CAN @ Thales – Beyond Exomars

ESA CAN Workshop 10/03/2016

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83230913-DOC-TAS-EN-002

The EXOMARS Mission

The ExoMars mission is split into two launches:

- The 2016 mission consists of a Trace Gas Orbiter (TGO) and an EDL Demonstrator Module (EDM)
- The 2018 mission consists of a Rover accommodated inside a Descent Module (DM) carried to Mars by a Carrier Module (CM)

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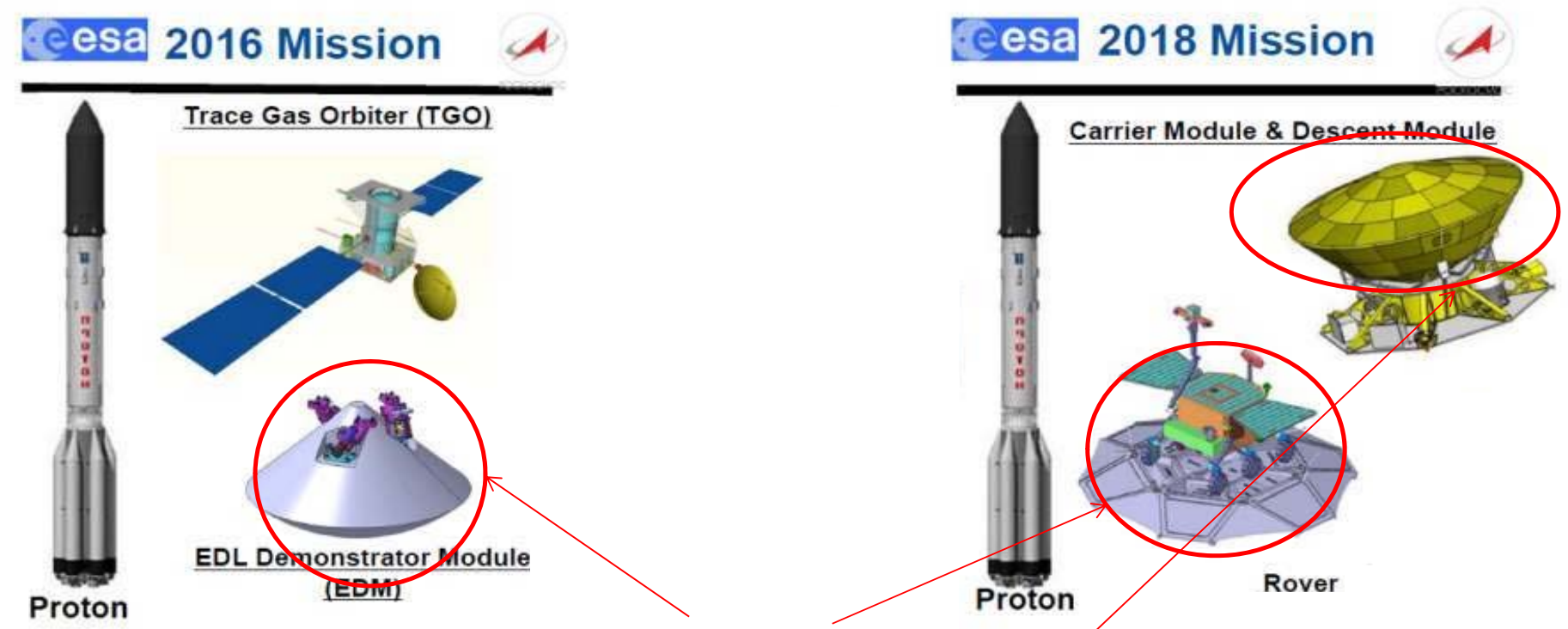


