The First ILRS Laser Transponder Mission: Laser Ranging to NASA's Lunar Reconnaissance Orbiter

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ABSTRACT

Since the launch in June 2009 of LRO, Laser Ranging (LR) to LRO has been a huge success, accumulating over 1000 hours of one-way laser ranging data. The participation of the global community of stations has been a very large part of that success. Ten stations around the world contribute to the ranging data, including NASA's Next Generation Satellite Laser Ranging (NGSLR) system, McDonald Laser Ranging System, many of the NASA MOBLAS systems, and four European stations. A brief overview of the LRO-LR technique will be followed by a summary of the results to date.

Background

LRO-LR is the first mission for the ILRS whose primary laser tracking method is transponder ranging. LRO-LR is a one-way (uplink only) ranging technique where the Earth laser station measures the fire times of its outgoing laser pulses and the Lunar Orbiter Laser Altimeter (LOLA), one of the instruments onboard LRO, measures the receive times [1] [2]. The range gate for the Earth received pulses in LOLA's detector #1 is called the Earth Window. During this window the detector is gated on to receive Earth events. LOLA performs signal processing on the received Earth events and provides the signal processing results to the ground via its housekeeping packets.

These housekeeping packets are routed through the LRO Mission Operations Center (MOC) to the LOLA Science Operations Center (SOC) where the relevant data is extracted and put into a real-time website which is displayed from the Crustal Dynamics Data Information System (CDDIS) server. This real-time LRO-LR website provides feedback to all participating stations while they are ranging to LRO. Unlike two-way ranging where the laser light returns to the station and provides the feedback, this website is the only feedback that the stations have while they are ranging to LRO. The latency of the website is nominally 10 to 20 seconds, but has been observed to be as long as several minutes.

Participating Stations

There are ten stations supporting laser ranging to LRO. These stations are shown in Table 1 along with their first successful ranges and their system characteristics.

An initial Call for Participation to ILRS stations was issued in 2008. The requirements on the ground stations includes laser energy density at the spacecraft (1 to 10 femtoJoules per sq.cm), wavelength (532.2 +/- 0.15 nm), number of pulses per second (no more than 28 Hz fire rate), fire timing resolution (100 picosecond), and the ability of the station software to use the ILRS Go/NoGo flag. The Call for Participation can be found on the LRO-LR website [3].

Written agreements were made with each of the stations. Included in the Agreements were the above system requirements, the need to maintain the security of the predictions, and the requirement to range to LRO only when scheduled.

Fire data is sent in from all stations in the Consolidated Ranging Data (CRD) format [4]. The files sent in from the stations have the file extension FRF for fire only data. NASA systems (NGSLR and MOBLAS) also send in their data in a NASA Internal Transponder Data Format (iTDF).

Station	Location	Synch to LOLA?	Firerate (Hz)	Max # / sec in LOLA window	Expected energy at LRO (fJ / sqcm)	Station Frequency Source	Date of first successful ranging to LRO	LR Status
NGSLR	Maryland, US	Yes	28	28	1 to 5	Maser (18-Oct-2010)	30-Jun-2009	Operational
MLRS, McDonald	Texas, US	No	10	2 to 4	1 to 10	Cesium	02-Jul-2009	Operational
MOBLAS-7, Greenbelt	Maryland, US	No	10	2 to 4	1 to 3	Maser (18-Oct-2010)	02-Jul-2009	Operational
Herstmonceux	Great Britain	Yes	14	14	1 to 3	Maser (13-May-2010)	13-Jul-2009	Operational
Zimmerwald	Switzerland	Yes	14	14	1 to 3	Ovenized crystal oscillator	20-Jul-2009	Operational
Wettzell	Germany	No	7	7	1 to 10	Cesium	30-Oct-2009	Operational
MOBLAS-6, Hartebeesthoek	South Africa	No	10	2 to 4	1 to 3	Maser	05-Dec-2009	Operational
MOBLAS-5, Yarragadee	Australia	No	10	2 to 4	1 to 3	Maser (14-May-2010)	25-Jan-2010	Operational
MOBLAS-4, Monument Peak	California, US	No	10	2 to 4	1 to 3	GPS steered Rubidum	03-Feb-2010	Operational
Grasse/MEO	France	No	10	2 to 4	1 to 10	Cesium	18-May-2010	Operational

Table 1: Participating ILRS stations and their characteristics

Four of the participating stations are NASA MOBLAS systems. These systems were modified to permit ranging to LRO. A new Windows computer with a Guidetech timing card (model GT658) was added to each system to provide the precision needed for the fires, and the systems were all modified to fire their laser at 10 Hz.

