National Aeronautics and Space Administration

SPACE TECHNOLOGY MISSION DIRECTORATE

FLIGHT OPPORTUNITIES

Accomplishments

Fiscal Year 2020

FLIGHT OPPORTUNITIES MISSION

CONTENTS

A DECADE OF FLIGHT OPPORTUNITIES

Total flights:	198
Payloads tested:	694
Technologies supported:	271

**As of the end of fiscal year 2020.*

NASA's Flight Opportunities program facilitates rapid demonstration of 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.

FY2020 QUICK LOOK

Payloads tested in flight	46
Successful flights	16
Commercial flight providers that flew in FY2020	7
Technologies selected for future flight tests	31

Credits: NASA

FLIGHT HIGHLIGHTS

By supporting the testing of promising space innovations aboard commercial suborbital flight vehicles, the Flight Opportunities program has a significant impact on advancing technologies that address NASA mission goals. In fiscal year 2020 (FY2020), some technologies flew for the first time, while others flew evolved versions and new designs informed by lessons learned on previous flights.

SUPPORTING FASTER, CHEAPER SMALL LAUNCH CAPABILITIES

In November 2019, UP Aerospace launched its SpaceLoft rocket-powered system on a flight funded by the company's NASA Tipping Point award, with support from Flight Opportunities. Among the technologies aboard was the Affordable Vehicle Avionics (AVA) project from NASA's Ames Research Center, a low-cost flight computer designed specifically for dedicated small launch vehicles – rockets that would send individual payloads into orbit on short notice and at lower cost than with currently available launch vehicles. Ames researchers applied learning from two previous SpaceLoft launches facilitated by Flight Opportunities, this time testing AVA's ability to provide the "brains" for UP Aerospace's own guidance and control system. This milestone is also aiding Spyder Orbital – a four-stage solid rocket motor vehicle that UP Aerospace is developing specifically for dedicated small payload launches.

The SpaceLoft mission also included tests of four other Flight Opportunities–supported technologies, all of which aim to improve small launch capabilities. They included an autonomous flight termination system from NASA's Kennedy Space Center, a micro-avionics system from Tyvak Nano-Satellite Systems, a transceiver prototype from the Federal Aviation Administration, and a Global Navigation Satellite System receiver from Qascom.

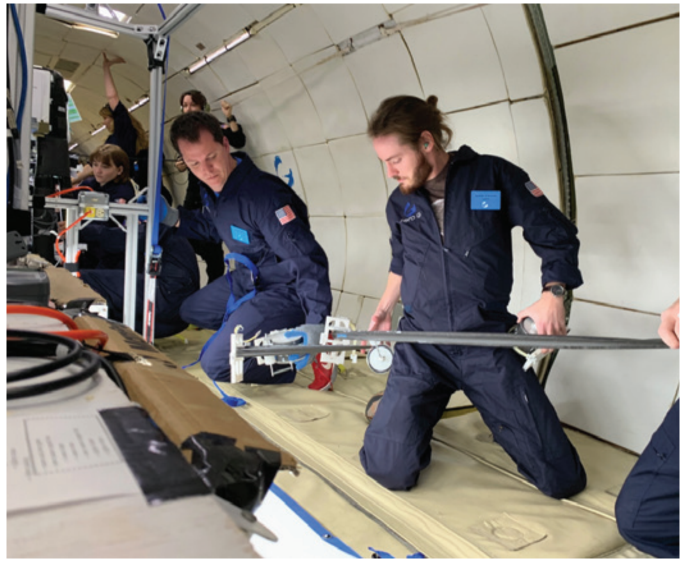
The SpaceLoft 14 rocket launches from Spaceport America in New Mexico on November 22, 2019, with several Flight Opportunities-supported technologies aboard, including the first fully integrated test of AVA with UP Aerospace's guidance and control system. Credits: UP Aerospace

ADVANCING A MINIATURE SOLAR OBSERVATORY AT THE EDGE OF SPACE

SwRI's SSIPP is prepared for launch on a World View balloon in November 2019. The low-cost, reusable observatory aims to break down barriers to studying the Sun from outside the effects of Earth's atmosphere. Credits: SwRI

In November 2019, a World View high-altitude balloon flight facilitated demonstration of the Solar Instrument Pointing Platform (SSIPP) from Southwest Research Institute (SwRI). The flight enabled researchers to collect 75 minutes of solar images and prove the concept of providing a flexible infrastructure similar to that of a ground-based solar observatory but in the near-space environment. The flight helped advance SwRI's goal of supporting the development of a range of new near-space instruments at relatively low cost, allowing scientists to experiment and develop new technologies without designing a custom observatory.

DEMONSTRATING RAPID TESTING AND REFLIGHT

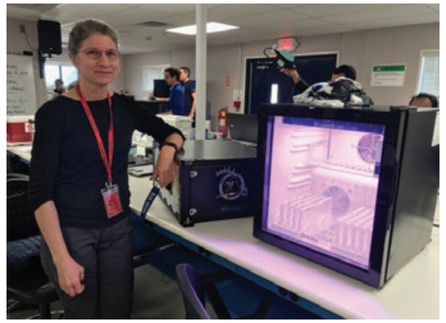


A lightweight spacecraft boom for deploying solar arrays and solar sails from North Carolina State University is tested on the G-FORCE ONE parabolic flight in November 2019. Credits: North Carolina State University

Zero Gravity Corporation conducted eight parabolic flights on its modified passenger airplane, G-FORCE ONE, in November 2019, enabling multiple flight tests of 10 technologies supported by Flight Opportunities. Taking place over the course of several days, the successive flights enabled researcher teams to make adjustments between flights as needed based on how their payloads performed in the brief intervals of microgravity encountered during each parabola.

FLIGHT HIGHLIGHTS

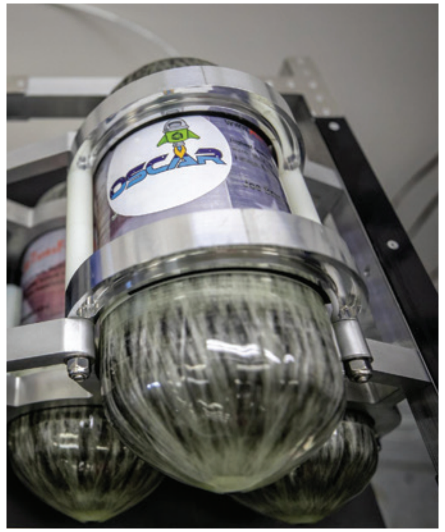
STUDYING BIOLOGICAL IMPACTS OF GRAVITY TRANSITIONS



Co-investigator Anna-Lisa Paul poses with a University of Florida technology designed to study plant responses to transitions in gravity levels. Credits: University of Florida

In December 2019, eight technologies were tested aboard Blue Origin's New Shepard rocket-based system, including an experiment from the University of Florida in Gainesville to explore what happens to the genes of biological organisms as they travel from Earth to space. The flight added to previously acquired data about how plants adapt to space and offered researchers the first clues about how those adaptations happen during transitions between gravity levels – learning essential to our understanding of the impact of space travel on biological organisms.

CONVERTING SPACE TRASH TO USEFUL GAS



Kennedy's OSCAR payload is ready for flight testing in December 2019. The technology is one of many tested in FY2020 that aims to address the challenges of long-duration human space exploration. Credits: NASA

Also aboard the December 2019 Blue Origin New Shepard flight was the Orbital Syngas Commodity Augmentation Reactor (OSCAR), a system from NASA's Kennedy Space Center designed to convert space waste into valuable gases. The technology has the potential to address both waste and power-generation challenges associated with long-duration space exploration.

