National Aeronautics and
Space Administration

NASA Small Spacecraft & Distributed Systems

Recent and Upcoming Technology Demonstrations and Development Efforts

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NASA Ames Research Center

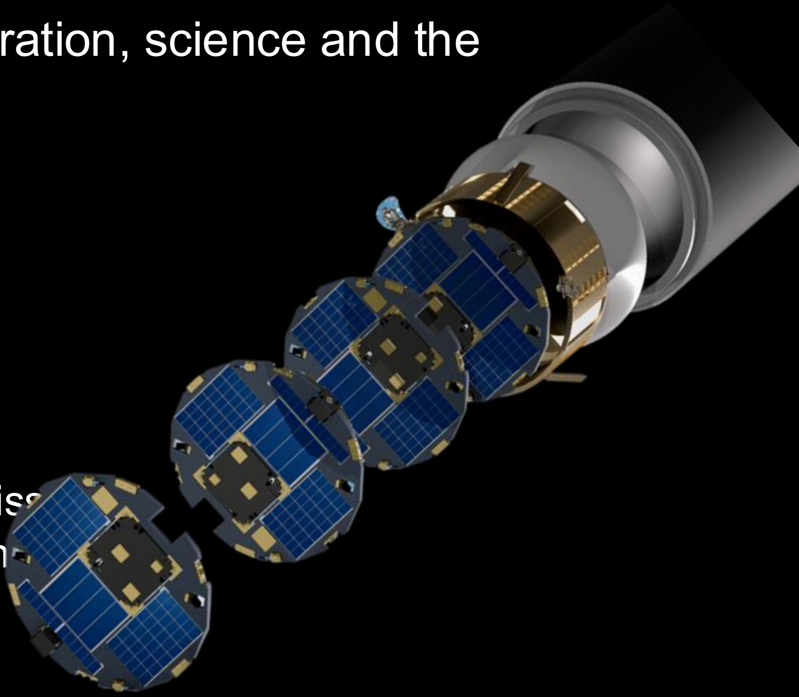
Blue Origin Visit

9 December 2025

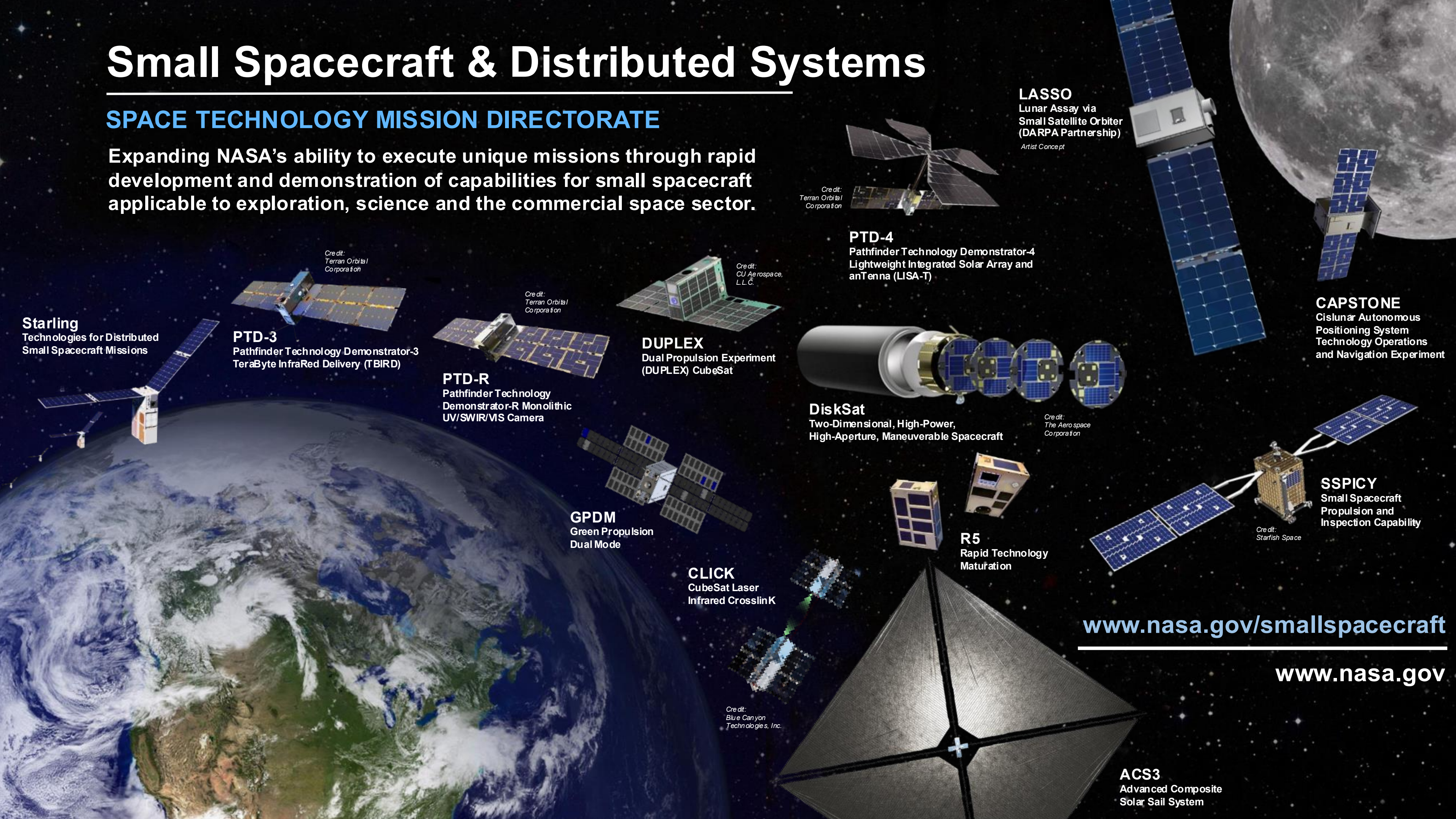
Small Spacecraft & Distributed Systems Objectives

The Small Spacecraft & Distributed Systems 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 mis
at new destinations and in challenging new environmen
- Enable the augmentation of existing assets and future missions with supporting small spacecraft.



DiskSat Spacecraft and Deployer
Image Credit: The Aerospace Corporation

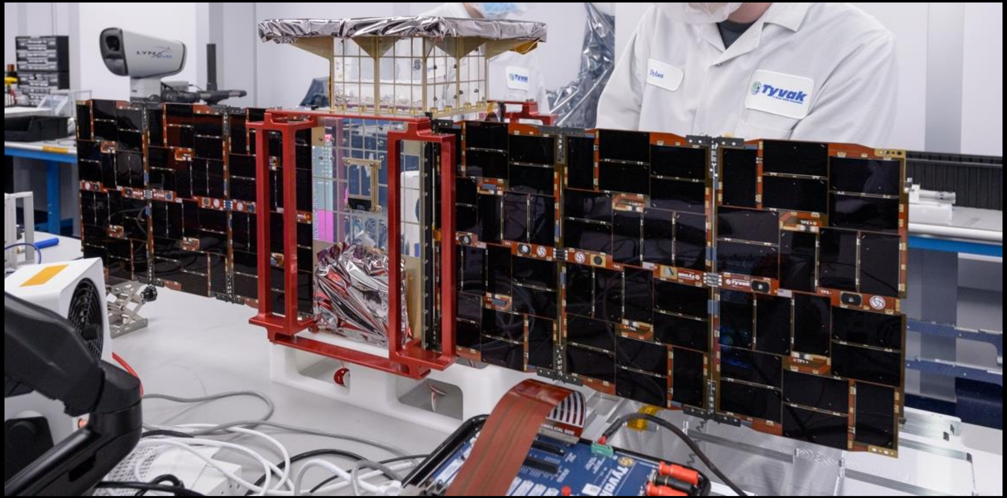

Small Spacecraft & Distributed Systems
SPACE TECHNOLOGY MISSION DIRECTORATE
Expanding NASA's ability to execute unique missions through rapid development and demonstration of capabilities for small spacecraft applicable to exploration, science and the commercial space sector.
LASSO
Lunar Assay via Small Satellite Orbiter (DARPA Partnership)
Artist Concept
Credit: Terran Orbital Corporation
PTD-4
Pathfinder Technology Demonstrator-4 Lightweight Integrated Solar Array and anTenna (LISA-T)
Credit: Terran Orbital Corporation
Credit: CU Aerospace, L.L.C.
Credit: Terran Orbital Corporation
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
CAPSTONE
Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment
DiskSat
Two-Dimensional, High-Power, High-Aperture, Maneuverable Spacecraft
Credit: The Aerospace Corporation
GPDM
Green Propulsion Dual Mode
SSPICY
Small Spacecraft Propulsion and Inspection Capability
Credit: Starfish Space
R5
Rapid Technology Maturation
CLICK
CubeSat Laser Infrared CrosslinK
Credit: Blue Canyon Technologies, Inc.
www.nasa.gov/smallspacecraft
www.nasa.gov
ACS3
Advanced Composite Solar Sail System

