SpaceWire Working Group #17

Overview of implementing SpaceWire in Thales satellites

Template reference : 100181670S-EN

Optical Observation and Sciences

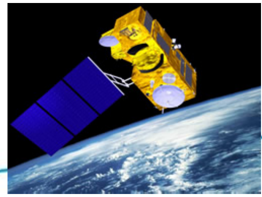
- **Thales Alenia Space implements SpaceWire**
  - In more than 12 satellites
  - In coming telecom satellites
  - In most missions for observation

- **With today 3 mission classes for observation**
  - LEO observation like GMES sentinel-1 and 3
  - Inter-planetary exploration like EXOMARS
  - GEO observation like Meteosat 3rd generation

- **Mastering achieved for 100Mb/s point-to-point links**

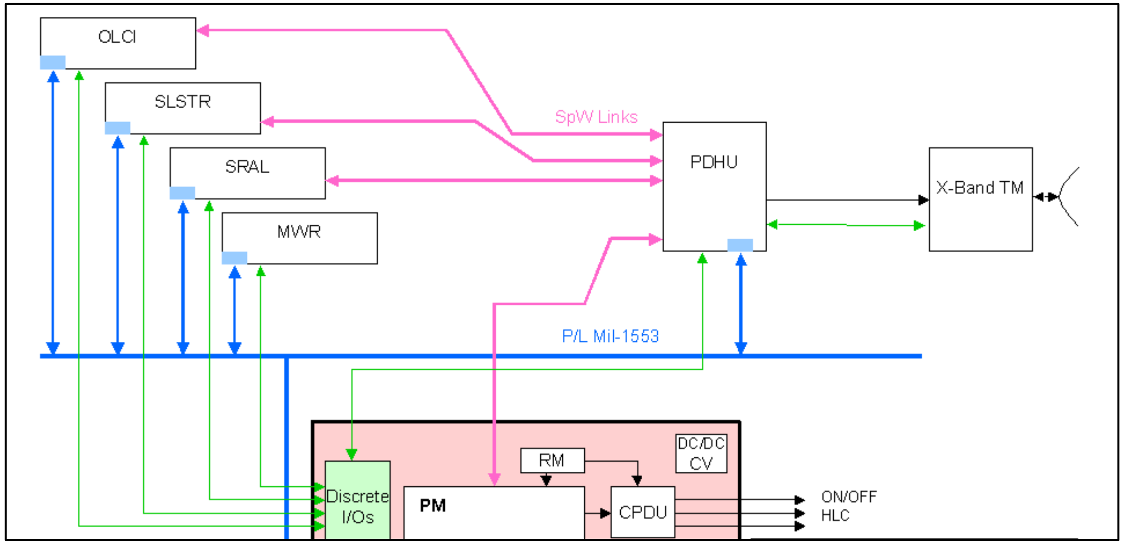
- **Process to be improved for**
  - Electrical architecture (protection, harness characterisation and sectioning)
  - Data-Handling architecture (synchronism, link margin and buffering with routers)
  - Allowing 200Mb/s full-duplex network with both mission data distribution and configuration command-control sharing same links

ThalesAlenia Space
A Thales / Finmeccanica Company



Sentinel-3 Satellite

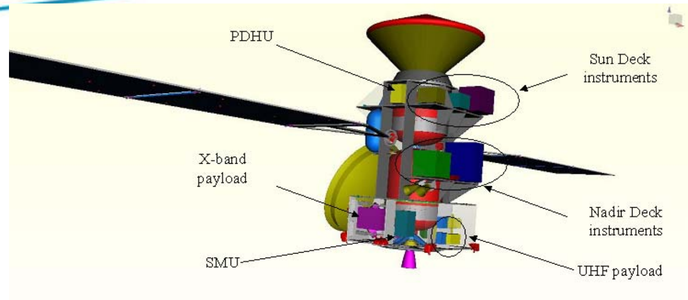
- **Each SpW link is dedicated to point-to-point communication**
- **Redundancy for a robust payload data management**



