Resource Prospector: The RESOLVE Payload J. Quinn[1], J. Smith[1,] , J. Captain[1], A. Paz[2], A. Colaprete[3], R. Elphic[3], K. Zacny[4] [1]NASA Kennedy Space Center, FL., [2]NASA Johnson Space Center, Houston, TX, [3]NASA Ames Research Center, Moffett Field, CA, [4] Honeybee Robotics, Pasadena, CA.

Introduction: Upon completion of the Apollo Program, space agencies did not return to the moon for decades. But in the 1990's, both the Lunar Prospector and Clementine missions hinted that there could be water ice present at the lunar poles. A decade later, the Lunar Crater Observation and Sensing Satellite (LCROSS) showed that Cabeus crater contains water ice and other volatiles [1]. Instruments onboard the Lunar Reconnaissance Orbiter (LRO) now reveal that water ice may also be present in areas that receive several Earth days of continuous sunlight each month.

In order to factor these potential resources into NASA's lunar exploration mission designs, we first need to evaluate the distribution and quantity of ice and other volatiles present at the poles and determine whether these can be easily harvested for use as a propellant or other mission consumable. To address these questions, NASA's Advance Exploration Systems (AES) Directorate has been developing a lunar volatiles exploration payload named RESOLVE. Now the primary science payload onboard the Resource Prospector (RP) mission, the RESOLVE payload consists of several instruments that collectively ground-truth and evaluate lunar volatile resources. Because existing orbital data has very low spatial resolution, the RESOLVE payload is mounted on a rover, enabling meter-scale resolution of volatile resources.

With the principal goal of defining the vertical and horizontal distribution of water ice on a sub-meter scale, RESOLVE is armed with a suite of sophisticated instruments. The Neutron Spectrometer Subsystem (NSS) is tasked with localizing elevated hydrogen concentration and identify sampling locations. The Drill Subsystem penetrates the subsurface down to 1 m depth and captures samples if needed. The Near-IR Volatiles Spectrometer Subsystem (NIRVSS) looks at the cuttings being generated by the drill and characterizes hydrocarbons, mineralogical context for the site, and the nature of water ice. If NIRVSS data determines more analysis is needed, the sample is transferred to the Oxygen and Volatile Extraction Node (OVEN) Subsystem. The OVEN (as the name implies), heats up the sample and evolved volatiles are transferred to the Lunar Advanced Volatiles Analysis (LAVA) Subsystem which identifies and quantifies species of volatiles via GC-MS.

RESOLVE subsystems completed a field test campaign and thermal vacuum chamber testing during the 2015 fiscal year. The following sections provide more details about each of the subsystems.

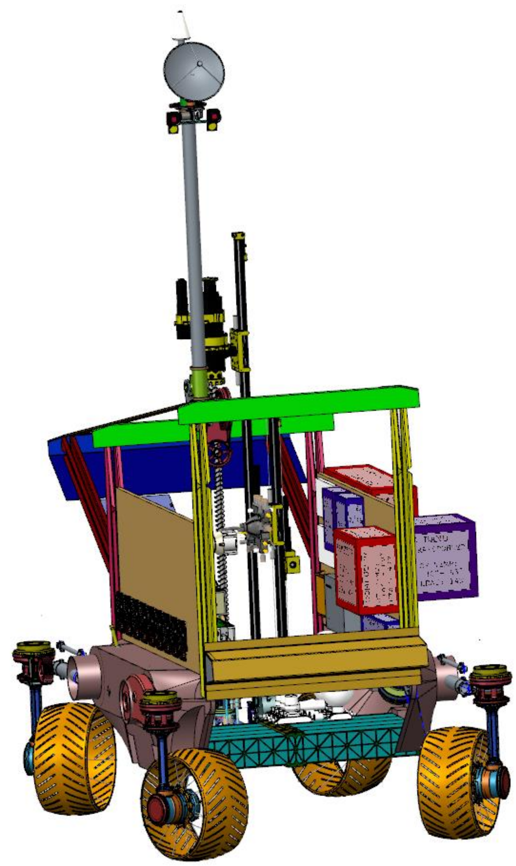

Figure 1. RESOLVE payload mounted inside the Resource Prospector Rover for the 2015 Field Campaign.

