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

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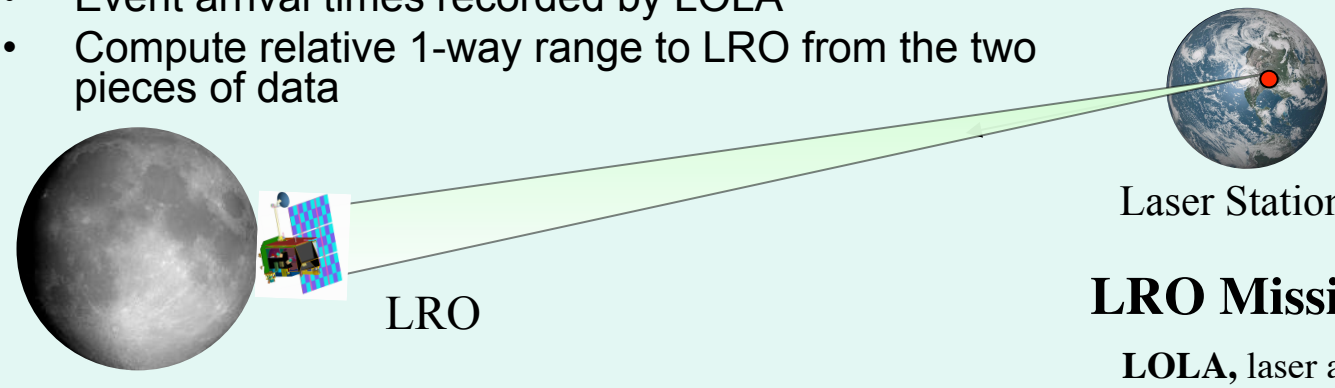
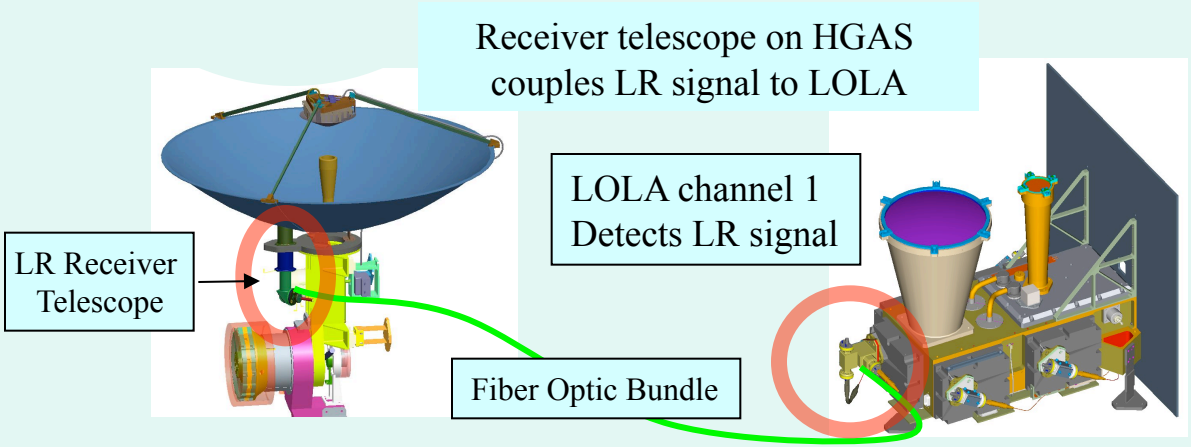
Lunar Reconnaissance Orbiter (LRO) – Laser Ranging (LR) Overview

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

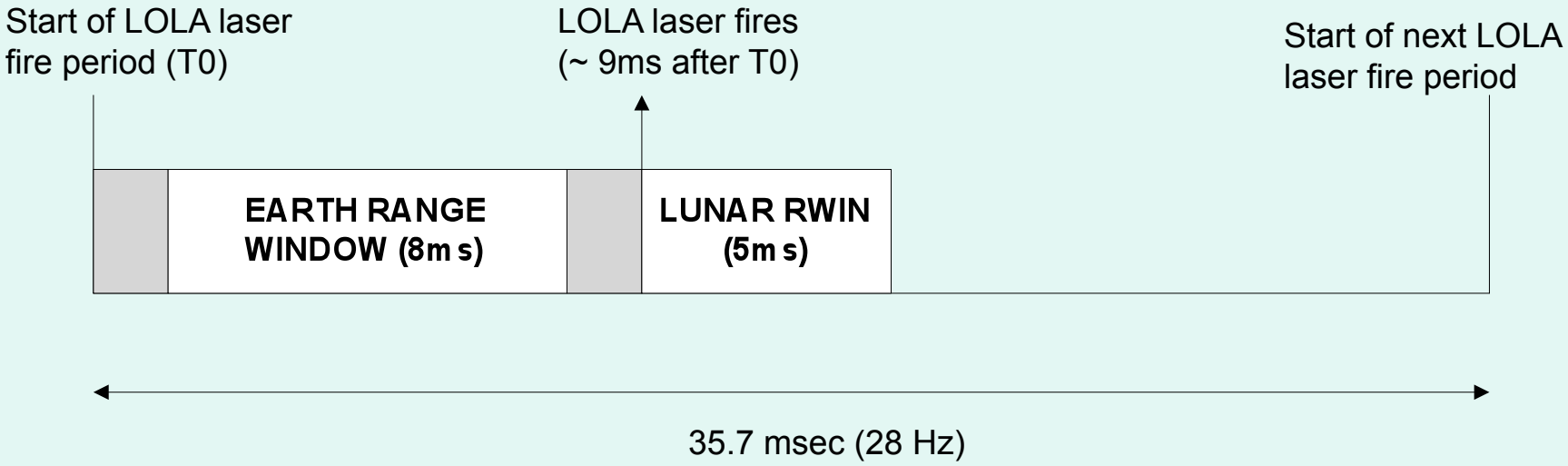
- We are working on a modification to the MOBLAS systems to allow MOBLAS-5 and MOBLAS-6 to participate.

