By Frank Morring, Jr.

NASA's upcoming robotic mission to the Moon will set some basic signposts for human exploration there far into the future, while giving Earthbound scientists a much better view of the distant past.

Developed by the U.S. space agency's Exploration Systems Mission Directorate as a source of detailed maps for the Moon base already in development, the Lunar Reconnaissance Orbiter (LRO) will join orbiters from China, India and Japan in producing the best look ever at Earth's natural satellite.

Exploration planners at NASA headquarters here and at the Constellation program office in Houston will use data from the 12-month mapping mission to begin picking a site for the human outpost that is the current U.S. human-exploration goal by 2020.

Scientists looking at the same data, which will offer unprecedented detail of terrain, slopes and solar illumination across the entire surface of the Moon, will begin gaining new answers to questions about its origins in a shattering collision between Earth and a Mars-size body, and the subsequent history of the inner Solar System.

Among the first questions to be answered will be how much the lunar surface has changed since the 1960s, when the Apollo program mapped the areas where the first astronauts landed.

"We want to image some of the area mapped by the Apollo program with our high-resolution camera in order to see how many impacts have occurred there in the past 30 years, and that will help us to improve the understanding of the meteor flux onto the Moon," says Richard Vondrak, LRO project scientist and deputy director of the Solar System Exploration Div. at NASA's Goddard Space Flight Center.

That data and the reams to follow as LRO maps the full lunar surface with its seven instruments will join a growing body of new knowledge about the Moon that started with the European Space Agency's Smart-1 mission in 2004-06 and continues with data collected by Japan's Kaguya (Selene), China's Chang'e and India's Chandrayaan-1.

The international constellation of robotic spacecraft at the Moon may herald an era of human exploration there in which the nations fielding them and others, including Russia, cooperate on an open-ended endeavor to build what former NASA Administrator Michael Griffin called a spacefaring civilization beyond low Earth orbit.

That cooperation already is in play on LRO. The team at Goddard that built the spacecraft drew on in-orbit environmental information from Chandrayaan to set up the thermal vacuum tests for the U.S. orbiter. Indian officials relayed data on the thermal environment in lunar orbit that required some changes in NASA's testing plans.

While it wasn't a showstopper, the Indian data were helpful in ensuring that the U.S. testing came closer to matching the environment the orbiter will encounter at the Moon, says Cathy Peddie, the deputy LRO project manager at Goddard. That favor will be returned once the LRO data set is released.

"Hopefully, we'll be of help to them and the Japanese and whoever else wants to go to the Moon," Peddie says.

If the LRO is successful in getting to the Moon, more U.S./Indian cooperation should be possible with the two orbiters working in tandem. Among the instruments LRO carries is an experimental 13-kg. (28.7-lb.) synthetic aperture radar known as Mini-RF, which is a version of a U.S.-supplied radar on Chandrayaan that went into operation on Nov. 17, 2008.

Plans call for the radar on Chandrayaan to act as a sort of scout for LRO, shooting strips across the lunar poles 8 km. (5 mi.) wide with a resolution of 150 km. at the surface. When something interesting turns up in that data set, the LRO radar will focus on it with its 30-km. resolution capability.

Among questions both radars will be trying to answer is one first raised by the Pentagon's Clementine testbed, which used the Moon as a target for experimental missile defense sensors. In 1996 the Clementine radar spotted what may have been the signature of water ice in the permanently dark floors of deep craters at the lunar South Pole. Ice, whether it is frozen water, carbon dioxide or even ammonia, would be an extremely valuable resource for future human explorers.

"We know that comets strike the Moon, and there are cold dark places on the surface where the volatiles, the gases from the comets, would condense and be preserved," says Vondrak. "The astronauts could use these volatiles, this water ice or other material, not only for human consumption, but also as a source of fuel for their rocket systems."

While the radars on both spacecraft will seek ice by the way it reflects radio-frequency signals, a Russian-built instrument on LRO will be the most powerful water-seeker on the U.S. spacecraft. LEND, or Lunar Exploration Neutron Detector, will produce high-resolution hydrogen maps based on the neutron flux produced when cosmic rays strike the lunar surface.

