AOCS SpaceWire Test Bench Preparation

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Final Presentation

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Outline

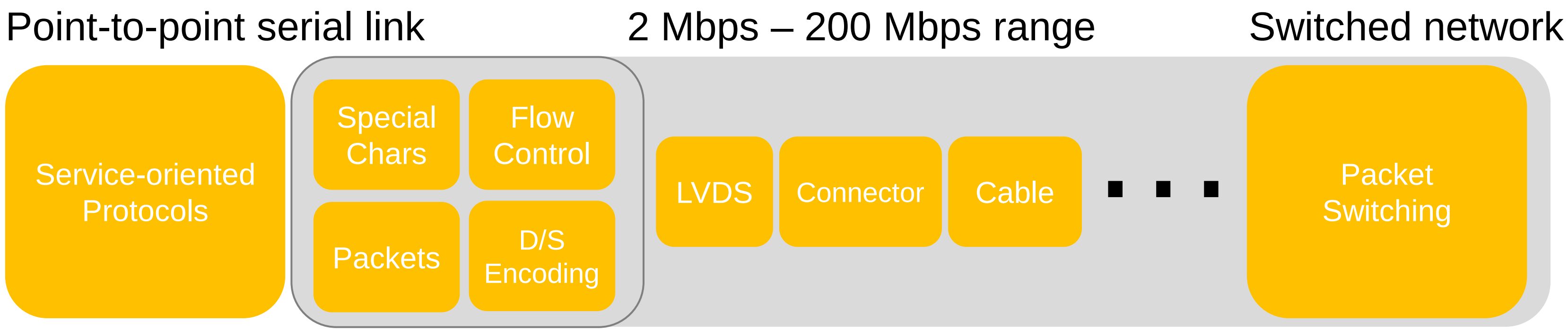
- Introducing the AOCS SpaceWire study
- Study logic and results
- Conclusion and perspectives

SAVOIR

- ## Space AVionics Open InteRface
  - Sensors & Actuators InterFace working group – SAIF (2009-2012)
  - Four ESA-supported solutions recommended for AOCS equipment
    - MIL-STD-1553B: widely used, ECSS standard published
    - Serial links based on RS422 standard: widely used, standard to be developed (protocol)
    - Analog: move towards fully digital interface, ensure availability of IP cores / low-cost implementation
    - SpaceWire: in deployment, ECSS standard published

Spacewire	Readily implementable with low impact on unit (power, dimension, mass) Variable data rates to suit application → AOCS applications use the lowest data rates of SpW.	New interface for AOCS units so lack of widespread support Harness mass Unclear whether point to point or network is best option. Potential ITAR issues for 3.3V line drivers. Concern that lots of parts are from Aeroflex (US) Impacts on AOCS system (especially cross coupling and FDIR issues) are unclear.

SpaceWire system



SpaceWire Standard

- ECSS-E-ST-50
  - 12C – physical and data links layers
  - 51C – minimal packet header
  - 52C – Remote Memory Access Protocol (RMAP)
  - 53C – CCSDS Packet Transfer Protocol (CPTP)

