EXPLORESPACE TECH
TECHNOLOGY DRIVES EXPLORATION

EXPLORE: Advanced Avionics
NASA Space Technology Mission Directorate

STMD welcomes feedback on this presentation. Please visit https://techport.nasa.gov/framework/feedback if you have any questions or comments regarding this presentation.

Advanced Avionics – Envisioned Future – Change Log

- 1/4/2023
  - Split Avionics Architecture technologies into 4 separate slides to improve readability and capture additional content
  - Added system context illustration for computing technologies as slide 7
  - Added “Avionics Architecture” technologies to slides 6, 10, and 14
    - Interoperable Avionics
    - Avionics Cybersecurity
    - Serviceable Avionics
    - Space Cloud Computing
  - Added “Advanced COTS Microelectronics Test Systems” to Foundational Technologies on slides 6, 10, and 15
  - Added “Develop radiation tolerant machine learning inference processor” to the gap closure plans for Artificial Intelligence (AI) Coprocessors on slide 12
- 1/11/2023
  - Incorporated editorial suggestions for reformatting and rewording
- 3/22/2023
  - Incorporated comments from NASA Centers on slides 6, 8, 9, 10, 11, 13, 16, and 18
  - Added reference to M2M objectives on slide 3
  - Changed interoperable avionics to green on slide 14
  - Added dust tolerant connectors to slides 5, 9, and 13

EXPLORE: Develop next generation high performance computing, communications, and navigation

Developing flight computing architectures and advanced avionics to enable increased onboard intelligence and autonomy for future exploration missions in harsh environments

Go — *Rapid, Safe, & Efficient Space Transportation*

- Develop nuclear technologies enabling fast in-space transits.
- Develop cryogenic storage, transport, and fluid management technologies for surface and in-space applications.
- Develop advanced propulsion technologies that enable future science/exploration missions.

Land — *Expanded Access to Diverse Surface Destinations*

- Enable Lunar/Mars global access with ~20t payloads to support human missions.
- Enable science missions entering/transiting planetary atmospheres and landing on planetary bodies.
- Develop technologies to land payloads within 50 meters accuracy and avoid landing hazards.

Live — *Sustainable Living and Working Farther from Earth*

- Develop exploration technologies and enable a vibrant space economy with supporting utilities and commodities
  - Sustainable power sources and other surface utilities to enable continuous lunar and Mars surface operations.
  - Scalable ISRU production/utilization capabilities including sustainable commodities on the lunar & Mars surface.
  - Technologies that enable surviving the extreme lunar and Mars environments.
  - Autonomous excavation, construction & outfitting capabilities targeting landing pads/structures/habitable buildings utilizing in situ resources.
- Enable long duration human exploration missions with Advanced Life Support & Human Performance technologies.

Explore — *Transformative Missions and Discoveries*

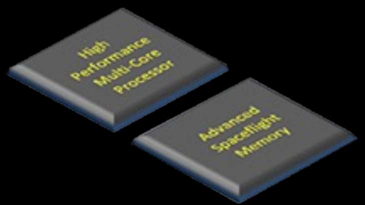
- Develop next generation high performance computing, communications, and navigation.
- Develop advanced robotics and spacecraft autonomy technologies to enable and augment science/exploration missions.
- Develop technologies supporting emerging space industries including: Satellite Servicing & Assembly, In Space/Surface Manufacturing, and Small Spacecraft technologies.
- Develop vehicle platform technologies supporting new discoveries.

Computing for:

- Advanced Propulsion
  Cryogenic Fluid Management(TX 1.1.3)
- Entry Descent & Landing (EDL)
  Real-Time Precision Landing Algorithms (TX 9.0)
- Autonomous Robotic Systems (TX 7.2.3)
- Environmental Control and Life Support System (ECLSS)
  Autonomous Clinical Care (TX 6.3.1)
- **Advanced Avionics**
  TX 2.1 Avionics Component Technologies
  TX 2.2 Avionics Systems and Subsystems
  TX 11.1 Software Development, Engineering, and Integrity
- Autonomous Systems & Robotics
  State Estimation, Terrain Mapping and Classification, 3D Modeling, Object Recognition, Path Planning, Fault Prognosis, Anomaly Detection, Resource Planning and Scheduling, Autonomous Navigation/Obstacle Avoidance, Autonomous Management of In Situ Activities (TX 4.0)
- Rendezvous and Docking Algorithms (TX 4.5)
- Sensors and Instruments
  Instrument Control and Science Data Processing (TX 8.1, TX 8.3)

