

# **NGSLR: Sharing Eye-safe Kilohertz SLR with Transponder Ranging**

**Jan McGarry, Tom Zagwodzki  
NASA Goddard Space Flight Center**

**Tom Varghese, Cybioms**

**John Degnan, SigmaSpace**

**Don Patterson, Bart Clarke, Tony Mann  
Honeywell Technology Solutions Incorporated**

**Jack Cheek, Peter Dunn, Tony Mallama  
Raytheon Information Systems**

**Randy Ricklefs, University of Texas**



# NGSLR 2khz Current Configuration

- Laser per pulse energy: 60 microjoules at telescope exit in 37cm diameter beam (eyesafe).
- Pulsewidth: ~ 300 picosec.
- Pulse repetition rate: variable from 2.0 khz to 1.96 khz. Switches between rep rates to prevent collision between fires and returns.
- Laser divergence: nominally 4-5 arcsec. Can modify this as needed. Less than 4 arcsec setting often used for LAGEOS.
- Telescope pointed behind, Risleys used to point laser beam ahead.
- Quadrant MCP: High Quantum Efficiency (~32%) Hamamatsu model R4110U-74-M004C.
- Discriminators with threshold setting nominally  $< 1/2$  single PE voltage.
- Receiver FOV: night: 25 arcsec, daylight: 11 arcsec.
- Mount pointing: ~ 1 arcsec. Starcal RMS:  $< 2.5$  arcsec.



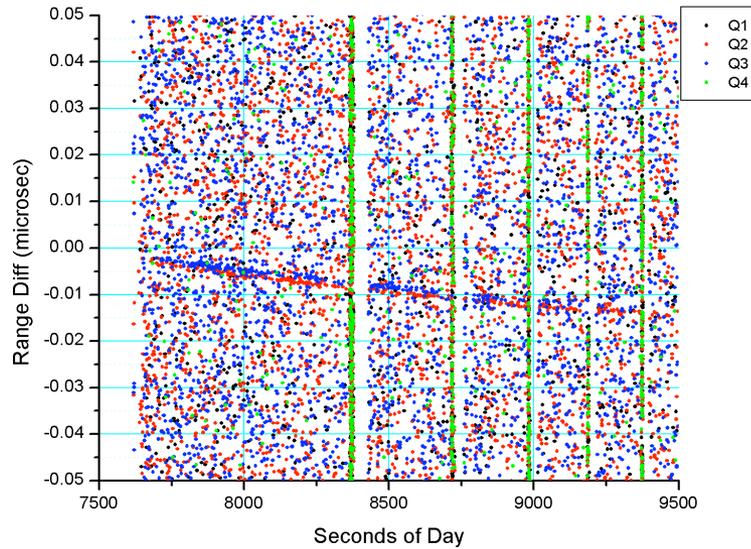
# Eyesafe 2khz Laser Ranging: Status

- Regularly ranging to LEOs and LAGEOS. LAGEOS returns are mostly above 30 deg elevation. Can range down to ~ 10 deg on LEOs.
- Have successfully ranged to GLONASS-95 (at high elevation).
- Problems with blanking are understood and we are working to resolve.
- Daylight operations just starting. Risley point-ahead issues had to be resolved before we could close the receiver FOV.
- Starcal automated. Operator currently required for laser ranging. Automation for ranging being worked.
- New I/O chassis allows us to more easily switch between ground calcs and satellites.
- New laser in development at GSFC by D.Coyle. Will give us ability to change rep rate from 1 Hz to 2khz, and to change energy from eyesafe to milliJoule level. Should allow ranging to GPS.

