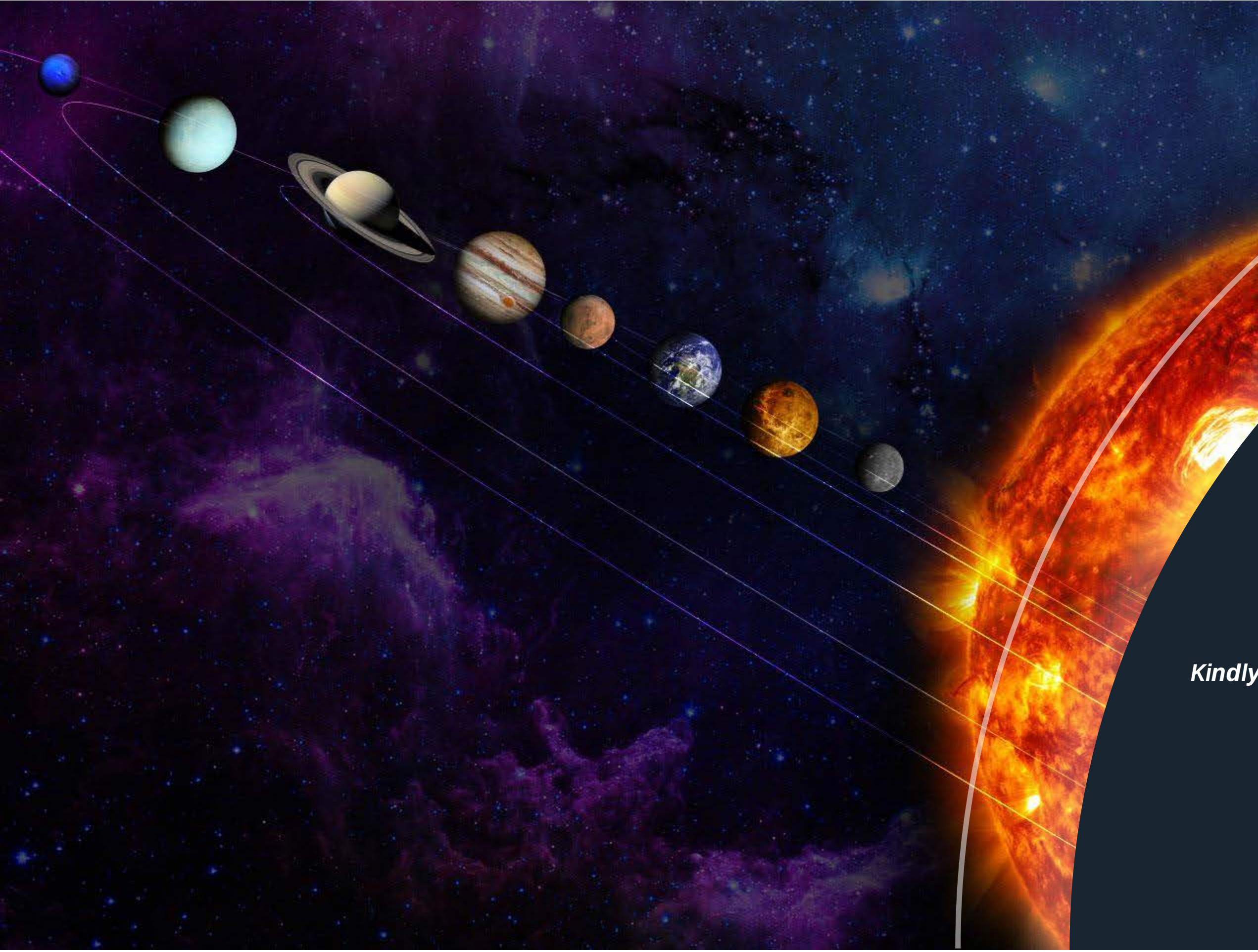


# A New Network Paradigm for the On-board Reference Architecture (OSRA-NET)

Marco Panunzio

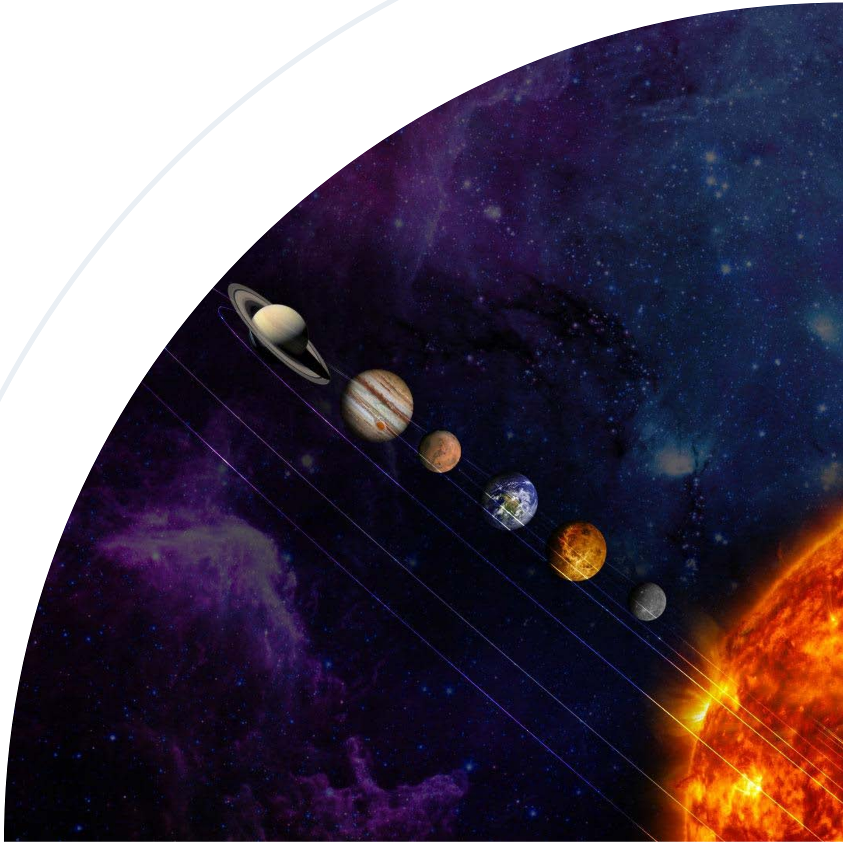
***Kindly Presented by: Christophe Honvault – ESA / ESTEC***

Final Presentation Days – ESA / ESTEC

ThalesAlenia Space
