



EXPLORE SPACE TECH

Advancing Space Technologies Through Suborbital and Orbital Flight

Dr. Nettie Roozeboom | Technologist, NASA's Flight Opportunities Program

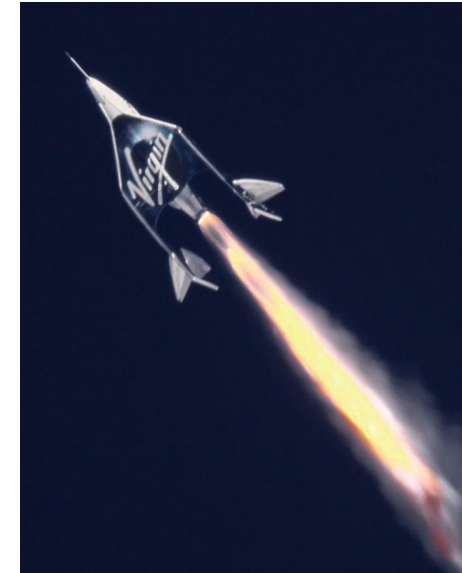
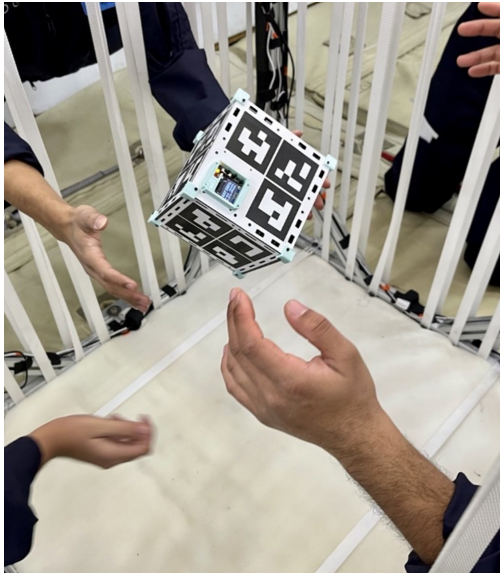
Bruce Yost | Director, Small Spacecraft Systems Virtual Institute

January 10, 2024

NASA'S FLIGHT OPPORTUNITIES PROGRAM

The **Flight Opportunities** program rapidly demonstrates technologies for space exploration, discovery, and the expansion of space commerce through suborbital testing with industry flight providers.

- Opportunities for external researchers via TechFlights solicitation and NASA TechLeap Prize
- Rolling opportunities for NASA-funded research – including SBIR awardees – and researchers from other government agencies
- Part of the Space Technology Mission Directorate
- Based at NASA Armstrong



SMALL SPACECRAFT TECHNOLOGY & FLIGHT OPPORTUNITIES PORTFOLIO

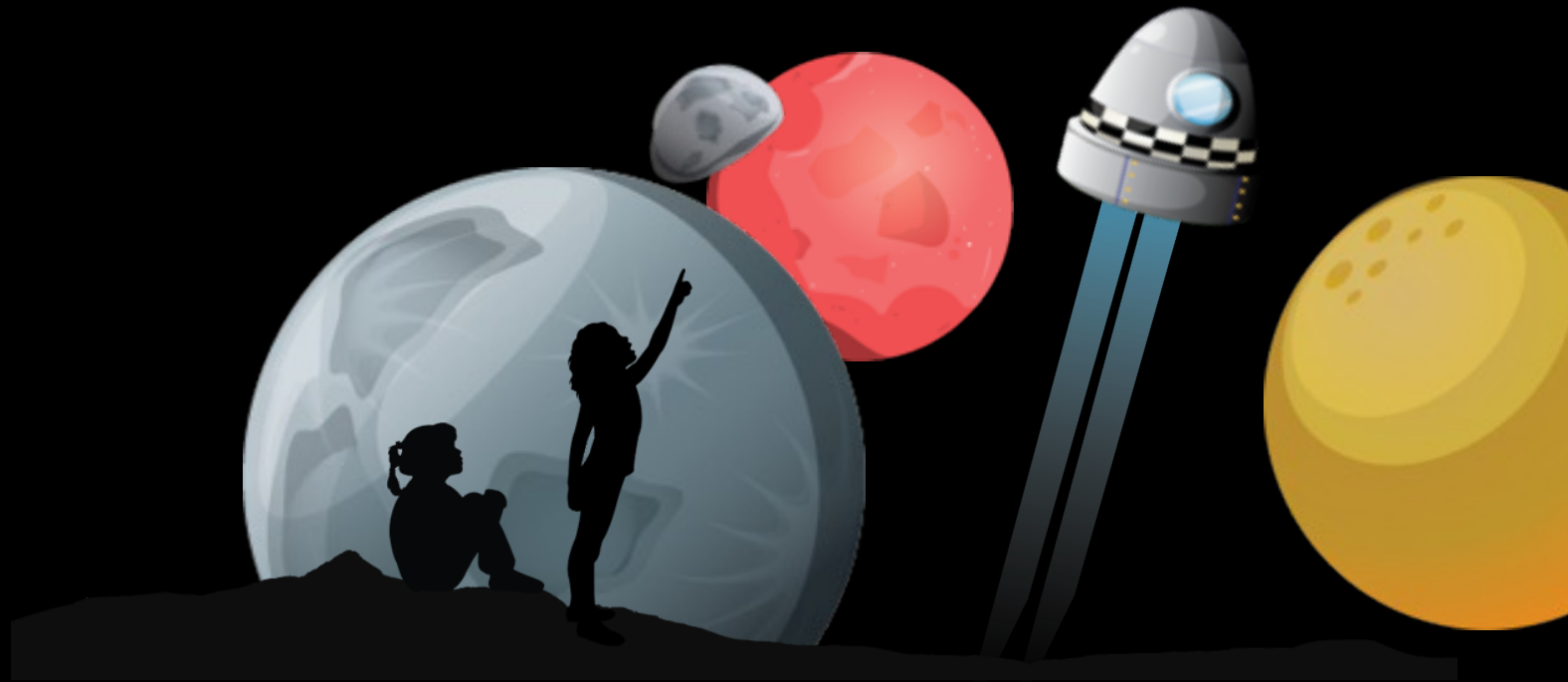
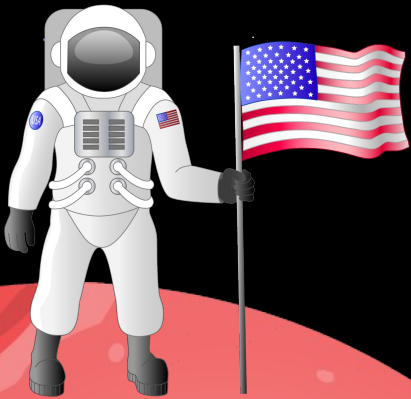
Flight Opportunities and Small Spacecraft Technology seek to **change the pace of space** exploration, discovery and space commerce.

