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TECHNOLOGY DRIVES EXPLORATION

High Performance Spaceflight Computing (HPSC) for Earth Science Applications

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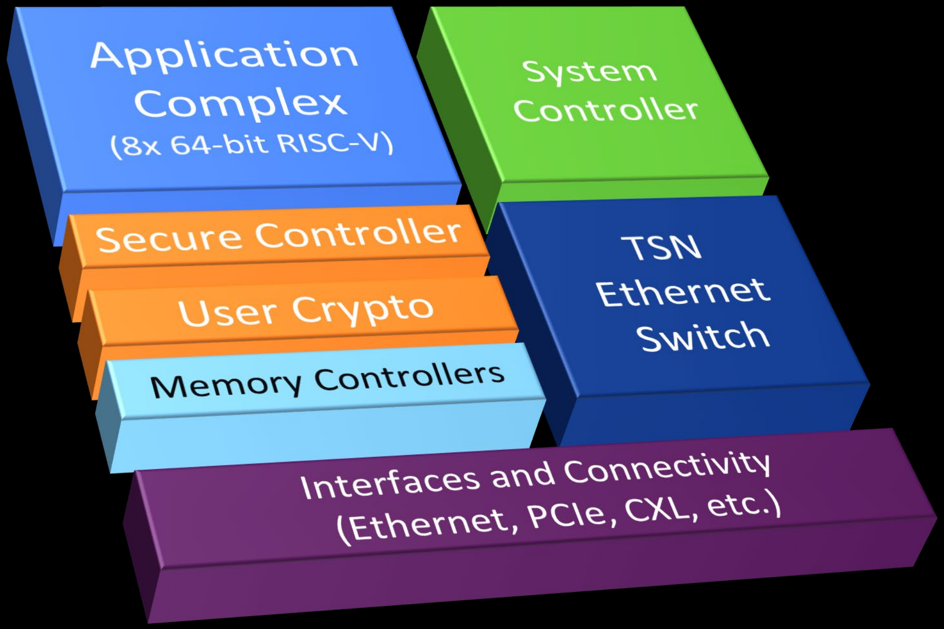
To be presented at the 2024 Earth Science Technology Forum (ESTF), Crystal City, VA, June 11-12, 2024

What is HPSC?



- **100X the computational capacity of current space flight processors**
- **Multicore architecture provides unprecedented flexibility between computational performance, power management, & fault tolerance**

- **NASA Program:** (Partnership jointly funded by STMD and Microchip): HPSC advances the capabilities of space-based computing for upcoming missions. Infusion targets across human, robotic, and science missions

- **Requirements:** Jointly developed by NASA, JPL, and Microchip

- **Fault-tolerant 10-core Heterogenous RISC-V Architecture:** Extremely high performance per watt. Radiation hard by design

- **Initial Delivery**: SoC, Evaluation Board, Software Stacks, Models, Education & Training, Application Support

- **Industry Eco-System**: Industry-funded, HPSC-compatible roadmap benefits NASA, JPL, mil-aerospace, & terrestrial applications for decades to come

- **Capability Advances:** Cost, Schedule, Risk reduction: Mission and science autonomy, intelligent vehicles, flagship science, crew assist. Software-based flexibility

Why HPSC is Critical to NASA

Missions demand more Compute & Autonomous capabilities

- Longer missions, harsh environments, long communication latency, higher mission complexity, lower power