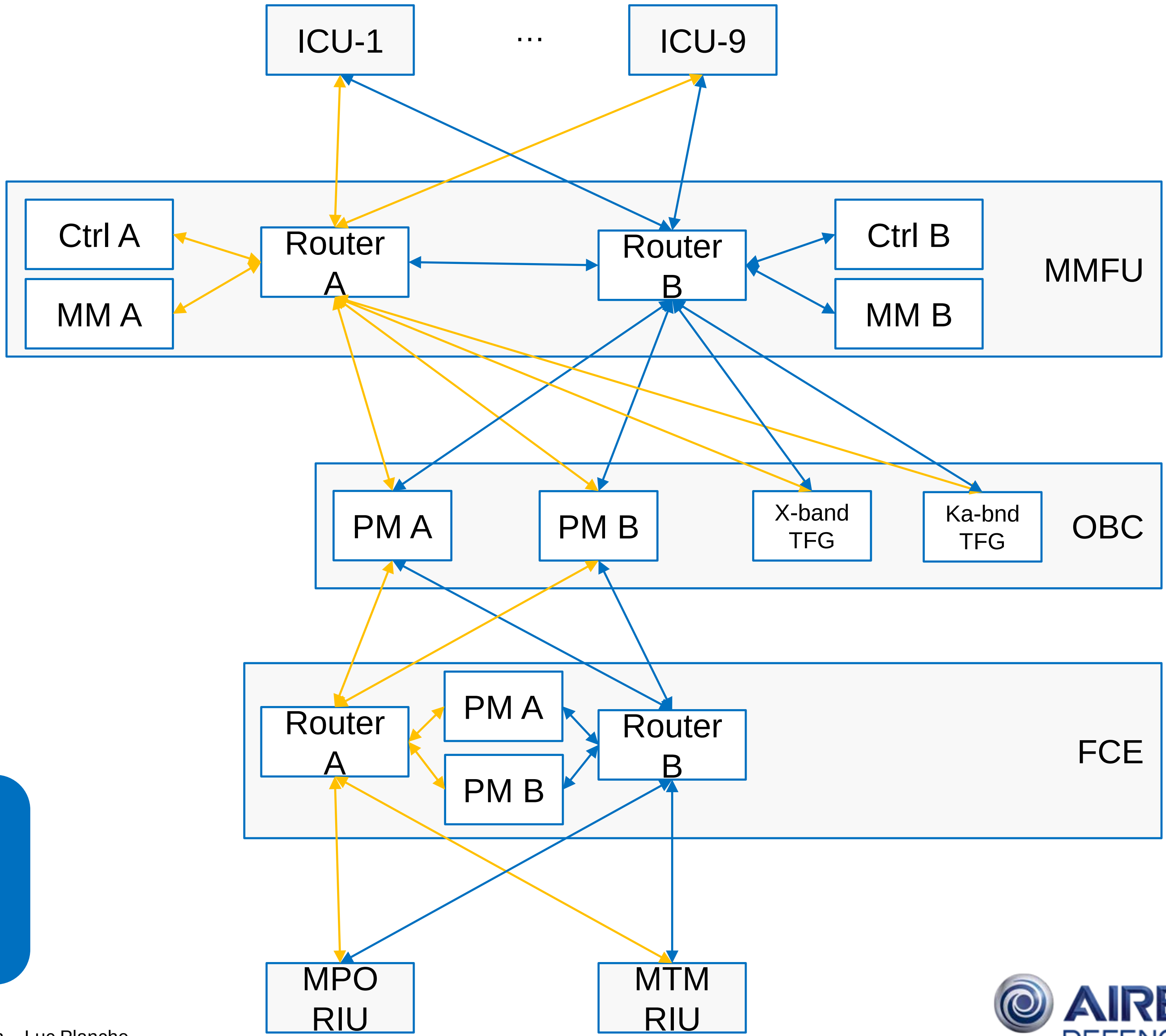
Components & Implementations

- Project/product-specific functions/protocols

Projects

- GAIA PTP PTP
- BepiColombo NET NET
- MetOp-SG NET
- JUICE NET PTP

SpaceWire in Bepi Colombo



Projects

Study objectives

- Confront the SpaceWire technology with the AOCS needs and architectures
- Assess the implications of implementing SpaceWire at AOCS sensors and actuators interface level, identifying constraints and opportunities
  - Does SpaceWire fit the requirements of an AOCS ?
  - Which opportunities are opened by using SpaceWire ?
  - Which developments would be required to support an AOCS implementation ?
- Prepare for a future test bench featuring sensor and actuator units

Study Logic

Context

- Setting up the analysis framework
  - AOCS Sensors and Actuators
  - Spacewire features
  - Opportunities

Reference Case

- Specification of a reference case
  - Reference mission
  - Reference architecture
  - SpaceWire architecture and protocols

Evaluation

- Analysis and simulations

Lessons Learnt

- Functional aspects
- Sensor/Actuator interfacing
- Communication system

Analysis framework – Scope of needs

- Physical architectures combining a variable set of sensors/actuators
- Functional aspects
- Command Control aspects
- System implementation aspects
  - Units redundancy, cross-strappings, reconfigurations
  - Avionics architecture vs AOCS architecture
  - Budgets (power, mass, accommodation)
- Recurring units

Analysis framework – Survey of AOCS sensors and actuators

Analog Units

Digital Sensing

SpaceWire use cases

Unit type	Nb of products	RS422 /RS485	MIL-STD-1553	SpaceWire	Analog
Analog sun sensor	4				x
Digital sun sensor	2	x		x	
Magnetometer	3				x
Analog Earth sensor	1				x
Digital Earth sensor	2	x	x		x
Single-head star tracker	5	x	x		
Multiple-heads star tracker	1	x	x		
Embedded star tracker	1			x	
GNSS receiver	4	x	x	x	
Gyroscope	4	x	x		
Navigation camera	(1)	x	x	x	
Reaction wheels	4	x	x		x
MTQ	2				x
Thrusters					x

