Alcatel Alenia Space - SpaceWire Overview

SpW Working Group meeting #6 – 18/05/2006

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Objective : AAS overview vs SpaceWire

- **Heritage in equipment, instrument & satellite**
- **Next Missions & Data-Rate trends**
- **System view of SpW usage for space architecture**
- **R&T study vs SpaceWire area**

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Heritage in high data-rates (1/8)

- Alcatel Alenia Space background in space projects
  - in equipment devoted to **Processing** and **Storage**
  - between **instrument** and **equipment**
  - into **Solid State Mass Memory** (SSM) for SAR or optical payload data
  - in Data **Compression**, Data **Encryption,** High Rate **Telemetry Formatting**.
- High Speed links were first used for equipment connection
  - data from a SAR/optical payload to the SSMM and from SSMM to Modulator
  - transfer internal to equipments when SpaceWire has reached the maturity.
- High speed links in telecom satellites
  - for telecom on-board processors

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Heritage in high data-rates (2/8)

The following standards have already been used

- HOTLink
  - 160-330Mb/s in RadarSat, Cosmo/Skymed...
- IEEE 1355, LVDS
  - 105-155Mb/s in RadarSat, Siral, Argos/Sarsat, Cosmo/Skymed...
- SpaceWire
  - 30-160Mb/s in HICDS, MIRANDOLA, GAIA PDHU demonstrator...
- HDMP GigaLink
  - 155-400Mb/s in Pléiades satellites

Specific developments

- LNR and LHD 160 Mb/s
  - both developed in the frame of SPOT 5 / HELIOS 2 French satellites

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Heritage in high data-rates (3/8)

Envisat Encoding and Switching Unit (ESU)

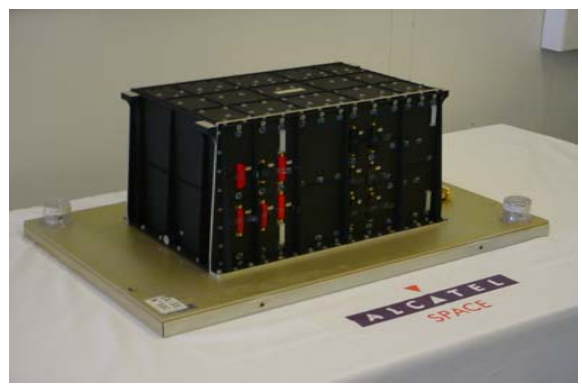
- 12x8 crossbar switch between instruments and X, L bands transmitters
  - 12x2 I/P @50Mb/s, 4x2 O/P @50Mb/s, 4x2 O/P @100Mb/s
  - ECL technology with high power consumption

Radarsat Advanced Ultra-fast Recording for On-board Radar Application (AURORA)

- 150Gbit SSMM & P/L controller
  - 4 I/P @ 216Mb/s HOTLink technology
  - 2 O/P @105Mb/s LVDS technology

Kompsat Digital Compression and Storage Unit (DCSU)

- 196Gbit SSMM, 20Mpixel/sec DCT compressor
  - 8 I/P @ 216Mb/s and 2 O/P @155Mb/s
  - HOTLink technology



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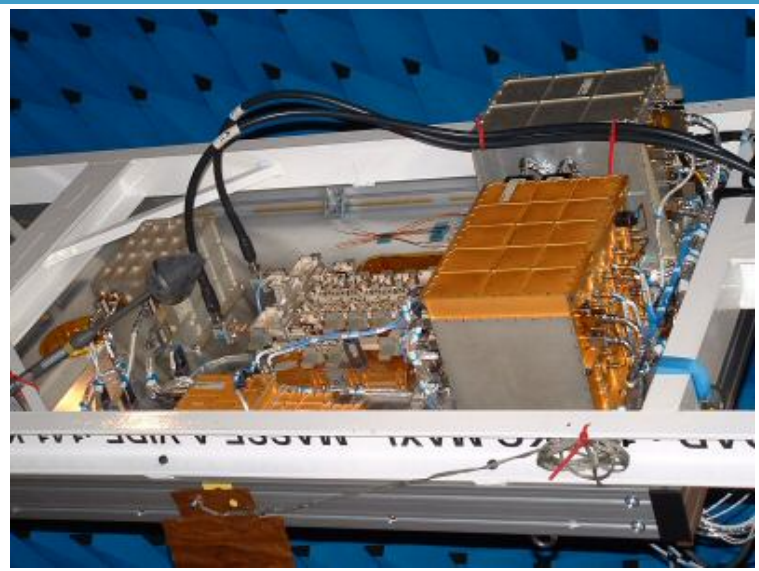
Heritage in high data-rates (4/8)

