Enabling technologies to meet future onboard data processing needs

Space Passive Components Days – 2013
ESTEC

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Introduction

Miniaturisation and performance increase in terrestrial applications – does to some degree apply to satellite technology as well.

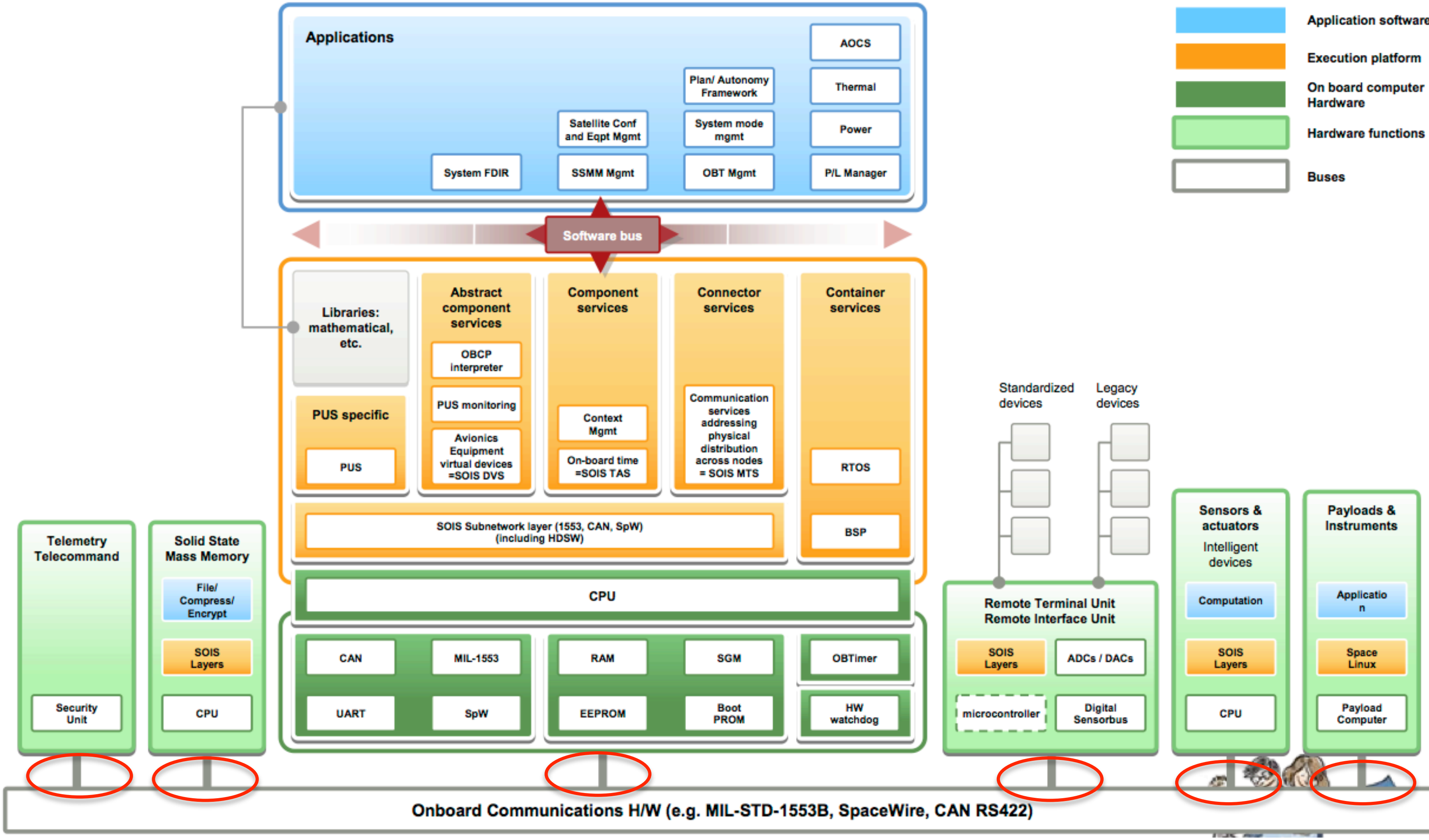
1990's

2013

Mass and power reduction is a recurrent topic – while at the same time **increasing data throughput**!