a Thales / Leonardo company

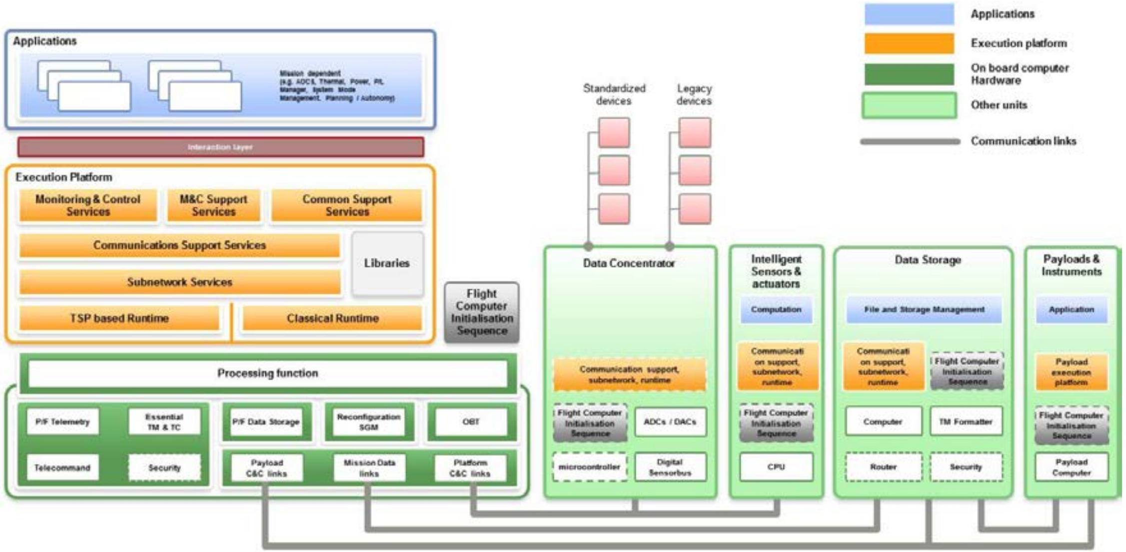
# Outline

- SAVOIR and SAVOIR-FAIRE
- Goals of the OSRA-NET Study
- Study organisation
- Analysis phase
- The OSRA-NET Requirements Specification
- Demonstrator and Case Study
- Case study
- Major results, lesson learnt and way forward