CAN + CANOPEN

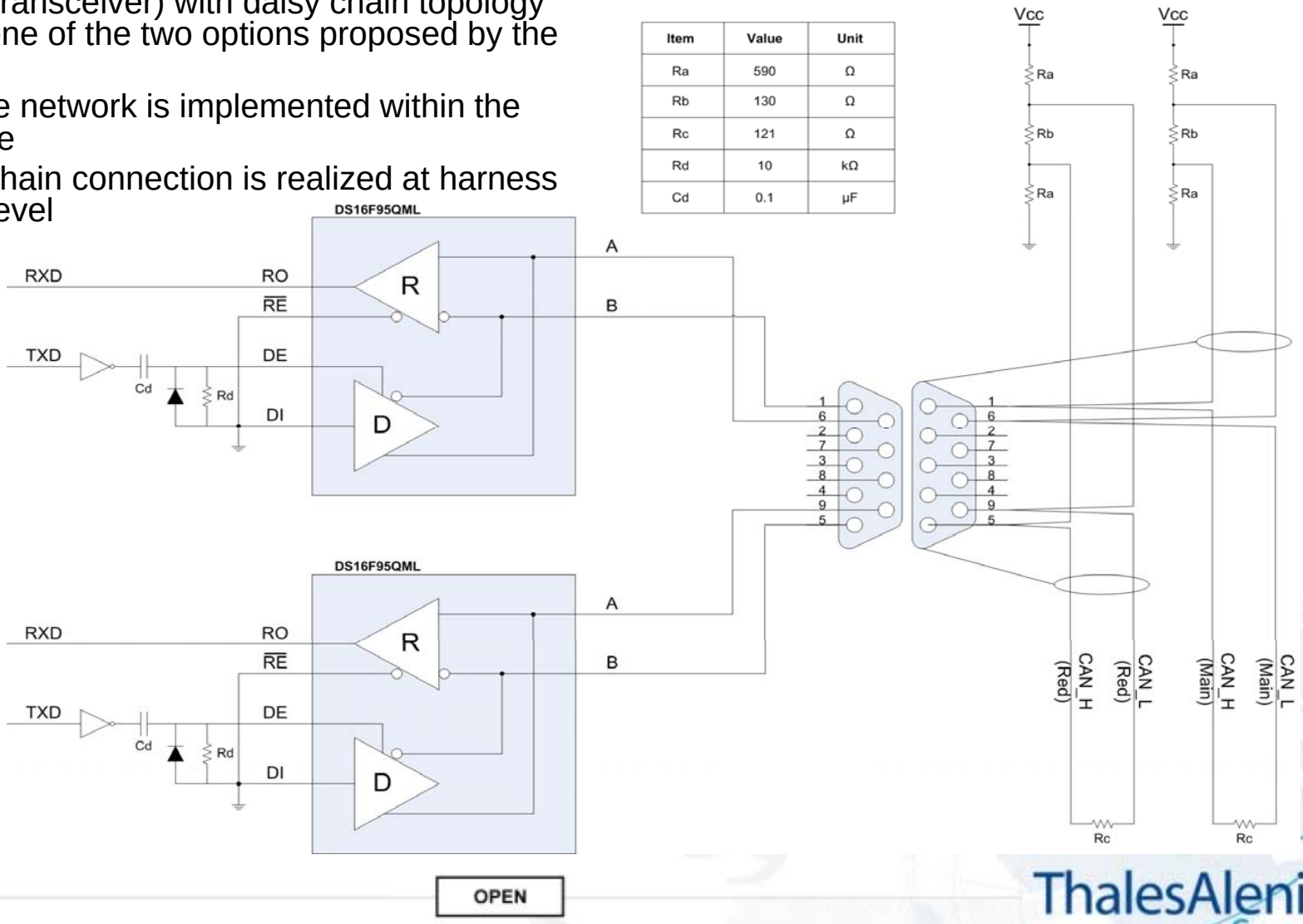
EXOMARS CAN Protocol

- The main CAN protocol requirement was:
  - All the EXOMARS CAN nodes shall implement the same protocol on top of the CAN data link Layer.
- The selected protocol is the CANOPEN:
  - Asynchronous PDO
  - Synchronous PDO
  - SDO expedited/segmented/block transfer
  - Heartbeats messages for reconfiguration management
- A full HW implementation of the EXM CANOpen protocol:
  - A VHDL IP Core (Canopen Controller IP Core) has been implemented (by SITAEL) to allow the connection of CPU-less nodes to the EXOMARS CAN networks.

Physical Layer

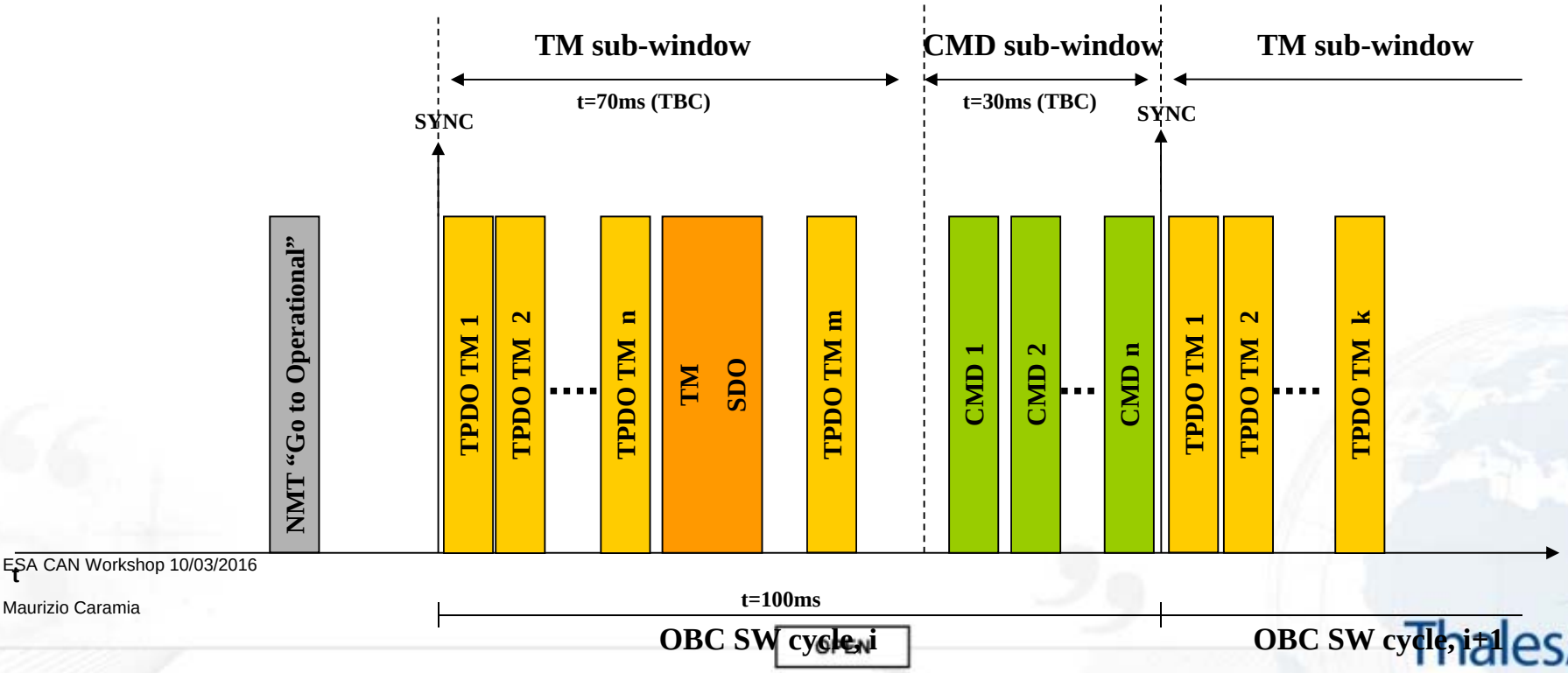
- The Selected physical layer is the RS485 (DS16F95 transceiver) with daisy chain topology according one of the two options proposed by the CAN ECSS
- The fail safe network is implemented within the master node
- The daisy chain connection is realized at harness connector level

