will consist of actual observations, rather than simulated sequences generated from a shape model. They will enable the viewer to see all the details of the topography, morphology, and distribution of compositional units as the viewing and illumination geometries change. Several different video sequences of Geographos are anticipated, including separate sequences for each imaging system and merged datasets. The LIDAR will provide the highest spatial resolutions (in four colors), the thermal-IR detector will provide nightside imaging, the UV/VIS camera will provide the highest resolution of the entire visible and illuminated surface during the 75 s before and after closest approach, and the UV/VIS plus near-IR detectors will map the mineralogy.

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SOURCES SOUGHT FOR INNOVATIVE SCIENTIFIC INSTRUMENTATION FOR SCIENTIFIC LUNAR ROVERS.

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Lunar rovers should be designed as integrated scientific measurement systems that address scientific goals as their main objective. Scientific goals for lunar rovers are (1) to develop a more complete understanding of the stratigraphy, structure, composition, and evolution of the lunar crust by close examination of the geology and geochemistry of multiple, wide-spaced landing sites on the Moon; (2) to improve the understanding of the lunar regolith and history of solar system events that have affected the lunar surface; (3) to improve the understanding of the lunar interior and set constraints on planetary evolution using geophysical techniques; and (4) to identify and characterize potential lunar "resources" that could be utilized by future human missions.

Teleoperated robotic field geologists will allow the science team to make discoveries using a wide range of sensory data collected by electronic "eyes" and sophisticated scientific instrumentation. Rovers need to operate in geologically interesting terrain (rock outcrops) and to identify and closely examine interesting rock samples. Analytical instrumentation should measure the maturity of soils and the chemical composition (major, minor, and trace) and mineralogy of soils and fresh surfaces of rock samples. Some ingenious method is needed to obtain fresh rock surfaces. Manipulator arms are needed to deploy small close-up cameras and lightweight instruments, such as alpha backscatter spectrometers, as "stethoscopes" to the clasts in boulders. Geoscience missions should also deploy geophysical packages.

Enough flight-ready instruments are available to fly on the first mission, but additional instrument development based on emerging technology is desirable. There are many interesting places to explore on the Moon (i.e., the lunar poles) and it is highly desirable to fly multiple missions with continuously improved instrument sets. For example, there are needs for (1) *in situ* reflectance spectroscopy measurements (with high spectral resolution TBD) to determine the spectra (~0.3–2.5 μm) and mineral contents of rocks and soils in a manner analogous to what is done from a distance by Earth-based telescopes or from lunar orbit; (2) Mössbauer spectroscopy to determine soil maturity and mineralogy and relative abundance of iron-bearing phases; (3) close-up images by a "field-lens" electronic camera with artificial lighting and good depth focus (autofocus?) allowing scientists in the control room to have the ability to make discoveries and document what has been analyzed by the analytical instruments; (4) precise and accurate analytical measurements of the chemical composition of soils and rocks—especially the critical determination of the Fe/Mg ratio and one or more of the large ion lithophile elements; (5) cryogenic systems to cool solid-state detectors such as infrared sensitive CCD arrays, Si(Li) X-ray or Ge gamma ray detectors; (6) multispectral imagery by CCD cameras including telephoto, metric, or panoramic; (7) boresited laser range-finding equipment with gimbals that read out angles for precise site survey; and (8) thermally evolved gas analysis.

Various instruments that are
needed to be developed for later
missions are described (o) [illegible]

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DRILL/BORESCOPE SYSTEM FOR THE MARS POLAR PATHFINDER.

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The primary goals of the Mars Polar Pathfinder (MPP) Discovery mission are to characterize the composition and structure of Mars' north polar ice cap, and to determine whether a climate record may be preserved in layers of ice and dust. The MPP would land as close as possible to the geographic north pole of Mars and use a set of instruments similar to those used by glaciologists to study polar ice caps on Earth: a radar sounder, a drill/borescope system, and a thermal probe. The drill/borescope system will drill ~50 cm into the surface and image the sides of the hole at 10-μm resolution for compositional and stratigraphic analysis.

Several uncertainties have guided the development of this instrument. It is presently not known whether the surface at the north pole consists of solid ice or packed snow, or how difficult it will be to drill. In order to more quantitatively investigate design and power requirements, we built a thermal chamber for testing the drill/borescope instruments under Mars-like conditions with complete remote control. To minimize the number of mechanisms and moving parts, an integrated drill/borescope system would be desirable for the MPP. However, for these initial tests we used separate off-the-shelf components: a Hilti model TE-10A rotary percussion drill, and an ITI 26-in rigid borescope attached to a Sony XC-999 cigar-type color CCD camera. The drill rotates at about 500 rpm while hammering at about 50 Hz, using about 150 W. Using a 1-in continuous-flute drill bit, it is able to drill through 12 in of –80°C solid ice in about two minutes, with no down-force applied except for its own weight. A talus pile of the low-density shavings forms around the surface, but the hole is left clear after the drill is retracted. The borescope is a hard-optics right-angled device with fiber-optic illumination at its tip. It is able to focus from near contact to infinity. The borescope has a 13° vertical field of view, which amounts to about 3 mm of vertical distance at the viewing distance in our 1-in-diameter holes. This equipment, and high-resolution vertical scans of two boreholes, are part of a videotape. We prepared three types of samples: pure ice, ice with dust layers, and snow with dust layers. To make the ice/dust sample we successively poured and froze a suspension of 2-μm cinder particles in water. The dust settles as the water freezes, and forms layers between clear ice. The first close-up images of the inside of a hole were taken in the solid ice/dust sample with the borescope as it is lowered slowly to the bottom. The ice in these images appears almost black, and the dust layers are reddish

