On-Board Payload Data Processing requirements and technology trends

European Workshop on On-Board Data Processing (OBDP2019)
ESA/ESTEC, Noordwijk, The Netherlands, 25/2/19

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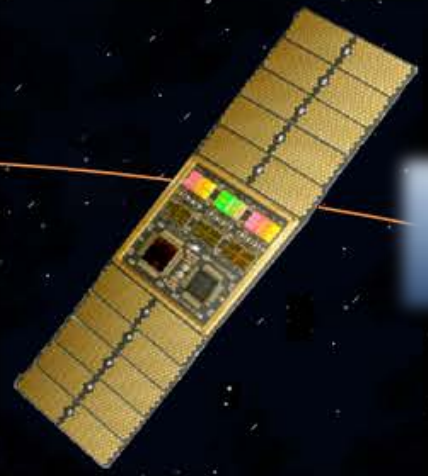
On-Board Payload Data Processing requirements and technology trends



Vision

Targets

Technologies

Developments

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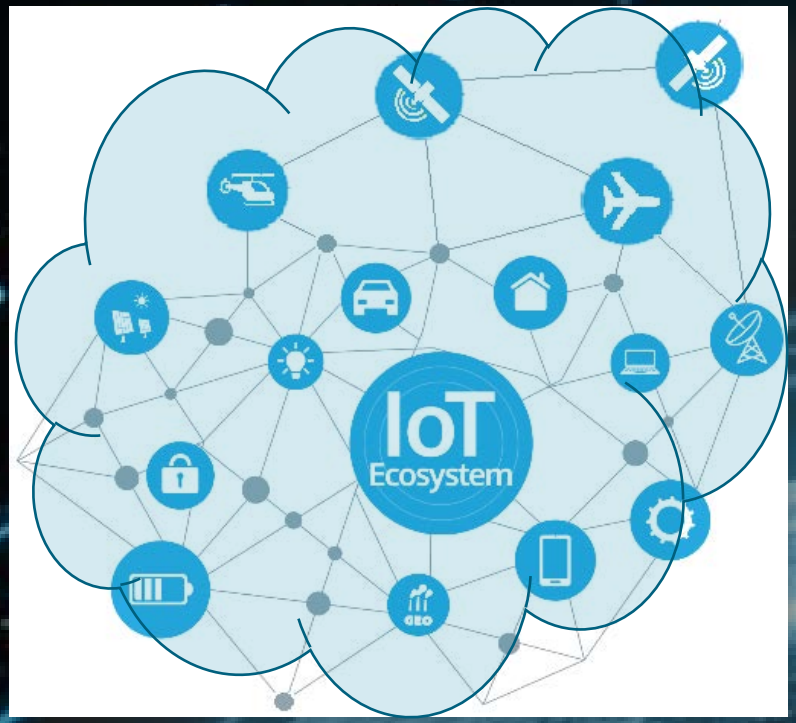
Our future is IoT @ any-time everywhere

Connected smart machines



Smart vehicles and robots in smart cities
Autonomous and Everywhere Connected

Machine learning | Big Data | Cloud | Artificial intelligence

SOFTWARE | Data Processing

Electronics

Today IoT

Tomorrow

Vehicles
Robots
Autonomous
Connected

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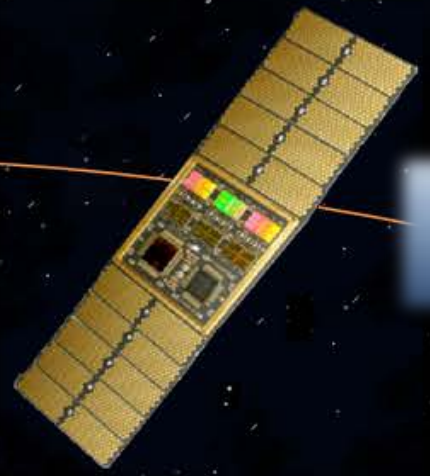
On-Board Payload Data Processing requirements and technology trends



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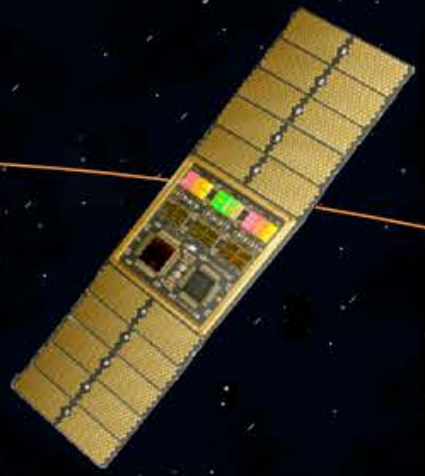
Targets 🎯

On-Board Data Processing

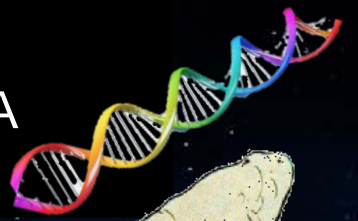


Computing Performance

OPEN

GFlops x Gbps / Watt / Kilo / cm^3…

Flexibility



Software, reprogrammable FPGA
interoperability, modularity

Robustness

Technology
Fault tolerance
Technology Independence

Determinism

Functional correctness
Time predictability

Programming efficiency

Portability
Testability TOOLS
Easy programing

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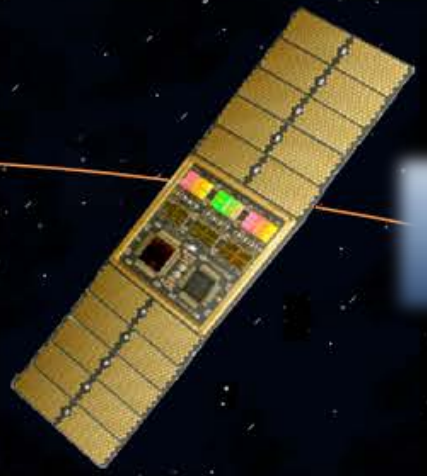
On-Board Payload Data Processing requirements and technology trends