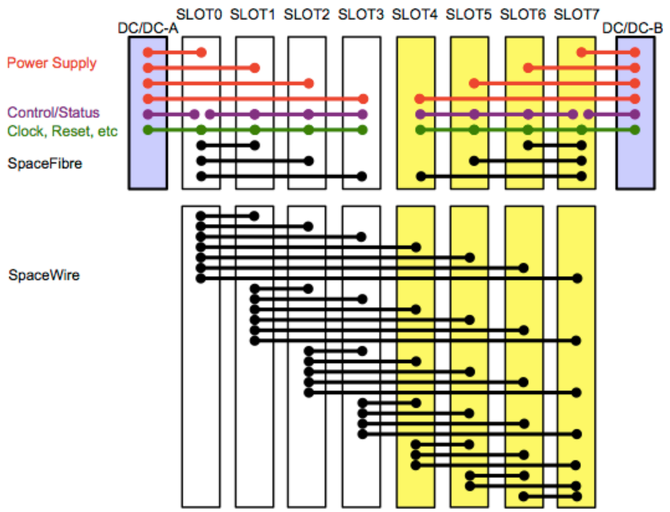
Passive Components and Space Avionics Open Interface Architecture

SAVOIR – Passive components in the physical layer



SpaceWire Backplane

1. ITT AO/1-6692/11/NL/LvH SpaceWire Backplane
2. Technology Research Program (TRP)
   a. Budget: 130k€
3. Awarded: SEA Ltd
   a. Subcontractors: Hypertac Ltd
4. Kick-Off: Q3 2011
5. Completion foreseen Q4 2013



SpaceWire Backplane
Key objectives

- Trade off different backplane architectures and technologies to produce a SpaceWire backplane specification for **ECSS standardisation**.
- The SpW-Backplane specification shall
    a. use a **standard backplane connector with clear path to a space qualified version**
        - ensure good signal integrity for high speed signals up to **2.5Gbit/s and beyond**.
    b. define a **variable/expandable number of slot/boards** for the backplane.
    c. define a number **SpaceWire interconnections and high speed serial links to co-exist on the backplane**.
    d. specify **fault tolerant power distribution**
    e. use an **appropriate number of SpW links, HSSL and discrete I/O per module**
    f. Host user defined **general I/Os**

Adopt Concepts from Existing Terrestrial Standards?
"Newer" standards

1. **PICMG AdvancedTCA 3.0 R3.0**
   a. The PICMG 3.0 "core" specification will specify board, backplane and shelf mechanicals, power distribution and the connectivity required for system management.
2. **PICMG AdvancedTCA 3.4 PCI Express**
   a. Define how PCI Express and PCI Express Advanced Switching transport is mapped onto PICMG 3.0
3. **PICMG AdvancedTCA 3.5 RapidIO**
   a. Define how Serial RapidIO transport is mapped onto PICMG 3.0
4. **PICMG EXP.0 R1.0**
   a. Define the connector, electrical, and mechanical requirements of 3U/6U System Boards, Peripheral Boards, Switch Boards, and Backplanes using PCI Express as peripheral interconnect with CompactPCI interoperability features.

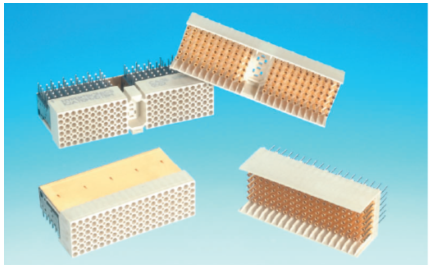
Adopt Concepts from Existing Terrestrial Standards?
"Newer" OPEN standards

