On-Board Networks and High Speed links

ESA - TEC-EDP - Dirk Thurnes

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On-board data handling networks – a motivation

- Current status
  - Several solutions exist for low-speed Command & Control and high-speed instrument data handling
    - Usually leads to two separate solutions for data handling
    - leads to unnecessary high number of interfaces and interconnects
  - New instrument, sensor & data processing concepts need Gbps of data transfer rate
    - High speed links need SerDes solutions to achieve this
      - SerDes needs higher protocols to work
      - Island protocol solutions developed by different space industries
      - not inter-operable, not standardized, tiny user base, high risk
  - Both points results in **complex design**, **many connectors**, **high mass**, **high volume**, **high costs**, …

=> less Science

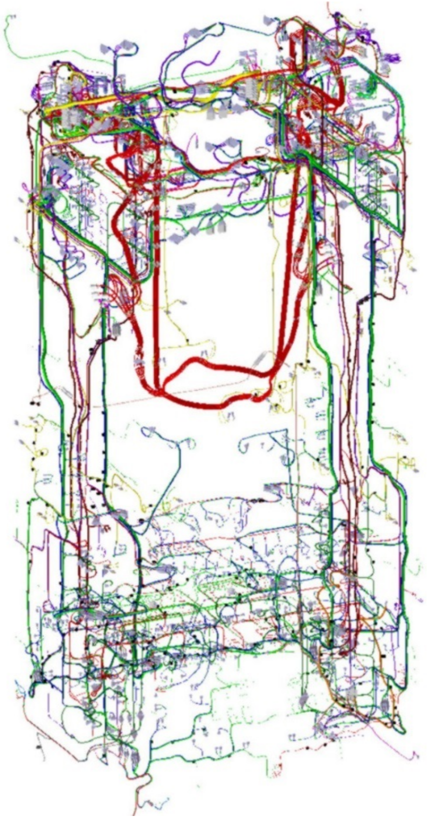
Why change – It was always like this

- Interface reduction is a recurrent topic, but
- Evolution on the topic seems to be difficult

"I'm involved in missions for 20 years and did not see a significant change on this over the years"

a system engineer

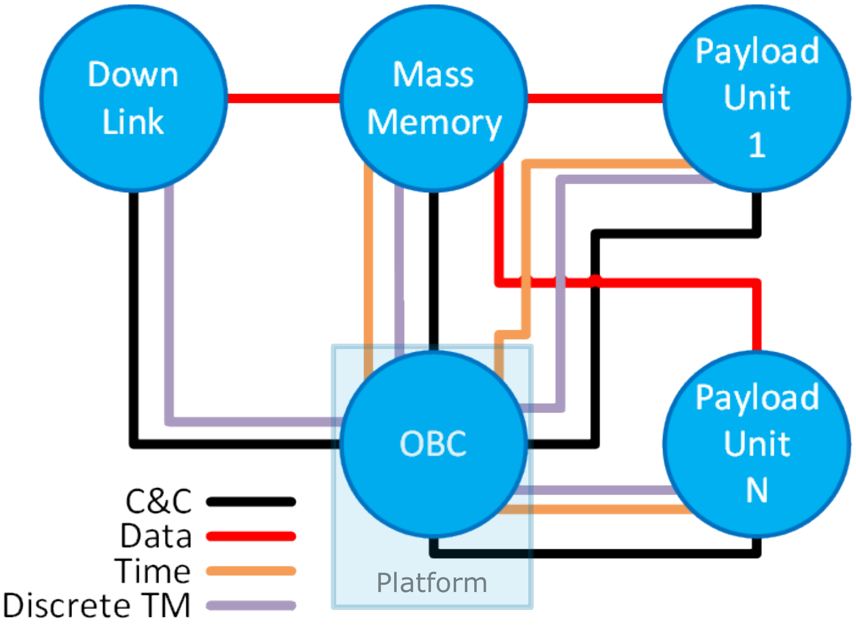
- Nevertheless it seems to make sense to think about it – A huge satellite has (SPCD 2013 – Malagoli)
  - 50.000 connections
  - 1.000 connectors
  - 20.000 meters of wires
  - harness mass exceeding 100kg



