Air Force Research Laboratory

NGSIS SpaceVPX (VITA 78), SpaceVPXLite, and RapidIO

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Charles Patrick Collier

Senior Electrical Research Engineer

AFRL Space Vehicles

Air Force Research Laboratory

Integrity ★ Service ★ Excellence

Bottom Line Up Front (BLUF)

What is wrong with just using legacy space electronics?

- Legacy space systems are often point solutions
- Re-use is not a priority
- Don’t have the full range of redundancy options (dual-string, M-of-N, etc.) built-in given the particular application and its needs.
- Internal interfaces are often proprietary and application specific
- Modules are not designed to inter-operate at either hardware or software level

Outline

- What is SpaceVPX?
- SpaceVPX Slot Profiles
- SpaceVPX Backplane Profile
- SpaceVPX Module Profile
- SpaceUM - Provisions for Redundancy and Fault Tolerance
- SpaceVPX Mechanical General Specifications
- Backup

What are SpaceVPX’ s Goals

- **Was created to bridge the VPX standards to the space market.**
  - SpaceVPX addresses both interoperability (as OpenVPX does) and space application needs (not in OpenVPX).
  - SpaceVPX defines Payload, Switch, Controller, and Backplane module profiles to meet needs of space applications
  - SpaceVPX adds features to the Utility Plane for fault tolerance
    - Point-to-point not bussed to tolerate faults: failure on module does not affect entire system.
    - Space Utility Module added to provide dual-redundant source for-Utility Plane implementations.
  - SpaceVPX defines use of SpaceWire for Control Plane over Ethernet (OpenVPX preferred solution).

What is SpaceVPX?

- **Develop**
  - Enhanced set of backplane specifications that are based upon existing commercial standards with added features required for space applications.

- **Increase**
  - Interoperability and compatibility between manufacturers and integrators, while simultaneously increasing affordability through the use of standard sets of hardware.

What is in SpaceVPX?

OpenVPX™

VITA 65

VITA 46.0 VPX™

VITA 46.3

SRIO on VPX

VITA 46.9

PMC/XMC

VPX™

VITA 46.11

Sys. Management

VITA 48.2

Conduction

VPX REDI™

SpaceVPX (VITA 78)

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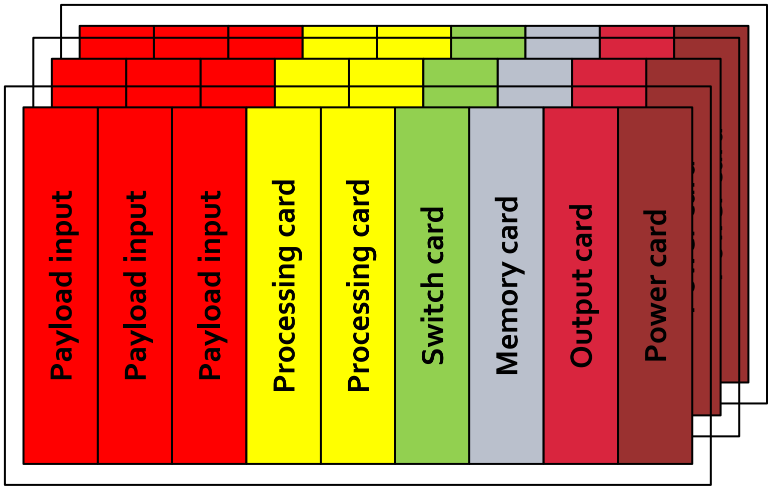
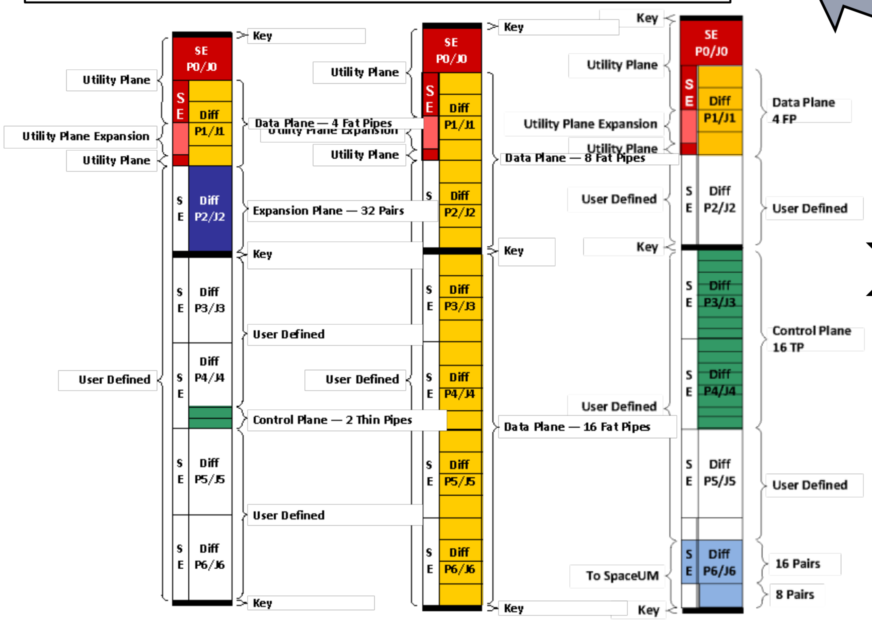
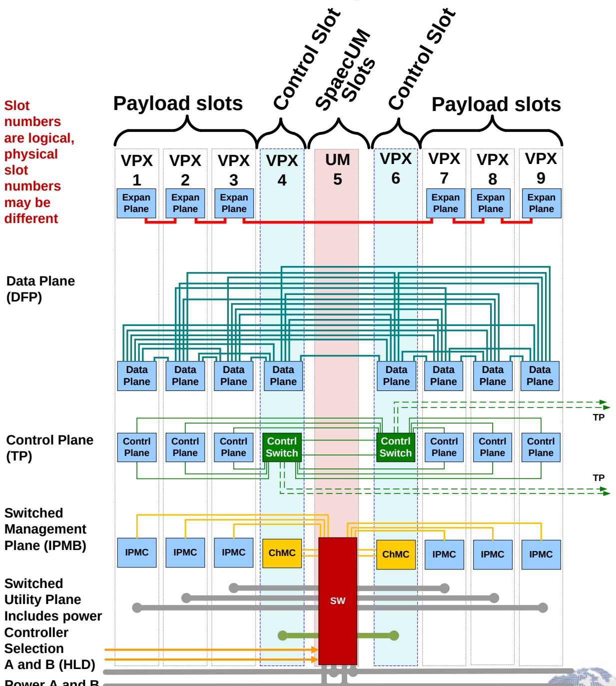
What is in SpaceVPX?



SATCOM System

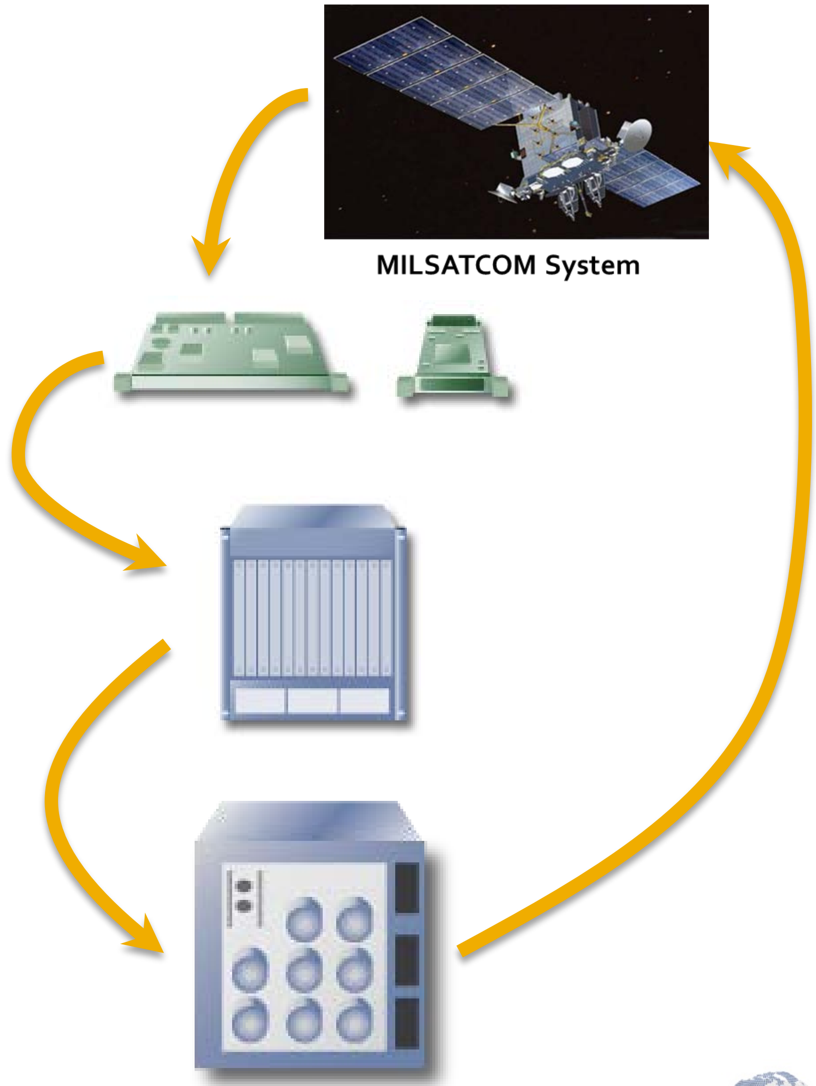




Distribution A. Approved for public release: distribution unlimited

Typical SpaceVPX Development Flow

- **Determine application requirements**
  - Size, weight and power
  - Processing, fabric and I/O requirements
- **Select overall system parameters**
  - 3U or 6U?
  - Switching topology?
  - Number and type of slots?
- **Assemble development vehicle**
  - COTS development chassis
  - COTS boards
  - COTS or custom RTMs
- **Design deployment system**
  - Typically custom backplane
  - Typically route I/O signals to custom I/O slot or bulkhead connector



Who is Involved in SpaceVPX?

Honeywell

BAE SYSTEMS

Microsemi

AEROFLEX

TE connectivity

HARRIS

BOEING

Orbital Innovation You Can Count On™

LOCKHEED MARTIN

COBHAM

CURTISS WRIGHT

NORTHROP GRUMMAN

SE

TEK

VITA Open Standards, Open Markets

CISCO

AEROSPACE Assuring Space Mission Success

Sandia National Laboratories

ELMA Your Solution Partner

L3 communications

Space & Missile Systems Center

Naval Research Laboratory Washington, DC

NASA

JPL Jet Propulsion Laboratory California Institute of Technology

smiths connectors

Amphenol

Who is Involved in the RapidIO Space Device Class?

RapidIO

ALTERA

FPGA: Arria
and Stratix Family

TEXAS INSTRUMENTS

DSP: several products
In TCI64xx family

LSI

Axxia Communications
Processor

freescale semiconductor

DSP, PowerQUICC & QorIQ multicore

BROADCOM

;416 family
lticore
cessor

IDT

Switches, Bridges & IP
CPS and Tsi Family

XILINX

FPGA: Virtex 4/5/6
families

Lattice Semiconductor Corporation

FPGA

MINDSPEED

Wireless Baseband Processor

octasic

DSP Oct22xx

ARM

HUAWEI

HISILICON

AMD

CAVIUM NETWORKS

Network Processor
Octeon 2 family

apm applied micro POWERING YOUR C

PowerPC based processors
460GT

Wintegra

Network Processor
WinPath3

intel

mobiveil Investors in Innovation

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Space Device Profiles

Two levels of profile “basic” and “enhanced” have been defined for RapidIO space devices along with requirements for switches vs. endpoints

- **Basic devices** include support for:
  - Baud rate class 1 (lane rates of 1.25, 2.5, and/or 3.125 Gbaud)
  - System sizes up to 16-bit addresses (maximum # of nodes is 65,534)
  - Part 8 error management extensions other than hot swap
  - Port-write error notification
  - Packet multicasting
- **Enhanced devices** include support for:
  - Revision 3.1 of the RapidIO specification
  - Baud rate classes 1 and 2 (adds lanes rates of 5 and/or 6.25 Gbaud)
  - Critical request flow (CRF)
  - Structurally asymmetric links (SAL)
  - Multiple error event capture (extended error log)
  - Pseudo-random binary sequence (PRBS) link diagnostics

Space Device Profiles (cont'd)

Two levels of profile "basic" and "enhanced" have been defined for RapidIO space devices along with requirements for switches vs. endpoints

- **Switch-specific** requirements to support:
  - Routing for up to 65K node systems
  - Distribution of multicast event control symbols with predictable, low latency
  - Multicast functionality and registers
  - Packet "time to live" timeout mechanism
  - Logical and transport layer error detection for maintenance packets
  - MECS time sync protocol
- **Endpoint-specific** required to support:
  - **Basic**
    - Accepting packets with alternative IDs to support multicasting
    - Logical layer error detection
  - **Enhanced**
    - MECS time synchronization protocol

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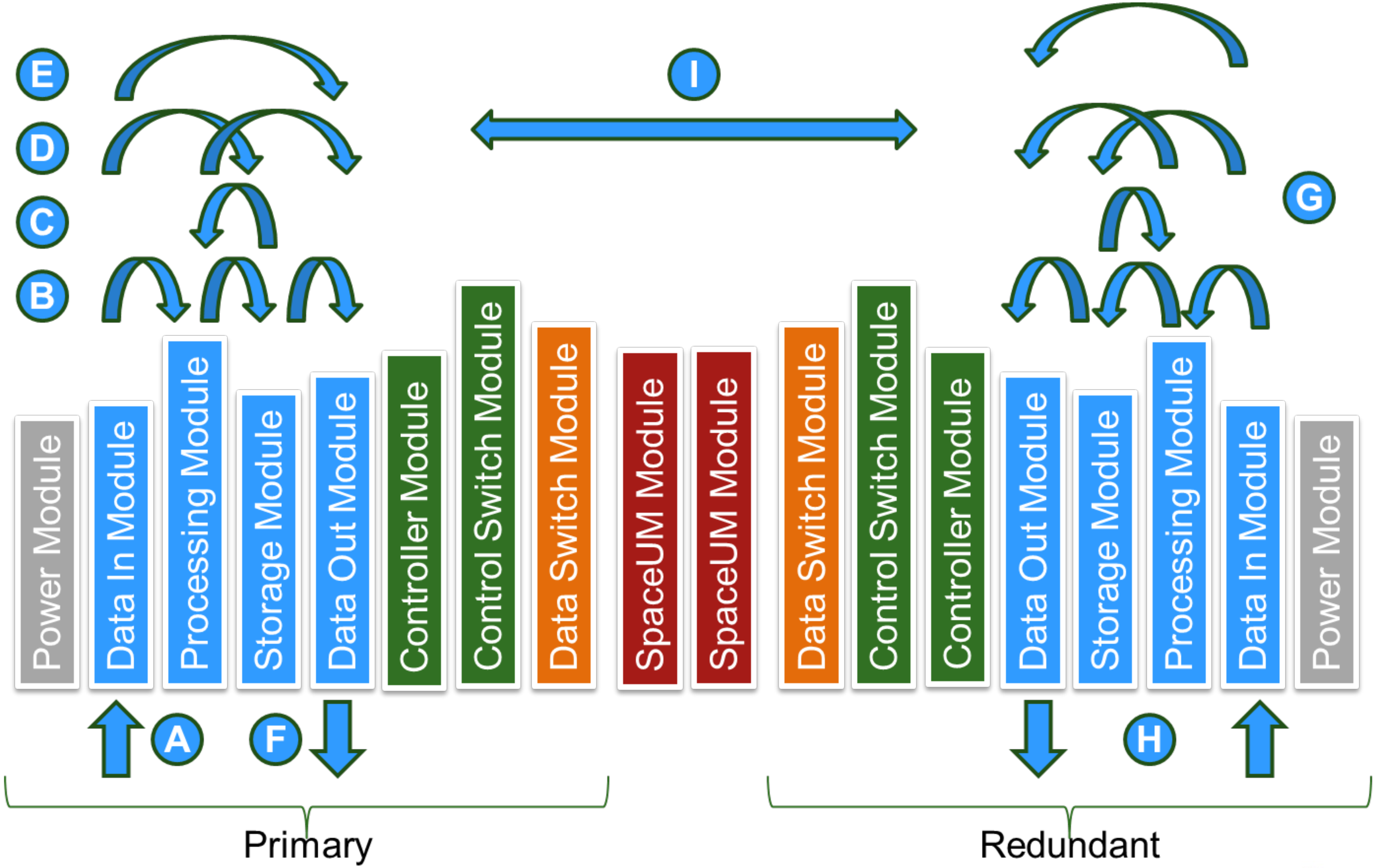
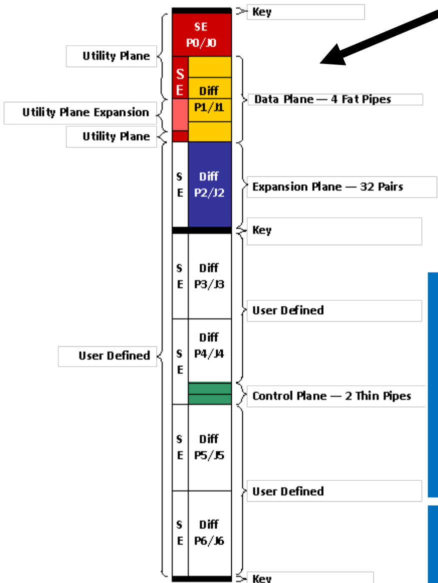
Basic SpaceVPX Payload Use Case



