Flight Opportunities and Small Spacecraft Technology Program Updates

NAC Technology, Innovation and Engineering Committee Meeting | March 19, 2020

Christopher Baker
NASA Space Technology Mission Directorate
Flight Opportunities and Small Spacecraft Technology Program Executive

CHANGING THE PACE OF SPACE

Through Small Spacecraft Technology and Flight Opportunities, Space Tech is pursuing the rapid identification, development, and testing of capabilities that exploit agile spacecraft platforms and responsive launch capabilities to increase the pace of space exploration, discovery, and the expansion of space commerce.

EXPLORE SPACE TECH

THROUGH SUBORBITAL FLIGHT

The 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

Photo Credit: Blue Origin

LEARN MORE: WWW.NASA.GOV/TECHNOLOGY

FLIGHT OPPORTUNITIES BY THE NUMBERS

Between 2011 and today…

- Supported **195** successful fights
- Enabled **676** tests of payloads
- **254** technologies in the portfolio
- **13** active commercial providers

In 2019 alone…

- Supported **15** successful fights
- Enabled **47** tests of payloads
- **86** technologies in the portfolio
- **9** active commercial providers

Numbers current as of March 1, 2020

TECHNOLOGY TESTED IN SUBORBITAL SPACE IS GOING TO EARTH ORBIT, THE MOON, MARS, AND BEYOND

Lunar Payloads

ISS

Mars 2020

Commercial Lunar Payload Services

Critical Space Exploration Solutions

Commercial Lunar Payload Services

Four companies selected as Commercial Lunar Payload Services (CPLS) providers leveraged Flight Opportunities-supported suborbital flights to test technologies that are incorporated into their landers and/or are testing lunar landing technologies under Flight Opportunities for others.

Draper Laboratory

Masten Space Systems

Astrobotic Technology

Blue Origin

Astrobotic Auto-landing System

Astrobotic Technology

The auto-landing system includes hazard detection, autonomous hazard avoidance, and terrain relative navigation, for high precision landing beyond Earth were GPS cannot be used.

Current exploration missions target large areas of statistically safe terrain—not precise enough for future NASA and commercial ambitions that require arrival at specific targets. The auto-landing system is designed to deliver payload to within 100 meters of a chosen destination while autonomously avoiding hazards.

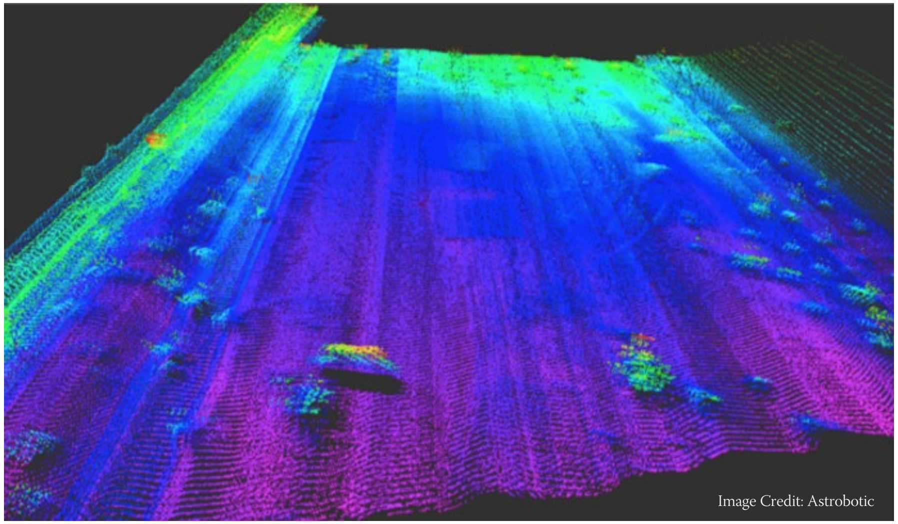


Image Credit: Astrobotic

FLIGHT TEST HIGHLIGHTS

Flight Provider: Masten Space Systems

Accurate detection of hazards larger than 25 cm

Successful closed-loop flight test, resulting in navigation to a safe landing location, including avoidance of mock hazards

INFUSION

Astrobotic's terrain relative navigation was further matured via a NASA Tipping Point award and will fly on Astrobotic's first trip to the Moon in 2021.