CryoSat SIRAL

- Altimeter data O/P link toward SSMM
  - 2 O/P @25Mb/s IEEE-1355 links



Argos/Sarsat 3 receiver

- Inter-processors IEEE-1355 links

COSMO Skymed Memory Unit for Space Application (MUSA)

- 600Gbit SSMM and P/L controller
  - 4 I/P @234Mb/s HOTLink technology
  - 2 O/P @155Mb/s LVDS technology

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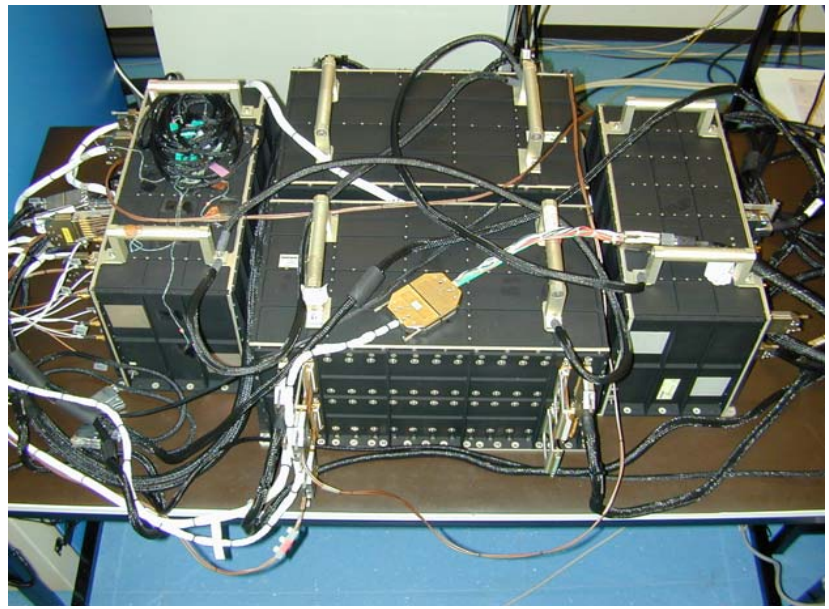
Heritage in high data-rates (5/8)

❑ 2 specific links developped for Spot5 Payload TMI and SSMM

- LNR (Fast Digital Links)
  - Inter equipment link between Video electronic up to the FCR (incl. compressor and SSMM) for SPOT 5 and Helios 2 mission.
  - Data rate of 160 Mbits/sec
  - LNR reused on IASI instrument



- LHD which is a “clone” of the Cypress Hotlink developped in MHS old BiCmos technology
  - Intra equipement link between memory module and I/O section. The interconnection off all the item is performed through an AsGa switch matrix
  - Data rate of 160 Mbits/sec were supported for this application

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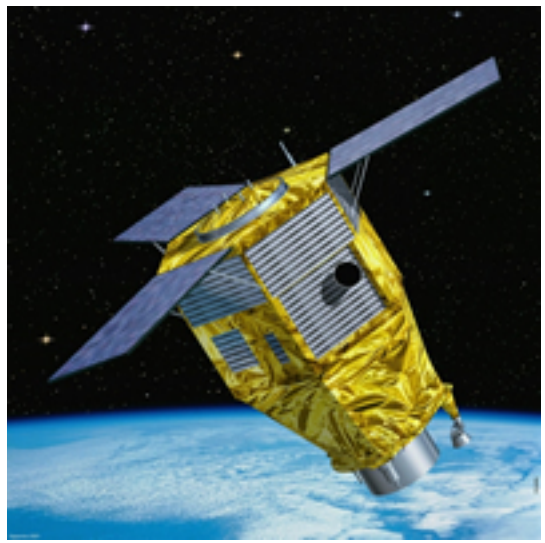
Heritage in high data-rates (6/8)

Pléiades satellites - Agilent HDMP



- In the frame of PLEIADES program
  - instrument needs with more than **400 Mbps** per channel
  - selection and caracterisation study of the High Speed link
- HDPM links now used for flight equipment
  - Video electronics equipment as output links
    - 15 links with more than 400 Mbps per link
  - Cyphering Unit as input link
    - 3 links 155 Mbps per link