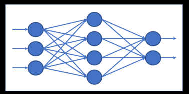
As a "foundational technology", advanced avionics will be embedded within systems that address many of the Moon-to-Mars objectives; including most of the Infrastructure and Transportation objectives and several of the Science and Operations objectives

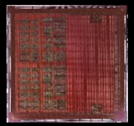
Advanced Avionics – Envisioned Future



HIGH PERFORMANCE SPACEFLIGHT COMPUTING

- Radiation-hardened general-purpose processor with vector processing, increased performance, and flexibility to adapt to mission specific performance, power, and fault tolerance needs
- Advanced spaceflight memory with radiation tolerance, increased capacity and improved performance
- Intelligent, efficient, multiple output Point-Of-Load (POL) power converters
- High performance Single Board Computer (SBC) incorporating high-performance general-purpose processors, advanced memory, point-of-load converters, and real-time operating system in industry standard form factors and bus architectures
- System software tools with vector support to leverage the capabilities and manage the complexity of advanced multi-core processors





OTHER COMPUTING ARCHITECTURES

- Artificial Intelligence (AI) coprocessors to enable autonomous landing, surface navigation, robotic servicing/assembly, fault detection/mitigation, distributed systems operations, science data processing, and tip and cue for remote sensing missions
- Spaceflight quantum computers
- Low power embedded computers to support distributed robotics architectures

INTERCONNECT

- Radiation-tolerant interconnects to support low latency onboard video, multi-gigabit instruments, onboard science, and enhanced autonomy applications; including end points, switches, physical layer devices, and software support
- Highly reliable, high-bandwidth deterministic wireless networks

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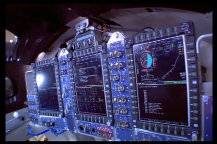
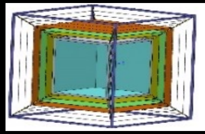
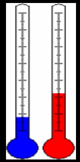
Advanced Avionics – Envisioned Future



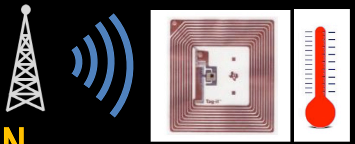
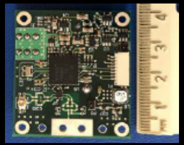
CREW INTERFACES

- Radiation-tolerant displays that can operate reliably for long durations mission beyond LEO
- Radiation-tolerant graphics processing that can operate reliably for long mission durations beyond LEO
- Heads Up Displays for Exploration EVA
- Crew voice and audio systems for deep space missions providing efficient compression of multiple streams, acoustic echo and noise cancellation, speech recognition and voice control, and wireless capabilities

EXTREME ENVIRONMENT AVIONICS

- Extreme temperature electronics capable of operating in environments with both high radiation and wide temperature ranges, including lunar/planetary surfaces or within nuclear systems
- Avionics packaging and thermal management technologies to enable avionics operation in extreme environments
- Dust tolerant connectors to enable interconnect on lunar and planetary surfaces

DATA ACQUISITION

- Wireless sensor networks to reduce harness mass and complexity, simplify integration and test, and improve system flexibility, serviceability, and expandability
- Low-cost, robust, high-accuracy data acquisition systems to enable distributed in situ monitoring of structures and subsystems on cost constrained missions

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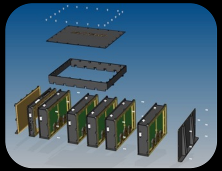
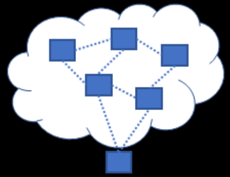
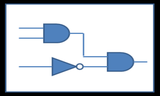
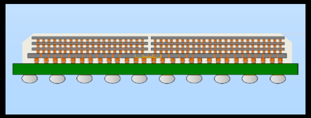
Advanced Avionics – Envisioned Future





AVIONICS ARCHITECTURES

- Interoperable avionics architectures allowing systems to be composed of standard interoperable modules from multiple vendors
- Cybersecurity tools providing defense-in-depth for spaceflight avionics
- Serviceable avionics architectures to simplify post-deployment servicing of avionics hardware
- Space cloud computing architectures allowing onboard processing to be distributed across multiple spacecraft or surface elements

