic centimeter," says John H. Hoffman of the University of Texas at Dallas. He concludes that "we have at least a factor of 10 less neon in the lunar atmosphere than previously predicted. This implies that greater than 90 percent of the neon coming from the sun is absorbed in the surface of the moon." The alpha particle spectrometer looked for radon in the lunar surface. According to Paul Gorenstein of American Science and Engineering Inc., at Cambridge, Mass., radon might be generated in concentrations of radioactive material or brought to the surface by volcanic or seismic activity. The instrument can see two types of radon activity. One type exists in its present form on the moon and one is a record of past emanations in the form of polonium 210, the decay product of radon. "We do indeed find evidence that radon emanation is present on the moon and is highly variable in time," says Gorenstein. From the Apollo 15 data Gorenstein found radon over the crater Aristarchus. The Apollo 16 instrument located an increase in polonium 210 at 40 degrees east longitude in the vicinity of Mare Fecunditatis. One lunar scientist characterized the orbital data so far examined as a dream fulfilled. "We got almost all of the activities that we had planned," says Richard A. Moke of MSC, "in spite of the command module problems that caused the mission to be cut short a day." □

Gravity-wave search: No support for Sadeh

One of the theoretically possible antennas for gravitational radiation is the earth itself. The passage of a gravitational wave through the earth should cause minute vibrations that, in principle, could be picked up by a sufficiently sensitive seismograph placed so as to record vertical fluctuations.

A few weeks ago Dror Sadeh of the University of Tel Aviv in Israel and the U.S. Naval Research Laboratory announced that he had detected gravity waves in this fashion (SN: 4/1/72, p. 213). At last week's meeting of the American Physical Society in Washington Sadeh was faced with opposition from a group at the University of California at Berkeley (R. A. Muller, Bruce Bolt, Terry Mast, Jerry Nelson and John Searloos) who tried to repeat his experiment and failed to find data they consider significant.

Sadeh's experiment was set up in a cave near Eilat, Israel. It was designed to record vertical seismographic data for "months or years" and integrate them—add them up—in such a way as to enhance and bring out clearly any signal that had periodic qualities.

A periodic signal due to gravity waves would be easier to distinguish convincingly from the random continuous background of seismic activity. Of the several theoretically possible sources of periodic signals, Sadeh concentrated on pulsars.

Sadeh was looking for gravity waves from pulsars because they should be strong enough to record and because theory gives ways to identify the particular source. The period of gravitational waves from a pulsar should equal twice the period of the pulsar's radio pulses. Furthermore the way in which the signal interacts with earth (producing motions on the order of a fraction of an angstrom) should yield a maximum record at times when the particular pulsar was rising or setting at the location of the seismograph.

It took four months of integration to find what Sadeh calls a significant signal. In a channel corresponding to a period interval between 0.56 and 0.6 seconds, maximum signals were found to repeat at nearly 24-hour intervals (23.87 hours). Looking at the record for days in October when the peak was at least twice as high as the record in other channels at times between 2 and 6 a.m., says Sadeh, "you can see which pulsar was rising." It was CP 1133. It turns out that twice the period of CP 1133's radio pulses lies within the period range in which the signal was found. Sadeh believes that he is recording gravity waves from CP 1133. In support of that contention he has charted the succession of maximum signal over several months and insists that it correlates with the rising and setting of CP 1133. Another signal was found in the channel recording periods between 0.33 and 0.34 seconds with a repetition of maximum intensity every 12 hours, but there is no known pulsar with a radio pulse period one-half of that.

The California group set up their seismograph in a shaft at Jamestown, Calif. Data were telegraphed to Berkeley for analysis. All that they find in their signals, they say, can be attributed to random seismological noise. They even find things that at first blush look like periodicities, but which can be explained as noise.

The Californians contend therefore that Sadeh's method of integrating the data could have given him spurious periodicities manufactured out of the random noise that is always present. In summing up their argument, Muller said: "It is impossible to tell whether the Sadeh data are due to noise or not."

Sadeh insists that it is possible to tell, and that his signals are real. He also mentions a periodic seismicity on the moon that could be "a sidereal periodicity" caused by CP 1133.

There are other solutions to the disagreement besides saying one or the other is in error. As the Californians continue to record, they may find a pulsar signal. Or there may be something special about the Eilat site: A questioner at the meeting asked whether the location might have some particular resonant quality so that it would record the waves from the pulsars while the Jamestown one would not. Sadeh replied that he does not like to think of the theoretical and practical consequences of such a peculiarity. "I would like to see other people do it and find it," he said.

Sadeh is going back to do more recording; the California group is doing likewise; and elsewhere in the world others are getting into it. Further results are eagerly awaited. □

Cometary evidence of a planet beyond Pluto

From time to time there have been suggestions that our solar system might have a tenth planet, either within the orbit of Mercury or outside the orbit of Pluto. In the April Publications of the Astronomical Society of the Pacific, a mathematician at the Lawrence Livermore Laboratory, Joseph L. Brady, presents what he says is, "some very interesting evidence of a planet beyond Pluto."

The evidence comes from calculations of the orbit of Halley's comet that Brady did with Edna M. Carpenter and Francis H. McMahon. Halley's comet is one of the best known and longest observed of the periodic comets. Its orbit passes from near the sun to the outermost reaches of the solar system, and its motion is thus a good way to test for the existence of large masses at great distances from the sun.

The computation of the cometary orbit by Brady, Carpenter and McMahon shows deviations that can be interpreted as evidence that Halley's comet is affected by a mass about three times that of Saturn located in an orbit about 65 times as far from the sun as the earth. The hypothetical planet would take about 512 years to go once around the sun. It would move in a retrograde sense—opposite to the orbital motion of the other nine planets—and its orbit would be inclined 60 degrees to the ecliptic, the plane of the earth's orbit. These last two facts would make the hypothetical body a very unusual member of the solar system. All the other planets go around the sun in the same direction, and all their orbital planes lie within a few degrees of the ecliptic.

Brady is a little dismayed at press reports last weekend that said he has discovered a new planet. He has not, but he believes the evidence for the existence of one to be stong enough to warrant a search. He also expects that the suggestion of a tenth planet will generate a sharp debate among astronomers. Nevertheless some observers are beginning to indicate a willingness to look. If the hypothetical planet exists, its position as seen from earth would be in the direction of the constellation Cassiopeia. □