2024-2027 Launch Schedule

Technology Demonstrations	Launch Timeframe
PY4: *Four CubeSat Swarm of PYCubed-Based Spacecraft*	Launched March 4, 2024
ACS3: *Advanced Composite Solar Sail System*	Launched April 23, 2024
R5 (S2 and S4): *Rapid Technology Maturation*	Launched July 3, 2024
PTD-4: *Pathfinder Technology Demonstrator-4: Payload: LISA-T High-Power Deployable Solar Array Antenna*	Launched Aug 16, 2024
PTD-R: *Monolithic UV/SWIR/VIS Camera*	Launched Aug 16, 2024
DUPLEX: *Dual Propulsion Experiment*	Launched Sept 14, 2025
R5 (S7): *Rapid Technology Maturation*	Launched Nov 28, 2025
DiskSat: *2D, High-Power, High-Aperture Maneuverable Spacecraft*	NET Dec 17, 2025
R5 (S3 and S5): *Rapid Technology Maturation*	NET Jan 16, 2026
GPDM*: Green Propulsion Dual Mode*	NET Jun 2026
SSPICY: Small Spacecraft Propulsion and Inspection Capability	NET Oct 2026
CLICK B/C: *CubeSat Laser Infrared CrossLinK*	NET Nov 2026

On-Orbit U-Class Technology Demonstration Missions

CAPSTONE
Launched: June 28, 2022
Status: Ongoing,
Extended to Dec 2026



Primary mission demonstrated ability to enter and maintain a near rectilinear halo orbit around the Moon as well as demonstrate one & two way ranging and autonomous spacecraft navigation. Extended mission demonstrating and testing technologies for autonomy and standards-based, interoperable communications and networking in the cislunar environment.

Image Credits: NASA

Upcoming SmallSat Technology Demonstration Mission

CAPSTONE 2

Joint NASA directorate near rectilinear halo orbit (NRHO) risk reduction and technology demonstration mission using a two-satellite constellation.

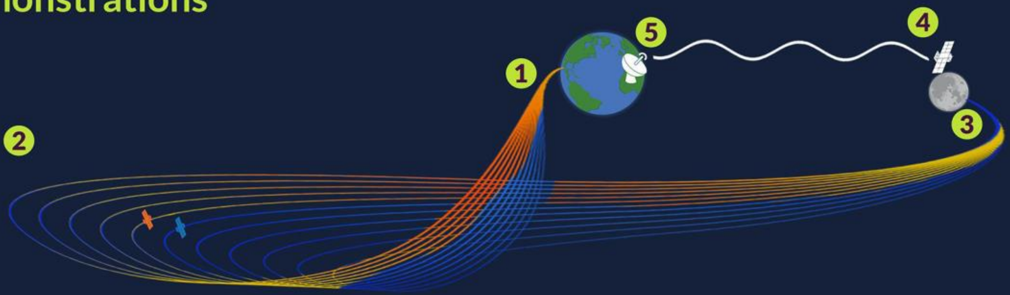
NASA Space Technology Mission Directorate Mission Benefits

- Autonomous Earth independent operations of distributed systems
- Autonomous navigation demonstration of state-of-the-art software suites (TRON, OpNav, AutoNGC, AstroNav, CAPS)
- Cislunar Communications, Position, Navigation and Timing
- Cislunar Space Situational Awareness

NASA Exploration Systems Development Mission Directorate Mission Benefits

- Artemis risk reduction of rendezvous proximity operations and loiter techniques in NRHO for future human missions to the Moon
- Radiation environment characterization of the cislunar environment

Objective: Cislunar Communication Demonstrations



1 **Launch:** Two space vehicles (SV) are launched aboard the same launch vehicle and delivered to their Trajectory Insertion Point.

2 **Transfer:** Both SVs utilize a Low-Energy Transfer (LET) for efficient arrival to the Near Rectilinear Halo Orbit (NRHO) insertion point.

3 **Insertion:** At the end of the LET, the SVs phase their arrival to Moon for both vehicles to insert into the same NRHO.

4 **Science:** Both vehicles participate in the mission objectives detailed below.

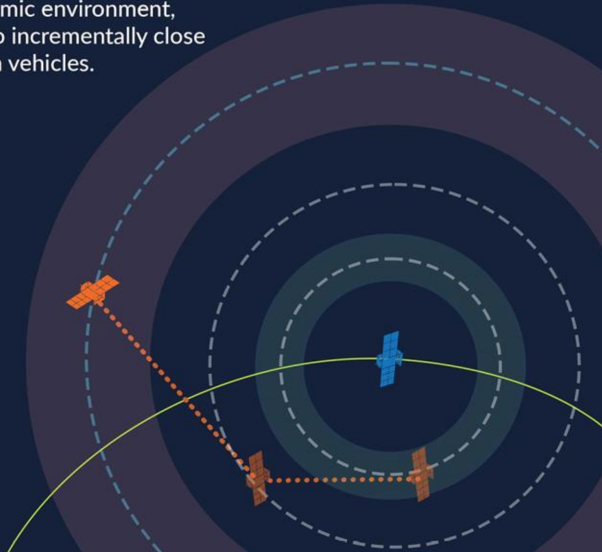
5 **Ongoing Cislunar Communications:** The mission will be supported by NSN, DSN, and commerical ground networks. This will characterize the performance of multiple services reducing risk for future lunar missions.

Objective: Environmental Characterization

CAPSTONE-02 will collect thermal and radiation data to better characterize the NRHO environment for future lunar exploration.

Objective: Rendezvous & Proximity Operations

CAPSTONE-02 will demonstrate RPO and loitering in a three body dynamic environment, utilizing a phased approach to incrementally close the relative distance between vehicles.



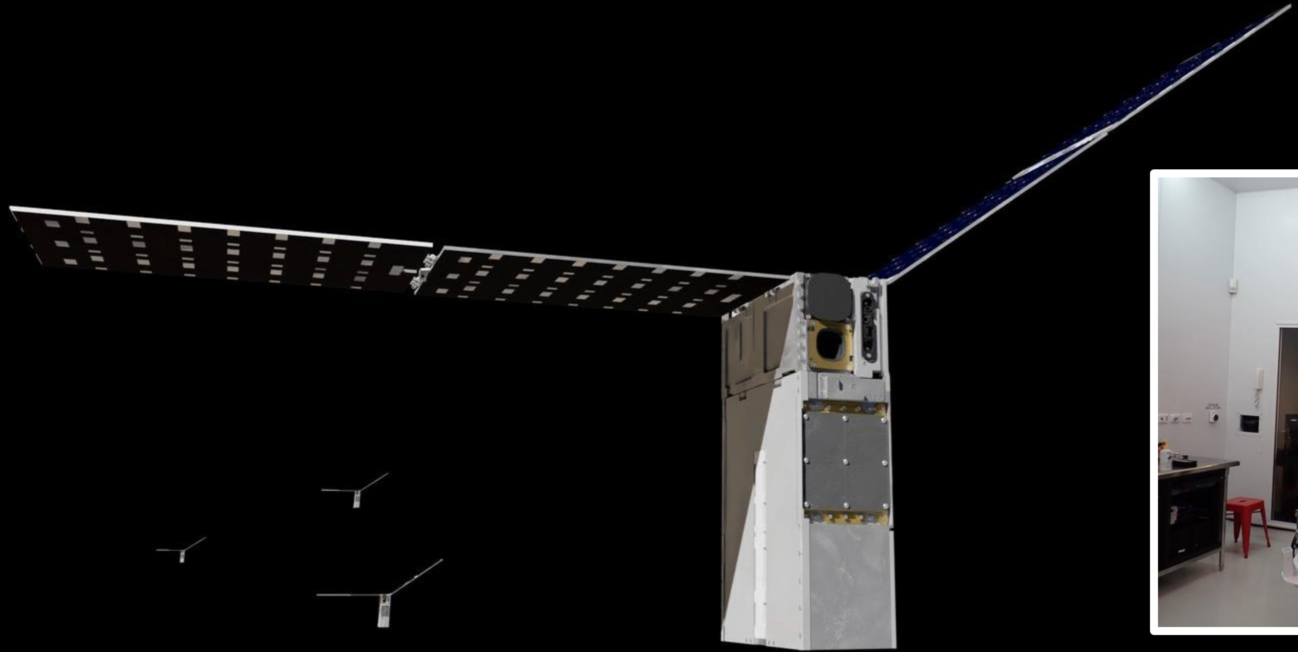
Objective: Relative Navigation Demonstrations

Space to Space Comm & Visual Imagery

- CAPSTONE-02 will leverage relative navigation technologies to decrease reliance on traditional space-to-ground radiometric data.
- Demonstrations include one-way space to ground ranging, space to space crosslink, and optical visual navigation.