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Heritage in high data-rates (7/8)

HICDS (Highly Integrated Control & Data System)

- HICDS is a ground demonstrator of an on-board computer including hardware and software
- HICDS is a ESA predevelopment for Bepi Colombo
- Industrial consortium: Saab / Alcatel Alenia Space

Implementation of SpW links in HICDS

- 2 sets of SpW links are internally implemented to connect:
  - Processor modules and TM/TC modules
  - Processor modules and Reconfiguration modules
- Point to point bidirectional links providing cross-strap between modules

External SpW link capability

- I/O board in HICDS has the capability to manage an external SpW link (hardware is implemented)
- Effort to connect this I/O to an external connector is limited

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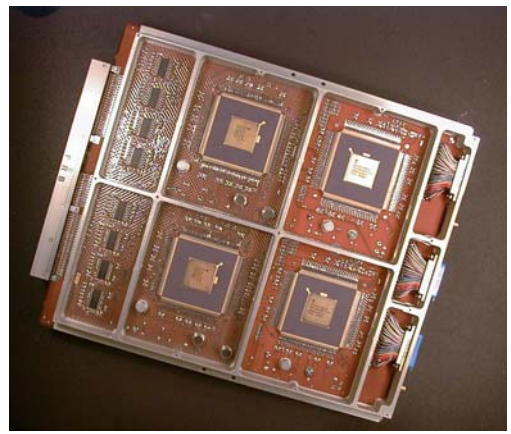
Heritage in high data-rates (8/8)

On-Board Processor for telecom satellites

Main constraints

- Parallel interfaces for communication with digital ASIC
- High speed serial links between boards
- Capability to operate at physical level, without complex configuration needs
- Very low tuning



Processing board

Main features

- COTS qualification
- LVDS links at 360 Mbits/s
- Global data rate over 10 Gbits/s

SYR3 DTP

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SpW use in future programs

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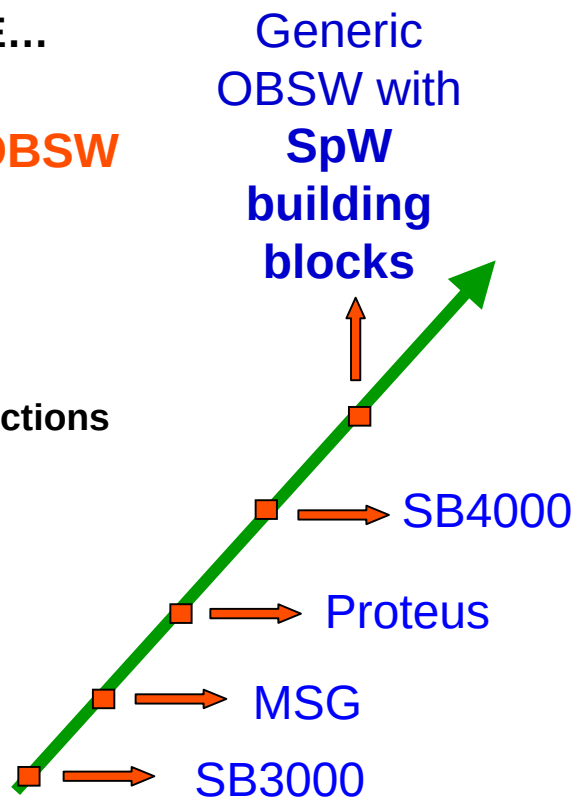
Next Missions & Trend
System approach (1/1)

❑ SpW studied and proposed by AAS

- In most future ESA projects
- As GAIA, MTG, GMES, BEPI/COLOMBO, EARTH-CARE…

❑ SpW library will be implemented in AAS generic OBSW

- Core on-board generic software
  - running on ERC32 or LEON2
  - Real time kernel OSTRALES
  - Standard library for DHSS, AOCS, thermal, power… functions
- Generic OBSW Flight qualified on most AAS satellites
  - Spacebus 3000 GEO telecom satellites family
  - Spacebus 4000 GEO telecom satellites family
  - MSG-1 to MSG-4 GEO meteorological satellites
  - Proteus LEO satellites family (Jason, Calipso, Corot …)



