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Novel lunar impactor cleansed of water

BY [STEPHEN CLARK](#)
SPACEFLIGHT NOW
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Nearly halfway through its crash course with the moon, NASA's lunar impact mission is being scrubbed of Earth water that could throw the probe off course and pollute potential ice on the moon.

The mission will pass the halfway mark this week on its way to a pinpoint collision with the moon on Oct. 9. Debris from the impact plume will be analyzed in search of water molecules scientists believe could exist inside craters at the lunar poles.

The Lunar Crater Observation and Sensing Satellite, or LCROSS, is tugging a two-and-a-half ton Centaur rocket coated in foam that collected water from humid air at the mission's Florida launch site.



The Centaur, painted white, stands on the launch pad before liftoff. Credit: Stephen Clark/Spaceflight Now

"When we're sitting on the pad, the Centaur, which we're impacting on the moon, is essentially a giant thermos bottle," said Tony Colaprete, the project's chief scientist at NASA's Ames Research Center in Moffett Field, Calif.

The Centaur consists of two propellant tanks holding chilled liquid hydrogen and liquid oxygen.

Foam applied to the outer shell of the rocket helps insulate the cold fuels from warm outside temperatures. But it can also attract and condense water from rain and humidity, common conditions at the Atlas 5 rocket's oceanfront launch pad at Cape Canaveral, Fla.

"The foam absorbs quite a bit of water while it's sitting there,

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even for the short amount of time that it's in the elements in Florida on the launch pad," Colaprete said.

Valves on the Centaur also build ice during fueling.

"If you've seen the launch video from the rocketcams during the launch, looking down the Centaur, you can see icicles literally hanging off near the fill and drain valves lower down on the Atlas 5. It is that accumulated ice that we want to get rid of," Colaprete said.

If the ice survived during the spacecraft's circuitous four-month voyage to the moon, the probe could be pushed off course and the scientific results of the \$79 million mission could be skewed.

"Our principal objective is to measure in situ water on the moon. We don't want to confuse our measurements by having some terrestrial water on the Centaur," Colaprete said.

"The interesting thing is even though space is a vacuum, the water can sustain itself there if it's cold enough," said Paul Tompkins, LCROSS flight director.

After propelling LCROSS and the Lunar Reconnaissance Orbiter toward the moon, the Centaur safed itself and vented leftover fuel from its tanks.

United Launch Alliance, builder of the Atlas 5 rocket, assured NASA the Centaur would contain less than 220 pounds of residual water, hydrogen and oxygen at the end of its mission.

Colaprete said the Centaur easily met that requirement, with the extra mass totaling approximately 143 pounds, according to engineers' best estimates.

Instruments that will sense lunar debris thrown up by the Centaur's impact shouldn't detect such small amounts of Earth water, according to Colaprete.

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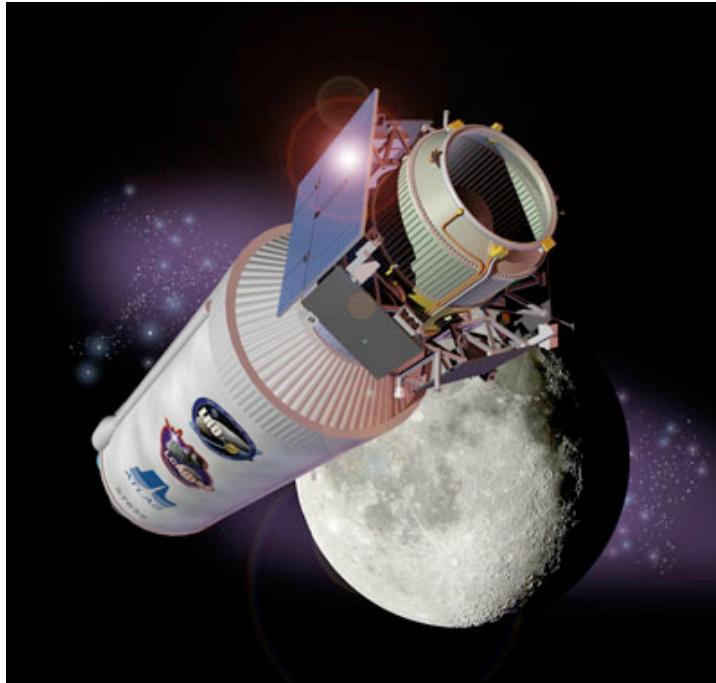
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Artist concept of the LCROSS shepherding spacecraft and Centaur voyaging to the moon. Credit: NASA

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But Colaprete noticed evidence of a water cloud trailing the spacecraft during instrument testing in the early days of the mission.

The water cloud was enough for the LCROSS navigation team to recommend a series of maneuvers called cold side bakeouts that turn the back side of the Centaur toward the sun. Such techniques had been discussed before launch, but were not in any mission plans.

