Call of Participation

Lunar Reconnaissance Orbiter Laser Ranging (LRO-LR) Experiment

Mission Objectives:

The Lunar Reconnaissance Orbiter (LRO, http://lunar.gsfc.nasa.gov/), scheduled for launch in April 2009 will support future human exploration of the Moon, while providing information about the physics of the moon and its surface. One of the principle instruments on board LRO is a laser altimeter (LOLA) to measure the topography of the lunar surface. The mission is expected to last about one year, and the measurements from all of the LRO instruments will include:

- Characterization of deep space radiation in lunar orbit
- Geodetic global topography
- High spatial resolution hydrogen mapping
- Temperature mapping in polar shadowed regions
- Imaging of surface in permanently shadowed regions Identification of near-surface water ice in polar cold traps
- Assessment of features for landing sites
- Characterization of polar region lighting environment

Mission Instrumentation:

LRO will have the following on-board instrumentation:

- Lunar Orbiter Laser Altimeter (LOLA)
- Lunar Reconnaissance Orbiter Camera (LROC)
- Lyman-Alpha Mapping Project (LAMP) telescope
- Lunar Exploration Neutron Detector (LEND)
- Diviner Lunar Radiometer Experiment (DLRE)
- Cosmic Ray Telescope for the Effects of Radiation (CRATER) detector
- Radar technology demonstration (mini-RF)

The LOLA science objectives are to determine:

- Topography of the Moon to an accuracy of +/- 1 meter with .1 meter resolution;
- Surface slopes in 2 directions to better that 0.5 degrees on a 50 meter scale;
- Surface roughness to 0.3 meters;
- Surface reflectance of the Moon at 1065 nm to ~5%;
- Establish a global geodetic coordinate system; and
- Improve knowledge of the lunar gravity field.

Laser ranging will significantly enhance the ability to achieve the LOLA science objectives

Laser Ranging Operations:

With the participation of laser ranging stations on the Earth, the LRO Laser Ranging (LRO-LR) system will provide one-way range measurements to an optical receiver package aboard the lunar orbiting spacecraft. In addition to the role that laser ranging will play in the LRO mission, it is also a fundamental step toward the development of transponder ranging for the SLR network.

An artist's conception of the LRO spacecraft in orbit about the Moon is shown below.

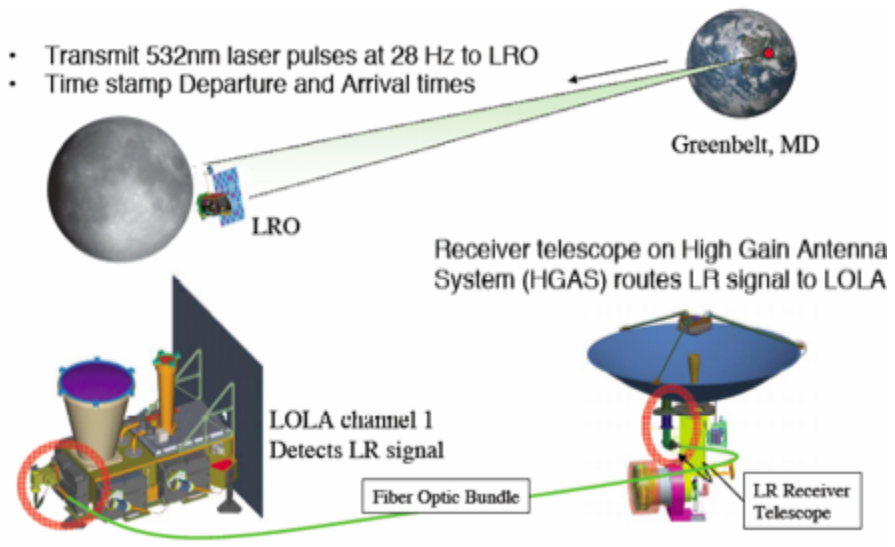

Figure 1: *The on-board LRO-LR system consists of a 2 cm aperture receiving telescope located on the LRO High Gain Antenna, and a fiber-optic link from the telescope to one of the LOLA receive channels. LOLA, which operates at 28 Hz, has an 8 ms Earth range window in which to receive laser pulses transmitted from Earth. An on-board filter restricts the received Earth laser wavelength to 532.20 ± 0.15 nm. LOLA time tags the arrival of Earth laser pulses in LRO Mission Elapsed Time (MET), and transmits that time to the LOLA Science Operations Center (LOLA SOC) via the LRO real-time RF link. Participating laser ranging stations will forward their fire times to the HTSI operations center, which will pass that information to CDDIS for retrieval by the LOLA SOC. The LOLA SOC combines the fire times with the LOLA Earth window receive times to calculate the one-way range measurement.*

