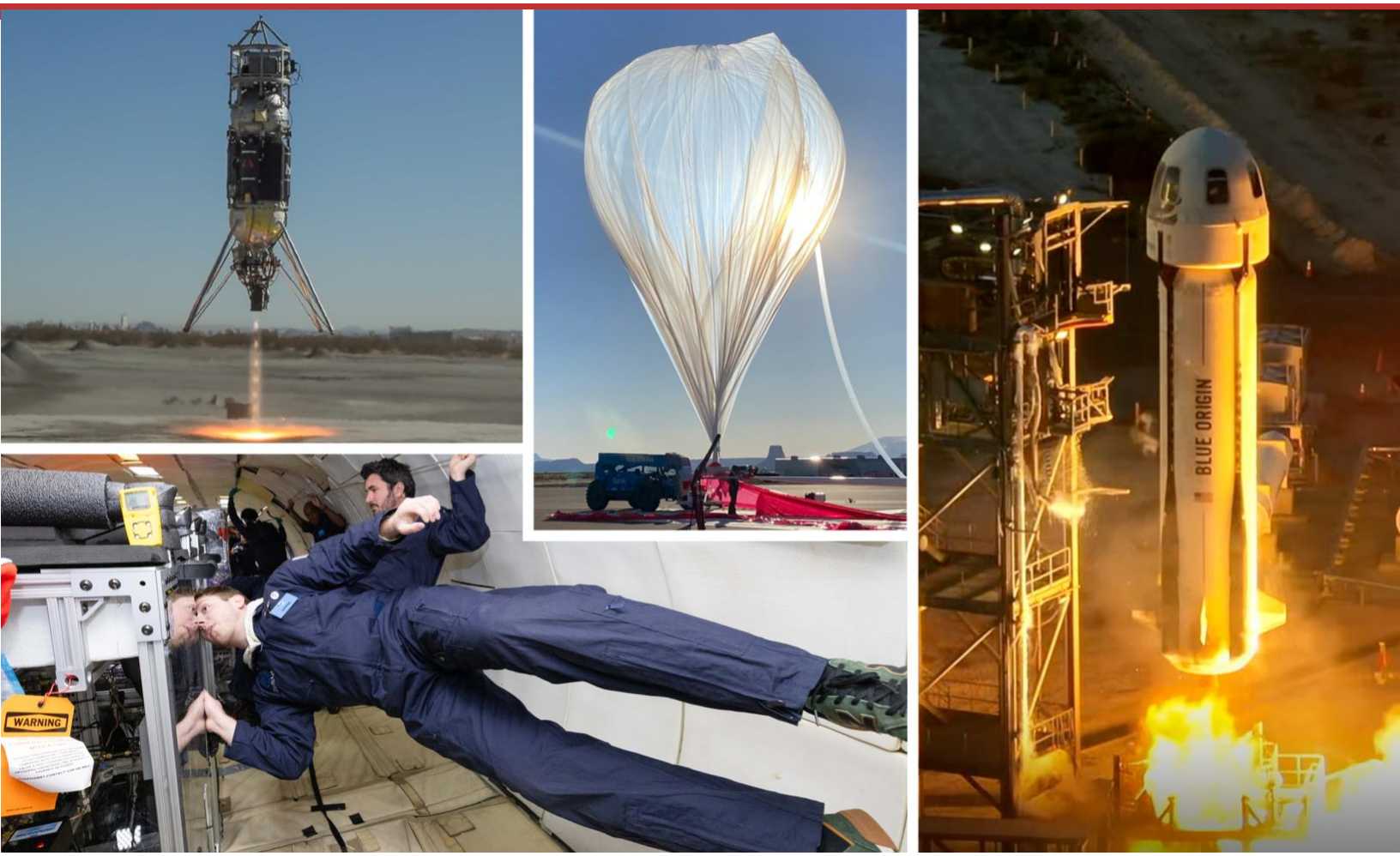
National Aeronautics and Space Administration