The chaser vehicle performs all RPO maneuvers while the target vehicle maintains its position in the NRHO.

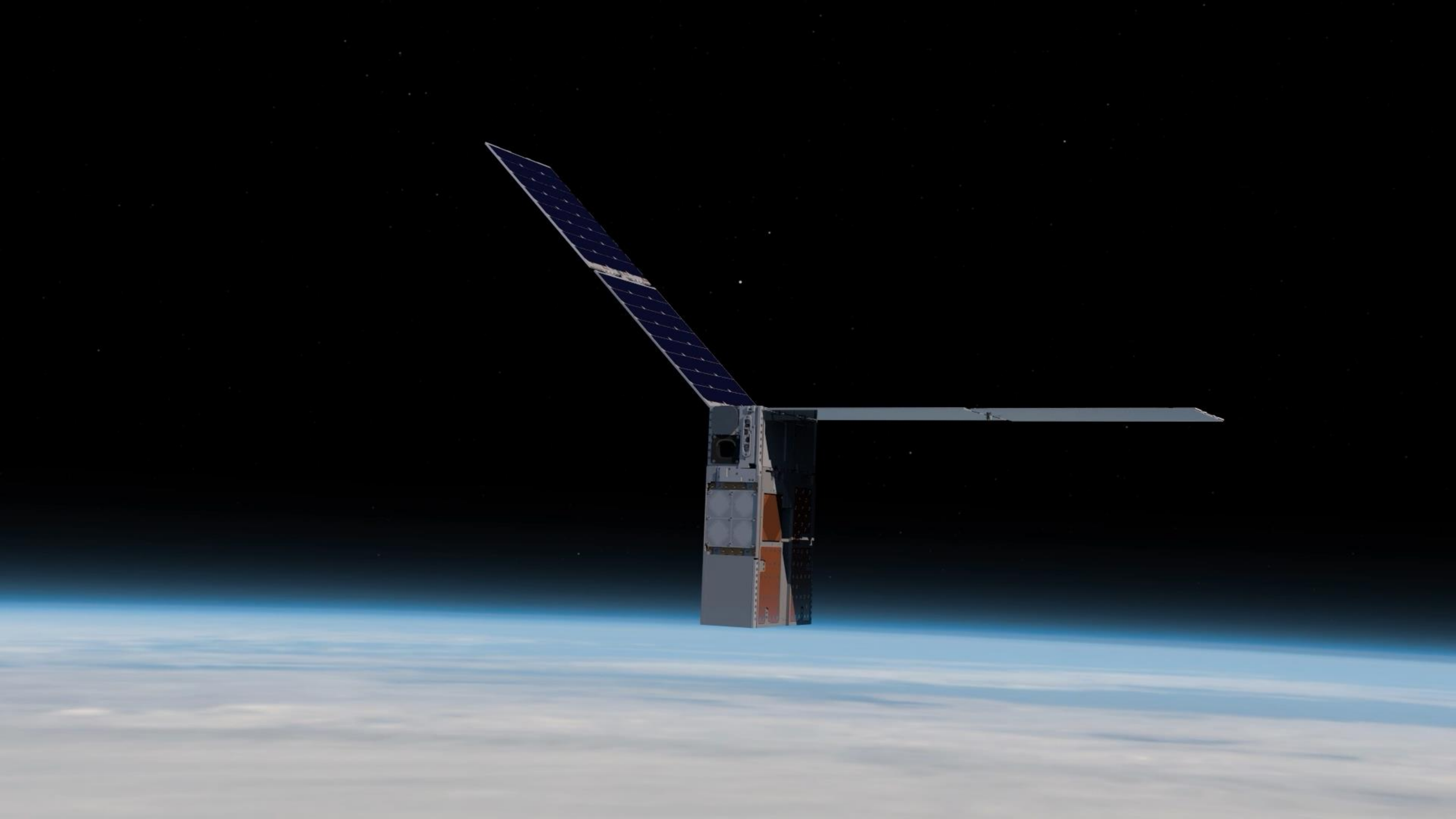
On-Orbit U-Class Technology Demonstration Mission



Starling Autonomous Swarm Technology

Starling's four 6U CubeSats launched on July 17, 2023 from Rocket Lab Launch Complex 1 in Mahia, New Zealand. Starling is demonstrating swarm maneuver planning and execution, communications networking, relative navigation, and autonomous coordination between spacecraft.

Image Credits: NASA.   Inset Image Credits: Rocket Lab



Starling 1.0 (Completed) – Results and Technology 'Firsts'

MANET
Communicate

- Cross-link networking between nodes
- First use of an Ad-Hoc network between multiple spacecraft.
- First demonstration of autonomous multi-hop data routing through multiple spacecraft.
- Implements B.A.T.M.A.N-adv protocol

StarFOX
Navigate

- Relative navigation without GPS.
- First demonstrations of autonomous angles-only navigation for a satellite swarm including:
    - First demonstration of multi-target and multi-observer relative navigation.
    - First autonomous initialization of navigation for unknown targets.
    - First simultaneous absolute and relative orbit determination.

ROMEO
Control

- Goal autonomous swarm reconfiguration and cluster maintenance.
- Demonstrated autonomous generation and execution of onboard of station-keeping maneuver plan for single spacecraft.

Distributed Spacecraft Autonomy
Operate

- First fully distributed autonomous operation of multiple spacecraft.
- First use of space-to-space communications to autonomously share state information between multiple spacecraft.
- First demonstration of fully distributed reactive operations onboard multiple spacecraft.
- First use of fully distributed automated planning onboard multiple spacecraft.
- First use of a general-purpose automated reasoning system onboard a spacecraft.

Starling 1.5 Goals and Objectives

Goals

- Demonstrate a model of space traffic management (STM) between two cooperative swarms/constellations with onboard conjunction assessment (CA) and collision avoidance (COLA) capabilities.
- Develop autonomous maneuvering methods and tools that could be operationalized for NASA flight missions

Project Objectives

- Demonstrate onboard conjunction assessment (CA) for Starling's planned maneuvers
- Demonstrate continuous CA checking of passive and active/maneuvering objects
- Demonstrate a ground-based space situational awareness (SSA) / space traffic management (STM) hub that facilitates on-orbit autonomous CA/COLA
- Demonstrate collision avoidance (COLA) maneuver of Starling spacecraft in response to an onboard CA detection

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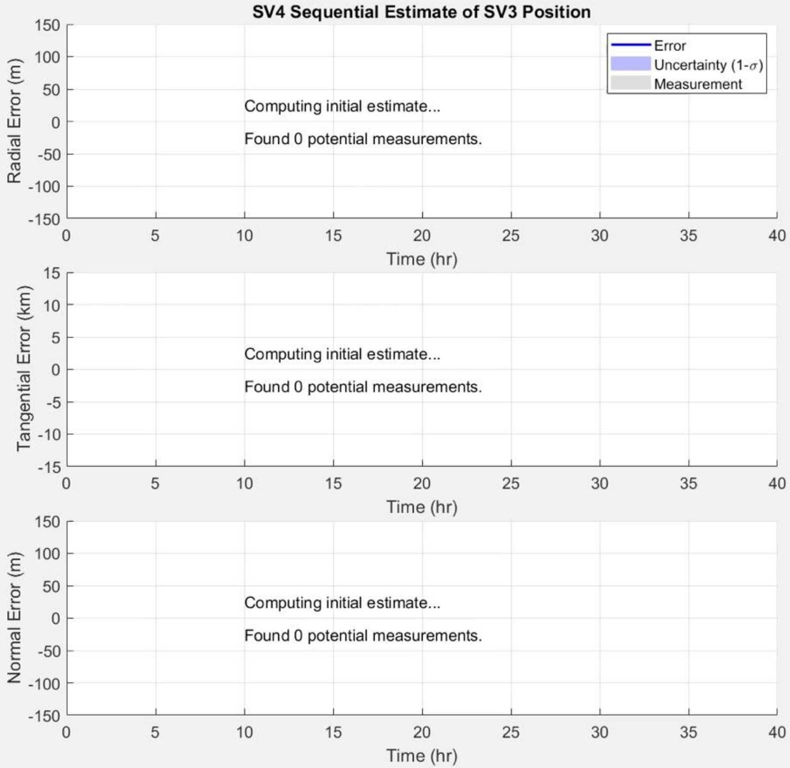
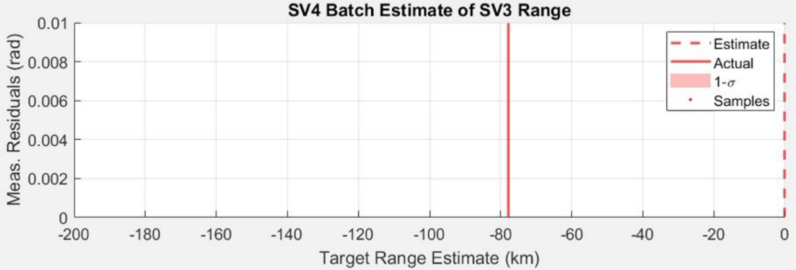
Starling 1.5 launched as Starling 1.0. Starling 1.5 operations are complete.