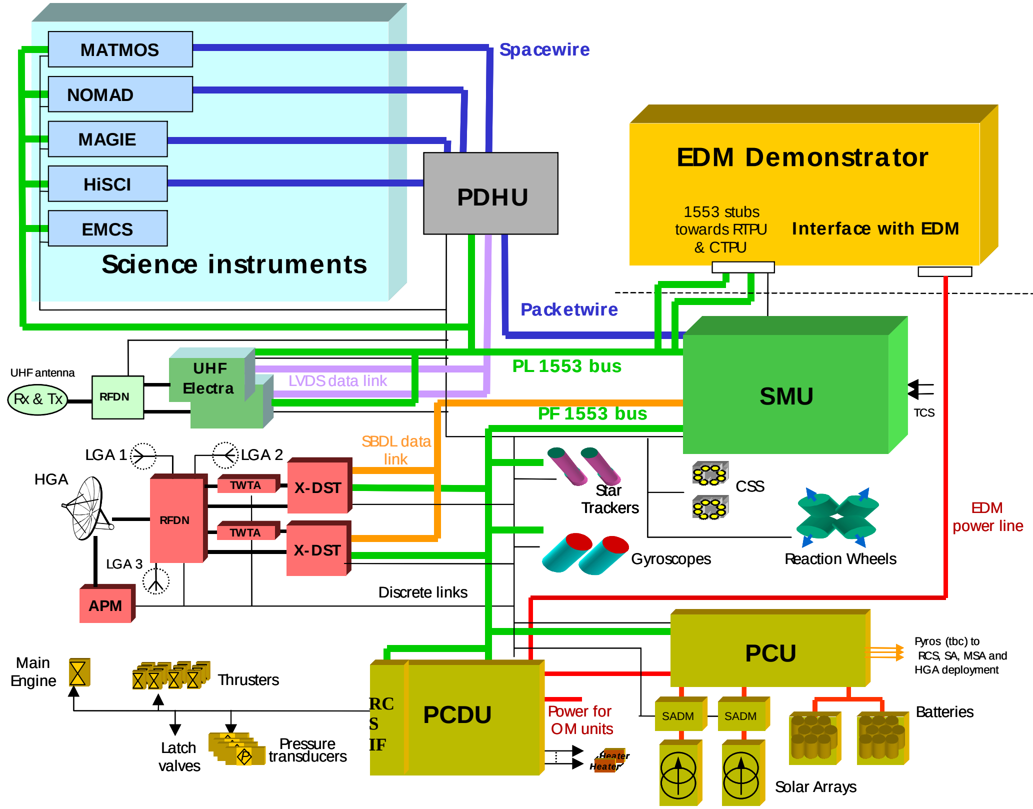
- **without interaction on the other links → no routing**
- **100Mb/s data-rate each ~ 300Mb/s TMI**
- **PDHU is able to handle 4 SpW sources**
- **1553 command-control bus kept for minimized risks**
- **Cross-strapping included in PDHU, for reducing harness mass and instrument's complexity**

