National Aeronautics and Space Administration

SPACE TECHNOLOGY MISSION DIRECTORATE

FLIGHT OPPORTUNITIES

Accomplishments | Fiscal Year 2021

CONTENTS

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.

"My program's work would be years behind where it is now without the repeatable, cost-effective flight testing facilitated by Flight Opportunities."

Dr. H. Todd Smith, Johns Hopkins University Applied Physics Laboratory

Credit: NASA/Lauren Hughes

FY2021 YEAR IN REVIEW

IN FISCAL YEAR 2021, FLIGHT OPPORTUNITIES:

Supported **83** payloads tested in flight

Managed **32** successful flights with commercial flight partners

Selected **36** new space technologies for the program

THE PROGRAM WORKED TO CHANGE THE PACE OF SPACE BY:

Introducing a new competition – the **NASA TechLeap Prize** – to connect with even more non-NASA organizations building space technologies

Supporting development of new flight capabilities for technology demonstrations with commercial flight providers

Increasing access for **small and early-stage organizations** to propose technologies for flight tests

Supporting the transition of impactful technologies to orbital missions

Providing strategic support to NASA technologies and programs and across NASA mission directorates

Facilitating rapid suborbital to orbital testing to help reduce the cost, complexity, and time required to advance the state of the art for small spacecraft

FLIGHT OPPORTUNITIES EXPANDED SUPPORT OF THE SUBORBITAL RESEARCH COMMUNITY WITH:

A new **Community of Practice initiative** to share best practices, lessons learned, and tools of the trade for suborbital flight tests

A **monthly webinar series** to help new researchers learn from seasoned professionals in the field

Regular lessons-learned insights in the **monthly newsletter** from our experienced flight campaign managers

THE PROGRAM HELPED INSPIRE THE NEXT GENERATION OF SPACE PROFESSIONALS BY:

Launching the **NASA TechRise Student Challenge**, giving students the opportunity to build and test a space technology on a suborbital flight

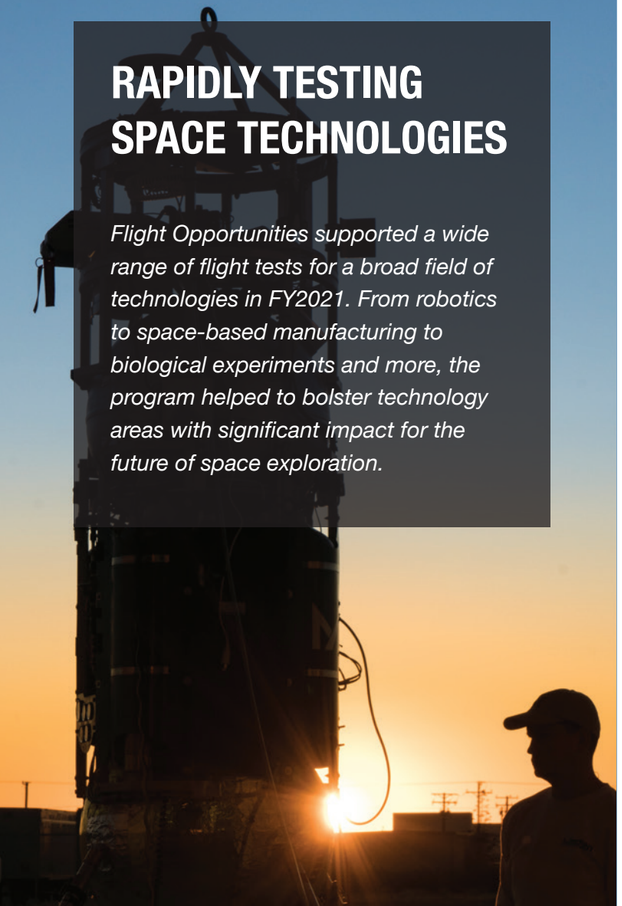
Providing **educational funding** to support university payloads in the annual NASA TechFlights solicitation

Supporting the **NASA CubeSat Launch Initiative** (CSLI) to enable university and high school students to build small spacecraft payloads

FLIGHT HIGHLIGHTS

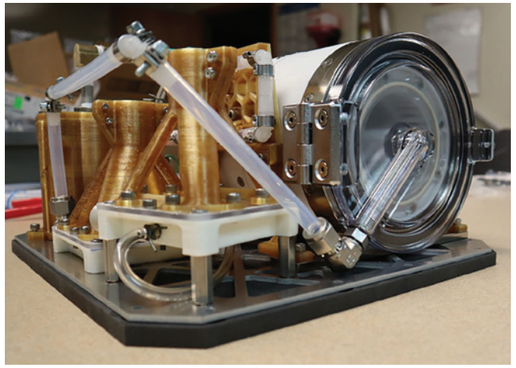
RAPIDLY TESTING SPACE TECHNOLOGIES

Flight Opportunities supported a wide range of flight tests for a broad field of technologies in FY2021. From robotics to space-based manufacturing to biological experiments and more, the program helped to bolster technology areas with significant impact for the future of space exploration.



Credit: Masten Space Systems

Testing Methods for Space-Based Harvesting of Super Foods and More



The microgravity LilyPond was one of several space technologies tested on New Shepard. The growth chamber uses capillary action to provide a stable water surface on which plants can grow. Credit: Space Lab Technologies

DATE AND LOCATION:
October 13, 2020
Van Horn, Texas

TECHNOLOGIES TESTED:
Multiple technologies spanning thermal management, remote sensing, biological research, space-based food production, and more. See pages 12–15 for full list.

FLIGHT VEHICLE:
New Shepard (Blue Origin)

This rocket-powered flight provided testing for a range of innovations for potential space-based use, including a hydroponic chamber for growing edible plants in space. Researchers tested the harvesting method with water lentils, a high-protein crunchy vegetable. These rapidly growing plants could be ideal for space because they do not require soil or other growing media – which means fewer materials, less mass, and less waste for resource-intensive space missions.

Dust on the Moon: Mitigating the Problems, Realizing the Promise

Masten's Xodiac lifts off from a launchpad in Mojave, California, for testing of Flight Opportunities–supported technologies. PlanetVac can be seen attached to the lander leg in the foreground. Credit: Masten Space Systems

DATE AND LOCATION:
November 12, 2020
Mojave, California

TECHNOLOGIES TESTED:
Ejecta STORM (University of Central Florida);
PlanetVac (Honeybee Robotics)

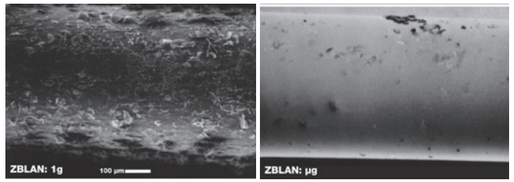
FLIGHT VEHICLE:
Xodiac (Masten Space Systems)

Lunar regolith poses both challenges and opportunities for exploration on the Moon. Among the problems: abrasion to valuable equipment caused by high-velocity regolith disturbances resulting from rocket plumes. Among the opportunities: the ability to send regolith samples from sites of high scientific value back to Earth for analysis. This flight test helped University of Central Florida researchers advance a sensor designed to collect data about the hazards of regolith disturbances. Meanwhile, researchers from Honeybee Robotics continued to mature their PlanetVac device for collecting lunar dust and soil for analysis in advance of a planned 2023 lunar mission.

"When you do a lunar mission, you really get one chance to get the measurements you need. So, you don't want to waste that. You have to do field testing to make sure you've validated all the different aspects of the sensor that you can."

Dr. Philip Metzger, Ejecta STORM principal investigator, University of Central Florida, Orlando

Advancing Innovations for In-Space Manufacturing and More



This scanning electron microscope image shows the surface defects caused by crystallization of ZBLAN fibers pulled on Earth (left) versus in microgravity (right). Flight Opportunities is investing in flight testing of space-based manufacturing methods for ZBLAN fibers to take advantage of the superior end result that may be achieved in space. Credit: NASA's Marshall Space Flight Center

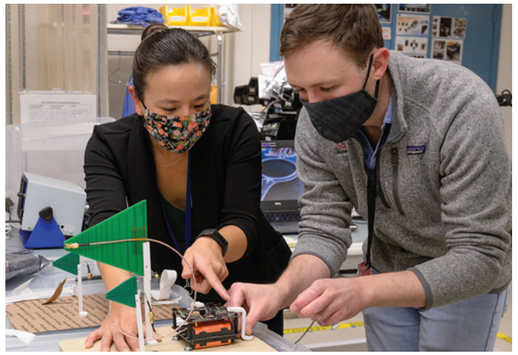
DATES AND LOCATION:
November 12-17 2020
April 28-May 4, 2021
Orlando, Florida

TECHNOLOGIES TESTED:
More than a dozen technologies from industry, academia, and NASA. See pages 12-15 for full list.

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

Space-based manufacturing advances were a highlight of these flight tests, with the goal of helping NASA improve on-site repair capabilities and other challenges of future lunar missions. Manufacturing technologies tested may also help address Earth-based challenges. For example, space-based production of ZBLAN fibers provides a smooth, clear, low-defect result – often superior to manufacturing the fibers on Earth. Flight Opportunities supported three ZBLAN-based technologies through NASA Small Business Innovation Research (SBIR) investments, which included these flight tests. The innovations will next be put to the test in demonstrations on the International Space Station and may ultimately be used for applications including fiber optics, sensors, and laser technologies.

