OVERVIEW OF IMPLEMENTING SPACEWIRE IN OBSERVATION SATELLITES FROM THALES ALENIA SPACE

Session: SpaceWire Missions and Applications

Long Paper

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ABSTRACT

Thales Alenia Space is implementing SpaceWire technology in most future space projects for observation missions. Today, three kinds of space applications are currently based on SpaceWire architectures for payload data handling, with low earth orbit observation satellites, planetary exploration carriers and geostationary observation satellites.

All various missions are briefly described and compared for SpaceWire implementation, showing how the SpaceWire use and perimeter is increasing from interfaces standardization up to interfaces optimization by merging of mission and configuration command/control data for exceeding limits of today architectures :

- the Sentinel-3 satellites for the provision of operational marine and land services, based on optical and microwave Earth observation payload,
- the ExoMars mission for Entry, Descent and Landing Module (EDM) of a payload on the surface of Mars,
- the MTG system will provide Europe's National Meteorological Services for both meteorological and climate applications.

1 INTRODUCTION

Thales Alenia Space is implementing SpaceWire technology in most future space observation missions. Today, three kinds of space applications are based on SpaceWire architectures for payload data handling, with low earth orbit observation satellites, planetary exploration carriers and geostationary observation satellites.

Main missions are briefly described and compared for SpaceWire implementation, listing the advantage and the criticality in implementing SpaceWire. The comparison on how the SpaceWire is used, shows that the SpaceWire perimeter is increasing from interfaces standardization, through interfaces optimization by merging of mission and configuration command/control data up to allowing to exceed limits of today architectures.

Since SpaceWire is now mature and suitable for space high speed communication, it is natural for Thales Alenia Space to implement it now in its first European LEO observation mission, i.e. GMES Sentinel-3. As a first SpW application at system level for Thales Alenia Space, the use of SpW links focus on high speed mission data distribution for which SpW bring advantages compared to previous solutions.

Then thanks to the preliminary achievements with LEO satellite, the use of SpW might be extended for planetary exploration orbiter. This solution is presently under analysis.

Finally the use of SpW for GEO observation satellite is obvious as for LEO ones, since such missions embed high speed instruments. Today, these missions are dedicated to operational meteorology. Furthermore, GEO meteorology requires continuous handling of high speed mission data flows without allowed outage for various payload modes based on multiple instrumen's, for which routing capability and fast imaging configuration command/control is required : SpW technology is today offering these services thanks to the routing and full-duplex capabilities.

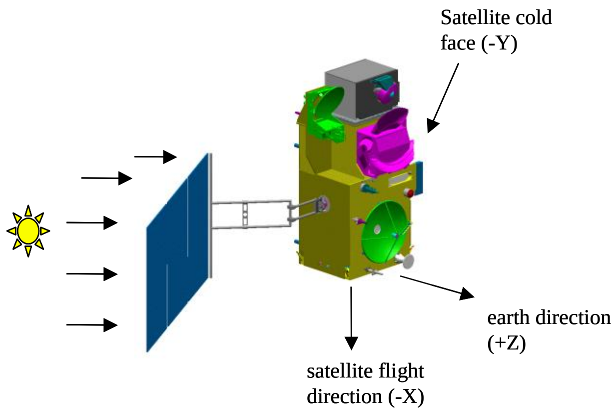
2 LEO OBSERVATION MISSIONS WITH SPACEWIRE

Thales Alenia Space is the prime contractor of the GMES Sentinel-1 and 3 programs. The four Sentinel-1 and 3 satellites embed several instruments which generate high rate data stream and since their development calendars fit with SpW technology maturity, it was the good targets for Thales Alenia Space to start SpW implementation at system level.

As first SpW implementation on a complete satellite's payload and since SpW is first suitable for high speed communication, Thales Alenia Space efforts focus on high speed mission data distribution from instruments to the mass memory for RF downlink.

2.1 SENTINEL-3 MISSION

In the frame of the Global Monitoring for Environment and Security program (GMES), the Sentinel-3 is a European polar orbit satellite system for the provision of operational marine and land services, based on optical and microwave Earth observation payload.



The Sentinel-3 Data Handling

architecture design has been driven by a) minimized development risks, b) system at minimum cost, c) operational system over 20 years.

