FIELD SCALE TESTING OF RESOLVE AT 2010 ISRU ANALOG TEST. J.E.Captain, J.W.Quinn, T.J. Moss, NASA (NE-L5, Kennedy Space Center, FL 32899, Janine.E.Captain@nasa.gov), and K.H. Weis, ASRC Aersopace Corp. (ASRC-15, Kennedy Space Center, FL, 32899)

Introduction: When mankind returns to the moon, there will be one aspect of the architecture that will totally change how we explore the solar system. For the first time in space exploration, we will take the initial steps towards breaking our reliance on Earth-supplied consumables by extracting resources from planetary bodies. Our first efforts in this area, known as *In Situ* Resource Utilization (ISRU), will be directed at extracting some of the abundant oxygen found in the lunar regolith. But the "holy grail" of lunar ISRU will be finding an exploitable source of lunar hydrogen. If we can find a source of hydrogen that can be reasonably extracted from the regolith, it would provide a foundation for true independence from Earth consumables. With in-situ hydrogen and oxygen (and/or water) we can produce many of the major consumables needed to travel to and operate on a sustainable lunar outpost. We would have water to drink, oxygen to breath, and rocket propellants and fuel cell reagents to enable extended access and operations across the moon. These items make up a huge percentage of the mass launched from the Earth and the consumables delivered to a lunar outpost. Producing them *in situ* would also significantly reduce the cost of operating a lunar outpost while increasing the payload capability for other lunar exploration objectives, such as science.

The Lunar Prospector mission found evidence of elevated hydrogen at the lunar poles, and measurements made at these locations from the Clementine mission bistatic radar have been interpreted as correlating to water/ice concentrations. At the South Pole, there is reasonably strong correlation between the elevated areas of hydrogen and permanently shadowed craters. More recently, LCROSS (Lunar Crater Observation and Sensing Satellite) and M^3 (Moon Mapping Mission) found strong evidence of water ice only centimenters below of the surface in the shadowed regions of the poles. However, the only way to truly answer the question of the type and availability of the hydrogen signal detected by these more recent missions is to go to the lunar poles and make direct measurements of the regolith. With this in mind, NASA initiated development of an experiment package named RESOLVE (Regolith & Environment Science and Oxygen & Lunar Volatile Extraction) that could be flown to the rim or into a permanently shadowed crater to answer the questions surrounding elevated hydrogen at the lunar poles.

RESOLVE is a drilling and miniature chemistry plant packaged onto a medium-sized rover that analyzes collected soil for volatile components prior to heating the soil and reducing it at high temperatures in the presence of hydrogen to produce water [1-3]. The RESOLVE Prototype consists of EBRC (Excavation and Bulk Regolith Characterization, i.e. a Drill and a Crusher), a Reactor, the Regolith Volatile Characterization (RVC) subsystem, the Lunar Water Resource Demonstration (LWRD) subsystem, the Regolith Oxygen Extraction (ROE) subsystem, and Ground Support Equipment (GSE). The RESOLVE Prototype processing module can be mounted onto any mobility platform that would accept its current mass and volume configuration. RESOLVE's capabilities include drilling one meter into soil, taking core samples, crushing them into 1 mm particles, delivering them to the Reactor, heating one quarter-meter core sample at a time and driving off volatiles, analyzing the volatiles, capturing the water and hydrogen evolved, and extracting oxygen by hydrogen reduction. The work performed in 2010 tested the volatiles characterization capabilities of this autonomous instrument during a Canadian Space Agency-lead activity on Mauna Kea, Hawaii.

The RESOLVE system was funded through a MAMMA proposal to participate in the 2010 International Lunar Surface Operations ISRU Analog Test. The RESOLVE system reconfiguration conducted for the field test included the following changes; power change to accommodate operation from a battery source, electronics rack repackaging for installation onto a rover, integration to Canadian Juno rover, transition to Wi-Fi 802.11 communication, and Reactor 2 install. The water capture system in the LWRD system was replaced with the capacitance sensor water capture system from the ROE system, and the hydrogen capture system was removed due to time limitations for the field test. Some of these changes were supported by funding from the Directorate Integration Office (DIO) in support of the field test.