Picking Up the PACE: Accelerating Development of Deep Space Technologies



Anh Nguyen (left), NASA's project manager for the V-R3x mission, and Stanford University's Max Holliday assemble a ground unit in a lab at NASA's Ames Research Center in California's Silicon Valley. Multiple V-R3x ground units tracked the payload aboard the high-altitude balloon during the flight test. Credit: NASA/Dominic Hart

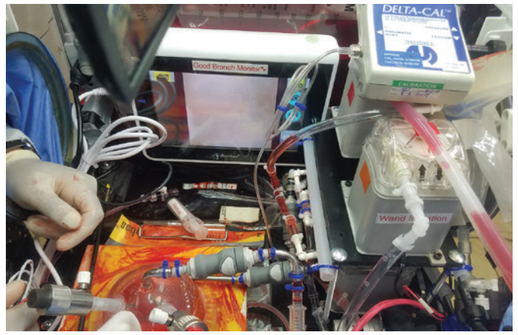
DATE AND LOCATION:
March 12, 2021
Baltic, South Dakota

TECHNOLOGY TESTED:
V-R3x (NASA's Ames Research Center)

FLIGHT VEHICLE:
Zero Pressure Balloon System (Raven Aerostar)

In its first suborbital flight test, NASA's new PACE initiative (see more information on page 19) supported demonstration of V-R3x – a technology designed to provide advanced communication and navigation capabilities among coordinated groups of CubeSats. Data collected on the high-altitude balloon flight will be added to that of an orbital flight test of three V-R3x CubeSats, which launched to space in January 2021. The in-space demonstration aims to enable determination of spacecraft location and distance between satellites in low-Earth orbit. This would support validation of new orbit determination and relative navigation algorithms.

Maturing Technologies Iteratively Through Successive Flight Tests



Automation of a surgical system designed for wound care was tested in space on Virgin Galactic's SpaceShipTwo. On parabolic flights (shown here), the simulated surgical procedure was performed by researchers. Credit: University of Louisville

DATE AND LOCATION:
May 22, 2021
Spaceport America, New Mexico

TECHNOLOGIES TESTED:
Electromagnetic Field Measurements on sRLV (Johns Hopkins University Applied Physics Laboratory); Collisions into Dust Experiment (University of Central Florida); Aqueous Immersion Surgical System (University of Louisville)

FLIGHT VEHICLE:
SpaceShipTwo (Virgin Galactic)

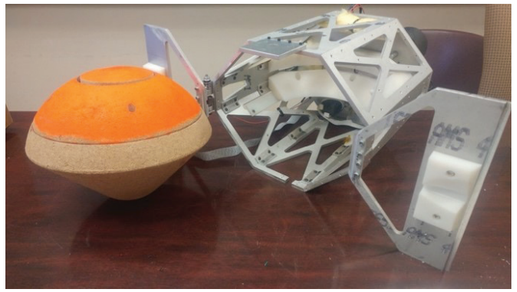
Testing on a rocket-powered space plane provided further advancement for three innovations previously tested through the program:

- Researchers from Johns Hopkins University Applied Physics Laboratory tested the latest version of an electromagnetic field measurement payload designed to collect vital information about environmental conditions inside a spacecraft. The technology could also add to knowledge about exposure to the lower ionosphere at suborbital flight altitudes and its potential impact on spacecraft and equipment.
- University of Central Florida researchers tested a new experiment setup (improved with experience from previous parabolic and rocket flight tests) designed to aid understanding of the behavior of dust and fine particles in response to human and robotic activities on planetary surfaces.
- Researchers from the University of Louisville automated functions for a surgical system designed to facilitate wound care during long-duration missions.

"By facilitating testing on commercial flight vehicles, Flight Opportunities has helped us mature not only our technology but also contribute and share what we've learned with other space medicine researchers and learn from their experiments as well."

Dr. George Pantalos, principal investigator for the Aqueous Immersion Surgical System, University of Louisville

Testing Thermal Protection and In-Orbit Payload Return Capabilities



The KREPE capsule (left) can carry small samples, instruments, and other cargo from low-Earth orbit back to Earth. Its metal enclosure opens to release it at the appropriate altitude. Credit: University of Kentucky

DATE AND LOCATION:
April 15, 2021
Madras, Oregon

TECHNOLOGY TESTED:
Kentucky Re-entry Capsule Experiment (KREPE) (University of Kentucky)

FLIGHT VEHICLE:
Small Balloon System (Near Space Corporation)

A balloon drop test enabled researchers to test a delivery system designed to carry research samples and other small payloads from the International Space Station back to Earth. Outfitted with a thermal protection system, the KREPE capsule is designed to survive re-entry into Earth's atmosphere and could also one day deliver small payloads to Mars or other celestial bodies with harsh atmospheric entry conditions. The balloon test was an important step in preparing the technology for testing as part of Northrup Grumman's NG-16 station resupply flight.

Assessing Methods for Improving Turbulence Detection

The HiDRON stratospheric glider from Stratodynamics is seen over New Mexico on June 6, 2021. Credits: Stratodynamics, Inc./UAVOS

DATES AND LOCATION:
June 1-6, 2021
Spaceport America, New Mexico

TECHNOLOGY TESTED:
Forward-Sensing Turbulence Detection Strategies (University of Kentucky, NASA's Langley Research Center)

FLIGHT VEHICLE:
HiDRON stratospheric glider (Stratodynamics)

A series of flights on a stratospheric glider enabled researchers to assess the performance of a wind probe and infrasonic microphone sensor. Together, the instruments are designed to improve turbulence detection capabilities for remote-piloted and autonomous aerial vehicles, including commercial aircraft and on-demand delivery drones. They may also be applicable to suborbital and low-Earth orbit vehicles. Launched from a high-altitude balloon, the glider enabled the instruments to capture wind velocity, direction, magnitude, and low-frequency sound waves in a flight environment not possible with conventional balloon-borne wind measurements.

Looking to the Clouds to Improve Climate Models on Other Planets – and Here on Earth

Raven Aerostar's Zero Pressure Balloon System is inflated for a launch to carry the NephEx payload on June 11, 2021. Credit: Raven Aerostar

DATE AND LOCATION:
June 11, 2021
Baltic, South Dakota

TECHNOLOGY TESTED:
NephEx (NASA's Ames Research Center)

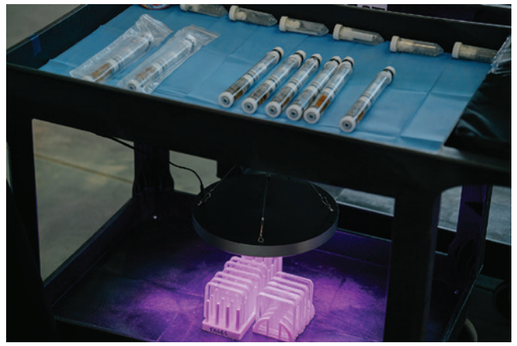
FLIGHT VEHICLE:
Zero Pressure Balloon System (Raven Aerostar)

This flight test enabled researchers to assess a new nephelometer called NephEx, a sensor that measures light scattering by airborne particles, including cloud droplets and ice particles. The device is designed to provide information about a cloud's water content as well as its impact on a planet's atmosphere or thermal and radiation environments. NephEx could also supplement common techniques for cloud and climate monitoring, such as remote sensing via satellite. The high-altitude balloon flight provided an important step in maturing the technology and assessing its capabilities to measure the size, concentration, and distribution of cloud particles – data critical to understanding the impact of clouds on a planet's climate.

"These launches are affordable and accessible and allow us to take important, iterative steps in the technology's development in an environment directly applicable to the way the technology would ultimately be deployed. They give us a lot of practice and learning quickly to ultimately arrive at a better final product."

Dr. Anthony Colaprete, NASA's Ames Research Center

Supporting the First Crew-Tended Experiment on a Suborbital Flight



Arabidopsis thaliana *plants are shown in Virgin Galactic's hangar under fluorescent lighting (below) and prepared in Kennedy Fixation Tubes (above) for a crew-tended experiment on SpaceShipTwo. Credit: University of Florida*

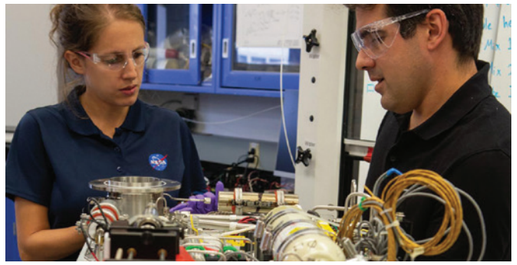
DATE AND LOCATION:
July 11, 2021
Spaceport America, New Mexico

TECHNOLOGY TESTED:
Space Plants (University of Florida)

FLIGHT VEHICLE:
SpaceShipTwo (Virgin Galactic)

In its first fully crewed spaceflight, Virgin Galactic carried a Flight Opportunities–supported biological experiment. A company crew member operated the space plants experiment on behalf of researchers from the University of Florida in Gainesville. Three plant-filled tubes were activated to release a preservative at critical data-collection stages during flight: at 1 *g* before the rocket boost, just before entering microgravity, and after the conclusion of microgravity. Researchers plan to use the data to assess the state of the plants at the cellular level at each stage of gravity as well as to better understand research opportunities for human-tended payloads.

Advancing a Method to Recycle Space Trash



OSCAR principal investigator Annie Meier (left) and team member Jamie Toro assemble the flight hardware for NASA's OSCAR in the Space Station Processing Facility at the agency's Kennedy Space Center in Florida. Note: This photo was taken prior to the onset of the COVID-19 pandemic. Credit: NASA

DATE AND LOCATION:
August 26, 2021
Van Horn, Texas

TECHNOLOGIES TESTED:
Six technologies spanning propellant gauging, biological research, regolith observations, space-based recycling, and more. See pages 12-15 for full list.

FLIGHT VEHICLE:
New Shepard (Blue Origin)

Among the technologies on this suborbital flight was a trash-to-gas conversion innovation called the Orbital Syngas/Commodity Augmentation Reactor (OSCAR), designed to convert trash and metabolic waste into a blend of useful gases, including carbon dioxide, water vapor, and methane. Astronauts could vent the generated gas into space or use it as building blocks for products such as water, oxygen, or even spacecraft propellants. This recycling technology could reduce the volume and mass of trash on long-duration missions, minimize launch mass from Earth, and promote sustainable human space exploration. The flight enabled early-career researchers to collect data to help validate OSCAR's conversion technologies and also added to thermal process data collected on the technology's first suborbital flight.

