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Using Analog Field Tests To Link and Prepare Science and In-Situ Resource Utilization for Future Space Missions

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Abstract

A major goal of NASA's human exploration program is to learn how to use the resources of space, known as In-Situ Resource Utilization (ISRU), to lower the cost and risk of human space exploration. Successful implementation of ISRU requires detailed knowledge of surface and subsurface materials, minerals, and volatiles that may be present. This same information is required to better understand the physical and geologic composition, structure, origin, and evolution of the Moon, Mars, and other extraterrestrial bodies of interest. It is also important to recognize that while ISRU and science objectives may be similar, the desired method or hardware to achieve the information desired may be drastically different. One method to promote understanding, coordination, and joint development of instruments and operations between Science and ISRU is the use of analog field demonstrations.

1. Introduction

For the last four years, NASA has performed a series of human lunar exploration studies, including the Lunar Architecture Team Phase I and II, the Constellation Architecture Team Trade Space 1, 2, & 3, and several Lunar Surface System mission scenarios. In July of 2008, the 14 international space agency members of the International Space Exploration Coordination Group agreed to collectively explore ideas and plans for human exploration of the Moon as a first step in jointly defining objectives and mission scenarios, with the goal of defining a global reference architecture for human lunar exploration by mid 2010. While performing significant lunar science has always been a major goal for all of these studies, the exact science performed and how it integrates into other human exploration activities has rarely been part of the main stream effort. Separate parallel studies and workshops, such as the NASA Advisory Council (NAC) "Workshop on Science Associated with the Lunar Exploration Architecture" in 2007, have been used to help prioritize science goals and objectives and how they relate to the on-going human exploration architecture studies. What is clear from the results of both of these efforts is that there is not only significant overlap and synergism between the goals and objectives for science and exploration, but that with proper planning and development, efforts in one can enable new objectives in the other, and vice versa. However, it is also clear that further efforts are required to link the separate Science and Exploration architecture and mission planning activities.

2. ISRU and Science

ISRU involves the understanding, collection, manipulation, and processing of local material into products for robotic and human exploration, such propellants, fuel cell reactants, life support consumables, thermal energy storage, and hardware/crew protection. To obtain these products, ISRU processes that may be incorporated into missions include extracting water and other volatiles from lunar permanently shadowed craters and Mars soil, extracting oxygen from lunar regolith minerals, processing the Mars atmosphere into oxygen and fuel, and performing civil engineering and construction tasks. Successful implementation of ISRU requires detailed knowledge of the type and distribution of resources that may be of interest, understanding of the potential impurities that could foul processing, and knowing the physical attributes of the lunar material to ensure excavation, material transport, and processing systems are designed properly. This requires 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. Hardware, instruments, and operations for ISRU are all common with science goals and objectives associated with 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. The implementation of ISRU for exploration can support and enable lunar science objectives 'Of the Moon', 'On the Moon', and 'From the Moon', while conversely science instruments and measurements are critical to understanding lunar resources, their distribution, and how to extract and process these resources with the minimum of development and implementation risk for human exploration. Similar synergism exists between ISRU and "Follow the Water" science objectives for Mars.

3. The Role of Analog Testing

In the constant reality of limited budgets, it is imperative that ISRU objectives, development, and implementation into robotic and human missions be coordinated and executed with scientific investigations. However, it is also important to recognize that while overall objectives may be the same, the desired method or hardware to achieve these objectives may be drastically different. One method to promote understanding, coordination, and joint development of instruments and operations in the near term is the use of analogue field demonstrations. Analog field demonstrations allow for evaluation of technologies and operations under reasonably realistic conditions. They also allow for independent development of instruments and technologies to common operation and mission needs. Technologies and operational procedures from both science and exploration can be added when available on a continuing basis of evolving overall integrated operations and capabilities that can be utilized in future flight missions. Performing analog tests with personnel from both ISRU and science together allows both sides to better tailor their instruments and operations to meet overall mission needs with the minimum of resources. It also demonstrates integration and operational procedures well in advanced of robotic precursor missions.

4. ISRU-Related Analog Field Tests

ISRU-related analog field tests are based around the 'Theme' of demonstrating the Lunar ISRU Cycle (Figure 1). To begin to understand how best to integrate, coordinate, and operate ISRU, mobility, and science hardware and systems for a future robotic mission to characterize polar volatiles on the Moon, a lunar analog field test was held in November, 2008 on Mauna Kea in Hawaii. The field test involved integration of the Regolith & Environment Science and Oxygen & Lunar Volatile Extraction (RESOLVE) experiment onto the Scarab rover. This first field test was successful in demonstrating several key aspects of a future robotic lunar polar mission including: autonomous dark navigation, semi-autonomous drill site selection, 6 core drilling and sample transfer operations, 6 sample volatile analysis cycles, 4 subscale oxygen extraction from regolith demonstrations, and use of Raman and Moessbauer spectrometers to evaluate mineral characteristics before and after processing.

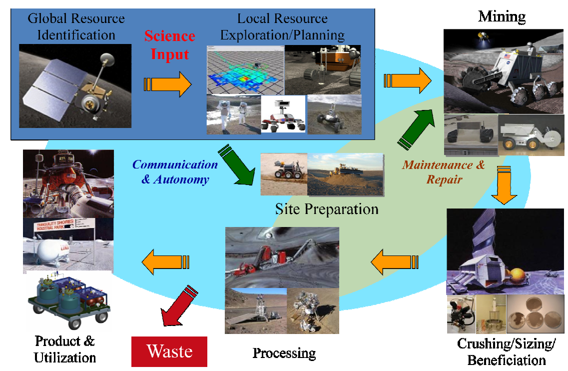

Figure 1: Lunar ISRU Cycle

A second lunar analog test was performed in February 2010 at the same location on Mauna Kea in Hawaii. For this field test, the RESOLVE experiment was integrated onto a tandem-rover provided by the Canadian Space Agency (CSA), and a larger suite of science instruments were tested including: ground penetrating radar, cone penetrometer, Moessbauer/X-Ray Fluorescence, Multispectral Microscopic Imager (MMI), and the Volatile Analysis by Pyrolysis of Regolith (VAPoR) sample reactor and mass spectrometer. This second field test allowed for greater access to varied terrain and understanding of the effectiveness of instrument data on site and resource mapping.

A third lunar analog test between NASA and CSA that would continue and expand the interaction and integration of ISRU and science instruments is currently under consideration.