Pre-Launch Testing of NGSLR Ranging to LRO

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Goal of LRO Laser Ranging

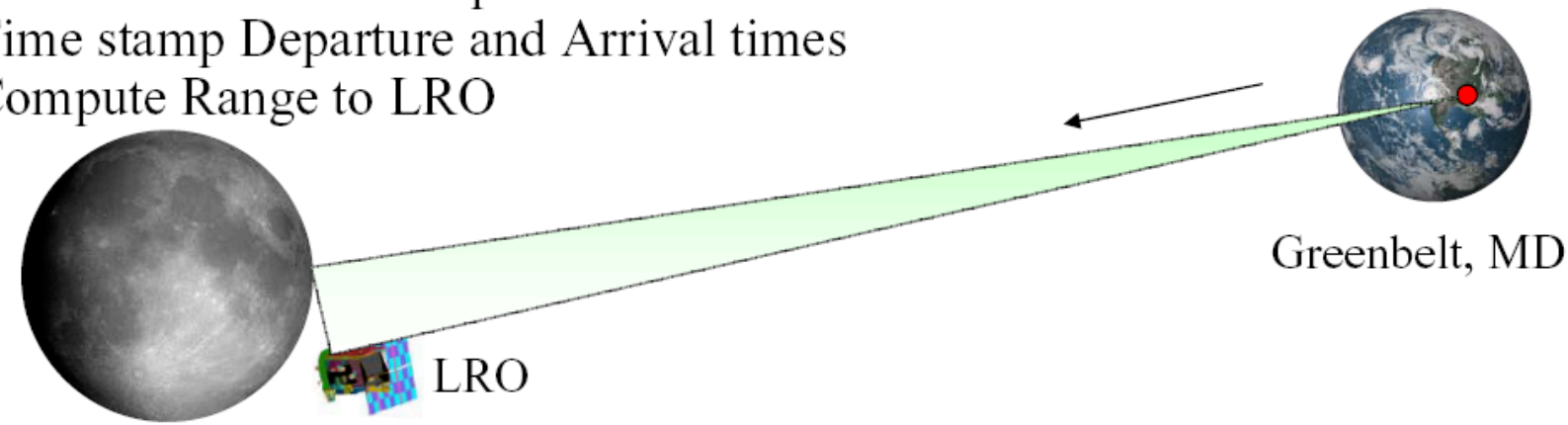
- Generate a precise LRO orbit
- Derive an improved lunar gravity field
- LRO orbit will be the reference for data from the Lunar Orbiter Laser Altimeter (LOLA) instrument
- LOLA provides high accuracy surface mapping

NGSLR to LRO Laser Ranging

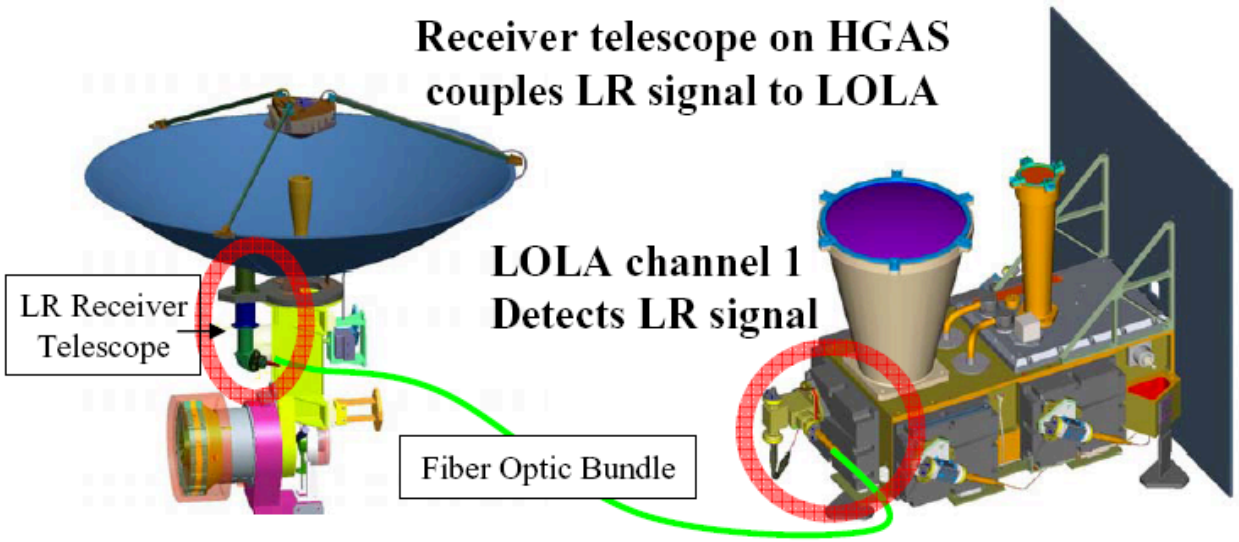
- Laser is 28 Hz, 50 milli-Joule, 532 nm
- Laser Ranging receiver telescope on High Gain Antenna
- Fiber optic bundle carries photons to LOLA receiver
- LOLA 28 Hz duty cycle has separate time windows for Earth and Moon pulses