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horizontal bands. Of course, we do not yet know what the subsurface of Mars' north polar cap will look like up close, but this experiment helps demonstrate the wealth of information that could be obtained. The first scan covers just 10 in of stratigraphy, which could represent many thousands of years of Mars climate history. The actual MPP borescope could be programmed to automatically search for layers, or the science team back on Earth could control its motion interactively. The other type of sample we looked at was composed of "snow" and dust layers. We formed small "snow" grains by spraying water mist into liquid nitrogen, then sprinkled layers of this "snow" into a bucket followed by fine layers of dust. Each dust layer was cemented with a small spray of liquid water. The sample was then allowed to anneal for several hours at –3°C before cooling to –80°C for drilling. The second sequence of close-up borescope images in the video shows parts of a scan of a hole drilled in a snow/dust sample. The snow grains are bright spheroids 50–100 µm in diameter and some dark dust particles can be seen scattered among them, especially near the dust layers.

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HONEYWELL'S COMPACT, WIDE-ANGLE UV-VISIBLE IMAGING SENSOR. D. Pledger[1] and J. Billing-Ross[2], [1]Honeywell Systems and Research Center, Bloomington MN 55420, USA, [2]Honeywell Satellite Systems Operation, Glendale AZ 85308, USA.

Honeywell is currently developing the Earth Reference Attitude Determination System (ERADS). ERADS determines attitude by imaging the entire Earth's limb and a ring of the adjacent star field in the 2800°–3000 Å band of the ultraviolet. This is achieved through the use of a highly nonconventional optical system, an intensifier tube, and a mega-element CCD array. The optics image a 30° region in the center of the field, and an outer region typically from 128° to 148°, which can be adjusted up to 180°. Because of the design employed, the illumination at the outer edge of the field is only some 15% below that at the center, in contrast to the drastic roll-offs encountered in conventional wide-angle sensors. The outer diameter of the sensor is only 3 in; the volume and weight of the entire system, including processor, are 1000 cm^3 and 6 kg respectively. END

The basic ERADS configuration has many unusual features that could also be utilized for purposes other than attitude reference. The ability to image over a 360° azimuth with a small, strapdown sensor could find application wherever surveillance of the entire surrounding field is desired. Because field-of-view is brought into the optical system in seven isolated segments, it is possible to use different wavebands for different parts of the view field. In order to utilize a fiber-optic field flattener, the incoming ultraviolet is downconverted with high quantum efficiency to visible radiation. The same sensor, therefore, can be used for visible wavelengths with only a change in the input filter. The segmentation of the field also makes it possible to isolate the effects of bright sources, such as the Sun, and continue operation in other areas.

The phototube provides the necessary gating and eliminates the requirement for a mechanical chopper. In conjunction with the antiblooming CCD, it provides a very wide dynamic range. The ERADS processor is designed to provide a complete image readout at 2 Hz, and this frequency is dynamically variable. ERADS is a very smart sensor, and a high degree of processing capability is built into it to provide object recognition and analysis. CCDs of 4 and 16 megapixels are becoming available that will allow expansion of ERAD's resolution capabilities in the future.

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GAMMA RAY/NEUTRON SPECTROMETERS FOR PLANETARY ELEMENTAL MAPPING. R. C. Reedy[1], G. F. Auchampaugh[1], B. L. Barraclough[1], W. W. Burt[2], R. C. Byrd[1], D. M. Drake[1], B. C. Edwards[1], W. C. Feldman[1], R. A. Martin[1], C. E. Moss[1], and G. H. Nakano[3], [1]Los Alamos National Laboratory, Los Alamos NM 87545, USA, [2]TRW Space and Technology Group, Los Angeles CA 90278, USA, [3]Consultant, Los Altos CA 94022, USA.

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Los Alamos has designed gamma ray and neutron spectrometers for Lunar Scout, two robotic missions to map the Moon from 100-km polar orbits. Knowledge of the elemental composition is desirable in identifying resources and for geochemical studies and can be obtained using gamma ray and neutron spectrometers. Measurements with gamma ray and neutron spectrometers complement each other in determining elemental abundances in a planet's surface.

Gamma rays with energies of ~0.2–10 MeV escaping from a planetary surface can map most elements using characteristic gamma rays [1]. NaI(Tl) gamma ray spectrometers on Apollo determined Th, Fe, Ti, K, and Mg over 20% of the Moon's surface [1], and a high-purity germanium gamma ray spectrometer (GRS) cooled by a passive radiator is on the Mars Observer, which will map Mars starting late in 1993 [2]. Our GRS is a high-purity n-type germanium (Ge) crystal surrounded by an CsI(Na) anticoincidence shield (ACS) and cooled by a split Stirling cycle cryocooler [3]. The ACS eliminates events in the Ge due to cosmic-ray particles, serves as a back-up gamma ray detector, and allows the GRS to be mounted close to the spacecraft. The cryocooler is the British Aerospace design marketed by TRW, and a pair of compressors and expanders are used to minimize vibration effects.

The fluxes of neutrons escaping from the Moon are very sensitive to hydrogen in the top meter of the surface and provide information on the abundance of elements that strongly absorb thermal neutrons [4]. The Mars Observer GRS will be the first instrument to measure neutrons from another planet using a special ACS designed to measure thermal and epithermal neutrons [2]. Our neutron spectrometer will measure fast and slow (epithermal and thermal) neutrons in the ranges of 0.5 MeV to 25 MeV and ~0.01–1000 eV respectively [5]. The fast neutron sensor consists of four boron-loaded plastic scintillator rods optically coupled to photomultiplier tubes. Thermal and epithermal neutrons will be measured with ^{3}He gas proportional counters. The epithermal counter will be wrapped with cadmium to remove thermal neutrons, and the "bare" counter measures both thermal and epithermal neutrons.

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