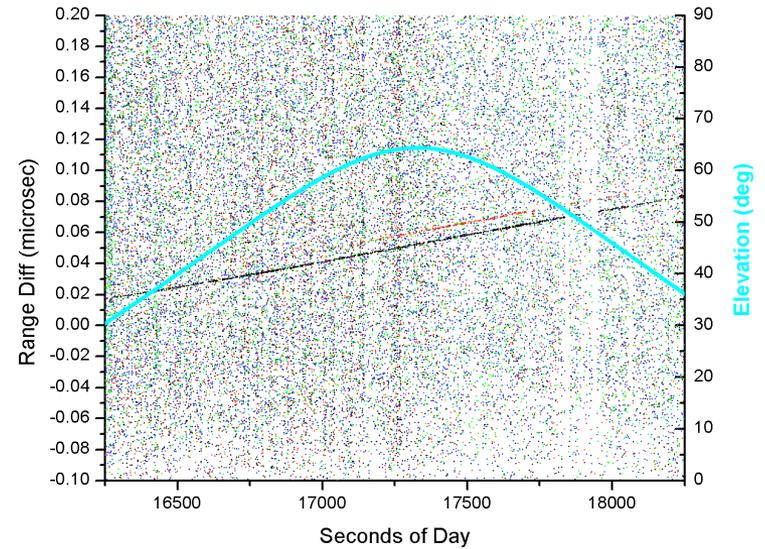


# Satellite Tracking with Eyesafe Laser

GLONASS95 - 01/31/2008

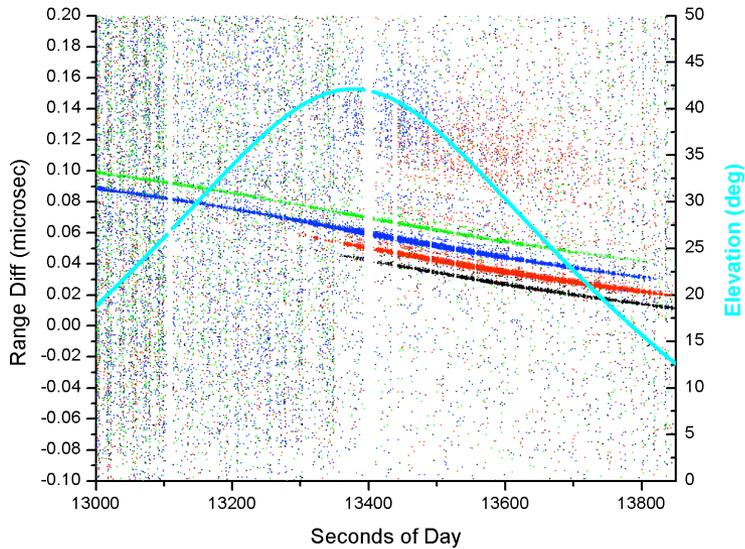


LAGEOS 8/22/2008

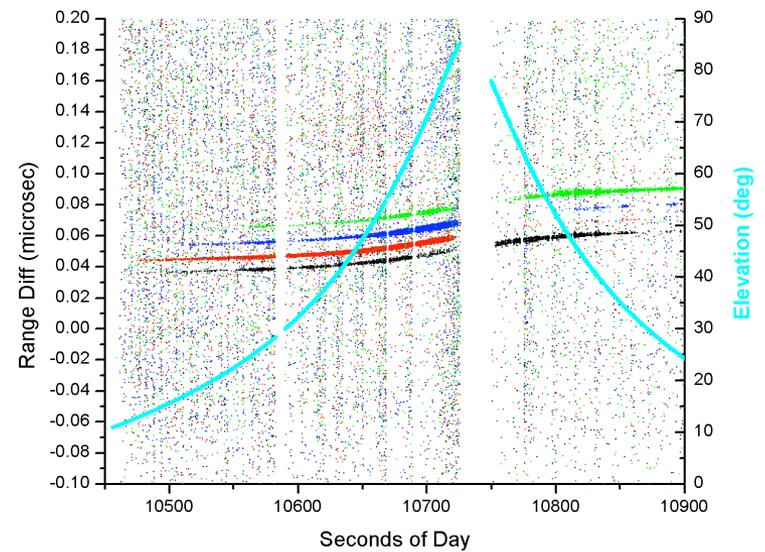


Different colors represent returns from different quadrants

AJISAI 9/24/2008



LARETS 9/24/2008



# Eyesafe 2khz Ranging: Remaining To Do

- Ground calibration: return rate is critical for accurate determination of the system delay. Need to come up with operational scheme for ensuring  $< 10\%$  return rate in quadrants.
- Detector quadrants are proving difficult to normalize and remain stable. Need to resolve this to do angular bias determination (needed for full automated ranging). Spot size on detector is important and it appears we have had too small an image. Center of detector may be showing signs of loss of sensitivity. Currently investigating sensitivity and have increased image size.
- Need to complete operator training (sharing 3 operators between MOB-7 and NGSLR).
- Want to complete collocation with MOBLAS-7 before LRO launch.
- Application for membership in ILRS will be completed in coming months.