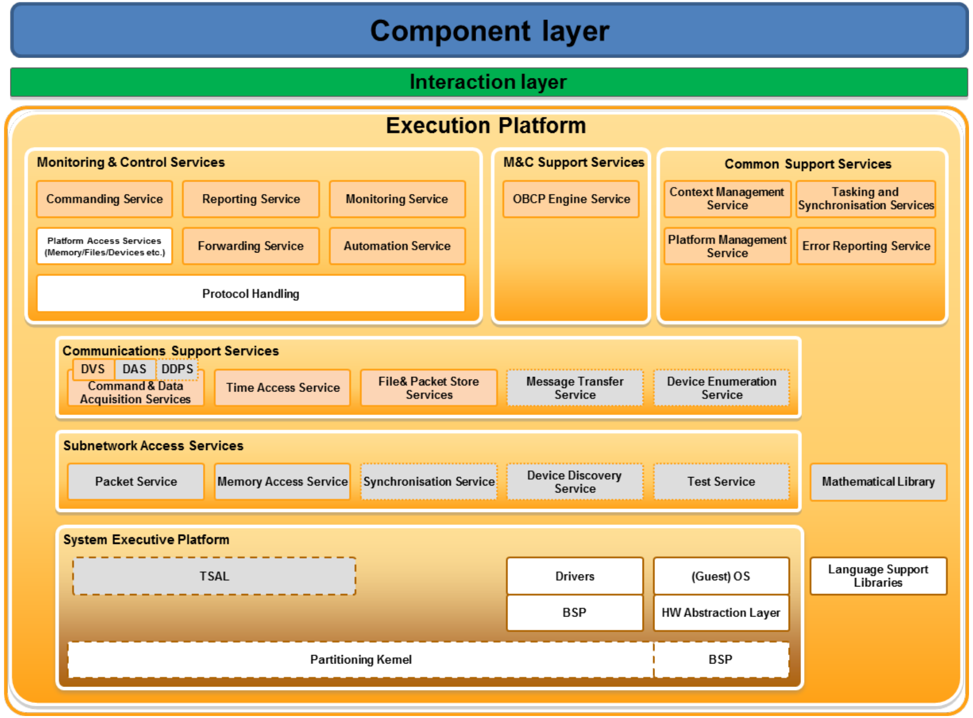
# SAVOIR Avionics System Reference Architecture (ASRA)

- Reference avionics architecture (HW + SW vision)
  - Addressing the full platform avionics perimeter
  - Payload C/C, Data Storage, Telemetry, Routing and Security
- Stays as agnostic as possible w.r.t. technology and implementation choices
  - "Functional Reference Architecture"
  - Yet mapping to current reference implementation technologies are provided and discussed (e.g., 1553, SpW, CAN)



# SAVOIR On-board Reference Architecture (OSRA)

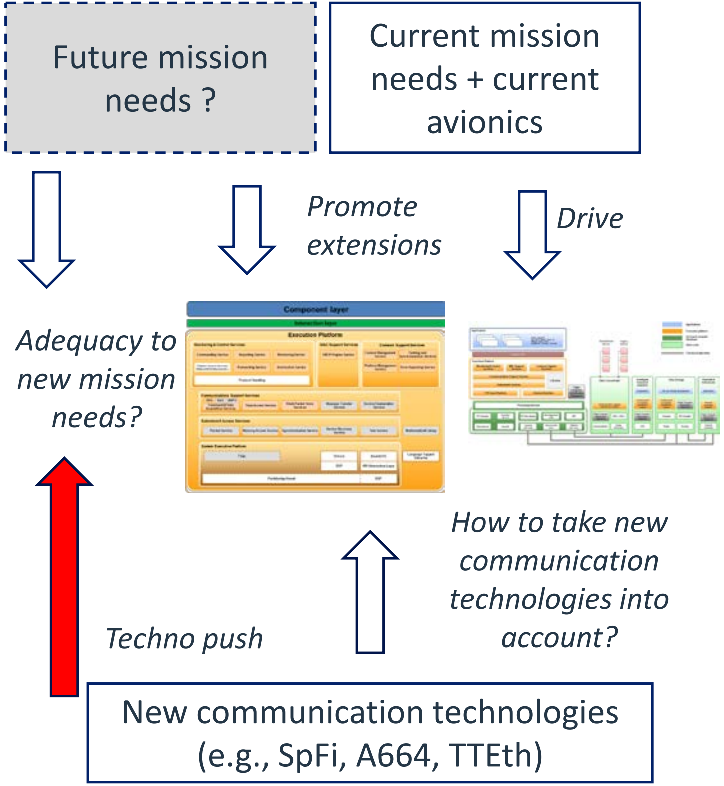
- Proposes a reference organisation of platform SW architecture in 3 layers
  - Component layer
    - for Mission-specific software
  - Execution platform
    - For Mission-independent software (e.g., generic services)
    - Oriented to re-use
  - Interaction layer
    - To guarantee independence of components from execution platform
    - Automatically generated
- Comes with an associated Model-Driven Engineering process
  - Semi-formal modeling of SW architecture design
    - Increased abstraction of design + precise SW / SW interface definition
  - Automated code generation
- Supports both "Classical" and Time and Space partitioning execution platform



