LCROSS: Finding Water at the Lunar South Pole

BY BRIAN H. DAY

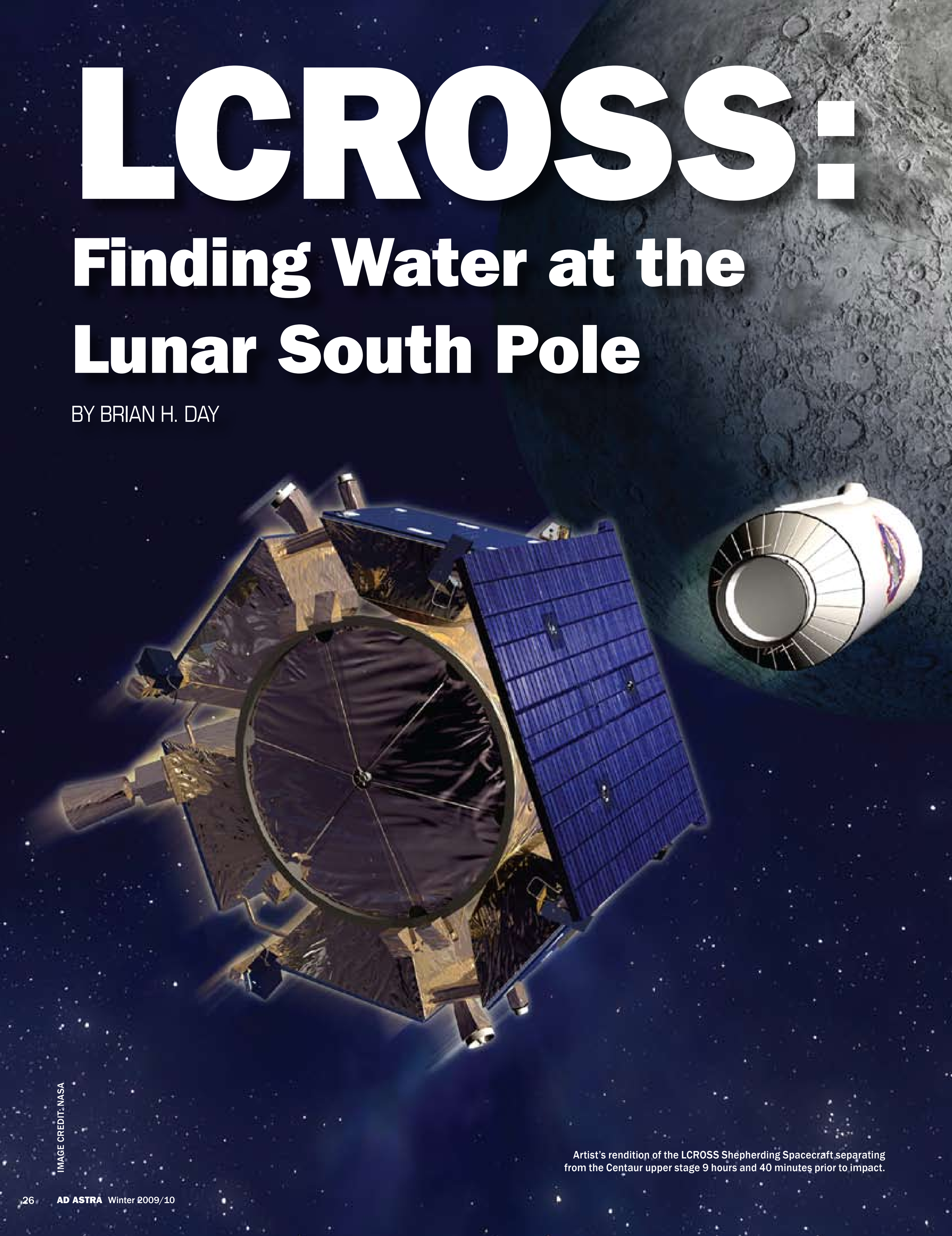
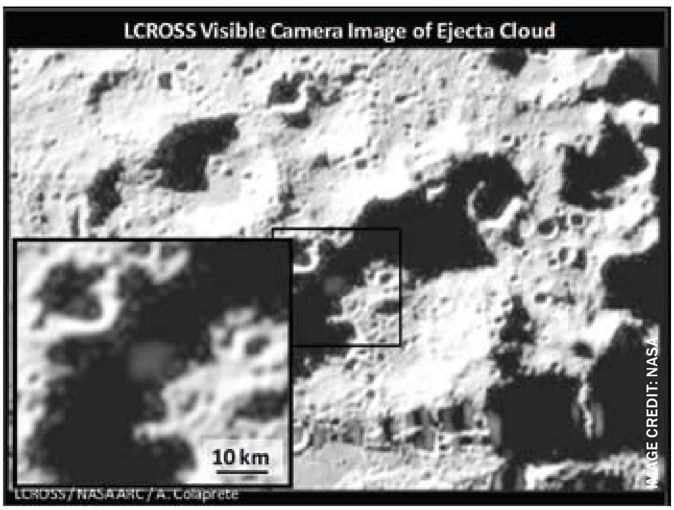


