Lunar Ice Discovery Mission

Discovery `96

Carnegie Mellon University

Scientists have speculated for over 20 years that water and gasses could be present frozen in the surface of the Moon in permanently shadowed craters around the lunar poles. The Clementine mission confirmed the presence of permanently shadowed areas and presented evidence suggesting that these areas contain water ice. The verification of these findings offers the prospect of deciphering the comet impact history of the Moon and Earth, and will transform the role of the Moon in space exploration. Hydrogen volatiles provide a basis for permanent human habitation, agriculture, and the manufacture of building materials. Water transformed into rocket fuel can send millions of tons of payload into low-earth orbit, or to Mars and beyond.

The Clementine data suggest that up to 15,000 square kilometers of cold traps exist, which are likely to contain ice up to two meters thick, up to 10 billion tons of ice in all. The sources for this ice include solar wind, cosmic dust and comet impacts. An upcoming NASA satellite mission, Lunar Prospector, will look at the polar regions and determine the presence of hydrogen atoms on the surface. While water is most likely the dominant ice, hydrogen could also be present in methanol, ammonia, or other compounds. The determination of the composition of volatiles requires a return to the surface of the Moon. Demonstrating the existence of distinct ice layers from separate comet impacts can only be done from the lunar surface and would be of major scientific importance.

The Lunar Ice Discovery Mission proposes to land a robotic Explorer in the lunar south pole region on December 24, 2000. This Explorer will visit multiple cold traps during its three month long mission, confirming the presence of water and other ices inside the cold traps. Using a cryogenic drill it will extract samples from depths of up to a meter and determine physical properties of the fragmental debris (regolith) that covers the lunar surface. A Regolith Evolved Gas Analyzer (REGA) will unambiguously determine the chemical and isotopic compositions of these volatiles. A Mossbauer spectrometer will provide information on the mineralogical content of regolith both inside and outside the cold traps. Finally, on-board cameras will return high-resolution color and infrared images of the Lunar surface.

The data returned from the Explorer will provide valuable information for the science community. The composition of volatiles at different sites and depths will allow scientists to refine their models for volatile deposition and removal mechanisms. The deposits are believed to have a complex stratigraphy, in which ice layers deposited at the time of comet impacts are interspersed with ice from other sources as well as with non-volatile debris emplaced by meteoroid impacts.

Like the rings of a tree, the stratigraphy will provide a 2 billion year timeline of the history of each cold trap. It may even allow the age of a cold trap to be determined, which would tell us when the Moon's rotational axis stabilized at its current angle. By examining different layers in the strata, the Explorer may determine individual comet compositions throughout history.

The mission will launch on a Delta II rocket and land on the Moon in a direct-descent trajectory. Unique to the Lunar Ice Discovery Mission is the Lander-Explorer. This innovative robotic spacecraft will land on its four wheels, transition from Lander to robotic Explorer and, without ramps or cumbersome deployment, embark on its scientific mission. Through dual use of structure, communications, power, sensing and computing, the Lander-Explorer reduces mission costs, development time and launch mass, enabling a 35kg payload for science instruments and cameras. The Lander-Explorer is 2.4m x 2.4m x 2m and has a landing mass of approximately 350kg.

The Lander-Explorer will be based on NASA's Nomad robot developed at Carnegie Mellon University (CMU). Nomad is traversing the barren Atacama desert during the summer of 1997, proving the Explorer's core robotic technology. The Explorer will use a cylinder of solar panels (much like a commercial satellite) to generate electricity. Batteries will store enough energy for 20-hour sorties into the dark cold traps. Wheeled locomotion will provide the traction, mobility and propulsion needed to cross the lunar landscape and cold traps. Safeguarded teleoperation combined with autonomous navigation techniques will allow the Explorer to deal with numerous situations during its three month long mission. Data from the science instruments and cameras will be transmitted back to Earth using NASA's Deep Space Network (DSN).

The mission's scientific investigation will be conducted by a science team led by Dr. Michael Duke, Lunar and Planetary Institute, Houston, and include Dr. James Arnold, UC San Diego; Dr. William Boynton, University of Arizona; Dr. John Hoffman, University of Texas; Drs. David McKay and Richard Morris, Johnson Space Center; and Dr. Eugene Shoemaker, U. S. Geological Survey, Flagstaff. Johnson Space Center (JSC) will provide the operations and trajectory analysis capabilities of its Mission Control Center as well as the development of the spectrometer and REGA. The Jet Propulsion Laboratory will provide mission design services, DSN services, cryogenic drill, infrared imaging sensors and related data interpretation.

The Lunar Ice Discovery Mission will be primed by CMU in partnership with LPI and JSC under the leadership of Dr. William Whittaker. A major aerospace partner will be enrolled to help control costs and provide flight experience. For fifteen years, the CMU team has led national research programs for robotic technologies and has produced field-worthy robots for missions and commercial enterprise. The team offers a decade of contributions to NASA telerobotics, with a lineage that includes the Ambler, Tesselator, Deadalus, Dante, Ratler, Demeter and Nomad research robots. Seasoned by these years of robotic design, development, and deployment, the Lunar Ice Discovery team will pursue management, programmatic, and technical activities during the feasibility study, refine first results in early phases of the project, and deliver a high-performance, high-return scientific mission at a cost of $133 million. Evaluated and supported by Freeman Dyson, Harrison Schmitt, Alan Binder, the Boeing Company, NASA Lewis, and the Space Studies Institute, the credentialed, qualified, and committed team of the proposed Lunar Ice Discovery Mission will deliver significant scientific data. Furthermore, the volatiles confirmed by the Lunar Ice Discovery Mission will make the Moon the gateway to Mars and the rest of the solar system.