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Targets

Technologies

Developments

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Technologies

Multi-cores

Performance

Challenges

Game change

Is not

a

requirement

Is

an enabling Technology for more Performance & Integration

Size

180nm

150nm

90nm

65nm

28nm

24nm

16nm

Power

more

GHz

Gbit/s

GFLOPS

per Watt

Resources sharing

Memory

caches

I/Os

FPU

Software Parallelism

SMP

AMP

MTAPI

OpenMP

OpenCL

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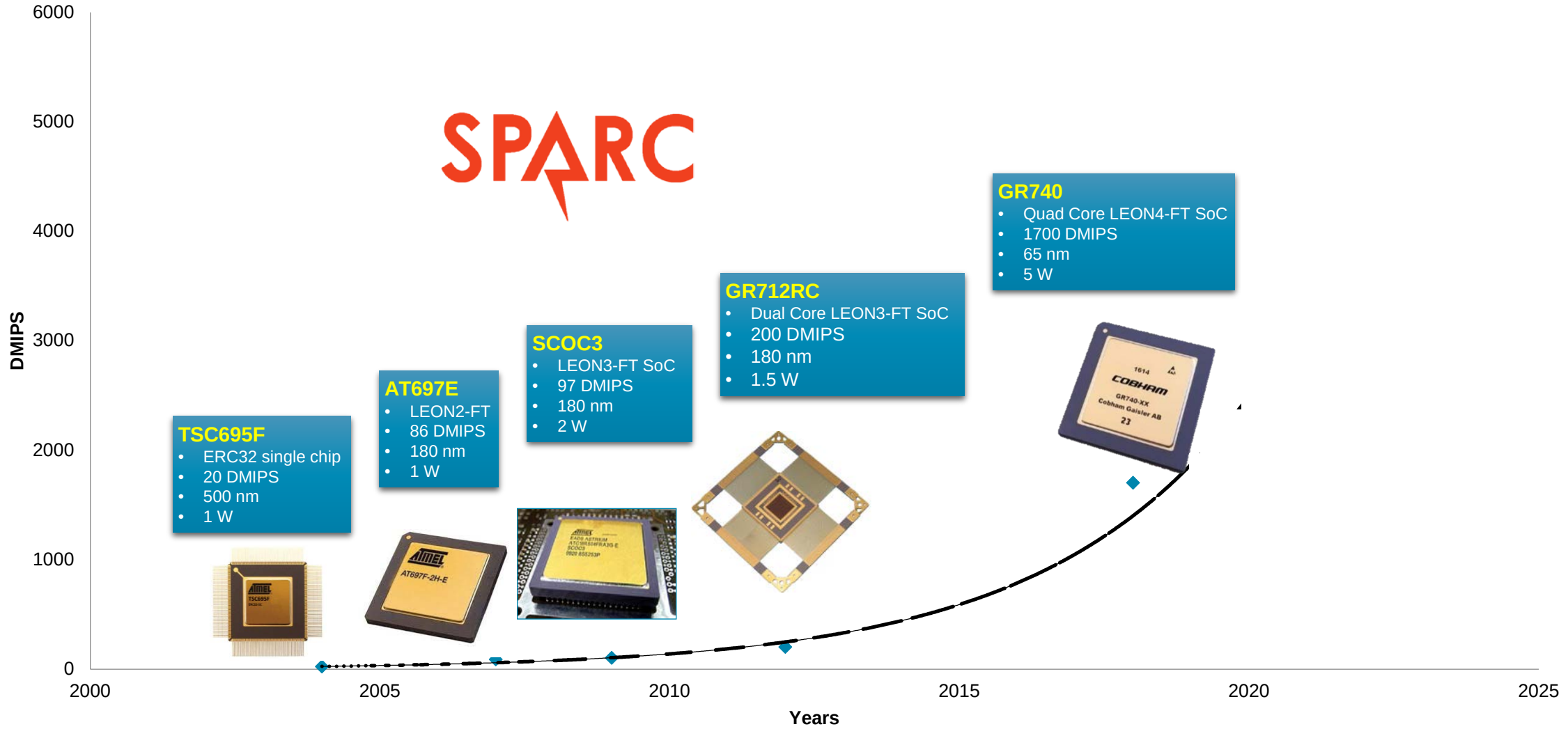
Space Processors



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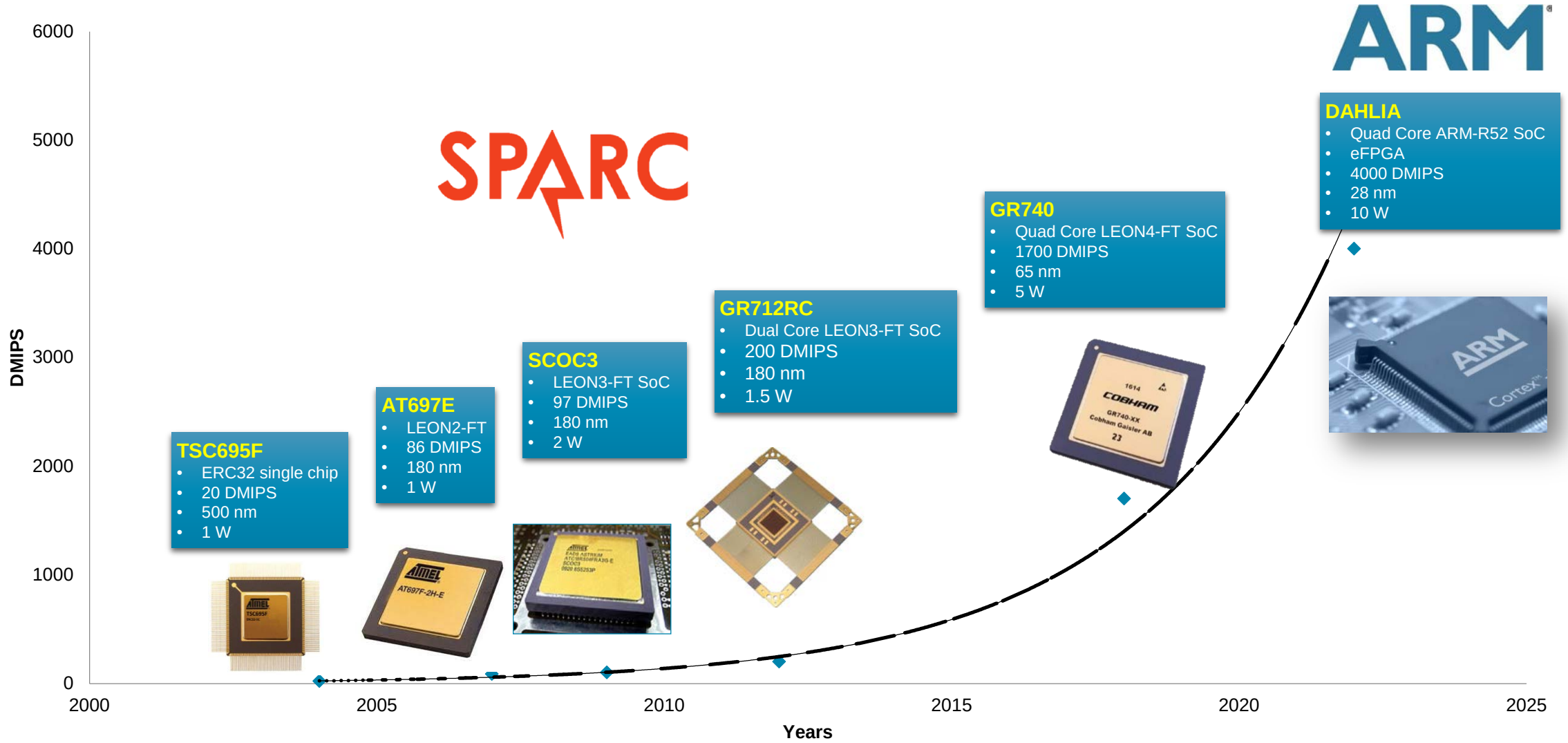
Space Processors



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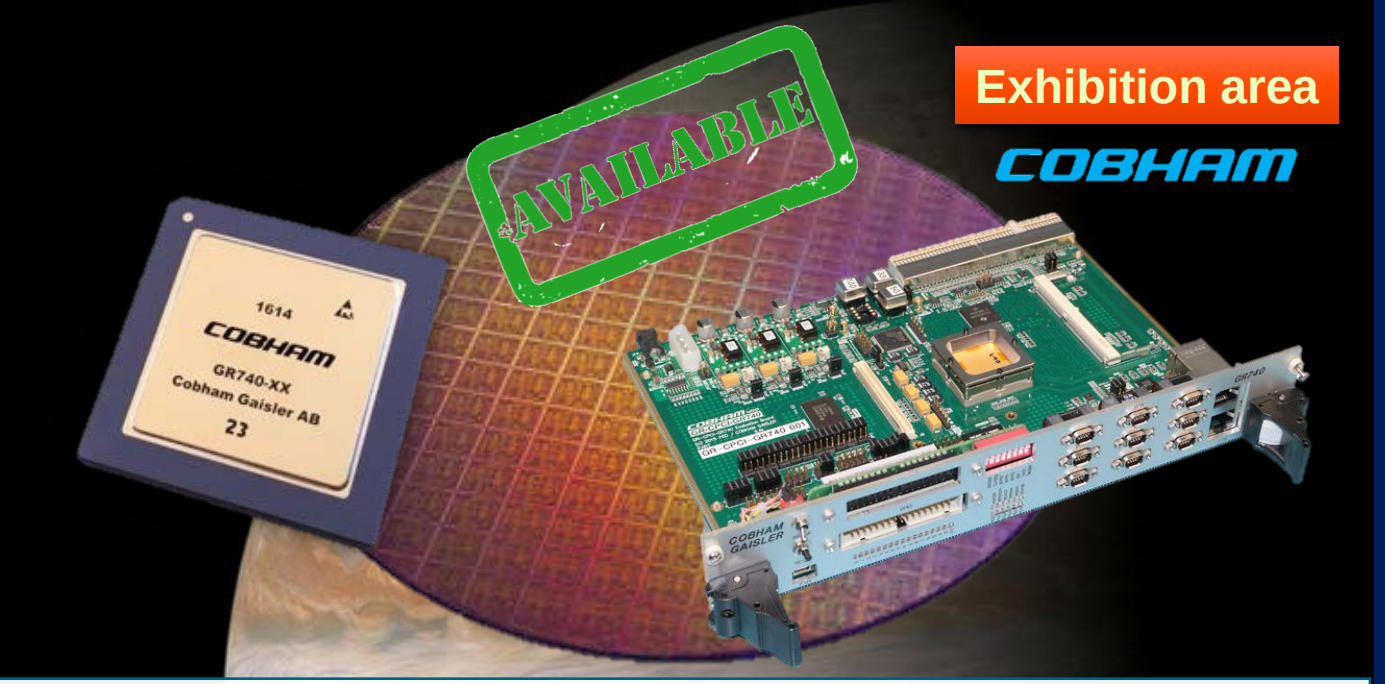

