NASA SBIR 2019 Phase I Solicitation

Z10.01 Cryogenic Fluid Management

Lead Center: GRC

Participating Center(s): JSC, KSC, MSFC

Technology Area: TA2 In-Space Propulsion Technologies

The Space Technology Mission Directorate (STMD) strives to provide the technologies that are needed to enable exploration of the solar system, both manned and unmanned systems. Cryogenic Fluid Management (CFM) is a key technology to enable exploration. Whether nuclear thermal propulsion or liquid oxygen/liquid methane is chosen by Human Exploration and Operation Mission Directorate (HEOMD) as the main in-space propulsion element to transport humans, CFM will be required to store propellant for up to five 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 In-Situ Resource Utilization (ISRU), oxygen will have to be produced, liquefied, and stored, the latter two of which are CFM functions for the surface of Mars. ISRU and CFM liquefaction drastically reduces the amount of mass that must be landed.

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 a methane upper stage, nuclear thermal propulsion, lander propulsion, aggregation stages, and ISRU in support of the NASA exploration mission objectives. Anticipated outcome of Phase I 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:

- Broad area cooling methods for cryogenic thin-walled metallic and/or composite propellant tanks (reduced and/or zero boil-off applications): 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. If tube-on-tank cooling is proposed, concepts are solicited for reliable, low thermal resistance manufacturing and attachment of cooling tubes to propellant tanks. 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 liquid hydrogen nuclear thermal propulsion system (3.5 g/s helium gas, 20K < T < 24K, 7m diameter, 8m tall tank).
- Cryogenic transfer line thermal coatings (ex. nano-structured, micro-structured, vapor deposition) for 0.5'' to 3'' OD tubing that can reduce the chilldown time (amount of time from room temperature to 77K) by at least 30% relative to uncoated standard stainless steel line in low-g. Coated lines should be able to maintain performance (reduction in chilldown time) after multiple (> 15) thermal cycles (room temperature to 77K and back). Proposed coatings should be oxygen compatible. Anticipated maximum allowable working

pressure is 500 psia.

- Lightweight all composite spherical tanks for cryogenic propellants. Spherical versus cylindrical tanks have improved thermal storage characteristics (due to reduced surface area to volume ratio), better packaging benefits (when considering engine and plumbing) and have inherently lower stresses due to geometry. While progress has been made on all-composite tanks, there is no state-of-art spherical tank designed for a target diameter range of 4-8ft, a max pressure of 500+ psig, helium permeability less than 1x10-4 sccs/m^2 (at 500 psi), and an operating temperature range of ambient to -320° F (LN_2); with goal of -423° F (LH_2). Proposals shall also include plans for oxygen compatibility and cryogenic LN_2 testing.
- Sub-grid CFD model of the nucleate boiling process for 1-g and low-g to be implemented into commercial industry standard CFD codes. The sub-grid model should capture the nucleation and growth of bubble on a heated wall and estimate the bubble departure frequency to be implemented via Lagrangian-Eulerian or Eulerian-Eulerian approaches for tracking the phases using discrete phase modeling (DPM), volume of fluid (VOF), Level Set, or Population Balance Methods. The boiling sub-grid model should be validated against available experimental data (with a target accuracy of 40%), with emphasis on cryogenic boiling data. The sub-grid model and implementation scheme shall be a contract deliverable.

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 are yet to be precisely defined; however, at least for early missions, proposed payloads should not exceed 15 kilograms in mass and not require more than 8 watts of continuous power. Smaller, simpler, and more self-sufficient payloads are more likely to be accommodated. Commercial payload delivery services may begin as early as 2020. Selection for award under this solicitation will not guarantee selection for a lunar flight opportunity.

The expected TRL for this project is 2 to 4.

References:

- Johnson et al. “Investigation into Cryogenic Tank Insulation Systems for the Mars Surface Environment” 2018 Joint Propulsion Conference Cincinnati, OH, July, 2018. Paper.
- Plachta, D., et al. "Zero Boil-Off System Testing" NASA TP 20150023073.