# Assessment **(2015)**

- ASRA + OSRA could adequately describe existing avionics and on-board software
- Technology references in the technical notes is mostly related to currently flying technology
  - e.g., 1553, SpaceWire, CAN in the OBC generic specification
- Strong ***techno push*** of new communication technologies (e.g., SpaceFibre, ARINC 664 P7, TTEthernet)
  - They require possible extensions of standards, methodologies, development practices and reference architectures (at avionics and software level)
  - Albeit they promise interesting advantages, what are the needs these technologies respond to? How is their design driven?

- How to ensure that new communication technology developments are driven so as to best respond to the right mission needs?
- How to ensure that the SAVOIR reference architectures can take into account these new needs, possibly by leveraging on new communication technologies?



# Goals of the OSRA-NET study

- To extend the concept of On-board Software Reference Architecture (OSRA) to new communication paradigms emerged in the past few years
  - Such as those promoted by SpaceFibre, ARINC 664 Part 7 or TTEthernet
- To enable the implementation of a multi-node On-Board Software Reference Architecture (OSRA-NET)
- To perform an impact analysis on all relevant SAVOIR, ECSS and CCSDS documents
- Two major areas of work
  - The specification of the high-level communication system requirements for the OSRA
  - The definition of an extended OSRA methodology and process for the analysis of communication needs
    - So as to confirm the feasibility of an architecture design spread on multiple nodes
    - To possibly refine such architectural design into OSRA components
      - To perform automated code generation and implementation
- To prototype an implementation of the new OSRA-NET methodology and of a suitable communication stack on spaceborne hardware
  - Extension of reference OSRA Toolchain
  - Execution of a case study demonstration of the new approach

# Overview of the OSRA-NET TRP Study

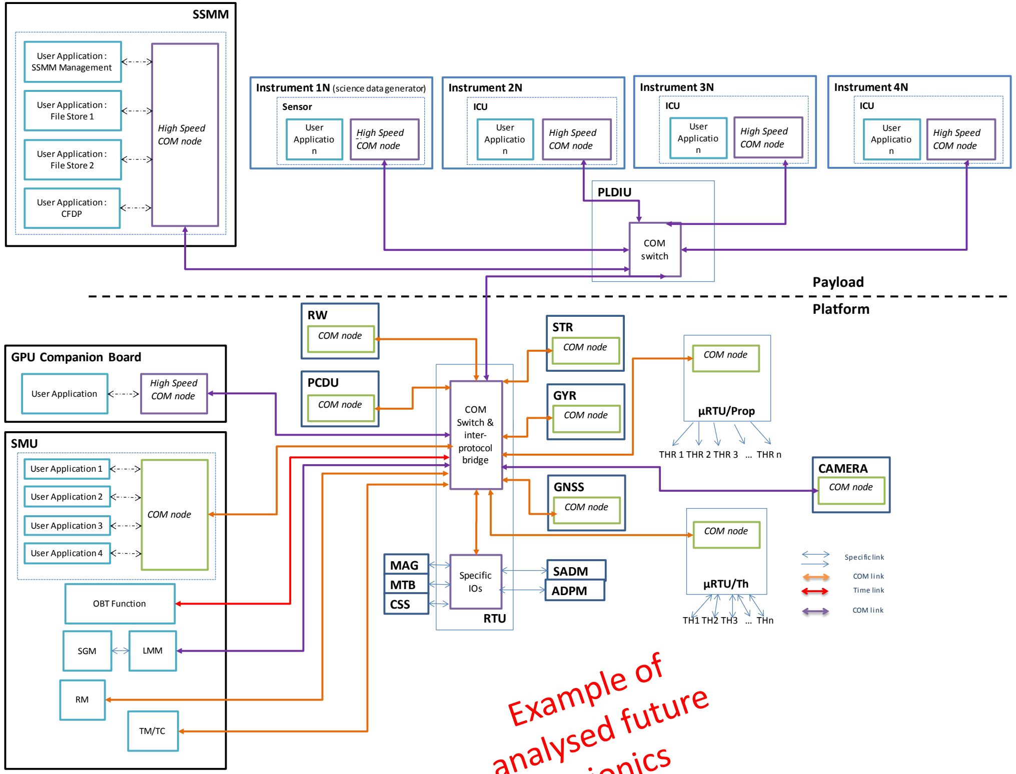
- R&D study (TRP) started in December 2015 and concluded in December 2017
- Analysis phase
  - Analysis of existing SAVOIR, ECSS, CCSDS standards
  - Methodology definition
  - Demonstrator technology selection
  - Case study preliminary definition
- Specification phase
  - Specification of OSRA-NET communication requirements
  - Impact analysis on existing standards
  - Consolidated Case Study
- Demonstrator implementation and case study execution
  - OSRA toolchain extension for OSRA-NET
  - Implementation of prototype OSRA-NET communication stack
  - Integration of communication stack into OSRA toolchain / TASTE
  - Case study modeling, implementation and execution
  - Extension of case study results to full-scale spacecraft

