National Aeronautics and Space Administration

SPACE TECHNOLOGY MISSION DIRECTORATE

FLIGHT OPPORTUNITIES

Accomplishments | Fiscal Year 2022

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FLIGHT OPPORTUNITIES MISSION

NASA's Flight Opportunities program rapidly demonstrates promising technologies for space exploration, discovery, and the expansion of space commerce through suborbital testing with industry flight providers. The program matures capabilities needed for NASA missions and commercial applications 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. Awards and agreements for flight tests are open to researchers from industry, academia, non-profit research institutes, and government organizations. These investments help advance technologies of interest to NASA while supporting commercial flight providers and expanding space-based applications and commerce.

"The Flight Opportunities program offers payload developers a unique chance to witness the performance of their hardware in a space-like environment. Our flights have been indispensable, along with the incredible support from NASA. These flights have helped us improve our hardware and provided a clear path towards advancing the technology for the International Space Station."

Dmitry Starodubov, principal investigator for Space Fibers 3, FOMS, Inc. (see story on page 14)

Credits: NASA/Michael DeMocker

Credits (front cover): World View

FISCAL YEAR 2022 IN REVIEW

In Fiscal Year 2022, Flight Opportunities:

- Supported **97** payloads tested in flight
- Supported **28** successful flights with commercial flight partners
- Selected **19** technologies for future flight tests

The Program Continued Changing the Pace of Space by:

- Launching all winning experiments from the first **NASA TechLeap Prize** – in just one year
- Partnering with the **Small Spacecraft Technology program** to offer hosted orbital testing opportunities
- Working collaboratively with other programs across NASA to **expand access to suborbital testing**
- Awarding **funding for testing** on commercial vehicles for promising space technologies
- Continuing **support for future commercial flight capabilities**, including lunar gravity and planetary re-entry environments

Flight Opportunities Supported the Suborbital Research Community by:

- Facilitating knowledge transfer to **over 3,000 members of the space community** through the program's monthly Community of Practice webinars and newsletter
- Providing flight campaign management to balloon, parabolic, and rocket-powered commercial flights across the U.S. to help **maximize success** of technology testing objectives
- **Making connections** between Flight Opportunities grantees and NASA programs and technologists to facilitate paths toward mission infusions

The Program Helped Inspire the Next Generation by:

- Supporting **57 student teams** in grades 6–12 from **37 U.S. states** and territories through the first NASA TechRise Student Challenge, offering hands-on STEM experience to more than 600 students
- Providing flight test experience to students made possible with **educational funding**

FLIGHT HIGHLIGHTS

Maturing Capabilities for Future Mission Needs

Flight Opportunities supported testing of a wide range of technologies and capabilities on commercial suborbital vehicles in FY2022. These tests moved payloads out of the lab and into relevant flight environments – increasing technology readiness levels, identifying necessary improvements, and advancing critical capabilities needed for future space missions. Cross-program collaboration enabled the program to leverage a variety of funding mechanisms to support rapid technology advancement through flight testing.

Credits: Zero Gravity Corporation

Advancing Space-Based Video Capture Techniques

Zandef Deksit's ExoCam in its metal cage rests on the desert surface of Mojave, California. Masten Space Systems's Xodiac VTVL vehicle can be seen in the ExoCam's viewfinder and in the distance. Credits: Zandef Deksit, Inc./Jason Achilles Mezilis

DATE AND LOCATION: October 14, 2021 — Mojave, California
FLIGHT VEHICLE: Xodiac (Astrobotic Technology, formerly Masten Space Systems)
FUNDING MECHANISM: NASA TechFlights award

Video capture during future Moon landings could play an important role in contributing to researchers' understanding of disturbances in lunar surface materials – called regolith – caused by the lander's rocket plume. This flight on a vertical takeoff vertical landing (VTVL) vehicle provided testing for the **ExoCam Module Lunar Lander Descent Imaging System** from **Zandef Deksit**. Simulating the movement of a lunar lander, the VTVL vehicle enabled researchers to evaluate an ejection mechanism to jettison a high-definition camera and regolith sensor onto the desert surface at specific altitudes just before landing. Once on the ground, the payload's camera captured video footage of the vehicle from the unique vantage point of the desert floor – a stand-in for the surface of the Moon.

Validating an On-Demand Payload Delivery System

The SpaceWorks RED-4U capsule in flight after being released from a Near Space Corporation high-altitude balloon at 103,000 feet. The parafoil guiding the capsule's descent was developed by Earthly Dynamics and Aerial Delivery Solutions. Credits: SpaceWorks Enterprises, Inc.

DATE AND LOCATION: October 19, 2021 — Madras, Oregon
FLIGHT VEHICLE: Small Balloon System (Near Space Corporation)
FUNDING MECHANISM: NASA TechFlights award

On-demand payload recovery from space could aid a variety of research and commercial space goals, including transport of small instruments and tools, biological samples, or science experiments returning to Earth from low-Earth orbit destinations. For this flight, the **Re-entry Device 4U (RED-4U) payload return capsule** from **SpaceWorks Enterprises** was suspended under a high-altitude balloon and released at an altitude of 103,000 feet. The 20-inch diameter capsule landed within 250 feet of its target touch-down destination, thanks to a guided parafoil. The flight was a milestone for evaluating key capabilities, including the capsule's altitude detection and the parafoil's autonomous guidance and control.

Improving Weather and Climate Data Collection Capabilities

Arizona State University CubeSounder team members Kyle Massingill (left) and Michael Baricuatro with their weather sensor payload integrated onto the World View balloon hardware. Credits: Arizona State University

DATES AND LOCATION: April 9–13, 2022 — Tucson, Arizona
FLIGHT VEHICLE: Stratollite (World View)
FUNDING MECHANISM: NASA TechFlights award

High-speed transmission of weather data from CubeSats and weather balloons is key to providing researchers with forecasting and climate information. For this flight, researchers from **Arizona State University** evaluated a small, lightweight, efficient 3D imaging sensor called the **CubeSounder**. The sensor is designed to provide state-of-the-art atmospheric sounding capabilities – gathering data on temperature, moisture, and water vapor – to reveal subtle changes in Earth's atmosphere. Reaching an altitude of 70,000 feet and logging more than 100 hours, the flight enabled researchers to validate the CubeSounder's ability to collect atmospheric data as 3D images. The technology could be used to provide climate data collection with lower size, weight, and power requirements than currently available sensors.

