Quantification of interplanetary laser ranging system requirements through bottom-up link simulations

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Interplanetary laser ranging (ILR) is an emerging technology for very high accuracy distance determination between Earth-based stations and spacecraft or landers at, for example, Martian or Jovian distances and possibly beyond. Current estimates of the attainable range measurement accuracy using this technology are at the mm- to cm-level. The technology has evolved from laser ranging to Earth-orbiting satellites, modified with active laser transponder systems at both ends of the link instead of the passive space-based retroreflectors.

Work is being performed in the ESPaCE project to evaluate in greater detail the potential and limitations of this technology. This will be done by means of concurrent, bottom-up laser link and dynamical simulations. The detection time tags of laser pulse transmissions and receptions, as well as noise signals, will be simulated directly from hardware and environmental models. Subsequently, the simulated data will be used for orbit determination and parameter estimation, allowing for a clear link between system characteristics and the attainable precision of science observables. The virtue of this approach is that the mapping of hardware and mission geometry characteristics to link performance is obtained directly from system models, allowing for a bottom-up characterization of this performance. It also allows for easy modifications of the fidelity of hardware system models in the simulations. The software will provide the framework for a reliable definition of ground- and space-based hardware requirements, as well as mission requirements of ILR mission architectures from top-level requirements.

The main software validation steps that will be performed are: 1) Comparing simulated laser ranging measurements to LRO to the measured full-rate data (in the statistical sense). 2) Comparing the results of orbit determination of the LAGEOS satellites to existing orbit estimates. 3) Comparing simulated noise levels of sources important in ILR to those measured by a ground station.

The analysis framework that will be set up is crucial for the future implementation of ILR, as it will assist in the quantification of the benefits of laser tracking for a given mission during the preliminary design stage. This could be done using either a dedicated instrumentation suite, or using a (modified) existing onboard laser system, such as a laser altimeter.