ularly xenon and germanium; emphasis there is on transuranics. A new cyclotron, the U-400, which will have a high energy constant, is now under construction. For lighter heavy ions it is expected to yield 40 MeV/nucleon and for uranium, 2 MeV/nucleon.

The Oak Ridge Heavy Ion Laboratory, which will use a Pelletron 25-MV tandem accelerator in combination with the existing Oak Ridge Isochronous Cyclotron, is scheduled for completion in 1979. Up to mass 40 (calcium) the combined accelerators will produce beams up to 22 MeV/nucleon. Up to mass 160 the beam energy will be above the Coulomb barrier of lead (about 5 MeV/nucleon). The energy for uranium ions will be about 3 MeV/nucleon.

The Daresbury Nuclear-Structure Facility, which is to have a 30-MV tandem accelerator, is also scheduled to operate in 1979. It is expected to reach about 14 MeV/nucleon for ions lighter than calcium. Its uranium capability is comparable to that of Oak Ridge.

The French national heavy-ion laboratory, GANIL, is scheduled for completion in 1980 and will replace ALICE (12 MeV/nucleon for light ions, 6 MeV/nucleon for krypton). Consisting of two separated sector-focused cyclotrons, the facility is expected to produce 100 MeV/nucleon for light ions, decreasing to 50 MeV/nucleon for krypton and 15 MeV/nucleon for gold. For $U^{36+}$, the machine is expected to reach 9 MeV/nucleon.

—GBL

## Lunar Polar Orbiter considered for 1980

Another lunar mission is being studied at NASA's Jet Propulsion Laboratory, the first US lunar mission since Apollo 17 in 1972. This one, to be launched in 1980, would be unmanned. It would consist of an instrumented polar-orbiting spacecraft (at an altitude of 100 kilometers) and a smaller companion subsatellite (at an altitude of 5000 km), which would serve to track the orbiter for gravity sensing when it is hidden from the Earth by the Moon. The ensemble would be launched by a single Delta launch vehicle. The spacecraft would orbit the moon for one year, examining the Moon's surface with a variety of instruments. These would measure lunar gravity, shape, magnetism and heat flow, and allow the determination of the chemical and mineral composition of the Moon's surface.

By surveying the Moon from pole to pole (at all longitudes) on both the near and far sides, the mission would expand to the entire moon the knowledge obtained from the small regions visited by previous US and Soviet missions. In fact, the Lunar Polar Orbiter would be the first global survey of a body other than the Earth, and as such it would serve as a prototype for other missions. Its cost is estimated at $100 million, a figure that includes the launch vehicle, tracking and data acquisition.

Some of the questions for which answers are sought are:

- Did the Earth and the Moon form originally from a common reservoir of material?
- Does the Moon have an iron-rich core like the Earth? If not, what is the source of magnetism found in lunar rocks?
- Is there evidence for large-scale movements of material in the Moon's interior similar to those that exist in the Earth today?
- What was the nature of the intense meteorite bombardment that altered the Moon's surface early in its history?
- Have the cold, permanently shadowed polar regions trapped volatiles, particularly water, that might be used as resources to support a lunar base?

Of the eight experiments selected for study, three would use advanced remote-sensing techniques based on gamma-ray, x-ray and reflection spectroscopy to create chemical maps of the lunar surface. A fourth experiment, spectro-stereo imaging, would provide photographic data to correlate these maps with surface features of the lunar landscape. The magnetometer and electron-reflection experiments would map the electrical and magnetic properties of the lunar surface and subsurface. The remaining two experiments would be on heat flow and gravity.

The x-ray experiment would detect K line emission from elements on the lunar surface with an array of proportional counters. This fluorescent emission is induced by solar x rays. Earlier experiments with Apollo 15 and 16 measured the ratio of aluminum to silicon, which varies markedly over the lunar surface and correlates well with structural features, according to Kinsey Anderson (Berkeley Space Sciences Laboratory). X-ray spectra of crater ejecta blankets may allow one to determine the thickness of layers of basalt lava.

The gamma-ray detector would be a 100-$cm^3$ active volume of hyperpure germanium cooled to a temperature below 125 K by radiating heat into space. Gamma-ray lines from the Moon come from naturally radioactive nuclides (especially thorium, uranium and potassium) and cosmic-ray induced radioactivity (which produces lines from iron, silicon, oxygen, magnesium, titanium, aluminum and silicon).

The spectro-stereo imaging experiment would contribute to surface compositional studies by taking multi-spectral images to be used to determine high-resolution boundaries between differing surface materials. The instrument would obtain high-resolution and stereographic images where coverage is now inadequate for photo-geologic interpretation. The images would be used also to compute photogrammetrically the coordinates of features outside the Apollo control net.

Some people have speculated that considerable quantities of water may be permanently frozen in permanently shadowed areas near the lunar poles. If so, Anderson explained, the characteristic 2.22-MeV line, resulting from deuterium formation as cosmic-ray neutrons interact with the hydrogen in the ice, will appear.

Although the Moon has either no overall magnetic moment, or at the most a very weak one, it is covered with thousands of small, magnetized patches; in addition it has a few larger magnetized regions. In one case, the magnetization is somehow associated with the geological process of tensional dislocation of the crust, Anderson said. The smaller patches may be caused by a little-understood process in which crater-forming meteorites "imprinted" an existing magnetic field into the lunar rocks some time in the past. The origin and disappearance of a global, ancient lunar magnetic field is a central problem of lunar and solar-system research, he went on. The ancient field could have originated in a now-dead core dynamo process. Another possibility is that there was a very strong field present throughout the early solar system. Lunar magnetic fields have been measured in the past by flux gate magnetometers flown in low-altitude orbits around the Moon or more recently by electron-reflection magnetometry. In the latter approach, the abundant low-energy electrons in space around the Moon strike its surface and are stopped. However, if the electrons move toward a magnetized region on the surface, they are reflected in a magnetic-mirror effect. This technique has been used to locate and measure the field strength of thousands of magnetic patches on the Moon's surface. One result has been to show that the smooth lunar lava oceans are relatively free of magnetism compared with the rugged, heavily cratered highlands.

The principal investigators on the Lunar Polar Orbiter mission are: James R. Arnold (University of California at San Diego), Merton E. Davies (Rand Corp), Robert P. Lin (Berkeley), Thomas B. McCord (MIT), Duane O. Muehlemann (Cal Tech), Roger J. Phillips (JPL), Christopher T. Russell (UCLA) and Jacob Trombka (Goddard Space Flight Center).

—GBL

## in brief

Nearly half a million images of planets and their satellites are being collected at the University of Arizona under an agreement with NASA. The Space Imagery Center is expected to operate by the end of this year. □