Providing Microgravity Testing for Space Innovations

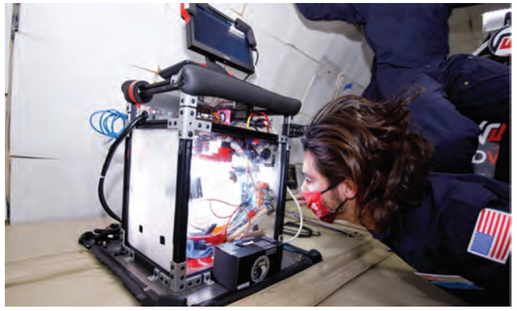
DATES AND LOCATIONS: November 16–19, 2021; December 7–15, 2021; May 9–12 and 16–17, 2022; June 27–28, 2022 — Orlando and Fort Lauderdale, Florida; Santa Maria, California

FLIGHT VEHICLE: G-FORCE ONE (Zero Gravity Corporation)

FUNDING MECHANISMS: NASA TechFlights, Tipping Point, and Small Business Innovation Research (SBIR) awards

Over the course of 19 parabolic flights in FY2022, 30 Flight Opportunities–supported technology payloads were put to the test in microgravity, advancing a wide range of capabilities for future space exploration needs. (See full list on pages 10–13.) Researchers flew alongside their payloads on a modified aircraft that performs a series of maneuvers to create multiple brief periods of weightlessness – enabling research teams to collect vital data about how their technologies perform in microgravity. Among the capabilities advanced on the flight were the following.

A team of researchers from MIT evaluate the performance of miniature robots for space-based assembly and inspections on a parabolic flight in December 2021. Credits: Zero Gravity Corporation/Steve Boxall



Carthage College student Nicolas Welker prepares to start a zero-gravity transfer of propellant simulant during a parabolic flight in November 2021. Credits: Zero Gravity Corporation/Steve Boxall

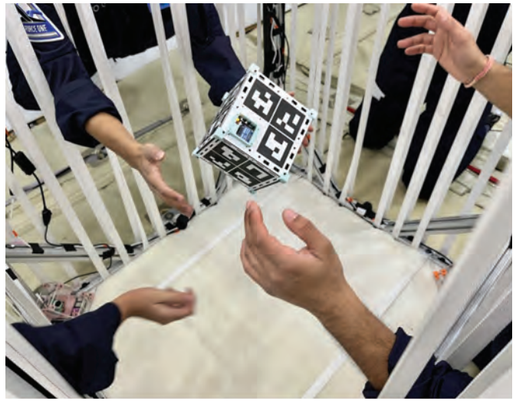
Space-Based Food and Farming

Sustainable food harvesting in space will be essential to ensuring astronauts have a ready supply of fresh nutrients to sustain their lives and work in space. Researchers tested technologies that could enable robotic seed delivery for large-scale space farms and tackle microgravity challenges such as keeping plant roots separated from their shoots.

Propellant and Cryogenic Management

In-space propellant transfer and refueling is a critical capability for sustained human presence in space. Research teams gathered data about how propellant behaves in microgravity and tested systems designed to:

- Gauge accurately the amount of propellant remaining in a spacecraft fuel tank
- Understand the effects of liquid slosh and dynamic spacecraft movements on gauging accuracy
- Monitor fuel tanks for propellant boiloff and structural health
- Address the need for vapor-free propellants for long-duration missions
- Develop predictive simulations for heat transfer of cryogenic propellants



A research team from University of California, Davis evaluates low-cost reaction wheels for CubeSats during a period of weightlessness on a parabolic flight in December 2021. Credits: Zero Gravity Corporation/Steve Boxall

Manufacturing and Structural Health

Parabolic flights helped researchers advance capabilities for the "make it, don't take it" approach to space habitats – that is, manufacturing needed supplies in space. Teams evaluated technologies that aim to:

- Enable on-demand printing of electronics
- Produce a reliable supply of replacement parts and structures for lunar and Martian habitats
- Deploy swarms of micro-robots to assess performance for part assembly and structural inspections
- Strengthen or repair existing space structures using ceramic foam inks with superior strength

Human Health and Biological Research

Understanding the impact of long-term space exploration on biological systems and ensuring astronaut health will be necessary for future missions. Research teams assessed technologies designed to provide wound and surgical care, limit space adaptation sickness, and perform clinical assays and diagnostic tests.

Lunar and Planetary Surface Exploration

Lunar exploration will require increased understanding of the effects of lunar dust on humans, robots, and equipment. Researchers tested technology to help increase that understanding and build predictive models of dust behavior to inform mitigation methods.

Small Spacecraft Capabilities

Lowering the cost of CubeSats and other small spacecraft could enable their use for a wider range of space-based tasks and research. Teams tested technologies designed to provide low-cost precise attitude and pointing control for small spacecraft and to manage their propellant levels.

> *"This flight taught us that the transition of a lab-based prototype instrument to a flight instrument – and its automated operation in a flight environment – is very challenging. This successful experiment is an important step in advancing the flight technology readiness of our instrument."*
>
> Richard Mathies and Anna Butterworth, co-investigators for Lab-on-a-Chip, University of California, Berkeley

Accelerating Time to Flight for Earth Observation Systems

DATES AND LOCATIONS: July 8, July 28, August 3, 2022 — Sioux Falls, South Dakota

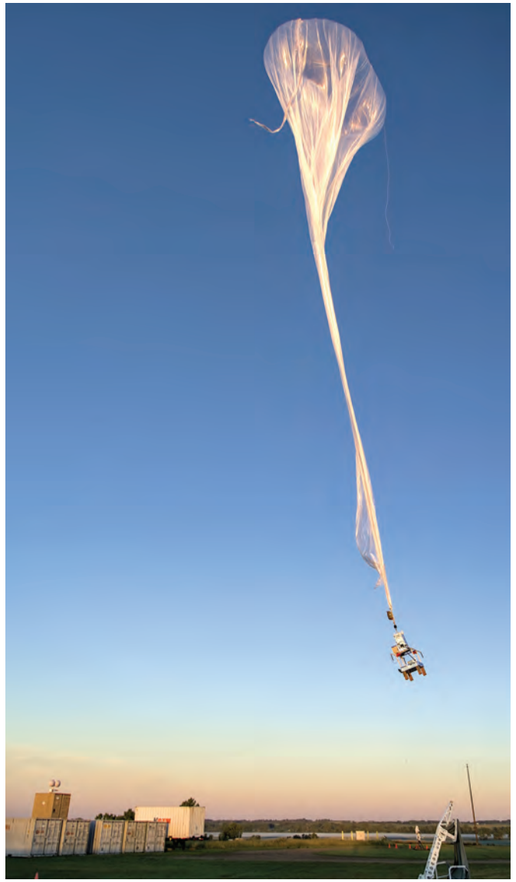
FLIGHT VEHICLE: Zero-Pressure Balloon System (Aerostar)

FUNDING MECHANISMS: NASA TechLeap Prize

Winners of the first NASA TechLeap Prize – Autonomous Observation Challenge No. 1 – launched their technologies on high-altitude balloon flights in FY2022, testing them at stratospheric altitudes. The challenge asked winners to develop small spacecraft observation technologies that can autonomously detect, locate, track, and collect data on transient events on Earth and beyond. The balloon flights enabled the teams – all first-time Flight Opportunities awardees – to gather valuable test data and gain experience with the full process of building a technology payload and bringing it from lab to flight test in less than one year.

Advancing Detection of Nascent Wildfires

Student members of the Bronco Space Lab at Cal Poly Pomona developed and launched a wildfire detection system called Bronco Ember. Combining a short-wave infrared camera with artificial intelligence, the system is designed to provide potentially faster, more accurate aerial detection of nascent wildfires, which often go undetected by current geolocation methods. The balloon flight enabled the team to evaluate the technology's efficacy and identify necessary improvements to its detection and tracking consistency – refinements they plan for the next generation of Bronco Ember.



