A retrospective of key DHS achievements in European Space programs

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Airbus Defence and Space

EDHPCs 2023
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Section 3

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This document has been assessed by the following Technical Rater:

Assessed and classified by:: R.Roques **Date classification completed: 2/10/2023**

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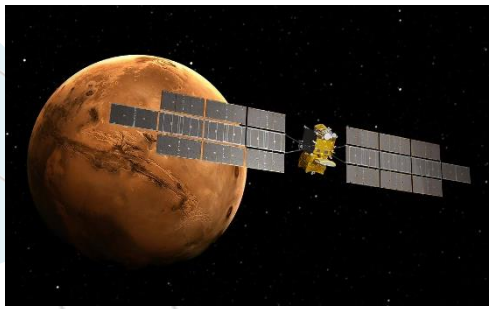
Standard Platforms, Product Policy & Rationalization

Highly Specific Dependable Architectures



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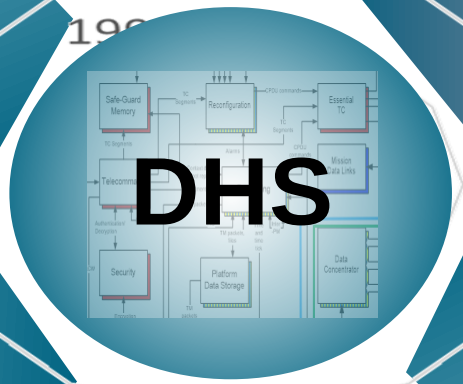
On-Board Data Handling



New Space & Constellations

A variety of DHS for a variety of Space domains with their own motivations

Laboratories in Space

AIRBUS

Standard Platforms, Product Policy & Rationalization

Highly Specific Dependable Architectures

To base solutions on European components

Successful Space component development during last decade : FPGAs, DSM, power, GaN

➔ **Valuable for sovereign programs**

➔ **Only a subset of mission needs anyway**

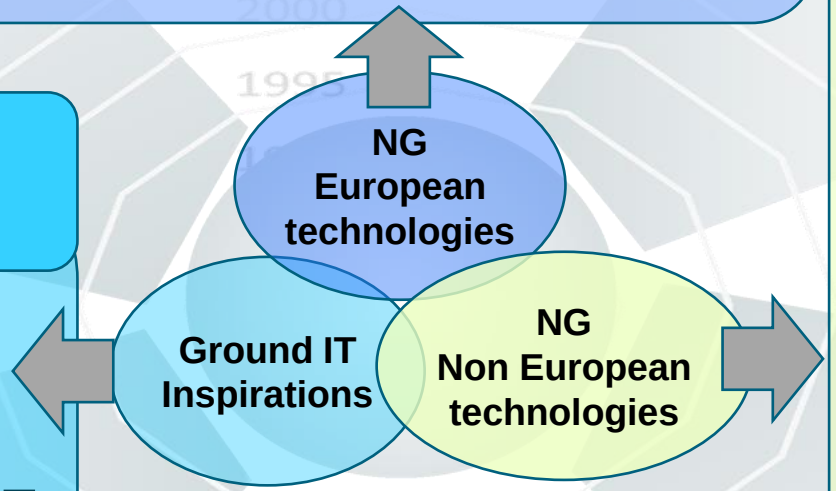
To be inspired by Ground IT

A long tradition of Space specific solutions, but more alignment on Ground IT opens new perspectives

➔ **Simplification**

➔ **Easier testing**

➔ **Open to heterogeneous SW**



Technologies: DHS decisions have always been at a crossroad of several influences

To use world class electronics for highly efficient missions

Many leading edge space compatible technologies still sourced outside Europe, driven by non Space market

➔ **A must for performance**

➔ **Not using them is not an option (in most cases)**

➔ **Little influence on specs and lifecycle**

New Space & Constellations

Laboratories in Space

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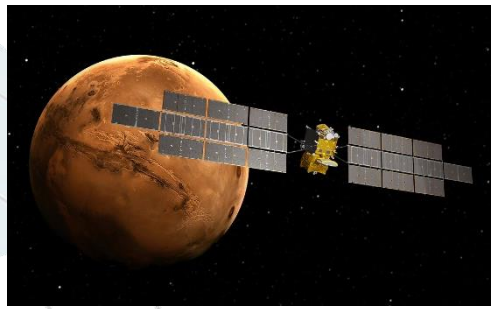
Standard Platforms, Product Policy & Rationalization

Highly Specific Dependable Architectures



New Space & Constellations

Laboratories in Space

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EUROSTAR E3000

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BEPI-COLOMBO
SolO
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GAIA
ROSETTA
ATV