Item	Value	Unit
Ra	590	Ω
Rb	130	Ω
Rc	121	Ω
Rd	10	kΩ
Cd	0.1	µF

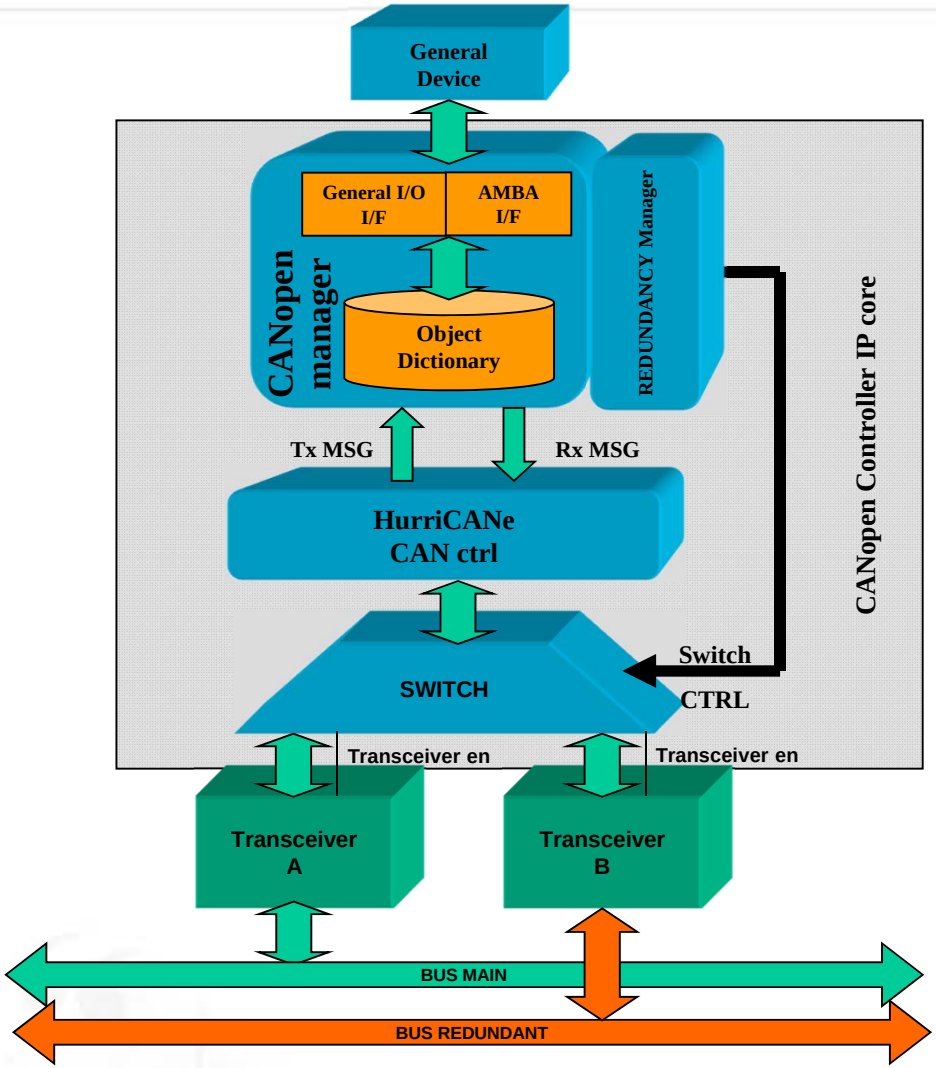


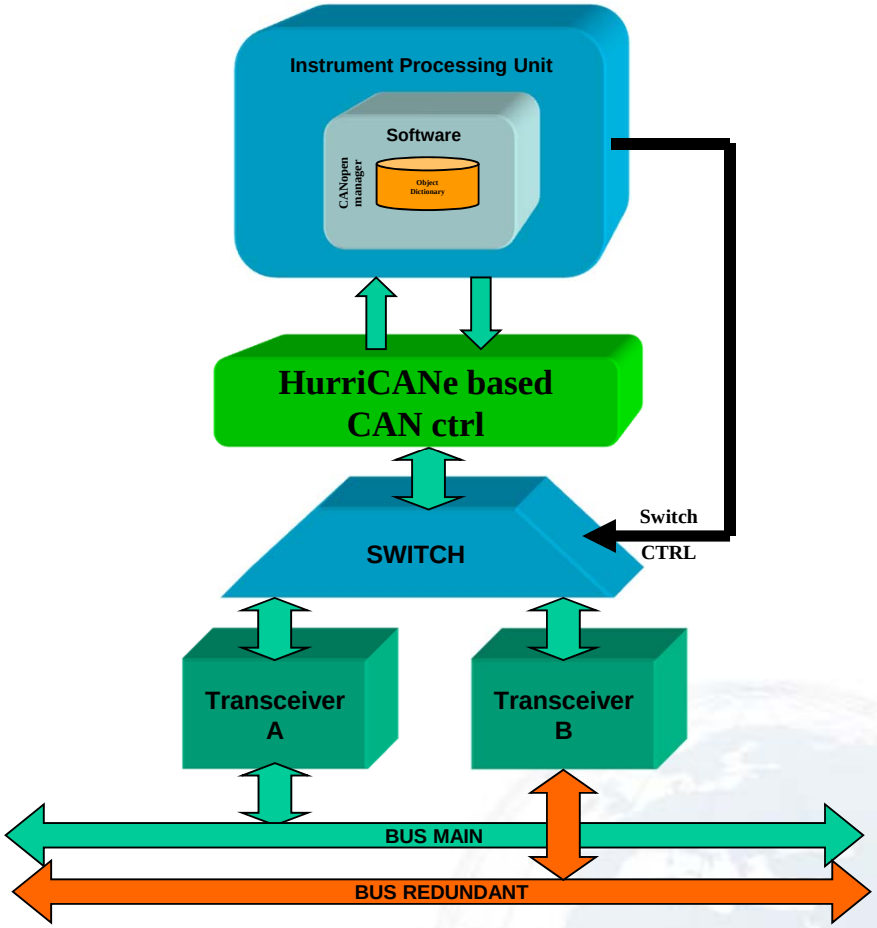
EXOMARS CAN Transfer Layer

- Taking into account that OBC SW cycle has a period of 100 ms during which TMs have to be acquired/elaborated and CMDs have to be generated, TM/CMD exchange will be regulated according to periodic timing windows delimited by two SYNC messages and divided into two phases: one dedicated to TMs reception (70ms) and one dedicated to CMDs generation (30). The period of each window will be 100 ms.
- After a node power-on, reset node, reset application or bus switch slaves nodes shall consider the first SYNC message received after an NMT command “Go to OPERATIONAL” as the start of the first TM/CMD window.



