

The background of the slide is a composite image of space exploration. On the left, a large, detailed Earth's moon is shown in a dark blue-grey color. Above it and to the left is a smaller, reddish-orange sphere, likely Mars. A small spacecraft is depicted in the distance, moving from left to right and leaving a bright, glowing blue trail behind it. The sky is a deep, dark blue filled with numerous white stars. In the bottom right corner, there is a black silhouette of a person's head and shoulders, facing left. The bottom of the slide shows a dark, silhouetted horizon line with some lighter, hazy clouds just above it.

EXPLORESpace TECH
TECHNOLOGY DRIVES EXPLORATION

NASA Avionics Technology Shortfalls

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NASA STMD Technology Shortfalls



- NASA's Space Technology Mission Directorate (STMD) leads the development, demonstration, and infusion of transformational technologies that enhance NASA's efforts to explore the unknown in space, benefit life on Earth, and solve critical stakeholder needs. STMD is refining its strategy for prioritizing technology investments, with the goal of evolving into a stronger and more resilient national tech base for civil space.
- In spring 2024, STMD kicked off an annual process for gathering feedback from the American aerospace community about their most pressing shortfalls, or identified areas requiring further development to meet future exploration, science, and other mission needs. The shortfall feedback will help produce an integrated list of prioritized civil space shortfalls, which will help guide STMD projects and investments.
- Through this prioritization effort, STMD will improve its ability to advance U.S. competitiveness, drive economic growth, and foster diverse talent to solve our nation's toughest technology challenges.

Idea Generation

OGAs

Industry

Academia

EOP

Hill

Mission Directorates

Centers

Industry

Academia

EOP

Hill

OGAs

Prioritized Shortfalls (Gaps)

6/26/2024



Mission Directorates



Centers

Investments/Projects

[illegible]

National Tech Base Priorities

Publicly-transparent, rigorously-developed process by which we establish our priorities based on comprehensive prioritized needs of our stakeholders



Roadmaps



Initial Tech Status

Capability Goals

Shortfalls At a Glance



- There are 193 shortfalls in total addressing 21 technology areas

Advanced Habitation Systems	Advanced Manufacturing	Advanced Materials and Structures
Autonomous Systems & Robotics	Avionics	Communication & Navigation
Cryogenic Fluid Management	Dust Mitigation	Entry Descent and Landing
Excavation Construction and Outfitting	ISAM & RPOC	In Situ Resource Utilization (ISRU)
Orbital Debris	Power	Propulsion (Non-Nuclear)
Propulsion (Nuclear)	Sensors & Instruments	Small Spacecraft
Surface Systems	Thermal	Miscellaneous

ISAM = In-Space Servicing, Assembly, and Manufacturing

RPOC = Rendezvous, Proximity Operations, and Capture



ID 709	Shortfall Title Nuclear Electric Propulsion for Human Exploration
Description Integrated Multi-MW HALEU NEP system employing a fission reactor-based heat source combined with a thermal-to-electric energy conversion scheme to drive an electric propulsion system. Supports NEP/Chem reference mission by providing efficient cruise ΔV for crewed/cargo Mars transportation system. CTE 1: Reactor and Coolant Subsystem (RXS) CTE 2: Power Conversion Subsystem (PCS) CTE 3: Power Management & Distribution (PMAD) Subsystem CTE 4: Electric Propulsion Subsystem (EPS) CTE 5: Primary Heat Rejection Subsystem (PHRS) Related Shortfalls <u>PROP-TBD: Reactor and Coolant Subsystem (RXS)</u> <u>PROP-TBD: Power Conversion Subsystem (PCS)</u> <u>PROP-TBD: Power Management & Distribution (PMAD) Subsystem</u> <u>PROP-TBD: Electric Propulsion Subsystem (EPS)</u> <u>PROP-TBD: Primary Heat Rejection Subsystem (PHRS) (High temperature heat rejection for nuclear applications)</u> <u>PROP-695: Multi-MW NEP</u> <u>PROP-372: In-space Xenon Transfer Technologies</u> Metrics - Power - Reactor Temperature - Radiator Temperature - Radiator Area - PMAD Efficiency - Total System Alpha	

