National Aeronautics and Space Administration

SPACE TECHNOLOGY MISSION DIRECTORATE

FLIGHT OPPORTUNITIES

ACCOMPLISHMENTS | Fiscal Year 2024

Astrobotic's Xodiac rocket-powered lander validated the trajectory of the NASA TechRise Student Challenge flight over a simulated lunar surface in May 2024. Built by Astrobotic in preparation for flights tests conducted as part of the NASA TechLeap Prize's Nighttime Precision Landing Challenge, the nearly 100-meter-by-100-meter 3D test field mimics the topography and optical properties of the Moon's surface. Credits: Astrobotic

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. These flight tests take technologies from ground-based laboratories into relevant environments to increase technology readiness and validate feasibility while reducing the costs and technical risks of future missions.

FY 2024 Year in Review

In fiscal year 2024, Flight Opportunities continued to change the pace of space by:

FY 2024 QUICK LOOK

- 84 payloads tested in flight
- 38 flights from 6 commercial providers
- 21 technologies selected for future flight tests

- **Expanding Commercial Flight Testing Opportunities:** Selected 15 commercial companies to receive contracts to provide suborbital and hosted orbital flight testing services.
- **Streamlining Payload Integration via "Universal" Systems:** Selected three winners of the NASA TechLeap Prize's Universal Payload Interface Challenge, which focused on enabling easy integration of diverse technology payloads onto various commercial suborbital vehicles, orbital platforms, and planetary landers, thereby reducing cost and complexity of technology maturation to support future space exploration missions.
- **Increasing Researcher Access to Testing Environments:** Supported a university researcher's flight aboard a Blue Origin suborbital rocket to conduct a hands-on experiment, leveraging the researcher's familiarity with the payload and biological experiment objectives.

On Aug. 29, 2024, University of Florida researcher Rob Ferl conducted a hands-on biological experiment while aboard Blue Origin's New Shepard reusable suborbital rocket system, marking the first time a NASA-funded researcher flew with their payload on a suborbital rocket. Credits: Blue Origin

> ***After years, decades even, of working with astronauts to conduct our experiments, it's an honor to be at the forefront of researchers conducting their own experiments in space.***
>
> – Rob Ferl, University of Florida researcher

Flight Opportunities enabled the advancement of innovations to ensure American leadership in the expanding space economy, including technologies for:

- **Landing at the Moon's Permanently Shadowed Regions:** Tested three technologies designed to help spacecraft land safely in dark areas of significant scientific interest on the Moon through nighttime flights with Astrobotic over the company's simulated moonscape.
- **Building the Space Economy and Supporting Human Exploration:** Tested 3D printing and other manufacturing technologies in reduced gravity with various commercial flight providers to advance fabrication of electronics, spare parts, biosensors, medical/dental appliances, pharmaceuticals, and more to support astronauts on long-duration missions as well as in-space manufacturing for Earth-based applications.
- **Enabling Astronomers to See Farther, Deeper, and in Greater Detail:** Supported a fluidic telescope experiment aboard Zero Gravity Corp. parabolic flights to determine if giant lenses and mirrors can be created from liquids in space to significantly reduce cost, construction time, and failure risk for space-based astronomy.

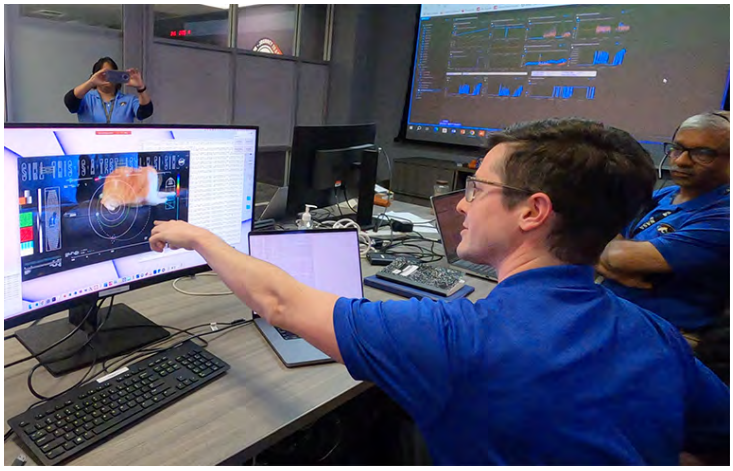
- **Advancing Small Spacecraft Capabilities:** Matured technologies to advance small spacecraft capabilities, including low-cost, non-toxic, wax-based fuels and innovations to help plan spacecraft movements more precisely, thereby increasing spaceflight operational safety and fuel efficiency.
- **Putting a "Cell Tower in the Sky" for Frontline Wildland Firefighters:** In partnership with the U.S. Forest Service and Aerostar, conducted 11-day flight test of STRATO (Strategic Tactical Radio and Tactical Overwatch) aboard a high-altitude balloon. The technology provided persistent LTE coverage and infrared thermal imagery to incident teams for several U.S. fires.

