Storable Propellant

Busek test-fires tiny RF gridded-ion thruster for CubeSat apps, using 'solid' iodine as fuel

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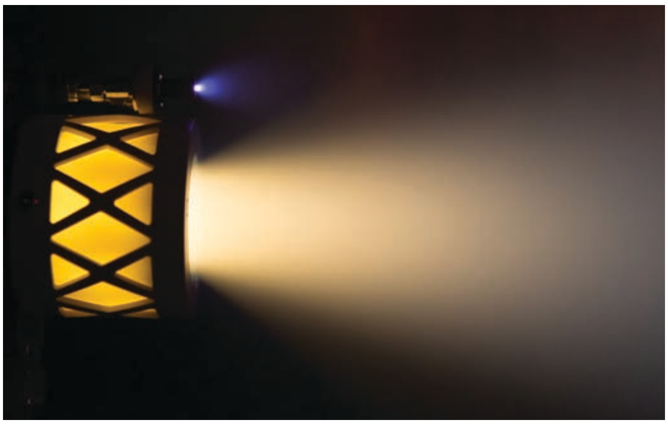
A high-efficiency radio-frequency (RF) ion microthruster in development could give engineers another approach to solar-electric propulsion (SEP) technology for deep-space exploration, particularly for the tiny CubeSat-based probes just coming into their own.

While large-scale SEP is considered necessary to preposition supplies on Mars for human explorers, work is underway at NASA and in universities on CubeSat-class missions to the Moon, Mars and other deep-space destinations as well. Of particular interest is SEP technology that uses iodine as a propellant instead of xenon.



BUSEK CO.

Busek has ground-tested an ion microthruster using iodine as a propellant, which has advantages for smallsats.

Iodine is easier to integrate into spacecraft and costs much less than the xenon typically used today. Although they sit next to each other in the periodic table, iodine is a solid that sublimates into a useful gas at relatively low temperature, while xenon in its ambient state is a gas that must be contained in a pressure vessel.

Busek Co., a privately held 50-person space-propulsion business in Natick, Massachusetts, has just demonstrated an RF gridded-ion thruster that uses iodine as a propellant and measures only 3 cm across. With iodine, the "BIT-3" thruster demonstrated a specific impulse of 3,500 sec. and a thrust measured at more than 1.4 mN. Designed to propel advanced CubeSats from geostationary to lunar orbits, using 60 watts of power it can generate a Delta-v (velocity change) of 2.5 km/sec. (1.5 mi./sec) with 1.5 kg (3.3 lb.) of fuel in a 13-kg spacecraft, the company says.

"Iodine is a substance that is stored as a solid on a spacecraft, because it has very high density," says Vlad Hruby, founder and president of Busek. "It also stores in small volume, in a zero-pressure tank. That means the tank can be conformal. You can stick it anywhere in the spacecraft, wherever you have space, and then you heat it up a little bit and it generates enough available pressure to feed [the propulsion system]."

Busek also has used iodine as a fuel in Hall-effect thrusters, and holds NASA small-business contracts for advanced technology development work aimed at deep-space smallsat SEP. The BIT-3 approach uses an RF coil to ionize the sublimated iodine gas, and electrically charged grids to accelerate the ions to the high velocity needed.

While the Hall thrusters are good for "Earth-centric" missions, the efficiency of the gridded-ion thruster makes it more attractive for deep-space applications.

"They have different niches, really," says Michael Tsay, chief scientist on the BIT-3 project at Busek. "The Hall thruster has very high thrust to power, so you can get higher thrust, but with slightly lower Isp [specific impulse]. The RF ion can give you very high Isp, but you get lower thrust. So it's mission-dependent."

For either application, iodine has another advantage over xenon that makes it more attractive as a secondary payload. Since it doesn't require a high-pressure tank, iodine is safer and less likely to damage a high-priced primary payload if something goes wrong.

Busek is working with NASA's Space Technology Mission Directorate (STMD) on the planned iodine satellite (iSat), a spaceflight demonstration of a 200-watt iodine-fueled Hall thruster the company will supply for a 6U or 12U CubeSat scheduled to fly in 2017. The U.S. space agency is also conducting work to advance the technology readiness level of a 600-watt iodine thruster.

"It eliminates the need for a high-pressure tank, and it stores more compactly, so it takes up less volume," says Andrew Petro, NASA program executive for the Small Spacecraft Technology Program within the STMD. "Those two features are especially important because of the small size of the small satellites we are trying to develop."

Deep-space SEP is a growing field in the smallsat industry. In addition to the work at NASA, the Aerospace Engineering Department at the University of Michigan is developing a xenon-fueled plasma thruster that uses a magnetic field to control the plasma plume after it emerges from a quartz-lined thruster (*AW&ST* Aug. 15, p. 24).

Iodine has advantages for small satellites, including much lower cost as industry finds new uses for xenon in fields as disparate as photography flashes and surgical anesthesia. But it may not be as scalable as xenon for the large-scale, multi-kilowatt applications NASA's human-spaceflight engineers are pushing as a way to move habitats, cargo carriers and other large payloads toward Mars (*AW&ST* June 23, p. 44).

"The challenge with iodine is feeding the propellant," says Petro. "With the xenon gas it is very simple; it's a pressurized gas, It will come out through a valve if you open it. The iodine has to sublime into a gas and be fed, and the larger amount of it you have, the more challenging it might be to engineer a tank that will feed that propellant in a consistent and reliable way. It certainly is possible, but it will probably take some more engineering to work that out. I haven't really seen much. I think the real attraction of the iodine is in the smaller spacecraft, because they already have the problem of limited volume. It is not as much of an issue for the bigger spacecraft."