NASA SMALL SPACECRAFT & DISTRIBUTED SYSTEMS (SSDS) PROGRAM - RECENT and UPCOMING TECHNOLOGY DEMONSTRATIONS and DEVELOPMENT EFFORTS

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ABSTRACT

NASA's Small Spacecraft & Distributed Systems (SSDS) program strengthens U.S. ability to conduct unique missions by rapidly developing and demonstrating capabilities for SmallSat exploration, science, and commercial space. In collaboration with NASA Centers, other government agencies, commercial industry, and academia, SSDS advances next generation SmallSat technologies like power, processing, propulsion, communications, autonomous navigation, architectures (swarms), and applications (AI/ML/Edge Computing)—to extend missions beyond LEO into cislunar and planetary space. Various investment mechanisms exist for SSDS to select and fund projects that will ultimately advance NASA's Moon to Mars Architecture.

Presented here are the latest achievements and findings from recently completed SSDS projects, along with updates from ongoing efforts and planned future work. Successful missions like Starling and CAPSTONE continue to demonstrate their capability after several years on-orbit. Advancements in next generation swarm configurations are being implemented by Starling for space traffic monitoring and management applications. Findings from recent SSDS flight projects are discussed: DiskSat, a unique SmallSat platform alternative to canisterized nanosatellites, launched December 2025 and is gathering data; the PTD series of missions concluded in December 2025. Current SSDS efforts are focused on addressing NASA Shortfalls relating to rendezvous and proximity operations, neuromorphic computing, and space situational awareness.

1 INTRODUCTION

The Small Spacecraft Distributed Systems (SSDS) program within NASA's Space Technology Mission Directorate (STMD) manages portfolio investments that range from lower technology readiness level (TRL) development projects to technology demonstration missions. SSDS collaborates with various organizations—NASA centers, other government agencies, commercial industry, and academia—to advance technologies for next generation small spacecraft to extend missions beyond LEO into cislunar and planetary space [1]. Technologies such as spacecraft power, processing, propulsion, communications, autonomous navigation, architectures (e.g., swarms), and applications (e.g., artificial intelligence (AI), machine learning (ML), and edge computing), and proximity operations all have high interest due to their potential capability.

Small spacecraft are not limited to Earth orbiting satellites but also include cislunar and interplanetary spacecraft, and later may also serve as planetary re-entry vehicles and landing craft. CubeSats are a special category of small spacecraft and are of particular interest because launch opportunities tend to be more frequent and affordable compared to other small spacecraft, due to the standard sizes and containerization of CubeSats. The evolution of the CubeSat platform reflects their widespread adoption and their foundation for modern SmallSat paradigms.

To foster the collaborative framework within SSDS projects, several investment mechanisms exist for SSDS to select and fund projects that will ultimately advance economic growth through innovation, especially in the space sector. These mechanisms include University partnerships (USTP), Announcements of Collaboration Opportunities (ACOs), Tipping Point partnerships, and Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR), and are competitive, open solicitations that proposers apply to. If applicable, flight demonstration options are implemented within SSDS, Flight Opportunities, and/or SmallSat testbeds. The maturity of SmallSat systems brought about by investments in technology, instruments, and supporting tools promotes industry-wide adoption of the platform for more complex, distant, and long-duration missions.

1.1 UNIVERSITY SMALLSAT TECHNOLOGY PARTNERSHIPS

Funded and managed by SSDS, the University SmallSat Technology Partnerships (USTP) initiative selects university teams to collaborate with NASA Centers on the development and testing of promising SmallSat technologies of interest over a two-year period [2]. Combining NASA's experienced workforce and advanced facilities with innovative academic researchers can help bridge technological gaps that currently limit full potential space exploration using a small spacecraft. Every USTP solicitation process targets specific small spacecraft capability areas— such as machine learning and edge computing, optical navigation, enhanced nanomaterials for advanced power electronics or thermal applications, attachment methods and deployables, or propulsive solutions. Results from these projects may lead to the development of technologies to improve the quality of small spacecraft data transmissions, integrated power and energy storage systems, power systems, and deorbiting systems amongst others.

Table 1 lists USTP's technology topic areas by year; the United States map in Figure 1 identifies the 22 states hosting 36 universities with either previous or ongoing USTP awards as well as the location of the 8 NASA centers, including NASA's Jet Propulsion Laboratory in Southern California, serving or have served as partners. To date, USTP has awarded 54 partnership projects. USTP-funded research has resulted in 20 planned or performed flight demonstrations, more than 50 papers and 30 conference presentations, and has involved over a hundred students at various stages in their academic pursuits.