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).



Ground Station Characteristics

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

	Synch?	FireRate	Events/second in Earth Window	Energy per pulse at LRO fJ/cm^2
NGSLR	YES	28Hz	28	2 to 5
MLRS	NO	10Hz	2 to 4	4 to 12
Zimmerwald	YES	28Hz	28	2 to 10
Herstmonceux	YES	7 or 14Hz	7 or 14	1 to 3
Mt Stromlo	YES	28Hz	28	3 to 14
MOBLAS	NO	5Hz	1 to 2	1 to 2

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/cm^2 or peak power of > 0.07 mW/cm^2 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.

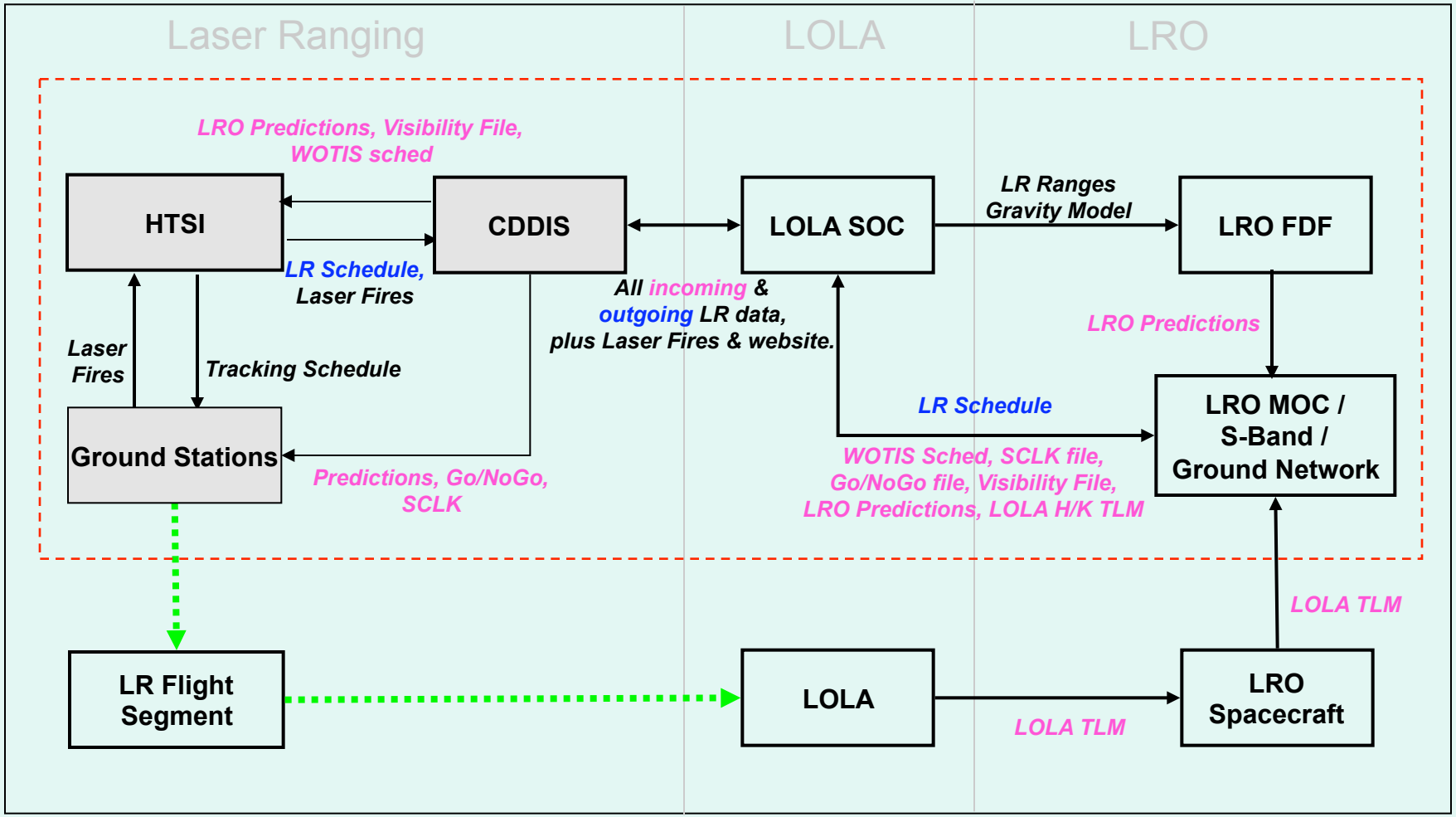
- Go/NoGo file. Set NoGo during Earth Cals, Reboosts & Emergencies.