DETECTING SEISMIC ACTIVITY ON OTHER PLANETS

Instruments that may help advance infrasound investigations on Venus and other planets are launched on a Raven Aerostar high-altitude balloon in July 2020. Credits: Sandia National Laboratories

Aeroseismometers from Sandia National Laboratories and NASA's Jet Propulsion Laboratory (JPL) were flight tested on high-altitude balloons from Raven Aerostar in July 2020. Data from the flight tests are helping scientists advance the state of the art for potential future infrasound investigations on Venus and other planets. Such studies could reveal whether these planets exhibit seismic shifts similar to our own earthquakes and may uncover valuable information about the planets' interior structures.

ADVANCING NAVIGATION TECHNOLOGY FOR NASA'S HUMAN LANDING SYSTEM

In September 2020, Psionic tested its commercial version of navigation Doppler lidar (NDL) technology on Masten Space Systems' Xodiac – a rocket-powered vertical takeoff and vertical landing (VTVL) vehicle that simulates some of the maneuvers of a lunar lander. Designed for precision landing in a very tightly defined area, NDL uses laser beams to provide information about the lander's velocity and distance relative to the ground. Originally developed at NASA's Langley Research Center, the technology was licensed by Psionic in 2016 for both space and terrestrial applications. The flight test added to data collected on previous VTVL testing of the technology in 2017, advancing Psionic's goal of producing flight-ready NDL units that could be used by companies on contract under NASA's Human Landing System Program.

Psionic's NDL payload is mounted to Masten's Xodiac in preparation for flight testing. The technology is one among many entry, descent, and landing innovations being advanced by NASA for lunar missions. Credits: Psionic

RAPIDLY VETTING SPACE-BASED SOLAR TECHNOLOGIES

In September 2020, researchers from The Aerospace Corporation continued their testing of a method to rapidly calibrate space solar cells with flights on high-altitude balloons from AM0CAL. The testing added to data collected on two 2019 flight campaigns. The technology aims to facilitate fast and inexpensive preliminary data collection for newly developed solar cells. This would make it much faster and cheaper to determine the optimal solar technologies for further testing in orbit, enable delivery of data to spacecraft solar array designers, and ultimately help to power missions to the Moon and Mars.

Researchers from The Aerospace Corporation and flight provider AM0CAL launch a space-based solar cell calibration payload from a high-altitude balloon in California's Mojave Desert in September 2020. Credits: AM0CAL

TECHNOLOGY TRANSITIONS

As technologies are matured through suborbital flight tests, they climb the technology readiness ladder, often transitioning to orbital testing opportunities or inclusion in NASA missions. In FY2020, several Flight Opportunities-supported technologies realized such success, including those bound for the Moon and beyond.

COMMERCIAL LUNAR PAYLOAD SERVICES SELECTIONS

In FY2020, NASA selected technologies from the Flight Opportunities portfolio for upcoming lunar missions – a significant achievement that highlights the culmination of the program's iterative flight testing to advance NASA goals. These innovations will be part of future NASA Commercial Lunar Payload Services (CLPS) flights in support of NASA's Artemis program.

Navigation Doppler Lidar

NASA'S LANGLEY RESEARCH CENTER

In January 2020, NASA selected Langley's navigation Doppler lidar (NDL) technology as a payload on two future CLPS missions. Tested on Flight Opportunities-facilitated flights with Masten Space Systems in 2017, the innovation provides precise velocity and range sensing during descent and landing for tightly controlled navigation and touchdown on the Moon. The two CLPS flights will test the technology further in advance of potential use on a crewed lunar mission.

> *"These flights, along with a 10-year period of technology development, have been instrumental in making the NDL technology available to commercial lunar landers for future NASA missions."*
>
> — Farzin Amzajerdian, principal investigator for NDL, NASA's Langley Research Center

Langley's NDL uses lasers that bounce off the ground and back to the instrument, providing velocity and range information upon approach for landing on the Moon. Credits: NASA/David C. Bowman

Autolanding System

ASTROBOTIC TECHNOLOGY

In June 2020, NASA announced the selection of Astrobotic to deliver the agency's Volatiles Investigating Polar Exploration Rover (VIPER) to the Moon's South Pole in late 2023. Astrobotic will deliver the rover on the company's Griffin lander using a lidar-based, hazard detection autolanding system matured with support from Flight Opportunities. The water-seeking mobile VIPER robot will help pave the way for crewed missions to the lunar surface beginning in 2024, advancing toward NASA's goal of long-term human presence on the Moon.

Astrobotic's lunar lander (seen here at NASA's Goddard Space Flight Center in May 2019) will deliver NASA's VIPER to the Moon as part of the CLPS initiative. Credits: NASA/Aubrey Gemignani

Radio Frequency Mass Gauge

NASA'S GLENN RESEARCH CENTER

This propellant-quantity gauging technique accurately determines the amount of cryogenic propellant in a tank while in low gravity or under maneuver conditions where sloshing is an issue. Thanks in part to flight testing facilitated by Flight Opportunities, the technology has been transferred to Intuitive Machines for integration on the company's CLPS lander vehicle with a lunar mission scheduled for 2021. The effort is a collaboration between NASA's Space Technology Mission Directorate and Science Mission Directorate.

A lunar lander from Intuitive Machines (seen here at NASA's Goddard Space Flight Center in May 2019) will carry a Flight Opportunities-supported propellant gauging technology as part of its lunar mission for NASA's Artemis program. Credits: NASA/Aubrey Gemignani

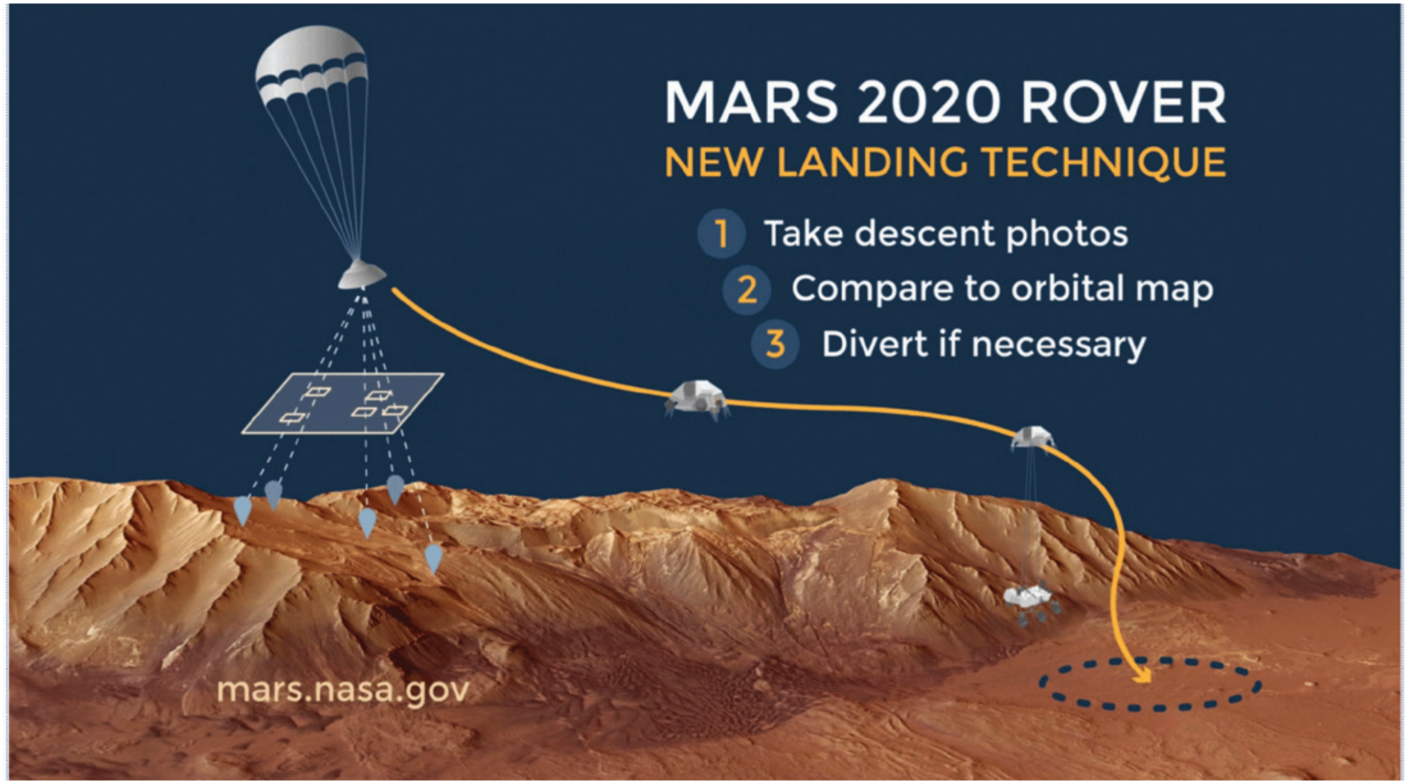
OTHER MISSIONS AND COLLABORATIVE EXPERIMENTS

Several technologies matured through Flight Opportunities transitioned to additional testing, exploration missions, and industry uses beyond the program, including work with other government agencies, NASA's Mars 2020 mission, and more. Recent highlights of these types of infusions include the following.