NGSLR to LRO Laser Ranging

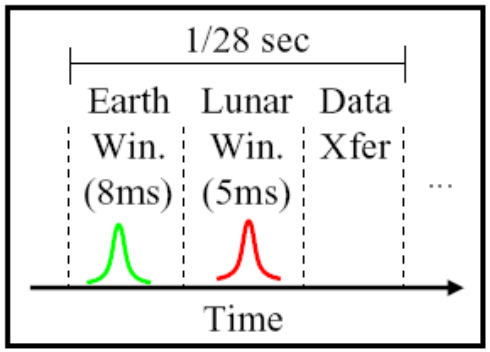
- Transmit 532 nm laser pulses at 28 Hz to LRO
- Time stamp Departure and Arrival times
- Compute Range to LRO



Receiver telescope on HGAS couples LR signal to LOLA



LR Timeshares LOLA Detector With Lunar surface returns



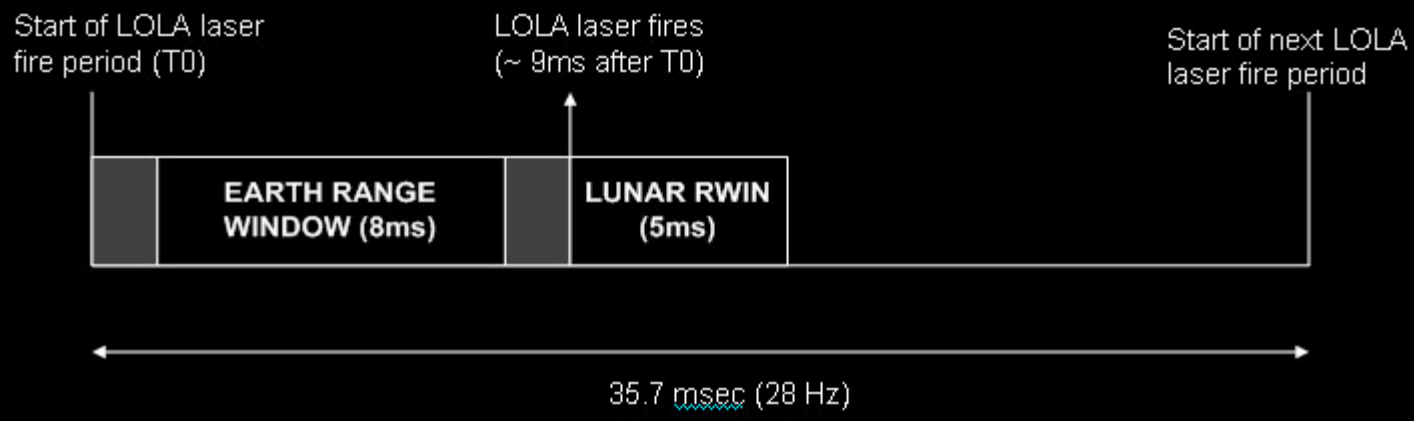
Testing Overview

- NGSLR testing program has 137 elements
- 19 are specific to LRO
- There are 4 general categories of LRO tests:
  1) Telescope must accurately point to LRO
  2) LRO is scheduled as highest priority target
  3) NGSLR software is correctly modified for LRO
  4) Laser fire is correctly controlled and measured

Tests Summarized in this Presentation

- Laser pulses arrive at the LR receiver during the LOLA Earth window
- Laser fire offset and frequency can be manually controlled
- Telescope pointing is correct and accurate