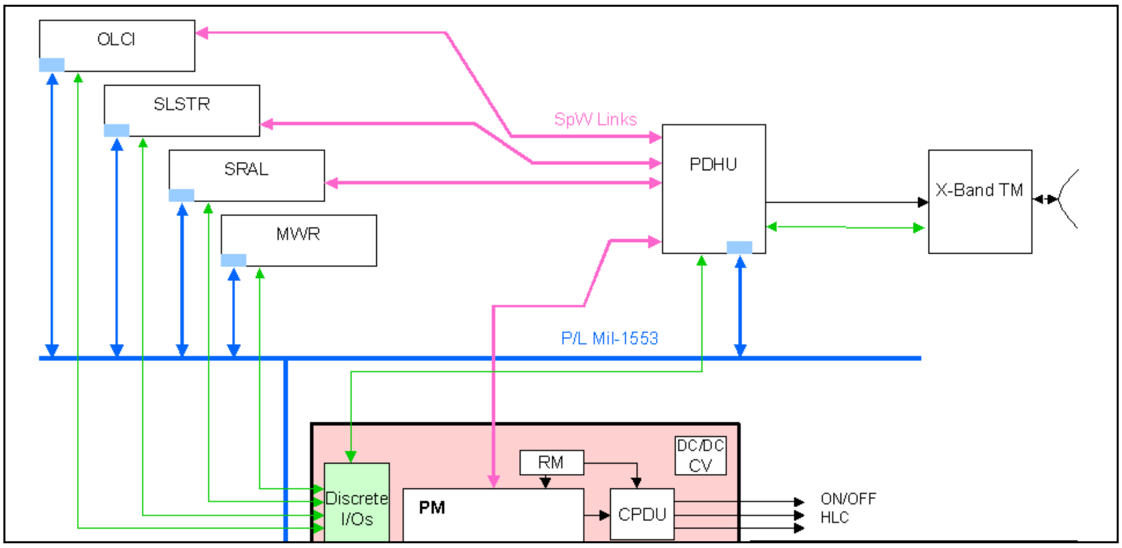
This has led to design architecture as robust as possible using a single Satellite Management Unit SMU computer as the platform controller, a single Payload Data-Handling Unit for mission data management, and to reuse existing qualified heritage.

The payload accommodates 6 instruments, sources of mission data. The 3 high rate instruments provide mission data directly collected through the SpW network, while the low rate instruments are acquired by the central computer for distribution through the SpW network to the mass memory. The PDHU acquires and stores all mission data for latter multiplexing, formatting, encryption and encoding for download to the ground.

SENTINEL 3 Satellite main features	
Instruments	Sea and Land Surface Temperature sensor (SLSTR) Ocean and Land Colour sensor (OLCI) Altimeter (SRAL) Microwave radiometer (MWR) GNSS receiver Doris receiver
Observation data	103 Gbit/orbit- 300 Mbit/s PLTM downlink data flow

2.2 SENTINEL-3 SPACEWIRE ARCHITECTURE

The payload architecture is built-up over a SpW network for direct collection of high rate SLSTR, OLCI and SRAL instrument's and indirect collection of low rate MWR, GNSS and DORIS instrument's plus house-keeping data through the Mil-Std-1553 bus by the SMU, all data being acquired from SpW links and managed by PDHU.

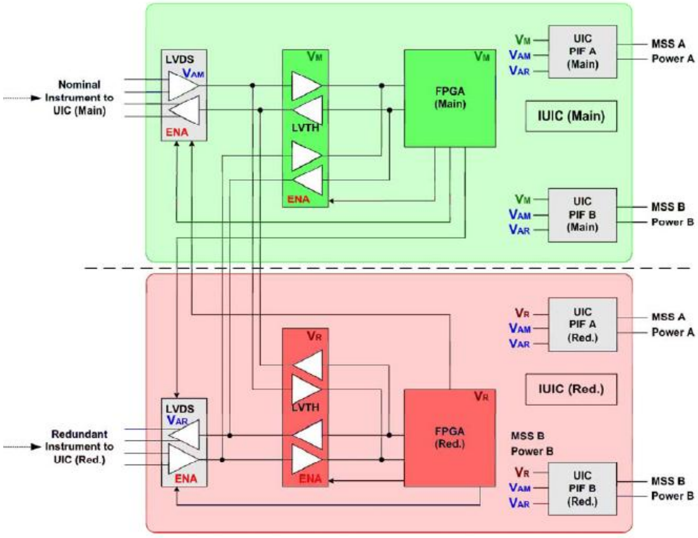


The mission data budget is easily accommodated thanks to SpW performance. Each SpW link being dedicated to point-to-point communication without interaction on the other links (no routing), the frequency is set according to the need plus a significant margin. The PDHU is able to handle the 4 SpW sources at up to 100Mb/s.