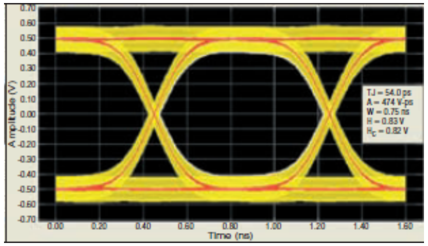
1. **ANSI VITA 46.0 (VPX) and 46.3 PCI-express over VPX**
   a. PCIe on VPX Fabric connector
2. **ANSI VITA 65 – OpenVPX (VITA)**
   a. Approved in June 2010
   b. Adapted for military/aerospace that needed ruggedized systems
   c. Specifies a minimum set of backplane configurations – also suitable redundant architectures.
   d. Gives clear information about data rate, routing topology and fabric topology that has to be used on the backplane.
   e. Contains a number of sub specifications for ruggedized solutions.
3. **ANSI VITA 78 – SpaceVPX**
   a. Draft released June 2013.
   b. Derived from OpenVPX
   c. Defines use of SpaceWire in the control plane

Which backplane connector?
Impedance matched connector or not?

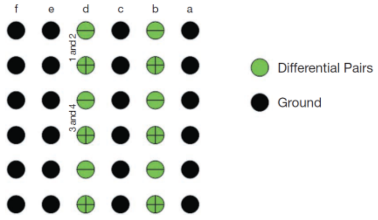
For SpW links from 200 Mbps up to 400Mbps

- Impedance matched connector may not be necessary.
- SpaceQ cPCI connector looked promising to fulfill SpW needs. (Hypertronics K2A)
    - It is not impedance matched
- Need careful diff. signal to ground pin arrangement to avoid crosstalk and signal distortions.





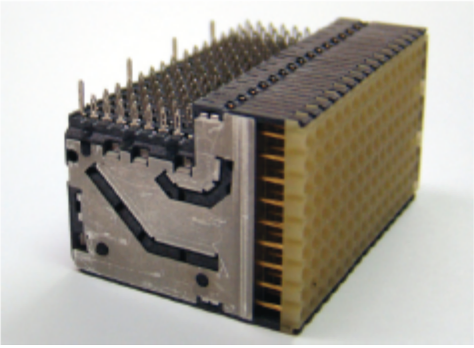
1.25Gbits w. NEXT

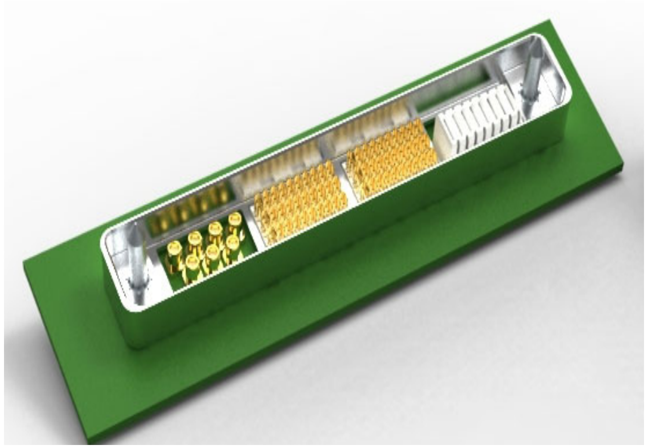


Which backplane connector?
Impedance matched connector or not?

For SpFi links from 2.7Gbps and beyond:

- Impedance matched connector is needed
- **No good Space Q alternative yet.**
- Some **promising candidates** are emerging
    - E.g. Hypertronics KVPX, Tyco HSR
- **Little information** is available
- **Pressfit** connectors are a problem
- **ITAR restrictions** may be a concern

