



Space Technology on ISS Update

NAC Technology, Innovation and Engineering Committee Meeting

Niki Werkheiser, NASA STMD, Game Changing Development Program Executive | March 2020

STMD Enabling Technology Innovation on ISS

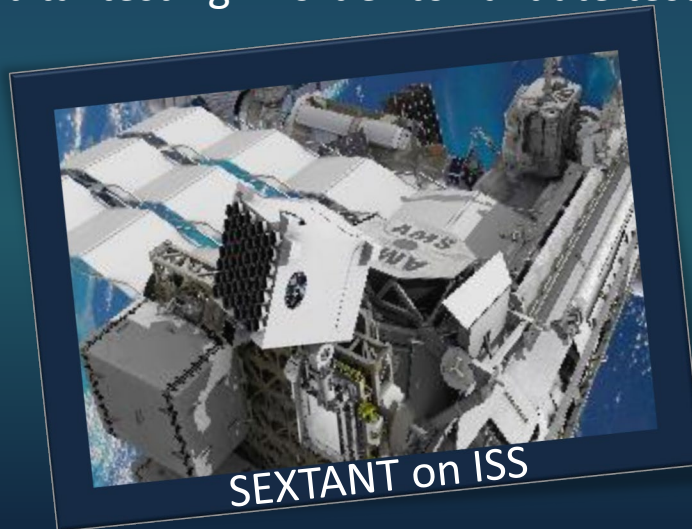


The International Space Station enables critical technology development necessary for testing in a realistic space & operational environment

- ❖ ISS serves as a key interface to space and operational environment testing of specific technology development experiments
 - Reduces the risk associated with requiring fully operational system to test a single experiment
 - Provides critical capability for human and robotic space exploration beyond Low Earth Orbit (LEO)
- ❖ Key technologies requiring these environments include fluid transfer, autonomy, in-space manufacturing and assembly, biologicals, materials, food production, and ECLSS
- ❖ Note: Flight Opportunities funds sub-orbital testing in order to validate testing and/or hardware prior to ISS flight.

Space Environment Testing

- Microgravity
- Thermal
- Vacuum
- LEO radiation
- Solar Heating



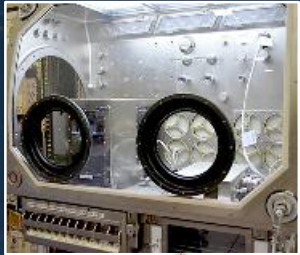
Operational Environment Testing:

- EVA
- Robotics
- Shirt Sleeve
- ISS Operational Systems
- Biological

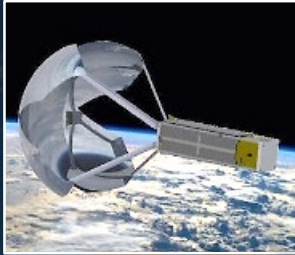
STMD Technologies on ISS



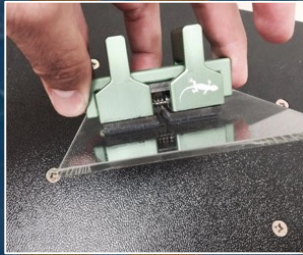
3D Printing in Zero Gravity Technology



ISARA & TechEdSat 6 CubeSats



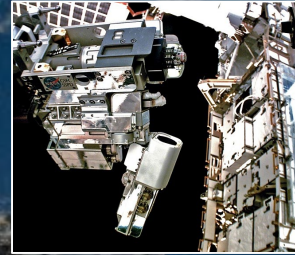
Gecko Gripper



Zero Boil-Off Tank (ZBoT)



Robotic Refueling Mission 3 (RRM3)



