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Reduction and analysis of one-way laser ranging tracking data from Wettzell ground station to LRO

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Abstract

One-way LR (Laser Ranging) has been performed routinely from ILRS (International Laser Ranging Service) ground stations to the LOLA (Lunar Orbiter Laser Altimeter) instrument which is onboard NASA's LRO (Lunar Reconnaissance Orbiter). This rather new type of tracking data can provide high accuracy spacecraft positioning over short and interplanetary distances. We present the current status of our effort to process, analyze and utilize this data type for LRO orbit determination and gravity field estimation.

1. Introduction

Satellite LR has being performed to track Earth satellites since 1964 and has reached an accuracy of a few millimeters nowadays. Providing such a high accuracy, this tracking type enables the development of greatly improved models in Earth science and fundamental research [1]. Examples for the application of this technique on a spacecraft or an object beyond Earth orbit such as LRO can be found in [2, 3]. Although ranging over such long distances is challenging, the benefit of the high precision positioning motivates the effort. In the LRO mission LR supports the development of a global lunar geodetic grid to the required accuracy [4]. This reference frame will be the basis for future lunar exploration missions [3].

2. One-way LR to LRO

Unlike various ranging techniques such as retro reflector or two-way transponder, LR to LRO is a one-way measurement and figure 1 shows the basic principle of this experiment. A ground station fires a laser pulse to LRO at a certain time and the received pulse is time stamped by the satellite. By calculating the light travel time between the receiving and the firing time, it is possible to derive a high precision range measurement with a RMS of 10 to 30 cm [5]. LR tracking of LRO is performed simultaneously as LOLA is ranging to the lunar surface. Incoming Earth range pulses are transmitted into the LOLA laser detector by a fiber optic cable that is attached to the HGA (High Gain Antenna), which is always oriented towards Earth.

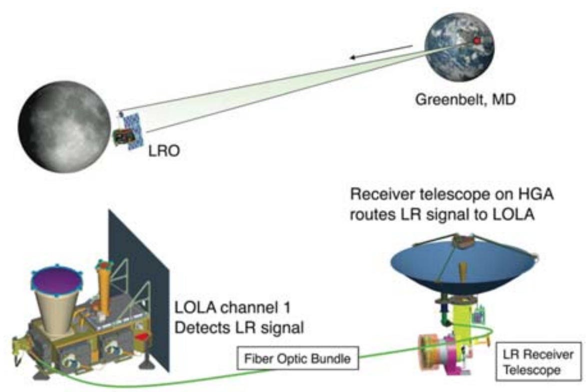

Figure 1: LR to LRO - basic principle [3]

3. Wettzell Ranging Campaign

Among the ILRS stations participating in the LRO-LR operation, we joined Wettzell in Germany during a campaign. Dates and times of two successful passes are listed in table 1. Both passes have a duration of about 35 minutes, while the laser was firing at a 14 Hz rate. The firing times are usually sent to GSFC (Goddard Space Flight Center) for further analysis. After receiving the firing times for these two passes, we paired them with the LOLA receive times.

Table 1: Wettzell LRO passes

Pass	Tue 15th Nov 2011	Wed 16th Nov 2011
Begin	1:49 am CET	4:02 am CET
End	2:24 am CET	4:37 am CET

4. Matching

We derived the preliminary results that are shown in Figure 2 and 3. We used the NAIF SPICE toolkit to predict light travel times for certain shots to then find the receive times that match those predictions best. In order to retrieve a predicted spacecraft position, we used LRO SPICE kernels, produced by inversion of radio tracking and Laser cross-over analysis [4]. There were totally 1844 out of 26726 out-going laser pulses matched successfully with corresponding LOLA receive times. Figure 2 shows the predicted light travel time from SPICE and the best matched shots for the pass of the 15th Nov 2011. The 4th order polynomial fit represents the orbit of the matched shots for that pass and enables a variation analysis of them. Figure 3 shows the deviation between the predicted light time in SPICE and the time difference between the matched shot. Besides the line shape similarity between the SPICE predicted light time and the calculated light time from matched out-going and received laser shots in figure 2, one can see a bias of about $1.6{\cdot}10^{-3}$s and a roughly $1.6{\cdot}10^{-6}$s increase of deviation value in figure 3. We found that the matched shots have a RMS of $2.1{\cdot}10^{-7}$s with respect to the polynomial fit, which is larger than the nominal LR RMS value obtained from all participating LR stations [5] and therefore the authors matching algorithm has to be revised. Apparently the regular grouping of shots over time is typical for LRO-LR from Wettzell since we see a similar pattern in previous results [5]. The goal is to incorporate the high precision one-way LR measurements as a new type of tracking data into orbit determination for improved spacecraft positioning and gravity field estimation [cf. 4].

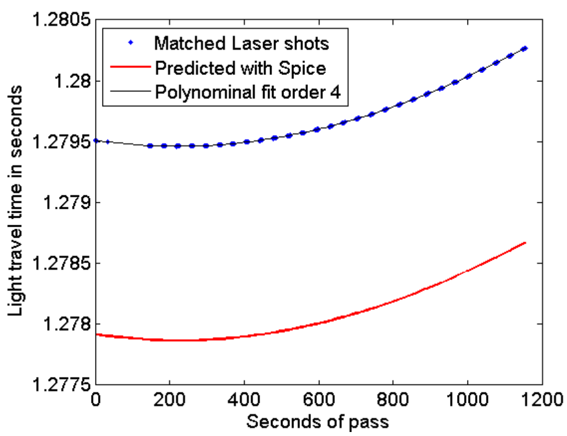

Figure 2: Predicted light time and matched shots

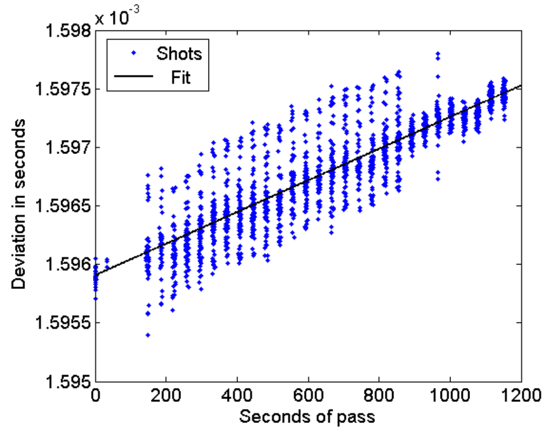

Figure 3: Difference between prediction and shots

6. Summary and Conclusions

From a Laser Ranging Campaign at Wettzell to LRO we received data from two successful passes. We have matched out-going and receive times with some remaining deviations which are currently under investigation. This type of tracking data will be used to improve orbit determination and gravity field estimation in future.

Acknowledgements

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References

[1] Degnan, J.: The history and future of Satellite Laser Ranging, 17th International Workshop on Laser Ranging, Bad Kötzting Germany, 2011.

[2] Neumann, G., et al.: Laser Ranging at Interplanetary distances, http://cddis.gsfc.nasa.gov, May 2012

[3] Zuber, M., et al: The Lunar Reconnaissance Orbiter Laser Ranging Investigation, Space Sci Rev, Vol. 150 Nr. 1-4, pp. 63 – 80, 2010.

[4] Mazarico, E., et al: Orbit determination of the he Lunar Reconnaissance Orbiter, J. Geod., 86, pp. 193-207, 2012.

[5] Mao, D., et al: Laser Ranging Experiments on LRO, 17th International Workshop on Laser Ranging, Bad Kötzting Germany, 2011.