NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Frequently Asked Questions (FAQ)

NASA High Performance Spaceflight Computing (HPSC) Processor

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NASA's Jet Propulsion Laboratory

1. **What is the NASA High Performance Spaceflight Computing (HPSC) processor?**

The NASA High Performance Spaceflight Computing (HPSC) processor is an advanced 5th generation reduced instruction set computer (RISC-V) CPU-based System on a Chip (SoC) which forms the core of computing systems designed to meet the rigorous demands of space missions. Developed in collaboration with JPL and industry partners led by Microchip Technology, HPSC provides enhanced computational power, reliability, and energy efficiency, making it ideal for space exploration and scientific research.

2. **What are the key technical features of HPSC?**

HPSC includes several key advancements that are critical for high reliability government and new space missions and fault-tolerant industrial and aerospace projects.

- <u>Multi-core Architecture</u>: HPSC features a heterogeneous, scalable multi-core RISC-V processor architecture with Integrated Vector Engines (Application Complex) that excels executing diverse workloads including artificial intelligence (AI) and machine learning (ML), Real-Time Control optimized for Advanced Autonomy for scientific applications.
- <u>Energy Efficiency</u>: HPSC delivers up to several orders of magnitude higher performance per watt than current space-qualified processors. HPSC has a high performance per watt compute efficiency with many user-controllable power islands and other capabilities to tailor compute needs with power consumption.
- <u>Radiation Hardening and Fault Tolerance</u>: HPSC is built to withstand the harsh conditions of space. The HPSC architecture contains radiation hardening and mitigation and advanced Fault Tolerance features throughout the hardware and software design.
- <u>Scalability</u>: HPSC is capable of scaling from small to large across multiple performance, power, size, and functionality parameters based on mission requirements. HPSC is optimized for use in low-cost LEO small-satellites all the way up to complex long-duration, deep-space missions. The HPSC product family offers a range of solutions, including both radiation-hardened and radiation-tolerant series, designed to meet the diverse requirements of space applications.
- <u>Real-Time Processing</u>: HPSC supports real-time data processing and networking for critical mission operations.
- <u>Time-Sensitive Networking (TSN) Ethernet Switch</u>: 240G TSN Ethernet switch with remote direct memory access (RDMA) over Converged Ethernet (RoCE) engine to support sensor fusion.
- <u>Extensibility</u>: Mission-specific functional accelerations are supported via high-speed, low-latency, point-to-point and coherent memory sharing Peripheral Component Interconnect Express (PCIe) and Compute Express Link (CXL) interfaces.
- <u>Comprehensive Security Solution</u>: HPSC supports a comprehensive, Defense-in-Depth, future-proof security solution with support for post-quantum cryptography.

- Secure Controller Subsystem: Integrated secure enclave for secure boot, encryption, key and secret handling and tamper detection.
- On-Shore, Trusted Supply Chain: Delivers a secure platform for developing and delivering secure systems. Advanced Anti-Tamper/Countermeasures which protect intellectual property.
- Side Channel Resistant Cryptographic Accelerators: Provides a complete package of cryptographic accelerators for use by applications running on the RISC-V Application Complex.

3. How can organizations get involved with HPSC development and deployment?

Organizations can participate in HPSC initiatives through:
- Project Engagements: Microchip is providing HPSC components and technology to many industries, Government Space, Department of Defense, Aerospace and New Space projects.
- Partnerships: Collaborating with NASA on joint missions or technology development projects.
- Ecosystem Development: Participate within the Sensor Open System Architecture (SOSA™) to develop standards for interoperable space avionics systems.
- Off-the-shelf Single Board Computer (SBC): Engage with multiple SBC vendors who are going to introduce commercially viable, flight-capable SBC products to the marketplace.

4. What are the benefits of adopting HPSC for space missions?

HPSC offers several advantages for space missions including:
- High Computational Power: HPSC's advanced multicore architecture provides significant computational capabilities, allowing for the processing of complex scientific data and real-time decision-making required for New Space Missions.
- Scalability: The HPSC's modular design allows for scalability, enabling it to meet the needs of various mission sizes and complexities, from small satellites to large interplanetary missions.
- Energy Efficiency: HPSC is optimized for compute efficiency and dynamic power management. HPSC is ideal for long-duration missions where power resources are limited, thus extending mission lifespans, and reducing operational costs.
- Radiation Hardening: HPSC is built to withstand the harsh conditions of space, including high levels of radiation, ensuring reliability and durability over extended periods.
- Real-Time Processing: HPSC is capable of handling real-time data processing and autonomous operations, critical for missions that require immediate responses to changing conditions.
- Radiation-Hardened and Radiation-Tolerant: Two families of HPSC with pin and software compatibility. High fault-tolerance that is vital for round-the-clock service reliability with unmatched cybersecurity and protection.

- Cost Efficiency: Reduced development costs because of HPSC high functional integration, Open-Source support, industry standard interfaces, eco-system support making missions more economically viable.
- Faster Time to Market and Time to Flight: The robust HPSC hardware and software ecosystem and extensive industry support services enable faster development cycles, reducing the time from project inception to launch.
- Innovation and Growth: Access to advanced computational capabilities fosters innovation and enables the exploration of more ambitious and complex missions, driving industry growth.