Onboard science data processing needs are increasing

- Increased sensor data bandwidth, limited downlink bandwidth

Traditional space processors cannot scale technically or commercially

- Legacy obsolescence and COTS face challenges for space environments

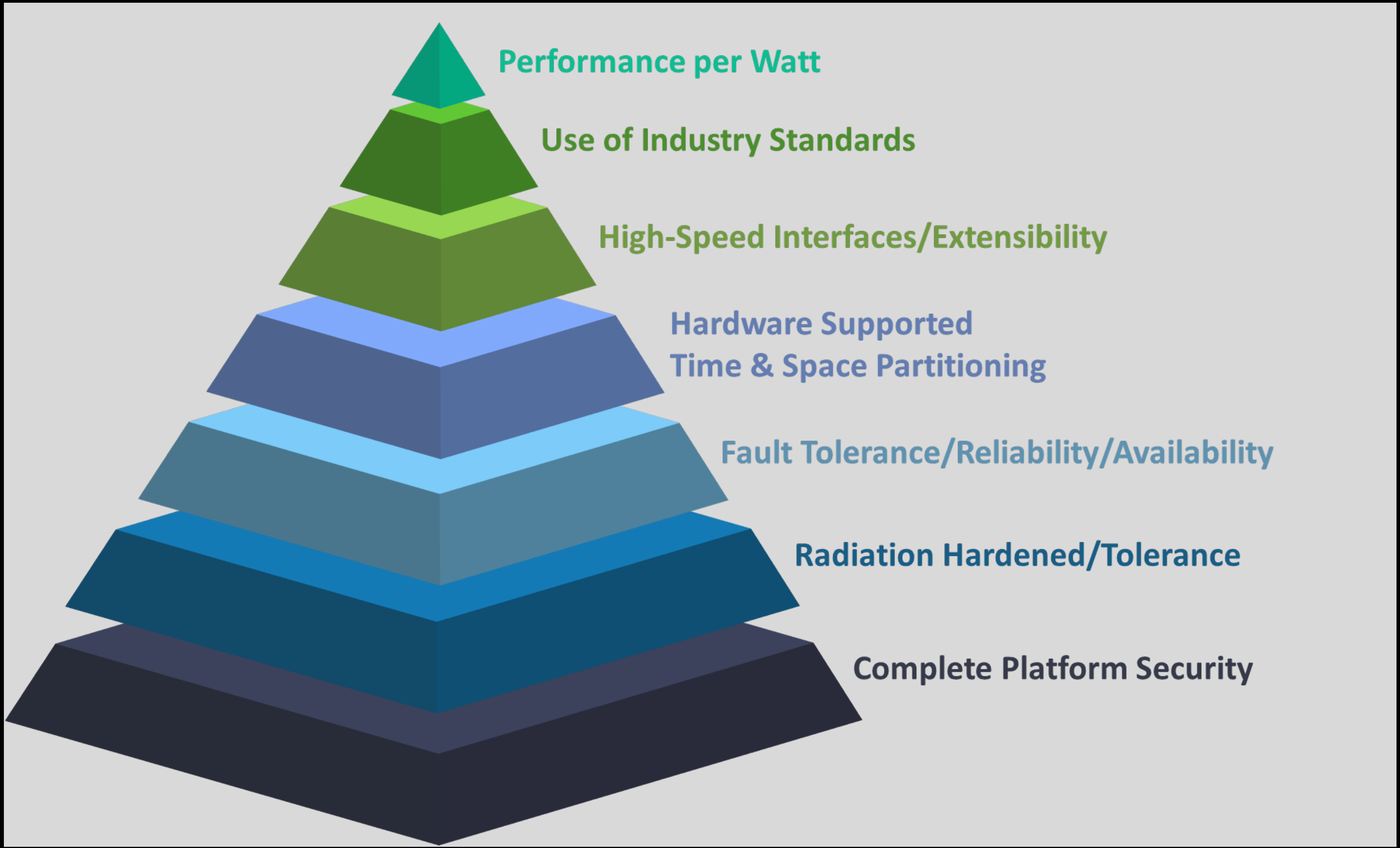
RadTol + Fault Tolerance + Power Efficiency + Security

- Required for mission critical apps
- Legacy tech does not support these capabilities well.

Software is Key. No one can afford their own software stack

- HPSC Open-source Ecosystem enablement with no barriers
- Design Re-Use, Partnerships, Industry Standards, Interoperability required for next-generation success

