NASA SBIR 2018 Phase I Solicitation

H1.01 Mars Atmosphere ISRU for Mission Consumables

Lead Center: JSC

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

Technology Area: TA7 Human Exploration Destination Systems

In-Situ Resource Utilization (ISRU) involves collecting and converting local resources into products that can be used to reduce mission mass, cost, and/or risk of human exploration.Â ISRU products that provide significant mission benefits with minimal infrastructure required are propellants, fuel cell reactants, and life support consumables.Â Â Production of mission consumables from in-situ Mars resources is enabling and critical for human exploration of the Mars surface and for minimizing the number and size of landers and the crew ascent vehicle.Â Â Innovative technologies and approaches are sought related to ISRU processes associated with collecting, separating, pressurizing, and processing gases collected from the Mars atmosphere.Â State of the art (SOA) technologies for these ISRU processes either do not exist, are too small of scale, or are too complex, heavy, inefficient, or consume too much power.Â

Specific areas of technology interest include the following:

Mars Atmosphere Collection and Separation:

- *Inlet Gas Dust Measurement* - To understand both the dust concentration before filtration as well as the effectiveness of dust filtration techniques, NASA is interested in a dust sensor to measure dust particles in the Mars atmosphere acquired for processing. Measurements need to be made in a flow of carbon dioxide (CO_2) up to 2.5 SLPM at Mars atmosphere pressure. The measurement technique should produce minimal modifications to the flow. The dust sensor needs to discriminate over a minimum of three particle sizing bins from 0.1 to 5.0 micron and detect particle concentrations from a few to hundreds of particles per cubic centimeter. The sensor needs to provide an analog or digital output to allow for remote monitoring and storage of particle counting data.
- *Rapid Cycle Adsorption Pump (RCAP)* - This process operates through adsorption and desorption of carbon dioxide (CO_2).Â The cycle time between absorption and desorption should be in terms of minutes to minimize adsorption material mass.Â To achieve this, the proposal must include the thermal management system to perform the adsorption/desorption cycle with a minimum of thermal energy loss.Â The proposals also must consider all the valving and an active flow device to move the Mars atmosphere through the unit during the CO_2 adsorption cycle.
- *CO_2 Freezing including active cooling (direct cryocooler or cryogenic fluid loop) and thermal management of freezing/heating that minimizes overall electrical energy* - Active cooling is required to achieve a minimum of âˆ’123Â° C (150) K during the freezing process.Â The design must state and withstand pressures potentially up to 1000 psi during CO_2 feeding.
- *Cryocooler for in-house NASA design that operates at 150 K with a thermal lift in the 200-300 W range* -

The cold fingers and flanges must be capable of 1000 psi to handle the liquid CO_2 pressures.Â The cryocooler would also need to be able to operate under Mars conditions with cooling supplied by the lander system.
- *Separation and storage of nitrogen (N_2) from Mars atmosphere* - Two options can be considered.Â Option one is separation of N_2 after the CO_2 has been removed at Mars atmosphere pressures based on the use of RCAP or CO_2 Freezing.Â Option two is separation of N_2 after the Mars atmosphere has been compressed up to 517 KPa (75 psi).

Carbon Dioxide (CO_2) Processing:

- *Microchannel Reverse Water Gas Shift (RWGS)* - The technology must demonstrate a CO_2 conversion efficiency to >50% in a single pass before any separation and recirculation occurs.Â The technology proposed should include inlet/outlet gas heat exchange and reactor thermal management to minimize thermal energy losses.Â The proposer needs to define the design and performance aspects associated with operating pressures ranging from a nominal pressure of 103 KPa (15 psi) up to 517 KPa (75 psi).
- *Solid Oxide Electrolysis (SOE)* - The technology must demonstrate a temperature ramp rate of >15Â° C/min. and redox stable electrodes for the production durations and rates below.Â The technology must be able to electrolyze dry CO_2, water (H_2O), or a combination of both CO_2 and H_2O.Â The proposer needs to define the design and performance aspects associated with operating pressures ranging from a nominal pressure of 55 KPa (8 psi) up to 103 KPa (15 psi), and the design impact associated with differential pressures from inside to outside and across the electrolyte during different phases of operation.Â In Phase I the technology must demonstrate â‰¥ 20 thermal cycles, and â‰¥ 70 thermal cycles for Phase II.Â The technology proposed should include thermal management of the SOE stack and inlet/outlet gas heat exchange to minimize thermal energy losses. Information and performance of the proposed technology in a second application as a fuel cell using previously produced oxygen and carbon monoxide is also of interest to NASA.Â
- *Alternative O_2 from CO_2 conversion technologies* - Besides RWGS and SOE, NASA is interested in alternative CO_2 conversion technologies as well.Â These technologies must exhibit >50% CO_2 to CO conversion in single pass, and the proposer must clearly state benefits in mass, power, volume, operating life, and/or complexity compared to RWGS or SOE.
- *Separation and recirculation of CO_2 from CO_2/CO streams* - Most O_2 to CO conversion processes have a significant amount of unreacted CO_2 in the exhaust stream after a single pass.Â NASA is interested in technologies that allow the unreacted CO_2 to be separated and recirculated back to the process inlet.Â RWGS and SOE reactors operate at high temperatures (>650Â° C) so exhaust gases may be at high temperature.Â The proposal must include both the recirculation pump and separation technologies required for the separation and recirculation system and define the temperatures, pressures, and separation efficiencies associated with these technologies.
- *Regenerable gas drying* - Oxygen and methane (CH_4) produced from Mars CO_2 must be dried before it is liquefied and stored.Â Also, hydrogen (H_2) from water electrolysis must be dried before delivery to fuel/chemical production reactors.Â NASA is interested in regenerable gas drying technologies that can remove water from O_2, H_2, and CH_4 streams.Â No service should be required for these units prior to completion of the ISRU plants operation.Â Recuperation of the removed water for subsequent use is highly desired.
- *Humidity Sensor for dry oxygen and methane* - Oxygen and methane produced from Mars CO_2 must be dried before it is liquefied and stored.Â NASA is interested in technologies for water vapor sensing down to 20 ppmv of water in oxygen and methane streams.
- *Dehydration resistant Proton Exchange Membrane (PEM) for water electrolysis and gas/water separators* - ISRU plants sent to Mars may be required to be for launch and during the cruise and landing phases before the system is activated.Â NASA is interested in dehydration resistant PEM materials for water electrolyzers and gas/water vapor separator membranes to allow for long term dry storage and delivery of ISRU systems.

Technology work in Phase I and hardware to be delivered at the conclusion of Phase II will be designed and built to operate under lunar polar shadowed crater and/or Mars surface environmental conditions, so thermal management during operation of the proposed technology will need to be specified in the Phase I proposal.

ISRU technologies for Mars missions must operate continuously (day and night) for very long durations (480 days) and at all possible atmosphere pressures, 700 to 1000 Pa (0.1 to 0.14 psi) and surface temperatures, which may reach a high of about 20Â° C (293 K) at noon, at the equator, to a low of about âˆ’153Â° C (120 K) at the poles, with the potential for significant temperature differences between day and night depending on the season and latitude.

The total production rate for initial human missions to Mars for ascent propellant are 2.2 kg/hour for O_2 production alone and 2.7 kg/hour oxygen and 0.68 hg/hour of methane for oxygen and fuel production.Â This correlates to approximately needing 6.6 kg/hr CO_2 for O_2 only and 2 kg/hr for O_2/CH_4 production.Â Since carbon dioxide processing may occur between 55 and 517 KPa (8 and 75 psi) and nominally at 103 KPa (15 psi) depending on the processing technology selected, proposers must state how the technology proposed changes in mass, power, volume, and complexity as a function of CO_2 delivery and process operating pressure.Â Proposers are allowed to consider the use of multiple units to achieve these production rates, but should justify the number of units proposed based on overall mass, power, thermal, and/or operation duration requirements. 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. Proposals will be evaluated on mass, power, volume, complexity, and technical feasibility.