# NASA SBIR 2015 Phase I Solicitation

## H1 In-Situ Resource Utilization

**Lead Center: JSC**

The purpose of In-Situ Resource Utilization (ISRU) is to harness and utilize resources (both natural and discarded material) at the site of exploration to create products and services which can enable new approaches for exploration and significantly reduce the mass, cost, and risk of near-term and long-term space exploration. The ability to make propellants, life support consumables, fuel cell reagents, and radiation shielding can provide significant benefits for sustained human activities beyond Earth very early in exploration architectures. Since ISRU can be performed wherever resources may exist, ISRU systems will need to operate in a variety of environments and gravities and need to consider a wide variety of potential resource physical and mineral characteristics. Also, because ISRU systems and operations have never been demonstrated before in missions, it is important that ISRU concepts and technologies be evaluated under relevant conditions (gravity, environment, and vacuum) as well as anchored through modeling to regolith/soil, atmosphere, and environmental conditions. While the discipline of ISRU can encompass a large variety of different concept areas, resources, and products, the ISRU Topic will focus on technologies and capabilities associated with acquiring and processing regolith/soil resources for mission consumable production and construction.Â

# Subtopics

### H1.01 Regolith ISRU for Mission Consumable Production

**Lead Center: JSC**

**Participating Center(s): GRC, JPL, KSC, MSFC**

In-Situ Resource Utilization (ISRU) involves collecting and converting local resources into products that can reduce mission mass, cost, and/or risk of human exploration. The primary destinations of interest for human exploration, the Moon, Mars and itâ€™s moons, and Near Earth Asteroids, all contain regolith/soil that contain resources that can be harvested into products. The resources of primary interest are water and other components that can be released from the regolith/soil by heating, and oxygen found in the minerals to make consumables for life support, power, and propulsion system applications. State of the art (SOA) technologies for many ISRU processes either do not exist, are too complex, are too inefficient (mass, power, and/or volume), or are not designed to operate in the extraterrestrial environment in which the resource is found, especially the micro-gravity environment for asteroids. The subtopic seeks proposals for critical technologies associated with the design, fabrication, and testing of hardware associated with extracting and transferring regolith/soil materials from extraterrestrial bodies and processing the material to extract water/volatiles and oxygen. Technologies developed under this subtopic are applicable to feasibility testing on parabolic flights and the ISS, assessment and processing of material on the redirected asteroid to trans-lunar space, and robotic precursor missions to the lunar poles and surface of Phobos and Mars. Proposals should address one or more of the categories below.

**Simulants for Ground Testing**

Â  Â  Â  1. Simulants for ordinary chondrites (LL, L, H) and carbonaceous chondrites (CI, CM) asteroids that replicate asteroid material characteristics such as physical (particle size/shape, particle size distribution, hardness), thermal, mineral/chemical , and volatile content for ground testing. Proposers must justify proposed simulant components and preparation based on documented research/publications.

**Regolith/Soil Acquisition and Preparation**

The first step in production of mission consumables from in situ resources is acquisition and preparation of the resource for processing. Proposals in this category should address one or more of the following:

Â  Â  Â  2. Excavation, transfer, and preparation of hydrated and icy-soil/regolith on Mars.

Â  Â  Â  3. Excavation, transfer, and preparation of asteroidal material from ordinary and carbonaceous chondrite asteroids.

Â  Â  Â  4. Excavation, transfer, and preparation of lunar polar icy regolith.

Notes: Proposals must address both the physical/mineral properties of the regolith/soil and the environmental conditions of the resources location. For item 3 proposals must address options for anchoring or maintaining position at the site of excavation to overcome forces applied during excavation and transfer of asteroidal material. Concepts need to minimize the generation of material that can float off and create a hazard. The proposal must identify the potential mass, power, and operation life impact of the selected option. All acquisition and preparation proposals must identify and address any issues with measuring and maintaining constant/known material transfer rates, and the impact of continuous versus batch-mode processing of the material. Proposals can combine regolith/soil acquisition and preparation with processing if it allows for reduced mass, power, and/or complexity.

