
Laser Ranging to the Lunar Reconnaissance Orbiter (LRO)

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Abstract

LRO will be launched in late 2008 carrying, amongst other payloads, the Lunar Orbiter Laser Altimeter (LOLA) which is a 1064nm laser altimeter for mapping the lunar surface, and the Laser Ranging (LR) receiver which is mounted on the earth-pointed High Gain Antenna (HGA). Laser Ranging with LRO (LRO-LR) is one-way from earth to spacecraft and will be used along with S-band tracking data and the LOLA altimeter data to develop an improved gravity model for both the near and far sides of the moon. SLR2000 will be the primary laser ranging station, but the project would like to extend an invitation to ILRS stations for their participation. The requirements for ranging include satisfying the laser wavelength (to match the onboard filter at 532nm), repetition rate (to hit the range window but minimize impact to the onboard threshold algorithm), transmit energy (to cross the detector threshold), and station timing (to ensure precise transmit time recording). The requirements are very similar to those for earth orbiting satellite laser ranging. We hope that many of you will consider participating in this exciting transponder experiment.

Introduction

LRO is a robotic component of the Moon to Mars vision proposed in January, 2004. LRO will be launched in October 2008 into a polar orbit around the Moon with an average altitude of 50 km. Lunar gravity necessitates orbital maintenance every 30 days (30-70 km altitude range) to maintain the polar orbit for the one-year nominal mapping mission. The LRO spacecraft has a suite of seven instruments: LOLA, a laser altimeter; LROC, a camera; LAMP, a Lyman alpha telescope; LEND, a neutron detector; DIVINER, a thermal radiometer; CRATER, a cosmic ray detector; and the mini-RF, radar technology demonstration. The LOLA altimeter addresses the geodetic measurement objectives of NASA's robotic lunar exploration program, in particular – "Determine the topography of the Moon to geodetic quality from global to landing-site relevant scales." and "Assess metre and smaller-scale features to facilitate safety analysis of potential future lunar landing sites".

The precise determination of the Lunar topography from LOLA data, and positioning of the measurements made by other LRO instrument suite on the lunar surface requires accurate LRO orbits. The LRO orbits will be determined by high quality tracking of LRO and improvement in the knowledge of the Lunar gravity field. To enhance the orbit determination, the LRO mission includes a one-way laser ranging (LR) capability. The LR data will provide a 10 cm precision measurement of the position of LRO. In conjunction with the LOLA data, LRO positional accuracies will be 50 to 100 m along track and 1 metre radially from the Lunar center of mass after improvement of the lunar gravity field. One SLR station (Greenbelt, MD) is presently planned to track LRO; we are hoping for a second US station and help from the international SLR network.

Measurement technique

The LRO-LR measurement is a one way range from earth to spacecraft with the ground station recording the time of the laser fire and the LOLA instrument onboard LRO recording the pulse arrival time. The 2 cm aperture LR receive telescope will be mounted on the spacecraft's High Gain Antenna (HGA). The optical signal will be routed via fiber optic cable to the LOLA instrument (see Figure 1). One of LOLA's five lunar detectors will receive the earth pulses as well as the lunar surface events.