Profiles in SpaceVPX

Slot Profile

A physical mapping of ports onto a slot's backplane connectors

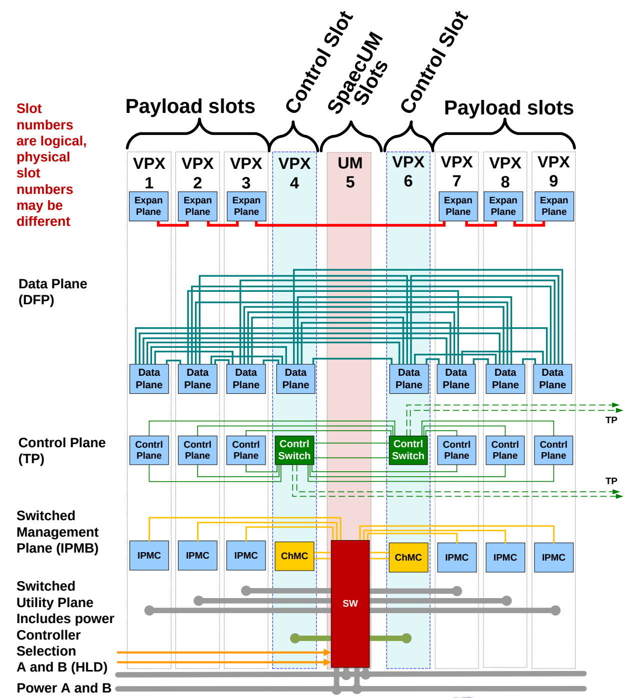


Extends a slot profile by mapping protocols to a module's ports

Module Profile

Profile Name	Data Plane 4 FP	Expansion Plane P2/J2	Control Plane 2 TP	User Defined
	DP01 to DP04		CPtp01 to CPtp02	P3/J3, P5/J5
MOD6-PAY-4F1Q2T-12.2.1-1-cc	sRIO 2.2 at 3.125 Gbaud per Section 5.2	sRIO 2.1 at 3.125 Gbaud per Section 5.2	SpaceWire per Section 5.2.1	User Defined DIFF pins

Backplane Profile



A physical specification of a backplane

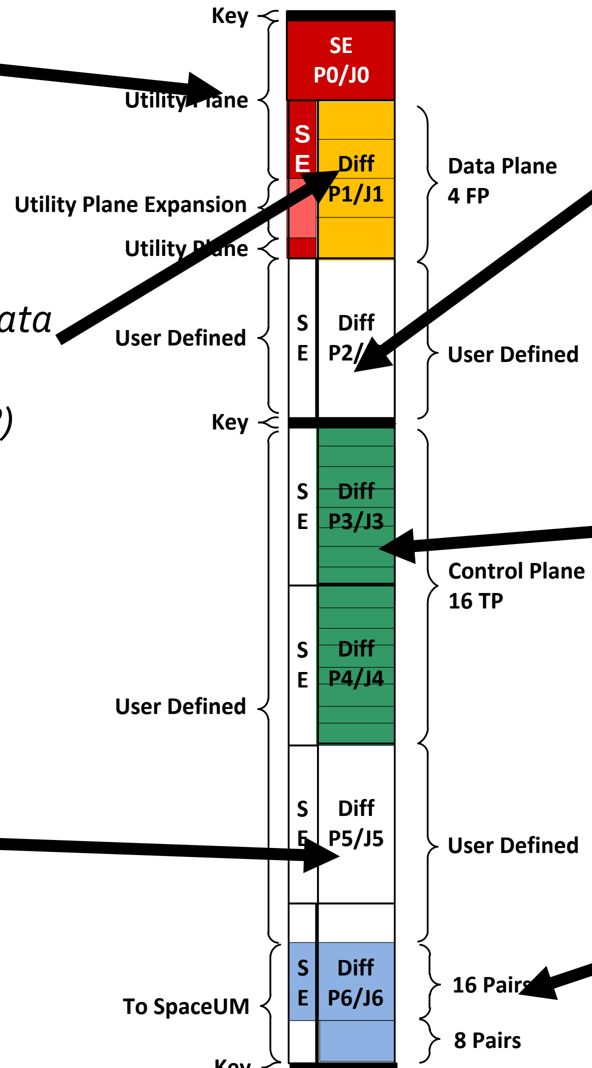
Also: Power Keying and Chassis profiles

Mapping Interfaces to SpaceVPX Slot Profiles

Utility plane provides power, configuration, timing and management input signals using I2C, CMOS and LVDS levels

Serial RapidIO (sRIO) is used for the data plane
x1 interface = 1 Ultra thin pipe (UTP)
x2 interface = 1 Thin Pipe (TP)
x4 interface = 1 Fat Pipe (FP)

Expansion Plane for additional Data FPs, Heritage I/Fs or User Defined Signals



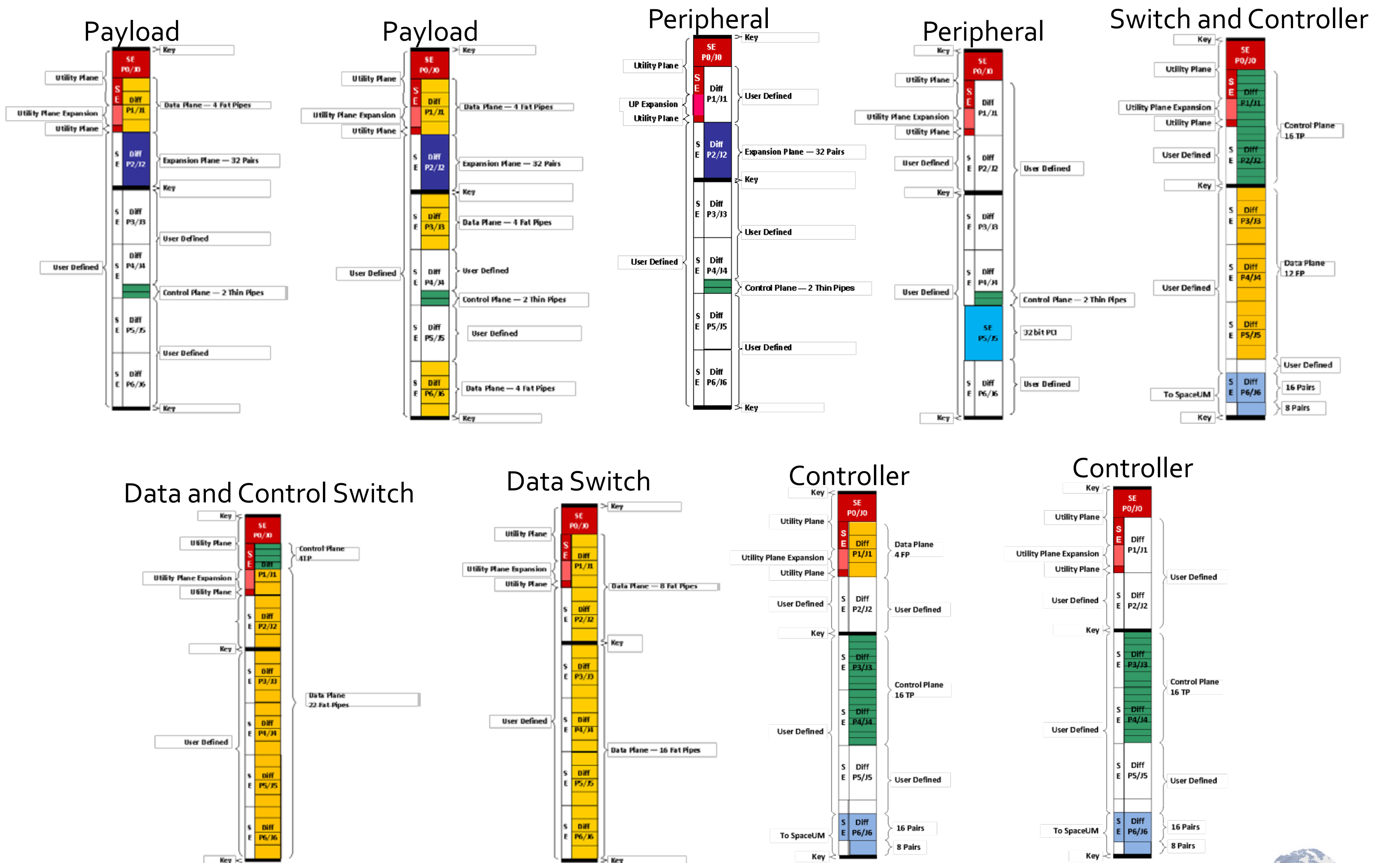
Expansion Plane for additional Data FPs, Heritage I/Fs or User Defined Signals

SpaceWire is used for the control plane
1 interface = 1 Thin Pipe (TP)

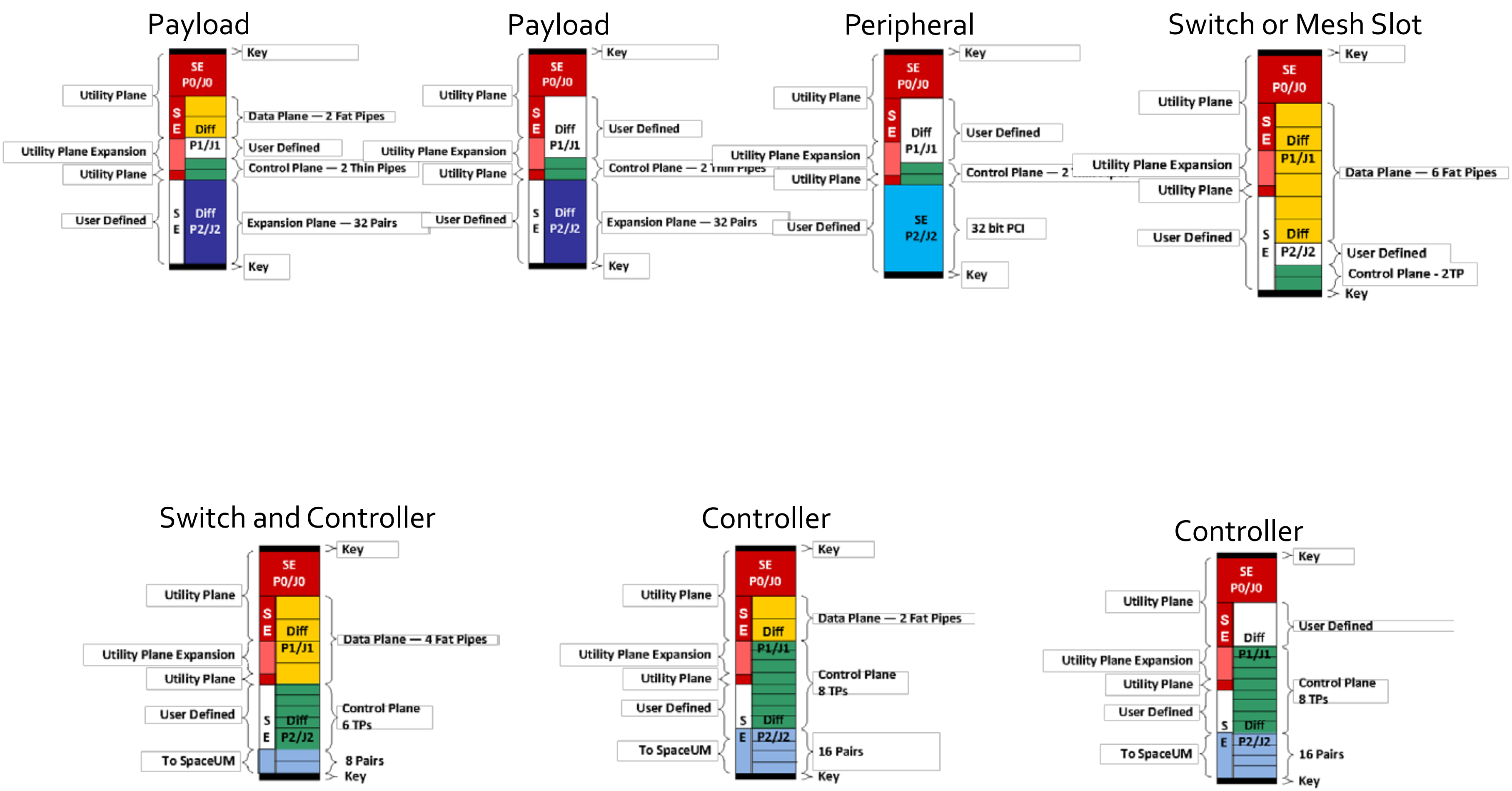
Signals to and from the SpaceUM

AFRL

6U Slot Profiles

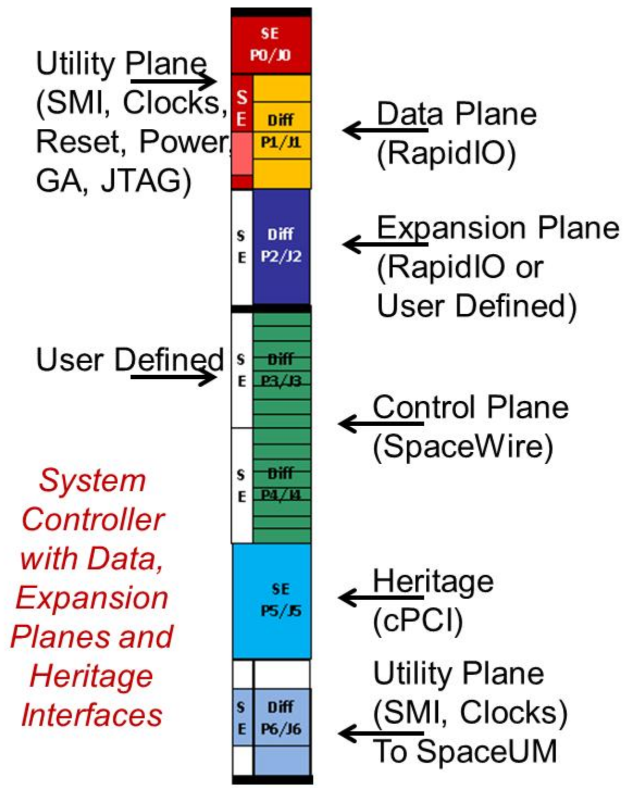


3U Slot Profiles

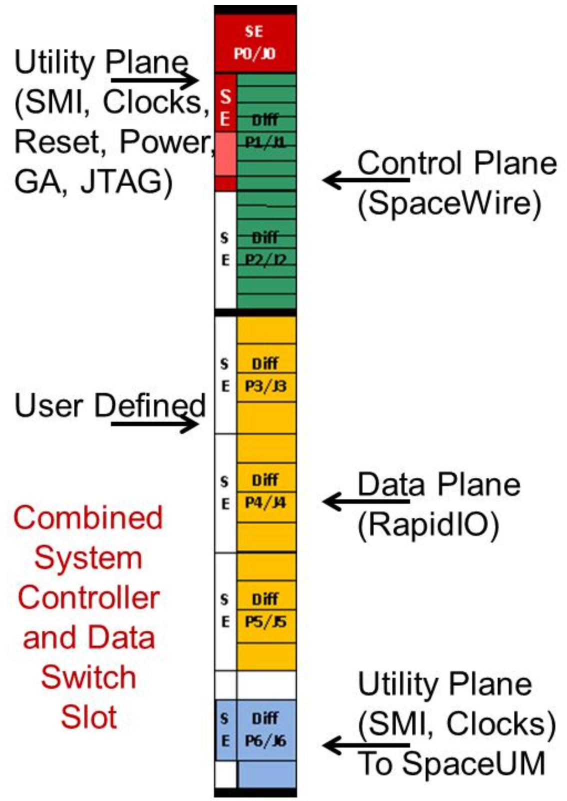


SpaceVPX 6U Slot Families

Payload Family:
Payload, Controller, Peripheral, Control Switch



Switch Family:
Data Switch, Switch & Controller, Control Switch



Pinouts are consistent throughout slot profile families enabling single design providing multiple slot types