# Study Organisation

- ESA
  - Technical Officer: Christophe Honvault – TEC-SWE
- Thales Alenia Space (Study Prime)
  - Analysis Phase – *Leader*
  - Process and Methodology Definition
  - Case Study Definition – *Leader*
  - OSRA-NET Communication Requirements Specification
  - Impact Analysis – *Leader*
  - Demonstrator and case study - *Support*
    - Extensions of the OSRA Component model (SCM)
    - Extension of case study results to full-scale spacecraft avionics
- GMV
  - Analysis Phase – *Support*
  - Case study definition – *Support*
  - Impact Analysis – *Support* for OSRA-related standards
  - Demonstrator and case study – *Leader*
    - Extension of OSRA Component model editor and SCM to TASTE transformation
    - Integrated communication and middleware architecture (with TASTE)
    - Case study execution
- Teletel
  - Technology selection – *Support*
  - Implementation of prototype OSRA-NET communication stack
- Bright Ascension
  - Analysis phase and Impact Analysis – *Support* for SOIS, MOS, CCSDS recommended practices

# Analysis of communication needs for current and future avionics

- Exomars TGO used as example of current avionics
- Star Tracker SW processing on platform OBC taken into account in the analysis
  - By using Iridium Next as example of operational avionics
- Analysis extended with needs for future science, EO, exploration missions




Example of analysed future avionics

# Analysis of communication needs for current and future avionics

- The analysis permitted to extract expected communication needs for devices of future avionics
  - Expected min-max message size
  - Frequency
  - Max Jitter / Latency
  - Need for timestamp

