# Laser Ranging to the Lunar Reconnaissance Orbiter (LRO-LR)

PIs: D. Smith & M. Zuber, MIT

- Over **2500** hours of 1-way laser ranging data collected since launch June 2009.

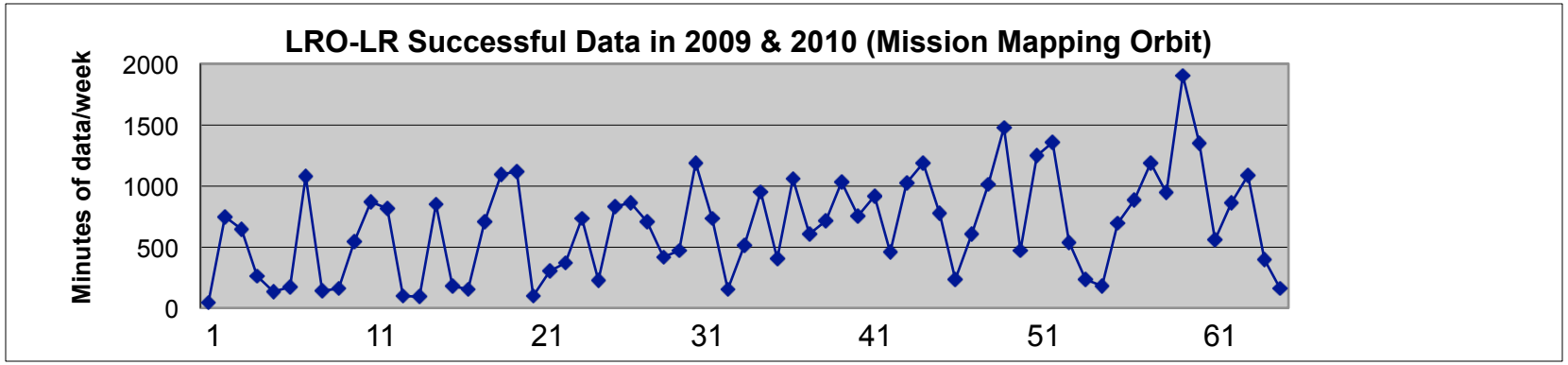
- NASA will be funding LRO-LR at least through FY13.

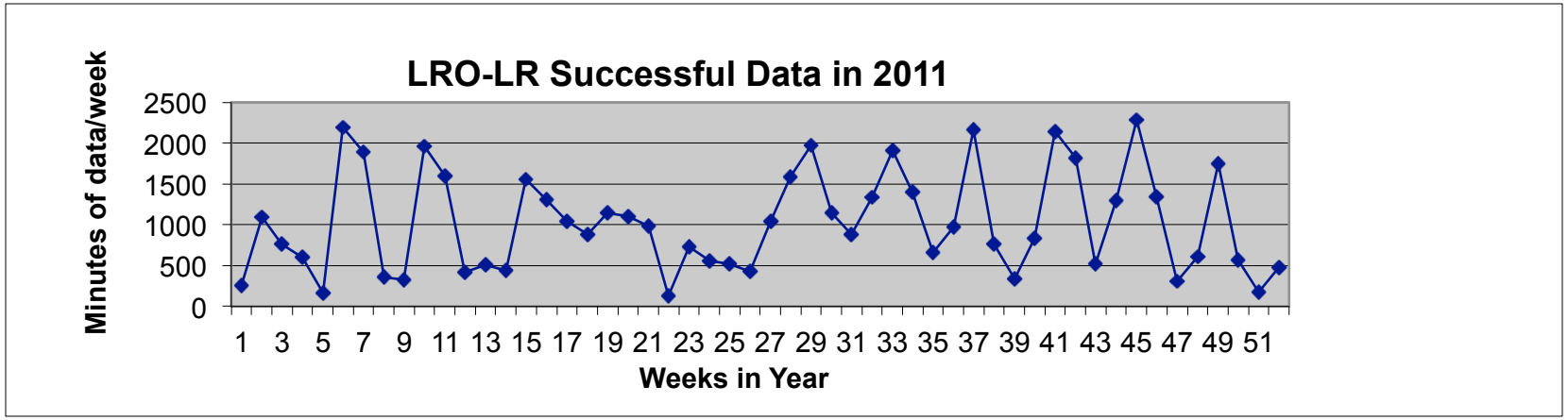
- Ten participating stations:

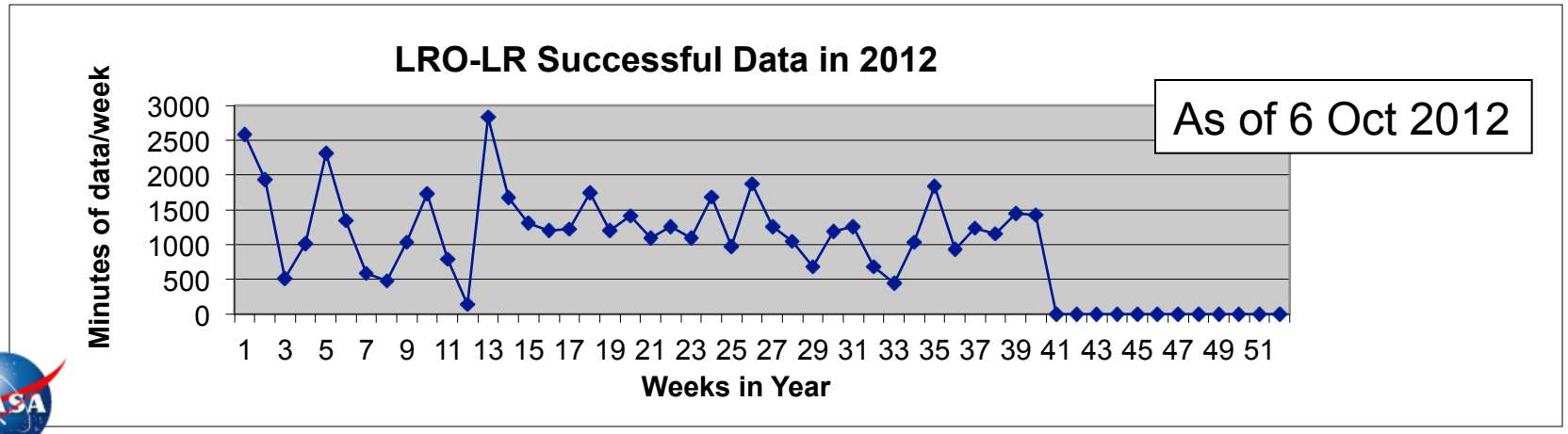
| Units are minutes | GO1L<br>NGSLR | GODL<br>MOB-7 | MDOL<br>MLRS | HERL<br>Herst. | ZIML<br>Zimmer. | WETL<br>Wettzell | HARL<br>MOB-6 | YARL<br>MOB-5 | MONL<br>MOB-4 | GRSM<br>Grasse |
|---|---|---|---|---|---|---|---|---|---|---|
| **TOTAL minutes in 2012** | **12400** | **7044** | **4394** | **474** | **394** | **47** | **686** | **7227** | **17703** | **299** |
| **Fraction of data in 2012** | **0.2447** | **0.1390** | **0.0867** | **0.0094** | **0.0078** | **0.0009** | **0.0135** | **0.1426** | **0.3494** | **0.0059** |
| **TOTAL min since launch** | **52354** | **12133** | **16398** | **1747** | **1355** | **161** | **1584** | **23533** | **37696** | **1676** |
| **Fraction of ALL data** | **0.3522** | **0.0816** | **0.1103** | **0.0118** | **0.0091** | **0.0011** | **0.0107** | **0.1583** | **0.2536** | **0.0113** |

- TOTALS to October 6, 2012:
  - + Total hours in 2012: 845.
  - + Hours since launch: 2521.

# Minutes of Successful Data at LRO per Week since Launch



# LRO-LR Analysis and Related Activities

- LR data analysis performed by Mao. LR data used to determine onboard oscillator drift which supports orbit determination. Orbit determination work ongoing (Rowlands).

- Lasercom work complete – paper submitted to OpticsExpress. X. Sun and team successfully transferred Mona Lisa image from NGSLR to LRO.

- In-house NASA R&D award given to X. Sun to do Time Transfer using LRO.
  - One year effort started October 2012.
  - Team includes Skillman, Gaebler, Hoffman, McGarry.
  - Initial transfer between NGSLR & MOBLAS-7. Then with MLRS. If time and resources permit, with Wettzell.

- Geometric solution of spacecraft location using 3-way simultaneous ranges will also be worked this year (Skillman) under NASA R&D.