6U Connector Guidelines

All: J0 & J1 Row G: Utility Plane

Data Switch:

- J1AB: Up to 4 TP Control
- J2, J3, J4, J5, J6, J1CD: Up to 22 FP Data

Integrated Switches: Data, Management and Control:

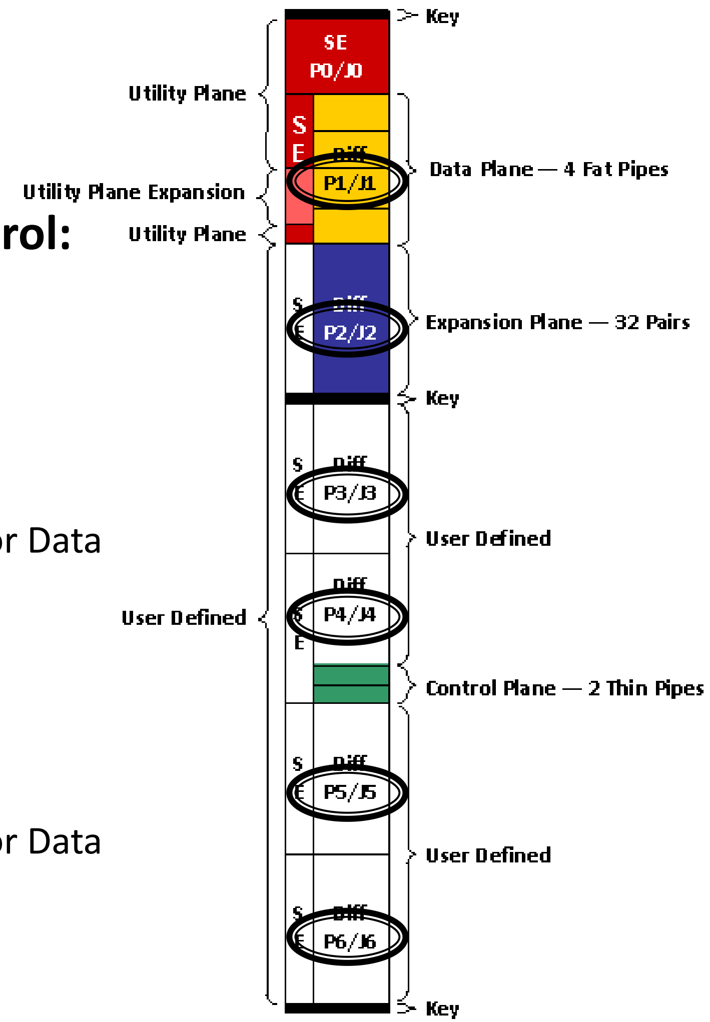
- J1, J2: up to 16 TP Control
- J4, J3, J5, J2: up to 16 FP Data
- J6: up to 4 SpaceUM Utility Plane Feeds

Payloads:

- J1, J3, J6: Up to 12 Data FP
- J2: Expansion - Daisy Chained Up to 32 Pairs of Heritage or Data
- J4D: Control 2 TP
- J5: Expansion – Heritage (PCI 32 bit)
- J6, J5: Optical or RF

Controllers (Payload Compatible)

- J1: Up to 4 Data FP
- J2: Expansion - Daisy Chained Up to 32 Pairs of Heritage or Data
- J4, J3: Up to 16 TP Control
- J5: Expansion – Heritage (PCI 32 bit)
- J6: up to 4 SpaceUM Utility Plane Feeds



Non-assigned pins may be user defined

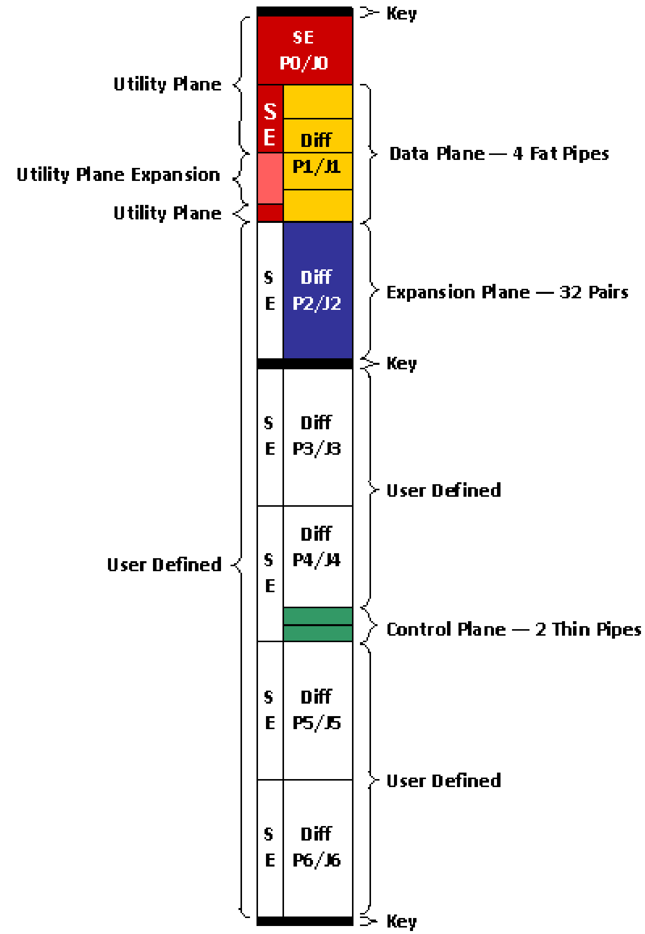
Payload Slot Profile (switched)

Possibility I
- Data-In Module
- Data-Out Module

Possibility II
- Data-In Module
- Processing Module
- Data-Out Module

Possibility III
- Data-In Module
- Processing Module
- Storage Module

Utilize User Defined Pins and Top of Card Connectors for Additional Capability



Any Combination of Payload Functions is Possible

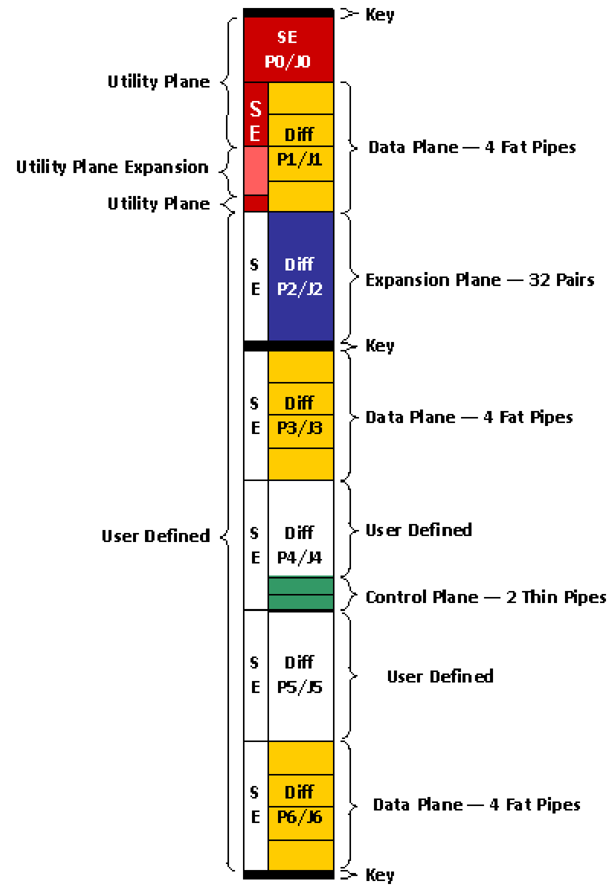
Payload Slot Profile (mesh)

Possibility I → Data-In Module, Data-Out Module

Possibility II → Data-In Module, Processing Module, Data-Out Module

Possibility III → Data-In Module, Processing Module, Storage Module

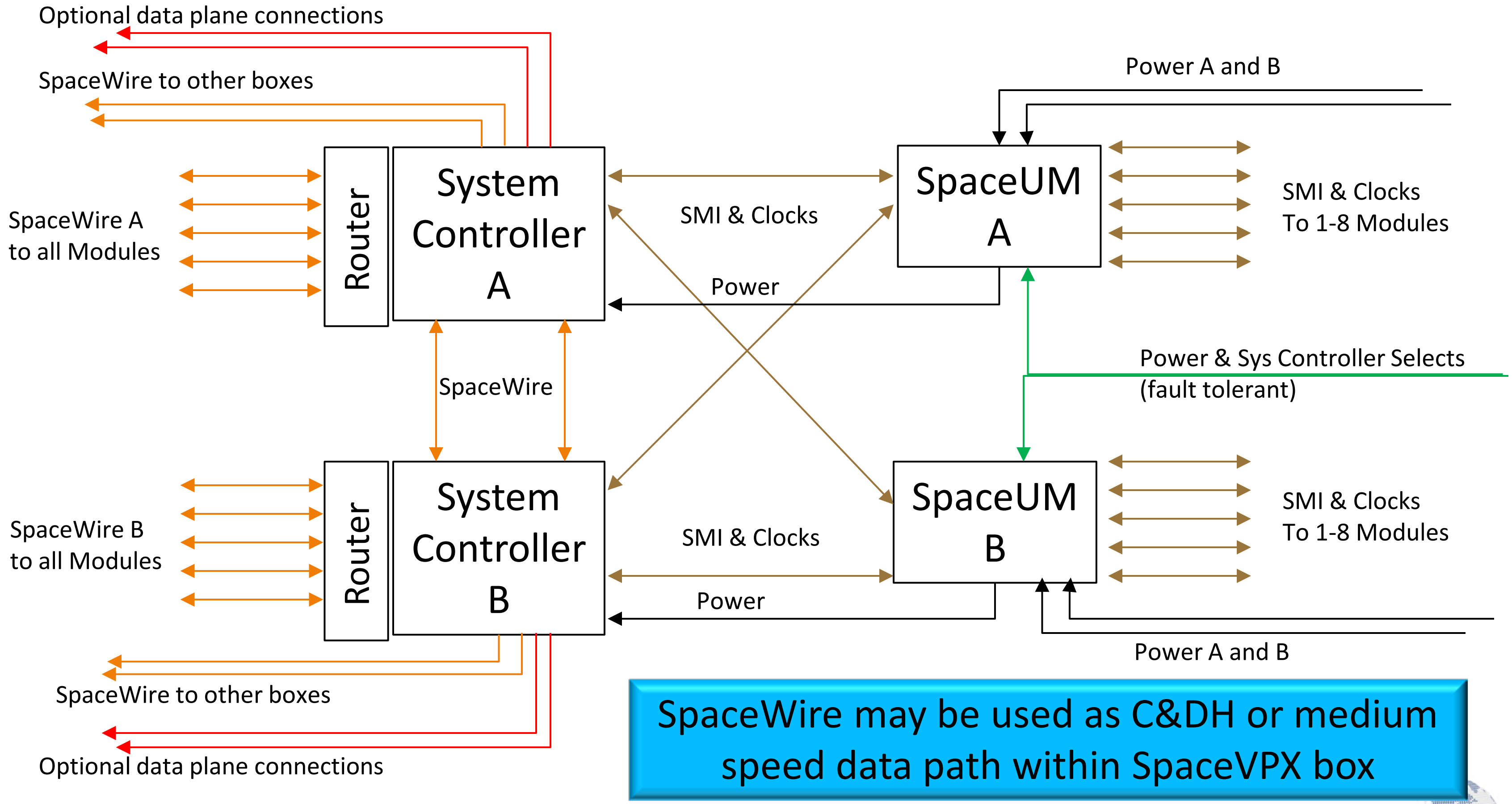
Utilize User Defined Pins and Top of Card Connectors for Additional Capability



Any Combination of Payload Functions is Possible

SpaceVPX System Controller

- Key element of SpaceVPX fault tolerance
- Power channeled to System Controller which then directs powering of other modules
- Uses System Management Interface (SMI) for chassis management then SpaceWire for Control Plane operations
- SpaceWire router defined with System Controller may be separated with cross-strapping



Controller Slot (with Data Plane Connection)

Possibility I

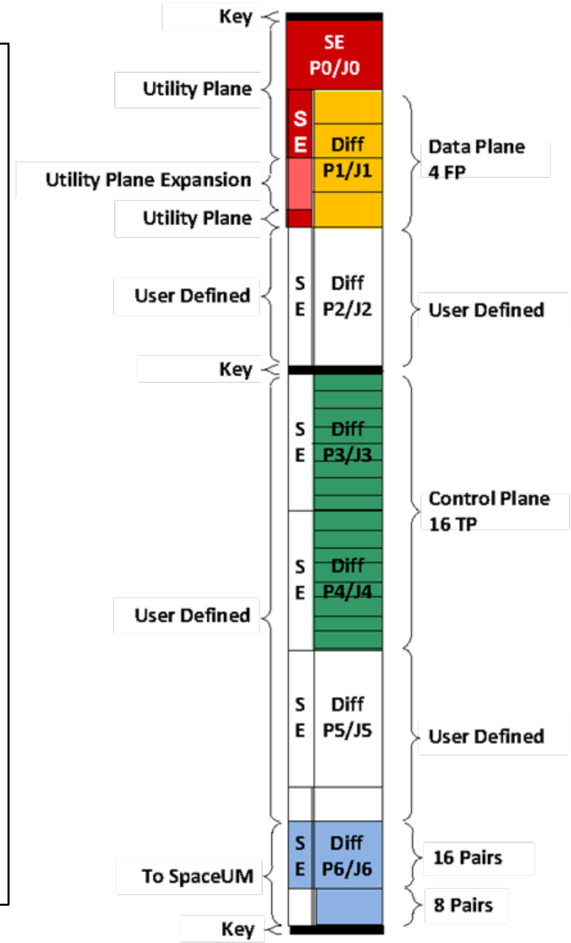
- Data-In Module
- Control Switch Module
- Controller Module

or

Possibility II

- Data-In Module
- Processing Module
- Control Switch Module
- Controller Module

Utilize User Defined Pins and Top of Card Connectors for Additional Capability



Any Combination of Payloads with Controller or Control Switch is Possible

Controller Slot (without Data Plane Connection)