DMS-R
COLUMBUS
BARTOLOMEO

ONEWEB GEN1
CO3D

European technologies
Ground IT Inspirations
Non European technologies

A non exhaustive selection of outstanding DHS developments

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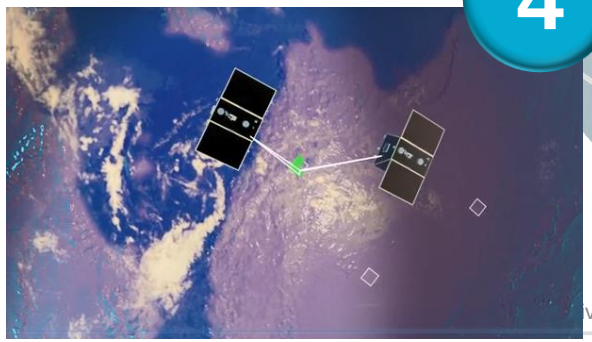
Standard Platforms, Product Policy & Rationalization

Highly Specific Dependable Architectures

New Space & Constellations



Laboratories in Space

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European technologies
Ground IT Inspirations
Non European technologies

DMS-R
1
COLUMBUS
BARTOLOMEO

4
ONEWEB GEN1
3D
EO Constellation

Focus on 4 adventures

ve of key DHS achievements in European Space programs

Domain	Lab (ISS)	DHS Definition period	1997-2000	Launch date	2008

Laboratories in Space

Columbus DMS (ISS)

Vital layer
- Highly reliable, MIL-STD-1750 proc.
- Satellite-like minimal software

HW commonality
- Between I/O units (CMU) and Vital computers (VTC)

COTS-based network hub/switch

COTS-based mass storage

Nominal layer
- **Pool of « standard computers »** (1 spare for 3 op'l) with SPARC processor and VME backplane
- **Ethernet** network, IP stack

« Standard P/L computer »:
- SPARC, VME
- Mezzanines

	VxWorks, UDP/IP, NFS	Data links	Ethernet, 1553, optical fibre

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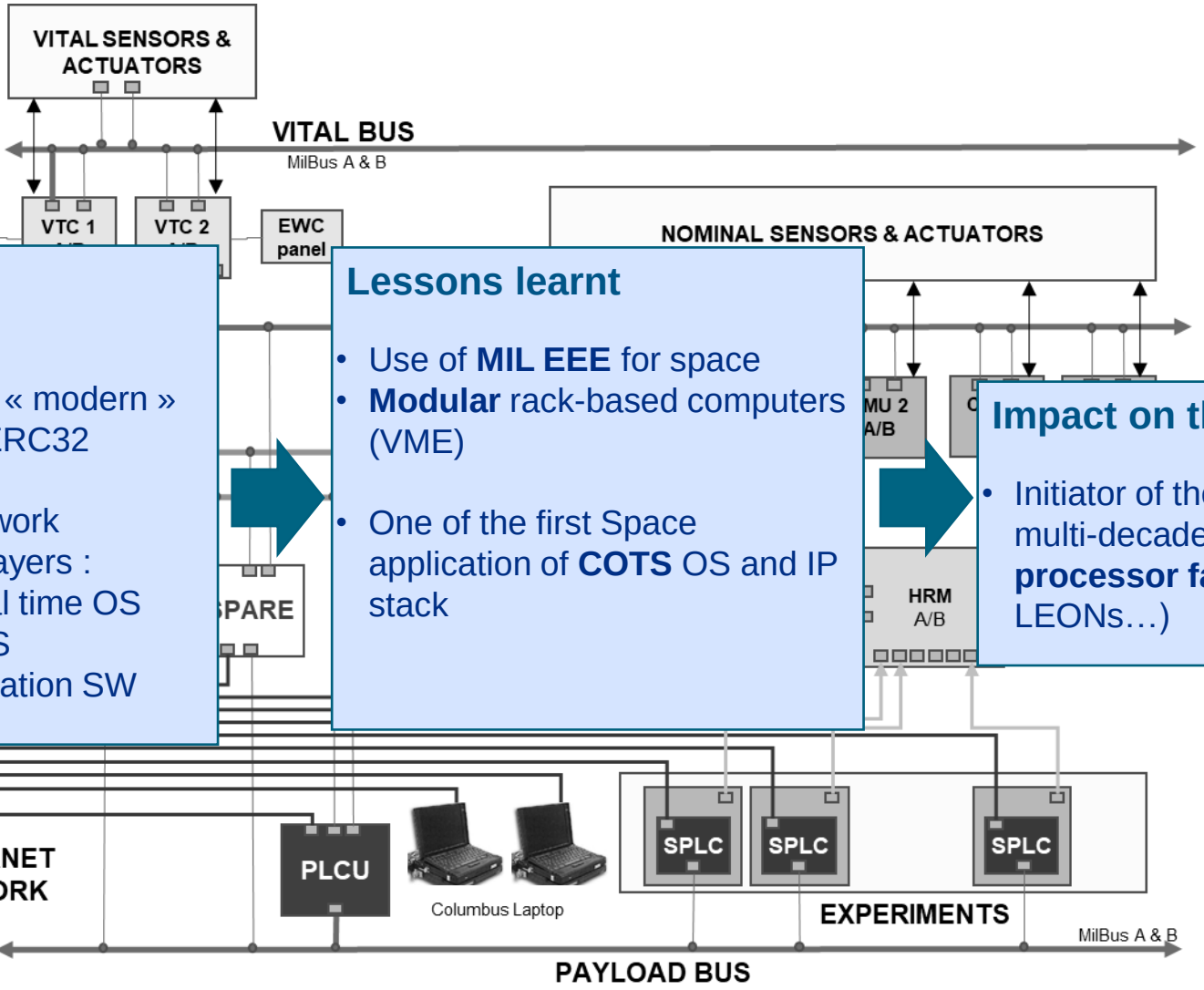
Domain	Lab (ISS)	DHS Definition period	1997-2000	Launch date	2008