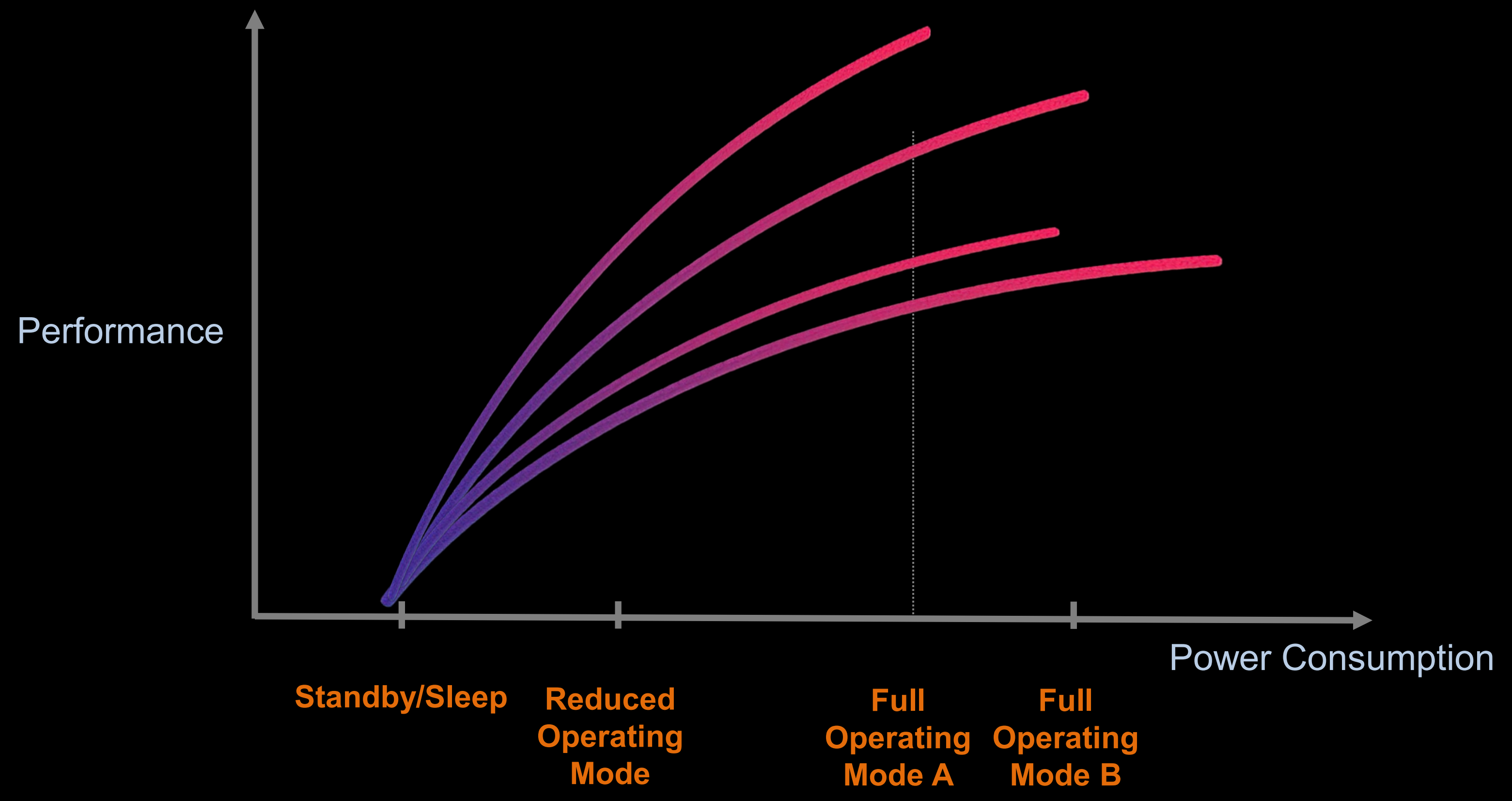
HPSC Foundational Capabilities



Radiation Tolerance, Fault Tolerance & Security Are Foundational Critical Capabilities

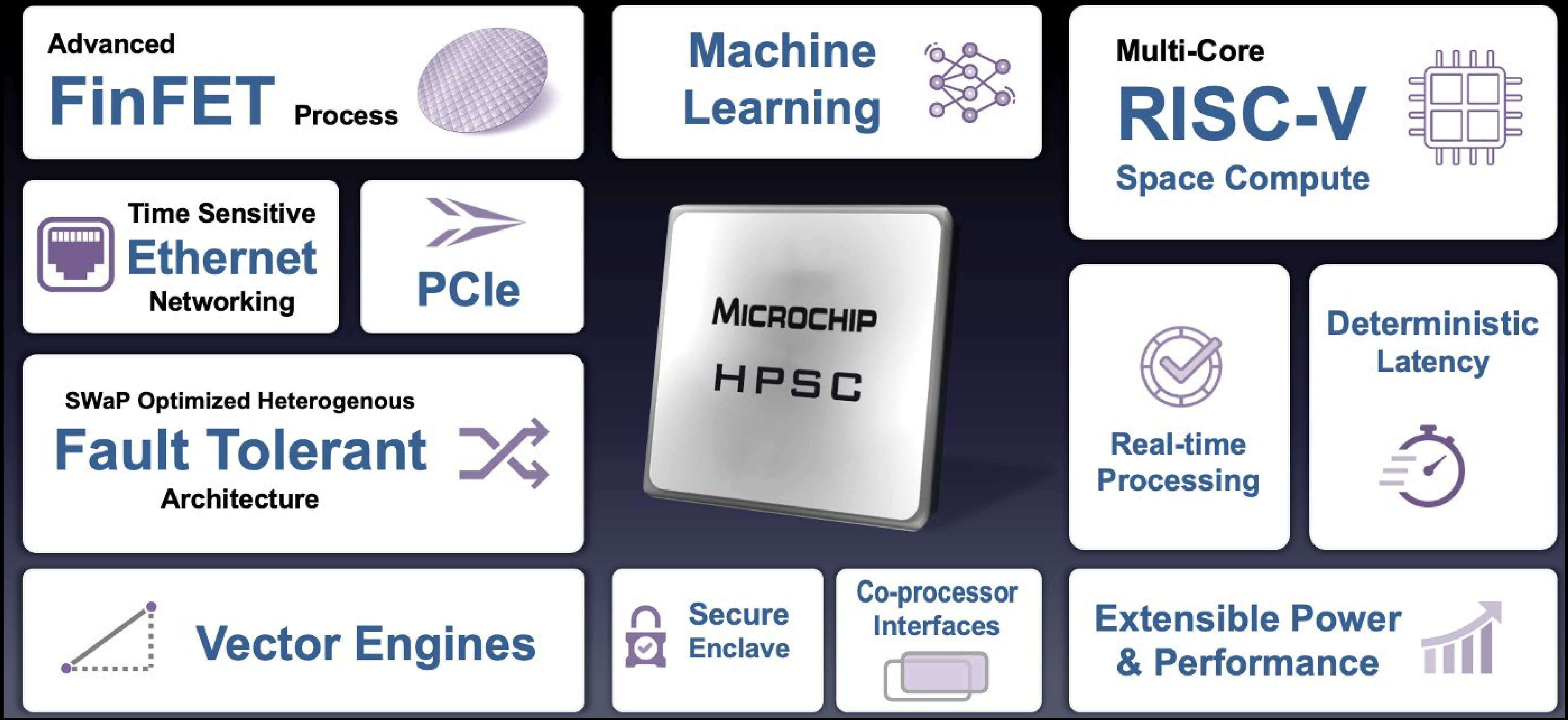
HPSC Scalability - Small to Large

Power, Performance, Fault Tolerance and other Functions: Scalable via Software Control