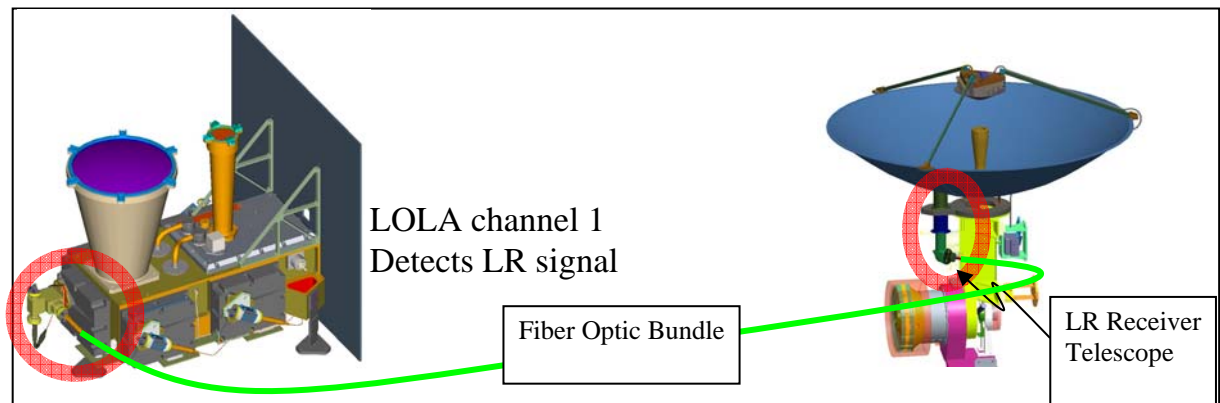


Figure 1: Optical signal path from HGA to LOLA instrument.

SLR2000 is the primary ground station for LRO-LR and is required to transmit at 28Hz (the LOLA instrument's fire rate), and to control its laser fire times to ensure that all pulses arrive in the LOLA earth windows as shown in Figure 2 [McGarry]. There is no corresponding requirement for other participating stations to control their laser fire times, however, to ensure a minimum of one pulse per second arrival in the earth window, fire rates of 5 Hz and 10 Hz should be used when the laser fire time is not controlled.

No ground station should fire at LRO faster than 28Hz. Events that occur outside LOLA's range windows (earth or lunar) are interpreted as noise and will affect the threshold level which is controlled by a feedback loop based upon the noise counts outside the windows.

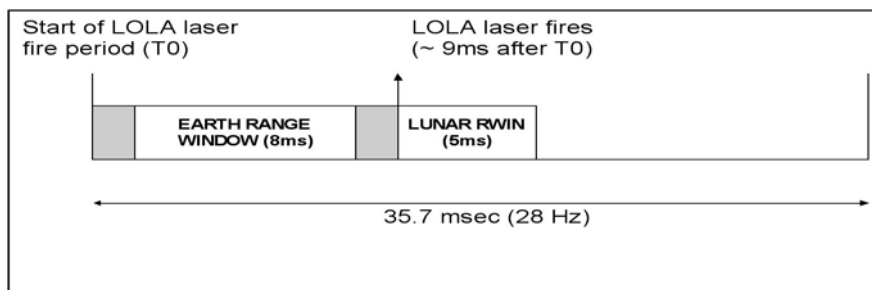


Figure 2: Timing of LOLA earth window relative to lunar window within the 28Hz laser fire period

Ground System Requirements

Stations participating in the LRO-LR experiment must satisfy the following requirements:

1. Deliver between 1 and 10 femtoJoules per square centimetre of signal to the receiver aperture. For SLR2000 with its 55 microradian laser divergence this translates into a transmit energy of 30 milliJoules per pulse.
2. The transmitting wavelength must be 532 nm. The exact wavelength will be determined in Spring 2007. The spacecraft filter is 3 Angstroms in width. A filter assembly will be sent to all interested stations later in 2007 to allow each station to determine if its laser meets the requirements.
3. The laser pulsewidth must be less than 8 nanoseconds.
4. The transmitted pulse time stamp accuracy must be maintained within 100 nanoseconds of UTC.
5. The system must measure the relative laser time of fire to better than 200 picoseconds (1 sigma) shot-to-shot over a 10 second period. Laser fire times must be recorded to better than 100 picosecond resolution.
6. The system should deliver at least one laser pulse to the LOLA earth window per second. The laser fire rate cannot exceed 28 Hz.
7. A shot to shot measurement of the output laser energy is desirable.
8. Data should be delivered to CDDIS in new ITDF (simple ASCII format) no slower than daily.

Most ILRS systems should have no problem meeting these requirements.

Other requirements will include coordination with the mission so that coverage can be limited to a single station at a time (at least initially), and reporting so that the mission knows ahead of time which stations will be participating each day.

Operational Considerations

The period of the LRO orbit is approximately 2 hours. The orbit is polar and precesses so that at times the entire 2 hour orbit will be visible from earth. Due to the constraints on the HGA pointing, however, only ~1 hour out of each 2 hour orbit will be available for earth ranging, no matter what the orbital orientation is.