5. How does using HPSC improve mission reliability and success rates?

HPSC can increase mission reliability and success in several ways with:

- Redundant Systems: Incorporating redundancy in critical components to ensure continued operation even in the event of a failure.
- Robust Error Correction: HPSC implements advanced error correction techniques throughout the architecture to mitigate the effects of cosmic radiation and other space hazards.
- Comprehensive Testing: HPSC is continuously tested at GlobalFoundries, Microchip, and other third-party industry partners. HPSC is subject to rigorous pre-launch testing to verify performance and reliability under mission-specific conditions.
- Adaptive Software: HPSC supports adaptive software systems that can dynamically adjust to changing mission parameters and environmental conditions.
- Dual-core lockstep operation: Enables the prompt detection of error during code execution, providing an opportunity to mitigate the fault proactively before it potentially develops into a critical issue.
- WorldGuard: An end-to-end hardware partitioning architecture that provides isolated code execution and data protection.
- DDR Enhanced Error Correction Engine: Supports correction of multiple errors and recovery from memory chip failures, exceeding the conventional Single Error Correction Double Error Detection (SECDED) method.

6. How does HPSC support advanced scientific research and exploration?

HPSC can support advanced scientific research and exploration by:

- Enhanced Data Processing: HPSC High-performance computing capabilities allow for the processing and analysis of vast amounts of scientific data, facilitating new discoveries and insights. HPSC supports AI and ML programming with embedded vector engines, or with external AI-processors through PCIe/CXL interfaces.
- Autonomous Operations: HPSC real-time processing and decision-making capabilities enable autonomous operations, reducing the need for constant human intervention and

allowing for more flexible and responsive mission profiles. This is especially critical for missions that operate at extreme distances from Earth-based control.
- Interoperability: HPSC offers compliance with industry standards and interfaces which ensures interoperability with existing and future space systems, enhancing collaborative research efforts.

7. **How does the use of HPSC in space projects impact long-term mission planning and sustainability?**

- Extending Mission Lifespan: The reliable HPSC design extends the operational lifespan of missions, maximizing the return on investment.
- Future-Proofing: The scalable and adaptable nature of HPSC systems ensures they can meet evolving mission requirements and incorporate future technological advancements.
- Enhanced Resilience: HPSC advanced error correction and redundancy features enhance the resilience of missions, reducing the risk of mission failure due to unforeseen challenges.

8. **What software ecosystem supports the HPSC and its RISC-V architecture?**

- RISC-V Open-Source Software: HPSC supports a comprehensive suite of open-source tools, libraries, and operating systems specifically optimized for the RISC-V and HPSC architecture, such as RTOS (real-time operating systems) and the Linux kernel.
- Industry Standards Compliance: HPSC adherence to industry-standard software protocols and interfaces, such as POSIX compliance, ensures interoperability and simplifies integration with other systems.
- Third-Party Tools and SDKs: Availability of commercial and third-party software development kits (SDKs) and tools, such as GCC and LLVM toolchains for RISC-V, enhances development and deployment processes.
- Customization and Flexibility: The open nature of RISC-V allows users to modify and extend software to meet specific mission requirements, enabling bespoke solutions tailored to unique challenges, while fully supporting industry-standard base functionality.
- Active Community and Continuous Improvement: A vibrant community of developers and researchers actively contribute to the HPSC, RISC-V and Mi-V ecosystems, providing continuous updates, enhancements, and support for innovative features and optimizations.
- Compilers and Debuggers: HPSC supports high-quality compilers like LLVM for RISC-V and debuggers such as Gnu Debugger (GDB) ensure efficient code generation and facilitate thorough troubleshooting.
- Simulation and Emulation: HPSC supports QEMU for RISC-V software-based simulation and emulation of HPSC environments, allowing for comprehensive testing and validation of software before deployment.

- Integrated Development Environments (IDEs): IDEs like Eclipse and Visual Studio Code with RISC-V plugins provide a cohesive development environment, enhancing productivity and code quality through features like syntax highlighting, code completion, and version control integration.
- Operating Systems: Real-Time Executive for Multiprocessor Systems (RTEMS), Yocto Linux, VxWorks and other commercial Real Time Operating Systems (RTOS)
- Libraries: OpenSBI, OpemMP, and OpenAMP for RISC-V multi-core programming; OpenBLAS, OpenCL, POCL, Eigen, FFTW for vector programming; OpenSSL and OpenOCD for security and debugging.
- Ethernet switch API and middleware

9. What are the different grades of HPSC SOCs available?

HPSC is strategically introduced in two families:

- The radiation-hardened HPSC-RH family is engineered to survive the extreme conditions found in Medium-Earth Orbit (MEO), Geosynchronous-Earth Orbit (GEP), deep space and planetary missions. This family is designed for environments where electronics are exposed to intense radiation levels.
- The radiation-tolerant HPSC-RT family is tailored to meet the requirements of Low Earth Orbit (LEO) constellation, where system designers often need to balance between cost and longevity. This family provides an optimal solution for missions where lower radiation levels allow for a more cost-effective approach.

By ensuring both the HPSC-RH and HPSC-RT families are pin and software compatible, users can create customized solutions for both LEO and deep space missions with a single development effort. This compatibility facilitates a streamlined design process, reduces development costs, and accelerates the deployment of space technologies across various orbital regimes.

10. How does my company participate and become a partner in the HPSC Ecosystem?

- The HPSC ecosystem is a multi-entity community that offers numerous benefits, including access to cutting-edge technology, collaborative opportunities with other industry leaders, and the ability to co-develop and integrate innovative solutions. Partners also gain visibility within the HPSC community and access to specialized training and resources.

11. Will there be an evaluation board for testing and software development?

- Yes, HPSC evaluation platforms are available from Microchip.