EXOMARS CANOPEN Implementation





The CANOPEN Controller IP Core

The CANOPEN software Stack

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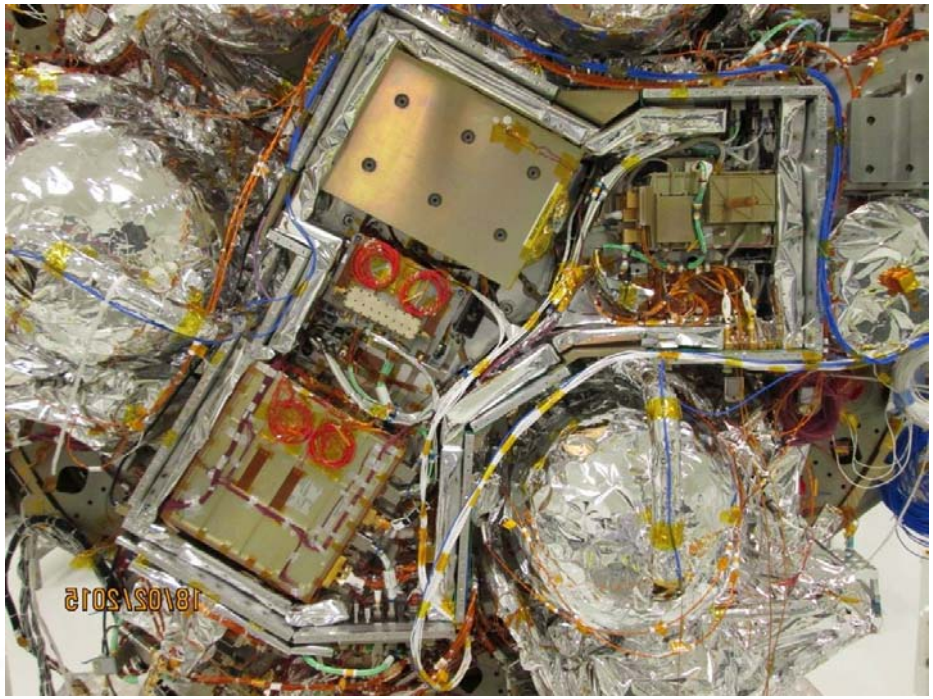
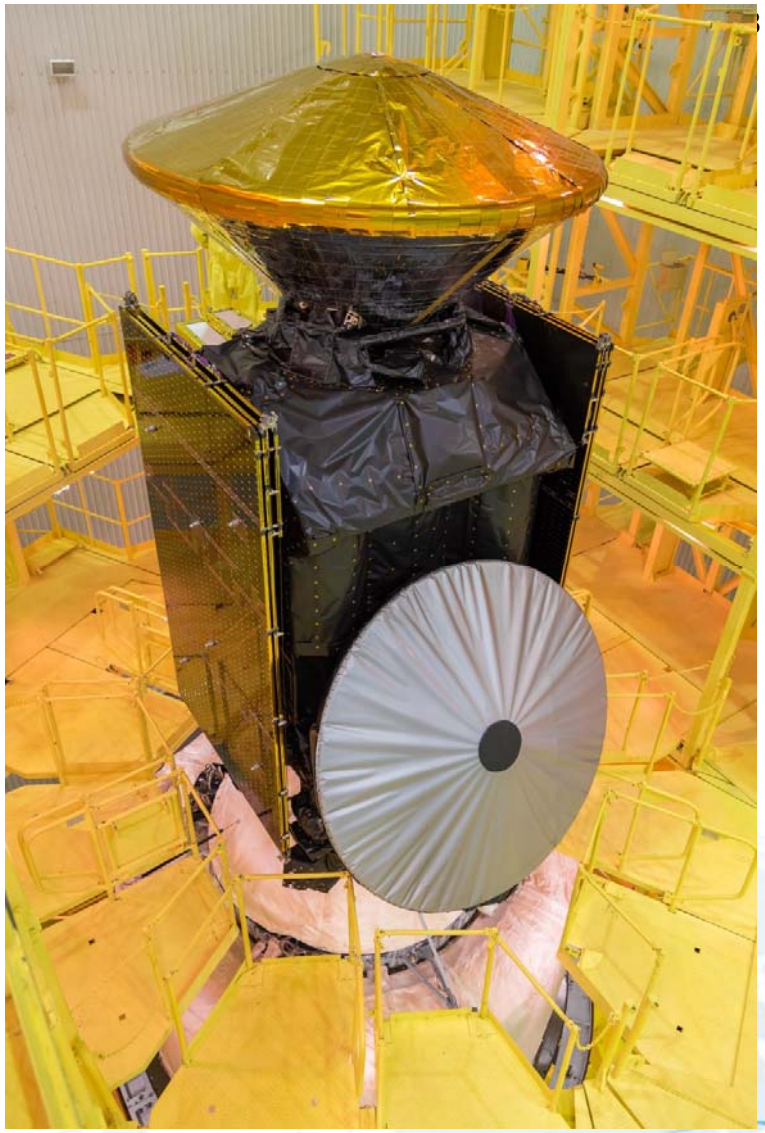
Follow the launch next Monday!!!





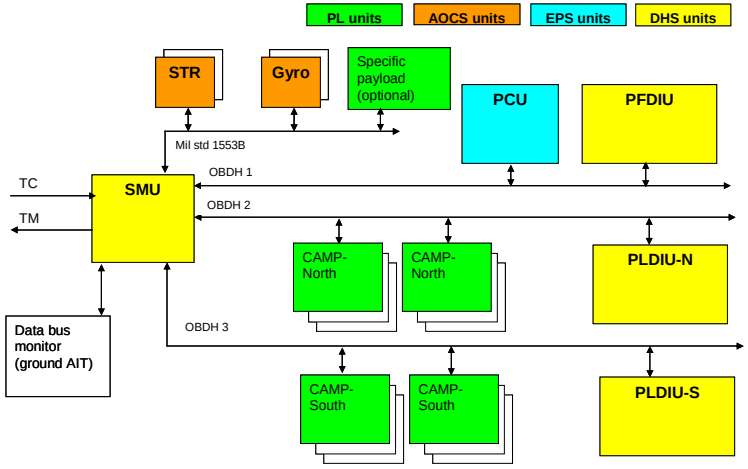
From Scientific to Telecom applications

Starting from the EXOMARS experience, TAS executed the ESA CABCOM study with the following main goals:

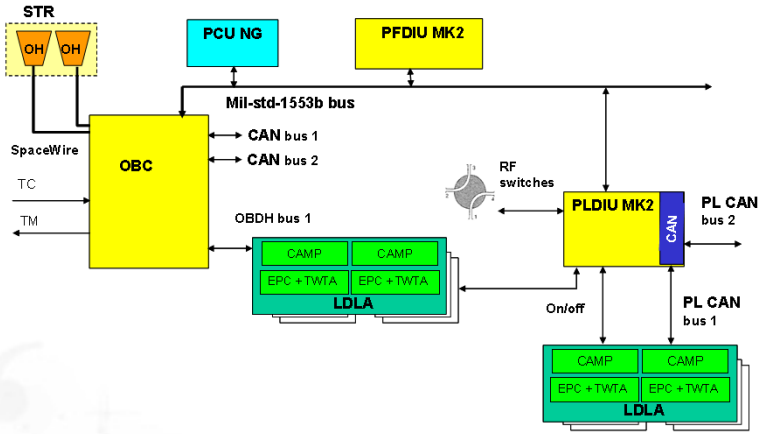
- To implement a fully ECSS-E-ST-50-15C compliant CAN bus solution for SATCOM
- To validate the implemented CAN solution in a dedicated test bench with HW in the loop
- To upgrade the CCIPC to include:
  - A-cyclic Synchronous PDO capability
  - Reception of Broadcast PDO for time distribution
  - Upgrade the CCIPC reconfiguration algorithm to support the infinite bus toggling.

CABCOM Proposed Solution

- The Thales Alenia Space platform Spacebus 4000 Avionics Architecture has been used as baseline SATCOM architecture for the CABCOM Study
- The Spacebus 4000 uses a mil-1553 bus for the Platform bus and a set of OHBH busses for the Payload bus



Spacebus 4000 Architecture



Upgraded Spacebus 4000 Architecture

- The Upgraded Avionic Architecture considers the replacement of the OBDH lines dedicated to the payload busses with the CAN bus.
- For the time being the Platform bus is still implemented with the mil-1553 bus
- The architecture still foresees possible connection of OBDH nodes to the payload bus

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CABCOM Proposed Solution

- The high level payload bus performances have been inherited from the Space bus 4000 requirements:
  - REQ-1: Bus rate: 500kbps
  - REQ-2: Number of nodes: 1 OBC with 1 CAN controller connected to two transceivers (selective bus architecture) + 120 Payload units, each with 1 CAN controller connected to two transceivers (selective bus architecture).
  - REQ-3: Every payload unit produces a 8-bytes TM every 32 s
  - REQ-4: 4 Payload units are able to produce also a 8-bytes TM every 100 ms for AIT and test purposes.
  - REQ-5: OBC can issue at maximum 1 TC per sec
- The above requirements are really easy to be implemented with the CAN bus.
  - Therefore a scalable architecture is proposed in order to satisfy the SATCOM requirements with different performances.

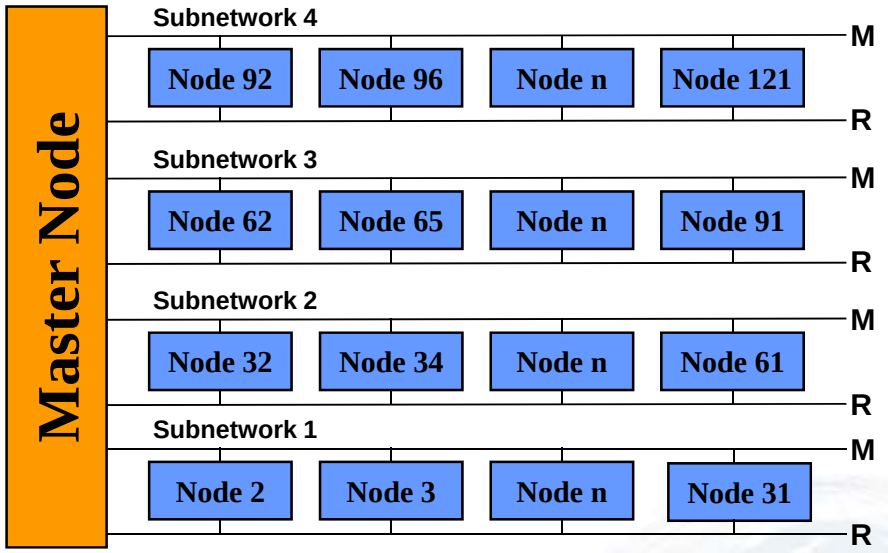
Requirement Discussion

- REQ-1: Bus rate: 500kbps
  - According the CAN bus performances the proposed solution allows the usage of the following data rates with a CAN qualified controller (HURRICANE):
    - 1 Mbps
    - 500 Kbps
    - 250 Kbps
    - 125 Kbps
- For the CABCOM study the 500Kbps has been used as baseline for the test bench implementation

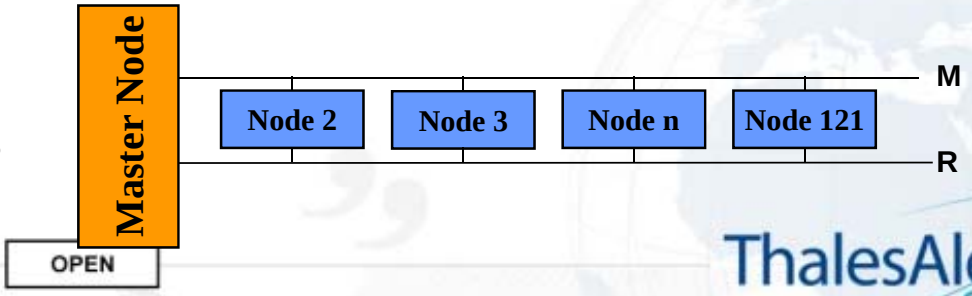
Requirement Discussion

- REQ-2: Number of nodes: 1 OBC with 1 CAN controller connected to two transceivers (selective bus architecture) + 120 Payload units, each with 1 CAN controller connected to two transceivers (selective bus architecture).

