Initial Results from the Lunar Orbiter Laser Altimeter (LOLA)

David E. Smith and Maria T. Zuber, MIT

Gregory A. Neumann and Erwan Mazarico, GSFC

and

do the LOLA Science and Instrument Team
• LOLA turned-on in lunar orbit on July 3, 2009.

• Continuous operation began July 13, 2009 in LRO 30x200 km Commissioning Orbit.

• S/c placed in mapping orbit (50x50 km) in mid-September, 2009.

• Valid altimeter measurements:
  – July 4-Oct 1: 345 million
  – Oct 2-Nov 1: 224 million
  – TOTAL as of Nov 16: 580 million

• Average altimeter data acquisition rate: ~90 measurements/s.

• Average along-track separation of measurements: ~18 m.
• LOLA lays down 5 parallel profiles 10 to 12 m apart.

• From 50-km orbit altitude:
  - observation area is 5 m in diameter
  - adjacent spots are 25 m apart.

• Green areas are FOV of detector, 20-m diameter.

• Laser pulses at 28 Hz – 140 measurements/s of altimetry, surface roughness and reflectance.
Altimeter Specifications

- Laser transmitter energy: ~2.5 mJ on laser 1 and ~2.7 mJ on laser 2 (~0.5 mJ per beam).

- Lasers operate at 1064 nm.

- A Diffractive Optical Element (DOE) splits single laser beam into 5 beams of 100 µrad divergence.

- Receiver is 14 cm in diameter.

- 5 detectors are fiber optically coupled to avalanche photodiodes.
Global Topography: Hammer Projection

ALL CHARTS HAVE SAME TOPOGRAPHY SCALE AND ALONG-TRACK SPACING OF 60 M AND ACROSS-TRACK SPACING OF 1/8 DEG (~4 KM AT EQU)
Power Spectrum reflects classes of structure:
- global shape
- mare basins
- craters, crater structures (rings, rims, ejecta), tectonics, lava flows

LOLA and Kaguya

NASA/GSFC/MIT/LOLA
View of lunar far side.

Data through Nov 1 included.

Orbit reconstructions by LRO Project.

NASA/GSFC/MIT/LOLA
South Pole-Aitken Basin

Basin center:
55.0° S
191.1° E

Basin axes:
970 x 720 km

Tilt:
-18.8°
Gridded Data Resolution

South Pole-Aitken

Along-track resolution: 60 m

Across-track resolution: 2 km at 60S after 4 months

Tsilolkovosky
Gagarin
Ingenii

NASA/GSFC/MIT/LOLA
View of western hemisphere.

Near side on right.

Data through Nov 1 included.

Orbit reconstructions by LRO Project.
Careful scrutiny of image shows spacing of ground tracks.
View of lunar eastern hemisphere.

Front side is at left.

Data through Nov 1 included.

Orbit reconstructions by LRO Project

NASA/GSFC/MIT/LOLA
Area includes the area of highest elevation so far observed (10.51 km, 201.48E, 5.13N)
View of lunar northern hemisphere from above pole.

Near side at bottom.

Data through Nov 1 included.

Orbit reconstructions by LRO Project.
View of lunar southern hemisphere from below pole.

Near side is at the bottom.

Data through Nov 1 included.

Orbit reconstructions by LRO Project
LOLA and LEND are jointly working to define locations of hydrogen rich areas, their relationship to topography, crater age and location, and to areas of “permanently” shadowed areas.

Objectives of the investigation include:
- Trying to determine if there is any relationship between amount of shadow and the amount of hydrogen
- The importance, or otherwise, of reflected sunlight and earthshine

We believe we need the highest resolution HEND and accurate topography for this work. We need more data, and time.
12,860 altimeter observations of the Antoniadi Crater

Maximum slopes exceed 24 degrees

All 5 profiles providing 100% altimetry. Profiles separated by 200 m to aid presentation
Charts show 2 secs of altimetry near the northern edge of SP-A with all 5 profiles operating at 100%. Left chart shows the measurements connected to show the individual profiles. Right chart shows the individual measurements.  
NOTE: The 5-profile swath of LOLA is 50 meters wide and the distance between measurements in a given profile is 50 meters.
Thermal blankets surrounding LOLA are exposed to thermal radiation from the Moon. When LOLA is over the sunlit side, LOLA’s performance is fully nominal (perfect!). When LOLA is over the dark side, the thermal blankets “freeze” at about 220K, contract and pull the laser beam expander, causing laser spots to move outside the detector fields of view.
LOLA Thermal Blankets

- Before launch, images of LOLA show thermal blankets around the receiver (large circular area) and laser beam expander (small circular area).

- Change in lunar thermal input to blanket surface causes the surface to become rigid, contract, and move the beam expander towards the receiver.

- Effect is reproduced on every orbit and begins as LRO crosses the terminator.
Orbit 1740: 610,000 Topography Observations

ALTIMETRY

LOLARDR_093161628, orbit 1740, $\beta=41.4^\circ$, $\lambda_{AsNode}=13.6^\circ$E

ENERGY

Spot 5

Spot 4

Spot 3

Spot 2

Spot 1

vertical line is the terminator location
• LOLA engineering model laser undergoing testing to provide insight into expected life laser lifetime.
• Effective 11.05.09:
  - 895M shots in air & vacuum
  - 891M shots in vacuum
• No significant degradation in laser energy.

Equivalent to 1 Year of continuous operation
Earth-based laser tracking stations are successfully ranging to LRO via LOLA for improved LRO timing and orbit determination.

LOLA: 10-cm range accuracy 28 Hz, 1064 nm

LR: 10-cm range precision 28 Hz, 532 nm

10-m fiber optic bundle carries LR Earth laser signal to LOLA channel-1 detector
Laser Ranging Status

• Routinely ranging to LRO from NASA NGSLR station in Greenbelt, MD.
• Also successfully ranged to LRO from:
  – MLRS, Texas
  – Herstmonceux laser station, UK
  – Zimmerwald, Switzerland
  – Wettzell, Germany
• Observations expected soon from NASA stations in Australia and South Africa
• Other approved participants from International Laser Ranging Service (ILRS) preparing to participate.
• LOLA has acquired nearly 600 million altimeter measurements since turn-on July 13 at an average rate of ~90 measurements/second, 7.8 million measurements per day.
• Along-track resolution is on average 18 meters in mapping orbit.
• Topographic precision is ~ 12 cm.
• Present orbital accuracy is ~ 20 meters radial, 150 meters along track.
• Data and DEM’s will be publicly released in February 2010 and every 3 months thereafter.
• Laser ranging to LRO is extremely successful.