Video Credit:
Stanford University

SV4 Tracker 2 View





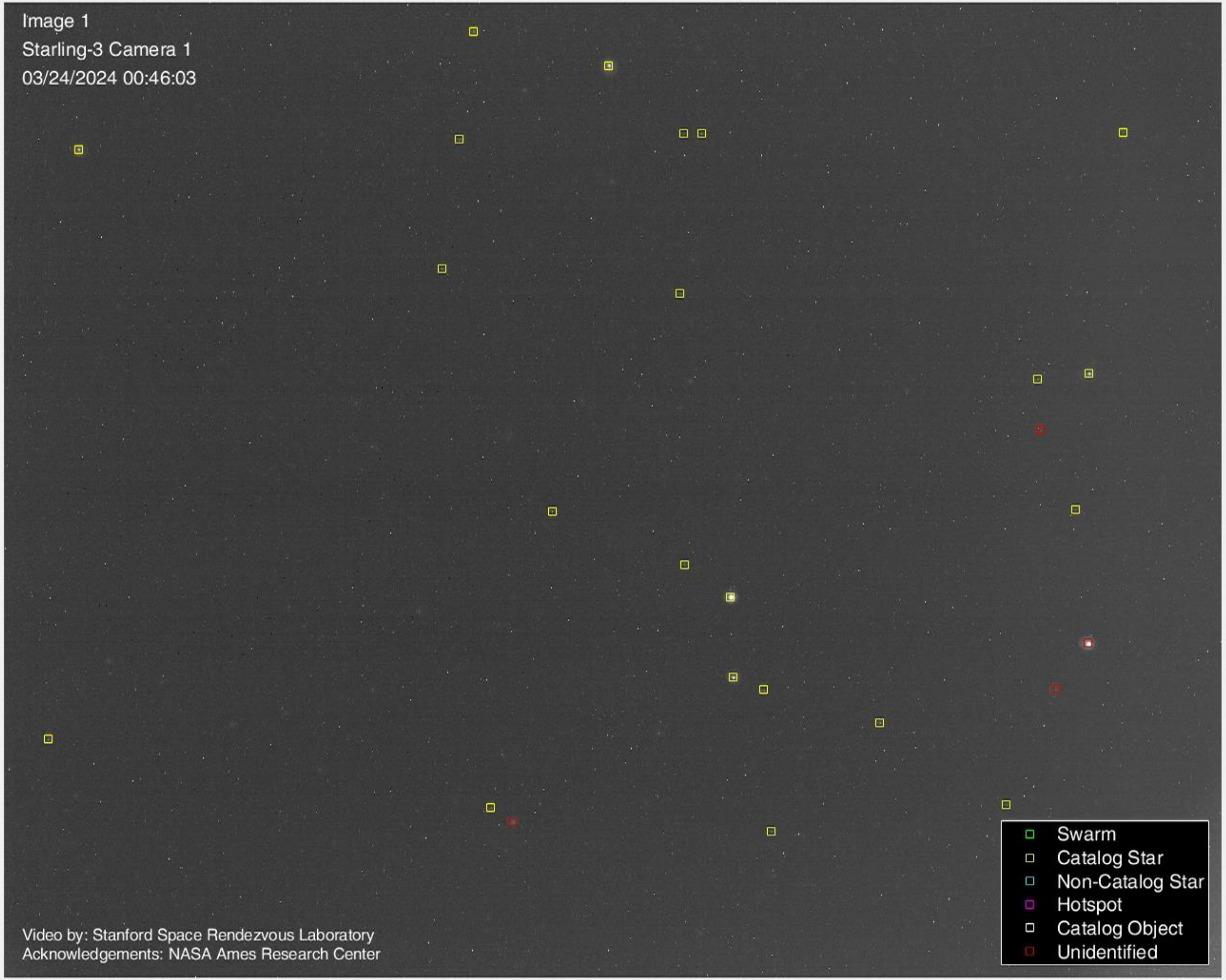
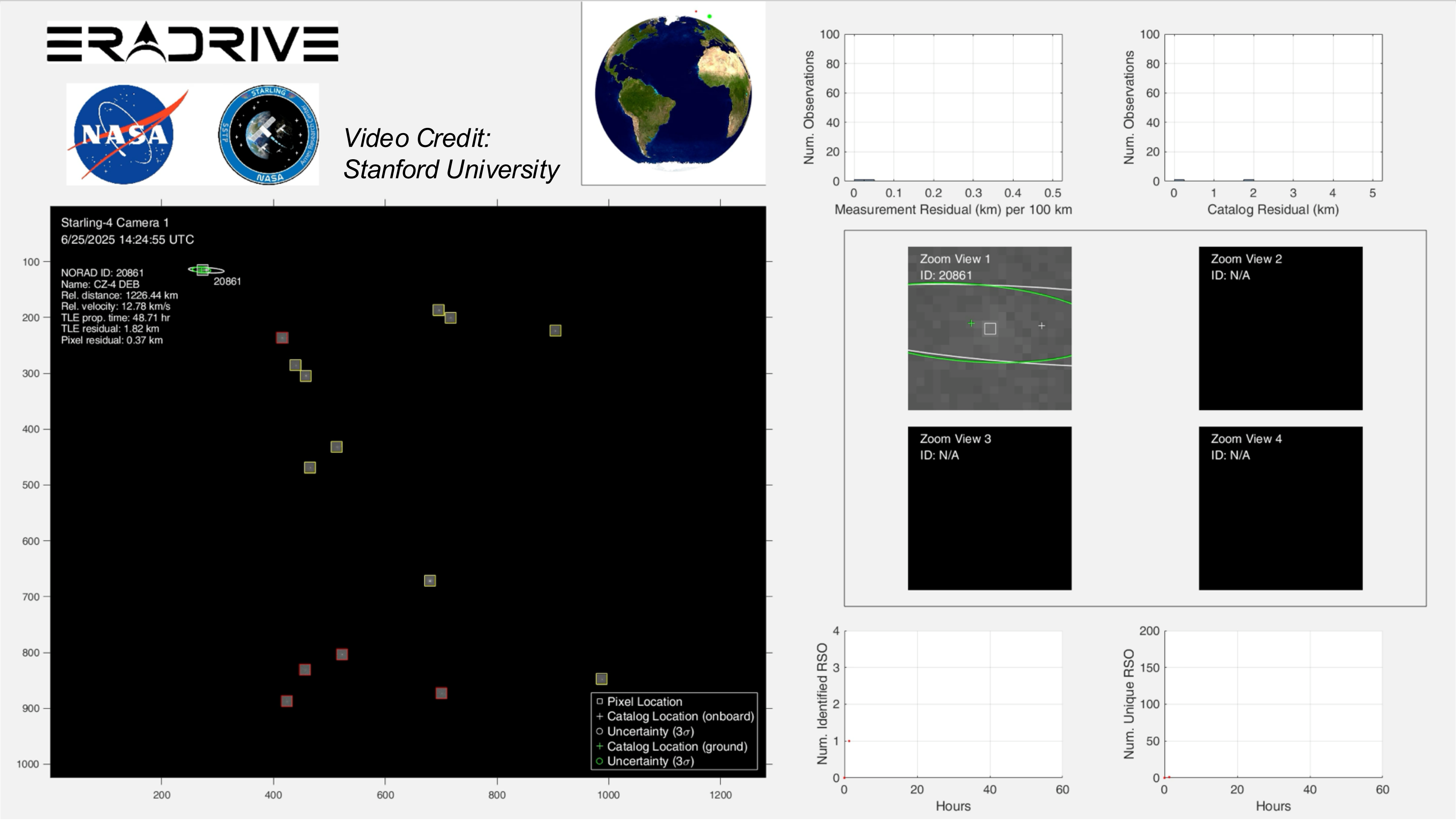
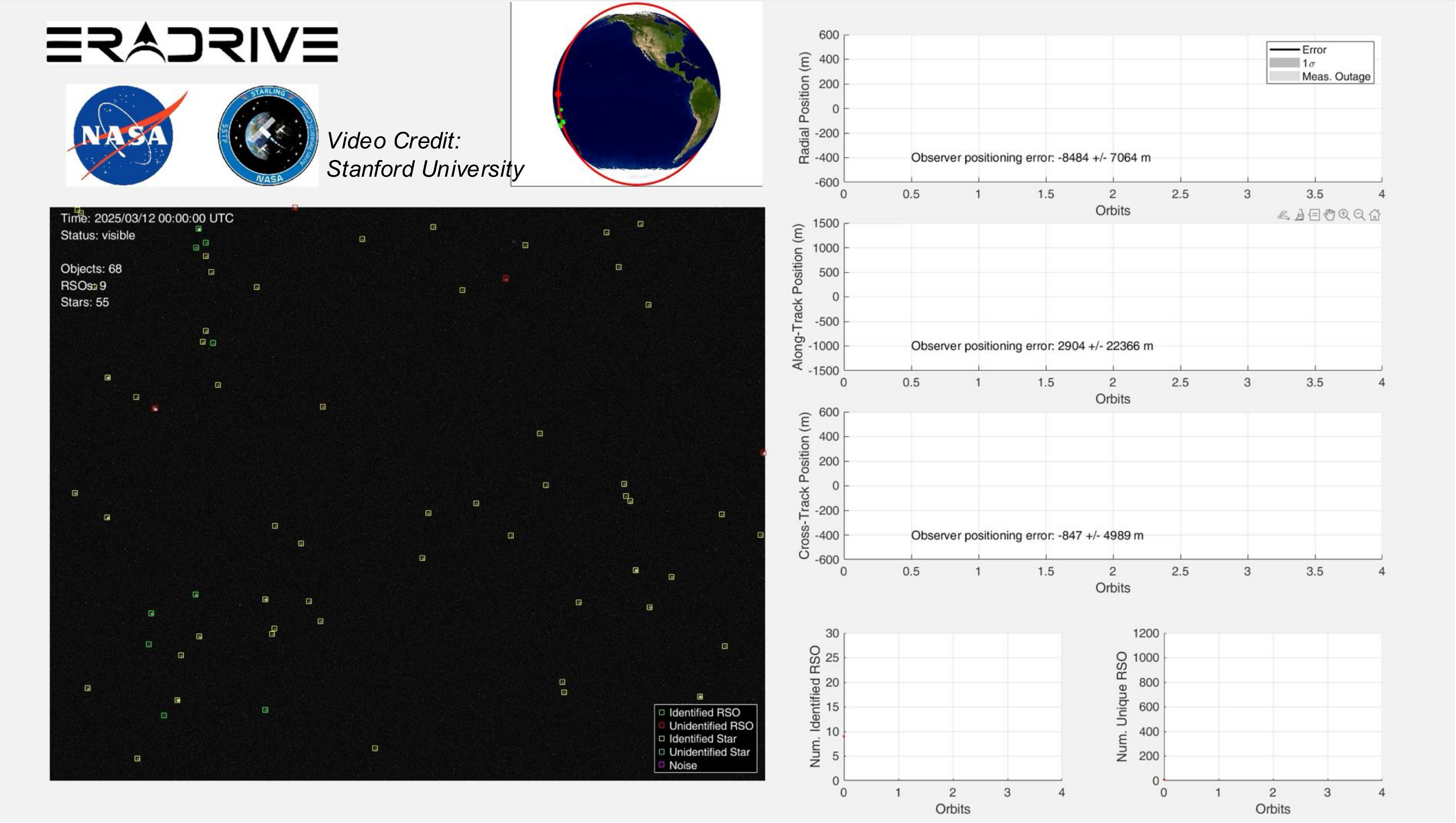