Laboratories in Space

Columbus DMS (ISS)



Main features

- Vital + Nominal
- 1st introduction of « modern » microprocessor (ERC32 SPARC)
- Ethernet data network
- Commercial SW layers :
  - Vxworks real time OS
  - UDP/IP, NFS
- Data driven application SW

Lessons learnt

- Use of **MIL EEE** for space
- **Modular** rack-based computers (VME)
- One of the first Space application of **COTS** OS and IP stack

Impact on the future

- Initiator of the European Space multi-decade **SPARC processor family** (ERC32, LEONs…)

Enabling HW Technologies

Ground IT inspired

uProc.	ERC32 MA31750	OS	VxWorks, UDP/IP, NFS	Data links	Ethernet, 1553, optical fibre

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Standard Platforms, Product Policy & Rationalization

Highly Specific Dependable Architectures

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European technologies
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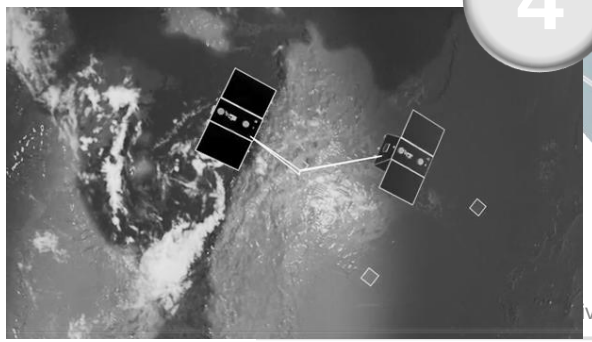
New Space & Constellations



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ONEWEB GEN1
EO Constellation

Laboratories in Space

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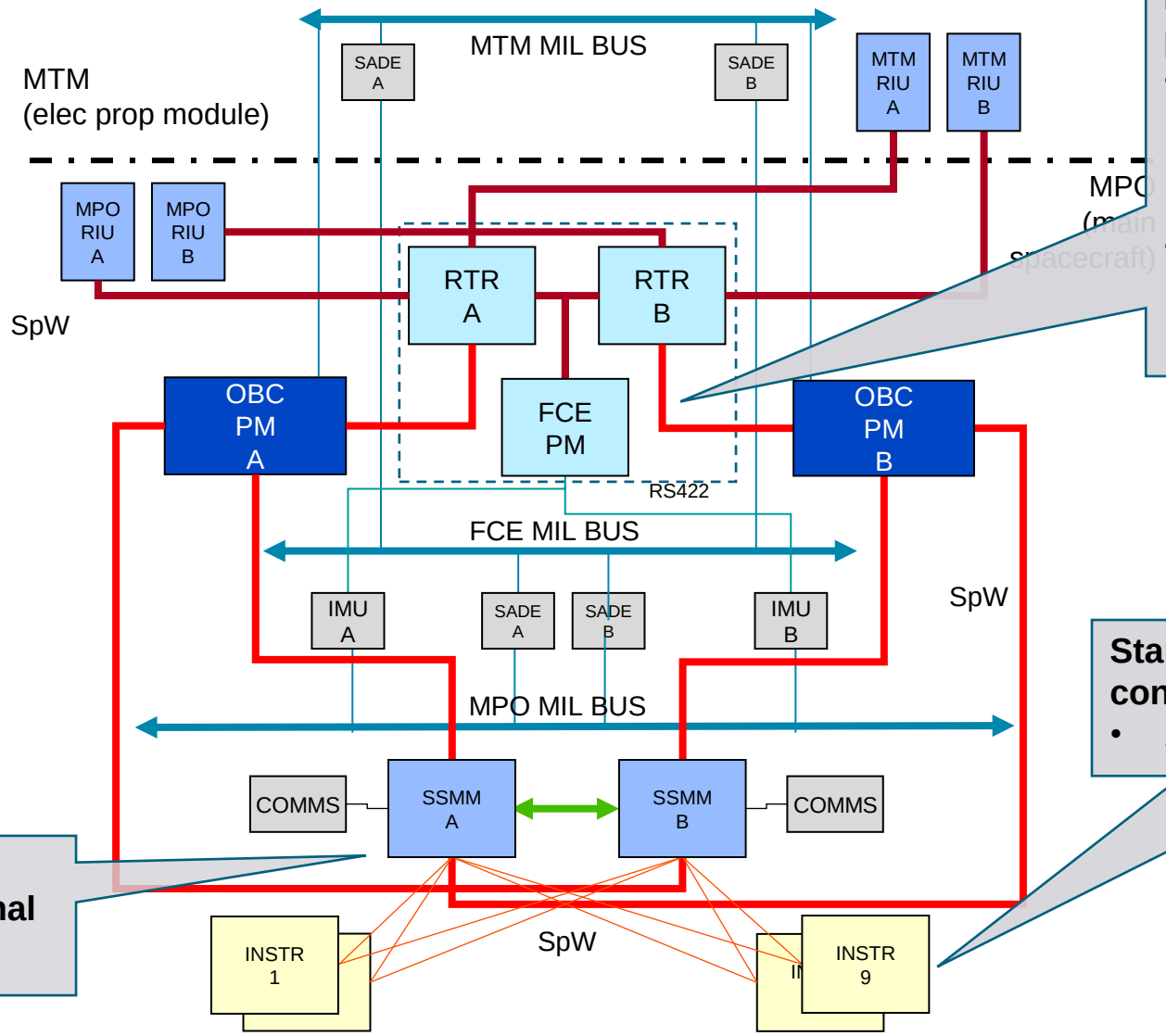
ive of key DHS achievements in European Space programs