IMAGE CREDIT: NASA

Artist's rendition of the LCROSS Shepherding Spacecraft separating from the Centaur upper stage 9 hours and 40 minutes prior to impact.

Near-infrared camera view revealing surface detail within the permanently shadowed area on the floor of Cabeus. The newly created Centaur impact crater is shown.



The visible camera image showing the ejecta plume about 20 seconds after impact.

When NASA's Lunar CRater Observation and Sensing Satellite (LCROSS) impacted near the lunar South Pole on Oct. 9, 2009, it sparked a resurgence of interest in lunar exploration.

In the months preceding the impact, robotic probes from Europe, Japan, India, and China completed successful studies from lunar orbit. Among the fascinating results from these probes was the discovery that the lunar regolith is less arid than previously thought. Small quantities of water molecules were mixed in with the lunar soil over a wide range of latitudes. This water in the lunar soil, while sparse, was a fascinating complement to earlier findings by the Clementine and Lunar Prospector probes in the 1990s. They found evidence that significant deposits of water ice may exist in permanently shadowed craters at the lunar poles. But that evidence was preliminary and subject to multiple interpretations. The question of ice at the lunar poles remained open, and it was this question that LCROSS was designed to answer.

Surprisingly, this ambitious mission got its start only a few years ago. In late 2005, with several years of development behind it, NASA's Lunar Reconnaissance Orbiter (LRO) mission was upgraded to an Atlas V launch vehicle. This provided up to 1,000 kg of extra payload capacity that could be launched to the Moon along with LRO. NASA requested proposals for secondary payloads, small missions that could accomplish valuable lunar science under tight constraints of development time, budget, and mass. Teams from NASA's Ames Research Center and Northrop Grumman joined to propose a mission that would directly test the theories of lunar polar ice deposits by directing an impactor into one of the permanently shadowed craters. Doing so would create a debris plume whose composition could be analyzed by a following spacecraft that would fly into the plume.

To meet the constraints, the LCROSS team saved mass and money by devising new uses for existing components. The Centaur upper stage of the Atlas rocket would be used as the impactor. A payload adapter ring coupling LRO to the Centaur would become the mechanical chassis for the spacecraft that would analyze the impact plume. Additional savings came from the instrumentation, which was based on off-the-shelf products. In early 2006, the LCROSS proposal won the competition, and development began to meet an October 2008 launch deadline.

LCROSS project scientists Dr. Anthony Colaprete and Dr. Kim Ennico review early results from the Centaur and spacecraft impacts.

After launch manifest delays of several months, LRO and LCROSS launched together from Cape Canaveral on June 18, 2009. Four days after launch, LRO entered lunar orbit and soon began its detailed observations of the lunar surface, including neutron emission studies pinpointing concentrations of hydrogen and possible ice deposits. LCROSS, still holding onto the Centaur, executed a flyby of the Moon to enter into a large, highly inclined Lunar Gravity Assist Lunar Return Orbit about the Earth-Moon system. Three of these orbits would position LCROSS for the steep trajectory it would need to excavate the lunar surface more than three months later.