Possibility I

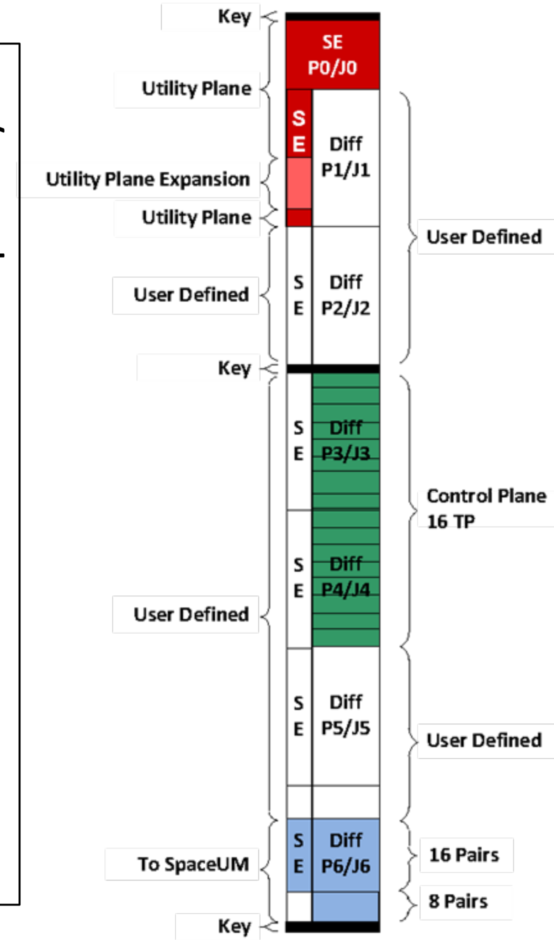
- Processing Module
- Controller Module
- Control Switch Module

or

Possibility II

- Storage Module
- Controller Module
- Control Switch Module
- Processing Module

Utilize User Defined Pins and Top of Card Connectors for Additional Capability



Any Combination of Payloads with Controller or Control Switch is Possible

Data Switch and Controller Slot Profile

Possibility I → Controller Module / Data Switch Module

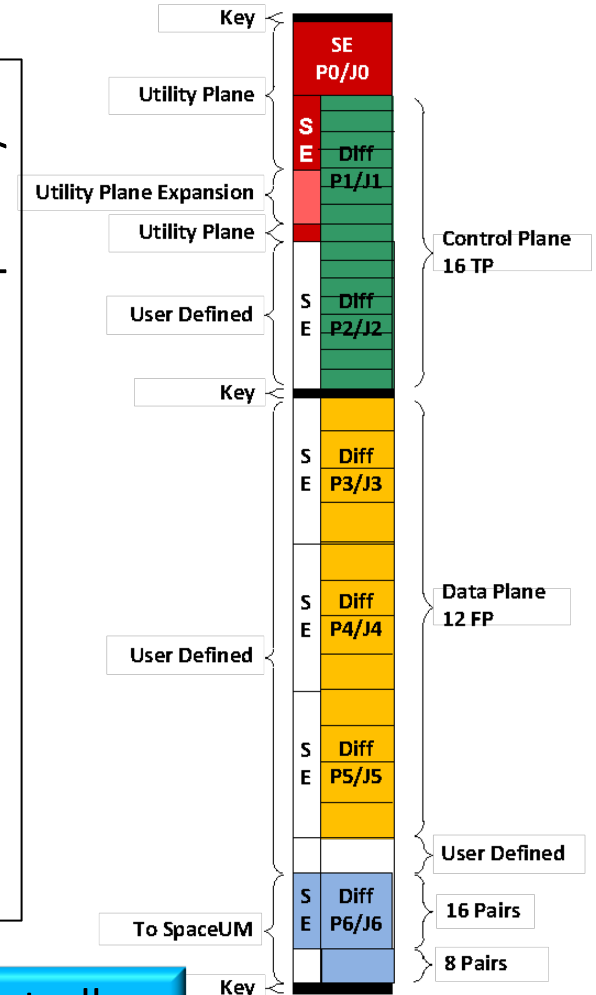
or

Possibility II → Control Switch Module / Data Switch Module

or

Possibility III → Controller Module / Control Switch Module / Data Switch Module

Utilize User Defined Pins and Top of Card Connectors for Additional Capability



Any Combination of Data Switch with Controller or Control Switch is Possible

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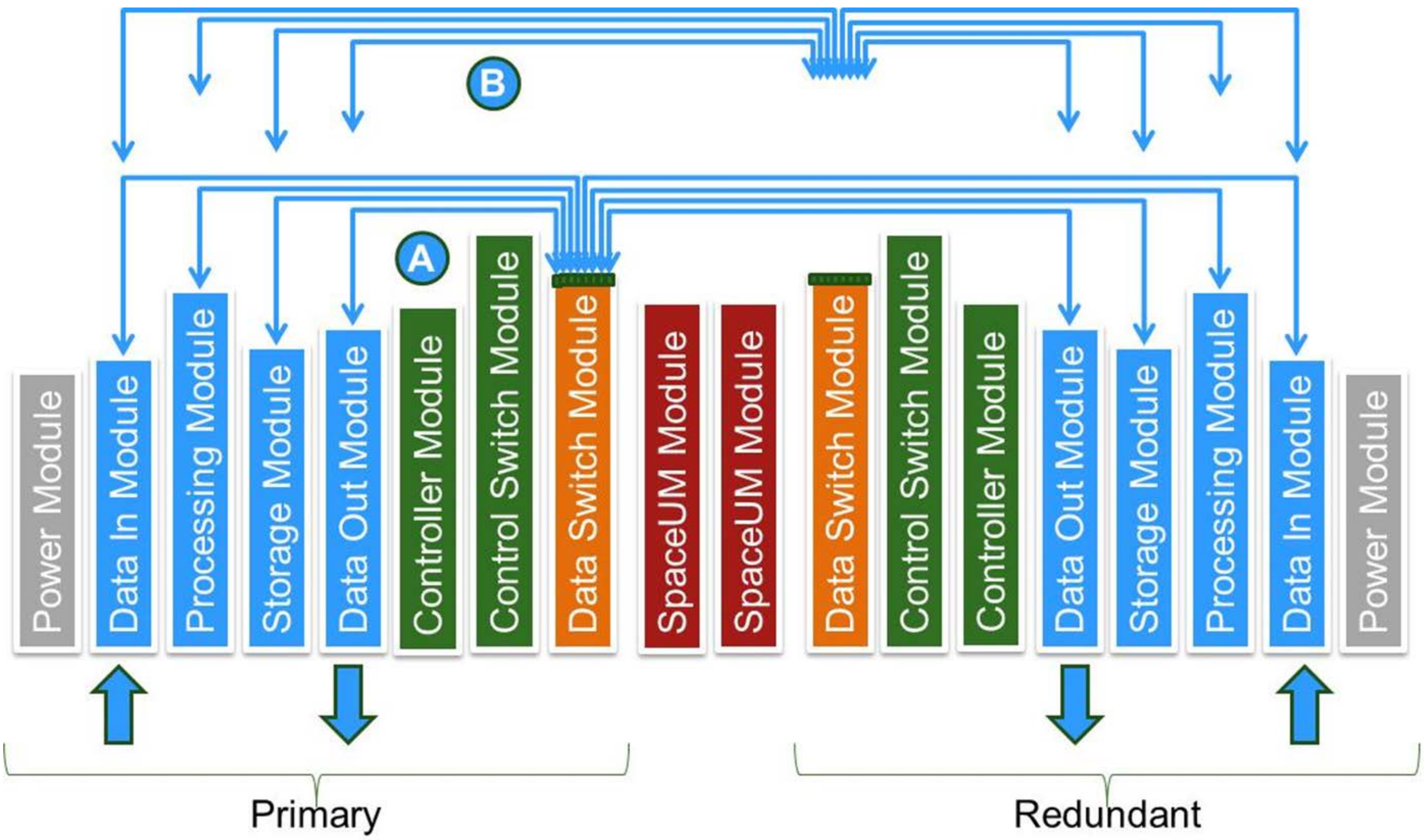
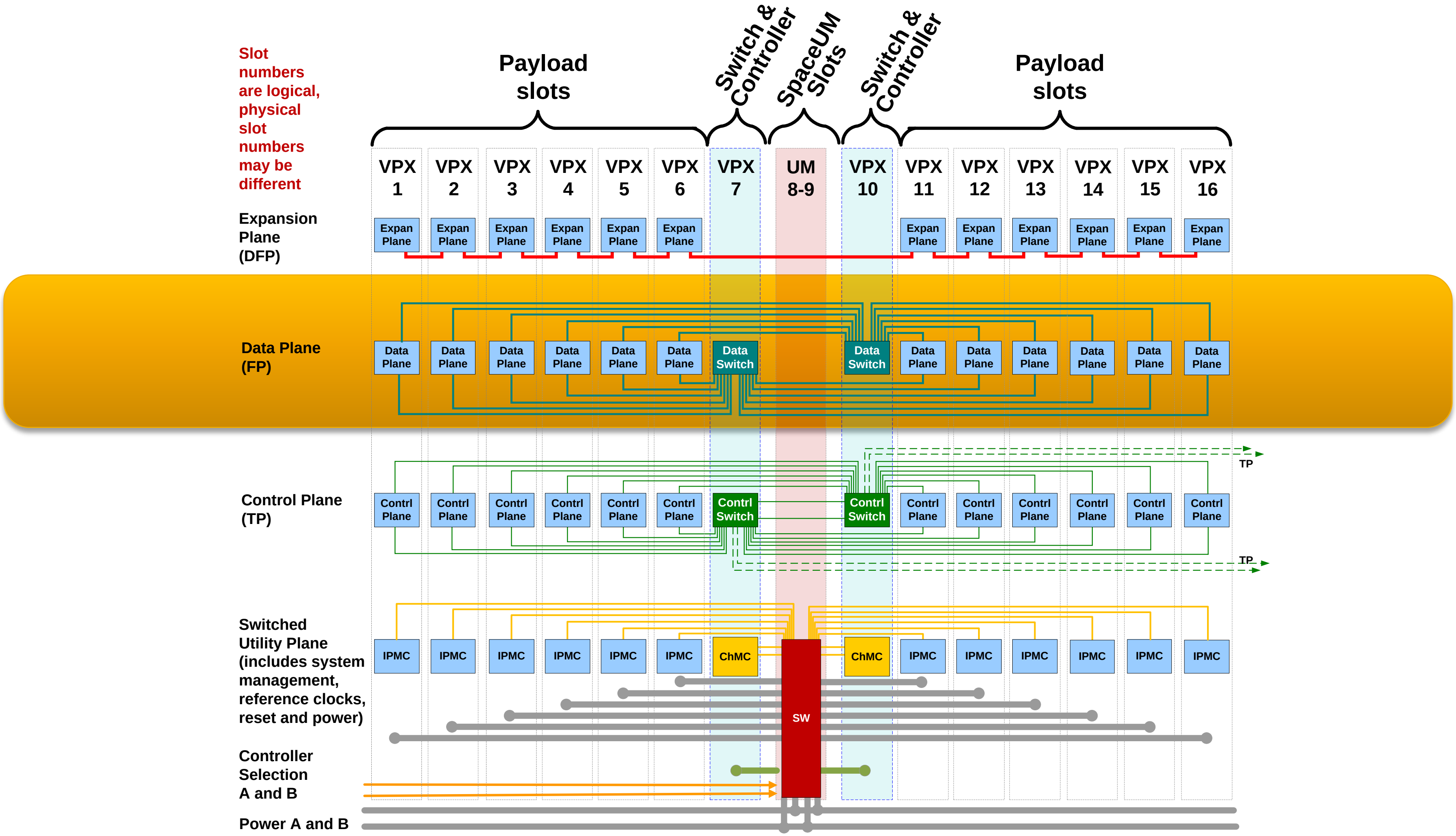
Data Plane Switch Topology