Radiation-Tolerant Computing System

Montana State University

Called “RadSat” for short, this system is implemented on a commercial off-the-shelf field programmable gate array and provides a reconfigurable and redundant architecture and robust, self-healing capabilities.

Radiation-tolerant computing will be needed on the Moon, where the lack of atmosphere as well as the magnetic field and radiation from the Sun will be a challenge for most terrestrial electronics.

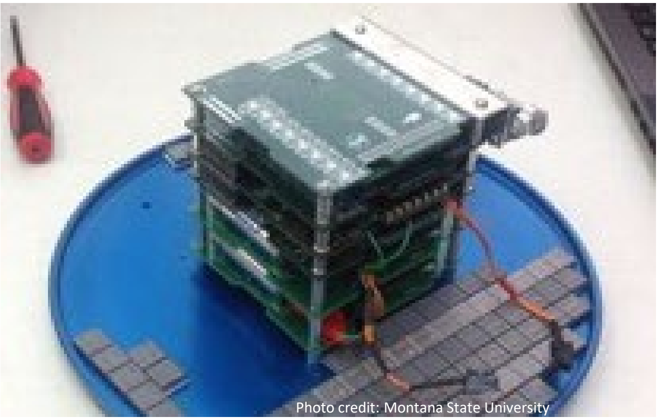


Photo credit: Montana State University

FLIGHT TEST HIGHLIGHTS

Flight Providers: UP Aerospace, Near Space Corporation

Tested the power and data logging systems

Enabled evaluation of thermal control analysis and data analysis systems

Confirmed that system was robust enough to survive tumultuous launch conditions

INFUSION

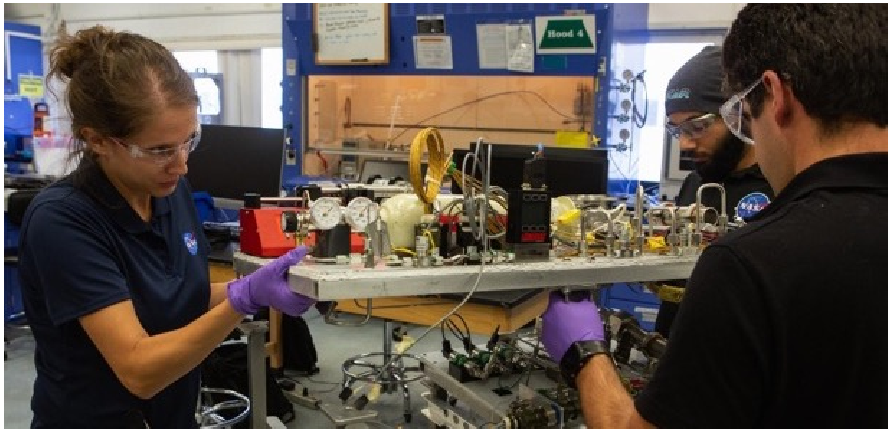
Selected for NASA’s CubeSat Launch Initiative, a Smallsat Technology Partnership, an Undergraduate Student Instrumentation Project, and a lunar demonstration as part of NASA’s Artemis program.

Orbital Syngas Commodity Augmentation Reactor (OSCAR)

NASA's Kennedy Space Center

OSCAR is a NASA Early Career Initiative experiment designed to take waste materials and burn it in a reactor to break it down into chemical sub-components that can be reused.

Recycling is critical for long-term habitation in space. As would be required for both sustainable cislunar presence and human missions to Mars.