Avionics Technology Shortfalls



High Performance
Onboard Computing to
Enable Increasingly
Complex Operations

Distributed Avionics to
Enable Improved
Performance and SWaP
Efficiency

Crew Audio/Visual
Interfaces for Long
Duration Missions
Beyond LEO

Advanced Data
Acquisition Systems for
Diverse Applications

Extreme Environment
Avionics

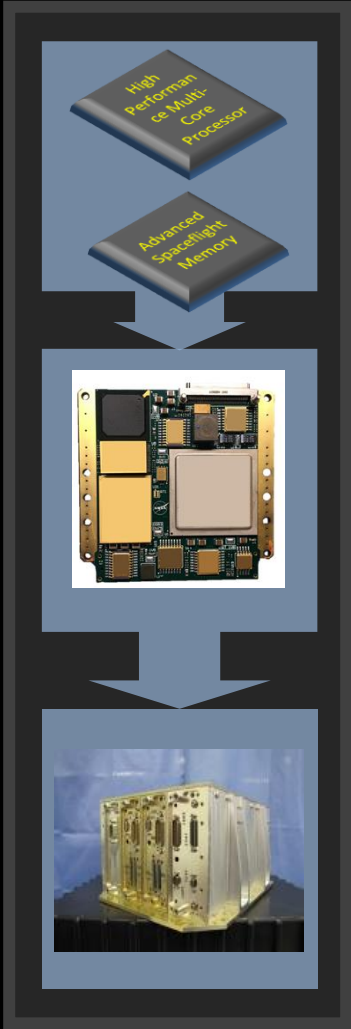
Next Generation
Avionics Architectures

Foundational
Technologies for Future
Avionics Devices and
Systems

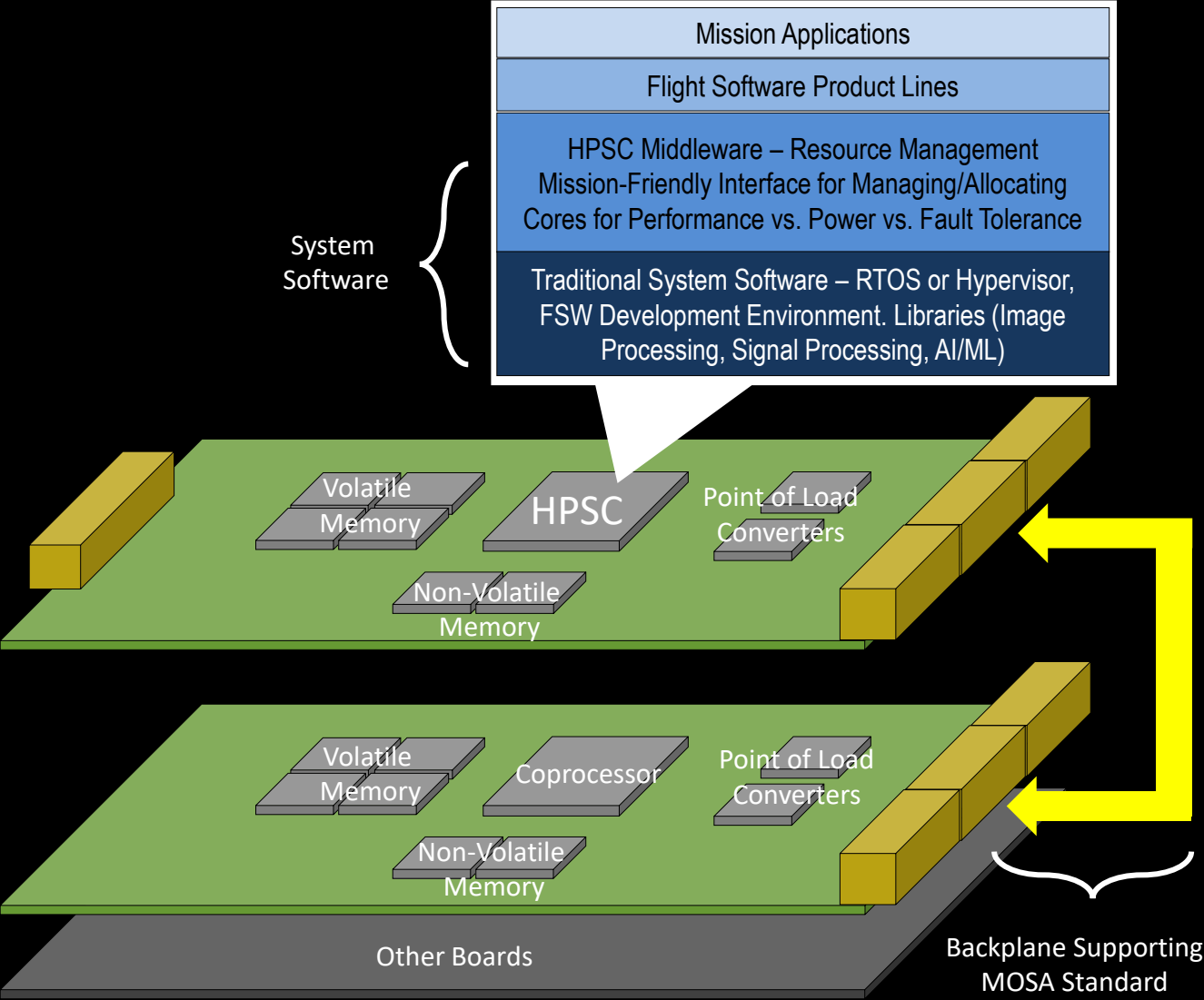
High Performance Onboard Computing to Enable Increasingly Complex Operations