Currently completing its sixth round of USTP projects, eight university teams were selected from a 2023 USTP solicitation requesting proposals in three topic areas: Earth- and GNSS-Independent Position Navigation and Timing for Small Spacecraft; Edge Computing and Machine-Learning

Architectures, Software, Platforms, and Devices for Small Spacecraft; High Specific Power Systems and Thermal Control for Small Spacecraft.

Table 1. NASA's USTP initiative technology topics throughout all six cohorts.

USTP Cohort	2013	2015	2016	2018	2020	2023
Technology Topic Areas	Communications	Avionics / Command & Data Handling Subsystem	Enhanced Power Generation and Storage	Instruments for SmallSats including Multiple SmallSats	Lunar Communications and Navigation Network	Earth- and GNSS-Independent Position Navigation and Timing for Small Spacecraft
	GN&C	Communication Subsystem	Cross-linking Communications Systems	Technologies That Enable Large Swarms of Small Spacecraft	SmallSat Propulsion for Lunar Missions	Edge Computing and Machine-Learning Architectures, Software, Platforms, and Devices for Small Spacecraft
	Propulsion	Ground Data Systems	Relative Navigation for Multiple Small Spacecraft	Technologies That Enable Deep Space Small Spacecraft Missions	Advanced Electrical Power and Thermal Management	High Specific Power Systems and Thermal Control for Small Spacecraft
	Power	Guidance Navigation & Control / Attitude Determination & Control Subsystem	Instruments and Sensors for Small Spacecraft Science Missions		*Solicitation encourages grant extensions for suborbital, and orbital flight demonstrations*	
	Science Instrument Capabilities	Payloads				
	Advanced Manufacturing	Power Subsystem				
		Propulsion Subsystem				
	Subsystem-Oriented **Manufacturing** **Instruments**	**System-Oriented** **LEO** **Instruments**	**Mission-Oriented** **Deep Space, Multi-Spacecraft** **Instruments**		**Return to the Moon**	**Earth Orbit & Deep Space** **Exploration Infrastructure**

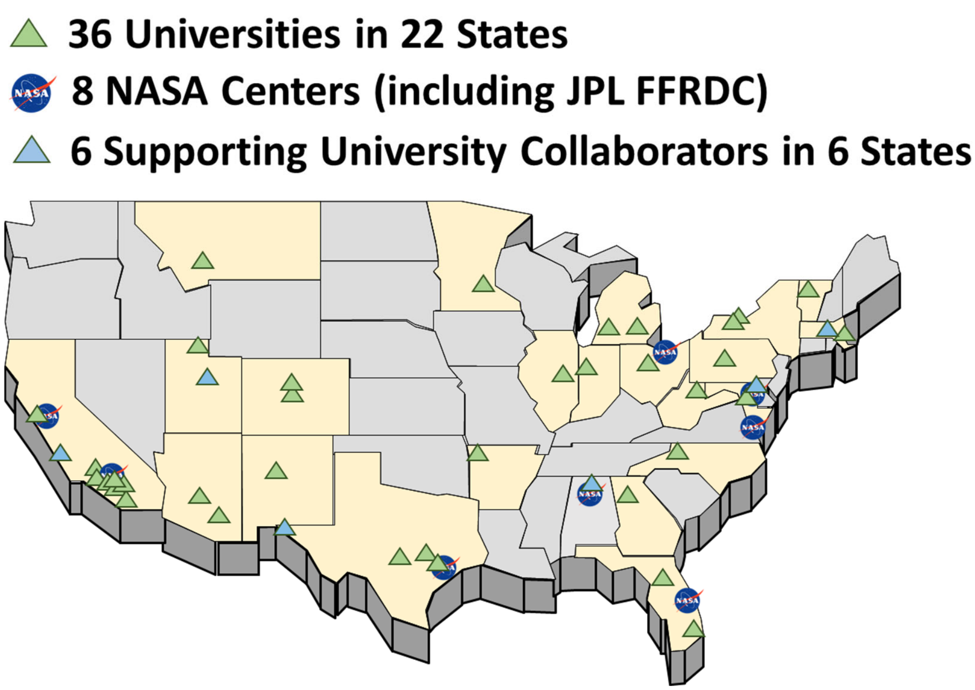

Figure 1. United States map indicating the locations of universities and NASA centers engaged in NASA's University SmallSat Technology Partnerships initiative as of January 2026. Credit: NASA.

