



# Use of Hawaii Analog Sites for Lunar Science and In-Situ Resource Utilization

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## Abstract

In-Situ Resource Utilization (ISRU) and lunar science share similar objectives with respect to analyzing and characterizing the physical, mineral, and volatile materials and resources at sites of robotic and human exploration. To help mature and stress instruments, technologies, and hardware and to evaluate operations and procedures, space agencies have utilized demonstrations at analog sites on Earth before use in future missions. The US National Aeronautics and Space Administration (NASA), the Canadian Space Agency (CSA), and the German Space Agency (DLR) have utilized an analog site on the slope of Mauna Kea on the Big Island of Hawaii to test ISRU and lunar science hardware and operations in two previously held analog field tests. NASA and CSA are currently planning on a 3rd analog field test to be held in June, 2012 in Hawaii that will expand upon the successes from the previous two field tests.

## 1. ISRU and Science

In-Situ Resource Utilization (ISRU) involves the collection, manipulation, and processing of local material into products for robotic and human exploration, such as propellants, fuel cell reactants, life support consumables, thermal energy storage, and hardware/crew protection. Just like mining on Earth, successful implementation of ISRU requires detailed knowledge of the type and distribution of resources present that may be of interest, understanding of the potential impurities that could foul processing, and knowing the physical attributes of the planetary material to ensure excavation, material transport, and processing systems are designed properly. In a similar manner, scientific investigations of the Moon involves determining the physical and geologic composition, structure, origin, and evolution of the lunar crust and subsurface as well as the location, distribution, and movement of solar, bombardment, and endogenous lunar volatiles. Both ISRU and science investigations require the

development and use of hardware and instruments for orbital and local mineral characterization, access to surface and subsurface materials, material processing to characterize volatiles and make products, and methods for evaluating process efficiency. Early missions for both scientific investigation and ISRU resource characterization and processing will most likely be performed robotically requiring remote operation, data collection, data integration and examination, and planning.

## 2. The Role of Analog Testing

The production of propellants, life support consumables, radiation shielding, and other mission critical products from in-situ materials and resources can significantly reduce the total mission mass, cost, and risk to the crew. However, there are five main risks that need to be addressed before mission planners will utilize ISRU capabilities into mission critical operations. These risks are: 1) the resource of interest is not at the site of exploration; 2) the resource is available but it is in a form or location not expected, or there are unexpected impurities with the resource that can cause problems; 3) the ISRU process does not operate properly in the actual environment compared to Earth-based testing (gravity, vacuum, temperature, radiation, etc.); 4) the ISRU process does not operate when actual in-situ resources are acquired and processed (i.e. maintenance, operating life, and performance degradation issues); 5) the products and services of the ISRU system are not compatible with the end-user (i.e. quantity and quality problems, or interface issues). To address these risks, NASA, CSA, and other international space agencies have utilized field demonstrations at analog sites to allow scientific and ISRU technologies and systems to be tested under applicable mission conditions. It also allows operations and procedures to be evaluated in conjunction with other mission systems. By including multiple organizations, analog field tests also promote the development and use of

international standards and interfaces while fostering teamwork and partnerships.

### **3. Infrastructure and Analog Sites on Hawaii**

When selecting a site for analog field testing of scientific instruments and ISRU hardware and systems to reduce the risk for future flight missions, NASA and CSA have focused on three main criteria: 1) mission applicability (terrain, rock distribution, mineral, chemical, and physical attributes of the surface and subsurface soils/regolith), 2) ease of access to the site for personnel and test equipment, and 3) availability of local infrastructure for personnel, maintenance, and logistics to support the analog operations. NASA and CSA have selected site(s) on the slope of Mauna Kea on the Big Island of Hawaii that meet the desired attributes in all three criteria for performing ISRU and scientific investigations. In particular, the roads and infrastructure on Mauna Kea that support the telescopes and visiting astronomers are major attributes with respect to the second and third selection criteria. In 2008 and 2010, a single site was selected at ~9000 near the visitor center on Mauna Kea, called Pu'u haiwahini to perform testing. This site provided terrain features and volcanic tephra that reasonably simulated lunar regolith physical and mineral characteristics required for excavation and oxygen extraction from regolith testing. New sites are now under evaluation that will provide much more diverse mineral and terrain features for enhanced science instrument and lunar polar ice/volatile experiment characterization testing. A site at ~12,000 feet on Mauna Kea south of the Very Long Baseline Interferometry (VLBI) antenna facility, known as 'Apollo Valley', that combines glacial and volcanic features is one site under evaluation for the 3<sup>rd</sup> International Hawaii Analog field test planned for June 2012.

### **4. Objectives for Next Field Test**

NASA, CSA, and DLR have jointly performed two field tests to date at the Pu'u haiwahini site on Mauna Kea. The first field test in Nov. 2008 was aimed at demonstrating the basic feasibility of lunar ISRU oxygen extraction from regolith and mobile prospecting for lunar polar ice/volatiles, and included hand held science instruments for physical and mineral characterization. DLR field tested the

lunar/Mars Mole for subsurface material collection. The second field test in Feb. 2010 built upon the successes from the first test by increasing the complexity and fidelity of the hardware and systems tested. More challenging terrain and remote operation capabilities from CSA and NASA centers were added. The 3<sup>rd</sup> International Hawaii analog field test will focus on integrating exploration and science objectives and hardware for two robotic mission scenarios: 1) Lunar ice & resource prospecting while performing full mission control operations and procedures and 2) Pre-deployment of multiple rovers for terrain and resource characterization before crew arrival.

### **5. Overview of Potential Science and ISRU Instrument Involvement**

For mission scenario 1 lunar ice and resource prospecting, NASA and CSA have agree to jointly test mobility platforms with the integrated Regolith & Environment Science and Oxygen & Lunar Volatile Extraction (RESOLVE) experiment. The RESOLVE experiment includes a neutron spectrometer and near infra-red spectrometer for sample location determination, a 1 meter coring drill for subsurface sample acquisition and transfer, and a reusable oven attached to a gas chromatograph/mass spectrometer for volatile characterization. For mission scenario 2 (at the time of writing this abstract), both NASA and CSA are in the process of identifying principal investigators and instruments associated with pre-deployment of multiple rovers for terrain and resource characterization. The NASA Moon-Mars Analog Mission Activity (MMAMA) call for proposals in the Science Mission Directorate will be used for instrument selection. For both mission scenario 1 and 2, remote operation and data collection from science instruments, rovers, and ISRU hardware, remote data integration to create a 3D understanding of the terrain and resources, and remote planning and execution of the mission scenarios will be included in analog field test. A local operation center will be established near the test site to perform initial checkout and operations before turning operation over to operations centers at NASA, CSA, and other participants. NASA and CSA are interested in identifying other participants that can enhance and expand upon the goals and objectives for the planned mission scenarios.