National Aeronautics and Space Administration

NASA's Small Spacecraft & Distributed Systems

Development and Demonstration of Technologies Enabling Swarms and New Spacecraft Platforms with AI and Edge Computing

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SSDS: Advancing Small Spacecraft Capabilities

Portfolio progressing from individual subsystem technologies toward distributed systems

- Uses small spacecraft to rapidly demonstrate, test, and mature new technologies
- Improves small spacecraft technologies while developing new operational concepts
- Advances technologies and mission architectures for NASA science and exploration with an emphasis on expanding the space economy
- Increasing focus on autonomy

SSDS SHIFT: Individual Subsystems ⟶ Coordinated Distributed Systems

The Vision: Enable Truly Distributed Autonomous System

AI-Enabled Small Spacecraft Swarms Operating with Minimal Ground Intervention

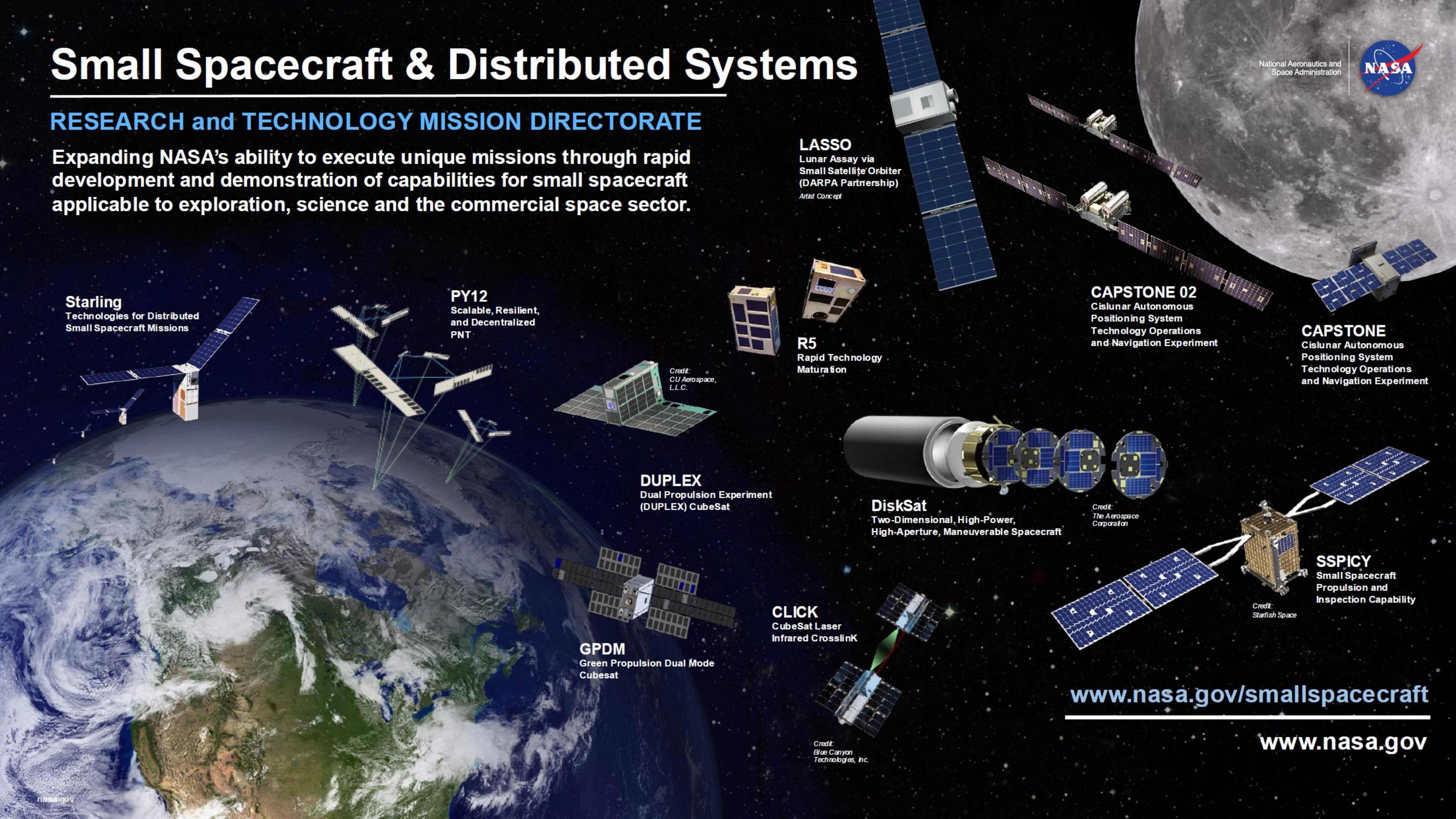
- Autonomy: Commissioning, operations, and anomaly resolution
- Communication / Coordination: Information sharing, self-organization, and self-negotiate tasking
- Data Analysis: analyze data on orbit, send only relevant data and/or results resolution