Validating a Moon-Bound Computing System Ahead of Its Lunar Debut

Flights on Raven Aerostar's Thunderhead Balloon System provided the latest testing for RadPC in advance of a lunar mission. Credit: Montana State University

DATES AND LOCATION:
July 27-28 and September 22-24, 2021
Sioux Falls, South Dakota

TECHNOLOGY TESTED:
RadPC (Montana State University)

FLIGHT VEHICLE:
Thunderhead Balloon System (Raven Aerostar)

Two high-altitude balloon flights enabled researchers to test a radiation-tolerant computing system called RadPC. The innovation is designed to replace failed processors in real time – and testing was needed to make sure the computing system can withstand the high-energy radiation particles emitted by the Sun and other celestial bodies. During more than 80 hours of flight time, researchers tested the computing technology against more than 3,000 injected system faults; the RadPC recovered from all of them successfully. The flights added to data collected during many other suborbital flights facilitated by Flight Opportunities, including sounding rocket and other balloon flights. The testing and validation were also critical preparation for a planned 2023 lunar demonstration of RadPC, which will enable assessment of its functionality for long-duration space missions.

"There would have been no chance of us achieving [the lunar mission infusion] without Flight Opportunities. There's simply no way you can get into these types of orbital missions unless you have flight heritage and you've shown through flight testing that you've actually taken the steps to understand how to build the systems NASA needs."

Dr. Brock LaMeres, principal investigator for RadPC, Montana State University

TECHNOLOGIES TESTED IN FY2021

Flight Date	Flight Provider	Flight Vehicle	Principal Investigator	Organization	Technology Name
Oct. 2, 2020	AM0CAL	High-Altitude Balloon	Justin Lee	The Aerospace Corporation	T0177: Rapid Calibration of Space Solar Cells in Suborbital Environments
Oct. 13, 2020	Blue Origin	New Shepard	H. Todd Smith	Johns Hopkins University Applied Physics Laboratory	T0022: Environment Monitoring Suite on Suborbital Reusable Launch Vehicle
			Franklin Robinson	NASA's Goddard Space Flight Center	T0173: Flow Boiling in Microgap Coolers - Embedded Thermal Management for Space Applications
			Charles Hibbitts	Johns Hopkins University Applied Physics Laboratory	T0217: Integrated Remote Imaging System (IRIS)
			Christine Escobar	Space Lab Technologies	T0220: Microgravity Investigation for Thin Film Hydroponics
			W. Kent Tobiska	Space Environment Technologies	T0221: ARMAS Suborbital
			Daniel Durda	Southwest Research Institute — Boulder	T0225: Box-of-Rocks Experiment II: Morphology and Sampling of Asteroid Regolith Simulants in Microgravity
			Kevin Supak	Southwest Research Institute — San Antonio	T0227: Microgravity Testing of a Large-Scale Liquid Acquisition Device for Cryogenic Fluid Management
			Robert Ferl	University of Florida	T0239: Biological Imaging in Support of Suborbital Science (FLEX)
			John M. Carson	NASA's Johnson Space Center	T0269: Safe and Precise Landing Integrated Capabilities Evolution (SPLICE)
Nov. 12, 2020–Nov. 17, 2020	Zero Gravity Corporation	G-Force One	Michael Menze	University of Louisville	T0209: Evaluation of Preserved Blood for Transfusion Therapy in Reduced Gravity
			Gregory Whiting	University of Colorado Boulder	T0245: Viability of In-Situ Lunar Manufacturing of Life Support Systems Using a Direct Writing Technique
			Konstantinos Sierros	West Virginia University	T0212: 3D Printing of Hierarchical Foams in Microgravity
			Kevin Crosby	Carthage College	T0218: Magneto-Active Slosh Control System for Spacecraft and Launch Vehicles
			Sridhar Gorti	NASA's Marshall Space Flight Center	T0252: Parabolic Flight Demonstration of Fluid Dispensing Tube Performance Limits for Drop Delivery
			Daniel Marshall	Mercury Systems	T0268: Orbital Fiber Optic Production Module (ORFOM)
			Chung-Lung Chen	University of Missouri	T0211: Electrowetting Enhanced Dropwise Condensation in the Zero-g Environment
			Kevin Crosby	Carthage College	T0229: Propellant Mass Gauging in Gateway Architecture Vehicles
			Mircea Badescu	NASA's Jet Propulsion Laboratory	T0248: Microgravity Testing of the Dual Rasp Sampling Tool/System
			Kasthuri Venkateswaran	NASA's Jet Propulsion Laboratory	T0249: Parabolic Flight Test of the Microgravity Tolerant Instrument for Automated Nucleic Acid Extraction (uTitan)
Nov. 12, 2020	Masten Space Systems	Xodiac	Kris Zacny	Honeybee Robotics	T0226: PlanetVac-Xombie2: Honeybee PlanetVac on the Masten Lunar Lander
			Philip Metzger	University of Central Florida	T0242: Maturing Ejecta STORM for Lunar Delivery
			Kris Zacny	Honeybee Robotics	T0253: Increasing Fidelity for Lunar Sample Collection
Mar. 12, 2021	Raven Aerostar	Zero Pressure Balloon System	Zachary Manchester	NASA's Ames Research Center	T0259: V-R3x - CubeSat Cross-Link, Ranging, and Coordinated Measurement Technology Demonstration for Future Distributed CubeSat Swarm Missions
Apr. 15, 2021	Near Space Corporation	Small Balloon System	Alexandre Martin	University of Kentucky	T0214: Technology Demonstration of the KREPE Capsule for Heat-Shield Validation

Flight Date	Flight Provider	Flight Vehicle	Principal Investigator	Organization	Technology Name
April 28, 2021–May 4, 2021	Zero Gravity Corporation	G-Force One	Amir Hirsa	Rensselaer Polytechnic Institute	T0219: Adapting the Ring-Sheared Drop (RSD) Technology as a Bioreactor
			Srihar Gorti	NASA's Marshall Space Flight Center	T0252: Parabolic Flight Demonstration of Fluid Dispensing Tube Performance Limits for Drop Delivery
			David Miles	University of Iowa	T0207: CubeSat Articulated Boom Option Optimization in Microgravity (CABOOM)
			Gregory Whiting	University of Colorado Boulder	T0245: Viability of In-Situ Lunar Manufacturing of Life Support Systems Using a Direct Writing Technique
			Kevin Crosby	Carthage College	T0191: Microgravity Propellant Gauging Using Modal Analysis: Phase III
			Michael Menze	University of Louisville	T0209: Evaluation of Preserved Blood for Transfusion Therapy in Reduced Gravity
			Stephen Caskey	Air Squared	T0263: Vapor Compression Refrigeration System for Cold Food Storage on Spacecraft
			Mark Pankow	North Carolina State University	T0228: Composite Origami for Spacecraft Solar Arrays and Deployable Structures
			George Pantalos	University of Louisville	T0287: Preparations for a Suborbital Evaluation of a Human Tended Surgical Fluid Management System
			Steven Collicott	Purdue University	T0206: Small-Sat Propellant Management Technology
			Kevin Crosby	Carthage College	T0229: Propellant Mass Gauging in Gateway Architecture Vehicles
			Alicia Carey	Redwire	T0284: Glass Alloy Manufacturing Machine - Acoustic Levitation Furnace (GAMMA-ALF)
			Joseph Paradiso	Massachusetts Institute of Technology	T0286: Autonomous Robot Swarms for Lunar Orbit Servicing and Space Asset Assembly
May 22, 2021	Virgin Galactic	SpaceShipTwo	H. Todd Smith	Johns Hopkins University Applied Physics Laboratory	T0015: Electromagnetic Field Measurements on sRLV
			Josh Colwell	University of Central Florida	T0036: Collisions into Dust Experiment on a Commercial Suborbital Vehicle
			George Pantalos	University of Louisville	T0155: Suborbital Evaluation of an Aqueous Immersion Surgical System for Reduced Gravity
Jun. 1–6, 2021	Stratodynamics	HiDRON	Sean Bailey	University of Kentucky	T0235: Assessment of Forward Sensing Turbulence Detection Strategies for Stratospheric Flight
Jun. 11, 2021	Raven Aerostar	Zero Pressure Balloon System	Anthony Colaprete	NASA's Ames Research Center	T0260: Nephelometer Experiment (NephEx)
Jul. 11, 2021	Virgin Galactic	SpaceShipTwo	Robert Ferl	University of Florida	T0201: Human Tended Space Biology: Enabling Suborbital Genomics and Gene Expression
July 27–28, 2021; Sept. 22–24, 2021	Raven Aerostar	Thunderhead Balloon System	Brock LaMeres	Montana State University	T0233: RadPC@Scale - Suborbital Flight Demonstration of a Radiation Tolerant Computer System at Scale
Aug. 11, 2021	UP Aerospace	SpaceLoft	Arwen Dave	NASA's Ames Research Center	T0142: Affordable Vehicle Avionics
Aug. 26, 2021	Blue Origin	New Shepard	Kevin Supak	Southwest Research Institute — San Antonio	T0227: Microgravity Testing of a Large-Scale Liquid Acquisition Device for Cryogenic Fluid Management
			Kevin Crosby	Carthage College	T0229: Propellant Mass Gauging in Gateway Architecture Vehicles
			Adrienne Dove	University of Central Florida	T0243: Exploring Electrostatic Regolith Interactions in Low-Gravity
			Annie Meier	NASA's Kennedy Space Center	T0247: Orbital Syngas Commodity Augmentation Reactor (OSCAR)
			John M. Carson	NASA's Johnson Space Center	T0269: Safe and Precise Landing Integrated Capabilities Evolution (SPLICE)

TECHNOLOGY TRANSITIONS AND MISSION INFUSIONS

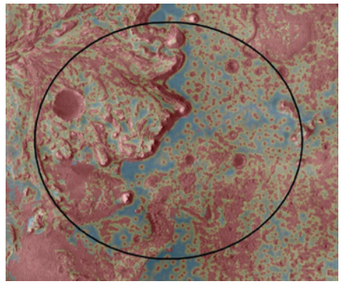
ADVANCING TECHNOLOGIES TO SPACE MISSIONS

From the International Space Station to the Moon, Mars, and beyond, infusion into space-based missions is a significant milestone for innovations tested and matured through Flight Opportunities. In FY2021, several Flight Opportunities–supported innovations transitioned to further testing on orbit or as part of major planetary missions.