Laser pulses arrive at the LR receiver during the LOLA Earth window



Laser pulses arrive at the LR receiver during the LOLA Earth window

Considerations for hitting the Earth window

- Modulo of time on spacecraft clock with 1 / 28 second must be 5 +/- 1 milliseconds
- SCLK file relates terrestrial time and spacecraft time
- MET = spacecraft time - offset
- Light-time of NGSLR-to-LRO range

Laser pulses arrive at the LR receiver during the LOLA Earth window

SCLK File:

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\begindata

SCLK_KERNEL_ID             = ( @2008-06-27/20:37:49.00 )

SCLK_DATA_TYPE_85          = ( 1 )
SCLK01_TIME_SYSTEM_85      = ( 2 )
SCLK01_N_FIELDS_85         = ( 2 )
SCLK01_MODULI_85           = ( 4294967296 65536 )
SCLK01_OFFSETS_85          = ( 0 0 )
SCLK01_OUTPUT_DELIM_85     = ( 1 )

SCLK_PARTITION_START_85    = ( 0.0000000000000E+00 )

SCLK_PARTITION_END_85      = ( 2.8147497671065E+14 )

SCLK01_COEFFICIENTS_85     = (

    0.0000000000000E+00     3.1579264184000E+07     1.0000000010000E+00
    1.5485503275008E+13     2.6786929218400E+08     1.0000000010000E+00 )

\begintext
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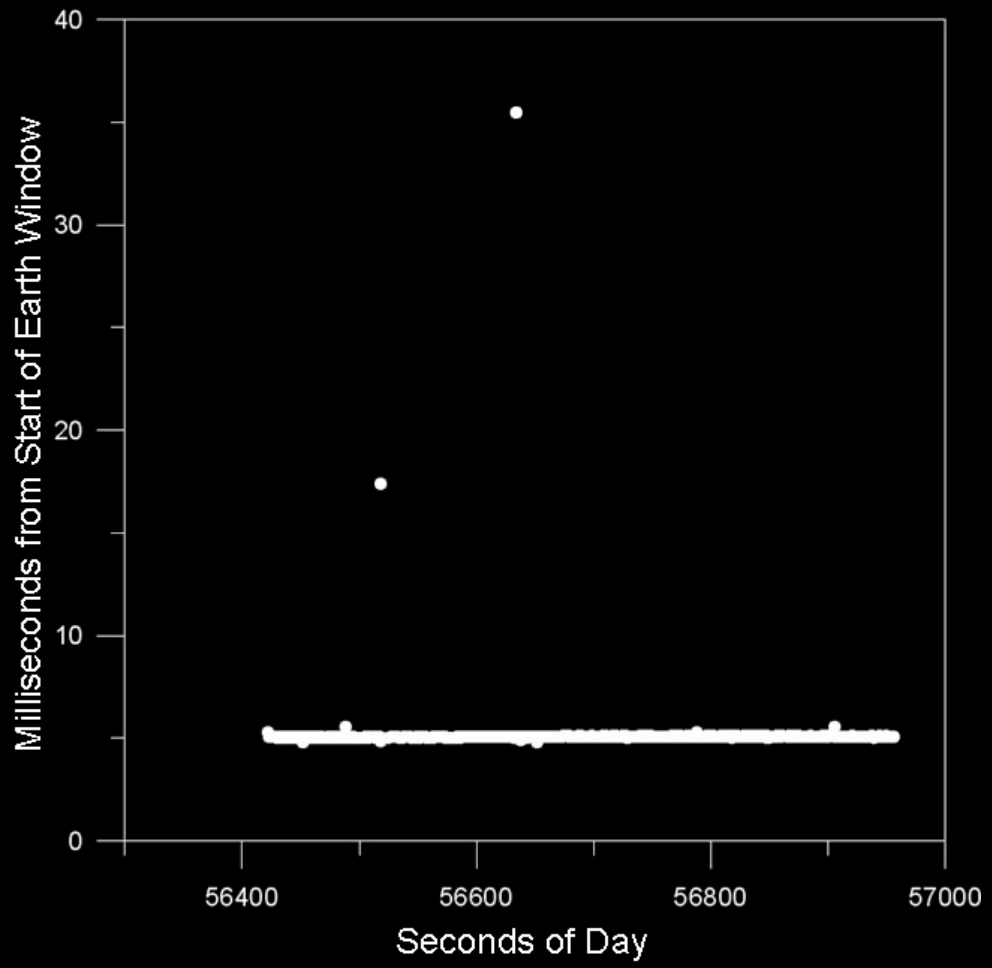
Ticks *Seconds* *Rate*

