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Application of asynchronous laser transponders to solar system and planetary science

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Since 1964, short pulse lasers have been used to range to artificial satellites equipped with passive retroreflectors. Today, a global network of 40 satellite laser ranging (SLR) stations, under the auspices of the International Laser Ranging Service (ILRS), routinely track two dozen international space missions with few millimeter precision using picosecond pulse lasers in support of Earth Science. Lunar Laser Ranging (LLR) began in 1969, shortly after NASA's Apollo 11 mission placed the first of five retroreflector packages on the Moon. For the past decade, work has been underway to extend these precise ranging capabilities beyond the Moon to interplanetary distances via the use of two-way asynchronous laser transponders.

In May 2005, the first two-way asynchronous laser transponder link was established between NASA's Goddard Space Flight Center and a laser altimeter instrument onboard the Messenger spacecraft enroute to Mercury. The Earth to spacecraft distance of 24.3 million km was measured with an unprecedented precision of 20 cm and was limited by the roughly 10 nanosecond pulsewidth and resolution of the onboard laser and timing receiver. The Messenger experiment was carried out in full daylight with very modest onboard laser energies ($<$20 mJ) and receive apertures (25 cm) and a relatively high threshold detector ($\sim$300 pe). In September 2005, approximately 500 laser pulses from the same GSFC station were observed by the Mars Observer Laser Altimeter (MOLA) receiver in Mars orbit at an even greater distance of 80 million km. A second Messenger experiment is planned for mid-June 2007 while the spacecraft is in the vicinity of Venus.

Compact transponder packages using readily space-qualifiable ultrashort pulse lasers, detectors, and time-of-flight receivers should permit centimeter range accuracies over interplanetary distances in the near future. In preparing for these missions, many of the passive satellite assets already in Earth orbit can be used today to test and validate interplanetary link analyses (including atmospheric effects), target acquisition and tracking strategies, and data reduction algorithms prior to spacecraft launch or even mission definition. Science applications of transponders include: characterization of the solar gravitational field, mass distribution, and rotation; centimeter accuracy planetary and lunar ephemeredes; mass distribution within the asteroid belt; and improved general relativity experiments. Planned transponder experiments to artificial satellites will also speed the development of laser communications systems, which would offer orders of magnitude more bandwidth in transferring high resolution sensor data from our planetary neighbors and their moons.