Space Technology Mission Directorate

Flight Opportunities Accomplishments

Fiscal Year (FY) 2025



In FY 2025, Flight Opportunities helped NASA prepare to return to the Moon, explore Mars, and ensure American leadership in space by flight testing technologies aboard a variety of vehicle platforms. Credits (clockwise from top left): Astrobotic, Future Engineers, Blue Origin, and Zero Gravity Corporation

Program Mission

Flight Opportunities rapidly demonstrates technologies for space exploration, discovery, and the expansion of space commerce. Through suborbital and hosted orbital testing with industry flight providers, the program matures capabilities needed for future missions while strategically investing in the growth of the U.S. commercial spaceflight industry.

FY 2025 Year in Review

Working with commercial providers, Flight Opportunities takes technologies out of ground-based laboratories and into relevant environments to increase technology readiness and validate feasibility while reducing the costs and technical risks of future missions. The program's impact in FY 2025 was significant, as described in this report.

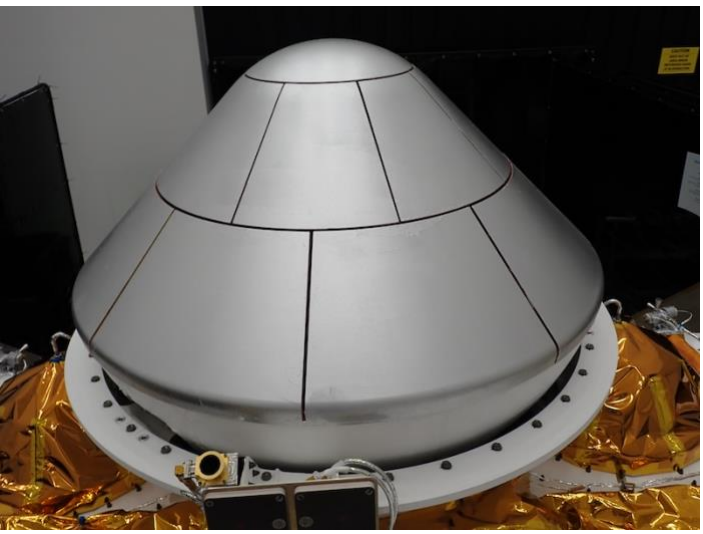
FY 2025 QUICK LOOK

- **97** payloads tested in flight
- **34** flights from **8** commercial providers
- **19** technologies selected for flight tests

Flight Opportunities enabled the advancement of innovations to ensure American leadership in lunar exploration and the expanding space economy, including:

- **Helping Ensure Successful Landings for Future CLPS Missions:** Fostered the testing and de-risking of systems that Astrobotic and Draper will use to land safely on the Moon during upcoming NASA-funded Commercial Lunar Payload Services (CLPS) deliveries.
- **Maturing Innovations Critical to Lunar Exploration:** Supported vehicle enhancements to simulate lunar gravity aboard Blue Origin's New Shepard reusable suborbital rocket system and then leveraged this new capability to advance technologies designed to address critical needs for lunar missions.

Flight Opportunities continued to change the pace of space by:



The Varda capsule that launched into low Earth orbit in June 2025 had heat shield technology licensed from NASA and manufactured by Varda to protect the pharmaceuticals to be processed in microgravity, expanding the U.S. space economy. Credits: Varda Space Industries

- **Enabling More Frequent Payload Returns for the Space Economy**: Helped Varda Space Industries manufacture and flight test a NASA-developed heat shield for its orbital capsule used for pharmaceutical and materials research and development, expanding the nation's space economy.
- **Increasing Flexibility and Speed with Big Leaps in Small Spacecraft Capabilities**: Matured miniature technologies, including a chip-sized navigation device and a micropropulsion system that uses water as fuel, to help power the next generation of quick-to-deploy and lower cost small spacecraft.
- **Accelerating and Streamlining Flight Test Preparations**: Supported three commercial and university teams as they developed universal solutions to simplify the process of integrating technologies into various commercial vehicles, reducing the time needed for flight testing.