Radio Frequency Mass Gauge



Astrobee



Fablab



2014

2015

2016

2017

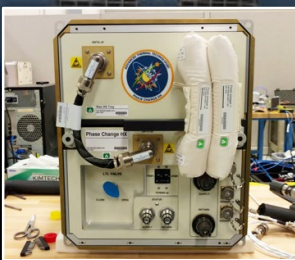
2018

2019

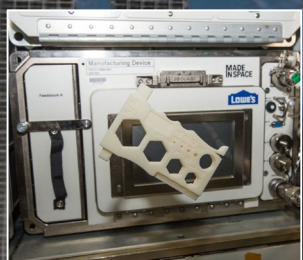
2020+



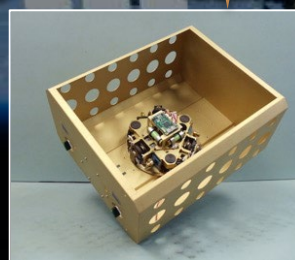
SPHERES-Slosh



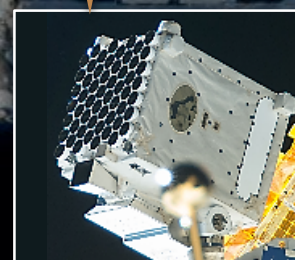
Phase Change Material Heat Exchanger



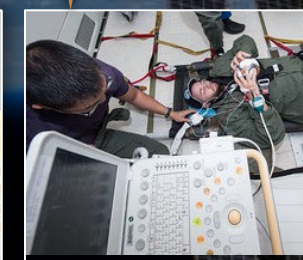
Additive Manufacturing Facility (AMF)



Vibration Isolation Platform



Station Explorer For X-ray Timing and Navigation Technology (SEXTANT)



Effects of Microgravity on Intracranial Pressure



Refabricator



Synthetic Biology

STMD Technologies on ISS



3D Printing in Zero Gravity Technology Demonstration – MSFC

- First 3D printer to successfully operate in the microgravity environment.
- Proof-of-concept test of the properties of fused filament fabrication additive manufacturing in the microgravity environment of the ISS; Performed via SBIR Ph. III with Made in Space, Inc.

SPHERES Slosh – ARC

- A demonstration to understand the fluid slosh in a microgravity environment.
- This investigation aimed to improve our understanding of how propellants within rockets behave in order to increase the safety and efficiency of future engine designs.

Phase Change Material Heat Exchanger (PCM HX) – JSC

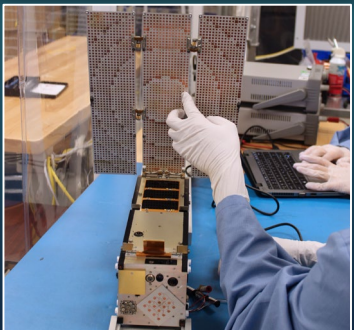
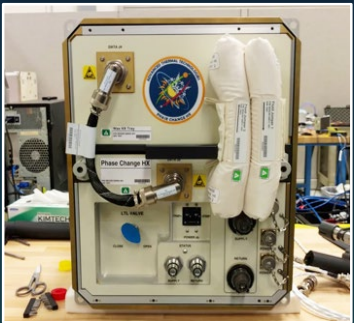
- A heat exchanger that stores energy by thawing wax using hot coolant. That energy is later rejected by the spacecraft's radiator, then refreezes the wax and prepares it for the next spike of heat load.
- Being integrated into Orion for NASA's Artemis II mission

ISARA CubeSat – JPL and the Aerospace Corporation

- Demonstrated that a small 3U-class satellite can achieve a very high 100 Mbps data rate using a small, low-cost, ground station
- First time a reflectarray antenna successfully completed a technology demonstration in space.

TechEdSat-6 CubeSat – ARC

- Demonstrated the first, successfully targeted de-orbit and re-entry maneuver using only drag by a nanosatellite; Built by San Jose State University students in partnership with AAC Microtec.
- This technology will ensure that satellites in LEO will disintegrate upon entering the Earth's atmosphere, which will decrease the amount of orbital debris in space.



STMD Technologies on ISS



Gecko Grippers – JPL

- Space-based hand tool can adhere objects to virtually any surface and features sticking power that is not affected by temperature, pressure, or radiation.
- Technology was licensed by OnRobot for terrestrial manufacturing applications.



Additive Manufacturing Facility (AMF) – Made in Space, Inc.

- AMF is a commercial manufacturing platform designed to print 3D parts in microgravity.
- It has produced over 115 tools, assets, and parts on ISS for NASA, Industry, Academia, and International Partners.



Vibration Isolation Platform – Controlled Dynamics

- Payload mounting interface that allows a payload to be undisturbed and float freely in the sway space of the platform.
- SBIR selected for NASA's Deep Space Optical Communications (DSOC) platform (scheduled to launch in 2022 aboard NASA's Psyche asteroid mission).