THALES

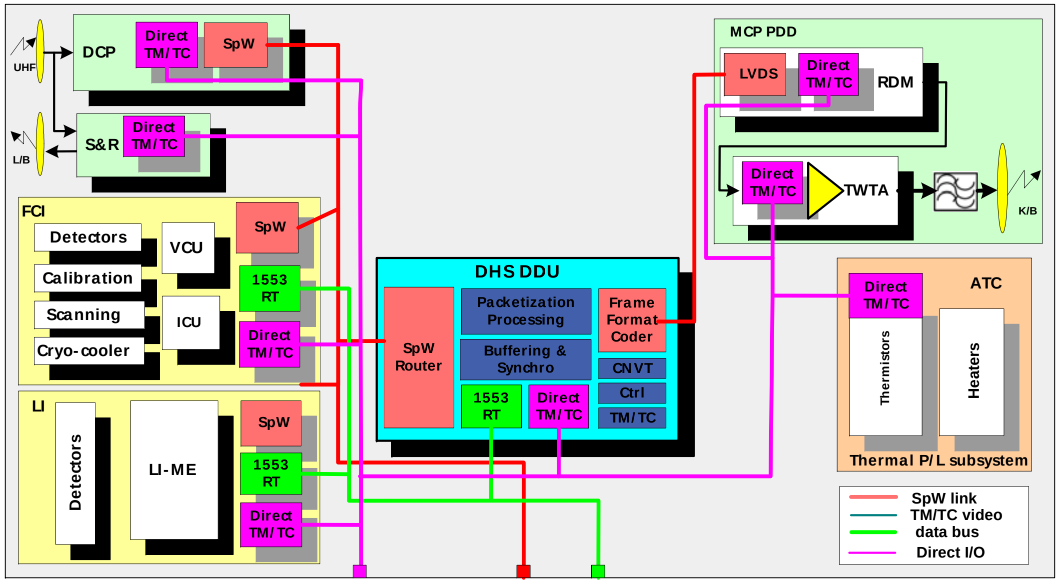
EXOMARS Orbiter



- **SpaceWire network to acquire and multiplex data from instruments**
  - low mass and consumption
  - for both mission data-handling and command/control through a unified payload network
- **Data flows 25Kb/s to 90Mb/s**
- **global science data volume**
  - < 15Gb per day
  - stored in PDHU Mass Memory
- **payload network**
  - built around the PDHU
  - 6 functional nodes:
    - 4 instruments,
    - the UHF transceiver
    - the SMU
  - cold redundant pair of SpW links
  - full cross-strapping redundancy implemented in the PDHU



- **For payload data network**
  - constant ground station visibility (GEO) continuous mission data transfer in real time without storage without any risk of bottleneck
  - 295Mb/s and 557Mb/s continuous downlink for imager and sounder S/C
  - 4 data sources per network (instrument's, transponder 30Mb/s – 80Mb/s)
  - full cross-strapping between each source - platform
  - Based on 200Mb/s link, PUS packet max 13KBytes size
  - Full-duplex used for instrument fast configuration (8MBytes data cmd)



Lesson learnt 1/3

- **Harness mass**
  - Over-sized for low data-rate and unidirectional link
    - Induce mass penalty
    - Implement internal cross-strap in order to reduce harness mass
  - Full-duplex mostly not used

  ➔ need of a lightest half-duplex harness

- **Harness sectioning and characterization**
  - Point-to-point link at 100Mb/s correct even with one sectioning
  - How to be sure correct link performance without characterization I.e. to tune data-rate without putting into question qualification
    - for higher data-rate and/or for more sectioning

  ➔ Abacus of link performance vs data-rates and sections could help

- **Redundancy & cross-strapping**
  - Internal cross-strapping implemented in PDHU equipment
  - Between nominal and redundant sources and PDHU nominal and redundant sides
  - To reduce harness and data source complexity
  - Efforts spent to implement a full and robust cross-strapping redundancy
    - for electrical protections to prevent failure propagation with hybrid configurations mixing 3.3V and 5V LVDS interfaces

Lesson learnt 2/3

- **Used Protocols & perimeters**
  - Most data transferred through PUS packets
    - Either directly in SpW cargo for point-to-point links
    - Or thanks to SpW CCSDS packet transfer protocol
  - RMAP use for SW debugging in on-board computer

- **Detector concern : data acquisition vs noise immunity**
  - due to the SpW asynchronism,
  - cannot prevent data transfer during optical signal acquisition
  - There is perturbation risk on detector signal quality
  - synchronized acquisition through a parallel bus is implemented
  - Then Data transferred by SpW in dedicated electronics

- **Command-control**
  - Today only for smart instrument configuration requiring large data transfer
  - Future saving area by merging mission data transfer and command-control over the same SpW link thanks to SpW full-duplex and high throughput
  - Not yet implemented waiting for robust way to
    - Ensure determinism and to manage synchronism
    - Implement full cross-strapping without failure propagation risk

Lesson learnt 3/3

- **Concern about actual maximum data-rate (200Mb/s)**
  - Of-the-shelf components supporting 200Mb/s as SpW-10X
  - Careful implementation required in PCB design and connection vs skew/jitter
  - 100Mb/s design OK, but highest speed useful to reduce harness, latency and buffer
  - What is the suitable maximum limit for a network 120, 160, 200 Mb/s ?
  - Conflicting positions from the space SpW community

  → characterisation through end to end bread boarding including harness ?

