

Cooking Up Water From the Moon? NASA Studies Water Extraction With Microwaves

October 19 2009, by Steve Roy



Dr. Ed Ethridge holds his “moon in a bottle” experiment in his lab at the Marshall Center. Ethridge and his team have successfully extracted water from simulated lunar soil using a standard one-kilowatt microwave oven. His research is opening new doors of opportunity to harvest water from the moon to sustain life and produce rocket propellant for future lunar missions. (NASA/MSFC)

(PhysOrg.com) -- Intrigued by NASA lunar missions in the 1990s which suggested the existence of ice within craters at the moon's poles, NASA scientist Dr. Edwin Ethridge and his team started cooking up a way to extract water from lunar soil.

Using a conventional kitchen microwave and lunar soil simulant -- created to have the same characteristics as lunar soil -- Ethridge and his team have literally cooked water out of the soil.

"Water is one of the most plentiful compounds in the universe," said Ethridge, the principal investigator for the Research Opportunities in Space and Earth Science, or ROSES, project at the Marshall Space Flight Center in Huntsville, Ala.

"Finding water ice on the moon and [Mars](#) creates a potential for In Situ Resource Utilization, or ISRU," said Ethridge. ISRU is the use of resources found on other astronomical objects, like the moon, to complete a science mission. "In this case," he said, "we could harvest water in the form of ice from the moon to sustain life and produce rocket propellant."

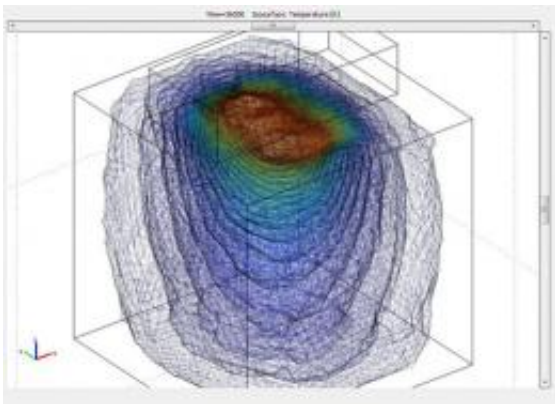
For five years, Ethridge, who holds a doctorate in materials science and engineering from the University of Florida in Gainesville, Fla., has been investigating the use of microwaves to extract water and other volatiles -- unstable gases like hydrogen and nitrogen -- from the moon's silicate rock top soil, called regolith.

His team, including Dr. William Kaukler of the University of Alabama in Huntsville's Center for Materials Research, and Frank Hepburn, also a Marshall Center materials engineer, has been learning how to extract water from the lunar permafrost -- soil with frozen water.

To construct the lab experiment, the team used a standard, one-kilowatt microwave oven, a quartz container with a simulant and a separate liquid nitrogen-cooled container with a simulant to mimic the ground under the top layer of regolith. They assembled a turbo-molecular [vacuum](#) pump to simulate the moon's vacuum environment and sealed a vacuum line from the pump to the flask collecting the water, frozen from a [liquid nitrogen](#) cold trap. They placed both containers of simulant in the microwave and heated them for two minutes.

"Cooking" the simulant helped the team understand how the molecules

in the soil react to microwave energy. The primary advantage of using that energy is that microwaves penetrate the soil, heating it from the inside out. The team found that when regolith is warmed from minus-150 degrees Celsius to minus-50 degrees, the water vapor pressure greatly increased. The simulated lunar vacuum drew the water vapor to the surface, permeating through the regolith particles. Then the water vapor collected on the cold trap and condensed back into ice. This process -- called sublimation -- uses heat to convert a solid into a gas and cools it to condense it back to a solid form without liquefaction.



Using multi-physics modeling tools, NASA scientists can predict the absorption of microwave energy into the simulated lunar soil as well as the temperature distribution. (NASA)

The regolith simulant and the cold trap were weighed before and after the experiment. The team found that 95 percent of the ice added to the regolith simulant was extracted in about two minutes," Kaukler said. "Of the extracted ice, 99 percent was captured in the cold trap."

The extracted ice can be used for multiple purposes to meet human needs at a lunar outpost. Water also can be split into hydrogen and

oxygen by a process known as electrolysis, which separates materials with the use of an electric current. Once split, the hydrogen and oxygen molecules could be used as a fuel or oxidizer. "Having water, we can obtain oxygen and have the ability to generate rocket fuel. This makes the moon a more viable test bed for space exploration," said Ethridge.

"With our experimental metrics using a one-kilowatt microwave, we found that if we could extract two grams of water ice per minute, we could collect nearly a ton of water per year," said Ethridge. "That would meet the initial manned lunar outpost water resupply requirement developed by NASA's ISRU Development and Planning Team."

There are multiple benefits of microwave extraction of ice as well. Microwaves of lower frequency can penetrate a meter or more into the regolith and release the ice without digging or disturbing the surface. "Eliminating the need to excavate saves equipment payload and more importantly, doesn't kick up dirt that could adversely affect the astronauts' spacesuits or equipment," Kaukler noted.

As the lunar regolith absorbs the microwaves, the energy is converted to heat. Heat is what is needed to vaporize the water, making the process energy efficient, Ethridge said.

"To extract the ice, we need to heat a large volume of regolith and the best way is using microwaves," Kaukler added. "Solar heating is not an option because the ice on the moon is in the shadowed craters where there is no sunlight. In addition, because the regolith is a superinsulator, other heating methods like solar, laser or electric heating only heats the surface. Microwave heating allows for deeper penetration into the soil."

Currently the team is measuring simulant materials properties at cryogenic temperatures and at different microwave frequencies. Using a multi-physics modeling software tool and measured materials properties,

Dr. Ethridge has created a three-dimensional model of the microwave absorption in the regolith. By using heat flow equations, the temperature of the soil is calculated as it heats up. "The development of these multi-physics calculation methods is useful for predicting how deep the energy will penetrate and how hot the [soil](#) will get," Ethridge said. "These types of calculations will be very important for the design and development of equipment to extract ice from the lunar permafrost at the moon's south pole."

Ethridge said his team is anxiously awaiting the findings from NASA's Lunar Crater Observing and Sensing Satellite (LCROSS) mission which impacted a lunar crater Oct. 9 in search of water. Spectral analysis of the impact plume will help quantify how much ice is hidden in the polar regions of the [moon](#).

"It is very important to know how much water there is and how deep it is under the lunar surface," Ethridge added. "Hopefully, LCROSS will find large quantities of [ice](#) and will help us know how much [water](#) we have to cook."

Provided by JPL/NASA ([news](#) : [web](#))

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