Description	Underlying Shortfalls
- Advanced radiation tolerant onboard computing systems are needed both in space and on surfaces to offer increased processing performance, input/output (I/O) bandwidth, and data storage - Flexibility is also needed to adapt power, fault tolerance, processing bandwidth, and I/O bandwidth to mission needs - Future computing systems should support open system avionics architectures that provide interoperability between modules sourced from different vendors - These systems will enable increased autonomy for crewed and robotic science missions, as well as onboard data reduction where sensor bandwidth exceeds downlink bandwidth	- High-Performance General-Purpose Processors for Deep Space Missions - Advanced Spaceflight Memory –Volatile and Non-Volatile - Point-Of-Load (POL) Power Converters - Coprocessors - High Performance Spaceflight Computing Software Tools - High Performance Spaceflight Computing (HPSC) Single Board Computer (SBC) - Modular & Interoperable Avionics Arch - Interoperable Avionics Modules - Avionics Cybersecurity - Quantum Computing - Low Power Embedded Computing Nodes



High Performance Onboard Computing to Enable Increasingly Complex Operations



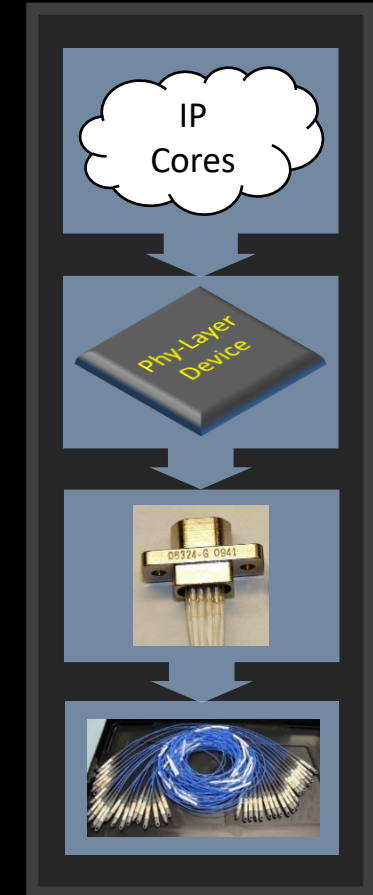
Board Types	Description
Power Supply Card (PSC)	Powers SpaceVPX chassis.
Utility Switch PIC	Provides point-to-point utility plane routing allowing PIC fault isolation.
Single Board Computer (SBC) PIC	Primary processor within chassis. Can optionally serve as system controller and chassis manager.
Co-processor PIC	Processing offload for primary processor. Cannot serve as system controller and chassis manager .
Switch PIC	Expands connectivity for data plane and/or control plane.
External I/O PIC	Provides connectivity outside the SpaceVPX chassis.
Data Storage PIC	Provides network attached storage for bulk memory storage.
SSD PIC	Provides solid state drive with tight coupling to SBC or co-processor.
Radio PIC	Provides uplink and downlink.