Credit: NASA

Maturing the Lander Vision System for NASA's Mars Perseverance Rover

NASA's Lander Vision System (LVS) is based on a terrain-relative navigation (TRN) and hazard avoidance system that photographs the surface beneath a descending spacecraft and matches it with onboard maps to determine vehicle location while also looking for unmapped hazards. Thanks in part to Flight Opportunities–supported testing on vehicles from Masten Space Systems, the technology was infused into NASA's Mars 2020 mission and played a critical role in the successful landing of the Perseverance rover on February 18, 2021. The LVS was used to guide the rover to a safe landing site at Jezero Crater – a scientifically interesting but geographically challenging stretch of terrain on the Red Planet.



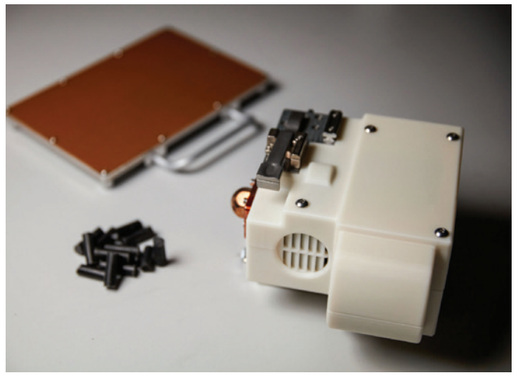
The Mars 2020 Perseverance rover relied on data depicted in this hazard map to help guide it to a safe landing. Safer landing areas are colored blue and green. To select the best location to touch down while avoiding damage to the rover, the spacecraft's TRN-based system took images of the terrain below during Perseverance's descent. Credit: NASA

"The testing that Flight Opportunities is set up to provide has proven so valuable that it's now becoming expected to do these types of flight tests. For LVS, those rocket flights were the capstone of our technology development effort."

Dr. Andrew Johnson, principal robotics systems engineer, NASA's Jet Propulsion Laboratory

Preparing Technologies for the International Space Station

Several experiments matured in part through Flight Opportunities testing made their way to the International Space Station in FY2021 aboard Northrop Grumman's NG-16 Cygnus spacecraft. The following were among the experiments that astronauts will conduct on the station.



A preflight view of the RRP suite, which arrived at the station aboard NG-16. The suite includes print heads, plates, and lunar regolith simulant feedstock. Credit: Redwire Space

3D PRINTING WITH LUNAR REGOLITH

A 3D printing project from Redwire Space is helping to advance practices for in-situ resource utilization for additive manufacturing of parts, tools, and structures on the lunar surface. Astronauts will use the station's Made In Space Additive Manufacturing Facility (made possible in part through early testing with Flight Opportunities) to demonstrate the Redwire Regolith Print (RRP) 3D printing suite as well as use of a regolith simulant as the feedstock.

STUDYING THE ROLE OF DESTRUCTIVE PROTEIN CLUSTERS IN NEURODEGENERATIVE DISEASES

The ring-sheared drop (RSD) experiment from Rensselaer Polytechnic Institute and NASA's Marshall Space Flight Center aims to help researchers understand the formation of potentially destructive protein clusters and their role in neurodegenerative diseases, including Alzheimer's and Parkinson's. Current work on the station will pick up from a previous version of the experiment that encountered operational challenges. The research team leveraged parabolic flights supported by Flight Opportunities, which were instrumental to returning the experiment to the station with high confidence of success.

"The April 2021 flight proved that our modified hardware is capable of deploying and pinning each of the protein solutions that we planned to use on the station. That experiment design resulted in successful deployments for each flight fluid experiment performed on the International Space Station during operations over the past several months."

Dr. Louise Strutzenberg, co-investigator for the RSD flight demonstration of Fluid Dispensing Tube Performance Limits for Drop Delivery, NASA's Marshall Space Flight Center

NEW TECHNOLOGY SELECTIONS

CHANGING THE PACE OF SPACE

From the solicitation of new technologies to the capabilities of program flight providers, Flight Opportunities continues to evolve to ensure its flight tests have far-reaching impact.

Credit: Blue Origin

TechLeap: A New Competition Approach

Announced in June 2021, the new NASA TechLeap Prize invited commercial businesses, academic institutions, entrepreneurs, and other innovators to compete for payload development funding and access to suborbital flight testing for innovative space technologies. Winning teams in the first challenge, Autonomous Observation Challenge No. 1, will develop and test payloads to help rapidly advance small spacecraft technologies for autonomous observation of events on Earth and beyond as well as to improve communications and computing power in small spacecraft applications.

The winning teams are:

- **The Bronco Space Club at Cal Poly Pomona (Pomona, California)**
  The team's Bronco Ember technology is designed to autonomously detect, track, and log terrestrial phenomena, such as wildfires.
- **Orion Labs, LLC (Nunn, Colorado)**
  The company plans to demonstrate the capabilities of quantum machine learning aboard a small spacecraft to reduce downlink bandwidth requirements.
- **Texas A&M University SEAK Lab (College Station, Texas)**
  The team plans to develop a system using visible and infrared imaging to identify and classify plumes in Earth's atmosphere automatically.

NASA TechLeap PRIZE

Support for Other NASA Programs and Technologies

In FY2021, Flight Opportunities continued to strengthen connections with a wide range of other NASA programs, providing access to suborbital flight tests to help advance the technology readiness of high-value innovations and prepare them for infusion in NASA missions. Highlights of this program support included:

- **Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR)**
  Flight Opportunities is investing in technologies funded by NASA's SBIR and STTR programs, providing suborbital flight testing to help mature these innovations.
- **International Space Station Research Integration Office**
  Support for suborbital testing of many innovations enables the technology advancement necessary for further demonstration on the International Space Station.
- **Payload Accelerator for CubeSat Endeavors (PACE)**
  Targeting at least one flight every 6 to 9 months, this initiative with NASA's Small Spacecraft Technology program aims to rapidly de-risk technologies via a combination of suborbital and orbital flight tests.
- **Game Changing Development**
  Flight tests for this program help bolster its mission to advance space technologies that may lead to entirely new approaches for NASA's future space missions and provide solutions to significant national needs.
- **Technology Demonstration Missions**
  Flight tests for this initiative help address its goal of bridging the gap between scientific and engineering challenges and the technological innovations needed to overcome them. The effort also supports early proof-of-concept tests and infusion of cost-effective, revolutionary new technologies into NASA, government, and commercial space missions.
- **Science Mission Directorate (SMD) Programs**
  Flight Opportunities increased collaboration with SMD programs in FY2021, including support for the Earth Science and Technology Office (ESTO), Payloads and Research Investigations on the Surface of the Moon (PRISM), and Research Opportunities in Space and Earth Sciences (ROSES).

"The PACE flight campaign for V-R3x was a success and could not have been completed without the Space Technology Mission Directorate and Flight Opportunities. The insight, knowledge, commercial partnerships, and oversight that the program provides are truly invaluable."

Dr. Anh Nguyen, project manager for PACE, NASA's Ames Research Center

FY2021 Technology Selections

NASA, industry, and academic technologies selected in FY2021 for future testing on suborbital vehicles

NASA'S AMES RESEARCH CENTER

Fluidic Telescope Experiment (FLUTE)

A method for developing fluidic optical components in microgravity conditions for use in space telescopes

Potential Impact: Advances in space-based astronomy using large fluidic components in place of lenses and mirrors, which could reduce costs, construction time, and failure risk

Lawn Dart Terrestrial Demonstration

Remote delivery of security commodities (e.g., communication, navigation, situational awareness/sensing, power) to the lunar surface, sponsored by the Air Force Research Laboratory

Potential Impact: Enabling publish-and-subscribe capabilities to civil, commercial, security, and allied consumers for safe operation in the lunar environment

NASA'S KENNEDY SPACE CENTER

Microgreens Root Zone/Shoot Zone Partitioned Planting Box

A harvesting system designed to distinguish between water loss from two parts of a plant, enabling safety testing of an entire crop canopy rather than just one plant at a time

Potential Impact: Growth of nutrient-dense crops to serve as a dietary supplement in space

Electrostatic Dust Lofting via Photoionization Under Artificial Lunar Gravity

Photoionization of lunar regolith grains, enabling observation of their electrostatic repulsion via high-speed imagery

Potential Impact: Validation of models used to predict how electrostatically charged dust may impact lunar missions, including risks to mechanical, thermal, and electronic systems

Electrodynamic Regolith Conveyor

A dust-tolerant technology designed to move lunar regolith particles with the use of generated dynamic electric fields rather than conventional rotating or vibrating actuation

Potential Impact: Use in future in-situ resource utilization operations on the Moon

Vibratory Lunar Regolith Conveyor

Technology that takes advantage of a "stick-slip" phenomenon to overcome static friction to convey granular materials up an inclined surface

Potential Impact: Improved methods for vertical transport of regolith for future lunar missions

In-Situ Resource Utilization Pilot Excavator Bucket Drum Flow

A regolith collection method that relies on bucket drum excavation technology with simultaneous opposing rotations to counteract excavation forces

Potential Impact: Use on the Moon and planetary bodies to enable digging with low-mass robotic excavators

Propellant Mass Gauging with Electrical Capacitance Tomography (ECT)

An ECT system designed to track propellant distribution in real time and previously shown to work during slosh and boiling in 1 *g*

Potential Impact: Improved mass gauging accuracy for launch vehicle and propellant tanks, decreasing risk and boosting performance

NASA'S GLENN RESEARCH CENTER

Material Flammability in Lunar Gravity

Burn tests to assess the flammability of solid materials in lunar and Martian gravity, designed to provide rating guidance for the many materials anticipated to be used on the Moon and Mars

Potential Impact: Crucial understanding of the impact of material flammability on spacecraft and habitat safety for deep space exploration missions

Lunar-*g* Transport of Dust Liberated from Spacesuit Fabric

An experiment leveraging ClothBot – a mechanical apparatus designed to autonomously stretch, shear, and crumple a patch of spacesuit material in a controlled manner to shed dust particles from the material