| | Traffic description | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Equipment | Datatype | Max Cargo size (bits) | Frequency (Hz) | Period (ms) | bit rate | AOCS sensitivity | Jitter requirement Value (ms) | Jitter requirement ROM | Latency (ms) Value (ms) | Latency (ms) ROM | Other requirements | QoS level | Time stamp (8 octets) | Proposed Class of Comm |
| Sensors | Magnetometers | AOCS | 12 | 8 | 125 | 100 bits/s | > 1 cycle | 1000 | 1 cycle | 1000 | 1 cycle | order of msg | | No | 2 |
| | Coarse Sun Sensors | AOCS | 96 | 8 | 125,00 | 770 bits/s | Low | 10 | 1 cycle | 10 | 1 cycle | order of msg | | No | 2 |
| | Gyro (Coarse/safe mode) | AOCS | 576 | 8 | 125,00 | 4,6kbits/s | 1 cycle | 2 | 1 cycle | 2 | 1 cycle | order of msg | | No | |
| | Gyro (fine-grained) | AOCS | 576 | 32 | 31,25 | 18kbits/s | 1 cycle | 2 | < 1 Cycle | 2 | < 1 Cycle | | | Yes | 8 |
| | Gyro (future) | AOCS | 576 | 32 | 31,25 | 18kbits/s | 1 cycle | 2 | < 1 Cycle | 1 | < 1 Cycle | | | TBD | 8 |
| | Star-Tracker (Smart) | AOCS | 8194 - 32777 | 8 | 125,00 | 65 to 262 kbits/s | 1 cycle | 1 | < 1 Cycle | 10 | 1 cycle | | | Yes | 2 |
| | Star-Tracker (Smart) | AOCS - Geo | 8194 - 32777 | 8 | 125,00 | 65 to 262 kbits/s | > 1 cycle | 2 | 1 cycle | 10 | > 1 cycle | | | TBD | 2 |
| | Star-Tracker | AOCS - Agility | 8194 - 32777 | 30 | 33,33 | 245 to 983 kbits/s | << 1 Cycle | 0 | << 1 Cycle | 1 | << 1 Cycle | | | Yes | 5 |
| | Camera - High Res. | AOCS - Rendez-vous | 41943040 | 8 | 125,00 | 335 Mbits/s | 1 cycle | 10 | < 1 Cycle | 100 | 1 cycle | | | Yes | 6 |
| | Camera | AOCS - Nav. Cam | 10485760 | 8 | 125,00 | 84 Mbits/s | > 1 cycle | 100 | > 1 cycle | 100 | > 1 cycle | | | Yes | 4 |
| | Camera | AOCS - Multi stage (1kHz) | 1000000 | 1000 | 1,00 | 1000 Mbits/s | > 1 cycle | 100 | | 100 | | | | Yes | 6 |
| | IR Spectrum Camera | AOCS | 2457600 | 1 | 1000,00 | 2,5 Mbits/s | > 1 cycle | 100 | | 100 | | | | Yes | 6 |
| | Payload sensors | Various - closed loop | Mission dependant | 100 | 10,00 | Mission dependant | << 1 Cycle | Mission dependant | << 1 Cycle | Mission dependant | << 1 Cycle | | | TBD | 5 |
| | Tachometer | AOCS | 30720 | 8 | 125,00 | 245 kbits/s | > 1 cycle | 10 | > 1 cycle | 100 | > 1 cycle | | | No | 3 |
| | Tachometer | AOCS - Agility Multi stage | Time stamp could be greater than actual value | 100 | 10,00 | TBD | 1 cycle | 1 | < 1 Cycle | | < 1 Cycle | | 1 | Yes | 5 |
| | GNSS | AOCS | 10000 | 1 | 1000,00 | 10 kbits/s | 1 cycle | 10 | 1 Cycle | 10 | 1 Cycle | | | Yes | 1 |
| | | AOCS | 14 | 1 | 1000,00 | 10 kbits/s | 1 cycle | 0,001 | << 1 Cycle | 0,001 | << 1 Cycle | | | Yes | 1 |
| Actuators | Magneto-Torquer Bars | AOCS | 12 | 0,125 | 8000,00 | neglectable | 1 cycle | 500 | < 1 Cycle | 8000 | 1 cycle | | 1 or 2 | No | 1 |
| | Thrusters (x28) | ACOS | 2800 | 8 | 125,00 | 22 kbits/s | <1 cycle | Mission dependant | | Mission dependant | | | 1 or 2 | No | 3 |
| | Thrusters - chemical | ACOS | 2800 | 256 | 3,91 | 720 kbits/s | < 1 cycle | 0,1 | <1 Cycle | 0,1 | <1 Cycle | no loss | 2 | TBD | 5 |
| | Thrusters - electrical | ACOS | No hard constraints due to propulsion cycles: several minutes and the imapct on trajectory is not immediate | | | | | | | | | | 1 or 2 | TBD | 1 |
| | Reaction Wheels | AOCS | 30720 | 8 | 125,00 | 250 kbits/s | 1 cycle | 10,00 | < 1 Cycle | 10,00 | 1 cycle | | 1 or 2 | Yes for some | 2 |
| | Reaction Wheels (high speed) | AOCS - Agility | 30720 | 100 | 10,00 | 3 Mbits/s | 1 cycle | 0,50 | < 1 Cycle | 1,00 | < 1 Cycle | No Loss of msg End of process in same cycle | 2 | TBD | 5 |
| Payload | Spectrometer | Science | 2,00E+08 | 10 | 100,00 | 2000 Mbits/s | N/A | N/A | N/A | N/A | N/A | | 0 or 1 | No | 4 |
| | Ultra HD Camera (4K) | Science | 9,95E+07 | 10 | 100,00 | 1000 Mbits/s | N/A | N/A | N/A | N/A | N/A | | 0 or 1 | No | 4 |
| | X Ray detector | Science | 1,80E+10 | 0,0303 | 33003,30 | 545 Mbits/s | N/A | N/A | N/A | N/A | N/A | | 0 or 1 | No | 4 |

