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Solar System Missions: Lunar Reconnaissance Orbiter

Mapping the Moon

Aira Astralis

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Conclusion

This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

The Lunar Reconnaissance Orbiter (LRO) is a NASA robotic spacecraft currently orbiting the Moon in an eccentric polar mapping orbit. Data collected by LRO have been described as essential for planning NASA's future human and robotic missions to the Moon. Its detailed mapping program is identifying safe landing sites, locating potential resources on the Moon, characterizing the radiation environment, and demonstrating new technologies.

Launched on June 18, 2009, in conjunction with the Lunar Crater Observation and Sensing Satellite (LCROSS), as the vanguard of NASA's Lunar Precursor Robotic Program, LRO was the first United States mission to the Moon in over ten years. LRO and LCROSS were launched as part of the United States's Vision for Space Exploration program.

The probe has made a 3-D map of the Moon's surface at 100-meter resolution and 98.2% coverage (excluding polar areas in deep shadow), including 0.5-meter resolution images of Apollo landing sites. The first images from LRO were published on July 2, 2009, showing a region in the lunar highlands south of Mare Nubium (Sea of Clouds). The total cost of the mission is reported as US$583 million, of which $504 million pertains to the main LRO probe and $79 million to the LCROSS satellite.

LRO has enough fuel to continue operations until 2027. Developed at NASA's Goddard Space Flight Center, LRO is a large (1,916 kg/4,224 lb) and sophisticated spacecraft. Its mission duration was planned for one year, but has since been extended numerous times after review by NASA. After completing a preliminary design review in February 2006 and a critical design review in November 2006, the LRO was shipped from Goddard to Cape Canaveral Air Force Station on February 11, 2009.

Launch was planned for October 2008, but this slid to April as the spacecraft underwent testing in a thermal vacuum chamber. Launch was rescheduled for June 17, 2009, because of the delay in a priority military launch, and happened one day later, on June 18. The one-day delay was to allow the Space Shuttle Endeavour a chance to lift off for mission STS-127 following a hydrogen fuel leak that canceled an earlier planned launch.

In 2024, it confirmed the highly accurate landing site of the first successful Japanese SLIM soft landing.

The mission exists because the Moon turned out to be unfinished business. When the United States stopped sending crews there in 1972, the scientific maps of the day still had blank patches, the poles had never been properly

surveyed, and the question of lunar water was a hypothesis rather than a resource inventory. LRO was designed to close all three gaps at once, and it did so in its first year, then spent the next decade and a half discovering how much more there was to find.

This book tells that story in layers. It begins with how a Moon-mapping mission came to be approved in an era when the Moon seemed finished, walks through the spacecraft and its instruments, follows the science results as they accumulated, and ends with the polar outposts that the mission's maps are now making possible. Along the way it pauses on the curiosities: a Mona Lisa transmitted by laser, a shrinking Moon, and a cave beside the Sea of

Tranquility.

LRO was also part of a wider moment. In the space of two years around its launch, three other lunar orbiters from three other countries were at work around the Moon, and the instruments on all of them kept confirming one another's findings. The lunar renaissance of the 2020s, with its landers and planned outposts, was incubated in that brief crowded season, and LRO is the last spacecraft of the cohort still flying. The orbiter carries a complement of six instruments and one technology demonstration:

Chapter 1: The Discovery of Lunar Reconnaissance Orbiter

Areas of investigation include selenodetic global topography; the lunar polar regions, including possible water ice deposits and the lighting environment; characterization of deep space radiation in lunar orbit; and high-resolution mapping, at a maximum resolution of 50 cm/pixel (20 in/pixel), to assist in the selection and characterization of future landing sites. In addition, LRO has provided images and precise locations of landers and equipment from previous and current lunar missions, including the Apollo sites.

The orbiter carries six instruments and one technology demonstration, and together they cover every part of that checklist.

The primary goal of the Cosmic Ray Telescope for the Effects of Radiation is to measure and characterize local energy transfer by charged particles in lunar orbit and its biological impacts.

The Diviner Lunar Radiometer Experiment measures lunar surface thermal emission to provide information for future surface operations and exploration. Lyman-Alpha Mapping Project (LAMP)

The Lyman-Alpha Mapping Project peers into permanently shadowed craters in search of water ice, using ultraviolet light generated by stars as well as the hydrogen atoms that are thinly spread throughout the Solar System. Lunar Exploration Neutron Detector (LEND)

The Lunar Exploration Neutron Detector provides measurements, creates maps, and detects possible near-surface water ice deposits.

The Lunar Orbiter Laser Altimeter investigation provides a precise global lunar topographic model and geodetic grid. Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Camera (NAC)

The Lunar Reconnaissance Orbiter Camera addresses the measurement requirements of landing site certification and polar illumination. LROC comprises a pair of narrow-angle cameras (NAC) and a single wide-angle camera (WAC). The two Narrow Angle Cameras feature a Cassegrain (Ritchey-Chretien) primary optics at f/3.59, with primary mirror diameter of 19.5 cm, using push-broom imaging.

The WAC provides visible and UV images at a scale of 100 meters/pixel in seven color bands over a 60 km swath.