FLIGHT TEST HIGHLIGHTS

Flight Provider: Blue Origin

OSCAR flew on Blue Origin the New Shepherd vehicle in December and successfully demonstrated zero-gravity trash to gas conversion in microgravity.

Video data shows the burn process, while the gas products were captured for later analysis. This data is being compared with 2 second and 5 second drop test results as well as tests in full gravity.

TRANSITION

HEOMD AES is funding further work in this area and a second flight sponsored by STMD is in work.

TECH FLIGHTS 2020 SOLICITATION – NOW OPEN

Seeking technologies for test on suborbital flights to:

- Support *sustainable lunar exploration*
- Foster the *commercialization of low-earth orbit* and the *expansion of economic activity into cislunar space*
- Foster the *utilization of commercial suborbital spaceflight*
- Demonstrate use of commercial suborbital flight for *research applications*

New provisions allowing for suborbital human tended payloads and educational opportunities

Photo Credit: Virgin Galactic

LEARN MORE: GO.NASA.GOV/32ASH7P

SPEED IS IMPERATIVE

Decreasing Time to First Flight

To rapidly get technology from lab to orbit, time from solicitation to first flight is critical

Current Average*: **21** Months

From Solicitation to First Flight

New Target: **< 9** Months

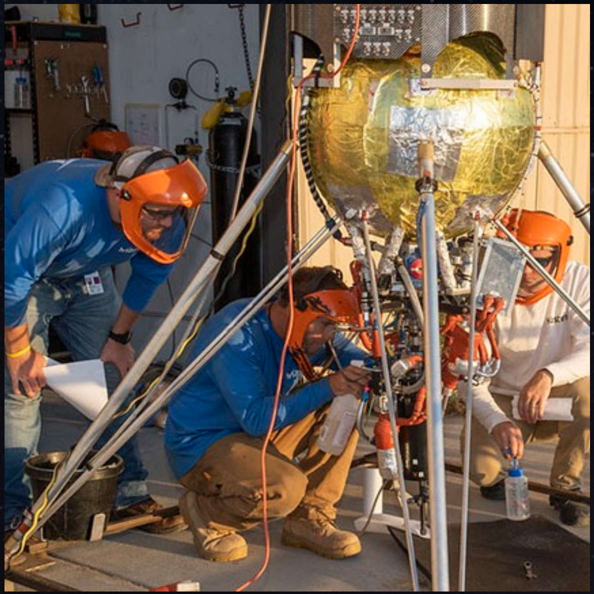
Minimizing Time Between Reflights

Iterative tests with quick turn-around times maximize impact

Current Average*: **10** Months

Between Reflights

New Target: **< 6** Months

* Data from 2017 and 2018 solicitations

EXPLORE SPACE TECH

WITH SMALL SPACECRAFT

The Small Spacecraft Technology program expands U.S. capability to execute unique missions through rapid development and demonstration of capabilities for small spacecraft applicable to exploration, science and the commercial space sector.

LEARN MORE: **WWW.NASA.GOV/TECHNOLOGY**

- Enable execution of missions at much **lower cost** than previously possible.
- Substantially **reduce time** required for development of spacecraft.
- Enable and demonstrate **new mission architectures**.
- Expand the capability of small spacecraft to execute missions at **new destinations** and in challenging new environments.
- Enable the **augmentation of existing assets and future missions** with supporting small spacecraft.

EXPLORATION PATHFINDING & DEEP SPACE SMALL SPACECRAFT

Small spacecraft afford an increasingly capable platform to precede and accompany exploration missions to the moon, Mars, and other destinations to scout terrain, characterize the environment, identify risks, and prospect for resources.

Examination of mission concepts highlighted the following technology gaps:

- **Deep Space Propulsion for Small Spacecraft**

  High impulse per unit of spacecraft and high total impulse, while remaining low power per unit of spacecraft and compatible with secondary payload launch restrictions. Tolerant to the deep space radiation and thermal environment. Onboard propulsion can be augmented by propulsive payload adapters or other means that extend the reach of ride share and small launch capabilities.

