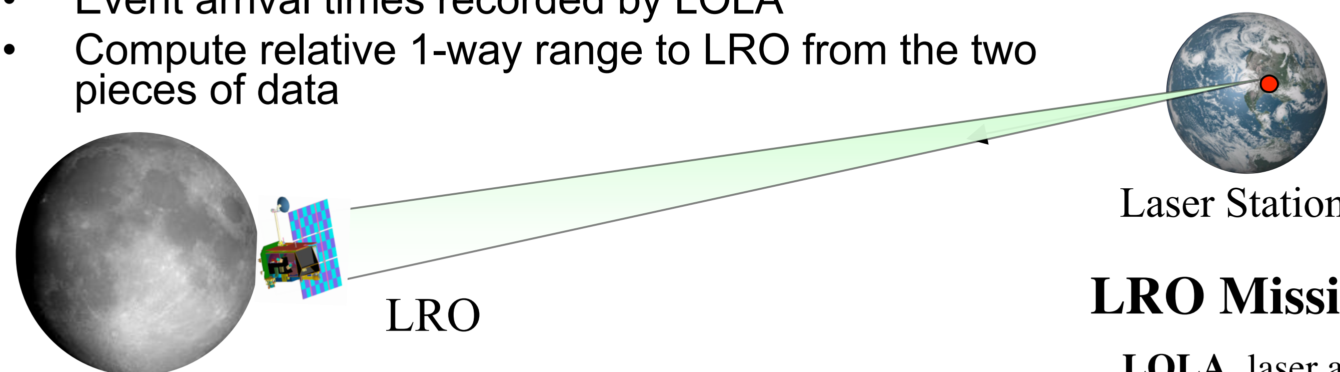
# Lunar Reconnaissance Orbiter (LRO) – Laser Ranging (LR) Overview

## LRO is requesting ILRS support 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

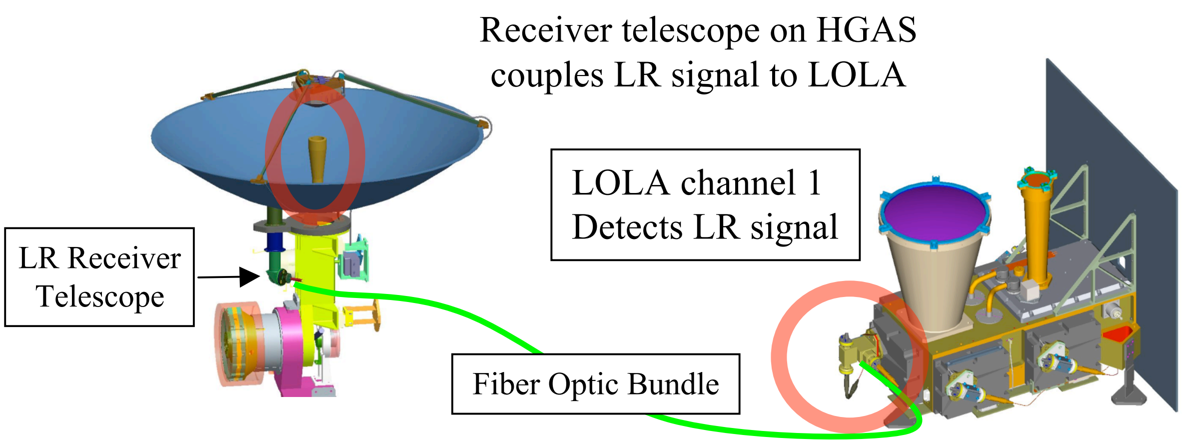
**LAMP,** Lyman alpha telescope

**LEND,** neutron detector

**DIVINER,** thermal radiometer

**CRATER,** cosmic ray detector

**mini-RF,** radar tech demo



# Laser Ranging Overview

- LR will support the precision orbit determination process that will, in conjunction with S-band tracking and LOLA altimetry, enable improved positioning of LRO and improvements to the lunar gravity field model.
  - 25 to 50 meter positioning of LRO in horizontal position over both lunar near and far side
  - Improve instrument targeting