Portfolio speed, flexibility, and access to a wide array of commercial suborbital / orbital capabilities provides opportunity to rapidly address technology gaps and emerging needs.

WHY?

To ensure **American leadership** in space...

...and **increase the rate of scientific discoveries** within our lifetimes.



COMMERCIAL VEHICLES MAKE FLIGHT OPPORTUNITIES POSSIBLE



Rocket-Powered Vehicles



Credits: NASA



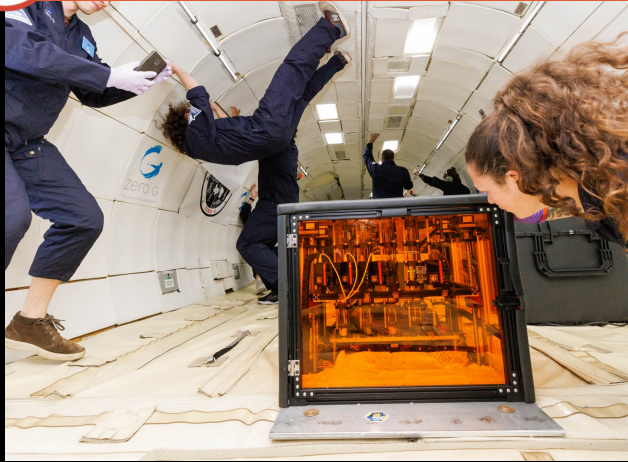
High-Altitude Balloons



Credits: World View Enterprises



Parabolic Flights



Credits: University of California, Berkeley



Vertical Takeoff Vertical Landing (VTVL) Vehicles



Credits: Lauren Hughes/NASA



Orbital Platforms Hosting Payloads



Credits: Firefly (formerly Spaceflight, Inc.)

WHAT DOES FLIGHT OPPORTUNITIES SUPPORT?

Innovators from:

- **Universities**
- **Industry**
- **Non-profit research institutes**
- **NASA**
- **Other government agencies**



Cryogenic Fluid Management



Advanced Materials, Structures, and Construction



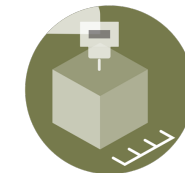
Entry, Descent, and Landing (EDL) and Precision Landing



Advanced Habitation Systems



Thermal Protection Systems and Thermal Management



Advanced Manufacturing



In-Situ Resource Utilization (ISRU)



Small Spacecraft Systems

FLIGHT OPPORTUNITIES



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



Challenges addressing specific NASA technology needs; previous awards have been up to \$650K to build payloads, plus access to a suborbital flight test



Competition to inspire the next generation of space researchers; offers hands-on insight into the design and test process used by NASA-supported researchers



Through collaborative internal and external relationships, the program takes advantage of opportunities to flight test valuable space technologies



To increase access to test opportunities in relevant environments, Flight Opportunities collaborates with other NASA initiatives like **SMD's ROSES** and **SOMD's SubC** to help them leverage the commercial flight ecosystem

Flights of Opportunity Examples:

- In-Space Manufacturing/ISS Program Office
- SBIR/STTR
- Intergovernmental support (Department of Defense, USDA)
- TechFlights Reflights

CLOSE TECHNOLOGY GAPS WITH NASA

TechPort

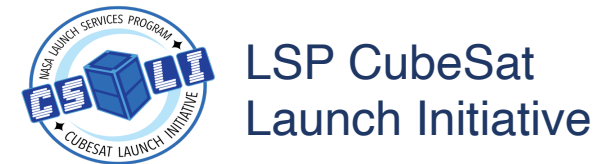
Match your solution to available funding opportunities:

techport.nasa.gov/opportunities



Flight Opportunities and Small Spacecraft Technology utilize a variety of mechanisms to mature innovative solutions from **proof-of-concept, to benchtop, to flight.**

We want to work with **academia, non-profit research institutes, and industry**, as well as **entrepreneurs, small businesses, and students** in order to close our technology gaps.



STMD Tipping Point Awards



Announcements of Collaboration Opportunity

Pathways to flight test for researchers with existing support:

Contact the programs directly.



Missions of Opportunity



Flights of Opportunity

NOW OPEN: NASA TECHLEAP UNIVERSAL PAYLOAD INTERFACE CHALLENGE

- The process to ensure payloads can properly interface with a host vehicle is currently complex, time-consuming, and can vary greatly from vehicle to vehicle, as well as between suborbital flights, orbital flights, and beyond.
- This challenge seeks interface systems that can efficiently integrate diverse payloads onto a range of flight vehicles, including suborbital, orbital, and planetary lander vehicles.
- Open to businesses, academic institutions, entrepreneurs, and other innovators.
- A maximum of 3 winners will receive up to \$650K in prizes and an opportunity to flight test their system.

E-mail us: questions@NASATechLeap.org

Register for the challenge and sign-up for the webinars at www.upic.nasatechleap.org

Register by Thursday, February 1, 2024 at 5 pm ET

Applications due Thursday, February 22, 2024 at 5 pm ET

[Share the challenge with your networks!](#)



www.upic.nasatechleap.org

FLIGHT OPPORTUNITIES IMPACT HIGHLIGHTS



Improving Storm Prediction via Small Spacecraft Constellations

TROPICS: Dual-spinning CubeSat bus uses microwave radiometer technology developed by MIT for small spacecraft

Tested in its early stages on parabolic flights in 2013

Launched May 2023 to gather data to understand the evolution of tropical cyclone intensity

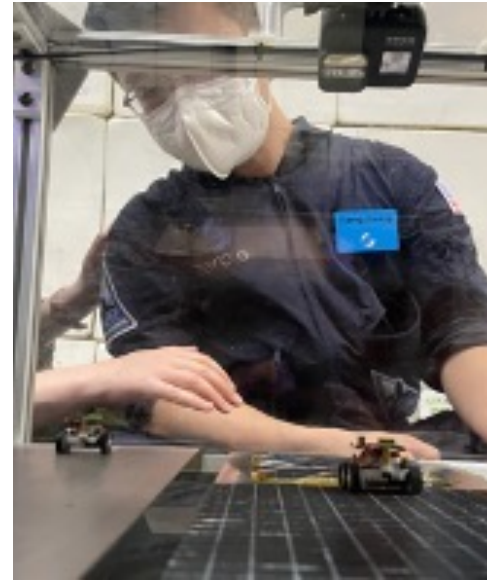


Wearable Vision-Aided Moonwalks

DMEN: Designed to provide terrain-relative navigation for landings in challenging space environments