Use AI & Edge computing
to enable fully “launch-and-forget” capable spacecraft swarms

What Could Large, Autonomous Spacecraft Swarms Enable?

Use cases difficult or impractical to implement using traditional single-spacecraft systems

- Simultaneous, Multi-point Science Data Collection: unique science cases collecting data in large volumes of space, and synthetic apertures
- Off-World Navigation: navigation and positioning in cislunar and deep space
- Space Situational Awareness: enhance space traffic management and collision avoidance in Earth orbit and beyond


Small Spacecraft & Distributed Systems
RESEARCH and 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.
National Aeronautics and Space Administration
NASA
LASSO
Lunar Assay via Small Satellite Orbiter (DARPA Partnership)
Artist Concept
CAPSTONE 02
Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment
CAPSTONE
Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment
Starling
Technologies for Distributed Small Spacecraft Missions
PY12
Scalable, Resilient, and Decentralized PNT
Credit: CU Aerospace, L.L.C.
R5
Rapid Technology Maturation
DUPLEX
Dual Propulsion Experiment (DUPLEX) CubeSat
DiskSat
Two-Dimensional, High-Power, High-Aperture, Maneuverable Spacecraft
Credit: The Aerospace Corporation
SSPICY
Small Spacecraft Propulsion and Inspection Capability
Credit: Starfish Space
GPDM
Green Propulsion Dual Mode Cubesat
CLICK
CubeSat Laser Infrared CrosslinK
Credit: Blue Canyon Technologies, Inc.
www.nasa.gov/smallspacecraft
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nasa.gov

SSDS Delivers Innovation Through Diverse Mechanisms

Mission implementation strategy includes industry partners, academia, and other government agencies

Competitive, Open Solicitations

- Announcements of Collaboration Opportunities (ACO)
- Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR)
- Tipping Points
- University SmallSat Technology Partnerships (USTP)

Partnerships

- Collaborations with academia, other government agencies, and NASA centers
- Public-private partnerships with industry

Targeted Investments

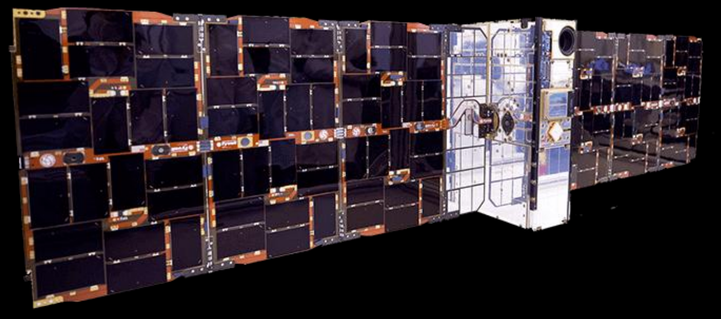
- Missions of Opportunity
- NASA in-house development
- Grants

University SmallSat Technology Partnership Successes to Date

- **36 Universities in 22 States**
- **8 NASA Centers (including JPL FFRDC)**
- **6 Supporting University Collaborators in 6 States**