The STRATO payload was flight tested in August 2024. (left) A U.S. Forest Service firefighter conducts a signal connectivity survey to ensure reliable communication from the STRATO payload. (right) Firefighters perform a firing operation on the Boulder fire while using STRATO-enabled Team Awareness Kit (TAK) devices to enhance situational awareness. Credits: Colorado Div. of Fire Prevention and Control Center of Excellence for Advanced Technology Aerial Firefighting/Austin Buttlar

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

- **Bringing Back Asteroid Samples:** The award-winning OSIRIS-REx researchers matured their system through parabolic flight testing in 2012 that allowed them to evaluate their design and determine how much simulated asteroid rocks and dust the system could capture in reduced gravity.
- **Returning to the Moon's Surface:** Two NASA-developed technologies conducted important suborbital flight tests that prepared them for a Commercial Lunar Payload Services (CLPS) mission flown in FY 2024. One was poised to aid the landing when the lander's navigation system encountered an issue, while the other helped verify the lander's propellant levels.

The sample return capsule from NASA's OSIRIS-REx mission touched down in the desert, Sept. 24, 2023. The sampling system was tested in reduced gravity more than a decade earlier through the Flight Opportunities program. Credit: NASA/Keegan Barber



Researchers successfully received a high-definition streaming video from deep space on Dec. 11, 2023, thanks in part to a vibration isolation platform tested through Flight Opportunities. Credits: NASA/JPL-CalTech

- **Enabling Deep-Space Optical Communications (DSOC) on Psyche Mission:** A vibration isolation platform matured through multiple flight tests across a variety of suborbital vehicles was used to demonstrate laser-based communications beyond the Earth-Moon system, providing key stabilization and pointing to achieve high-rate communication from record-breaking distances.

Flight Opportunities inspired the next generation and supported the flight test community by:

- **Supporting University CubeSat Development:** Provided suborbital testing and other support in advance of orbital flight testing for NASA's University SmallSat Technology Partnerships as well as NASA's CubeSat Launch Initiative, inspiring teams from universities, high schools, and non-profit organizations.
- **Broadening Access to Science, Technology, Engineering and Mathematics (STEM) Skills:** Offered hands-on STEM educational experiences to 60 winning teams in grades 6-12 through the 2023-2024 NASA TechRise Student Challenge, bringing the total number of student participants over the past three years to more than 1,600 from 47 states as well as the District of Columbia, Puerto Rico, and Guam.
- **Sharing Lessons Learned:** Expanded knowledge transfer efforts by providing an online Lessons Learned Library, leveraging insights from the successful monthly webinars and further benefitting the ~3,500 members of the program's community.

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Student Challenge experiment to study the properties of the non-Newtonian fluid "oobleck" at 80,000 feet aboard a World View high-altitude balloon. Credits: Colegio Otoquí, Bayamón, Puerto Rico

FY 2024 Program Highlights

Enabling Hands-On Testing During Suborbital Flight

August 29, 2024, marked the first time a NASA-funded university principal investigator (PI) conducted a hands-on experiment aboard a commercial suborbital rocket, representing a new era of flight testing.

During the Blue Origin flight, the PI successfully operated the payload to measure plants' biological response to changes in gravity. He used specialized tubes to biochemically "freeze" the plants' gene expression at various stages of gravity, while the co-PI simultaneously did the same on the ground as a control.

Not only did this flight test yield valuable scientific insights to support future missions to the Moon and Mars, but it also provided insights that will aid other researchers considering how to most impactfully leverage opportunities to fly with their payloads aboard suborbital flights.