Matured through flight tests on high-altitude balloons and suborbital rockets

Integrated with wearable kinematics tech for 2022 field tests to collect data that will support the agency's moonwalking preparations



Miniature Robots for the Lunar Surface

MIT's AstroAnt: Designed to support autonomous vehicle inspection and maintenance

Matured through a series of parabolic flights in 2021

Will be deployed on a CLPS mission to lunar South Pole



Optical Fiber Production on the International Space Station

Both Mercury Systems and FOMS, Inc. used parabolic flights to validate their technologies ahead of ISS demonstrations

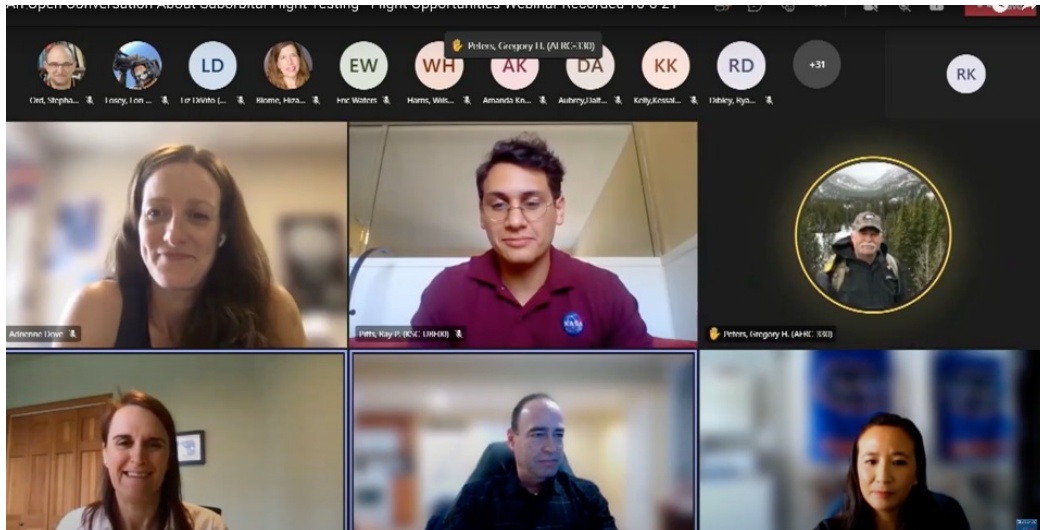
Collaboration with NASA Johnson's In-Space Production Applications (InSPA) project

SUPPORTING THE FLIGHT TEST COMMUNITY

Community of Practice Webinars

Designed to distill and share most important lessons learned by suborbital researchers.

First Wednesday of each month 10 am PT



**October 6, 2021 Community of Practice -
An Open Conversation About Suborbital Flight Testing**

Flight Opportunities Newsletter

www.nasa.gov/flighthopportunities

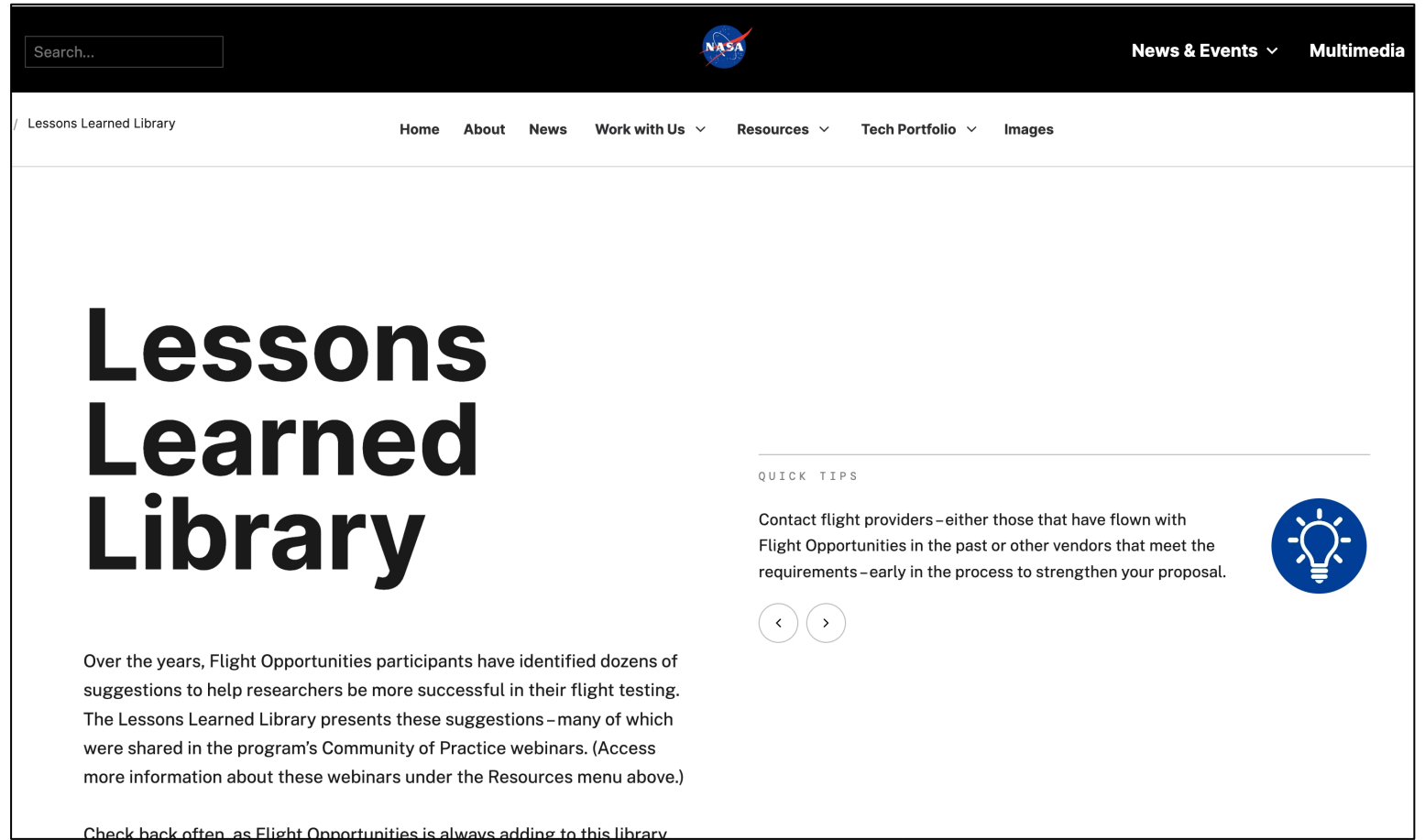


An ongoing collection of best practices and suggestions to help researchers optimize their flight test outcomes

Designed to support researchers as they move through each part of the flight testing process:

- Getting involved with the program
- Preparing proposals
- Step-by-step suggestions for getting ready to fly
- Best practices for payload design
- Top tips for each type of flight platform

Practical tips are linked to helpful clips from the program's monthly Community of Practice webinar.