- **Affordable Radiation Tolerance for Small Spacecraft Missions**

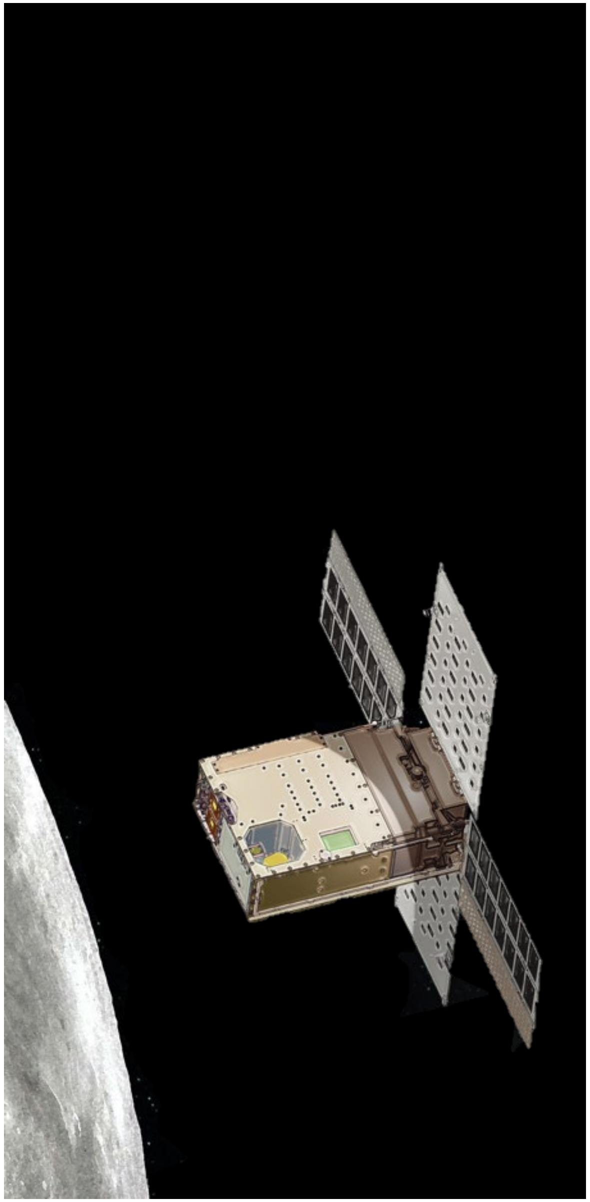
  Low cost approaches to adding radiation tolerance to commercial off the shelf avionics and other subsystems to increase reliability for deep space missions without sacrificing the ability to leverage innovations in the commercial sector.

- **Deep Space Navigation and Attitude Determination for Small Spacecraft**

  Key technology need is highly accurate position knowledge and precision timing technology for spacecraft that do not depend on GPS or other Earth centric aids.

- **Enabling Technologies for In-situ Resource Detection and Terrain Surveying by Small Spacecraft**

  Compact spacecraft size impacts both power generation and sensor apertures, limiting instrument capabilities. Solutions include large deployable systems for solar power collection and radio frequency sensing, synthetic apertures, and innovative extremely low orbit data collection.



EXPLORATION SUPPORT & AFFORDABLE DISTRIBUTED MISSIONS

Distributed systems of small spacecraft can responsively provide cost effective communications, mission monitoring, and inspection, and other in space infrastructure for exploration missions and cis-lunar commercial activity. Large constellations of small spacecraft can enable affordable multipoint measurement of time variant phenomena and smaller more tightly controlled formations can be used for long baseline interferometry and synthetic aperture synthesis.

Examination of mission concepts highlighted the following technology gaps:

- **Deep Space Communications and Interoperable Relays for Small Spacecraft**

  Analogous to emerging LEO communications constellations, small spacecraft can operate as local relays in cislunar space providing a link to farside landers or surface operations.

