NASA SBIR 2016 Phase I Solicitation

H1 In-situ Resource Utilization (ISRU)

In-situ Resource Utilization (ISRU) involves any hardware or operation that harnesses and utilizes ‘in-situ’ resources (natural and discarded) to create products and services for robotic and human exploration. ISRU products and services can be used to reduce Earth launch mass or lander mass by not bringing everything from Earth, reduce risks to the crew and/or mission by reducing logistics, increasing shielding, and providing increased self-sufficiency, or reduce costs by needing less launch vehicles to complete the mission and/or through the reuse of hardware and lander/space transportation vehicles. An important aspect of ISRU is to make mission critical consumables for propulsion, life support, and fuel cell power systems and feedstock for in-situ manufacturing and construction. Production of propellants allows for significant savings in launch or landed mass and transportation and lander reuse. Production of feedstock for manufacturing and construction processes from local and recycled materials with little or no Earth provided binders/reactants can provide significant improvements in failure recovery, shielding, self-sufficiency, and eventual infrastructure growth. 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.

Subtopics

H1.01 In situ Resource Utilization - Production of Feedstock for Manufacturing and Construction

Lead Center: JSC

Participating Center(s): ARC, GRC, JPL, KSC, LaRC, MSFC

The overall goal of in-situ Resource Utilization (ISRU) is to transform available resources, both natural and man-made, on extraterrestrial surfaces into usable materials and products that assist in sustaining and growing human exploration capabilities. ISRU involves all the steps associated with identifying, collecting, and converting local resources into products that can reduce mission mass, cost, and/or risk. It is imperative that novel technologies be developed to effectively utilize these resources for mission critical consumables, as well as to produce feedstock for additive manufacturing of replacement parts, construction for habitat, and infrastructure expansion. In the case of Mars, carbon dioxide and other atmospheric constituents, along with regolith and water/ice can be harvested for basic elements that could be utilized to generate various simple and complex organic and inorganic compounds, composites and products. The subtopic seeks proposals for critical technologies associated with the design, fabrication, and testing of hardware associated with one or more of the areas of interest below:

- *Plastic production for in-space additive manufacturing* - Production of plastic that can be fed into in space manufacturing devices. Define and demonstrate all steps required for conversion of some or all of the following in-situ constituents (H_2, CO, CO_2, O_2, N_2, and CH_4) into a final plastic product. It is expected that intermediate products, such as longer chain hydrocarbons, alcohols, aromatics, etc. will be required to achieve final plastic production. Proposals will need to identify all the steps and intermediate products. Phase I proposals will need to demonstrate critical steps, especially the first step from the list of starting constituents. Each step in Phase I can be performed/demonstrated individually. Phase II proposals will need to demonstrate all steps in an integrated manner. Production rates for plastic production will initially be low at 1 to 5 kg/day. Ability to breakdown and recycle the plastic produced is desired but not required. If additional constituents are required to make in-situ plastic, proposer can include them but will need to identify whether the constituents can be obtained in-situ or needs to be brought from Earth. Information on thermoplastic feedstock glass transition temperature and melting point properties for 3D printer plastic feedstocks that might be useful can be found at: (http://3dprintingfromscratch.com/common/3d-printer-filament-types-overview/). Since the loads and environments of the parts made using the feedstock are not known at this time, it is recommended that the properties be commensurate with commercially available feedstocks. Some desired characteristics of the parts made from the feedstock are high temperature resistance, low moisture adsorption, and ability to bond using adhesives. Feedstock produced must be tested in a commercially available additive manufacturing device in Phase II.

- *Metal extraction from extraterrestrial material for additive manufacturing* - Metal extraction from extraterrestrial material including lunar regolith, Mars soil, and ordinary and carbonaceous chondrites asteroidal material. Regeneration of any reactants used in the metal extraction process is required. Metals found in extraterrestrial material such as iron, aluminum, silicon, magnesium, and nickel are desired for future in-situ additive manufacturing. It is not expected that the quality and purity of the extracted metals will be to the same standard obtained from terrestrial processes so proposer needs to consider the possible extraction method and subsequent purity of the feedstock. In Phase I, the proposer is required to demonstrate the feasibility of extracting the desired feedstock. Methods used for extraction can be physical/chemical or biological. In Phase II, these feed stocks should be ready for introduction into a fabrication process by being pre-processed to have appropriate physical properties and forms (e.g., granulated, spooled wire, plate, billet, ingots, etc.). Manufacturing processes should be identified and feasibility demonstrated using the regolith derived feed stocks in partial and/or micro gravity environments. Regolith acquisition and delivery of up to 100 kg/hour can be assumed as an input material stream. Using a waste stream from another ISRU process to produce feedstock for fabrication may be considered such as regolith that has already been processed to extract water or oxygen from minerals.
- *ISRU for additive construction techniques* - Bulk or modified regolith can also be used as a construction material (with or without a binder) to form a material that can be extruded to produce a floor, structural wall, or ceiling, or into bricks or slabs for landing pads, roads, and shielding. These construction material can be used for making structures, shelters, radiation shielding, and thermal shading and for micrometeorite protection. Binders and additives must be less than 10% by mass of the construction material feedstock. Use of binders that can also be produced in-situ are preferred. Use of water is not excluded, but steps to be taken mitigate losses and amounts used and lost must be clarified to compare to non-water based construction materials. In Phase II, demonstration of the feasibility of additive construction using construction material feedstock is required (demonstration in partial or micro gravity environments is desired). For extruded materials a linear printing rates 30 to 100 cm/minute is desired. Bricks and slabs should have ability to be joined or interlocked.

All proposals need to identify the state-of-the-art of applicable technologies and processes. Proposals must address the physical/mineral properties of the regolith/soil used. Proposers must specify whether the process is performed in batches or by continuous processing with appropriate sealing techniques to minimize reactant/product losses identified.