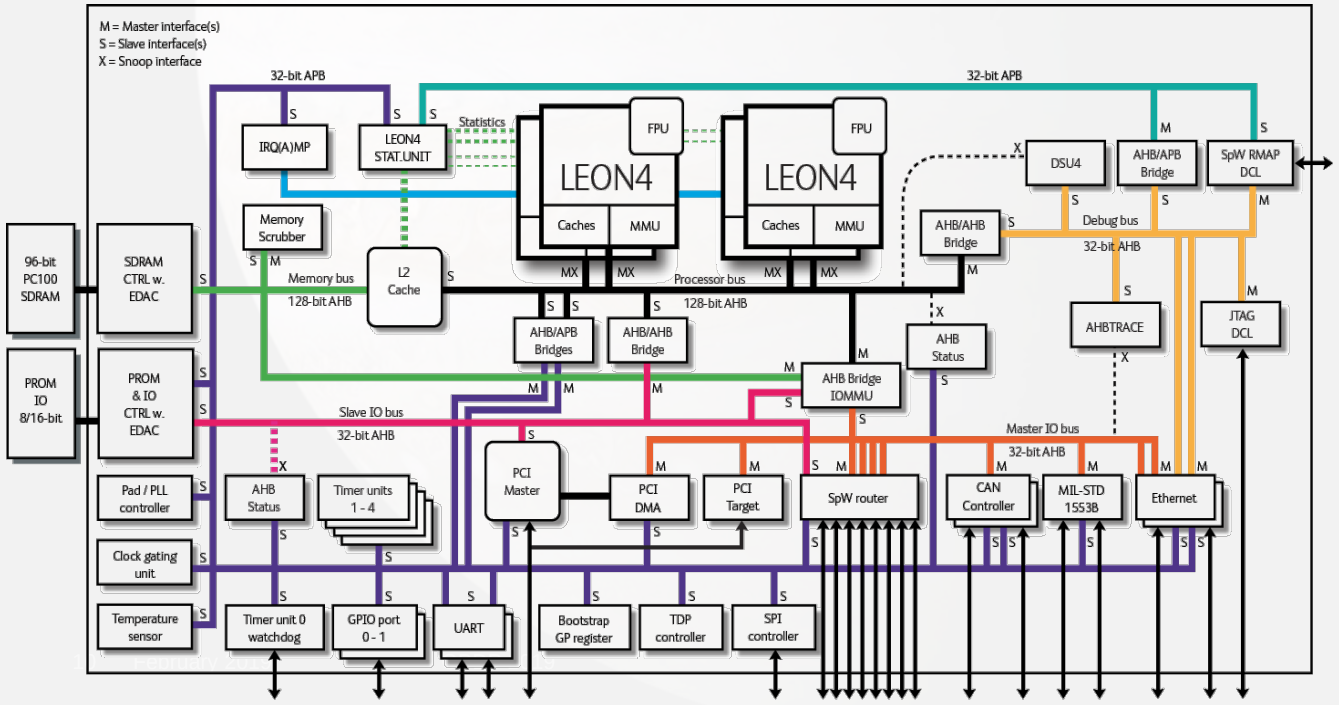

65nm Bulk CMOS Technology

- High performance / low power consumption
- **Fault Tolerant design** → robustness in space environment

GR740 – Quad-Core LEON4FT designed for multi-processing

High performance for data processing

Standard interfaces for spacecraft control

- 4 x LEON4 FT with dedicated MMU and FPU
- 8-port SpaceWire Router
- PCI, Ethernet, 1553, CAN bus
- 64-bit PC100 SDRAM memory I/F

SPARC Compliant SCD V8

Courtesy of COBHAM
www.Cobham.com/Gaisler

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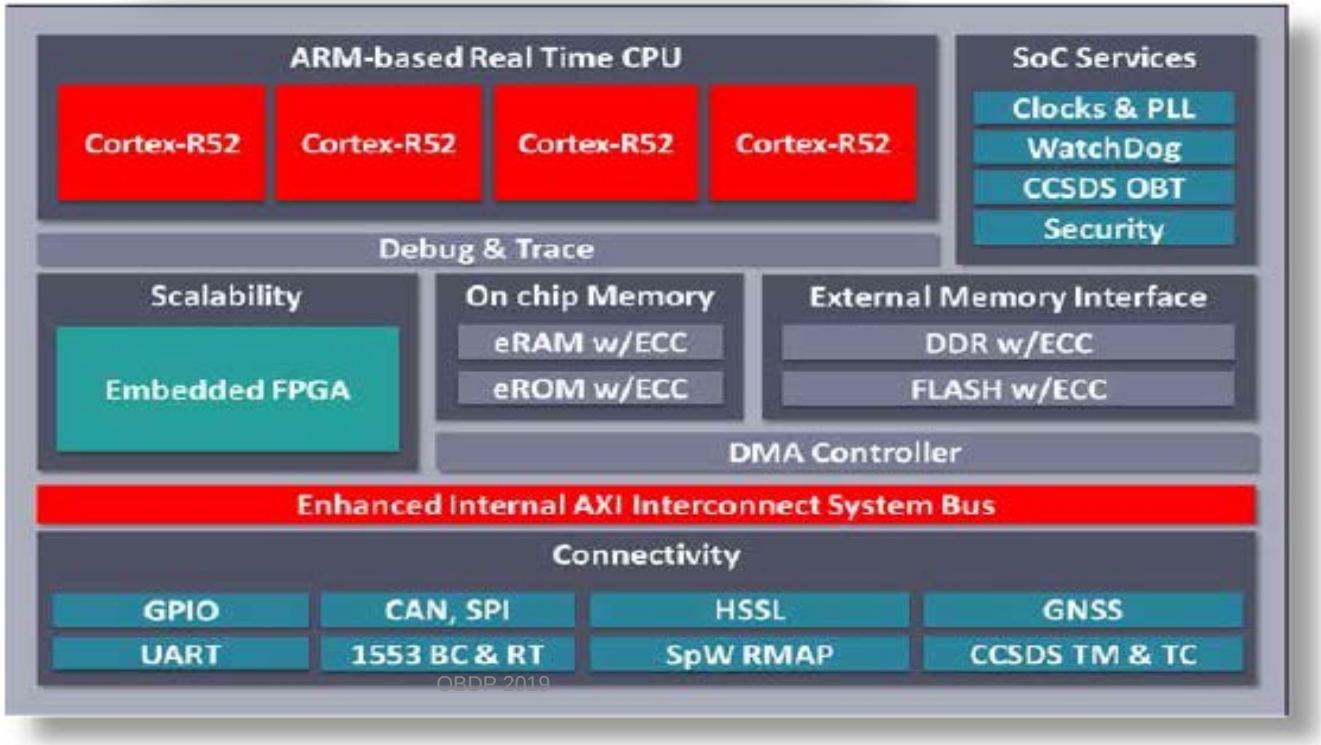
Exhibition area