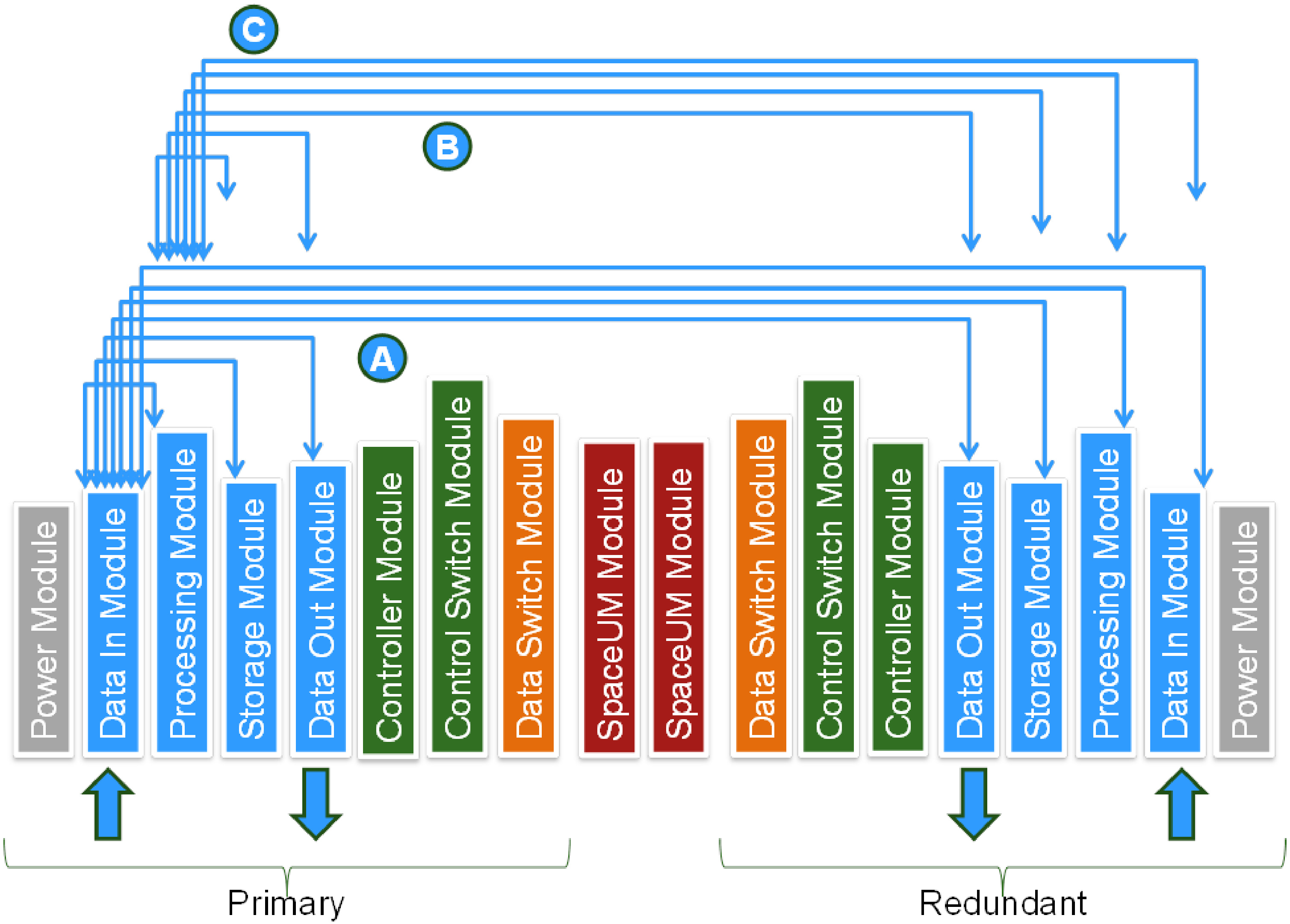


Data Plane in SpaceVPX

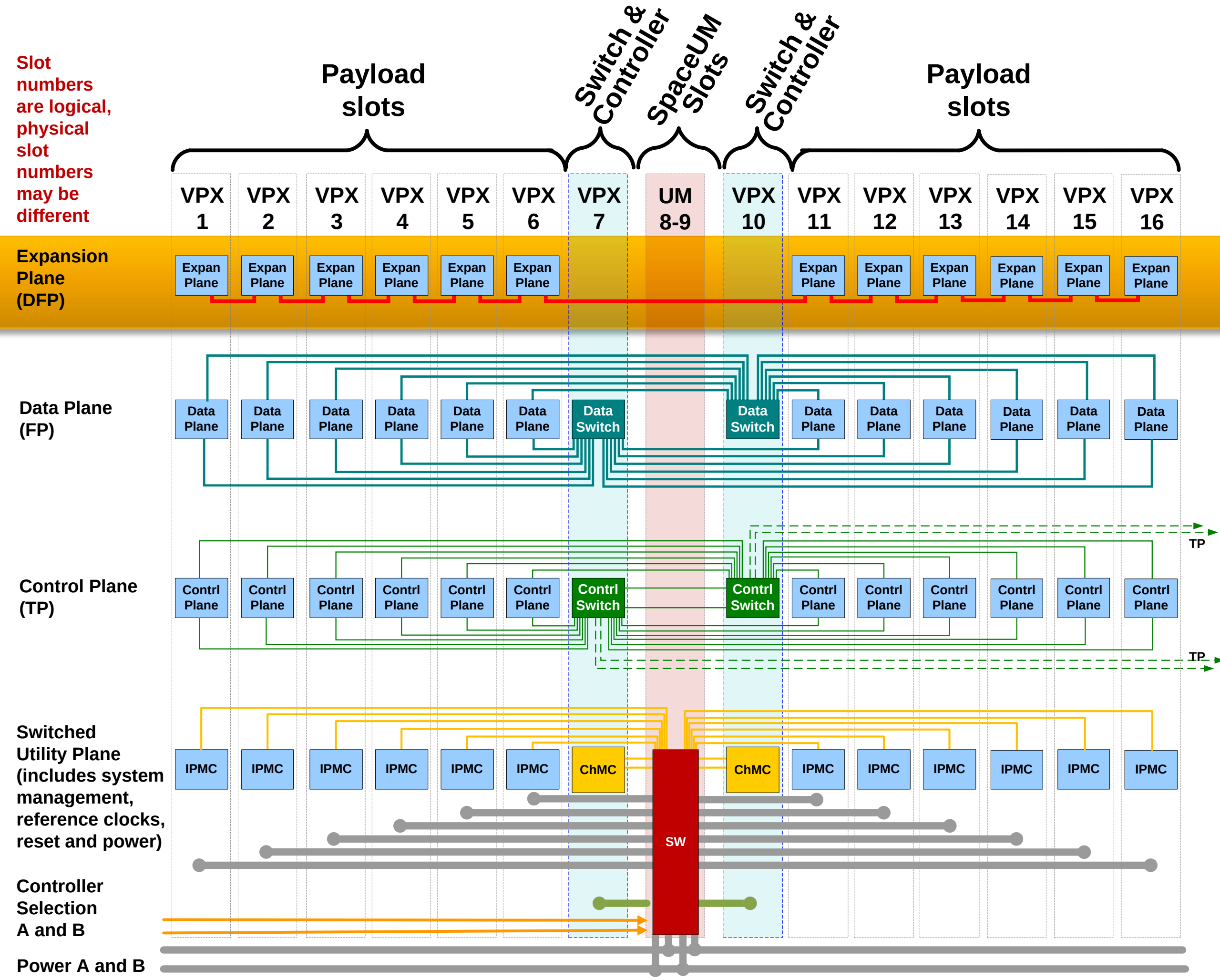


- High-throughput, predictable data movement without interfering with other traffic
- Examples: Serial RapidIO or PCI Express

Data Plane Mesh Topology



Expansion Plane in SpaceVPX



- Tightly coupled groups of boards and I/O
- Heritage Interfaces (PCI)

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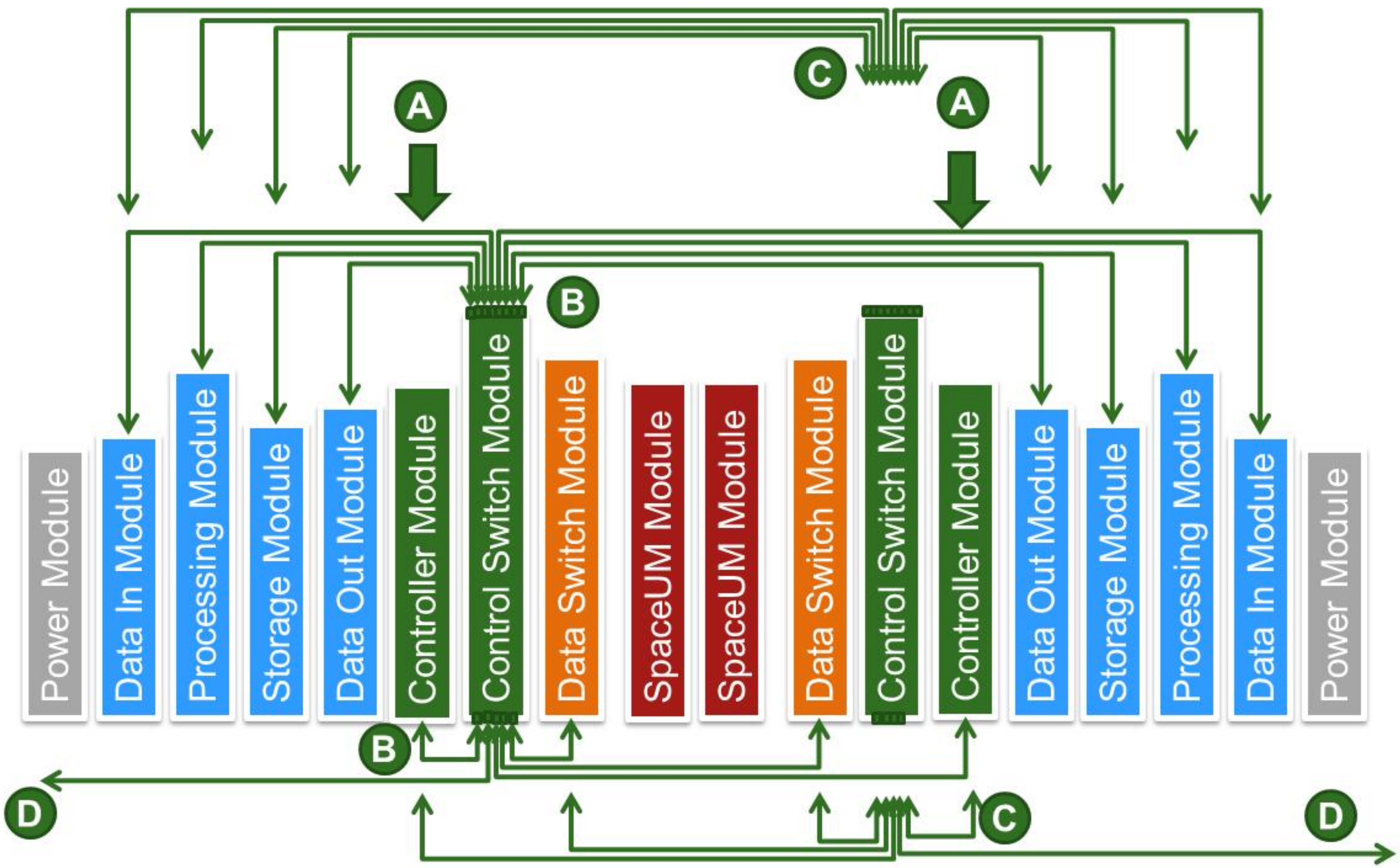
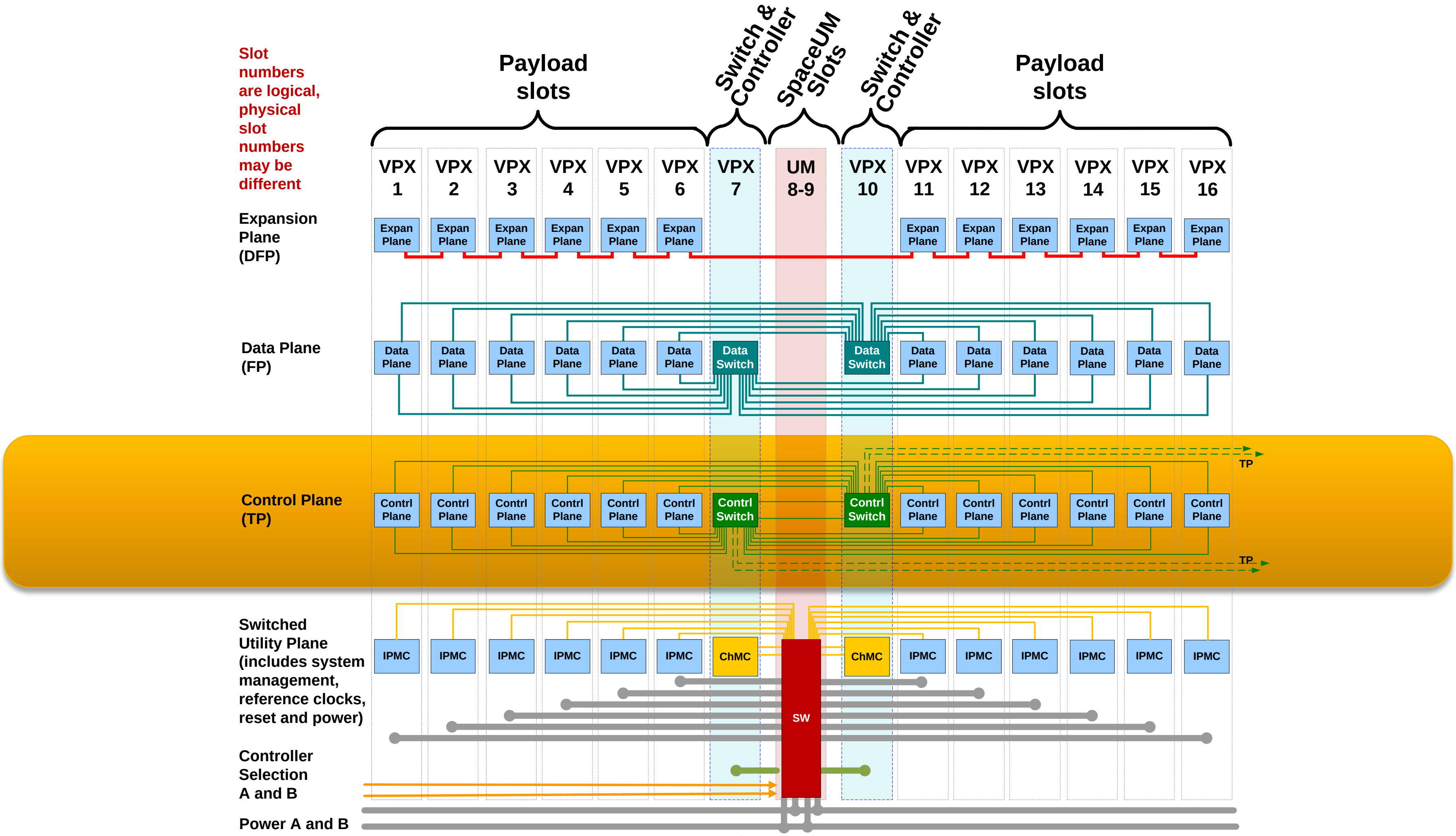
Control Plane Switch Topology