- Two different physical layers are considered according the CABCOM study requirements**:**
  - **RS-485 network**
    - Four subnetwork composed of 31 node each operated in time multiplexing by a single master



  - **ISO-11898 network**
    - A single network with 120 nodes operated in time multiplexing by a single master



Requirement Discussion

REQ-3: Every payload unit produces a 8-bytes TM every 32 s

- This requirement can be implemented in several different ways with the CANOpen protocol; therefore in order to fully exercise the CANOpen and ECCIPC capabilities the following three different slave nodes will be implemented:
  - Asynchronous-NODE (A-NODE): this node implements only Asynchronous on-request telemetries (4 TPDOs and 4 RPDOs) . Representative of the MEGA ASIC.
  - Synchronous-NODE (S-NODE): this node implements only Cyclic Synchronous Telemetries and configuration non-acknowledged commands (1 S-TPDO and one RPDO).
  - Acyclic-Synchronous-NODE (AS-NODE): this nodes implements only Acyclic Synchronous telemetries and configuration non-acknowledged commands (1 AS-TPDO and 2 RPDOs).

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Requirement Discussion

REQ-4: 4 Payload units are able to produce also a 8-bytes TM every 100 ms for AIT and test purposes.

- This requirement can be easily satisfied with the A-NODE by oversampling the TM_RQST1 or TM_RQST3 from the Test Equipment

REQ-5: OBC can issue at maximum 1 TC per sec

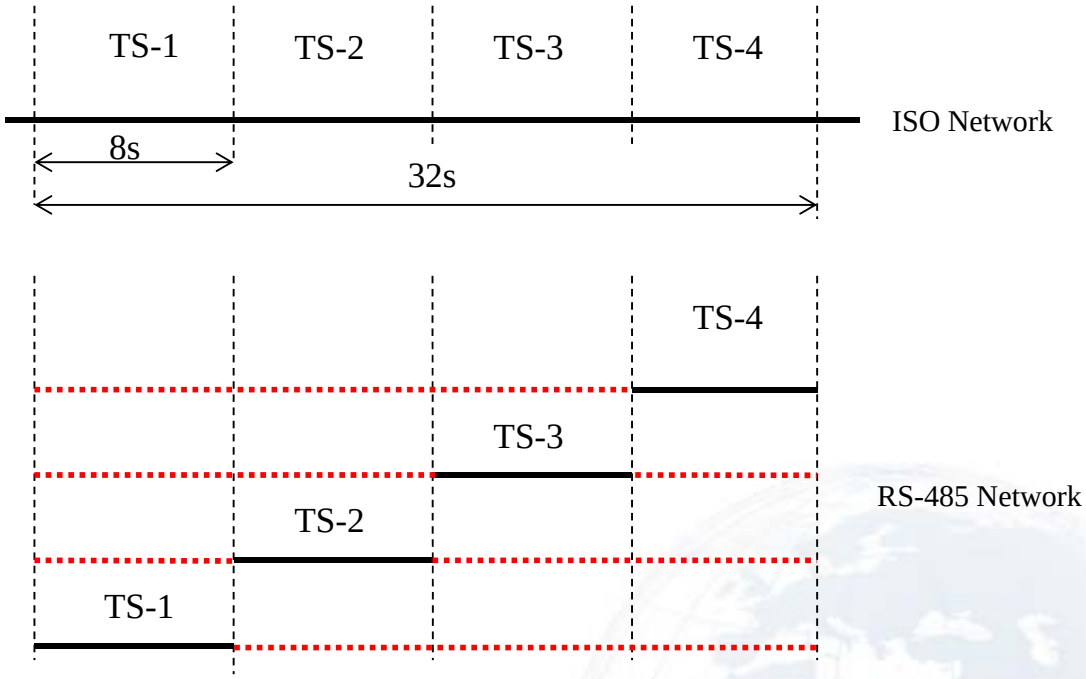
- This requirement is not fully understood:
  - REQ-3 imposes that each SLAVE node generates 8-bytes TM every 32 s; this means that it shall be sampled every 32 seconds; thus the network acquisition loop shall be closed in 32 seconds.
  - REQ-2 imposes a total number of 120 SLAVE nodes; therefore 120 nodes shall be sampled in 32 seconds.
  - In the worst case scenario all nodes are type A-NODE (on-request TMs) that means a commanding period of 32/120=~270ms
  - In the best case scenario, all nodes are type S-NODE that means NO need of commands.
  - In the average scenario there is an equal distribution of A-NODEs and S-NODEs; in this case a commanding frequency of 2Hz (500ms) is acceptable.
  - NOTE that AS-NODEs are to be considered as A nodes for the command frequency computation.
- For the CABCOM study, a commanding frequency of 2Hz is considered as baseline.

Proposed Protocol Solution

- The Proposed protocol solution is fully applicable to both RS-485 and ISO-11989 CAN networks. It is based on a time multiplexing technique to access to the 120 nodes in the proposed acquisition cycle of 32 seconds.

- Four 8 seconds Time Slices (TS) are dedicated to access to different Nodes:
  - TS-1: Nodes from 2 to 31
  - TS-2: Nodes from 32 to 61
  - TS-3: Nodes from 62 to 91
  - TS-4: Nodes from 92 to 120

- The only difference between the RS-485 and the ISO-11898 solutions is that for the RS-485 solution each TS corresponds to a dedicated RS-485 subnetwork.