Notional Board Types

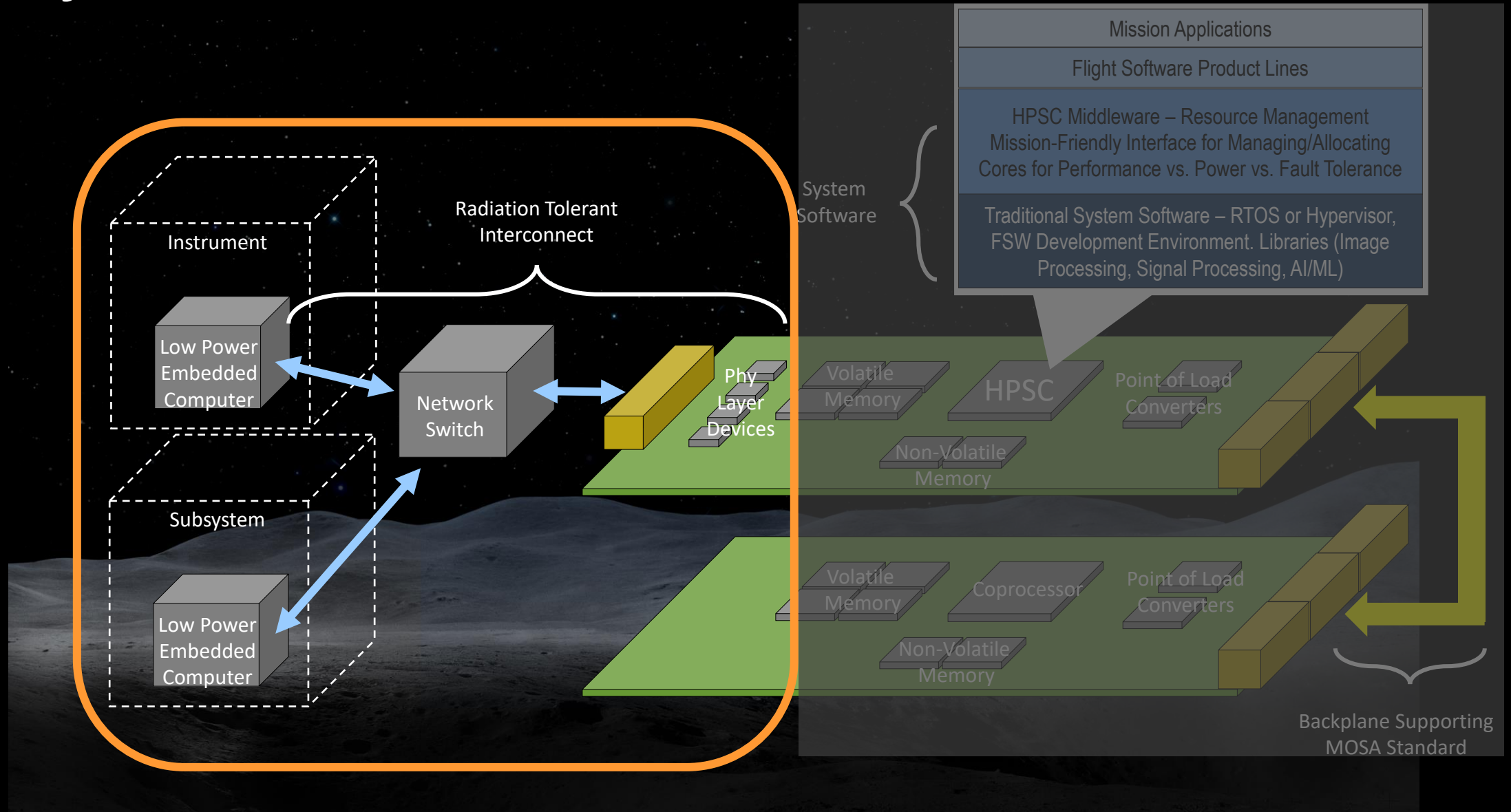
Distributed Avionics to Enable Improved Performance and SWaP Efficiency