Lander Vision System for Mars Perseverance Rover

NASA'S JET PROPULSION LABORATORY

The Lander Vision System (LVS) is a terrain-relative navigation (TRN)-based system that photographs the terrain beneath a descending spacecraft and matches it with onboard maps to determine vehicle location. Thanks in part to testing on Masten Space Systems vehicles supported by Flight Opportunities, the technology was infused into NASA's Mars 2020 mission and the technology was launched on the Mars 2020 Perseverance rover on July 30, 2020. It will aid the rover's landing and navigation when it reaches the Red Planet in February 2021.



The Lander Vision System on the Mars 2020 Perseverance rover is based on terrain-relative navigation, a technique matured in part through flight tests facilitated by Flight Opportunities. Credits: NASA/JPL-Caltech

Autonomous Flight Termination System

NASA'S KENNEDY SPACE CENTER

The Autonomous Flight Termination System (AFTS) allows a rocket to independently determine if it is off course and, if necessary, self-destruct. Thanks in part to testing on UP Aerospace's SpaceLoft rocket-based system with support from Flight Opportunities, AFTS has been transferred to at least 35 recipients, including other government agencies and industry partners Rocket Lab and SpaceX. NASA is collaborating with the Italian Space Agency to investigate interoperability between the system's GPS and the European Space Agency's Galileo constellation, which would increase signal coverage and improve performance. The technology is also being considered for a Commercial Lunar Payload Services (CLPS) lunar lander mission and for use on the Lunar Gateway. In FY2020, progress was made on integrating the system for upcoming Rocket Lab launches.

> *"AFTS is not only an important endeavor for NASA to make launch operations safer and more efficient from a time and cost perspective, but through the transfer of this enabling technology, it also has a multiplier effect across the entire space industry."*
>
> — Shawn Quinn, Director of Engineering, NASA's Kennedy Space Center

CLPS VEHICLE PROVIDERS

Four companies building landers as part of NASA's CLPS initiative leveraged Flight Opportunities-supported suborbital flights to test technologies that are incorporated into their vehicles:

- Astrobotic Technology
- Blue Origin
- Draper
- Masten Space Systems

ARTEMIS HUMAN LANDING SYSTEM DEVELOPERS

Two of the three teams selected to develop human landing systems for NASA's Artemis program include flight providers or companies that tested technologies through flights supported by Flight Opportunities:

- Blue Origin
- Draper
- Dynetics

TECHNOLOGIES TESTED IN FY2020

Flight Date	Flight Provider	Flight Vehicle	Principal Investigator	Organization	Technology Name
November 2019	**World View**	*Tycho-20*	Craig DeForest	Southwest Research Institute - Boulder	T0085: Southwest Research Institute (SwRI) Solar Instrument Pointing Platform
November 2019	**Zero-G**	*G-Force One*	Jacob Chung	University of Florida - Gainesville	T0189: Demonstration of Optimal Chilldown Methods for Cryogenic Propellant Tanks in Reduced Gravity
			Mark Pankow	North Carolina State University	T0205: Lightweight Strain-Energy Deployed Spacecraft Booms
			Steven Collicott	Purdue University	T0206: Small-sat Propellant Management Technology
			David Miles	University of Iowa - Iowa City	T0207: CubeSat Articulated Boom Option Optimization in Microgravity (CABOOM)
			Kevin Crosby	Carthage College	T0218: Magneto-Active Slosh Control System for Spacecraft and Launch Vehicles
November 2019	**Zero-G**	*G-Force One*	Brandon Farmer	Nexolve Corporation	T0203: LISA-T Microgravity Deployment Demonstration
			Jamal Yagoobi	Worcester Polytechnic Institute	T0208: Investigation of Gravity Effects on Electrically Driven Liquid Film Boiling: A Microgravity Flight Campaign in Preparation of ISS Flight Experiment
			Michael Menze	University of Louisville	T0209: Evaluation of Preserved Blood for Transfusion Therapy in Reduced Gravity
			Chung-Lung Chen	University of Missouri - Columbia	T0211: Electrowetting Enhanced Dropwise Condensation in the Zero-*g* Environment
			Konstantinos Sierros	West Virginia University	T0212: 3D Printing of Hierarchical Foams in Microgravity
November 2019	**UP Aerospace**	*SpaceLoft*	Lisa Valencia	NASA's Kennedy Space Center	T0165: Autonomous Flight Termination System (AFTS)
			Jeffrey Kwong	Tyvak Nano-Satellite Systems	T0200: Micro-Avionics Multi-Purpose Platform (MicroAMPP)
			Nick Demidovich	Federal Aviation Administration Office of Commercial Space Transportation	T0223: Universal Access Transceiver (UAT) Automatic Dependent Surveillance Broadcast (ADS-B)
			Oscar Pozzobon	Qascom	T0246: GPS/Galileo Receiver for Human Exploration and Operations Mission Directorate (GARHEO)
			Arwen Dave	NASA's Ames Research Center	T0270: Affordable Vehicle Avionics (AVA)
			Jerry Larson	UP Aerospace	T0271: Spyder: Critical Technology Demonstration Tests
December 2019	**Blue Origin**	*New Shepard*	Sean Casey	Silicon Valley Space Center	T0023: Measurement of the Atmospheric Background in the Mesosphere
			Josh Colwell	University of Central Florida	T0052: Collection of Regolith Experiment (CORE) on a Commercial Suborbital Vehicle
			Rob Ferl	University of Florida - Gainesville	T0053: Validating Telemetric Imaging Hardware for Crew-Assisted and Crew-Autonomous Biological Imaging in Suborbital Applications
			Peter Lee	Ohio State University	T0187: Evaluation of Gravity Sensing Mechanisms in Tissue-Engineered Skeletal Muscle
			Kevin Crosby	Carthage College	T0191: Microgravity Propellant Gauging Using Modal Analysis: Phase III
			Kevin Supak	Southwest Research Institute - San Antonio	T0202: Suborbital Testing of Liquid Acquisition Devices for Cryogenic Fluid Management
			W. Kent Tobiska	Space Environment Technologies	T0221: ARMAS Suborbital
			Anne Meier	NASA's Kennedy Space Center	T0247: Orbital Syngas Commodity Augmentation Reactor (OSCAR)
July 2020	**Raven Aerostar**	*Zero Pressure*	Daniel Bowman	Sandia National Laboratories	T0237: Flight Test of a Balloon-borne Aeroseismometer
September 2020	**Masten Space Systems**	*Xodiac*	Steve Sandford	Psionic	T0256: Psionic Navigation Doppler Lidar: Precision Navigation Sensor for Lunar Missions
September 2020	**AM0CAL**	*High-altitude balloon*	Justin Lee	The Aerospace Corporation	T0177: Rapid Calibration of Space Solar Cells in Suborbital Environments

Flight Opportunities supports the testing of technologies in a wide variety of relevant environments. Flights from commercial providers offer access to many vehicle types, each with its own unique environment and capabilities for testing. The following information highlights the general categories of vehicles available for testing.