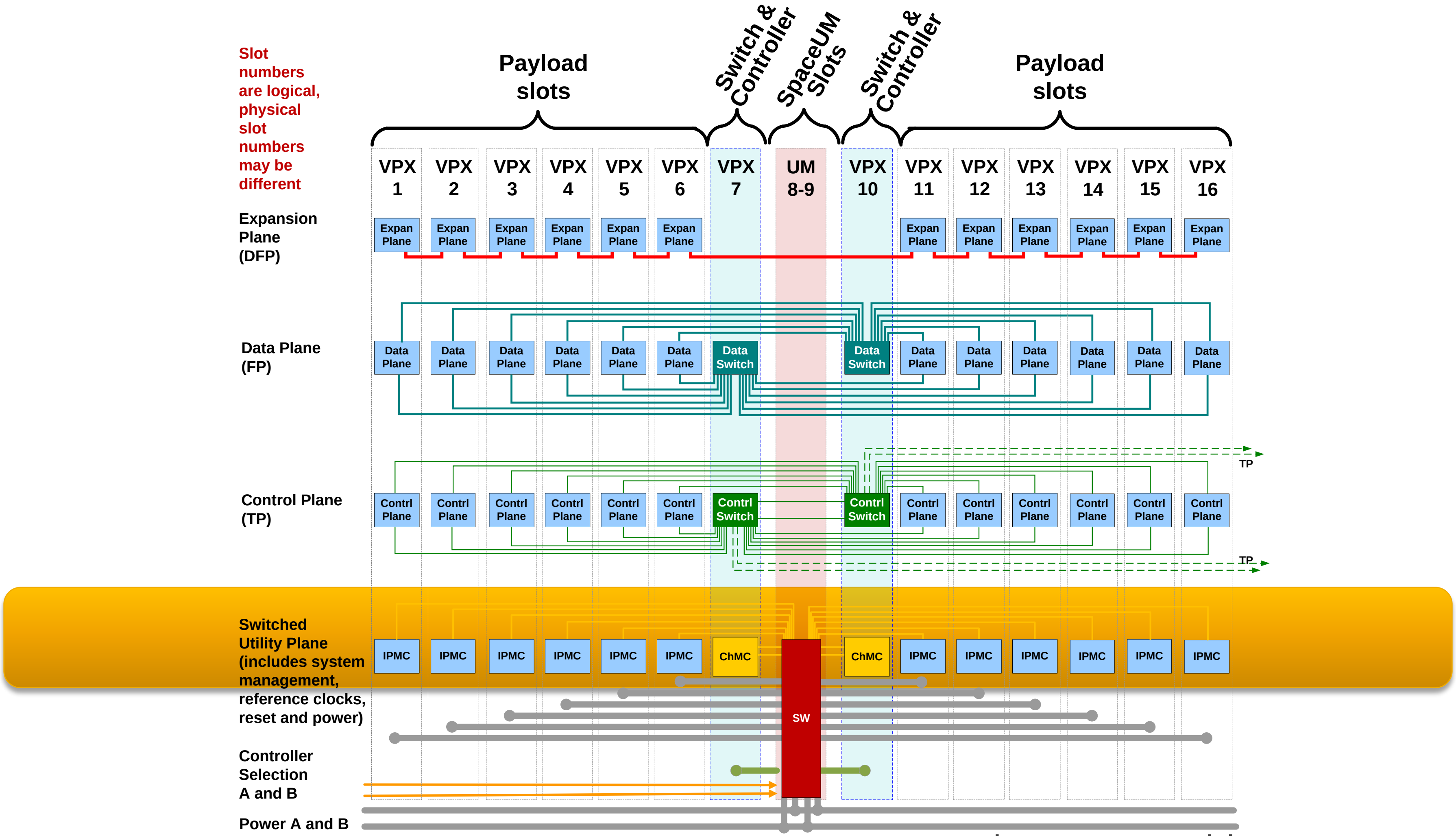


Control Plane in SpaceVPX



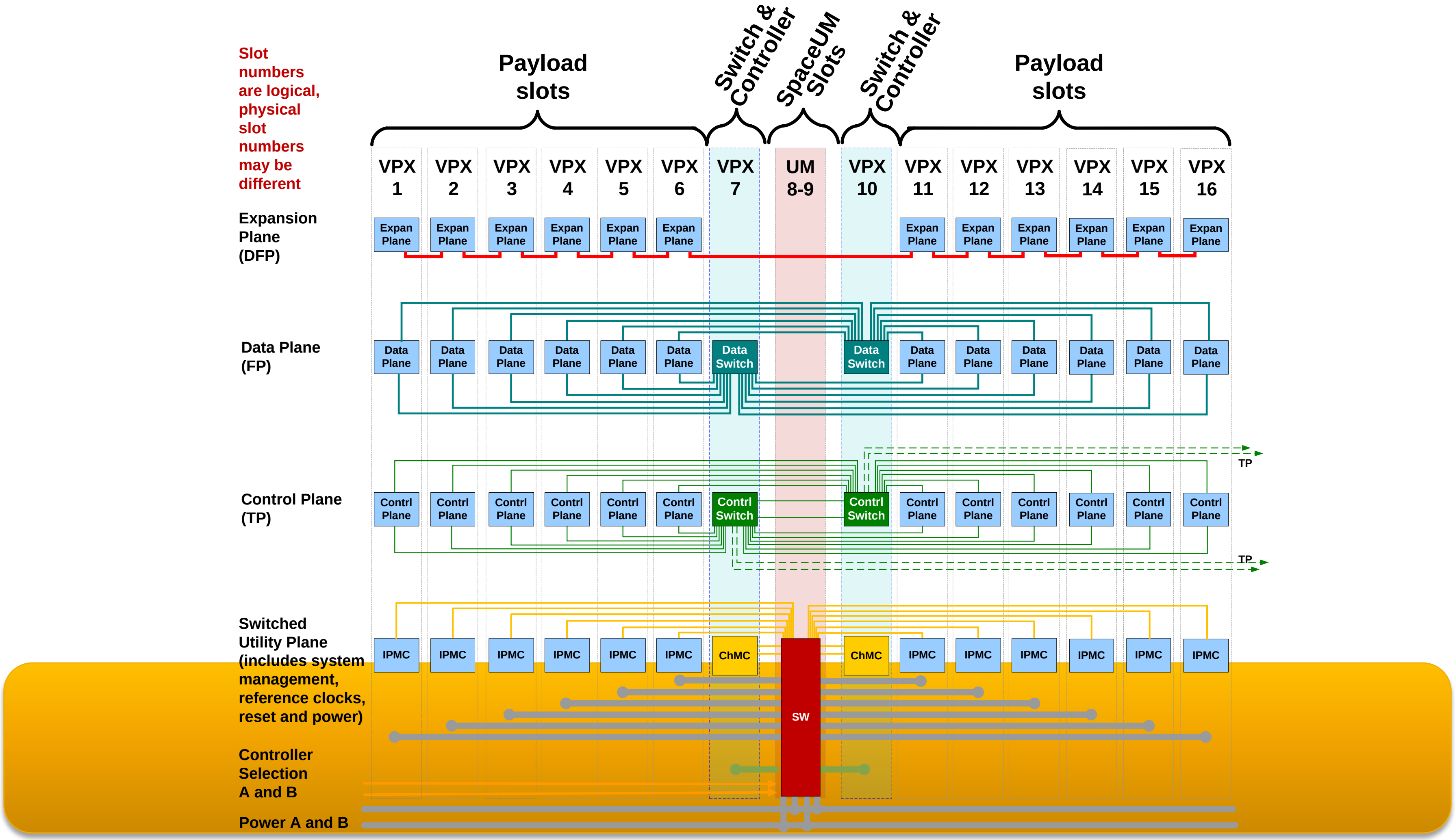
- Reliable, packet-based communication for application control, exploitation data
- Typically Gigabit Ethernet for Commercial and SpaceWire for Space Applications

Utility System Management in SpaceVPX



- Low-power
- Defined by VITA 46.0 and 46.11
- Prognosticates/diagnoses problems
- Can control module power

Utility Clocks, Reset and Power in SpaceVPX



- Power pins and various utility signals
  - Utility plane provides power, configuration, timing and management input signals using I2C, CMOS and LVDS levels

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Example Set of 6U Module Profiles

Profile Name	Data Plane 4 FP	Expansion Plane P2/J2	Control Plane 2 TP	User Defined
	DP01 to DP04		CPtp01 to CPtp02	P3/J3, P5/J5
MOD6-PAY-4F1Q2T-12.2.1-1-cc	sRIO 2.2 at 3.125 Gbaud per Section 5.2	sRIO 2.1 at 3.125 Gbaud per Section 5.2	SpaceWire per Section 5.2.1	User Defined DIFF pins
MOD6-PAY-4F1Q2T-12.2.1-2-cc	sRIO 2.2 at **5.0 Gbaud** per Section 5.2	sRIO 2.1 at **5.0 Gbaud** per Section 5.2	SpaceWire per Section 5.2.1	User Defined DIFF pins
MOD6-PAY-4F1Q2T-12.2.1-3-cc	sRIO 2.2 at **6.25 Gbaud** per Section 5.2	sRIO 2.1 at **6.25 Gbaud** per Section 5.2	SpaceWire per Section 5.2.1	User Defined DIFF pins
MOD6-PAY-4F1Q2T-12.2.1-4 to 6-cc	sRIO 2.2 at 3.125/5/6.25 Gbaud per Section 5.2	**User Defined – DIFF Pins**	SpaceWire per Section 5.2.1	User Defined DIFF pins
MOD6-PAY-4F1Q2T-12.2.1-7 to 9-cc	sRIO 2.2 at 3.125/5/6.25 Gbaud per Section 5.2	**User Defined – SE Pins**	SpaceWire per Section 5.2.1	User Defined DIFF pins
MOD6-PAY-4F1Q2T-12.2.1-1n-cc	sRIO 2.2 per Section 5.2 **defined by "n" above**	**defined by "n" above**	SpaceWire per Section 5.2.1	User Defined J3=SE pins J5=DIFF pins
MOD6-PAY-4F1Q2T-12.2.1-2n-cc	sRIO 2.2 per Section 5.2 **defined by "n" above**	**defined by "n" above**	SpaceWire per Section 5.2.1	User Defined J3=DIFF pins J5=SE pins
MOD6-PAY-4F1Q2T-12.2.1-3n-cc	sRIO 2.2 per Section 5.2 **defined by "n" above**	**defined by "n" above**	SpaceWire per Section 5.2.1	User Defined SE pins

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SpaceVPX Concept Development

- Three concepts developed
  - **Concept 1** – Redefine an existing OpenVPX connector block as a second Utility/Management plane block (similar to P0/P1)
    - Incompatible with existing OpenVPX modules
  - **Concept 2** – Extend the existing Open VPX connector by adding a second Utility/Management plane block (P7/P8 similar to P0/P1)
    - Extends module height from 6U to 6U+TBD
    - Partially compatible with existing OpenVPX modules
  - **Concept 3** – Add one or more Space Utility/Management (SpaceUM) modules with independent support for each OpenVPX module
    - The SpaceUM module receives redundant Utility and Management Plane signals through the backplane and selects one set to be forwarded to the OpenVPX module Utility/Management plane signals
    - Allows use of existing OpenVPX modules in appropriate flight applications

SpaceVPX Redundancy

- Each of the interconnect planes defined by OpenVPX are supported by SpaceVPX as fully cross-strapped single-fault tolerant capable
  - Control, Data and Expansion plane redundancy is provided using the existing OpenVPX connectivity
    - Ability to utilize M-of-N payload module redundancy to support either higher reliability or degraded modes of operation
  - The SpaceVPX Utility and Management plane redundancy is a major departure from OpenVPX
    - OpenVPX uses single-source, bused power distribution
    - OpenVPX uses single-source, bused clock, reset and management distribution
  - Each interconnect plane can be implemented with reduced fault tolerance when desired

SpaceVPX Fault Tolerance

Goal

SpaceVPX is to achieve an acceptable level of fault tolerance, while maintaining reasonable compatibility with OpenVPX components, including connector pin assignments. For the purposes of fault tolerance, a module is considered the minimum redundancy element. The Utility Plane, Management Plane, and Control Plane are all distributed redundantly and in star topologies to provide fault tolerance.

For Space applications, the major fault tolerance requirements are listed below:

- Dual-redundant power distribution (bussed) (**Section 3.2.1**) where each distribution is supplied from an independent power source.
- Dual-redundant management distribution (point-to-point cross-strapped) where each distribution is supplied from an independent management controller to a SpaceUM module that selects between the A and B management controllers for distribution to each of the slots controlled by the SpaceUM module.
- Card-level serial management (**Section 3.4.3**)
- Card-level reset control
- Card-level power control
- Timing/synchronization/clocks, Matched length, low-skew differential (**Section 3.4.2**)
- Fault tolerant Utility Plane selection (bussed) (**Section 3.3**)
- Dual-redundant Data planes (point-to-point cross-strapped)
- Dual-Redundant Control planes (point-to-point cross-strapped) (**Section 3.2.3**)
- VITA 78 infrastructure allows for fully managed FRUs and for dumb FRUs

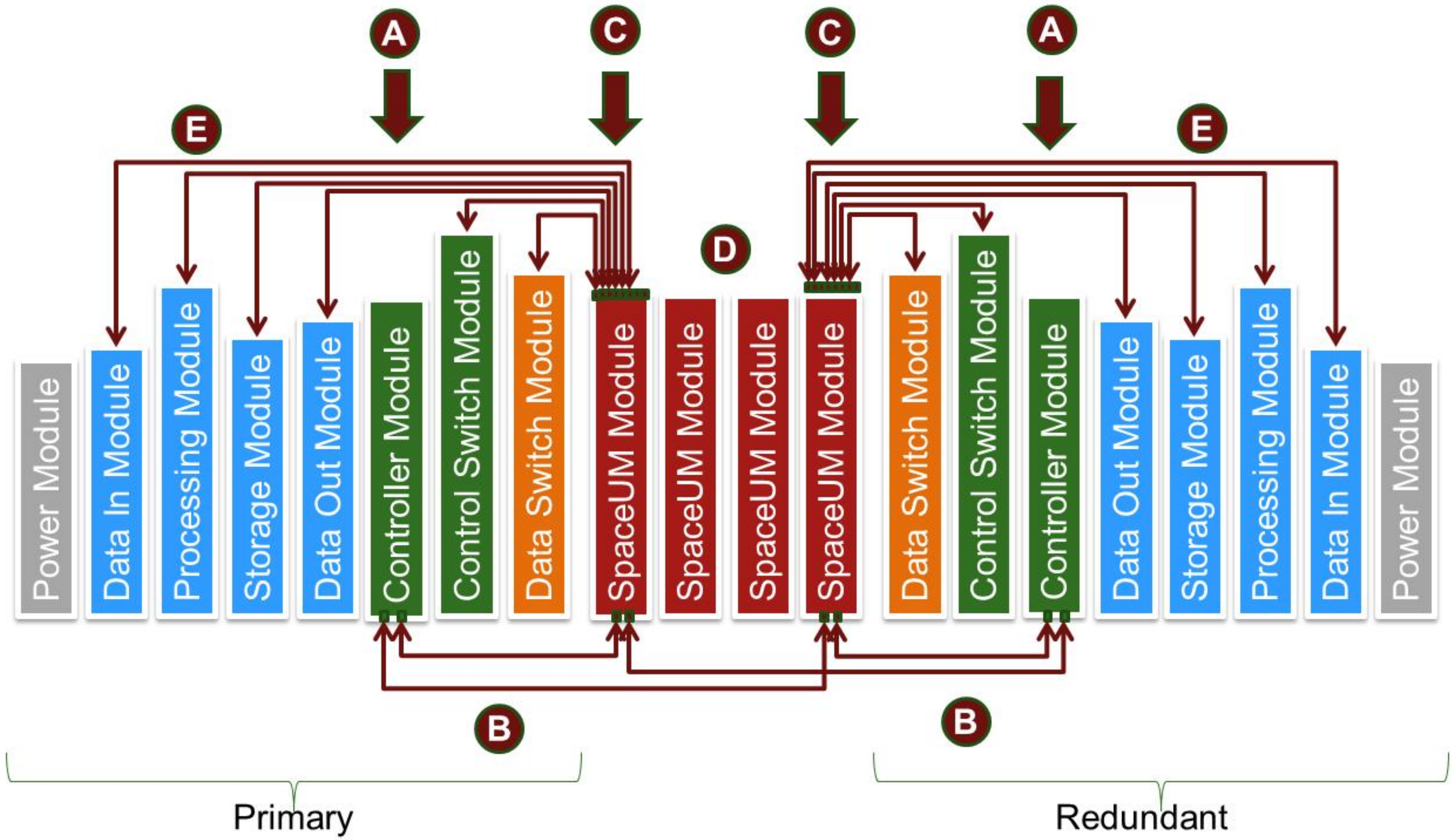
Space Utility Management

- Architecture
  - Provides single-fault-tolerance with limited increase in SWaP
    - One SpaceUM module supports eight VPX slots
  - Scalable to very large units
    - Maximum of 31 VPX slots and 4 SpaceUM slots
  - Dual-redundant power distribution
    - Allows traditional space methods
  - Dual-redundant management distribution
    - Traditional capability using improved methods
  - Accommodates supplier-preferred methods for implementing interoperable products
- Topology
  - Traditional tree-topology is familiar to space suppliers
  - Flexible command/status interface options allow tailoring to customer needs

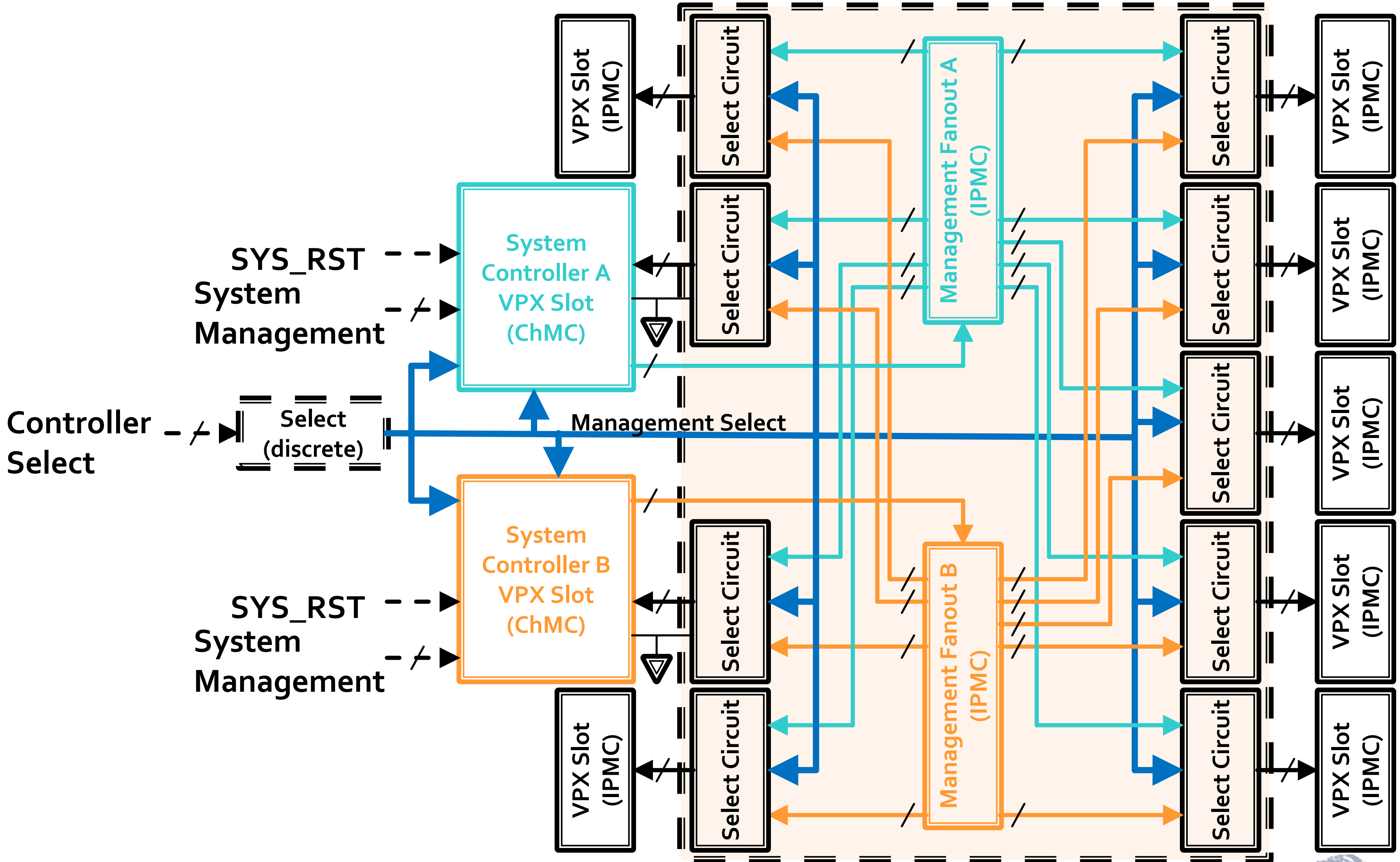
System Management

- **Leverages the VITA 46.11 industry standard**
  - Limited subset to minimize complexity
- **Defines an alternative light-weight protocol for less complex systems**
- **Basic functions supported**
  - Individual module power on-off control
  - Individual module reset control
  - Individual module status monitoring
- **Advanced capabilities**
  - Module-level telemetry acquisition
    - Voltage, temperature, digital state, etc.
  - Module-level functional control
    - Sub-function power control, register access, memory access, etc.

