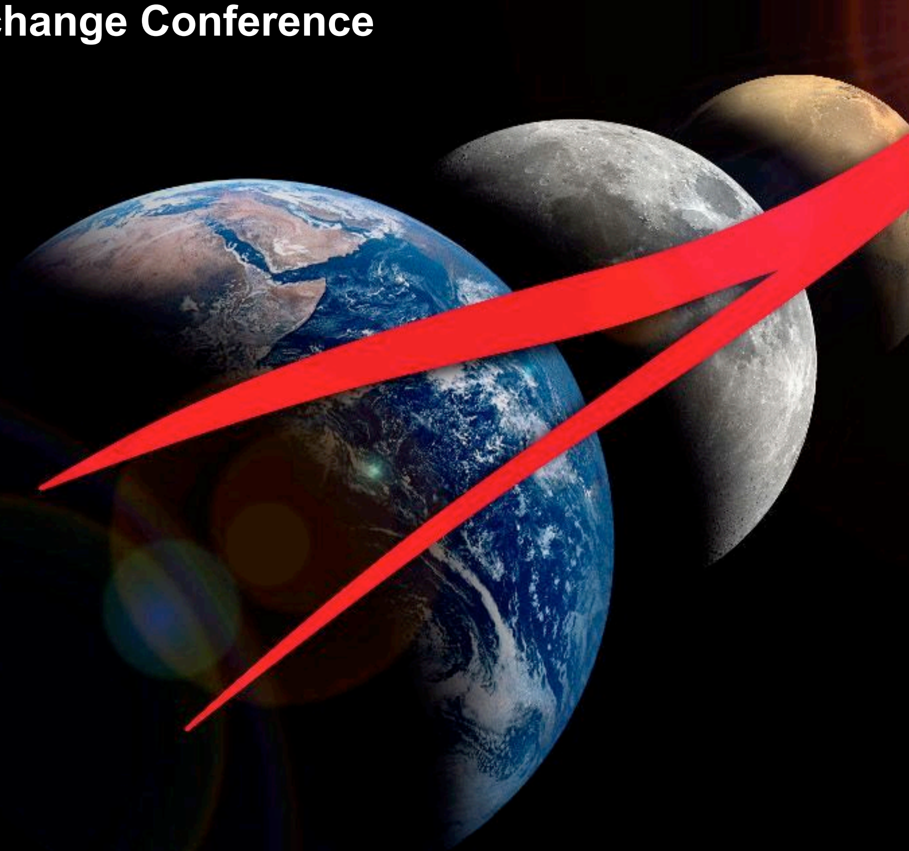
Avionics for Exploration

Technology Exchange Conference
November 2007



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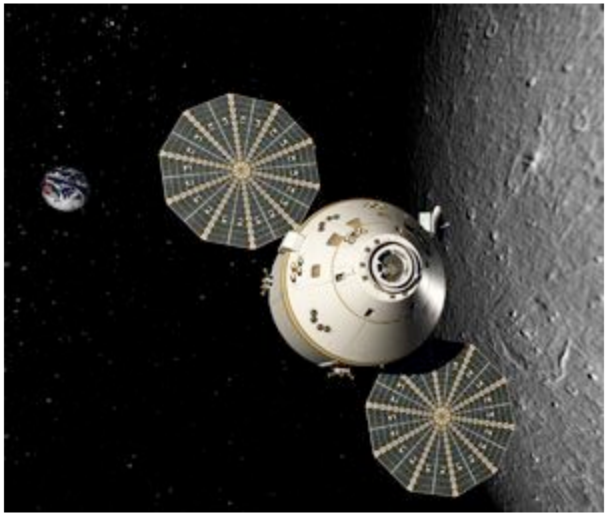
CONSTELLATION

Purpose

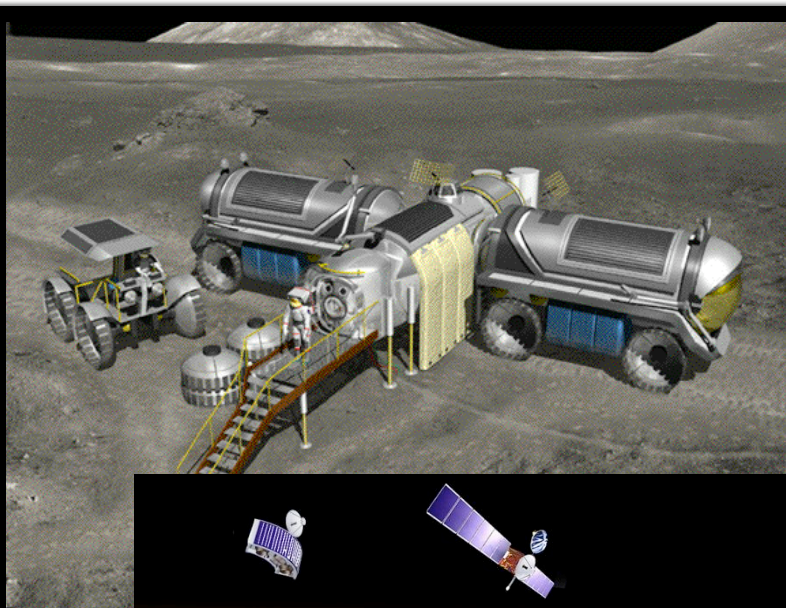
- Make NASA personnel available to interact with industry, academia, and other organizations to foster new ideas
- Present NASA mission avionics drivers
- Present initial ideas to meet NASA's future avionics needs
- Solicit ideas to help meet future NASA mission needs

