National Aeronautics and Space Administration

Fiber Optic Sensing System

Jonathan Lopez and Nathan Rick prepare the hypersonic Fiber Optic Sensing System for vibration tests in the Environmental Laboratory at NASA's Armstrong Flight Research Center in Edwards, California. Testing on a machine called a shaker proved that the system could withstand the severe vibration it will endure in hypersonic flight, or travel at five times the speed of sound. NASA/Jim Ross

The Fiber Optic Sensing System (FOSS) developed for aeronautics research at NASA's Armstrong Flight Research Center in Edwards, California, has proven it can operate in the harsh environment of space. The technology could play a key role in the safe and efficient management of cryogenic fuels critical to Moon and Mars missions.

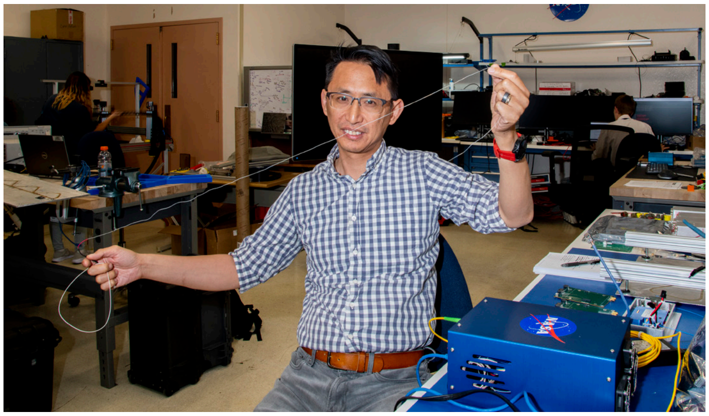
The FOSS may also address technical challenges not only for NASA but for industries as varied as medical, automotive, and civil engineering. Innovative applications could include monitoring the structural health of bridges.

Traditionally, collecting data from research aircraft required miles of wiring, harnesses to secure those wires, and bulky sensors that added weight and complexity to aircraft systems. By contrast, FOSS uses a single, hair-thin optical fiber – up to 40 feet long – that can deliver up to 2,000 data points. The system processes information up to every half inch along the fiber at rates up to 100 times per second.

It can measure strain, shape, temperature, liquid level, and operational loads in real time. Researchers at NASA Armstrong continue to develop the technology to reduce its size, weight, and power requirements, broadening its potential for future missions and commercial use.

Flight Research

A hypersonic version of FOSS, designed to measure temperature and strain on high-speed vehicles,



NASA's Armstrong Flight Research Center's FOSS, Fiber Optic Sensing System, in 2022 supported tests of a system designed to turn oxygen into liquid oxygen, a component of rocket fuel. Patrick Chan, electronics engineer, and NASA Armstrong's FOSS portfolio project manager, shows fiber like that used in that testing. A new series of tests is set for late 2025.
NASA/Carla Thomas

is set to fly at hypersonic speeds for the first time – greater than Mach 5, or five times the speed of sound – integrated on two research rockets to monitor structural temperatures in summer 2025.

Using FOSS, NASA collects data on the strain placed on vehicles during flight, along with temperature measurements. This information helps engineers access the condition of a rocket or aircraft, increasing safety and improving reliability.

The hypersonic FOSS will also be installed on a much slower T-34 aircraft operated by NASA Armstrong. This testing will help monitor the system's durability and long-term measurement accuracy compared to traditional sensors.

FOSS in Space

During NASA's Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) mission, FOSS collected temperature data, demonstrating its readiness to monitor spacecraft systems in extreme environments.

The LOFTID demonstration launched Nov.10, 2023, carrying 1,400 FOSS sensors embedded on three optical fibers totaling 60 feet in length. The fibers were arranged in a spiral pattern on LOFTID's nose, while the main FOSS unit was mounted in the LOFTID reentry vehicle's midsection.

The system provided a detailed thermal map of the heat LOFTID encountered during its re-entry through Earth's atmosphere before landing in the Pacific Ocean. The measurement system survived the rigors of spaceflight, and the temperature data collected matched the readings from a separate onboard system, validating its performance.

NASA Armstrong researchers also developed a cryogenic version of the system, called CryoFOSS, to support future deep space missions. CryoFOSS was used during testing of a system designed to liquefy oxygen – as it would on the Moon or Mars – for use as return-trip fuel. By producing fuel on-site, missions could avoid carrying return fuel from Earth, significantly reducing launch weight and overall mission cost.

In 2022, during tests at NASA's Glenn Research Center in Cleveland, CryoFOSS measured temperatures inside a tank as gaseous oxygen was chilled and condensed to a liquid at minus 297 degrees Fahrenheit. The test used a 77-inch-tall tank capable of holding up to 528 gallons. A 140-inch optical fiber embedded with 330 sensors and used, and the results were compared against a second temperature measuring system.

In June 2025, additional CryoFOSS sensors – mounted on a strand measuring about 20 feet – were installed on the outer surface of the neon cooling loop of the prototype tank. These sensors will monitor cryocooler performance during tests planned for late 2025. The sensors were fabricated and calibrated at NASA Armstrong before installation on the tank at NASA Glenn.

A tank is used in CryoFILL experiments to liquefy oxygen at minus 290 degrees Fahrenheit as it could be done on the Moon or Mars. The tests conducted at NASA's Glenn Research Center in Cleveland used Fiber Optic Sensing System (FOSS) developed by NASA's Armstrong Flight Research Center, in Edwards, California, to measure oxygen temperatures inside the tank. NASA/Bridget Caswell

National Aeronautics and Space Administration

Armstrong Flight Research Center
4800 Lilly Ave.
Edwards, CA 93523
www.nasa.gov/armstrong

www.nasa.gov

FS-2025-08-110