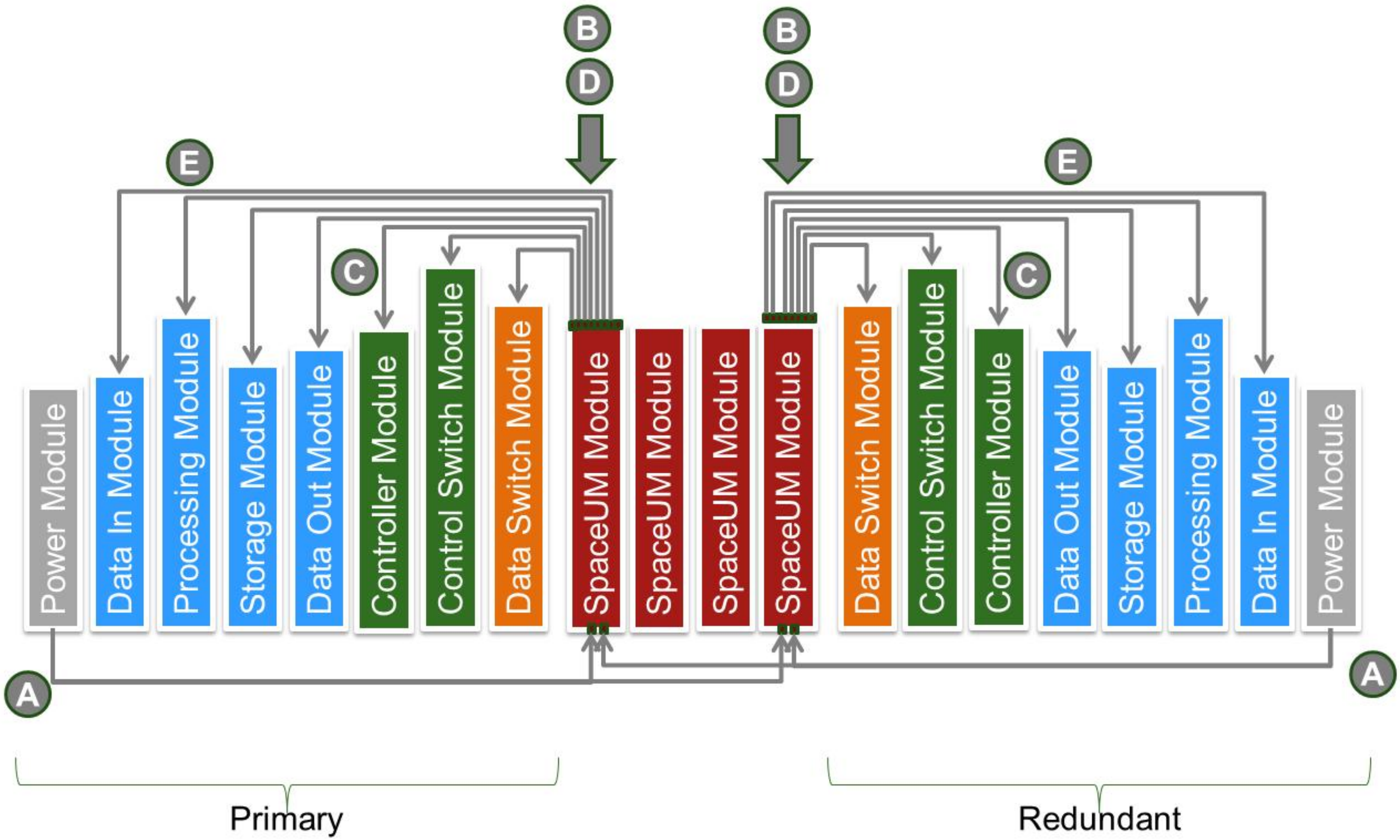
System Controller/Utility Plane



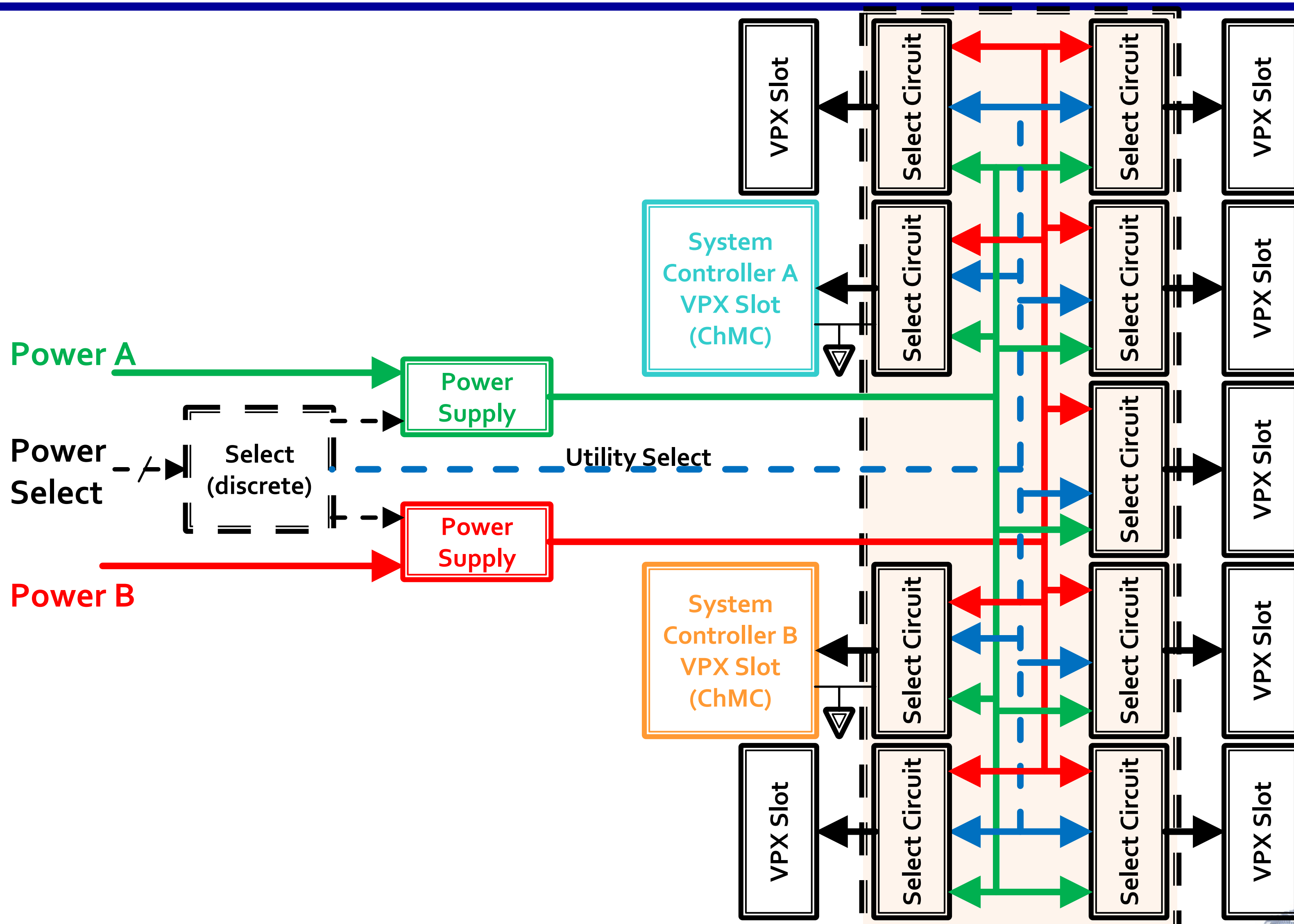
SpaceVPX Management Distribution Topology



Power/Utility Plane



SpaceVPX Power Distribution Topology



Outline

- What is SpaceVPX?
- SpaceVPX Slot Profiles
- SpaceVPX Backplane Profile
- SpaceVPX Module Profile
- SpaceUM - Provisions for Redundancy and Fault Tolerance
- **SpaceVPX Mechanical General Specifications**
- Backup

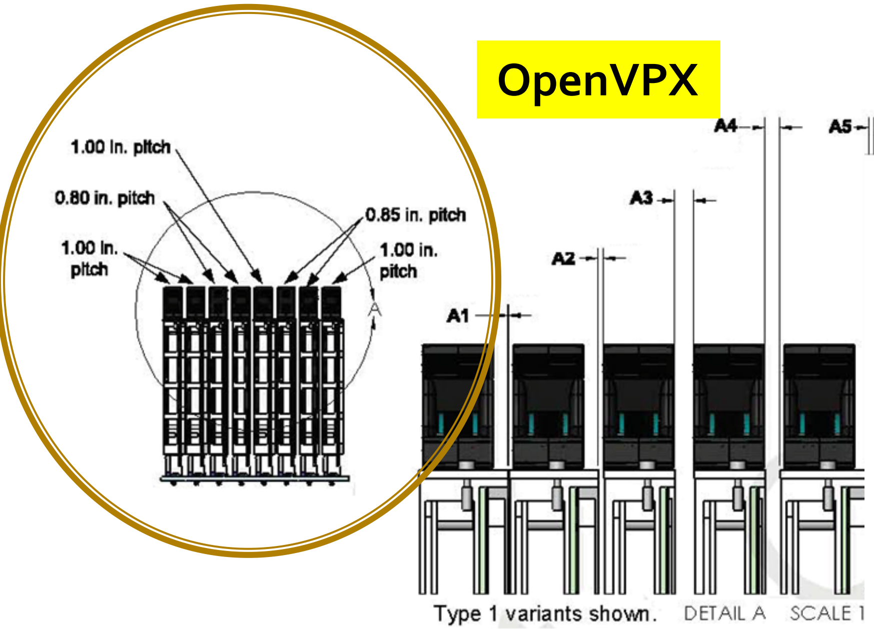
Mechanical

- **General Form Factor – VITA 46**
- **Conduction Cooled Modules – VITA 48.2**
  - Updated figures
  - Screw and tab modules with addition of threaded holes
  - Separate extraction tool for non-levered modules
- **Pitch – 0.8”, 1.0”, 1.2” (default)**
  - Multiple pitch cards may be used
- 160 mm standard length
  - 220, 280 and 340 mm allowed
- **Accommodates larger wedgelock**
- **Connections to PWB ground allowed**
- **Connector – VITA 46, VITA 60 or VITA 63 may be used**

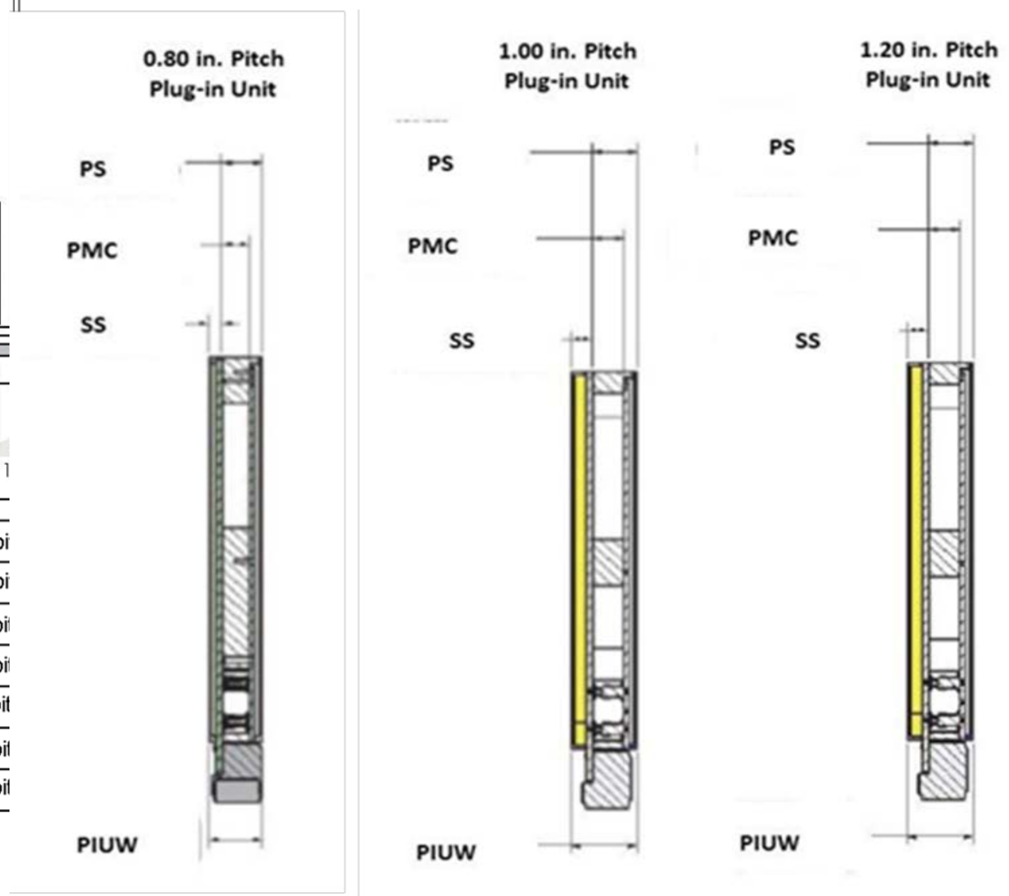
Strongly leverages existing OpenVPX mechanical infrastructure and standards

6U and 3U Form Factor Plug-In Unit Dimensions

OpenVPX



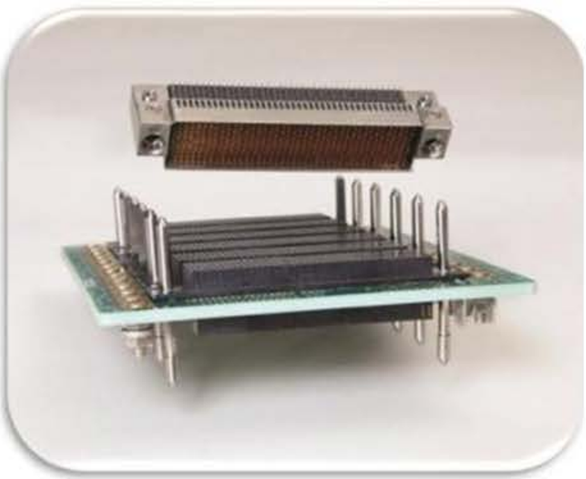
SpaceVPX

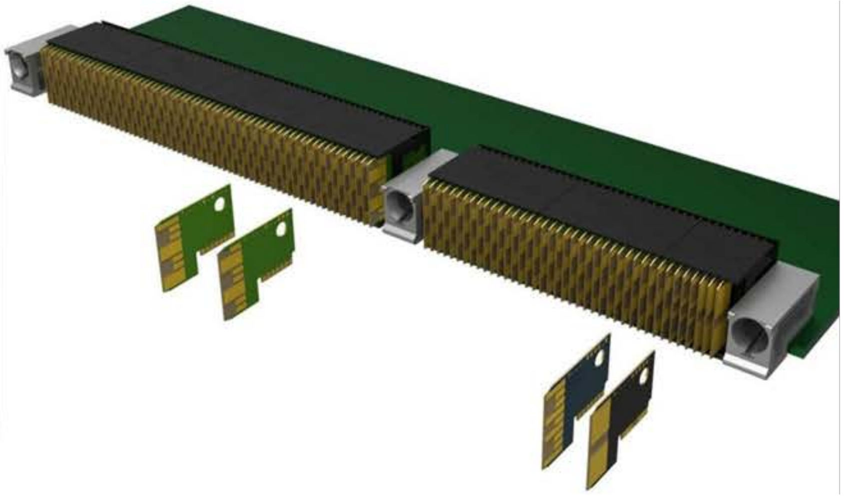


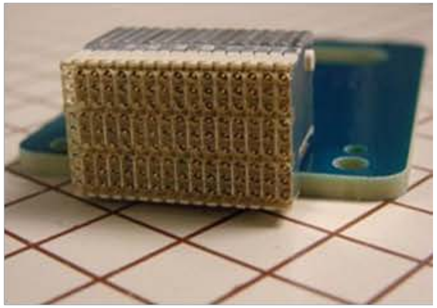
Dimension	Description
A1	Minimum gap between back of 1.00" plug-in unit and front edge of adjacent 1.00" pi
A2	Minimum gap between back of 1.00" plug-in unit and front edge of adjacent 0.80" pi
A3	Minimum gap between back of 0.80" plug-in unit and front edge of adjacent 0.80" pi
A4	Minimum gap between back of 0.80" plug-in unit and front edge of adjacent 1.00" pi
A5	Minimum gap between back of 1.00" plug-in unit and front edge of adjacent 0.85" pit
A6	Minimum gap between back of 0.85" plug-in unit and front edge of adjacent 0.85" pi
A7	Minimum gap between back of 0.85" plug-in unit and front edge of adjacent 1.00" pi

VITA Connector Options

- 3 VITA standard connectors as candidates (TE Connectivity, Amphenol, and Smith Connectors).
- A fourth candidate is under development (IEH Corp.); however, the product is nascent.
- The SpaceVPX (VITA 78) did not make a connector recommendation.
- Insufficient information largely the reason for a “No Go” on a recommendation.