- **Network & routing**
  - Full duplex capability is mostly not used
    - neither for time code nor command-control
    - Except for some smart instrument configuration
  - replaced by data multiplexing through memory, with advantage to be deterministic
    - when low need of bi-directional communication (no command-control)
  - Next steps require to implement routing to take advantage of full-duplex
    - Difficult to master a network implementation
      - for deterministic aspect
      - For FDIR vs failure propagation between redundancies
  - Highest (≥200Mb/s) data-rate required to minimize latency, buffers and recovery

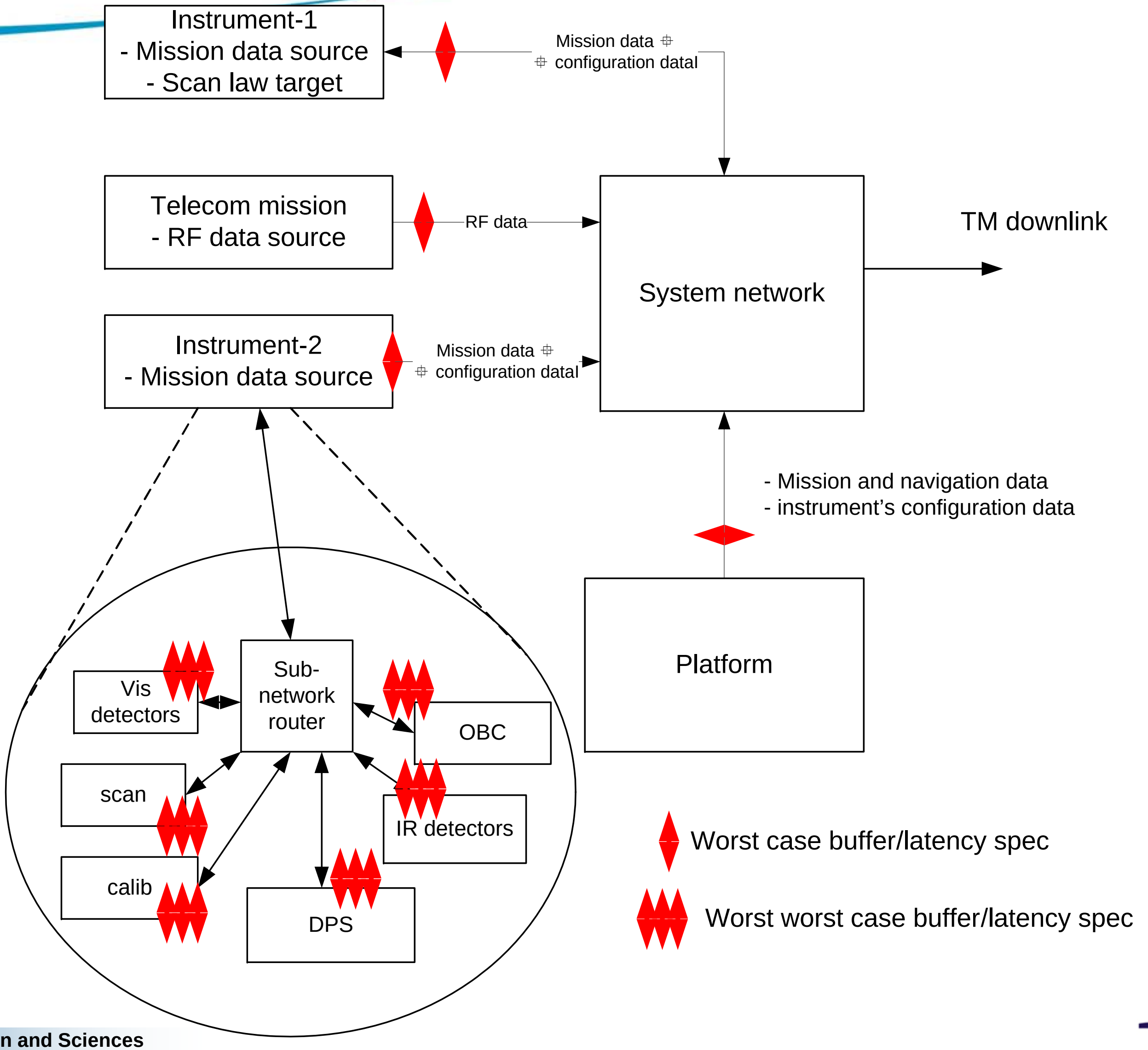
Concern about network/routers 1/3

- **Optimization thanks to the implementation of SpW routers**
  - The full-duplex capability of the SpW to be used for instrument's command-control
    - In order to reduce amount of interfaces, links and harness
  - Need of fastest link capability to minimize design vs sporadic bottleneck
    - In order to reduce size of buffers and time to recover

- **But high technical and contractual complexity**
  - due to asynchronous behaviour, require to support sporadic routing bottleneck
  - Need to size source buffers and link margin to prevent outage and loss
  - System specification based on system worst case assumptions, I.e. packet maximum delay to access the router and link data-rate
    - Since any packet from any source to same target can arrive at same time
    - No way to force synchronization between sources nor packets
    - No system traffic analysis possible before ITT since no data profile available
  - Becomes critical in case a source implement also a sub-network (router) at its level
    - Over-design driven by flow down of requirements cumulating worst cases
    - For link margin and buffer size to recover the outage and prevent loss of data

➔ **All data source designs depend on the design of other data sources !**

Concern about network/routers 2/3



Concern about network/routers 3/3

- **It is not possible to have one unique contractor for the complete network**
  - Would solve the problem and allow to late tune based on consolidated traffic