- 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



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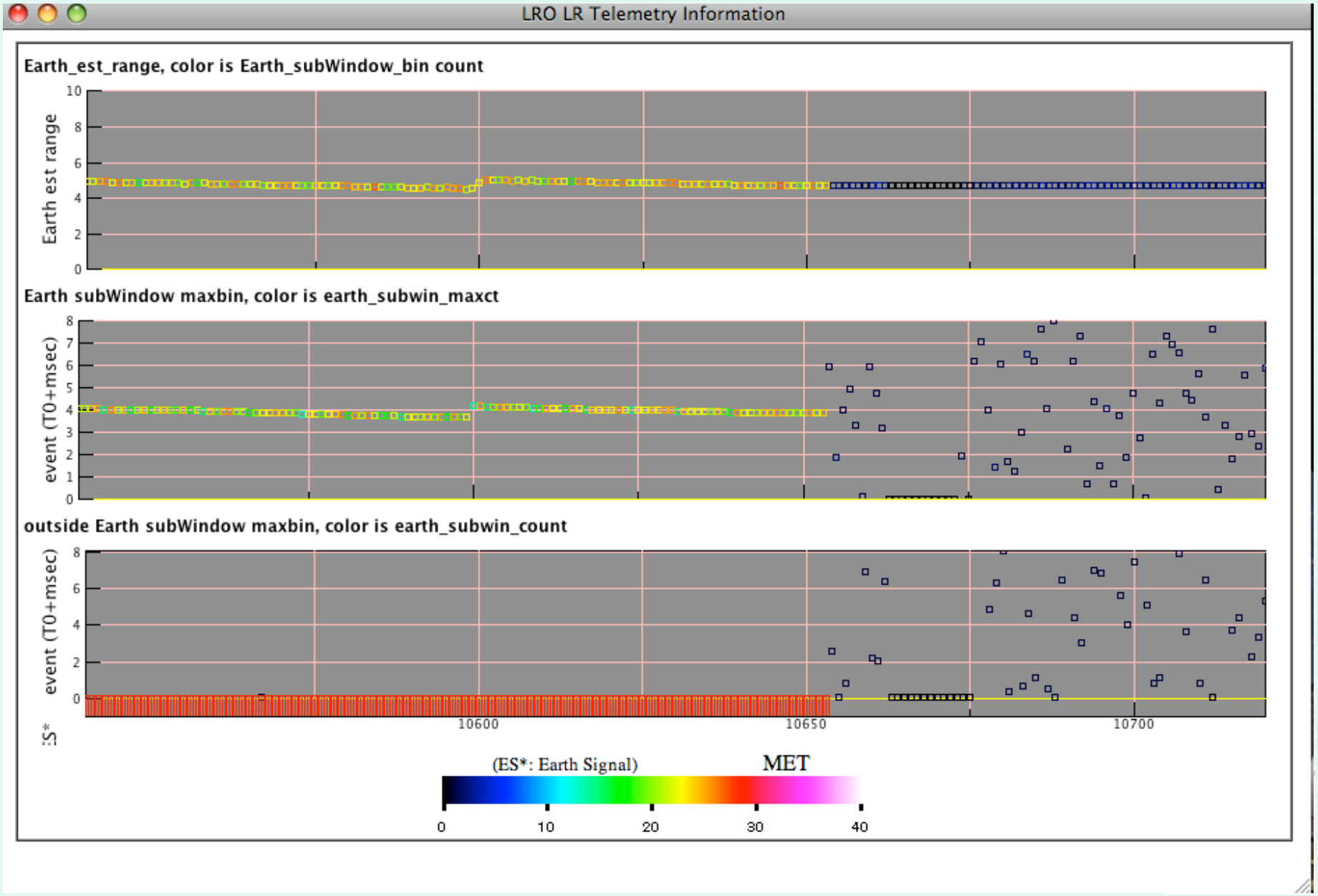
Real-time Feedback from Spacecraft

- 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.
- Global Network Testing: January through April 2009.
- Testing of MOBLAS modifications at MOBLAS-7: Jan 2009.
- MOB-5 and MOB-6 make modifications and join testing: Feb 2009.
- LRO launch April 24, 2009. Commissioning May 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:**

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