Orion Labs' Quantum Earth Observatory launches on an Aerostar high-altitude balloon from the company's facility in Sioux Falls, South Dakota, on July 28, 2022. The observatory hardware is housed in the gondola carried below the balloon. Credits: Orion Labs/Margarita Reyes

The Orion Labs team makes final hardware checks on their Quantum Earth Observatory payload prior to launch. From left to right: Frank Soboczenski, Philippe Ludivig, Sara Jennings, and Kolbron Schoenberger. Credits: Orion Labs/ Margarita Reyes

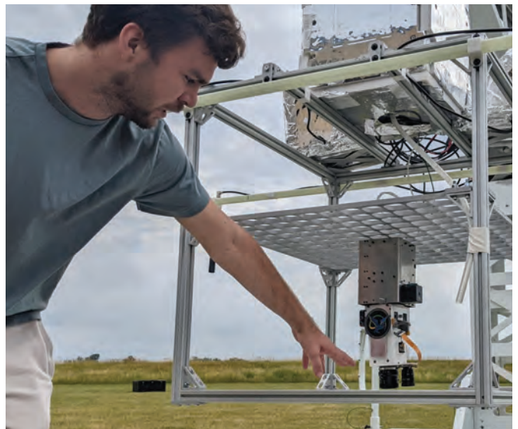
Validating Quantum Machine Learning

Small business Orion Labs developed and tested the Quantum Earth Observatory (QEOBS) – a four unit–sized CubeSat designed to demonstrate how onboard data processing and quantum machine learning can result in reduced downlink requirements. Its capabilities could significantly reduce the bandwidth needed for small spacecraft to send data about terrestrial events back to Earth. During the flight, QEOBS collected thousands of images of small dams and waterways, processing the image data onboard and efficiently downlinking only data about confirmed dam detections to the ground. The flight results will help the team identify specific Earth observation use cases for the technology and prepare for a potential future demonstration on a small spacecraft.

Testing a Satellite System for Plume Identification

Developed by students at Texas A&M University's Systems Engineering, Architecture, and Knowledge (SEAK) Lab, the Satellite for Natural and Artificial Plumes (SNAP) uses gimbaled cameras to collect image data and a computing system to process the data using a trained neural network to identify and track Earth-based plumes. The technology could contribute to monitoring of fire, pollution, and volcanic activities. The balloon flight enabled image collection and testing of SNAP's plume-tracking capability as well as identification of necessary improvements to its onboard computing system, leading to a troubleshooting and mitigation plan in advance of a second flight slated for 2023.

> *"When we launched the TechLeap Prize in 2021, we wanted to accelerate access to flight testing and expand the diversity of ideas and solutions brought to the NASA table. These organizations are building innovative payloads and literally getting them off the ground – in less than one year."*
>
> Danielle McCulloch, Program Manager (Acting), NASA's Flight Opportunities program



Zachary Gaines, a senior in Cal Poly Pomona's Bronco Space Lab, points out the camera and sensor used in the team's Bronco Ember technology to detect and track wildfires. Credits: Aerostar/Anastasia Quanbeck

TECHNOLOGIES TESTED IN FY2022

Flight Date	Flight Provider	Flight Vehicle	Principal Investigator	Organization	Technology Name
October 14, 2021	Masten Space Systems	Xodiac	Jason Mezilis	Zandef Deksit	T0304 Deployment Test for ExoCam Module Lunar Lander Descent Imaging
October 19, 2021	Near Space Corporation	Small Balloon System	Tyler Kunsa	SpaceWorks Enterprises	T0297 Enabling Low-Cost, Autonomous Recovery of Small Payloads from Low-Earth Orbit
November 16-19, 2021	Zero Gravity Corporation	G-FORCE ONE	Kevin Crosby, Ph.D.	Carthage College	T0191 Microgravity Propellant Gauging Using Modal Analysis: Phase III
			Chung-Lung Chen	University of Missouri	T0211 Electrowetting Enhanced Dropwise Condensation in the Zero-*g* Environment
			Susana Zanello	IMEC USA Nanoelectronics Design Center	T0236 Silicon-Based Microfluidic Blood Test for Spaceflight
			Markus Wilde	Florida Institute of Technology	T0275 Microgravity Test of Autonomous Multiple Cycle Farming System
			Kevin Crosby, Ph.D.	Carthage College	T0277 Propellant Gauging During On-Orbit Refueling and Transfer Operations
			Konstantinos Sierros, Ph.D.	West Virginia University	T0294 Particle-Based Foams Spraying in Microgravity
			Ram Prasad Ghandiraman	Space Foundry	T0312 Plasma Jet Printing for In-Space Manufacturing
			Gioia Massa	NASA's Kennedy Space Center	T0313 Microgreens Root Zone/Shoot Zone Partitioned Planting Box
			Brandon Kirkland	Redwire (formerly Made In Space)	T0331 Vulcan Advanced Hybrid Manufacturing (VULCAN)
December 7–15, 2021	Zero Gravity Corporation	G-FORCE ONE	Steven Collicott	Purdue University	T0206 Small-Sat Propellant Management Technology
			Ranga Narayanan	University of Florida	T0278 Testing a Novel Technology for a Key Material Property Measurement – Application to Advanced Manufacturing in Space
			Stephen Robinson	University of California, Davis	T0280 Zero-*g* Technology Demonstration of Low-Cost Three-Axis CubeSat Attitude Control with Hard Disk Drive Reaction Wheels
			Steven Collicott	Purdue University	T0281 Enhancing Suborbital Tech Advancement Through Automated Control of High-Definition Video Systems
			Steven Collicott	Purdue University	T0285 Integrating Microgravity Medical Suction and Microgravity Surgical Facility
			Joseph Paradiso	Massachusetts Institute of Technology	T0286 Autonomous Robot Swarms for Lunar Orbit Servicing and Space Asset Assembly
			Stephen Robinson	University of California, Davis	T0290 Capturing Human Adaptations in Novel Gravitational Environments in Space (CHANGES)
			Adrienne Dove	University of Central Florida	T0292 Strata-2P – Characterizing Sensor-Regolith Interactions in Reduced-Gravity
			Robert Anderson	NASA's Jet Propulsion Laboratory	T0295 Soil Properties Assessment Resistance and Thermal Analysis (SPARTA)
			Ram Prasad Ghandiraman	Space Foundry	T0312 Plasma Jet Printing for In-Space Manufacturing
			Gioia Massa	NASA's Kennedy Space Center	T0313 Microgreens Root Zone/Shoot Zone Partitioned Planting Box
			Hantang Qin	Iowa State University	T0325 3D Printing of Flexible Electronics for In-Space Manufacturing and Investigations via Microgravity Parabolic Flight Tests
			Dmitry Starodubov	NASA's Johnson Space Center	T0326 Space Fibers 3 Preflight