- **Timing Architectures / Relative and Absolute Position Knowledge (without GPS)**

  Expanding distributed mission architectures to deep space requires highly accurate position knowledge and precision timing that does not depend on GPS or other Earth centric aids. Access to DSN ranging may not be available for multiple concurrent small missions, blocked by terrain for surface operations, or limited by radio capabilities for smaller missions. In concert with other available signals of opportunity, small spacecraft can provide relative ranging or triangulation to aid lunar navigation.

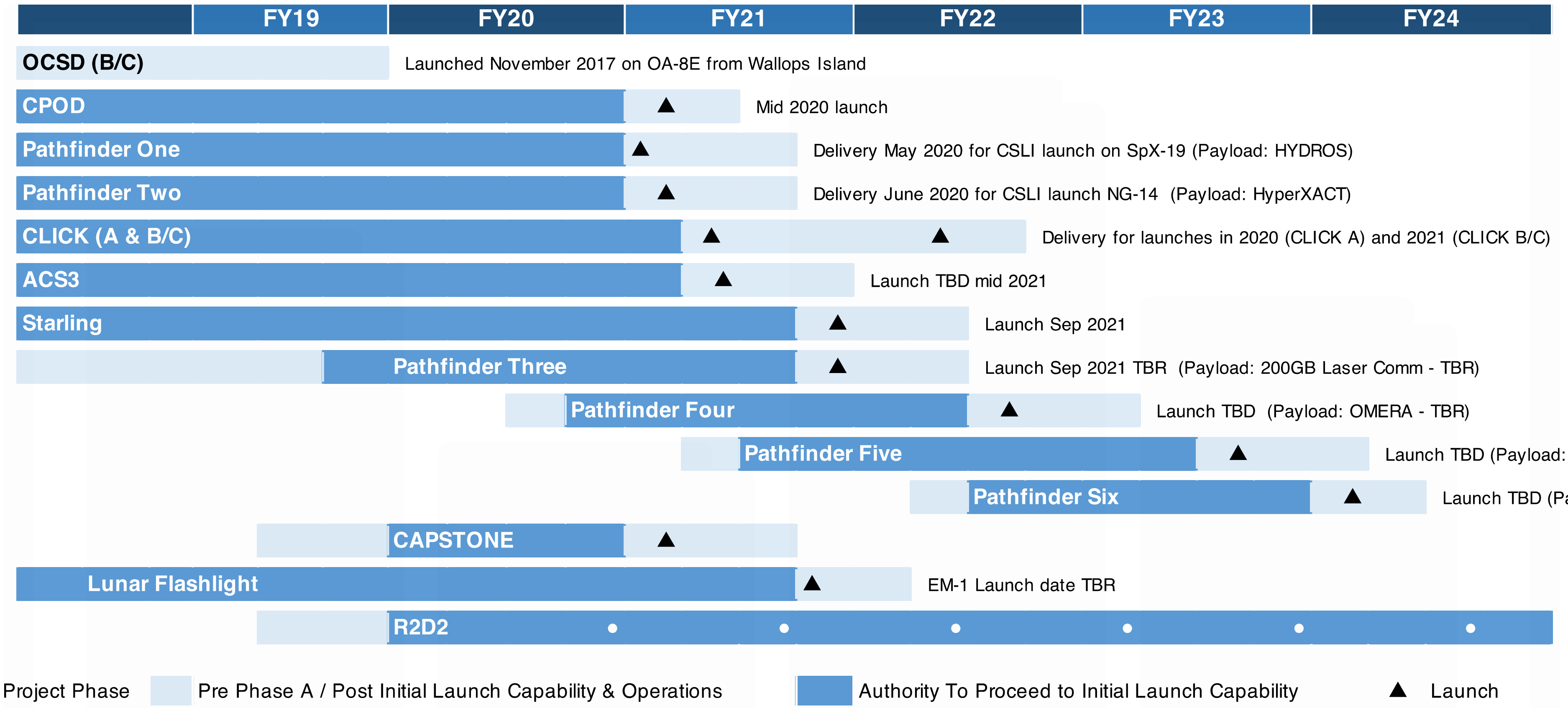
- **Autonomy and Constellation Management**

  Consolidated command and control for affordable, efficient operations. Expanding to deep space increases the need for scalable system autonomy, ground independent systems, and distributed intelligence across the constellation / formation.