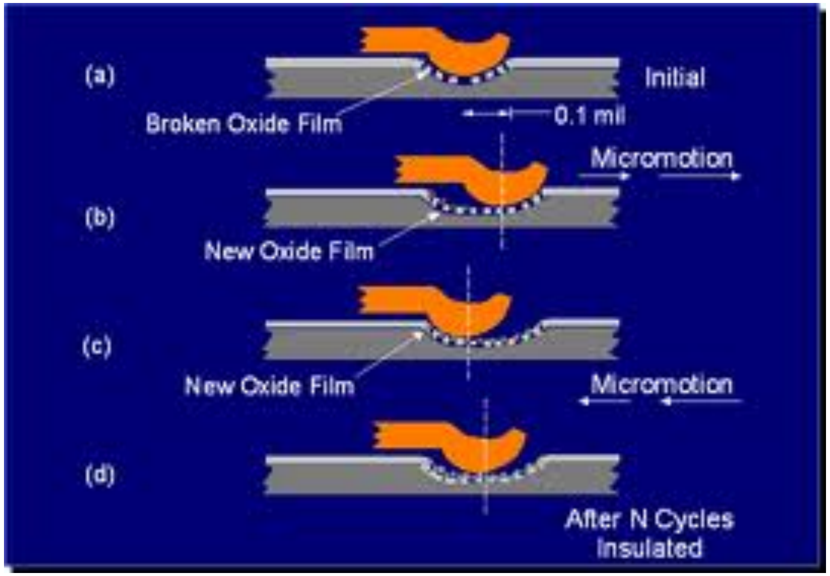




Other requirements for the connector

Impedance matched and high density,- but

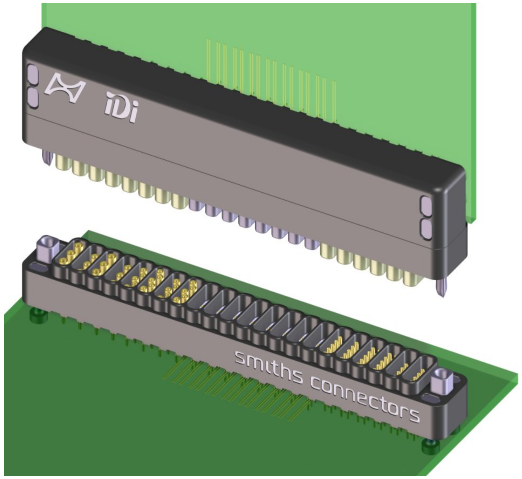
a. Must show no pin fretting when subjected vibration
b. No corrosion during long term exposure
c. Support an appropriate number of mate and de-mate cycles.
d. Acceptable insertion force levels.
e. Space approved materials



Candidate connector for SpW backplanes

- A modular approach proposed by Hypertac Ltd is under evaluation.
- Its suitability is measured against requirements such as:

- Suitable for 3U and 6U card form factors
- Minimized mass
- Compatible with ECSS-Q-ST-70C, Q-70-71, Q-ST-70-02
- Alignment pin and connector keying
- Support minimum 4 SpW links
- 100Ohm differential impedance
- Diff. pairs shielded against cross talk
- Support link rates of up to 2.75 Gbaud
- Support up to 12 power pins (e.g. +/- 12V and 5V etc)
- Ample amount of pins for discrete signals



Low Mass SpaceWire Cable

- ITT AO/1-6214/09/NL/LvH Low Mass SpaceWire
- Technology Research Program (TRP)
    - Budget: 150k€
- Awarded: Axon Cable Ltd
    - Subcontractors: Star Dundee and EADS Astrium
- Kick-Off: Q3 2010
- Completed: Q4 2012

Image by courtesy of Axon Cable

Low Mass SpW cable - Activity Scope

1. **Define and measure electrical parameters** of the ECSS-E-ST-50-12C cable as a reference for a new cable design
2. Identify the appropriate **shielding** for the cable
3. **Connector/Cable bonding**
4. Identify **suitable materials** to obtain lower mass of the SpaceWire cable
5. Perform **electrical performance validation** and **mechanical endurance tests**
6. Provide a draft proposal for **updating the ECSS-E-ST-50-12C cable specification**

Characterisation of an ECSS-E-ST-50-12C Cable - Specification

SpaceWire Reference Sample

a. Qualified according to ESCC3902.003.01.