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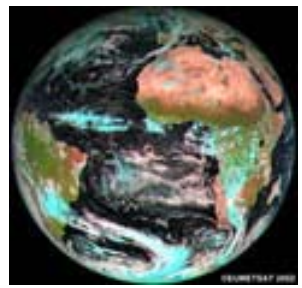
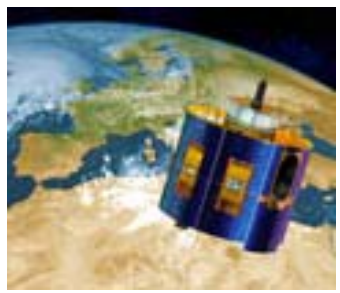
Next Missions & Trend
MTG Meteosat Third Generation (1/4)

❑MTG Program



- **ESA development on behalf of Eumetsat**
- **Geostationary meteorological program**
- **Meteosat MSG follow-on**
- **2015 to 2030 Operational period**
- **Imager, lightning and sounder type instruments**



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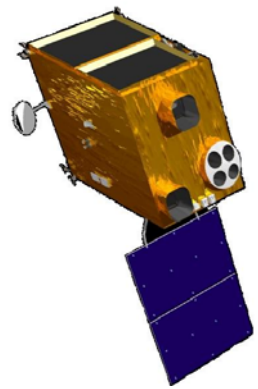
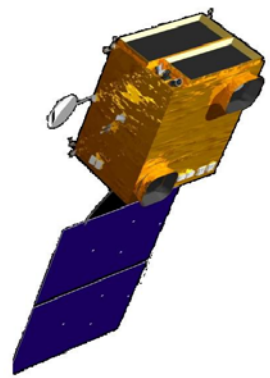
Next Missions & Trend
MTG Meteosat Third Generation (2/4)

❑MTG specificities



- **Meteorological geostationary satellites**
  - **High resolution instruments** ☞ **high data-rates**
  - **Low RF downlink bandwidth** ☞ **on-board reduction**
  - **Continuous earth imaging** ☞ **real-time processing**
  - **No mission outage** ☞ **robust design**
  - **European approach** ☞ **lossless compression**

- **Accommodation of several instruments**
  - **European industrial organization** ☞ **modular and standard**
  - **Parallel real time processing** ☞ **distributed resources**
  - **Over one to several satellites** ☞ **on-board network**



- **1Mb/s, 100Mb/s, 200Mb/s and 500Mb/s class Instruments**
  - **Challenge for bandwidth allocation with redundancies**
  - **Complex network with balance of static and dynamic switching**

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Next Missions & Trend
MTG Meteosat Third Generation (3/4)

❑ SpaceWire is promising for MTG architecture :

- **Efficient industrial organization and Reduce integration and validation effort**
  - **standard interfaces** ☞ **easy interface & validation between S/Co**
  - **Modular design** ☞ **design & validation breakdown vs IOS**
  - **Routing capability** ☞ **parallel real-time processing**
  - **“All in one” instrument interface** ☞ **reduced physical interface with RTC**
    - **For data distribution**
    - **TM/TC command/control**
    - **Synchro, datation, interrupt**

- **But, system evaluation required to ensure**
  - **TM/TC command/control over SpW** ☞ **reliability, CCSDS packet standard…**
  - **Efficient redundancy** ☞ **network topology, network validation**
  - **Accommodation of stream >120Mb/s** ☞ **network complexity vs serial links**

- **But, shifts design complexity to system level**
  - **Exchange specification between equipment and S/Co, mainly for command/control**

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MTG Payload over SpW network

- **Complete instrument handling trough SpaceWire**
  - For all management communications
    - Data distribution, command/control and synchronization
  - Optimized Payload vs traditional architecture
    - One SpW link against one high speed serial link plus one 1553/OBDH bus

- **Intensive RTC use at instrument level**
  - Allows to implement all above management functions
  - But requires to duplicate OBSW Telemetry Telecommand Function
    - To acquire and format telemetry packets at each instrument level
    - To interpret and execute command packet at each instrument level
    - With same performance and capability than central data-handling system
      - ✓ Reliability, CCSDS packet format, diagnostic, time-tag command…
    - Develop and implement S/W within RTC LEON2 for TM, TC Functions (TTF)