- **Inter-spacecraft Networking**

  Cross link communications and ad hoc networking approach that is resilient to multiple lost nodes and scalable beyond dozens of nodes to potentially 100s. Prior rules based networking architectures saturated bandwidth between nodes limiting their operational use and scalability.

UPCOMING SMALL SPACECRAFT DEMONSTRATION MISSIONS



Mission Key

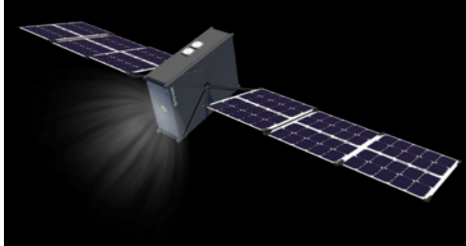
OCSD: Optical Communications and Sensor Demonstration
CPOD: CubeSat Proximity Operations Demonstration
CLICK: CubeSat Laser Intersatellite Crosslink
ACS3: Advanced Composites Based Solar Sail
CAPSTONE: Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment

Starling: Distributed spacecraft mission demo.
Lunar Flashlight: Map water and volatiles at the lunar south pole
PTD: Pathfinder Technology Demonstrator
R2D2: Rapid Reaction Development and Demonstration (● Target Mission Cadence)

UPCOMING SMALL SPACECRAFT DEMONSTRATION MISSIONS

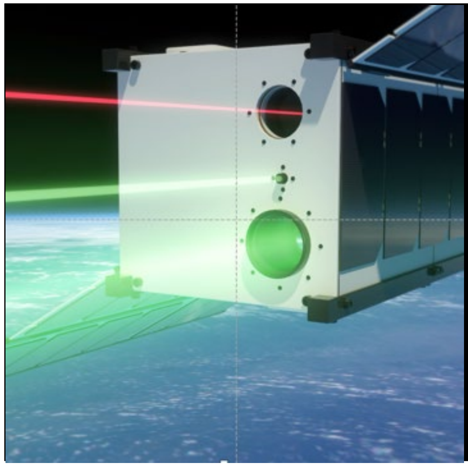
CubeSat Proximity Operations Demonstration (CPOD)

Demonstration of rendezvous, proximity operations and docking using two 3U CubeSats. (Awaiting Launch)



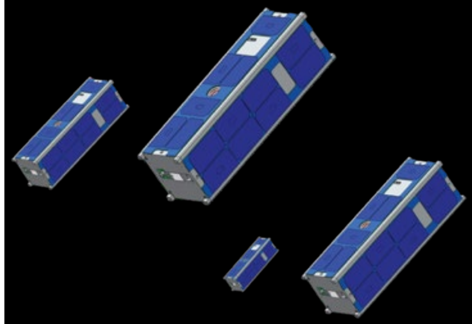
Pathfinder Technology Demonstrator (PTD)

Series of demonstrations for new small spacecraft subsystems.* Leverages public-private partnerships, commercial spacecraft and services.



CubeSat Laser Infrared Crosslink (CLICK)

Demonstration of full-duplex optical communication crosslink and precision ranging between two CubeSats.