  - But impossible due to mandatory industrial breakdown

- **Need for a network architect**
  - Responsible of end to end data transfer from sources to consumers with budget report
  - Will not solve contractual issues nor prevent over-design & over-cost
    - Any out of specification coming from a part of the network will induce modification and impact on other parts, I.e. from a contract to other contracts
    - Over-design since each contracted module have to support a link rate and a maximum packet delay to access to the network based on a theoretical worst case; become worst with sub-network
  - In case buffers could be implemented at router level
    - Modification from one source will not impact other sources design
    - modification would only be managed by one contractor
    - When traffic analysis is secured with consolidated data profile, the network responsible can tune and optimize buffers

→ Instead of network that works, network that makes us work !!!

Conclusion

- **Implementing SpW with point-to-point links (without routers) allows to**
  - reduce interface complexity up to 100Mb/s
  - to separate interface management and development between contractors
  - easily build EGSE and check functional behaviour.

- **Need for some improvements**
  - Optimisation for unidirectional “low” data-rate ➔ **need for lightest harness**
  - design effort shall also be spent to define cross-strapping
    ➔ **Need of electrical an data-handling architecture rules**
  - require a way to synchronize communication ➔ **Need of deterministic protocol**
  - Characterization of the actual SpW performance needed
    - For section (bracket, feed-through) ➔ **harness characterisation needed**
    - Highest link data rate, 200Mb/s ? ➔ **max speed assessment needed**

- **Mastering of network/routing for**
  - payload command/control merging with mission data distribution, bringing interface and harness optimization
  - avionics AOCS performance and extended operability
    - management of high throughput sensors – currently implemented
    - involvement of instrument’s in the AOCS control loop – currently studied

➔ **Need for determinism, robust FDIR and suitable process vs industrial organisation**

THANK YOU !