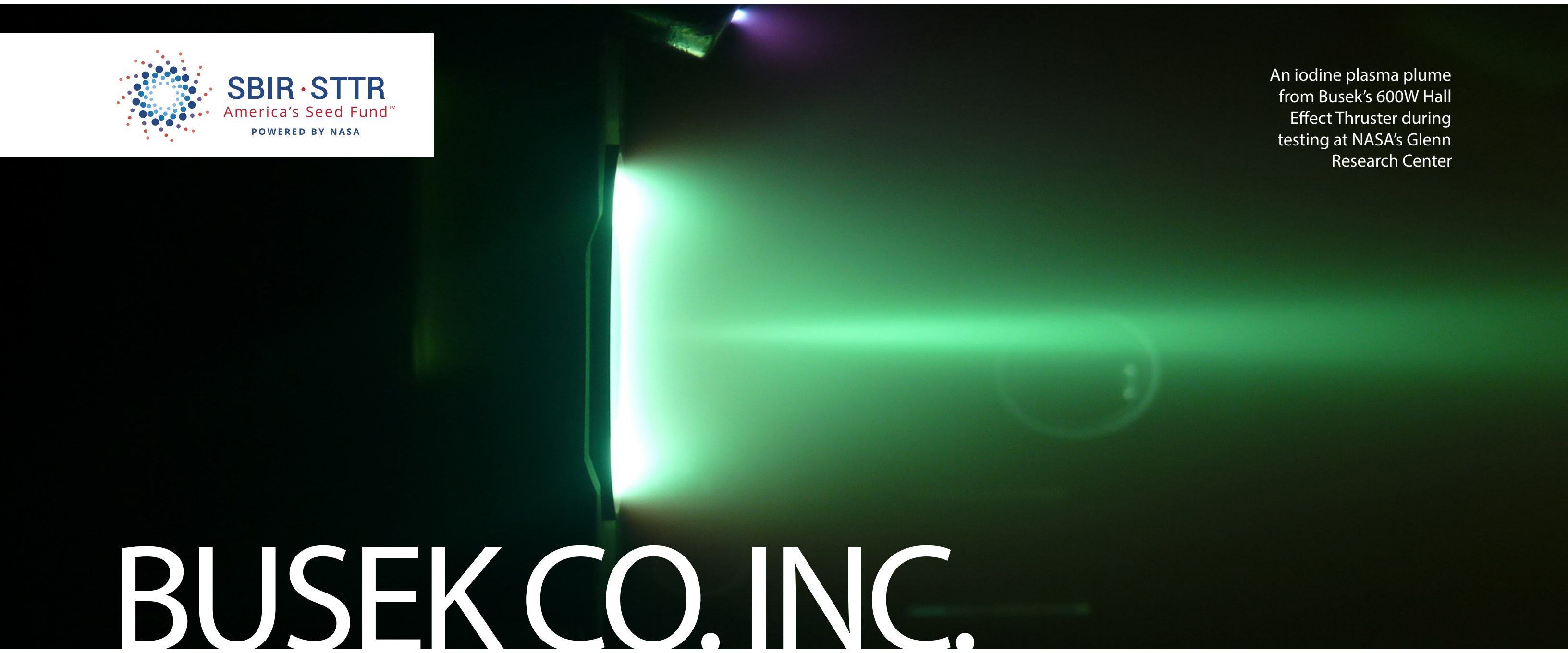

An iodine plasma plume from Busek's 600W Hall Effect Thruster during testing at NASA's Glenn Research Center

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BUSEK CO. INC.

A modern spacecraft performing interplanetary missions may change velocity by more than 20,000 miles per hour (32,000 km/hr). To achieve these speeds, Hall Effect Thrusters and other forms of ion propulsion may be used. For decades, xenon has been the gas of choice for most of NASA's solar electric propulsion (SEP) systems. However, alternate propellants are needed for future missions. The high-pressure storage requirements of xenon gas coupled with fluctuating costs due to limited availability have prompted scientists to seek out alternative propellants and compatible propulsion systems.

PROJECT
Iodine Hall Thruster for Space Exploration

MISSION DIRECTORATE
Space Technology

PHASE III SUCCESS
Over $3 million in Phase III and follow-on contracts with NASA and the USAF

SNAPSHOT
Busek has revolutionized solar electric propulsion technology by pioneering the use of iodine propellant, resulting in efficient, compact, low mass and high performance space propulsion systems.

