Towards a Unified, Scalable, and Highly Capable Next Generation Avionics Interconnect: The NEXUS Approach

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Outline

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- NEXUS Technology
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- An Standardization Effort
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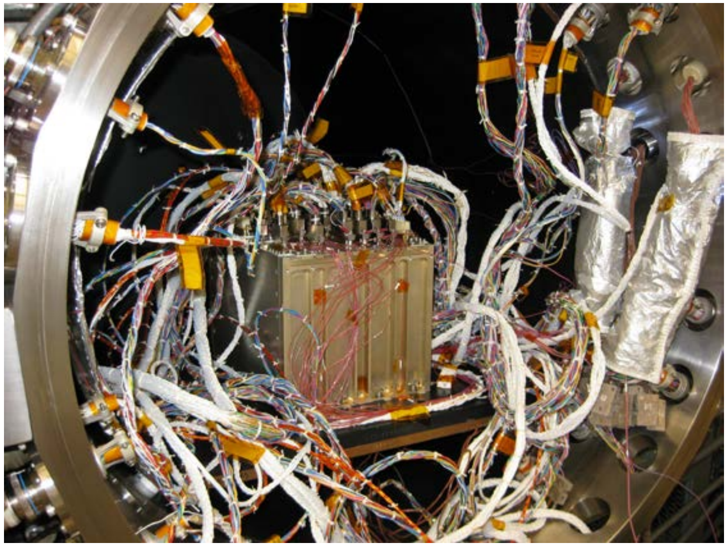
- Acknowledgement

Motivations

So, why are we here?



And what should we do in the future?

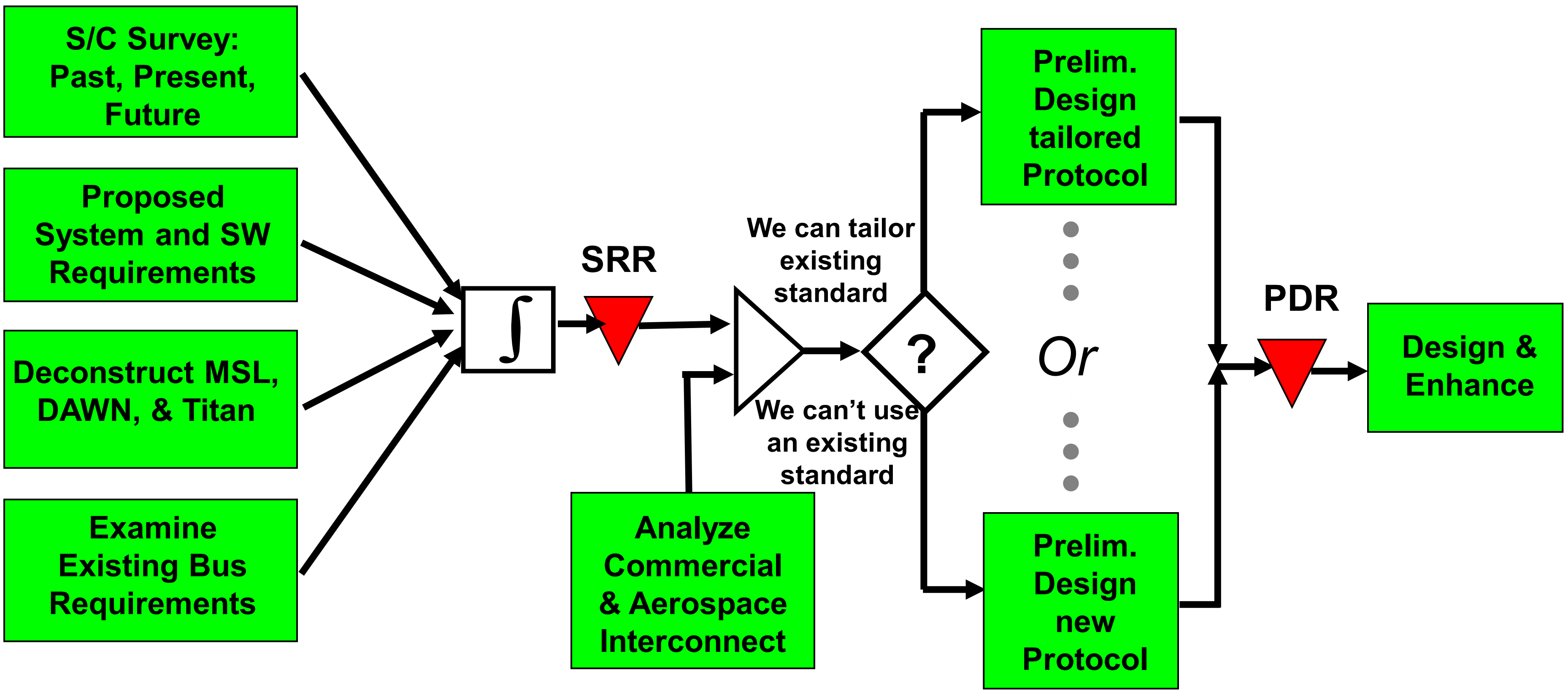
- High-speed instruments of a Gbps-bandwidth
    - SARs and hyper-spectrometers;
- On-board multi-core computing paradigm;
- Guaranteed real-time determinism with sub-microsecond latency/jitter for tight control loops;
- Fractionated spacecraft and sample return missions that requires separability and scalability
- More suitable physical layer technology such as wireless and fiber optics.

