RESOLVE Projects: Lunar Water Resource Demonstration and Regolith Volatile Characterization

In Situ Resource Utilization (ISRU) Oxygen Production

To sustain affordable human and robotic space exploration, the ability to live off the land at the exploration site will be essential. NASA calls this ability *in situ* resource utilization (ISRU) and is focusing on finding ways to sustain missions first on the Moon and then on Mars.

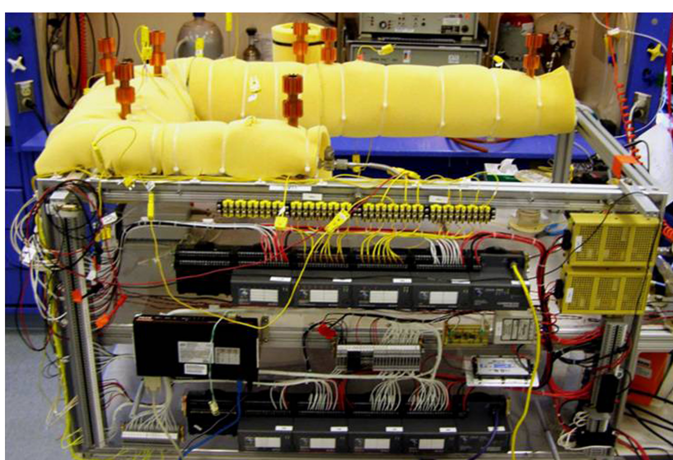
The ISRU project aims to develop capabilities to technology readiness level 6 for the Robotic Lunar Exploration Program and early human missions returning to the Moon. NASA is concentrating on three primary areas of ISRU: (1) excavating, handling, and moving lunar regolith, (2) extracting oxygen from lunar regolith, and (3) finding, characterizing, extracting, separating, and storing volatile lunar resources, especially in the permanently shadowed polar craters.

To meet the challenges related to technology development for these three primary focus areas, the Regolith and Environment Science and Oxygen and Lunar Volatile Extraction (RESOLVE) project was initiated in February 2005, through funding by the Exploration Systems Mission Directorate. RESOLVE's objectives are to develop requirements and conceptual designs and to perform breadboard concept verification testing of each experiment module. The final goal is to deliver a flight prototype unit that has been tested in a relevant lunar polar environment.

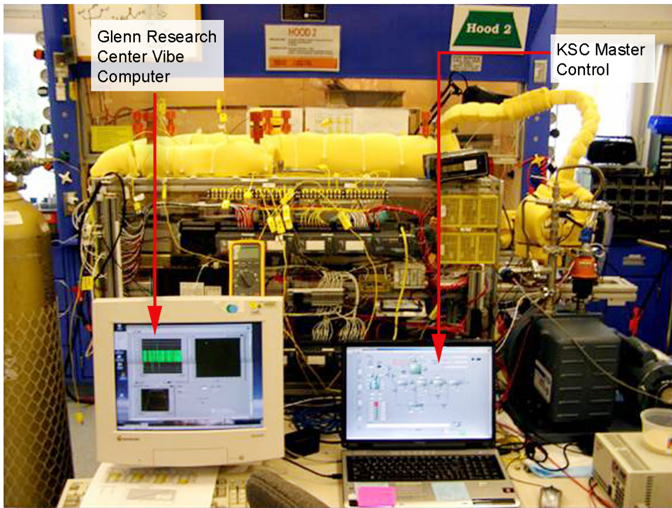
Here we report progress toward the third primary area—creating ways to find, characterize, extract, separate, and store volatile lunar resources. The tasks include studying thermal, chemical, and electrical ways to collect such volatile resources as hydrogen, water, nitrogen, methane, and ammonia. We approached this effort through two subtasks: lunar water resource demonstration (LWRD) and regolith volatile characterization (RVC).

For the LWRD, we

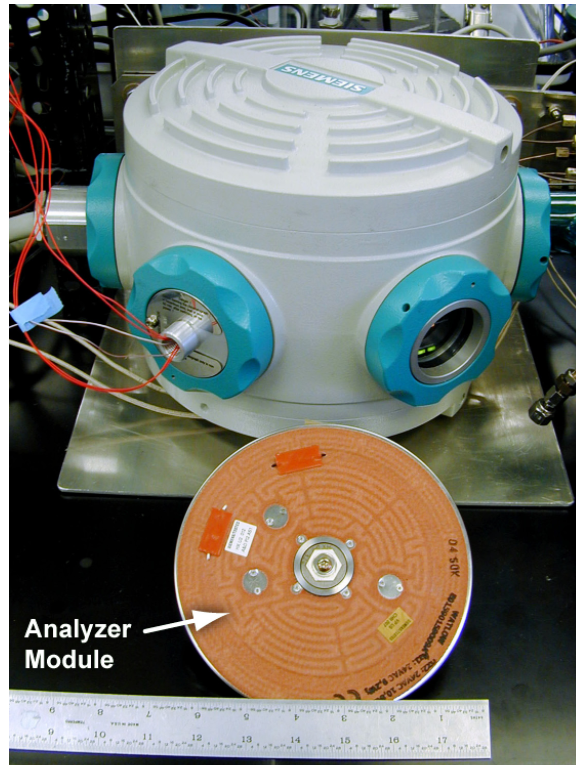
- developed methods for capturing and releasing hydrogen and water from a representative sample consisting of lunar simulant and representative gas mixtures,
- produced a water droplet from the captured water,
- reacted the water from the droplet in an electrolyzer to form hydrogen and oxygen,
- designed and built an engineering breadboard unit to demonstrate hydrogen and water capture from a representative sample, and
- performed a successful integrated test with RVC, demonstrating hydrogen and water capture, as well as electrolysis of water to form hydrogen and oxygen.



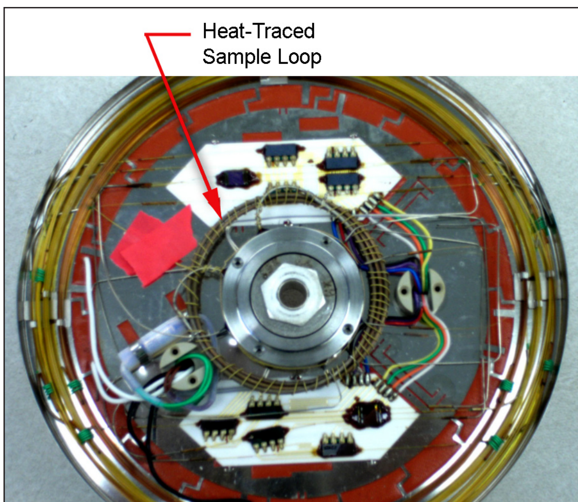
Final LWRD module.



Integrated LWRD/RVC engineering breadboard unit, showing computer controls.



Siemens MicroSAM GC and Analyzer Module.



Nichrome wire heat tracing for Siemens MicroSAM GC sample loop.

For the RVC, we

- identified a commercially available, process-control gas chromatography (GC) system of unusually small size, with extensive microelectromechanical systems technology capable of separating and quantifying gases of interest in short analysis times,
- modified the GC system to enable better quantification of water,
- optimized the GC system for water, hydrogen, and helium analysis, and
- developed an analysis method to successfully separate and quantify all permanent gases used in the representative samples (hydrogen, nitrogen, carbon dioxide, and carbon monoxide), including water.

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