Laser pulses arrive at the LR receiver during the LOLA Earth window

Determine the fractional part of MET seconds:
Convert UT to ET
Find the interval for the ET in the SCLK file
(ET = 0 corresponds to epoch of J2000)
Delta ET = ET – Seconds at start of interval
Delta Ticks = Delta ET / Rate at start of interval
Add Delta Ticks to Ticks at the start of interval
Spacecraft seconds = Ticks / 65536 (nominal rate)
Subtract the Offset
Add the NGSLR-to-LRO range
Take the modulus with 1 / 28 second

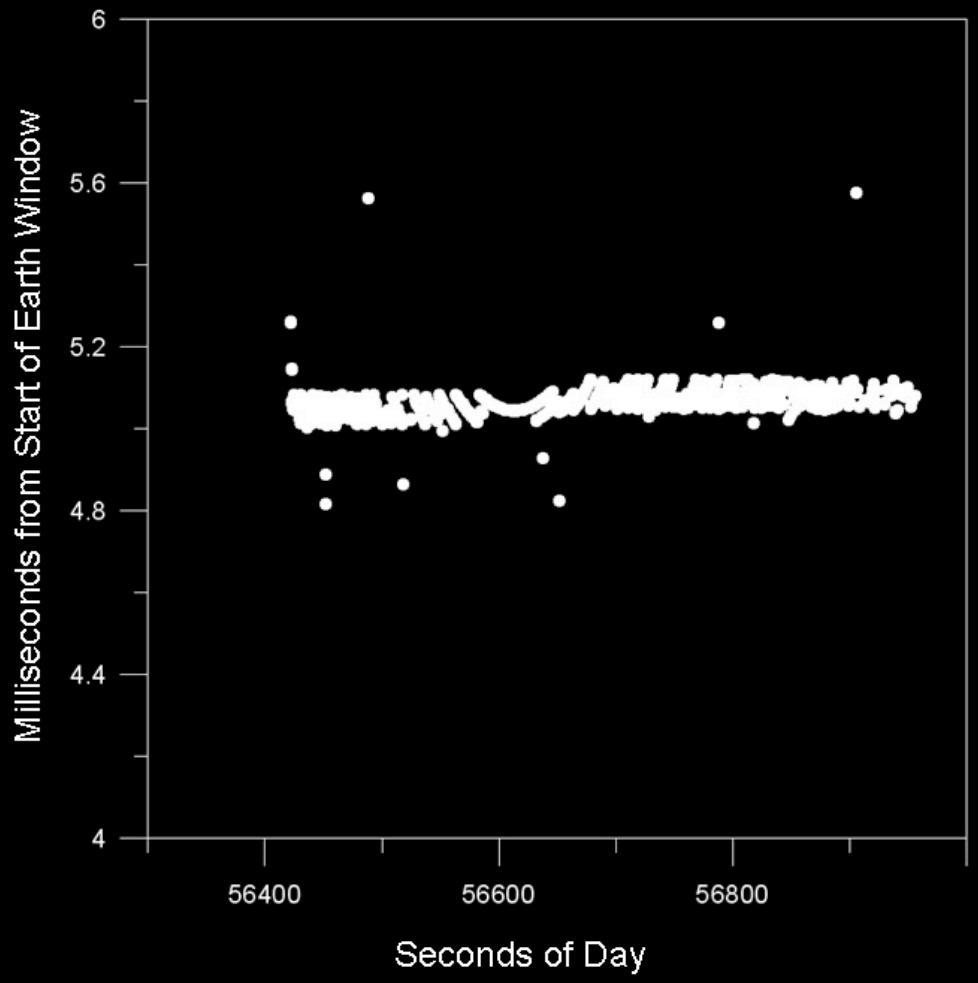
Laser pulses arrive at the LR receiver during the LOLA Earth window

99.9% are within
5 +/- 1 msec.