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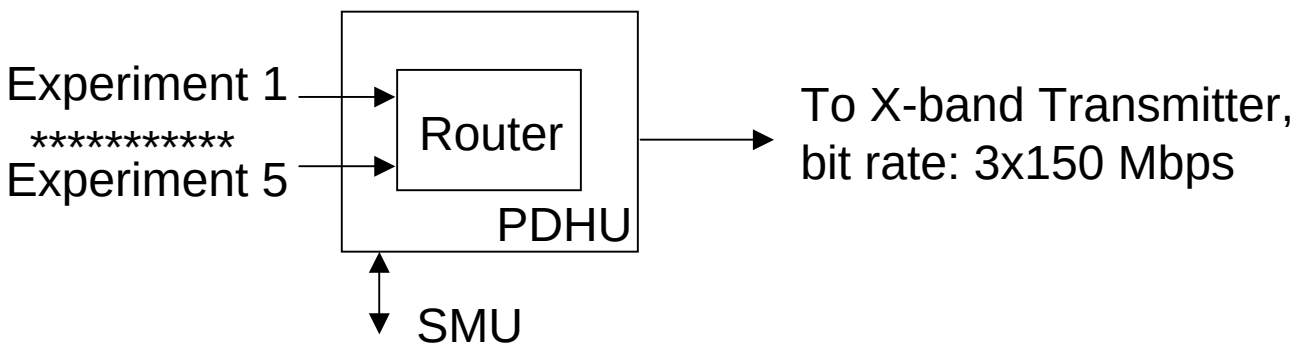
GMES S3 sentinel satellite - Spacewire (SpW) network

- SpW network on board the S3 satellite for SSMM data exchange
- Network built around a router in the Payload Data Handling Unit (PDHU)
- Router with 8 ports
  - 7 for the 5 experiments, 1 for the Satellite Management Unit (SMU), 1 for SSMM
- 110.1 Mbps total data rate for experiments with 55 Mbps, 6 Mbps, 36 Mbps, 13 Mbps, 0.1 Mbps
- The SpW network bitrate will be set to 200 Mb/s allowing 45% margin



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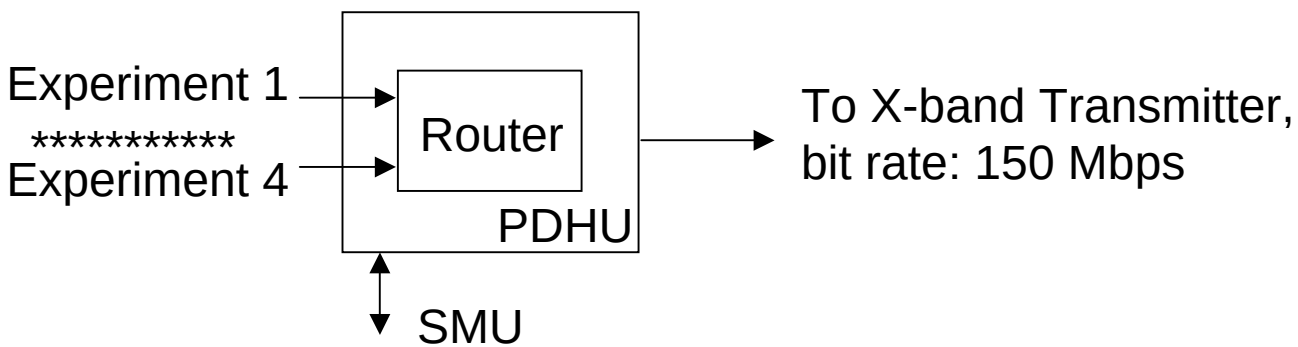
EarthCare Spacewire (SpW) network

- SpW network on board the EarthCare satellite for SSMM data exchange
- Network built around a router located in the PDHU, as for the S3 satellite
- Router with 6 ports (4 for the experiments, 1 for the SMU, 1 SSMM)
- The Experiments Data Rates are 0.82 Mbps, 0.52 Mbps, 0.26 Mbps, 0.002 Mbps, thus giving a total of 1.62 Mbps
- The SpW network bitrate will be set to 10Mb/s



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Next Missions & Trend

Generic OBSW (1/2)

- **SpW use impacts on the generic software architecture is studied**
  - **Transition**
    - **from a system where OBSW is master and all others RT are slave**
    - **to a peer-to-peer system where OBSW is able to receive data from RT asynchronously**
  - **Impacts on :**
    - **Hardware dependant software :**
      - **which I/F shall be provided by the CDMU provider to access to the SpW hardware?**
      - **which requirements has to be implemented by this interface ?**
    - **Middleware layer**
      - **add a new bus on command/acquisition services**
      - **add a network management component in charge of providing network maintenance facilities**
    - **Equipment management**
      - **how to handle asynchronous events ?**
      - **Handling of routers/links states ?**
    - **FDIR**
      - **What kind of SpW network monitoring to perform ?**
      - **What are the possible recovery actions ?**

