NASA MPCV Use of Ethernet

Time Triggered Gigabit Ethernet on NASA's Crewed Exploration Vehicle

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NASA CEV / Orion / MPCV History / Future

Time Frame	Event / Activity
2004-2005	Phase 0 CEV Proposal – Fly off between two teams
2005-2006	New Administrator – CEV Capsule Vehicle Proposal – Two teams, one winner
Sept 2006	NASA Announcement - Lockheed Martin Team wins!
2006-2010	Orion Spacecraft - Mission, Test Plans, Capabilities Evolve
Oct 2009	Augustine Commission Report
Feb 2010	President announces Constellation cancellation
May 2010	Pad Abort Test Successful – Launch Abort System works
Sept 2010	Multi-Purpose Crew Vehicle (MPCV) Program with EFT-1, EM-1, AA-2, and EM-2 Flights
Oct 2013	EFT-1 Power On
Sept 2014	***EFT-1 Planned Flight – Delta 4***
4Q 2017	***MPCV EM-1 Uncrewed Lunar Flight – ESA SM / SLS***
4Q 2020	***EM-2 1st Crewed Flight – ESA SM / SLS***

Orion Current Status

- EFT-1 – Uncrewed Flight to Test Major Crew Module (CM) Subsystems - Heat Shield, Parachutes, Avionics, SW, etc.
  - Vehicle Structure currently in JSC O&C Building
  - Major Components installed
  - Initial Power On (IPO) Scheduled for October
  - SW – Flight & Ground SW completing verification, ready for IPO
  - Integration and Testing Planned for most of next year
  - Flight Scheduled for late 2014
- EM-1 – Uncrewed Flight to Test Crewed Exploration Readiness
  - Lunar Orbit Mission – 14+ days
  - Includes ESA European Service Module – Main Propulsion, Thermal Radiators, Solar Arrays & Gimbals, Power Generation, Attitude and Translation Thrusters
  - Heading to PDR in 2014
- EM-2 – 1st Crewed Mission
  - Adds remainder of Environmental Control & Life Support System (ECLSS)
  - Adds Displays and Controls

Shuttle Heritage Communications Drove Orion Requirements and Approach

- Space Transportation System / Space Shuttle – Unique in many ways
  - Fly By Wire for combined Space and Aero vehicle
  - Highly Redundant - Hot Redundancy - Dissimilar SW Backup
- Required Multiple Communications Functions
  - Command & Status across 24 MIA Buses – MIL-STD-1553 like
  - Displays across MIL-STD-1553 (e.g. IDP to MEDS)
  - Instrumentation across RS-422 (e.g. PCMMU to IDP)
  - Audio for crew
  - Time Distribution from MTU
  - Video / Imagery (after Columbia) across IEEE-1394a
  - Note: Shuttle implemented separate Communications Paths / Technologies
- Discrete and Independent Comm / Wiring a two-edged sword
  - Keeps Safety critical traffic physically separate from non-critical traffic
  - Physical separation drives up mass, power, and component failure instances
- Orion Required to support all these Communications Functions While Minimizing Size, Weight, and Power (SWaP) and Cost

Network Technology Investigations

- During Proposal Phase, LM conducted multiple trade studies pertaining to Onboard Data Network technologies, topologies, and implementations
  - ~30 different technologies / standards assessed
  - Star, Ring, Bus, and Hybrid topologies considered
  - Single and multiple technologies in same and different topologies considered
  - Separation of different functions considered
- Proposal evolved from mixed implementations toward single implementation
- Driven by technology maturity (including Space applications), SWaP, and Cost
  - CEV challenged by launch vehicle capacity – mass always an important factor

Proposal Baseline IEEE-1394b

- CEV Proposal included IEEE-1394b for Onboard Data Networks
  - The Upside
    - Sufficient bandwidth for all expected communications functions, including video
    - SAE Standard (AS5643) for application to Flight Control / Safety Critical Systems
    - Used on JSF – LM in house experience
    - Used on Shuttle – post-Columbia, for Tile Inspection Video System
    - Ring configuration potentially provides 1FT – Bullet proof
  - The Downside
    - Auto reconfiguration
    - Concerns about mission duration and existing implementations
    - Radiation hardening