Laser pulses arrive at the LR receiver during the LOLA Earth window

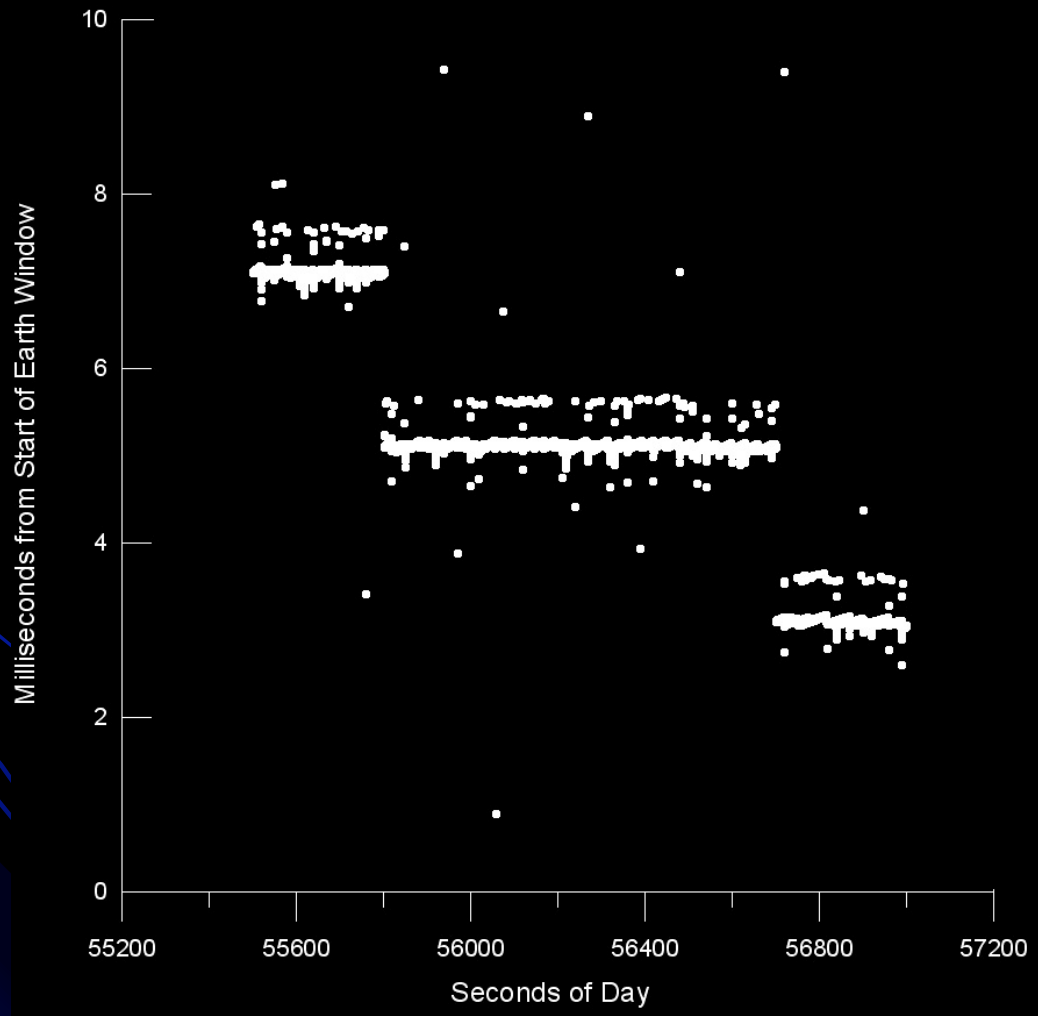
99% are within
5.0 +/- 0.1 millisecond



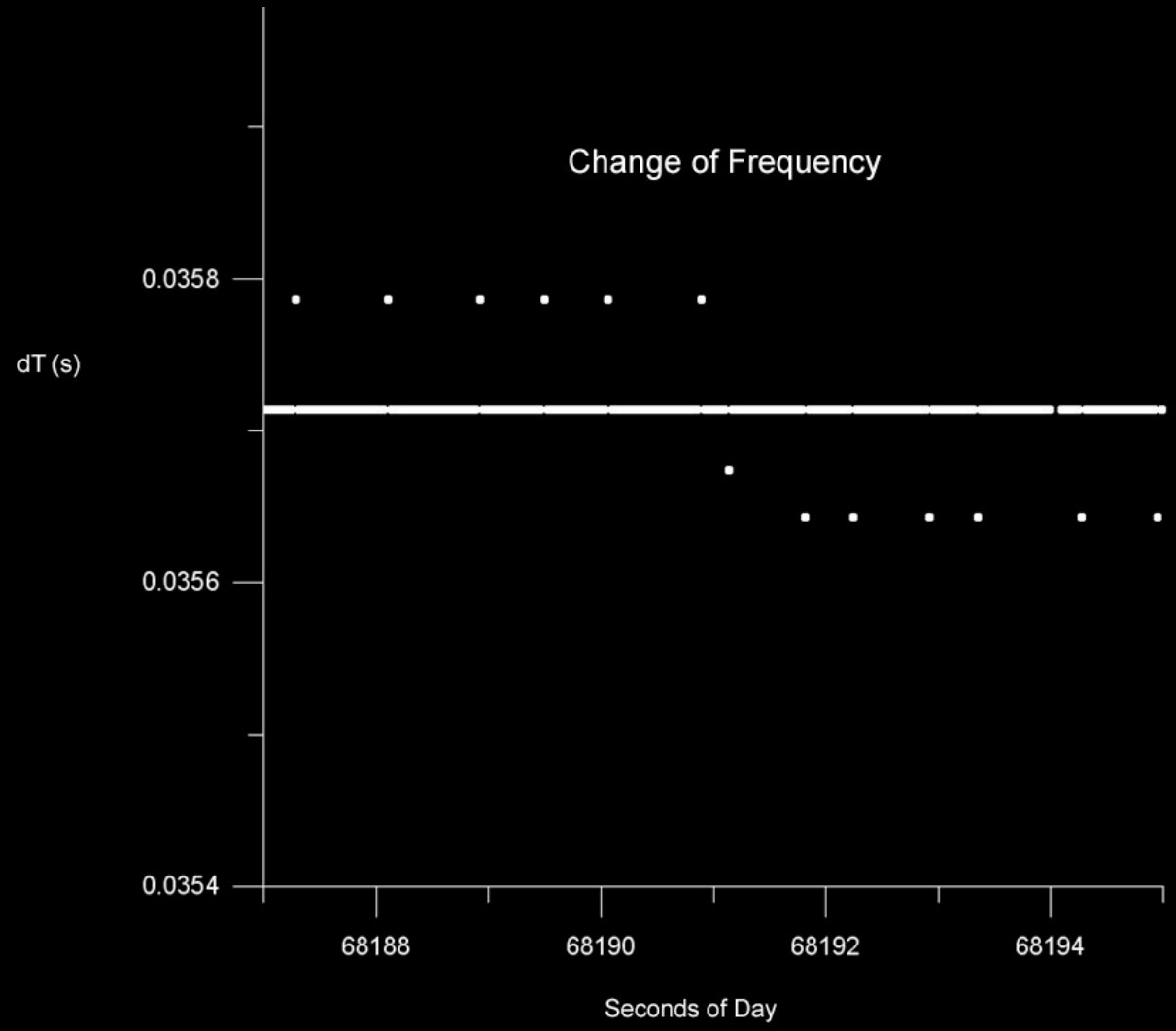
Laser fire offset and frequency can be manually controlled

- Command offsets from -35.7 ms to +35.7 ms