Domain	Science & Exploration	DHS Definition period	2009-2011	Launch date	2018



No interrupt of critical function processing

- **Dedicated computer** (FCE) takes over critical functions (attitude control) during OBC reconfiguration
- Access to RIU from both Nominal and Vital computers via **SpW routers**

Standard SpW interface controller for experiments

- AT7913E RTC device

Mass Memory
SpW based **internal** architecture

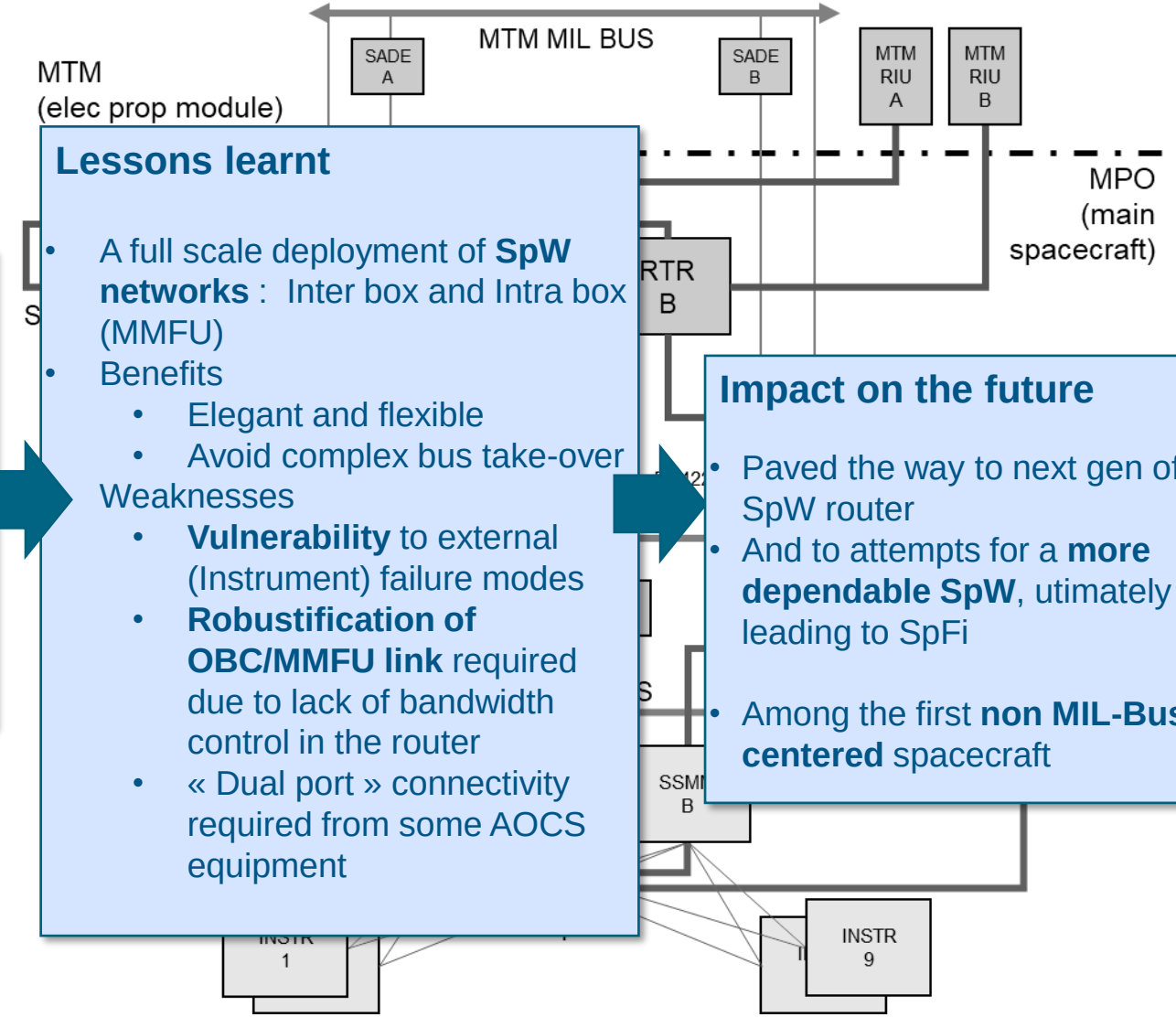
uProc.	ERC32SC	OS	RTEMS	Data links	1553, SpW