HPSC Performance & Power are Dynamically Tunable based on Mission Needs

HPSC – Architecture Highlights



NASA Science: HPSC Use Cases

Rovers & Helis

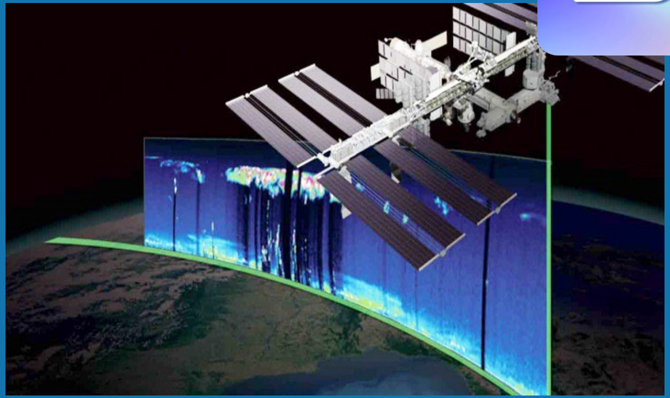
- Vision Processing
- Motion/Motor Control
- Nav Planning
- Science Instruments
- Communication
- Power Management
- Thermal Management
- Fault Detection/recovery

Landers

- Hard real-time compute
- High-rate sensors w/zero data loss
- High level of fault protection/fail over

High Bandwidth Instruments

- Real-time sensor data
- Non-mission critical
- High bandwidth sensors
- Large calibration sets in non-vol memory