Past missions focused on improvements in power, propulsion, processing and comm

Enable efficient swarm maintenance, data collection and transmission

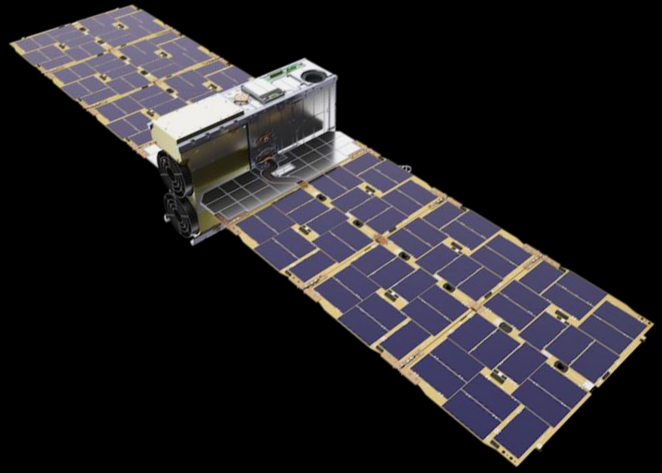


Pathfinder Technology Demonstrator (PTD-3)

Launched:
May 25, 2022

TeraByte InfraRed Delivery (TBIRD) technology payload demonstrated optical communications downlink at 200 gigabits per second, a world record

Image Credits: Terran Orbital



Pathfinder Technology Demonstrator (PTD-R)

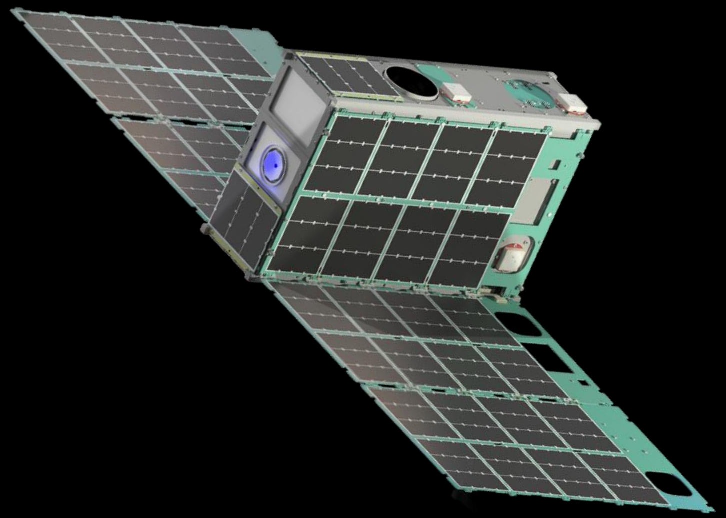
Launched:
August 16, 2024

Demonstrate a new type of UV and SWIR telescope that may be used in a wide range of applications.

Image Credits: Terran Orbital

Currently,SSDS focuses on autonomy, while continuing to advance subsystem gaps

DUPLEX demonstrates an inherently safe propulsion system



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.

Currently,SSDS focuses on autonomy, while continuing to advance subsystem gaps

GPDM will demonstrate ASCENT based combined low-thrust and high thrust propulsion

Green Propulsion Dual Mode (GPDM)
Launch Timeframe: NET Oct 2026

Demonstrate chemical and electrospray characteristics (higher thrust and higher efficiency) for in-space propulsion using ASCENT / green propellant on a 6U-sized CubeSat.