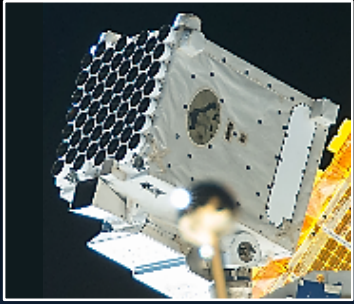


Zero Boil-Off Tank (ZBOT) – GRC

- Space Life & Physical Sciences Research and Applications Gravitational Research Team demonstrated the use a volatile fluid that boils at 86 F, to simulate a cryogen, in order to test active heat removal and forced jet mixing as alternative means for controlling tank pressure for volatile fluids.
- NASA STMD using the results from the investigation to improve tank design for long-term cryogenic liquid storage and pressure control.

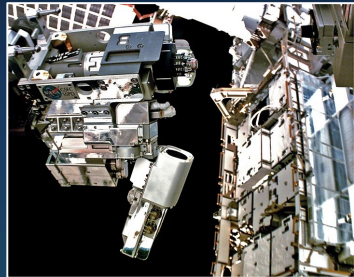


STMD Technologies on ISS



Station Explorer for X-ray Timing and Navigation Tech (SEXTANT) – GSFC

- Demonstrated a GPS-like absolute position determination capability by observing millisecond pulsars, which will enable autonomous navigation throughout the solar system and beyond.
- Used 56 X-ray telescopes, detectors, and other advanced technologies to detect X-ray photons from these powerful, flashing beams of light, estimating their arrival times at the spacecraft.



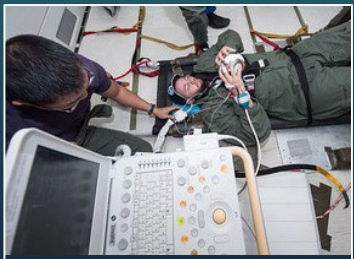
Robotic Refueling Mission 3 (RRM3) – GSFC

- The objective was to demonstrate the first transfer and long-term storage of liquid methane in microgravity. However, the demo experienced issues powering up its cryogen coolers. As a result, the temperature of the liquid began to rise and the liquid methane was turned into a gas was safely vented from the payload. While RRM3 can no longer perform a cryogenic fuel transfer, its four months on station taught NASA about the technology needed to store and transfer cryogenic fuel in space. The mission will carry out other planned operations with servicing and inspection tools.



Radio Frequency Mass Gauge (RFMG) – GRC

- In conjunction with RRM3, the objective is to determine the amount of cryogenic propellant in a tank while in low gravity or where slosh is an issue. While RFMG continues to acquire monthly data on Robotic Refueling Mission-3 (RRM-3) to demonstrate sensor survivability in space conditions, it is unable to meet full mission objectives since there is no cryogenic fuel in the tank after venting.



Effects of Microgravity on Intracranial Pressure (ICP) – University of Texas

- Measured ICP in volunteers with a permanent port in their head for cancer treatment.
- Has informed long-term investigations conducted on the ISS to better protect astronauts' visual health.

STMD Technologies on ISS



Astrobee – ARC

- The robotic helpers, equipped with a suite of cameras and a robotic arm, free up valuable time for astronauts aboard the ISS by performing routine tasks like maintenance and tracking inventory.
- Free-flying robot system provides a guest science research platform
- 3 cube robot system: Honey, Bumble and Queen



Refabricator – MSFC

- Refabricator is the first integrated 3D printer and recycler in space. However it experienced a failure with the novel recycler filament extrusion bonding system in 2019. Additional bonder testing is being performed prior to decommissioning. The Refabricator was able to successfully manufacture a tensile specimen on the ISS in Feb. 2020 which will be brought back soon for further testing and evaluation aboard SpaceX-20 in April 2020



BioNutrients/Synthetic Biology – ARC

- BioNutrients demonstrates a technology that enables on-demand production of human nutrients during long-duration space missions.
- The process uses engineered microbes to generate carotenoids to supplement potential vitamin losses from food that is stored for very long periods.



