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Microelectrospray Thrusters

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Sponsoring Program(s)

Space Technology Mission Directorate
Game Changing Development

Project Description

Propulsion technology is often a critical enabling technology for space missions. NASA is investing in technologies to enable high value missions with very small spacecraft, even CubeSats. However, these nanosatellites currently lack any appreciable propulsion capability. CubeSats are typically deployed and tumble or drift without any ability to transfer to higher value orbits, perform orbit maintenance, or perform de-orbit. Larger spacecraft can also benefit from high precision attitude control systems. Existing practices include reaction wheels with lifetime concerns and system level complexity. Microelectrospray thrusters will provide new propulsion capabilities to address these mission needs.

Electric propulsion is an approach to accelerate propellant to very high exhaust velocities through the use of electrical power. Typical propulsion systems are limited to the combustion energy available in the chemical bonds of the fuel and then acceleration through a converging diverging nozzle. However, electric propulsion can accelerate propellant to ten times higher velocities and therefore increase momentum transfer efficiency, or essentially, increase the fuel economy. Fuel efficiency of thrusters is proportional to the exhaust velocity and referred to as specific impulse (I_{sp}). The state-of-the-art (SOA) for CubeSats is cold gas propulsion with an I_{sp} of 50–80 s. The Space Shuttle main engine demonstrated a specific impulse of 450 s. The target I_{sp} for the Mars Exploration Program (MEP) systems is >1,500 s. This propellant efficiency can enable a 1-kg, 10-cm cube to transfer from low-Earth orbit to interplanetary space with only 200 g of propellant.

In September 2013, NASA's Game Changing Development program competitively awarded three teams with contracts to develop MEP systems from Technology Readiness Level-3 (TRL-3), experimental concept, to TRL-5, system validation in a relevant environment. The project is planned for 18 months of system development. The target objectives of the project are provided in table 1.

Table 1: MEP phase 1 project objectives.

Metric	Goal
I_{sp}	≥1,500 s
Thrust	≥100 µN
Power	≤10 W
System Efficiency	≥70%
Mass	≤100 g
Volume	≤100 cm^3
Demonstrated Life	≥200 hr
Predicted Life	≥500 hr

Due to the ambitious project goals, NASA has awarded contracts to mature three unique methods to achieve the desired goals. Some of the MEP concepts have been developed for more than a decade at the component level, but are now ready for system maturation. The three concepts include the high aspect ratio porous surface (HARPS) microthruster system, the scalable ion electrospray propulsion system (S-iEPS), and an indium microfluidic electrospray propulsion system.

The HARPS system is under development by Busek Co. The HARPS thruster is an electrospray thruster that relies on surface emission of a porous metal with a passive capillary wicking system for propellant management. The HARPS thruster is expected to provide a simple, high ΔV and low-cost solution. The HARPS thruster concept is shown in figure 1. Figure 1 includes the thruster, integrated power processing unit, and propellant reservoir.

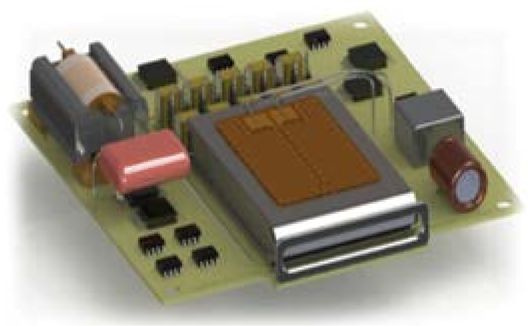

Figure 1: Busek HARPS system concept.

The S-iEPS development is led by the Massachusetts Institute of Technology (MIT). The MIT S-iEPS benefits from many years of component level development and experimentation. The S-iEPS is a microelectromechanical system based on ionic liquid emission. An electrostatic field is used to extract and accelerate both positive and negative ions from a conductive salt that remains liquid over the operational temperature range. The concept is scalable in that the thrusters can produce flat panel thrusters. Thruster pairs are used emitting the positive and negative ions to maintain charge balance. A pair of S-iEPS is shown in figure 2.

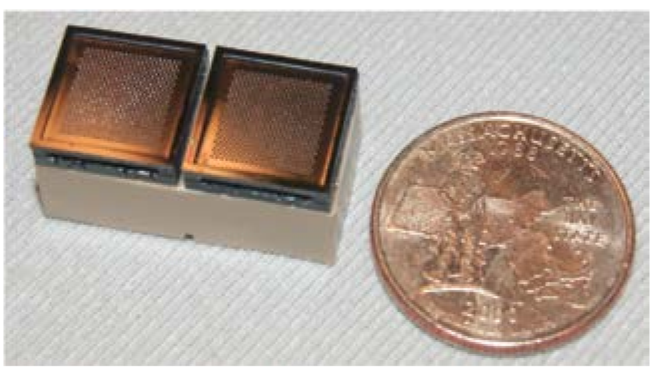

Figure 2: MIT S-iEPS thruster pair.

The Jet Propulsion Laboratory (JPL) is leading a liquid metal, indium, propellant based microfabricated thruster relying on a capillary force-driven propellant management system with no pressurization, no valves, and no moving parts. The indium thruster concept will push the limits of microfabrication techniques to produce a compact and scalable thruster. The JPL thruster is targeting 200 µN of thrust and 5,000 s I_{sp} at <10 W and 80 g. Figure 3 illustrates the JPL indium thruster concept.

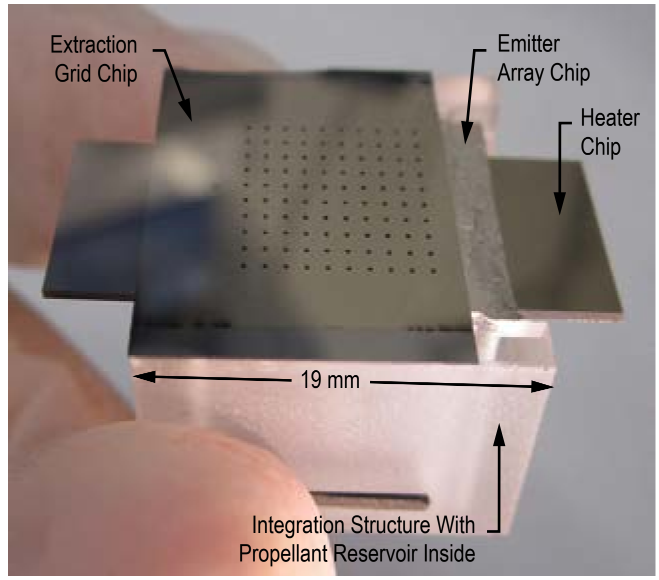

Figure 3: JPL indium thruster.

Anticipated Benefits

The benefits of MEP technology include significant improvement in low power electric propulsion efficiency, high ΔV capability for CubeSats, and high I_{sp} density over alternatives.

Potential Applications

The application targets for the MEP systems include primary propulsion for small spacecraft, attitude control, and precision propulsion for future missions.

Notable Accomplishments

This project has made significant progress to date, including integrated system testing. By summer of 2015, the project will mature the concepts to TRL-5, deliver a prototype system, and perform long-duration testing of each of the concepts.