For a robust payload data management, redundancy is required. Full cross-strapping of all SpW links was abandoned for reducing harness mass, instrument's complexity and increasing the reliability vs failure propagation.

All mission data sources (OLCI, SLSTR, SRAL and SMU) provide data through two cold redundant interfaces and harnesses. The PDHU being critical as the central point of the mission data management, implements a full cross-strapping between nominal and redundant sources interfaces and its nominal and redundant sides.

SENTINEL Mission data budget		
Mission data source	continuous data rate	Link data rate
OLCI	31 Mb/s	100Mb/s
SRAL	14 Mb/s	50Mb/s
SLSTR	5 Mb/s	50Mb/s
MWR, GNSS, DORIS, HK	200Kb/s	10Mb/s



Specific efforts in design activities were spent to implement efficiently a full cross-strap redundancy within PDHU : suitable protections were implemented to prevent any risk of failure propagation from one interface to the others.

The PDHU SpW interfaces are performed thanks to a specific FPGA, instrument's ones are based on ESA Atmel SMCS-332 and SMU ones is implemented by an EPICA ASIC circuit developed by Thales Alenia Space.

The SpW full duplex capability is not used neither for synchronization nor for command/control since there is no PDHU routing capability between instrument's and SMU :

- instrument's synchronisation is ensured by basic OBT broadcast over Mil-Std-1553 bus associated to the occurrence of a PPS pulse.
- all command/control of the payload is performed through dedicated Mil-Std-1553 communication bus.

All mission data are PUS formatted at source level and transferred over SpW without additional transport protocol, i.e. one SpW cargo carrying one PUS packet : transport protocol is not needed for such point to point communication links.

2.3 SENTINEL-3 SPACEWIRE BACKGROUND

The previous similar payload architecture were based on unidirectional serial links as space LVDS interface or LNR (French acronym for fast digital line) which requires a qualification process of commercial components. Thanks to standardized SpW links, design is simplified since development of source and destination sides can be developed in parallel with low constraints : different circuit may be implemented as SMSC-332 for instruments, FPGA for PDHU and EPICA ASIC for SMU. It also allows to tune data-rate without putting into question qualification.

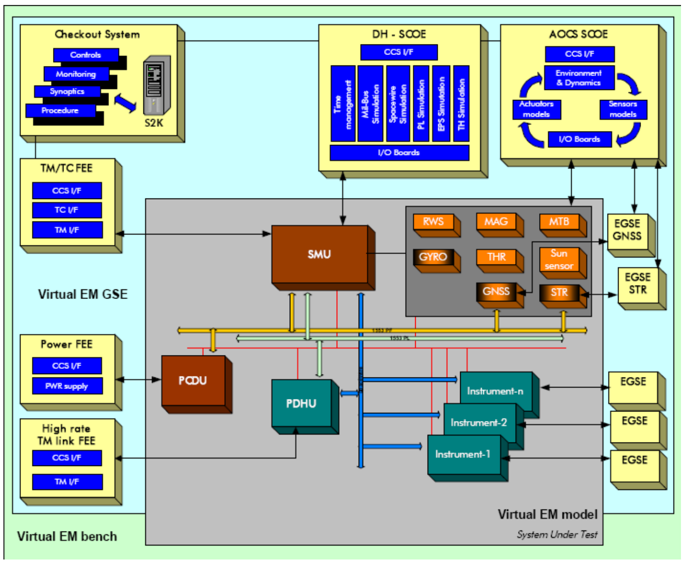
On other ends difficulties were encountered in implementing SpW for :

- robust cross-strapping redundancy
- harness and connector bracket impact on performance
- detector's data acquisition vs noise immunity

The two first critical points are also encountered for alternative LVDS or NLR design. The following preventive actions are performed :

- concentrate redundancy cross-strapping at PDHU, with intensive design activities to implement suitable protection against failure propagation
- plan advanced bread-boarding as part of virtual EM satellite test campaign for pre-validation of SpW communication

The last point concerning detector noise is due to the asynchronism of the SpW which prevents to synchronize the data transfer outside the optical signal acquisition slot : to prevent such perturbation risk on detector signal quality, a synchronized acquisition through a parallel bus is more suitable for detector's links.