- Command frequency changes of +/- 100 us/s
- Analyze commanded recorded fire times
- Compare commanded and measured offsets and frequencies

Laser fire offset and frequency can be manually controlled



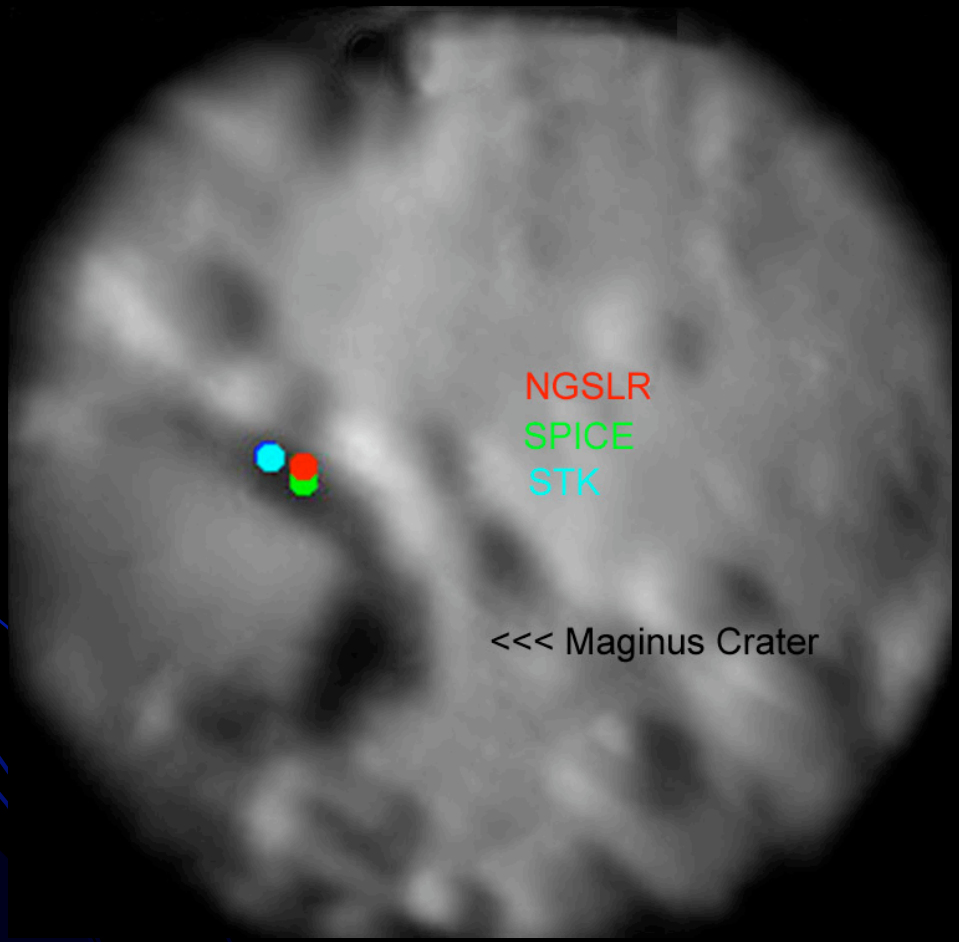
Laser fire offset and frequency can be manually controlled