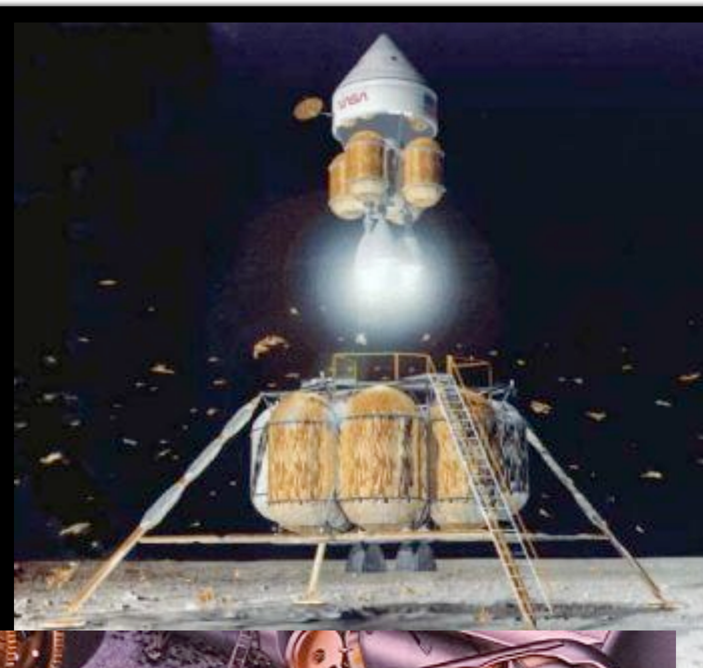
Overview

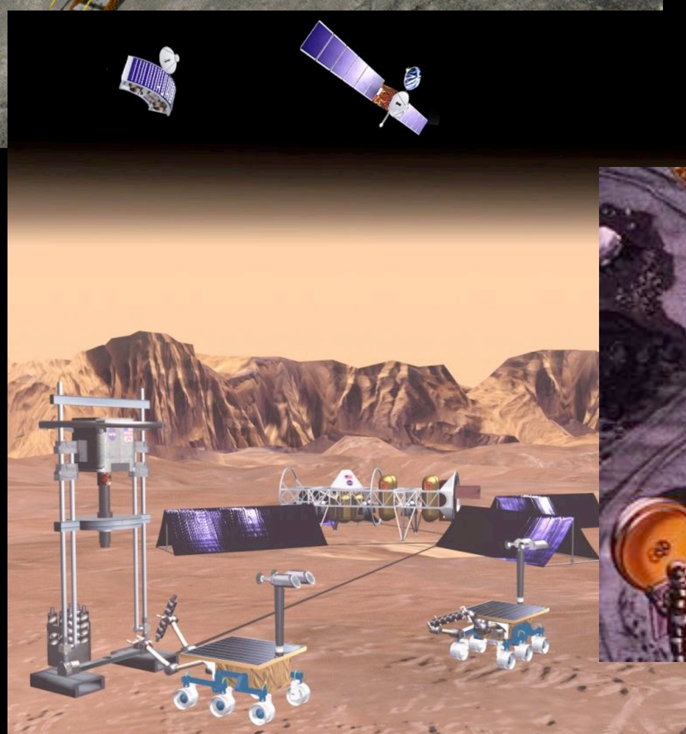
- NASA Avionics Presentation
- Feedback
- Break into splinter groups if desirable
- 1-on-1 sessions
- Discussion “on the floor” at avionics exhibit

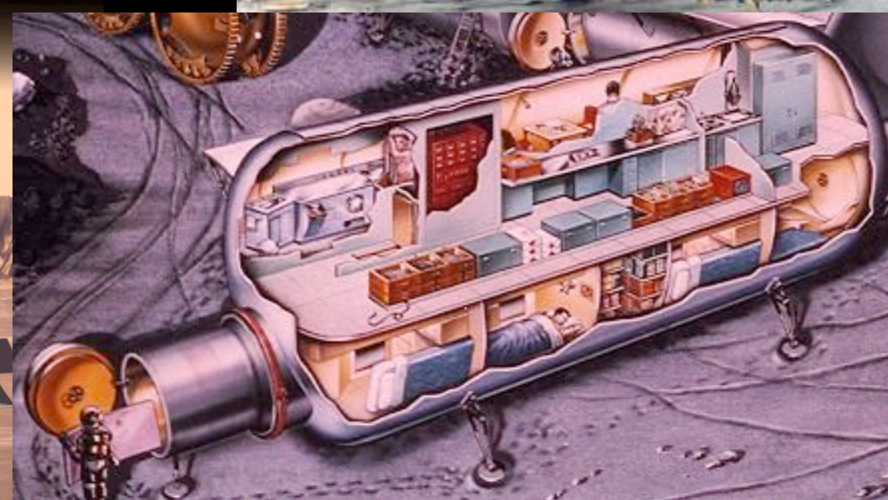


Future Missions









Avionics Drivers

- **Safety**
  - Reliability, Fault Tolerance, Human Rating
- **Survivability**
  - Ascent, Descent, Radiation, Vacuum
  - Long Duration Exposure
- **Resource limitations**
  - Power, Mass, Volume
- **Performance**
  - Video Rates, Autonomy, Docking, Landing
- **System of systems**
  - Interoperability, Managing complexity, Commonality
- **Affordability**
  - Development/Mission Cost, Durability, Repair/Maintenance
- **Evolving Architecture**
  - Flexible, Scalable, Extensible, Adaptable, Reusable