Domain	Science & exploration	DHS Definition period	2009-2011	Launch date	2018

Bepi Colombo

Main features

- **Pragmatic redundancy** concept
- Maximise reuse of existing OBC/DHS
- **SpW intensive** architecture with numerous SpW routers
- ERC32 computers



Lessons learnt

- A full scale deployment of **SpW networks** : Inter box and Intra box (MMFU)
- Benefits
  - Elegant and flexible
  - Avoid complex bus take-over

Weaknesses

- **Vulnerability** to external (Instrument) failure modes
- **Robustification of OBC/MMFU link** required due to lack of bandwidth control in the router
- « Dual port » connectivity required from some AOCS equipment

Impact on the future

- Paved the way to next gen of SpW router
- And to attempts for a **more dependable SpW**, utimately leading to SpFi
- Among the first **non MIL-Bus centered** spacecraft

Enabling HW Technologies

European Tech (mostly)

uProc.	ERC32SC	OS	RTEMS	Data links	1553, SpW

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Standard Platforms, Product Policy & Rationalization

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MetOp-Second Generation

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Highly Specific Dependable Architectures

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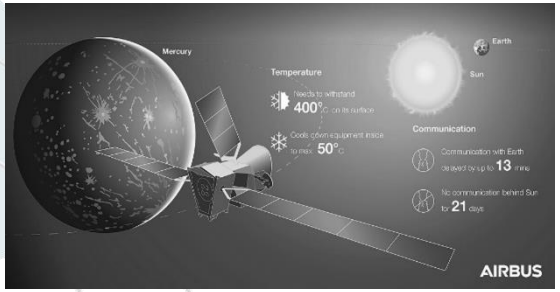

European technologies
Ground IT Inspirations
Non European technologies

DMS-R

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COLUMBUS
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New Space & Constellations

ONEWEB GEN1

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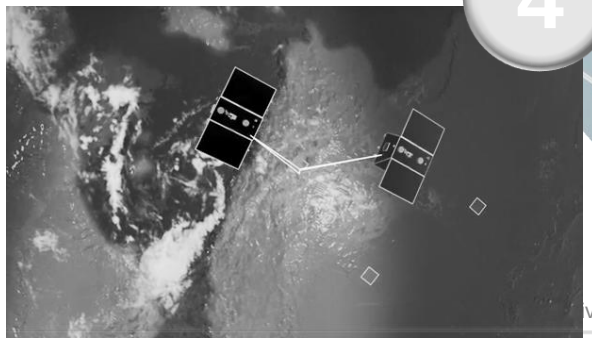
EO Constellation



Laboratories in Space

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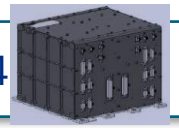
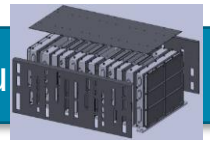
ve of key DHS achievements in European Space programs

