National Aeronautics and Space Administration

Micro-Electrospray Thrusters
by NASA's Space Technology Mission Directorate

Propulsion technology is often critical for space missions. High-value missions could be done with very small spacecraft, even CubeSats,[1] but these nanosatellites currently have little propulsion capability. After CubeSats are deployed, they usually just tumble or drift away from the transport spacecraft. They cannot transfer to higher value orbits, maintain their orbit, or even deorbit. Larger spacecraft would benefit from high-precision attitude-control systems to maintain the desired orbit and point in the desired direction. Existing attitude-control systems, like reaction wheels, are very complex and may have insufficient lifetimes. NASA is investing in Microfluidic Electrospray Propulsion (MEP) thrusters to provide the new propulsion capabilities to address both of these mission needs.

Electric Propulsion

Chemical propulsion systems are limited to the combustion energy available in the chemical bonds of the fuel and the acceleration provided by a converging-diverging nozzle. Electric propulsion uses electric power to accelerate propellant to very high exhaust velocities—up to 10 times greater than for chemical propulsion. This increases the momentum transfer efficiency or the fuel economy. The propellant efficiency of thrusters, which is proportional to the exhaust velocity, is referred to as the "specific impulse," or I_{SP}, measured in seconds. The state of the art for CubeSats is cold gas propulsion with an I_{SP} of 50 to 80 s. The chemical propulsion main engine for the space shuttles demonstrated an I_{SP} of 450 s. However, the target I_{SP} for MEP systems is greater than 1500 s—enough to transfer a 1-kg 10-cm cube from low Earth orbit to interplanetary space with only 200 g of propellant.

Status and Development Phases

In September 2013, NASA's Game Changing Development (GCD) program awarded 18-month Phase I contracts to three teams. The teams are developing MEP systems from an experimental concept to a system validated in a relevant environment. In addition, the teams will be competing for a Phase II contract to mature one system to a prototype demonstrated in space. Table 1 shows the target objectives for Phase I. Results are expected in early 2015.

Table 1.—MEP Phase I objectives

Metric	Goal
Specific impulse, I_{SP}	≥1500 s
Thrust	≥100 μN
Power	≤10 W
System efficiency	≥70 percent
Mass	≤100 g
Volume	≤100 cm^3
Demonstrated life	≥200 hr
Predicted life	≥500 hr

Three-Pronged Approach

The three concepts include the High Aspect Ratio Porous Surface (HARPS) microthruster system, the Scalable ion Electrospray Propulsion System (S-iEPS), and an indium MEP system.

HARPS—Busek Co. is developing the HARPS system, which employs an electrospray thruster that relies on the surface emission of charged ionic liquid droplets and ions from a porous metal with a passive capillary wicking system for propellant management. The HARPS thruster is expected to provide a simple, high-ΔV,[2] low-cost solution. Figure 1 shows the thruster and its integrated power processing unit as well as the propellant reservoir.

[1] *These can be cubes as small as 10 cm (less than 4 in.) on a side.*

[2] *Change in velocity.*

ARCHIVED

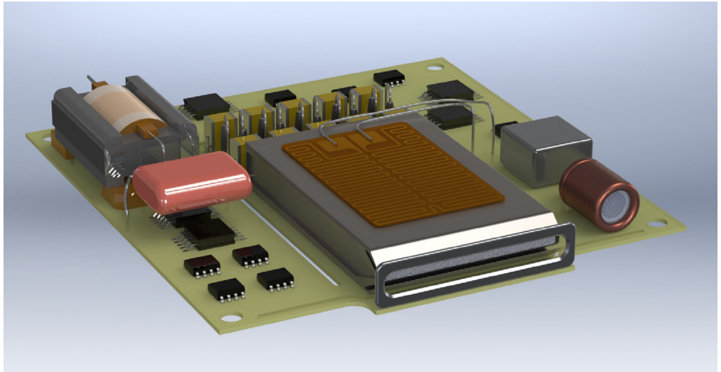

Figure 1.—Concept for Busek's HARPS thruster.

S-iEPS—The Massachusetts Institute of Technology (MIT) is leading the development of the S-iEPS, which is benefiting from many years of component-level development and experimentation. This microelectromechanical system (MEMS) is based on ionic liquid emission. An electrostatic field is used to extract and accelerate both positive and negative ions from a conductive salt that stays in the liquid state over the full operational temperature range. Thruster pairs (Fig. 2) emit positive and negative ions to maintain charge balance. The concept could be scaled up to produce flat-panel thrusters.