SLR stations may operate in either of two modes. In the first mode, stations will transmit at 28, 14 or 7 Hz, synchronized to arrive at the spacecraft within the 8 ms Earth range window. Stations will be required to accurately set their firing times according to project provided predictions and to use the mission supplied SCLK files to convert UTC to spacecraft mission elapsed time (MET) in order to ensure arrival of the laser pulses within the LOLA earth window. Near real-time (nominally within 10-20 seconds) feedback through the RF link will provide stations with notification of likely successful events.. The LOLA onboard signal processing algorithm will perform a once per second analysis of the earth window data to determine if it is “seeing” ground laser events. The algorithm data will be placed on a CDDIS Web site for all participating laser ground stations to access.

In the second mode, stations will transmit asynchronously. All returns that arrive within the Earth range window will be forwarded for match up with firing times at the LOLA SOC . The second mode requires less precision in operations, but will give lower data yield (10 hz asynchronous operation will give 2 – 4 events in the LOLA earth window per second). In no case may ranging operations exceed 28 Hz, as it will adversely affect the LOLA threshold loop. In this mode, signal processing information will most likely not be available from LOLA, but LOLA receive energies will be plotted on the website to aid in the determination of acquisition.

The Goddard Flight Dynamics Facility (FDF) will be producing predictions for LRO in the ILRS CPF format. Stations will track open-loop on assigned transits. Although we anticipate only a few vulnerable periods for the satellite (during on orbit calibration), there will be periods of scheduled and/or unscheduled LRO events where the range window will not be available, therefore participating stations must follow the ILRS restricted tracking requirements. A Go/NoGo flag will be provided by the LRO mission and will be accessible through ftp and the feedback Web site. Stations must implement the Go/NoGo control software and demonstrate its operational assurance prior to participation. .

A visible transit of LRO will take approximately 1 hour. Stations will be requested to schedule for full transits, without interruption. Stations should plan for several transits per week. Initially, only one station will operate per transit. As we build experience with the data, any problems with pass overlap should be overcome, and simultaneous operations will be scheduled. Scheduling will be coordinated by the LRO Mission Operations Center (MOC). LRO schedules will not be subject to deviation. Stations will be able to attempt ranging at all or none of the station-specific scheduled times, but will NOT have the freedom to attempt at times outside of the scheduled window.

The laser ranging data will be consolidated to provide 1 Hz relative range measurements to the spacecraft at 10cm precision. The combination of S-band, laser ranging, and LRO science data will be used to produce a gravity model with sufficient accuracy to calculate the spacecraft position to within 50 m along track, 50 m cross track, and 1 m radial. Laser ranging data will improve the determination of the LRO position to sub-meter accuracy with respect to the Earth and the center of the Moon, and knowledge of the lunar gravity field.

Ground System Requirements:

General:.

- Delivered energy at the spacecraft: 1 - 10 femtoJoules per sq.cm; (e.g. 30mJ per pulse for 10 arcsec laser divergence through a standard clear atmosphere);
- Wavelength: 532.2 +/- 0.15 nm;
- Pulse width maximum: 8ns;
- Accuracy of transmitted pulse time stamp: <100 ns of UTC;
- Relative shot-to-shot interval knowledge over a 10 sec period: <200 ps (1 sigma);
- Resolution of recorded time of each shot: <100 psec resolution;
- Deliver laser pulses into the LRO Earth window at least once per second
- Maximum laser firing rate: 28 Hz

- Shot to shot measurement of the output laser energy desirable;
- Data delivery: to CDDIS in new ILRS CRD format within 12 hours,

Additional Requirements for the Synchronous Mode:

- Synchronous stations MUST get their laser events into the LOLA Earth Window or risk compromising the LOLA onboard threshold settings. Stations must make use of the latest SCLK file from the MOC and their own laser fire delays to calculate their firing times, and the actual laser fire (not the commanded!) must be within 1 millisecond of the calculated fire time.