Because the LCROSS shepherding spacecraft has a fixed solar panel, the stack must stay in the same orientation during most of the mission to generate electricity. That means the other side of the Centaur remains very cold.

"It's so cold that the ice just sits there and doesn't sublime very well, and certainly doesn't migrate out of the foam," Colaprete said.

To remedy the situation, engineers sent commands for LCROSS to rotate the spacecraft 180 degrees.

"We rotate the entire spacecraft around, go off of solar panel power and run on battery power, and just let that back side of the Centaur warm up," Colaprete said.

Like ice on the Centaur side normally warmed by the sun, frozen water embedded in the cold part of the rocket will slowly turn to gas and float into space.

"Once it gets exposed to that sunlight, it will warm up and those water constituents will start to bake out of the surface of the Centaur," Tompkins said.

LCROSS navigators were concerned the uncontrolled Centaur could turn its cold side toward the sun after separating from the shepherding spacecraft.

Boiling off water creates a small propulsive impulse that could push the Centaur off course right before impact. Scientists want to precisely aim the impactor to a specific point inside the target crater, so any errors could affect science results.

"Those little molecules coming off and subliming actually impart their exit velocity to the Centaur and actually push it off target," Colaprete said.

Now cruising nearly 300,000 miles from Earth, LCROSS has already completed two cold side bakeouts. At least one more maneuver is planned before impact.

The first bakeout produced a velocity change of more than one-tenth of a foot per second, enough force to cause a "significant targeting error," Colaprete said.

Several pounds of water boiling off could push the Centaur nearly two miles off course, according to Colaprete.

Officials waited a month after the mission's June 18 launch to begin the bakeouts. The first few days were spent turning on the spacecraft and preparing for a swing past the moon.

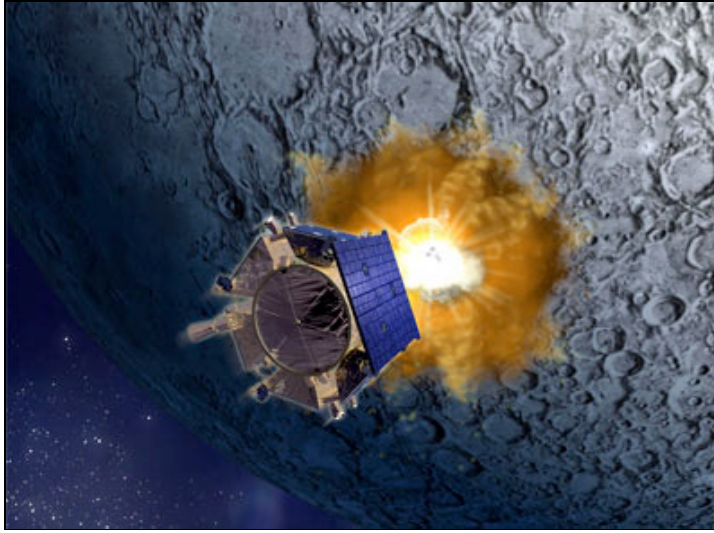
"The first week was just maddening for us on LCROSS. We had to essentially get all our trajectories right, get the swingby right and commission the payload for swingby calibrations. Once we did all that and we could actually catch our breath and catch up on our sleep, then we started saying, 'OK, let's assess our situation,'" Colaprete said.

The swingby used lunar gravity to send LCROSS into a distant Earth orbit to set up for the October impact.

"We swung from the Earth all the way out to lunar distance, and just as the moon goes by, it threw us into this super-high inclination, highly elliptical orbit around the Earth, but at about lunar distance. What that allowed us to do is phase our orbit such that in three months, we come back on the moon again and have a direct impact in the south pole," Tompkins said.

LCROSS will separate from the Centaur less than 10 hours before getting back to the moon. The probe will slow itself down, allowing the empty rocket to pull ahead and strike the moon about four minutes before the shepherding spacecraft.

The tightly choreographed impact sequence will occur around 1130 GMT (7:30 a.m. EDT) on Oct. 9, excavating more than a million pounds of lunar material, including potential water ice.



The LCROSS shepherding spacecraft observes the Centaur's violent impact with the lunar surface. Credit: Northrop Grumman

Scientists still have not picked a target for the impact, but it will probably be one of eight permanently shadowed craters near the moon's south pole, according to Colaprete.

Those eight craters were selected before launch based on the best available data from international lunar orbiters and ground-based radar.

Officials are busily studying early results from LRO's mission to narrow down the list of finalists. A science meeting at Ames next week will include extensive discussion of potential impact sites.

"Out of that meeting, I'll come away with hopefully a much more narrow list, from eight or so, which it is now, to maybe one or two," Colaprete said.

Colaprete will make the final decision in early September, in time for LCROSS to fire its engines and tweak its trajectory to line up with its destination.

NASA tentatively plans to announce the target crater around Sept. 10.

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