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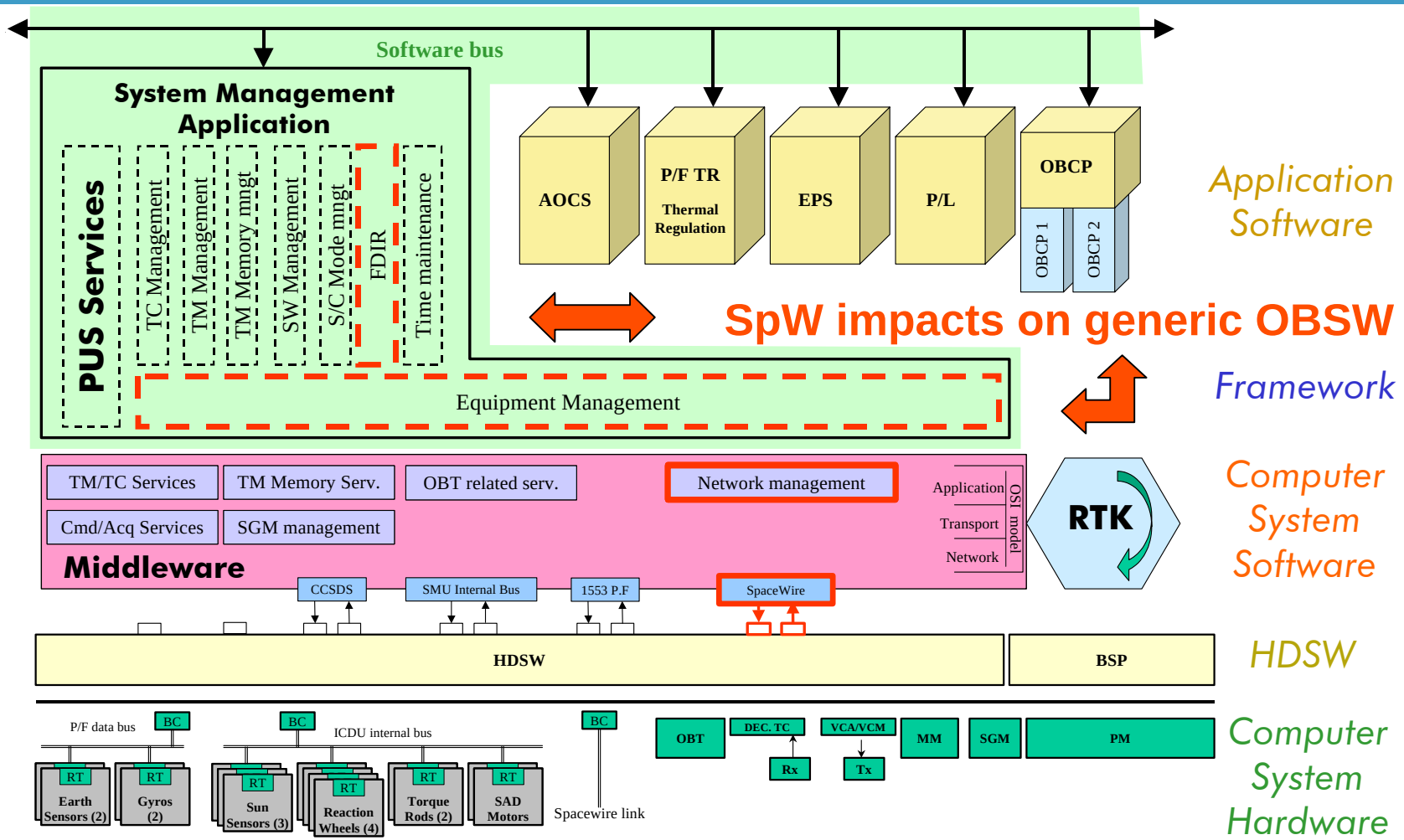
Next Missions & Trend

OBSW architecture (2/2)



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Future equipment

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Next Missions & Trend
AAS-I HotLink (1/1)