Flight Opportunities transitioned technologies from flight test to new development opportunities, demonstrations, and missions, such as:

- **Going to the Moon via Commercial Deliveries:** In FY 2025, five technologies tested via Flight Opportunities commercial suborbital flights went to the Moon aboard Firefly Aerospace's Blue Ghost Mission 1 and the Intuitive Machines IM-2 mission, demonstrating that lessons learned during flight testing help researchers prepare technologies for lunar missions.
- **Commercializing a Next-Generation Fuel Cell System**: A hydrogen electrical power system from Teledyne Energy Systems reached commercialization after testing through Flight Opportunities, demonstrating the ability to function autonomously in microgravity and potentially to survive lunar night.
- **Assessing Changes to Astronauts' Spatial Orientation**: Advanced through parabolic flight tests supported by Flight Opportunities, a technology to measure changes in sensorimotor responses in reduced gravity was used in preflight/postflight tests during 2025 crewed missions with SpaceX and Axiom Space.
- **Providing Wi-Fi and Commercial Satellite Data Relay in Space:** Increases in technology readiness made through flight testing on various platforms enabled Solstar Space to transition its in-space Wi-Fi and commercial satellite data relay technology for use in U.S. Space Force in-space servicing, assembly, and manufacturing applications as well as demonstrations currently scheduled for 2026 in partnership with Momentus Space.
- **Enabling Safer and More Frequent Launches**: As of Sep. 30, 2025, an autonomous flight termination unit (AFTU) tested through Flight Opportunities has been transferred to 48 U.S. companies and is shifting norms nationwide to make launches more efficient.

The program helped train the next generation by:

- **Teaching Critical Skills to the Future U.S. Technical Workforce:** Provided 6th-12th graders from 60 U.S. schools with hands-on payload development experience in the fourth iteration of the TechRise Student Challenge, bringing the total number of student participants to more than 14,000 from 55 U.S. states and territories while also fostering the U.S. space industry by using commercial vehicles for the TechRise flights.
- **Supporting University and High School CubeSat Development:** Offered suborbital testing and subject matter expertise in advance of orbital flights for NASA's University SmallSat Technology Partnerships and CubeSat Launch Initiative as well as the Air Force Research Laboratory's University Nanosatellite Program.

The Lunar PlanetVac instrument, developed by Honeybee Robotics and tested through Flight Opportunities, shown on the lunar surface in March 2025. Credits: Firefly Aerospace

Testing three designs for a water separator during 2022 parabolic flights enabled Teledyne Energy Systems to down-select and integrate the best option into its commercial space fuel cell in 2025. Credits: Zero Gravity Corp.

Testing aboard parabolic flights in 2012-2014 prepared a technology to assess astronauts' sensorimotor responses during long-duration missions for crewed spaceflight in 2021-2025. Credits: NASA/Robert Markowitz

FY 2025 Program Highlights

Providing Navigation Information on the Way to the Moon

Flight Opportunities began FY 2025 with a flight aboard an UP Aerospace sounding rocket to test the interoperability of two Global Navigation Satellite System (GNSS) constellations: the U.S. Global Positioning System (GPS) and the European Union's Galileo system. The goal was to determine if GPS and Galileo can work together to provide comprehensive access to positioning, navigation, and timing (PNT) information for spacecraft traveling to and operating around the Moon.

The flight test brought together researchers from NASA, the European Space Agency, and the Italian Space Agency to assess the performance of two receivers in a highly dynamic environment, including speeds of more than 3,000 miles per hour and a spin rate of seven revolutions per second. During the flight, the receivers tracked the rocket's PNT successfully and with high accuracy, validating that GPS and Galileo signals can be used on the way to and around the Moon. Augmenting GPS with Galileo or other GNSS signals not only offers space vehicles better real-time information but also holds potential to strengthen our nation's international collaborations. The flight test also benefitted the LuGRE payload for a Commercial Lunar Payload Services (CLPS) mission (see page 8).

