National Aeronautics and Space Administration

EXPLORE SPACE TECH

Advanced Avionics

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Avionics Overview

- While avionics is broadly defined as the electronics systems used within aircraft, and spacecraft, this presentation focuses more narrowly on space systems.

- Here we define avionics as the hardware and software infrastructure necessary for the command and control of spacecraft and surface assets, thereby providing the onboard intelligence and interconnection to integrate the functions of other subsystems and manage their operation as a whole.

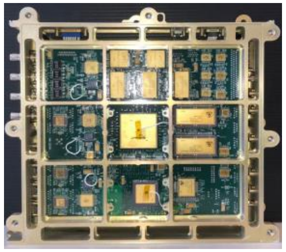
- Avionics can be viewed as a foundational technology, providing resources to enable many other functions within space systems. As an example, autonomous landing systems rely on the computing provided by avionics.

- Avionics components are often embedded within other instruments and subsystems. Examples include Field Programmable Gate Arrays (FPGAs) embedded within Software Defined Radios (SDRs), and processors and memory embedded within science instruments.

- Some functions that are sometimes defined as being within scope of avionics include power systems, communication, and navigation. These areas are not addressed here but are included within other presentations.

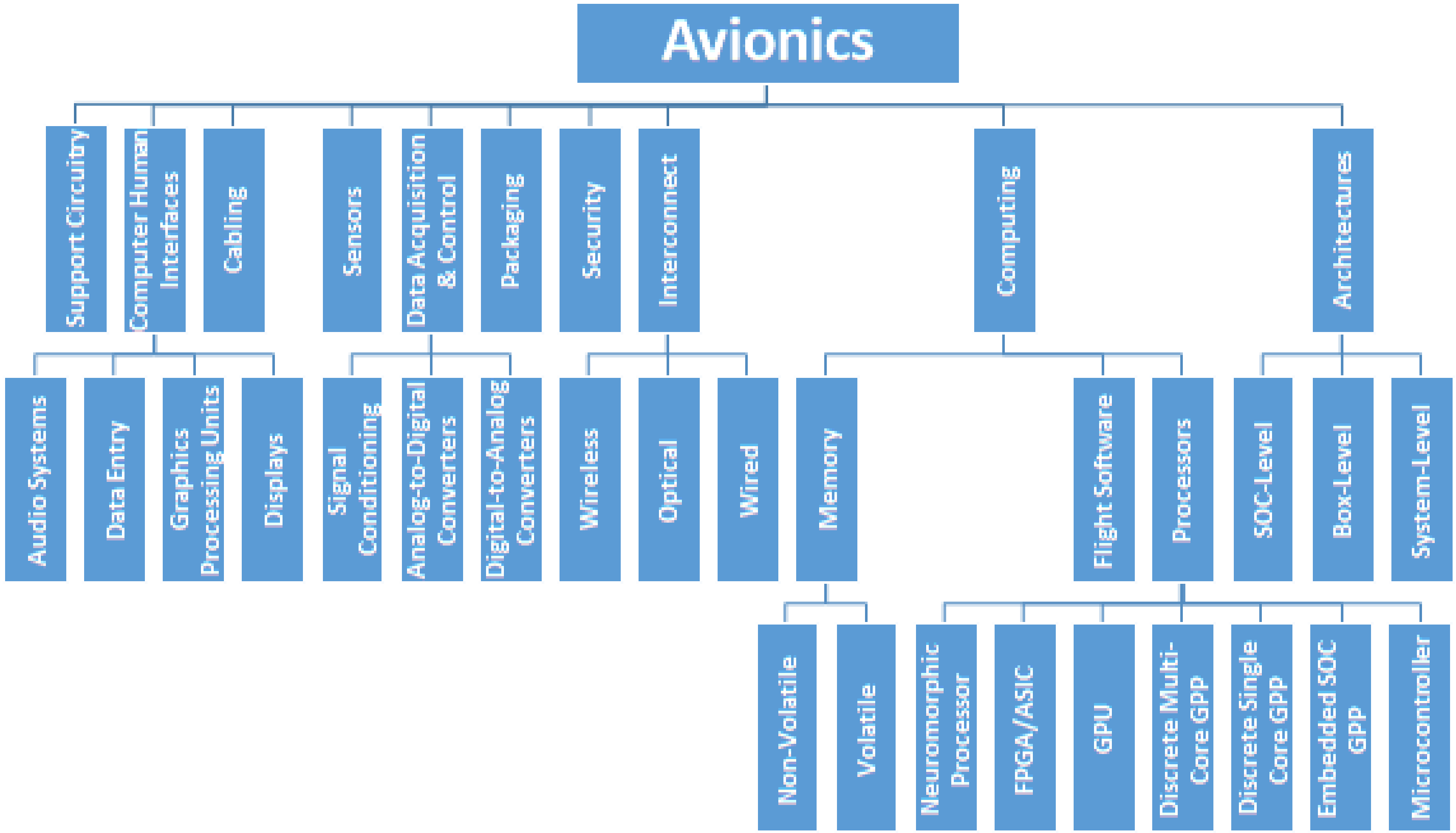
Modular Unified Space Technology Avionics for Next Generation (MUSTANG)