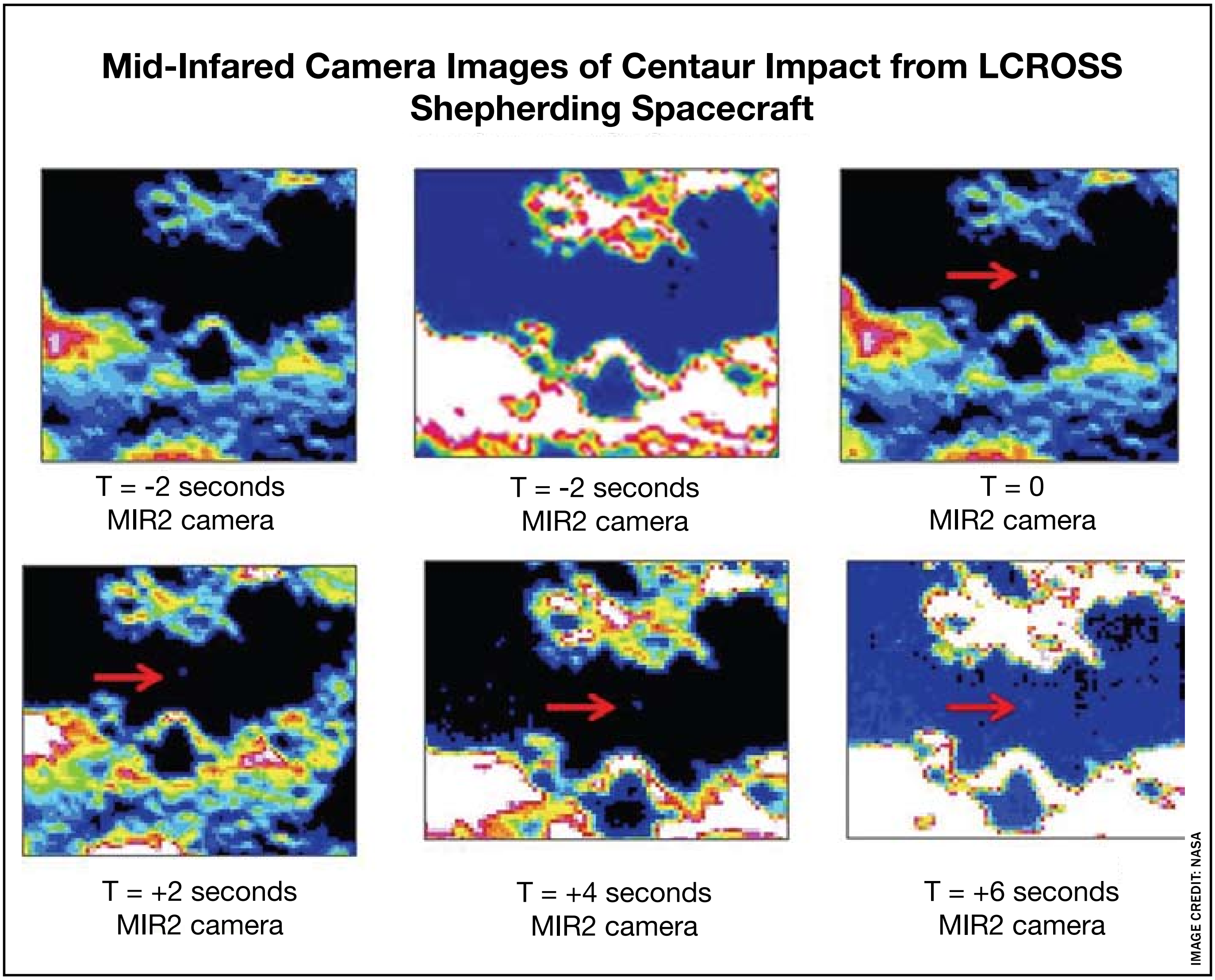
During the Lunar Gravity Assist Lunar Return Orbit, data from LRO and previous probes, including Japan's Kaguya, helped the LCROSS team refine their targeting options. On Sept. 28, 11 days before impact, NASA announced that

LCROSS's target was the crater Cabeus. This decision required careful analysis from the LCROSS science team and the lunar science community. The latest data indicated that Cabeus showed the highest hydrogen concentrations at the South Pole. However, Cabeus' location, depth, and surrounding terrain meant that the impact plume might be somewhat obstructed for viewing from the Earth. The question of observability from the Earth was further complicated by a wide range in estimates of the amount of material that would be lofted to a visible elevation. But all agreed that even with these uncertainties, amateur and professional observations were very worthwhile.