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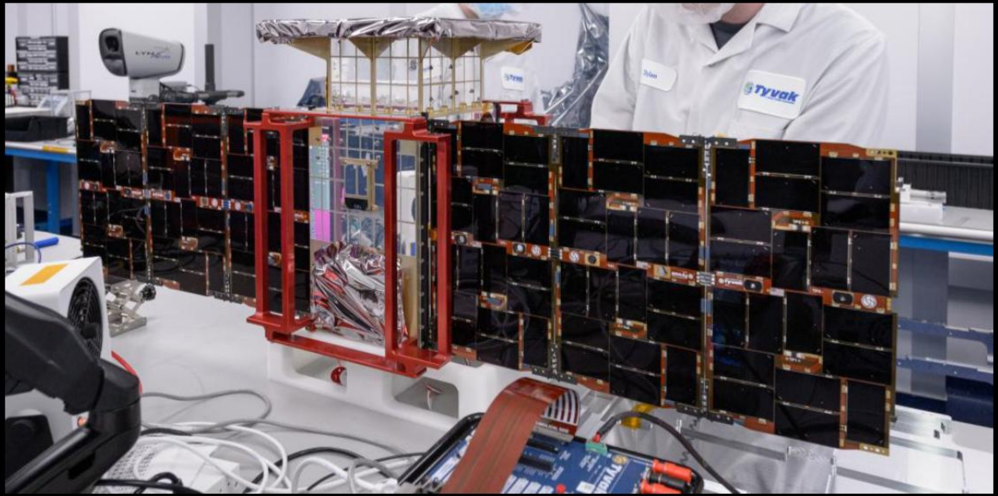
CAPSTONE demonstrated autonomous spacecraft navigation at the moon

CAPSTONE

Extending Autonomy to Cislunar Space

Launched: June 28, 2022

Status: Completed May 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 demonstrated and tested technologies for autonomy and standards-based, interoperable communications and networking in the cislunar environment.

Currently,SSDS focuses on autonomy, while continuing to advance subsystem gaps

SSPICY will demonstrate inspection of debris objects utilizing an autonomous software suite

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.