NanoXplore

BRAVE



28nm FD-SOI Technology

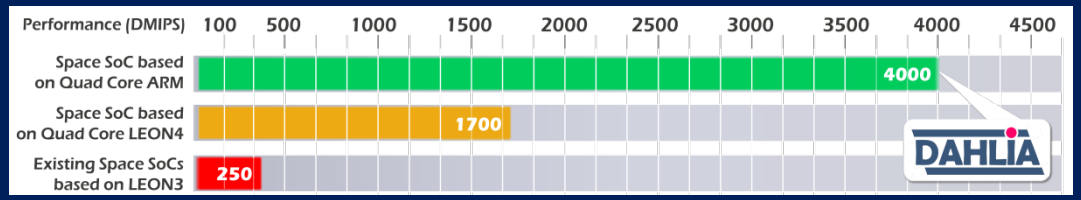
- High performance with low power consumption
- High robustness in radiation environment

DAHLIA

a powerful combination of innovative technology adapted for Space

4 x ARM Cortex-R52

- ARM's most advanced processor for safety
- Flexible on Chip Hardware functions with eFPGA



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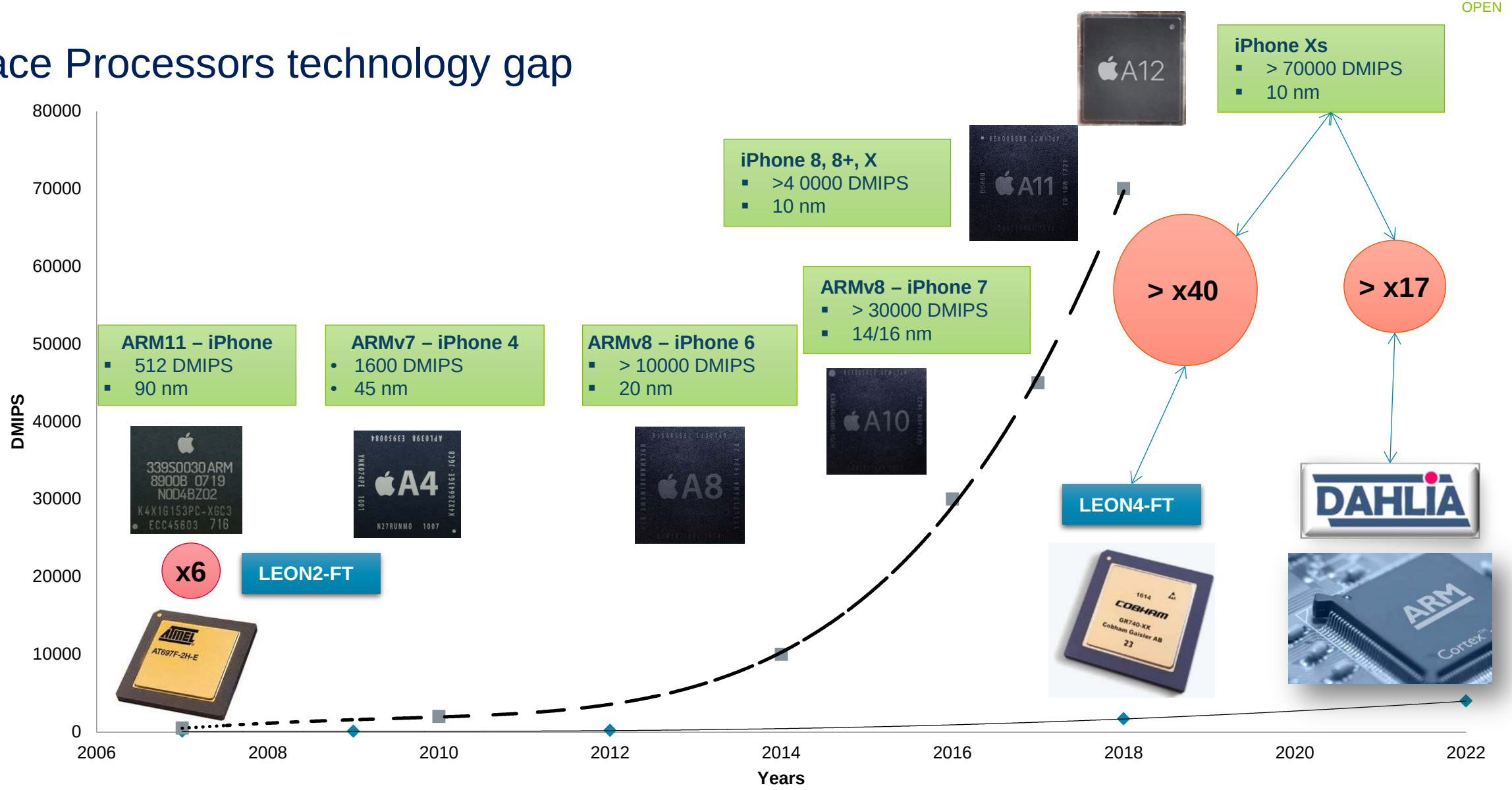
Space Processors technology gap



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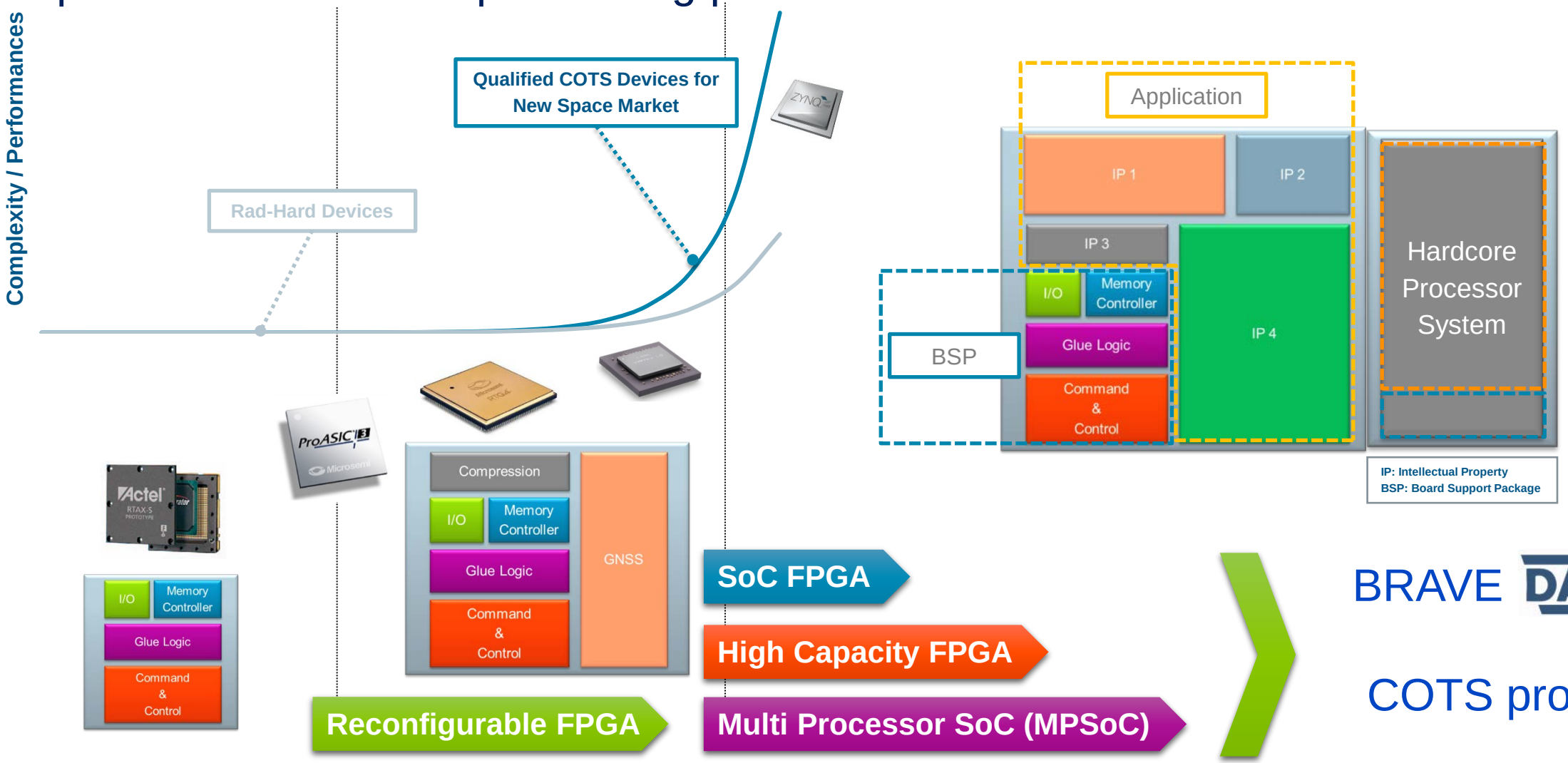
Space FPGA → more processing performance