- LR will provide 1-way range measurements between earth station(s) and LRO to better than 10cm precision.
  - SLR2000 transmits laser pulses at 532.2 nm synchronized to the LOLA instrument operating cycle of 28 Hz.
  - Participating ILRS stations transmit asynchronously (eg MLRS at 10 Hz).
  - LOLA detects the LR signals and transmits this information and receive energies in the LOLA telemetry packet for “real-time” feedback to stations.
  - LOLA SOC generates range data from ground station fire times and LOLA receive events.

# LRO-LR Status at SLR2000

- Laser for LRO installed and aligned
- Laser beam expander and laser attenuator build in progress
- Aircraft avoidance RADAR installed and boresighted with telescope
- Operational tracking/ranging software modified to handle LRO requirements. Software testing in progress.
- Data flow path (from SLR2000 and MLRS through to CDDIS and LOLA SOC) has been automated and successfully tested.
- Predictions from FDF are in testing by LR GS team (supported by LOLA Science Team).
- Earth Ranging tests are being performed as part of LOLA hardware checkout.

# Ground System Requirements

• Deliver between 1 and 10 femtoJoules per sq.cm of signal to the receiver aperture.  For SLR2000 (55 microrad  laser divergence) ➔ 30mJ per pulse.

• Wavelength must be 532.2 +- 0.15 nm.   LRO filter throughput will be 50% at 532.05 and 532.35 nm (many ILRS stations fall within this wavelength region).

• Laser pulsewidth =< 8ns (onboard system bandwidth is ~6ns).

• Maintain the transmitted pulse time stamp accuracy to within 100 ns of UTC.

• Measure the relative laser time of fire to better than 200 ps (1 sigma) shot-to-shot over a 10 sec period.   Laser fire time must be recorded to <100 psec resolution.

• Deliver laser pulses into the LOLA earth window at least once per second. Laser fire rate cannot exceed 28 Hz because it will affect LOLA threshold!

• Shot to shot measurement of the output laser energy is desired.

• Data should be delivered to CDDIS in new CRD format daily (or faster).

# Operational Considerations

• LRO orbit is nominally 50 km, polar, with 2 hour period.  Orbital velocity is 1.6 km/sec.  LRO is on near side of moon ~ 1 hour out of every two.

• LRO MOC requires knowledge (1 week in advance) of which stations will be ranging and when.  Scheduling will be coordinated by HTSI (Horvath). Schedule for LRO ranging will also be sent back to all the participating stations.

• Predictions will be in new CPF (generated by FDF at NASA/GSFC) and will be provided only to participating stations.

• Fire times should be sent in new CRD format to CDDIS.

• CDDIS will host website which will contain real-time LOLA Telemetry and other pertinent information for stations:  http://lrolr.gsfc.nasa.gov

