To the Moon: Faster, Cheaper—and Better

by Paul D. Spudis

Since the last *Apollo* astronaut left the Moon 20 years ago, the agenda for its scientific exploration has not changed. Despite its closeness, there is still much we have to learn about Earth's satellite. We have yet to complete a global reconnaissance and to map its surface composition, topography and morphology.

To accomplish these tasks, we need to map the entire Moon from orbit and deploy a global network of geophysical stations equipped with instruments such as seismometers and heat-flow probes. Then we will select particularly interesting sites for in-depth study, taking measurements on site and collecting samples for return to Earth. Finally, human scientists, assisted by robotic helpers, will conduct lunar fieldwork to understand more completely lunar processes and history.

This plan has been triggered by NASA's drive to implement President Bush's proposed Space Exploration Initiative, which would send humans back to the Moon to pick up where *Apollo* left off, and then on to Mars. As a beginning, the Office of Exploration is planning to launch a series of small robotic probes to the Moon within the next few years. [However, Congress is reluctant to fund SEI, and recently "zeroed out" two proposed lunar missions. See World Watch, page 17.]

This series of three missions will include both orbiters and landers, targeted to answer a variety of scientific questions. But of equal importance to their scientific merit will be the proof that such missions can be executed much more inexpensively and more quickly than has become the norm. This so-called new paradigm of "faster, cheaper, better" is actually a return to the operational and managerial philosophy of an earlier, more successful NASA.

So, can we do meaningful science with such a program? Most emphatically, yes!

Mapping Resources

The first mission in the current plan is a polar-orbiting satellite to map surface chemistry and mineralogy.

This spacecraft will carry a gamma-ray spectrometer, which measures natural radioactivity and secondary radiation induced when cosmic rays strike the surface. It will also be equipped with an X-ray spectrometer, which measures surface fluorescence induced by X rays from the Sun hitting the surface. The gamma-ray experiment will give us a global map of thorium, uranium and most of the major elements, while the X-ray instrument will tell us about the distribution of aluminum, magnesium and some other significant rock-forming elements.

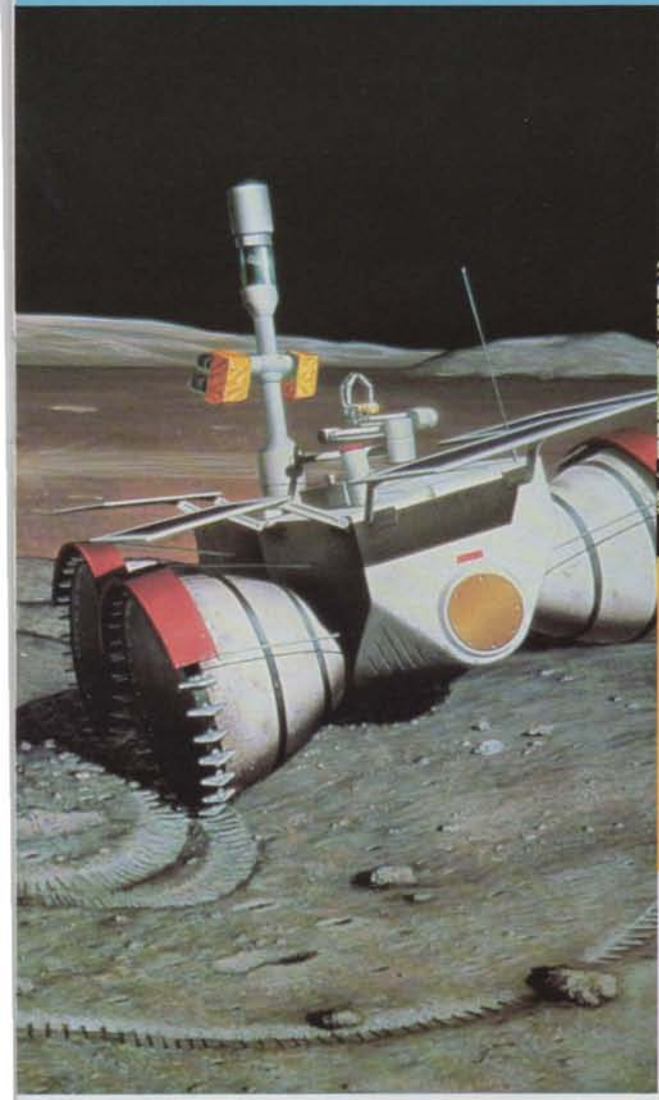
The orbiter will also carry an imaging spectrometer designed to diagnose the minerals present, especially the important rock-forming ones such as plagioclase (a calcium-aluminum silicate) and olivine and pyroxene (magnesium- and iron-rich silicates).