(1) *Non-recurring equipment for interplanetary missions, excluding landing phases.*

Analysis framework – Opportunities

Built-in synchronisation

- Functional synchronisation

High rate Low latency

- End-to-end functional delay
- Units operations
- Variability of AOCS architectures

Asynchronous communications

- GNSS data
- FDIR events

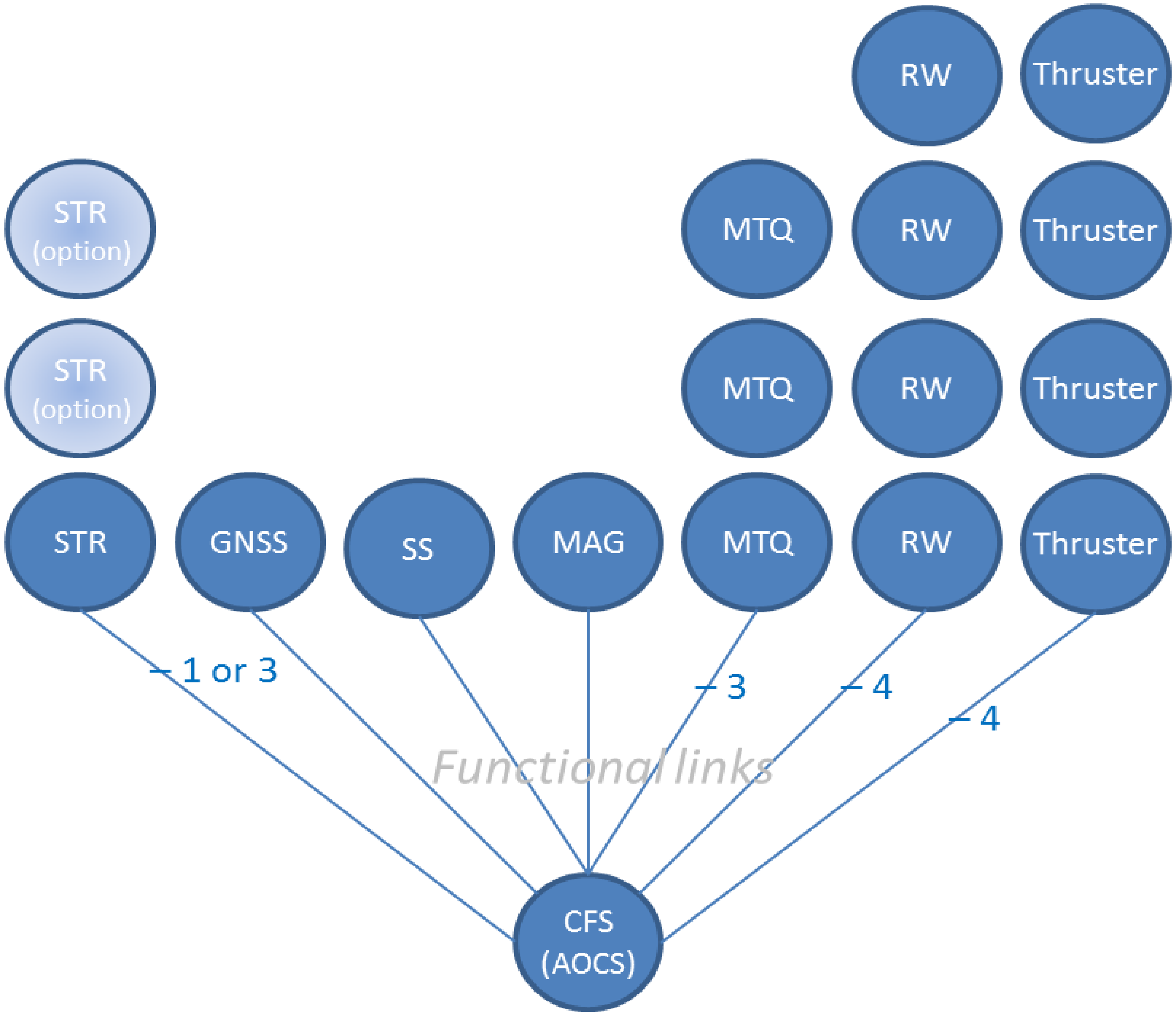
Standard Interface

- AOCS standard

Reference Case

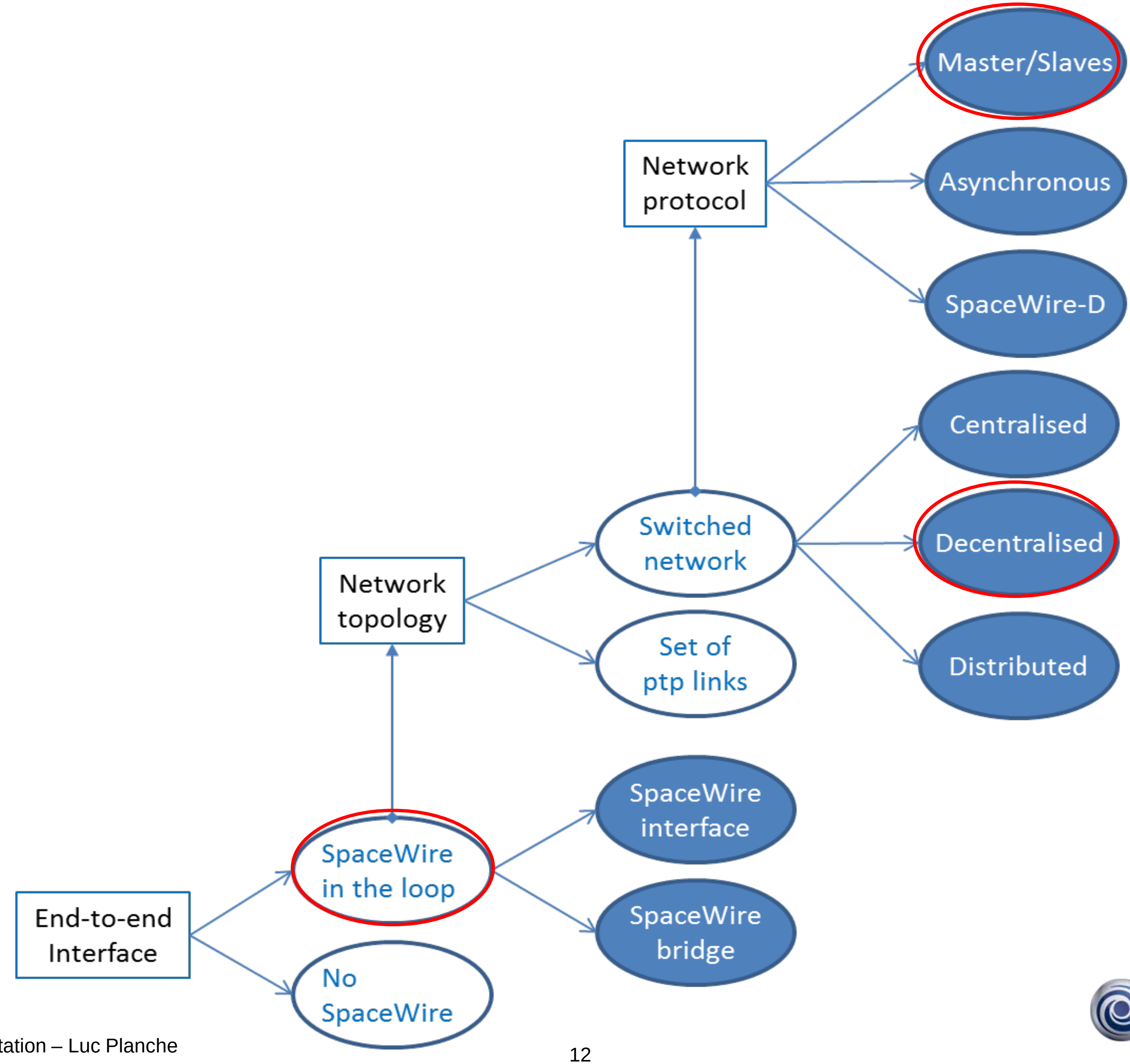
Mission & Configuration

- Sentinel 5P