Domain	Earth Observation	DHS Definition period	2014	Lau	5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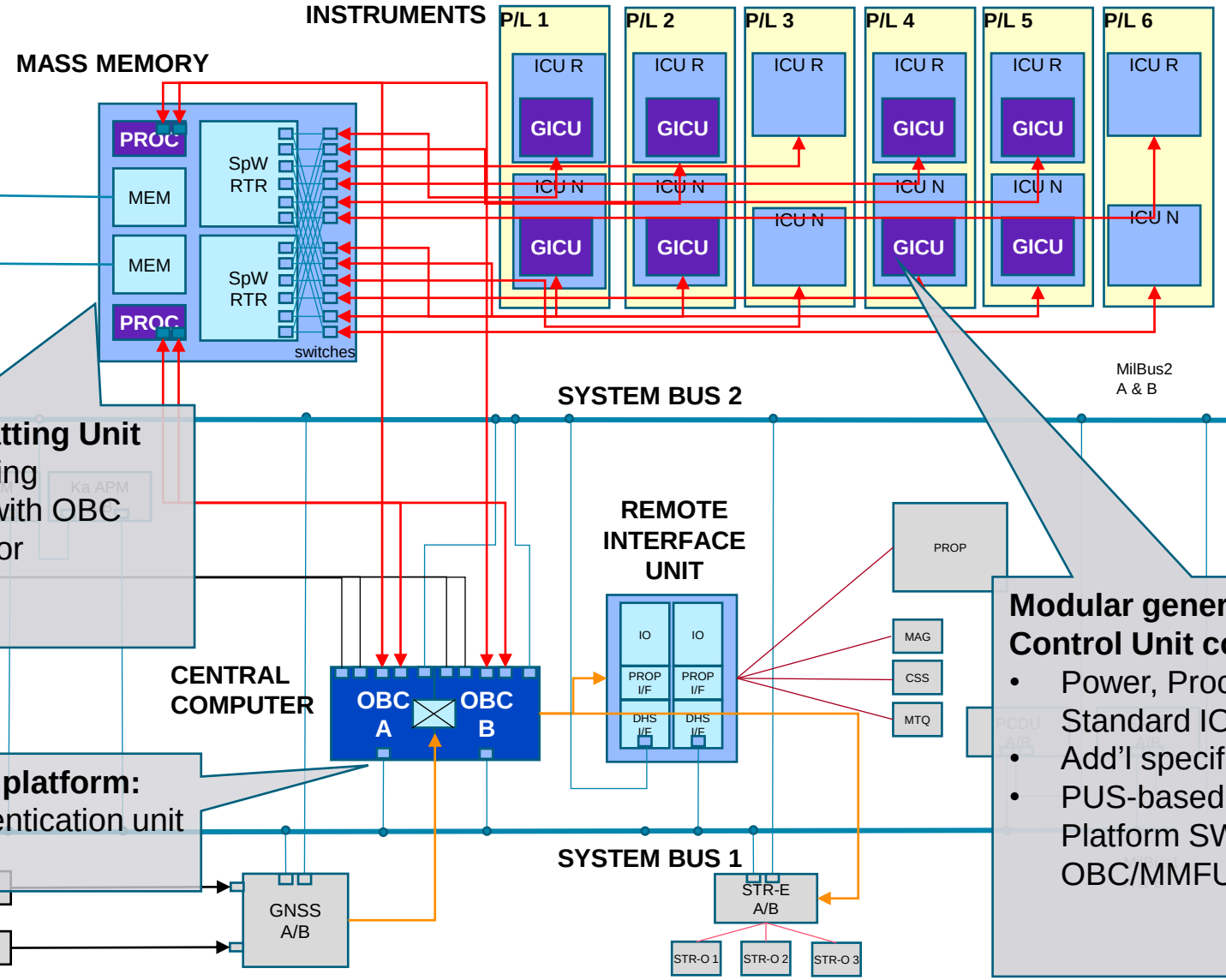
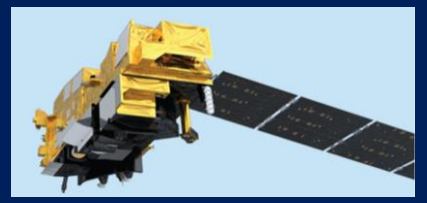
Product Policy & Rationalization
MetOp 2nd Generation

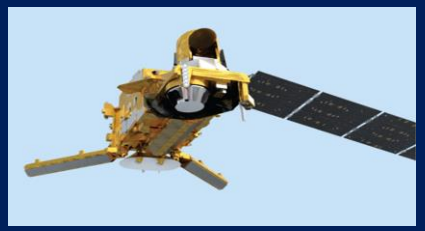


Mass memory & formatting Unit
- Control function sharing technology and SW with OBC
- SpaceWire network for instrument i/f
- **Flash**-based storage

AstroBus AS400 avionics platform:
- OBC with CCSDS authentication unit
- High modularity RIU

Modular generic Instrument Control Unit core :
- Power, Processor, Standard IO modules
- Add'l specific modules
- PUS-based Execution Platform SW derived from OBC/MMFU one