University of Florida researcher Rob Ferl (seated) and co-PI Anna-Lisa Paul practice the experiment to study the effect of gravity transitions on plants' gene expression. Credits: University of Florida

Improving Firefighter Safety with STRATO

On Aug. 4, 2024, the Aerostar Thunderhead balloon system carried the STRATO payload to the stratosphere for flight testing. The U.S. Forest Service's common-operating picture (WFTAK) used by wildland firefighters in the field displays incident information to enhance situational awareness. The red line represents the perimeter of the Snag fire on Aug. 14, while the blue circle represents LTE connectivity provided by the STRATO payload. Credits: Colorado Division of Fire Prevention and Control Center of Excellence for Advanced Technology Aerial Firefighting/Austin Buttlar

Designed to address various communications challenges in wildland firefighting, STRATO aims to provide persistent cell coverage from the stratosphere, enabling real-time communication between firefighters and incident command posts, as well as valuable heat and spatial information to help them better understand the fire's characteristics.

The 11-day flight test in August 2024 aboard an Aerostar high-altitude balloon occurred over Idaho's West Mountain Complex. STRATO successfully provided a persistent, strong LTE signal in areas with heavy tree canopy and canyonlike terrain. STRATO also provided useful imagery, including the first views of the Snag fire. The collaboration was led by NASA, the U.S. Forest Service, and Aerostar and involved numerous other federal, state, and local agencies and commercial companies.

Making It Easier to Integrate Diverse Payloads onto Flight Vehicles

Launched in October 2023, the third NASA TechLeap Prize — the Universal Payload Interface Challenge — focused on the development of a universal interface to streamline the integration of technology payloads with a variety of host vehicles for flight testing. Currently the integration process is complex and time consuming, increasing the burden on the technology development effort. Streamlining the process will help accelerate the pace of technology maturation to support future space exploration missions.

The three winners of this challenge — Aegis Aerospace, Ecoatoms, and a student team from the University of California, Los Angeles — received an initial $200,000 award with the opportunity to win additional awards for a total of up to $650,000 plus the chance to flight test their interface system at no cost to them.

Detecting Hazards in the Dark

Delivering small landers to scientifically interesting places on the Moon, Mars, and elsewhere involves landing safely amid hazardous terrain on dark, shadowed surfaces. The TechLeap Prize's Nighttime Precision Landing Challenge was designed to advance the affordability and reduce the complexity of landing spacecraft in these conditions. Three winners worked to develop less expensive, smaller, and lower mass systems for detecting hazards in the dark from at least 250 meters above the surface — taller than an 80-story building.

Flight tests began shortly after midnight on August 10, 2024, when Astrobotic's Xodiac rocket-powered lander carried a payload from University of South Florida above the company's Lunar Surface Proving Ground — a moonscape test site in Mojave, California. Testing of payloads from Falcon ExoDynamics and Cal Poly Pomona's Bronco Space club continued in the ensuing weeks.

The flight test of the Falcon ExoDynamics payload — one of the winners of the NASA TechLeap Prize's Nighttime Precision Landing Challenge — took place around 10:00 p.m. PDT on Sept. 5, 2024, aboard Astrobotic's Xodiac rocket-powered lander vehicle. Credits: NASA/Matthew Kuhns

Expanding Flight Testing Capabilities

As part of efforts to ensure that researchers have access to a broad range of commercial flight test capabilities, NASA selected 15 commercial companies to receive contracts under the Flight Opportunities program's fourth Suborbital/Hosted Orbital Flight and Payload Integration Services solicitation. These industry flight providers will carry payloads into the relevant environments required to advance technologies' readiness for use in future missions, including challenging gravity, pressure, thermal, and vibration conditions. To expand access to new flight test capabilities, these contracts added two new capabilities: hosting of payloads on orbital platforms and flying NASA researchers on qualified suborbital rocket-powered systems.

