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Lunar Reconnaissance Orbiter (LRO)

Outlook

- On September 16, 2010, the LRO completed the exploration phase of its mission. Scientists will continue to study data returned to Earth by the LRO spacecraft
- The LRO and LCROSS lifted off aboard an Atlas V launch vehicle from Cape Canaveral at 5:32 p.m. EST on June 18, 2009
- The LCROSS impacts the lunar surface on October 9, 2009

Orientation

Description. The Lunar Reconnaissance Orbiter (LRO) is the first phase of the Lunar Precursor Robotics Program, which is intended to increase the amount of available information about the Moon for application in eventual human missions.

Sponsor. NASA's Goddard Space Flight Center manages the Robotic Lunar Exploration Program.

Status. The LRO is in the implementation phase. The Critical Design Review was completed in November 2006. The LRO lifted off aboard an Atlas V launch vehicle from Cape Canaveral on June 18, 2009. The LRO also carried the Lunar Crater Observation and Sensing Satellite (LCROSS).

Total Produced. None

Application. Create topographic maps of the Moon, detect space radiation and its potential effect on humans, and search for resources on the lunar surface, especially water.

Price Range. NASA spent $546 million through FY10 on the LRO. It spent $73 million for the addition of the LCROSS.

Contractors

Prime

Goddard Space Flight Center, GSFC	http://www.nasa.gov/centers/goddard/home/index.html, NASA Bldg 03 Rm S22 M/S 6, Greenbelt, MD 20771-0001 United States, Tel: + 1 (301) 286-8955, Prime (LOLA)

Subcontractor

Malin Space Science Systems Inc	http://www.msss.com, PO Box 910148, San Diego, CA 92191 United States, Tel: + 1 (858) 552-2650, Ext: 500, Email: ravine@msss.com (LROC)
Russian Space Research Institute,	http://www.iki.rssi.ru/eng/index.htm, 84/32 Profsoyuznaya St, Moscow, 117997 Russian

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IKI	Federation, Tel: + 7 095 333 5212, Fax: + 7 095 913 3040 (LEND Instrument)
Southwest Research Institute	http://www.swri.org/, 6220 Culebra Rd, PO Drawer 28510, San Antonio, TX 78228-0510 United States, Tel: + 1 (210) 648-5111 (LAMP)

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Technical Data

The LRO weighs about 1,000 kilograms and carries a 100-kilogram payload of instruments that conduct observations about the lunar surface and atmosphere. The instruments consist of radar, lasers, high-resolution cameras, and a miniature synthetic aperture radar sensor.

The satellite is based on a three-axis stabilized pointed platform. The LRO is powered by solar arrays and a Li-Ion battery. It uses a Ka-band high-rate downlink capable of sending information at 100-300 Mbps, or 900 GB per day. The spacecraft was loaded with approximately 500-700 kilograms of fuel.

Instrumentation. The following instruments have been selected for use on the LRO; parts of their descriptions have been abstracted from NASA documentation:

CRaTER. The primary mission of this instrument is to characterize the global lunar radiation environment and its biological impacts. The hardware is expected to consist of a single, integrated sensor and electronics suite. The front of the CRaTER sensor is based on standard-stacked detector, cosmic ray telescope systems. The CRaTER telescope consists of five ion-implanted silicon detectors, mounted on four detector boards and separated by three pieces of tissue-equivalent plastic. All five of the silicon detectors are 2 centimeters in diameter. Principal investigator is Harlan Spence, Boston University, Massachusetts.

DIVINER. The objective of DIVINER is to measure lunar surface temperatures at scales that provide essential information for future surface operations and exploration. DIVINER is a multichannel solar reflectance and infrared filter radiometer. It is a nine-hannel filter radiometer that utilizes uncooled thermopile detector arrays. The DIVINER structure consists of an instrument optics bench assembly (OBA), an elevation/azimuth yoke, and an instrument mount. Principal investigator is David Paige, University of California, Los Angeles.

LAMP. The Lyman-Alpha Lamping Project is a "low-risk, high-heritage" investigation based on a rebuild of an existing instrument. LAMP uses an imaging UV spectrometer that consists of high- and low-voltage power supplies, command and data handling electronics, a telescope mirror, and a double delay line detector. The LAMP investigation offers to exploit reflected Lyman alpha radiation and starlight to spectrally identify the locations of any exposed water-ice deposits and demonstrate the feasibility of low-light starlight/sky-glow vision applications for operational use on future landed missions. Principal investigator is Alan Stern, Southwest Research Institute, Boulder, Colorado.

LEND. The Lunar Exploration Neutron Detector instrument has passive collimators of neutrons that provide very high spatial resolution maps of neutron emissions at the lunar surface. No other neutron instrument with this imaging capability has ever flown in space. LEND's nine neutron sensors will enable the creation of high-resolution hydrogen distribution maps with sensitivity of about 100 parts per million of hydrogen weight and horizontal spatial resolution of 5 kilometers. It will also foster the characterization of surface distribution and column density of possible near-surface water ice deposits in the Moon's polar cold traps. Principal investigator is Igor Mitrofanov, Institute for Space Research (IKI), and Russian Federal Space Agency, Moscow.

LOLA. The Lunar Orbiter Laser Altimeter investigation will provide a precise global lunar topographic model and geodetic grid. NASA says topography at scales from local to global is necessary for landing safely, and it preserves the record of the evolution of the surface that contributes to decisions as to where to explore. The topographic model provided by LOLA will be at a level that will allow safe landings and enhance exploration-riven mobility once on the lunar surface.