Potential Impact: Validation and refinement of numerical dust models for space-based habitats

NASA'S JET PROPULSION LABORATORY

Multiphase Microfluidics for Chemical Analysis Systems

Multiphase reservoirs for sample mixing and bubble migration, featuring a high-voltage electric field and apparatus shapes to help drive the gas phase to a desired location and prevent bubbles from blocking outlet/inlet channels

Potential Impact: Insight into the occurrence of unexpected phase behavior

Soil Properties Assessment, Resistance, and Thermal Analysis (SPARTA)

A versatile, miniature, multi-tool instrument designed to provide in-situ measurements of regolith densities as well as geomechanical, thermal, electrical, and chemical properties of dry or icy soils and permafrost on planetary surfaces

Potential Impact: Enabling fundamental measurements needed for in-situ resource utilization on the lunar surface

NASA'S JOHNSON SPACE CENTER

Hermes LunarG

Lunar dust mitigation and regolith characterization experiments, including use of flight-proven hardware tested on the International Space Station, lunar simulants released during lunar gravity, and cameras for data collection

Potential Impact: Improvement in dust mitigation methods needed for lunar exploration

NASA'S MARSHALL SPACE FLIGHT CENTER

Project Duneflow

Direct characterization and comparison of both old and new regolith simulants under a lunar gravity field

Potential Impact: Advancements in manufacturing of geotechnical simulants, leading to better testing of excavation and regolith conveyance systems

AUBURN UNIVERSITY

Three-Dimensional Plume-Surface Interaction and Crater Formation Dynamic Measurements

Novel, non-intrusive stereo imaging to analyze the time-resolved, 3D crater-formation process in reduced- and lunar-gravity environments

Potential Impact: Improvements in modeling accuracy for assessing the risk of lunar dust and debris during future Moon landings

CREARE

Lightweight, Hybrid Screen-Channel Device for Advanced Cryogenic Fluid Management

A device designed to rapidly transfer cryogenic liquids across a wide range of operating conditions while preventing vapor ingestion into the transfer pump

Potential Impact: Improvements to current fuel transfer methods, making existing spacecraft suitable for long-duration missions

FOMS

Space Fibers 3 Preflight

A system designed to enable fully automated manufacturing of optical fiber

Potential Impact: Deployment on the International Space Station (planned for 2022), paving the way for space-based industrial processing of unique, high-value materials such as ZBLAN optical fibers

HEETSHIELD

Thermal Protection for Hypersonic Missions

Insulation materials designed for tight folding and easy storage, with the capability to alleviate two primary modes of heat transfer: radiation and gas conduction

Potential Impact: Improved performance and reduction in bulk for thermal protection systems on planetary entry vehicles

IOWA STATE UNIVERSITY

3D Printing of Flexible Electronics for In-Space Manufacturing

A 3D printing technology based on electrohydrodynamic inkjet printing using electrical fields and forces

Potential Impact: Space-based fabrication of sensors and electronics

OKLAHOMA STATE UNIVERSITY

Ionizing Radiation Dosimeters for Use in the Upper Atmosphere

Evaluation of potential degradation to the signal quality of various dosimeters caused by rocket vibration

Potential Impact: Improved dosimeter designs and validation of computer models for ionizing radiation

REDWIRE SPACE

Vulcan Advanced Hybrid Manufacturing System

A multi-material manufacturing system for in-orbit, lunar, and Martian operations designed to autonomously produce component parts out of multiple metals and polymers in variable gravity

Potential Impact: Enabling reliable in-situ supply of replacement parts and structures to meet changing exploration mission needs

SPACE FOUNDRY

Plasma Jet Printing for In-Space Manufacturing

A plasma jet printing system designed for microgravity with the aim of reducing post-processing and ink dependency for production of a wide range of devices, particularly electronics

Potential Impact: On-demand fabrication of products needed for long-duration crewed missions and acceleration of low-Earth orbit commercialization

UNIVERSITY OF CALIFORNIA, SANTA BARBARA

Root-Like Burrowing Device

A pneumatic tip-extending device with self-anchoring and burrowing capabilities

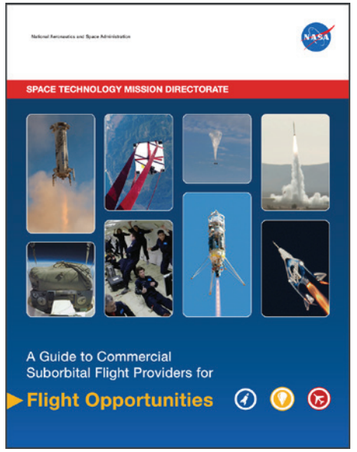
Potential Impact: Enabling delivery of subsurface sensors deep under planetary surfaces

Raven Aerostar's high-altitude balloon is inflated the morning of its March 12, 2021, flight to test NASA's V-R3x technology in Baltic, South Dakota – an effort made possible by the agency's new PACE initiative. Read more about the flight on page 6. Credits: Raven Aerostar

SUPPORT FOR VEHICLE CAPABILITY ENHANCEMENTS

Flight Opportunities continually seeks to expand options for flight testing, through both new vehicle capabilities and test regimes. Made possible through contracts, Space Act Agreements, and purchase of payload space, activities in FY2021 included support for:

- **Masten Space Systems**
  Expansion of testing capabilities for spacecraft navigation and landing systems through development of the Xogdor vehicle
- **Rocket Lab**
  Exploration of re-entry and recovery capabilities for the company's small launch vehicles
- **Blue Origin**
  Capabilities for lunar gravity environments on the New Shepard rocket-powered vehicle
- **UP Aerospace**
  Development of Spyder Orbital to include high-altitude parabolas via the rocket's first stage, advance high-performance propulsion capabilities for dedicated small payload launches for orbital missions, and achieve planetary re-entry test environments



Download our Guide to Commercial Suborbital Flight Providers to learn more about the flight vehicles available to Flight Opportunities-supported researchers:

https://go.nasa.gov/3mqWbFq

EDUCATIONAL OUTREACH

INSPIRING THE NEXT GENERATION

In FY2021, Flight Opportunities continued support for flight tests of university payloads and field experience for student researchers, and introduced a new student competition as well. Through these resources, the program provides valuable, hands-on field experience to those looking toward careers in science, technology, and space exploration.

Credit: UP Aerospace

TechRise: A New Student Competition for Suborbital Flight Testing

In its first year, NASA's new TechRise Student Challenge invited teams of sixth- to twelfth-grade students to design, build, and launch experiments on suborbital rockets and balloon flights during the 2021–2022 school year.

The contest aims to inspire deeper understanding of:

- Earth's atmosphere
- Space exploration
- Coding and electronics
- The value of test data

Participants submitted ideas for research related to a wide range of areas, including:

- Climate
- Remote sensing
- Space exploration

Winning teams receive:

- $1,500 to build their payloads
- An assigned spot on a NASA-sponsored commercial high-altitude balloon or suborbital rocket flight
- Opportunities for engagement with NASA and technology communities
- Exposure to potential careers in science, technology, and space exploration

Educational Opportunities with TechFlights

NASA's annual TechFlights solicitation continues to provide an option to fund educational activities conducted as part of suborbital flight tests. This support provides university students with hands-on experience developing and testing space technologies. They also gain real-world field experience with the planning and logistics that go into a full flight campaign, alongside professionals in the field.

Researchers from University of Colorado Boulder leveraged parabolic flights to test a direct writing technique that could be used for in-situ lunar manufacturing of life support systems. Note: Flight participants were required to provide proof of vaccination or negative COVID-19 test results prior to flight. Credit: Zero Gravity Corporation/ Steve Boxall

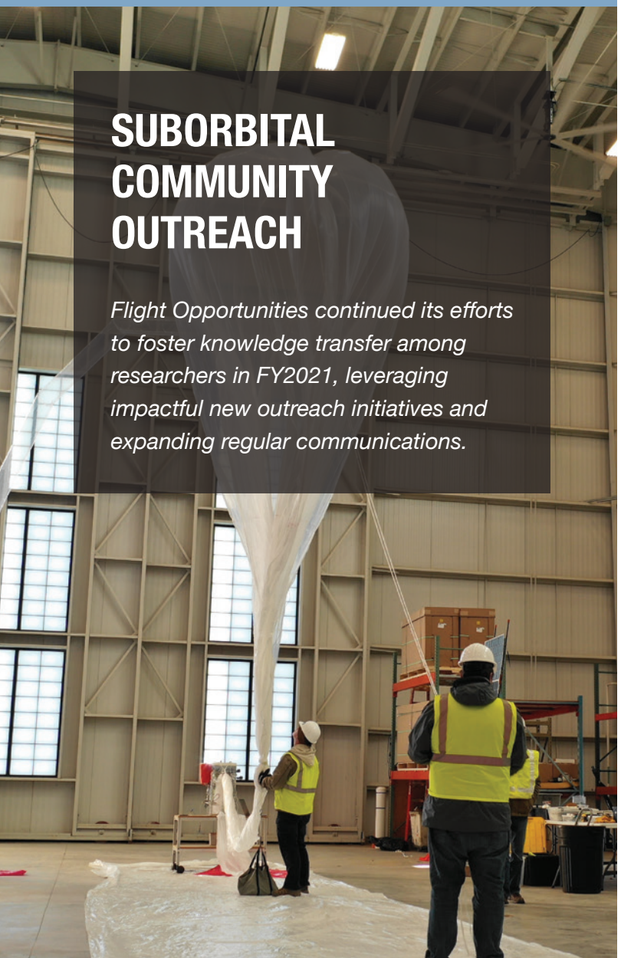
"This was the first time our student group experienced a flight project like this, and we learned so much from the other research teams on the flight, from our Flight Opportunities campaign manager, and from our flight provider. Even though we had a big learning curve, these flights were a huge success."

