National Aeronautics and Space Administration

Leveraging Commercial Flight Testing to Advance Lunar Surface Technologies

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INTRODUCTION

Suborbital flight testing is an invaluable but often overlooked tool that can be used to advance space research and technology development more quickly. NASA's Flight Opportunities program leverages commercial flight providers to accelerate the maturation of space technologies using suborbital rocket-powered vehicles, aircraft flying parabolic trajectories, high-altitude balloons, and orbital platforms that can host payloads. Exposure to relevant space environments can validate a technology's functionality in a cost-efficient and timely manner, reducing risk ahead of longer, more expensive missions, including missions to the Moon and Mars.

Since 2011, Flight Opportunities has supported over 271 flights with more than 899 tests of payloads. These flight tests have supported the maturation of technologies and research with applications for lunar and planetary exploration. This poster illustrates:

- Ways for U.S. researchers from industry, academia, and non-profit research institutes – as well as those from NASA and other government agencies – to engage with the Flight Opportunities program, including information on the program's solicitations and challenges
- How principal investigators (PIs) can make the most of their flight tests and design them with a future lunar or other application in mind
- Why suborbital flight testing has become a best practice for NASA-supported technologies across disciplines
- Resources available for prospective and seasoned investigators, including a monthly Community of Practice webinar series, the Flight Opportunities newsletter, and one-one-ones with Flight Opportunities team members

TECHNOLOGIES AND RESEARCH APPROPRIATE FOR FLIGHT TESTING

Under the umbrella of NASA's Space Technology Mission Directorate (STMD), Flight Opportunities advances STMD's mission to rapidly develop, demonstrate, and transfer revolutionary, high pay-off space technologies. STMD organizes the agency's technology investments into a strategic framework with focus areas to drive technology development.

Technologies and experiments that fit the four "thrusts" of NASA's Strategic Technology Framework and will enable NASA's future exploration missions are well suited for flight testing through Flight Opportunities. Examples include:

- **GO:** Cryogenic fluid management
- **LAND:** Entry, descent, landing; precision landing, thermal protection systems
- **LIVE:** In situ resource utilization; advanced thermal management; advanced materials, structures, and construction; advanced habitation systems
- **EXPLORE:** Advanced manufacturing; small spacecraft systems

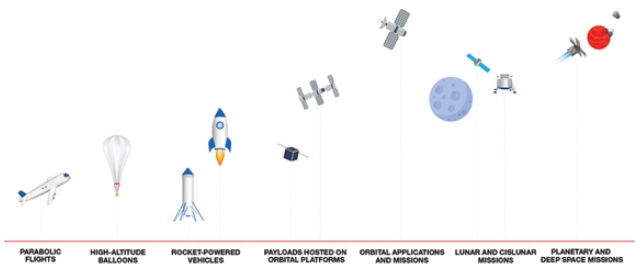
FLIGHT OPPORTUNITIES MECHANISMS

NASA TECHFLIGHTS	Includes topic areas that address agency and mission goals; up to $1M to purchase flights on suborbital or hosted orbital platforms directly from any eligible U.S. commercial flight provider
NASA TechLeap PRIZE	Challenges addressing specific NASA technology needs; previous awards have been up to $650K to build payloads, plus access to a suborbital flight test
NASA TECHRISE STUDENT CHALLENGE	Competition to inspire the next generation of space researchers; offers hands-on insight into the design and test process used by NASA-supported researchers
Flights of Opportunity and Agency Initiatives	Through collaborative internal and external relationships, the program takes advantage of opportunities to flight test valuable space technologies from NASA and other government programs, including but not limited to: • NASA's In-Space Manufacturing and ISS Program Office • NASA's Science Missions Directorate (SMD) — ROSES — Human Research Program — Biological and Physical Sciences • Suborbital Crew program • EPSCoR • SBIR/STTR • Intergovernmental support (Department of Defense, USDA) • TechFlights Reflights

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



AVAILABLE FLIGHT VEHICLES

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.

Rocket-Powered Vehicles

This category includes both suborbital reusable launch vehicles (sRLVs) 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, and electronics and information technology systems.

High-Altitude Balloons

Large balloon systems reach a nominal altitude of 30 kilometers 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, spacecraft communications technologies, and other instruments and technologies that may benefit from high-altitude observations (both to ground and into space) and drop tests.