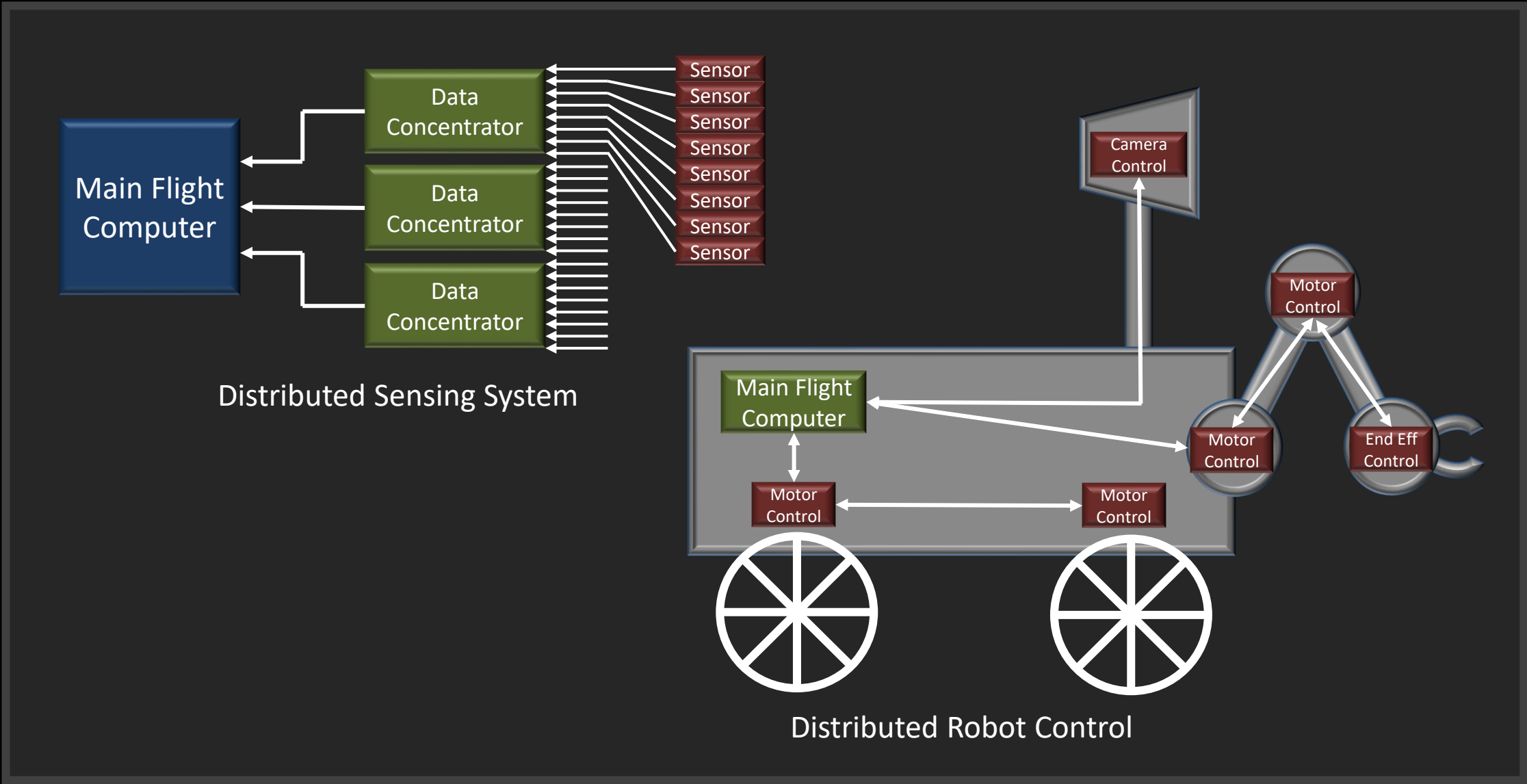
Description	Underlying Shortfalls
• Distributed avionics technologies are needed to allow the disaggregation of avionics functions within spacecraft or surface systems, thereby providing performance improvement, SWaP (size, weight, and power) reduction, and simplified integration and maintenance • Technologies are also needed to implement next generation wired and wireless avionic networks with high reliability with increased bandwidth for deep space missions • These networks must also accommodate traffic classes with varying levels of criticality	• Low Power Embedded Computing Nodes • Radiation Tolerant High Bandwidth Interconnect • Next Generation Physical Layer Technologies for Deep Space Mission • High Bandwidth Deterministic Wireless Networks • Distributed Avionics Architectures • Simulation and Analysis Tools for Mixed Criticality Networks



Distributed Avionics to Enable Improved Performance and SWaP Efficiency



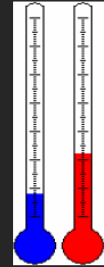
Distributed Avionics to Enable Improved Performance and SWaP Efficiency



Extreme Environment Avionics



Description	Underlying Shortfalls
- Avionics are needed that can operate reliably in harsh lunar and planetary thermal, radiation, and dust environments - These environments will vary widely across crewed and science missions - Applications include lunar surface systems that can survive lunar night without heaters, sensor and actuators on spacecraft and surface systems that operate in environments without active thermal control, and high temperature electronics for Venus missions	- Extreme Environment Electronics for Science Missions - Extreme Environment Electronics for Crewed Missions - Avionics Thermal Management for Extreme Environments - Dust Tolerant Avionics Connectors - Cold and Dust Tolerant Interface Seals



Extreme Environment Avionics



- Avionics must operate in extreme environments, which can vary widely between missions
 - Thermal
 - Typical “Warm” Avionics: 0 – 40°C
 - Lunar Surface: -200°C – 120°C
 - Mars Surface: -150°C – 20°C
 - Venus Surface: 470°C
 - Cryogenic Instrument: -230°C
 - Radiation
 - Most avionics have requirements to tolerate < 100 kRad Total Ionizing Dose (TID)
 - Some missions require > 1MRad TID
 - Lunar dust
 - Abrasive!
 - Concern for connectors, especially fiber optic