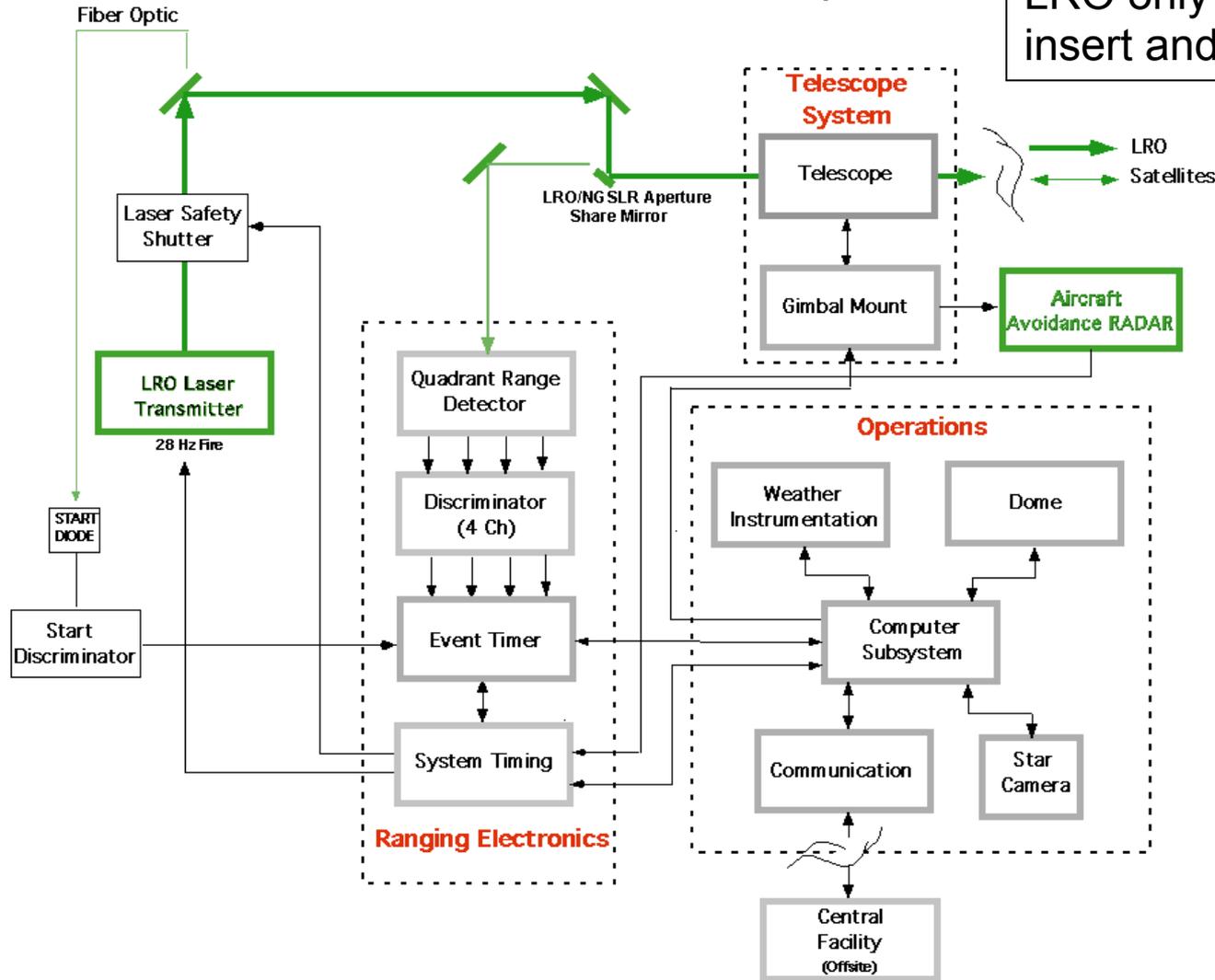
# Accommodating LRO-LR

- 50 milliJoule, 28 hz Northrup-Grumman laser added to system (532.2 nm wavelength, 6 nanosec pulsewidth).
- Removable kinematic mirror mount added to launch LRO transmit beam, and ensure easy transition between SLR and LRO lasers.
- Aircraft avoidance radar added to system (LRO laser not eyesafe).
- I/O chassis added to provide single toggle switch between SLR and LRO in the electronics.
- Cesium added to system to provide 10 Mhz ext. trigger to Event Timer.
- Same start diode, Event Timer and RGG used for both SLR & LRO.
- Modifications added to software to support LRO: more precision in fire-time recording, control of laser to hit Earth Window, automated processes removed, recorded all fires, and CRD added as output.