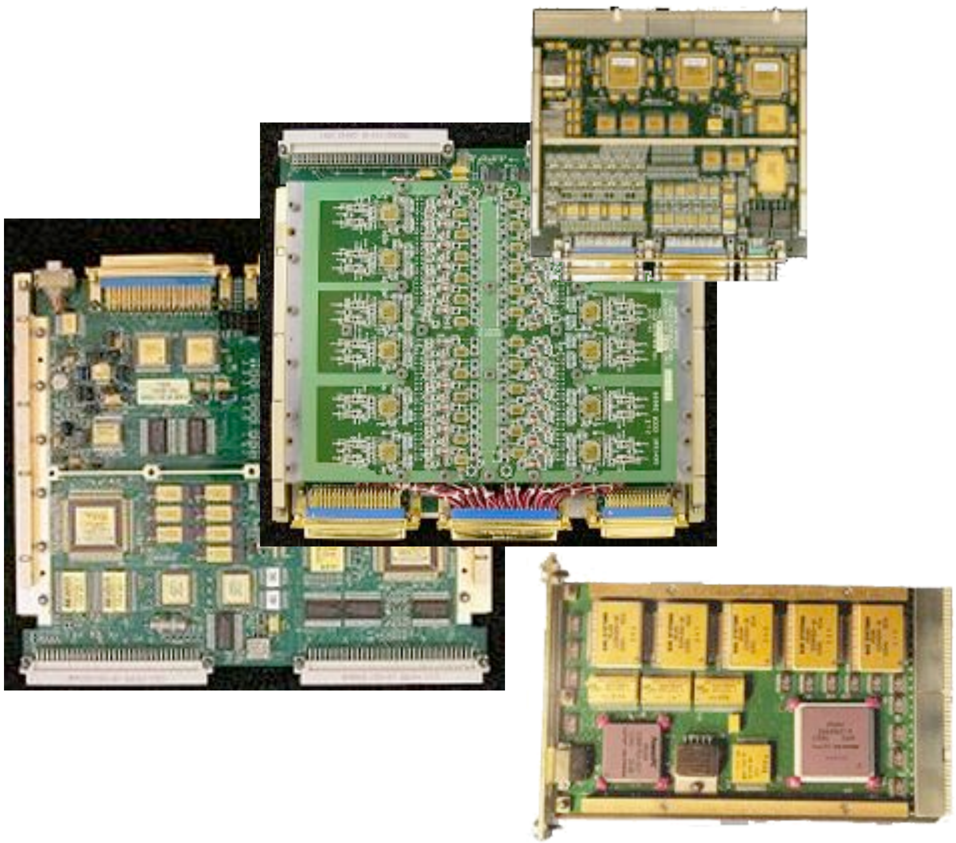
Avionics: Goal, Issues

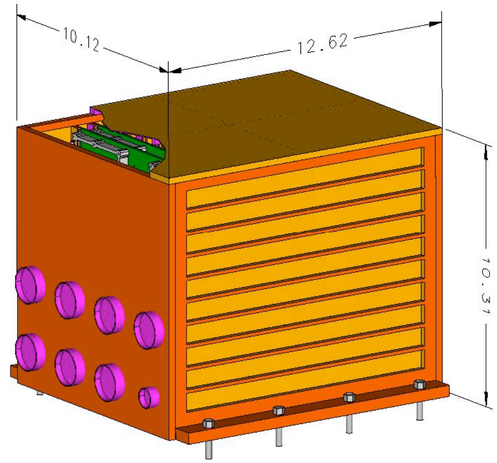
- **Avionics Goal: Provide extensible interoperable avionics solutions for a broad class of NASA exploration missions to optimally meet or exceed requirements while managing the logistics of development, deployment, and maintenance of avionics in the Constellation architecture.**

- **Current Avionics Issues**
  - Little commonality
    - Making sparing untenable for lunar missions
  - Box-level line replaceable units (LRUs)
    - Untenable maintenance philosophy for outpost missions
  - Point designs
    - Little flexibility, adaptability, or opportunity for design variation to accommodate multi-use avionics
  - High power, volume, and mass
    - Need to leverage approaches that optimize "system performance"

Where We Are Today

- **Dominated by custom solutions, often vendor proprietary**
  - Limited use of standards with many exceptions

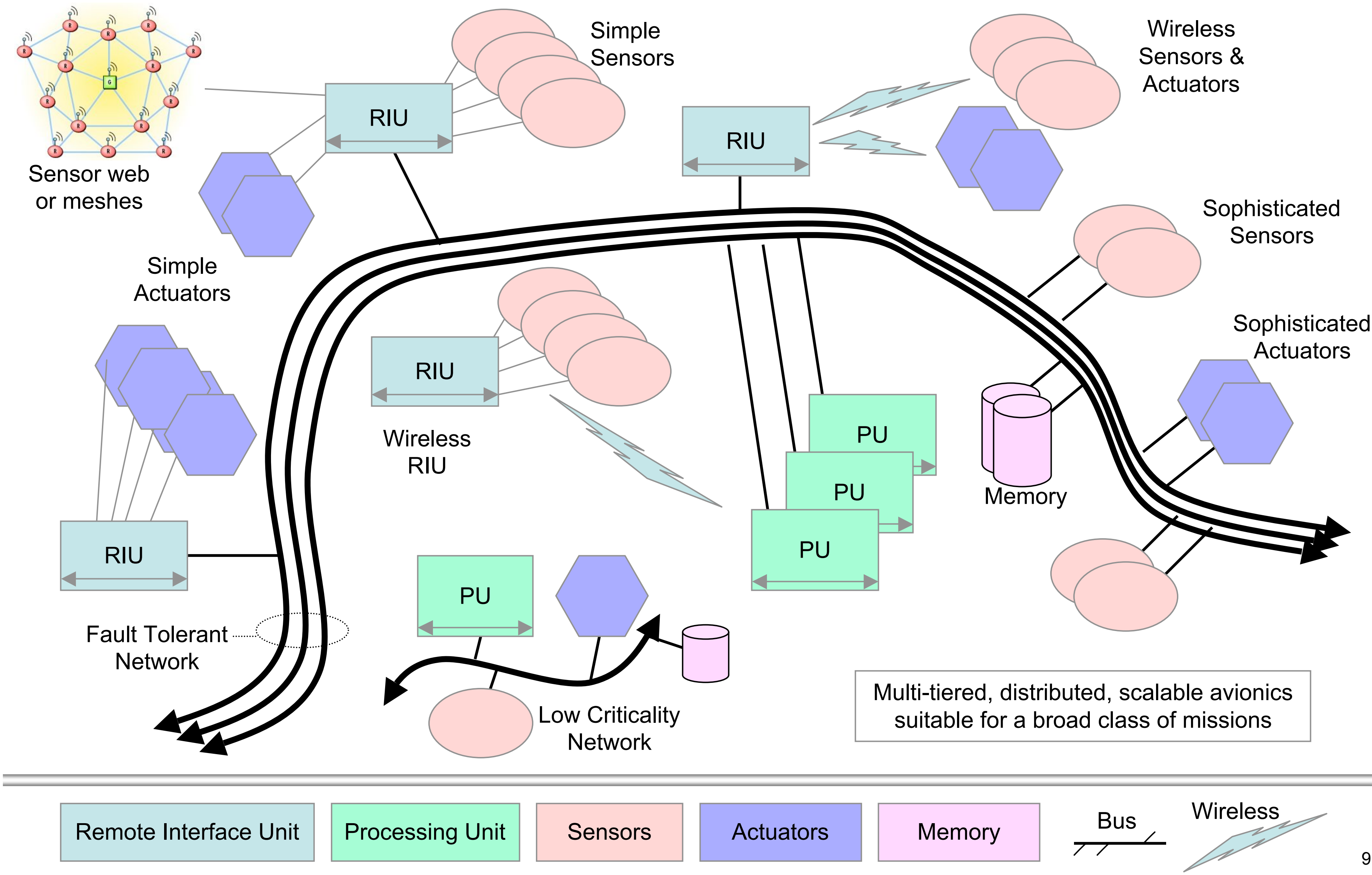




Some Ideas for Future Avionics Systems

- Tunable Avionics
- Scalable Avionics
- Reconfigurable Avionics
- Redundancy Management
- Wireless Technologies
- Storage technologies
- Software Approach
- Self-Describing Systems
- Radiation Mitigation
- Managing Power
- Business Models and Investment Strategy