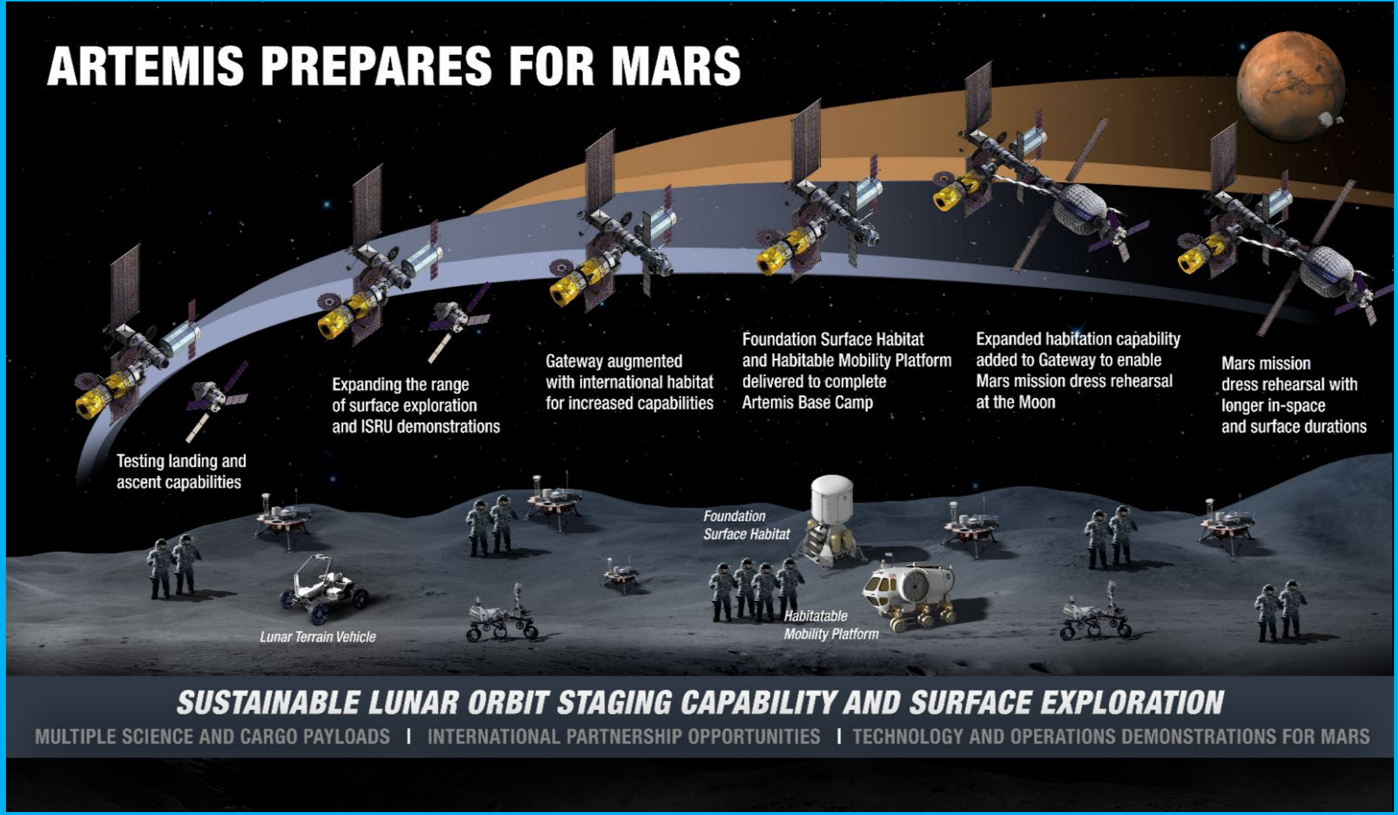


Smallsats

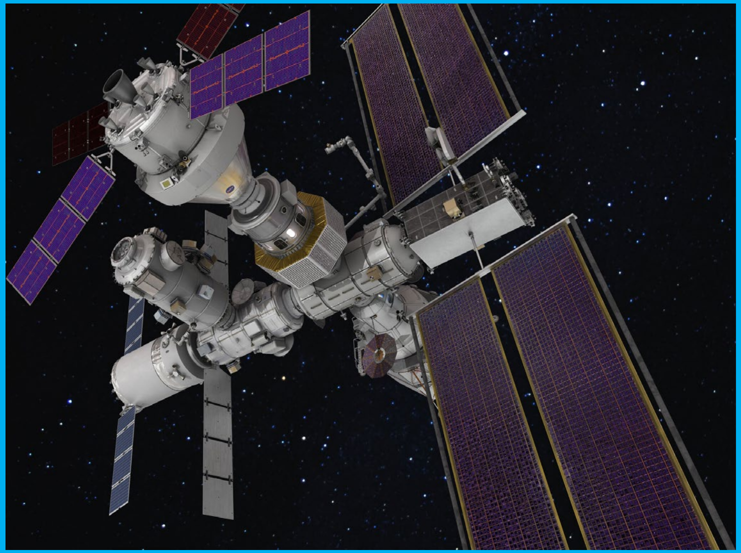
- Hard & soft real-time
- Guidance & Control
- Autonomy & crosslink communication
- Sensor data processing
- Autonomous science

NASA Crew Exploration: HPSC Use Cases

- Robotics working independently and collaboratively with crew
- Robotics enabling lunar surface infrastructure
- Autonomous landing systems
- Increased autonomy extends missions beyond LEO
- Support for Earth independent operations

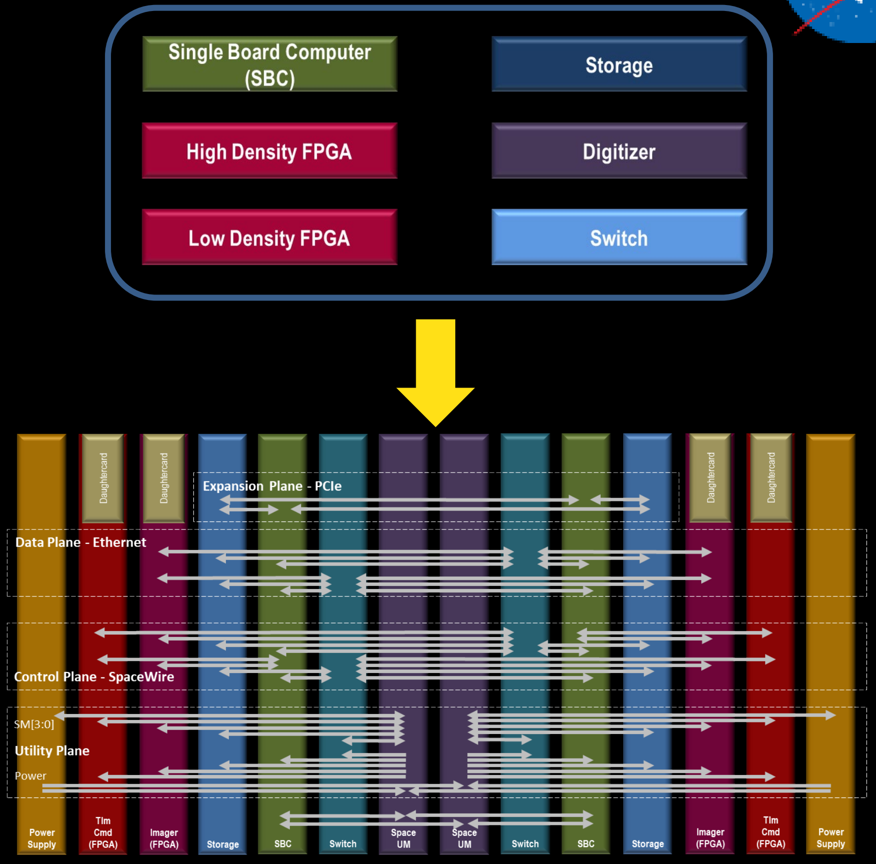


Gateway - Full Configuration in Orbit



The HPSC Ecosystem

- **In tandem with HPSC development, NASA is working to the develop the "ecosystem" that is necessary to accelerate the infusion of HPSC into upcoming missions**
- **Hardware**
  - **NASA and industry partners are working within SOSA™ (Sensor Open System Architecture) to develop an interoperable SpaceVPX avionics specification**
  - **This will allow cards from different vendors to interoperate within a chassis**
  - **These cards can form the building blocks for HPSC-based avionics**
- **Software**
  - **The use of the RISC-V ISA allows HPSC to leverage a broad range of existing software tools and libraries**