Lunar Surface



Mars Surface



Europa

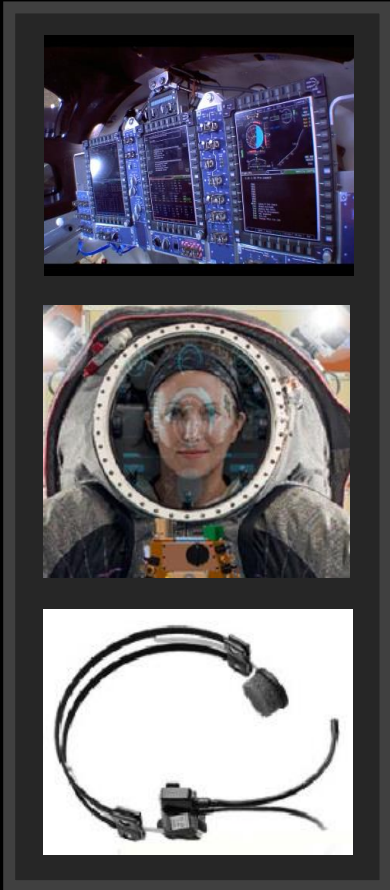


Venus

Crew Audio/Visual Interfaces for Long Duration Missions Beyond LEO



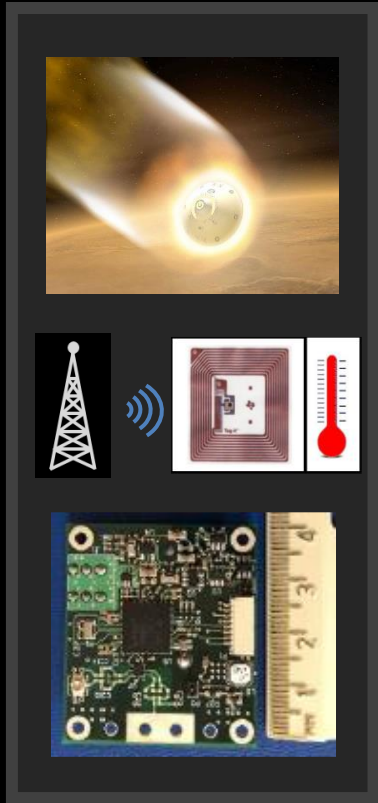
Description	Underlying Shortfalls
• Crew voice and audio systems are needed that can operate reliably for long duration missions beyond LEO • Crew interface needs span a variety of applications ranging from suits for EVA to crewed habitats to unpressurized rovers • Enhanced audio system capabilities are also needed, including speech recognition, to increase ease of use for crew	• Displays (Two Dimensional Visual Electronic) for Deep Space Missions • Graphics Processing for Deep Space Missions • Heads Up Display (HUD) Optics for Exploration EVA • Crew Voice and Audio Systems for Deep Space Missions • Consistent Crew Interfaces for Deep Space Missions • Speech Recognition for Autonomous Crew Operations • Projection Displays for Deep Space Missions • Resource Constrained Graphics Rendering • Deep Space Information Technology (IT) Infrastructure



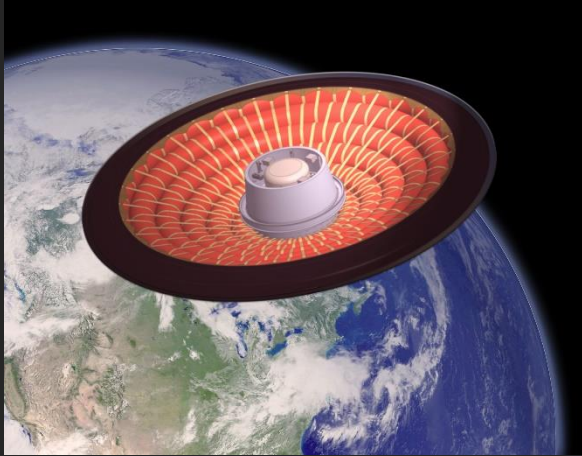
Advanced Data Acquisition Systems for Diverse Applications



Description	Underlying Shortfalls
• Data acquisition technology advances are needed to reduce the SWaP and cost and improving flexibility • Applications include low cost data acquisition systems for small and cost constrained missions to implement aerocapture sensing systems • Additionally, wireless sensing is needed to reduce harness mass/complexity, simplify integration and maintenance, and provide flexibility to modify instrumentation on orbit for crewed missions • For robotic science missions, wireless sensing is needed for connectivity to deployed or rotating assemblies	• Low Cost, Robust, High Accuracy Data Acquisition Systems • Wireless Sensor Networks • Low Cost Mixed Signal Application Specific Integrated Circuits (ASICs)

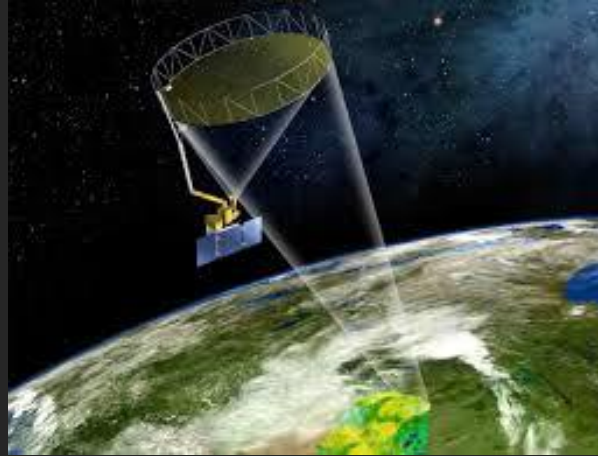


Advanced Data Acquisition Systems for Diverse Applications



Hypersonic Inflatable Aerodynamic Decelerator (HIAD)