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MPSoC
COTS
RAD HARD
FPGA
Multicores
Software
L2 cache memories
CPU
CPU
CPU
CPU
PLL
512 CORE GPU
I/O
8 CORE CPU
CVA
KALRAY
MPPA MANYCORE
1614
COBHAM
GR740-XX
Cobham Gaisler AB
23
Microsemi.
RTG4
Software
Software

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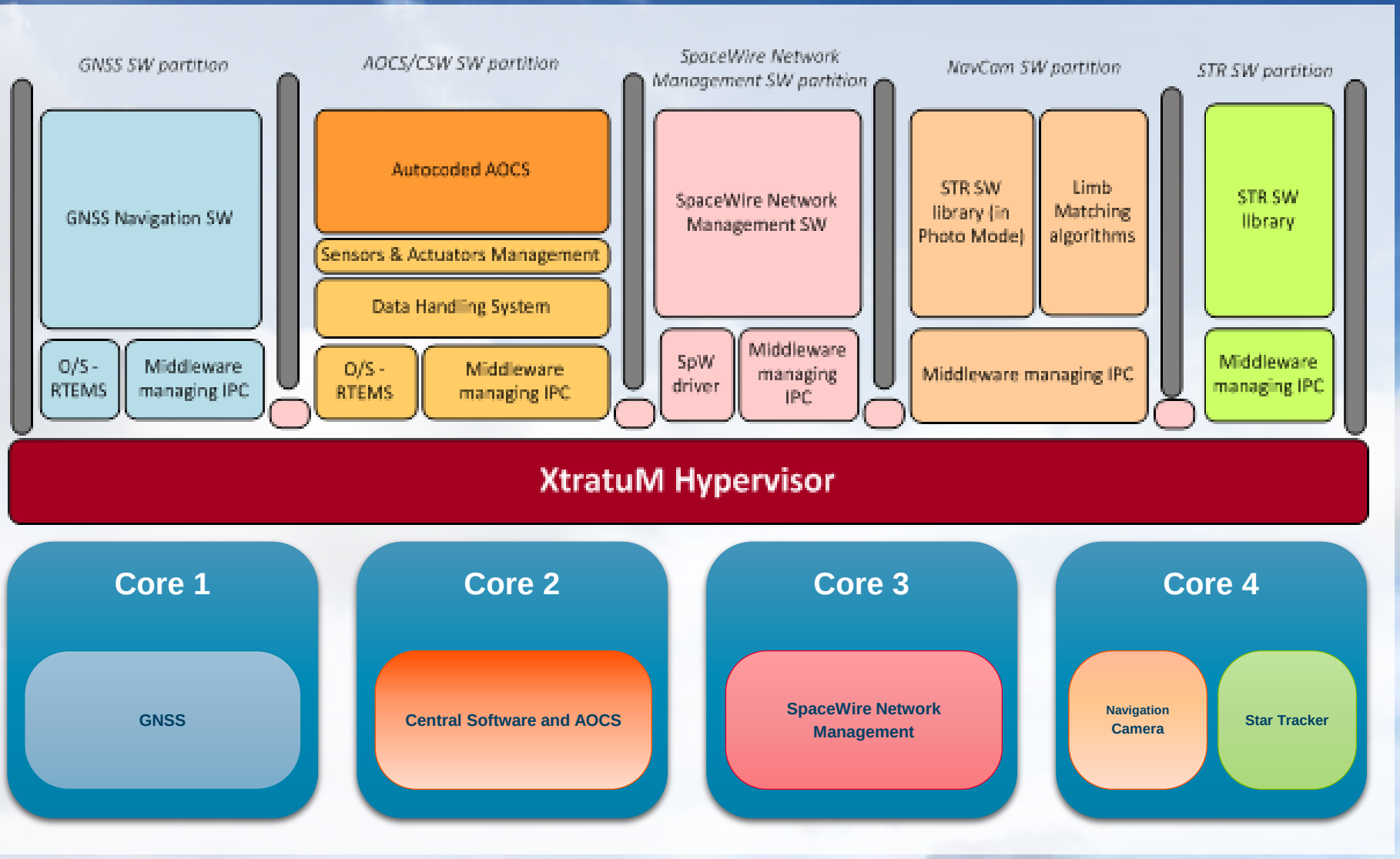
Software: Integrated Spacecraft Data Handling – IMA style

From ESA Study Prototyping a SpaceWire AOCS



Satellite Central Software

- TSP Hypervisor
  - Xtratum / PikeOS
- Operating Systems
  - RTEMS or others

Asymmetrical Multi Processing

- Static partition mapping

- LEON 4 (GR740) ☑
- ARM (DAHLIA)
- COTS (ARM, PowerPC)