Multi-material Fabrication Laboratory (FabLab) – MSFC

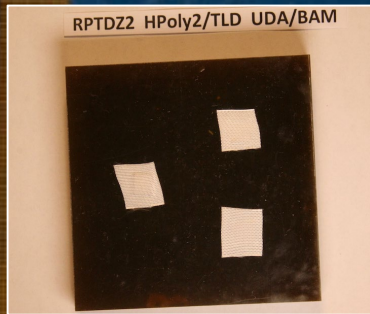
- Space-based, multi-material, on-demand fabrication capability to develop and demonstrate manufacturing with metals and electronics on long-duration missions. .
- Implemented through a NextSTEP-2 Broad Agency Announcement with industry with ISS flight planned for 2021-22.

Materials International Space Station Experiments (MISSE)

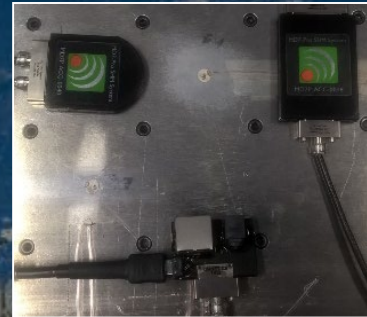


Since MISSE-9, STMD has selected 38 experiments for on orbit exposure. Of these, 26 have flown to ISS

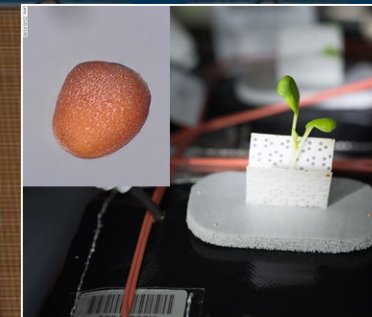
MISSE-10 Radiation Protection Technologies Demonstration



MISSE-12 On Orbit Structural Health Monitoring



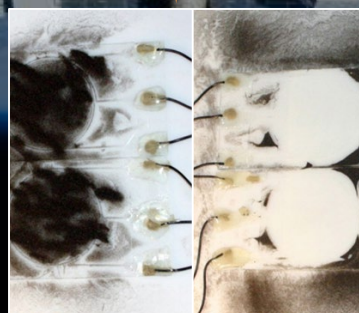
MISSE-14 MISSE-SEED



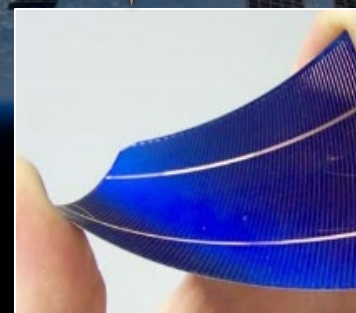
2016 2017 2018 2019 2020 2021 2022



MISSE-9 Space Environmental Effects on Additively Manufactured Materials



MISSE-11 Electrodynamic Dust Shield (EDS) Experiment



MISSE-13 Next Generation Solar Cell Qualification

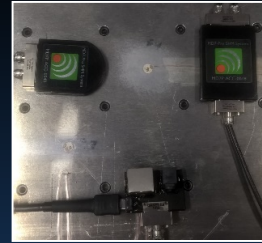
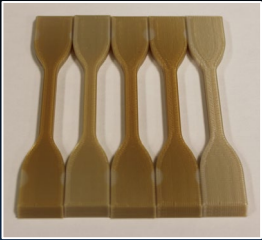
Release of MISSE-15 call is tentatively planned for April 2020

Materials International Space Station Experiments (MISSE)



MISSE-9

- Space Environmental Effects on Additively Manufactured Materials
- Polymeric Materials and Composites Experiment
- Ultraviolet Radiation Sensor
- Ram Tantalum Carbon Fiber Laminate
- *Zenith* Tantalum Carbon Fiber Laminate
- Charge Dissipation Film Environment Test
- STF Space Suit Layup (Passive)

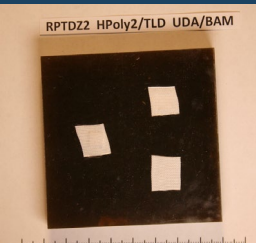


MISSE-12

- On-orbit Structural Health Monitoring
- Spectra Fiber Reinforced Radiation Shielding Structural Composites
- Space Environment Effect on Bio-Inspired Radiation-Resistant Polymer Composites
- Space Hybrid Photonic Integrated Circuits
- Electro-optic polymer films for tunable diffractive telescope
- Radiation Shielding Properties of Novel & Baseline Materials