Low-cost data acquisition systems



Soil Moisture Active Passive (SMAP) Spacecraft Large Deployable Antenna

Wireless sensing systems

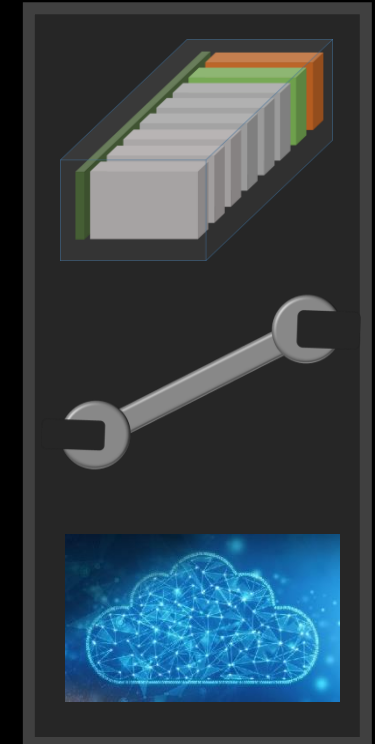


Inflatable Crew Habitat Concept

Next Generation Avionics Architectures



Description	Underlying Shortfalls
• Avionics architectures are needed with modularity and interoperability to enable systems to be developed using standard products from multiple vendors • Architectures are also needed that provide electrical and mechanical interfaces that enable robotic servicing • Additionally, technologies are needed to enable space cloud computing architectures where onboard computing tasks can be efficiently and reliably distributed across multiple spacecraft to surface systems, thereby providing high performance processing to resource constrained systems	• Modular & Interoperable Avionics Arch • Serviceable Avionics • Space Cloud Computing

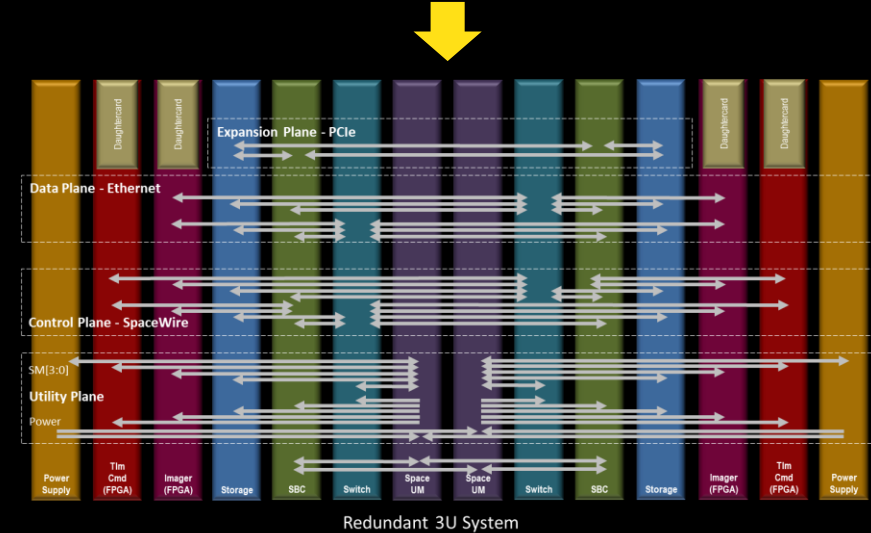


Next Generation Avionics Architectures



- NASA is currently working with industry to establish interoperable SpaceVPX standards at the avionics card level
 - Allow system developer to compose a system using an ecosystem of cards from multiple vendors that can interoperate
 - Standardization work is ongoing within the SOSA™
 - Further industry in the SOSA Space Subcommittee (S3C) is welcome
- Other form factors are needed for applications with more restrictive SWaP constraints

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Radio PIC	Provides uplink and downlink.