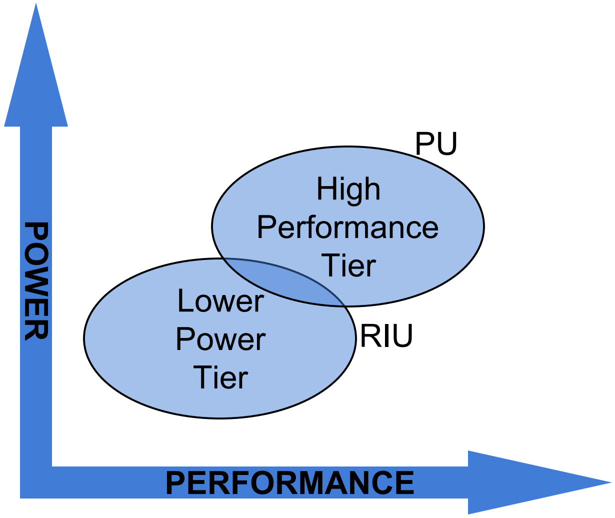
Where We Want to Be

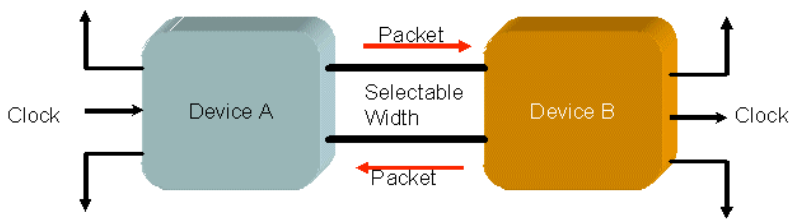


Multi-Tier Tunable Avionics

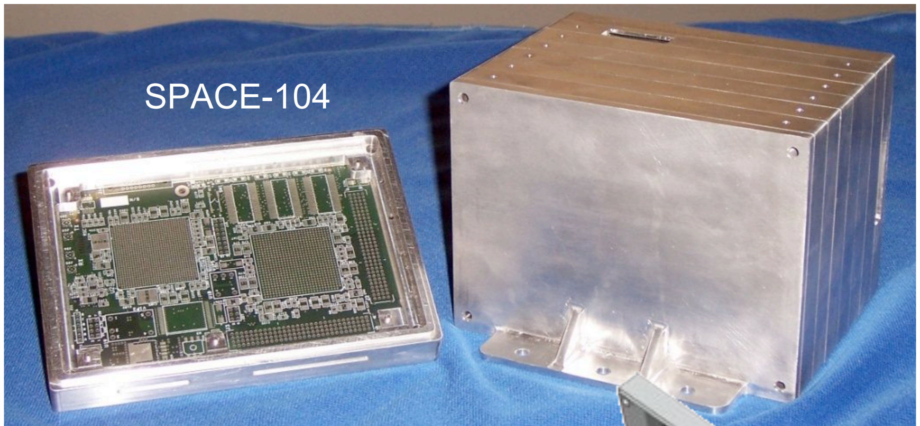
♦ **Use of Tunable Processor Units, Remote Interface Units, and Bus Interconnect to optimize designs to meet requirements of varied missions with common designs while managing power**

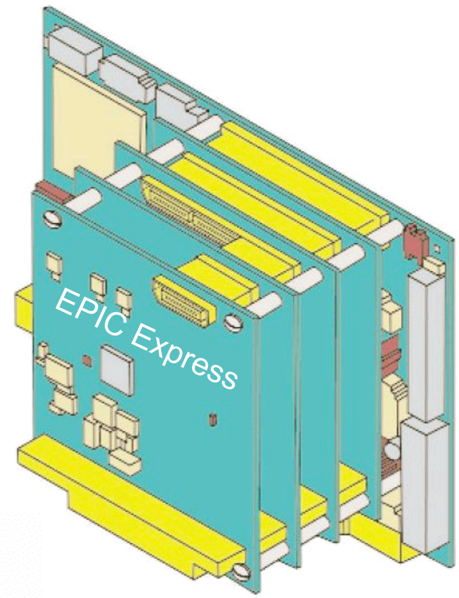
- **<u>Tunable Processor Units (PUs) provide high top-end performance</u>** with traditional RTOS functionality extended for redundancy management and other middleware functionality. Reconfigurable computing (RC) to special purpose high throughput applications.
- **<u>Tunable Remote Interface Units (RIUs) are designed for IO scalability and optimized for power</u>**, **<u>mass, and volume.</u>** The RIU's capability is comparable to a microcontroller rather than the general purpose microprocessor of the PU.
- **<u>Buses with tunable bandwidth</u>** (i.e. tunable frequency and/or data width) allows matching the interconnect to the mission requirements. Meet determinism requirements for critical system while supporting IP-based interoperability