When impact occurred on Oct. 9 at 11:31 UT, instruments aboard LCROSS had the best view. LCROSS's mid-infrared cameras captured the flash from the Centaur impact and the thermal glow from the newly created crater. The visible light camera imaged the impact plume. The near-infrared camera imaged fine detail on the floor of Cabeus, including the Centaur's crater. But the real story came from the spectrometers aboard LCROSS. Members of the science team are thrilled with the quantity and quality of the data these instruments returned.

These spectrometers demonstrated that Cabeus does indeed harbor water in significant quantities. LCROSS's near-infrared spectrometer observations clearly show absorption bands from H_2O. Observations with the ultraviolet/visible spectrometer show emission from hydroxyl (OH) molecules. This emission resulted from water molecules that were lofted into the intense ultraviolet light from the Sun and broken apart into H and OH. The strengths of the spectral lines indicate that substantial amounts of water (at least 100 kg) were lifted into the one-degree field of view of LCROSS's instruments, making measurements of the vapor and debris composition. But as LCROSS Principal Investigator Anthony Colaprete points out, "The spectra show more than just water; there's a lot of interesting stuff there." The science team has significant work ahead to identify the numerous substances recorded by LCROSS's spectrometers. The story of LCROSS is just beginning to unfold.

Brian H. Day is mission education and public outreach lead for the LCROSS program at NASA Ames Research Center.



A time series of images collected with the mid-infrared camera (MIR2). The first image (left to right) shows the Cabeus crater before impact, while the next image shows this same scene with enhanced contrast stretching and no sign of impact apparent yet. These frames are followed by images of Cabeus approximately zero, two, four, and six seconds after Centaur impact. The thermal signature of the impact is detected clearly by the MIR2 camera. The arrows point to the thermal signature of the impact as detected by the LCROSS spacecraft. Images are presented in false color and are stretched to enhance contrast.