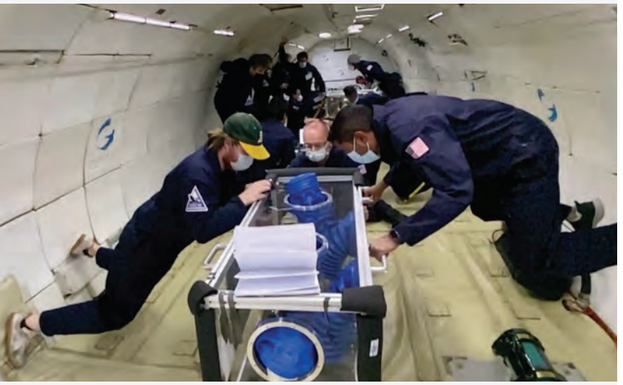
TECHNOLOGIES TESTED IN FY2022

Flight Date	Flight Provider	Flight Vehicle	Principal Investigator	Organization	Technology Name
April 9–13, 2022	World View	Stratollite	Sean Bryan	Arizona State University	T0289 CubeSounder: Flying a Novel 3D Weather Imaging Sensor on a High-Altitude Balloon
May 9–12, 2022	Zero Gravity Corporation	G-FORCE ONE	Kevin Crosby, Ph.D.	Carthage College	T0277 Propellant Gauging During On-Orbit Refueling and Transfer Operations
			Richard Mathies	University of California, Berkeley	T0279 Flight Testing of a Microfluidic Biochemical Analysis Lab-on-a-Chip
			George Pantalos	University of Louisville	T0287 Preparations for a Suborbital Evaluation of a Human-Tended Surgical Fluid Management System
			Hayden Taylor	University of California, Berkeley	T0293 Evaluation of Computed Axial Lithography for Rapid, Volumetric Additive Manufacturing Under Low-Gravity Conditions
			Thomas Conboy	Creare	T0311 Lightweight, Hybrid Screen-Channel Device for Advanced Cryogenic Fluid Management
			Hantang Qin	Iowa State University	T0325 3D Printing of Flexible Electronics for In-Space Manufacturing and Investigations via Microgravity Parabolic Flight Tests
			Jed Storey	NASA's Kennedy Space Center	T0327 Propellant Mass Gauging in Microgravity with Electrical Capacitance Tomography
May 16–17, 2022	Zero Gravity Corporation	G-FORCE ONE	Thomas Valdez	Teledyne Energy Systems	T0273 Hydrogen Electrical Power System (HEPS)
			Ranga Narayanan	University of Florida	T0278 Testing a Novel Technology for a Key Material Property Measurement – Application to Advanced Manufacturing in Space
			Emilio Baglietto	Massachusetts Institute of Technology	T0283 Reduced Gravity Experiments to Advance CFD Boiling Models for Cryogenic Fluid Management Systems
			Konstantinos Sierros	West Virginia University	T0294 Particle-Based Foams Spraying in Microgravity
June 27–28, 2022	Zero Gravity Corporation	G-FORCE ONE	David Miles	University of Iowa	T0207 CubeSat Articulated Boom Option Optimization in Microgravity (CABOOM)
			Stephen Robinson	University of California, Davis	T0280 Zero-*g* Technology Demonstration of Low-Cost Three-Axis CubeSat Attitude Control with Hard Disk Drive Reaction Wheels
			Stephen Robinson	University of California, Davis	T0290 Capturing Human Adaptations in Novel Gravitational Environments in Space (CHANGES)
			Issam Mudawar	Purdue University	T0291 Reduced Gravity Experiments to Measure Cryogenic Two-Phase Heat Transfer Coefficients for Future In-Space Transfer Systems
			Ram Prasad Ghandiraman	Space Foundry	T0312 Plasma Jet Printing for In-Space Manufacturing
July 8, 2022	Aerostar	Zero-Pressure Balloon System	Cristian Rodriguez	Bronco Space Club at Cal Poly Pomona	T0334 Bronco Ember: Autonomous Nascent Wildfire Detection and Prevention
July 28, 2022	Aerostar	Zero-Pressure Balloon System	Sara Jennings	Orion Labs	T0333 Quantum Machine Learning Enhanced Sensor Combination for Earth Observation (QMLS-EO)
August 3, 2022	Aerostar	Zero-Pressure Balloon System	Ben Gorr	SEAK Lab at Texas A&M University	T0335 Satellite for Natural and Artificial Plumes (SNAP)

TECHNOLOGY TRANSITION HIGHLIGHTS

Space Mission Infusions and Commercialization

Technologies matured through flight testing with Flight Opportunities made progress in transitioning to space-based missions and commercial applications in FY2022. Such milestones highlight the impact of iterative testing on helping to increase the likelihood of success for these innovations – both in space and here on Earth.



(Left to right) Matthew Kathan, Dr. Victor Grubsky, and Avinash Vasudevan of Mercury Systems conduct tests on the latest generation of their optical fiber manufacturing hardware on a parabolic flight by Zero Gravity Corporation in November 2020. Credits: Mercury Systems

Preparing Optical Fiber Manufacturing for the International Space Station

Space Fibers 3 from FOMS, Inc., and the Orbital Fiber Optic Production Module (ORFOM) from Mercury Systems both aim to enable automated, on-demand manufacturing of optical fibers in space. Both systems leverage NASA suborbital research that demonstrated significant performance improvements in ZBLAN optical fibers (short for zirconium barium lanthanum aluminum sodium fluoride) when manufactured in zero gravity compared with fibers produced in ground-based labs. These superior fibers could be useful in many applications, such as telecommunications, lasers for medical and scientific uses, spectroscopy, thermal imaging, military applications, and more.

Suborbital Flight Milestones

Flights on Zero Gravity Corporation's G-FORCE ONE parabolic aircraft enabled the research teams to validate hardware improvements for their fiber manufacturing systems as well as:

- Demonstrate the full manufacturing process at 0 *g*, 1 *g*, and lunar gravity
- Redesign a fiber preform processing capability
- Test two separate approaches to automating optical fiber draws to decrease astronaut interaction requirements
- Refine and rehearse crew instructions for station astronauts

Transition to Station Demonstration

As part of NASA's In Space Production Applications (InSPA) project, both Space Fibers 3 and ORFOM transitioned to the International Space Station as part of a SpaceX Commercial Resupply Services mission (CRS-25), arriving July 16, 2022. The orbital demonstrations on the station are intended to enable InSPA to assess results and inform future hardware improvements and steps toward potential optical fiber manufacturing in space in the coming years.

Maturing Propellant Gauging for Space- and Earth-Based Applications

Carthage College's modal propellant gauging (MPG) is a non-invasive, inexpensive, robust method designed to gauge settled and unsettled liquid propellant at resolutions of 1% for settled propellants and 2–4% for unsettled, sloshing propellants. The method is designed to address the needs of NASA's Space Launch System (SLS) rocket and Orion spacecraft architectures, which require in-space gauging accuracy of 1% for remaining propellant mass and leak detection.