An other advantage of using standardized SpW is found in EGSE development which is easier and cheaper thanks to existing SpW building blocks for data acquisition, simulation and investigation.

The SpW routing capability is replaced by data multiplexing when pick up from various large memory buffers before formatting, coding, encrypting for downlink to the ground. This missing routing capability prevents smooth transition for both payload synchronization and command/control allowed by SpW full-duplex, since SMU and instrument's cannot communicate directly through the SpW network.

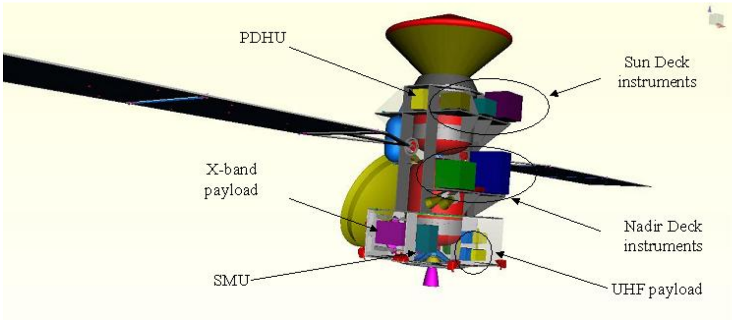
3 INTER-PLANETARY EXPLORATION CARRIER WITH SPACEWIRE

The inter-planetary missions can present an interesting target for SpW implementation due to the advantages of lower consumption w.r.t. Mil-Std-1553 bus, lower mass and flexibility in accommodating several instruments on a unified payload network for both mission data-handling and command/control.

Today the SpW implementation in inter-planetary missions is taking benefit of heritage from in-going developments, with a basic use as for sentinel missions.

3.1 EXOMARS MISSION

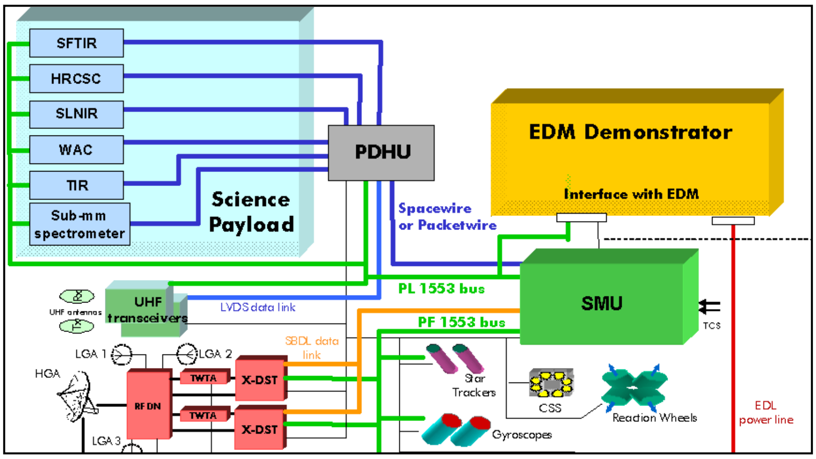
The ExoMars mission shall accomplish the technological objective with Entry, Descent and landing Module (EDM) of a payload on the surface of Mars, the scientific objective to support the search and localization of Methane sources on Mars and the data relay with Rover on Mars.



The payload sources are the UHF source with the EDL for proximity links with martian rovers, and the 6 science instruments that remotely sense the Martian atmosphere and surface.

3.2 EXOMARS SPACEWIRE ARCHITECTURE

A SpaceWire network is candidate to acquire and multiplex data from these various instruments. The payload network accommodates 6 instruments and a UHF tranceiver as proximity data link with martian rovers for their command/control messages.



Science instruments provide various data flows from 25Kb/s to 90Mb/s. The global science data volume is estimated to be lower than 15Gb per day. Science data are stored into the PDHU Mass Memory.

The payload network built around the PDHU ensures communication with 8 functional nodes: 6 instruments, the UHF transceiver and the SMU. For consumption and mass constraints, the cold redundant pair of SpW links is foreseen with a full cross-strapping redundancy implemented in the PDHU.