FOUNDATIONAL TECHNOLOGIES

- Advanced 2.5D/3D packaging supporting heterogeneous integration enabling miniaturization and improved performance
- Advanced semiconductor process nodes and libraries to enable next generation radiation hard devices
- Low-cost, radiation-hardened mixed-signal ASICs
- Advanced test systems accelerating radiation and reliability testing of complex COTS microelectronics devices

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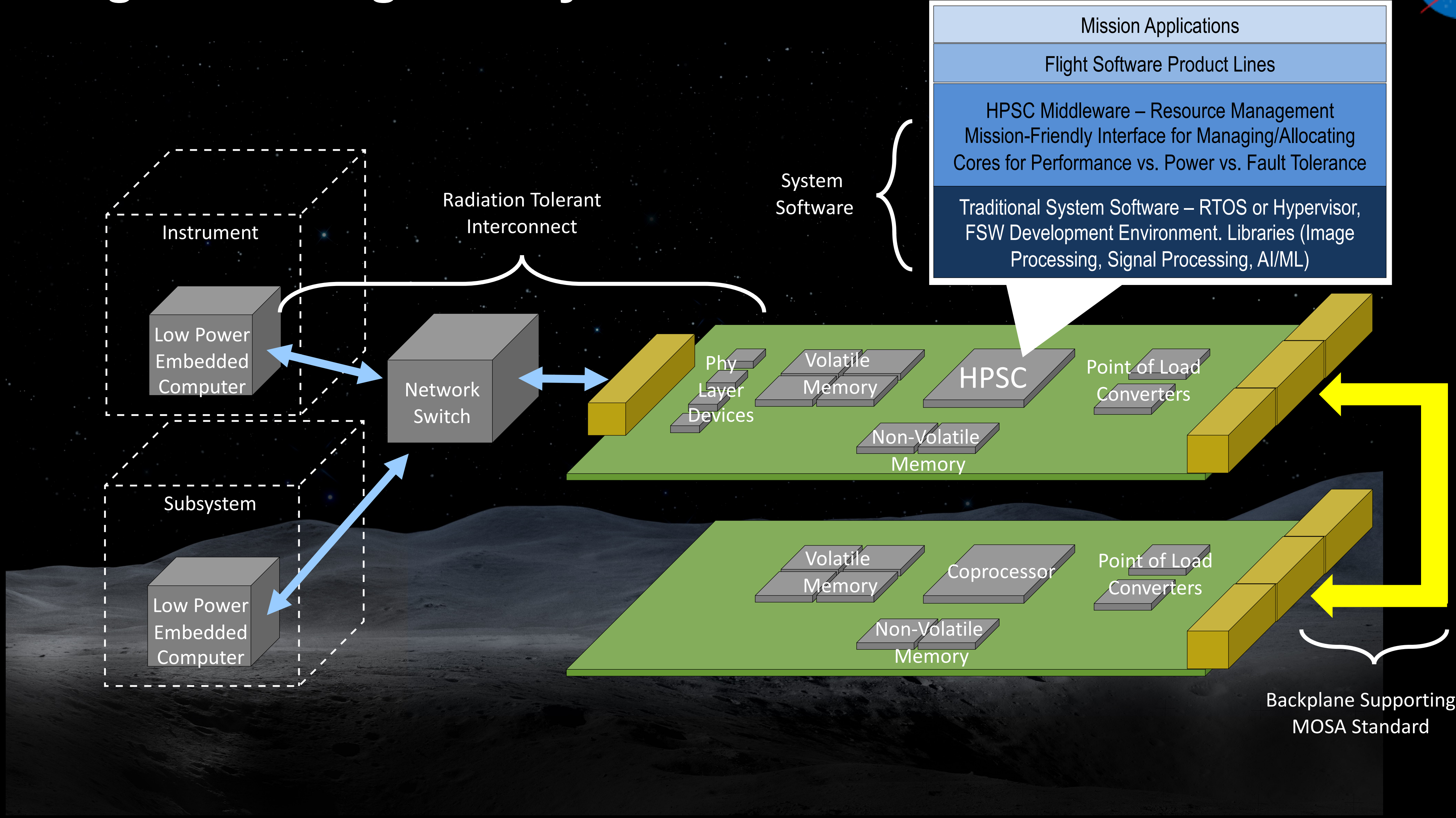
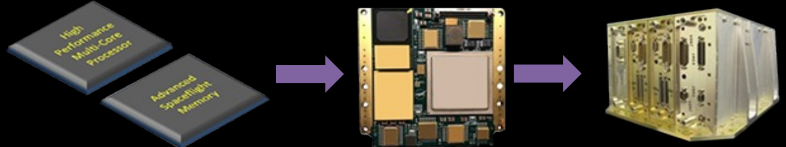
Computing Technologies – System Context