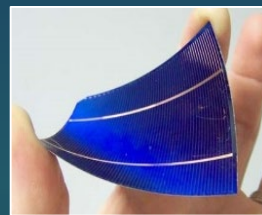
MISSE-10

- Radiation Protection Technologies Demonstration
- Developed under the NASA SBIR; Polymers and Composites Experiment-2 (PCE-2)
- Innovative Coatings Experiment (ICE)



MISSE-13

- Next Generation Solar Cell Qualification
- CORIN® XLS/PTFE, Evaluation of Multifunctional Radiation Shielding Material Against Long Duration Space Environment
- Evaluation of New Thermal Protection Systems for Sample Return Missions
- Polymers and Composites Experiment-4 (PCE-4)
- Shear-Thickening Fluid (STF)-Treated Space Suit Layups
- Space Evaluation of Highly-Absorptive Coated Wafers



MISSE-11

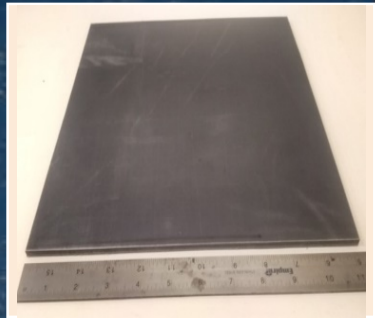
- Electrodynamic Dust Shield
- 3D-MAT On-Orbit Exposure
- Space Qualification Studies of Quad Photodiode
- Focal Plane Array and Solar Paint
- Risk Reduction for Mars Ice Home Materials
- Materials Experiment for Long Duration Exploration



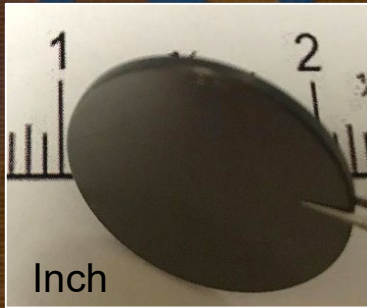


Planned ISS Demonstrations

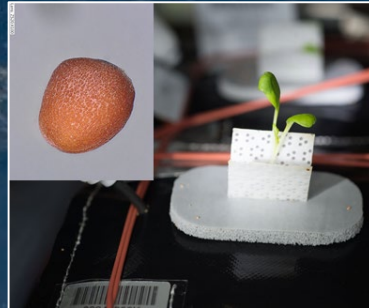
MISSE-14 Long Duration Space Environment – Utilization of MISSE



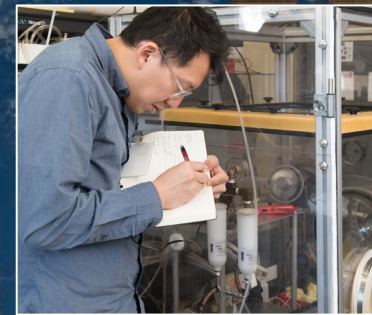
MISSE-14 Tunable MWIR filters based on exotic PCM



MISSE-14 Effect of Long Duration Space Exposure on Seeds



NASA Earth, Air and Space Prize – Aerosol Sensor



2020

2021

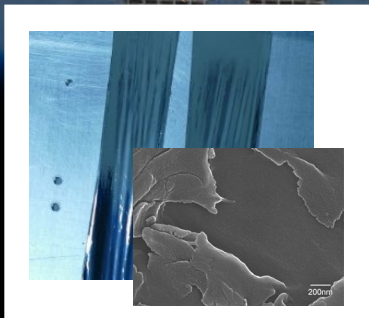
2022

2023

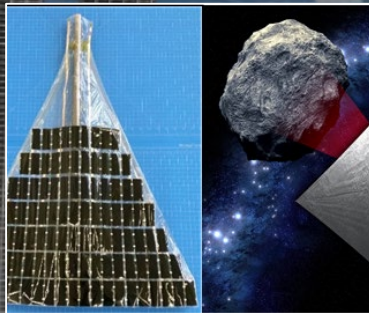
2024

2025

2026-



MISSE- 14 Damage assessment on new sail/deorbit materials of ACS3 LEO demonstrator



Space Durability Testing of CORIN® XLS/PTFE Manufactured with a Continuous Process

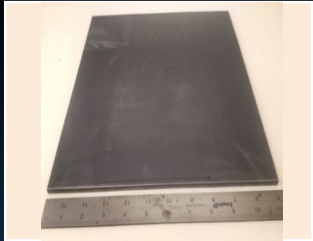


3D Habitat Centennial Challenge - Microgravity Investigation of Cement Solidification