Image 1
Starling-3 Camera 1
03/24/2024 00:46:03
Swarm
Catalog Star
Non-Catalog Star
Hotspot
Catalog Object
Unidentified
Video by: Stanford Space Rendezvous Laboratory
Acknowledgements: NASA Ames Research Center

StarFOX+: Autonomous SSA (2025)



EraDrive Arc: Resilient PNT (2025-26)



StarFOX: Autonomous Swarming (2023-24)

- First on-orbit demo of autonomous optical navigation for a swarm
- Leverages onboard star tracker images to enable:
  - Relative navigation for multiple observers and multiple targets
  - Autonomous initialization of relative navigation for unknown targets (right)
  - Autonomous absolute navigation for the swarm
- Strong robustness and performance in flight:
  - Radial/normal position error: tens of meters
  - Along-track position error: <1% of target range

StarFOX+: Autonomous SSA (2025)

- First on-orbit demo of autonomous detection and identification of resident space objects
- Spaceborne SSA:
  - Uplink catalog of RSOs to the observer satellite
  - Match objects in images to RSOs in catalog
  - Downlink measurements to improve catalog data
- Strong robustness and performance in flight:
  - >2500 objects identified so far at a maximum distance of 3000 km
  - Measurement residuals typically less than 100 m per 100 km

EraDrive Arc: Resilient PNT (2025-26)

- First on-orbit demo of autonomous, resilient optical positioning
- New optical PNT system:
  - Match objects seen in camera images to identities in RSO catalog
  - Use catalog objects as ‘beacons’ with known positions to triangulate observer’s orbit
- High-fidelity simulations using flight software:
  - >20,000 simulated RSOs
  - Radiometrically consistent image rendering
  - Achieves autonomous positioning without GPS or prior orbit knowledge

NEXT-GENERATION MULTI-AGENT SWARM STUDY

Goal: Demonstrate the first autonomous lunar swarm

ID #	Objective
MO-1	Demonstrate a rapid autonomous lunar swarm mission.
MO-2	Demonstrate autonomous lunar swarm mesh networking.
MO-3	Demonstrate autonomous lunar Earth-independent CP&T.
MO-4	Demonstrate autonomous lunar swarm navigation.
MO-5	Demonstrate autonomous lunar RSO signal detection.
MO-6	Demonstrate autonomous lunar RSO orbit determination.

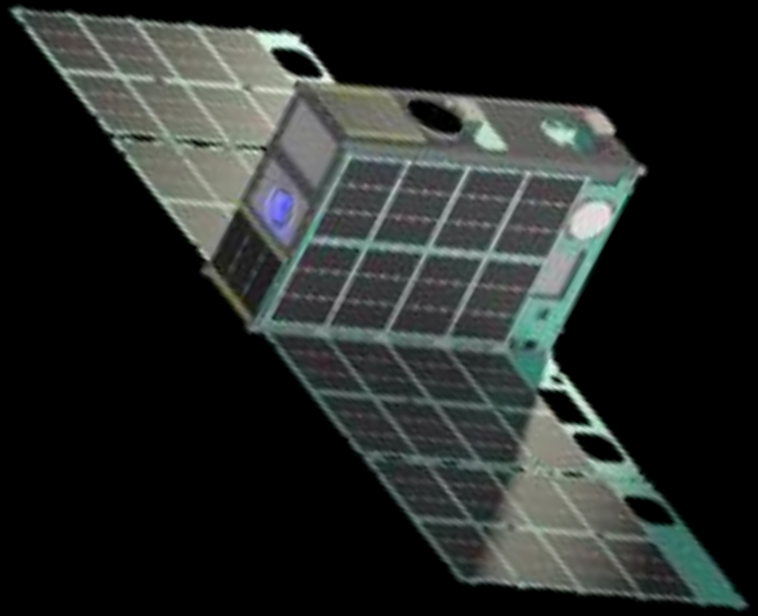
SPACE TRAFFIC MONITORING / MANAGEMENT (STM/M) STUDY

Goal: Demonstrate an on-orbit space traffic monitoring and management capability

ID #	Objective
MO-1	Autonomous and collaborative on-orbit tracking of RSOs
MO-2	Autonomous on-orbit RSO characterization (size, type, etc.)
MO-3	On-orbit tracking of small (<10cm) debris objects
MO-4	Distributed on-orbit RSO catalog updating and sharing