An Oct. 2024 flight test with UP Aerospace validated that GPS and Galileo signals can provide valuable navigation data for lunar missions. Credits: NASA/Anh Nguyen, Quascom, European Space Agency

Landing Safely and Precisely on Treacherous Lunar Terrain

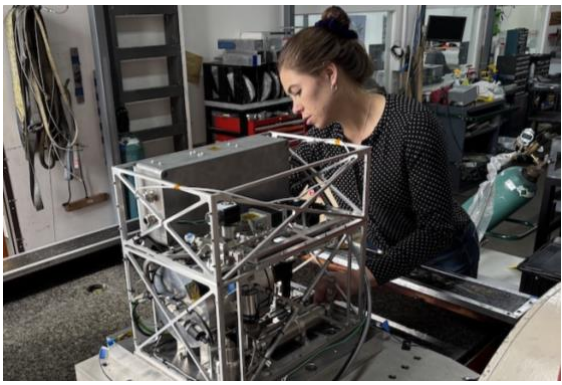
Because landing on the hazardous terrain of the Moon is challenging, Flight Opportunities leveraged Astrobotic's Xodiac lander vehicle as well as their testbed of simulated lunar terrain in the Mojave Desert for the testing, refining, and de-risking of two technologies that will help guide upcoming NASA-funded CLPS deliveries:

- **Astrobotic's advanced hazard detection lidar sensor** successfully captured high-precision data, progressing to a new readiness level as it prepares to guide a safe and precise landing at the Moon's South Pole during the company's Griffin Mission One.
- **The Draper Multi-Environment Navigator (DMEN) technology**, a vision-aided system to help spacecraft land with greater precision, took flight in 2025 not only aboard Xodiac but also on Blue Origin's New Shepard suborbital rocket, building on earlier tests on high-altitude balloons — all supported by Flight Opportunities. This iterative testing increased DMEN's technology readiness as Team Draper prepares to land at Schrödinger Basin on the Moon's far side.

In November 2025, Astrobotic tested its hazard detection lidar sensor aboard its Xodiac lander (top) flying over its simulated lunar terrain (bottom) in preparation for its upcoming CLPS mission to the Moon. Credits: Astrobotic

Increasing U.S. Capacity to Prepare Technologies for Lunar Missions

The tools needed to explore the Moon are varied, but they share a common challenge: All must function optimally in lunar gravity, which is one-sixth Earth's gravity and nearly impossible to replicate in ground-based laboratory testing. To address this, Flight Opportunities supported vehicle capability enhancements that enabled Blue Origin's New Shepard reusable suborbital rocket system to create lunar gravity conditions, thus expanding our nation's capacity to test and de-risk technologies in preparation for missions to the Moon. Blue Origin's February 2025 flight provided two minutes of simulated lunar gravity for testing more than a dozen innovations designed to find water, excavate and build structures with regolith, mitigate lunar dust, protect astronauts from flammable materials, cool electronic devices, and more — addressing critical shortfalls for the Artemis program, planetary exploration, and commercial space missions.



Honeybee Robotics prepared a lunar anchoring device for testing on a February 2025 Blue Origin suborbital flight that simulated the Moon's gravity. Credits: Honeybee Robotics

Heating Up the U.S. Orbital Economy with Thermal Protection Shields

When the Varda Space Industries W-4 capsule launched into low Earth orbit in June 2025, it represented the culmination of a multi-year collaboration benefiting both NASA and the U.S. space industry. NASA's Ames Research Center had pioneered a robust yet flexible and lightweight protective material known as C-PICA. As the first company to license C-PICA, Varda used NASA-made tiles to protect its first three W-series capsules beginning in 2023. NASA also helped Varda set up processes for manufacturing C-PICA themselves. W-4 is the first to use Varda-made C-PICA to protect the capsule and its contents as it returns to Earth early in FY 2026. Through this license, technical support, and real-world flight test, NASA is helping advance a growing sector of in-space manufacturing that depends on effective heat shields to safely return products to Earth.