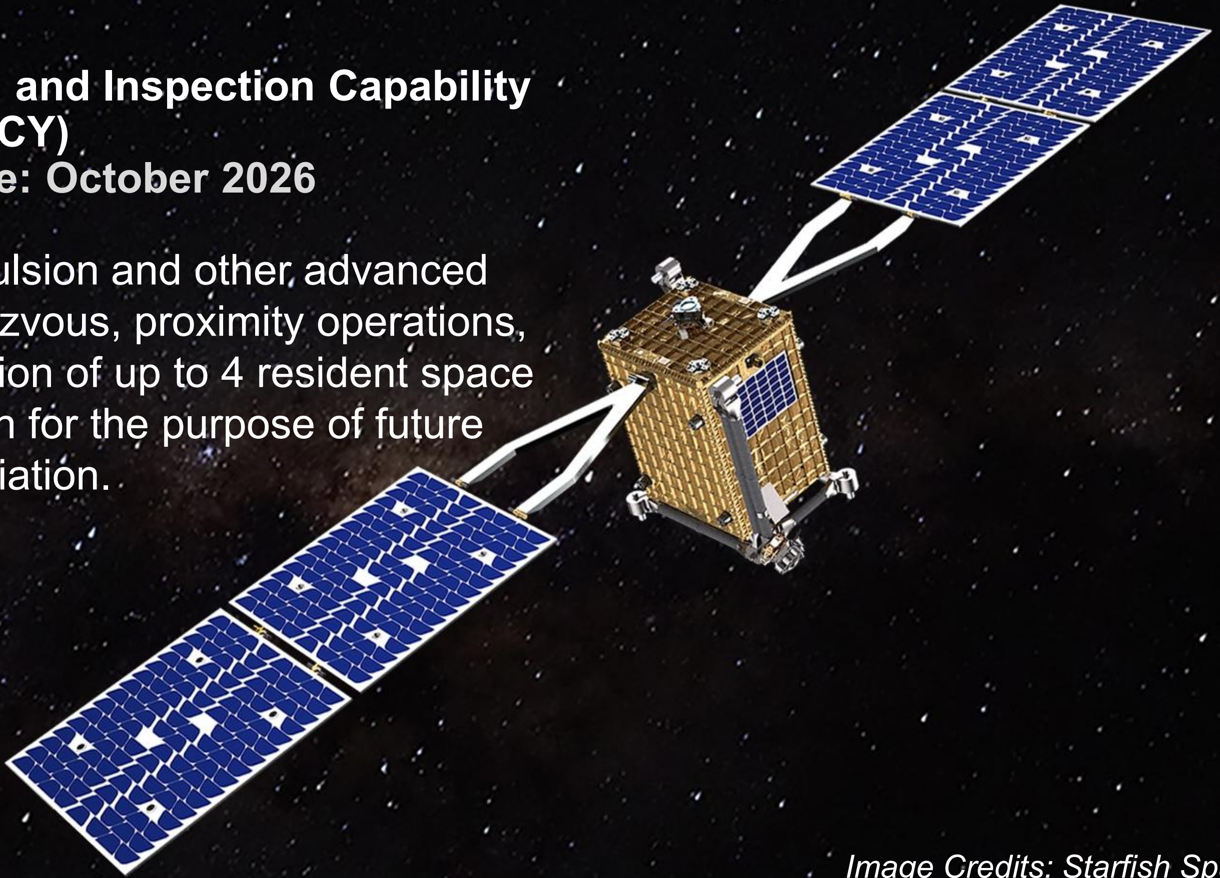


Image Credits: Starfish Space 11

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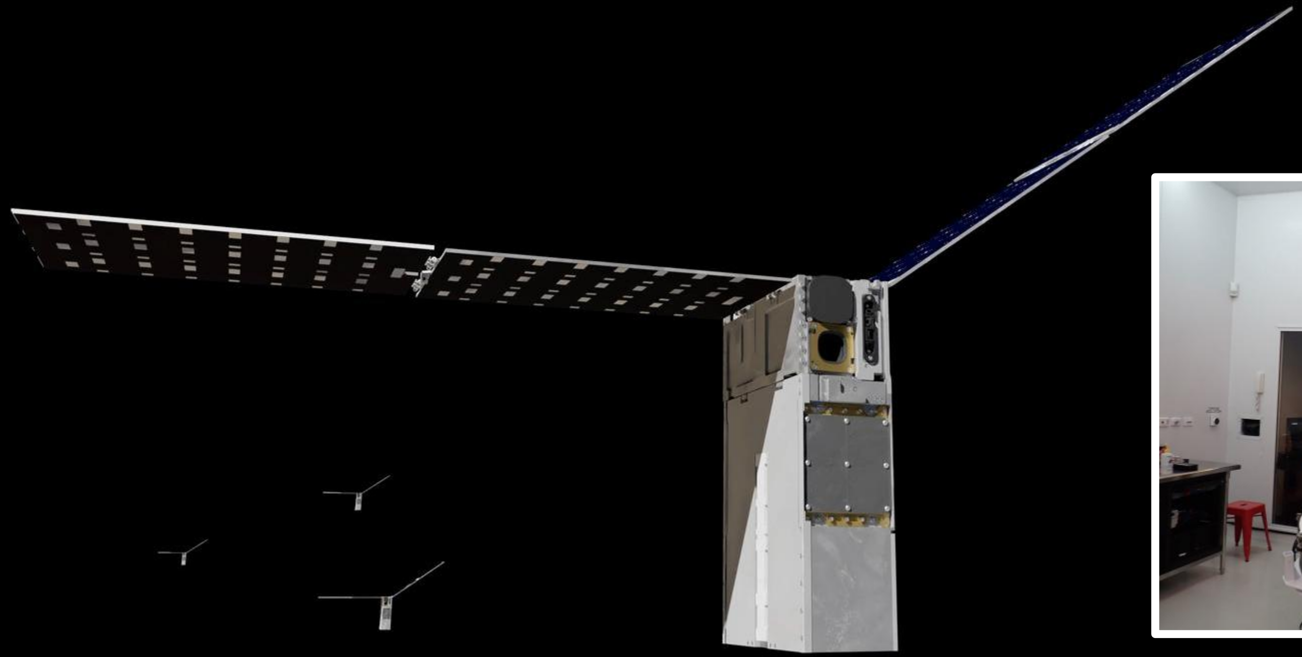
Starling demonstrated autonomous maneuvers, novel comm networking and relative navigation between 4 spacecraft

