Fueling the Low Earth Orbit Economy

Orbit Fab's Gas Stations in Space

BY STEPHENIE LIVINGSTON, *Staff Writer*

A year before Orbit Fab completed tests on the International Space Station (ISS) for hardware designed to refuel spacecraft in orbit, Furphy—as the project is dubbed—was a napkin sketch, and the company was only months old.

It was 2018 and Orbit Fab was a startup with high hopes. The company had ambitions to build an in-space propellant supply chain: Gas Stations in Space™. They knew in-orbit refueling would extend the life of satellites and provide more flexibility to the industry, thus creating a more sustainable space-based economy. But first, they needed to test their hardware in space—and the ISS National Laboratory provided the perfect platform to do it.

Furphy was designed to be Orbit Fab's first in-space refueling demonstration and a chance to show the space industry that the company could back its futuristic vision with real hardware. After submitting an ISS National Lab proposal and being awarded a flight project in the summer of 2018, the company handed over hardware for a December launch on SpaceX's 16th Commercial Resupply Services mission just four and a half months later. The napkin sketch became a reality with the speed that the company has come to be known for, thanks to working with the ISS National Lab, said Orbit Fab co-founder and chief development officer Jeremy Schiel, who co-led the Furphy project.

"Currently, there's no flexibility in the industry—you build a satellite for single use, and it cannot deviate from that, primarily because it runs out of fuel," Schiel said. "So, we're fundamentally changing the entire industry."

Orbit Fab's investigation on the ISS was essential to understanding tank dynamics and pump systems in the microgravity environment where the technology must perform, an impossible task on Earth, Schiel said. Through the Furphy project, Orbit Fab successfully validated its technology. It showed the space industry that the company is a real contender to become the propellant supplier and refueling servicer in space.

Results provided Orbit Fab with proof-of-concept data to show investors, stakeholders, and potential customers, said James Bultitude, Orbit Fab's chief technology officer. "It enabled us to fly a real space mission and get real scientific results far faster than anything else we could have done on the ground," he said. Since completing the Furphy project, Orbit Fab has gone on to develop in-space refueling technology that is now commercially available.

Exploring the Business Potential of In-Orbit Refueling

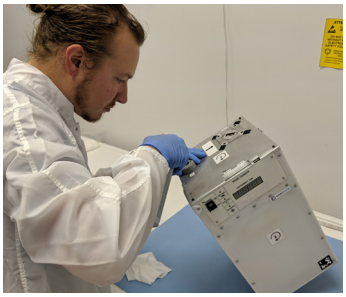
Before Orbit Fab was founded in January of 2018, Schiel and Daniel Faber, co-founder and CEO, went to various companies within the space industry and asked a simple question: What could you do with an extra tank of fuel? The response was overwhelming, according to Schiel. "We heard that many companies would see a huge increase in revenue just by having an extra kilogram of propellant in orbit," he said. "And so, after talking with several potential customers, we knew there was a business here."

At the center of Orbit Fab's mission is the idea that a robust space-based economy requires sustainable in-orbit fueling capabilities. The company's vision for the future of space is comparable to what happened on Earth when the world went from steam engines to oil and gas readily available to industry: the global shipping economy's worth went from the millions to trillions within a century.

"That was all unlocked because people had fuel to move goods and services around," Schiel said. "We're doing the same thing for space."

However, in space, fuel systems operate much differently than on the ground. On Earth, gravity forces fuel to the bottom of a car's fuel tank while a pump pushes it through the fuel pipeline to the engine. Space is a different story: liquid propellants float inside tanks and act more unpredictably. Pumps and tanks in space must be designed to deal with these difficulties.

Orbit Fab was up to the challenge and developed a pump system to move propellent between a refueling depot and spacecraft. The company also designed fuel tanks with internal baffling (panels that direct flow and help prevent sloshing) to reduce motion from liquid flow. However, the technology needed to be tested in space to ensure it worked as designed. Through the Furphy project on the ISS, Orbit Fab could test its technology and analyze pump and tank dynamics during refueling in a microgravity environment. Orbit Fab's tests on the ISS used water, but the same technology could support a wide range of propellants for spacecraft thrusters, said Bultitude. This could include common propellants like hydrazine and "green" alternatives like high test peroxide, which Orbit Fab plans to manufacture by the end of its first decade as a company.

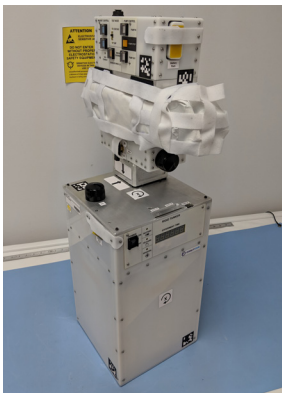


James Bultitude, Orbit Fab's chief technology officer, performs final cleaning and inspection of the rigid tanker during hardware handover to NASA before its flight to the ISS on SpaceX CRS-16.

Orbit Fab

Taking Furphy to Space

For the Furphy project, a rigid tanker the size of a 12U CubeSat (a class of nanosatellites about 20 cm by 34 cm) was filled with three gallons of water and sent to the ISS. Orbit Fab also sent an empty and compressed FlexTank™ made from silicone elastomer, which expands as it is filled in space. Because the project included a rigid tank filled with liquid, it was considered a hazardous payload, and the company worked day and night to ensure the investigation launched safely.