Search...

NASA

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Lessons Learned Library

Home About News Work with Us ▾ Resources ▾ Tech Portfolio ▾ Images

Lessons Learned Library

QUICK TIPS

Contact flight providers – either those that have flown with Flight Opportunities in the past or other vendors that meet the requirements – early in the process to strengthen your proposal.

< >

Check back often as Flight Opportunities is always adding to this library.

STAY ENGAGED:

[NASA.GOV/FLIGHTOPPORTUNITIES](https://www.nasa.gov/flightopportunities)

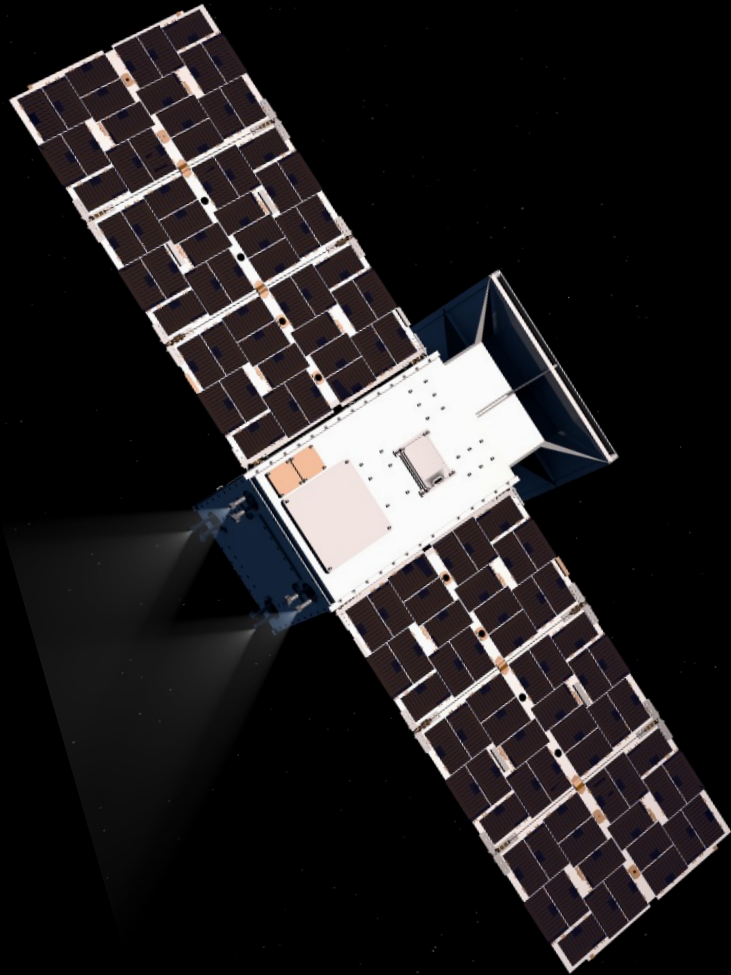
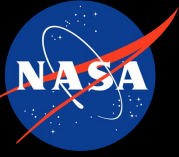
[NASA.GOV/SMALLSPACECRAFT](https://www.nasa.gov/smallspacecraft)

Visit our websites for more information and resources, including our newsletter and monthly Community of Practice webinars.

Reach out:

NASA-FlightOpportunities@mail.nasa.gov





NASA Small Spacecraft Technology Program & Small Spacecraft Systems Virtual Institute

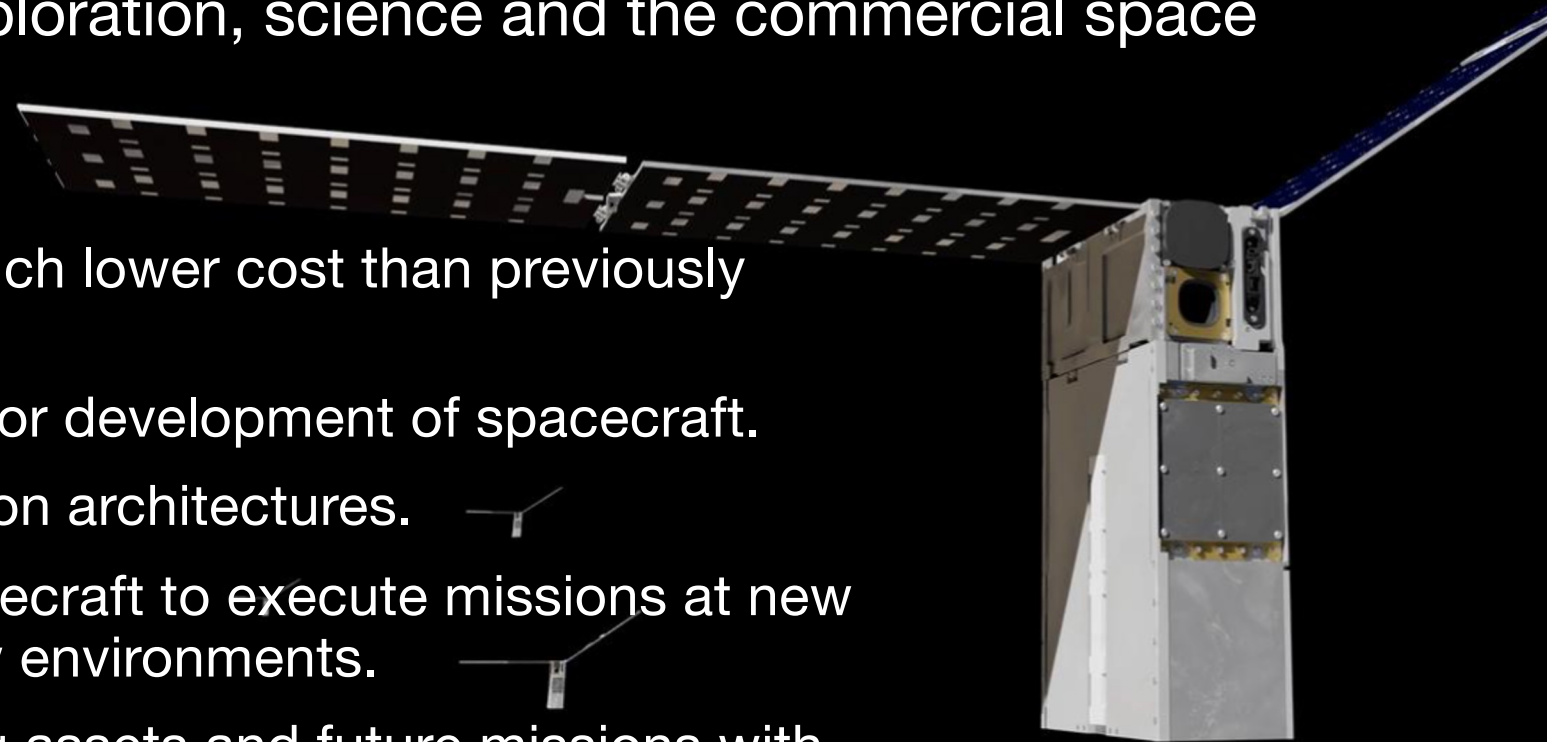
Bruce D. Yost
*Director, Small Spacecraft
Systems Virtual Institute
(S3VI)*