Objectives

- *NEXUS* (NEXt bUS)
  - A research task funded by JPL R&TD program
  - Develop a common highly-capable, highly-scalable next generation avionics interconnect with the following features:
    - ❑ Transparently compatible with wired, fiber-optic, and RF physical layers
    - ❑ Scalable fault tolerant (sub-microsecond detection/recovery latency)
    - ❑ Scalable bandwidth from 1 Kbps to 10 Gbps
    - ❑ Guaranteed real-time determinism with sub-microsecond latency/jitter
    - ❑ 20% - 50% wire mass reduction
    - ❑ Low power (< 100mW per Gbps)
    - ❑ Light-weight (< 5000 logic gate footprint)
    - ❑ A clear and feasible path-to-flight to ensure infusion into future NASA/JPL missions

Technical Approach

1. Survey past, current, and future space missions
2. Develop a set of spacecraft avionics interconnect requirements
3. Assess the state-of-the-art existing protocols with respect to the developed requirements and decide the design approach
4. Develop the NEXUS protocol specification
5. Design and Implement the NEXUS protocol



Survey Findings

- 15 past, current, and future space missions were surveyed with respect to its interconnect requirements
- Key findings
  - Aggregate bandwidth is orders of magnitude greater than traditional avionics "backbone" buses such as 1553B
  - Instrument are the biggest drivers on bandwidth, and are expected to be even more so in the future
  - Missions with complex operation scenarios are big drivers in C&DH and ACS
  - Need to accommodate physical separation events is a large driver for many future S/Cs
  - Hybrid ad-hoc solutions lead to a overwhelming interconnect maze that complicates design, integration, and testing, and increase wire mass and power consumption
  - Instruments requiring coordinated precision is the biggest driver in real-time performance