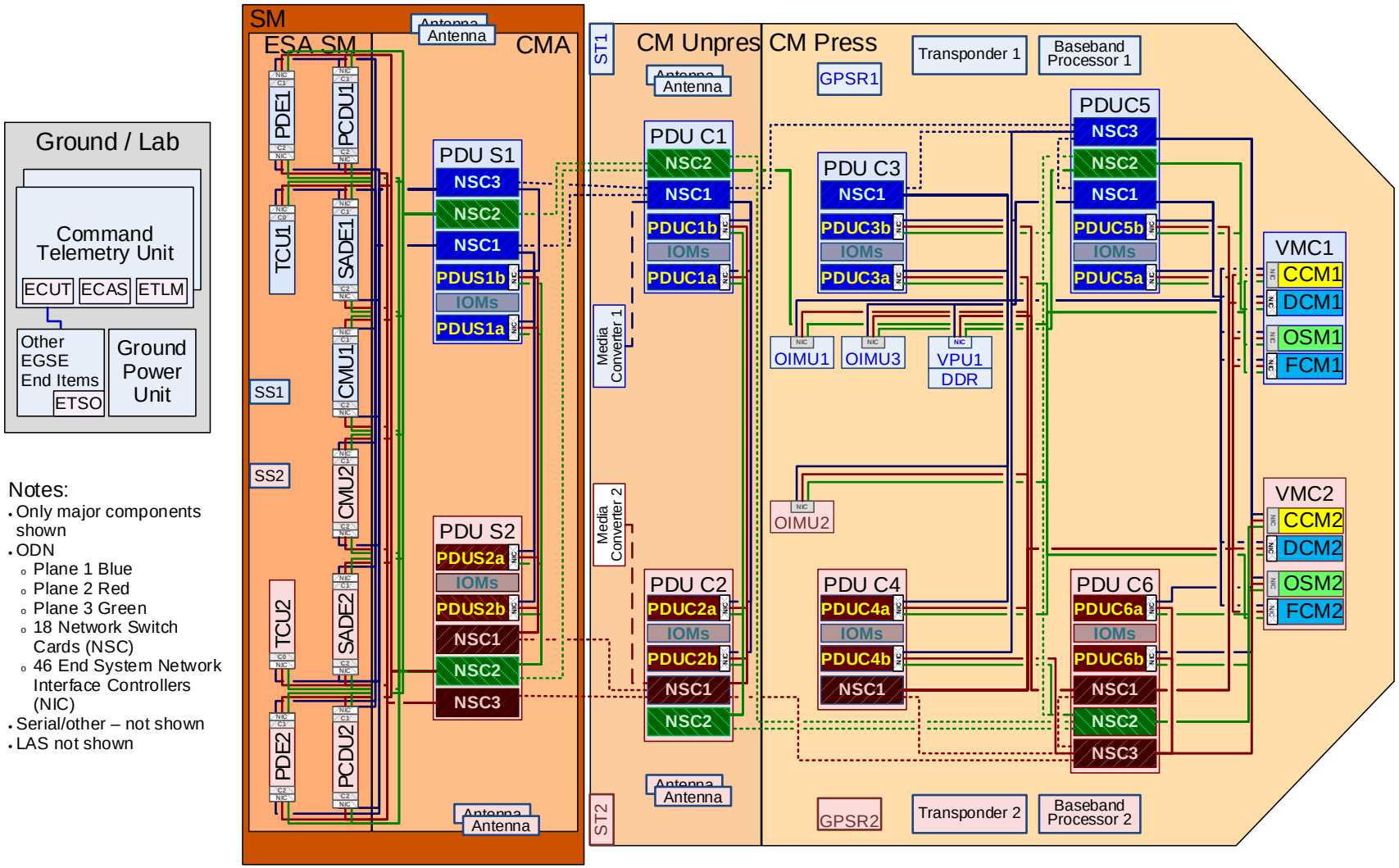
Evolution to TT-GbE

- Network Switch / Network Interface designs supports needed functionality
  - Time synchronization
  - Multiple Traffic Classes – command, status, audio, video, etc.
- Eliminates Automatic Dynamic Reconfiguration
- Significant Progress on Time Triggered Ethernet Hardware designs
  - 1000Base-CX Serializer/Deserializer (SerDes) circuit design available
  - Time-Triggered Firmware Available
  - Suppliers begin producing Connectors / Wiring
  - Prototype HW available for network integration testing
- SAE Standard Created – AS6802
  - Participation by NASA, Honeywell, TTTech, Lockheed Martin and many others

Ethernet “Flavors” on MPCV

- Main Onboard Data Network (ODN) implemented with IEEE-802.3 1000Base-CX
  - 4 wires, 8B10B encoding, sufficient BW, sufficient max link distance
  - Quadrax connectors meet microwave-like signal characteristics
- Auxiliary equipment uses IEEE-802.3 100Base-TX
  - Crew portable equipment in CM
  - Developmental Flight Instrumentation (DFI) in various locations
- Vehicle / Ground Umbilical uses Fiber IEEE-802.3 1000Base-SX
  - Launch Vehicles are taller than 25m
  - Electrical isolation is a good thing

MPCV EM-1 ODN Major Components



Notes:

- Only major components shown
- ODN
  - Plane 1 Blue
  - Plane 2 Red
  - Plane 3 Green
  - 18 Network Switch Cards (NSC)
  - 46 End System Network Interface Controllers (NIC)
- Serial/other – not shown
- LAS not shown

Conclusion

- Ethernet in Space and Safety Critical Applications is Real
- TT-GbE works well
- Doesn’t solve all problems, but does free Avionics Architect from those pesky 1553 32W x 2By Max Messages