Picture: Courtesy of ADS - SPCD 2013

From now on, focusing on Payload Interfaces

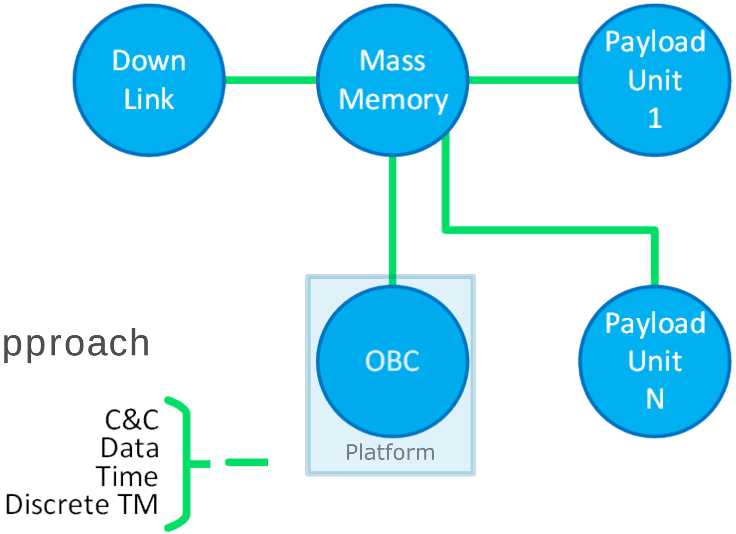
- Instrument Data
  - SpaceFibre, WizardLink, SpaceWire
- Command & Control
  - SpaceWire, CAN, MIL-1553, UART
- Timing
  - 1 Pulse per Second synchronization
- Discrete Signals (ECSS-E-ST-50-14C based)
  - Digital
    - Switch operation
    - Status detection
  - Analog
    - Power telemetry
    - Temperature telemetry



Rem: Payload telemetry not related to Payload units not addressed here (see ADCSS presentation mentioned on next slide)

Solution: Mixed-criticality messages network

- Combine all the services in a single solution
  - Command and Control
  - Instrument data
  - Time distribution
  - Analog and digital telemetry



- Enabling functions for **mixed-criticality network** approach
  - **Multi-gigabit link**
    - instrument data rate
    - low jitter time distribution
  - Protocol which provides **Quality-of-Service** for Command & Control applications
  - **Change of mind of system engineers**

⇒ **Make better use of available cables and cable bandwidth**
(R. Janssen, TEC-EDM)

Detailed presentation: ADCSS 2017 – D. Thurnes – "Reduction of the Harness – the One Interface Illusion - reloaded"
https://indico.esa.int/indico/event/182/session/1/contribution/13/material/1/0.pdf

A possible solution - SpaceFibre

- SpaceFibre is
  - the successor of (and is compatible with) SpaceWire
  - allows 15 times higher data rates up to 6.25 Gbps (10 Gbps on fibre)
  - targeted for mixed-criticality networks and data streaming applications
  - ECSS standardized (public review finished)
  - available now in TRL6 for payload networks and point-2-point links
- Has been designed with constraints of space applications in mind
  - Low resource needs, suited for space qualified devices
  - Error detection and correction (or not, if you prefer that)
  - Familiar Quality-of-Service concepts
  - Galvanic isolation (copper **and** fibre based harness)
  - Lessons learned of 20 years of SpaceWire integrated

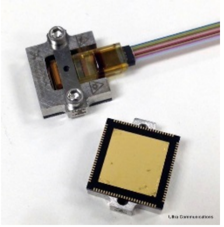
Alternative High Speed Links

- Ethernet based approaches like Time-Sensitive Networking (TSN)
  - wide user base, available COTS protocol anaylsers can be used
- Multi-Gbit/s high speed links use SerDes devices
  - these are protocol independent
    - ⇒ commercial devices and COTS PHY test equipment can be used
- But are commercial SerDes devices and functional blocks in FPGA/ ASICs/ processing devices suited for space? It seems to be sure that
  - we need a protocol with powerful **error detection and correction**, as well as
  - **Quality-of-Service** to deal with shortcomings of commercial devices for mixed-criticality networks
  - protocol implemented in hardware (NOT software) due to reliability requirements
- **are such features included in terrestrial protocols and devices?**