NEXUS Requirements

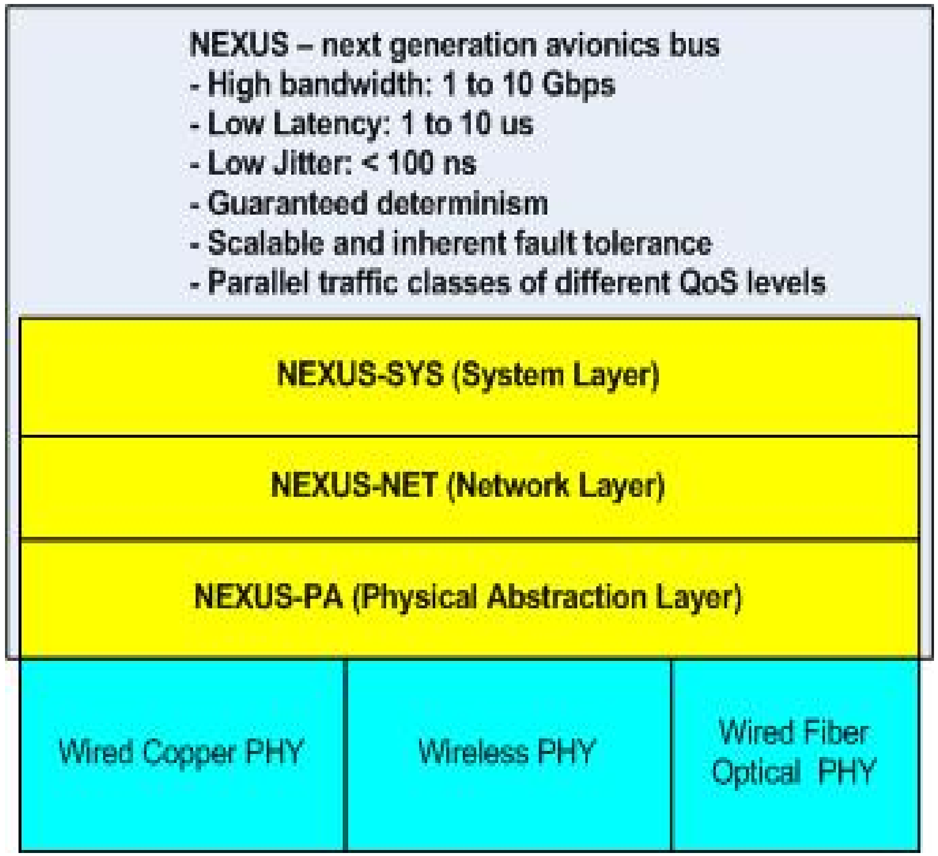
- A detailed set of 94 NEXUS desirements has been developed and reviewed
- It is divided into 20 categories

No.	Requirement Categories
1.0	Physical Layer Compatibility
2.0	Operational Mode
3.0	Protocol
4.0	Topology
5.0	Scalability
6.0	Reconfiguration
7.0	Modularity
8.0	Commercial Standard Compatiblity
9.0	Legacy System Compatiblity
10.0	Bandwidth
11.0	Real-Time Operation and Control
12.0	Fault Tolerance Level
13.0	Fault Detection
14.0	Fault Response
15.0	Testability
16.0	Electrical Isolation
17.0	Power/Bandwidth Management
18.0	Radiation Level
19.0	EMI Sensitivity
20.0	Temp Range Op & Non-Op

Notes:

1. The categories are listed from high-level to low-level; i.e., from generic to specific
2. The ordering does not reflect the importance of the categories

NEXUS Architecture



Protocol Survey

- An evaluation matrix was developed based on the requirements
- 13 commercial and avionics protocols were assessed against the evaluation matrix
- 13 protocols were down-selected to four protocols
  - tt-GbE
  - Ring Bus
  - SpaceWire
  - Serial RapidIO
- A depth assessment was conducted and the final working baseline protocol was chosen
  - Serial RapidIO

Key Driving Differentiators

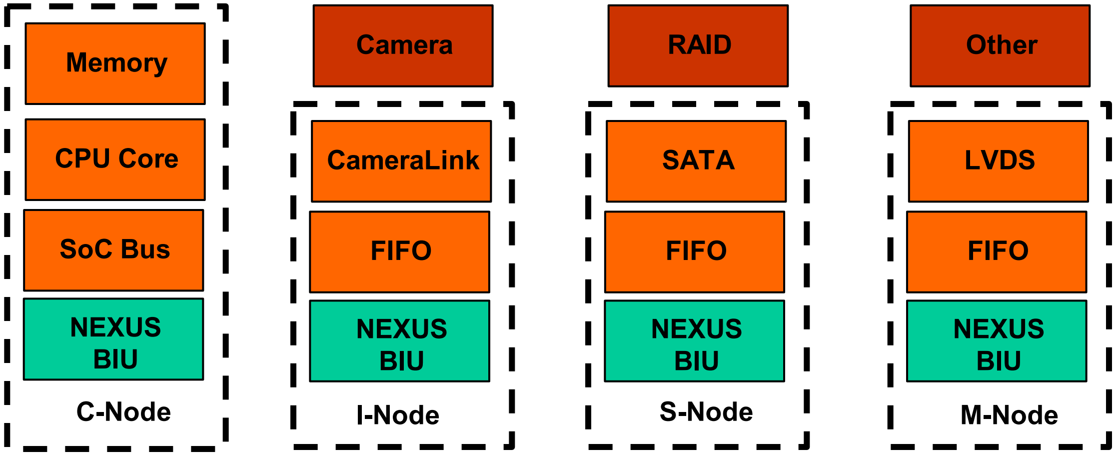
- Serial RapidIO has the following salient features among four protocols:
  - Transparent compatibility with wired and fiber-optic
  - Applicable to chip-to-chip, board-to-board, and box-to-box
  - Light-weight and modular (features are configurable)
  - Low power with less than 192 mW per node
  - Scalable fault tolerance with link-level error detection
  - Scalable bandwidth up to 3.125 Gbps per lane
  - Real-time with sub-microsecond latency and jitter
  - Switch-based flexible topology
  - Built-in shared-memory support with low S/W overhead
  - Embedded provisions allow backward-compatible protocol extension