Redundant 3U System

Operating Systems	Languages	Modern Tools	Industry Standards
VxWorks	C	LLVM	OpenMP
RTEMS	C++	OpenBLAS	OpenGL
Linux	Rust	NumPy	OpenCL
	Python	OpenCV	SPIR

Notional Earth Science Use Case – Land Imaging

- Earth Science multispectral land imaging ESPA-Grande-class smallsat (one of several in a constellation)

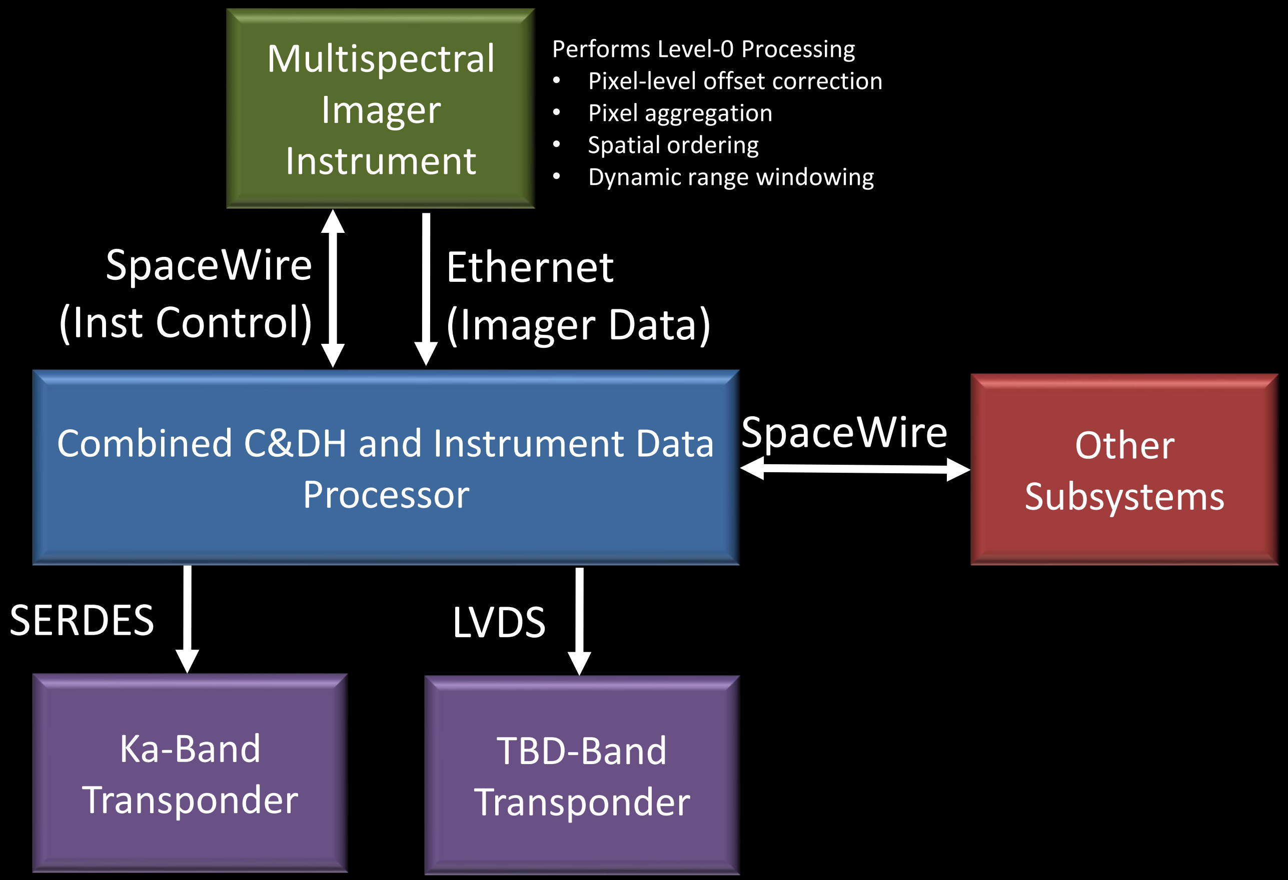
- Combined spacecraft avionics and science data processing in a single box
- Collecting data from push-broom imager

- Onboard science data processing for compression, data prioritization, and event detection