  - LEO platform with slew capability
  - Gyroless



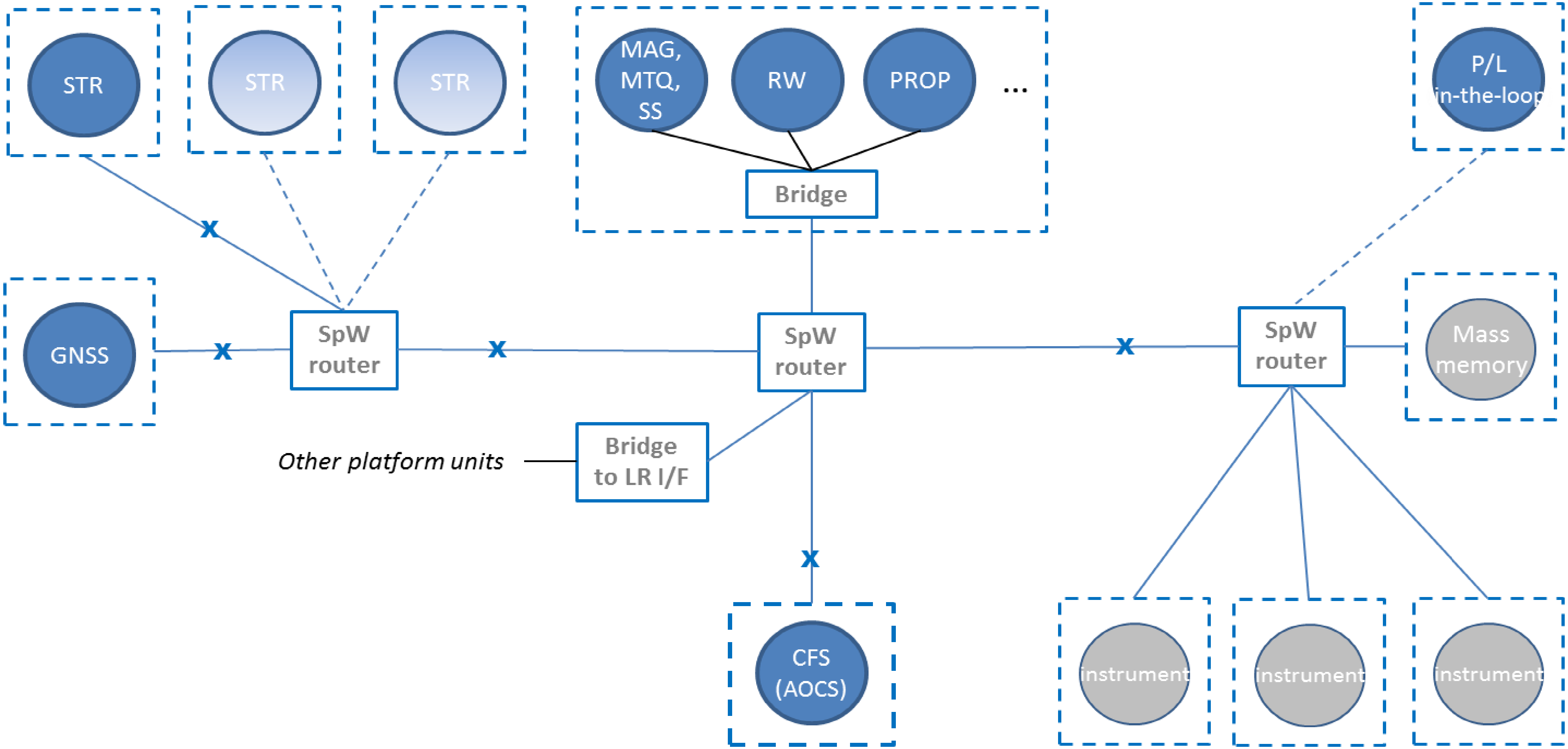
Reference Case

Communication Architecture



Reference Case

Communication Architecture



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Evaluation

Key Parameters

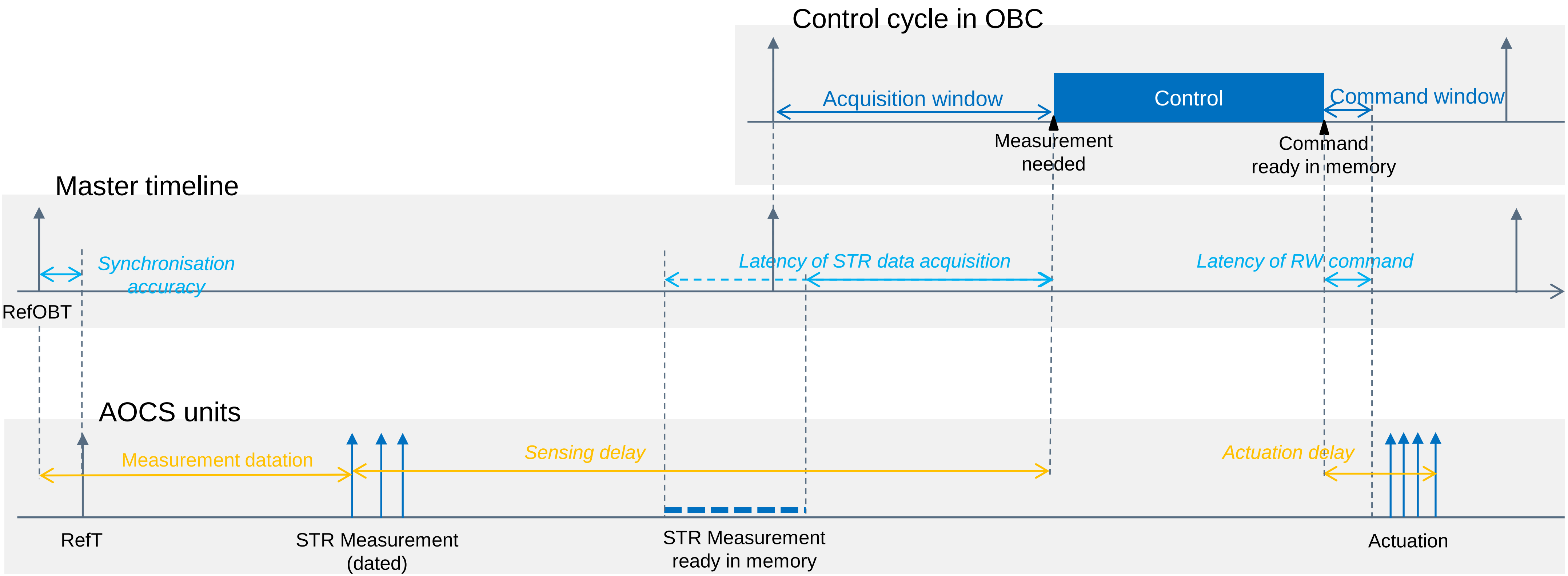
- ## Functional parameters

Key functional parameter	Dependency	Expected impact
Datation of STR measurement data	STR local time is synchronised to the On-Board Time thanks to dedicated signal. This signal is implemented by a SpaceWire timecode.	Negative (reference implementations with discrete lines are with sub-µs accuracy while SpW is in the range 1-50µs). However timecode propagation delay can be tuned by increasing the link rate.
Synchronisation jitter between independent axis	STR (same for Gyros) equipments are synchronised thanks to dedicated signals. These signals are implemented by a single SpaceWire timecode broadcasted throughout the SpaceWire network.	Possibly yes (negative). This parameter is first handled at network design level in order to have equivalent paths.
Latency of STR measurement data	STR measurement data are embedded within one or several SpaceWire packet.	Positive. A typical value is less than 15.625ms for a 62.5ms AOCS cycle (16Hz). The improvement is to be assessed in relation to other latency sources contributing to the 15.625ms figure.

- ## Implementation and context parameters
  - Link rates, router characteristics
  - Trafic, overheads, functional rates, fault injection

