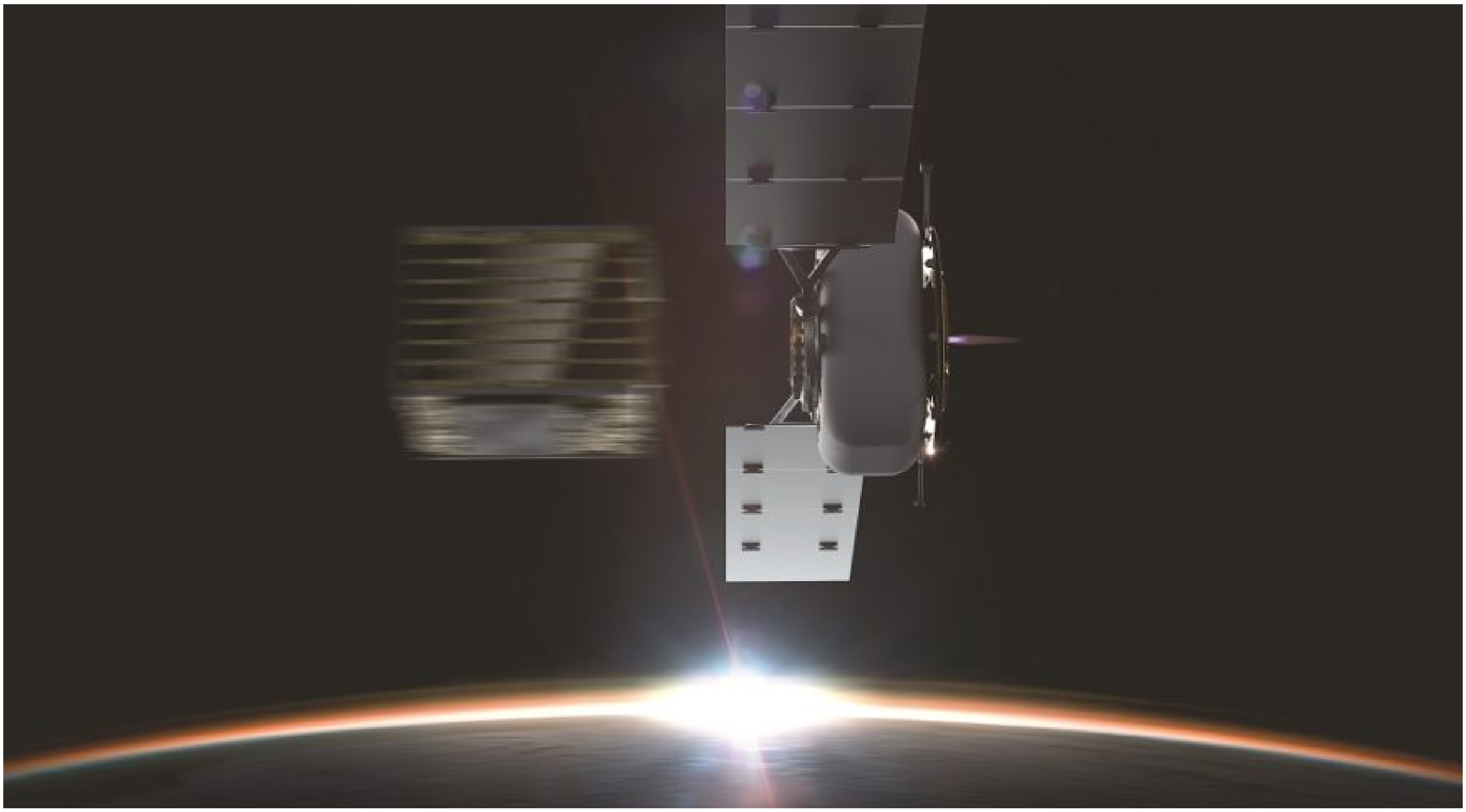
SPACENEWS

Water propulsion technologies picking up steam

by **Debra Werner** — August 27, 2019



Momentus Space has announced plans to move satellites from one orbit to another with its Vigoride and Vigoride Extended shuttles. Both spacecraft rely on Momentus' water plasma propulsion. Credit: Momentus Space

This article originally appeared in the Aug. 19, 2019 issue of SpaceNews magazine.

When the Aerospace Corp. launched the Optical Communications and Sensor Demonstration in 2017, one mission objective was to test water-fueled thrusters. At the time, the idea was fairly novel. Two years later, water-based propulsion is moving rapidly into the mainstream.

Capella Space's first radar satellite and HawkEye 360's first cluster of three radio-frequency mapping satellites move in orbit by firing Bradford Space's water-based Comet electrothermal propulsion system. Momentus Space and Astro Digital are testing a water plasma thruster on their joint El Camino Real mission launched in July. And an updated version of the water-fueled cold gas thrusters the Aerospace Corp. first flew in 2017 launched in early August.

"Water is an ideal propellant," said Mikhail Kokorich, Momentus founder and president. "It can be used as-is in solar thermal, nuclear or electrothermal engines. In addition, water can easily be broken down into hydrogen and oxygen."