Suborbital Flight Milestones

Flights on Zero Gravity Corporation's G-FORCE ONE parabolic aircraft and Blue Origin's New Shepard rocket-based system have enabled researchers to:

- Demonstrate MPG's ability to gauge at resolutions of 1% for settled propellant and 2–3% for unsettled, sloshing propellant
- Validate a computational fluid dynamics model of how modal gauging is affected by propellant slosh and other vehicle dynamics
- Develop models of the slosh dynamics of the Orion spacecraft propellant tanks

Commercialization Success

As a result of multiple suborbital flight tests supported by Flight Opportunities, Carthage College has achieved several commercialization successes with MPG:

- Airbus has adopted MPG for a one-year study as part of its zero-emission commercial passenger jet program. The study is the culmination of a project for which five Carthage College undergraduates won the prestigious Lemelson-MIT Prize in 2020.
- Seattle-based Spaceflight is commercializing MPG for use on its Sherpa-class spacecraft via a Small Business Technology Transfer (STTR) grant with the U.S. Air Force.
- NASA's Commercial Lunar Payload Services (CLPS) contractor Intuitive Machines has installed the MPG technology on its Nova-C lunar lander test articles.

> *"I'm grateful for the support from both Flight Opportunities and Zero Gravity Corporation over the years. Our recent successes show that all of this work is starting to translate into tangible results."*
>
> Kevin Crosby, Ph.D., principal investigator for MPG, Carthage College

Carthage College students (left to right) Taylor Peterson, Alana King, Liam Carls, and Dalton Callow, take a moment to pose with the modal propellant gauging payload experiment during a parabolic flight in November 2021. Credits: Zero Gravity Corporation/Steve Boxall

NEW TECHNOLOGY SELECTIONS

Identifying Innovations for Future Mission Needs

Leveraging a wide range of funding mechanisms, including prizes, challenges, solicitations, and cross-program collaboration (see page 20), Flight Opportunities identified and selected promising innovations in FY2022 for testing on commercial suborbital vehicles. Each selection aims to provide key capabilities that address technological gaps for future space missions.

NASA's TechLeap Prize

In FY2022, winners of the first NASA TechLeap Prize – **Autonomous Observation Challenge No. 1** – launched their payloads on high-altitude balloons just one year after the challenge was announced (details on pages 8–9). In addition to this speed to flight, another goal of the competition model was to identify and select new organizations and innovations that may not have previously been awarded funding through traditional solicitations.

For 2022, the program worked with NASA's entry, descent, and landing experts to develop a challenge statement that specified key technology gaps to be addressed in achieving the goal of landing in or near permanently shadowed regions of the Moon. The result was the **Nighttime Precision Landing Challenge No.1**, with three winners announced in July 2022:

- **The Bronco Space Club at Cal Poly Pomona *(Pomona, California)*:** The team's technology uses a light projector; light detection and ranging (lidar); and advances in computer vision, machine learning, and robotics to generate a map of lunar terrain.
- **Falcon ExoDynamics *(El Segundo, California)*:** The company's system uses a high-resolution camera, floodlight, small gimbal, and graphics processing unit to perform terrain sensing in the dark.
- **University of South Florida's Institute of Applied Engineering *(Tampa, Florida)*:** The institute's solution uses commercial-off-the-shelf lidar sensors and simultaneous mapping algorithms to form a complete topographical map of a given search area.

> *"TechLeap has been a great learning experience for us… The skills we've developed – time management, working with technology vendors, NASA, and a flight provider – were incredibly valuable."*
>
> Cristian Rodriguez, principal investigator for Bronco Ember (see page 8), Cal Poly Pomona

NASA TechLeap PRIZE

NASA's TechFlights Solicitation

As the Flight Opportunities program's longest-standing funding mechanism, the TechFlights solicitation annually provides funding to researchers from industry, academia, and non-profit research institutes for flight testing of innovative technologies.

NASA TECHFLIGHTS

Selections for TechFlights 2021 were announced in early FY2022, providing NASA investments in demonstration of technologies for space exploration, scientific discovery, Earth observation, and space commerce activities with each awardee receiving up to $650,000. The awardees are the following.

Astrobotic Technology

Testing of a lidar-based hazard detection system for lunar and planetary landings will allow researchers to evaluate the sensor's performance in an operational environment.

PLANNED TO FLY ON: Astrobotic Technology's Xodiac vertical takeoff vertical landing system

Blue Origin

The company will evaluate small, low-cost, ultra-wideband sensors as an alternative to conventional rendezvous and docking technologies, which are often expensive and bulky.

PLANNED TO FLY ON: Blue Origin's New Shepard rocket-based system

Carthage College

A student team will test piezoelectric sensors for their ability to accurately identify the location and distribution of the liquid surface during propellant transfer in microgravity. This capability is necessary for engine restart of spacecraft and for propellant transfer between in-space fuel depots and visiting spacecraft.

PLANNED TO FLY ON: Zero Gravity Corporation's G-FORCE ONE parabolic aircraft and Blue Origin's New Shepard

Center for Applied Space Technology

Center researchers will evaluate a new process and system for printing cells and bioink mixtures for applications in large-scale production of living cells and basic 3D cellular structures.

PLANNED TO FLY ON: Zero Gravity Corporation's G-FORCE ONE

Ecoatoms

Researchers will test a new process for developing biosensor coatings, leveraging microgravity to manufacture smoother and more sensitive biosensors than can be produced on Earth.

PLANNED TO FLY ON: Blue Origin's New Shepard

Researcher Support

Research teams and others interested in participating in the Flight Opportunities program can access a range of resources to share flight test best practices, network with others in their fields of research, and stay up to date on news and opportunities.

Subscribe to the Flight Opportunities Newsletter

This bimonthly publication provides news about recent flight testing activities, opportunities for funding, mission infusion success stories, lessons learned, and more.

https://bit.ly/3Cy5pFC

Join the Community of Practice Webinar Series

This monthly offering brings together Flight Opportunities leadership in conversation with program-funded researchers to share insights about suborbital flight testing and strategies for increasing the likelihood of mission infusion, commercialization, and other successful outcomes. Subscribe to the newsletter to receive webinar announcements.

Honeybee Robotics

The company will examine a system for testing viscous bubble behavior in lunar gravity conditions to increase researchers' understanding of molten regolith electrolysis techniques that could be used to extract oxygen from lunar soil.

PLANNED TO FLY ON: Blue Origin's New Shepard

Purdue University

This researcher-tended experiment will enable testing of a technique for modeling the behaviors of less toxic, "green" propellant to gather data on potential solutions for non-traditional propellant management.

PLANNED TO FLY ON: Virgin Galactic's SpaceShipTwo rocket-based system

San Diego State University

Also part of the 2020 NASA SmallSat Technology Partnerships Initiative, the university's phased-array antenna transceiver project aims to advance development of an antenna suitable for reliable lunar communication that is more efficient than currently available technologies.

PLANNED TO FLY ON: Aerostar's zero-pressure high-altitude balloon system

University of Florida

University researchers plan to test a method for minimizing propellant boiloff using surface roughness by applying a thin-film coating to a cryogenic tank as a potential fuel-conserving approach.