Performances	**Type**	**Max**	**Nominal**
Metrics	External diameter	7.5mm	6.9mm
	Mass	<85g/m	
Electrical	Electrical resistance	<239 Ω/Km	207 Ω/Km
	Insulation	>5 G Ω under 500Vdc	>5 G Ω under 500Vdc
	Capacitance	<50 pF/m	45pF/m
	Impedance	100Ω+/-6	100 Ω
	Insertion losses		<1dB/m @ 400Mhz
	Propagation factor	4.3ns/m	4.25ns/m
	EMI	>45dB	>60dB

Characterisation of an ECSS-E-ST-50-12C cable - Applicable electrical parameters

The most pertinent parameters to express are the:

S21 – Transmission coefficient (insertion loss)

S22 – Reflection coefficient (return loss)

NEXT – Near End Cross Talk

FEXT – Far End Cross Talk

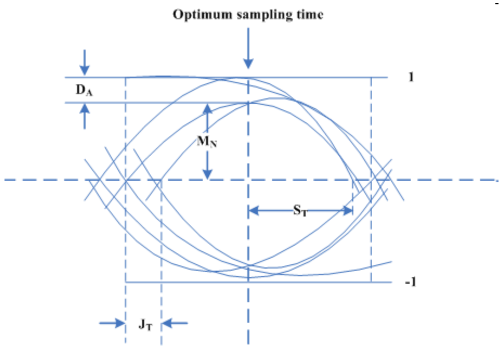
Primary and **Secondary** Parameters (RLCG)

Characteristic Impedance - Z_c

Skew - both intra-pair and pair to pair skew

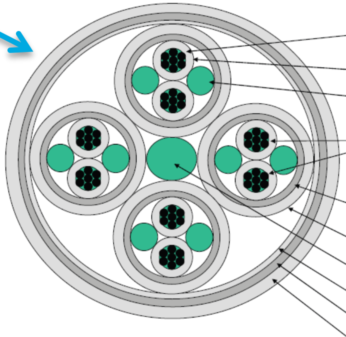
Shield effectiveness - Z_t

Eye Pattern measurements is good way to verify many of the individual parameters



Ways to reduce the cable mass

1. **Use lighter materials**
   a. Use aluminium shields instead of copper
   b. Use lighter insulator material
      – a-PTFE instead of e-PTFE
   c. Use lighter outer jacket material
      – Kapton tape instead of PFA
2. **Different construction techniques**
   a. Remove insulation between pairs
3. **Increase flexibility**
   a. Use more strands in the twisted pair wires
      – AWG2819 instead of AWG2807



Some performance figures

ESCC3902.003	Variant 1 (Current SpW)	Variant 03 P551259
Mass (g)	80 max	**42 max**
Overall Φ (mm)	7 max	**6.5 max**
Static Bend Radius (mm)	45	**25**
Dynamic bend radius (mm)	60	30
Flexibility VS var1	0	+
Impedance (Ω)	100+/-6	100+/-6
Capacitance (pF)	<50 / 90	<50 / <90
Rdc (Ω/m)	0.23	0.23
Intra pair Skew (ps/m)	<80	**<50**
Inter pair skew (ps/m)	<130	**<100**
α (dB/m) @1Ghz L cable for -6dB attenuation	-1.5 4.5m max*	**-1.4** 4.6m max*
RL (dB) up to 2Ghz	-9 max	-9 max

Impedance matched connector for SpW

- During the Low Mass SpW activity a survey was conducted to identify suitable 100ohm impedance matched connector alternatives.
- Some solutions exist but were at the time of the survey no viable solutions due to:
    a. Large form factor
    b. Sub-optimal shield terminations for a SpW Cable
    c. ITAR restrictions on some products
    d. Long lead times
- A suitable connector option for SpW is still sought after