Parabolic Flights

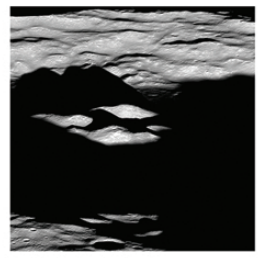
Aircraft flying this profile achieve brief periods of reduced gravity – capable of achieving zero gravity, lunar gravity, Martian gravity, or even asteroid gravity levels – through a series of maneuvers called parabolas. They can be used for testing technologies such as space-based medical experiments, biological experiments, robotic systems, in-space manufacturing methods, cryogenic fluid management techniques, and electronics and information technology systems.

Orbital Platforms Hosting Payloads

In collaboration with NASA's Small Spacecraft Technology program, Flight Opportunities now offers orbital platforms hosting payloads. These platforms provide power and communications to the payload, and perform at least one orbit around the Earth. Payloads may remain attached to the orbital stage(s) of a launch vehicle or be hosted on a satellite. They can be used for testing payloads that require extended periods of microgravity.

RECENT LUNAR TECHNOLOGY TESTING

NASA TechLeap Winners Advance Technology to Aid Lunar Landings



This image of the Moon's Bhabha crater illustrates the dark and rocky terrain of the lunar surface. This challenging environment requires advanced sensing systems that enable precision landing technology to safely deliver spacecraft. Credits: NASA/Arizona State University

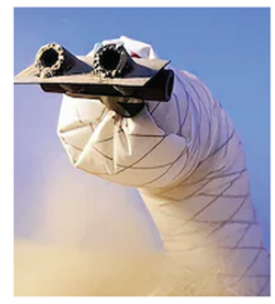
In July 2022, NASA named three winners in the agency's second TechLeap Prize competition, Nighttime Precision Landing Challenge No. 1, with the aim of enabling the agency to identify low-cost sensing systems that can map terrain in the dark from an altitude of 250 meters or higher. Such technology will be critical for future space exploration, which will require spacecraft of various sizes to land routinely and precisely in challenging terrain, such as the rocky and often dark or shadowed areas of the Moon's cratered surface. The winning teams were awarded an initial $200,000 prize to help mature their technology, with the opportunity for each to win up to a total of $650,000 in prizes as well as a suborbital flight test on a commercial rocket-powered landing vehicle.

Lunar Gravity Capabilities on Blue Origin's New Shepard

In March 2021, NASA expanded options for evaluating the performance of technologies in lunar gravity via support for new testing capabilities on Blue Origin's New Shepard reusable suborbital rocket system – enabling the agency to test and de-risk innovations critical to achieving the goals of the Artemis program, as well as lunar surface exploration and Moon-bound commercial applications.

New Shepard's upgrades will allow the vehicle to use its reaction control system to impart a rotation on the capsule. As a result, the entire capsule essentially acts as a large centrifuge to create artificial gravity environments for the payloads inside.

Current NASA-supported payloads scheduled for the first lunar gravity flight aim to advance a variety of technology priorities, including:



- **Lunar Regolith Properties:** Six instruments and experiments designed to test the fundamental physical, electrostatic, and chemical properties of lunar regolith, as well as the mechanical behavior of surface materials under excavation and processing
- **Life Detection:** Experiment will test microfluidic processing under lunar gravity for life detection instrument designed for Europa
- **Crew Safety:** Scenario planning for flame front propagation
- **Dust Mitigation:** Two lunar dust mitigation experiments to understand lunar dust electrostatic charge environment
- **Robotic Exploration:** Burrowing mobility system called "Root-Like Robots" Subsurface access, lava tube exploration and crewed-lander/habitat inspection

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. While NASA and NASA-supported researchers should contact the Flight Opportunities team directly about internal funding opportunities, eligible non-NASA investigators can apply to the program's annual TechFlights solicitation or compete for payload development funding and access to flights through NASA's TechLeap Prize.

Dual-Anonymous Peer Review

The Space Technology Mission Directorate is strongly committed to ensuring that proposal review is performed in an equitable and fair manner that reduces the impacts of any unconscious biases. In addition to other techniques, Flight Opportunities uses a dual-anonymous peer review (DAPR) process where the identities of both reviewers and proposers are not shared until after the technical merit has been evaluated for all anonymized proposals.