Tethers Unlimited takes the later approach with Hydros-C, a thruster that relies on electrolysis to split water into its constituent elements before burning it in a bipropellant nozzle.

"The result is good fuel economy and good thrust," said Robert Hoyt, Tethers Unlimited chief executive.

NASA plans to test a variety of cubesat technologies including Hydros-C on its first Pathfinder Technology Demonstrator. PTD-1 is scheduled to fly to the International Space Station in November before traveling to a higher altitude to deploy from a Cygnus cargo tug. Meanwhile, Millennium Space Systems, a Boeing subsidiary, is integrating Hydros-C in its Altair spacecraft bus.

A CLEAN, ABUNDANT FUEL

Tethers Unlimited began investigating water propulsion years ago because water poses no harm to technicians during satellite integration nor to payloads riding alongside small satellites into orbit, Hoyt said. Water propellant also fits into Tethers Unlimited's long-term vision of creating a sustainable in-space ecosystem.

"Water is a resource around which an economy and marketplace in space could develop," Hoyt said. Initially, water required to fuel propulsion systems will launch from Earth but later it could be extracted from the moon or asteroids, he added.

Kokorich agreed, saying water is likely to be the first and most important resource mined on asteroids and on the moon. Once mined, companies will propel spacecraft, satellites and in-space transportation vehicles, like the shuttles Momentus is developing, with water, he added.

Deep Space Industries, the firm that developed the Comet propulsion system before it was acquired by Bradford in January, celebrated the long-term vision of extracting water from celestial bodies to fuel spacecraft. Bradford is more focused on the near-term potential for water to fuel missions in Earth orbit.

"It's non-toxic, easy to transport, easy to fuel up and you can put it on a rideshare without any trouble," said Bradford Director Ian Fichtenbaum. Small satellites equipped with water-based propellants are welcome on small rockets, he said, adding, "many of the small launchers have no facilities for hydrazine loading and no plans for that."

Purdue University graduate student Katherine Fowee and postdoctoral research associate Anthony Cofer work on a new micropropulsion system for cubesats. Credit: Purdue University

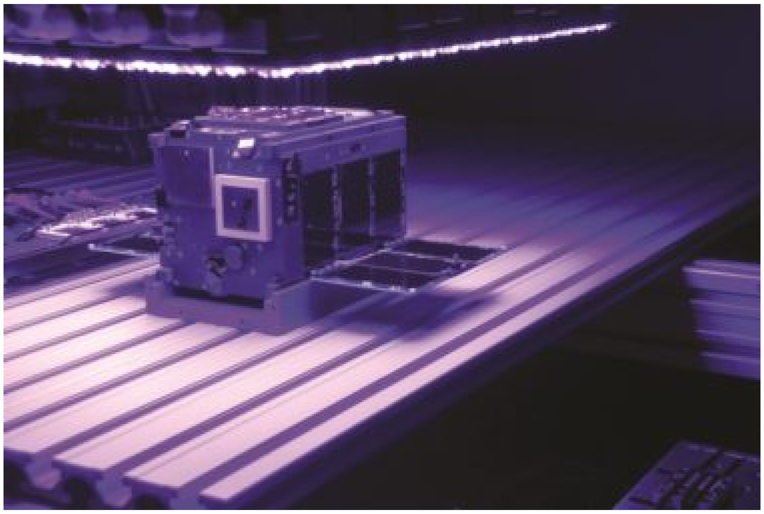
BlackSky is preparing to launch an Earth observation satellite built by LeoStella, the Spaceflight Industries-Thales Alenia Space joint venture, equipped with Bradford's Comet thruster on the next flight of the Rocket Lab Electron rocket. At press time, the launch was scheduled for Aug. 16.

While cubesats with electric and chemical propulsion can win approval to accompany larger satellites on some rockets, the safety review process can be arduous. After enduring that review process, Aerospace Corp. engineers spent years developing steam thrusters.

The first ones flew in 2017 on the two-satellite Optical Communications and Sensor Demonstration mission, also known as AeroCube 7. AeroCube 7 launched as a secondary payload on a ULA Atlas 5 rocket that sent a classified National Reconnaissance Office satellite into orbit.

After some initial problems with ice plugging the nozzle, the Aerospace Corp. turned up the temperature on both thrusters and fired them to move the AeroCube 7 satellites toward one another, according to "The NASA Optical Communications and Sensor Demonstration Program: Proximity Operations," a paper presented in August 2018 at the Small Satellite Conference in Logan, Utah. An updated version of AeroCube 7's steam propulsion launched from Cygnus Aug. 7 on AeroCube 10.

Universities around the world also are developing new water-based propulsion systems.NASA awarded Purdue University funding in 2018 to launch a miniature water-fueled thruster, Film Evaporation MEMS Tunable Array, or FEMTA, on Blue Origin's New Shepard suborbital rocket in 2021. (MEMS stands for micro-electro-mechanical system.)



Aerospace Corp.'s steam-propelled AeroCube 10 launched Aug. 7 from a Cygnus space tug. Credit: Aerospace Corp.