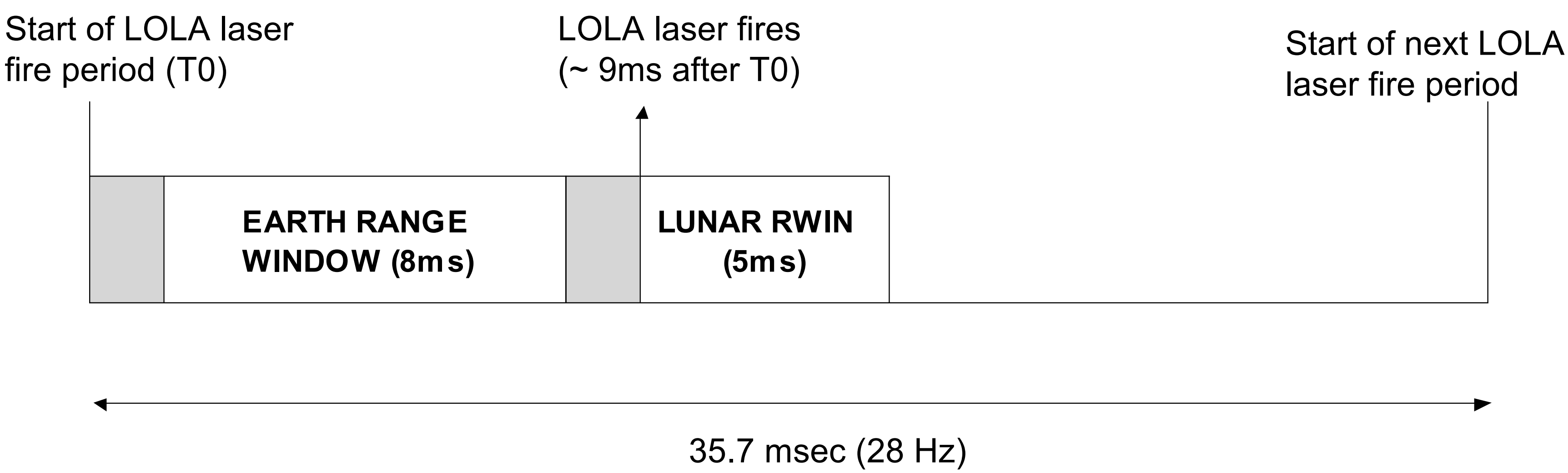
• Still working the Go/No-Go flag issue.

# 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.

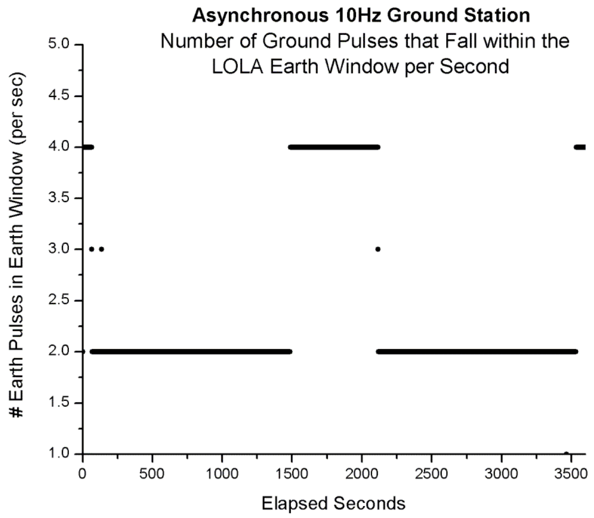
- Need to either synchronize the ground laser fires to LOLA to ensure pulses land in every Earth Window, or fire asynchronously to LOLA (eg 10Hz).