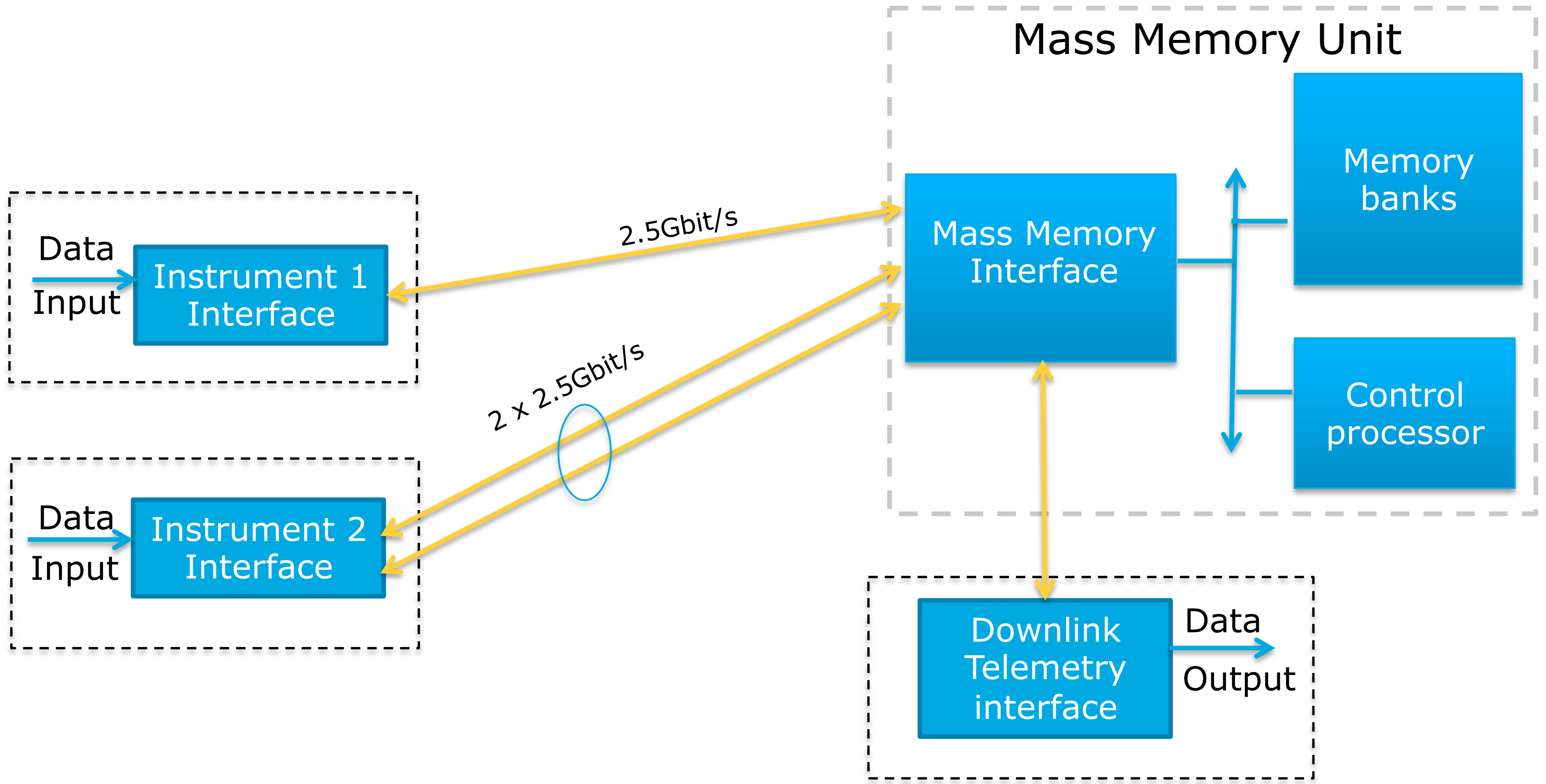
High Speed Serial Links - Payload applications

1. **Payload data transfer rates** is steadily increasing
   a. Onboard data links operating in the Gigabit/s range is becoming a common requirement.
      – e.g. channel link or Wizard link
   b. Future earth observation missions steadily aims to increase resolution and science return which translates to higher data rates.
2. **Mass memory units** will have to support such links both externally and internally
   a. Several links required for recording and playback
   b. Internal high speed signaling over backplanes
3. **Cables and connectors**
   a. Support high speed digital signal rates operating at Gbit/s.
   b. Compact and lightweight space qualified assemblies