Key Enhancements for Serial RapidIO

- Enhancements are being made by exploiting existing SRIO provisions without breaking backward compatibility
  - Guaranteed real-time determinism
  - Complete testability using in-band maintenance packets
  - Reduced bandwidth of 1 kbps using slow clock
  - Links with hybrid bandwidths within a network
  - Scalable fault tolerance level
  - Multiple power operational modes

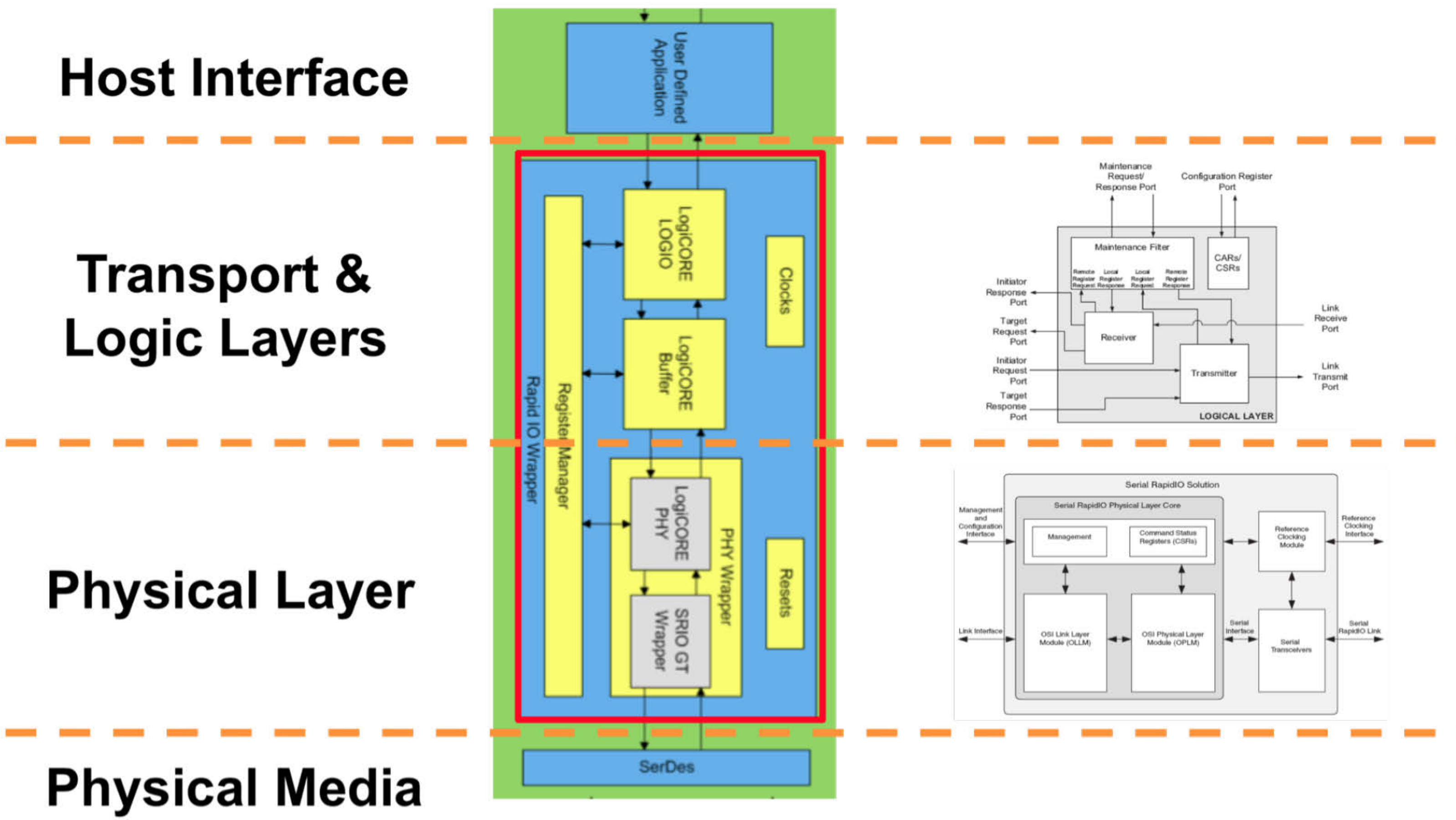
NEXUS Hardware Testbed

- NEXUS Bus Interface Units (BIU)
  - Can be integrated into 4 types of NEXUS nodes in terms of front end types