1.2 SMALL BUSINESS INNOVATION RESEARCH

NASA's Small Business Innovation Research (SBIR) program within STMD supports small businesses in developing innovative technologies aligned with the federal government's research and development needs, with the potential for commercialization or infusion into NASA missions [3]. The Civil Space Technology Shortfalls identify critical technology gaps across civil and commercial space missions that guide NASA's strategic technology investments. Each SBIR-funded investment is aligned with highly ranked technology shortfalls where meaningful advancements have the potential to substantially enhance U.S. leadership in space exploration. SBIR investment mechanisms provide structured pathways for commercial partners to contribute to the sustainable exploration of the Moon and beyond.

Standard annual SBIR Phase I and Phase II awards (starting 2026 increased to $225,000 over 6 months and $1,275,000 over 24 months, respectively) are designed to advance early-stage concepts through incremental development [3]. At the conclusion of Phase I and II awards, small businesses may pursue follow-on Phase II opportunities that, in some instances, can require matched funding from external investors to accelerate development toward near-term infusion into NASA missions or commercial markets [4]. A Phase II Extended option allows a continuation of the Phase II contract for an additional 6–12 months. For technologies that have matured beyond the iterative Phase I/II development cycle, the Civilian Commercialization Readiness Pilot Program (CCRPP) provides a pathway to transition technologies into NASA missions and/or commercial applications. CCRPP requires a minimum external investment of $500,000, which NASA matches between $500,000 and $2.5 million [5]. The performance period is typically 24 months. Phase II Sequentials offer another mechanism up to $4 million for maturing technologies with a clear path to near-term NASA mission infusion [6].

SSDS manages SBIR-funded investments that are maturing capabilities small spacecraft can implement for NASA's Moon-to-Mars architecture, Artemis and Gateway programs, and Orbital Debris and ISAM Implementation Plans. The 2025 SBIR Phase 1 topics were small spacecraft propulsion, access beyond low Earth orbit (LEO) for small spacecraft, and rendezvous and proximity operations (RPO) functionality on small spacecraft.

1.3 NASA ANNOUNCEMENT of COLLABORATION OPPORTUNITY and TIPPING POINTS

NASA's Announcement of Collaboration Opportunity (ACO) and Utilizing Public-Private Partnerships to Advance Tipping Point Technologies solicitations fund research, development and demonstration of innovative technologies that fulfill NASA's needs for missions to the Moon, Mars, and other deep space destinations. These opportunities are focused on industry-developed space technologies that can advance the commercial space sector as well as benefit future NASA missions. For ACOs, NASA provides technical expertise and test facilities, as well as hardware and software to aid industry partners in maturing technologies. For Tipping Points, NASA provides funding that is usually augmented by in-kind contributions from the partner. Information on NASA's Tipping Points and ACOs is available as well as links to current solicitations.

To accelerate the maturation of commercially developed space technologies that are approaching a critical TRL "tipping point," SSDS partners with industry through public–private agreements. STMD's Tipping Point solicitations focus on technologies with strong commercial potential that require additional development to become viable capabilities for NASA and the broader space ecosystem. These technologies are necessary for long-term lunar and Martian exploration, including the Artemis campaign. The most recent Tipping Point selections managed within SSDS emphasize Efficient and Affordable Propulsion Systems with two of these propulsion-focused partnerships currently managed by SSDS [7].

CU Aerospace, LLC of Champaign, Illinois, NearSpace Launch, and the University of Illinois at Urbana-Champaign built and tested a 6-unit (U) CubeSat equipped with two different propulsion systems. These systems were developed with NASA SBIR funding and offer high-performance, low-cost, and safe pre-launch processing. The two propulsion systems are the Fiber-fed Pulsed Plasma Thruster (FPPT) [8] and Monofilament Vaporization Propulsion (MVP) [9]. The Fiber-fed Pulsed Plasma Thruster system uses an electric pulse to vaporize Teflon, using the resulting ions to deliver strong, efficient thrust while using very little fuel. The Monofilament Vaporization Propulsion system draws from extrusion 3D printer technology, heating and vaporizing Delrin, another common polymer material, to create continuous lower levels of thrust. Both systems are inherently safe because they do not use any pressurized tanks or toxic chemicals.

The 6U CubeSat, shown in Figure 2 (A) and (B), was launched on September 14, 2025, and was deployed from the International Space Station on December 2, 2025, see Figure 2 (C). Initial on-orbit checkout was successful. During the mission, these two propulsion systems and other key technologies that are important to the small spacecraft missions in LEO and deep space will be demonstrated.