3.3 EXOMARS SPACEWIRE SPECIFITIES

The SpW bring the great advantage to easily accommodate instrument's with fluctuating data-rates.

Due to heritage from sentinel development, synchronization and data multiplexing are not foreseen using SpW time-codes and routing capability. A further improvement with routers could save mass and harness with a unified PL network for both synchronization, mission data and command/control.

4 GEO OBSERVATION WITH SPACEWIRE

Observation satellites from the geostationary orbit are characterized by implementing high rate instrument's with continuous mission data transfer to the ground, thanks to the constant ground station visibility. They require real time system with high throughput without any risk of bottleneck since there is no on-board storage.

These kind of missions are, up to now, dedicated to meteorological missions. Thales Alenia Space is prime contractor of meteosat satellites for more than 30 years, preparing now the third generation of meteosat satellites.

4.1 MTG MISSION

The MTG system will provide Europe's National Meteorological Services, with improved imaging and new infrared sounding capabilities for both meteorological and climate applications. The MTG space segment is based on 6 geostationary satellites carrying complementary payloads, built around a fast SpaceWire network for an unified mission and configuration data management, merging science and RF data, with more than 300Mbps continuous downlink.

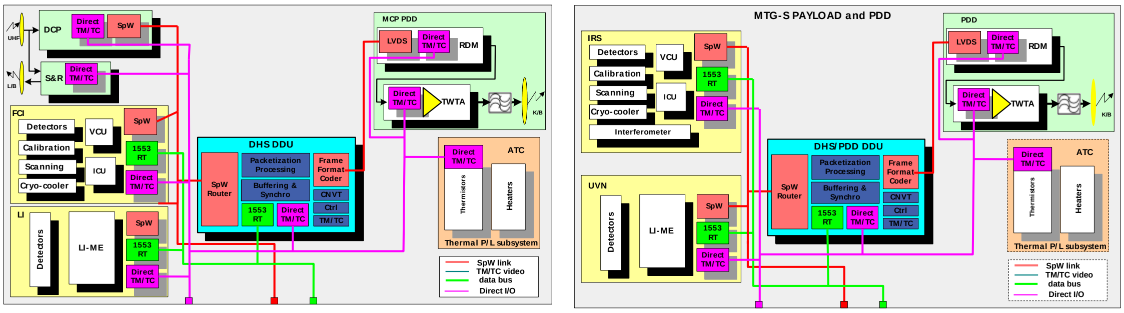
4.2 MTG SPACEWIRE ARCHITECTURE

The MTG satellites accommodate respectively the FCI imager, LI imager and the DCP digital transponder for the imager S/C, and the IRS and UVN sounders for the sounder S/C, over a payload SpW network for mission data distribution and instrument's configuration with a total high rate telemetry of respectively 295Mb/s and 557Mb/s after RS concatenated encoding and encryption.

MTG Imager Mission data budget		
Mission data source	continuous data rate	Total flow coded encrypted
FCI	64 Mb/s	295 Mb/s
LI	4 Mb/s	
DCP	44 Mb/s	
HK/INR	< 1Mb/s	

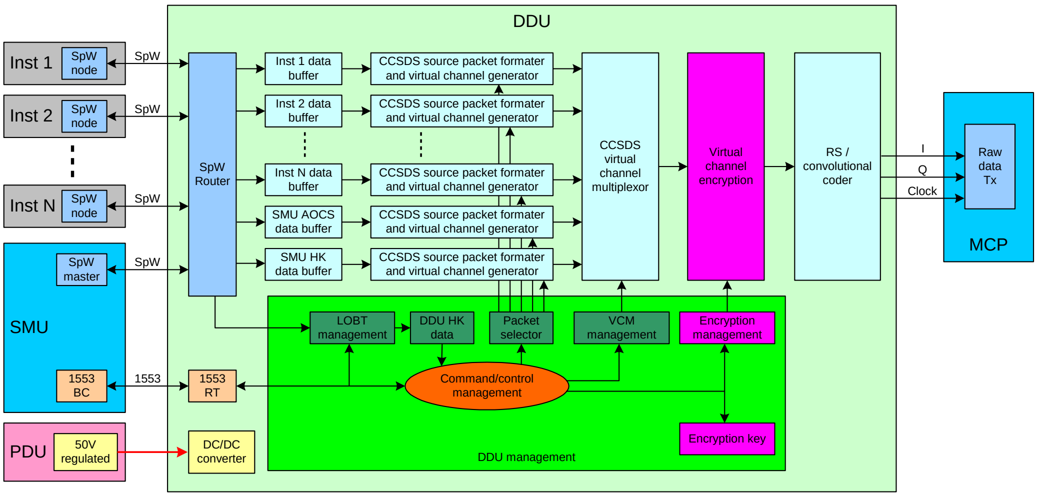
MTG Sounder Mission data budget		
Mission data source	continuous data rate	Total flow coded encrypted
IRS1	91 Mb/s	557 Mb/s
IRS2	93 Mb/s	
UVN	54 Mb/s	
HK/INR	< 1Mb/s	