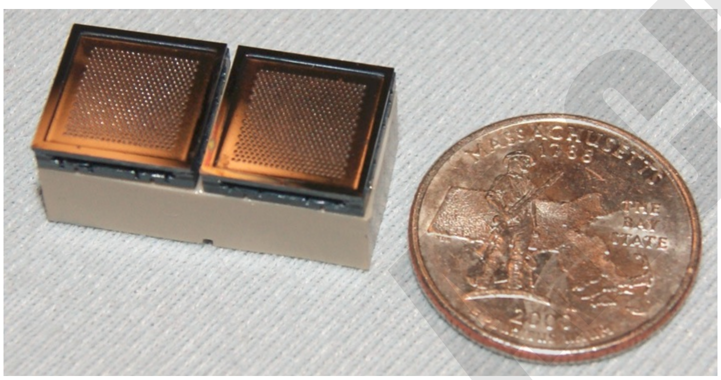

Figure 2.—Thruster pair for MIT's S-iEPS.

Indium MEP—The Jet Propulsion Laboratory (JPL) is leading the development of a liquid metal (indium) propellant microfabricated thruster (etched on silicon chips similar to how computer chips are produced). It relies on a capillary-force-driven propellant management system with no pressurization, no valves, and no moving parts. This effort is pushing the limits of microfabrication techniques to produce a compact and scalable thruster. The target is an indium thruster (Fig. 3) that produces 200 μN of thrust and 5000 s of I_{SP} at less than 10 W and with a dry mass less than 10 g and the capability of more than 10 g of propellant.

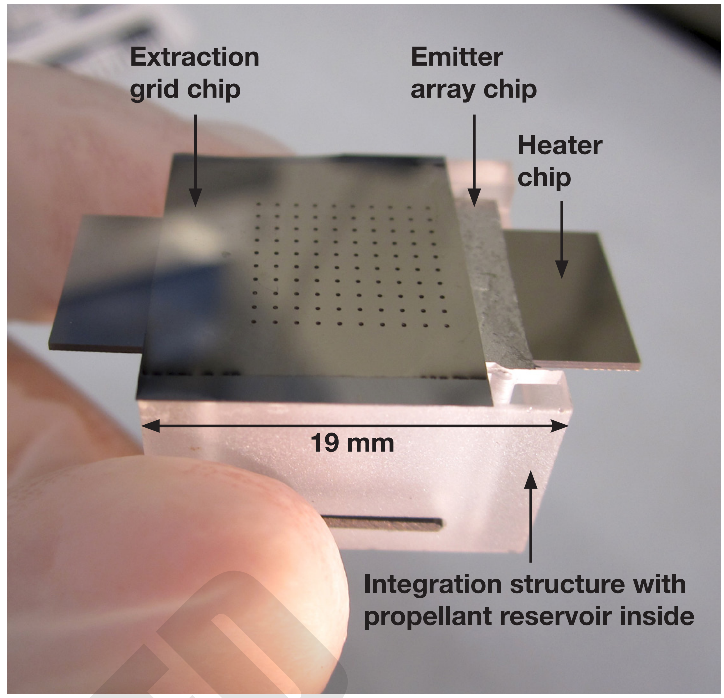

Figure 3.—Concept for JPL's indium MEP thruster.

A Promising Future

MEP technology has the potential to enable small spacecraft to make large maneuvers and to transfer to different orbits, opening a market for high-value, low-cost missions. MEP may also enable high-precision pointing on larger spacecraft-like telescopes that search for Earth-like planets.

The MEP Project and other GCD efforts can be followed at http://gcd.larc.nasa.gov/projects/microfluidic-electrospray-propulsion/

NASA's Game Changing Development (GCD) program investigates ideas and approaches that could solve significant technological problems and revolutionize future space endeavors. GCD projects develop technologies through component and subsystem testing on Earth to prepare them for future use in space. GCD is part of NASA's Space Technology Mission Directorate.

PS–01149–1213
FS–2013–12–041–GRC

For more information about GCD, please visit http://gameon.nasa.gov/

ARCHIVED