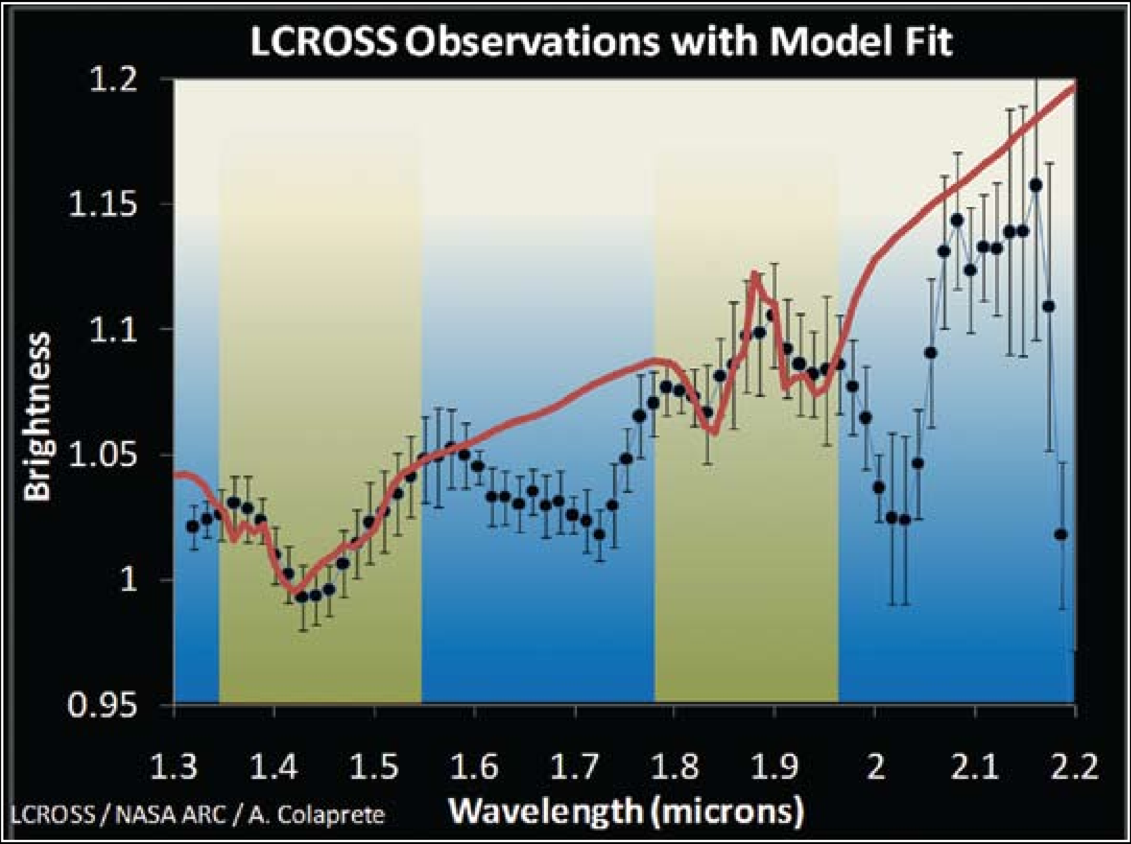


IMAGE CREDIT: NASA

Data from the down-looking near-infrared spectrometer showing several absorption bands. The yellow areas indicate water absorption bands. Note that the observed spectrum in these areas matches the absorption spectrum for water vapor (red curve).

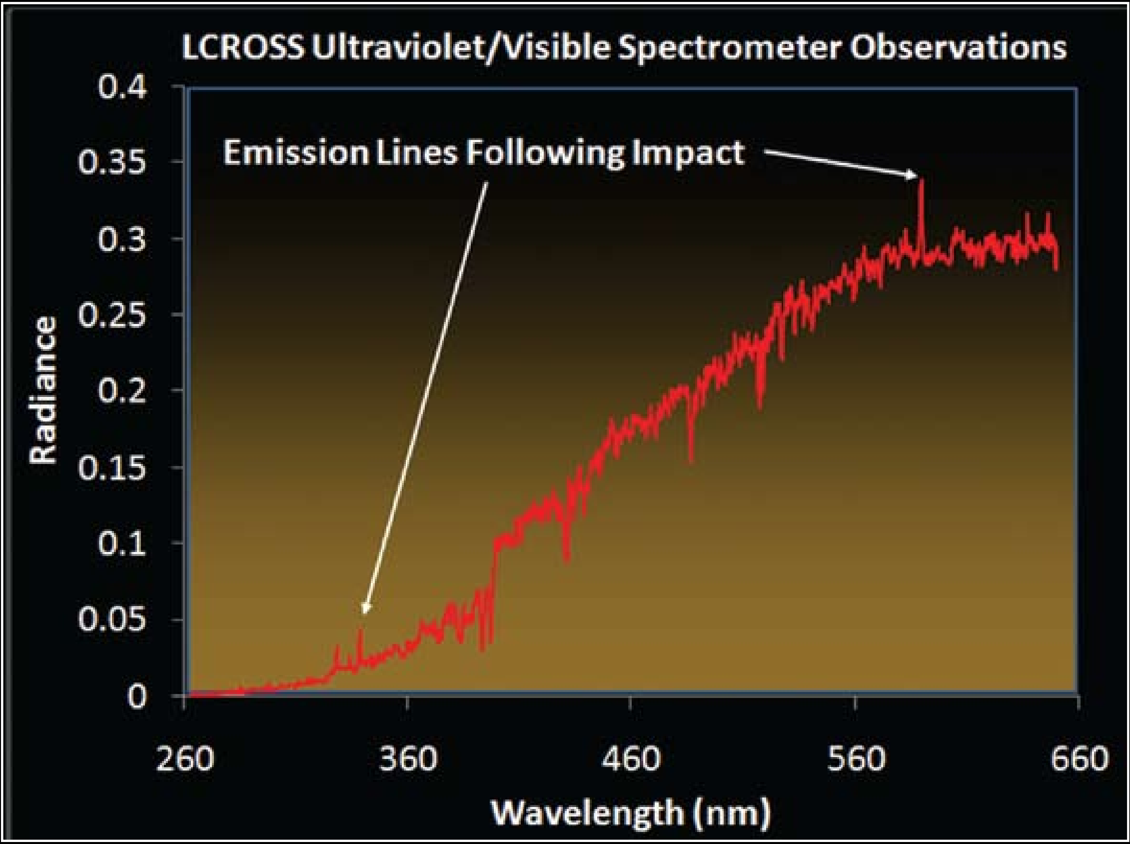


IMAGE CREDIT: NASA

Data from the ultraviolet/visible spectrometer taken shortly after impact, showing emission lines including the 309 nanometer hydroxyl line.