2024 AIAA SciTech Forum

SMALL SPACECRAFT TECHNOLOGY PROGRAM OBJECTIVES

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.

- 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.



Starling Spacecraft
Image Credit: NASA



Small Spacecraft Technology Program

SPACE TECHNOLOGY MISSION DIRECTORATE

Expanding NASA's ability to execute unique missions through rapid development and demonstration of capabilities for small spacecraft applicable to exploration, science and the commercial space sector.



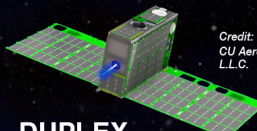
Starling
Technologies for Distributed Small Spacecraft Missions



PTD-3
Pathfinder Technology Demonstrator-3 TeraByte InfraRed Delivery (TBIRD)

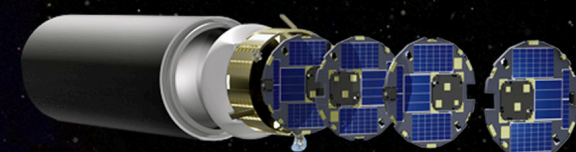


PTD-R
Pathfinder Technology Demonstrator-R Monolithic UV/SWIR/VIS Camera



DUPLEX
Dual Propulsion Experiment (DUPLEX) CubeSat

Credit: CU Aerospace, LLC.



DiskSat
Two-Dimensional; High-Power, High-Aperture, Maneuverable Spacecraft



PTD-4
Pathfinder Technology Demonstrator-4 Lightweight Integrated Solar Array and anTenna (LISA-T)



CAPSTONE
Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment

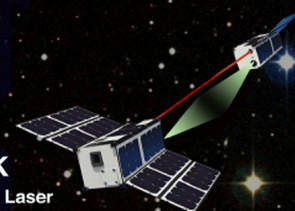


Credit: ExoTerra Resource, LLC.

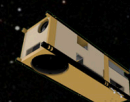
Courier
Solar Electric Propulsion Module



