National Aeronautics and Space Administration

From Flight Test to the Moon: Demonstrating Lunar Technologies, Instruments, and Experiments with NASA's Flight Opportunities Program

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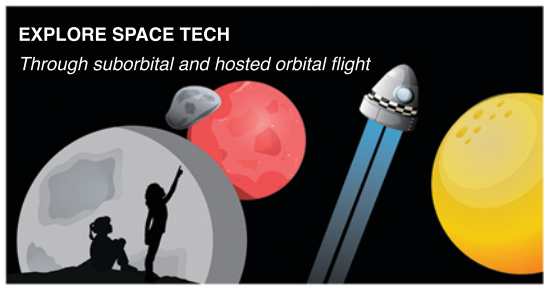
INTRODUCTION

NASA's Flight Opportunities program serves the agency by providing access to suborbital and hosted orbital flight tests with commercial providers as well as subject matter expertise on flight testing a range of payload types aboard a variety of platforms. Researchers across NASA, at other federal agencies, and beyond can engage with the program to flight test their technologies, instruments, and experiments. Cost-effective and timely access to relevant space environments can help advance technology readiness levels and reduce risk ahead of longer, more expensive missions, including missions to the Moon and Mars.

Since 2011, Flight Opportunities has supported hundreds of flights with more than 1,000 payload tests. These flight tests have supported the maturation of technologies and research with applications for lunar exploration and the development of resilient lunar infrastructure.



MECHANISMS FOR FUNDING FLIGHT TESTS

Flight Opportunities creatively uses a variety of funding mechanisms to mature innovative solutions for the nation's technology needs, engaging academia, non-profit research institutes, industry, and entrepreneurs to address technology shortfalls.

Non-government researchers can propose for payload development and flight test funding through the program's challenges and solicitations. Researchers currently supported by NASA or another government organization can work with the program directly through "Flights of Opportunity," accessing commercial flight tests through the program's IDIQ (Indefinite Delivery/Indefinite Quantity) contracts.

Challenges:

NASA TechLeap PRIZE

Open to U.S. commercial businesses, academic or non-profit research institutions, entrepreneurs, and independent innovators; provides funding and flight test opportunity.

Solicitations: Eligibility varies according to the solicitation.

NASA TECHFLIGHTS · SBIR·STTR America's Seed Fund · University SmallSat Technology Partnerships · Tipping Points · Announcements of Collaboration Opportunity

Flights of Opportunity:

- **Open to:**
  - — NASA personnel
  - — Competitively selected NASA-funded projects
  - — Other government agencies
- **Request Flight Opportunities support for flight testing with NASA-contracted flight providers**
  - — 15 U.S. commercial companies
- **Flight Opportunities also helps you:**
  - — Identify test environment
  - — Establish mechanism/agreement
  - — Prepare for flight

GETTING STARTED WITH FLIGHT OPPORTUNITIES

Interested researchers are encouraged to reach out to Flight Opportunities at any time outside of an open solicitation and stay up-to-date with current opportunities via the Flight Opportunities newsletter. In addition, there are several other resources available to researchers interested in engaging with the program, including the monthly Community of Practice webinar series, an online flight test lessons learned library, and a portfolio of previously tested technologies as well as opportunities to meet one-on-one with the program team and a tool to prepare for these interactions.

Researchers within and outside of NASA are encouraged to reach out to Flight Opportunities at any time. Learn more at **nasa.gov/flightopportunities**.

RELEVANT TEST ENVIRONMENTS

Flight Opportunities facilitates access to a variety of test environments that replicate conditions encountered on lunar and planetary missions. Relevant environment test conditions include, but are not limited to:

- Microgravity and weightlessness
- Challenging landing navigation
- High-altitude solar exposure
- Extreme temperatures and vacuum
- Atmospheric re-entry
- Radiation

Commercial flight providers utilize a variety of different vehicles to provide these test profiles and support the advancement of investigators' research or technology development plans.

Vertical Takeoff Vertical Landing (VTVL) Vehicles

These vehicles provide a controlled descent and landing from various altitudes, often specializing in the testing of entry, descent, and landing technologies.

Parabolic Flights

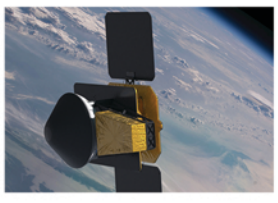
These airplanes achieve brief periods of reduced gravity through a series of maneuvers called parabolas. These flight profiles can be used for testing technologies that need to operate in zero or reduced gravity.

High-Altitude Balloons

These systems can reach altitudes of up to approximately 100,000 feet (or 30 kilometers) and typically sustain flights of hours, days, or even weeks at a time, offering exposure to relevant pressure and thermal environments as well as external views of the Earth below. High-altitude drop of payloads is also an option.

Suborbital Reusable Launch Vehicles

These vehicles reach high altitudes — nominally nearly 50 miles (or 80 kilometers) — providing two or more minutes of continuous reduced gravity and/or exposure to the space environment.



