SBIR/STTR
Small Business Innovation Research / Small Business Technology Transfer

NASA SBIR 2021 Phase I Solicitation

Z10.01 Cryogenic Fluid Management

Lead Center: GRC

Participating Center(s): JSC, MSFC

Scope Title:

Cryogenic Fluid Management (CFM)

Scope Description:

This subtopic seeks technologies related to cryogenic propellant (e.g., hydrogen, oxygen, methane) storage and transfer to support NASA's space exploration goals. This includes a wide range of applications, scales, and environments consistent with future NASA missions. Such missions include, but are not limited to, upper stages, ascent and descent stages, refueling elements or aggregation stages, nuclear thermal propulsion, and in situ resource utilization (ISRU). Anticipated outcome of Phase I proposals is expected to deliver proof of the proposed concept with some sort of basic testing or physical demonstration. Proposals shall include plans for a prototype and demonstration in a defined relevant environment (with relevant fluids) at the conclusion of Phase II.

- Integrated refrigeration cycles for a combination of hydrogen and oxygen liquefaction on the lunar surface. Cycles should be initially sized for at least 11.7 metric tons per year (3.3 kg/hr of oxygen and 0.4 kg/hr of hydrogen). It is desired to minimize the mass and power of the system. Proposals should compare total input power and mass to liquefaction of fluids separately. The main contaminate is water; while the final contamination level is not known, some sensitivity should be explored in the 10s of ppm range in each stream. For Phase I, the main product should be cycle analysis and configuration, including the key sensitivities of the cycle. Phase II should include some level of buildup and test/demonstration of system.
- Subgrid computational fluid dynamics (CFD) of the film condensation process for 1g and low-gravity (lunar or martian) to be implemented into commercial industry standard CFD codes. The subgrid model should capture the formation and growth of the liquid layer as well as its movement along a wall boundary. The condensation subgrid model should be validated against experimental data (with a target accuracy of 25%), with emphasis on cryogenic fluid-based condensation data. The subgrid model and implementation scheme should be a deliverable. Phase I should be focused on simplified geometries (vertical plates/walls), while Phase II should be focused on complicated geometries (full propellant cylindrical).
- Integrated cryogenic propellant gas generation system for lander vehicles and supporting architecture: Design and develop concepts to enable integrated cryogenic propellant gas generation for lander vehicle reactor coolant system (RCS) gas accumulators. Proposers shall consider vehicle designs that use either liquid hydrogen/liquid oxygen or liquid methane/liquid oxygen main propellant combinations. Designs shall be capable of outputting a minimum 3,000-psia storage press at 300-K storage temperature and meeting the following minimum mass gasification rates: 0.1 g/sec hydrogen, 0.3 g/sec methane, and/or 0.5 g/sec oxygen. The gas generation system shall demonstrate novel integration into alternate vehicle heat sources such as thermal control systems, active CFM cooling systems, fuel cells, internal combustion (I/C) engines,

electrical power systems, pumps, etc. Proposed gas generation system shall not couple to vehicle main engines or RCS thruster during firing operations. Proposers should consider integration into vehicle system architectures, mass efficiency, and minimization of propellant waste. Phase I effort should include vehicle integration concept design, design of autogenous pressurization hardware, and test demonstration of autogenous pressurization hardware using liquid cryogens. Phase II should focus on system refinement and a scale test demonstration using liquid propellants.
- Develop cryogenic mass flow meters applicable to liquid oxygen and methane, having a volumetric flow measurement capacity of 1 to 20 L/min (fluid line size of approximately ½ in.), of rugged design that is able to withstand launch-load vibrations (e.g., 20g rms), with remote powered electronics (not attached to the flowmeter), able to function accurately in microgravity and vacuum environment, and having measurement error less than +/- 0.5% of the mass flow rate reading. Ability to measure bidirectional flow, compatibility with liquid hydrogen, and ability to measure mass flow rate during two-phase flows is also desired. Designs that can tolerate gas flow without damage to the flowmeter are also desired. Goal is proof of concept end of Phase I, working flowmeter end of Phase II.

Expected TRL or TRL Range at completion of the Project: 2 to 4
Primary Technology Taxonomy:
Level 1: TX 14 Thermal Management Systems
Level 2: TX 14.1 Cryogenic Systems
Desired Deliverables of Phase I and Phase II:

- Hardware
- Software

Desired Deliverables Description:

Phase I proposals should at minimum deliver proof of the concept, including some sort of testing or physical demonstration, not just a paper study. Phase II proposals should provide component validation in a laboratory environment, preferably with hardware deliverable to NASA.

State of the Art and Critical Gaps:

CFM is a crosscutting technology suite that supports multiple forms of propulsion systems (nuclear and chemical), including storage, transfer, and gauging, as well as liquefaction of ISRU-produced propellants. The Space Technology Mission Directorate (STMD) has identified that CFM technologies are vital to NASA's exploration plans for multiple architectures, whether it is hydrogen/oxygen or methane/oxygen systems, including chemical propulsion and nuclear thermal propulsion. Several recent Phase IIs have resulted from CFM subtopics, most notably for advanced insulation, cryocoolers, and liquid acquisition devices.

Relevance / Science Traceability:

STMD strives to provide the technologies that are needed to enable exploration of the solar system, both manned and unmanned systems; CFM is a key technology to enable exploration. Whether liquid oxygen/liquid hydrogen or liquid oxygen/liquid methane is chosen by Artemis as the main in-space propulsion element to transport humans, CFM will be required to store propellant for up to 5 years in various orbital environments. Transfer will also be required, whether to engines or other tanks (e.g., depot/aggregation), to enable the use of cryogenic propellants that have been stored. In conjunction with ISRU, oxygen will have to be produced, liquefied, and stored, the latter two of which are CFM functions for the surface of the Moon or Mars. ISRU and CFM liquefaction drastically reduces the amount of mass that has to be landed.

References:

1. Johnson, et al. "Comparison of oxygen liquefaction methods for use on the Martian surface." Cryogenics 90, 60-69, 2018.
2. Green, R. and Kleinhenz, J. "In-Situ Resource Utilization (ISRU) Living off the Land on the Moon and Mars." American Chemical Society National Meeting & Exposition; March 31, 2019 - April 04, 2019; Orlando, FL; United States.

3. Stochl, R., et al. "Autogenous pressurization of cryogenic vessels using submerged vapor injection." NASA-TM-104516, 1991.