Telescope pointing is correct and accurate

- Simulated an LRO pass
- Used NASA Flight Dynamics Facility predictions
- Acquired images of Moon with NGSLR camera
- Marked telescope pointing on the NGSLR images
- Compared telescope pointing with:
  - STK image data provided by FDF
  - Lunar coordinates generated by a SPICE program

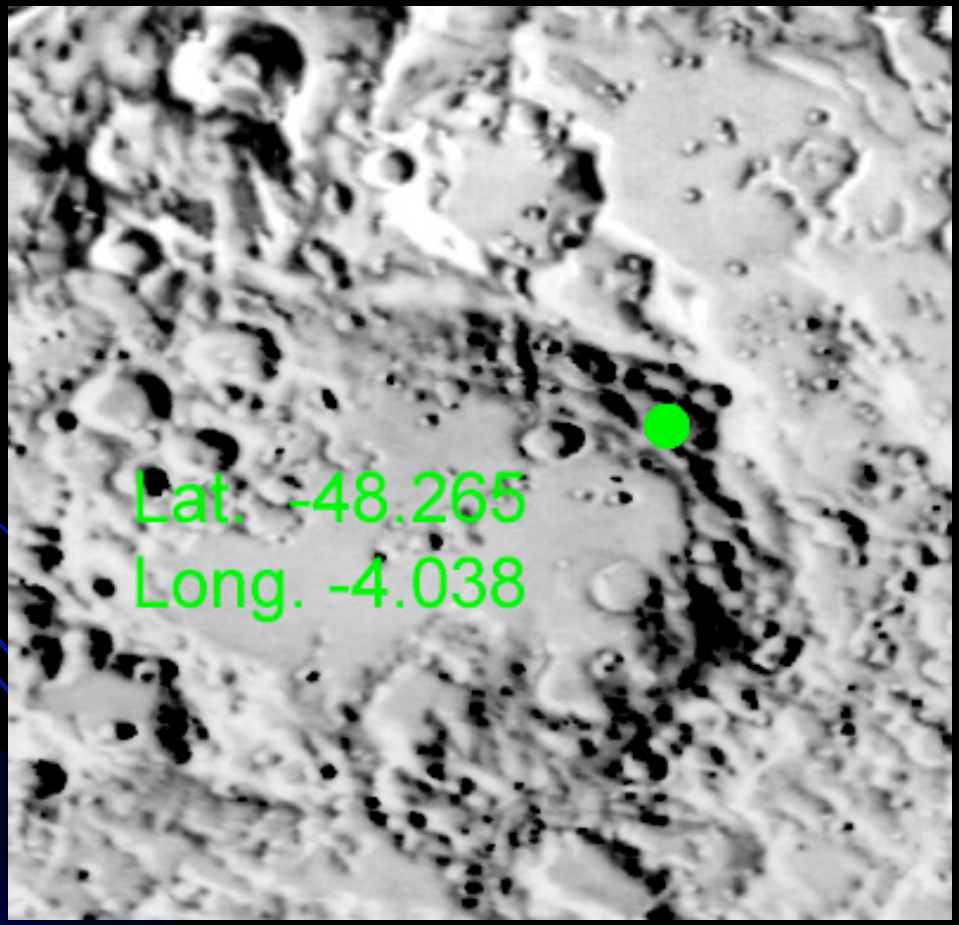
Telescope pointing is correct and accurate