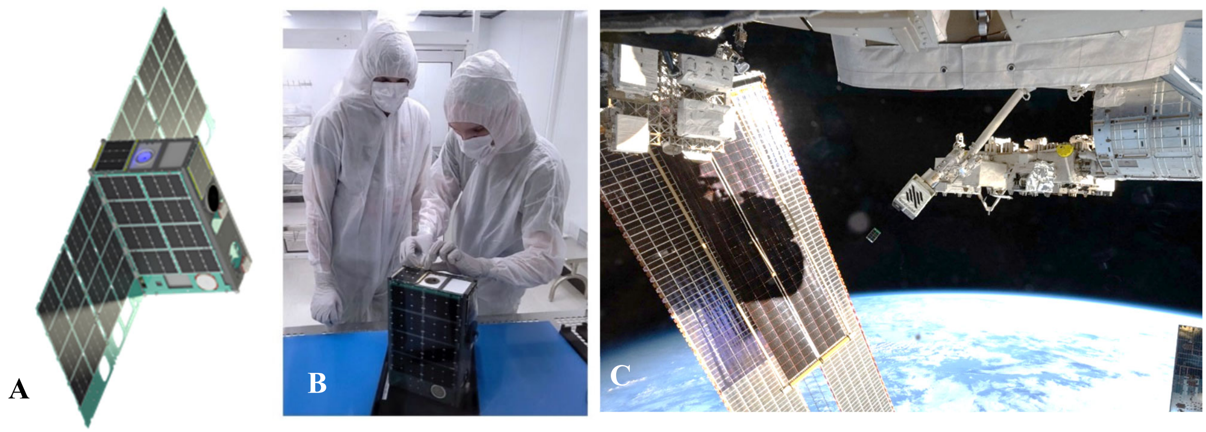

Figure 2. (A) CAD image of DUPLEX; (B) Final cleanroom inspection of DUPLEX spacecraft Credits: CU Aerospace, LLC, Credits: CU Aerospace, and (C) Deployment of DUPLEX from the International Space Station on December 2025. Credit: NASA.

2 FLIGHT PROJECTS and EXTENSION MISSIONS

The current flight projects SSDS manages demonstrate whether the demonstrated technologies function as expected, what their limitations are, and what developments are still needed for successful integration into future space missions. The following missions had launch timeframes between 2022-2025, and all are either currently functioning as planned or have concluded.

Selected as an ACO project in 2019 under the Advanced Communications, Navigation and Avionics topic, Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) serves as a pathfinder to help future space missions navigate more efficiently around the Moon and to Mars. The 12U, 25-kilogram spacecraft shown in Figure 3 (C) launched on June 28, 2022, and entered a unique elliptical lunar orbit, called a near-rectilinear halo orbit, in cislunar space [10] which was determined by the primary payload, CAPS. Since then, CAPSTONE has been characterizing the orbital dynamics in support of NASA's Artemis architecture. By May 2023, CAPSTONE successfully validated navigation technology that is going to be implemented on Lunar Gateway and captured its first lunar images near the Moon’s North Pole during a close approach to the Moon on May 3, 2023, see Figure 3 (B).

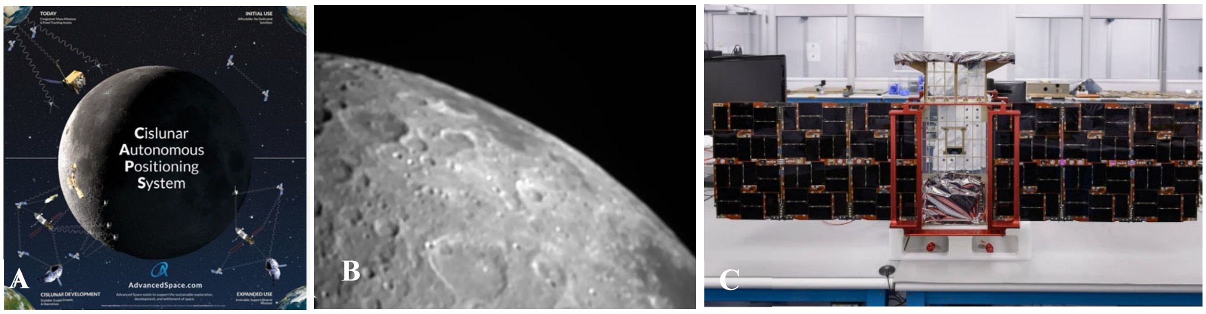

Figure 3 (A) Concept of operations for the Cislunar Autonomous Position System; (B) An image of the Moon captured May 3, 2023, by CAPSTONE while near its closest approach to the Moon's North Pole; and (C) CAPSTONE spacecraft. Credits: Advanced Space, LLC, all rights reserved.