The LOLA instrument pulses a single laser through a Diffractive Optical Element (DOE) to produce five beams that illuminate the lunar surface. For each beam,

LOLA measures time of flight (range), pulse spreading (surface roughness), and transmit/return energy (surface reflectance). With its two-dimensional spot pattern, LOLA unambiguously determines slopes along and across the orbit track. Principal investigator is David Smith, NASA Goddard Space Flight Center, Greenbelt, Maryland.

LROC. The Lunar Reconnaissance Orbiter Camera has been designed to address two of the LRO measurement requirements: landing site certification and polar illumination. The LROC consists of two narrow-angle camera heads to provide 0.5-meter-scale panchromatic images over a 5-kilometer swath; a wide-angle camera head (WAC) to provide images at a scale of 100 meters in seven color bands; and a common Sequence and Compressor System (SCS) to sequence image acquisition by all camera heads and compress their data before transmission to the spacecraft. Principal investigator is Mark Robinson, Northwestern University, Evanston, Illinois.

LCROSS. In April 2006, NASA selected the Lunar Crater Observation and Sensing Satellite to equip the LRO. The LCROSS will be used to examine the composition of lunar dust for the existence of water-ice particles using spectral analysis. The Centaur upper stage of the Atlas V launch vehicle will crash into the Shackleton crater, located at the lunar South Pole, to create a particle plume for analysis by the LCROSS. NASA's Ames Research Center is partnered with Northrop Grumman Space Technology for development of the LCROSS.

Artist's Rendition of the LRO

Source: GSFC

Program Review

Background. The LRO, as part of the Lunar Precursor Robotics Program (LPRP), is the first in a series of robotic probes to the Moon. Managed by the Goddard Space Flight Center in Maryland, the LPRP involves a series of unmanned, information-gathering missions to the Moon as part of the effort toward returning astronauts safely to the Moon sometime between 2015 and 2020, with a possible goal of establishing long-term bases.

NASA's First Trip to the Moon in Over a Decade

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The LRO will be the first mission sent to the Moon by NASA since the Clementine and Lunar Prospector missions in 1994 and 1998, respectively. The primary mission of the LRO, which orbits the Moon on a polar axis, is to gather information about the effects of space radiation on astronauts, create more detailed topographic maps of the lunar surface, and attempt to determine what resources are on the Moon and how easily accessible they are. NASA especially wants to study the availability of water on the poles. Some scientists believe there could be up to 10 billion tons of frozen water on the Moon. Without water, or a readily available source of hydrogen and/or oxygen, setting up long-term bases on the Moon will be very difficult, as NASA will have to transport huge amounts of water.

Competition for Additional Instruments

In June 2005, NASA made an announcement of an opportunity to provide the scientific instruments that will equip the LRO. NASA held an individual competition for each instrument.

Larger Launch Vehicle, Increased Program Cost

NASA originally intended to launch the LRO aboard a Delta II launch vehicle, at a total mission cost of approximately $400 million. LRO program officials have instead selected to launch the LRO aboard a more expensive Atlas V. Total program cost for the LRO has increased nearly one-third to approximately $546 million.

LRO Passes Critical Design Review

By late 2006, the LRO had passed its Critical Design Review, allowing it to enter the implementation phase of its development – specifically, systems integration and product fabrication. The Critical Design Review is a key step in program development during which the design is validated to ensure it meets program requirements prior to manufacturing and integration. The review was conducted at NASA's Goddard Space Center.

The LRO lifted off aboard an Atlas V launch vehicle from Cape Canaveral at 5:32 p.m. EST on June 18, 2009. The launch vehicle also carried the Lunar Crater Observation and Sensing Satellite (LCROSS). On June 23, the LRO entered lunar orbit, and by September 17, testing and calibration of the spacecraft was completed.

On October 9, 2009, the LCROSS impacted the lunar surface. The LRO observed the impact and will continue to pass over the site in an attempt to increase scientists' understanding of lunar craters.

On September 16, 2010, the LRO completed the year-long exploration phase of its mission. It produced a comprehensive map of the lunar surface. NASA scientists will continue to study the data sent to Earth from the LRO. Program management moved from NASA's Exploration Systems Mission Directorate to the Science Mission Directorate at the agency's headquarters in Washington, D.C.

Timetable

Month	Year	Major Development
Feb	2003	President George W. Bush announces new vision of space exploration
Mar	2004	NASA establishes Robotic Lunar Exploration Program; Lunar Reconnaissance Orbiter (LRO) first in series of robotic probes
Jun	2005	Announcement of Opportunity for instruments on LRO
Apr	2006	LCROSS selected as addition on LRO
Nov	2006	LRO passes Critical Design Review
Jun	2009	LRO launched aboard Atlas V with LCROSS
Sep	2009	LRO testing and calibration completed; mapping begun
Oct	2009	LCROSS impacts lunar surface

Forecast Rationale

The Lunar Reconnaissance Orbiter (LRO) has completed the exploration phase of its mission. The spacecraft, which launched in June 2009, has provided an enormous amount of data for NASA scientists. However, with the exploration phase completed, and with no major developments in the LRO program likely, this report will be archived next year.

The LRO was part of NASA's Lunar Precursor Robotic Program (LPRP), which was intended as a precursor to manned missions to the Moon. However, the Obama administration has radically changed NASA's plans for future human exploration efforts. With the cancellation of the Constellation program, it is unlikely that the U.S.

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will return humans to the Moon within the forecast period.

Despite the cancellation of Constellation, NASA plans to continue to send robotic missions to the Moon. However, these missions will not affect the LRO, which has already completed its objectives. Funding will not be made available, other than for continued study of the data sent to Earth from the spacecraft.

The data sent to Earth from LRO is vital to scientists studying the make-up and origins of the solar system. Scientists will continue to study that data for years to come, but major LRO program developments have been completed. No production is expected in the 10-year forecast period.

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