A similar instrument on NASA's low-cost Lunar Prospector orbiter in the late 1990s didn't have enough resolution for scientists to determine whether the hydrogen signatures it detected were confined to the polar craters, but LEND should be able to pinpoint them within or outside the crater walls.

The LRO also will carry an imaging ultraviolet spectrometer called LAMP (for Lyman-Alpha Mapping Project) that scientists hope will be able to use starlight and ultraviolet skyglow as illumination to look into the permanently dark regions, in part to see if there is any water frost on the surface. A piggyback lunar impactor - the Lunar Crater Observation and Sensing Satellite - will kick up a plume of debris from a dark, cold crater bottom for analysis by spacecraft and terrestrial sensors, again in an effort to find ice (see p. 46). Any volatiles preserved at the poles also would have significant scientific value.

"On the Moon we expect that there will be this record of essentially the story of the Earth-Moon system," Vondrak says. "By looking at the ices, the volatiles at the lunar poles, it will help us to understand the history of cometary bombardment, and by analyzing the material we'll be able to tell its origins."

In a similar vein, the detailed topographic maps to be produced by the Lunar Orbiter Laser Altimeter (LOLA) and the Lunar Reconnaissance Orbiter Camera (LROC) should give scientists new insight into the outer structure of the Moon. That same data will help exploration planners map safe routes across the rugged surface and pick an outpost site with enough sunlight to permit solar-powered operations at first.

"The guaranteed resource we have [on the Moon] is sunlight," says Vondrak. "If we have landings at the polar regions, we believe there are elevated locations, hills or small mountains at the poles where the Sun is always above the horizon, and therefore we can use this as a source of electricity and warmth for the astronauts on the Moon."

Rounding out the LRO instrument suite will be the Cosmic Ray Telescope for the Effects of Radiation (Crater), which will map the radiation environment to help planners protect astronauts and perhaps their crops, and Diviner, an infrared filter radiometer designed to map global day and night surface temperatures. The exact date of the LRO's launch must be carefully timed so the sunlight angle on the lunar surface is correct for Diviner readings.

Peddie, the deputy project manager, says the original LRO concept called for only two or three instruments. But stability problems with the fuel load needed to get the baselined Delta II launch vehicle to send the spacecraft to the Moon forced a switch to the Atlas V, making room for more instruments and the Lcross impactor (AW&ST Jan. 9, 2006, p. 15).

"Having all seven instruments, I think were just going to be blown away with the data set we get later this year," Peddie says.

The launch date for the mission has been moved to May 20-24. The Atlas V 401 will take the 1,916-kg. lunar orbiter and the Lcross impactor, which weighs about 901 kg., into a direct-transfer trajectory to the Moon, with a 1-hr. launch window each of two or three days in a launch opportunity that occurs every two weeks, according to Peddie.

Immediately after launch, control of the mission will shift to the Mission Operations Center at Goddard. The LRO spacecraft will configure itself and acquire the Sun autonomously, allowing controllers to command deployment of the solar array and high-gain antenna.

If necessary, Goddard will order a mid-course correction 24 hr. after launch to correct any errors in the trajectory, and start activating some of the instruments. LEND must begin its calibration before it enters lunar orbit, and Crater also will be activated on the way to the Moon.

Depending on when the launch occurs, four or five days later the spacecraft will be commanded into its first lunar orbit insertion maneuver. Those maneuvers will continue for a few days, moving the spacecraft from its initial orbit into a commissioning orbit of about 30 X 216 km.

The LRO will spend roughly the next 60 days in commissioning and calibration of the remainder of its instruments. After that, Goddard will command a series of three mission orbit insertion maneuvers designed to get LRO into its operational 50-km. polar orbit.

The nomimal mission following commissioning will be 12 months. Until the mission slipped from April to May, the total cost, including spacecraft development, testing, launch, a 60-day commissioning period and a year of science, would have been $504 million, Peddie says. The one-month delay will likely add to that figure.