NASA SBIR 2018 Phase I Solicitation

Z10.02 Propulsion Systems for Robotic Science Missions

Lead Center: GRC

Participating Center(s): JPL, MSFC

Technology Area: TA2 In-Space Propulsion Technologies

The Science Mission Directorate (SMD) needs spacecraft with more demanding propulsive performance and flexibility for more ambitious missions requiring high duty cycles, more challenging environmental conditions, and extended operation. Planetary spacecraft need the ability to rendezvous with, orbit, and conduct in-situ exploration of planets, moons, and other small bodies in the solar system.Â Mission priorities are outlined in the decadal surveys for each of the SMD Divisions. (https://science.nasa.gov/about-us/science-strategy/decadal-surveys) Future spacecraft and constellations of spacecraft will have high-precision propulsion requirements, usually in volume-, mass-, and power-limited envelopes.Â

This subtopic seeks innovations to meet SMD propulsion in chemical and electric propulsion systems related to sample return missions to Mars, small bodies (like asteroids, comets, and Near-Earth Objects), outer planet moons, and Venus. Additional electric propulsion technology innovations are also sought to enable low-cost systems for Discovery class missions, and low-power, nuclear electric propulsion (NEP) missions. The roadmap for in space propulsion technologies can be found at the following Office of Chief Technologist website (https://www.nasa.gov/sites/default/files/atoms/files/2015_nasa_technology_roadmaps_ta_2_in-space_propulsion_final.pdf).Â

Proposals should show an understanding of the state-of-the-art (SOA), how their technology is superior, and of one or more relevant science needs. The proposals should provide a feasible plan to fully develop a technology and infuse it into a NASA program.Â In addressing technology requirements, proposers should identify potential mission applications and quantify the expected advancement over SOA alternatives.

Advanced Electric Propulsion Components

Towards that end, this subtopic seeks proposals that explore uses of technologies that will provide superior performance, reduce complexity, increase reliability, and/or lower cost for high specific impulse/low mass electric propulsion systems. These technologies include:Â

- Long-life heaters for hollow cathodes made with lanthanum hexaboride (LaB_6) or other materials.Â In order to achieve reliable cathode ignition, the LaB_6 heaters typically must operate at 1500 â€“ 1700Â° C.Â Reproducible fabrication processes that minimize unit-to-unit variations in performance and lifetime will be critical for the practical adaptation of a new heater technology.
- High-temperature electromagnets for Hall thrusters, capable of operating reliably at >500Â° C.
- 3D printing of magnetic materials for Hall thruster magnetic circuits.

- Low-cost gas distributors capable of achieving a high degree of flow uniformity in Hall thruster anode gas feeds.
- Advanced ceramics for Hall thruster discharge chambers.Â
- Feed systems for ultra-high-Isp gridded ion thrusters running on lithium propellant.Â

This subtopic also seeks to mature and demonstrate iodine electric propulsion technologies. Iodine propellant has two key advantages over the SOA xenon propellant: (i) increased storage density and (ii) reduced storage pressure.Â These key advantages permit iodine propulsion systems with conformal storage tanks, reduced structural mass, and reduced volume compared with the SOA xenon, while retaining similar thrust, specific impulse, and thruster efficiency. Technologies of interest include, but are not limited to:Â

- Robust and electrically efficient iodine storage and delivery technology (scalable 1 kg to 100 kg iodine) for sub-kilowatt Hall Effect and Ion thrusters:
    - Computational models are desired to evaluate novel iodine feed system concepts and CONOPS. Modeling capabilities of interest include, but are not limited to:
        - Optimizing power consumption and iodine mass transport.
        - Predicting sublimation rate and system pressures.
        - Understanding expected anomalies such as iodine deposition, clog formation, clog recovery, and material interactions.
    - Proposals are desired that systematically validate new modeling predictive capabilities with appropriate experimental demonstrations and perform investigations where existing literature is insufficient.
    - High-reliability, long-life iodine storage and delivery systems are desired that package efficiently in volume-limited spacecraft, minimize spacecraft energy consumption, minimize thermal loading on spacecraft structures and neighboring components, and can remain quiescent for long periods with minimal or no maintenance or degenerative material interactions. Proposals are desired that offer supporting analysis or experimental evidence that a concept has merit. Proposals should provide a plan to theoretically refine the design concept, construct a prototype with a minimum 1 kg iodine capacity, perform experimental analysis in a relevant environment, refine the concept as necessary, and demonstrate. Demonstrations need not be performed with an operational thruster, but should be integrated in a test apparatus that reasonably replicates the fluid-dynamic and thermodynamic loads expected when integrated in a complete system. GivenÂ the currentÂ lack of demonstratedÂ high lifeÂ iodine compatible cathodes, hybrid feed systems are preferentially desired, which accommodate an iodine thruster matched with a xenon cathodeÂ (High life iodine compatible cathodes are also sought in this subtopic).
- High-reliability, long-life, compact, low-power iodine feed subsystem technologies are desired, including:
    - Iodine compatible high-accuracy pressure sensors, novel propellant flow control and metering technologies, filtration, propellant management devices, etc.
    - New iodine-compatible materials, coating, or otherwise innovative construction techniques leading to long-life, reliable, and corrosion resistant components.
- Iodine compatible cathodes with lifetimes of at least 2,000 hours, goal of greater than 10,000 hours.**Â**

Solar/Electric Sail Propulsion

This subtopic seeks sail propulsion innovations in three areas for future robotic science and exploration missions:Â

- Large solar sail propulsion systems with at least 1000 square meters of deployed surface area for small (<150 kg) spacecraft to enable multiple Heliophysics missions of interest.
- Electric sail propulsion systems capable of achieving at least 1 mm/sec2 characteristic acceleration to support Heliophysics missions of interest and rapid outer solar system exploration.
- Electrodynamic tether/sail propulsion systems capable of generating from the Lorentz Force delta-V sufficient to de-orbit from altitudes up to 2,000 km and to maintain a small (< 500 kg) spacecraft in LEO at altitudes up to 400 km for 5 years enabling Earth ionospheric and plasmasphere investigations.Â

Design solutions must demonstrate high deployment reliability and predictability with minimum mass and launch volume and maximum strength, stiffness, stability, and durability.Â In the case of tethers, advancements are neededÂ for tether deployment and control, and for dynamic modeling/simulation and ground test methods, due toÂ the high rate of space mission failures and anomalies for tether systems. For electric sail concepts and related future flight demonstrations, wire/tether deployment and control is considered one of the highest riskÂ areas for successful flight.Â

Innovations are sought in the following areas:Â

- Novel design, packaging, and deployment/control concepts.
- Lightweight, compact components including booms, substrates, and mechanisms.
- Validated modeling, analysis, and simulation techniques.
- Ground and in-space test methods.
- High-fidelity, functioning laboratory models.*Â*

Note:Â Cubesat propulsion technologies for spacecraft smaller than 27U should be submitted to STMD subtopic: Z8.01 - Cubesat Propulsion Systems