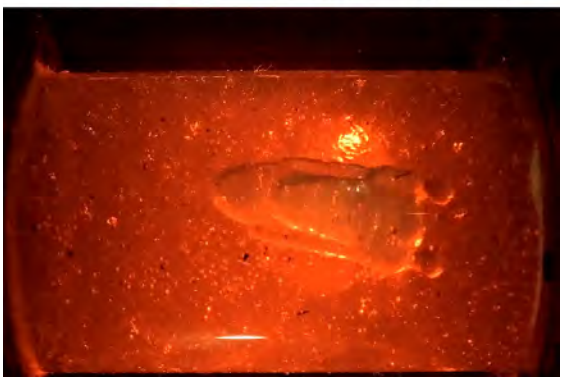
Supporting Commercial Production of Thermal Protection Material

Under a 2023 Tipping Point award managed by Flight Opportunities, Varda Space Industries has been maturing NASA's cost-effective and mass-efficient thermal insulator material known as C-PICA for commercial production. When used as a heat shield, NASA's C-PICA protects a spacecraft as it enters a planet's atmosphere. Varda's 2023 award is helping the small business establish its heat shield material production and conduct further flight testing of C-PICA, which is integral to the company's in-space production and return to Earth of its pharmaceutical products. During FY 2024, Varda installed equipment and began producing and optimizing small batches of NASA-quality C-PICA. The company is now on track to produce a C-PICA heat shield for a re-entry flight test in 2025.

A capsule containing the first products manufactured in space by Varda Space Industries lands at the Utah Test and Training Range on Feb. 21, 2024. Credits: Varda Space Industries/John Kraus

Building the Space Economy and Supporting Human Exploration

Several technologies designed to enable the in-space manufacturing of supplies needed by astronauts on long-duration missions or commercial products that offer advantages over their made-on-Earth counterparts were tested during FY 2024 with Blue Origin, Virgin Galactic, and Zero Gravity Corporation. These payloads were designed to:



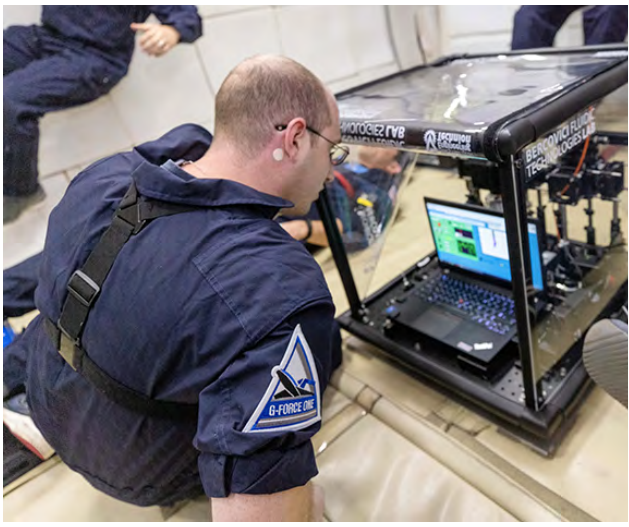
- Use light to solidify liquid and gel materials in a single step rather than 3D printing in layers
- Produce biosensors with smoother and more uniform layers for improved sensing
- Offer efficient bioprinting for large-scale production of cells and tissues in low Earth orbit
- Provide on-demand manufacturing of electronics in microgravity
- Enable pharmaceutical and institutional researchers to discover formulations for new products or to reformulate existing products
- Produce resins and polymer composites that contain suspended particles for reinforcement or greater functionality

In FY 2024, the Flight Opportunities program supported the testing of a variety of technologies for in-space manufacturing across several flight platforms, including (top-right) a system to advance biosensor production in low Earth orbit (Credits: Ecoatoms, Inc.), (top-left) hardware to test crystallization conditions (Credits: Zero Gravity Corp.), and (bottom) a 3D printer that transforms liquid material into solid pieces, as demonstrated by this space shuttle figurine produced during flight testing with Virgin Galactic (Credits: Univ. of California, Berkeley).

Enabling Astronomers to See Farther, Deeper, and in Greater Detail

The future of space-based astronomy requires large telescopes to study high-priority targets, such as early galaxies and Earth-like exoplanets. To achieve large apertures while staying within the size and weight limits for flight, NASA researchers are exploring using liquid to create the needed optical components in space.

As with many technologies in the Flight Opportunities portfolio, flight testing for this "fluidic telescope" is an example of the program's fly-fix-fly ethos. Parabolic testing with Zero Gravity Corp. in August 2024 built on insights gained during similar flights conducted in November 2022. The PI also leveraged those insights — as well as others gained during April 2022 testing aboard the International Space Station — to secure funding in early 2023 from the NASA Innovative Advanced Concepts (NIAC) program, which nurtures visionary ideas that could transform future NASA missions.