Space Shuttle Glass Cockpit



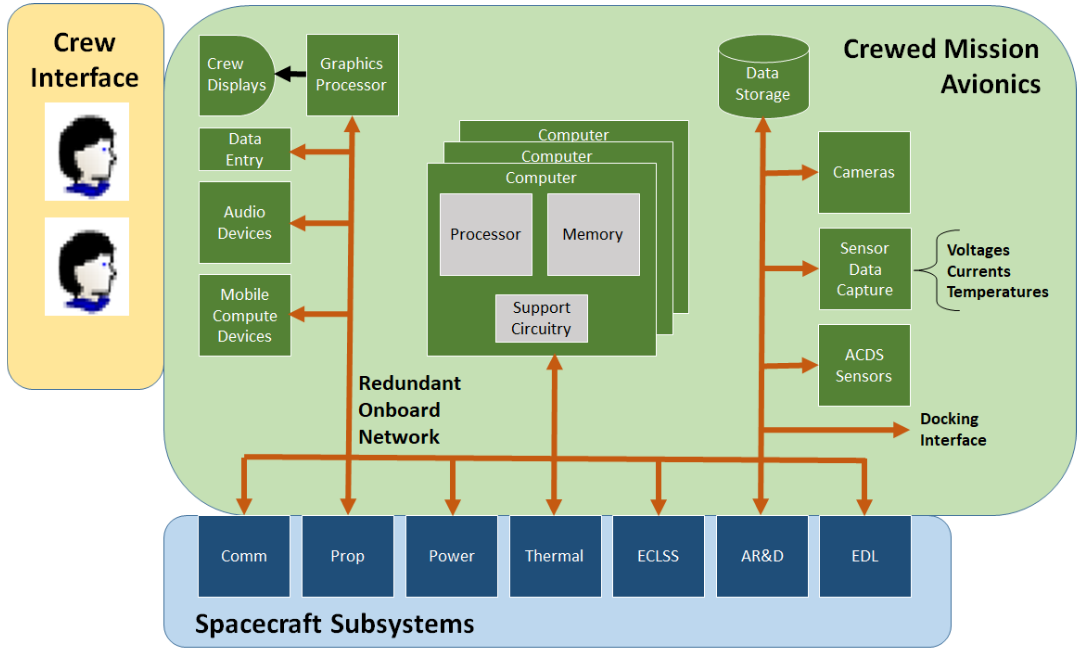
Roman Space Telescope Processor Board

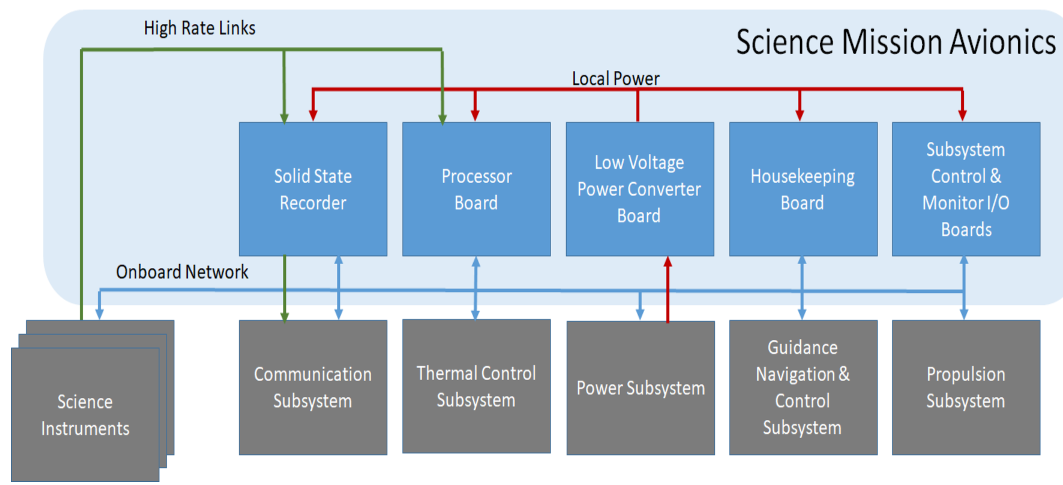
Fundamental Technologies



Avionics Examples

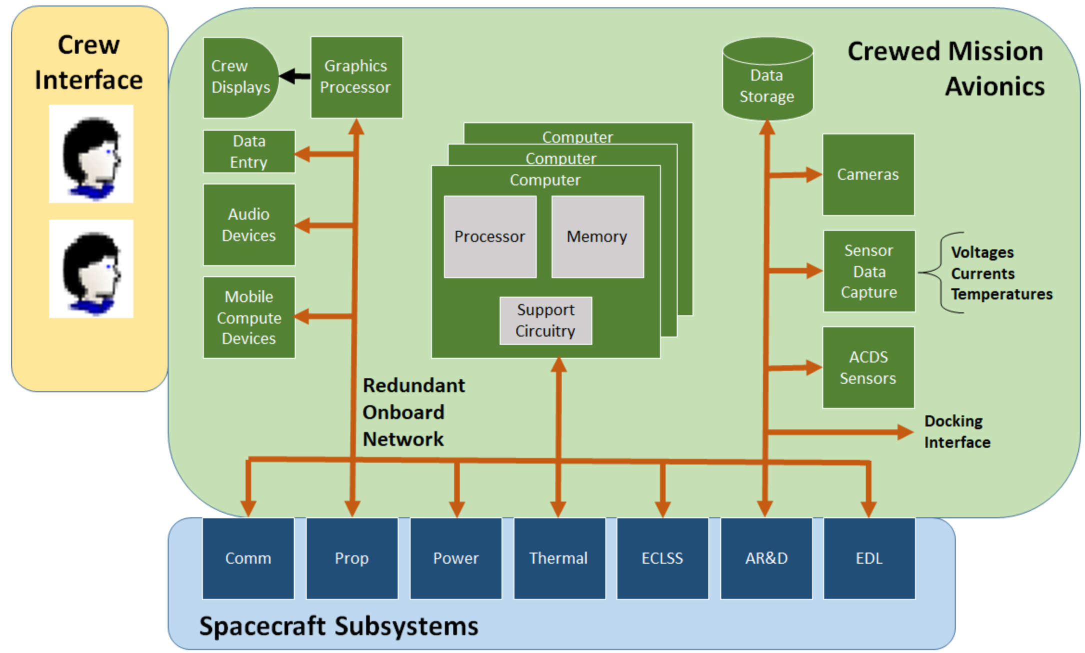
- Avionics within crewed and robotic science missions have significant commonality.
  - Computing
  - Onboard Networks
  - Data Storage
  - Subsystem Control
  - Housekeeping Sensing
  - Flight Software

