National Aeronautics and Space Administration

SPACE TECHNOLOGY MISSION DIRECTORATE

FLIGHT OPPORTUNITIES

Researchers from the University of California, Davis test a CubeSat technology during a November 2022 parabolic flight supported by Flight Opportunities. Credits: Zero Gravity Corporation / Steve Boxall

Accomplishments | Fiscal Year 2023

Program Mission

Flight Opportunities rapidly demonstrates technologies for space exploration, discovery, and the expansion of space commerce. Through suborbital 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 2023 Year in Review

In fiscal year 2023, Flight Opportunities continued to change the pace of space by:

- **Expanding Commercial Flight-Testing Opportunities:** Released the program's fourth flight and payload integration services solicitation to industry, seeking new suborbital and hosted orbital test capabilities in cooperation with the Small Spacecraft Technology program;
- **Advancing Technology for In-Space Science:** Partnered with the Biological and Physical Sciences Division of NASA's Science Mission Directorate on the CERISS (Commercially Enabled Rapid Space Science) initiative in the TechFlights 2023 solicitation to advance biological and physical sciences research capabilities with the commercial space industry;
- **Increasing Access to Relevant Test Environments:** Broadened access to commercial flight test options throughout the Agency, including through the Science Mission Directorate's ROSES (Research Opportunities in Space and Earth Science) solicitation and other programs; and
- **Enabling Researcher-Tended Suborbital Flights:** Worked with NASA's Suborbital Crew program, which is conducting safety case reviews of commercial suborbital vehicles to qualify their readiness for flying Government researchers with their payloads.

A high-altitude balloon from Aerostar ascends during a June 2023 flight test. Credits: Fresh Produce

FY 2023 QUICK LOOK

- 31 payloads tested in flight
- 20 flights from 6 commercial providers
- 24 technologies selected for future flight tests

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:** Readied technologies designed to help spacecraft land safely in the dark in areas of great scientific interest on the Moon from winners of the NASA TechLeap Nighttime Precision Landing Challenge;
- **Enhancing Communications for Frontline Wildland Firefighters:** Supported testing and ongoing payload development with Aerostar, the U.S. Forest Service, the National Interagency Fire Center, and NASA's Ames Research Center for a suborbital system designed to help manage wildland fires by providing a continuous wireless broadband signal between firefighters out in the field and the incident command post;

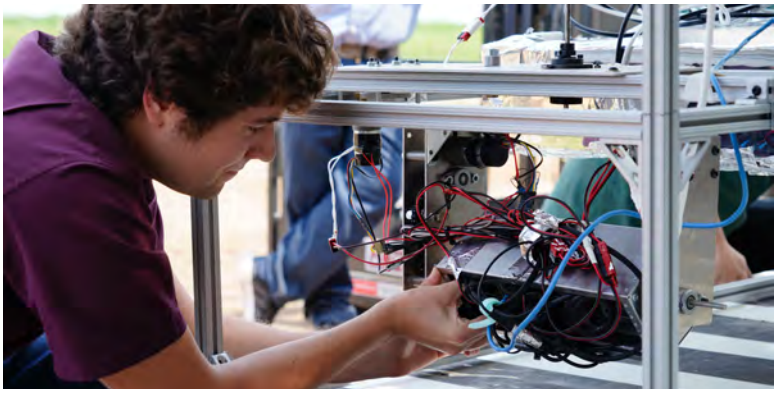
- **Advancing Small Spacecraft Capabilities:** Matured small spacecraft innovations previously developed through NASA's University SmallSat Technology Partnerships program in a variety of application areas, including electrospray propulsion, heat management, optical communications, and navigation/timing; and
- **Protecting Crew Health on Long-Duration Missions:** Demonstrated space-based medical and biological technologies via parabolic flights with Zero Gravity Corporation, including autonomous sampling of biological data as well as devices to monitor for spaceflight-associated neuro-ocular syndrome and to maintain astronauts' sensorimotor conditioning.

