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
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 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.

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

In its first suborbital flight test, NASA’s new PACE initiative (see more information on page 19) supported demonstration of V-RX – 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-RX 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:

1. 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.

2. 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.

3. 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

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

**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. Credit: 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.

“…”

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 1g 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 Mok (left) and team member Jackie Testo 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)

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.

**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
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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.

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 the 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

“Testing that Flight Opportunities is set up to provide has proven to be 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.

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.

“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

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.

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
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.

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.

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

Credit: Blue Origin
NEW TECHNOLOGY SELECTIONS

FY2021 Technology Selections

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

**NASA’S AMES RESEARCH CENTER**

**Fluiddic Telescope Experiment (FLUTE)**
A method for developing fluidic optical components in microgravity conditions for use in space telescopes

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

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**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

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**NASA’S KENNEDY SPACE CENTER**

**Microgreens Root Zone/Shoot Zone Partitioned Planting Box**
A harvesting system designed to serve as a dietary supplement in space

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

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**Electrostatic Dust Levitation via Photoionization Under Artificial Lunar Gravity**
Photodissociation 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

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**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

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**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

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**NASLE'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: Nuclear understanding of the impact of material flammability on spacecraft and habitat safety for deep space exploration missions

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**Lunar-G Transport of Dust Liberated from Seasuit 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

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**NASLE'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

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**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

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**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
NEW TECHNOLOGY SELECTIONS

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

OKLAHOMA STATE UNIVERSITY
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

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

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 that flight on page 6. Credit: Raven Aerostar
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.

**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.

**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.

“[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

Credit: Zero Gravity Corporation/Steve Boxall

“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”

Credit: UP Aerospace
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

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

“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
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240 Brett Swetnam | Draper | Draper Multi-Environment Navigator (SMEN) | T009: Entry, Descent, and Landing
241 Steven Collicott | Purdue University | Spacecraft Pointing Control and Zero-G Sift | T003: Propulsion Systems
242 Philip Metzger | University of Central Florida | Maturing Ejecta STORM for Lunar Delivery | T009: Entry, Descent, and Landing
243 Achenes Dove | University of Central Florida | Exploring Electrophoretic 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 | T001: Propulsion Systems
245 Gregory Whiting | University of Colorado Boulder | Viability of In-Situ Lunar Manufacturing of Life Support Systems Using a Direct Writing Technique | T006: Human Health, Life Support, and Habitation Systems
246 Annis Meier | NASA’s Kennedy Space Center | Orbital Synaggos Commodity Augmentation Reactor (OSCAR) | T004: Robotic Systems
247 Gregory Whiting | University of Colorado Boulder | Viability of In-Situ Lunar Manufacturing of Life Support Systems Using a Direct Writing Technique | T006: Human Health, Life Support, and Habitation Systems
248 Philip Metzger | NASA’s Goddard Space Flight Center | Microfluidic Biochemical Analysis Lab-on-a-Chip | T008: Sensors and Instruments
250 Allen Parker | NASA’s Armstrong Flight Research Center | Increased Fidelity for Lunar Sample Collection | T004: Robotic Systems
251 Vivek Vedavati | NASA’s Goddard Space Flight Center | In-Space Coating Development Utilizing Atomic Layer Deposition | T008: Sensors and Instruments
253 Kris Zacny | Honeywell Robotics | Increasing Fidelity for Lunar Sample Collection | T004: Robotic Systems
255 Tim Lachenmeier | GSSL | Data Bus for NASA’s Long-Duration High-Altitude Balloons | TX11: Software, Modeling, Simulation, and Information Processing
257 Dayne Kemp | NASA’s Ames Research Center | Intrepid Particle Detector | T006: Human Health, Life Support, and Habitation Systems
259 Zachary Manchester | Stanford University | V-Rix – CubeSat Cross-Link, Ranging, and Coordinated Measurement Technology Demonstration for Future Distributed CubeSat Swarm Missions | T003: Communications, Navigation, and Orbital Debris Tracking and Characterization Systems
260 Anthony Calapai | NASA’s Ames Research Center | Nephelometer Experiment | T008: Sensors and Instruments
261 Sonja Hassawi | NASA’s Jet Propulsion Laboratory | Next-Generation, Miniature High-Resolution Spectrometers | T008: Sensors and Instruments
262 Jeffrey Dillon | NASA’s Goddard Space Flight Center | Investigation of Gravity Effects on Electrically Driven Liquid Film Boiling | TX14: Thermal Management 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 Strakes 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
269 John M. Carson | NASA’s Johnson Space Center | Safe and Precise Landing Integrated Capabilities Evolution | T009: Entry, Descent, and Landing
270 Aveen Dave | NASA’s Ames Research Center | Affordable Vehicle Avionics in Flight | TX02: Flight Computing and Avionics
274 Richard Rocker | Lab | Proposal to the NASA Space Technology Announcement of Collaborative Opportunity | T009: Entry, Descent, and Landing
275 Markus Wilde | Florida Institute of Technology | Autonomous Multi-Cycle Crop Farming System | TX07: Exploration Destination Systems
276 Candice Hovel | imac USA Nanoelectronics Design Center | Electrophysiology Recording of Neuronal Networks During Suborbital Spaceflight | T006: Human Health, Life Support, and Habitation Systems
277 Kevin Crosby | Carnegie College | Propellant Gauging During On-Orbit Refueling and Transfer Operations | TX01: Propulsion Systems
278 Ranga Narayan | University of Virginia | Novel Technology for a Key Material Property Measurement in In-Space Manufacturing | T003: Materials, Structures, Mechanical Systems, and Manufacturing
279 Richard Mathews | University of California, Berkeley | Microfluidic Biochemical Analysis Lab-on-a-Chip | T006: 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 | T002: Flight Computing and Avionics
281 Steven Collicott | Purdue University | Enhancing Suborbital Technology Advancement Through Automated Control of High-Definition Video Systems | T002: Flight Computing and Avionics
282 Vaerme Reuma | imac USA Nanoelectronics Design Center | Functional Integration of Lens-Free Imaging in Suborbital Flight | T006: Human Health, Life Support, and Habitation Systems
283 Emilio Baglietto | Massachusetts Institute of Technology | Computational Fluid Dynamics Boiling Models for Cryogenic Fluid Management Systems | T001: Propulsion Systems
284 Alicia Carey | Redwire Space | Glass Alloy Manufacturing Machine – Acoustic Levitation Furnace | T014: Materials, Structures, Mechanical Systems, and Manufacturing
285 Steven Collicott | Purdue University | Integrating Monoray Medical Surgery and Monoray Surgical Facility | T006: Human Health, Life Support, and Habitation Systems
286 Joseph Paradiso | Massachusetts Institute of Technology | Autonomous Robot Swarms for Lunar Orbit Servicing and Space Assets Assembly | TX10: Autonomous Systems
287 George Pantaleo | University of Louisville | Human Tended Surgical Fluid Management System | T006: Human Health, Life Support, and Habitation Systems
288 Allison Piza | Mitsubishi Materials | Enabling In-Situ Resource Utilization in Space Through Gas Fermentation | TX07: Exploration Destination Systems
289 Sean Byrann | Arizona State University | CubeSounder | TX13: Ground, Test, and Surface Systems
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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

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