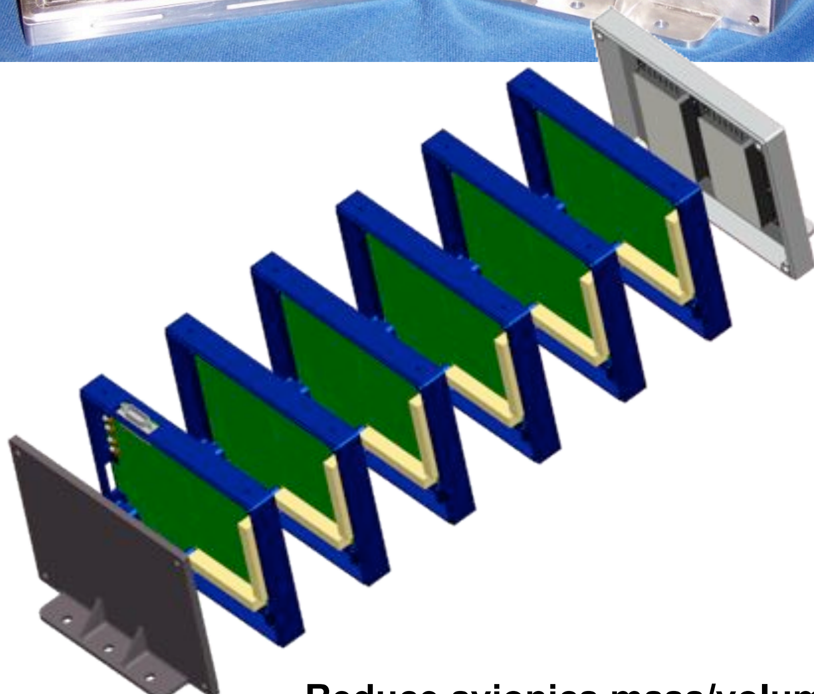


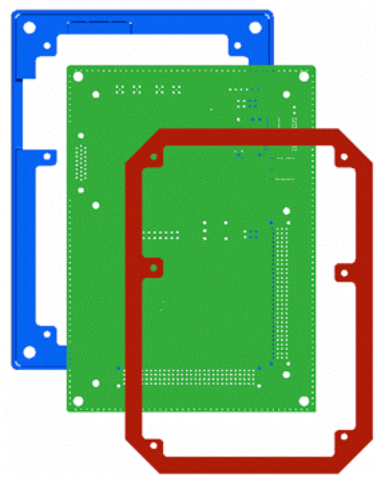


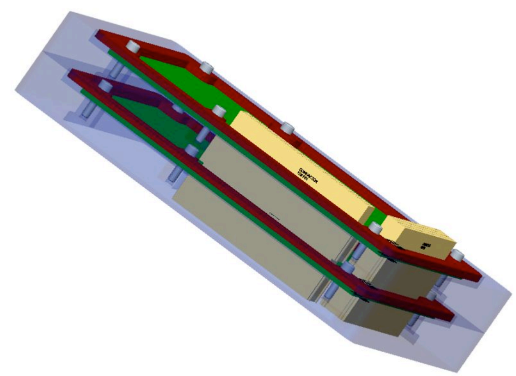
Modular Scalable Avionics







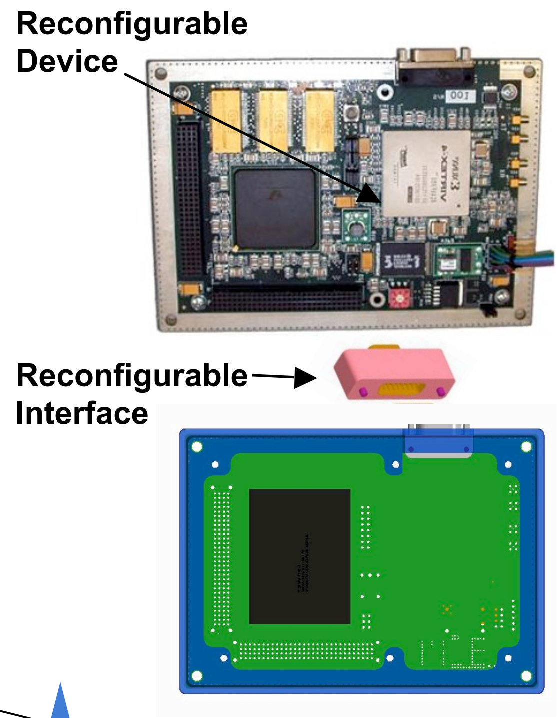


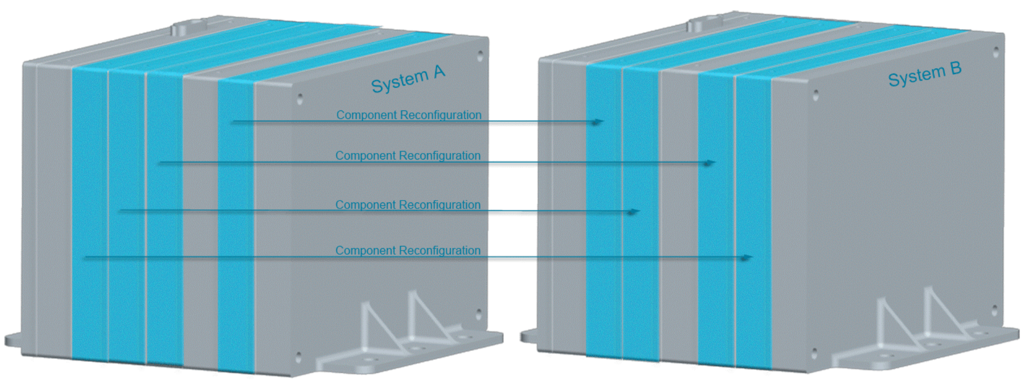


Reduce avionics mass/volume, leverage industry standards, and develop a common modular maintainable standard for space avionics systems

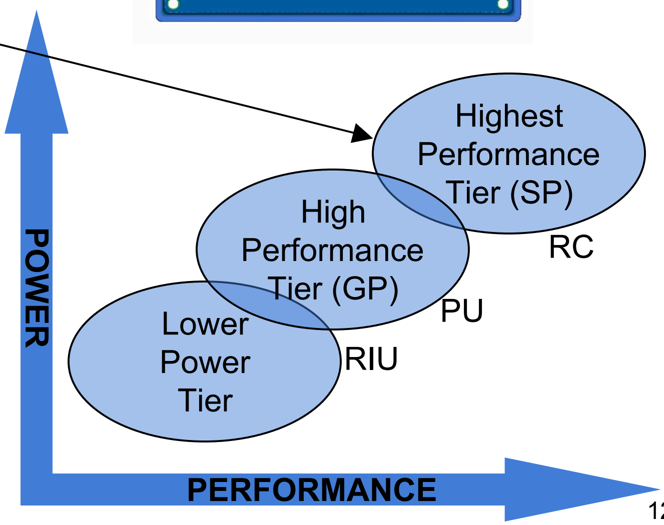
Reconfigurable Avionics

- **Devices, modules, or systems can be reconfigured to support multiple mission and applications with common designed.**
- **Potential benefits**
  - Reduction of spares
  - High performance for selected applications
    - video processing, DSP, software radio, real-time hazard avoidance,…
  - Reduced power for selected applications