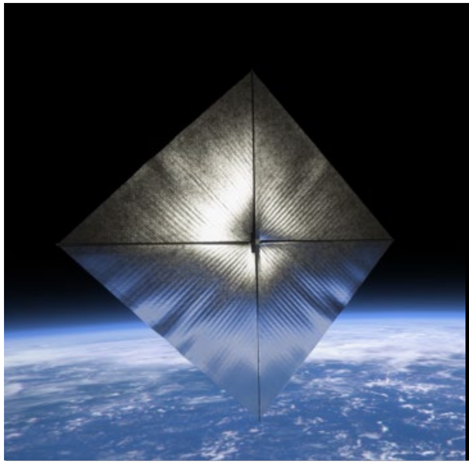


Starling

Distributed spacecraft mission capability demonstration that extends prior investments in inter-spacecraft networking, autonomous operations, and formation flight.

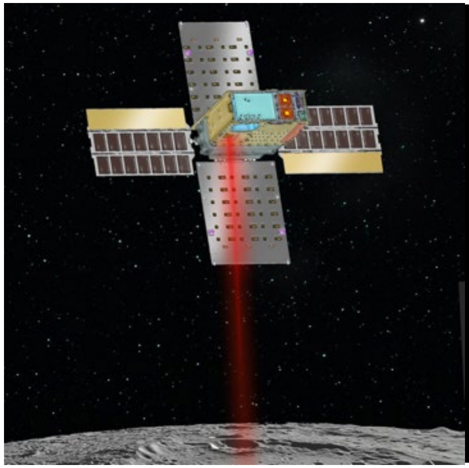
* Current PTD payloads include: (1) HYDROS water based thruster. (2) HyperXACT attitude determination and control. (3) High bandwidth laser communications. (4) OMERA Reflectarray for communications and radar. (5) LISA-T high-power low-volume solar array

UPCOMING SMALL SPACECRAFT DEMONSTRATION MISSIONS



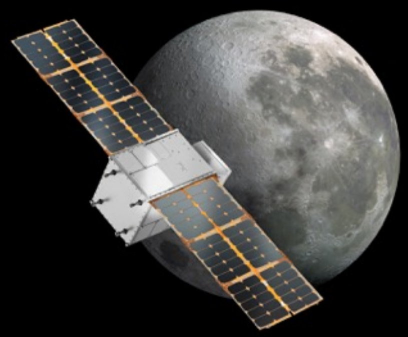
Advanced Composites Based Solar Sail (ACS3)

Demonstration of new composite booms to enable mission capable solar sails



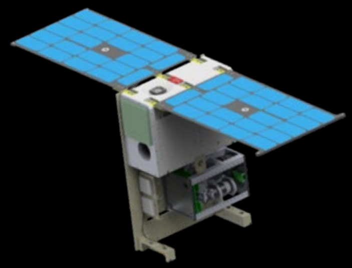
Lunar Flashlight

Characterize lunar in-situ resource utilization potential. Measure quantity and distribution of surface ice deposits in lunar south pole cold traps with a compact laser spectrometer.



Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE)

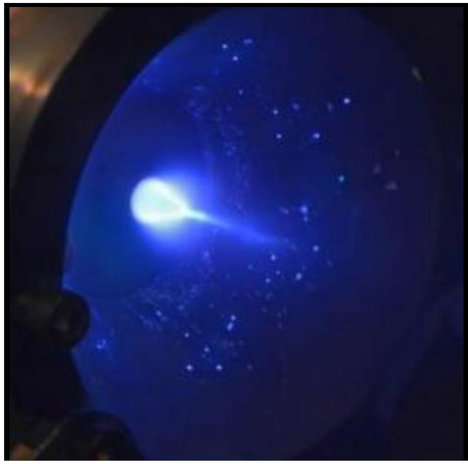
Pathfinder for entry into and operations in Gateway NRHO and test of lunar peer to peer navigation capability.



