THE LUNAR RECONNAISSANCE ORBITER: INSTRUMENTATION AND LESSONS LEARNED.

R. R. Vondrak[1] and J. W. Keller[1], [1]Code 690, Goddard Space Flight Center, Greenbelt MD 20771.

Introduction: The Lunar Reconnaissance Orbiter spacecraft (LRO), launched on June 18, 2009, began with the goal of providing key information needed for the return of humans to the Moon and for future robotic missions. It was initiated as a Discovery-class mission by NASA's Exploration Systems Mission Directorate (ESMD, which later became part of NASA's Human Exploration and Operations Mission Directorate (HEOMD). After spacecraft commissioning, the ESMD phase of the mission began on September 15, 2009 and was completed on September 15, 2010 when operational responsibility for LRO was transferred to NASA's Science Mission Directorate (SMD). In the ESMD phase, LRO's objectives included the search for surface resources, evaluation of potential landing sites, and investigation of the lunar radiation environment. The SMD Science Mission was scheduled for 2 years and will be completed in September of 2012. An extended science mission is currently under review and a determination will be made by August 2012. Under SMD, the mission focuses on a new set of goals related to understanding the geologic history of the Moon, its current state, and what it can tell us about the evolution of the Solar System.

The measurement requirements for LRO were identified by an Objectives and Requirements Definition Team consisting of experts from the lunar science and engineering communities. The LRO instruments were solicited through a competitive process initiated by a joint Announcement of Opportunity from ESMD and SMD. A detailed description of each of the instruments was previously published in an LRO volume of Space Science Reviews[1]. An image of the spacecraft depicting locations of the instruments is shown in Figure 1 and summary information for each instrument is shown in Figure 2. The instruments include ***Lunar Orbiter Laser Altimeter (LOLA)***, PI, David Smith, NASA Goddard Space Flight Center, Greenbelt, MD, ***Lunar Reconnaissance Orbiter Camera (LROC)***, PI, Mark Robinson, Arizona State University, Tempe, Arizona, ***Lunar Exploration Neutron Detector (LEND)***, PI, Igor Mitrofanov, Institute for Space Research, and Federal Space Agency, Moscow, ***Diviner Lunar Radiometer Experiment (DLRE),*** PI, David Paige, University of California, Los Angeles, ***Lyman-Alpha Mapping Project (LAMP)***, PI, Alan Stern, Southwest Research Institute, Boulder, Colorado, ***Cosmic Ray Telescope for the Effects of Radiation (CRaTER)***, PI, Harlan Spence, University of New Hampshire, New Hampshire, and ***Mini Radio-Frequency Technology Demonstration (Mini-RF)***, P.I. Ben Bussey, Applied Physics Laboratory, Maryland.

In Figure 2 we also include ***Lunar Ranging (LR)*** (PI, David Smith), since it employs the LOLA instrument for precision orbit deterrmination, although conventionally it would be considered part of the spacecraft guidance and navigation subsystem. LRO is the first planetary spacecraft to use Earth-based laser tracking for precision orbit determination.

LRO has a large number of instruments so that complementary measurements could be made to reduce ambiguity and to and to make as comprehensive a set of observations as possinle with remote sensing techniques. Figure 3 illustrates the role that each instrument plays tocontribute to the success of the LRO mission, as stated by the ESMD Level 1 requirements and the required performance to reach minimum and full mission success.

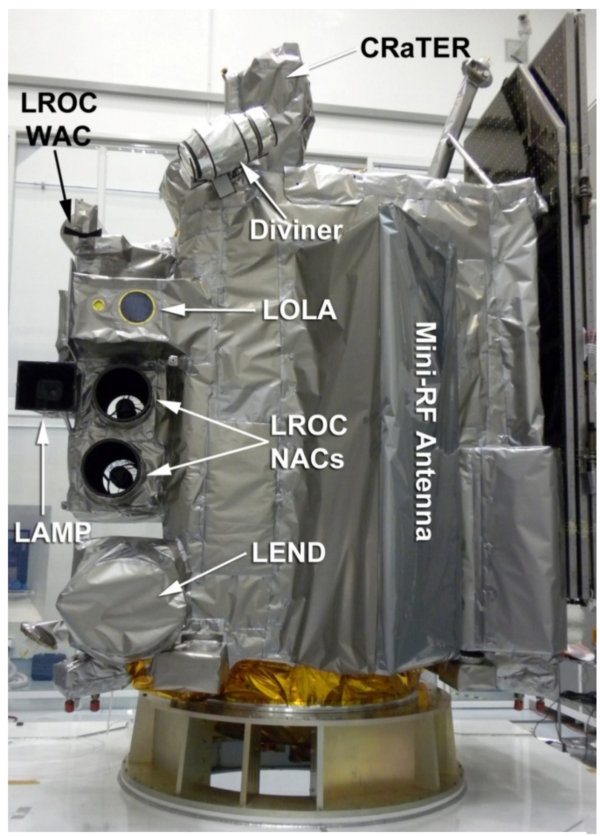

Figure 1 The fully assembled and thermal blanketed spacecraft.