On-Orbit U-Class - 2019 Tipping Point Project

Dual Propulsion Experiment

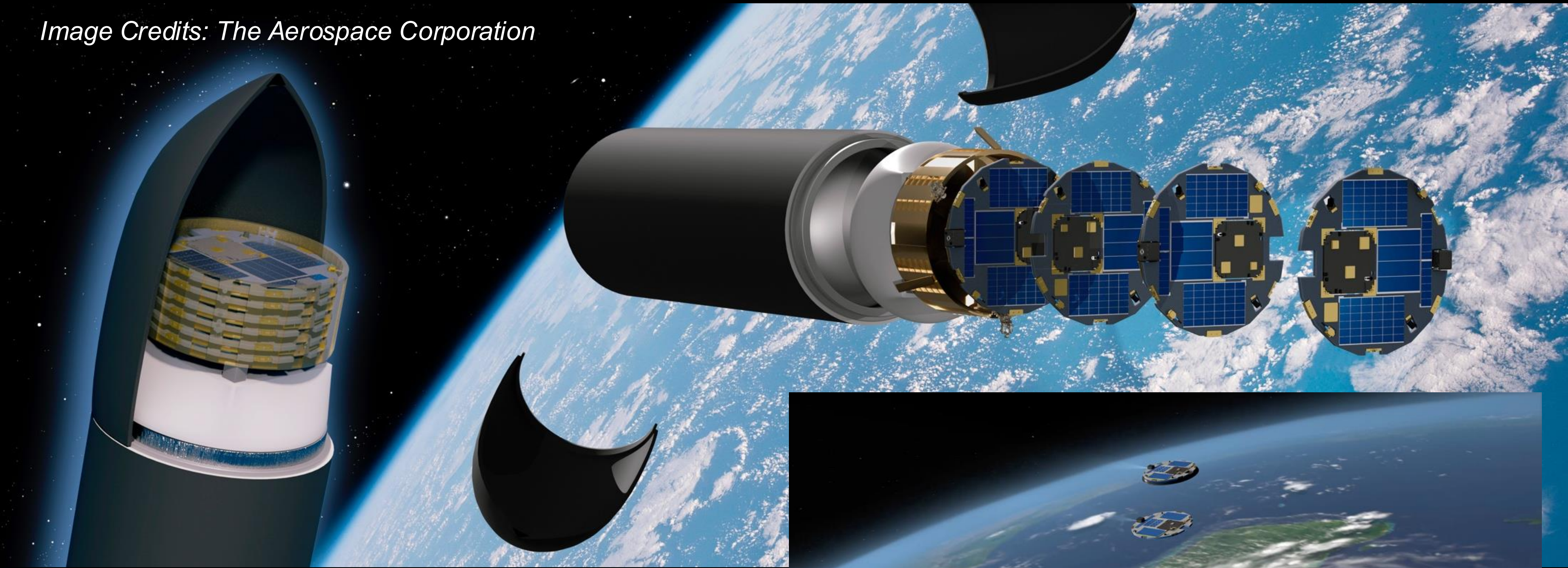


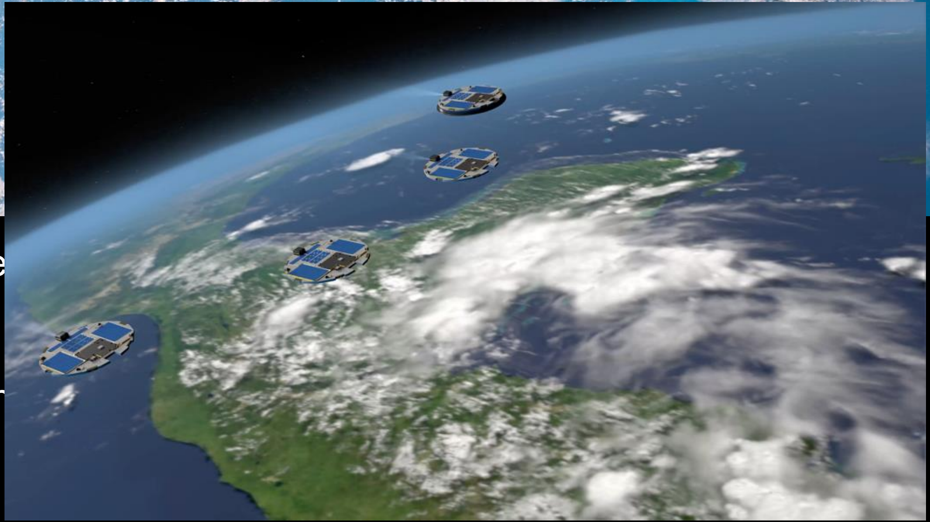
A 6U Dual Propulsion Experiment (DUPLEX) CubeSat. Both propulsion systems, the Fiber-fed Pulsed Plasma Thruster and Monofilament Vaporization Propulsion, were developed with NASA SBIR funding.

Launched: September 14, 2025
ISS Deployment: December 2, 2025

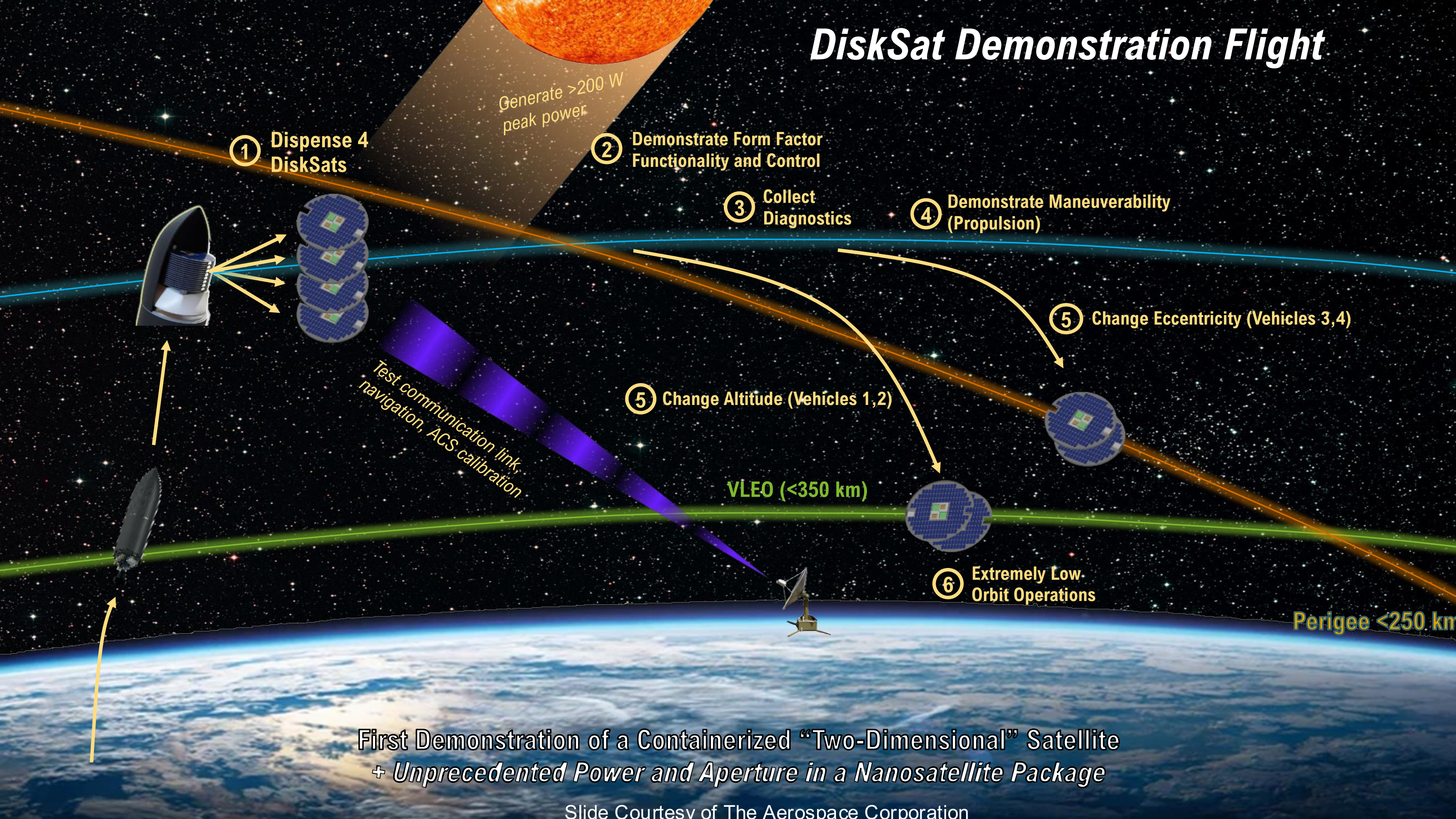
Image Credits: CU Aerospace, LLC.

Image Credits: The Aerospace Corporation





DiskSat DiskSats are high-power and high-aperture alternatives to CubeSats. They are launched in tight stacks but are deployed individually to ensure no recontact between satellites. This first DiskSat demonstration is slated for launch NET December 17, 2025.