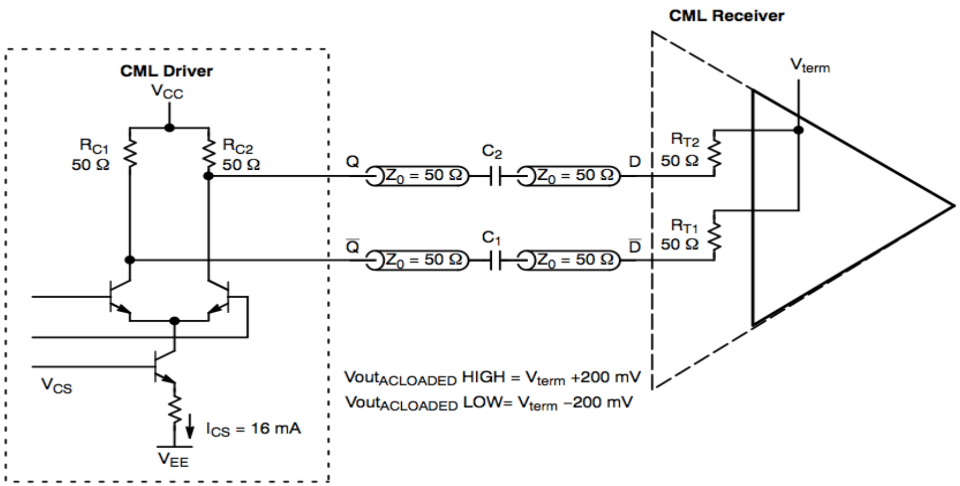
SpaceFibre highlights

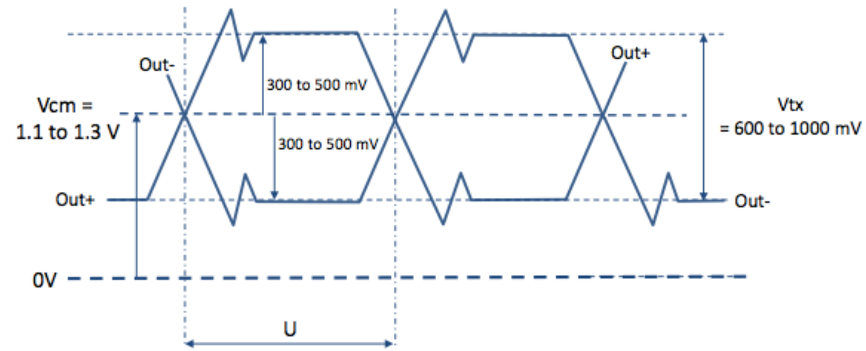
- Supports both **optical** and **copper** based physical layer
- **Current Mode Logi**c (CML) signaling for copper
- **8/10 Bit encoding** for DC balance and enabling AC coupling.
- **Link initialization mechanism**
- **Quality of service**
  - Retry mechanism for link recovery w.o. data loss
  - Virtual Channels with bandwidth allocation
- **Lanes** – use multiple links to increase throughput
- **Compliant to the protocols and routing mechanisms defined in the SpaceWire standard**