Rapid Reaction Development and Demonstration (R2D2)

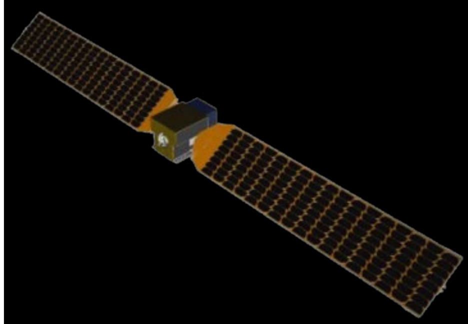
Initiative to rapidly test and de-risk emerging technology from industry, academia, and government though orbital and suborbital demonstrations.

UPCOMING SMALL SPACECRAFT DEMONSTRATION MISSIONS



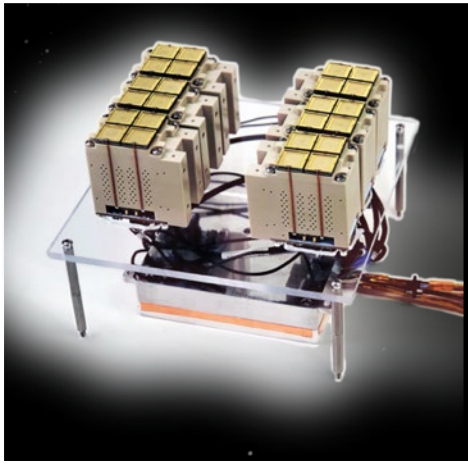
Dual Propulsion Experiment (DUPLEX)

Public-private partnership with CU Aerospace to flight test two fiber fueled CubeSat propulsion systems



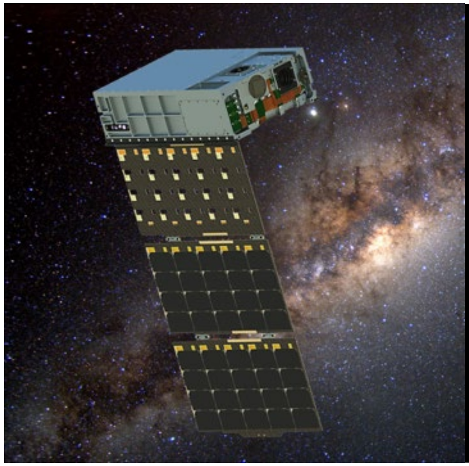
Courier Solar Electric Propulsion (SEP) Demonstration

Public-private partnership with ExoTerra Resource to flight test a micro Hall effect thruster, power system, and solar arrays for a micro SEP system



Tiled Ionic Liquid Electrospray (TILE) Propulsion Demonstration

Public-private partnership with Accion to flight test an extremely compact modular electric propulsion system that uses non-volatile ionic salt propellant.



X-NAV Autonomous Navigation Demonstration

Public-private partnership with Blue Canyon Technologies for a CubeSat autonomous navigation solution to reduce need for navigational aid from ground stations on Earth.

Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE)

Advanced Space LLC with Tyvak Nano-Satellite Systems Inc. and commercial launch procured by HEOMD from Rocket Lab USA

Objectives:

- Rapid demonstration leveraging American small businesses to test autonomous relative navigation for Gateway and other lunar missions, verify NRHO orbital dynamics, and demonstrate novel low-energy transfers to cislunar space
- Execute a cislunar mission in under $30M (including launch) and in under 3 years

Current Status:

- Kick-off of SBIR Phase III award in September 2019
- System Requirements Review, Preliminary Design Review, and Critical Design Review complete
- Flight hardware delivery in late 2020
- Early 2021 launch and lunar transfer
- Mid-2021 start of demonstration operation in cislunar space with completion of the mission in 2022

FAILURE (TO INNOVATE) IS NOT AN OPTION

- Small spacecraft and responsive launch (including suborbital) represent a potential “disruptive innovation” for space exploration and utilization.
- We need to preserve the community’s agile development and risk tolerant approach.
- We need to harness the fast pace of innovation and leverage the evolving capabilities in industry and academia to enable unique, more affordable, and more resilient missions.


EXPLORE