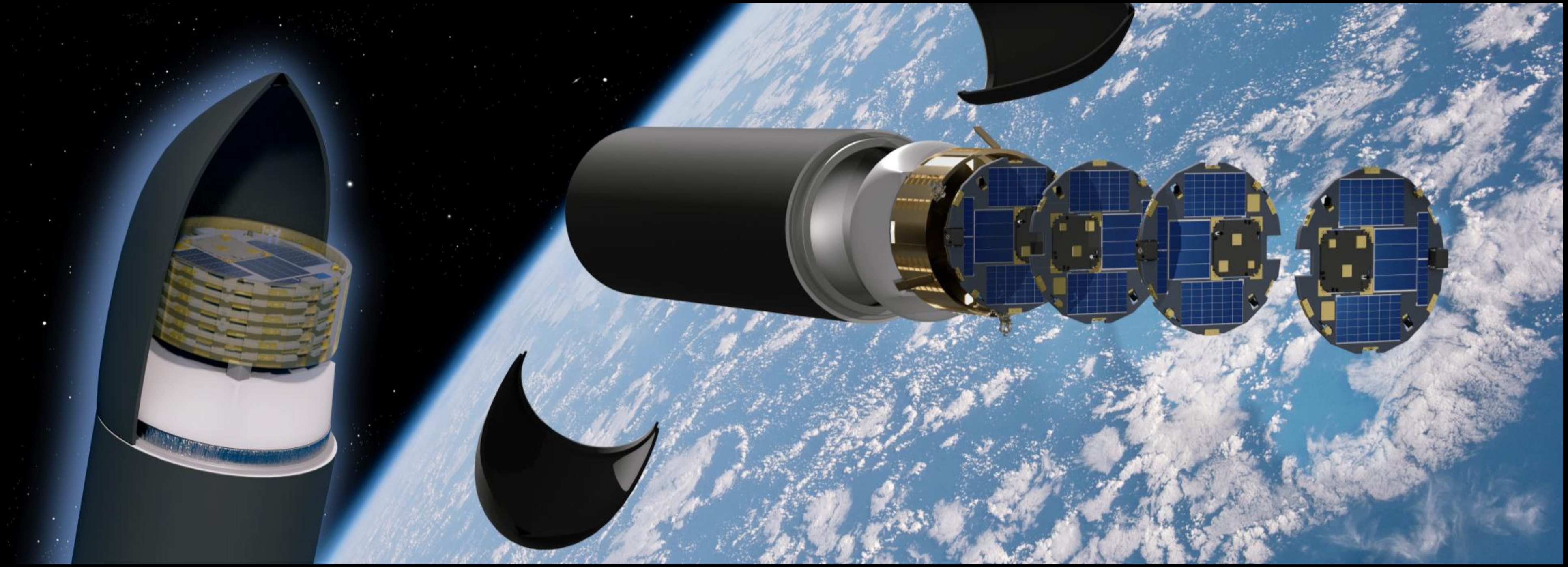


Starling's four 6U CubeSats launched on July 17, 2023 from Rocket Lab Launch Complex 1 in Mahia, New Zealand.

Image Credits: NASA. *Inset Image Credits: Rocket Lab*

Currently,SSDS focuses on autonomy, while continuing to advance subsystem gaps

DISKSAT demonstrates a new spacecraft form factor



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. DiskSat demonstration mission launched December 18, 2025.