Dr. Gregory Whiting, University of Colorado Boulder

Support for NASA's CubeSat Launch Initiative (CSLI)

CSLI provides another avenue for university and high school students as well as non-profit organizations to gain exposure to orbital flight testing – and Flight Opportunities continued to support testing for CSLI payloads in FY2021. High school and college students can access low-cost opportunities to conduct scientific investigations and technology demonstrations in space. The initiative enables students, teachers, and faculty to obtain hands-on flight hardware development experience with CubeSats.

SUPPORTING RESEARCHERS



SUBORBITAL COMMUNITY OUTREACH

Flight Opportunities continued its efforts to foster knowledge transfer among researchers in FY2021, leveraging impactful new outreach initiatives and expanding regular communications.

Credit: Stratodynamics

Community of Practice: Conversation, Best Practices, and Lessons Learned

Introduced in early FY2021, the new Community of Practice initiative is designed to increase engagement, knowledge transfer, resource sharing, and dissemination of lessons learned among program-supported investigators and organizations. Resources include a monthly webinar series featuring moderated conversations with researchers alongside program personnel and representatives from flight providers. Attendees include other program-supported researchers, who learn flight testing best practices, as well as researchers interested in proposing technologies to the program. Participants come away with a better understanding of how to submit a technology of value to NASA and the space industry and conduct effective flight tests.

The monthly Community of Practice webinar series features conversations with Flight Opportunities personnel and researchers to share information, resources, and knowledge about suborbital flights. Credit: NASA

Monthly Newsletter: Flight News, Events, Opportunities, and More

Flight Opportunities continued its monthly newsletter, reaching over 2,500 members of the space community, including investigators, flight providers, and industry enthusiasts. Expanded content in FY2021 included:

- A lessons-learned column to support researchers new to suborbital flights
- News about vehicle availability and capability enhancements
- NASA program opportunities for funding of technology development and/or testing
- Information about NASA prizes and competitions

"The flights helped us uncover many things that we had not encountered in our ground-based testing, resulting in very important lessons learned. The results are helping us optimize both our design and our thinking."

- Dr. Chung-Lung Chen, principal investigator for the Electrowetting Enhanced Dropwise Condensation Experiment, University of Missouri

Subscribe to the Flight Opportunities newsletter to keep up with the latest program news and learn about upcoming Community of Practice webinars and events:

https://bit.ly/3Cy5pFC

ACTIVE TECHNOLOGY PORTFOLIO

#	Principal Investigator	Organization	Technology Name	NASA Taxonomy
3	Sathya Gangadharan	Zero-G Horizons Technologies	Investigation to Determine Rotational Stability of On-Orbit Propellant Storage and Transfer Systems Undergoing Operational Fuel Transfer Scenarios	TX01: Propulsion Systems
15	H. Todd Smith	Johns Hopkins University Applied Physics Lab (APL)	Electromagnetic Field Measurements on Suborbital Reusable Launch Vehicles (sRLV)	TX08: Sensors and Instruments
22	H. Todd Smith	Johns Hopkins University APL	Environment Monitoring Suite on sRLV	TX08: Sensors and Instruments
23	Sean Casey	Silicon Valley Space Center	Measurement of the Atmospheric Background in the Mesosphere	TX08: Sensors and Instruments
36	Josh Colwell	University of Central Florida	Collisions into Dust Experiment	TX07: Exploration Destination Systems
76	H. Todd Smith	Johns Hopkins University APL	Vertically Aligned Carbon Nanotubes for Earth Climate Remote Sensing	TX08: Sensors and Instruments
114	H. Todd Smith	Johns Hopkins University APL	Graphene Ion Membranes for Earth and Space Applications	TX08: Sensors and Instruments
142	Amela Zanacic	NASA's Ames Research Center	Affordable Vehicle Avionics	TX15: Flight Vehicle Systems
155	George Pantalos	University of Louisville	Aqueous Immersion Surgical System for Reduced Gravity	TX06: Human Health, Life Support, and Habitation Systems
156	Julie Brisset	University of Central Florida	Suborbital Particle Aggregation and Collision Experiment-2 (SPACE-2)	TX11: Software, Modeling, Simulation, and Information Processing
173	Franklin Robinson	NASA's Goddard Space Flight Center	Flow Boiling in Microgap Coolers – Embedded Thermal Management for Space Applications	TX14: Thermal Management Systems
177	Justin Lee	The Aerospace Corporation	Rapid Calibration of Space Solar Cells in Suborbital Environments	TX03: Aerospace Power and Energy Storage
187	Peter Lee	Ohio State University	Gravity Sensing Mechanisms in Tissue-Engineered Skeletal Muscle	TX06: Human Health, Life Support, and Habitation Systems
189	Jacob Chung	University of Florida	Optimal Chilldown Methods for Cryogenic Propellant Tanks in Reduced Gravity	TX02: Flight Computing and Avionics
191	Kevin Crosby	Carthage College	Microgravity Propellant Gauging Using Modal Analysis: Phase III	TX01: Propulsion Systems
194	Steve Ord	NASA's Ames Research Center	SFEM-3	TX15: Flight Vehicle Systems
196	H. Todd Smith	Johns Hopkins University APL	JANUS 3.0: Enabling Game-Changing External Environment Payload Accommodation	TX08: Sensors and Instruments
201	Rob Ferl	University of Florida	Human-Tended Space Biology: Enabling Suborbital Genomics and Gene Expression	TX06: Human Health, Life Support, and Habitation Systems
204	Julie Brisset	University of Central Florida	Dust In-Situ Manipulation System (DIMS)	TX06: Human Health, Life Support, and Habitation Systems
206	Steven Collicott	Purdue University	Small-Sat Propellant Management Technology	TX01: Propulsion Systems
207	David Miles	University of Iowa	CubeSat Articulated Boom Option Optimization in Microgravity (CABOOM)	TX04: Robotic Systems
209	Michael Menze	University of Louisville	Evaluation of Preserved Blood for Transfusion Therapy in Reduced Gravity	TX06: Human Health, Life Support, and Habitation Systems
211	Chung-Lung Chen	University of Missouri	Electrowetting Enhanced Dropwise Condensation in the Zero-g Environment	TX06: Human Health, Life Support, and Habitation Systems
212	Konstantinos Sierros	West Virginia University	3D Printing of Hierarchical Foams in Microgravity	TX12: Materials, Structures, Mechanical Systems, and Manufacturing

#	Principal Investigator	Organization	Technology Name	NASA Taxonomy
213	R. Michael Banish	University of Alabama	Transport Properties of Fluids for Exploration	TX14: Thermal Management Systems
214	Alexandre Martin	University of Kentucky	KRUPS Capsule for Heat-Shield Validation	TX09: Entry, Descent, and Landing
215	Alina Alexeenko	Purdue University	FEMTA Micropropulsion System for Interplanetary Smallsat	TX01: Propulsion Systems
216	Steven Collicott	Purdue University	Zero-g Slosh Model Technology	TX01: Propulsion Systems
217	Charles Hibbitts	Johns Hopkins University APL	Integrated Remote Imaging System	TX02: Flight Computing and Avionics
218	Kevin Crosby	Carthage College	Magneto-Active Slosh Control System for Spacecraft and Launch Vehicles	TX01: Propulsion Systems
219	Amir Hirsa	Rensselaer Polytechnic Institute	Adapting the Ring-Sheared Drop Technology as a Bioreactor	TX06: Human Health, Life Support, and Habitation Systems
220	Christine Escobar	Space Lab Technologies	Thin-Film Hydroponics	TX06: Human Health, Life Support, and Habitation Systems
221	W. Kent Tobiska	Space Environment Technologies (SPACEWX)	ARMAS Suborbital	TX06: Human Health, Life Support, and Habitation Systems
224	Charles Hibbitts	Johns Hopkins University APL	Integrated Remote Imaging System – UltraViolet	TX08: Sensors and Instruments
225	Daniel Durda	Southwest Research Institute – Boulder	Box-of-Rocks Experiment II: Morphology and Sampling of Asteroid Regolith Simulants in Microgravity	TX04: Robotic Systems
226	Kris Zacny	Honeybee Robotics	PlanetVac-Xombie2: Honeybee PlanetVac on the Masten Lunar Lander	TX04: Robotic Systems
227	Kevin Supak	Southwest Research Institute – San Antonio	Large-Scale Liquid Acquisition Device for Cryogenic Fluid Management	TX01: Propulsion Systems
228	Mark Pankow	North Carolina State University	Composite Origami for Spacecraft Solar Arrays and Deployable Structures	TX12: Materials, Structures, Mechanical Systems, and Manufacturing
229	Kevin Crosby	Carthage College	Propellant Mass Gauging in Gateway Architecture Vehicles	TX01: Propulsion Systems
230	Marion Turnbull	Mayo Clinic – Jacksonville	Autonomous Sampling Technology for Biological Research During Suborbital Rocket Flight	TX06: Human Health, Life Support, and Habitation Systems
231	H. Todd Smith	Johns Hopkins University APL	Application of Europa-Clipper Technology for Lunar Radiation Hazard Identification and Characterization	TX06: Human Health, Life Support, and Habitation Systems
232	W. Kent Tobiska	Space Environment Technologies (SPACEWX)	ARMAS Dual Monitor Pre-Operations Mission Demonstration	TX06: Human Health, Life Support, and Habitation Systems
233	Brock LaMeres	Montana State University	Radiation Tolerant Computer System at Scale	TX02: Flight Computing and Avionics
234	Bryan Chan	Night Crew Labs	GNSS Radio Occultation Autonomous System for Commercial Space Weather Applications	TX08: Sensors and Instruments
235	Sean Bailey	University of Kentucky	Forward Sensing Turbulence Detection Strategies for Stratospheric Flight	TX09: Entry, Descent, and Landing
236	Susana Zanello	imec USA Nanoelectronics Design Center	Silicon-Based Microfluidic Blood Test for Spaceflight	TX06: Human Health, Life Support, and Habitation Systems
237	Daniel Bowman	Sandia National Labs	Balloon-Borne Aeroseismometer	TX08: Sensors and Instruments
238	John Wikswo	Vanderbilt University	Integrated Microfluidic Pump and Valve Experiment Control System	TX06: Human Health, Life Support, and Habitation Systems