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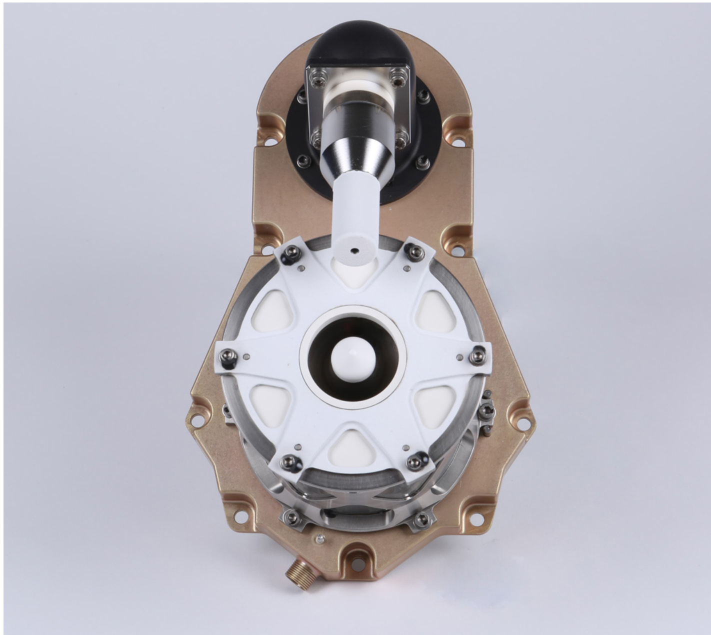
Busek Co. Inc., which has been developing state of the art Hall thrusters and solar electric propulsion systems for over two decades, had a vision that iodine would provide all of the known benefits of xenon without the inherent challenges.

"Iodine was a complete change in approach for Hall thrusters," says Dr. James Szabo, Chief Scientist for Hall Thrusters at Busek. "Because you can launch at a much lower cost with fewer volume restrictions, this isn't just mission enhancement – it's mission enabling."

Iodine offers NASA immense benefits when compared to xenon including mass and cost savings. Iodine may be stored as a solid in low volume, low mass, low cost propellant tanks – an attractive feature when volume capacity on a spacecraft is extremely limited. This is in contrast to the high pressure, high mass, high cost tanks required for xenon Hall thruster systems. However, the team at Busek had to be sure that performance was not compromised by the use of iodine.

In 2010, the first ever demonstration of an iodine fueled Hall thruster occurred at Busek with Air Force funding. It was discovered that thruster efficiency and exhaust velocity were equal to what was achieved with xenon on Busek's thruster designs. With this new knowledge in hand, the Natick, Massachusetts-based company responded to a NASA Small Business Innovation Research (SBIR) solicitation and proposed an iodine Hall thruster for the agency's specialized missions. Busek won a Phase I award and aligned with NASA Glenn Research Center.



LEFT The Busek BHT-200 was the first U.S. developed Hall Effect Thruster to fly in space (TacSat-2, 2006)

RIGHT An iodine compatible 600 W Hall Effect Thruster (BHT-600-I) was an SBIR Phase II deliverable

While the Phase I project tested a very large thruster at power levels up to and exceeding 10 kilowatts, a Phase II objective was to scale down the system. The thruster was transitioned to a 600 Watt system, which is better sized for future Discovery Class missions. The Phase II project also saw the development of an iodine compatible hollow cathode, a power processing unit (PPU), and an improved iodine feed system (IFS).

> "SBIR has been invaluable, enabling us to do this groundbreaking research and development. We were given funding to take risks and do research in the lab that a bigger corporation wouldn't be able to do."
>
> BUSEK CO. INC.
> CHIEF SCIENTIST FOR HALL THRUSTERS
> DR. JAMES SZABO

The project has since led to numerous additional contracts including awards to develop a 200-watt iodine fueled Hall thruster system for the iSAT (Iodine Satellite) mission. Glenn Research Center (GRC), Marshall Space Flight Center (MSFC), and USAF Space and Missile Systems Center (SMC) are playing critical roles in this program which targets launch readiness in Spring of 2017.

Busek has also been working with a spacecraft launch provider and NASA Ames Research Center to develop small spacecraft delivery systems that would benefit from the availability of iodine Hall thrusters.

"A lot of credit goes to the NASA SBIR program, which enables cost-effective innovation and risk-taking in R&D. Busek developed the first U.S. Hall thrusters to fly in space and alternate propellant research is an extension of that work," adds Szabo. "Taking concepts from the drawing board to flight is what we do."

Iodine Hall thruster systems can fill a wide range of spacecraft and missions, ranging from CubeSats (small satellites) up to large geostationary satellites and interplanetary probes.

Iodine fuel is also attractive for gridded ion engines – a sister technology to Hall Effect Thrusters. Busek is contracted to build iodine fueled Radio Frequency (RF) gridded ion engines for Morehead State University's Lunar IceCube and Arizona State University's LunaH-Map space probes. These 6U spacecraft will launch on the first flight of NASA's Space Launch System (SLS) in 2018. Exploration Mission 1 will carry 13 CubeSats to test innovative technologies that will ultimately enable future Mars missions.

Busek also believes its iodine Hall thrusters are an excellent fit for LEO, MEO and GEO applications as well as planetary exploration and asteroid redirect missions. Another important use for the technology is de-orbiting spacecraft at end of life, mitigating the risk of space debris.

As with many of NASA's end goals, iodine Hall thrusters are designed to make space exploration more feasible, compact, and cost effective, with the immediate goal of getting to Mars. The agency believes iodine can find a nice niche in the space market, allowing them to plan for multiple missions at a fraction of the cost.