Data Archive:

The CDDIS is the Satellite Laser Ranging data repository and one of two interfaces to the International Laser Ranging Service stations around the world. The CDDIS will provide the data conduit for the ground stations as well as archiving the data and hosting the feedback Web site.

Coordinated Global Station Testing

Stations will be required to demonstrate their preparedness for the mission by taking part in a coordinated global LRO-LR test period prior to launch. During this test, predictions and schedules will be delivered via CDDIS, and stations will fire their lasers as if they were ranging to LRO, recording laser fire times in CRD format, and sending this information back to HTSI.

Agreement:

An agreement will be signed between NASA and the responsible agency for the station in which NASA agrees not to make any claims against the Station, station contractors or subcontractors, or their respective employees for any LRO damage arising from these ranging operations, whether such damage is caused by negligence or otherwise, except in the case of willful misconduct.

Key Contacts:

Principle Investigators:	Dr. David Smith/GSFC (David.E.Smith@nasa.gov)
(LOLA & LRO-LR)	Prof. Maria Zuber/MIT (zuber@mit.edu)
Ground Station Technical Contact:	Jan McGarry/GSFC (jan.mcgarry@nasa.gov)
Data Center (CDDIS)	Carey Noll/GSFC (carey.noll@nasa.gov)
LRO-LR Instrument Scientist:	Dr. Xiaoli Sun/GSFC (xiaoli.sun-1@nasa.gov)
LOLA Science Team contacts:	Dr. Gregory Neumann/GSFC (Gregory.A.Neumann@nasa.gov)
	Dr. Frank Lemoine/GSFC (Frank.G.Lemoine@nasa.gov)
	Mark Torrence/GSFC (Mark.H.Torrence@nasa.gov)
ILRS Contact for LRO-LR:	Dr. Michael Pearlman/SAO (mpearlman@cfa.harvard.edu)

Call for Proposals:

The NASA LRO-LR Project solicits proposals from established ILRS laser ranging stations to participate in the LRO-LR ranging activity.

Schedule:

- Issue of Call: May 12, 2008
- Proposals due: Jun 30, 2008 (extended to Nov 30, 2008)
- Evaluation and selection: July 28, 2008 (extended to Dec 30, 2008)
- Preliminary Station Testing: August 2008 (moved to January 2009)
- Coordinated Global Station Testing: September 2008 (now Feb thru Mar 2009)
- Participants meeting: October 2008 Workshop in Poznam

Submission: Proposals should be sent to:
Jan McGarry
NASA GSFC, Code 694
Greenbelt MD 20771

Questions regarding the proposal should be directed to:
Jan.McGarry@nasa.gov
Mark.H.Torrence@nasa.gov
mpearlman@cfa.harvard.edu

Please send your intent to propose to the above emails by May 30th.

Proposal Content:

1. A statement of interest and intent to participate;
2. A description of your timing system and the laser fire measurement;
3. A statement on the planned readiness of the ranging system including the implementation of the Go/No-Go software;
4. A statement of which mode you plan to operate, and your station characteristics for ranging to LRO (laser energy, pulsewidth, divergence, wavelength, and firing rate, and an estimated absolute pointing accuracy);
5. If operating in synchronous mode, a description of how you will control your laser fire;
6. A description of how your station satisfies or will satisfy the requirements above including a link calculation of the anticipated signal energy density and peak power at the LRO aperture;
7. A description of your prediction and scheduling cycle;
8. Your plan for integrating the new CRD data format into your station operation;
9. A statement on your level of commitment to the tracking schedule.

If there are certain aspects of the requirements that a station cannot meet, we would like to try to accommodate wherever possible, so please send in a proposal, indicating where you are having problems meeting the requirements.

Proposal Evaluation:

The project seeks the widest possible participation from stations that can meaningfully contribute. Stations may join after the program begins as they build and demonstrate capability.

Proposal will be evaluated by the LRO-LR team and stations will be notified by early January 2009.