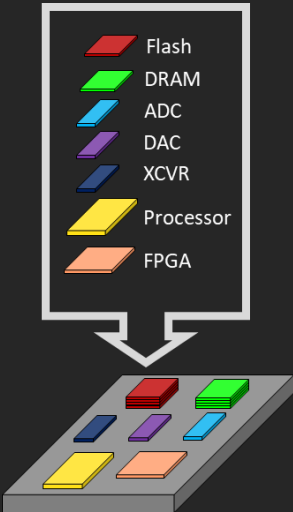
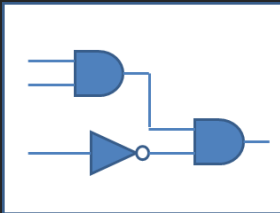
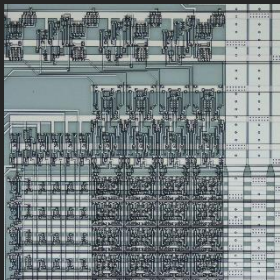


Modular Interoperable SpaceVPX Avionics

Foundational Technologies for Future Avionics Devices and Systems



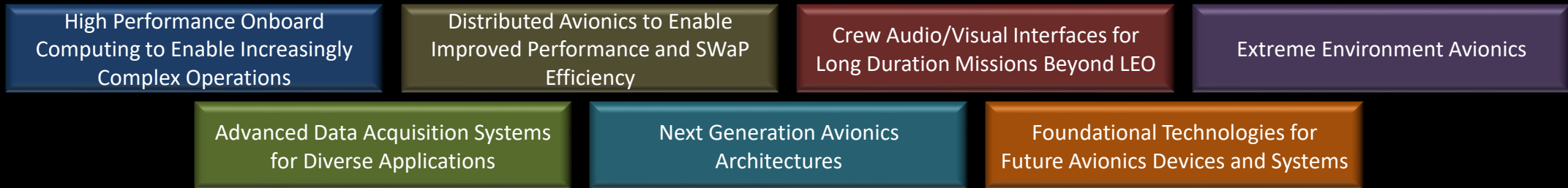
Description	Underlying Shortfalls
- Foundational technology advances are needed to enable the next generation of onboard computing systems, avionics systems, sub systems and components - Technologies are needed to design, fabricate, and package next generation radiation hardened microelectronics - Libraries and tools are needed to allow implementation of the next generation of space microelectronics on emerging semiconduction fabrication processes - Packaging advances are also needed to provide miniaturization and performance improvement for future space microelectronics - Additionally, testing technologies are needed to improve the efficiency and effectiveness of COTS device testing, enabling broader use of leading edge COTS devices in future avionics systems - Technologies to enable future safety critical avionics are needed, both at the component and architecture level	- Advanced Electronics Packaging - Radiation Hardened By Design and Tools (RHBD) Libraries - Advanced Test Systems for COTS Microelectronics - Avionics Modeling and Simulation for System Design and Evaluation - Low SWaP Fault Tolerance Architectures for Long Duration Missions - Circuit Design Approaches for High Integrity Devices



In Summary



- NASA STMD is refining its strategy for prioritizing technology investments, with the goal of evolving into a stronger and more resilient national tech base for civil space
- As a first step, STMD kicked off an annual process for gathering feedback from the American aerospace community about their most pressing shortfalls
- Stakeholder feedback on these shortfalls will influence NASA STMD priorities for future technology investment
- Seven avionics shortfalls have been identified



- **We welcome your feedback on these shortfalls!**
 - **What's missing?**
 - **Do you have a technology can helps address an avionics shortfall?**

Acronym List



AI	Artificial Intelligence	IT	Information Technology	POL	Point of Load
ASIC	Application Specific Integrated Circuit	ISRU	In Situ Resource Utilization	PROP	Propulsion
COTS	Commercial Off the Shelf	kRad	kiloRad	PSC	Power Supply Card
DARPA	Defense Advanced Research Projects Agency	LEO	Low Earth Orbit	RHBD	Radiation Hardened By Design
EOP	Executive Office of the President	ML	Machine Learning	RPOC	Rendezvous, Proximity Operations & Capture
EPS	Electric Propulsion System	MOSA	Modular Open Systems Architecture	RTOS	Real Time Operating System
EVA	Extra-Vehicular Activity	MRad	MegaRad	RXS	Reactor and Coolant Subsystem
IEEE	Institute of Electrical and Electronics Engineers	MW	MegaWatt	SBC	Single Board Computer
ISAM	In-Space Servicing, Assembly, and Manufacturing	NASA	National Aeronautics and Space Administration	SMAP	Soil Moisture Active Passive
HALEU	High-Assay Low-Enriched Uranium	NEP	Nuclear Electric Propulsion	SOSA	Sensor Open Systems Architecture
HIAD	Hypersonic Inflatable Aerodynamic Decelerator	OGA	Other Government Agency	SSD	Solid State Drive
HPSC	High Performance Spaceflight Computing	PCS	Power Conversion Subsystem	STMD	Space Technology Mission Directorate
HUD	Heads Up Display	PHRS	Primary Heat Rejection System	SWaP	Size Weight and Power
I/O	Input/Output	PIC	Plug-In Card	S3C	SOSA Space Subcommittee
IP	Intellectual Property	PMAD	Power Management and Distribution	TID	Total Ionizing Dose