PLANNED TO FLY ON: Zero Gravity Corporation's G-FORCE ONE

Other NASA Program and Internal Technology Selections

Flight Opportunities hleps address flight testing needs for innovations funded by other NASA programs – including Small Business Innovation Research (SBIR) and Game Changing Development. This includes technologies funded by other NASA programs in industry and academia as well as those developed by NASA innovators. The program selected several projects in FY2022 for future testing on commercial vehicles.

Creare

As part of an SBIR Phase II-E grant, the company's researchers plan to demonstrate functionality of key two-phase pumped loop technologies in a microgravity environment with the aim of providing effective thermal control.

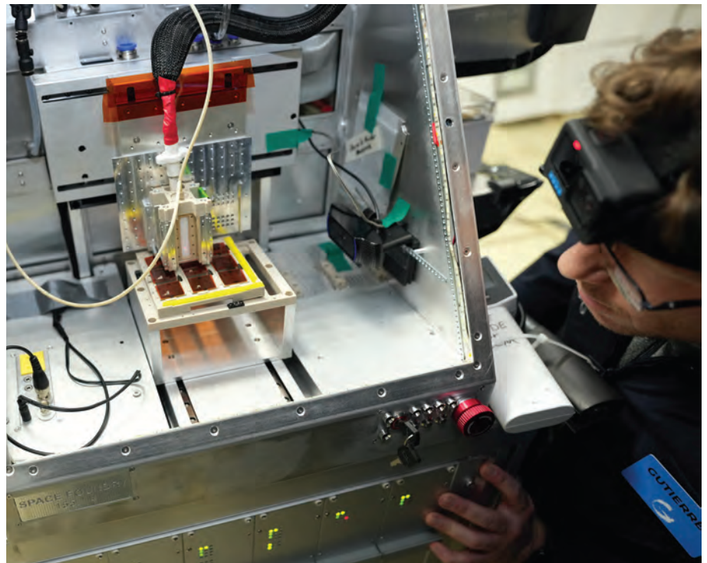
PLANNED TO FLY ON: Blue Origin's New Shepard

Honeybee Robotics

The company's researchers plan to test a new device that uses compressed gas to remove dust from the scientifically important subsurface of rocks, regolith-covered ices, critical equipment such as solar panels, and sealing surfaces.

PLANNED TO FLY ON: Blue Origin's New Shepard

Innovators from Space Foundry tested a system designed for high-throughput plasma jet printing of conductive metal inks on parabolic flights in late 2021 and June 2022. The system is being evaluated as part of NASA's On-Demand Manufacturing of Electronics project. Credits: Zero Gravity Corporation/Tasha Dixon



NASA's Ames Research Center

Working in collaboration with the U.S. Forest Service, researchers plan to evaluate the technical, operational, and financial feasibility of using stratospheric balloon platforms to provide last-mile data and communications capabilities for remote incidents, including active wildfire management.

PLANNED TO FLY ON: Aerostar's Thunderhead balloon system

NASA's Ames Research Center

Researchers plan to assess the viability of a small optical laser communication payload for use as a secure and assured communications method on stratospheric balloon platforms to support future advanced free-space optical communications on orbit.

PLANNED TO FLY ON: Aerostar high-altitude balloon system

NASA's Armstrong Flight Research Center

For this unique project, researchers plan to deploy a legacy vibration, temperature, and atmospheric sensor on a new launch system from SpinLaunch in an effort to test the flight environment of the system.

PLANNED TO FLY ON: SpinLaunch (new platform in development)

NASA's Marshall Space Flight Center

As part of NASA's On-Demand Manufacturing of Electronics project, researchers have partnered with Sciperio and Techshot to assess the components of a custom designed nScript multi-material printer with an advanced toolplate that aims to enable creation of both printed electronics and metals with a single system.

PLANNED TO FLY ON: Zero Gravity Corporation's G-FORCE ONE

University of California, Los Angeles

Researchers will assess a high-precision, continuous-time, compact navigation module designed for cislunar and lunar missions, including inertial navigation for autonomous pinpoint landings and diverse surfaces.

PLANNED TO FLY ON: Aerostar high-altitude balloon system

A New Dual-Anonymous Peer Review Process for Technology Selections

TechFlights 2022 was released in May 2022, announcing up to $750,000 in funding per awardee. The addition of a dual-anonymous peer review process to this solicitation is aimed at decreasing unconscious bias in the proposal review process. Selections are expected in January 2023.

"Each year, the group of technologies proposed for the TechFlights solicitation is more impressive, and this year's selections address some of NASA's critical technology gaps. In addition, we are pleased to see new researchers and organizations participating in TechFlights."

John Kelly, Senior Advisor,
NASA's Flight Opportunities Program

CROSS-PROGRAM COLLABORATION

In FY2022, Flight Opportunities continued to strengthen connections with a wide range of other NASA programs, providing access to suborbital flight tests through a variety of funding mechanisms to help advance technologies of value to NASA and industry. Highlights of these collaborations included the following.

Small Spacecraft Technology Program

Flight Opportunities increased collaboration with the Small Spacecraft Technology program in FY2022, adding support for commercial hosted orbital payload opportunities to the annual TechFlights solicitation.

Game Changing Development (GCD)

By providing access to suborbital flights, Flight Opportunities is helping to bolster GCD's mission: to advance space technologies that may lead to entirely new approaches for NASA's future space missions. Highlights of this support in FY2022 included progress toward a lunar gravity testing capability on Blue Origin's New Shepard and flight tests of technologies under development by GCD's On-Demand Manufacturing of Electronics (ODME) project.

Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR)

Support for SBIR/STTR-funded technologies through suborbital flight testing helped advance their technology readiness levels, potentially leading to subsequent awards and, ultimately, infusion into NASA missions and/or commercialization.

International Space Station Research Integration Office

Suborbital flight testing in FY2022 allowed for risk reduction and hardware validation for optical fiber manufacturing technologies that transitioned to the station for space-based demonstration (see page 14).

Science Mission Directorate (SMD) Programs

Flight Opportunities continued collaborating with SMD programs in FY2022, with highlights including the addition of support for commercial suborbital flight testing as part of NASA's Astrophysics Research and Analysis program and Heliophysics-Low Cost Access to Space through the agency's Research Opportunities in Space and Earth Sciences (ROSES) 2022 solicitation.

The SpaceX Dragon space freighter, on its 25th Commercial Resupply Services mission, approaches the International Space Station carrying 5,800 pounds of new science experiments and crew supplies, including optical fiber manufacturing technologies that were matured through Flight Opportunities. Credits: NASA

SUPPORT FOR VEHICLE CAPABILITY ENHANCEMENTS

Through contracts, Space Act Agreements, and purchase of payload space, Flight Opportunities continued its support for capability enhancements for select commercial suborbital flight vehicles in FY2022. These new capabilities are expected to expand the options available to the space research community for flight testing. Recent activities included support for the following.