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

- **Improving Storm Prediction from Space:** MIT's (Massachusetts Institute of Technology's) dual-spinning CubeSat bus is a key element in NASA's TROPICS (Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats) mission – a four CubeSat constellation observing tropical cyclones from space;
- **Testing "Rovable" Miniature Robots on the Moon:** MIT Media Lab's mini-robot, AstroAnt, will head to the Moon's South Pole for a demonstration of its contactless temperature monitoring capabilities on a Lunar Outpost rover in 2024; and
- **Simulating Vision-Aided Moonwalks:** Draper's Multi-Environment Navigator was integrated with the company's wearable kinematics technology and used in simulated moonwalks in the Arizona desert with NASA's Joint Extravehicular Activity and Human Surface Mobility Test Team.

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

- **Broadening Access to Science, Technology, Engineering, and Mathematics (STEM) Skills:** Offered hands-on STEM educational experience to 60 winning teams in grades 6-12 in the second iteration of the NASA TechRise Student Challenge, bringing the total number of student participants in TechRise to approximately 1,100 from 44 U.S. states and territories over the past two years;
- **Supporting University CubeSat Development:** Provided financial support and suborbital testing in advance of orbital flight testing for NASA's CubeSat Launch Initiative teams from universities, high schools, and non-profit organizations; and
- **Sharing Lessons Learned:** Continued knowledge transfer efforts, including a monthly Community of Practice webinar series and newsletter, reaching over 3,500 members of the space community.



Ben Gorr of Texas A&M University prepares his payload for flight testing on a high-altitude balloon in May 2023. This was a reflight for winners of the TechLeap Autonomous Observation Challenge No. 1, enabling each team to further advance their technology (see page 4). Credits: Aerostar

FY2023 Program Highlights

Expanding Flight Testing Capabilities

Flight Opportunities released its Suborbital/Hosted Orbital Flight and Payload Integration Services 4 solicitation to industry with the objective of identifying commercial providers to fly payloads in the relevant environments required to advance technologies' readiness for use in future missions. This includes the use of suborbital vehicles as well as orbital platforms – in cooperation with NASA's Small Spacecraft Technology program – to test payloads at high altitudes, under reduced gravity, in a vacuum, and in other challenging spaceflight conditions.

This new solicitation was designed to replace contracts for existing flight test services as well as add new capabilities, including hosting payloads in orbit and flying NASA researchers on suborbital flights. It aims to increase available testing options for researchers to advance their technologies and expand opportunities for a wider range of commercial companies to support suborbital and orbital flight testing for NASA. New contracts are anticipated to be in place by the second quarter of FY 2024.

Using Competitions to Quickly Address Current Technology Needs

The NASA TechLeap Prize enables researchers to compete for funding to address technology gaps of significant interest to the Agency. TechLeap is conducted under the America COMPETES Act, and is administered by small business, Carrot, the challenge coordinator. This fiscal year saw several key achievements.

Sara Jennings is team lead for the Orion Labs TechLeap project, which aims to demonstrate how quantum machine learning aboard a spacecraft can reduce data processing to the ground for a variety of Earth observation tasks. Credits: NASA

Winners of the first challenge – Autonomous Observation Challenge No. 1 – were able to fly, fix issues, and fly again less than a year after their first individual flight tests. Their technologies were developed to autonomously detect, locate, track, and collect data on short-lived events, such as wildland fires, unique aerosol dispersions (like dust and steam plumes), or events on other planetary bodies, such as geysers on the icy moons of Saturn and Jupiter. The second high-altitude balloon flight in May 2023, which had all three payloads aboard together, cost-effectively gave the teams a longer sensing and data collection opportunity.

In addition, the three winners of the second TechLeap challenge – Nighttime Precision Landing Challenge No. 1 – have been developing their unique innovations to detect hazards in the dark from an altitude of 250 meters (820 feet) or higher. By processing their sensing system data in real time, these technologies are designed to help spacecraft land safely in areas of great scientific interest on the Moon. Flight testing is scheduled for early 2024 aboard Astrobotic's Xodiac lander testbed in Mojave, California.

Beyond technology maturation, the structure of TechLeap has allowed winners to make additional advancements. For example, Orion Labs leveraged its TechLeap win to make several connections that enhanced the small startup company's flight test plans, including priority access to three free quantum computers through a partnership with International Business Machine's (IBM's) Quantum Education Program. As another example, two-time winner Bronco Space – an undergraduate aerospace club at California State Polytechnic University, Pomona – used a portion of their prizes to make infrastructure investments that have enabled growth of the club and expansion of its portfolio of space technology development, CubeSat projects, and launches.