Hosted Orbital Platforms

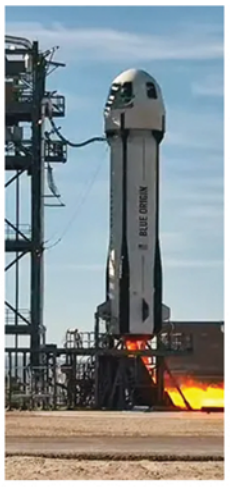
These platforms include small spacecraft, satellites, launch vehicle stages, or orbital spacecraft. Platforms provide power and communications to their hosted payloads.

LUNAR GRAVITY SIMULATION CAPABILITIES

Several of the industry flight providers under contract with Flight Opportunities offer vehicles uniquely suited to testing technologies ahead of lunar missions, including: Blue Origin's New Shepard rocket with capabilities for lunar gravity and microgravity; aircraft from Zero Gravity Corporation that fly parabolic trajectories, simulating lunar gravity (as well as Martian and microgravity); and platforms that can host payloads in orbit, providing extended periods of microgravity.

Simulated Lunar Gravity via Suborbital Rocket. Seventeen technologies flew aboard Blue Origin's New Shepard reusable suborbital rocket system on Feb. 4, 2025. The flight provided approximately two minutes of simulated lunar gravity, allowing researchers to test and de-risk innovations that could address critical shortfalls for the Artemis program, planetary exploration, and commercial space missions.

During the flight test, the payload capsule detached from the booster and spun at approximately 11 rpm to simulate lunar gravity for the NASA-supported payloads inside. Vehicle capability enhancements to enable this simulation of lunar gravity during suborbital flight were supported by development funding and early purchase of payload space by Flight Opportunities as part of its strategic investment in the U.S. spaceflight industry.



LUNAR INFUSION HIGHLIGHTS

Several lunar technologies tested through the program have been infused into space missions, including seven that went to the Moon through the NASA Commercial Lunar Payload Services (CLPS) initiative, which supports the delivery of science and technology payloads to the Moon's surface for testing. For those seven technologies, flight tests helped research teams reduce their technologies' risks and prepare them for NASA CLPS deliveries. Below are three Flight Opportunities–tested technologies that went tc the Moon aboard Firefly Aerospace's Blue Ghost Mission 1 in early 2025.

PlanetVac: Regolith Sample Collection

- PlanetVac uses compressed gas to gather regolith from celestial surfaces, transferring samples from a lander vehicle's footpads through pneumatic hoses to a collection container. It takes only a few seconds to obtain the sample using virtually no power.
- From 2018 to 2020, during tests supported by Flight Opportunities on Xodiac — an Astrobotic VTVL vehicle — PlanetVac successfully collected more than 220 grams of simulated regolith. **Flight tests showed PlanetVac could survive launch/landing and successfully capture and deliver regolith samples, proving its worthiness for a lunar mission.**
- During Blue Ghost Mission 1, PlanetVac successfully collected, transferred, and sorted lunar regolith from the Moon using pressurized nitrogen gas, demonstrating a low-cost, low-mass solution for robotic sample collection.

RadPC: Radiation-Tolerant Computing

- RadPC is designed to provide increased computer reliability in the presence of high-energy radiation at a fraction of the cost of existing solutions. Based on commercial off-the-shelf components, the system has a redundant core architecture that replaces faulted processors in real time.
- Flight Opportunities–supported testing began in 2014 aboard sounding rockets, including one flown by UP Aerospace, which helped demonstrate that RadPC could withstand the forces of a rocket launch. Aboard Aerostar high-altitude balloons, RadPC flew for more than 100 hours above 75,000 feet — outside of the majority of Earth's atmosphere and thus exposed to space radiation — enabling researchers to validate various subsystems. **These flight demonstrations were crucial to preparing RadPC for two demonstrations on the International Space Station in 2022 as well as selection for the Blue Ghost CLPS mission.**
- During the CLPS mission, RadPC successful operated in transit and on the lunar surface, verifying low-cost solutions to mitigate radiation effects on computers to make missions safer and more cost effective.

LuGRE: Leveraging Earth-Based GNSS Signals

- To validate the interoperability of the GPS and Galileo GNSS (Global Navigation Satellite System) in the highly dynamic environment typical of a launch vehicle, researchers developed a flight test payload that combined two receivers that used both satellite navigation systems to determine precise location, velocity, and time of a sounding rocket. One of those receivers also was tested to improve positioning, navigation, and timing for applications in future lunar missions, both in cislunar environments and during landing.
- During a 2024 flight test supported by Flight Opportunities aboard an UP Aerospace sounding rocket, researchers demonstrated the effective use of a multi-constellation (GPS-Galileo) multi-frequency GNSS receiver on a launch vehicle. Researchers used flight data to perform experimental evaluations of the benefits of interoperability between GPS and Galileo constellations. **The effort with Flight Opportunities provided extremely valuable data to aid in ongoing research and optimization of the technology.**
- On the Blue Ghost mission, LuGRE (Lunar GNSS Receive Experiment) — which included one of the GNSS receivers — acquired and tracked satellite network signals, marking the first time a navigation solution has been achieved using GNSS in lunar orbit and on the Moon.

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