NASA SBIR 2009 Phase I Solicitation

X3 Lunar In-Situ Resource Utilization

The purpose of In Situ Resource Utilization (ISRU) is to harness and utilize resources at the site of exploration to create products and services which can enable and significantly reduce the mass, cost, and risk of near-term and long-term space exploration. In particular, the ability to make propellants, life support consumables, fuel cell reagents, and radiation shielding can significantly reduce the cost, mass, and risk of sustained human activities beyond Earth. To perform these tasks on the lunar surface, detailed knowledge of the terrain, local minerals and potential resources, and the behavior and characteristics of lunar regolith is extremely important. Lastly, since ISRU systems and operations have never been demonstrated before in missions, it is important that ISRU concepts and technologies be evaluated under relevant conditions (1/6 g and vacuum) as well as anchored through modeling to lunar soil and environmental conditions. With this in mind, the ISRU Project within the Exploration Technology Development Program (ETDP) has initiated development and testing of hardware and systems in two main focus areas: (1) Oxygen Extraction from Regolith, including regolith feed/removal; and (2) ISRU Development & Precursor Activities to evaluate alternative resource processing and product concepts.

The purpose of the following subtopics is to develop and demonstrate hardware and software technologies that can be added to on-going analysis and ISRU capability development and demonstration activities in ETDP to meet Outpost architecture and surface manipulation objectives for near and long term human exploration of the Moon.

Subtopics

X3.01 Oxygen Production from Lunar Regolith

Lead Center: JSC

Participating Center(s): GRC, KSC, MSFC

Oxygen (O_2) production from lunar regolith processing consists of receiving regolith from the excavation subsystem into a hopper, transferring that regolith into a chemical or an electrochemical reactor, intermediate reactions to produce O_2 and regenerate reactants if required, purification of the O_2 produced, and removal of processed regolith from the reactor to an outlet hopper. Three O_2 production from lunar regolith reaction concepts are currently under development: Hydrogen reduction, Carbothermal reduction, and Molten Oxide Electrolysis at initial lunar Outpost production scale of 1 to 2 MT per year (70% per year operations). This subtopic is seeking hardware, subsystem, and system components and technologies for insertion and integration into on-going oxygen extraction from regolith development and demonstration efforts. Items of particular interest are:

- Move feedstock material from hopper on ground to 2 m height for reactor inlet hopper; 40 kg/hr; material size
- Inlet/outlet regolith hopper design and valve/seal concepts with no gas leakage, 1000's of operating cycles with abrasive lunar material, and minimum heat loss.

- Removal of 5 to 10 kg of molten material from molten electrolysis cell with metal slag processing and purification into individual metals.

- Water condensers that use the space environment for water condensation/separation with minimal energy usage.

- Gas Separators that provide low pressure drop separation of the system and product gas streams from impurities (e.g., HCl, HF, H_2S, SO_2); the process should be regenerable and the output contaminant concentration should be less than 50ppb.

- Removal of dissolved ions in water by methods other than de-ionization resins to meet water electrolysis purity requirements (minimum resistivity of 1M-Ohms-cm). Ions of interested are dissolved metal ions (Fe, Cr, Co, Ni, Zn) at concentration of 0.01% and dissolved anions (Cl, F, S) at concentrations of 0.01%-2%. The process should be regenerable, minimize consumables, and minimize water loss.

- Contaminant resistant, high temperature water electrolysis concepts.

- Advanced reactor concepts for carbothermal reduction or molten oxide electrolysis.

Phase 1 proposals should demonstrate technical feasibility of the technology or hardware concept through laboratory validation of critical aspects of the innovation proposed, as well as the design and path toward delivering hardware/subsystems in Phase 2 for incorporation into existing development activities. Interface requirements for on-going development efforts will be provided after selection. Proposers are encouraged to use the Lunar Sourcebook at a minimum for understanding lunar regolith material parameters in the design and testing of hardware proposed. It is also recommended that JSC-1a simulants be used during testing unless a more appropriate simulant can be obtained or manufactured.

X3.02 Lunar ISRU Development and Precursor Activities

Lead Center: JSC

Participating Center(s): GRC, KSC, MSFC

The incorporation of ISRU concepts is an on-going effort which requires an evaluation of the benefits and risks through computer modeling and testing under laboratory, analog field, and simulated lunar environmental conditions (1/6 g and vacuum). While excavation and oxygen extraction from regolith are included in lunar architecture plans, it is recognized that evaluating the feasibility and benefits of other technologies and concepts not ready for insertion into these efforts should be pursued. This subtopic is aimed at providing development support capabilities and hardware to advanced potentially beneficial ISRU concepts not yet ready for incorporation into current ISRU system laboratory and field test activities. Proposals aimed at the following are of particular interest:

- Mineral beneficiation concepts to separate iron oxide-bearing material from bulk regolith; up to 20 kg/hr based on hydrogen reduction. Hardware/concepts need to be designed for compatibility with both 1/6 g flight experiments and ground vacuum experiments.

- Lunar regolith storage and granular flow computer models, devices, and instruments to evaluate regolith flow and manipulation under 1/6 g flight and ground vacuum experimental conditions.

- Granular materials mixing and separation for reactor feedstock conditioning: remove material > 0.5 cm diameter before dumping into storage bin during excavation operation for oxygen extraction from regolith.

- Processing concepts for production of carbon monoxide, carbon dioxide, and/or water from plastic trash and dried crew solid waste using solar thermal or electrical/heat energy. In-situ produced oxygen or other reagents/consumables must be identified and quantified; recycling schemes for reagents to minimize consumables should be evaluated.

- Thermal energy storage and utilization using bulk or processed regolith.

Phase 1 proposals should demonstrate technical feasibility of the technology and/or subsystem through laboratory validation of critical aspects of the innovation proposed, as well as the design and path toward delivering hardware/subsystems in Phase 2.