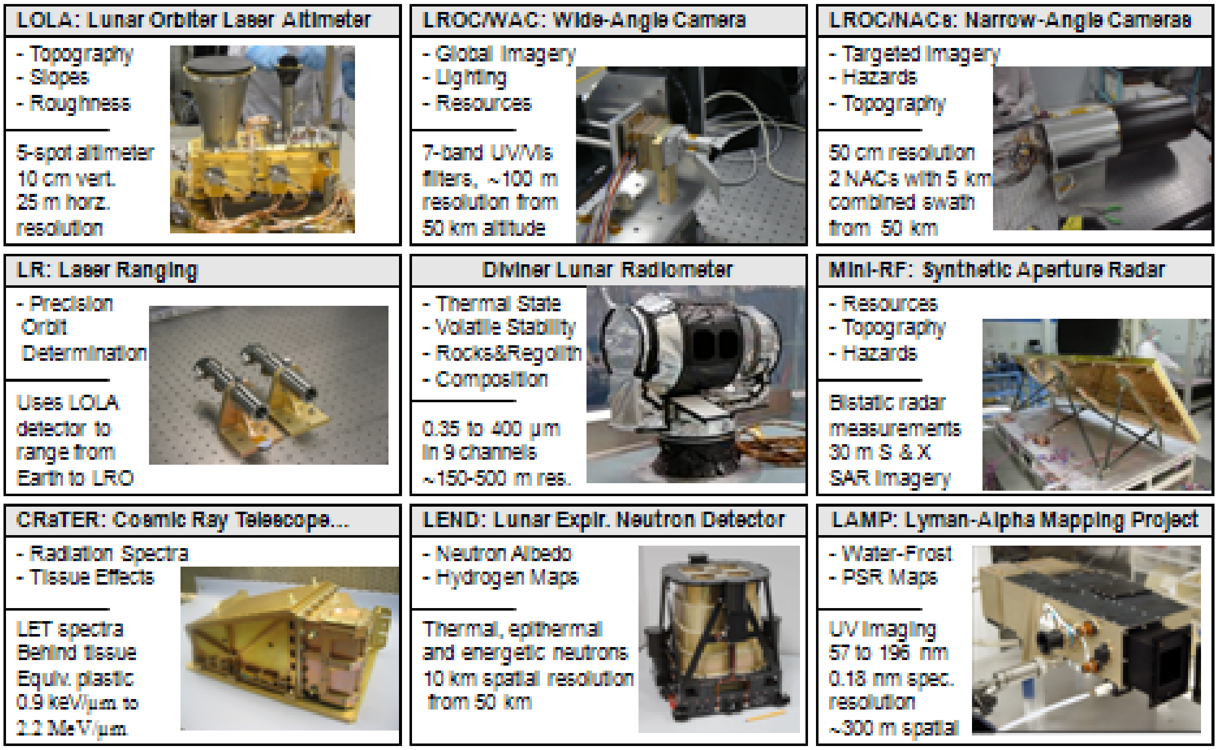

Figure 2. The LRO suite of instruments uses multiple techniques to obtain a set of observations of the Moon and the lunar environment.

	Objectives	LRO Requirements	CRaTER	DLRE	LAMP	LEND	LOLA	LROC	Mini-RF
1	Find Safe Landing Sites	M30 M40 – Global geodetic grid 10 cm vertical, and at the poles, 50 m horizontal resolution					▲	▲	●
		M80 – Identify surface features & hazards		▲			▲	▲	●
2	Locate Potential Resources	M90 – Characterize the polar region illumination environment		▲			▲	▲	
		M50 – Provide lunar temperature map from 40 - 300K, 5 K precision over full diurnal cycle.		▲					
		M60 – Image the permanently shadowed regions.			▲		▲	●	
		M70 - Identify putative deposits of water-ice			▲	▲	▲		●
		M100 - Characterize lunar mineralogy		▲	●	●	●	▲	●
		M110 - Hydrogen mapping				▲		●	
3	Life in the Space Environment	M10 - Characterize the deep space radiation environment at energies in excess of 10 MeV	▲			▲			
		M20 - measure the deposition of deep space radiation on human equivalent tissue.	▲						
4	New Technology	P160 - Technology demo	●				●		▲

Minimum Success (M30 M40 – M90)

Full Success (all requirements)

▲ Level 1 Requirements
● Contributions– may require additional analysis to exploit

Figure 3. LRO Level 1 Requirements and Critereia for Minimum and Full Mission Success for the ESMD Exploration Mission.

This presentation will focus on the LRO instruments and lessons learned from their development and operation. We will also briefly describe significant results from the LRO mission, which include but are not limited to the development of comprehensive high resolution maps and digital terrain models of the lunar surface; discoveries on the nature of hydrogen distribution, and by extension water, at the lunar poles; measurement of the day and night time temperature of the lunar surface including temperature down below 30 K in permanently shadowed regions (PSRs); direct measurement of Hg, H_2, and CO deposits in the PSR at Cabeus crater, evidence for recent tectonic activity on the Moon, and high resolution maps of the illumination conditions as the poles.

References: [1] Vondrak, R.R., Keller, J.W., and Russell, C.T., (Ed.s), 2010, Lunar Reconnaissance Orbiter Mission, New York, Springer.