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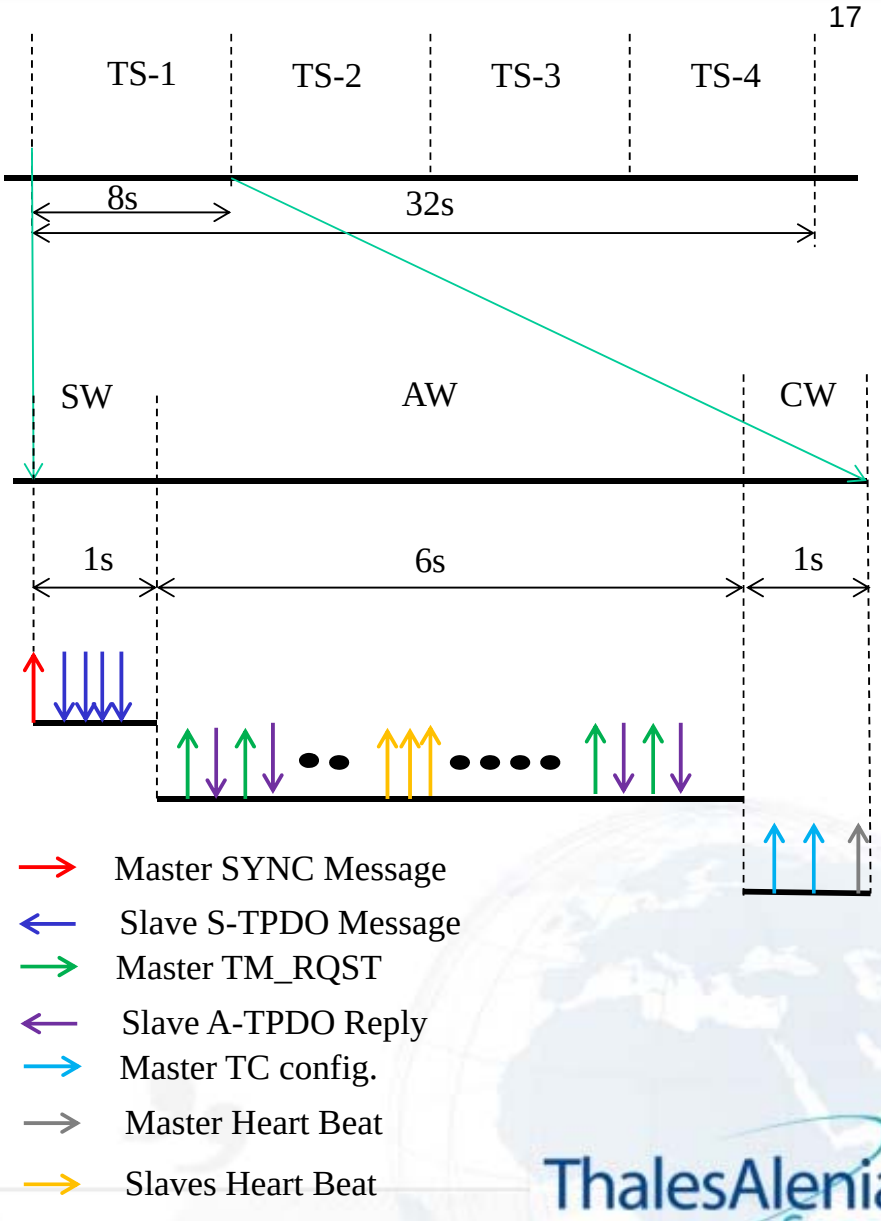
Time Slice (TS) organization

Each TS is organized in different windows in which different message transaction will be applied:

- Synchronous Window (SW):
  - in this window only Synchronous PDO transactions are allowed
  - The window starts with the SYNC message generated by the Master and last 1 second
  - After the SYNC message, all the S-TPDO generated by the NODEs belonging to the specific TS will be received by the Master
  - The synchronous windows Length parameter of each Slave node will be set to avoid S-TPO transmission outside the SW
- Asynchronous Window (AW):
  - In this window only the Asynchronous On-request transactions are allowed.
  - The Master will send the TM_RQST command to all slaves belonging to this window
  - The Slave will reply with the requested parameter
  - A complete transaction (Master Request and Slave Reply) will be completed before the start of a new transaction.
  - Only requests to the nodes belonging to the specific TS will issued by the Master
  - The AW will last 6 seconds
- Configuration Window (AW):
  - In this window only the Configuration (non-acknowledged) commands will be issued by the Master
  - After the Configuration Commands the Master Shall issue its HearthBeat Message
  - The AW will last 1 seconds



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Proposed Protocol main outcome

- Advantages
  - The Proposed solution is fully applicable to Both RS-485 and ISO-11898 physical Layers. Only the Master subnetwork multiplexing management shall be added to the RS-485 configuration
  - The Proposed solution with rigid Time Slices and Windows simplifies:
    - The network configuration
    - The network debug
    - The network Schedulability Analysis
    - The Master implementation
    - The scaling of the network performances according the:
      - Number of nodes
      - Selected Bus data rate
- Disadvantages
  - The Bus does not use the maximum CAN/CANOpen capabilities
  - The Maximum possible bus load is lower than the maximum CAN bus capabilities
- Conclusion
  - The proposed solution fits with the SATCOM requirements and allows easy performances adaptation to the different mission needs.

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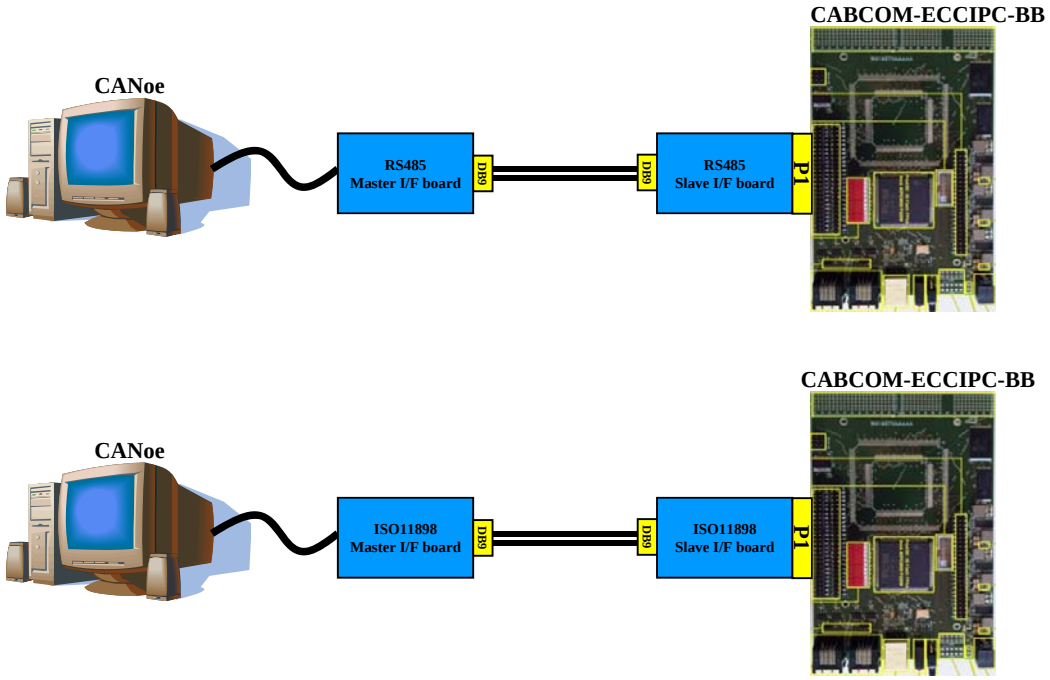
CABCOM Test Bench

- The implementation of the two different RS485 and ISO11898 physical layers required the development of four different interface boards to allow the connection of the CANoe with the ECCIPC-BB.