The Miniature Radio Frequency radar demonstrated new lightweight synthetic

aperture radar (SAR) and communications technologies and located potential water-ice. About 1.6 million names were submitted.

Prior to the LRO's launch, NASA gave members of the public the opportunity to have their names placed in a microchip on the LRO. The deadline for this opportunity was July 31, 2008. About 1.6 million names were submitted. On June 23, 2009, the Lunar Reconnaissance Orbiter entered into orbit around the Moon after a four-and-a-half-day journey from the Earth. When launched, the spacecraft was aimed at a point ahead of the Moon's position.

A mid-course correction was required during the trip in order for the spacecraft to correctly enter Lunar orbit. Once the spacecraft reached the far side of the Moon, its rocket motor was fired in order for it to be captured by the Moon's gravity into an elliptical lunar orbit. A series of four rocket burns over the next four days put the satellite into its commissioning phase orbit where each instrument was brought online and tested.

On September 15, 2009, the spacecraft started its primary mission by orbiting the Moon at about 50 km (31 mi) for one year. After completing its one-year exploration phase, in September 2010, LRO was handed over to NASA's Science Mission Directorate to continue the science phase of the mission. It would continue in its 50 km circular orbit, but eventually would be transitioned into a fuel-conserving "quasi-frozen" elliptical orbit for the remainder of the mission.

NASA's LCROSS mission culminated with two lunar impacts at 11:31 and 11:36 UTC on October 9. The goal of the impact was the search for water in the

Cabeus crater near the Moon's south pole, and preliminary results indicated the presence of both water and hydroxyl, an ion related to water. On January 4, 2011, the Mini-RF instrument team for the Lunar Reconnaissance Orbiter (LRO) found that the Mini-RF radar transmitter had suffered an anomaly. Mini-RF has suspended normal operations.

Despite being unable to transmit, the instrument is being used to collect bistatic radar observations using radar transmissions from the Earth. The Mini-RF instrument has already met its science mission success criteria by collecting more than 400 strips of radar data since September 2010.

In January 2013, NASA tested one-way laser communication with LRO by sending an image of the Mona Lisa to the Lunar Orbiter Laser Altimeter (LOLA) instrument on LRO from the Next Generation Satellite Laser Ranging (NGSLR) station at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

The commissioning phase that followed orbit insertion was a careful,

instrument-by-instrument shakedown. Each payload was powered up, checked against ground calibration data, and exercised over selected lunar targets before mission scientists signed off on it. The discipline paid off: by the time the primary mission formally began in September 2009, every instrument was returning science-quality data, and the first views released to the public, published on July 2, 2009, showed a region of the lunar highlands south of Mare Nubium in sharp detail.

LRO's instruments were built by a coalition of institutions rather than a single center. Goddard delivered the laser altimeter, Arizona State University ran the camera suite, UCLA led the thermal radiometer, the Southwest

Research Institute built the ultraviolet mapper, MIT and the University of New Hampshire partnered on the radiation telescope, and the neutron detector came from Russia's Space Research Institute, making the payload itself an early example of post-Cold War space cooperation. The miniature radar, meanwhile, was a joint demonstration of radar technology for future planetary missions.

The choice of a polar orbit was itself a design decision of consequence. Earlier lunar orbiters had often flown near-equatorial paths that kept them over the same familiar ground; LRO circles the Moon from pole to pole, so the entire surface rolls beneath it as the Moon rotates, and every point gets repeated coverage under changing illumination. The two-hour orbit period carries the spacecraft around the Moon about a dozen times a day.

Getting to the launch pad took almost as much engineering as the spacecraft itself. LRO was the first of what was planned as a series of robotic precursor missions, and its development overlapped with the policy shifts that would eventually reshape the whole program. By the time the design reviews were done in late 2006, the mission had survived a change of directorates, a replanned rocket assignment, and a launch slip of nearly a year, and had emerged as the only precursor mission of its class actually to fly.

The instruments earned their berths in open competition. Each payload was selected in the mid-2000s from proposals by institutions across the country and abroad, judged on the science it promised per pound and per watt, and the winning suite covered the mission's checklist so completely that no single instrument has ever been redundant. It remains a model of how a small mission can buy big capability.

The cruise to the Moon was brief and uneventful by design. A direct trajectory from Florida needed just one small trajectory correction over the four-and-a-half-day crossing, and the Deep Space Network tracked the spacecraft

continuously as it closed the distance. Arrival day, June 23, 2009, ended with the braking burn behind the Moon, out of contact with Earth, and the confirming signal a short time later from the far side: the Moon had a new satellite.

The weeks that followed were the mission's first public triumphs. The release of the first pictures in early July gave newspapers a fresh Moon to print, and the topographic slices from the laser altimeter soon followed. For a mission justified in budget language, it was a reminder that lunar exploration sells itself the moment people can see the surface again at new resolution.

Even the spacecraft's name was a deliberate bridge to the past. Lunar Orbiter, the title of the 1960s mapping fleet that certified Apollo's landing sites, was borrowed for a mission doing the same job with instruments the earlier era could not have imagined, and the echo was intended: the United States had returned to lunar orbit as a matter of continuity, not novelty.

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ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.