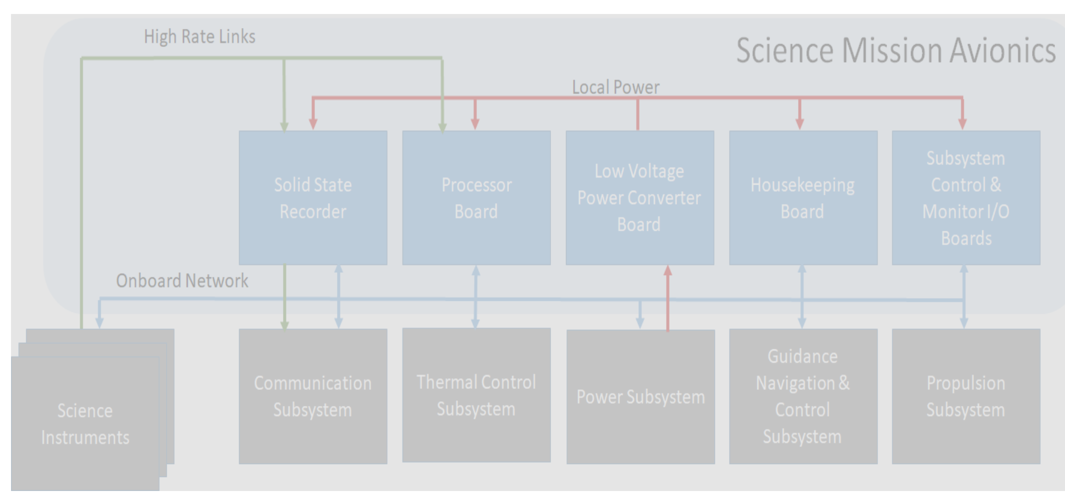




Avionics Examples – Crewed Missions

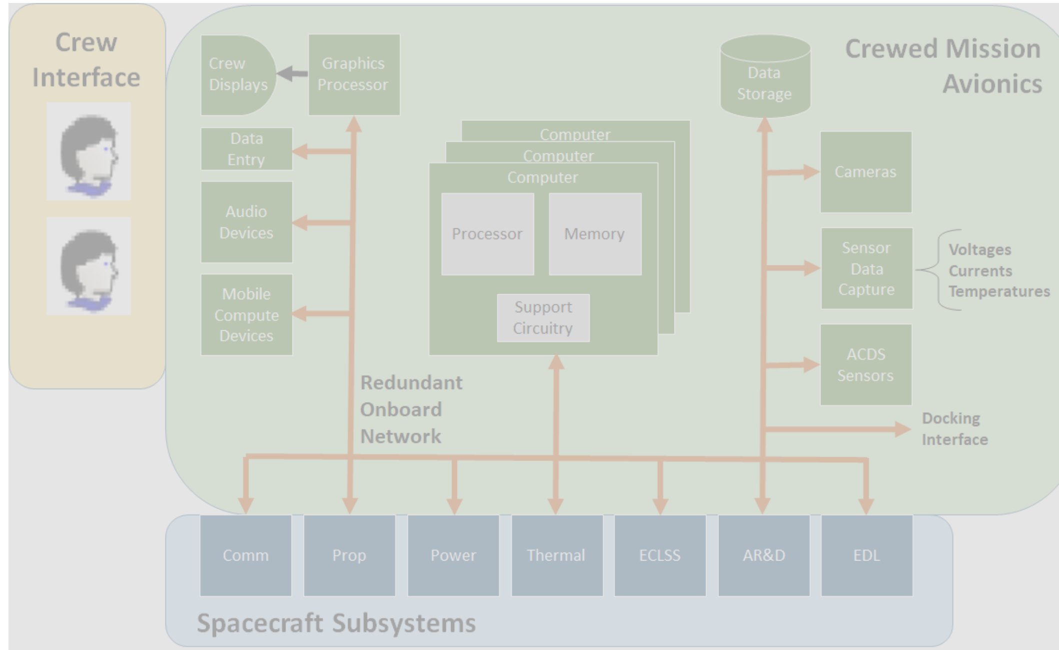
- Unique aspects of crewed mission avionics include:
  - Includes computer human interfaces
  - Greater degrees of redundancy to ensure crew safety
  - Increased complexity
  - Serviceability

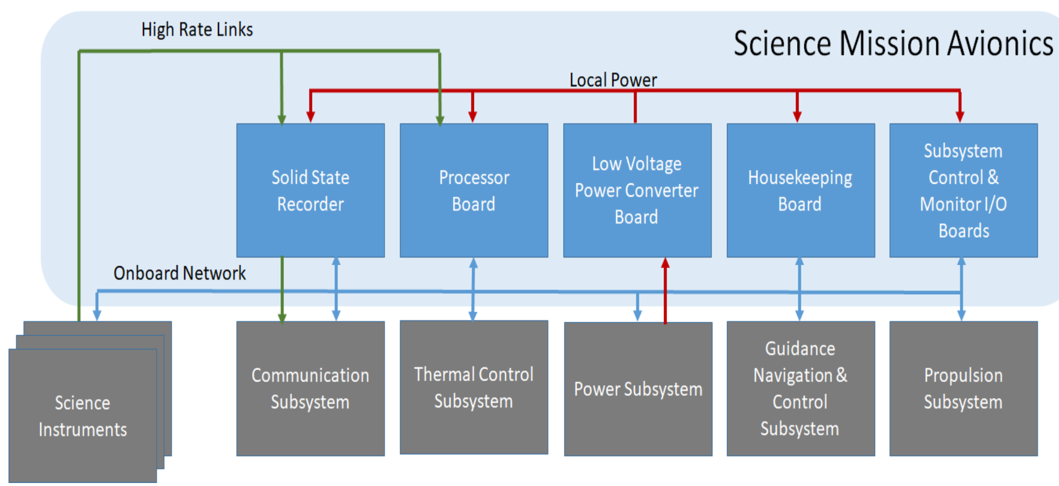




Avionics Examples – Science Missions

- Unique aspects of robotic science missions include:
  - Much wider variability of mission sizes, which can drive more tightly constrained size, weight, and power (SWaP) requirements
  - Redundancy tailored to specific mission requirements
  - Missions deployed to much harsher environments (i.e. Europa, Venus)
  - Limited serviceability (historically)