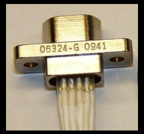


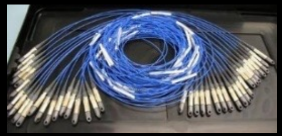
Advanced Avionics – State of the Art



HIGH PERFORMANCE SPACEFLIGHT COMPUTING

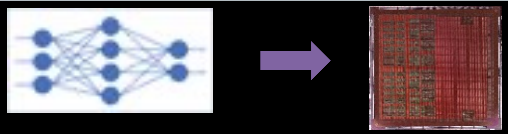
- Processors – Current missions either using radiation-hardened processors with limited performance, or higher performance redundant COTS-based processors limiting power efficiency
  - *Target - 3-5X performance improvement over current space processors for general purpose processing (GPP), parallel processing acceleration, and flexibility to adapt performance, power, and fault tolerance to mission needs*
- Memory – Radiation-hardened memories lack capacity and/or performance, while COTS-based memories are susceptible to radiation induced upsets
  - *Target - Radiation-hardened memory with 4-8X the capacity and/or performance of existing radiation-hardened memories*
- Point-Of-Load (POL) Power Converters – Current POL converters provide a limited number of outputs and lack embedded fault tolerance
  - *Target - Radiation-hardened, high efficiency POL converters leveraging wide-bandgap technology with at least 3 outputs, bus interface, and embedded fault tolerance*
- Single Board Computer (SBC) – Current SBCs using radiation-hardened processors have limited performance, as well as limited power and performance scaling capability
  - *Target - Radiation-hardened SBC in industry standard form factor with 5X GPP improvement, parallel processing, with ability to scale power and performance*
- HPSC Software Tools – Current system software tools do not support the complexity of the High Performance Spaceflight Computing (HPSC) multicore processor
  - *Target - System software tools with parallelism and vectorization support to allow developers to fully leverage the capabilities and flexibility of the HPSC processor*





INTERCONNECT

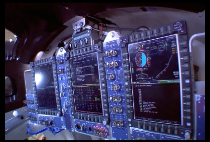
- Wired – Current onboard wired networks lack bandwidth to support increased sensor data rates of future missions
  - *Target - Wired networks with 10X bandwidth improvement*
- Wireless – Current onboard wireless networks only support low criticality needs
  - *Target - Wireless networks for critical applications in crewed and robotic missions*



OTHER COMPUTING ARCHITECTURES

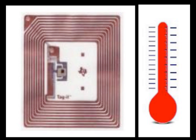
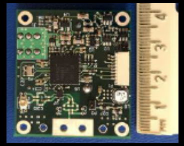
- Artificial Intelligence (AI) Coprocessors – COTS devices exist, but with unknown radiation performance and applicability to NASA onboard processing tasks
  - *Target - Radiation-tolerant AI coprocessors for NASA missions*
- Quantum Computing – Quantum computing technology is emerging, but small number of qbits limit processing capability, large infrastructure, and power requirements limit even terrestrial applications
  - *Target – Quantum computers tailored for onboard processing applications and environments*
- Low Power Embedded Computers – Current spaceflight robotics systems employ centralized architectures, which increases network bandwidth, latency, power, and system complexity
  - *Target – Low power embedded computers enabling distributed architectures*

Advanced Avionics – State of the Art



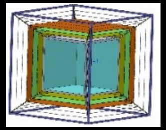
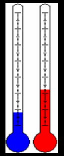
CREW INTERFACES

- Crew Displays and Graphics Processors – Current spaceflight technologies offer limited visual performance and have uncharacterized radiation risks for long duration missions beyond LEO
  - *Target - Radiation-tolerant displays and graphics processors that can support displays with minimum of 1080p 30fps for Lunar and Mars mission durations (note - graphics processors are also applicable for other onboard processing functions)*
- Crew Voice and Audio Systems – Current systems offer limited performance and have uncharacterized radiation risks for long duration missions beyond LEO
  - *Target - Radiation-hardened system with efficient compression, speech recognition for voice control, and active noise control for Lunar and Mars mission durations*