- The master I/F boards are needed to interface the CANoe tool with the selected physical layer interface.
  - RS485 transceiver: DS16F95
  - ISO11898 transceiver: SN65HVD233

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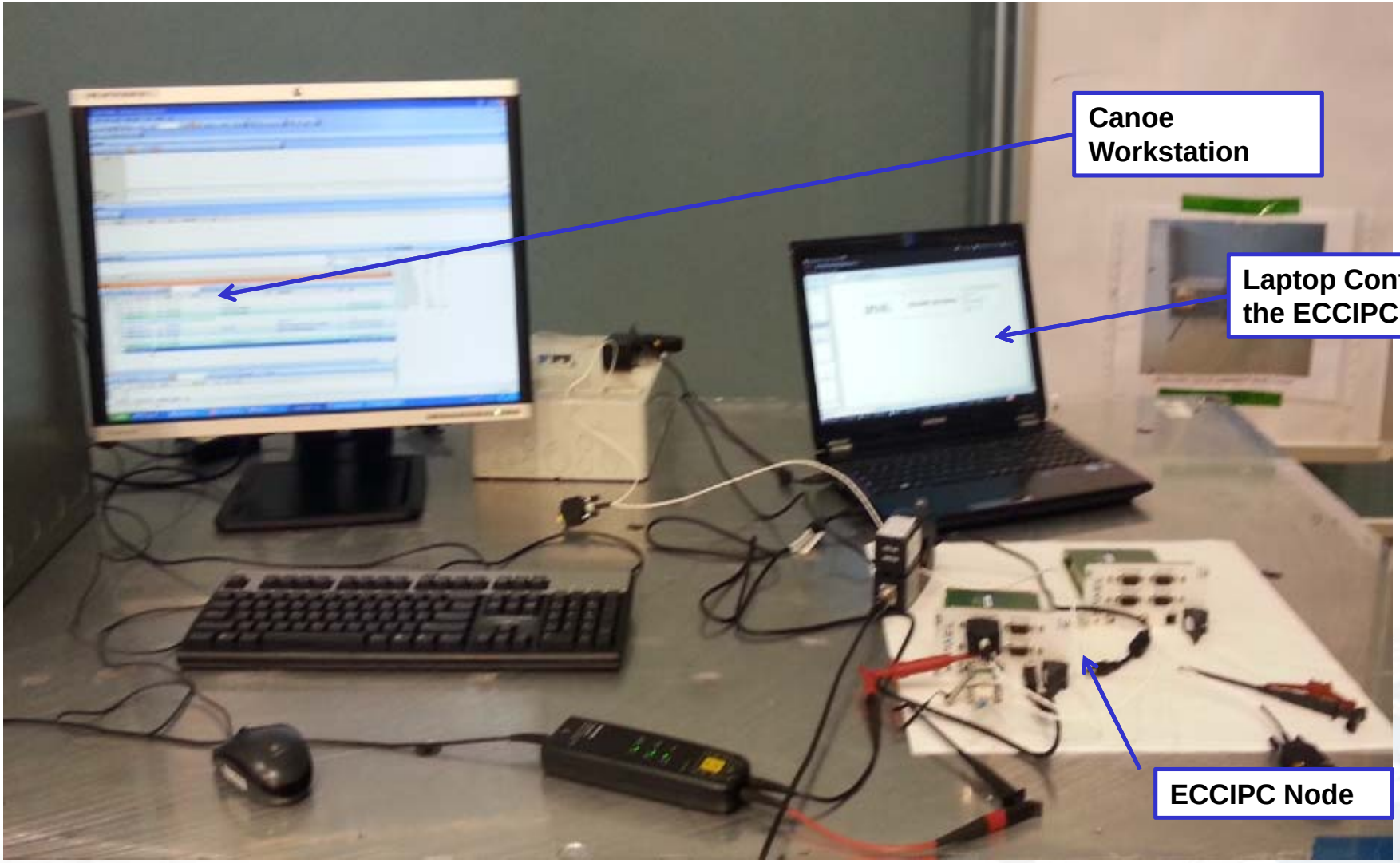
CABCOM Test Bench



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CABCOM Validation Test Campaign

- The CABCOM Validation test campaign has been split in two steps:
  1. Protocol Validation Test Campaign; It covers:
     a) Validation of the bus initialization procedure
     b) Validation of the Communication Layer in terms of:
        - Time Slice timings
        - Windows Timing
        - Message transactions inside windows
     c) Validation of the redundancy management

     NOTE:
     1. the CAN Layer is considered already validated by the CAN controller
     2. The CANOpen Layer is considered already validated by the CCIPC, ECCIPC and CANOe SW for the Master

  2. Electrical Test Campaign
     1. Verification of the ISO-11898 performances in terms of:
        a) Conducted Susceptibility
        b) Conducted Emission

Conclusions

- As conclusion of the overall study, it is evident that the ISO solution is to be preferred to the RS-485 solution. In particular the capability of the ISO transceiver to drive up to 120 nodes on the same physical line simplifies some of the communication layer initialization, synchronization and reconfiguration procedures.
- Also, from a pure electrical/EMC point of view, the ISO11898 transceiver and lines are really robust to noise but additional test are required to identify the EMC masks reporting the real limits of this solution.
- With respect to the EXOMARS mission implementation; the CABCOM solution totally avoided the usage of the CANopen SDO service. The different CANOpen PDO capabilities have been demonstrated to be sufficient for any application not requiring exchange of big data volumes or files. The expedited SDO protocol is anyway useful for NODEs configuration or eventually for the implementation of “Plug&Play” capabilities.
- It is to be again highlighted that the CAN bus performances are well above the identified SATCOM performances requirements, in fact, test results demonstrates that the peak bus load is only 2.8% of the available bandwidth and moreover this peak is reached only during the start-up of the network when all the nodes are configured and synchronized.
- The study has been implemented fully in line with the ECSS rules and it shall be highlighted that no deviation or missing functions in the published ECSS have been identified.
- Probably a more flight representative electrical test campaign of the ISO11898 physical layer may provide further suggestions/requirement for a future issue of the ECSS-E-ST-50-15C.

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