- HOTLink devices are in obsolescence

- Replaced by SpaceWire in future equipment
  - SpaceWire up to 160 Mb/s useful data rates
  - SpaceFiber when available for higher data rates

- In addition to SpW, a possible candidate is HDMP GigaLink
  - Tx and Rx with parallel to serial transform for point to point transfer
  - Very high data-rate from 120Mb/s up to 1.25Gb/s
  - hides from the user all the complexity
    - of encoding, multiplexing, clock extraction, demultiplexing and decoding
  - Qualified for space in Pléiades program at more than 400 Mb/s

- HDMP considered as baseline for KOMPSAT-3 SSR proposal

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Next Missions & Trend
AAS-I MIRANDOLA (1/1)

Multi **I**nput **R**ecorder **AND O**n-board **L**arge **A**rray [**MIRANDOLA**]

- Multi User High speed scalable 4x103Gb SSMM and P/L Controller
  - up to 16 users access at high data rates
  - 16 I/O channels with 16 SpaceWire links @200Mb/s (160 net)
- Breadbording activity is running.
- Baseline for
  - GAIA PDHU
  - Bepi Colombo SSMM

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MACH Multiple Access Communication Handler

- Multiple Access Communication Handler
  - Gathers SpaceWire interfaces and SDRAM controller
    - SpW interface controller from MARESS PMDC
    - SDRAM controller from RadarSat & Cosmo/Skymed programs
  - Implements Multiple Access Communication Protocol (MACP)
    - Command, Reply, Data, Interrupt messages
  - Can also exchange SpW packets with RMAP
  - Versatile device for SpaceWire multi-purpose
- FPGA under final verification before ASIC foundry
- Demonstrator to be delivered for GAIA PDHU
- Proposed for Bepi-Colombo SSMM

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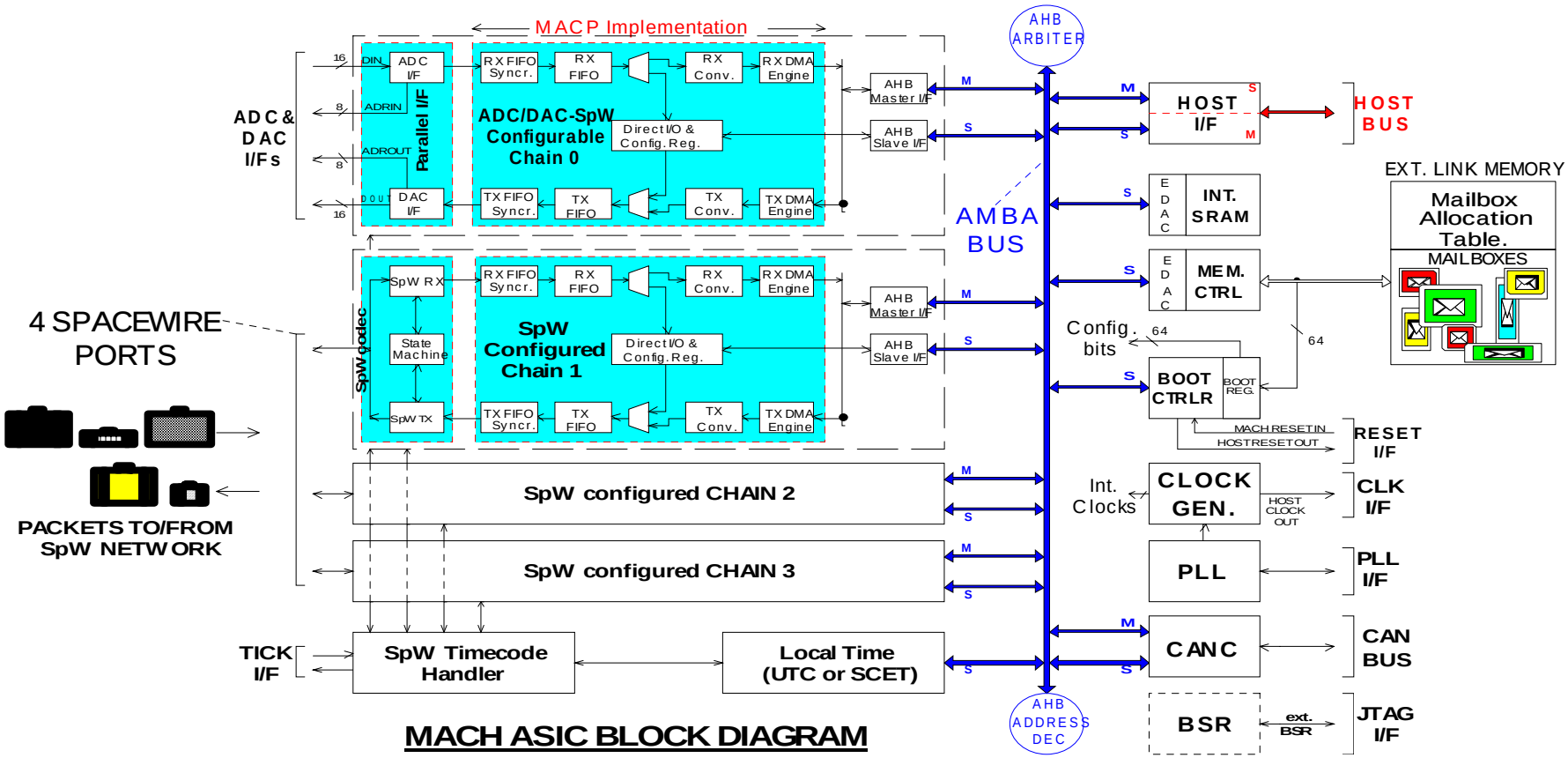
Next Missions & Trend
AAS-I – MACH (2/4)