Experimental value, Approximation

# OSRA-NET Communication System Requirement Specification

- Provides generic requirements related to the communication needs for avionics systems currently under development and that could be foreseen in future missions
- It can therefore be considered as a common-core of requirements that is expected to be relevant to a sizeable range of future missions
- Addresses
  - Capability requirements (Communication needs requirements, QoS)
  - Communication infrastructure requirements
  - Error handling and FDIR
  - System-level communication requirements
- Reviewed at study level and separately by SAVOIR-UNION Working Group
- Already getting attention in the community!
  - e.g., mapping to SpaceFibre performed by ESA / University of Pisa, ADCSS 2017
- Currently being transformed in a SAVOIR document by ESA

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"A New Network Paradigm for the On-board Reference Architecture"
(OSRA-NET)

TN03: OSRA communication network specification

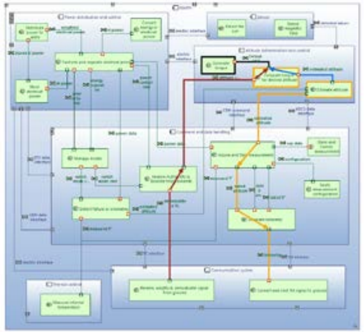
| Written by | Responsibility + handwritten signature if no electronic workflow tool |
|---|---|
| Adrien Charlet | Avionics R&D architect |
| Brice Dellandrea | Head of Avionics R&D and feasibility studies department |
| Marco Panunzio | OSRA-NET Project Manager |
| **Verified by** | |
| Marco Panunzio | OSRA-NET Project Manager |
| **Approved by** | |
| Marco Panunzio | OSRA-NET Project Manager |

Approval evidence is kept within the documentation management system.

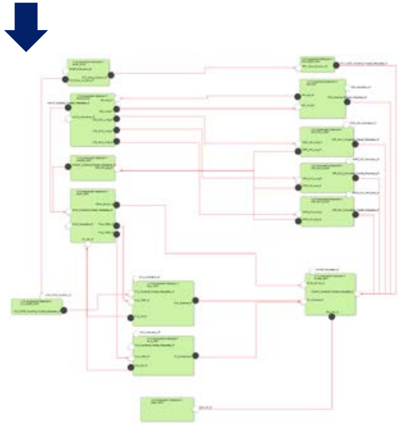
A major output of the activity!

# OSRA-NET methodology

System / Avionics modeling



OBSW modeling

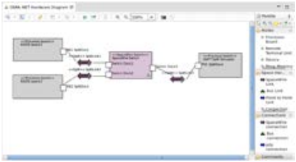


- System / Avionics modeling
  - Modeling languages such as Capella or SysML
  - Goal: Enable ***Coarse-grained*** communication analysis
    - Oriented to
      - Preliminary communication sizing
      - Avionics system feasibility

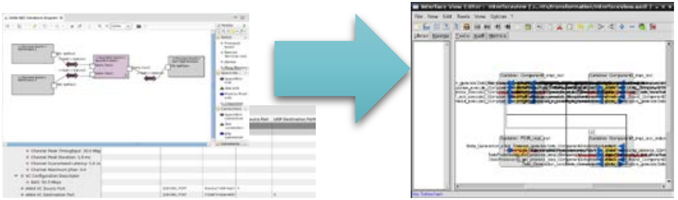
- OBSW modeling
  - Leveraging on e.g., the OSRA component model
  - Goal: Enable ***Fine-grained*** communication analysis
  - Capitalise on avionics modeling effort => coherent model transformation is required
  - Refinement of communications with knowledge of
    - Communication patterns used at OBSW level
      - E.g., send, request / response, etc…
    - Overhead due to full communication protocol stack
      - Hardware Comm Protocol + SW comm protocols + software real-time architecture

# Demonstrator infrastructure development

- Development of an ARINC 664 P7 SW stack for spaceborne technology
  - ARINC 664 P7 over SpW physical medium
  - For RASTA LEON2 and iSAFT PVS (SpW EGSE)
- Development of extensions to the OSRA component model and editors
  - Communication properties, Virtual Channels, new hardware entities…



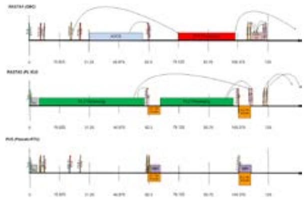
- Extension of the TASTE toolchain
  - To support the same new modeling concepts
  - To integrate the ARINC 664 P7 Communication Stack



