NASA SBIR 2019 Phase I Solicitation

Z10.02 In-Space Electric Propulsion Component Technologies

Lead Center: GRC

Participating Center(s): JPL

Technology Area: TA15 Aeronautics

In-Space Electric Propulsion Component Technologies

Electric Propulsion for space applications has shown tremendous benefit to a variety of NASA, commercial, and DoD missions. The electric propulsion systems currently under development have uncovered challenges and limits to these technologies. 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. Proposers are expected to show an in-depth understanding of the current state-of-art (SOA) and quantitatively (not qualitatively) describe improvements over relevant SOA technologies that substantiate investment in the new technology. Proposers must also quantitatively explain the operational benefits of the new technology from the perspective of improving or enabling mission potential. Proposals outside of the scope described below shall not be considered.

These technologies of interest include:

- Advanced magnetics for Hall/ion thrusters. Specifically:
    - High temperature capable magnetic components (>500° C).
    - 3D printing of magnetic materials.

- Advanced Hall/ion cathode technologies. Experimental demonstration backed by theoretical or computational modeling are preferred. Specifically:
- Advanced materials for Hall thruster systems. Specific areas of interest include:

    - Lower cost fabrication techniques for cathode assemblies.
    - Advanced cathode emitter materials
    - Long-life heaters for hollow cathodes made with barium oxide (BaO), lanthanum hexaboride (LaB6) or other materials. In order to achieve reliable cathode ignition, barium oxide cathodes must operate at 1050 - 1200° C while the LaB6 heaters typically must operate at 1500 – 1700° C. 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 emissivity (>0.6) coatings and/or surface treatments suitable for use with high-temperature (300-500° C) electric propulsion components with long operating times (>20 kh).
    - High-voltage (>600 V), high-temperature harnessing capable of long-term (>20 kh) vacuum operation over temperature ranges of -100° C to 400° C.

Low-cost, high-temperature anode gas distributors capable of achieving a high degree of flow uniformity in Hall thruster discharge channels through use of innovative designs and/or fabrication techniques.

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. 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.

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 is covered under OCT's TA-02 In-Space Propulsion.

Expected TRL for this project is 4 to 5.

Precision Low-Noise Micropropulsion for Fine Pointing of Astronomical Observatories

Future astronomical observatories are facing two critical challenges:

- Advanced astrophysical and exoplanet science demand increasingly longer observing times with more precise pointing and wavefront error stability requirements.
- The performance and lifetime of reaction wheels is limited.

For the first challenge, solar pressure and torque demand that space-based observatories have active, continuous control of pointing, typically using reaction wheels as the actuator, which have limited pointing performance and create large amounts of mechanical noise. Large and heavy vibration isolation stages are typically used to protect the instruments from the vibrations and jitter induced by reaction wheels. But for many new mission concepts using higher resolution detectors or coronagraphs to block starlight, vibration isolation systems struggle to achieve the necessary wavefront error stability, required to be less than 1 nanometer. New, lower-noise actuators or "active" vibration isolation technology for large deployable structures are an attractive alternative. For the second challenge, reaction wheel failure has limited the lifetime of many astronomical observatory missions. Longer life actuators would be necessary to justify replacement of high-heritage reaction wheels.

Most micropropulsion systems are being developed for high-impulse, low-power applications as a "miniature" equivalent to existing propulsion options with just a few throttle points. However, as fine pointing actuators, mainly pushing back against solar pressure (7 µN / m^2), precision microthrusters do not need to demonstrate high thrust or impulse. Instead, low thrust noise (< 1 µN/?Hz) over a continuous throttle range (5-100 µN) is necessary to replace reaction wheels. For any application including precision pointing, increased reliability and lifetime >4 years are also critical. If such propulsion systems could be developed, NASA and commercial space-based observatories would have better pointing performance without need for expensive and heavy structure for vibration isolation or the likely lifetime limitation of using reaction wheels.

Anticipated environments for these devices will be typical for L_1/L_2 or Earth-trailing orbits with similar radiation dose requirements of "deep space" or even GEO-like orbits. Thermal environment varies from mission to mission, but often the thrusters will be placed orthogonal to the plane that is generating the solar pressure, which usually means in the shade or partial shade. As an example, typical operating environment temperatures for ST-7 were 0° C - 50° C with non-operating temperatures stretching to -20° C - 75° C.

This technology is critical to the Physics of the Cosmos and Exoplanet Exploration Programs in the Astrophysics Directorate, both of which have added microthrusters for precision control on their list of high priority technologies. Example missions include Laser Interferometer Space Antenna (LISA) and Habitable Exoplanet Observatory (HabEx), which have both baselined precision microthrusters instead of reaction wheels.

Expected TRL for this project is 4 to 6.