MACH ASIC BLOCK DIAGRAM

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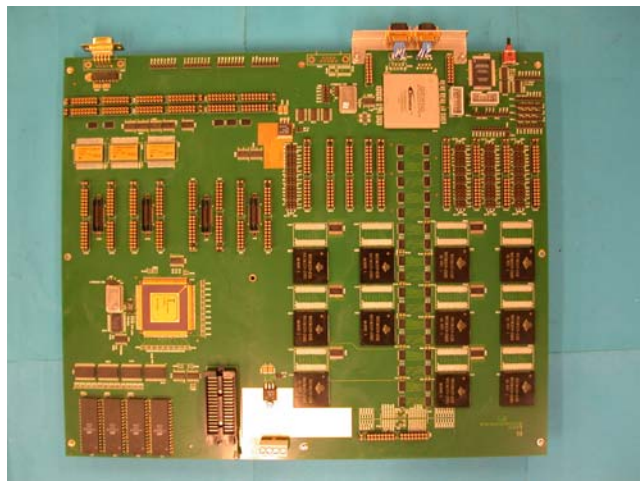
Next Missions & Trend
AAS-I – MACH (3/4)

- Simplifies the I/O task of intelligent nodes minimising their S/W overhead while exchanging data with other nodes of the network

- MACH operations can be driven
  - locally by a Host μP through the Host I/F
  - remotely by another SpW node
    - ✓ through the exchange of MACP Command/Reply
    - ✓ allows to build SpW dumb nodes (without a Host μP)
    - ✓ highly autonomous in the exchange of I/O data



- 4 SpW DS Links (full duplex, 200 Mbit/s point to point link)
- useful 1280 (2x160x4) Mbps net data rate
- full compliance with SpW standard (Rec. ECSS-E50-12A – January 2003)

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Next Missions & Trend
AAS-I – MACH (4/4)

❑ Gateway operating mode example

- SpW codec can be optionally removed from 1 of 4 SpW chains to allow parallel I/O access suitable to sensor data acquisition and control (e.g. ext. ADC&DAC)

❑ SSMM operating mode example

- provides up to 65536 concurrent independent DMA channels to access the partitions of a memory array

❑ DSP operating mode example

- support continuous scientific data acquisition (e.g. video image sequence from a Spectrometer or SAR) pipelined with DSP processing
- Sensor data are stored in fixed point format (as signed/unsigned, fractional/integer) or directly in floating point format

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Conclusion (1/1)

Promising link for space architecture

- High data rates with low consumption
- Standardised and full duplex
- Multi-points connection using routers

→ **Intensive use for data and all command/control exchange with harness reduction and redunded pathes**

To be studied

- Protection against failure propagation, nom/redundant pathes
- System evaluation incl. OBSW qualification vs SpW component behaviour
- System validation approach as H/W-S/W test, simulation tool
- Very high data rate need (1Gb/s range), need of SpaceFiber

→ **high interest of design rules as part of a SpW user book**

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