ROCKET-POWERED VEHICLES

This category includes both suborbital launch vehicles that reach high altitudes and may include periods of microgravity as well as lander vehicles that specialize in entry, descent, and landing (EDL) technologies. Both of these classes of vehicles are typically recoverable and reusable after launch. They can be used for testing:

- EDL and navigation systems
- Atmospheric and surface sampling
- Biological experiments
- Robotic systems
- In-space manufacturing methods
- Electronics and information technology systems

Blue Origin's New Shepard rocket-powered system. Credits: Blue Origin

"Flight Opportunities has brought to the forefront new and innovative flight providers from the commercial sphere. The wide range of available vehicles gives our supported researchers a broad range of relevant flight environments available for testing."

— John Kelly, Program Manager, Flight Opportunities

HIGH-ALTITUDE BALLOONS

Large balloon systems reach a nominal altitude of 30 km and can also typically sustain the longest duration of the suborbital vehicles – hours, days, or even weeks at a time. This makes them ideal for payloads that benefit from extended periods of data collection. These systems are ideal for testing:

- Sun-sensitive and solar instruments
- Earth-observation instruments
- Communication systems (from high altitudes to ground)
- Other instruments and technologies that may benefit from high-altitude observations (both to ground and into space) and drop tests

World View's Stratollite high-altitude balloon system. Credits: World View

PARABOLIC AIRCRAFT

These airplanes achieve brief periods of reduced gravity through a series of maneuvers called parabolas. Parabolic flights can be used for human-tended testing of technologies that need to operate in the absence of gravity, such as:

- Space-based medical experiments
- Biological experiments
- Robotic systems
- In-space manufacturing methods
- Electronics and information technology systems

The payload cabin of Zero Gravity Corporation's G-FORCE ONE parabolic aircraft. Credits: Zero Gravity Corporation

NEW TECHNOLOGY SELECTIONS

The Flight Opportunities "Tech Flights 2020" solicitation resulted in the selection over $16 million of demonstration work proposed by industry, academia, and private labs for suborbital testing of technologies that address topic areas aligned with NASA priorities. The program selected 31 promising innovations — the most ever chosen through the solicitation. The 2020 awards also included new elements that allow researchers to accompany and tend to their technology aboard suborbital spacecraft and to add educational opportunities to their primary payload.

TOPIC 1: SUPPORTING SUSTAINABLE LUNAR EXPLORATION AND THE EXPANSION OF ECONOMIC ACTIVITY INTO CISLUNAR SPACE

Carthage College

A modal propellant gauging method will be tested during continuous liquid transfer, establishing the first microgravity tests of a technique to identify the location and distribution of the liquid surface during propellant transfer.

Draper

An entry, descent, and landing technology for hazard detection will be evaluated, building on its previous flight heritage on high-altitude balloons.

Florida Institute of Technology

The mechanical system of a plant incubator will be tested to validate its operation in microgravity and inform development of a larger scale space farming system.

Honeybee Robotics

A tool for evaluating the soil strength of near-Earth asteroids will be tested, with the aim of reducing mission risk to asteroids with high commercialization and mining potential.

Mango Materials

A membrane-based bioreactor will be tested to evaluate, adapt, and ultimately optimize gas delivery methods that may enable sustainable in-situ 3D printing in space.

Massachusetts Institute of Technology

- Two different kinds of robots – a "rovable" and an "inchworm" – will be tested to evaluate their potential to support in-space manufacturing and assembly of modular structures.
- A suite of imaging technologies will be used in experiments to help understand boiling models that are critical for the management of cryogenic propellant systems in microgravity.

New Jersey Institute of Technology

Factors impacting liquid nitrogen flow stability will be evaluated to enhance the safety of spacecraft propellant management.

Purdue University

- A medical suction device integrated with a microgravity surgical facility will be evaluated, with the aim of delivering a combined system prototype for suborbital testing.
- A liquid-vapor nitrogen system will be evaluated with the goal of advancing the state of the art for long-term cryogenic propellant storage in space.
- A sensor payload will be used to gather data about the heat transfer from a lander's rocket plume to its legs, with the goal of informing robust designs for future landers.
- An experiment aimed at enabling development of highly accurate models for the prediction of flow boiling rates will be conducted, with the goal of improving space-based propellant management.

Stanford University

A method of using acoustic fields will be tested to evaluate its ability to monitor propellant levels and tank integrity in microgravity.

The Aerospace Corporation

A method of pressurizing the contents of a cryogenic liquid storage tank will be evaluated in reduced gravity to determine improvements compared to traditional methods.

University of California, Davis

A suite of sensors and a display technology will be evaluated to determine the system's effectiveness as a non-pharmaceutical countermeasure for space adaptation sickness.

University of Central Florida

Technologies that help characterize the interactions between sensors and planetary regolith will be evaluated, enabling researchers to better understand the formation of small particles and layered structures in low gravity.

University of Florida

Unique measurement approaches will be used to evaluate a new method for manufacturing metals and alloys in microgravity.

University of Louisville

An aqueous immersion surgical system will be used to establish surgical protocols for spaceflight, addressing the potential need for methods of treating medical emergencies in space.

West Virginia University

A particle-based, foam-spraying 3D printer will be tested to investigate the use of ceramic and metal foams to strengthen and/or extend the in-service lifetimes of pre-existing 3D-printed structures in space, potentially reducing mission costs.

Zandef Deksit

A high-definition imaging system designed to capture the first ever video of a lunar lander's final descent and landing taken from the Moon's surface will be evaluated, with the goal of enabling the collection of data on how lander plumes will interact with and disrupt lunar regolith.

Virgin Galactic's VSS Unity and WhiteKnightTwo take off from Mojave Air and Space Port. Credits: Virgin Galactic

NEW TECHNOLOGY SELECTIONS

TOPIC 2: FOSTERING THE COMMERCIALIZATION OF LOW-EARTH ORBIT AND UTILIZATION OF SUBORBITAL SPACE

Arizona State University

The ability of a 3D weather imager will be tested to determine its ability to improve weather forecasting.

imec USA

- A measurement system designed to monitor the effects of spaceflight on the electrical activity of human cells in space will be evaluated.
- A compact digital holography system will be evaluated to assess its capabilities for capturing images at subcellular resolution without the need for optics or mechanical parts.

