Interplanetary laser ranging - an emerging technology for planetary science missions

Dominic Dirkx (d.dirkx@tudelft.nl), Bert L.A. Vermeersen
Faculty of Aerospace Engineering, Delft University of Technology, The Netherlands

Laser ranging to Earth-orbiting satellites is one of the main pillars of satellite geodesy. Over interplanetary distances, an active two-way system is required to perform laser ranging, in which Earth-based and space-based transponder systems independently fire laser pulses, timed asynchronous laser ranging. This can be used for highly precise (mm- to cm-level) ranging and time transfer, allowing improved estimation of a variety of planetary science observables. Work is being performed in the ESPACE project to simulate these links, allowing for a quantitative, bottom-up analysis of the added value of a laser ranging system for interplanetary missions.

Overview

Previous analyses of attainable interplanetary laser ranging (ILR) accuracy estimate its at the mm- to cm-level, similar or better than those to retroreflectors. Additional advantages of laser tracking include:

- No ionospheric and solar coronal influence on laser pulse
- Use of network of existing, stable detection and transmission systems (ground and space-based)
- Low free-space loss

Laser ranging is intended to complement the radiometric Doppler and VLBI measurement.

High noise levels are expected at small solar incidence angles, due to stray light in the optical detection system. Additionally, high planetary noise levels are inherent in many ILR mission architectures.

Clock stability and detection system precision at both ends of the link can limit the attainable measurement precision. However, the stability of the spacecraft clock need not be of the same order as that of the ground station.

Link simulations

Research into the quantitative influence of defining parameters of ILR systems is being performed in the FP7 ESPACE project (Thuillot et al. 2010). This is done using the Tudat software library by means of concurrent simulation of:

- Laser pulse propagation
- Laser transceiver system performance
- Dynamics of both ends of the laser link

Top-level software functionality is shown in Fig. 3. Planned validation steps are:

- Simulation of LRO measurements
- Orbit determination of the LAGEOS satellite
- Comparison of modeled noise levels to those measured by a SLR station

Simulations of interplanetary architectures will allow for improved, bottom-up understanding of the limiting parameters and a reliable definition of laser system and mission requirements from science requirements.

Mission applications

A typical ILR mission architecture is used by the Phobos Laser Ranging concept, illustrated in Fig. 2.

Interplanetary laser ranging can be applied in a variety of mission architectures. Laser transponders can be placed on both the surface of celestial bodies, as well as onboard satellites. This could allow, for, among others:

- Sub-meter accuracy planetary ephemerides
- Accurate deformation measurement of bodies
- Improved knowledge of rotation behavior of bodies
- Improved gravity field mapping
- Testing of general relativity

Examples of mission proposals using the technology are GETEMHE, PLR, SAGAS, LATOR and TIPO.

Conclusions

Interplanetary laser ranging has the potential to allow improved estimation of planetary science observables through mm- to cm-level range accuracies. The work performed in this study will focus on determining the system, mission and operational requirements from science requirements through bottom-up simulation of interplanetary laser links and dynamics.

Case studies of a number of interplanetary architectures will be used to assess the performance of missions with and without laser transponder system, quantifying the added value of the system for various science observables.

This work is financially supported by the EC FP7 Grant Agreement 263466.