NASA's technical support helped Varda manufacture the C-PICA thermal protection tiles for the W-4 capsule flight launched in June 2025. Credits: Varda Space Industries

Fostering Solutions for Complex Challenges

The Flight Opportunities program's innovative NASA TechLeap Prize engages U.S. companies and universities in solving complex challenges in space exploration in service of NASA missions. Compared to a traditional solicitation, the prize model streamlines selection and funding, allowing winners to start work and be ready for flight more quickly. It also enables greater opportunities for NASA subject matter experts to provide payload development support via site visits, increasing the potential for project success.

- **Space Technology Payload Challenge:** To advance solutions for multiple shortfalls, Flight Opportunities released this challenge, evaluated hundreds of applications, and awarded prize funds to 10 winners. Now, these teams are readying their payloads for flight testing in FY 2026.
- **Universal Payload Interface Challenge:** All three winning teams completed the build phase in April 2025. In FY 2026, these teams are expected to demonstrate how their solutions streamline the process of connecting payloads to various commercial vehicles for flight testing, integrating a payload developed at Carthage College with Virgin Galactic's spaceplane. Simplifying the complex payload integration process with a universal solution will reduce time to flight across the U.S. space industry.

Expanding Exploration and Discovery in Reduced Gravity

During two series of parabolic flights aboard a Zero Gravity Corporation aircraft in FY 2025, researchers conducted experiments and tested technologies to prepare for future lunar, Martian, and other space missions. The payloads they flight tested included innovations designed to:

- Crush and process lunar soil into a form that can power machines
- Deploy solar panels or open and close antennas without using a motor via self-folding "smart" materials
- Melt and re-shape metal into rods, tubes, wire, and other products to enhance astronauts' ability to reuse material in space
- Fabricate circuits, sensors, and antennas in space with a nanoparticle 3D printer, enabling astronauts to make what they need without waiting for materials to arrive from Earth
- Characterize microscopic bubbles that could facilitate development of in-space life support functions, such as food production, oxygen recovery from carbon dioxide, wastewater processing, and horticulture
- Serve as a robotic lab assistant to help prepare scientific samples and operate lab equipment in microgravity, allowing astronauts to focus their limited time on more complex tasks

During two parabolic flight campaigns in FY 2025, Auburn University tested self-folding materials for use in lightweight, dust-resistant designs to deploy solar arrays and to open/close antennas. Credits: Zero Gravity Corp.

Parabolic flights readily allow researchers to test their payload, make adjustments, and fly again, following the Flight Opportunities program's fly-fix-fly ethos. This approach quickly advances technology readiness and provides critical flight heritage to foster infusion of these technologies in future missions.

The June 2025 maiden launch of the Spyder vehicle demonstrated UP Aerospace's capability to fly large payloads at hypersonic speeds for cost-effective testing of U.S. government projects. Credits: White Sands Missile Range

Building the U.S. Commercial Space Industry's Hypersonic Capabilities

The maiden flight of UP Aerospace's Spyder hypersonic launch system at White Sands Missile Range in June 2025 represented an important step in building the U.S. commercial space industry's capacity to test large payloads (up to 400 pounds) at five times the speed of sound. With this flight, Spyder demonstrated its ability to evaluate stability, control, and thermal management systems for re-entry vehicles, providing fast-turnaround, lower cost testing services for U.S. government projects focused on space exploration and national security. NASA supported UP Aerospace in achieving this milestone with two Announcement of Collaborative Opportunity (ACO) partnerships and a Tipping Point award managed by Flight Opportunities and with technical expertise from NASA's Marshall Space Flight Center. NASA's support also helped UP Aerospace establish its own solid rocket motor manufacturing facility, reducing the company's reliance on other suppliers.