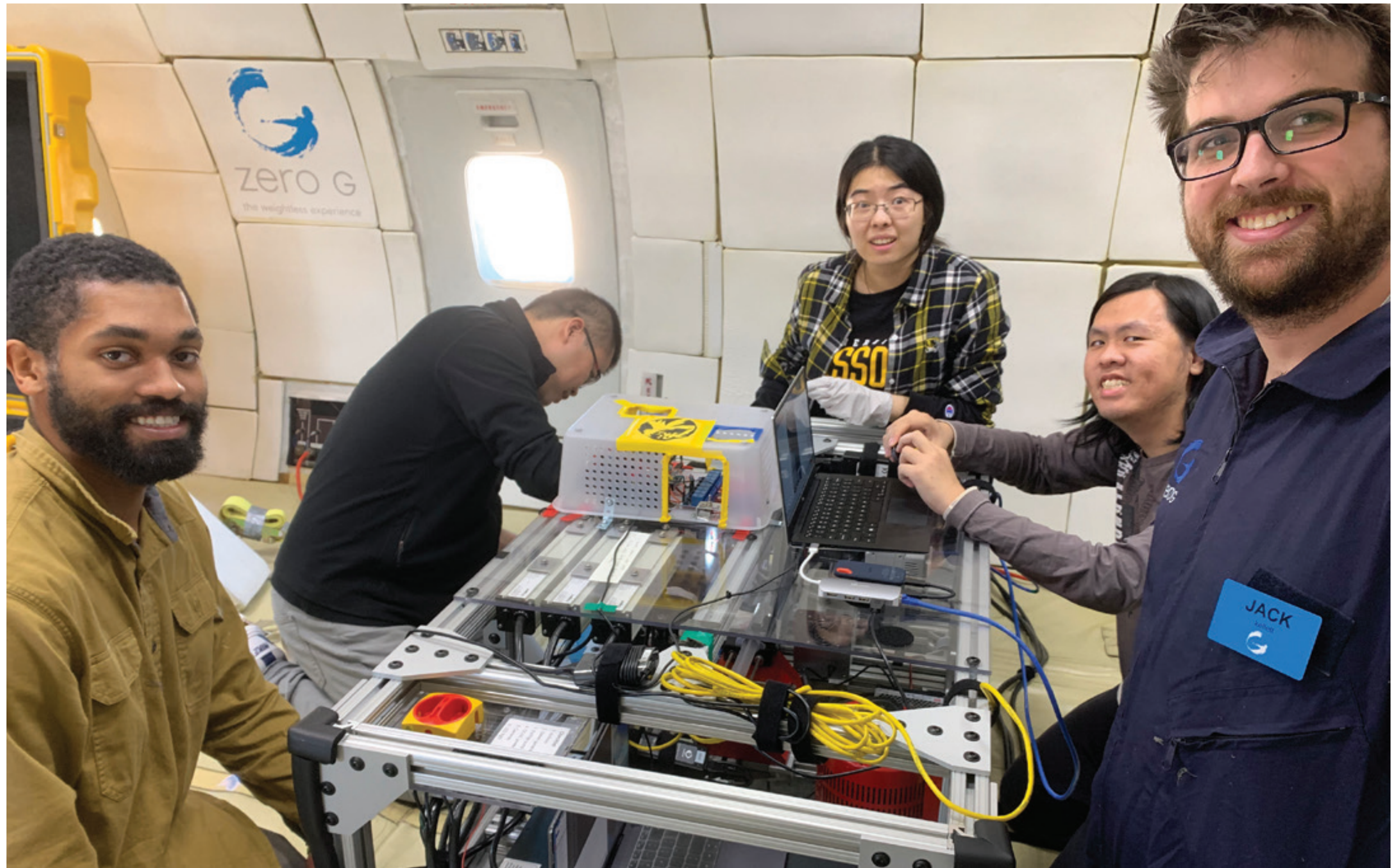
Massachusetts Institute of Technology

Microgravity behavior of beeswax and paraffin will be evaluated as possible low-cost, non-toxic alternatives to traditional rocket fuels.

Montana State University

Autonomous hardware to help researchers understand the impacts of launch and landing on yeast will be tested, with the goal of advancing insight into how biological organisms adapt to various stages of spaceflight.

A research team from the University of Missouri surrounds their payload during a parabolic flight campaign on Zero Gravity Corporation's G-FORCE ONE aircraft in November 2019. Credits: University of Missouri



Purdue University

A handheld, automated video control system will be tested as a possible tool for suborbital flight experiments that rely on video to monitor operations, record data, and aid post-flight technology assessments.

Southwest Research Institute

A broadband imaging system will be evaluated by the principal investigator aboard, capturing video through the cabin windows of a suborbital spacecraft. A biomedical harness will also be used to collect in-flight human heart rate and blood flow data. This is the first selection under the new NASA policy that allows non-NASA researchers to propose to fly with their research on NASA-supported suborbital spacecraft flights.

Spaceworks Engineering

A guided re-entry and recovery device will be evaluated as a means for enabling low-cost, autonomous recovery of small payloads from low-Earth orbit.

University of California, Berkeley

- A new additive manufacturing technique will be tested to determine its ability to print both biomaterial and engineering components in the same machine during microgravity conditions.
- A "lab on a chip" consisting of a programmable microfluidic analyzer will be tested to assess its ability to perform clinical assays that could be crucial for human health in space.

University of California, Davis

A low-cost, three-axis CubeSat attitude control mechanism with hard disk drive reaction wheels will be tested to assess the technology's pointing and stabilization in microgravity.

Blue Origin's New Shepard rocket-powered system descends toward a touchdown in west Texas. Credits: Blue Origin

"We are excited to have selected more technologies for Flight Opportunities than we have in any prior year. We are leaning forward into the future with these selections, including our first of a researcher-tended payload on a suborbital spaceflight."

— Christopher Baker, Program Executive, Flight Opportunities

During FY2020, Flight Opportunities built new connections with a variety of other NASA programs. The goal: to identify high-value technologies that could benefit from suborbital flight testing to help advance them to mission infusion. These collaborations ultimately aim to expand access to commercial suborbital flight testing by integrating Flight Opportunities program activities with existing technology development plans.

PAYLOAD ACCELERATOR FOR CUBESAT ENDEAVORS (PACE)

Flight Opportunities has partnered with NASA's Small Spacecraft Technology program to help increase the pace of getting innovations to the Moon and beyond by rapidly de-risking technologies via a combination of suborbital and orbital flight tests. The PACE initiative seeks to leverage a consistent form factor for both suborbital and orbital tests as well as enable suborbital test data to inform orbital test plans. In FY2020, three NASA technologies were selected for flight tests on high-altitude balloons to validate system performance:

NASA's Ames Research Center

- A particle detector instrument called INTREPID that discriminates between neutrons and gamma rays and may enable the characterization of radiation environments on small satellites and rovers as well as identification of potentially habitable environments
- A CubeSat architecture with flexible and modular systems designed to enable low-cost, rapid technology demonstrations to help meet NASA's safety and reliability standards and offer a nearly plug-and-play solution for CubeSat avionics
- A low-cost, low-SWaP (size, weight, and power) autonomous networking and navigation technology called V-R3x designed to enhance coordination among multiple spacecraft while limiting the need for ground-based infrastructure and control

The first suborbital flights for NASA's PACE initiative will be carried out in 2021 on a high-altitude balloon from Raven Aerostar. Credits: Raven Aerostar

SMALL BUSINESS INNOVATION RESEARCH AND SMALL BUSINESS TECHNOLOGY TRANSFER (SBIR/STTR)

Flight Opportunities is supporting SBIR/STTR technology developments by investing in suborbital flight testing for relevant Phase II projects. In FY2020, initial progress was made toward parabolic testing of a vapor compression refrigeration system from Air Squared designed for cold food storage on future exploration missions.