Masten Space Systems

Expansion of heavy-lift testing and capabilities for spacecraft lunar and Martian navigation and landing systems through development of Xogdor, a new vertical takeoff vertical landing vehicle, including:

- Defining vehicle requirements for increased payload capacity to 200 kg, increased altitude range of up to 30 km, supersonic descent capability, and closed-loop control
- Commenced vehicle design analysis

Blue Origin

Capabilities for testing in lunar gravity conditions on the New Shepard rocket-powered vehicle, including:

- Completion of critical design review
- Progress toward qualification and manufacturing readiness review
- Selection of 13 NASA-funded payloads for flight testing in New Shepard's lunar gravity conditions

Rocket Lab

- Exploration of re-entry and recovery capabilities for small launch vehicles' first stage

UP Aerospace

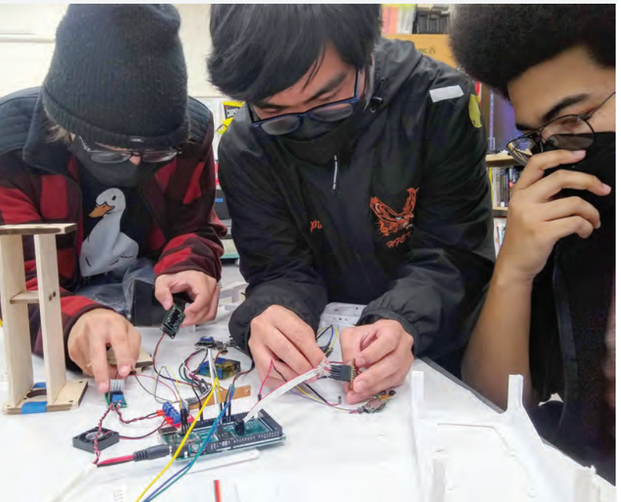
- Development of the new Spyder Orbital vehicle, to include longer microgravity conditions, dedicated small payload launches for orbital missions, and planetary re-entry test environments
- Commenced a trade study in coordination with NASA Early Career Initiative's Additive Manufacturing of Thermal Protection Systems project with the goal of future testing of advanced thermal protection systems as Spyder vehicle hypersonic payloads

An artist's rendering of the new Xogdor rocket, which aims to test descent and landing technologies at high subsonic speeds. Credits: Masten Space Systems

EDUCATIONAL OUTREACH

Paving a Path for Space Education

Flight Opportunities continued to provide educational support for students from middle school through undergraduate levels in FY2022, leveraging a variety of funding mechanisms to provide hands-on experience with space technology experiments.



Team members from TechRise winner Sewanhaka High School in Floral Park, New York, work together to assemble an integrated circuit as part of a payload that they will test on an Aerostar high-altitude balloon in 2023. Credits: Sewanhaka High School

TechRise: Reaching a Diverse Group of Young Students

Launched in 2021, NASA's TechRise Student Challenge invites teams of sixth- to 12th-grade students to design, build, and launch experiments on suborbital vehicles. Nearly 600 teams applied to the inaugural challenge, representing 5,000 students from across the country.

The 57 winning teams were announced in January 2022, hailing from 37 U.S. states and territories and including more than 600 students. Winning proposals included:

- Measuring greenhouse gases
- Space farm irrigation systems
- Lunar dust mitigation
- Exploring human health in space
- Understanding the effects of microgravity on liquids, 3D printing, and more

Winning teams each received $1,500 to build their experiments and a NASA-funded spot to test them, either on suborbital rocket flights operated by Blue Origin or UP Aerospace or on a high-altitude balloon flight from Aerostar. Flights for the first cohort of winning experiments are expected to commence in early 2023.

The next TechRise Student Challenge was announced in August 2022, and winners are expected to be announced in January 2023.

TechFlights Educational Opportunities

The 2022 TechFlights solicitation continued to include additional funds for educational opportunities, providing resources for colleges and universities to offer hands-on experience with suborbital flight tests for K-12 or undergraduate students. Working alongside a teacher, professor, or faculty member, these teams gain field experience to complement classroom learning. The 2022 solicitation allowed up to 20% of the total proposed funding to support educational activities.

> *"This is what education is all about. As educators, we provide opportunities for our students to go beyond the classroom and into the real world. These four students from a small, rural farming community in Northwest Ohio tackled this tech challenge. They will be one of 57 teams in the nation to launch their experiment on a suborbital vehicle. It doesn't get any better than that."*
>
> Sheila Killam, STEAM (science, technology, engineering, arts, and math) teacher at Fayette Junior/Senior High School, Fayette, Ohio

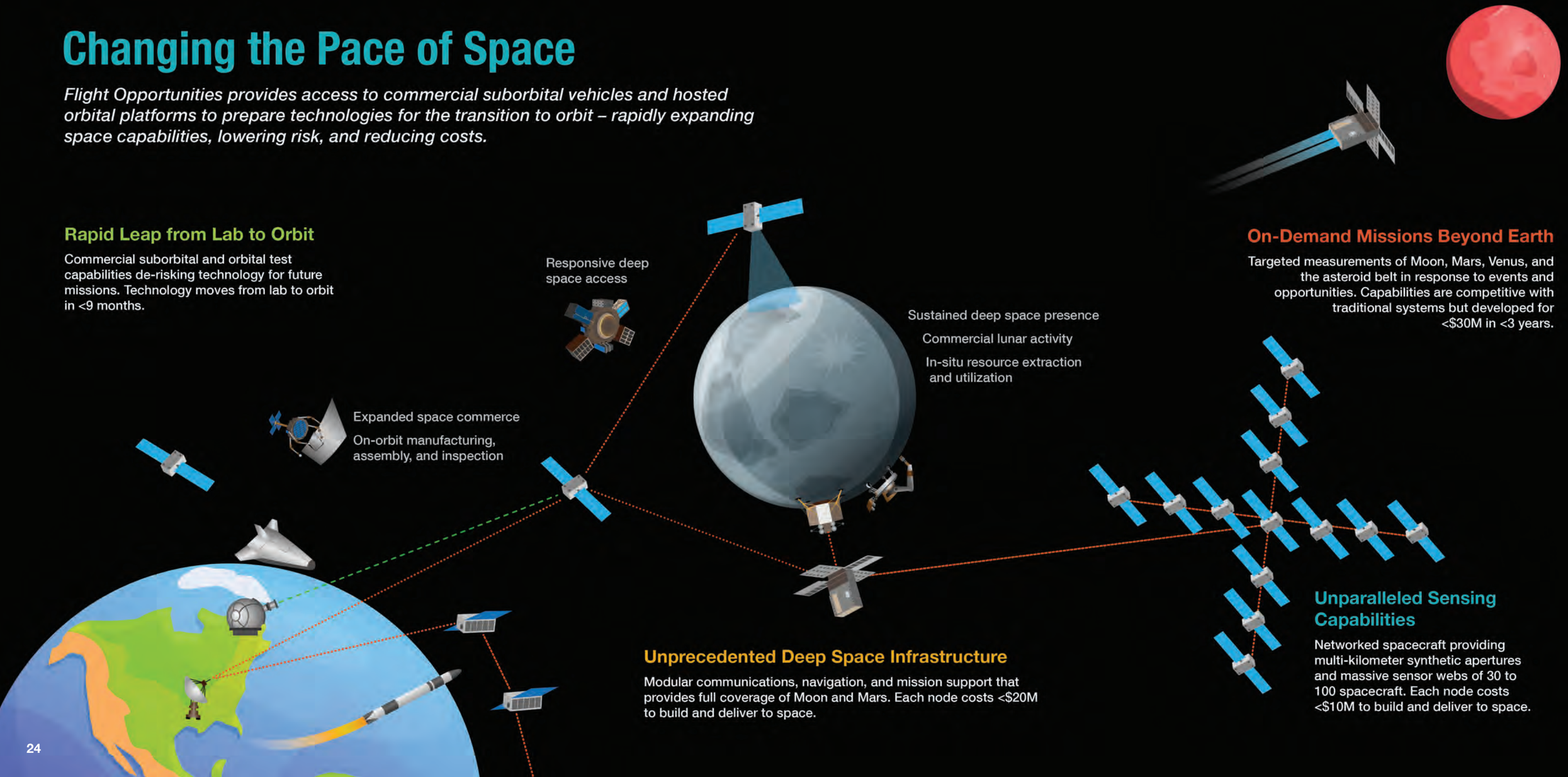
Support for NASA's CubeSat Launch Initiative (CSLI)