Reaching Toward New Robotic Arm Capabilities

As FY 2025 came to a close, Flight Opportunities selected Astro Digital as the commercial flight provider for testing a robotic arm capable of manipulating objects, using tools, and — uniquely — walking across spacecraft surfaces while in orbit. Motiv Space Systems developed the robotic arm with funding from NASA's Small Business Innovation Research (SBIR) program. Anticipated to launch in FY 2027, this Fly Foundational Robots demonstration is expected to lay the groundwork for missions in which robotic tools can refuel and repair spacecraft in deep space, construct habitats and infrastructure ahead of astronaut arrivals, and maintain life support systems on lunar and Martian surfaces as well as to help manufacture products in space that benefit life on Earth. This effort is accelerating the maturation and commercialization of robotic systems that are pivotal for building a thriving in-space economy.

Engaging the Next Generation of the U.S. Technical Workforce

Complementing its mission to foster the development of the U.S. space industry, Flight Opportunities continued to provide a hands-on opportunity for middle and high school students to gain engineering, computing, and electronics skills that will be required for America's future technical workforce. Through NASA's 2024-2025 TechRise Student Challenge, more than 530 students from 50 states and territories worked to turn their science and technology experiment ideas into reality. The 60 student teams received $1,500 and technical support to design and build their experiments; then they flew their payloads on a World View high-altitude balloon and analyzed the resulting data.

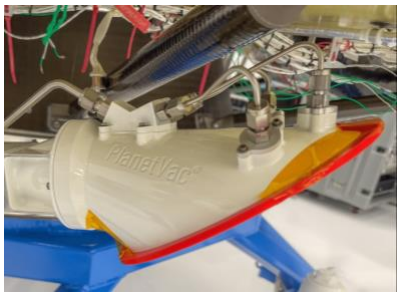
Also in FY 2025, Flight Opportunities opened the 2025-2026 challenge, and applicants will join the ranks of more than 14,000 students who have submitted TechRise experiment ideas to NASA. Flight Opportunities expects to announce winners in January 2026 and fly their experiments in summer 2026 aboard a World View balloon or Virgin Galactic's spaceplane.



Students across the country — including from (left to right) Ness City Junior/Senior High School in Kansas, Decatur High School in Georgia, and Old Colony Regional Vocational Technical High School in Rochester, Massachusetts — prepared experiments for the June 2025 high-altitude balloon flight with World View, gaining real-world, hands-on experience in the skills needed to advance the U.S. aerospace economy.

Notable Mission Infusions and Transitions

Five Technologies Go from Suborbital Tests to the Moon



PlanetVac. Credits: Firefly Aerospace

The U.S. commercial space industry reached a milestone in March 2025, with two lunar landings through NASA's Commercial Lunar Payload Services (CLPS) initiative. These missions — the Firefly Aerospace Blue Ghost Mission 1 and the Intuitive Machines IM-2 mission — included technologies that Flight Opportunities helped advance with testing aboard high-altitude balloons, parabolic flights, and rocket-powered vehicles between 2014 and 2024:

- **PlanetVac** from Honeybee Robotics, a Blue Origin company, used compressed gas to gather regolith from celestial surfaces.
- **Radiation-Tolerant Computing (RadPC)** from Montana State University increased computer reliability in the presence of high-energy radiation at lower cost than other solutions.
- **Lunar GNSS Receiver Experiment (LuGRE)** from NASA's Goddard Space Flight Center and the Italian Space Agency tracked Earth-based navigation signals on the Moon's surface.
- **AstroAnt** from the MIT Media Lab Space Exploration Initiative is a miniature robot to provide diagnostics and servicing of rovers on the Moon.
- **Automated Radiation Measurement for Aerospace Safety (ARMAS)** from Space Environment Technologies monitored radiation to help protect on-board equipment.