Putting a Cell Tower in the Sky to Help Wildland Firefighters

A technology gap has plagued our nation's wildland fire management efforts: persistent communication challenges. Line-of-sight radio communications in rugged terrain and limited cell phone coverage in remote areas hamper the sharing of critical information between the incident command post (ICP), managing firefighting resources from miles away, and the firefighters in the field. To close this gap, researchers at flight provider Aerostar, the U.S. Forest Service, the National Interagency Fire Center, and NASA's Ames Research Center are collaboratively developing the STRATO (Strategic Radio and Tactical Overwatch) technology. When mounted on a high-altitude balloon, STRATO is designed to provide real-time observations and continuous wireless broadband signal between the ICP and wherever firefighters are in the field.

> ***"Providing wildfire fighters with a critical link to their command post via LTE [Long-Term Evolution] is a big step forward that we've been pursuing for several years. Having a major flight demonstration like this is exciting, and we're extremely grateful to the Flight Opportunities program."***
>
> – Nick Young, engineer, Aerostar

During two internal test flights in FY 2023, Aerostar mitigated technical challenges, and the system achieved its 50-nautical-mile target for signal transmission. The full proof-of-concept flight test over an active wildland fire – expected to take place no earlier than spring 2024 – is a key step in demonstrating the potential for a stratospheric platform to give firefighters the communications capabilities and real-time observation data they need.

Exploring Optical Communications in the Stratosphere

In an example of how other U.S. Government agencies can leverage support and flight provider contracts from Flight Opportunities, the Naval Information Warfare Center Pacific successfully demonstrated an optical communication link from the ground to a stratospheric balloon on August 30, 2023. The SOLD (Stratospheric Optical Link Demonstration) project also incorporated essential support and collaboration from NASA's Ames Research Center. SOLD is designed to explore optical communications in the stratosphere and demonstrate the supporting capabilities needed to achieve such optical links while also overcoming the challenges of operating in the stratospheric environment.

An Aerostar stratospheric balloon carrying the SOLD payload prepares to launch on August 30, 2023. Credits: Naval Information Warfare Center Pacific

Advancing Space-Based Medical Technology

As humans venture farther into space and for longer periods of time, medical issues will become more common – and taking a trip back to Earth to treat them less feasible. Parabolic flights on Zero Gravity

The University of Louisville's Surgical Fluid Management System includes a clear dome that creates a tight seal to a patient's skin and provides insertion points for surgical instruments without letting fluids escape, preventing blood droplets and other fluids from wounds or surgical sites from floating into a spacecraft cabin. Credits: Zero Gravity Corporation/Steve Boxall

Corporation's G-FORCE ONE allowed teams to test the performance of space-based medical innovations that could address these issues. For example, researchers from Purdue University and University of Louisville tested technologies that aim to control and contain bleeding and facilitate surgery in space. Researchers from the University of California, Berkeley and the University of Utah flew their lab-on-a-chip technology that could be used to help monitor astronaut health. Both teams collected data that will help inform future upgrades and advances to their technologies with the aim of expanding medical capabilities needed for long-duration spaceflight.

These flights tested a wide range of other cutting-edge technologies, including:

- Autonomous sampling for biological research
- Cryogenic fluid management and modeling
- Affordable small spacecraft reaction wheels
- 3D-printing techniques
- Space-based development of optical components
- Devices to monitor for SANS (spaceflight-associated neuro-ocular syndrome) and to maintain sensorimotor conditioning

Supporting Tests of Dust Sensor to Aid Future Lunar Landings

When spacecraft land on the Moon or Mars, the rocket exhaust plume creates regolith ejecta – abrasive dust and large particles moving at high speeds – that can damage the lander and surrounding structures. Understanding how a rocket engine's exhaust affects this ejecta will help mission designers plan more effectively for lunar landings by allowing them to model the soil erosion rate, the particle size distribution, and the velocities associated with plume-surface interaction. Researchers from the University of Central Florida developed a laser-based instrument named Ejecta STORM (Sheet Tracking, Opacity, and Regolith Maturity) to answer this need.

With support from NASA's Flight Opportunities program, the researchers are embracing the "fly, fix, fly" ethos to quickly advance their technology. Starting in September 2023, Astrobotic's Xodiac vehicle flew four tethered flights, enabling researchers to test their instrument's integration with a lander and operation in flight conditions that simulated the plume effects of a lunar lander. These tests build on data collected during a 2020 flight campaign that also leveraged Xodiac.