The partnership between Advanced Space LLC of Westminster, Colorado, CAPSTONE's developer, and NASA Goddard Space Flight Center is advancing a navigation system designed for operations between Earth and the Moon. This system has the potential to supplement NASA's Deep Space Network and support future exploration missions. Now operating for more than 1,000 days in lunar orbit, CAPSTONE is the longest-running SSDS flight project and continues to reduce risks for Artemis. Follow-on activities include refinement and testing of the CAPS software, conduct mission analyses that support NASA's Artemis program are described below.

Launched on July 17, 2023 into a sun-synchronous orbit, the Starling mission continues to advance the readiness of technologies for cooperative groups of spacecraft, also known as distributed missions, clusters, or swarms. In the first 9 months on-orbit, Starling's primary mission successfully tested swarm maneuver planning and execution, communications networking, relative navigation, and autonomous coordination between four 6U CubeSats. Starling completed the objectives for the networking experiment by automatically establishing a network in space and demonstrating both point-to-point communication and data routing. Additionally, Starling was able to eliminate global navigation satellite system (GNSS) dependencies and exploit the Starling swarm to enhance the robustness and autonomy of optical navigation [11]. The technology that provided the distributed, autonomous, scalable navigation was matured through SSDS's USTP initiative in 2018 between Stanford University of Palo Alto, California and NASA Ames Research Center. The polar orbit provides complete global coverage over multiple orbits giving the Distributed Spacecraft Autonomy payload the best opportunity for the Starling swarm to detect atmospheric phenomenon and demonstrate the ability to autonomously react to data collected in the space environment.

The first extension mission, Starling 1.5, tested technologies for automated space traffic coordination using the Starlink constellation. In collaboration with SpaceX, an automated system was designed to warn operators about possible conjunctions, i.e., when two objects exceed the tolerance for a close

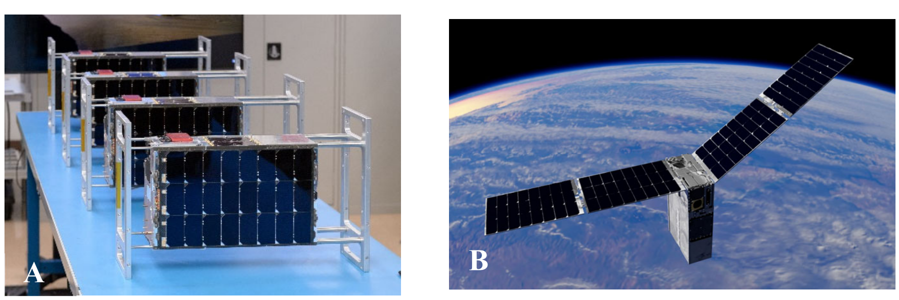

Figure 4. (A) All four Starling spacecraft in the lab after integration, and (B) artistic representation of a Starling spacecraft on-orbit. Credits: NASA.

approach along their orbital paths. Satellite operators were able to submit trajectories and receive conjunction data quickly, then accept responsibility to maneuver away from a potential risk. In this test, Starling accepted maneuvering responsibility, then autonomously planned and executed the maneuver to resolve a conjunction simulation test with a Starlink satellite. The second extension to Starling, called Starling 1.5+, demonstrated Resident Space Object detection and tracking using optical sensors. This technology using commercial off-the-shelf (COTS) star-trackers could enable greater situational awareness and early warning to spacecraft operators to prevent spacecraft collisions [11].

Another pathfinder mission SSDS supports is the development and characterization of a new circular satellite platform called DiskSat that launched December 18, 2025. Developed by The Aerospace Corporation of El Segundo, California, and funded by SSDS, DiskSat is an alternative approach to the standard canisterized CubeSat platform. This first demonstration deployed four plate-shaped spacecraft that are 1 meter in diameter and 2.5 centimeters thick from a unique dispenser, see Figure 5. DiskSat's large surface area can provide high power, can support a large aperture needed for future missions, standardized launch interface, and low-cost characteristic of CubeSats [12][13]. The launch dispenser worked as designed, communications with ground network were successful and the team is currently in the checkout and initialization phase.