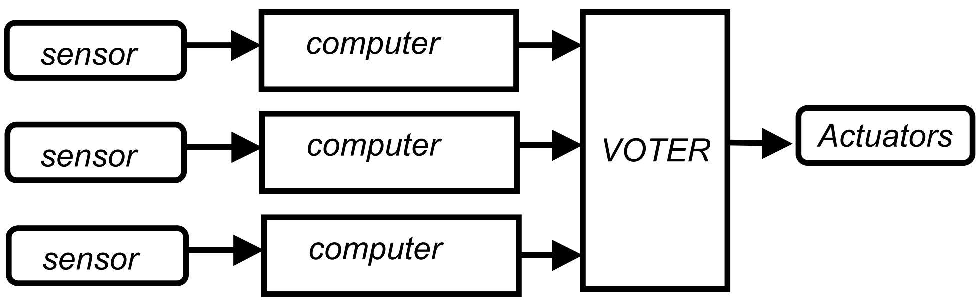


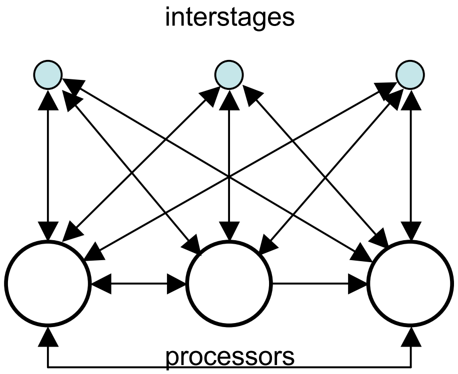
Reconfigurable Modules



Redundancy Management

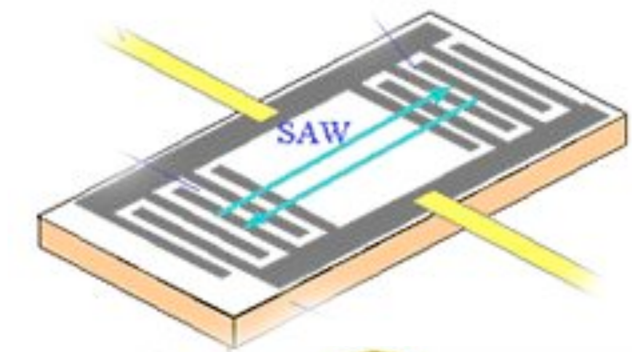
- For effective fault-tolerance a proven-reliable redundancy management hardware/software solution is required. This solution needs to be designed into the avionics architecture from inception and should provide transparent error-free synchronization and data transfer.
- Redundancy management requirements vary from 0, 1, to 2 fault tolerant systems with various strategies (real-time masking, cold-sparing, switchover, etc). Multiple strategies need to be supported.
- Combine redundancy management strategies, with reconfigurable computing and modular-layer software can provide a flexible (mission selectable) redundancy management solution.
- Well defined interfaces to application-independent redundancy management.

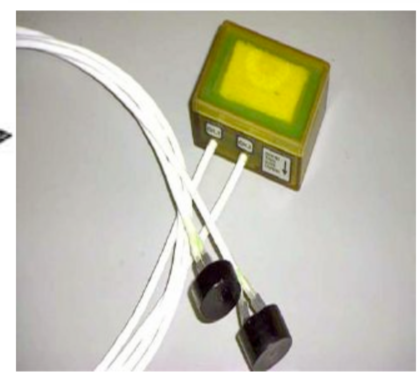


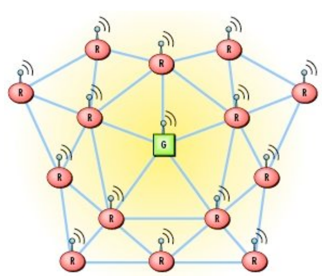


Wireless Interconnectivity

- **Wireless has the potential to reduce wiring harness mass and improve system maintainability**
  - Supports deferred sensor placement allowing better decision making
- **Wireless technologies to reduce internally hard-wired communications requires study and development**
  - Passive and/or active sensor networks
  - Tracking/RFID
  - Wireless instruments
  - Wireless PDAs, laptops
  - Wireless voice comm
  - Sensor web/mesh technology

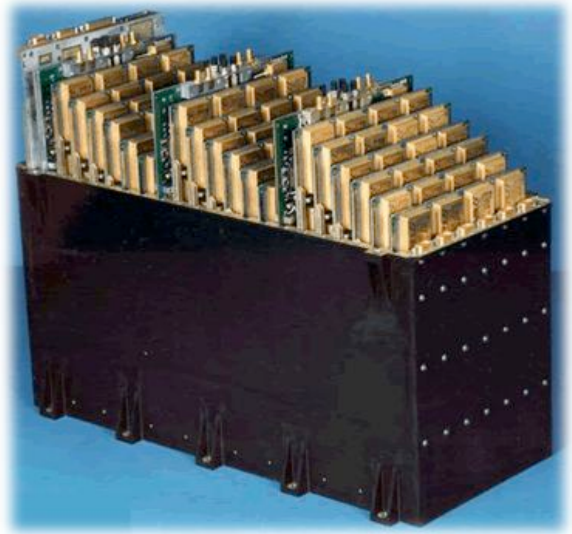






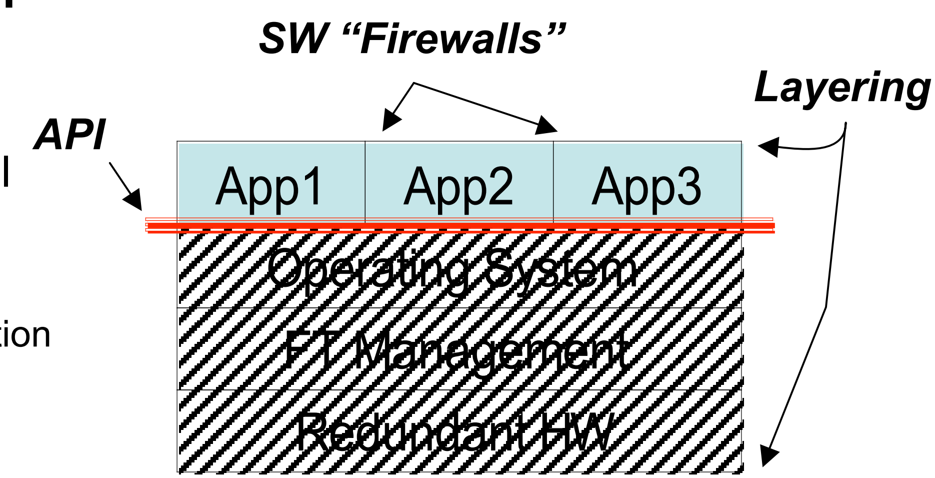
Storage Capability

- Memory technologies have always been unique (RAM, disk/tape, EEPROM, FLASH, etc.) and present challenges in the space environment (SEEs, TID, loads, vacuum, etc.).
- Both volatile and non-volatile (NV) memory are needed for program and data storage. Telemetry must be buffer during communication outages and during high bandwidth events. Documentation must be stored for a paperless cockpit.
- Reliable scalable memory solutions are needed to support mission requirements.
- Network-based distributed repositories enables sharing of resources

