

## NASA's Lunar Reconnaissance Orbiter (LRO) and Lunar Crater Observation and Sensing Satellite (LCROSS)

On June 18, 2009, NASA launched the [Lunar Reconnaissance Orbiter](#) (LRO) and the [Lunar Crater Observing and Sensing Satellite](#) (LCROSS) aboard an Atlas V 401 rocket. These missions are part of the Lunar Precursor Robotic Program at NASA's Marshall Space Flight Center as the initial steps in the planned human return to the Moon outlined by President George W. Bush in the 2004 Vision for Space Exploration.

On September 17, 2009, LRO [completed](#) its testing and calibration phase and entered its mapping orbit at 31 miles above the lunar surface. A year later, the \$540 million orbiter, with a payload of six instruments and one technology demonstration, had completed a topographic map of the Moon. Using LRO data, scientists [revealed](#) the Moon's geologically complex past, which featured numerous meteoric impacts that transformed the surface. This milestone marked the end of LRO's exploration phase and the beginning of its science phase, expected to last from two to four more years. NASA's Goddard Space Flight Center built and manages the mission, with a contribution from the Institute for Space Research in Moscow.

LRO's companion mission, LCROSS, had the objective of verifying the existence of water on the Moon and was managed by NASA's Ames Research Center with its spacecraft partner, Northrop Grumman. LCROSS executed a fly-by of the Moon on June 23, 2009 and was later confirmed to have enough fuel to accomplish its mission objectives, appeasing concerns that [arose](#) in August. On October 9, 2009, LCROSS [impacted](#) the [Cabeus](#) crater on the Moon's south pole, four minutes after and several kilometers away from where its Centaur upper stage hit the surface. The impacts created plumes of dust that were measured by instruments aboard the spacecraft and by astronomers who participated in the [LCROSS Observation Campaign](#).

On November 13, 2009, after having more [time](#) to analyze data from the impact, NASA [announced](#) the existence of water on the Moon. The preliminary results were based on observations by a near-infrared spectrometer and an ultraviolet visible spectrometer that measured the wavelengths produced by different compounds in the plume. The discovery answers a question that arose in 1999 when NASA's Lunar Prospector found large amounts of hydrogen at the Moon's South Pole and first suggested the presence of water.

On October 21, 2010, NASA [revealed](#) new data showing that the Moon is chemically active and the Cabeus crater has [50% more water](#) than originally estimated (though it is still a very small amount, about 6% by mass of the top lunar soil), and a water cycle. The water – in the form of “mostly pure water ice grains” – is irregularly distributed in pockets and apparently came from a variety of sources. Analysis of the plume also revealed the presence of large amounts of volatile compounds, such as methane and ammonia, and metals such as sodium and mercury. Water and other useful resources on the Moon could potentially be retrieved by humans in future exploration missions and may point to the need for exploration of other locations where comparable processes may have taken place.

LRO and LCROSS results have been featured in several papers in [Science](#) magazine and the missions graced the cover of Science twice in six weeks (September 17, 2010 and October 22, 2010).