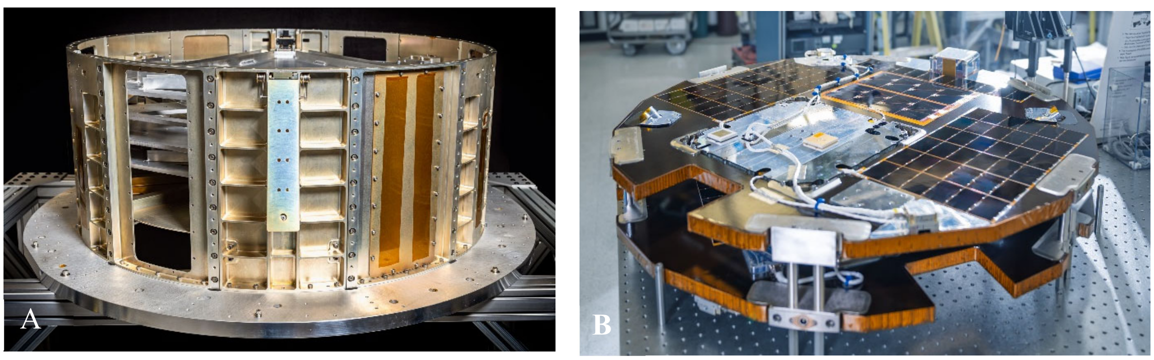

Figure 5: (A) Disksat dispenser, and (B) two DiskSat spacecraft before integration
Credits: The Aerospace Corporation.

The Green Propulsion Dual Mode (GPDM) project is a 6U CubeSat demonstrating the propulsion capability of a dual mode (chemical and electrospray) propulsion system using a low toxicity or "green" monopropellant. Dual mode propulsion is highly desired for the capability to perform high impulse (chemical) and high efficiency (electrospray) space translation maneuvers. The Advanced Spacecraft Energetic Non-Toxic (ASCENT)-based propellant is a proven monopropellant in chemical thrusters [14] and its ionic properties make it a viable candidate for electrospray propulsion. With this propellant, GPDM combines both chemical and electrospray modes into one system to demonstrate low-thrust trajectory maneuvers and precision attitude control in space. Numerous collaborators associated with this project, spanning across academia, industry, and NASA, and there exists high interest in the small spacecraft community for this capability to be demonstrated. GPDM is slated for launch mid-end 2026. Figure 6 (A) is of a GPDM model at the SmallSat Conference in Logan, Utah in 2024.

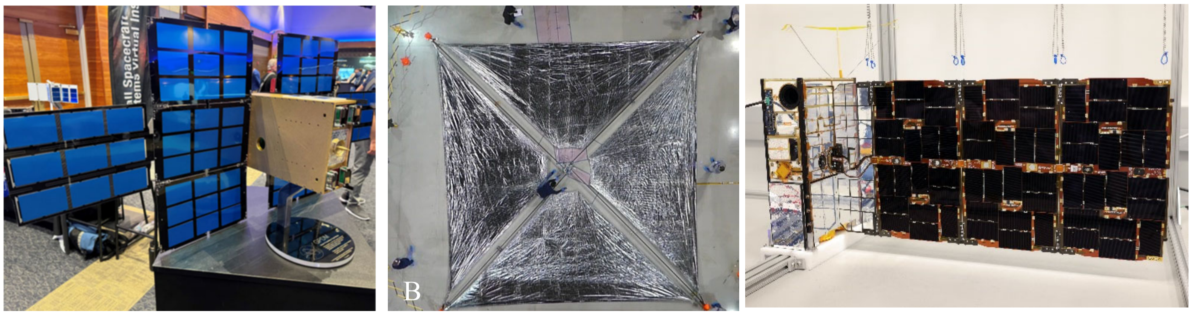

Figure 6. (A) GPDM model and (B) ACS3 unfurled solar sail. Credits: NASA. (C) PTD-R spacecraft. Credit: Terran Orbital Corporation.

The Advanced Composite Solar Sail System (ACS3) was a technology demonstration of a 12U spacecraft that launched April 23, 2024, and deployed a solar sail approximately 84 m^2. ACS3 used novel lightweight booms made of composite materials. The four booms span the diagonals of a square and unspool to reach seven meters in length, pulling with it a solar sail that when fully deployed is a square-shaped sail measuring approximately nine meters per side. The composite booms are made from a flexible polymer material reinforced with carbon fiber, known for its robustness and resistance to bending and warping due to changes in temperature. Figure 6 (B) shows ACS3's sail unfurled in the laboratory.