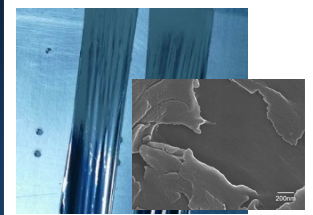
Vascular Tissue Centennial Challenge - Human vascularized organ tissue

MISSE- 14 Planned for ISS



Evaluation of Multifunctional Radiation Shielding Material Against Long Duration Space Environment – LaRC

- Develop a multifunctional composite material as a part of a spacecraft or habitats to provide shielding effectiveness against Galactic Cosmic Rays and secondary particles, enhanced structural integrity, and durability against overall space environment



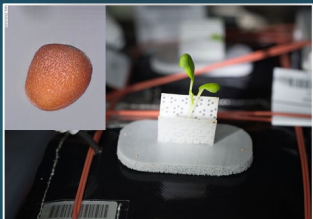
Space environmental damage assessment on new sail/deorbit materials of Advanced Composite Solar Sail System (ACS3) 6U CubeSat low Earth orbit (LEO) Demonstrator – LaRC, National Institute of Aerospace (NIA)

- Development of space environment resistant metallized polymer membrane (thermal blanket, MLI) for Lunar Gateway element modules and space radiation resistant coating and fabric for habitat and astronaut suits.



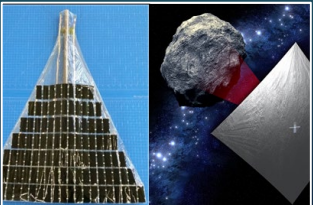
Tunable mid-wave infrared (MWIR) filters based on exotic phase-change materials (PCM) – LaRC, NIA

- Effort to provide a new active IR filter technology that can be utilized for remote sensing on-board the Artemis command module.



MISSE–SEED: Effect of Long Duration Space Exposure on Crop Seeds – KSC

- Provide critical information for identifying seed storage requirements for Artemis tests and enabling deep space fresh crop production.



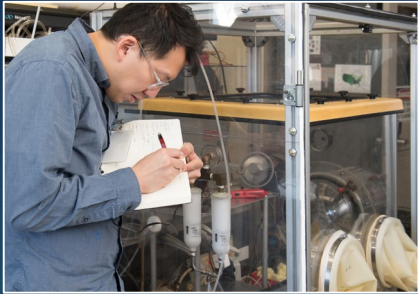
Space Durability Testing of CORIN® XLS/PTFE Manufactured with a Continuous Process – LaRC and NeXolve

- To replace Kapton® film (used during the Apollo era) with more durable film for multilayer insulation blankets, flexible solar cell array substrates, flexible antenna array substrates, etc., on Artemis missions

Prizes and Challenges Planned for ISS



- Cement Solidification Experiment**— MSFC, Pennsylvania State University
- 3DPH Challenge Runner,-up, Pennsylvania State University, developed an experiment to investigate cement solidification in microgravity. Over 100 mixed samples returned informing the development of a specialized, small-scale 3D-printer slated for an ISS demonstration.



- NASA Earth, Air and Space Prize** – Applied Particles Technology, LLC
- Teams were asked to develop robust, durable, inexpensive, efficient, lightweight, and easy-to-use sensors to detect tiny airborne particles, known as aerosols, and monitor air quality for space and Earth environments; 20 submissions, 3 finalists selected were awarded \$50,000 to develop prototype.
 - ISS Demonstration is being planned



- Vascular Tissue Challenge** – Deadline September 2020
- Teams were asked to create thick, metabolically-functional human vascularized organ tissue in a controlled laboratory environment while maintaining metabolic functionality throughout a 30-day survival period.
 - Teams must also submit a Spaceflight Experiment Concept that details how they would further advance an aspect of their tissue vascularization research on the ISS.
 - In cooperation with STMD, CASIS will be flying the ISS demonstration flight.

What's next....



- The ISS is a demonstrated platform for technology demonstrations which STMD leverages to test a variety of technologies, systems and materials that informs future exploration missions.
- SMTD will continue to look for opportunities to utilize the ISS as a test bed for future technologies, including cryogenic fluid management, in-space manufacturing, and a multitude of other capabilities.



Technology Drives Exploration