# NGSLR Block Diagram for LRO Operations

NGSLR BLOCK DIAGRAM for LRO Operations



Switching between SLR and LRO only requires one mirror insert and one switch toggled



# Operations During LRO-LR

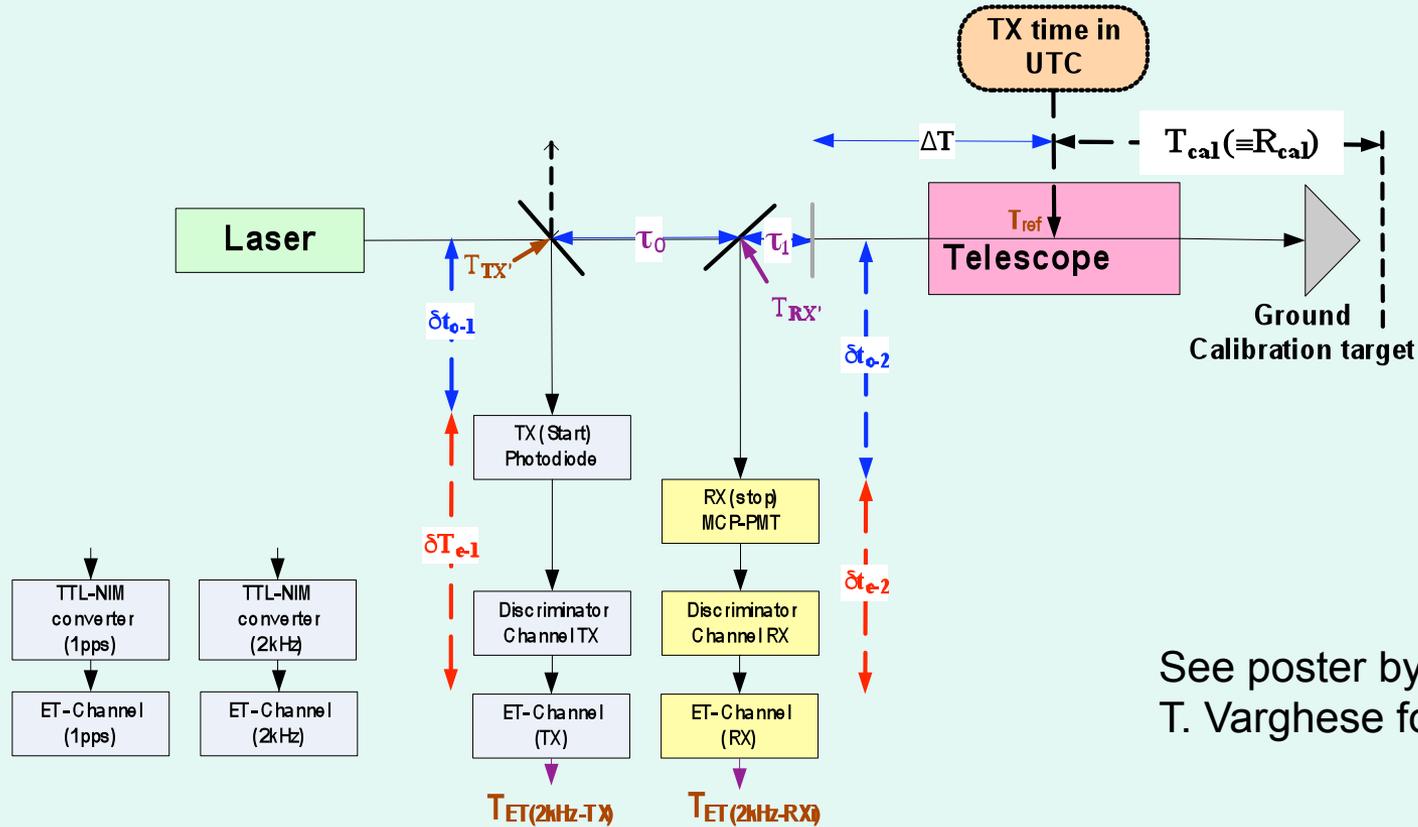
- Two-shift operation at NGSLR for ~ 1 year from launch.
- 4 days a week, 10 hours per day per person. Shifts will move with lunar visibility (~ 1 hour per day).
- LRO is on near side of moon 1 hour out of every two. Ranging to LRO will occur whenever LRO is on near side of moon and moon is above 20 deg. Operations will switch back to SLR during off hours.