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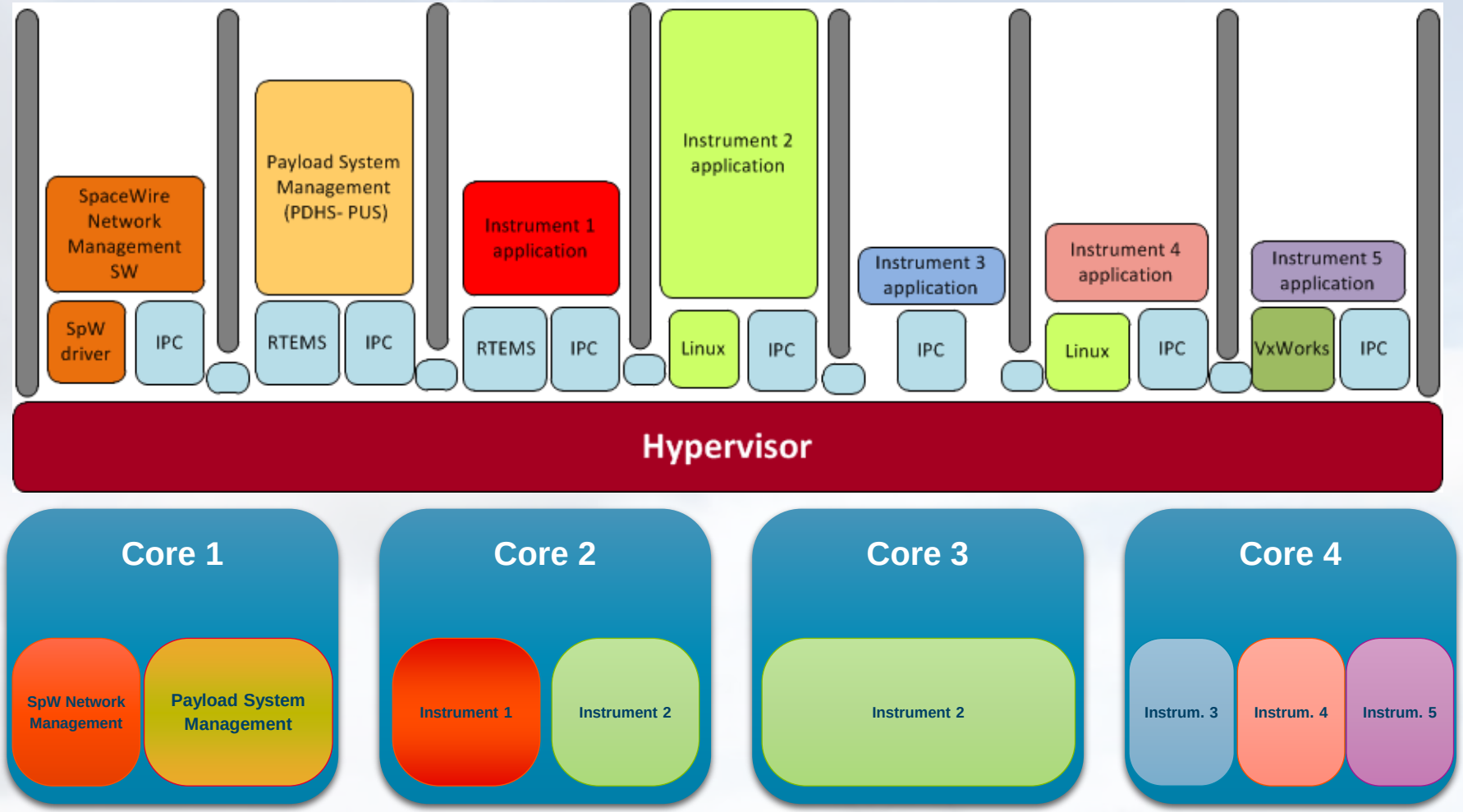
Software: Integrated Instruments Control and Data Processing



Payload Data Handling Software

- S/W partitioning
  - Independent software development validation & integration
  - Mixed criticality
- Operating System
  - Choice of the payload systems integrator and instrument developers
- LEON 4 (GR740)
- ARM (DAHLIA)
- COTS (ARM, PowerPC)

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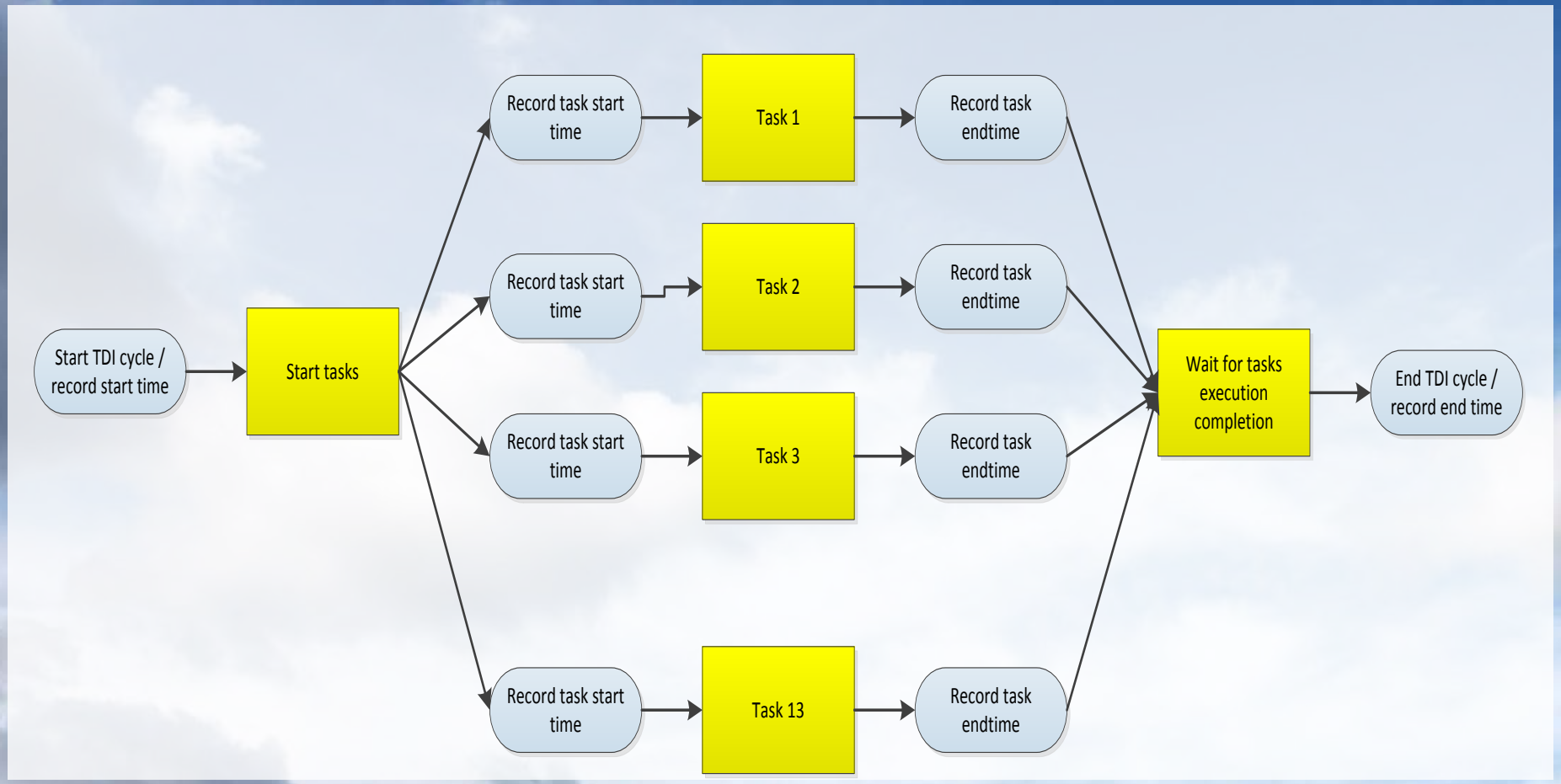
High Performance Payload Data Processing



Payload Data Processing

S/W Parallelisation

- RTEMS (SMP, MTAPI)
- OpenMP, OpenCL…

Multicore processor

- LEON 4 (GR740)
- ARM (DAHLIA)
- COTS (ARM, PowerPC)

Manycore

- MPPA (Kalray)
- GPUs
- RC64 (RamonChips)
- HPDP (Airbus)

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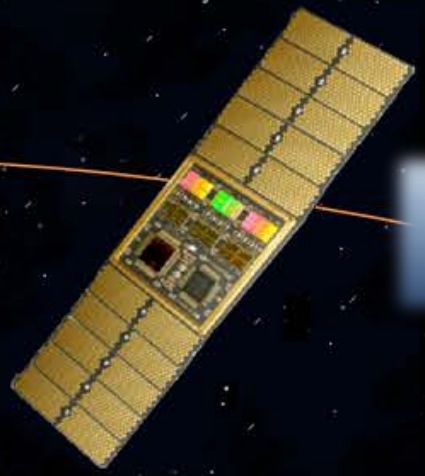
On-Board Payload Data Processing requirements and technology trends



