Modern European Capabilities for the Processing of Gound-Linked 4-Way Satellite-to-Satellite Measurements, Deep Space Orbit Determination and Subsequent Global Lunar Gravity Field Determination

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Despite obvious improvements from Lunar Prospector, one of the key issues in lunar science remains the understanding of the global gravity field, as the presently available ground-based satellite measurements are confined to the lunar near-side, and therefore under-sample the potential field. Over the past years studies of robotic lunar science missions, like MORO and LunarStar, may be considered to be the primary drivers behind the development of know-how and modern software tools in support of a global lunar gravity field experiment as well as global planetary gravity field determination via satellite-to-satellite tracking (SST) in general. Based on DLR/GSOC's strong experience in orbit determination (OD), through its participation in various Earth-orbiting and deep space projects, in combination with modern in-house approaches for flight dynamics software development in the 1990s, this gave the impetus for the implementation of a new deep space OD program named DEEPEST [1].

The launch and on-orbit operation of Lunar Prospector (LP), starting in early 1998, provided an opportunity to verify the prototype of DEEPEST - operated on a simple PC platform - for OD of a lunar orbiter. With the consent of NASA, 3-way line-of-sight Doppler measurements were collected, over a period of six weeks in the summer of 1998, by the DLR 30 meter deep space antenna at Weilheim, by passively listening to tracking signals uplinked by operational Deep Space Network (DSN) stations. At a noise level of about 0.5 mm/s, initial OD analysis using the new software and the new lunar gravity model LP75G revealed 2.5-day arc residual RMS values of about 4 mm/s and 1 mm/s for edge-on and face-on tracked geometries, respectively. Despite the slightly increased noise inherent to the 3-way Doppler data compared to 2-way measurements, where the uplink and downlink stations are the same, the primary residual signatures are due to the systematic lack of observations from the far-side of the Moon, which is clearly reflected in the OD results.

An encouraging conclusion was therefore that the data collected by the 30 m dish could be employed in an attempt to improve the Lunar Prospector-derived LP75G gravity field model. Approximately 5 weeks of data were used to improve the full model of degree and order 75, with the sixth week of data left for verification purposes. As a result, post-fit OD results were improved to about 2.5 mm/s RMS for 3-day arcs, and the radial orbit consistency was improved to about 5-10 m for 24 hour overlaps. Although the data set in principle is too weak for high order and degree gravity field recovery independent from the Lunar Prospector project efforts, it is concluded that the available software tools and hardware are ready to be applied in future missions and dynamical modelling.

Recently, following an extension of DEEPEST to handle 4-way SST observations, initial OD simulations have statistically proven the benefit of far-side data from a target-relay-ground tracking link, a fact that is well-known from previous studies. Near-future (2004) flight opportunities for such an experiment are expected to be provided by the Japanese SELENE-1 spacecraft, consisting of a duo of a low-orbiting target and a high-orbiting relay satellite. The above results all point out the strong potential and readiness for this.

Key words: Lunar Prospector, 3-Way Doppler Tracking, Deep Space Orbit Determination Software, Global Lunar Gravity Field Determination, Inter-Satellite Tracking, SELENE

[1] DEEPEST = Deep Space Trajectory Propagation, Estimation and Tracking Data Simulation Software. This software has been developed at German Aerospace Centre / German Space Operations Centre (DLR/GSOC) and is property of this institution