Teams from universities, high schools, and non-profit organizations gain exposure to orbital flight testing through CSLI, enabling low-cost avenues for conducting scientific and technology demonstrations on CubeSats. In addition to financial support, Flight Opportunities provided suborbital testing for payloads supported by CSLI in FY2022 – an important step in helping teams assess the performance of their payloads and make necessary improvements before launching them to orbit.

Students from University of California, Davis test a system designed to train astronauts to limit head movements in order to mitigate spaceflight-induced motion sickness on a parabolic flight in June 2022. Credits: Zero Gravity Corporation/Tasha Dixon

Changing the Pace of Space

Flight Opportunities provides access to commercial suborbital vehicles and hosted orbital platforms to prepare technologies for the transition to orbit – rapidly expanding space capabilities, lowering risk, and reducing costs.



Rapid Leap from Lab to Orbit

Commercial suborbital and orbital test capabilities de-risking technology for future missions. Technology moves from lab to orbit in <9 months.

Responsive deep space access

Sustained deep space presence

Commercial lunar activity

In-situ resource extraction and utilization

Expanded space commerce

On-orbit manufacturing, assembly, and inspection

On-Demand Missions Beyond Earth

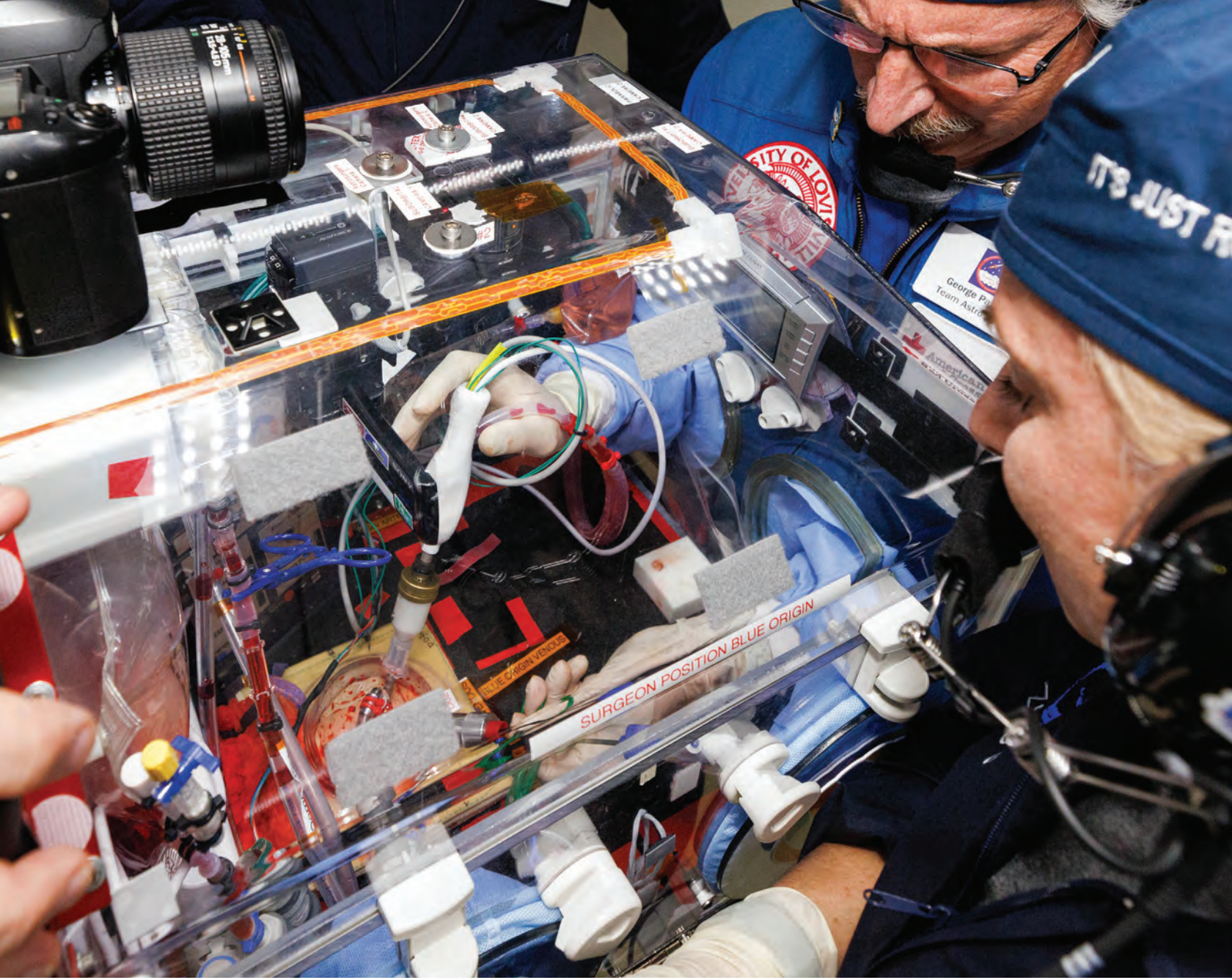
Targeted measurements of Moon, Mars, Venus, and the asteroid belt in response to events and opportunities. Capabilities are competitive with traditional systems but developed for <$30M in <3 years.

Unprecedented Deep Space Infrastructure

Modular communications, navigation, and mission support that provides full coverage of Moon and Mars. Each node costs <$20M to build and deliver to space.

Unparalleled Sensing Capabilities

Networked spacecraft providing multi-kilometer synthetic apertures and massive sensor webs of 30 to 100 spacecraft. Each node costs <$10M to build and deliver to space.



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www.nasa.gov

NP-2022-01-64-AFRC

University of Louisville researchers evaluate a space-based surgical system and medical suction device on a parabolic flight with Zero Gravity Corporation in May 2022. Credits: Zero Gravity Corporation/Steve Boxall