Multiple rounds of parabolic flight testing enabled Edward Balaban of NASA's Ames Research Center to test various liquids, geometries, and deployment mechanisms to optimize future development of the fluidic telescope. Credits: Zero Gravity Corp./Steve Boxall

Inspiring the Artemis Generation and Building STEM Skills

A World View high-altitude balloon prepares to launch 39 student payloads for the TechRise 2023-2024 flight test on Aug. 12, 2024, in Page, Arizona. Credits: NASA

Complementing its primary mission to rapidly demonstrate technologies for space exploration, discovery, and the expansion of space commerce, Flight Opportunities enables middle and high school students to experience this process for themselves through NASA's TechRise Student Challenge. The 60 student teams selected for 2023-20024 received $1,500, a flight box, and technical support to design their experiment, build their payload, flight test it on an Astrobotic rocket-powered lander or a World View high-altitude balloon, and analyze the data post-flight.

Teams submitting proposals for the 2024-2025 challenge will join the ranks of more than 11,000 students from across the U.S. who have submitted experiment ideas to NASA for TechRise. Winners will be announced in January 2025.

> ***[Students] not only acquire technical knowledge but also learn essential skills like effective communication and critical thinking. The prospect of seeing their ideas materialize into a tangible project, one that will ascend about 70,000 feet into the stratosphere, is both thrilling and educational.***
>
> – Amy Becker, Clear Creek Middle School, Ellijay, Georgia

Notable Mission Infusions and Transitions

OSIRIS-REx Benefitted from Flight Testing

In March 2024, the mission team for OSIRIS-REx — NASA's successful effort to collect a sample from an asteroid and return it to Earth — received two prestigious awards: the Robert Goddard Memorial Trophy and the Robert J. Collier Trophy. This well-deserved recognition is a testament to the importance of suborbital flight testing. The OSIRIS-REx researchers matured their regolith sampling system in 2012 during parabolic flight testing provided through the Flight Opportunities program. During these flights, they evaluated their design and determined how much simulated asteroid rocks and dust the system could capture in reduced gravity.

Evaluating OSIRIS-REx sampling system in microgravity via Flight Opportunities in 2012. Credits: NASA/James Blair

Flight Tested Technologies Go to the Moon

Before the Intuitive Machines IM-1 mission touched down on Feb. 22, 2024 — the nation's first Moon landing in 50+ years — two technologies received important flight testing to prepare for the journey:

- **Navigation Doppler Lidar (NDL):** Using a laser to measure a spacecraft's altitude and thus providing a lighter and more accurate option than radar-based systems, NASA's NDL was tested on the Astrobotic (formerly Masten Space System) Xodiac rocket-powered lander in 2017 via Flight Opportunities. During IM-1, NDL was poised to aid when the lander's navigation system encountered an issue.
- **Radio Frequency Mass Gauge (RFMG):** A series of parabolic flights in 2011 supported by Flight Opportunities helped NASA advance this technology for measuring how much propellant is available in a fuel tank in microgravity. During the IM-1 mission, RFMG helped Intuitive Machines verify the propellant levels in the lander.

IM-1 was one of the first of NASA's CLPS (Commercial Lunar Payload Services) initiative, and future CLPS missions will include other technologies with Flight Opportunities heritage, further demonstrating the value of flight testing in achieving NASA's space technology goals.

Artist's concept of a lander descending to the lunar surface with assistance from NDL. Credits: NASA

In 2011, Dr. Gregory Zimmerli tested the RFMG in microgravity on parabolic flights supported by Flight Opportunities. Credits: Devin Boldt

Enabling Deep-Space Communications

A vibration isolation platform technology matured through Flight Opportunities was part of NASA's first demonstration of laser-based communications beyond the Earth-Moon system. Eight flight tests across a variety of commercial suborbital vehicles from Blue Origin, UP Aerospace, and Virgin Galactic took place between 2013 and 2019. These flights enabled small business Controlled Dynamics to "fly-fix-fly" and make key advancements to the platform designed to protect delicate equipment from spacecraft vibrations. This progress ultimately led to the platform's infusion into NASA's historic Deep Space Optical Communications (DSOC) experiment aboard the Psyche mission, which launched on October 13, 2023. In helping DSOC achieve "first light" from 10 million miles away — about 40 times father than the Moon is from Earth — the platform contributed to future human missions beyond Earth orbit.

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