    - *C-Node*: Interfaces with the flight computer
    - *I-Node*: Interfaces with instrument detector (camera, radar ADC boards, etc)
    - *S-Node*: Interfaces with storage disk array
    - *M-Node*: Interfaces with any other types of front end
  - Is capable of providing scalability of performance/power consumption
  - Can serve as design templates as reference design



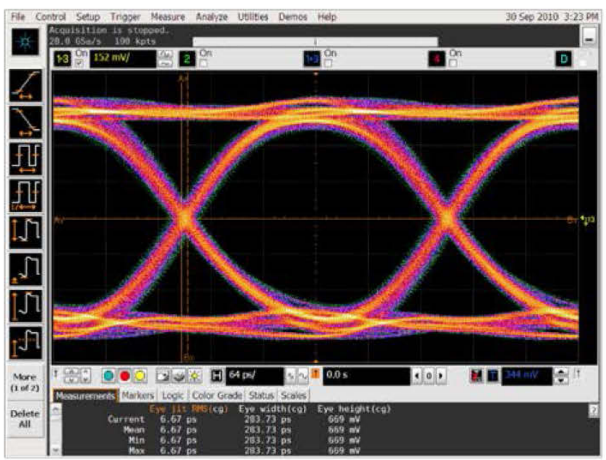
NEXUS Hardware Testbed - BIU

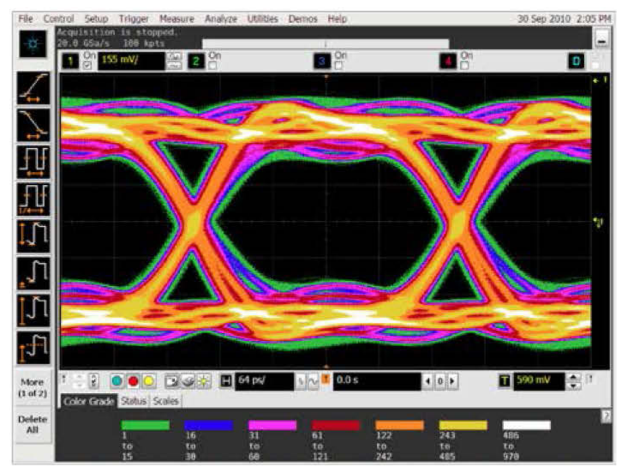
- NEXUS BIU
  - Developed the NEXUS BIU based on Xilinx Serial RapidIO IP core



