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RESOLVE for Lunar Polar Ice/Volatile Characterization Mission

G.B. Sanders (1), W.E. Larson (2), J.W. Quinn (2), A. Colaprete (3), M. Picard (4), D. Boucher (5)
(1) NASA Johnson Space Center, TX USA, (2) NASA Kennedy Space Center, FL USA, (3) NASA Ames Research Center, CA USA, 43) Canadian Space Agency, Quebec, Canada, (4) Sudbury, ON. Canada, gerald.b.sanders@nasa.gov/Fax (281) 483-2428

Abstract

Ever since data from the neutron spectrometer instrument on the Lunar Prospector mission indicated the possibility of significant concentrations of hydrogen at the lunar poles, speculation on the form and concentration of the hydrogen has been debated. The recent impact of the Lunar Crater Observation and Sensing Satellite (LCROSS) along with thermal, topographic, neutron spectrometry, and radar frequency data obtained from the Lunar Reconnaissance Orbiter (LRO) have provided more information suggesting significant amounts of water/ice and other volatiles may be available in the top 1 to 2 meters of regolith at the lunar poles. The next step in understanding what resources are available at the lunar poles is to perform a mission to obtain 'ground truth' data. To meet this need, the US National Aeronautics and Space Administration (NASA) along with the Canadian Space Agency (CSA) have been working on a prototype payload known as the Regolith & Environment Science and Oxygen & Lunar Volatile Extraction experiment, or RESOLVE.

1. Introduction

The presence of large concentrations of accessible hydrogen and/or water at the lunar poles could have profound implications on the design and affordability of initial and long-term human Lunar and solar system exploration architectures. In particular, the ability to make propellants, life support consumables, and fuel cell reagents can significantly reduce mission cost by reducing launch mass by eliminating the delivery of consumables from Earth and enabling transportation system reusability; lowering risk by reducing dependence on Earth; and enabling extended surface operations and science by providing an energy rich environment and affordable access to multiple surface targets. The purpose of the RESOLVE experiment is to address fundamental science and resource questions such as "What resources are available on the Moon, where are they, and in what form?" as well as critical engineering questions, such as "How will we mine these resources, what extraction process is the most practical and efficient, and what are the engineering challenges to be faced in this environment?" The environment in the permanently shadowed regions at the poles is especially challenging due to the extremely low temperature (<40 K) and the unknown physical properties and content of trapped gases in the regolith and ice (if present). Two generations of RESOLVE have been built and tested and the 2nd generation of RESOLVE was field tested twice in Hawaii on the slope of Mauna Kea. The RESOLVE experiment is now in the 3rd generation of design which is aimed at both a mission simulation field test in June of 2012 and lunar environment simulation (vacuum) testing in 2014.

2. RESOLVE Overview

The RESOLVE experiment is a payload that can be mounted on a lander or preferably a rover. It consists of the following subsystems: 1) sample site selection subsystem (neutron spectrometer and near infra-red spectrometer), 2) sample acquisition and transfer subsystem (1 meter core drill and core transfer device), 3) sample processing subsystem (reusable sample heating oven), and 4) volatile characterization and water capture subsystem (gas chromatograph/ mass spectrometer with water capture device). The RESOLVE experiment also includes its own structure, avionics, power conditioning and management, and thermal management subsystems, but requires power and communications from a lander or rover.

The mission of primary interest for lunar ice/volatile characterization will consist of a lunar rover and RESOLVE payload that is capable of mapping the horizontal distribution of hydrogen bearing volatiles, and be capable of taking subsurface ground samples at a depth of up to one meter for analysis. The one meter core will then be divided into 8 segments to be heated up to 900 C with released gases analyzed for water and other volatiles that may be present. After all volatiles have been released, hydrogen would then be added to the sample to remove oxygen via the hydrogen reduction reaction. The mission would last ~5 to 7 days and perform 3 to 5 sample collection and processing operations in an area of several square kilometers.

3. Previous RESOLVE Designs [1, 2]

The RESOLVE experiment project started in 2005 through a NASA Internal Call for Proposals. The 1st generation of RESOLVE was aimed at subsystem design feasibility. Subsystem hardware for all process steps were built and independently tested. For the 1st generation of RESOLVE, separate reactors were designed and built for evolving lunar volatiles and extracting oxygen from regolith via the hydrogen reduction method. For volatile characterization, a COTS Siemens gas chromatograph was modified to meet mission measurement requirements and both hydrogen and water adsorption capacitance beds were incorporated as redundant measurement methods. A core drill with sample capture device for the complete 1 meter sample length was designed and built by NORCAT under contract to NASA with support from CSA.

In 2007, the 2nd generation of RESOLVE was initiated with the aim at building a 'flight-like' experiment package. Packaging and mass reduction efforts for the major subsystems were started, but work on minimizing avionics, power, and ground support equipment to operate in Earth's atmosphere were not. A new combined volatile extraction/ hydrogen reduction reactor was designed and built and both the sample collection drill and volatile characterization subsystems were modified from the 1st generation design. The 2nd generation RESOLVE was field tested for the first time in Nov. 2008 mounted on the 'Scarab' rover built by Carnegie Mellon University (CMU) under a NASA contract, and utilized a Neptec TriDAR camera for nighttime navigation and drill site selection, under a CSA contract.

After the success of the field test in 2008, a subsequent field test was planned and performed in 2010 at the same analog location on Hawaii aimed at examining terrain and remote mission operation aspects not evaluated in the first field test.

4. RESOLVE 3rd Generation

In June 2010, the design phase of the 3rd generation of RESOLVE was initiated. The aim of this generation is to design and build a complete RESOLVE experiment, including power and thermal management, avionics, and structure to flight mass and power requirements of <60 kg and <200 Watts average. Included in the next generation RESOLVE is the addition of a neutron spectrometer and near infra-red spectrometer for the new sample site selection subsystem. The 3rd generation design effort will be performed in two stages. Stage 1 is a design that can operate under field test conditions and evaluate all operations and procedures associated with a 5 to 7 day mission on the Moon operated from NASA and CSA centers with mission applicable communication capabilities. Stage 2 is to modify the design for full operation under lunar environment conditions including thermal and radiator capabilities.

At the time of submitting this abstract, the 3rd generation RESOLVE experiment has completed its Preliminary Design Review for Stage 1. Also planning between NASA, CSA, and the University of Hawaii Hilo have started for the 3rd International Hawaii analog field test planned for June 2012.

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