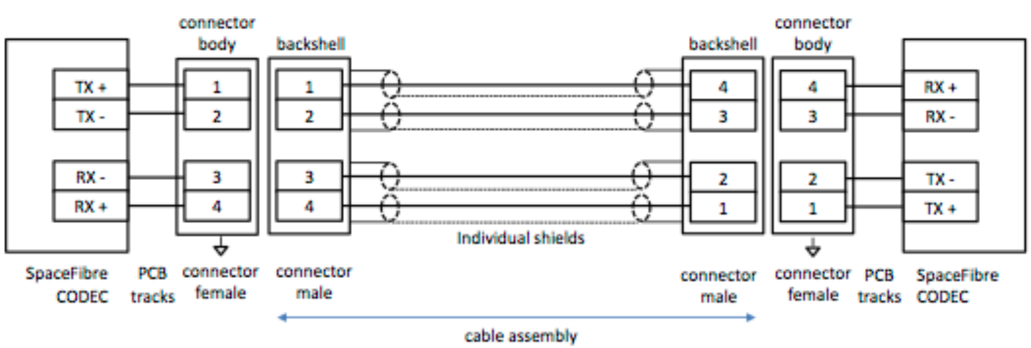
SpaceFibre in payload applications

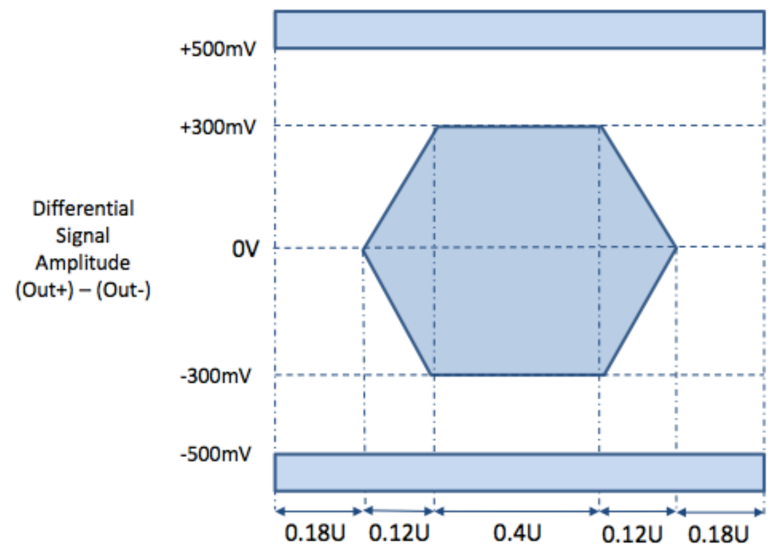


SpaceFibre physical layer



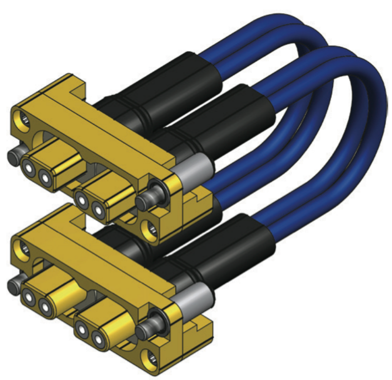


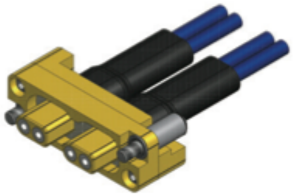




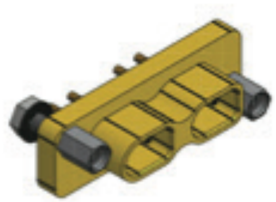
SpaceFibre – cable assemblies

1. Connectors proposed for the SpFi cable assemblies
    a. AxoMac – ESCC Variant 8 for cable assemblies
    b. Axomac – ESCC Variant 2 or 11 for unit
2. Proposed flight cable
    a. Axon - 07072-ST-MDSA HDR -01

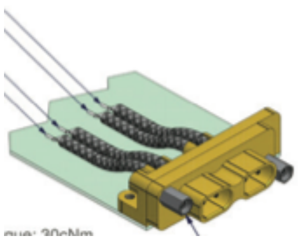




Variant 8



Variant 2

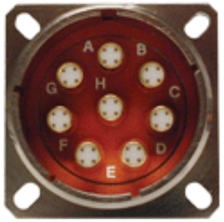


Variant 11

3. Optical cable assemblies are TBD

Other solutions?

1. **Twinax** or **Quadrax** types of connector may offer a neat high speed solution.
    a. MIL-DTL-38999 housing
    b. Rugged D-Sub housing



2. Twisted pair or coax?
    a. The electrical interface must be compatible with coaxial cables
        – CML and VML is, while LVDS is not.
    b. Twisted introduce more jitter over distance than a coaxial cables but can be used for applications in the 2Gbit/s range.

Images by courtesy Sabritec inc.

Thank you