Prospecting While Roving: Two prospecting instruments are used to localize elevated hydrogen and water distribution. The Neutron Spectrometer Subsystem (NSS) is the payload's "bloodhound" so to speak, and operates in close connection with Resource Prospector's rover. The NSS instrument detects the equilibrium neutron flux emitted from the surface of a planetary body. As such the NSS allows for the localized detection of elevated hydrogen concentrations, enabling better selection of locations for subsequent drilling and volatile analysis. The NSS has the unique capability of measuring hydrogen to depths of up to 1 meter. The NSS instrument has flight heritage, having flown on orbiting missions such as Lunar Prospector, Mars Odyssey, Mercury, MeSSENGER, and LRO. The instrument was modified to operate as a surface-based instrument.

The second prospecting instrument is the Near-IR Volatiles Spectrometer Subsystem (NIRVSS). NIRVSS hardware is based on the flight heritage of the spectrometer flown onboard LCROSS, with spectral ranges adjusted to λ 1.6–3.4μm by inclusion of a different detector. This spectrometer has the ability (in conjunction with NSS) to map surface materials such as hydroxyl distribution as well as mineralogy composition. NIRVSS can also image the drilled cuttings and characterize higher mass compounds, mineralogical context with depth, and form of water.

Sampling and Heating the Regolith: The RP drill is used to acquire subsurface samples for analysis by two of RESOLVE's spectrometers. The RP drill is based on the Mars Icebreaker drill developed for capturing samples of ice and ice-cemented ground on Mars [2]. The drill consists of a rotary-percussive drill head, a sampling auger, and a brushing station for sample transfer. In its current design, the drill has the ability to acquire samples at depths of 80 cm, however, the flight drill will have a 1 m depth capability. The drill can capture samples "on demand" at specific depths allowing stratigraphy to be preserved. The auger-based, on-demand sampling approach utilizes the local environment to maintain regolith temperatures in situ before analysis with RESOLVE's GC-MS [3].

The regolith acquired by the drill is accepted by RESOLVE's Oxygen and Volatile Extraction Node or OVEN subsystem. OVEN is responsible for the step-wise heating of the regolith sample in a sealed receptacle at temperatures up to 450 °C. The temperature, pressure and pressure rise rate of the vapors generated within the OVEN subsystem are recorded as a function of heat input over time. The OVEN subsystem is reusable, with fill and dump sample capabilities allowing for multiple measurements. The evolved gas/vapor generated by the heating of the regolith is passed to the Lunar Advanced Volatile Analysis (LAVA) Subsystem for identification and quantification of volatile constituents.

Volatile Analysis: The LAVA Subsystem accepts OVEN's effluent gas/vapor and identifies and quantifies volatiles below the atomic number 65 using a GC-MS. This includes the detection of such compounds of interest like H_2, He, CO, CO_2, CH_4, H_2O, N_2, NH_3, H_2S, and SO_2. A unique feature of the LAVA GC-MS, which is different from previously flown instruments, is its fast sample analysis. The MS has the ability to scan the entire targeted mass range at about a rate of 6 times per second. This technique allows for sample analysis to be completed in less than 2 minutes (as opposed to an average time of 25 minutes). The LAVA subsystem also has the unique capability of capturing water vapor evolved during OVEN's heating operations, and condensing it into a water droplet for visualization back on Earth.

References: [1] Colaprete et al., (2010). Detection of water in the LCROSS ejecta plume. Science. [2] Zacny et al., (2013) Reaching 1 m Deep on Mars: The Icebreaker Drill, Astrobiology. [3] Kleinhenz et al. (2015), Impact of Drilling Operations on Lunar Volatiles Capture: Thermal Vacuum Tests, AIAA SciTech 2015.

Acknowledgements: The project has been funded by the NASA Advanced Exploration Systems Directorate and NASA's Space Technology Mission Directorate