Predictions for LRO will be generated in CPF format. Code for non-earth orbiting satellites will be made available to all ILRS stations by Randy Ricklefs later this year [Ricklefs].

Feedback will be provided from LOLA in its housekeeping telemetry which will be delivered in semi-real-time from the spacecraft, through the LOLA Science Operations Center (SOC), to CDDIS. LOLA will be performing signal processing on the data in the earth window and should be able to recognize earth laser pulses that are fired synchronously to LOLA at 14 or 28Hz. Laser fire rates of 5 and 10 Hz will not be recognized by LOLA, however, the website, <http://lrolr.gsfc.nasa.gov>, will contain other information as well (possibly a Go-NoGo flag), so participating stations should check it when ranging to LRO.

The flow of all of the data for LRO-LR is shown in Figure 3.

Stations interested in participating as a ground station for LRO-LR are invited to contact the authors or Michael Pearlman (mpearlman@cfa.harvard.edu).

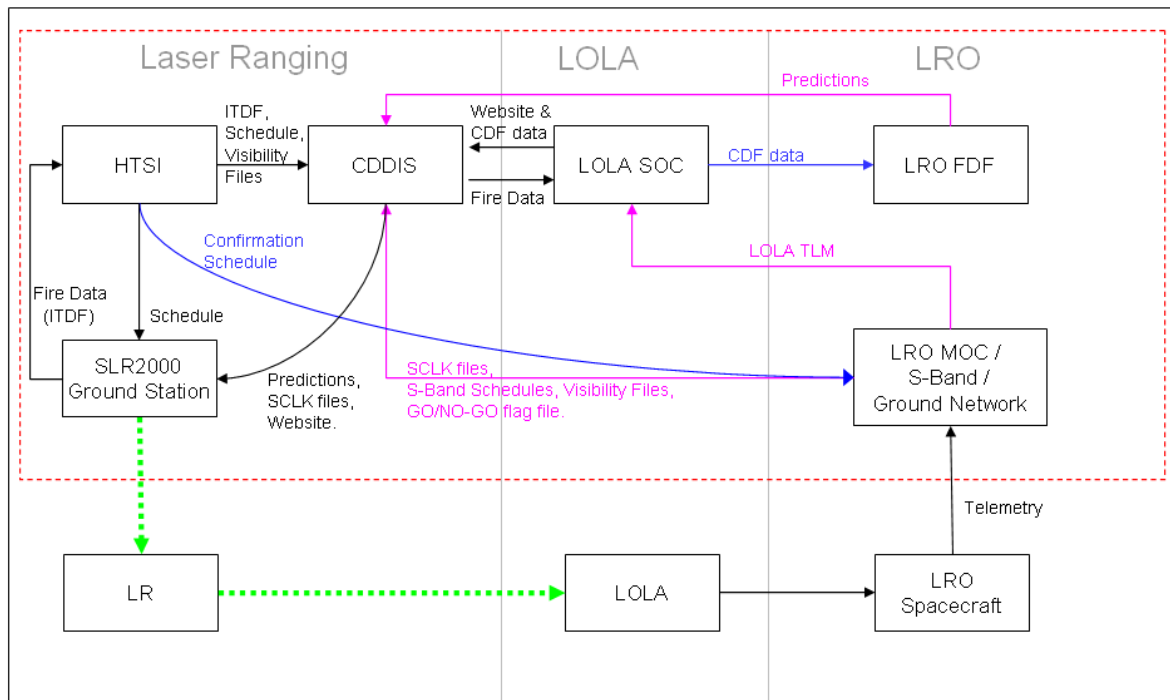


Figure 3: LRO-LR data flow block diagram.

References

- [1] McGarry, J., and T. Zagwodzki, "SLR2000: The Path Toward Completion," in this Proceedings.
- [2] Ricklefs, R., "Consolidated Laser Prediction and Data Formats: Supporting New Technology", in this Proceedings.