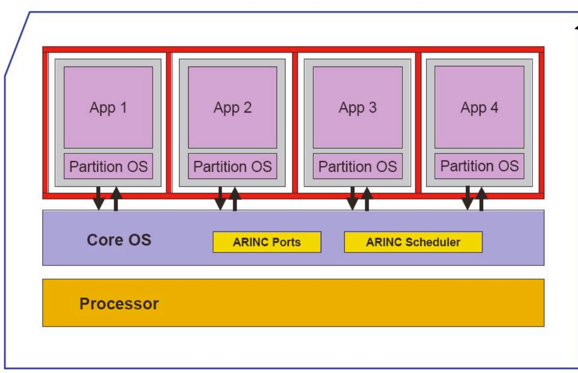


Modular-Layered-Partitioned Software Support

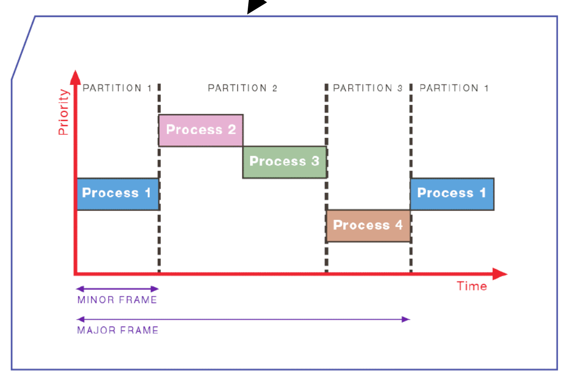
- **The avionics concept should mesh with a modular layered software concept that provides:**
  - Multiple levels of abstraction with well defined interfaces between layers
    - RTOS functionality
    - Redundancy management & abstraction
    - I/O management
    - Software partitioning
      - Firewalls for functions of different criticality
    - Network/Communication abstraction
    - Well defined application interfaces



ARINC 653 Functionality Support

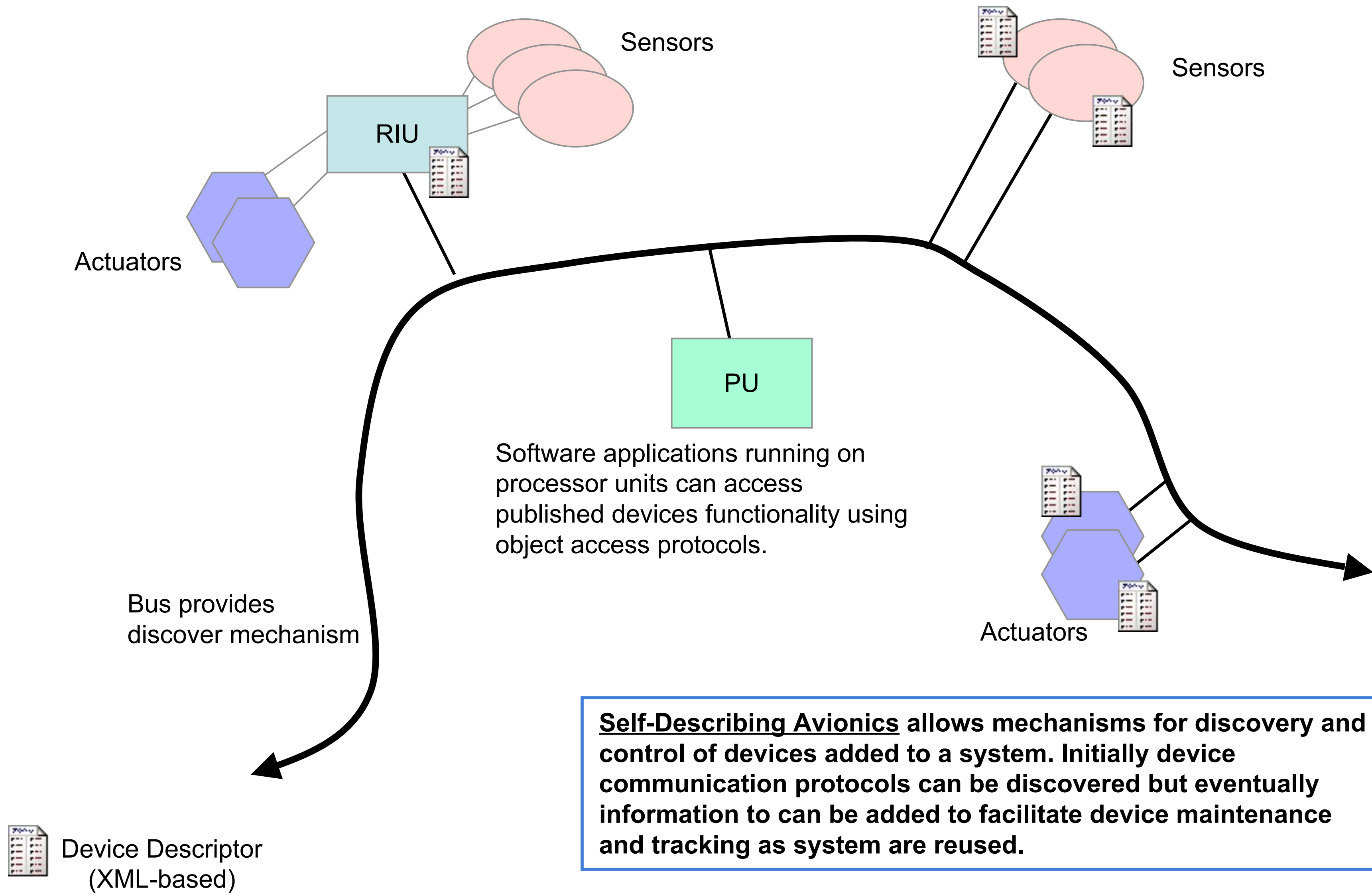


Space Partitioning



Time Partitioning

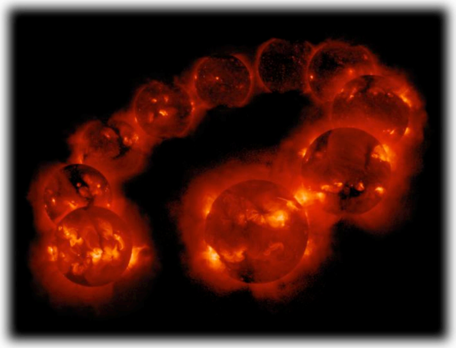
Self-Describing Avionics & Software



<u>Self-Describing Avionics</u> allows mechanisms for discovery and control of devices added to a system. Initially device communication protocols can be discovered but eventually information to can be added to facilitate device maintenance and tracking as system are reused.