The Pathfinder Technology Demonstrator (PTD) mission series is comprised of four missions to demonstrate and advance technologies in the following areas: propulsion to advance the capability to maneuver small science platforms and send small spacecraft to deep space; high-bandwidth laser communications to increase the amount of data that can be transmitted from the spacecraft to the ground; power systems with increased capacity necessary for missions in deep space, and imaging technology that may be used in a wide range of applications. The mission series uses a commercial Terran Orbital 6U spacecraft bus and avionics platform common to all PTD missions. The PTD mission series is an example of industry-inspired small spacecraft innovation that offers affordable, rapid turn-around opportunities to demonstrate technologies needed to increase the capability and utility of small spacecraft.

Table 2: Completed PTD missions

	Launched	**Payload**	**Outcome**	**Collaborators**
PTD-1	Jan 24, 2021	Hydros-C propulsion system	Baseline data for Hydros propulsion on PUNCH.	Tethers Unlimited
PTD-3	May 25, 2022	High-bandwidth laser communications, TeraByte InfraRed Delivery (TBIRD)	Achieved 200 gigabit per second (Gbps) throughput on a space-to-ground optical link between a satellite in orbit and Earth.	Massachusetts Institute of Technology Lincoln Laboratory and NASA Goddard Space Flight Center
PTD-4	August 16, 2024	Deployable solar array with an integrated antenna (LISA-T)	Experiment did not deploy as planned; data gathered.	NASA Marshall Space Flight Center
PTD-R	August 16, 2024	Ultraviolet and short-wave infrared optical sensing (Deep Purple)	Mission completed in December 2025 and all mission objectives were met.	Lawrence Livermore National Laboratory, Terran Orbital, and NASA Launch Services Program

On August 16, 2024, the third and fourth PTD technology demonstrations, PTD-4 and PTD-R respectively, launched. PTD-R, pictured in Figure 6 (C) demonstrated simultaneous monolithic ultraviolet (UV) and short wavelength infrared (SWIR) optical sensing from space for the first time in a CubeSat form factor. The combined dual telescope payload, called 'Deep Purple', was built by Lawrence Livermore National Laboratory of Livermore, California and successfully provided imagery of ground objects, resident space objects and celestial objects. Figure 7 is an image of the Moon taken by Deep Purple using ultraviolet imaging. The intention of PTD-4 was to demonstrate a high-power, low-volume deployable solar array with an integrated antenna called the Lightweight Integrated Solar Array and anTenna, or LISA-T, developed by NASA Marshall Spaceflight Center. While the team was unable to overcome the challenges to fully extend the payload's central boom, some power generation and communication operations were conducted, and helpful lessons learned on deployment challenges were captured.

Figure 7: The Moon in UV and SWIR, with a mapping of UV/SWIR to RGB as described in the text. Credit: Lawrence Livermore National Laboratory.

Another PTD mission was PTD-3 that completed its mission and set a Guiness book of world records for fastest satellite data downlink. This mission demonstrated a CubeSat less than 20 kilograms can deliver throughput up to 500 gigabits, which is on par with high-capacity geostationary communications satellites [15]. Lastly, the Water-based propellant Hydros-C propulsion system demonstrated on PTD-1 was the base line for a larger Hydros propulsion system on NASA's Polarimeter to Unify the Corona and Heliosphere (PUNCH) mission (four ~40 kg spacecraft) that launched March 11, 2025 [16].

3 FUTURE WORK

All ongoing SSDS projects that were awarded in 2025 are maturing technologies directly in alignment with NASA's Civil Space Technology Shortfalls. Moving forward, SSDS is focused on supporting the development of space situational awareness and space traffic management objectives performed by small spacecraft.

In 2024, SSDS awarded SBIR Phase III funding to Starfish Space of Seattle, Washington to develop Small Spacecraft Propulsion and Inspection Capability (SSPICY), a demonstration mission with electric propulsion and other advanced capabilities to perform rendezvous, proximity operations, and inspection activities. Additionally, SSPICY will characterize up to four, US-origin resident space objects in LEO. In-space inspection helps to characterize the physical state of a satellite, gather data on what may leave spacecraft stranded, and improve the understanding of fragmentations and collisions, a difficult but critical factor in a sustainable space operating environment [17]. These activities are foundational for critical capabilities to achieve long-term space presence, and SSPICY is designed to mature technologies needed for U.S. commercial capabilities for satellite servicing and logistics. Starfish Space has accomplished successful Mission Concept and Mission Design Reviews and is currently integrating the spacecraft. The current launch schedule is at the end of 2026.