Astrobotic's Xodiac rocket-powered lander during the 2023 flight tests in Mojave, California. Four tethered flights enabled researchers to test Ejecta STORM's integration with a lander and operation in flight conditions that simulated the plume effects of a lunar lander. Credits: Astrobotic

The experiment from the middle school team at Herberger Young Scholars Academy (Glendale, Arizona) measured the effects of high altitude on solar panel energy output. Credits: Herberger Young Scholars Academy

Another 13 student teams successfully developed flight-ready payloads for testing on UP Aerospace's SpaceLoft suborbital rocket. However, the vehicle experienced an in-flight anomaly that resulted in the loss of the payloads. This incident highlighted that, despite the collective experience of the industry, many things must go right on any spaceflight. Affected student teams have been offered another flight as part of TechRise 2023-2024.

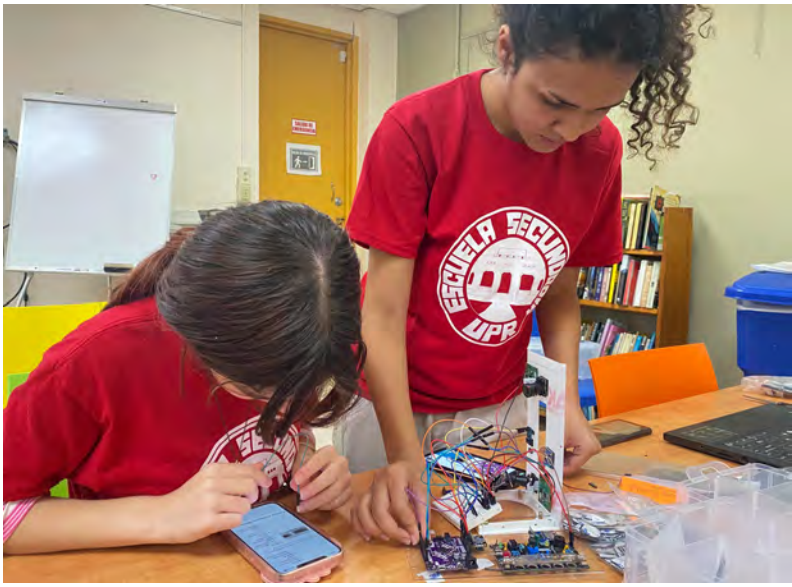
Winners in the 2023-2024 NASA TechRise Student Challenge will be announced in January 2024 and receive $1,500 to design, build, and launch science and technology experiments on a World View high-altitude balloon or Astrobotic's Xodiac rocket-powered lander.

> ***To see the culmination of more than a year's work by students, teachers, Future Engineers, and Flight Opportunities team members has truly been an amazing opportunity.***
>
> – Jack Chen, teacher leading the TechRise team at Sewanhaka High School in Floral Park, New York

Inspiring the Artemis Generation with the NASA TechRise Student Challenge

The NASA TechRise Student Challenge offers students in grades six through 12 hands-on experience with the full flight test process – from designing an experiment and building the flight payload to undergoing flight testing and analyzing the data post-flight. TechRise is administered by small business Future Engineers, the challenge coordinator.

Summer 2023 marked a series of suborbital flight tests that flew a total of 93 science and technology experiments from middle and high school teams, including a total of 80 payloads on high-altitude balloons with Aerostar (50 payloads across two flights) and World View (30 payloads). These flights allowed students to gather data on experiments in a variety of technical areas, including radiation sensing, solar panel development, and the measurement of greenhouse gases.



Escuela Secundaria de la Universidad de Puerto Rico's team tested a wearable radiation sensor made from an algae biomass, which they hope could be used not only for future space applications but also to address marine algae overgrowth in Puerto Rico. Credits: Escuela Secundaria de la Universidad de Puerto Rico

Advancing the Space Economy and Biological and Physical Sciences

In January 2023, Flight Opportunities announced the selection of nine technologies for flight testing as part of the 2022 TechFlights solicitation. In May 2023, the program released the 2023 TechFlights solicitation, which called for proposals from researchers to flight test space technologies and capabilities that support global lunar utilization, a robust lunar economy, and/or a growing LEO (low-Earth orbit) to GEO (geosynchronous-Earth orbit) economy through future commercial commodities and services.