INTERNATIONAL SPACE STATION RESEARCH INTEGRATION OFFICE

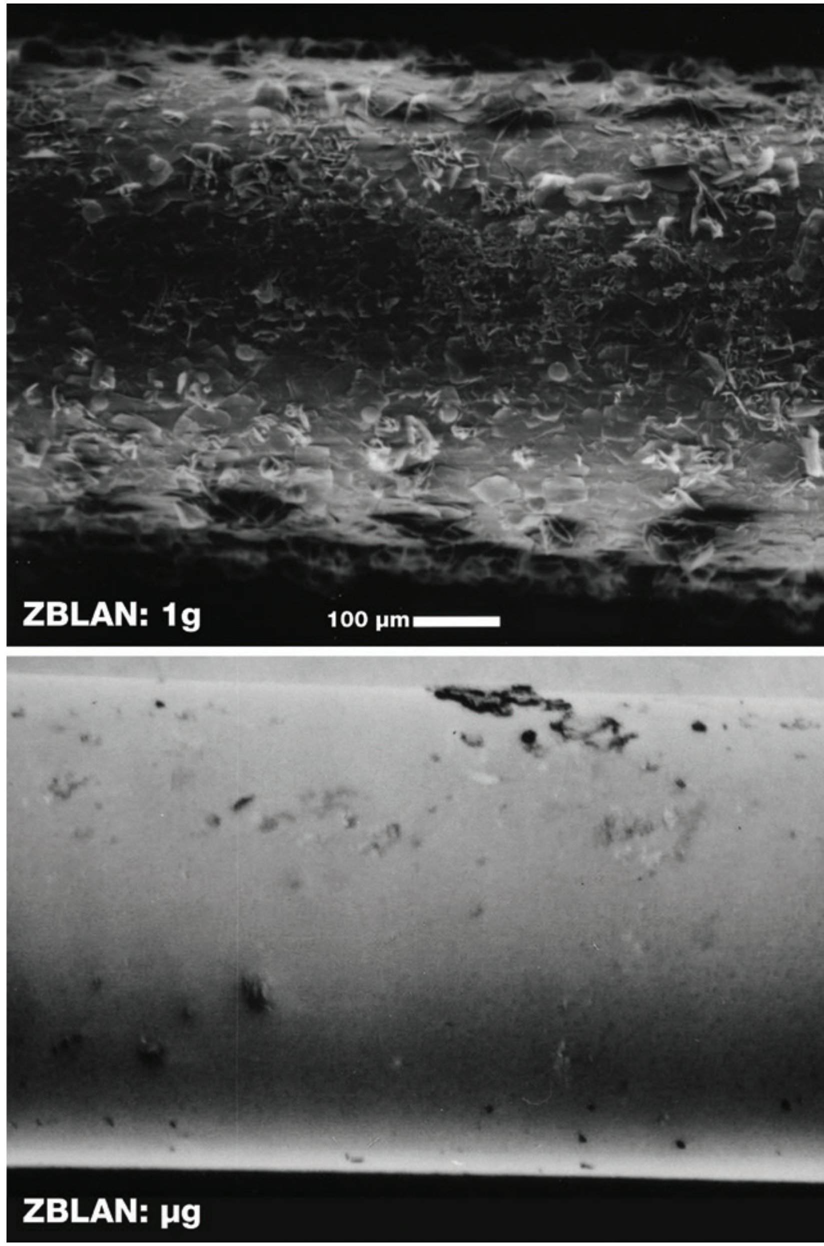
In FY2020, Flight Opportunities collaborated with the International Space Station Research Integration Office at NASA's Johnson Space Center to support technology development targeted for station deployment. Functional and operational tests aboard suborbital vehicles will be used to help lower technical risk and hasten technology development. In FY2020, Flight Opportunities selected two efforts related to the manufacturing of ZBLAN (ZrF_4-BaF_2-LaF_3-AlF_3-NaF)-based optical fiber in microgravity for flight testing.

Mercury Systems (formerly Physical Optics Corporation)

Improved techniques for manufacturing ZBLAN-based optical fiber in low gravity will be characterized by testing a ruggedized fiber draw module that can be automatically initiated to produce longer fiber lengths.

Made In Space

Researchers will test an early-stage engineering development unit for a Glass Alloy Manufacturing Machine – Acoustic Levitation Furnace (GAMMA-ALF) – a containerless processing system of glass preforms for fiber optics using acoustic levitation.



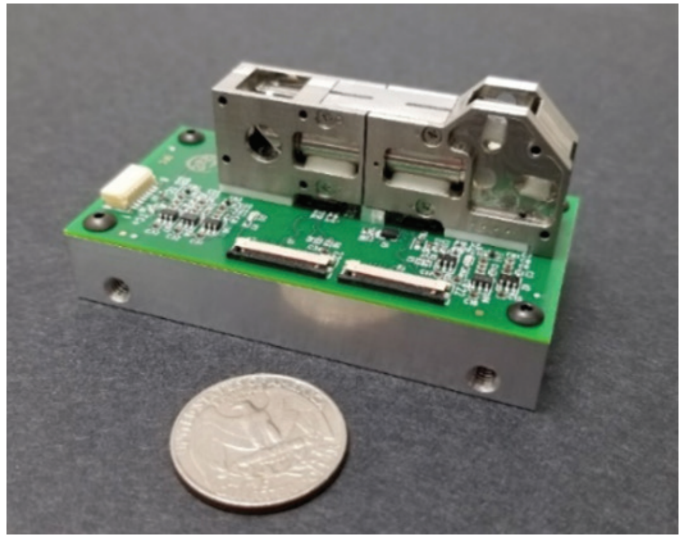
Two collaborative projects will investigate the advantages of manufacturing ZBLAN-based optical fiber in microgravity. These scanning electron microscope images show the surface of ZBLAN fibers pulled in microgravity (ug) and on Earth (1g). Manufacturing in microgravity may help sidestep the crystallization that occurs in Earth-based processing. Credits: NASA

OTHER NASA PROJECT AND PROGRAM SELECTIONS

In FY2020, Flight Opportunities identified a variety of technologies integral to a wide range of NASA projects and programs that could benefit from suborbital tests to advance project and mission goals.

NASA's Jet Propulsion Laboratory (JPL)

- Researchers will analyze a dual-rasp surface sampling tool designed to operate in the gravitational environment of Enceladus, the sixth-largest moon of Saturn.
- Flight testing will aid assessment of an automated DNA extraction device that could eliminate the need for returning samples to Earth for analysis, potentially accelerating diagnostics on orbital missions.
- Researchers will evaluate a spatial heterodyne spectroscopy interferometric technique that enables data collection with Hubble-level sensitivity but over a very narrow bandpass of interest.



JPL's heterodyne spectrometer is just 58 grams, with optics, electronics, and mechanics included. It will be evaluated as an option for gathering high spectral data on mass-limited space missions. Credits: NASA

NASA's Ames Research Center

Researchers will test a nephelometer on a high-altitude balloon, collecting data about the properties of the interiors of planetary clouds, including size, density, and state of matter of cloud particles, to help inform cloud models and climate simulations.

NASA's Goddard Space Flight Center

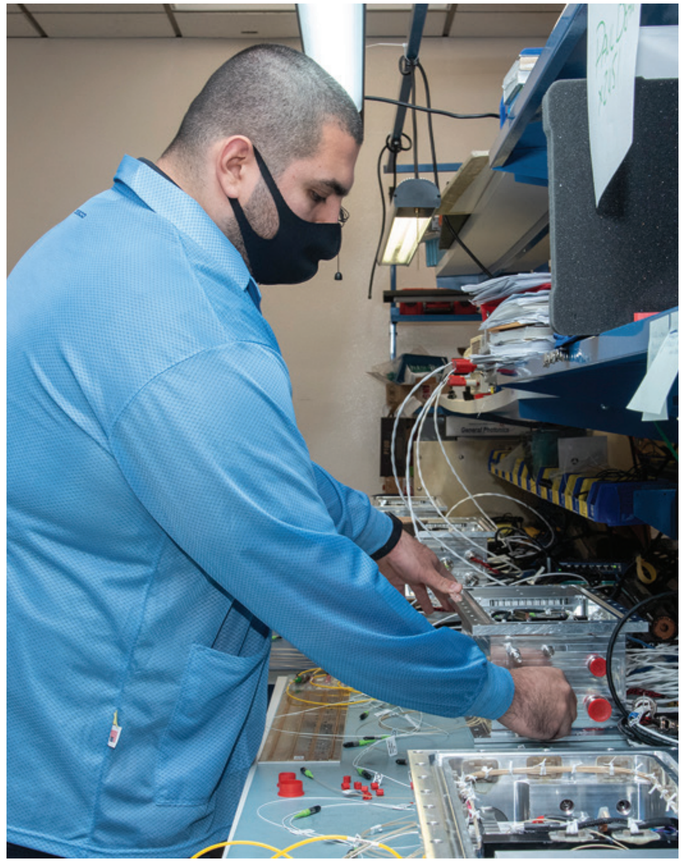
- Researchers will leverage flight tests to evaluate atomic layer deposition – an in-space additive manufacturing technique – for fabricating multi-functional coatings, particularly for large telescope mirrors.
- An electrically driven thin-film boiling system will be evaluated in advance of an International Space Station experiment for thermal management use across a wider thermal range than possible with current methods.

NASA's Marshall Space Flight Center

Researchers will test an improved fluid-dispensing tube design critical to International Space Station experiments that aim to advance understanding of protein aggregation associated with neurodegenerative diseases.

