Geophysical Research Abstracts
Vol. 12, EGU2010-1025-2, 2010
EGU General Assembly 2010

Science Investigations with Laser Ranging to the Moon and Mars/Phobos: Recent Advances, Technology Demonstrations, and New Ideas

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Since it's initiation by the Apollo 11 astronauts in 1969, LLR has strongly contributed to our understanding of the Moon's internal structure and the dynamics of the Earth-Moon system. The data provide for unique, multi-disciplinary results in the areas of lunar science, gravitational physics, Earth sciences, geodesy and geodynamics, solar system ephemerides, and terrestrial and celestial reference frames. However, the current distribution of the retroreflectors is not optimal, other weaknesses exist. A geographic distribution of new instruments on the lunar surface wider than the current distribution would be a great benefit; the accuracy of the lunar science parameters would increase several times.

We are developing the next-generation of the LLR experiment. This work includes development of new retroreflector arrays and laser transponders to be deployed on the lunar surface by a series of proposed missions to the moon. The new laser instruments will enable strong advancements in LLR-derived science. Anticipated science impact includes lunar science, gravitational physics, geophysics, and geodesy. Thus, properties of the lunar interior, including tidal properties, liquid core and solid inner core can be determined from lunar rotation, orientation, and tidal response. Anticipated improvements in Earth geophysics and geodesy would include the positions and rates for the Earth stations, Earth rotation, precession rate, nutation, and tidal influences on the orbit. Strong improvements are also expected in several tests of general relativity. We address the science return enabled by the new laser retroreflectors.

We also discuss deployment of pulsed laser transponders with future landers on Mars/Phobos. The development of active laser techniques would extend the accuracies characteristic of passive laser tracking to interplanetary distances. Highly-accurate time-series of the round-trip travel times of laser pulses between an observatory on the Earth and an optical transponder on Mars/Phobos could lead to major advances in science investigations of Mars/Phobos. Technology is available to conduct such measurements with a picosecond timing precision which could translate into mm-level accuracies achieved in ranging between the Earth and Mars/Phobos. The resulting Mars Laser Ranging (MLR) would provide new opportunities for robust advances in the tests of relativistic gravity and the properties of Martian interior, including liquid core, could be determined from Martian rotation, orientation, tidal response. Alternatively, Phobos laser Ranging (PLR) would benefit the study of Phobos and the Martian system. Given the current technology readiness level, PLR could be started in 2011 for launch in 2016 for 3 years of science operations. We discuss the PLR's science objectives, instrument, and mission design. We also present the details of science simulations performed to support the mission's primary objectives.

The work described here was carried out at the Jet Propulsion Laboratory, California Institute of Technology under a contract with the National Aeronautics and Space Administration.