Vision

Targets

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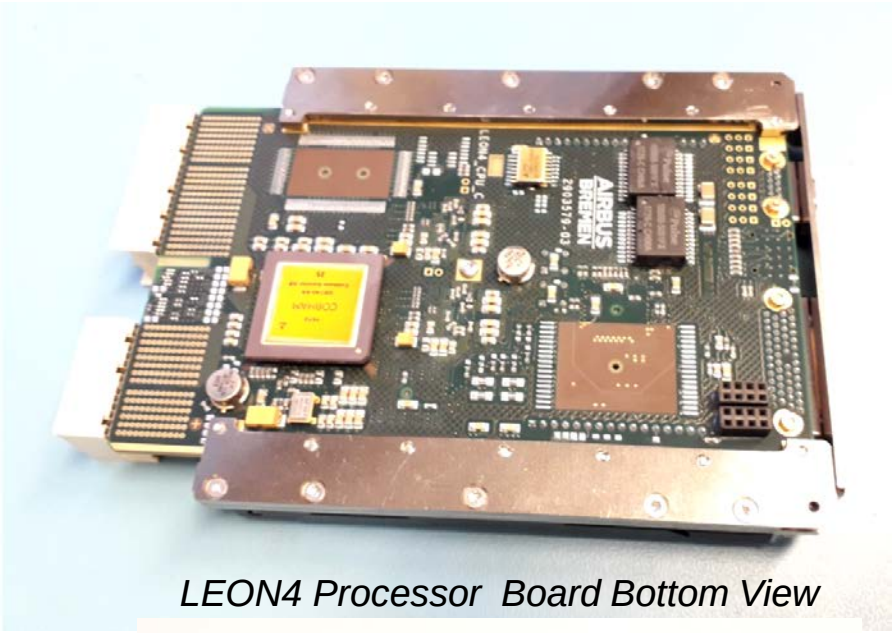
SPINAS computer (OBC-SA project)

Monday @ 14:30

Wednesday @ 15:20

On-Board Computer System Architecture project (DLR)

- Objective
  - Open Modular Architecture (Space cPCI Serial)
  - Modular S/W with Time and Space Partitioning (PikeOS)
  - High performance multicore processing for resource sharing
  - Miniaturisation (3U boards, <5kg)
- Features
  - High reliability SPARC V8 CPU (GR740)
    - 4 cores @ 250 MHz
    - 459 DMIPS per core
  - 256 MB SDRAM (+EDAC)
  - 2x Gigabit Ethernet
  - 8x SpaceWire up to 300Mbit/s
  - Redundant MIL-STD-1553B
  - 2x CAN, 2x RS422
  - Watchdog for system reliability



LEON4 Processor Board Bottom View

SPINAS EQM Computer Box

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COTS based Reliable Architecture (COBRA)

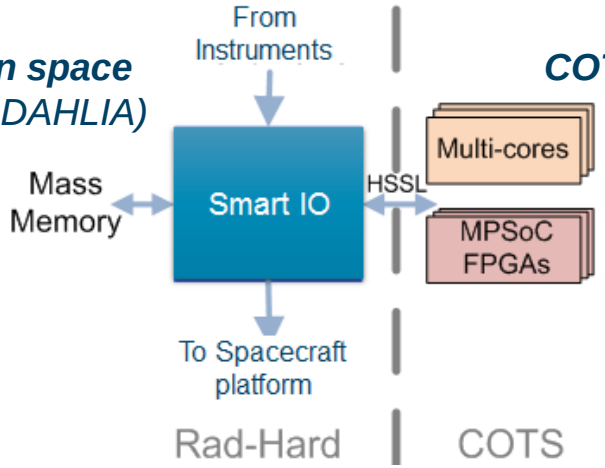
Monday @ 14:50

COBRA Concept

- ESA study « High Performance COTS based Computer »

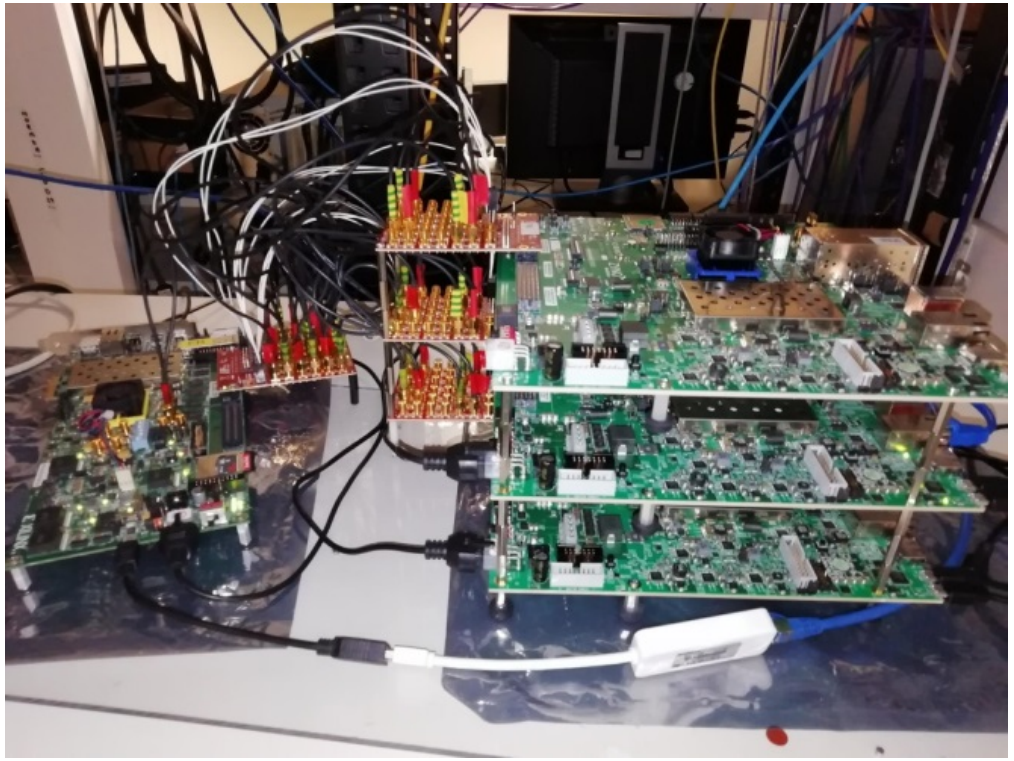
Robust device in space
(GR740, BRAVE, DAHLIA)

COTS High Performance devices
(FPGA, DSP, MPSoC, GPU,…)



- HW/SW codesign : Development methodology & tools
- Applications:
  - Low cost highly integrated processing platform
  - advanced image processing
  - Autonomy (navigation mission planning, AI…)
  - SDR radar/telecom…

COBRA demonstrator



COBRA demonstrator with 3 PM based on Zynq Ultrascale +

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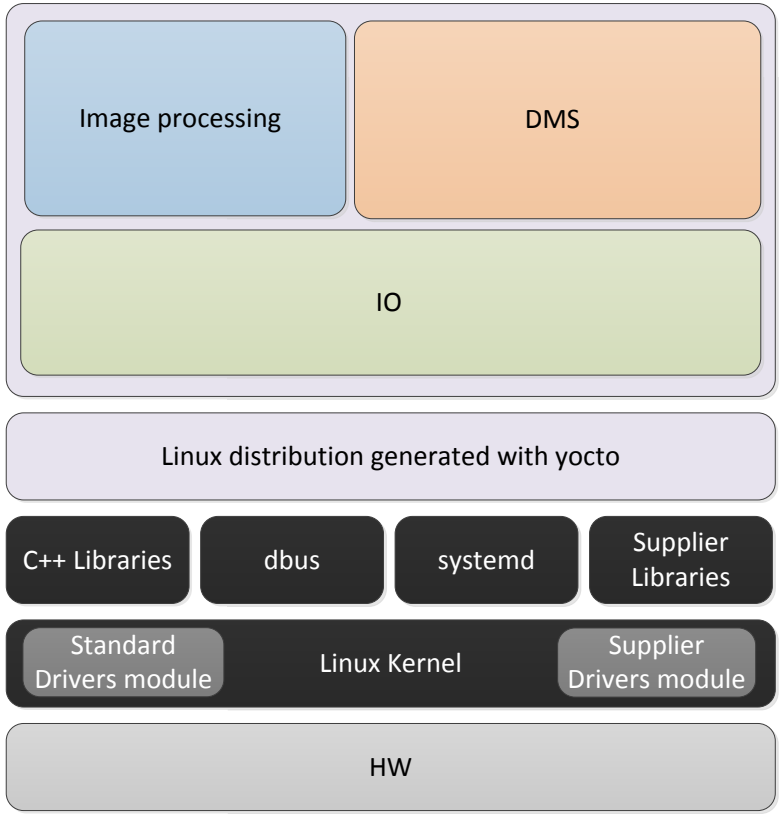
OPAZ