esa EUMETSAT

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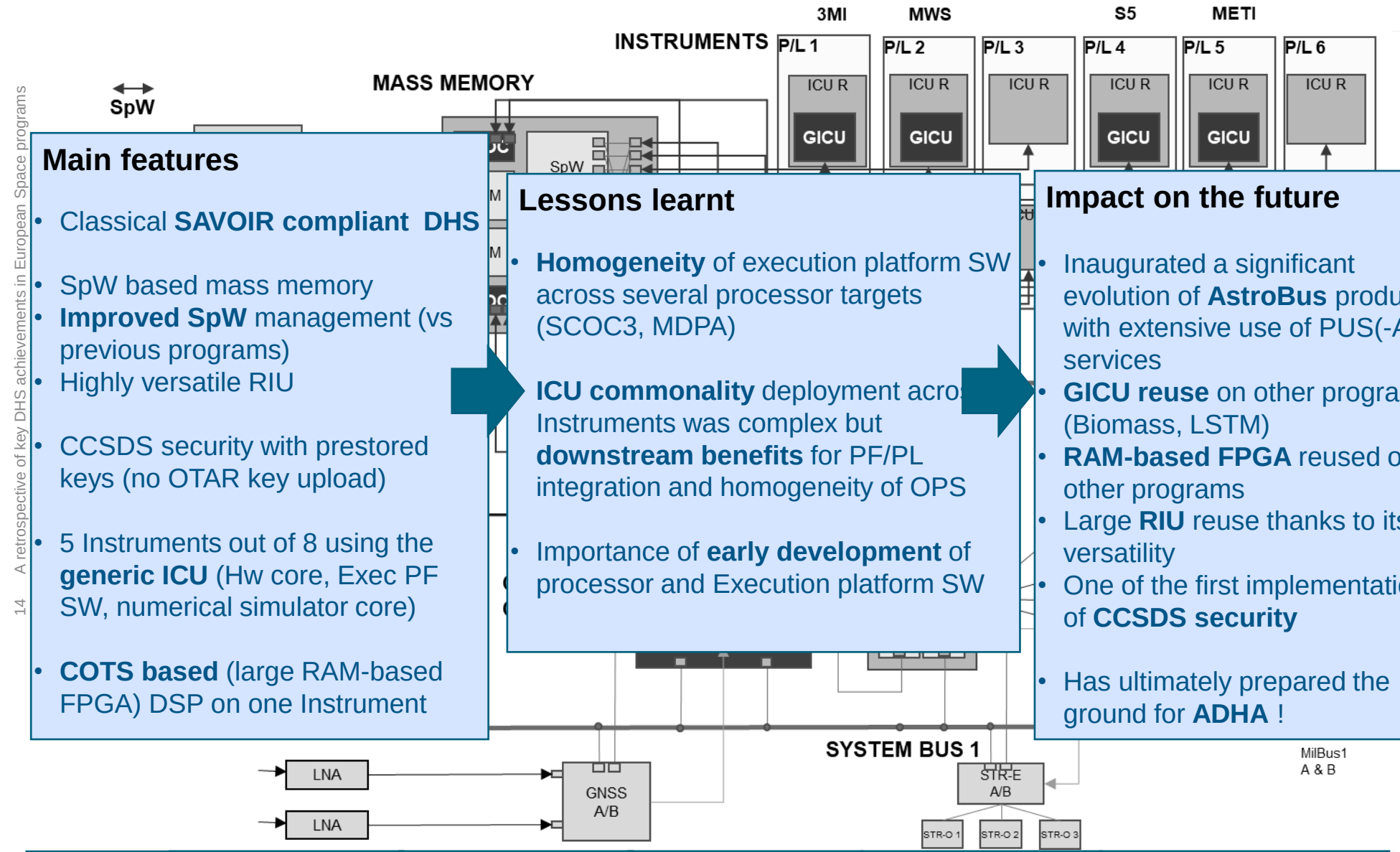
uProc.	LEON2/3	OS	RTEMS	Data links	1553, SpW

Domain	Earth Observation	DHS Definition period	2014-2016	Launch date	2025

Product Policy & Rationalization

MetOp 2nd Generation



Main features

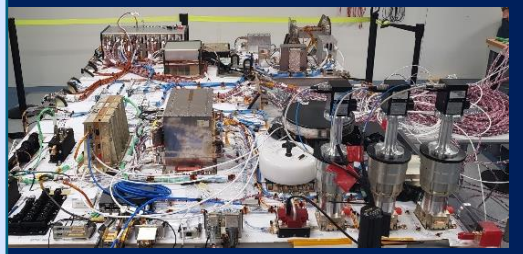
- Classical **SAVOIR compliant DHS**
- SpW based mass memory
- **Improved SpW** management (vs previous programs)
- Highly versatile RIU
- CCSDS security with prestored keys (no OTAR key upload)
- 5 Instruments out of 8 using the **generic ICU** (Hw core, Exec PF SW, numerical simulator core)
- **COTS based** (large RAM-based FPGA) DSP on one Instrument

Lessons learnt

- **Homogeneity** of execution platform SW across several processor targets (SCOC3, MDPA)
- **ICU commonality** deployment acro Instruments was complex but **downstream benefits** for PF/PL integration and homogeneity of OPS
- Importance of **early development** of processor and Execution platform SW

Impact on the future

- Inaugurated a significant evolution of **AstroBus** product with extensive use of PUS(-A) services
- **GICU reuse** on other programs (Biomass, LSTM)
- **RAM-based FPGA** reused on other programs
- Large **RIU** reuse thanks to its versatility
- One of the first implementations of **CCSDS security**
- Has ultimately prepared the ground for **ADHA** !



European Tech — *Enabling HW Technologies*

Non European Tech (FPGA)

uProc.	LEON2/3	OS	RTEMS	Data links	1553, SpW

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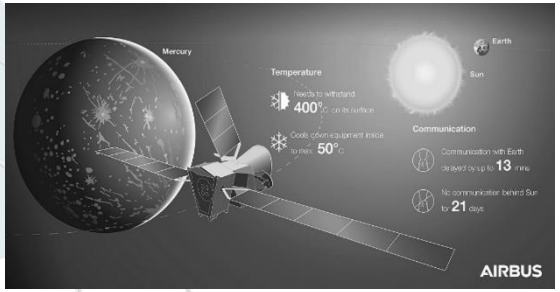
Standard Platforms, Product Policy & Rationalization

Highly Specific Dependable Architectures



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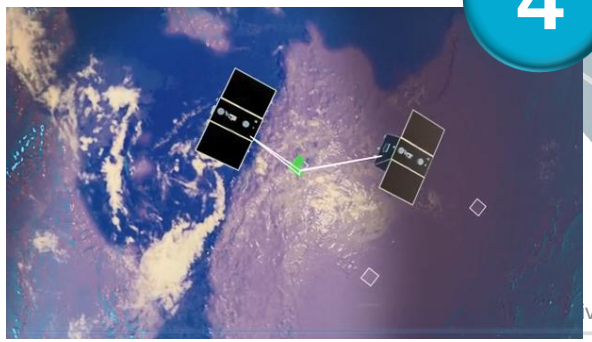
New Space & Constellations