Avionics Challenges

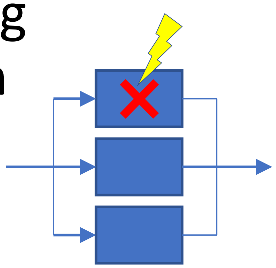
- Radiation
  - Total Ionizing Dose (TID) can cause performance degradation and failure, and single event effects can cause data corruption, functional upsets, and permanent failure.

- Temperature
  - While most missions maintain avionics operating temperatures between 0^{O}C and 40^{O}C, temperature extremes for other missions can range from -180^{O}C (shadowed lunar surface) to 470^{O}C (Venus surface).

- Mission Lifetime
  - The planned mission lifetime can range widely between missions. Some smallsat missions can have planned durations of less than a year, while crewed missions and flagship science missions can have durations up to 15 years.

Avionics Challenges

- Resilience
  - Avionics must provide sufficient resilience to meet mission objectives in the presence of faults. Depending on mission requirements, this can be achieved through operational approaches (i.e. placing a spacecraft in known safe state), architectural redundancy, supervisory circuits (i.e. watchdog timers, overvoltage/current protection circuitry), and high reliability component selection.



- Other Challenges
  - Planetary protection requirements may require harsh processing prior to launch.
  - Some planetary environments are caustic (Venus atmosphere).

Advanced Avionics Technology Gaps

Note that some of these gaps are beyond the scope of SBIR investments.

Theme	Computing Architectures	Onboard Data Storage	Computer Human Interfaces
Outcomes	Onboard computing to enable autonomous landing, surface navigation, robotic servicing/assembly, and data processing for crewed and robotic science missions.	Storage to support nominal and contingency mode operations for crewed missions.	Crew displays and controls that provide crew situational awareness that can operate reliably in Cis-lunar and Mars environments.
Gaps	• General Purpose Processors • Coprocessors • Memory • POL Converters • Machine Learning Devices • High Performance Single Board Computer • High Performance Computing Software Infrastructure	• Onboard Mass Data Storage	• Radiation Tolerant Displays • EVA Heads Up Display (HUD) Optics • Graphics Processor Units (GPUs) • Audio System • Mobile Computing Devices

Advanced Avionics Technology Gaps

Theme	Radiation Tolerant Interconnect	Avionics Sensors	Extreme Environment Electronics
Outcomes	Onboard networks to enable high bandwidth video and sensor communication for crewed and robotic science missions, while ensuring integrity of mission critical and time critical command/control traffic.	Sensors to enable crew situational awareness, as well as navigation and robotic servicing/assembly for crewed and science missions.	Electronics with sufficient temperature ranges to enable systems that can survive the temperature extremes of the lunar surface and planetary environments.
Gaps	• High Bandwidth Network Protocols • High Bandwidth Physical Layer Devices • High Rate Deterministic Wireless Networks • Smart Power Bus	• Imaging Sensors • Proximity Sensors • Wireless Sensor Network	• Extreme Temperature Electronics • High Radiation Electronics

"Push" Technologies of Interest

Theme	Technology
Advanced Computer Human Interfaces	• Speech recognition • Virtual Reality/Augmented Reality (VR/AR)
Reduced SWaP Electronics	• Advanced Packaging • Additively Manufactured Electronics • Mixed Signal Structured ASICs
Reduced SWaP Interconnect	• Miniaturized and/or reduced mass wiring conductors, connectors, and shielding • Data-over-power networks
Next Generation Computing Devices	• Integrated photonics
Security	• Defense in depth software security

Summary

- Future crewed and science missions will present new challenges:
  - Increased autonomy
  - Increased sensor data rates
  - Harsh environments
  - Increased volume of data to manage
  - Long mission durations

- Advanced avionics technologies are needed to meet these needs.