The FlexTank™ and rigid tank are shown here during a final connection test before launching to the ISS on SpaceX CRS-16 in 2019.

Orbit Fab

Once the payload was onboard the ISS, NASA astronaut Christina Koch tested the pump system's ability to transfer liquid between the tanker and FlexTank™ and the ability of the FlexTank™ to expand in microgravity. The test was successful, and Orbit Fab demonstrated liquid transfer between the two tanks in space.

The Furphy project also tested how tanks refueled in space are affected by propellant loads at various levels. To do this, Orbit Fab examined the dynamics of the tanker and FlexTank™ when filled with different amounts of liquid (full, half-full, a quarter-full, etc.). For each liquid level, Koch would spin the tanker, then stop it and release it to observe the tanker's behavior. Koch did the same with the FlexTank™.

Opening a New Frontier

The name "Furphy" was inspired by an Australian mobile water tank at the turn of the 20th century with the same name. The original Furphy water tank was transported via a horse-drawn cart and helped to open a new frontier in Australia—much like Orbit Fab plans to do with fuel and the space frontier.

This allowed Orbit Fab to test how well the internal baffling in the tanks reduced sloshing and residual momentum. After all the tests were complete, the water in the tanker was transferred into the space station's water supply—the first time a private company had supplied the ISS with water.

While the pumps worked well during testing with no leaks detected, and the liquid inside the tanks behaved similarly to what the company predicted, there were a few issues that Orbit Fab discovered in microgravity. The tests revealed some faults with the pump and electrical designs.

NASA astronaut Christina Koch onboard the ISS with Orbit Fab's FlexTank™ (left) and the rigid tanker (right) during testing.

NASA

"We made some design mistakes that we immediately went about correcting, which was really awesome," Bultitude said. "We had a wire that shorted on the ISS, but we managed to figure out why, and overnight, we replicated the problem on the ground and modified our engineering to remedy it."

Through successful testing on the ISS, Orbit Fab advanced the technology readiness level (TRL) of its pump system and tanks from TRL-4 to TRL-8, moving the technology closer to commercialization.

Making Big Space Industry Moves

Furphy's results continue to inform the company's engineering of future in-space tankers that will enable the refueling of satellites in orbit. With the experience and lessons gained from the project, Orbit Fab is on its way to manifesting its vision: a robust, sustainable economy in space that runs on fuel supplied by the company's fuel depots and fuel shuttles. Fuel depots are big, simple satellites full of propellants. Fuel shuttles are complex satellites that will act as servicers to pick up fuel from the depot and deliver it to the customer's spacecraft.

"So, we're not just a fuel supply chain," Schiel said. "We are a refueling service on top of the supply chain."

The company has already developed the first-ever commercially available in-space fueling port called RAFTI™ (Rapidly Attachable Fluid Transfer Interface) and the first-ever operational propellant depot in low Earth orbit (LEO), Tanker-001 Tenzing. Orbit Fab's first two GEO (geosynchronous Earth orbit) fuel shuttles will be commissioned in 2023. By providing robust refueling services in space, thereby increasing the flexibility and value of satellites, Orbit Fab is making it possible for other satellite servicing companies to perform additional maintenance tasks that further optimize satellite performance and lifespan, such as attitude control, momentum management, and relocation.

"We helped open up the space infrastructure to refueling and servicing," Schiel said. "When we started this business, there were eight satellite servicing companies. Now there are more than 100 globally."

In January 2022, Orbit Fab obtained its first customer. Astroscale, a company developing innovative in-orbit servicing solutions across all orbits, signed an agreement to refuel the company's LEXI (Life Extension In-Orbit) Servicer spacecraft; making LEXI the world's first operational commercial satellite designed to be refueled. The LEXI Servicer is expected to launch to GEO by 2026, where it will perform life extension

and other services for various customers. The RAFTI™ interface will make refueling the LEXI Servicer possible as Astroscale engineered the spacecraft's rendezvous and docking technology to allow LEXI to dock with Orbit Fab's refueling depots and shuttles.

"Think of RAFTI™ as the gas cap and interface when you refill your car," said Carolyn Belle, director of advanced systems at Astroscale. "This partnership for refueling allows us to get more use out of LEXI, just like we are helping our customers get more use out of their spacecraft."

Orbit Fab's GEO fuel shuttle will resupply Astroscale's fleet of LEXI Servicers with up to 1,000 kilograms of propellant. Schiel said Orbit Fab plans to deploy dozens of fuel tankers and shuttles in the next five to 10 years, positioning the company to refuel customer satellites in LEO, GEO, and cislunar space (the region of space from the Earth to the Moon). The plan is to be able to transfer fuel from tankers directly to operational satellites, which will be much more sustainable for several reasons, including reducing the number of fuel shuttles needed, according to Belle.

"We will not have to build new servicing spacecraft every time one runs out of fuel," Belle said. "We also will have to launch fewer additional spacecraft, which saves on emissions and resources."

And while in-orbit refueling is something that people have been interested in for a long time, no one pushed the technology and space-industry-related national and international policy forward to make it happen until Orbit Fab came along, Belle said. "Now, we have companies like Orbit Fab stepping up to say they want to do the hard work to make this possible."