NEXUS Hardware Testbed - Configurations

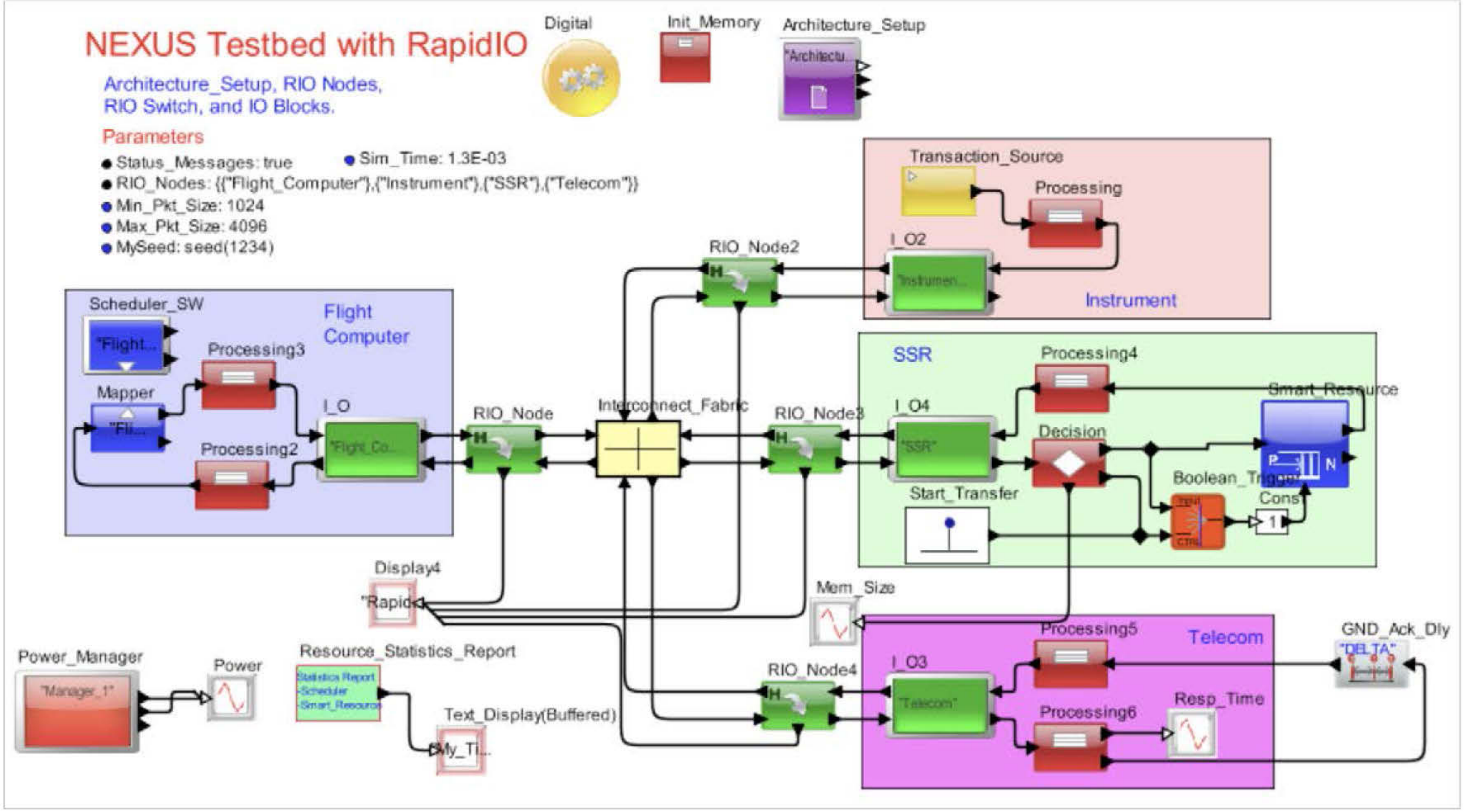
HW Testbed	Testbed 1	Testbed 2	Testbed 3	Testbed 4	Testbed 5
No. of Nodes	1	2	2	4	2
Topology	loopback	Point-to-point	Switch-based	Switched	Point-to-point
Components	Endpoint	Endpoint	Endpoints + Switch	Endpoints + Switch	Endpoint
Probe	Chipscope	Chipscope	RapidFET	RapidFET	Chipscope
PHY	Copper				Fiber





NEXUS Software Testbed

- NEXUS Software Testbed
  - Based on a sophisticated modeling and simulation tool VisualSim by Mirabilis Design, Inc
  - Allow implementation and evaluation of identified enhancements



Next Generation Spacecraft Interconnect Standard

- A next generation spacecraft interconnect standardization organization is formed
- It consists of representatives from USAF, NASA, NRO and other space agencies
- It will also include representatives from stakeholders in government, industry and academia.
- Currently it is a Working Group (WG) under the Computer Systems Technical Committee in AIAA

Summary

- A unified interconnect such as NEXUS can be used to meet performance, power, size, reliability requirements of all ranges of equipment/sensors/actuators at chip-to-chip, board-to-board, box-to-box boundary.
- It is designed in a modular and configurable fashion under a common interconnect standard and is used via adaptation
- Serial RapidIO provides a viable baseline

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