RadPC. Credits: Firefly Aerospace

Future CLPS missions will include other technologies with Flight Opportunities heritage (see page 4 for examples), reflecting the impact of flight testing in achieving NASA's space technology goals.

Incorporating Flight Test Data into NASA Design Software

Parabolic flight test of cryogenic line chilldown in microgravity. Credits: NASA

University of Florida researchers collected data over five years from Flight Opportunities–supported parabolic flight tests that advanced a method for cooling propellant before transferring it to a receiving tank, a critical process for minimizing propellant loss when refueling in space. The Aerospace Corporation used the data to develop models for NASA's Marshal Space Flight Center to incorporate into the Generalized Fluid System Simulation Program (GFSSP) software for flow analysis of rocket engine turbopumps and propulsion systems. As a result, the GFSSP now includes several new models that can be used in predicting heat transfer during chilldown of cryogenic transfer lines in space and on Earth.

Advancing Vestibular and Spatial Orientation Assessments

Varying gravity in long-duration spaceflight can alter sensorimotor responses, resulting in disorientation, dizziness, motion sickness, and more. Assessing these changes can help keep astronauts safe. The Sensorimotor Assessment and Rehabilitation Apparatus (SARA), developed by Johns Hopkins University School of Medicine uses a handheld device to capture changes in ocular function resulting from sensorimotor shifts in reduced gravity. Thanks to advancements from parabolic flights supported by Flight Opportunities, a portion of SARA was used in preflight-versus-postflight testing on the SpaceX Inspiration4 mission in 2021 and Fram2 Mission in 2025, four Axiom Space missions between 2022 and 2025, and the Polaris Dawn Mission in 2024. SARA has also been adapted for military use and could potentially be applied to clinical settings.

Providing Commercial Satellite Data Relay Wi-Fi Service in Low Earth Orbit

With support from Flight Opportunities, Solstar Space demonstrated its in-space Wi-Fi technology on four flight tests from 2013 to 2018, confirming that commercial satellite networks can provide internet and voice communications in space. Resulting advancements have led to several transitions, including:

- In 2024, AFWERX awarded Solstar SBIR contracts to further develop its space-based commercial satellite data relay technologies to address U.S. Space Force needs for in-space servicing, assembly, and manufacturing as well as other applications in low Earth orbit and beyond.
- In 2025, Solstar teamed up with Momentus Space to provide narrowband internet connectivity and local in-space Wi-Fi during an orbital flight scheduled for launch in early 2026.

Solstar leveraged the Flight Opportunities program's fly-fix-fly ethos to advance their space-based commercial satellite data relay and Wi-Fi technologies through flight tests aboard a high-altitude balloon, a sounding rocket, and (shown here) the New Shepard suborbital rocket. Credits: Blue Origin

Two tests with UP Aerospace helped prepare NASA's autonomous flight termination unit for commercialization success. Credits: NASA

Elevating Safety and Efficiency with Autonomous Flight Termination Unit

The decision to terminate a flight after launch is a weighty one and — until recently — one that ground control personnel had only seconds to make. Today, this weight is lifted by the autonomous flight termination unit (AFTU), a self-contained system to evaluate data and terminate a flight if needed. It was advanced with Flight Opportunities–supported tests on UP Aerospace sounding rockets in 2018 and 2019 and is now required at U.S. federal ranges. NASA's Kennedy Space Center developed the AFTU with Sagrad, Inc., and shared the design free of charge through 48 technology transfer agreements (as of Sep. 30, 2025), one of which allowed Sagrad to develop a smaller and less expensive AFTU. The wide availability of this technology matured through Flight Opportunities has shifted norms nationwide to make launches safer and more efficient.

Learn more about Flight Opportunities: www.nasa.gov/flightopportunities