LOLA OBSERVATIONS OF THE MOON. D. E. Smith¹, M. T. Zuber¹, G. A. Neumann², F. G. Lemoine², E. Mazarico², M. H. Torrence³, T. H. Duxbury³, J. Head III³, O. Aharonson³, and the LOLA Science and Instrument Team, ¹Earth, Atmospheric and Planetary Sciences, MIT, Cambridge, MA 02139 smithde@mit.edu, zuber@mit.ed, ²NASA Goddard Space Flight Center, Greenbelt, MD 20871 gregory.a.neumann@nasa.gov, frank.g.lemoine@nasa.gov, erwan.m.mazarico@nasa.gov, mark.h.torrence@nasa.gov, ³George Mason University tduxbury@gmu.edu, ⁴Brown University James_Head@brown.edu, ⁵Caltech oa@gps.caltech.edu.

Introduction: The LOLA instrument on LRO has been operating continuously since July 13, 2009 and as of Nov 30 had acquired 777 million altimeter measurements of the lunar topography, and increasing at 216 million/month. LOLA is a 5-beam laser altimeter operating at 28 Hz with each beam illuminating a 5-meter spot from the nominal 50-km altitude orbit. The instrument creates 5 parallel profiles approximately 12 meters apart with observations separated by approximately 56 meter along each profile [1].

Instrument Operations:
Commissioning Phase. The initial orbit of LRO was approximately 30x200km in which the spacecraft and the instruments were checked out. LOLA was turned on July 3 for two days and both laser were checked out. LOLA was switched on “permanently” on July 13 and remained in the end of Commissioning Phase in mid-September. The instrument was shown to be able to range successfully to the lunar surface from an altitude of about 190 km, a factor a two larger than was expected. However, there was evidence that the instrument was acquiring more successful data on the sunlit side than on the lunar dark-side. During this Phase the instrument acquired a significant quantity of valuable altimetry data over the southern hemisphere where the spacecraft altitude was lower. Boresight alignment of the LOLA receiver and the spacecraft was checked out by passively observing the illuminated Earth. Alignment of the laser transmitter with the receiver was checked by pointing the laser at the Earth and the LOLA signal being acquired at an Earth tracking station.

Mapping Phase. LRO entered its mapping phase in mid September; a near circular orbit of 50 km with a polar inclination. LOLA has been operating continuously since this time and by the end of November 2009 had acquired 777 million valid topographic measurements which is increasing at a little over 200 million per month. The average separation of altimetry measurements along track for all 5 beams taken together is approximately 18 meters and the across track separation, which depends on the number of orbits of the moon, was approximately 5 to 6 km at the end of November.

When LOLA is over the sunlit side of the Moon all 5 laser beams get laser returns from the surface continuously and the instrument acquires data at its full rate of 140 measurements/second. Over the dark side of the moon only 2 of the 5 beams acquire significant data. This light to dark effect has been shown to be caused by a contraction of the thermal blankets over the colder parts of the Moon that surround LOLA that moves the transmit beam expander a few hundred milli-radians. The overall LOLA data acquisition rate is between 80 and 90 valid altimeter measurements/second. The quality of an individual altimeter measurement has been shown to be approximately 12 cm on flat surfaces.

The LRO spacecraft is routinely tracked by USN Doppler and range tracking. LRO also has a high precision laser tracking system that employs laser stations on Earth that make one-way laser range (LR) measurements to a small optical receiver on the LRO High Gain Antenna that carries the photons to one of the LOLA detectors [2]. The Earth laser stations operate at 28Hz, or some fraction, and the data are returned to Earth via the LOLA data stream. These observations, accurate to a few cm averaged over a few seconds, enable precise positioning of LRO to be derived and improvement in the lunar gravity model.

Science Results:
The altimetry data have been used to develop digital elevation models (DEM’s) and Figure 1 shows the west and eastern hemispheres of the moon. These images are based upon the data obtained through Nov 30 2009. Clearly evident are South Pole Aiken, Orientale basin and the farside highlands.

Figure 1. The western and eastern hemispheres of the Moon developed from LOLA DEM altimeter data. South Pole Aitken is in the lower left of the left image. The range in elevation is -9 to +9 km.

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Figure 1. The western and eastern hemispheres of the Moon developed from LOLA DEM altimeter data. South Pole Aitken is in the lower left of the left image. The range in elevation is -9 to +9 km.
The 5 LOLA beams are co-registered with the overlap region of the LROC narrow angle cameras (NACs) and an example of a LOLA 5-profile pass is shown in Figure 2 [3]. The image shows how the the 5-beam LOLA data reveal the complex structure of a small crater about 300 meters in diameter near the equator at longitude 312.

![Figure 2. A short segment of an LROC image with LOLA data superimposed, and the actual topography shown above [3]. The image shows a little over 1 second of LOLA data (about 1.8 km along track). The crater in the center of the image is about 300 m across and 20 meters deep.](image)

Note how the individual beams show the variation in depth and slope of this approximately 20 meter depth crater over a swath width of 50 meters after a very smooth ramp up to the crater rim.

LOLA data are also being used to identify regions of permanent shadow and areas of near permanent sunlight in the polar regions. The LOA DEMs have been compared favorably with LROC wide-angle camera images for the definition of shadowed areas.

The LOLA data for the first 3 months of the lission will be released through the Planetary Data System March 2010 and subsequently at 3 month intervals.

**References:**