GPDM
Green Propulsion Dual Mode



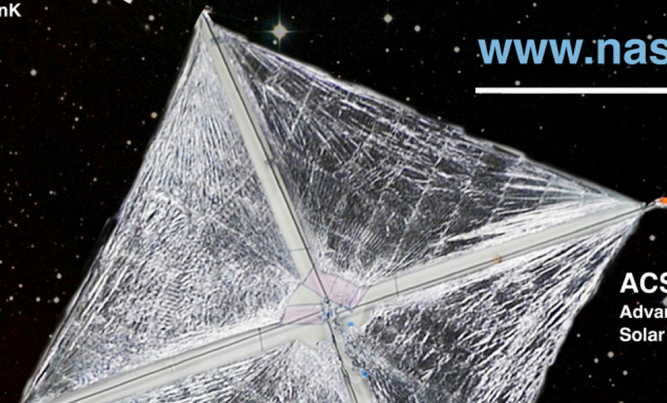
CLICK
CubeSat Laser Infrared Crosslink



R5
Rapid Technology Maturation



PY4
Four-CubeSat Swarm of PyCubed-Based Spacecraft

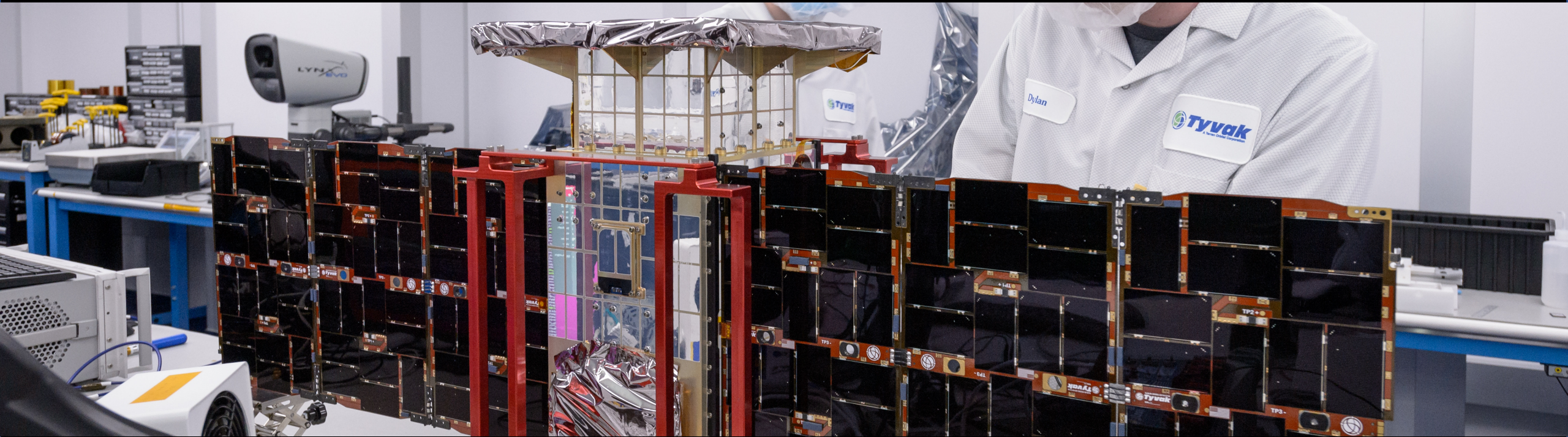


ACS3
Advanced Composite Solar Sail System

www.nasa.gov/smallspacecraft

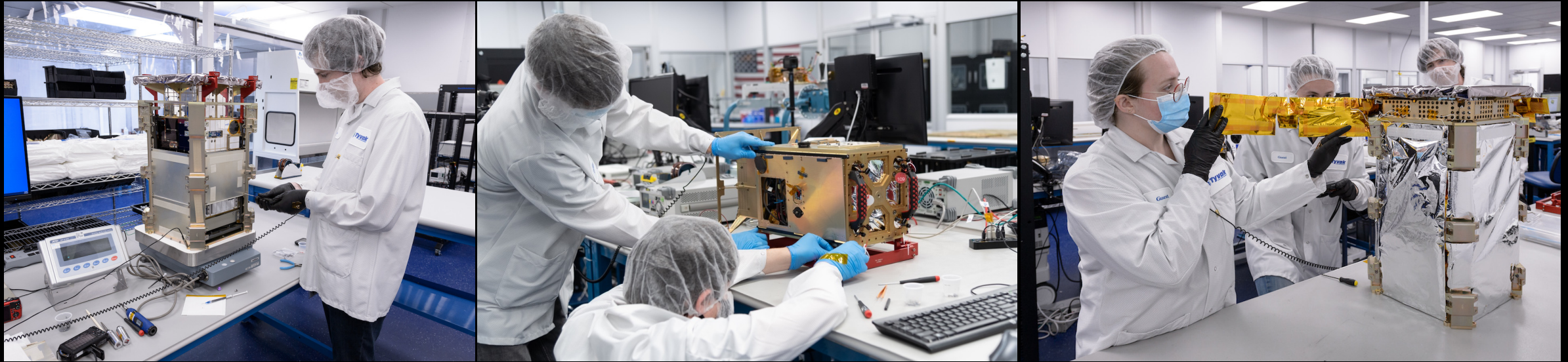
www.nasa.gov

CAPSTONE - LAUNCHED JUNE 28, 2022 – CURRENTLY IN LUNAR ORBIT



Demonstrated ability to enter and maintain a near rectilinear halo orbit around the Moon. Demonstrated one & two way ranging and autonomous spacecraft navigation.

CAPSTONE INDUSTRY AND ACADEMIC PARTNERS

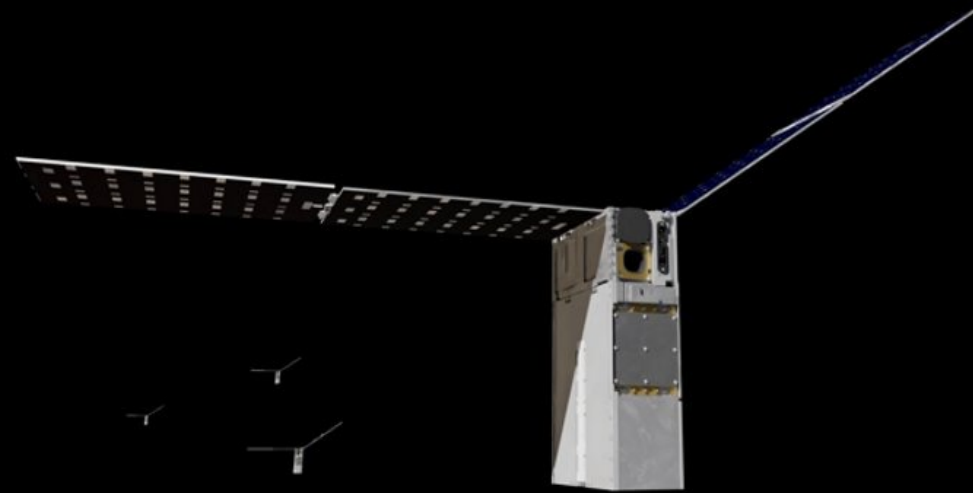


CAPSTONE represents an innovative collaboration between NASA and its partners to provide rapid results and feedback to inform future exploration and science missions.

- Advanced Space of Westminster, Colorado, developed and is operating CAPSTONE.
- Terran Orbital Corporation, of Irvine, California, designed and built the CubeSat platform.
- Stellar Exploration, Inc. of San Luis Obispo, California, provided the propulsion system.
- Rocket Lab USA, Inc., of Long Beach, California, provided the launch service.

The mission is also supported by the Space Dynamics Laboratory, Orion Space Solutions, Tethers Unlimited, Inc., and Morehead State University.

STARLING 1.0 – LAUNCHED JULY 17, 2023 – ENGAGED IN ON-ORBIT OPERATIONS



Starling's mission includes four main demonstrations: swarm maneuver planning and execution, communications networking, relative navigation, and autonomous coordination between spacecraft.

Technology Demonstrations Include:

- Cluster flight control algorithms: (*ROMEEO – Onboard Cluster Flight Control*)
- Network communication protocols: (*MANET – Crosslink/Networking*)
- Relative navigation algorithms: (*StarFOX –Relative Navigation*)
- Autonomous reactive operations software: (*DSA – Distributed Spacecraft Autonomy*)

NASA STARLING 1.0/*1.5 INDUSTRY & ACADEMIC PARTNERS



NASA partners with the following industry and academic entities for Starling's demonstrations:

- Blue Canyon Technologies of Boulder, Colorado, designed and manufactured the spacecraft buses and provides mission operations support
- Rocket Lab USA, Inc., provided launch and integration services

Partners supporting Starling's payload experiments include:

- Stanford University's Space Rendezvous Lab in California
- Emergent Space Technologies of Laurel, Maryland
- CesiumAstro of Austin, Texas
- L3Harris Technologies, Inc., of Melbourne, Florida
- NASA Ames – with funding support by NASA's Game Changing Development program within STMD

*The Starling 1.5 extended mission is developing technology and operational protocols for autonomous maneuvering coordination between spacecraft constellations to enable nascent space traffic management capabilities. Among other partners, SpaceX is an industry partner for this demonstration.

UNIVERSITY SMALLSAT TECHNOLOGY PARTNERSHIP SUCCESSES TO DATE

- **Investments:**

- Over \$30,000,000 awarded
- 54 partnerships in 6 cohort years
- 36 universities in 22 states (+6 supporting collaborators in 6 states)
- 8 of 10 NASA centers partnered