# Getting Pulses into the LOLA Earth Window

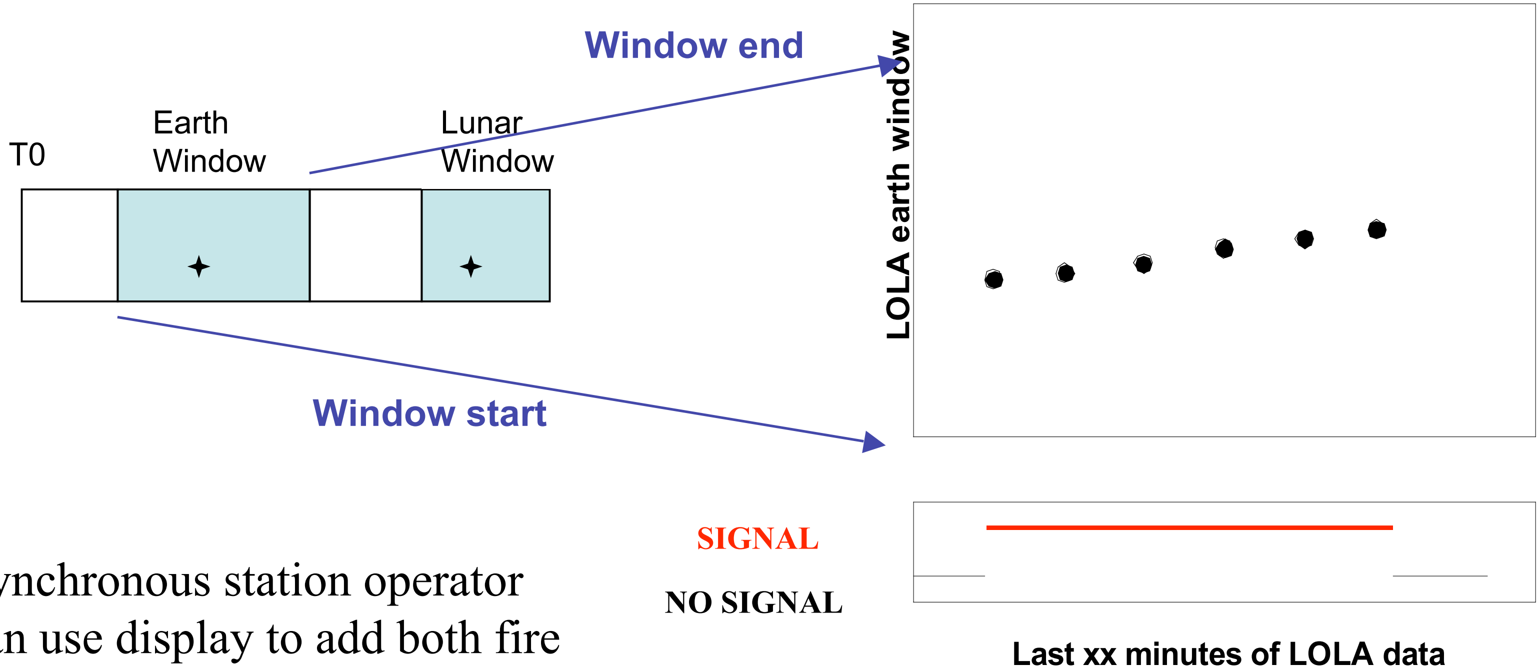
- **Method #1 (SLR2000): synchronize to LOLA**
  - -Must compensate for range changes (5-10 msec per hour).
  - -Knowledge of UTC to spacecraft MET will be good to < 3 msec.
  - -Start of LOLA fire interval (35.7 ms) is sychronized to MET.
  - -LOLA earth window opens 1.0 msec after start of fire interval.
  - -LOLA earth window is open for 8 msec.

- **Method #2: run asynchronous to LOLA but at a fire rate that ensures at least one pulse per second into the earth window.**
  - -Ground system fire rate of 10Hz ensures 2-4 pulses per second get into the earth window.
  - -No control of laser is needed.



# Website Feedback from LOLA

- LOLA onboard algorithm determines if it sees earth pulses and if so it estimates the earth pulse event time.
- Each dot represents estimate over one second of time.
- If synchronous fire control is in the LOLA Earth Window the dots will form a straight line with small slope.
- Onboard algorithm will probably not be able to pick out asynchronous ground laser fires but LOLA SOC ground processing software can.
- Receive energies will also be sent down in real-time telemetry.




Synchronous station operator can use display to add both fire time bias to control laser fire.

# SUMMARY

- ➢ Additional stations ranging to LRO can shorten time to an improved lunar gravity model. The wider the global coverage the better.

- ➢ LOLA SOC is expected to be able to handle multiple stations ranging to LRO at same time – but global coordination (scheduling) will need to be performed.

- ➢ Please join us in the first operational ILRS Transponder Ranging.

- ➢ Contacts:
  - – ILRS contact for LRO-LR: Mike Pearlman
  - – Ground station technical questions: Jan McGarry
  - – LRO Project PIs: Dave Smith (NASA/GSFC), Maria Zuber (MIT)
  - – Instrument Scientist for LRO-LR: Xiaoli Sun (NASA/GSFC)