DATA ACQUISITION

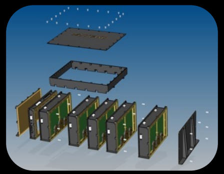
- Wireless sensor networks – Current onboard sensing requires harnessing, which incurs a mass penalty
  - *Target - Readout systems and diverse onboard wireless sensor node types*
- Data Acquisition (DAQ) Systems – Current entry descent and landing DAQ systems are too costly to deploy on wide range of missions
  - *Target - 10X cost reduction for distributed in situ monitoring of structures and subsystems on cost constrained missions*

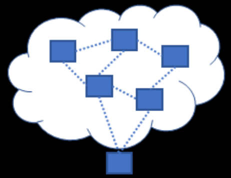




EXTREME ENVIRONMENT AVIONICS

- Extreme Temperature/Radiation Electronics – Only limited functions have been implemented that can operate in environments with both high radiation and wide temperature ranges, including lunar/planetary surfaces and nuclear systems
  - *Target – Diverse set of circuit functions to enable systems that can operate in Lunar surface, planetary surface, and nuclear systems environments with both high radiation and wide ranges of operating temperatures*
- Packaging and Thermal Management Technologies – Current approaches limit the ability to operate at extreme cold and hot temperatures
  - *Target - Packaging and thermal management technologies that can be tailored to operate across wide temperature ranges for Lunar or planetary missions*
- Dust Tolerant Connectors – Military standard connectors offer some dust protection for terrestrial applications
  - *Target - Connectors that can protect against lunar and planetary dust while operating and surviving in extreme temperature and radiation environments*

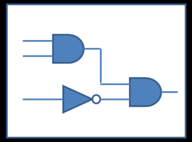
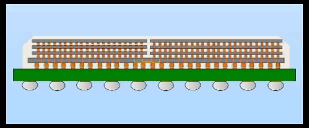
Advanced Avionics – State of the Art





AVIONICS ARCHITECTURES

- Interoperable Avionics – Current avionics architectures lack interoperability
  - *Target – Avionics Modular Open Systems Architectures (MOSA) allowing interoperability between a diverse set of modules*
- Avionics Cybersecurity – Current avionics lack robust defense in depth cybersecurity protection
  - *Target – Software tools providing secure boot, cybersecurity policy management, with automated detection and reaction to potential intrusions within avionics systems*
- Serviceable Avionics - Current avionics do not facilitate post-deployment robotic servicing
  - *Target – Avionics chassis and interconnect architectures that simplify crewed or robotic servicing and module level swapping*
- Space Cloud Computing - Current avionics approaches confine onboard processing within an individual spacecraft or surface element
  - *Target – Software architectures and tools that allow onboard processing applications to seamlessly utilize compute resources that are disaggregated across multiple platforms*

FOUNDATIONAL TECHNOLOGIES

- Advanced 2.5D/3D Packaging and Heterogeneous Integration (HI) – These exist in industry, but lack spaceflight qualification
  - *Target - Qualified 2.5D/3D packaging and HI for NASA missions*
  - Advanced Semiconductor Process Nodes/Libraries – Existing 45nm RHBD libraries lack the density and performance needed for next generation of computing devices
  - *Target - Libraries with 2X/4X the performance/density of existing RHBD libraries*
- Low-Cost Mixed Signal ASICs – Custom mixed-signal ASIC NRE cost limits infusion
  - *Target - Radiation-hardened structured ASIC platforms to reduce NRE cost*
- Advanced COTS Microelectronics Test Systems – The cost and schedule of COTS microelectronics radiation and reliability testing is impacted by the capabilities of current test systems
  - *Target – Accelerated test preparation for radiation and reliability testing of complex microelectronics devices, thereby expediting the infusion of COTS microelectronics into avionics*

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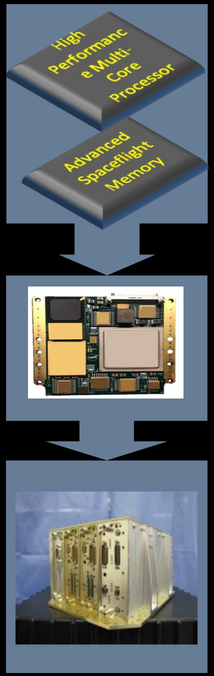
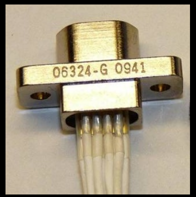
Advanced Avionics Gap Closure Plans