DiskSat Demonstration Flight
Generate >200 W peak power
1 Dispense 4 DiskSats
2 Demonstrate Form Factor Functionality and Control
3 Collect Diagnostics
4 Demonstrate Maneuverability (Propulsion)
5 Change Eccentricity (Vehicles 3,4)
Test communication link, navigation, ACS calibration
5 Change Altitude (Vehicles 1,2)
VLEO (<350 km)
6 Extremely Low Orbit Operations
Perigee <250 km
First Demonstration of a Containerized "Two-Dimensional" Satellite
+ Unprecedented Power and Aperture in a Nanosatellite Package
Slide Courtesy of The Aerospace Corporation

Upcoming SmallSat Technology Demonstration Missions – 2026

Small Spacecraft Propulsion and Inspection Capability (SSPICY)

Launch Timeframe: October 2026

Demonstrate electric propulsion and other advanced capabilities to perform rendezvous, proximity operations, inspection, and characterization of up to 4 resident space objects in LEO of US origin for the purpose of future remediation.

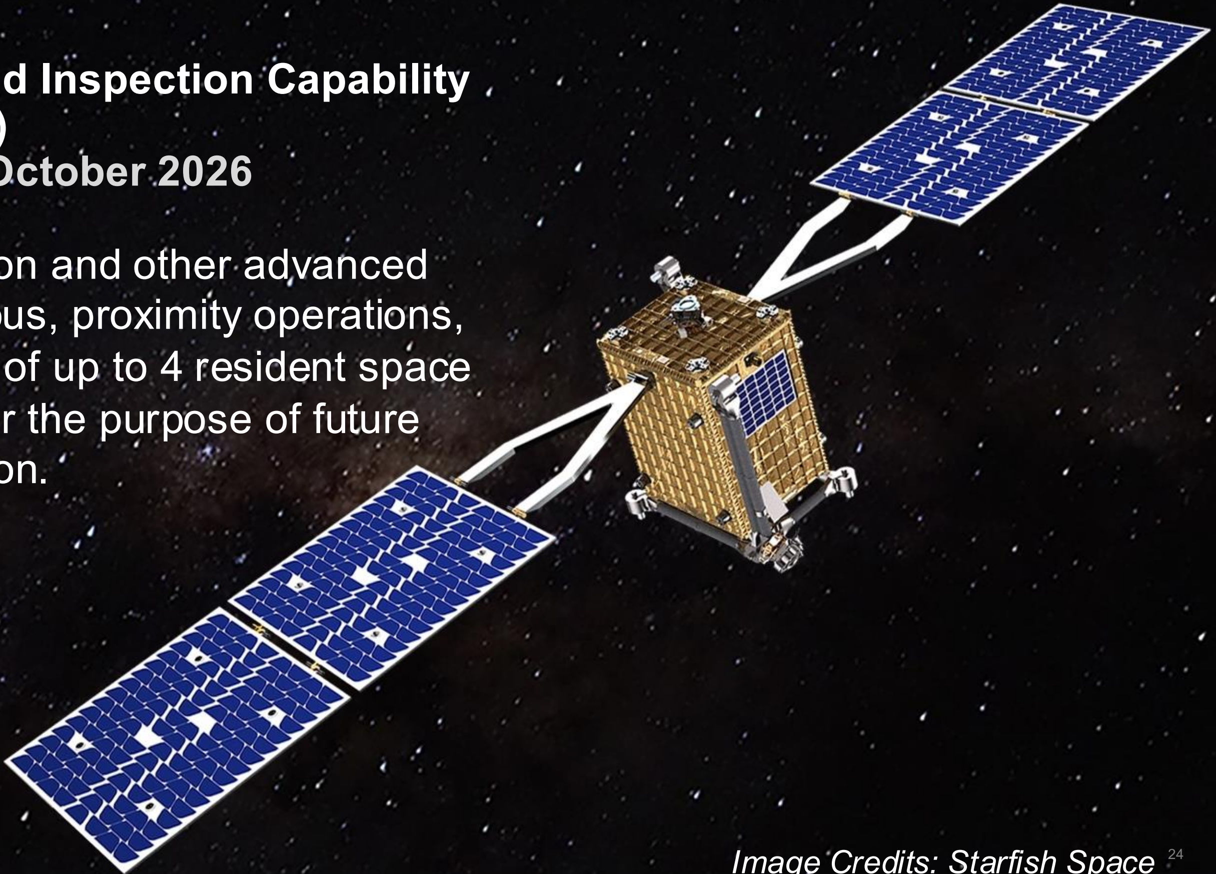


Image Credits: Starfish Space

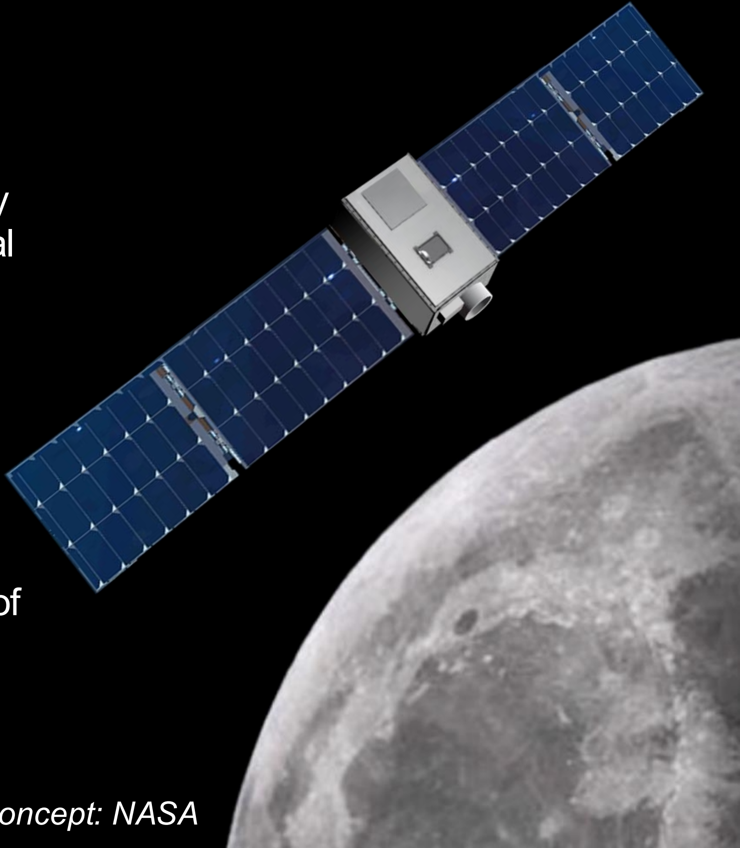
Upcoming SmallSat Technology Demonstration Missions – 2027

Lunar Assay via Small Satellite Orbiter (LASSO) – DARPA Solicitation

Launch Timeframe: 2027

The LASSO project aims to develop technologies to support the conduct of operations in support of space situational awareness by developing both autonomous satellite navigation in stressing orbital conditions and increasing satellite maneuverability through continuous dynamic repositioning based on changing conditions, with the added benefit of creating a proven reserve model for resources relevant to ISRU on Earth's Moon.

The LASSO program seeks performers to design, test, build, and deliver a spacecraft capable of determining all areas on the Moon that contain greater than 5% water concentration with a resolution of no larger than four-square kilometers.



Notional LASSO Concept: NASA

University SmallSat Technology Partnership Successes to Date

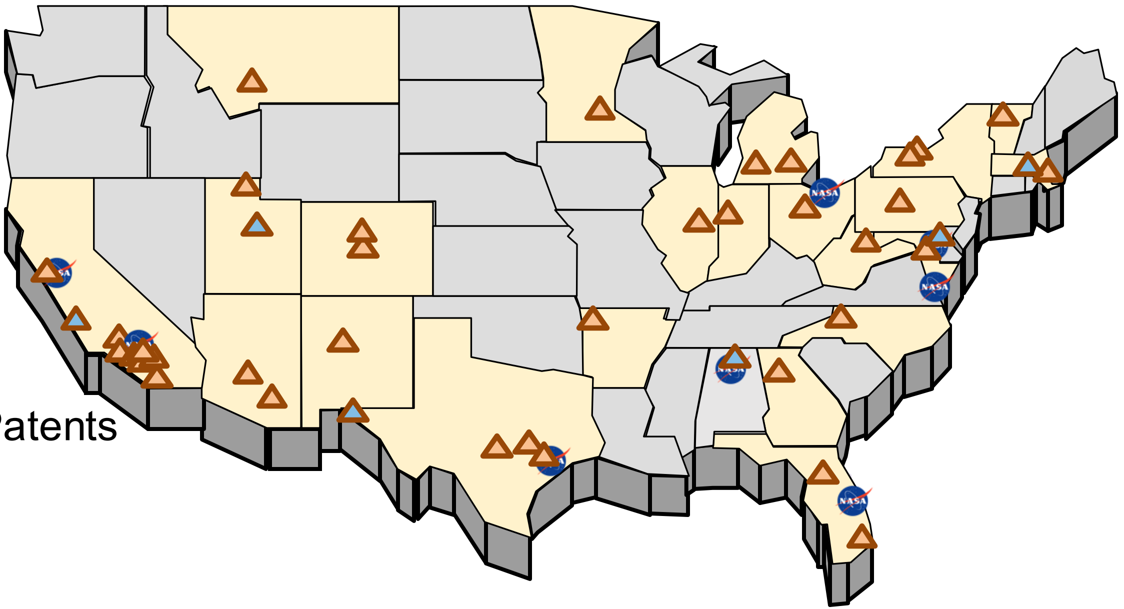
Investments:
- Over $30,000,000 awarded
- 54 partnerships in 6 cohort years
- 36 universities in 22 states (+6 supporting collaborators in 6 states)
- 8 of 10 NASA centers partnered