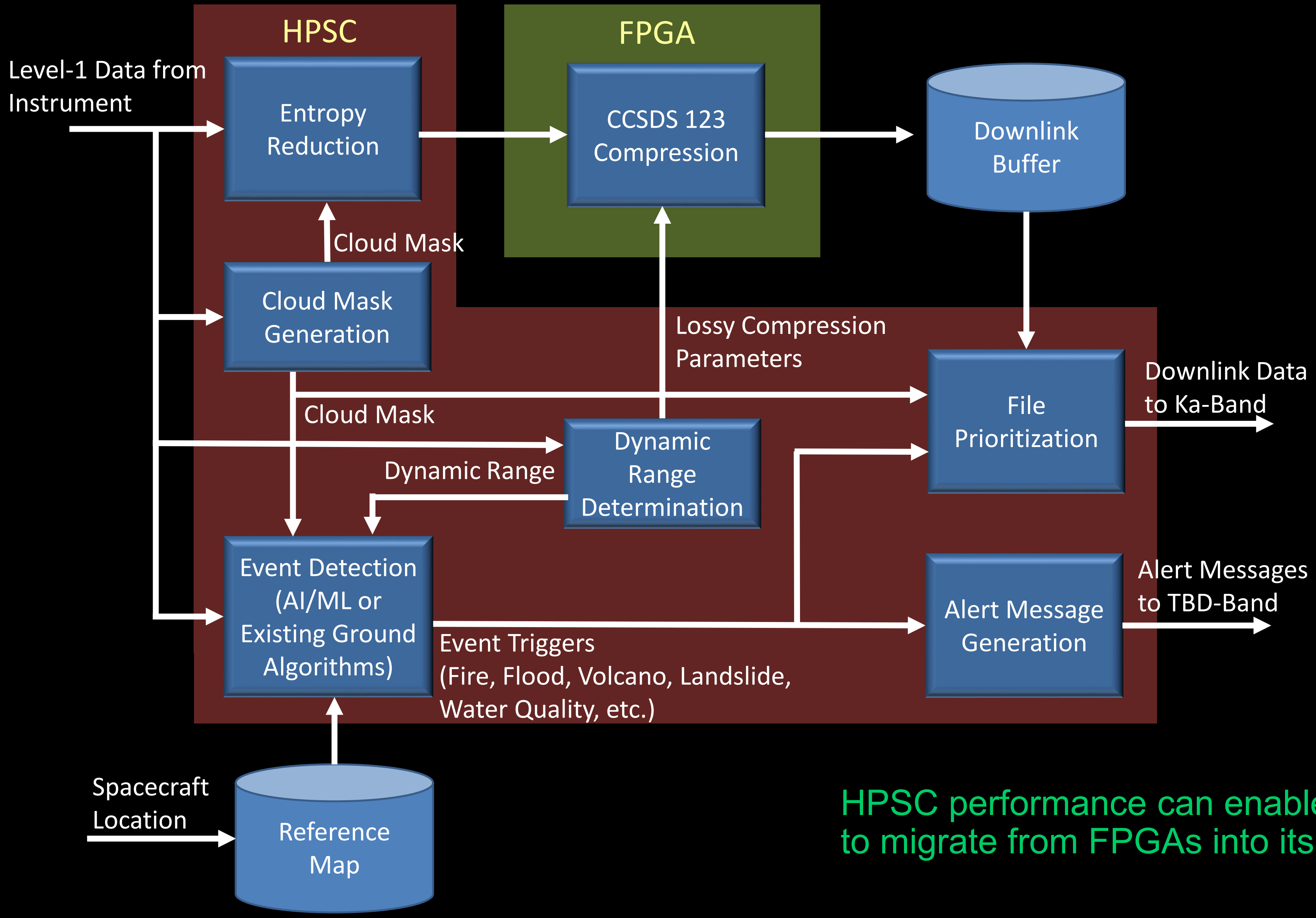
- High priority events are sent via low latency links to end users and the larger sensor web

- Single string system, as system-level redundancy is provided via the larger constellation

- May need selective redundancy for spacecraft avionics functions to ensure de-orbiting