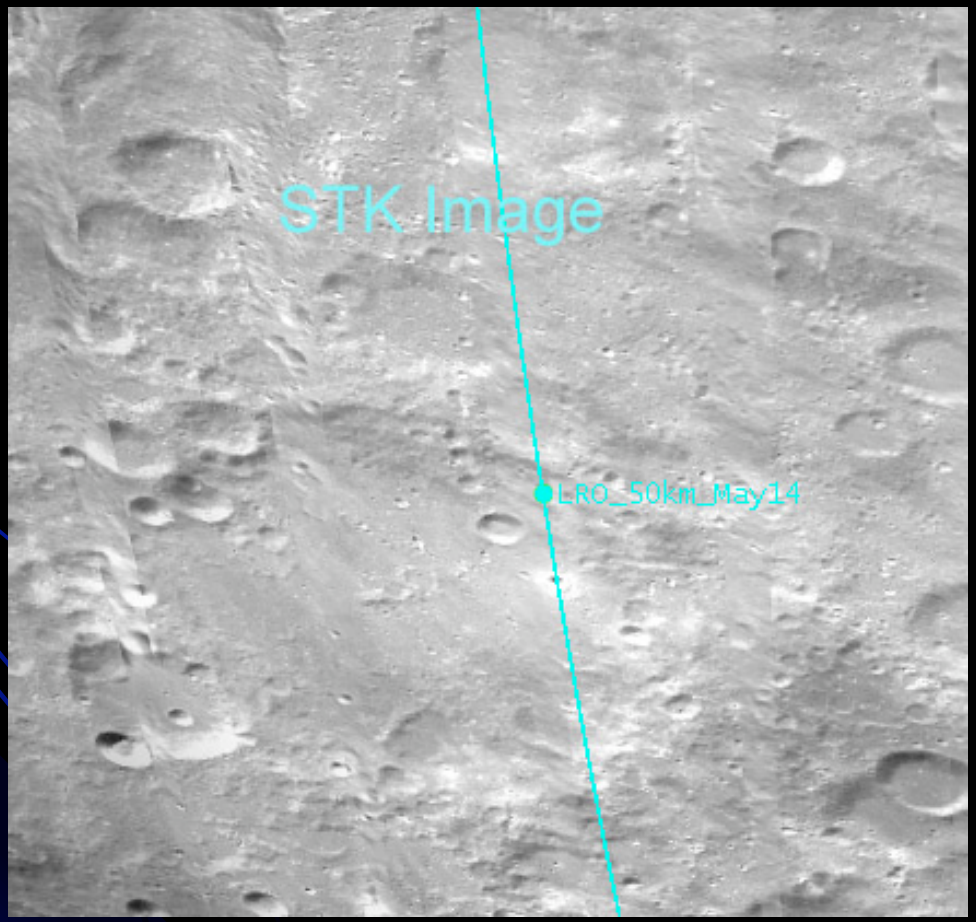
Telescope pointing is correct and accurate

- SPICE Kernels:
  - NGSLR position, custom generated kernel
  - Earth and Moon positions, DE421
  - LRO position, special orbit kernel from FDF
  - Lunar ‘Mean Earth’ reference frame
- Point-ahead correction (SPICE: XCN+S)
  - Transmission
  - Converged Newtonian light time correction
  - Stellar aberration
- Plotted lunar coordinates
  - USGS airbrushed shaded relief map
  - Warped to ULCN2005

Telescope pointing is correct and accurate



Telescope pointing is correct and accurate



Telescope pointing is correct and accurate

- NGSLR versus SPICE → 2.4 arc s (rms)
- Largest difference ~4 arc s
- NGSLR versus STK → 3.2 arc s (rms)
- Largest difference ~5 arc s

Summary

- The LRO portion of the NGSLR testing program is nearly complete
- The telescope will track LRO correctly and accurately
- LRO will be scheduled as the highest priority target
- NGSLR software is correctly modified for LRO
- Laser fire is correctly controlled and measured