**Soil/Regolith Processing for Mission Consumables**

Once the soil/regolith has been acquired and prepared, it is ready for processing. Proposals in this category should address one or more of the following:

Â  Â  Â  5. Water/volatile extraction and separation from carbonaceous chondrites asteroidal material. Identify potential contaminants for subsequent cleaning based on the method utilized for volatile extraction. Besides water, carbon-based gases are of significant interest for fuel and plastic production. Proposals should consider additional steps (higher temperatures, reactants, etc.) that may increase the extraction and collection of carbon-based gases. Proposers are also encouraged to examine the applicability of micro-gravity asteroidal processing techniques for crew/trash waste processing.

Â  Â  Â  6. Water/volatile extraction and separation from lunar polar icy material. Identify potential contaminants for subsequent cleaning based on the method utilized for volatile extraction.

Â  Â  Â  7. Water vapor and other volatile separation and collection from other gases/liquids. Separation techniques must address potential contaminants.

Â  Â  Â  8. Regenerative dust separation from product and reactant gases.

Â  Â  Â  9. Oxygen extraction from ordinary and carbonaceous chondrites asteroidal material. Regeneration of reactants used in oxygen extraction is required.

Â  Â  Â  10. Metal extraction from ordinary and carbonaceous chondrites asteroidal material. Regeneration of reactants used in metal extraction is required.

Notes: Proposals must specify whether the process is performed in batches or by continuous processing with appropriate sealing techniques to minimize reactant/product losses identified. Proposers are encouraged to address more than one of the Soil/Regolith Processing needs above. Proposals can combine regolith/soil processing with acquisition and preparation if it allows for reduced mass, power, and/or complexity. Proposals addressing only item 7 or 8 need to identify the potential soil/regolith processing technique it is applicable for as well as minimum and maximum flow rates and/or product/reactant concentrations.

**Further Requirements for Proposals**

All proposals need to identify the SOA of applicable technologies and processes:Â

- *For Lunar polar-based ISRU* - Assume ice content in regolith is between 5 and 10% at temperatures below 100 K. Regolith excavation down to at least 1 meter below the surface is required for Phase II. Proposals must address material transfer, handling, and processing of polar material under temporary sunlight and continuous shadowed solar/thermal conditions.
- *For Mars-based ISRU* - Assume hydrated soils between 3 and 15% (nominal 8%); icy soils containing 40% or more of ice. Soil excavation down to a minimum of 0.5 meters below the surface is required for Phase II. Proposals must recognize and address issues with perchlorate minerals in the Mars soil during processing and product separation. For hydrated soils, proposals must consider meeting time averaged excavation and processing rates of 3.5 to 7 kg/hr (8%) to 9 to 19 kg/hr (3%) soil to achieve time averaged water extraction and processing rates of 0.55 to 1.125 kg/hr. Proposals must consider and address operating life issues for surface applications that can last for up to 480 days of continuous operation.*Â*
- *For Asteroid-based ISRU* - Technologies requested are subscale to allow for future testing on the reduced gravity assets and the ISS, but must be extensible to larger scale applications. For testing on the ISS, proposed hardware will need to process resource materials on the order of hundreds of grams to 5 kilograms within 1 to 5 hours to investigate gravity-dependent/independent phenomena. Proposed technologies must show extensibility to future ISRU missions to an asteroid which will require an increase in acquisition and processing by 1 to 2 orders of magnitude with material excavation/acquisition down to at least 3 meters. Proposals must address design and operation issues associated with performing material transfer, handling, and/or processing of solid material with gas, liquid, or molten reactants under micro-gravity and vacuum conditions. Regolith processing reactors must further address material transfer into the reactor before processing and removal from the reactor after processing while minimizing loss of reactants/products and minimizing contamination of external surfaces.Â