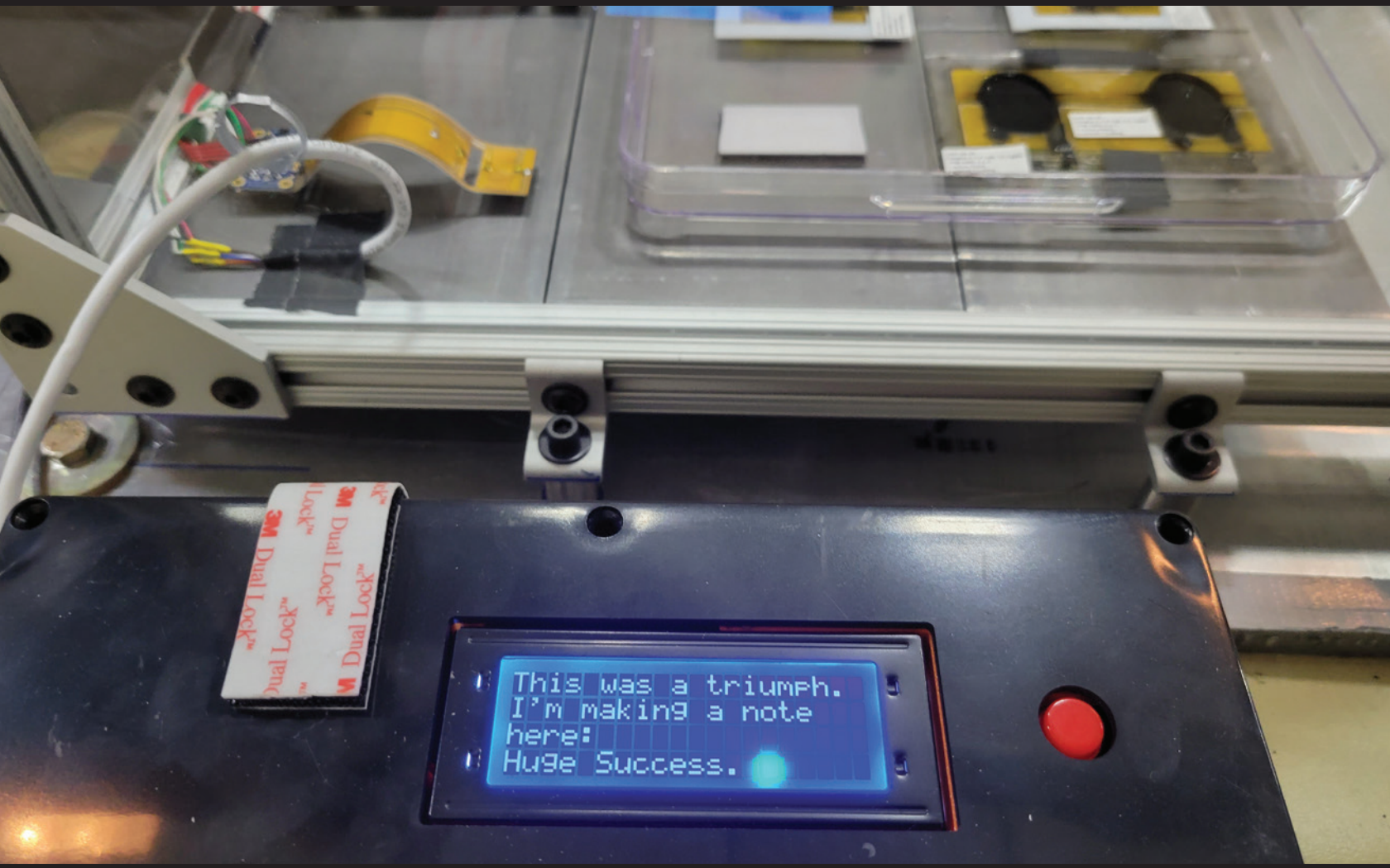
#	Principal Investigator	Organization	Technology Name	NASA Taxonomy
239	Rob Ferl	University of Florida	Biological Imaging in Support of Suborbital Science	TX06: Human Health, Life Support, and Habitation Systems
240	Brett Streetman	Draper	Draper Multi-Environment Navigator (DMEN)	TX09: Entry, Descent, and Landing
241	Steven Collicott	Purdue University	Spacecraft Pointing Control and Zero-g Slosh	TX01: Propulsion Systems
242	Philip Metzger	University of Central Florida	Maturing Ejecta STORM for Lunar Delivery	TX09: Entry, Descent, and Landing
243	Adrienne Dove	University of Central Florida	Exploring Electrostatic Regolith Interactions in Low-g	TX13: Ground, Test, and Surface Systems
244	Jacob Chung	University of Florida	Determination of Cryogenic Pool Boiling and Subsurface Helium Pressurization Characteristics in Reduced Gravity	TX01: Propulsion Systems
245	Gregory Whiting	University of Colorado Boulder	Viability of In-Situ Lunar Manufacturing of Life Support Systems Using a Direct Writing Technique	TX06: Human Health, Life Support, and Habitation Systems
247	Annie Meier	NASA's Kennedy Space Center	Orbital Syngas Commodity Augmentation Reactor (OSCAR)	TX06: Human Health, Life Support, and Habitation Systems
248	Mircea Badescu	NASA's Jet Propulsion Laboratory	Dual Rasp Sampling Tool/System	TX04: Robotic Systems
249	Kasthuri Venkateswaran	NASA's Jet Propulsion Laboratory	Microgravity Tolerant Instrument for Automated Nucleic Acid Extraction (uTitan)	TX06: Human Health, Life Support, and Habitation Systems
250	Allen Parker	NASA's Armstrong Flight Research Center	Advancing Fiber Optic Sensing Technology for Space Applications	TX08: Sensors and Instruments
251	Vivek Dwivedi	NASA's Goddard Space Flight Center	In-Space Coating Development Utilizing Atomic Layer Deposition	TX08: Sensors and Instruments
252	Sridhar Gorti	NASA's Marshall Space Flight Center	Fluid Dispensing Tube Performance Limits for Drop Delivery	TX06: Human Health, Life Support, and Habitation Systems
253	Kris Zacny	Honeybee Robotics	Increasing Fidelity for Lunar Sample Collection	TX04: Robotic Systems
254	H. Todd Smith	Johns Hopkins University APL	Chip-Scale Satellites for Earth, Lunar, and Cislunar Space Applications	TX08: Sensors and Instruments
255	Tim Lachenmeier	GSSL	Data Buoy for NASA's Long-Duration High-Altitude Balloons	TX11: Software, Modeling, Simulation, and Information Processing
256	Steve Sandford	Psionic	Psionic Navigation Doppler Lidar: Precision Navigation Sensor for Lunar Missions	TX17: Guidance, Navigation, and Control (GN&C)
257	Dayne Kemp	NASA's Ames Research Center	Intrepid Particle Detector	TX06: Human Health, Life Support, and Habitation Systems
258	Dayne Kemp	NASA's Ames Research Center	Advanced Developments Projects Flight Avionics	TX02: Flight Computing and Avionics
259	Zachary Manchester	Stanford University	V-R3x – CubeSat Cross-Link, Ranging, and Coordinated Measurement Technology Demonstration for Future Distributed CubeSat Swarm Missions	TX05: Communications, Navigation, and Orbital Debris Tracking and Characterization Systems
260	Anthony Colaprete	NASA's Ames Research Center	Nephelometer Experiment	TX08: Sensors and Instruments
261	Sona Hosseini	NASA's Jet Propulsion Laboratory	Next-Generation, Miniature High-Resolution Spectrometers	TX08: Sensors and Instruments
262	Jeffrey Didion	NASA's Goddard Space Flight Center	Investigation of Gravity Effects on Electrically Driven Liquid Film Boiling	TX14: Thermal Management Systems
264	James J. Miller	NASA Headquarters	Multi-Global Navigation Satellite System Receiver Payload	TX16: Air Traffic Management and Range Tracking Systems

#	Principal Investigator	Organization	Technology Name	NASA Taxonomy
265	Nick Demidovich	Federal Aviation Administration	Spacecraft Black Box Technology Modules for Commercial Spacecraft	TX16: Air Traffic Management and Range Tracking Systems
266	Nick Demidovich	Federal Aviation Administration	General Aviation Strobe for Commercial Reusable Launch Vehicles	TX16: Air Traffic Management and Range Tracking Systems
267	Nick Demidovich	Federal Aviation Administration	Commercial Space Vehicle Tracking Using ADS-B Technology	TX16: Air Traffic Management and Range Tracking Systems
268	Daniel Marshall	Mercury Systems	Orbital Fiber Optic Production Module	TX12: Materials, Structures, Mechanical Systems, and Manufacturing
269	John M. Carson	NASA's Johnson Space Center	Safe and Precise Landing Integrated Capabilities Evolution	TX09: Entry, Descent, and Landing
270	Arwen Dave	NASA's Ames Research Center	Affordable Vehicle Avionics in Flight	TX02: Flight Computing and Avionics
272	David Masten	Masten Space Systems	Reusable Suborbital Vehicle for Terrestrial Testing of Landing Technologies	TX09: Entry, Descent, and Landing
273	Thomas Valdez	Teledyne Energy Systems	Hydrogen Electrical Power System	TX03: Aerospace Power and Energy Storage
274	Richard French	Rocket Lab	Proposal to the NASA Space Technology Announcement of Collaborative Opportunity	TX09: Entry, Descent, and Landing
275	Markus Wilde	Florida Institute of Technology	Autonomous Multiple Cycle Farming System	TX07: Exploration Destination Systems
276	Candice Hovell	imec USA Nanoelectronics Design Center	Electrophysiology Recording of Neuronal Networks During Suborbital Spaceflight	TX06: Human Health, Life Support, and Habitation Systems
277	Kevin Crosby	Carthage College	Propellant Gauging During On-Orbit Refueling and Transfer Operations	TX01: Propulsion Systems
278	Ranga Narayanan	University of Florida	Novel Technology for a Key Material Property Measurement for In-Space Manufacturing	TX12: Materials, Structures, Mechanical Systems, and Manufacturing
279	Richard Mathies	University of California, Berkeley	Microfluidic Biochemical Analysis Lab-on-a-Chip	TX06: Human Health, Life Support, and Habitation Systems
280	Stephen Robinson (2)	University of California, Davis	Low-Cost Three-Axis CubeSat Attitude Control with Hard Disk Drive Reaction Wheels	TX02: Flight Computing and Avionics
281	Steven Collicott	Purdue University	Enhancing Suborbital Technology Advancement Through Automated Control of High-Definition Video Systems	TX02: Flight Computing and Avionics
282	Veerle Reumers	imec USA Nanoelectronics Design Center	Functional Integration of Lens-Free Imaging in Suborbital Flight	TX06: Human Health, Life Support, and Habitation Systems
283	Emilio Baglietto	Massachusetts Institute of Technology	Computational Fluid Dynamics Boiling Models for Cryogenic Fluid Management Systems	TX01: Propulsion Systems
284	Alicia Carey	Redwire Space	Glass Alloy Manufacturing Machine – Acoustic Levitation Furnace	TX12: Materials, Structures, Mechanical Systems, and Manufacturing
285	Steven Collicott	Purdue University	Integrating Microgravity Medical Suction and Microgravity Surgical Facility	TX06: Human Health, Life Support, and Habitation Systems
286	Joseph Paradiso	Massachusetts Institute of Technology	Autonomous Robot Swarms for Lunar Orbit Servicing and Space Asset Assembly	TX10: Autonomous Systems
287	George Pantalos	University of Louisville	Human Tended Surgical Fluid Management System	TX06: Human Health, Life Support, and Habitation Systems
288	Allison Pieja	Mango Materials	Enabling In-Situ Resource Utilization in Space Through Gas Fermentation	TX07: Exploration Destination Systems
289	Sean Bryan	Arizona State University	CubeSounder	TX13: Ground, Test, and Surface Systems