Evaluation

Temporal view



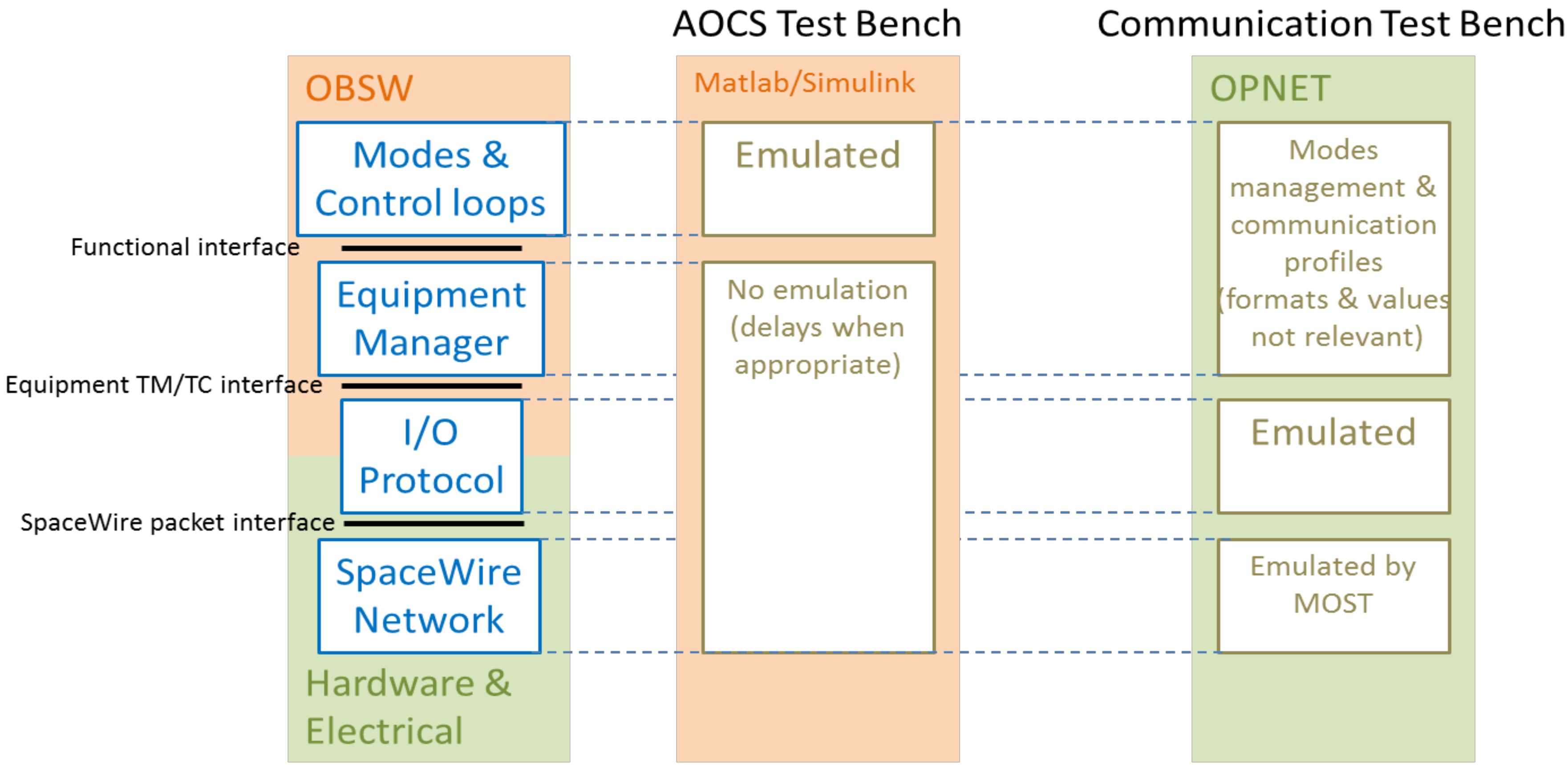
Key Functional Parameter

Monitor

Evaluation

Ressources

- Simulation benches



Lessons Learnt

AOCS Function & Performance

- SpaceWire, when used as AOCS communication backbone and with ad-hoc rate (higher than 10Mbps) has no impact at functional level.
  - Same range of performances than with current architectures, with no modification of the AOCS controller or the sensors/actuators.
  - Attitude knowledge error acceptable

- Margins in AOCS acquisition and commanding time windows
  - Increase the volume of data acquired
  - Increase the time window available to execute the control algorithms (but CPU throughput increases)
  - Reduce the end-to-end functional delay
    - Positive impacts on RPE (but other contributors) and post-manoeuver damping

Operations

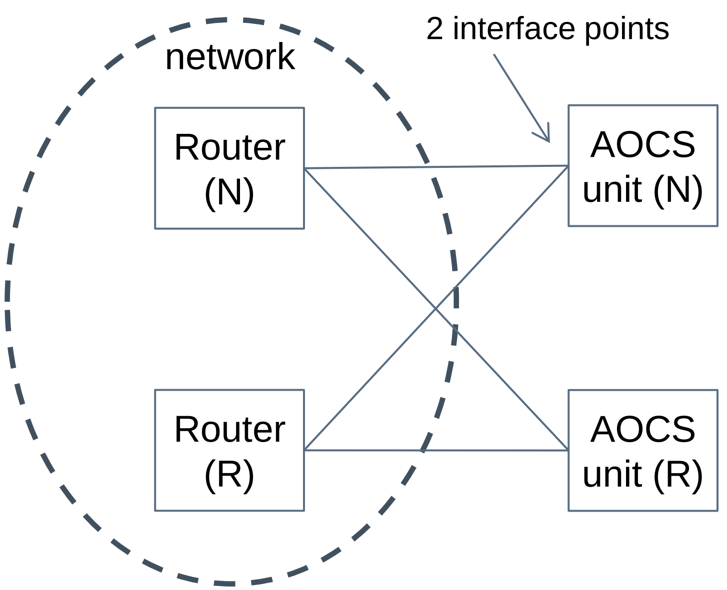
- Simpler and more efficient operations
  - Large data transfers e.g. remote memory patch/dump
  - Relaxed telemetry definition,
  - Telemetry acquisition independent from the operational mode e.g. large, multi-purpose TM packets
  - Diagnostic/Configuration
  - Oversampling