Some of the participating ground stations control their laser fires to ensure the pulses arrive when the LOLA Earth Window is open. These systems are referred to as synchronous ranging stations. NGSLR, Herstmonceux and Zimmerwald are all synchronous stations. All other systems are asynchronous. The MOBLAS systems and Grasse all fire at 10 Hz. MLRS fires at approximately 10 Hz. Systems that fire at 10 Hz get two pulses per second into the LOLA Earth Window most of the time, and occasionally they will get four pulses per second into the Window. Wettzell fires at 7 Hz and they tune their fire frequency to match the range-rate.

Laser Ranging Results

As of this Workshop there were over 1000 hours of Laser Ranging data collected from all of the stations. NGSLR has over 45% of the global data collected since launch, with Yarragadee at 18%, Monument Peak at 15%, and MLRS at 13%. The global data rate appears to be increasing as shown in the plot of Figure 1.

In the early months after launch only a single station was scheduled to range to LRO at any time. This was to give the stations some experience in using the real-time LRO-LR website for feedback. Simultaneous ranging to LRO by two or more stations allows comparison of station ranging and biases. Three-way simultaneous ranging can potentially provide a geometric solution of the spacecraft location. Simultaneous ranging opportunities are now scheduled for all NGSLR, MLRS, MOBLAS-7

(Greenbelt), and MOBLAS-4 (Monument Peak) passes. In addition Grasse and Zimmerwald are also always scheduled for simultaneous ranging opportunities. More stations will be simultaneously scheduled in the near future.

The first successful ranging to LRO was done by NGSLR on June 30, 2009. The first successful three-way simultaneous ranging was performed on November 1, 2010 by NGSLR, MLRS and Monument Peak. There have been many two and three-way simultaneous passes to LRO over the last 2 years and one successful four-way simultaneous pass as of this Workshop (NGSLR, MOBLAS-7, MLRS and Monument Peak).

Analysis of the LR data is reported in D. Mao's paper in this Proceedings[5].

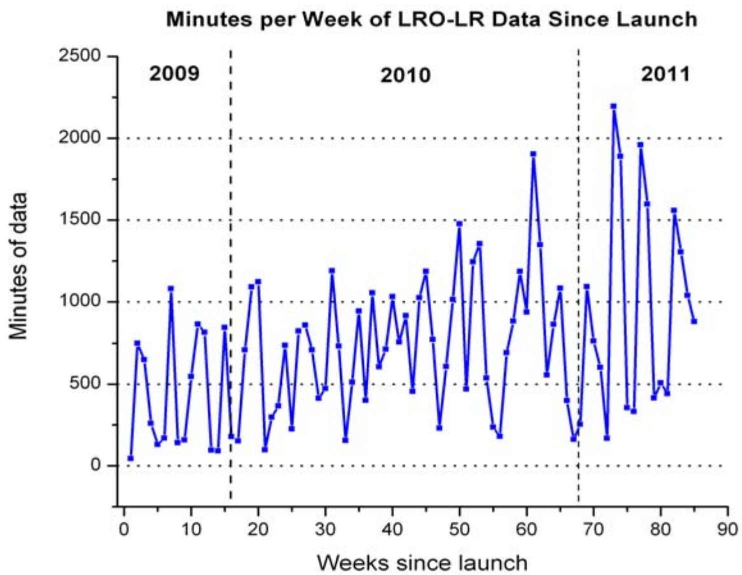

Figure 1: Plot of LR data from launch (June 2009) to present

Summary

With LRO-LR entering year 3 of successful operations, one-way (uplink only) laser transponders have now been proven to work operationally. Thanks to the support of the ILRS and the participating stations, over 1000 hours of LR data has been collected and used to determine spacecraft time to UTC, and will be used to provide more precise orbits. In addition time transfer between ground stations using LRO will be attempted later in 2011, initially between Wettzell and NGSLR.

LRO will move from its current Mission Mapping circular orbit of 50 km to an elliptical 30 km x 200 km orbit late in 2011. LRO-LR is expected to continue through 2012.

For details, pictures, and the latest information please see: http://lrolr.gsfc.nasa.gov

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