#	Principal Investigator	Organization	Technology Name	NASA Taxonomy
290	Stephen Robinson	University of California, Davis	Capturing Human Adaptations in Novel Gravitational Environments in Space	TX06: Human Health, Life Support, and Habitation Systems
291	Issam Mudawar	Purdue University	Cryogenic Two-Phase Heat Transfer Coefficients for In-Space Transfer Systems	TX01: Propulsion Systems
292	Adrienne Dove	University of Central Florida	Strata-2P – Characterizing Sensor-Regolith Interactions in Reduced Gravity	TX08: Sensors and Instruments
293	Hayden Taylor	University of California, Berkeley	Computed Axial Lithography	TX12: Materials, Structures, Mechanical Systems, and Manufacturing
294	Konstantinos Sierros	West Virginia University	Particle-Based Foam Spraying in Microgravity	TX12: Materials, Structures, Mechanical Systems, and Manufacturing
295	Robert Anderson	NASA's Jet Propulsion Laboratory	Soil Properties Assessment Resistance and Thermal Analysis	TX04: Robotic Systems
296	Sheila Nielsen	Montana State University	Autonomous Hardware to Evaluate Impacts of Launch and Landing on *Candida albicans* Adaptation to Spaceflight	TX06: Human Health, Life Support, and Habitation Systems
297	Tyler Kunsa	SpaceWorks Enterprises	Enabling Low-Cost, Autonomous Recovery of Small Payloads from Low-Earth Orbit	TX09: Entry, Descent, and Landing
298	Steven Collicott	Purdue University	Nucleation of Cryogenic Bubbles in Spacecraft Liquid Acquisition Devices	TX01: Propulsion Systems
299	Danielle Wood	Massachusetts Institute of Technology	Paraffin and Beeswax Formation in Microgravity for Low-Earth Orbit Propulsion Applications	TX01: Propulsion Systems
300	Boris Khusid	New Jersey Institute of Technology	Stability of In-Space Cryogenic Systems	TX01: Propulsion Systems
301	Steven Collicott	Purdue University	Lander-Style Vehicle Plume-Structure Heat Transfer Monitoring	TX09: Entry, Descent, and Landing
302	Brett Streetman	Draper	Draper Multi-Environment Navigator Hazard Detection Campaign	TX09: Entry, Descent, and Landing
303	Fu-Kuo Chang	Stanford University	Integrated Acoustic Technology for Boil-Off Control, Mass Gauging, and Structural Health Monitoring in Cryogenic Fuel Tanks	TX01: Propulsion Systems
304	Jason Mezilis	Zandef Deksit	ExoCam Module Lunar Lander Descent Imaging	TX09: Entry, Descent, and Landing
305	Samuel Darr	The Aerospace Corporation	Non-Condensable and Autogenous Unsettled Cryogenic Pressurization Schemes in Reduced Gravity	TX01: Propulsion Systems
306	Kris Zacny	Honeybee Robotics	Asteroid Soil Strength Evaluation Tool	TX09: Entry, Descent, and Landing
307	Alan Stern	Southwest Research Institute – San Antonio	Enhancing Commercial Suborbital Vehicle Utilization and Collecting New Suborbital Scientific Data	TX08: Sensors and Instruments
308	David Scarborough	Auburn University	Three-Dimensional Plume-Surface Interaction and Crater Formation Dynamic Measurements in Reduced Gravity Environments	TX09: Entry, Descent, and Landing
309	Prashant Singh	Mississippi State University	Thermal Transport Characterization of Phase-Change Material	TX14: Thermal Management Systems
310	Eric Benton	Oklahoma State University	Ionizing Radiation Dosimeters for Use in the Upper Atmosphere	TX06: Human Health, Life Support, and Habitation Systems
311	Thomas Conboy	Creare	Lightweight, Hybrid Screen-Channel Device for Advanced Cryogenic Fluid Management	TX01: Propulsion Systems
312	Ram Prasad Gandhiraman	Space Foundry	Plasma Jet Printing for In-Space Manufacturing	TX12: Materials, Structures, Mechanical Systems, and Manufacturing
313	Gioia Massa	NASA's Kennedy Space Center	Microgreens Root Zone/Shoot Zone Partitioned Planting Box	TX06: Human Health, Life Support, and Habitation Systems
314	Charles L. Finley	NASA's Ames Research Center	Lawn Dart Terrestrial Demonstration	TX05: Communications, Navigation, and Orbital Debris Tracking and Characterization Systems
315	James Phillips	NASA's Kennedy Space Center	Electrostatic Dust Lofting via Photoionization Under Artificial Lunar Gravity	TX13: Ground, Test, and Surface Systems
316	Aaron Olson	NASA's Kennedy Space Center	Electrodynamic Regolith Conveyor	TX04: Robotic Systems
317	Kristen John	NASA's Johnson Space Center	Hermes LunarG	TX04: Robotic Systems
318	Jennifer Edmunson	NASA's Marshall Space Flight Center	Project Duneflow	TX04: Robotic Systems
319	James Mantovani	NASA's Kennedy Space Center	Vibratory Lunar Regolith Conveyor	TX04: Robotic Systems
320	Jason Schuler	NASA's Kennedy Space Center	In-Situ Resource Utilization Pilot Excavator Bucket Drum Flow	TX04: Robotic Systems
321	Aaron Noell	NASA's Jet Propulsion Laboratory	Multiphase Microfluidics for Chemical Analysis Systems	TX01: Propulsion Systems
322	Benjamin Sumlin	NASA's Glenn Research Center	Low-g Transport of Dust Liberated from Spacesuit Fabric	TX06: Human Health, Life Support, and Habitation Systems
323	Robert Anderson	NASA's Jet Propulsion Laboratory	SPARTA Blue	TX04: Robotic Systems
324	Paul Ferkul	NASA's Glenn Research Center	Material Flammability in Lunar Gravity	TX06: Human Health, Life Support, and Habitation Systems
325	Hantang Qin	Iowa State University	3D Printing of Flexible Electronics for In-Space Manufacturing and Investigations	TX12: Materials, Structures, Mechanical Systems, and Manufacturing
326	Dmitry Starodubov	FOMS	Space Fibers 3 Preflight	TX12: Materials, Structures, Mechanical Systems, and Manufacturing
327	Jed Storey	NASA's Kennedy Space Center	Propellant Mass Gauging in Microgravity with Electrical Capacitance Tomography	TX01: Propulsion Systems
328	Steve Miller	HeetShield	Enabling Technology for Thermal Protection on Hypersonic Missions	TX09: Entry, Descent, and Landing
329	Edward Balaban	NASA's Ames Research Center	Fluidic Telescope Experiment	TX08: Sensors and Instruments
330	Jason Hartwig	NASA's Glenn Research Center	A Reduced-Gravity Chilldown and Transfer Investigation Using Cryogens	TX01: Propulsion Systems
331	Brandon Kirkland	Redwire Space	Vulcan Advanced Hybrid Manufacturing	TX12: Materials, Structures, Mechanical Systems, and Manufacturing
332	Nicolas Naclerio	University of California, Santa Barbara	Root-Like Burrowing Device	TX04: Robotic Systems
333	Sara Jennings	Orion Labs	Quantum Machine Learning Enhanced Sensor Combination for Earth Observation	TX05: Communications, Navigation, and Orbital Debris Tracking and Characterization Systems
334	Cristian Rodriguez	Cal Poly Pomona Bronco Space Club	Bronco Ember: Autonomous Nascent Wildfire Detection and Prevention	TX08: Sensors and Instruments
335	Ben Gorr	Texas A&M University	Satellite for Natural and Artificial Plumes	TX08: Sensors and Instruments

FLIGHT OPPORTUNITIES

Rapid Demonstration of Space Technologies



An electronic transmission conveys the delight of researchers from MIT after gathering successful flight data on a parabolic flight in April 2021. Credit: Zero Gravity Corporation/Steve Boxall

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www.nasa.gov

Front cover image: Researchers from the University of Iowa tested their CubeSat Articulated Boom Option Optimization in Microgravity (CABOOM) experiment in spring 2021 on Zero Gravity Corporation's G-FORCE ONE aircraft with funding from Flight Opportunities. Credit: Zero Gravity Corporation/Steve Boxall

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