(Green =Funded, Yellow = Partially Funded, Red = Unfunded)

HIGH PERFORMANCE SPACEFLIGHT COMPUTING	
Radiation-hardened general-purpose processor	Define a High Performance Spaceflight Computing (HPSC) processor concept that maximally leverages microelectronics technology advances for high reliability applications. Engage industry to develop and commercialize a radiation-hardened multi-core HPSC processor that addresses the computing needs of future NASA missions and broader markets. Leverage other government computing investments, as well as COTS developments, that are suitable for NASA use.
Advanced spaceflight memory	Fund the development and qualification of radiation-hardened non-volatile memory. Leverage other government agency investments in development of other radiation-hardened memory devices. Test emerging COTS memory technologies and identify devices that are suitable for NASA applications.
Point-Of-Load (POL) power converters	Leverage SBIR to develop intelligent, radiation-hardened multi-output POL converters that leverage industry smart power bus standards. Secure program funding for post Phase II commercialization.
Single Board Computer (SBC)	Define advanced avionics architectures that leverage HPSC capabilities. Develop spaceflight computer boards to demonstrate in those architectures. Engage industry to develop and commercialize spaceflight HPSC SBCs in industry standard form factors.
HPSC Software Tools	Port real-time operating systems, develop tools, and HPSC Middleware tools to support the full HPSC architecture. Assess existing libraries for image processing, signal processing, and machine learning, and augment as needed for HPSC architecture.



INTERCONNECT	
Radiation-tolerant interconnect	Leverage the HPSC concept studies and the NESC SpaceVPX Interoperability Study to select optimal interconnect standards for further development. Engage with standards organizations to ensure that evolution of selected standards meet future NASA mission needs. Assess availability of components required (i.e. endpoints, switches, physical-layer components) for a robust ecosystem for the selected standards, and leverage SBIR to develop needed components.
Highly reliable, high bandwidth deterministic wireless networks	Engage academic institutions to develop novel techniques that extend the capabilities of space-based wireless networks in time-sensitive and safety-critical applications. Leverage SBIR/STTR as a follow on to implement for space flight demonstration.



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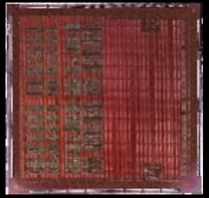
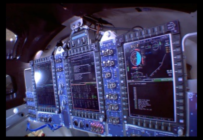
OTHER COMPUTING ARCHITECTURES	
Artificial Intelligence (AI) coprocessor	Evaluate viability of COTS coprocessor devices and foundational technologies for NASA AI applications within the RadNeuro and the NEPP programs. Devise system-level radiation mitigation approaches to address susceptibilities in COTS devices. Demonstrate coprocessors and mitigation approaches via ground radiation testing and flight demonstrations. Study the optimal mapping of onboard (AI) applications to candidate processing architectures and devices. Develop radiation tolerant machine learning inference processor.
Quantum Computing	Explore candidate use cases for onboard quantum computing and compare performance with other computing technologies. Assess radiation susceptibilities of quantum computing and potential mitigations. Define concept for spaceflight quantum computer and develop prototype.
Low power embedded computers	Develop distributed avionics architecture to enable modular, interoperable, and reusable robotic systems. Define low power embedded computer concepts that are consistent with that architecture and can meet SWaP and extreme environmental requirements. Perform NASA development of proof-of-concept low power embedded computer, and then engage small business for further development and commercialization.



CREW INTERFACES	
Radiation-tolerant displays	Under ESDMD Polaris project, characterize the radiation performance of candidate display pixel technologies and support circuitry. Transfer knowledge from Polaris project to industry for development and commercialization of radiation-tolerant displays for future NASA exploration missions.
Radiation-tolerant graphics processing	Engage small business to characterize radiation performance of COTS Graphics Processor Units (GPUs) and develop system-level radiation mitigation approaches suitable for use in future NASA exploration missions. Specifically, develop system-level mitigation approaches for transient errors due to single event effect (SEE).
Heads Up Display (HUD) Optics	Advance development of Heads Up Display (HUD) optics under ESDMD Polaris project to advance xEMU displays. Continue development efforts for xEMU partnering with academia and industry.
Crew voice and audio systems	Engage, current NASA programs, industry partners, and small business to develop systems that can meet future mission environments and incorporate speech recognition capabilities.