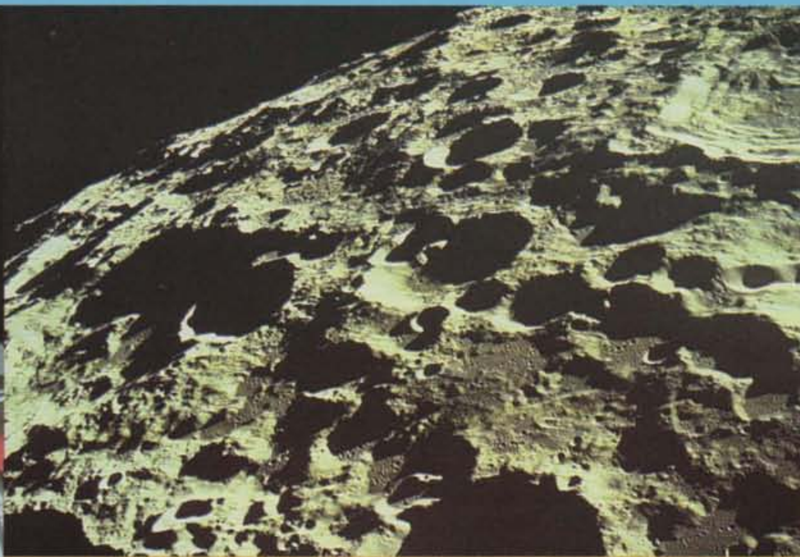
Using the information gathered by these instruments, we can construct a global map of surface mineralogy, and increase our understanding of the variations in crustal composition. By adding this new information to the superb data base provided by the *Apollo* lunar samples, we can more confidently address the geologic processes that shaped our Moon.

Tugging at Gravity

The second mission will deploy an orbiter to map the Moon's gravity field and terrain. We already know that the Moon has a very complex gravity field, shaped by mascons (mass concentrations) that perturb orbiting spacecraft and cause their orbits to decay. By using radio to track the orbiter carefully as the Moon tugs at it, we can map the lunar gravity.

Although the Moon was the first extraterrestrial object explored during the Space Age, we actually know its terrain very poorly. To understand its shape, topography and surface morphology, we will use two instruments, an altimeter and a camera for digital imaging.





Above: The back side of the Moon is still largely unexplored territory. Until the Space Age, no human had ever seen it. The Soviets first photographed it in 1959 with their Luna 3 *spacecraft. The US followed with the* Lunar Orbiter *in 1966. Finally, the* Apollo *astronauts orbiting the Moon took photographs like this one of its heavily cratered surface. Despite these cursory looks, this hemisphere of the Moon is still largely* terra incognita. *We must send many more spacecraft before we know it well.* Photograph: NASA

Left: A small robotic rover, about 1 meter long, is a candidate for a payload to be carried to the Moon by an Artemis *lander. The rover would survey a landing site for humans to use on their return to the Moon. NASA scientists and engineers feel they can carry out such a mission expeditiously and inexpensively by using an expendable launch vehicle and small, cleverly designed spacecraft.* Painting: Pat Rawlings, Science Applications International Corporation

With the altimeter, which can use either a radar or laser beam as a ranging source, we can measure the height of the spacecraft from the lunar surface, and use these data to derive a map of the surface topography.

The camera allows us to distinguish surface features as small as 50 meters (165 feet). Moreover, it will provide the first image set that covers the entire Moon uniformly, from the same perspective.

Together these experiments will give us global maps of the terrain of the Moon, creating a cartographic data base that will serve the needs of both science and exploration.

On the Surface

The third mission will begin the on-site investigations necessary before we can understand the details of lunar processes and history. One current concept is to deploy a robotic rover, to be delivered by a landing vehicle we are calling *Artemis*. This rover could be sent on several types of missions, but here I will consider a resource-prospecting mission.

Many people have speculated on how we might use lunar resources, and among the most plausible ideas is to extract oxygen and hydrogen from the soil to make rocket propellant and water to supply a human outpost on the Moon.

The first *Artemis* can land about 65 kilograms (140 pounds) on the Moon, enough to accommodate two minirovers. The rovers would carry high-definition, stereo cameras to map the site and locate small craters, blocks and major landforms.

A set of remote sensing instruments will measure the chemical and mineralogical properties of the site. For prospecting, we will need to measure the chemistry (particularly the iron and titanium content) and the maturity of the soil (a measure of the duration of its exposure to solar radiation), as well as the amounts of gases (mostly hydrogen) implanted in the lunar dust by the solar wind (a stream of charged particles blowing out from the Sun).

Using detailed maps, on scales of a few meters, we can see the variations in these properties and so determine how we can best extract resources needed to support human operations and eventually habitation on the Moon.

Timely Missions, Well Conceived

The three missions I have described here can all be accomplished within the next three years. Each will cost between $100 million and $150 million —including the launch vehicle. They will not only provide high-quality data, they will also give us a much-needed capability—to fly small, focused missions on a rapid but technically prudent schedule.

When we can conceive and conduct missions in a timely manner, we will be able to follow up discoveries quickly or undertake new exploration with advanced techniques. Such a program of robotic space exploration is not only faster and cheaper, it is also better.

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