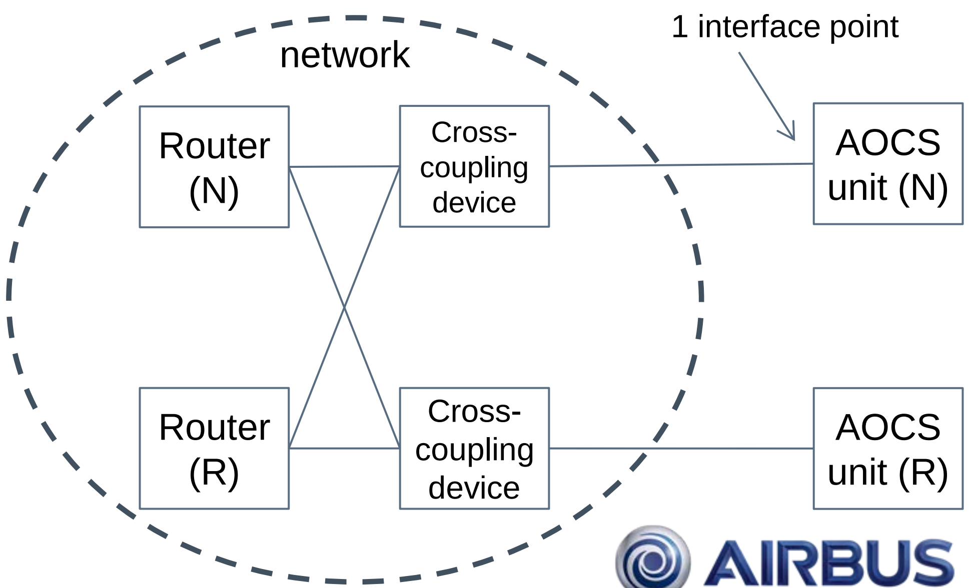
- Asynchronous (low end-to-end latency) events, generated by the remote unit
  - no real benefit, as event latency is not a time-critical need

Lessons Learnt

AOCS sensor/actuator interface

- Approach common to all AOCS units
  - Range = intelligent unit (STR) to simple terminal (OHU)
  - Compatible with a switched network implementation
- Requirements on the interface
  - Standard protocol stack (cross-projects)
  - Performance
    - Minimal/variable link rate
    - Buffering capability compatible with the network operation/communication profile
  - Redundancy & cross-strapping





AOCS Sensor/Actuator interface

RIU

Opportunity

Need

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(1) Non-recurring equipment for interplanetary missions, excluding landing phases.

SpaceWire Protocol stack

Unit-specific / CCSDS

Transaction Frame

RxAP

SpaceWire
(Packet layer)

- SpaceWire network
- One controller (CDMU), many slaves
- Timed transactions frame
- Support to network FDIR
- Acknowledged transactions
- Posted transactions (to different units)

Remote Queue Access Protocol

- Motivation
    - Packet –orientation
    - Relaxed synchronisation constraint
    - Fits to hardware
- Features
    - One terminal, several « queues »
    - Fixed set of parameters per terminal
    - Push/pull or Write/Read operation modes
- Benefits
    - Queue ID's may be standardised to support a functional / non functional service
        - Does it fit an RMAP utilisation profile?
- Examples
    - Single queue (per direction), R/W CCSDS packets
    - Single queue, push/pull CCSDS packets, event terminal
    - Multiple queues, push/pull CCSDS packets, event terminal, separate functional channels
    - Multiple queues, one place / queue, R/W
    - Single queue, one place / queue, R/W

Conclusion and Perspectives (1/2)

- Centralised sensor architecture
  - Set of direct links
  - Implementations already exist
  - No need for a standard
- AOCS network
  - Brings some degree of flexibility at functional and operational levels
    - Not all units concerned
  - Brings some degree of flexibility at configuration level
  - Interface standard to be established
- Avionics network
  - More units out of the scope of opportunities
  - Isolation required if payload system included

Conclusion and Perspectives (2/2)

- Consolidate the study findings
  - Demonstrating other AOCS architectures
  - Representative implementation integrating functional and communication models
- Consolidate the envisaged SpaceWire extensions
  - Protocol stack
  - Selective delivery of synchronisation signals
  - Bridging
- Consolidate the network FDIR
  - Using state-of-the-art SpaceWire components
  - Failure modes for slave terminal (fail-silent behaviour)
  - Networks integration (Firewall)
- Perform system-level case studies
  - Budgets
  - Need for a standalone router unit?

Thank you for your attention !

Questions ?

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