Advanced Avionics Gap Closure Plans

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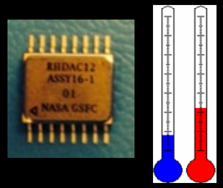
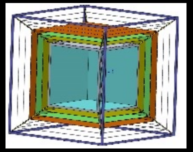
EXTREME ENVIRONMENT ELECTRONICS

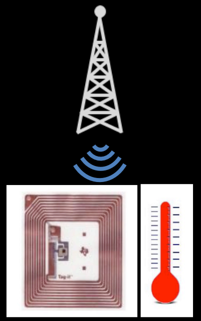
Extreme temperature/radiation electronics	Under the SMD ColdTech and HOTTech programs along with STMD LSII and LuSTR programs, develop and characterize radiation-hardened extreme temperature design libraries in SiGe and SiC for implementation in digital and mixed-signal devices for infusion into NASA missions. Assess extreme temperature electronics from other industries for potential NASA use.
Avionics packaging and thermal management for extreme environments	Under the STMD PALETTE project, develop set of packaging and thermal management technologies so that avionics developers can utilize to implement passively controlled packaging for widely ranging mission environments. Infuse PALETTE technologies into lunar and planetary instruments and subsystems.
Dust Tolerant Connectors	Test existing spaceflight qualified connectors in relevant environments. Engage industry to enhance connector designs and materials to address issues uncovered during testing.

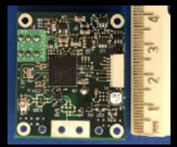




DATA ACQUISITION

Wireless sensor networks	Develop and demonstrate enhanced wireless sensor nodes with an implementation path for hardware that can operate reliably in harsh environments. Demonstrate in testing, support, and flight applications as needed. Specific solutions for crewed missions may be compatible with the Radio-frequency identification (RFID) Enabled Autonomous Logistics Management (REALM) system, leveraging additive manufacturing technology to provide miniaturization.
Low-cost, robust, high-accuracy data acquisition systems	Leverage SBIR to develop a radiation-tolerant low-cost data acquisition system technology. Secure program funding for post Phase II commercialization.

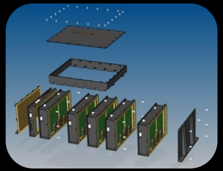


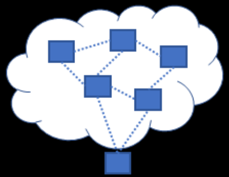


Advanced Avionics Gap Closure Plans

(Green =Funded, Yellow = Partially Funded, Red = Unfunded)

AVIONICS ARCHITECTURES	
Interoperable Avionics	Engage with industry, other government agencies, and relevant standards organizations in revising the VITA-78 (SpaceVPX) standard to ensure module interoperability. Engage with industry to develop interoperable SpaceVPX modules. (Green)
Avionics Cybersecurity	Leverage SBIR to develop tools for modeling avionics cybersecurity vulnerabilities. Leverage SBIR to develop onboard tools for sensing and reacting to potential intrusions within avionics. Secure program funding for post Phase II commercialization. (Red)
Serviceable Avionics	Assess robotic servicing options and constraints for harnessing mating and de-mating, as well as avionics module removal and insertion. Prototype and evaluate serviceable avionics implementation options. Engage industry and other agencies to develop serviceable avionics standards. (Red)
Space Cloud Computing	Explore candidate use cases for space cloud computing and model their performance on cloud computing architectural options. Engage industry to develop software tools implementing optimal cloud computing architectures. (Red)