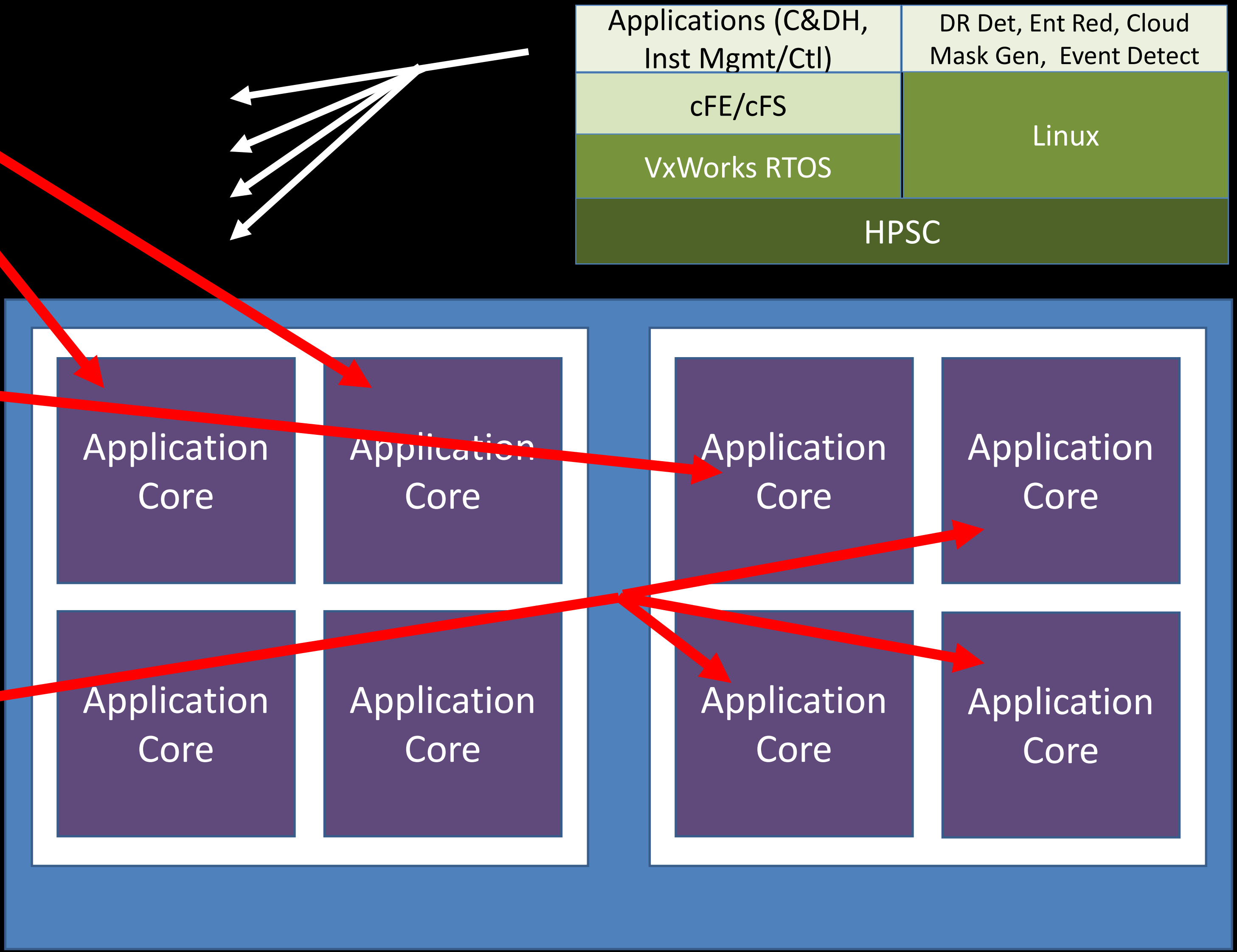
Notional Processing Flow



HPSC performance can enable processing to migrate from FPGAs into its processors

Notional Software Architecture

- C&DH Application
- Instrument Management and Control Application
- Event Detection Management and Message Generation Application
- Cloud Mask Generation
- Dynamic Range Determination
- Entropy Reduction
- Event Detection Applications (varying by spacecraft location)
  - Fire
  - Flood
  - Volcano
  - Landslide
  - Water Quality



HPSC Next Steps

- **Ready Today**
  - HPSC Documentation
  - HPSC Software and models

- **Coming Soon**
  - HPSC Cycle Accurate Emulator – Supports early benchmarking
  - Opportunity exists to benchmark algorithmic kernels for instrument processing, May 2024 – Nov 2024

- **Coming Q1 CY2025**
  - HPSC Evaluation Boards
    - To be available commercially to developers across NASA
    - Facilitate for application development and benchmarking

- **Coming Q4 CY2025**
  - Qualified HPSC Devices

- **Ongoing**
  - Work with industry to establish the HPSC ecosystem for our future missions (SBC, peripheral hardware, software)

We seek near-term engagement with Earth Science user community to expedite HPSC infusion

Acronym List

AI	Artificial Intelligence	Open BLAS	Open Basic Linear Algebra Subprograms
C&DH	Command and Data Handling	OpenCL	Open Computing Language
CXL	Compute Express Link	OpenCV	Open-Source Computer Vision
EELV	Evolved Expendable Launch Vehicle	OpenGL	Open Graphics Library
ESPA	EELV Secondary Payload Adapter	OpenMP	Open Multiprocessing
ESTF	Earth Science Technology Forum	NumPy	Numerical Python
EELV	Evolved Expendable Launch Vehicle	PCIe	Peripheral Component Interconnect Express
FET	Field Effect Transistor	RISC	Reduced Instruction Set Computer
FPGA	Field Programmable Gate Array	RTEMS	Real-Time Executive for Multiprocessor Systems
HPSC	High Performance Spaceflight Computing	SBC	Single Board Computer
JPL	Jet Propulsion Laboratory	SERDES	Serializer Deserializer
LEO	Low Earth Orbit	SOC	System-On-a-Chip
LLVM	Low Level Virtual Machine	SOSA	Sensor Open Systems Architecture
LVDS	Low Voltage Differential Signaling	STMD	Space Technology Mission Directorate
ML	Machine Learning	TBD	To Be Determined
NASA	National Aeronautics and Space Administration	TSN	Time-Sensitive Networking
NumPy	Numerical Python	VPX	Virtual Path Cross-Connect