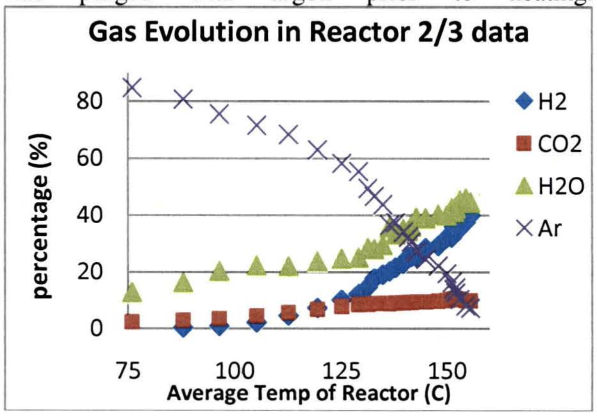
The electronics rack repackaging was dictated by a desire to be mobile and mount on the tandem rover unit. This showed a more lunar like configuration than the previous 6' ruggedized rack mount electronics rack that was moved into position beside the rover and connected before processing could commence. Brackets were installed on the compact rack to interface with the Canadian Juno Rover.

As an alternative to the previous communication architecture, a broad Wi-Fi mesh was supplied by NORCAT that would allow enough bandwidth for both the drill and chemistry plant to communicate over a single link. To this end a wireless switch with multiple Ethernet ports was mounted on the rover. This allowed communication to be established simply plugging the system into this switch, thus attaching the MEC to the field site network. This communication change also allowed for remote command and control capabilities. The RESOLVE chemistry plant was controlled from Kennedy Space Center, FL with live video and data streaming through the Canadian Space Agency's Ex-DOC facility and satellite link.

Scientific Goals: In addition to the modifications to the RESOLVE system for the field test, one of the main scientific goals of the deployment for RESOLVE was to show quantitation of hydrogen and water evolution as a function of temperature. To allow this the reactor was doped to provide volatile evolution upon heating.

Water doping of the soil was performed by two methods. The first method was to simply expose the dried and sieved tephra sample to atmospheric conditions. The tephra absorbs a small amount of water from the moisture in the atmosphere, typically coming to a water content of about 1% by weight. The water content of samples treated in this manner was measured up to 150 C in open air with a laboratory soil moisture analyzer. Higher water concentrations of water were achieved by doping a small amount of tephra with liquid water and adding the doped sample to the reactor.

Several methods of doping the reactor with hydrogen were explored in the laboratory. The method chosen for this field test was the use of a metal hydride. Metal hydrides are typically used to generate and store hydrogen, however most metal hydrides cannot be exposed to air. For our specific application, the metal hydride had to store hydrogen at room temperature, survive a transfer in air to the reactor, and release hydrogen as it was heated to 150 C. The hydride chosen was Hy-stor 207, a lanthanum nickel aluminum metal hydride. The challenge of using this metal hydride in the air safely was overcome by passivating the surface in a controlled environment. To prevent a flammable mixture of gas in the reactor during heating, the reactor was purged with argon prior to heating.



Results: The RESOLVE system on the tandem unit selected and sampled at 4 locations in the field test. These sites were chosen to resemble a mission propecting for volatiles on a crater rim and within the crater basin. RESOLVE successfully demonstrated the detection of low levels of hydrogen and water from the tephra during the field test. The above figure shows the reactor gas composition of volatiles as a function of temperature. In addition, RESOLVE demonstrated remote command/control, operation from battery power, integration onto a new rover platform, and the ability to process samples while roving.

References:

[1] Kleinhenz, J., et. al (2008). 47th Aerospace Sciences Meeting and Exhibit. American Institute for Aeronautics and Astronautics. AIAA-2009-1203
[2]Lueck, D. E. , et.al (2008) *CP969, Space Technology and Applications International Forum—STAIF 2008,* 149-156.
[3]A. Muscatello, et.al (2009) 47th AIAA Aerospace Sciences Meeting, 1202.