For the future SS&DS plans missions that both further and use autonomy

PY12 furthers the vision of a Launch & Forget AltPNT + SSA capability

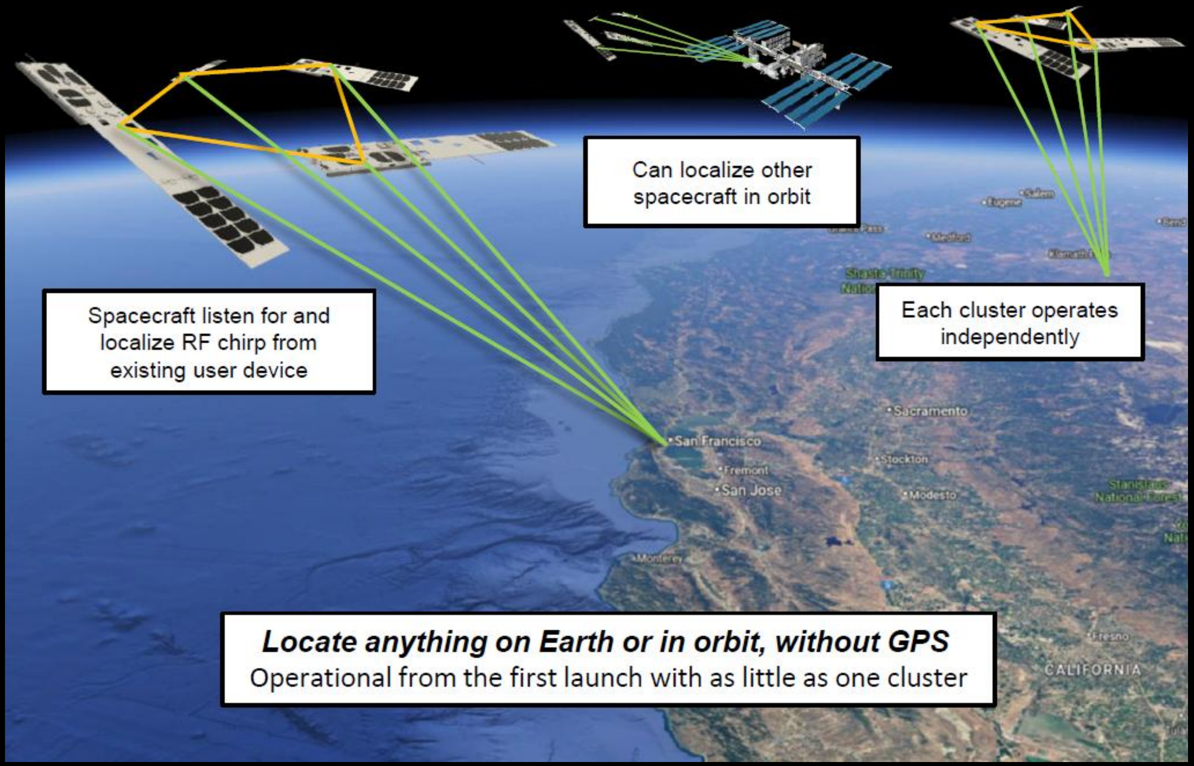


Image Credits: EarthTraq

EarthTraq PY12 system

- **Time-of-Arrival** Based Localization Technique
- **No GPS**, DSN, or ground-based tracking
- **10-meter accuracy** + instantaneous velocity possible
- Under **$100K per satellite**, hot-swappable, cheap & fast to deploy to LEO
- Cluster of 4+ for ad-hoc **private PNT**
- Scales to large **deployment of 1000+** to make it nearly impossible to disrupt service

For the future SS&DS plans missions that both further and use autonomy

CAPSTONE 02 will demonstrate improved autonomous navigation and SSA at the moon

Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE02)

Launch Timeframe: 2027

Demonstrate rendezvous and proximity operations, autonomous navigation, and cislunar communication capabilities while continuing to characterize the radiation environment at the Moon.

Conclusion

- SSDS has advanced small spacecraft technologies since 2012, transitioning from subsystem demonstrations to autonomous distributed swarms.
- The program’s long-term vision is for swarms to operate with “launch-and-forget” autonomy, handling commissioning, operations, data collection, and analysis independently.
- Missions like Starling and CAPSTONE are key milestones, with upcoming projects (CAPSTONE 02, SSPICY) further maturing technologies for autonomous swarm architectures.
- Future plans include expanding these capabilities to lunar and deep space missions

Exploring the secrets of the universe for the benefit of all.

nasa.gov