Advanced Avionics Gap Closure Plans

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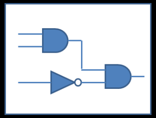
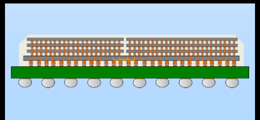
FOUNDATIONAL TECHNOLOGIES	
Advanced 2.5D/3D packaging and heterogeneous integration	Develop conventional and additively manufactured 2.5D and 3D packaging technologies for low production volume devices. Engage Nextflex consortium to develop qualification methods for additively manufactured spaceflight electronics, and then demonstrate on smallsat missions. Engage industry on the development of qualification methods for 3D packaging.
Advanced Semiconductor Process Nodes/Libraries	Under NASA STMD funding, perform radiation characterization and modelling of the Global Foundries 22FDX process and automotive grade design libraries. Leverage other government and industry efforts in radiation-hardened deep submicron processes and libraries.
Low-Cost Mixed Signal ASICs	Engage industry to develop radiation-hardened mixed-signal structured ASIC platform to broadly meet NASA mission needs.
Advanced COTS Microelectronics Test Systems	Leverage SBIR to develop advanced test systems for COTS microelectronics that provide improved insight into device behavior, accelerate the development of device-specific test configurations and execution code, and expedite radiation and reliability tests.





Advanced Avionics – Next Steps for Currently Unfunded Technologies

CREW INTERFACES	
• Assess radiation susceptibilities and mitigations, and engage industry to develop and commercialize radiation-tolerant displays for future NASA exploration missions and crew voice and audio systems for future NASA exploration missions	Priority 1
HIGH PERFORMANCE SPACEFLIGHT COMPUTING	
• Leverage SBIR to develop intelligent, radiation-hardened multi-output POL converters that leverage industry smart power bus standards.	Priority 2
INTERCONNECT	
• Engage with standards organizations to ensure that evolution of selected standards meet future NASA mission needs	Priority 3
• Leverage SBIR to develop technologies needed (i.e., endpoints, switches, physical components) for a robust ecosystem that supports the selected standards	Priority 7
• Engage academia to extend wireless network technology to meet the reliability and determinism needed by NASA applications for both crewed and robotic missions	Priority 8
LOW POWER EMBEDDED COMPUTER	
• Develop distributed avionics architecture to enable modular, interoperable, and reusable robotic systems	Priority 4
• Define low power embedded computer concepts that are consistent with that architecture and can meet SWaP and extreme environmental requirements	Priority 5
LOW-COST DATA ACQUISITION SYSTEMS	
• Leverage SBIR to a radiation-tolerant low-cost data acquisition system technology, then secure program funding for post Phase II commercialization	Priority 6

Conclusions

- The highest priorities for advanced avionics are:
  - Continued investment in High Performance Spaceflight Computing (HPSC), and underlying technologies such as POL converters
  - Continued investments in crew interfaces
- The next priority should be development of interconnect technologies to enable avionics architectures that address increasing sensor bandwidth, and can leverage the increased compute capabilities provided by HPSC
- Other priorities include development of low power embedded computers to support distributed robotics architectures, and development of low-cost, robust, high-accuracy data acquisition systems to enable distributed in situ monitoring of structures and subsystems on cost constrained missions
- Additionally, opportunities should be sought to leverage SBIR/STTR to address lower priority gaps

Acronyms

- AI – Artificial Intelligence
- ASIC – Application Specific Integrated Circuit
- COTS – Commercial off the shelf
- DAQ – Data Acquisition
- ECLSS – Environmental Control and Life Support System
- EDL – Entry, Descent, and Landing
- ESDMD – Exploration Systems Development Mission Directorate
- EVA – Extravehicular Activity
- GPP – General Purpose Processing
- GPU – Graphics Processor Units
- HI – Heterogeneous Integration
- HPSC – High Performance Spaceflight Computing
- HUD – Heads Up Display
- ISRU – In Situ Resource Utilization
- LEO – Low Earth Orbit
- LPEC – Low Power Embedded Computer
- LSII – Lunar Surface Innovation Initiative
- LuSTR – Lunar Surface Technology Research
- ML – Machine Learning
- NEPP - NASA Electronics Parts and Packaging Program
- NESC – NASA Engineering & Safety Center
- NRE – Non-recurring Engineering
- PALETTE – Planetary and Lunar Environment Thermal Toolbox Elements
- POL – Point-Of-Load
- REALM – RFID Enabled Autonomous Logistics
- RFID – Radio-frequency Identification
- RHBD – Radiation-Hardened By Design
- SBC – Single Board Computer
- SBIR – Small Business Innovation Research
- SEE – Single Event Effect
- SMD – Science Mission Directorate
- STMD – Space Technology Mission Directorate
- STTR – Small Business Technology Transfer
- SWaP – Size, Weight, and Power
- TX – Taxonomy
- VITA – VMEbus International Trade Association
- xEMU – eXploration Extravehicular Mobility Unit