NASA's Armstrong Flight Research Center

Flight testing will help researchers evaluate the viability of the Fiber Optic Sensing System (FOSS) – an innovative method of collecting strain and temperature measurements with high precision – for space-based applications.



A project from Armstrong will investigate the viability of a ground-proven system for collecting strain and temperature measurements for space-based applications. Here, NASA research engineer Jonathan Lopez prepares a compact version of the system, known as a FOSS rocket box. Credits: NASA

NASA Headquarters and NASA's Kennedy Space Center

Researchers aim to validate that GPS and Galileo signals can be used for lunar/cislunar positioning, navigation, and timing. They will fly two different multi-Global Navigation Satellite System (GNSS) receivers on a suborbital flight and then use the test data to down-select one receiver to fly on a lunar lander and/or cislunar spacecraft.

OTHER GOVERNMENT AGENCY SELECTIONS

NASA also partners with other government agencies to test technologies that are relevant to the aerospace community. Three technologies were selected in FY2020 for flight testing:

Federal Aviation Administration Office of Commercial Space Transportation

- Flexible, high-speed, low-cost data acquisition and storage systems and black box technology will be evaluated for use as a flight data repository.
- Researchers will leverage an existing, atmospheric flight-proven modern general aviation LED strobe to investigate its applicability to commercial space vehicles when operating in the National Airspace System.
- Technology that aims to address the shortcomings of current ADS-B equipment will be tested on a reusable launch vehicle flight to assess its ability to handle the dynamic environment of spaceflight.

TECHNOLOGY PORTFOLIO

Number	PI	Organization	Technology	NASA TX Number
T0003	Sathya Gangadharan	Embry-Riddle Aeronautical University	Investigation to Determine Rotational Stability of On-Orbit Propellant Storage and Transfer Systems Undergoing Operational Fuel Transfer Scenarios	TX01: Propulsion Systems
T0191	Kevin Crosby	Carthage College	Microgravity Propellant Gauging Using Modal Analysis: Phase III	TX01: Propulsion Systems
T0206	Steven Collicott	Purdue University	Small-sat Propellant Management Technology	TX01: Propulsion Systems
T0215	Alina Alexeenko	Purdue University	Spaceflight Testing of FEMTA Micropropulsion System for Interplanetary Smallsat	TX01: Propulsion Systems
T0216	Steven Collicott	Purdue University	Zero-*g* Slosh Model Technology: Knowledge Payload	TX01: Propulsion Systems
T0218	Kevin Crosby	Carthage College	Magneto-Active Slosh Control System for Spacecraft and Launch Vehicles	TX01: Propulsion Systems
T0227	Kevin Supak	Southwest Research Institute - San Antonio	Microgravity Testing of a Large-Scale Liquid Acquisition Device for Cryogenic Fluid Management	TX01: Propulsion Systems
T0229	Kevin Crosby	Carthage College	Propellant Mass Gauging in Gateway Architecture Vehicles	TX01: Propulsion Systems
T0241	Steven Collicott	Purdue University	Spacecraft Pointing Control and Zero-gravity Slosh – Knowledge Payload	TX01: Propulsion Systems
T0244	Jacob Chung	University of Florida - Gainesville	Determination of Cryogenic Pool Boiling and Subsurface Helium Pressurization Characteristics in Reduced Gravity	TX01: Propulsion Systems
T0177	Justin Lee	The Aerospace Corporation	Rapid Calibration of Space Solar Cells in Suborbital Environments	TX02: Flight Computing and Avionics
T0217	Charles Hibbitts	The Johns Hopkins University Applied Physics Laboratory (APL)	IRIS: An Integrated Remote Imaging System - External Environment Remote Sensing from Suborbital Reusable Launch Vehicles	TX02: Flight Computing and Avionics
T0233	Brock LaMeres	Montana State University - Bozeman	RadPC@scale - Suborbital Flight Demonstration of a Radiation Tolerant Computer System at-Scale	TX02: Flight Computing and Avionics
T0258	Dayne Kemp	NASA's Ames Research Center	Advanced Developments Projects (ADP) Flight Avionics	TX02: Flight Computing and Avionics
T0207	David Miles	University of Iowa - Iowa City	CubeSat Articulated Boom Option Optimization in Microgravity (CABOOM)	TX04: Robotic Systems
T0225	Daniel Durda	Southwest Research Institute - Boulder	Box-of-Rocks Experiment II: Morphology and Sampling of Asteroid Regolith Simulants in Microgravity	TX04: Robotic Systems
T0226	Kris Zacny	Honeybee Robotics	PlanetVac-Xombie2: Honeybee PlanetVac on the Masten Lunar Lander	TX04: Robotic Systems
T0248	Mircea Badescu	NASA's Jet Propulsion Laboratory	Microgravity Testing of the Dual Rasp Sampling Tool/ System	TX04: Robotic Systems
T0253	Kris Zacny	Honeybee Robotics	Increasing Fidelity for Lunar Sample Collection	TX04: Robotic Systems
T0259	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
T0155	George Pantalos	University of Louisville	Suborbital Evaluation of an Aqueous Immersion Surgical System for Reduced Gravity	TX06: Human Health, Life Support, and Habitation Systems
T0187	Peter Lee	Ohio State University	Evaluation of Gravity Sensing Mechanisms in Tissue-Engineered Skeletal Muscle	TX06: Human Health, Life Support, and Habitation Systems

Number	PI	Organization	Technology	NASA TX Number
T0201	Rob Ferl	University of Florida - Gainesville	Human Tended Space Biology: Enabling Suborbital Genomics and Gene Expression	TX06: Human Health, Life Support, and Habitation Systems
T0204	Julie Brisset	University of Central Florida	Dust In-situ Manipulation System (DIMS)	TX06: Human Health, Life Support, and Habitation Systems
T0209	Michael Menze	University of Louisville	Evaluation of Preserved Blood for Transfusion Therapy in Reduced Gravity	TX06: Human Health, Life Support, and Habitation Systems
T0211	Chung-Lung Chen	University of Missouri - Columbia	Electrowetting Enhanced Dropwise Condensation in the Zero-g Environment	TX06: Human Health, Life Support, and Habitation Systems
T0219	Amir Hirsa	Rensselaer Polytechnic Institute	Adapting the Ring-Sheared Drop (RSD) Technology as a Bioreactor	TX06: Human Health, Life Support, and Habitation Systems
T0220	Christine Escobar	Space Lab Technologies	Microgravity Investigation for Thin Film Hydroponics	TX06: Human Health, Life Support, and Habitation Systems
T0221	W. Kent Tobiska	Space Environment Technologies	ARMAS Suborbital	TX06: Human Health, Life Support, and Habitation Systems
T0230	Marion Turnbull	Mayo Clinic - Jacksonville	Autonomous Sampling Technology for Biological Research During Suborbital Rocket Flight	TX06: Human Health, Life Support, and Habitation Systems
T0231	H. Todd Smith	The Johns Hopkins Applied Physics Lab	Application of Europa-Clipper Technology for Lunar Radiation Hazard Identification and Characterization	TX06: Human Health, Life Support, and Habitation Systems
T0232	W. Kent Tobiska	Space Environment Technologies	ARMAS Dual Monitor Pre-Operations Mission Demonstration (ARMAS DM POMD)	TX06: Human Health, Life Support, and Habitation Systems
T0236	Susana Zanello	imec USA Nanoelectronics Design Center	Silicon-Based Microfluidic Blood Test for Spaceflight	TX06: Human Health, Life Support, and Habitation Systems
T0238	John Wikswo	Vanderbilt University	An Automated, Instrumented Evaluation Platform for Validating the Performance of a Novel, Integrated Microfluidic Pump and Valve Experiment Control System for Tissue-Chips-In-Space and Chemical Mixing Experiments in Microgravity	TX06: Human Health, Life Support, and Habitation Systems
T0239	Rob Ferl	University of Florida - Gainesville	Biological Imaging in Support of Suborbital Science	TX06: Human Health, Life Support, and Habitation Systems
T0245	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
T0247	Anne Meier	NASA's Kennedy Space Center	Orbital Syngas Commodity Augmentation Reactor (OSCAR)	TX06: Human Health, Life Support, and Habitation Systems
T0249	Kasthuri Venkateswaran	NASA's Jet Propulsion Laboratory	Parabolic Flight Test of the Microgravity Tolerant Instrument for Automated Nucleic Acid Extraction (uTitan)	TX06: Human Health, Life Support, and Habitation Systems
T0252	Sridhar Gorti	NASA's Marshall Space Flight Center	Parabolic Flight Demonstration of Fluid Dispensing Tube Performance Limits for Drop Delivery	TX06: Human Health, Life Support, and Habitation Systems
T0257	Dayne Kemp	NASA's Ames Research Center	Intrepid Particle Detector	TX06: Human Health, Life Support, and Habitation Systems
T0263	Stephen Caskey	Air Squared	Vapor Compression Refrigeration System for Cold Food Storage on Spacecraft	TX06: Human Health, Life Support, and Habitation Systems
T0036	Josh Colwell	University of Central Florida	Collisions into Dust Experiment (COLLIDE) on a Commercial Suborbital Vehicle	TX07: Exploration Destination Systems