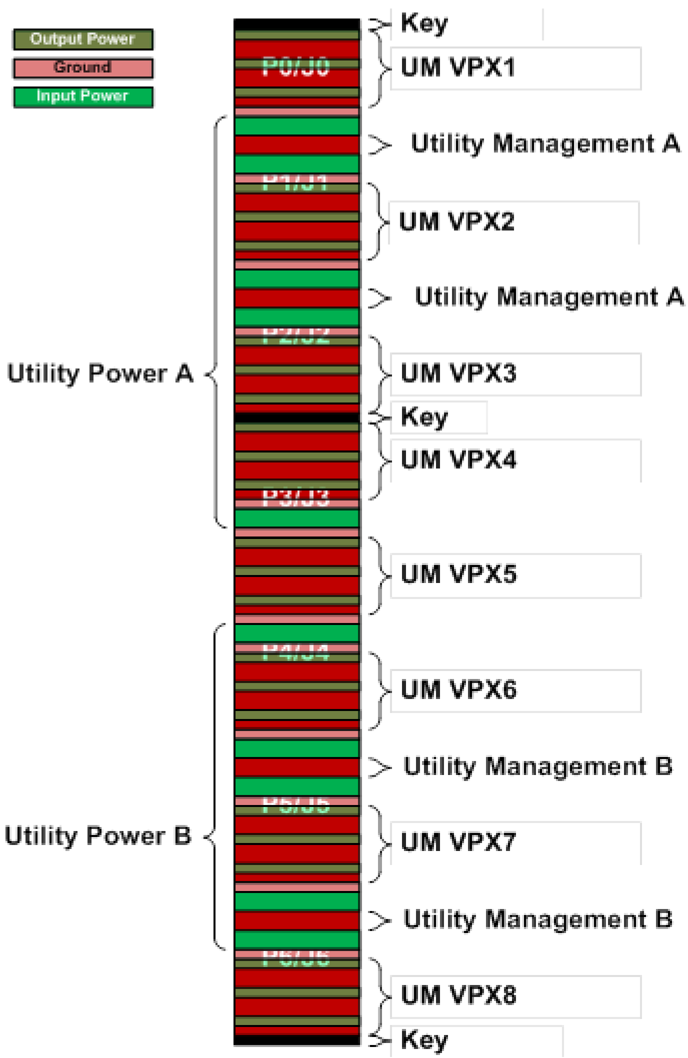


6U SpaceUM Connector

- Currently two vendors are designing and building SpaceUM connectors

- TE Connectivity
- Smith Connectors

- Each SpaceUM connects to a maximum number of 8 slots.



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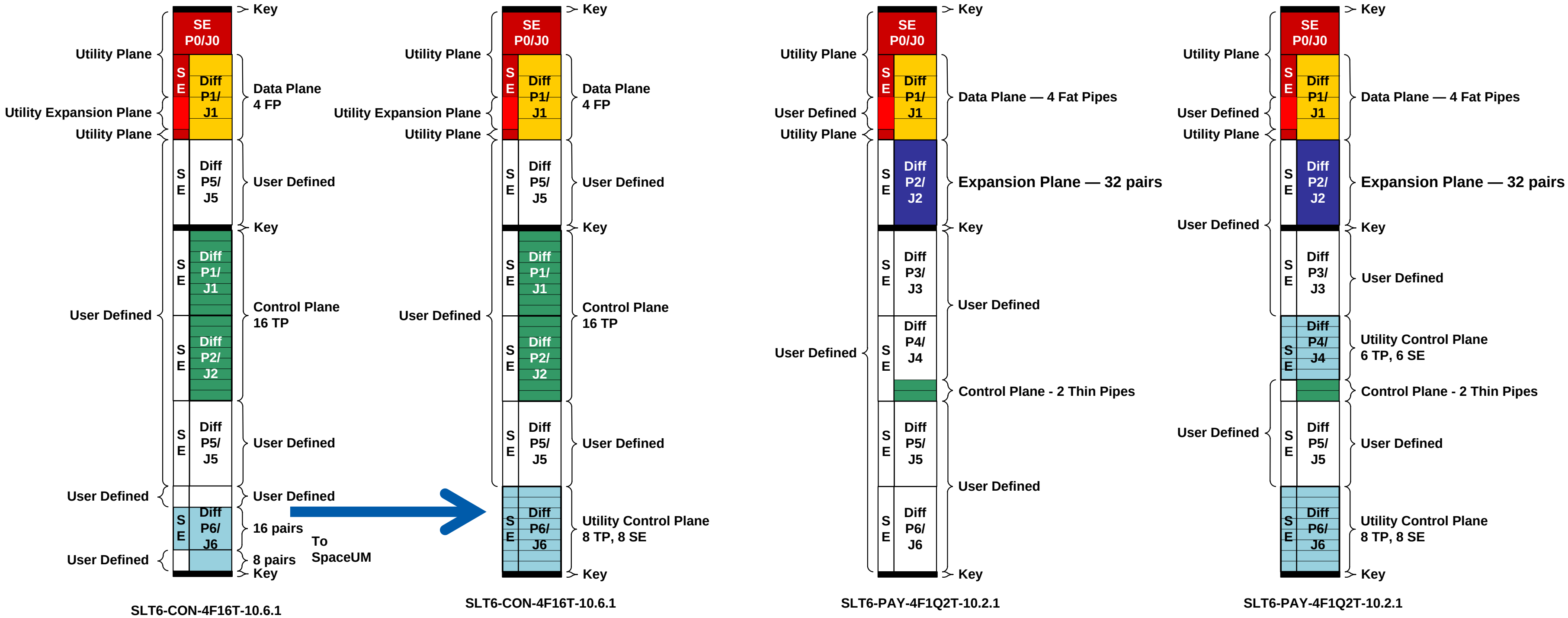
Two SpaceVPX Modular Open System approach available

- **SpaceVPX with Space Utility Modules (SpaceUMs)**
- All the benefits of SpaceVPX with:
- I2C System Management
- Two additional clocks or timing strobes radially distributed
- Standard Interoperable SpaceUM design
- Extensibility to large 6U systems

- **SpaceVPX with Direct Utility Control (SpaceVPXlite)**
- All the benefits of SpaceVPX with:
- High TRL legacy power switching & OpenVPX compatibility
- Cross-strapping utilities
- Lowest Size, Weight and Power
- Ideal for 3U and small 6U systems

Utility Controllers fit into existing SpaceVPX profiles by mapping "User Defined" pins



Controller Slot Profile
SpaceUM control pins re-mapped

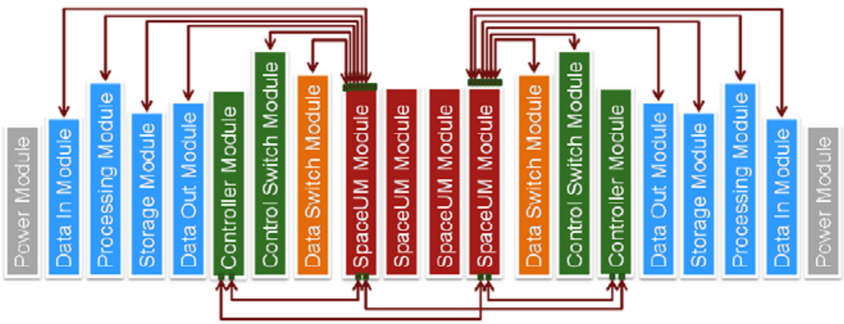
Payload Slot Profile with added Utility Controls for a 16-slot system

Like OpenVPX, SpaceVPX Slot Profiles Standardize the Module Pin-out

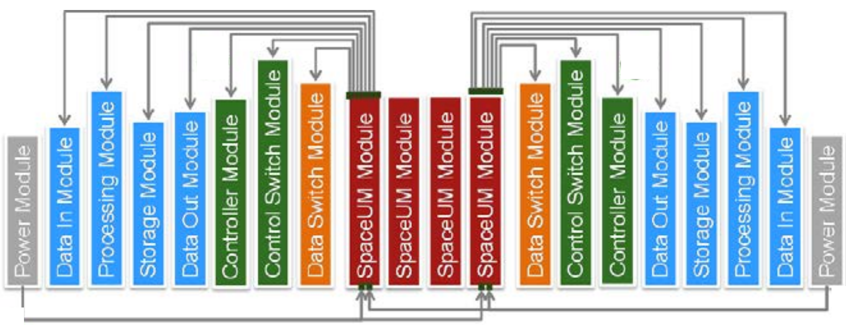
SpaceUM and Direct Utility Control Topologies

SpaceUM implementation

All resets, clocks and utilities go through SpaceUM



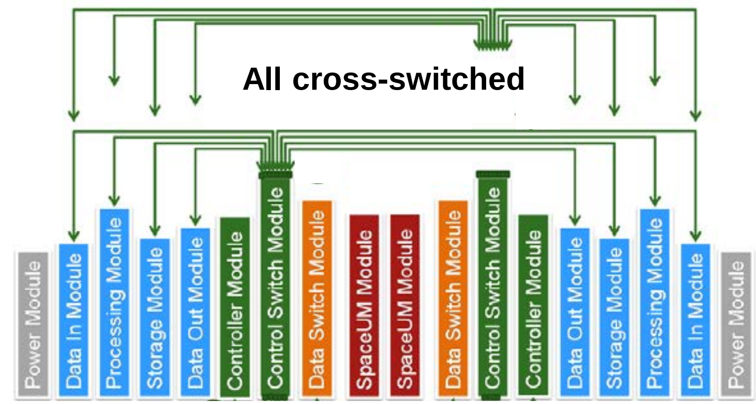
All VPX power supplies go through SpaceUM



Power controls are high reliability SpaceVPX I2C System Management signaling

Direct Utility Control Non-SpaceUM implementation

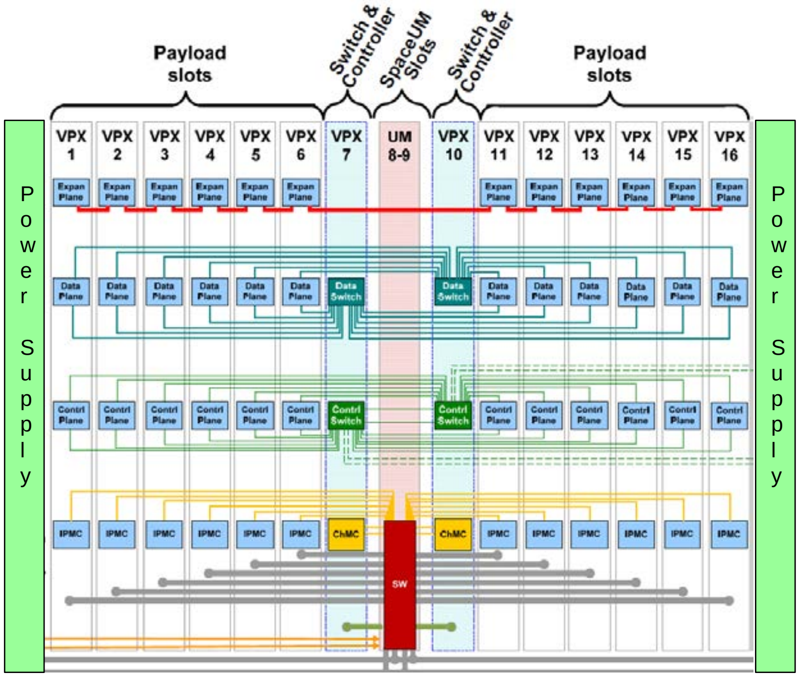
Adds resets, clocks, utility bus distribution directly to payload modules



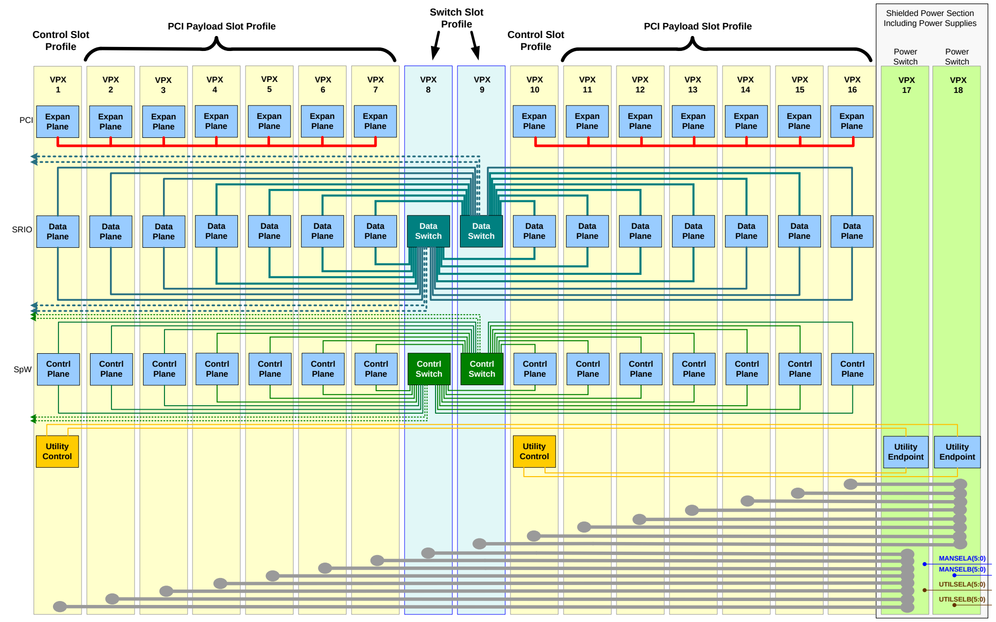
Power controls are simple robust differential discrete on/off digital or analog signaling capable of long distance transmission

Supports power switching in the power supply, on the backplane or in a separate module (no backplane required)

Side-by-Side Topology Comparison With and Without SpaceUM



Topology of SpaceVPX BKP-CEN16-11.2.2-n



Similar topology without SpaceUM

- Two slots consumed by the SpaceUM
- High current switching on SpaceUM near digital circuits
- Many connection points adds impedance and noise to power
- Clocks & resets pass twice through SpaceUM connector
- Complex serial protocol needed for power switching
- Non-cross-strapped dual redundant clocks and resets

- Adds two more payload slots
- All power switching in EMC controlled section
- Power distributed through conventional de-coupled planes
- Clock & reset routes shielded by ground planes pt. to pt.
- Discrete differential on/off controls to the power supplies
- Cross-strapped dual-redundant clocks and resets

Direct Utility Control Trades the Extensibility of the SpaceUM for Lower SW&P

Questions?