- **Results:**

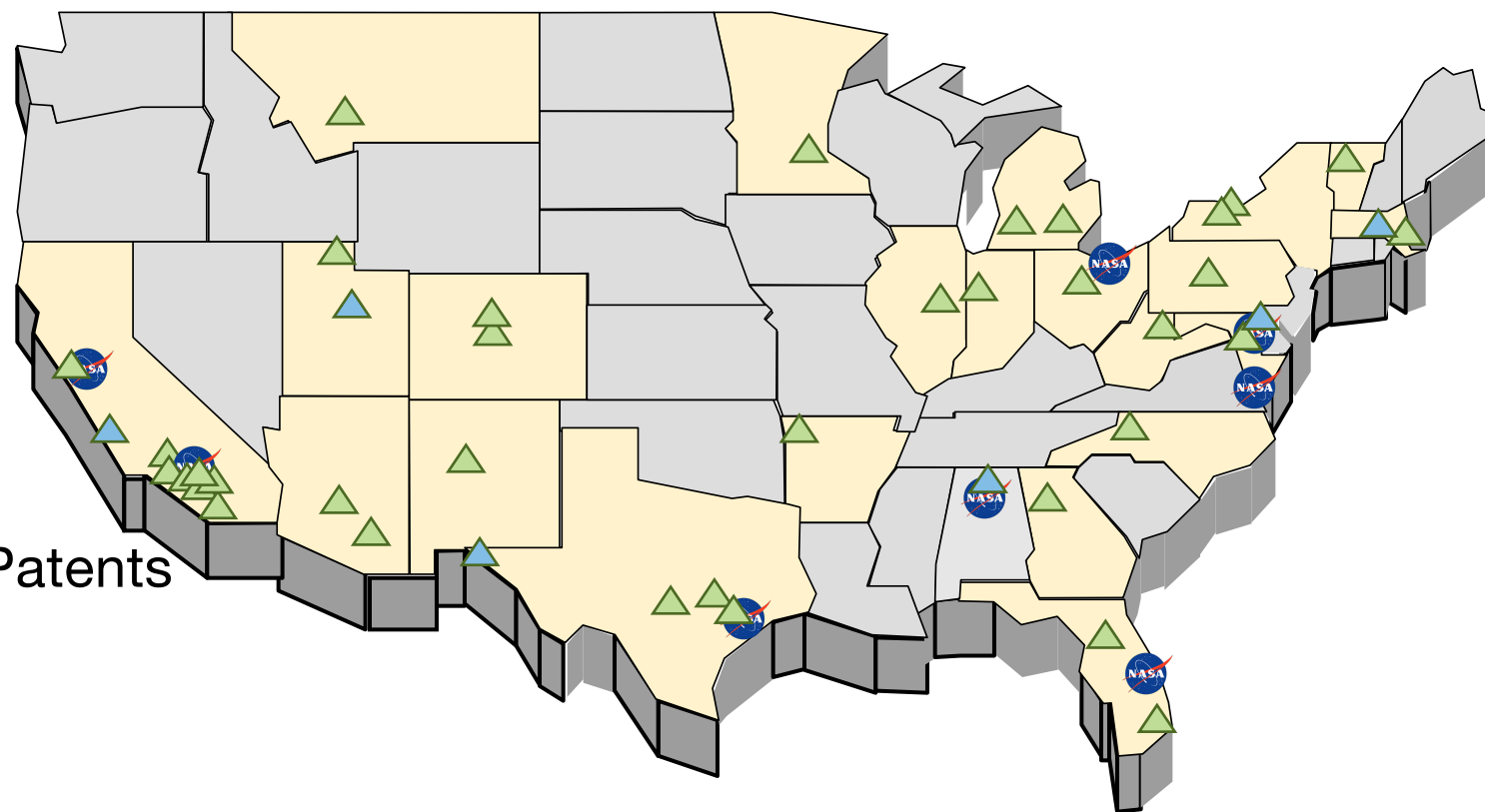
- 24 flight demonstrations performed/planned
- 1 Intersatellite Network Planning/ Routing tool software open-sourced

- Numerous New Technology Reports/Patents
- 30+ conference presentations
- 50+ papers published
- 100+ students involved
- Many technology readiness levels (TRL) raised

▲ 36 Universities in 22 States

🚀 8 NASA Centers (including JPL FFRDC)

▲ 6 Supporting University Collaborators in 6 States





Small Spacecraft Systems Virtual Institute (S3VI)



Promoting Innovative Concepts

Building Community through:

Sharing Knowledge

- SmallSat LEARN Forum
- Community of Practice Mission Accomplished Webinar Series
- Access to Space Announcements
- S3VI Quarterly Newsletter
- CubeSat 201

Building Tools

- Small Spacecraft Reliability Initiative Knowledge Base Tool
- Small Spacecraft Information Search
- State of the Art Report
- Space Mission Design Tools Collection
- Anomaly Alert Reporting System

Connecting People and Ideas

- Industry Days Webinar Series
- SmallSat Technology Partnerships – TechExpo
- Cross-Agency Collaboration

Community of Practice Webinar Series

Pathfinder for Autonomous Navigation: Flight Demonstration of Commercial Off-the-Shelf Technologies for Spacecraft Rendezvous and Docking

Mason Peck
Advisor and Co-PI from Stewart Allen, Kyle Kral, and Mason Peck
NASA S3VI Team
January 2021

Small Spacecraft Reliability Initiative Knowledge Base

Explore > Interactive Tree

- Hover over or click a **section** node to expand its children
- Hover over a **topic** node to preview the topic and click to open

- CONCEPTUAL DESIGN
- PLANNING AND MANAGEMENT
- DETAILED DESIGN AND ANALYSIS
- MANUFACTURING
- INTEGRATION AND TEST
- LAUNCH
- OPERATIONS

- INTEGRATION
- DAY-IN-THE-LIFE TESTING
- EMI/EMC TESTING
- ACCELERATED LIFE TESTING
- ELECTRONICS FUNCTIONAL TESTING
- BAKE OUT
- RADIATION TESTING
- LAUNCH ENVIRONMENT TESTING

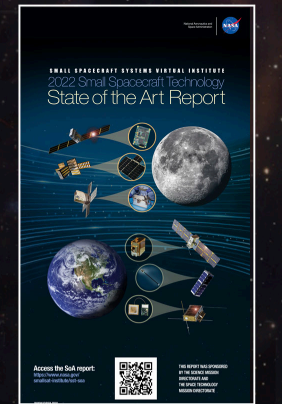
Identifying Emerging Technology Opportunities

www.nasa.gov/smallsat-institute



Bruce D. Yost
Director, Small Spacecraft Systems Virtual Institute
Bruce.D.Yost@nasa.gov

Small Spacecraft Technology State of the Art Report



Small Spacecraft Information Search

SMALLSATELLITE INFORMATION SEARCH

Search for satellite information.