"What is unique about this flight testing is that the payload will be located on the outside of the launch vehicle so that the FEMTA propulsion system can be tested in real spaceflight conditions (both vacuum and low gravity)," Alina Alexeenko, FEMTA principal investigator, said by email.

FEMTA, a tiny thruster manufactured in batches on silicon wafers, measures one centimeter by one centimeter by 0.3 millimeters. It consumes less than one watt of electrical power and provides thrust that mission operators can tune to levels as low as a few tens of micronewtons, about the weight of a single eyelash, for fine attitude control of small satellites or large deployable structures, Alexeenko said.

The University of Tokyo built a cubesat equipped with Aquarius, a resistojet propulsion system fueled by water. The Aqua Thruster Demonstrator or AQT-D cubesat, which houses an Aquarius thruster, is slated to travel to the International Space Station in September on a Japanese cargo resupply mission. AQT-D will later be deployed from the Japanese Experiment Module, according to "AQT-D: Demonstration of the Water Resistojet Propulsion System by the ISS-Deployed CubeSat," a paper presented Aug. 4 at the Small Satellite Conference.

Water propulsion enthusiasts are celebrating all the innovation. "Just as oil powered the industrial revolution on Earth, water will power the space industrial revolution," Kokorich said.

Until then, spacecraft manufacturers and launch providers are simply relieved to find fuel workers can handle without donning Self-Contained Atmospheric Protective Ensemble, or SCAPE suits.

LOG IN WITH

OR SIGN UP WITH DISQUS ?

Name

Paul_Scutts • 9 months ago • edited

It's ironic, it was steam that powered the industrial revolution in the eighteenth/nineteenth centuries and it will be steam that will power the Solar System revolution of the twenty-first/second centuries. Good old water(ice), a truly miraculous substance.

5 ^ | ⌄ • Reply • Share ›

Cjones1 • 9 months ago

I imagine the frozen methane of the outer planets will be used for propulsion and for other means. Afterall, the air we breath is mostly Nitrogen.
The innovations in using water will definitely benefit fuel cell development and provide the other component necessary for the air we need.

2 ^ | ⌄ • Reply • Share ›

John F. Bramfeld • 9 months ago

How do you end up with more energy burning the H and O than you require to split them apart? It seems too good to be true.

1 ^ | ⌄ • Reply • Share ›

MatthewL → John F. Bramfeld • 9 months ago • edited

They're not burning the H and O, they're turning them into a plasma and accelerating them via electric fields. This isn't about energy efficiency.

5 ^ | ⌄ • Reply • Share ›

John F. Bramfeld → MatthewL • 9 months ago

Unlimited takes the later approach with Hydros-C, a thruster that relies on electrolysis to split water into its constituent elements before burning it in a bipropellant nozzle."

^ | ⌄ • Reply • Share ›

Nathaniel → John F. Bramfeld • 9 months ago

They're still not aiming for energy efficiency, they're trading Isp for thrust. You should read their paper from IEEE. The other thrusters mentioned have higher Isp but lower thrust compared to Hydros.

^ | ⌄ • Reply • Share ›

And you believe that why? ➦ John F. Bramfeld • 9 months ago

You don't. Energy is lost in electrolysis, hydrogen drying, and liquefaction. There is also the mass penalty the added subsystems require to consider as well.

MatthewL is right, this isn't about energy efficiency. This isn't about propellant mass efficiency either. The goal is turning water into the proverbial wine without invoking miracles.

1 ^ | ˅ • Reply • Share ›

TheBrett • 9 months ago

Fascinating. Makes sense that it could work as a cold thruster, although I wonder what the ISP is.

1 ^ | ˅ • Reply • Share ›

Ian1102 ➦ TheBrett • 9 months ago

175 sec for Comet
http://bradford-space.com/p...

4 ^ | ˅ • Reply • Share ›

Nathaniel ➦ TheBrett • 9 months ago

Momentus is projecting up to 1100 seconds. Don't forget that density also comes into play - a spacecraft that has ten times (this number is plucked out of thin air, it's the concept that matters) the propellant in the same volume but only half the ISP of another craft will still come out ahead in total delta-V.

1 ^ | ˅ • Reply • Share ›

billsimpson • 9 months ago

One BIG problem with water. It expands when it freezes at a rather high freezing point temperature for tanks and pipes in space. It is cold up there. Other than that, it would be wonderful.
I suspect that will be a significant problem on Mars. All water will need to be kept warm, so it doesn't freeze and break things. With a permafrost subsoil, that won't be easy.

1 ^ | ˅ 1 • Reply • Share ›

Streetwind ➦ billsimpson • 9 months ago

I expect that active heating to keep the water liquid is more or less a no-brainer here. All of these propulsion systems are electric in some form, be it a resistojet, a plasma generator, or an electrolysis setup. All of those things require a non-trivial amount of power, which the spacecraft will be designed to provide. And when the thruster isn't firing? Well, then the spacecraft provides excess power. Might as well invest it into heating.

6 ^ | ˅ • Reply • Share ›