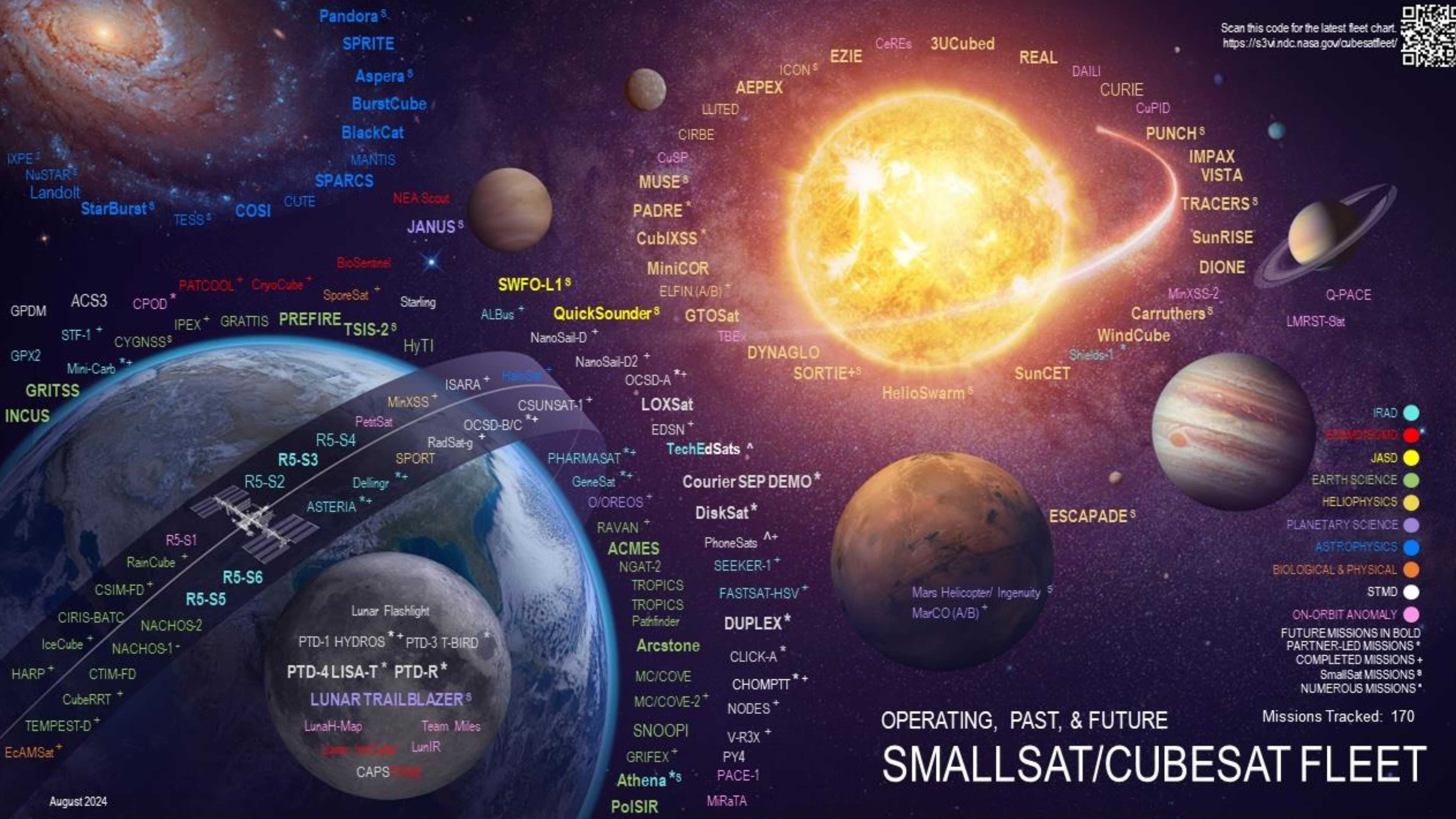
Results:
- 26 flight demonstrations performed/planned
- 1 Intersatellite Network Planning/ Routing tool software open-sourced
- Numerous New Technology Reports/Patents
- 30+ conference presentations
- 50+ papers published
- 100+ students involved
- Many technology readiness levels (TRL) raised

36 Universities in 22 States

8 NASA Centers (including JPL FFRDC)

6 Supporting University Collaborators in 6 States




Scan this code for the latest fleet chart.
https://s3vi.ndc.nasa.gov/cubesatfleet/
OPERATING, PAST, & FUTURE
SMALLSAT/CUBESAT FLEET
Missions Tracked: 170
August 2024
IRAD
JASD
EARTH SCIENCE
HELIOPHYSICS
PLANETARY SCIENCE
ASTROPHYSICS
BIOLOGICAL & PHYSICAL
STMD
ON-ORBIT ANOMALY
FUTURE MISSIONS IN BOLD
PARTNER-LED MISSIONS *
COMPLETED MISSIONS +
SmallSat MISSIONS S
NUMEROUS MISSIONS ^
Pandora S
SPRITE
Aspera S
BurstCube
BlackCat
MANTIS
SPARCS
IXPE S
NuSTAR S
Landolt
StarBurst S
TESS S
COSI
CUTE
NEA Scout
JANUS S
BioSentinel
PATCOOL +
CryoCube +
SporeSat +
Starling
GPDM
ACS3
CPOD *
IPEX +
GRATTIS
PREFIRE
TSIS-2 S
HyTI
STF-1 +
CYGNSS S
GPX2
Mini-Carb *+
GRITSS
INCUS
ISARA +
MinXSS +
PetitSat
R5-S4
R5-S3
R5-S2
RadSat-g +
SPORT
Dellingr *+
ASTERIA *+
R5-S1
RainCube +
CSIM-FD +
R5-S6
R5-S5
CIRIS-BATC
NACHOS-2
IceCube +
NACHOS-1 +
HARP +
CTIM-FD
CubeRRT +
TEMPEST-D +
EcAMSat +
Lunar Flashlight
PTD-1 HYDROS *+
PTD-3 T-BIRD *
PTD-4 LISA-T *
PTD-R *
LUNAR TRAILBLAZER S
LunaH-Map
Team Miles
LunIR
CAPS
SWFO-L1 S
ALBus +
QuickSounder S
NanoSail-D +
NanoSail-D2 +
CSUNSAT-1 +
OCSD-B/C *+
PHARMASAT *+
GeneSat *+
O/OREOS +
RAVAN +
ACMES
NGAT-2
TROPICS
TROPICS Pathfinder
Arcstone
MC/COVE
MC/COVE-2 +
SNOOPI
GRIFEX +
Athena *S
PolSIR
OCSD-A *+
LOXSat
EDSN +
TechEdSats ^
Courier SEP DEMO *
DiskSat *
PhoneSats ^+
SEEKER-1 +
FASTSAT-HSV +
DUPLEX *
CLICK-A *
CHOMPTT *+
NODES +
V-R3X +
PY4
PACE-1
MiRaTA
ICON S
LLITED
AEPEX
CIRBE
CuSP
MUSE S
PADRE *
CubIXSS *
MiniCOR
ELFIN (A/B) +
GTOSat
TBEx
DYNAGLO
SORTIE+S
HelioSwarm S
SunCET
EZIE
CeREs
3UCubed
REAL
DAILI
CURIE
CuPID
PUNCH S
IMPAX
VISTA
TRACERS S
SunRISE
DIONE
MinXSS-2
Q-PACE
Carruthers S
LMRST-Sat
WindCube
Shields-1 *
ESCAPADE S
Mars Helicopter/ Ingenuity S
MarCO (A/B) +

NASA