Flight Opportunities also collaborated with NASA's CERISS (Commercially Enabled Rapid Space Science) initiative to develop one of the topics for the 2023 solicitation. CERISS aims to advance biological and physical sciences research capabilities, such as sample preparation and analysis technologies, for use in microgravity. Flight testing such space technologies through the Flight Opportunities program is expected to help scientist astronaut missions on the International Space Station and at commercial LEO destinations, as well as mature automated hardware for experiments beyond LEO, such as on the lunar surface.

Notable Mission Infusions and Transitions

Improving Storm Prediction with Small Spacecraft Constellations

NASA's TROPICS mission launched in May 2023. The mission's four CubeSats are gathering data to understand the evolution of tropical cyclone intensity. The TROPICS CubeSats incorporate a technology that was tested in its early stages on Flight Opportunities–supported parabolic flights in 2013.

> ***"The testing through Flight Opportunities was the first time we saw how well our technology worked in microgravity. It gave us the findings we needed to eventually incorporate it on a CubeSat mission."***
>
> – Dr. Kerri Cahoy, Massachusetts Institute of Technology

The two TROPICS mission launches in May 2023 (one of which is shown here) carried CubeSats that incorporate a technology tested in its early stages on Flight Opportunities–supported parabolic flights in 2013. Credits: Rocket Lab

Referred to as a dual-spinning CubeSat bus, the MIT-developed technology enabled the use of microwave radiometers – previously used only on large satellites – on CubeSats about the size of a two-liter bottle. The Flight Opportunities testing was the first effort to demonstrate the CubeSat-sized spinning mechanisms in a microgravity environment. Now this capability is enabling TROPICS to demonstrate that Earth science data can be obtained with improved resolution, greater flexibility and reliability, and extremely low-cost launches.

"Rovable" Miniature Robots Head to the Lunar Surface

Matured through a series of parabolic flights supported by Flight Opportunities, MIT's miniature robot AstroAnt will head to the Moon's South Pole for a technology demonstration test on the Lunar Outpost MAPP-1 (Mobile Autonomous Prospecting Platform) rover. The MAPP-1 rover is expected to be delivered to the lunar surface in 2024 by the Intuitive Machines Nova-C lander, as part of the Agency's CLPS (Commercial Lunar Payload Services) program.

Designed to support autonomous vehicle inspection and maintenance, the AstroAnt robot is equipped with a thermopile that can take contactless temperature measurements. The AstroAnt will maneuver across the top of the rover, taking measurements of its radiator. These data will help with monitoring the rover's thermal system and can be used to inform NASA's Artemis III crewed mission.

On Flight Opportunities–supported flights in May and December 2021, MIT tested "rovable" robots to evaluate their swarm mobility and inspection capabilities in microgravity. The technology – now known as AstroAnt – will be deployed on a Lunar Outpost mission to the Moon's South Pole, expected in 2024. Credits: MIT Space Exploration Initiative

Leveraging Navigator Technology for Wearable Vision-Aided Moonwalks

A NASA engineer takes a simulated moonwalk in the Arizona desert in October 2022, using a system that incorporates the Flight Opportunities–tested DMEN navigation technology from Draper. Credits: Draper

Designed to provide terrain-relative navigation for landings in challenging space environments where the Global Positioning System (GPS) is not available, like the lunar South Pole, the DMEN (Draper Multi-Environment Navigator) technology was matured by Draper through flight tests on commercial high-altitude balloons and suborbital rockets supported by Flight Opportunities.

Beyond landings, however, DMEN could also help astronauts traverse the Moon, as tested in October 2022 outside Flagstaff, Arizona. After advancing the system through suborbital testing, Draper integrated DMEN with its wearable kinematics technology for the field tests led out of NASA's Johnson Space Center with NASA's Joint Extravehicular Activity and Human Surface Mobility Test Program, in collaboration with the Science Mission Directorate. With the desert serving as an environmental analog of the lunar South Pole – including lighting and topography – NASA engineers wore Draper's technology as they took simulated moonwalks. Data collected from the field test will support the Agency's moonwalking preparations for Artemis III. DMEN is also slated for use in Draper's upcoming lunar mission supported by NASA's CLPS program.