The payload data network is built around a Data Distribution Unit DDU that implements SpW routers for 3 instruments (FCI, LI, DCP or IRS1, IRS2, UVN) communication and one SMU for INR auxiliary data collection and network management. The network supports full cross-strapping between each terminal (instrument's and SMU) and DDU leading to a total of 16 terminal ports based on to independent nominal and redundant DDU SpW-10X routers.



The network architecture is identical for both imager and souder configurations. The network is running at 200Mb/s on all links providing large margins. The large margin vs data distribution and the asynchronous behaviour of the SpW link, allow to accommodate variable instrument's data flow according to their operational modes. For example the UVN instrument provides 40Mb/s in normal mode or 125Mb/s in commissioning mode.

The SpW time code distribution is not used for payload synchronization due to the instrument heritage : a classical OBT associated to a PPS pulse is broadcast through the payload Mil-Std-1553 command control bus.



Thanks to the implementation of SpW routers, the full-duplex capability of the SpW is used for command/control messages required to configure quickly instrument's without outage : large configuration tables are loaded from SMU mass memory into the instrument's through SpW links. i.e. 135Mb data transfert between 2 consecutive image acquisitions.

All messages are formatted with ECSS Packet Utilization Standard and distributed over the SpW network with ECSS SpW CCSDS transfer protocol, using user field for identifying the virtual channel for the high telemetry destination.

4.3 MTG SPACEWIRE SPECIFITIES

The MTG satellites will be the first space mission in Thales Alenia Space for implementing and using complete SpW network capability with a full cross-strapping redundancy with SpW-10X routers and full duplex used for command/control configuration messages with large tables.

Thanks to SpW standardization of physical layer and transport protocols, the PL network architecture, development and validation is simplified with well defined interfaces between the 3 instrument's and Payload Data Downlink contractors.

Similar payload were studied for the japanese satellites Himawary 8 and 9, for which Thales Alenia Space proposed to use the SpW full duplex capability to implement an active motion compensation of an US imager : the platform provided gyroscopic data at 100Hz through the SpW network to the instrument, in order to compensate by the scan mechanism attitude error for a very accurate and stable imager pointing.

5 CONCLUSION ON SPACEWIRE IMPLEMENTATIONS

As shown above, with Thales Alenia Space missions using SpaceWire (more than 12 satellites), the SpW is more and more implemented with increasing functional perimeter from mission data distribution up to configuration.

As first outcomes, implementing SpW allows to reduce interface complexity and separate interface management and development between different contractors for each side of the communication. This advantage was not possible using high speed specific line as LNR which required qualification process and common procurement.

Availability of qualified SpW tools allows to easily build EGSE and check functional behaviour.

System design effort shall be also spent at beginning of the project to define suitable redundancy concept with adequate protection preventing failure propagation as part of general construction and design specification.

The main encountered drawbacks are the procurement delays of SpW components and the lack of qualification tables or characterization tools for actual performance with final harness configuration : this is also applicable with alternative fast links as LNR.

The SpW is also analyzed in R&T and advance projects. In particular it was found interesting for IXO mission to cope with high rate data transfer over long distance. The low SpW consumption was also found attractive for new avionics sensors as far as its harness weight could be mitigated.

In next future, the use of SpW could be extended for payload command/control bringing interface and harness optimization, as soon as the determinism and FDIR for command/control messages distribution is ensured either by an efficient protocol or by architecture design rules. Then when real time performance and reliability are granted, it would also allows some interesting improvements in avionics area mainly for AOCS performance and extended operability : management of high throughput sensors and involvement of instrument's in the AOCS control closed loop for accurate satellite pointing and active motion real time compensation.