Reliable Radiation Tolerant Systems

- **Lunar Environment**
  - Primary Radiation Sources:
    - Galactic Cosmic Rays
      - Constant Rate
      - Omni-Directional
    - Solar Flares
      - 11 year cycle – 4 quiet/7active, log-normal intensity distribution
      - Typical flare lasts approx 24 hours, with highest energy particles arriving first
  - No lunar magnetosphere
    - No shielding from Solar Radiation or Galactic Cosmic Rays (GCRs)



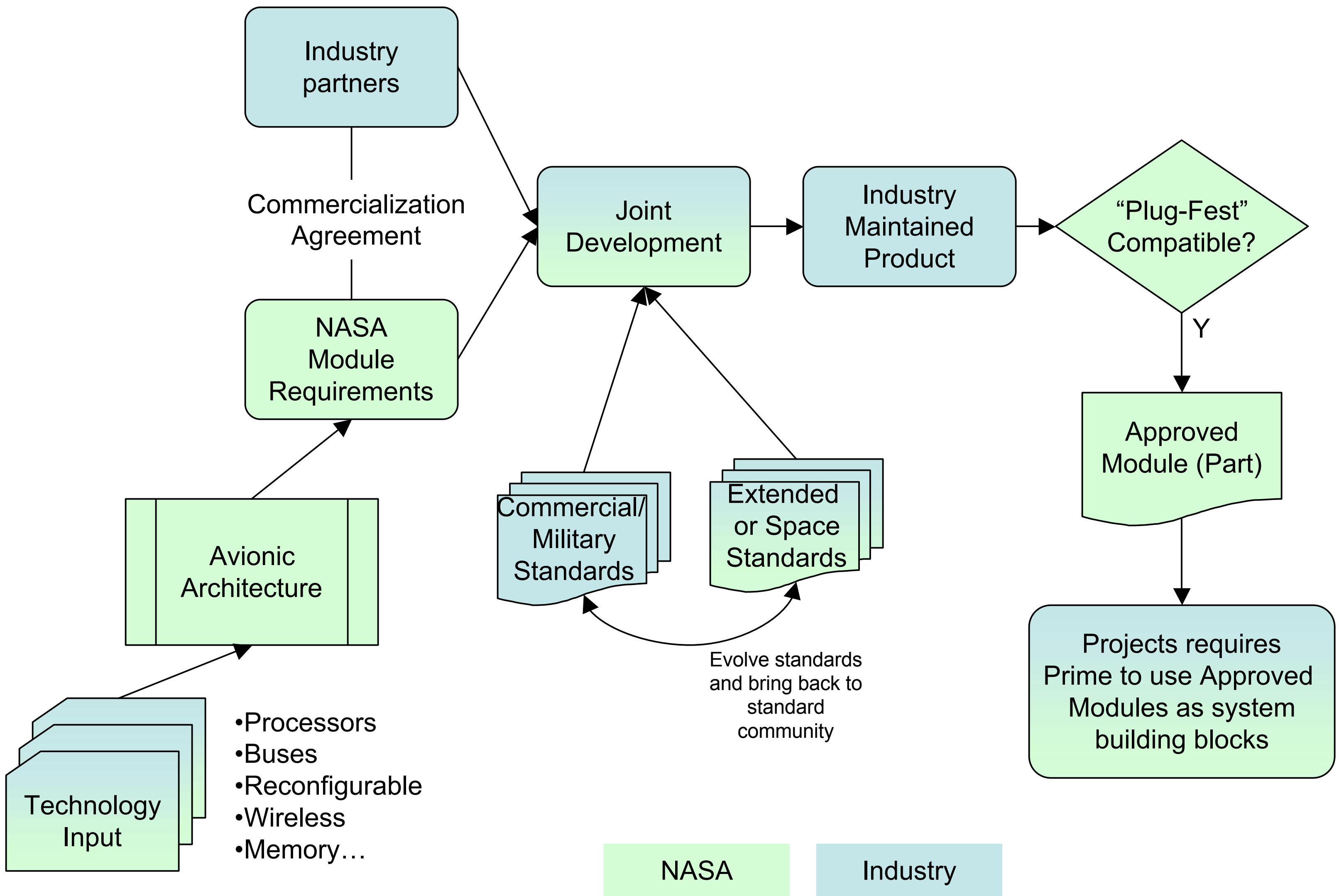
- **Lunar radiation environment affecting device life is modest**
  - CMOS devices screened for TID and Latchup can be utilized but appropriate testing and qualification are needed to ensure reliability
  - SOI devices are preferred when available
    - latchup immune, better upset resilience
- **Single event upsets require mitigation, upset rates can be significant**
  - Redundancy
    - System level (i.e. 1FT/2FT architecture)
    - Device level (i.e. TMR)
    - Encoding (i.e. EDAC)
    - Time redundant (i.e. TTMR)
  - Restart/Reset techniques
- **Commercial/military screened devices should be used along with rad-hard by design parts when available to improve reliability**

Reducing Power

- **Leverage current & next generation of low power devices when possible**
  - Obtained through feature shrink and voltage scaling
  - Still requires redundancy for fault-tolerance and SEU mitigation
    - Adverse effect on SEU tolerance
- **Clock and data rate tuning**
- **Sleep modes and performance throttling**
  - Requires software management
- **Multi-tier modular system allow for optimization of designs**
  - Choose module grain-size to control overhead
    - Single function or reconfigurable modules
- **Power reduction through reconfigurable “co-processor” when appropriate.**

$$Power = \alpha N C V^2 f + V I_{OFF}$$

Possible Development/Acquisition Approach



Next Generation Architecture