High speed links – the next leap

- Optical Physical Layer
  - Make electro-optical transceiver available
    - Laser and Receive diodes are suited for space applications, but
    - Laser driver and receiver transimpedance amplifiers are not
    - Possible solutions from Radiall, Reflex Photonics or Ultracomm
  - optical harness and connectors are available

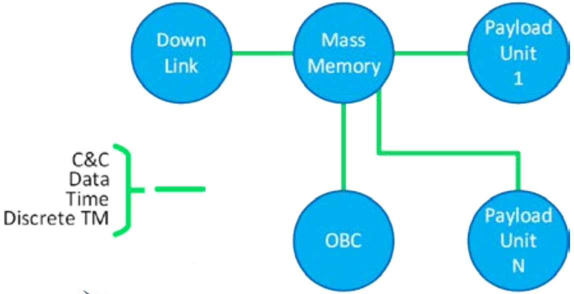
- Advantages
  - Small footprint (connector and harness)
  - perfect galvanic isolation
  - no EMC and grounding issues
  - low mass, scales nicely
  - long distance (e.g. launchers)



- The problem => get missions to adopt it

Conclusion

- High speed serial links with suitable protocol allow mixed-criticality networks
  - Allows reduction of the interfaces
  - Results in less interconnects
  - Results in more efficient satellite design
  - Provides more resources for science & application



- SpaceFibre is a suitable solution for this approach
  - Future-proof data transfer bandwidth
  - Standardized protocol => interoperability, low risk
  - Commercial Ethernet based solutions could be an alternative (to be demonstrated)
- Next steps
  - Adopt mixed-criticality network in upcoming missions
  - make optical fibre based solutions a reality
  - build more efficient satellites, free resources, do **more Science !**

Thank You

Backup Slides

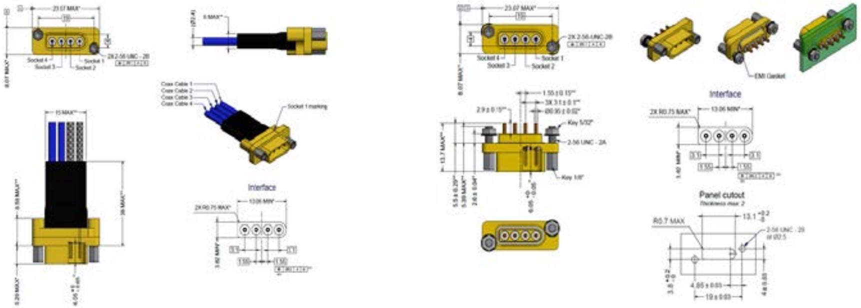
SpaceFibre – Current Status (1/3)

- SpFi ECSS standard
  - ECSS-E-ST-50-11C ready for publication
  - WG members from Airbus DS, Cobham Gaisler, IngeniArs, OHB, RUAG Space, STAR-Dundee, Thales Alenia Space

- SpFi Network Node IP cores
  - available from 4 different European providers (ESA, Gaisler, IngeniArs, Star-Dundee)
  - Implementation demonstrated on RTAX2000, RTG4 and several Xilinx devices
  - Successful interoperability tests, including JAXA and ROSCOSMOS IP cores
- SpFi Network Router IP core
  - Available from Star-Dundee
  - Successfully demonstrated in RTG4 FPGA

SpaceFibre – Current Status (2/3)

- SpFi enabled hardware
  - FPGA: RTG4, Brave Large/ Ultra, Xilinx
  - Processors: DAHLIA, Ramon Chips RC64
- SpFi FM Harness and Connectors
  - Available from Axon, based on AXOMACH series
  - ESCC standards available, publication expected in 2018
    - ESCC Detail Spec No.3409/001, 3401/088 and 3401/089
- Network simulators
  - SpaceFibre models available for
    - OMNeT++
    - OPNET
    - NS-3 (to come)



SpaceFibre – Current Status (3/3)