4
ONEWEB GEN1
EO Constellation

Laboratories in Space

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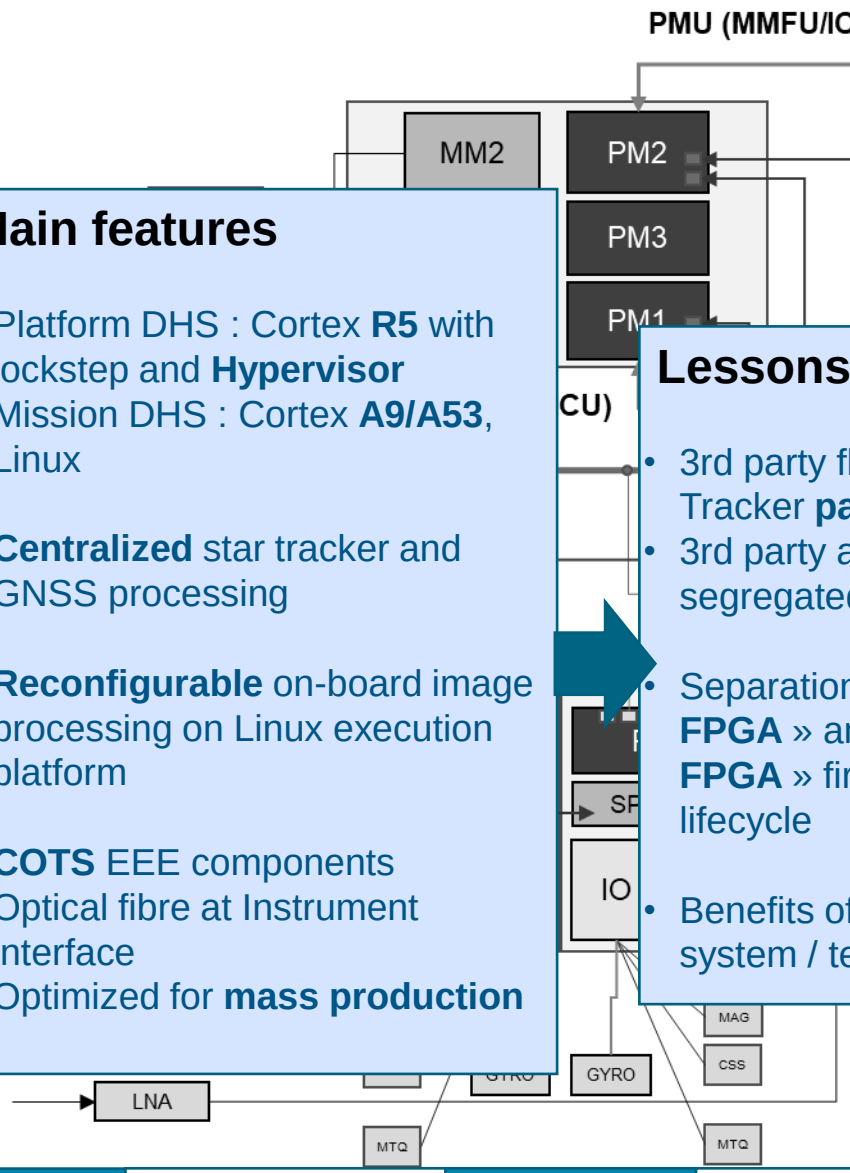
ve of key DHS achievements in European Space programs

Domain	EOS	DHS Definition period	2018-2021	Launch date	2019 (OW1) 2024

New Space & Constellations

NG EO constellation



Main features

- Platform DHS : Cortex **R5** with lockstep and **Hypervisor**
- Mission DHS : Cortex **A9/A53**, Linux
- **Centralized** star tracker and GNSS processing
- **Reconfigurable** on-board image processing on Linux execution platform
- **COTS** EEE components
- Optical fibre at Instrument interface
- Optimized for **mass production**

Lessons learnt

- 3rd party flight SW in Star Tracker **partition**
- 3rd party application SW in segregated area
- Separation between « **basic FPGA** » and « **application FPGA** » firmware development lifecycle
- Benefits of flight system / ground system / test system **continuity**

Impact on the future

- Innovative **operations** concept
- Commercial but rad tolerant **part list**
- **FPGA reconfiguration** algorithms
- FPGA **SEE mitigation**

A further step already under study. Physically more integrated while using similar principles

Enabling HW Technologies

Ground IT inspired

Non European COTS Tech

uProc.	ARM	OS	RTEMS, XtratuM, Linux	Data links	Ethernet, CAN, Optical fibre

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Conclusion

- A variety of DHS solutions which reflect the variety of Space missions
- In constant evolution, taking the best from available technology

- Over time, we note a remarkable continuity in architecture principles : this is key to deliver dependable systems and reflects the sustainability of European know-how
- DHS are getting more and more flexible, closer to ground IT standards to support new concepts of operations, decrease end-to-end costs and are more easily maintainable