NASA SBIR 2017 Phase I Solicitation

H1.02 Mars Soil Acquisition and Processing for In Situ Water

Lead Center: JSC

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

Technology Area: TA7 Human Exploration Destination Systems

Innovative technologies and approaches are sought related to ISRU processes associated with excavating and processing soils on Mars to remove, collect, and clean in-situ water for subsequent use in oxygen and fuel production or delivery to the habitat for life support and radiation shielding usage. Proposals must consider and address operating life issues for Mars surface applications that can last for up to 480 days of continuous (day/night) operation. All proposals need to identify the State of the Art of applicable technologies and processes. Hardware to be delivered at the conclusion of Phase II will be required to operate under Mars surface pressure, atmosphere constituent, and temperature conditions. Therefore, thermal management during operation of the proposed technology will also need to be specified in the Phase I proposal. Requirements and specifications for Mars surface conditions and soil properties can be found in the ISRU Topic Description. Phase I proposals for innovative technologies and processes must include the design and test of critical attributes or high risk areas associated with the proposed technology or process. Proposals will be evaluated on mass, power, complexity, and the ability to achieve hardware specifications below.

Technologies are sought for excavation and transfer of hydrated and icy Mars soils. For hydrated soils, the excavated soil can be delivered to a centralized soil processing plant or processed on the excavation rover itself. The amount of water content in the hydrated Mars soil can vary from as low as between 1.5 and 2% on the surface at almost all locations on Mars to above 10% depending on the location and mineral. The concentration of water may also increase below a desiccated layer of soil at the surface, so technologies for excavation and transfer need to consider soil properties and water content as a function of depth and minerals and should be applicable to a range of landing sites where icy soils do not exist. The need to excavate down to at least 0.5 meters should be considered. The amount of water content in icy Mars soil can vary greatly as a function of depth and latitude. Based on analysis of Mars orbital data, proposers should assume a minimum of 10% by weight of water/ice up to 90%. Due to human landing and ascent considerations, Mars water based resources should be constrained between +/1 50 deg. latitude. Based on the potential high water content by mass in icy soils, it is expected that icy soil excavated will be either processed in-situ or on the excavation rover itself. Proposers should also assume that up to 0.5 m of soil may exist above icy soils and that excavation down to at least 1 meter is required. Proposers should note the impact on concept mass, power, and complexity for excavation down to 3 meters. Proposals should consider water loss due to hardware temperature, material agitation, and duration of soil exposure to the environment before transfer to soil processing systems. Note requirements for the mobility platform associated with hydrated soil excavation and transfer will be included in the H8 Robotic Systems Topic.

Technologies are sought for processing of hydrated and icy Mars soils to extract water. Soil processing for water extraction needs to consider the range of water content in Mars soils and water extraction rates defined below. Proposals for soil processing also need to define potential water loss due to valve/enclosure sealing for closed soil reactors or losses due to exposure to the surrounding environment or soil for open soil reactors. Proposals need to

consider what other volatiles and contaminants are released due to soil processing/heating. Proposed solutions that perform in a non-continuous fashion are acceptable, as long as they achieve the same total production quantities on a daily or weekly basis. Understanding the change in mass, power, volume, complexity, and contaminant release as a function of water content in the soil, heating temperature, and heating method are important factors in selection. Power needed for the proposed technology operation should be differentiated between electrical and thermal, and consideration should be given on how the thermal management system and the Mars environment could minimize the need for electrical-to-thermal energy conversion.

Based on past and recent human Mars exploration mission studies, to meet ascent propellant production rates with margin, approximately 1.6 kg/hr of water must be collected and cleaned for subsequent processing. At this time, 3 soil processing units for extraction of water from Mars soils is baselined for human Mars missions. Multiple excavation and processing units are allowed, but should be justified based on overall mass, power, thermal, and/or operation duration requirements. Proposers can submit combined excavation and soil processing technologies.

Technologies are sought for the separation, collection, and cleaning of water released from soil processing of hydrated and icy Mars soils. Separation of contaminants from water can be performed in the vapor phase during release or after collection, but technologies need to be regenerative. Separate and multiple technologies for collection, separation, and cleanup can be proposed for any one or all of the functions (separation, collection, and cleaning) All must operate in conjunction with the soil processing reactors for the soil/water production rates, contaminants, and mission durations specified above. It is encouraged that proposers for soil processing of Mars soils also consider including technologies requested below for water separation, collection, and cleanup since the two technology needs can be highly interconnected. Multiple units are allowed, but should be justified based on overall mass, power, thermal, and/or operation duration requirements. Water will need to be clean enough to be fed to a proton exchange membrane (PEM) water electrolysis unit.

Proposals for ISRU hardware for Mars material excavation, transfer, and processing for the extraction of water need to consider physical, mineral, and volatile characteristics and variations for hydrated and icy soils, as well as the types of volatiles and contaminants released during heating. Information on potential Mars water-based resources and mineral properties can be found in the recent Mars Water In-Situ resources Utilizations (ISRU) Planning (M-WIP) Study posted at https://mepag.jpl.nasa.gov/reports/Mars_Water_ISRU_Study.pdf, and information on what volatiles and contaminants are released due to soil processing/heating can be found in “Volatile, Isotope, and Organic Analysis of Martian Fines with the Mars Curiosity Rover” by Leshin et al., For example, besides water, varying amounts of CH_3CI, HCN, SO_2, HCI, and H_2S were released as a function of temperature. Further research and evaluation of mineral properties, constituents, and potential contaminants based on different hydrated and icy soil minerals is highly recommended and should be addressed in proposals.