Avionics System Architecture for NASA Orion Vehicle

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What is Orion?

- The Orion Crew Exploration Vehicle will provide a capability to deliver humans to space reliably and return them safely
- Orion is currently under development by NASA, Lockheed Martin, and other industry partner
- The first Orion spaceflight will be an uncrewed flight test
Orion Concept of Operations

- Potential Orion mission objectives include delivering a crew to the International Space Station, transporting a crew to a near-Earth objects, and providing emergency return capability from the International Space Station

- Crew of 4
- Crew launch from Kennedy Space Center
- Ocean landing off California coast
- Ability to abort during launch
Orion Subsystems

• Orion contains the following vehicle subsystems:
  – Propulsion
  – Vehicle power
  – Life support
  – Communications
  – Docking adapter
  – Structures
  – Pyrotechnics
  – Displays and Controls
  – Parachutes
  – Guidance & Navigation
  – Mechanisms
  – Crew Systems
  – Thermal Control
  – Thermal Protection

• The Orion Avionics subsystem must provide an infrastructure to command, control, and monitor all of these subsystems
Orion Avionics Architecture

• Orion uses an IMA-based high integrity architecture with the following elements:
  • Vehicle Management Computers (VMCs)
    • Provides a central computing platform to host software applications for a variety of vehicle subsystems
  • Time-Triggered Ethernet (TTEthernet) Onboard Data Network
    • Provides priority-based network communications via time triggered, rate constrained, and best effort traffic classes
  • Power and Data Units (PDUs)
    • Provides sensor data gathering, actuator control, and power distribution for critical vehicle subsystems
Orion Avionics Architecture

- Flight Computer (VMC)
- Flight Computer (VMC)
- High Speed, High Integrity Data Network
- I/O Units (PDU)
- Navigation Equipment
- Personal Use Port
- Displays and Controls
- Docking Unit

Propulsion, Pyrotechnics, Environmental Control, etc.
Orion Avionics - Network

- Orion uses Time Triggered Ethernet (TTEthernet) to provide high-integrity, deterministic data network communications across the vehicle
  - The data network is deterministic to guarantee latency and response time for critical sensors and effectors
  - Traffic classes (time triggered, rate constrained, and best effort) allow prioritization of network data
  - Cross-comparison of data provides fault containment at the network switches and safety critical interfaces
The original Orion architecture contained two Ethernet-based data networks:

- A flight-critical control bus that handled time-sensitive and/or safety critical commands
- A general-purpose data bus that handled non-critical traffic such as video and personal crew equipment
Orion Network Unification

• However, to reduce vehicle size, weight, and power while maintaining acceptable reliability, Orion collapsed both networks into one, TTEthernet-based infrastructure.

• Critical or time-sensitive data utilized time-triggered or rate-constrained TTEthernet traffic classes.

• Video and personal crew data utilized the best effort TTEthernet traffic class.
Orion Avionics - *Integrity*

- Orion VMCs utilize a self-checking pair of processors to ensure the integrity of commands issued to vehicle subsystems.

  - Each VMC contains two processors.
  - Each processor independently runs the same applications.
  - The processor outputs are bit-by-bit compared to one another.
  - If any miscompares are detected between the outputs, that command is truncated.
Orion Avionics - Partitioning

- Orion VMCs utilize time and space partitioning of software and memory to ensure faults do not propagate between systems
  - VMCs execute code for a variety of software applications supporting various vehicle systems
  - Code for each software application is located in a unique, specific memory space
  - Each software application runs during a specific, periodic slice of time
  - As a result, faults from one system will not threaten the execution of other systems’ code
Orion Avionics - Redundancy

• Orion avionics uses simple redundancy (minimum one fault tolerance) to ensure that commands are successfully received

  • A command follows the following sequence:
    • A command is generated on each VMC
    • It is then sent simultaneously over two plane of the Data Network
    • The valid command is received from both VMCs at each of two PDUs
    • The PDUs send control signals initiated by the commands to redundant effectors