Select Search

S3VI Web Portal

Small Satellite Missions Blog

Small Spacecraft Systems Virtual Institute

Recent SmallSat News

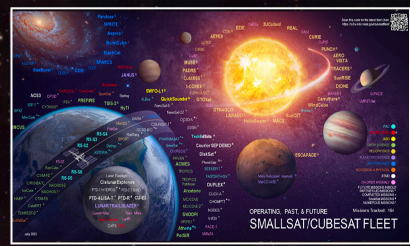
S3VI Newsletter

Small Spacecraft Systems Virtual Institute

Community Engagement

Upcoming Opportunity Due Dates & Events

SmallSat / CubeSat Fleet Chart

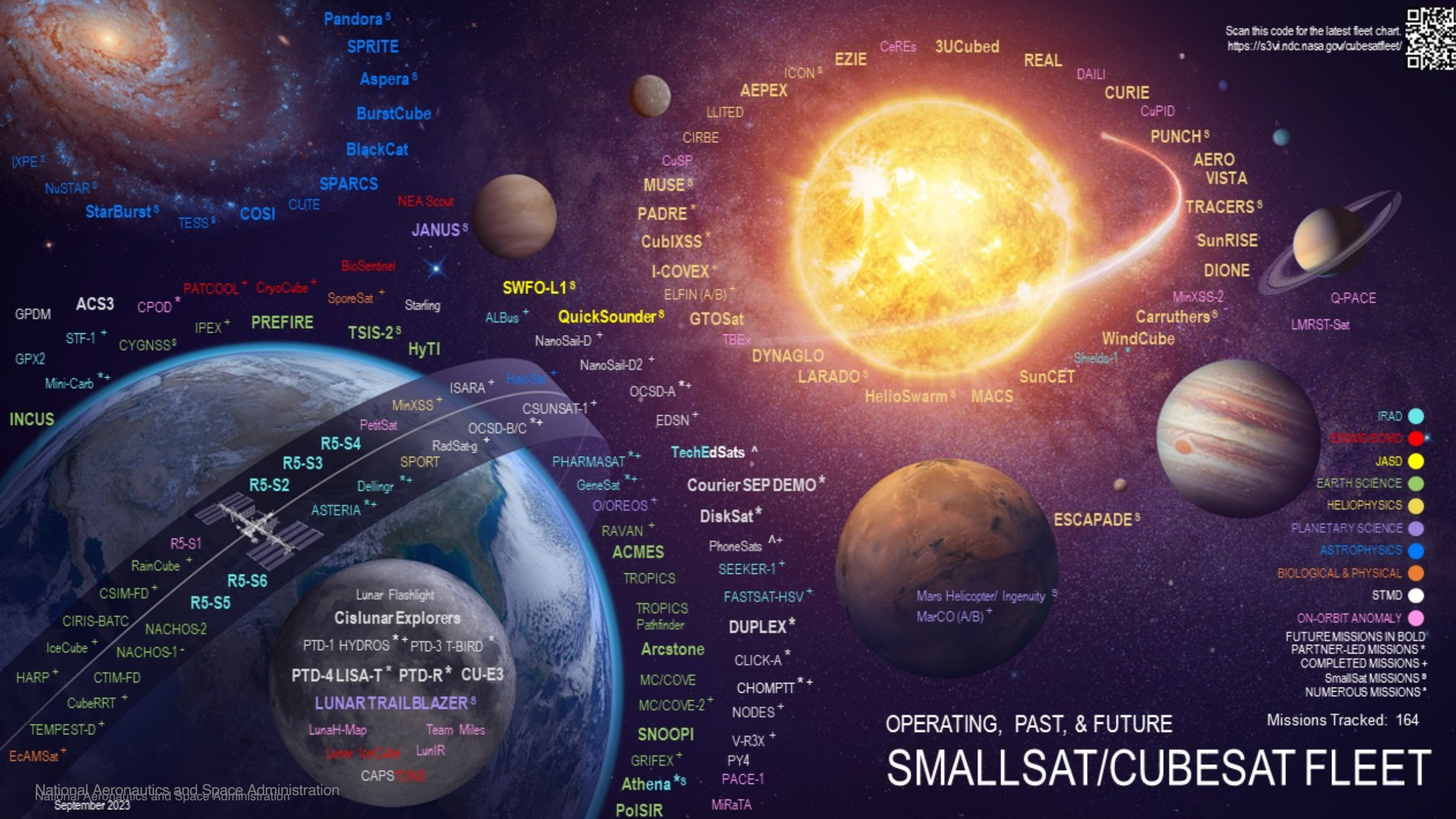


NASA SmallSat LEARN Forum



LaunchPortal: Potential Rideshare Opportunities

Mission Name	Launch Date (NET)	Primary Orbit	Apogee (km)	Perigee (km)	Inclination (deg)	Insertion	Rideshare Adapter
JPSIS-2	11/1/22	S30, Polar	810	810		1225 LTAN	None; USA C-Adapters surrounding LEO TD secondary payload. (no rideshare opportunities available)
IMAP	2/1/25	L1			28	C3 max <= -0.5	ESPA Grande (no rideshare opportunities available)
SPHERE-X	2/28/25	S50	650	650		6am MLTAN	Full SPA (no additional RS opportunities available)
JPSIS-3	2025-2027	S50				1330 MLTAN	TBD
COSI	2025-09	LEO	550	550	5	TBD	TBD
SENTINEL 6B	2025/11	LEO	1336	1336	66	TBD	TBD
NEO SURVEYOR	2026/05	L1				C3 (std)	TBD
MUSE	2027/04	S50	620	620	97.9	6am MLTAN	TBD
VERITAS	2028-2030	Venus/E					
OPC	2028-2030	L1	400	400		C3-17	TBD



- IRAD ●
- ESSM/D/SSMD ●
- JASD ●
- EARTH SCIENCE ●
- HELIOPHYSICS ●
- PLANETARY SCIENCE ●
- ASTROPHYSICS ●
- BIOLOGICAL & PHYSICAL ●
- STMD ●
- ON-ORBIT ANOMALY ●
- FUTURE MISSIONS IN BOLD
- PARTNER-LED MISSIONS *
- COMPLETED MISSIONS +
- SmallSat MISSIONS §
- NUMEROUS MISSIONS *

OPERATING, PAST, & FUTURE SMALLSAT/CUBESAT FLEET

Missions Tracked: 164

S3VI RESOURCES AVAILABLE TO ALL

The S3VI provides the US SmallSat research community with access to mission enabling information and maintains engagement with small spacecraft stakeholders in industry, government and academia.

The S3VI resources listed below are available to all at: <https://www.nasa.gov/smallsat-institute/>

Contact us at: agency-smallsat-institute@mail.nasa.gov

Community of Practice Webinar Series

Small Spacecraft Reliability Initiative Knowledge Base Tool

LaunchPortal

Small Spacecraft Guidebooks

United Nations Office of Outer Space (UNOOSA) Systems Engineering Webinar Series

NASA Small Spacecraft State of the Art Report

S3VI WebPortal

Quarterly S3VI Newsletter

Small Spacecraft Information Search

Space Mission Design Tool Catalog

S3VI is sponsored by NASA's Space Technology Mission Directorate