## Remaining To Do at NGSLR for LRO

- Complete one-way system delay determination.
- Complete independent timing verification tests with LRO-LR Instrument Scientist.



# One-way System Delay



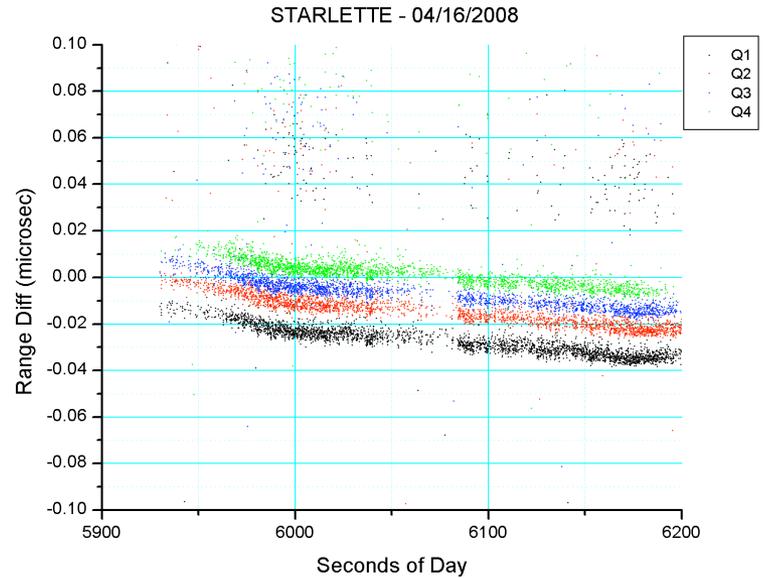
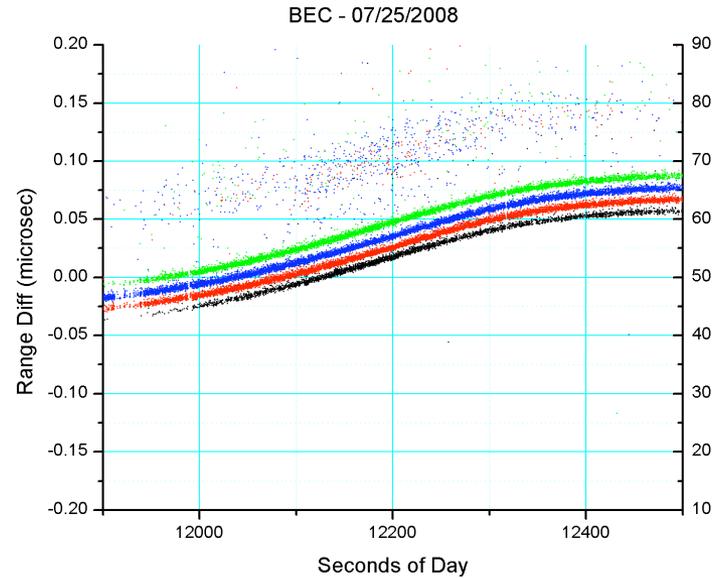
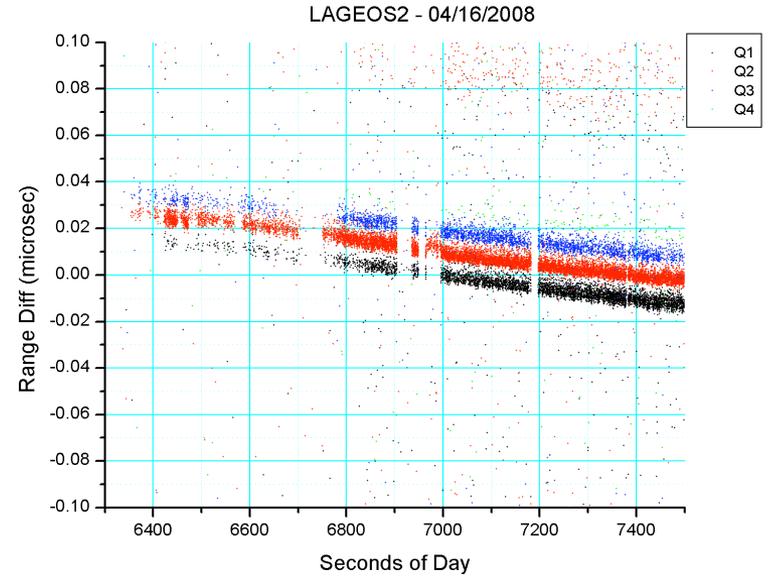
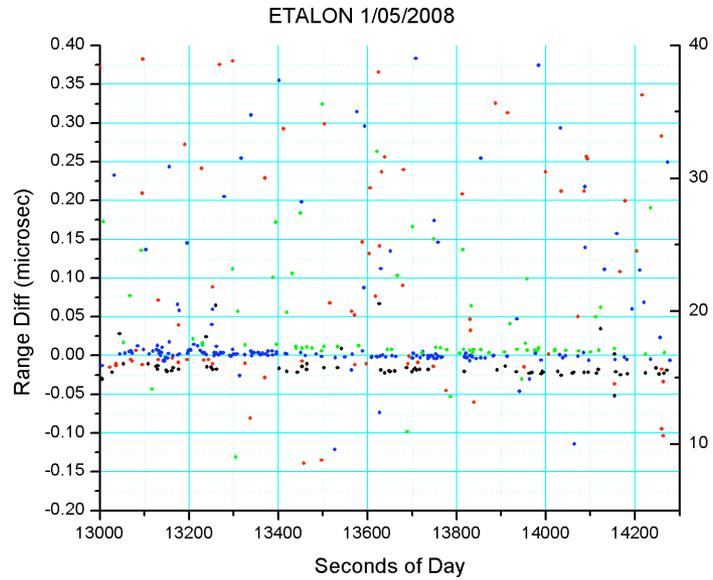
See poster by  
T. Varghese for details

$$\Delta T = (1/2) \{ \Delta T_{ET(2kHz-RX2)} - \Delta T_{ET(2kHz-RX1)} - 2T_{survey} \}$$

$$T_{REF} = T_{ET(2kHz-Tx)} - \delta t_{o-1} - \delta T_{e-1} + \tau_0 + \tau_1 + \Delta T$$



# Satellite Tracking with LRO Laser



# Summary

- Eyesafe ranging even at kilohertz rates has proven difficult, but is now close to being operational.
- Collocation is expected by the end of the year.
- New 2khz laser should be ready by spring 2009. Test with preliminary version of laser expected in November 2008.
- Completion of ranging automation will go on in parallel with making the system operational for SLR.
- NGSLR is basically ready for LRO operations, with only a single test remaining, and the completion of the one-way system delay determination.
- LRO launch is now 4/24/2009. Laser ranging to LRO will be for at least one year. SLR tracking will coexist with LRO-LR operations.