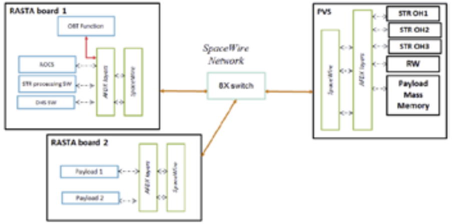
- Verification tests and Integration Tests (Communication Timing)

# Overall case study process flow

- Definition of a small-scale yet representative case study
  - Not representative of functionality but of communication traffic
  - Star Tracker with processing on OBC, Reaction Wheels, Payload Science TM, PF HK, PL HK
- Case study modeling with the OSRA(-NET) Component model + code generation with TASTE
- Deployment of case study on final demonstrator configuration
  - 1 RASTA board as PF, 1 RASTA board as PL, 1 iSAFT PVS as pseudo-RTU
- Case study execution and verification report
- Extension of results via analysis to full-scale spacecraft avionics



+ taste



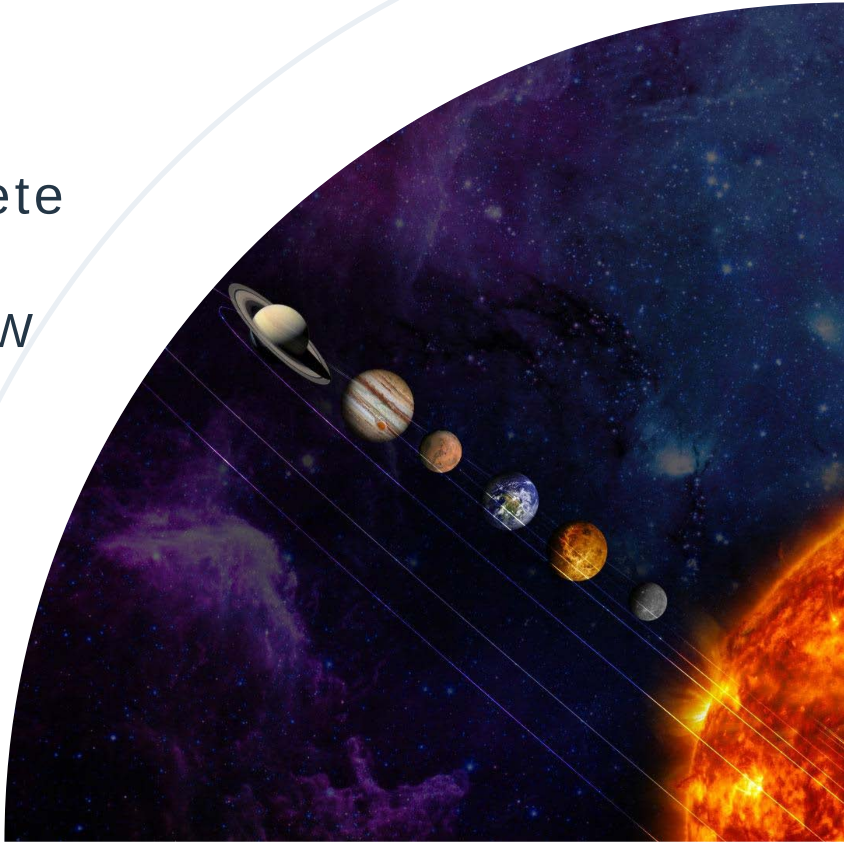

# Overall results

- Major results
  - An analysis phase to gather communication needs of current and future avionics
  - Impact analysis on ASRA, OSRA, generic OBC specification, SAVOIR MASAIS, etc…
  - OSRA-NET communication
  - OSRA-NET methodology
  - Extension of OSRA metamodels, and toolchain
  - Implementation of ARINC 664 P7 over SpW network
    - On RASTA LEON2 + iSAFT PVS
  - Prototype demonstrator with small-scale yet representative case study

# Overall results

- Lessons learnt and future work
  - Feasibility and performance of complex communication stack in SW
    - Take advantage of future heterogenous target such as the Compact Reconfigurable Avionics (multi-core processor + reconfigurable FPGA)
    - Benefit from HW / SW algorithm co-design!
  - Communication analysis engines
    - And relationship with avionics and OBSW modeling process
  - Detailed communication protocol information for fine-grained protocol overhead
  - Recommendations for improvement of TASTE middleware real-time architecture
  - Avionics modeling to SW modeling transformation bridges (e.g., Capella to OSRA SCM)

- Curious? Want to know more?
- You are kindly invited to the complete final presentation of OSRA-NET
  - To be held in the next TEC-ED / TEC-SW FPD session! (*)
  - May 2018



(*) Weather permitting…