CAPSTONE 2 is a follow-on mission that will use two spacecraft to leverage the findings from its predecessor mission to further characterize the halo orbit in cislunar space and demonstrate advanced technologies as an Artemis risk reduction mission. A CAPSTONE-02 spacecraft will collect thermal and radiation data to further characterize the stability of the halo orbit and demonstrate relative navigation technologies—including one-way space-to-ground ranging, space-to-space crosslink, and optical visual navigation— to decrease reliance on traditional space-to-ground radiometric data. Other objectives include rendezvous and proximity operations (RPO) with both CAPSTONE 2 spacecraft, where one will act as the “chaser” vehicle performing RPO maneuvers and the “target” vehicle maintains its position in the cislunar halo orbit. CAPSTONE-02 is anticipated to launch in 2028.

The PY12 system offers a novel approach to satellite-based positioning, developed by EarthTraq of San Carlos, CA. It uses a time-difference-of-arrival based localization technique, independent of Global Positioning System (GPS). Clusters of four satellites, launched in three separate clusters, will receive RF signals and use triangulation to determine the position of the emitter. The spacecraft can track ultra-low-SWaP-C (size, weight, power, and cost) devices on the ground, provide a PNT service like GPS by providing position information direct-to-device, or precisely determine the orbit and velocity of other space objects. The PY12 spacecraft are built from COTS hardware, enabling a quick and affordable deployment to LEO. A cluster of four or more satellites enables an ad-hoc private Positioning Navigation and Timing (PNT) network, and the system scales to the deployments of hundreds of satellites, making it nearly resilient and robust against outages. Long-term, SSDS is interested in both terrestrial and deep space applications. The PY12 swarm mission concept includes 12 clustered EarthTraq spacecraft that also host neuromorphic processors, envisioned as an on-orbit testbed for AI, edge computing, enhanced DSA, and PNT technologies. An SBIR phase I has been awarded to EarthTraq to develop the capability to host AI and edge computing capabilities onboard the PY12 spacecraft.

Managed by DARPA, the Lunar Assay via Small Satellite Orbiter (LASSO) project aims to develop and demonstrate technologies that support space situational awareness. Using an autonomous satellite navigation developed for stressing orbital conditions and increasing satellite maneuverability through continuous dynamic repositioning based on changing conditions, results in a robust and agile spacecraft that can navigate through crowed environments. Additionally, the LASSO project is creating a proven reserve model for resources relevant to in-situ resource utilization (ISRU) on the Moon. The LASSO project 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 kilometres [18]. With a current launch timeframe in early 2029, NASA’s contribution to LASSO will be subject matter expertise, launch, and operations support.

4 CONCLUSION

NASA organizations responsible for technology, science, exploration, and space operations periodically identify a wide range of potential applications for small spacecraft to support a sustained presence in cislunar and deep space environments. These applications depend on closing key technological gaps in areas like RPO, advanced in-space propulsion, and PNT—capabilities that enable small spacecraft to perform functions integral to NASA’s Moon-to-Mars architecture, the Artemis and Gateway programs, and Orbital Debris and ISAM Implementation Plans. Emphasis on small spacecraft stems from their significantly reduced cost compared to larger conventional spacecraft, faster development timelines, and greater responsiveness. In some cases, their small size and ability to be deployed in relatively large numbers open mission opportunities not feasible with larger satellites.

NASA’s SSDS program within STMD has been a key driver of these small spacecraft advancements and recognizes their vast potential in supporting NASA’s lunar and deep space exploration goals. SSDS provides a reliable pathway for maturing and demonstrating small spacecraft capabilities for future lunar and deep space missions. As platforms for Earth observation, heliophysics, and deep space applications, small spacecraft technology foster partnerships across organizations with shared interests and collaborative objectives. All SSDS projects contribute collectively toward this overarching mission.

SSDS investments have led to the demonstration of networked constellations of small spacecraft that can operate in a synchronized manner without resources from the ground; demonstrated capabilities for the purpose of future space debris remediation; development of a highly desired dual-mode propulsion system; deployment of a modern disk-shaped spacecraft constellation; and served as demonstration platforms for advanced small spacecraft capability on NASA missions. Future SSDS efforts focus on narrowing the technological gap for space situational awareness and space traffic monitoring, such as an automated system for ensuring that multiple sets of spacecraft can operate safely while in relative proximity.

The anticipated applications of small spacecraft are wide-ranging. NASA's early and sustained investment in small-spacecraft technologies enables highly capable missions equipped with scientific instruments and supports the future development of deep-space infrastructure. These spacecraft could ultimately help capture and relay greater volumes of scientific data from LEO and, later, from cislunar and planetary space.

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