# Time Transfer using LRO-LR

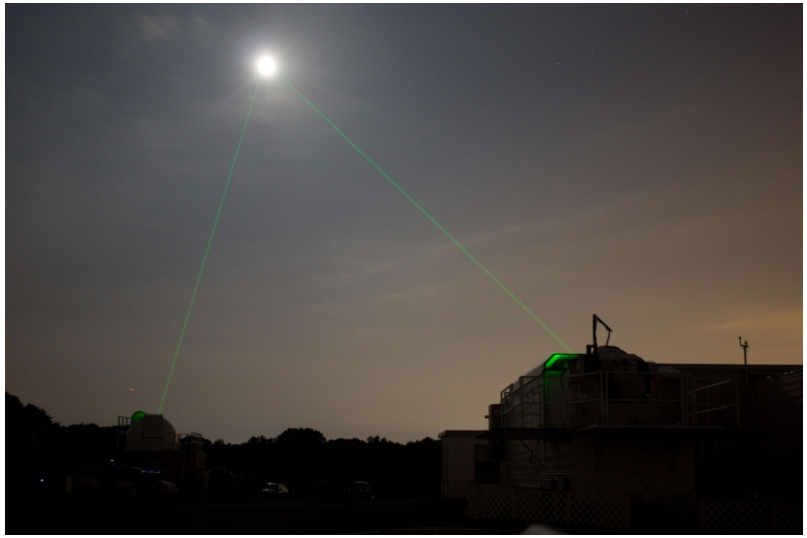
- Time transfer involves highly stable frequency sources (Cesium or Hydrogen Maser) and 2 frequency GPS receivers.

- DICOM All View GPS receiver (Czech Republic) promises CV accuracy to 1 nanosecond GPS time.

- Measure transmit delay of each participating station to reduce problem to single biased range at LRO.

- Significantly increase accuracy of one way laser ranging data to LRO.

- Tie USNO master clock to NGSLR time via GPS, transfer master clock to other stations via LRO clock.

# LRO Orbit Determination with GRAIL420c1a
# Orbital Solutions for 14 days

| | LR only | | S-band only | | | | S-band plus LR | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | rms (m) | num | rms (cm/sec) | num | rms (m) | num | rms (cm/sec) | num | rms (m) | num | rms (m) | num | |
| 20090831 | 0.29 | 5203 | 0.05 | 64679 | 1.16 | 57407 | 0.05 | 64742 | 1.22 | 57407 | 0.41 | 5203 | 20090831 |
| 20091023 | 0.30 | 15954 | 0.08 | 76259 | 1.09 | 70984 | 0.10 | 76261 | 2.21 | 70984 | 0.39 | 15954 | 20091023 |
| 20091120 | 0.22 | 16613 | 0.05 | 74957 | 0.77 | 68530 | 0.06 | 75124 | 0.80 | 68530 | 0.23 | 16613 | 20091120 |
| 20100309 | 0.17 | 10338 | 0.05 | 72156 | 1.32 | 67421 | 0.06 | 72424 | 1.54 | 67421 | 0.20 | 10338 | 20100309 |
| 20100405 | 0.27 | 9859 | 0.05 | 69298 | 1.39 | 63528 | 0.06 | 69632 | 1.72 | 63528 | 0.29 | 9859 | 20100405 |
| 20100419 | 0.28 | 21185 | 0.06 | 70072 | 1.44 | 64602 | 0.08 | 70627 | 1.71 | 64602 | 0.30 | 21185 | 20100419 |
| 20100530 | 0.29 | 19306 | 0.05 | 78974 | 0.79 | 74166 | 0.07 | 79600 | 1.41 | 74166 | 0.30 | 19306 | 20100530 |
| 20100614 | 0.22 | 20554 | 0.06 | 64239 | 0.96 | 60551 | 0.07 | 64304 | 1.16 | 60551 | 0.23 | 20554 | 20100614 |
| 20110507 | 0.38 | 17397 | 0.70 | 66540 | 1.93 | 59389 | 0.72 | 66540 | 1.51 | 59389 | 0.39 | 17397 | 20110507 |
| 20110520 | 0.16 | 11978 | 1.02 | 66650 | 2.22 | 60286 | 1.03 | 66650 | 1.66 | 60286 | 0.22 | 11978 | 20110520 |
| 20110630 | 0.32 | 11524 | 0.71 | 65279 | 2.66 | 57984 | 0.72 | 65279 | 2.64 | 57984 | 0.36 | 11524 | 20110630 |
| 20110810 | 0.69 | 20800 | 0.08 | 79229 | 1.18 | 71040 | 0.11 | 79229 | 1.50 | 71040 | 0.70 | 20800 | 20110810 |
| average | 0.30 | 15059 | 0.25 | 70694 | 1.41 | 64657 | 0.26 | 70868 | 1.59 | 64657 | 0.34 | 15059 | average |

**Average RMS** 30 cm (1 nsec) | 2.5 mm/s | 3.0 mm/s | 34 cm

More on this in Mark Torrence's talk on Friday