❖ SpaceFibre test equipment

- ➢ Protocol analyzer available from 3 different providers (ESA, IngeniArs, Star-Dundee)

Picture: IngeniArs, SpaceART

Picture: Star-Dundee, Star-Fire

Picture: ESA, SpFi Analyzer

- ➢ Physical Layer testing COTS equipment from several manufacturers
  - o Transmitter: LeCroy WaveMaster SDA
  - o Receiver: Keysight J-BERT M8020A

Unlocking Measurement Insights for 75 Years

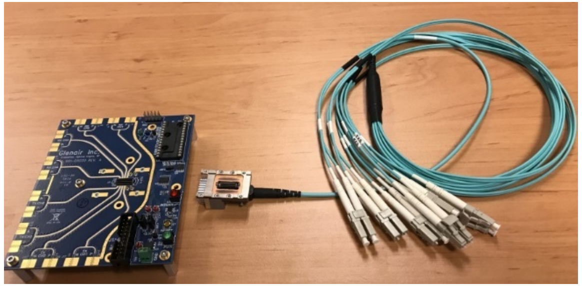
- ➢ EGSE providers
  - o Celestia-STS EDTE
  - o Teletel iSAFT

SpaceFibre – the next steps (1/3)

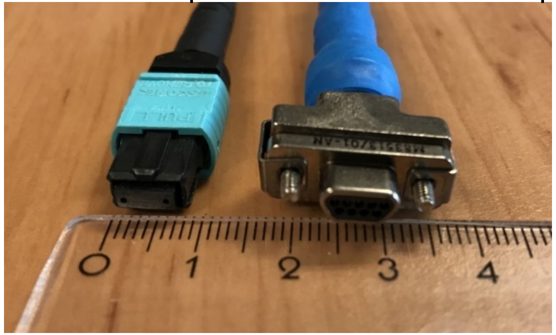
- Make SpaceFibre available in 65nm (6.25 Gbps) or 28nm (12.5 Gbps) ASIC technology
  - SpaceFibre Interface Chip
    - SpaceFibre enabled SerDes with common interfaces (parallel, SpW, I2C)
    - use case: allows for low complexity FPGA solutions, heritage designs
    - under development in ESA
    - up to FPGA demonstration, ASIC run to be funded
  - SpaceFibre Routing Switch
    - Basic functions defined and already used in development programs
    - Requirements consolidation on-going for advanced features
    - up to FPGA demonstration, ASIC run to be funded
- Transaction Layer to be defined for end-2-end QoS

SpaceFibre – the next steps (3/3)

12 Fibre transceiver & Harness

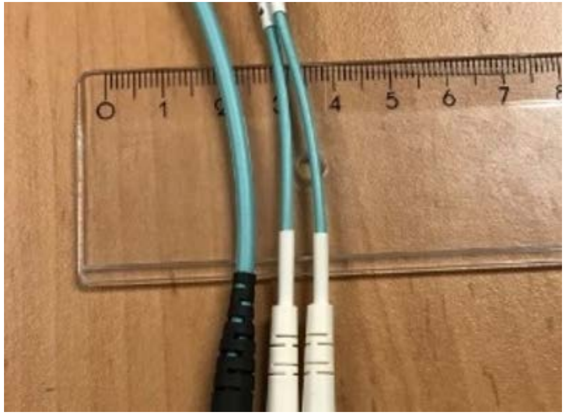


Optical connector
6 SpFi links at 10Gbps each
smaller than SpW connector at 200Mbps



Harness diameter
12 Fibre 60 Gbps (6x10 Gbps)
vs single SpW cable (200 Mbps)

Harness scalability
Single vs 12 fibre cable –
scales nicely



- Not to forget
  - no EMC issues
  - no grounding problems

SpaceFibre – Roadmap

2021

- Radiation-hardened SpaceFibre ASICs available.

2019

- Finalization of 'transaction layer'
- ASIC designs become available.

2018

- SpaceFibre ready to be adopted by missions
- Several IP cores available for network node and router
- Network simulation tools available
- Complete suit of test equipment available
- ECSS and ESCC standards to be published

SpaceFibre