NASA SBIR 2020 Phase I Solicitation

Z10.01 Cryogenic Fluid Management

Lead Center: GRC

Participating Center(s): JSC, MSFC

Technology Area: TA2 In-Space Propulsion Technologies

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. Anticipated outcome of Phase 1 proposals are 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.

Desired technology concepts are listed below in order of priority:

- Develop cryogenic mass flow meters applicable to liquid oxygen and methane, having a volumetric flow measurement capacity of 1 - 20 L/min (fluid line size of approximately ½ inch), 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 bi-directional 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 1. Working prototype flow meter end of Phase 2.
- Broad area cooling methods for cryogenic composite propellant tanks (reduced and/or zero boil-off applications or liquefaction): Design and integration concepts must exhibit low mass, high-heat transfer between cooling fluid and propellant in tank, high heat exchanger efficiency (>90%), and operate in reduced gravity environments (10-6 g worse case). Proposers should consider structural and pressure vessel implications of the proposed concept. Target applications include liquid oxygen liquefaction system (16 g/s neon gas, 85K < T < 90K, pressure drop < 0.25 psia, 2.6m diameter, 3m tall tank) and reduced and/or zero boil off liquid hydrogen nuclear thermal propulsion system (3.5 g/s helium gas, 20K < T < 24K, 7m diameter, 8m tall tank).
- Cryogenic liquid/vapor phase separators capable of delivering single-phase liquid flow at least up to 10 gallons per minute, void fractions up to 30%, with an emphasis on minimizing pressure drop across the separator. Devices should be able to maintain performance (phase separation at highest flow rate) after multiple (> 15) thermal cycles (room temperature to 77K and back). Phase separator should tolerate transient (transfer line and separator are chilling down). Phase 1 concept should yield a proof of concept using liquid cryogens. Phase 2 should focus on minimizing phase separator pressure drop, overall

integration of phase separator into transfer system (i.e. where to route the vapor), and development a unit to test in liquid hydrogen.

NASA has plans to purchase services for delivery of payloads to the Moon through the Commercial Lunar Payload Services (CLPS) contract. Under this subtopic, proposals may include efforts to develop payloads for flight demonstration of relevant technologies in the lunar environment. The CLPS payload accommodations will vary depending on the particular service provider and mission characteristics. Additional information on the CLPS program and providers can be found at this link: https://www.nasa.gov/content/commercial-lunar-payload-services. CLPS missions will typically carry multiple payloads for multiple customers. Smaller, simpler, and more self-sufficient payloads are more easily accommodated and would be more likely to be considered for a NASA-sponsored flight opportunity. Commercial payload delivery services may begin as early as 2020 and flight opportunities are expected to continue well into the future. In future years it is expected that larger and more complex payloads will be accommodated. Selection for award under this solicitation will not guarantee selection for a lunar flight opportunity.

References

1. Johnson et al. “Investigation into Cryogenic Tank Insulation Systems for the Mars Surface Environment” 2018 Joint Propulsion Conference Cincinnati, OH, July, 2018. Paper.

2. Plachta, D., et al. "Zero Boil-Off System Testing" NASA TP 20150023073.

3. Hartwig, J.W., "Liquid Acquisition Devices for Advanced In-Space Cryogenic Propulsion Systems" Elsevier, Boston, MA, November, 2015.

Expected TRL or TRL range at completion of the project 2 to 4

Desired Deliverables of 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

Cryogenic Fluid Management is a cross-cutting technology suite that supports multiple forms of propulsion systems (nuclear and chemical), including storage, transfer, and gauging, as well as liquefaction of ISRU (In-Situ Resource Utilization) produced propellants. STMD (Space Technology Mission Directorate) has identified that Cryogenic Fluid Management (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; cryogenic fluid management is a key technology to enable exploration. Whether liquid oxygen/liquid hydrogen or liquid oxygen/liquid methane is chosen by HEO (Human Exploration and Operations) 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.