TECHNOLOGY PORTFOLIO

Number	PI	Organization	Technology	NASA TX Number
T0015	H. Todd Smith	APL	Electromagnetic Field Measurements on Suborbital Reusable Launch Vehicles	TX08: Sensors and Instruments
T0022	H. Todd Smith	APL	Environment Monitoring Suite on Suborbital Reusable Launch Vehicles	TX08: Sensors and Instruments
T0023	Sean Casey	Silicon Valley Space Center	Measurement of the Atmospheric Background in the Mesosphere	TX08: Sensors and Instruments
T0076	H. Todd Smith	APL	Demonstration of Vertically Aligned Carbon Nanotubes for Earth Climate Remote Sensing	TX08: Sensors and Instruments
T0114	H. Todd Smith	APL	Technology Demonstration of Graphene Ion Membranes for Earth and Space Applications	TX08: Sensors and Instruments
T0196	H. Todd Smith	APL	JANUS 3.0: Enabling Game Changing External Environment Payload Accommodation on Suborbital Reusable Launch Vehicles	TX08: Sensors and Instruments
T0224	Charles Hibbitts	APL	Integrated Remote Imaging System - Ultraviolet	TX08: Sensors and Instruments
T0234	Bryan Chan	Night Crew Labs	Flight Testing a GNSS Radio Occultation Autonomous System for Commercial Space Weather Applications	TX08: Sensors and Instruments
T0237	Daniel Bowman	Sandia National Laboratories	Flight Test of a Balloon-borne Aeroseismometer	TX08: Sensors and Instruments
T0250	Allen Parker	NASA's Armstrong Flight Research Center	Advancing Fiber Optic Sensing Technology for Space Applications (FOSS)	TX08: Sensors and Instruments
T0251	Vivek Dwivedi	NASA's Goddard Space Flight Center	In-Space Coating Development Utilizing Atomic Layer Deposition (ALD)	TX08: Sensors and Instruments
T0254	H. Todd Smith	APL	Suborbital Flight Testing of Chip-scale Satellites for Earth, Lunar and Cislunar Space Applications	TX08: Sensors and Instruments
T0260	Anthony Colaprete	NASA's Ames Research Center	Nephelometer Experiment (NephEx)	TX08: Sensors and Instruments
T0261	Sona Hosseini	NASA's Jet Propulsion Laboratory	Flight Demonstration and Maturation of the Next Generation of Miniature High-resolution Spectrometers	TX08: Sensors and Instruments
T0214	Alexandre Martin	University of Kentucky	Technology Demonstration of the KRUPS Capsule for Heat-Shield Validation	TX09: Entry, Descent, and Landing
T0235	Sean Bailey	University of Kentucky	Assessment of Forward Sensing Turbulence Detection Strategies for Stratospheric Flight	TX09: Entry, Descent, and Landing
T0240	Brett Streetman	Draper	Draper Multi-Environment Navigator (DMEN) Suborbital Rocket Campaign	TX09: Entry, Descent, and Landing
T0242	Philip Metzger	University of Central Florida	Maturing Ejecta STORM for Lunar Delivery	TX09: Entry, Descent, and Landing
T0269	John M. Carson	NASA's Johnson Space Center	Safe and Precise Landing - Integrated Capabilities Evolution (SPLICE)	TX09: Entry, Descent, and Landing
T0156	Julie Brisset	University of Central Florida	Suborbital Particle Aggregation and Collision Experiment-2 (SPACE-2)	TX11: Software, Modeling, Simulation, and Information Processing
T0255	Tim Lachenmeier	GSSL Inc.	Data Buoy for NASA's Long Duration High Altitude Balloons	TX11: Software, Modeling, Simulation, and Information Processing

Number	PI	Organization	Technology	NASA TX Number
T0212	Konstantinos Sierros	West Virginia University	3D Printing of Hierarchical Foams in Microgravity	TX12: Materials, Structures, Mechanical Systems and Manufacturing
T0228	Mark Pankow	North Carolina State University	Composite Origami for Spacecraft Solar Arrays and Deployable Structures	TX12: Materials, Structures, Mechanical Systems and Manufacturing
T0268	Daniel Marshall	Physical Optics Corporation	Orbital Fiber Optic Production Module (ORFOM)	TX12: Materials, Structures, Mechanical Systems and Manufacturing
T0243	Adrienne Dove	University of Central Florida	Exploring Electrostatic Regolith Interactions in Low Gravity	TX13: Ground, Test, and Surface Systems
T0173	Franklin Robinson	NASA's Goddard Space Flight Center	Flow Boiling in Microgap Coolers - Embedded Thermal Management for Space Applications	TX14: Thermal Management Systems
T0189	Jacob Chung	University of Florida - Gainesville	Demonstration of Optimal Chilldown Methods for Cryogenic Propellant Tanks in Reduced Gravity	TX14: Thermal Management Systems
T0213	R. Michael Banish	University of Alabama - Huntsville	Transport Properties of Fluids for Exploration	TX14: Thermal Management Systems
T0262	Jeffrey Didion	NASA's Goddard Space Flight Center	Investigation of Gravity Effects on Electrically Driven Liquid Film Boiling: A Suborbital Reusable Launch Vehicle Experiment in Preparation for an ISS Flight Experiment	TX14: Thermal Management Systems
T0194	Stephan Ord	NASA's Ames Research Center	SFEM-3 (SlamStick)	TX15: Flight Vehicle Systems
T0270	Arwen Dave	NASA's Ames Research Center	Affordable Vehicle Avionics (AVA)	TX15: Flight Vehicle Systems
T0271	Jerry Larson	UP Aerospace	Spyder: Critical Technology Demonstration Tests	TX15: Flight Vehicle Systems
T0264	James J. Miller	NASA Headquarters	Multi-Global Navigation Satellite System (GNSS) Receiver Payload	TX16: Air Traffic Management and Range Tracking Systems
T0265	Nick Demidovich	Federal Aviation Administration Office of Commercial Space Transportation	Flight test of Spacecraft Black Box Technology modules for Commercial Spacecraft	TX16: Air Traffic Management and Range Tracking Systems
T0266	Nick Demidovich	Federal Aviation Administration Office of Commercial Space Transportation	First Demonstration of General Aviation Strobe for Commercial Re-usable Launch Vehicles (RLVs)	TX16: Air Traffic Management and Range Tracking Systems
T0267	Nick Demidovich	Federal Aviation Administration Office of Commercial Space Transportation	Commercial Space Vehicle Tracking using ADS-B Technology	TX16: Air Traffic Management and Range Tracking Systems
T0256	Steve Sandford	Psionic	Psionic Navigation Doppler LIDAR: Precision Navigation Sensor for Lunar Missions	TX17: Guidance, Navigation, and Control

FLIGHT OPPORTUNITIES

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