Laser Ranging to the Lunar Reconnaissance Orbiter (LRO): a Global Network Effort

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Lunar Reconnaissance Orbiter (LRO) – Laser Ranging (LR) Overview

Sub-network of ILRS will support LRO for one-way laser ranging

- Transmit 532 nm laser pulses at <= 28Hz to LRO
- Time stamp departure times at ground station
- Event arrival times recorded by LOLA
- Compute relative 1-way range to LRO from the two pieces of data

LRO Mission Includes:

- LOLA, laser altimeter
- LROC, camera
- LAMP, Lyman alpha telescope
- LEND, neutron detector
- DIVINER, thermal radiometer
- CRATER, cosmic ray detector
- mini-RF, radar tech demo
ILRS Station Participation

- NGSLR is primary ground station for LRO-LR
- MLRS is participating as part of NASA network
- Three other ILRS stations have submitted responses to “Call for Participation”:
  - Herstmonceux
  - Zimmerwald
  - Mt Stromlo
- Other stations have expressed interest in participation:
  - Wettzell
  - Matera
  - Grasse

- We are working on a modification to the MOBLAS systems to allow MOBLAS-5 and MOBLAS-6 to participate.
One LOLA Detector does both Earth and Lunar

- Two range windows in one detector: fixed 8 msec earth and up to 5 msec lunar.

- Range to LRO changes ~ 5-10 ms over an hour’s visibility.

- Need to either synchronize the ground laser fires to LOLA to ensure pulses land in every Earth Window, or fire asynchronously to LOLA (eg 10Hz).

Start of LOLA laser fire period (T0) | LOLA laser fires (~ 9ms after T0) | Start of next LOLA laser fire period

- EARTH RANGE WINDOW (8 m s)
- LUNAR RWIN (5 m s)

35.7 msec (28 Hz)
Ground Station Characteristics

- Station fire rate and probable events per second in LOLA Earth Window with system configurations as we currently understand them:

<table>
<thead>
<tr>
<th>Station</th>
<th>Synch?</th>
<th>FireRate</th>
<th>in Earth Window</th>
<th>Energy per pulse at LRO</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGSLR</td>
<td>YES</td>
<td>28Hz</td>
<td>28</td>
<td>2 to 5</td>
</tr>
<tr>
<td>MLRS</td>
<td>NO</td>
<td>10Hz</td>
<td>2 to 4</td>
<td>4 to 12</td>
</tr>
<tr>
<td>Zimmerwald</td>
<td>YES</td>
<td>28Hz</td>
<td>28</td>
<td>2 to 10</td>
</tr>
<tr>
<td>Herstmonceux</td>
<td>YES</td>
<td>7 or 14Hz</td>
<td>7 or 14</td>
<td>1 to 3</td>
</tr>
<tr>
<td>Mt Stromlo</td>
<td>YES</td>
<td>28Hz</td>
<td>28</td>
<td>3 to 14</td>
</tr>
<tr>
<td>MOBLAS</td>
<td>NO</td>
<td>5Hz</td>
<td>1 to 2</td>
<td>1 to 2</td>
</tr>
</tbody>
</table>

Requirement: between 1 – 10 femtoJoules per square centimeter at LRO and between 1 and 28 events per second in LOLA Earth Window.

- Stations that can deliver energy densities of > 10 fJ/cm² or peak power of > 0.07 mW/cm² at LRO will need to modify their configuration. This will be worked out prior to predictions being available.
Input Data Files and Data Products

- Predictions (CPFs) generated by GSFC Flight Dynamics Facility (FDF):
  - Use same as for Earth orbiting satellites, except that
  - These predictions are already point-ahead (no extra point-ahead calculation should be performed)
  - Accuracy: < 4 km (3D, 3 sigma)

- SCLK file relates spacecraft time to UTC for synchronous firing.

- Go/NoGo file. Set NoGo during Earth Cals, Reboosts & Emergencies.

- Data product from station is CRD with following information:
  - Firetimes with accuracy of < 100 nanosec, and mean inter-arrival time knowledge error of less than 200 picosec over a 10 sec period.
  - Weather information.

- Data product from LOLA Science Team will contain ranges generated from combining ground fires and corresponding spacecraft events.

- All data products will be hosted on CDDIS.
Laser Ranging Network Block Diagram

**Laser Ranging**
- HTSI
- CDDIS
- Laser Fires
- Tracking Schedule

**LOLA**
- LOLA SOC
- Predictions, Go/NoGo, SCLK
- All incoming & outgoing LR data, plus Laser Fires & website.

**LRO**
- LRO FDF
- LRO Predictions
- LRO MOC / S-Band / Ground Network

**Ground Stations**
- Predictions, Go/NoGo, SCLK

**LR Flight Segment**
- Laser Fires

**Ground Systems**
- Data inputs to LR-GS
- Data outputs from LR-GS

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- Laser
- Data Flow
Real-time Feedback from Spacecraft

- Website: http://lrolr.gsfc.nasa.gov hosted on CDDIS.
- “Real-time” spacecraft telemetry display will be password protected.
- Delay from “real-time” will be between 10 – 30 seconds.
- Stations can use display to determine if their fires are being detected at LRO/LOLA, and where their pulses are falling in the Earth Window.
- Synchronously stations can use website to modify their fire times, if desired:
  - to move their returns earlier in LOLA Earth Window (pulse arrivals earlier in the window have a higher probability of detection because this is a single stop receiver)
  - to “scan” if LRO/LOLA is not detecting their pulses
Real-time telemetry website
Station Scheduling and Testing

- **Ground station scheduling**
  - Stations will be given suggested tracking times from LRO
  - At first only a single station will be scheduled at any given time
  - Eventually as many as 3 station may be scheduled together
  - Multiple stations will make LRO-LR website use more challenging

- **Global network testing**
  - Fake LRO orbital predictions placed on CDDIS
  - Schedules will be delivered with period to fire
  - Participating stations will be asked to fire using LRO predictions for at least 15 minutes and to send fire data in CRD format
  - Fake LRO pass data will be displayed on website
  - Results of test will be posted to CDDIS
Schedule of Events

➤ Need to discuss system configuration for stations that can deliver > 0.07mW/sqcm: November 2008.

➤ Remaining stations interested in participating turn in proposals by December 2008.

➤ Agreements between stations and LRO project signed: Dec 2008.


➤ Testing of MOBLAS modifications at MOBLAS-7: Jan 2009.

➤ MOB-5 and MOB-6 make modifications and join testing: Feb 2009.


➤ LR operations ~ June 24, 2009.
SUMMARY

- Laser Ranging to LRO supports the LOLA Science Team’s generation of an improved lunar gravity model.

- The more stations participating and the better the global coverage, the faster the gravity model can be generated.

- This will be the first time the ILRS will participate in transponder ranging, and the first ranging to a satellite orbiting the moon.

- If you would like to participate in this ground-breaking mission, please send us your proposals:
  - Jan.McGarry@nasa.gov
  - Mark.H.Torrence@nasa.gov
  - Carey.Noll@nasa.gov
  - mpearlman@cfa.harvard.edu

Thanks to those stations who have agreed to participate!!!