Tuesday @ 16:30
Poster session

- Optical Payload for Zephyr
  - Camera RGB 18cm over 1km²
  - Camera RGB 2m over 100km²
  - Live transmission
- Fully based on HW and SW COTS
- Embedded Linux:
  - Yocto distribution
  - SystemD : init and system manager
  - dBus : Inter process communication bus
- Keep it small and simple (KISS) design principle



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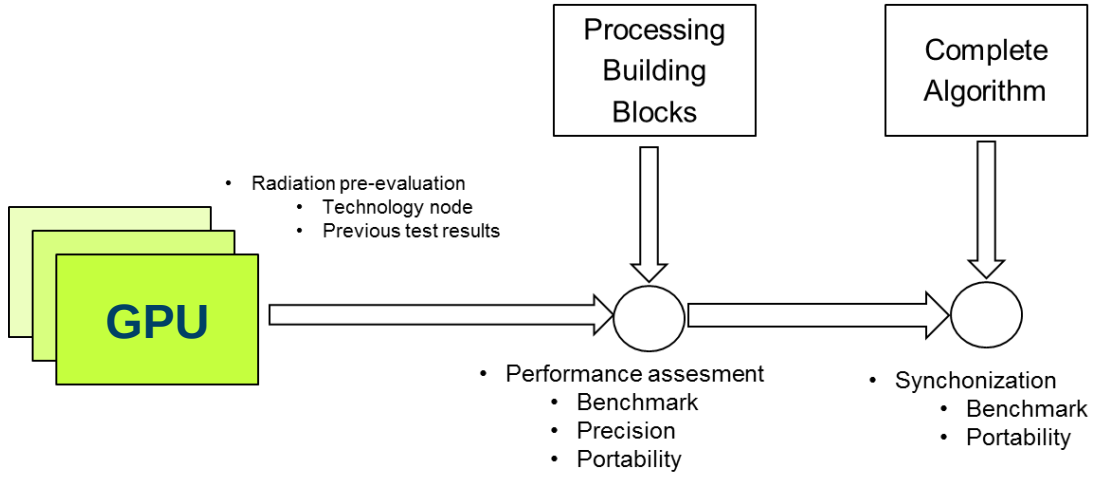
LPGPU4S - Low Power GPUs for Space

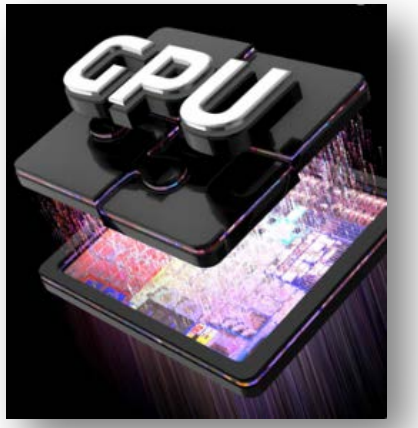
ESA Study with the Barcelona Supercomputing Center

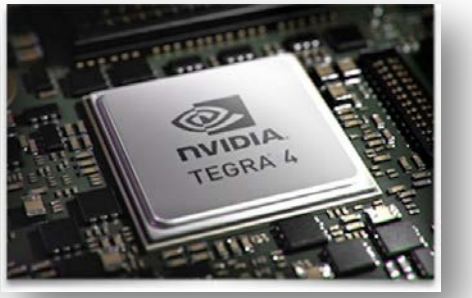
- Evaluation of Low Power GPUs for Space
  - Analysis of many GPU products
  - Main criteria's for evaluation
    - Technology robustness vs. radiation
    - Performance assessment (incl. power consumption)
    - Parallel Programming model
    - Licensing scheme
  - Application benchmarks

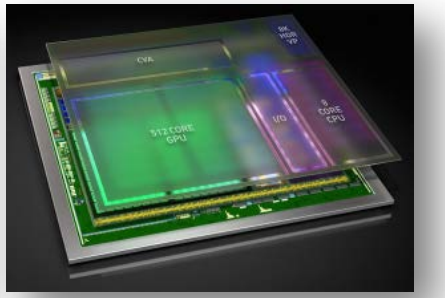
Wednesday @ 12:30

Evaluation methodology







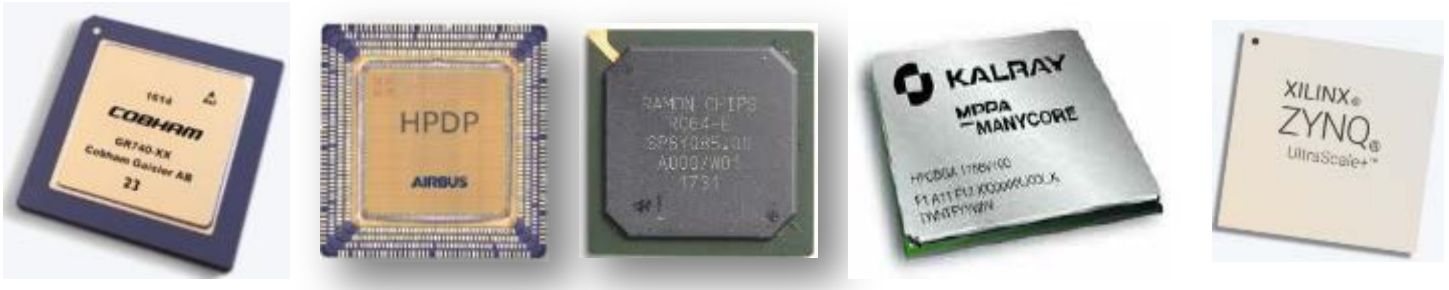


HP4S – High Performance Parallel Payload Processing for Space

ESA Study with the Barcelona Supercomputing Center

- S/W parallelisation with OpenMP
  - Selection of suitable MC targets
  - Adaptation/development of OpenMP
  - Application benchmarks
- Main criteria's for target selection
  - Technology robustness vs. radiation
  - HW compatibility with the OpenMP
  - Evaluation kit availability
  - S/W ecosystem and porting effort
  - Range of applications
- Evaluation benchmarks / use cases
  - ESA generic P/L processing benchmarks
  - GAIA VPU
  - Image processing
  - active mirrors
  - Robotics: disparity map, inverse kinematics

Target	Supplier	Type	Application	RH
GR740	Cobham-Gaisler	Quad Core Leon GPP	General purpose	Yes
MPPA	Kalray	80 cores clustered Processor Array (Coolidge)	General purpose with intensive Data flow	No
Zynq	Xilinx	Quad Core ARM53 on MPSoC	General purpose with internal FPGA accelerator	No
RC64	Ramonchip	64 DSP cores NoC	DSP	Yes
HPDP	Airbus-DS	40 cores Processor Array	Data flow intensive processing	Yes



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Conclusion

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Rad-hard space computers

- **Processing elements**
  - LEON family up to GR740
  - BRAVE family (DAHLIA , FPGA + MPSoCs)
  - Manycores (HPDP, RC64)
  - ASICs

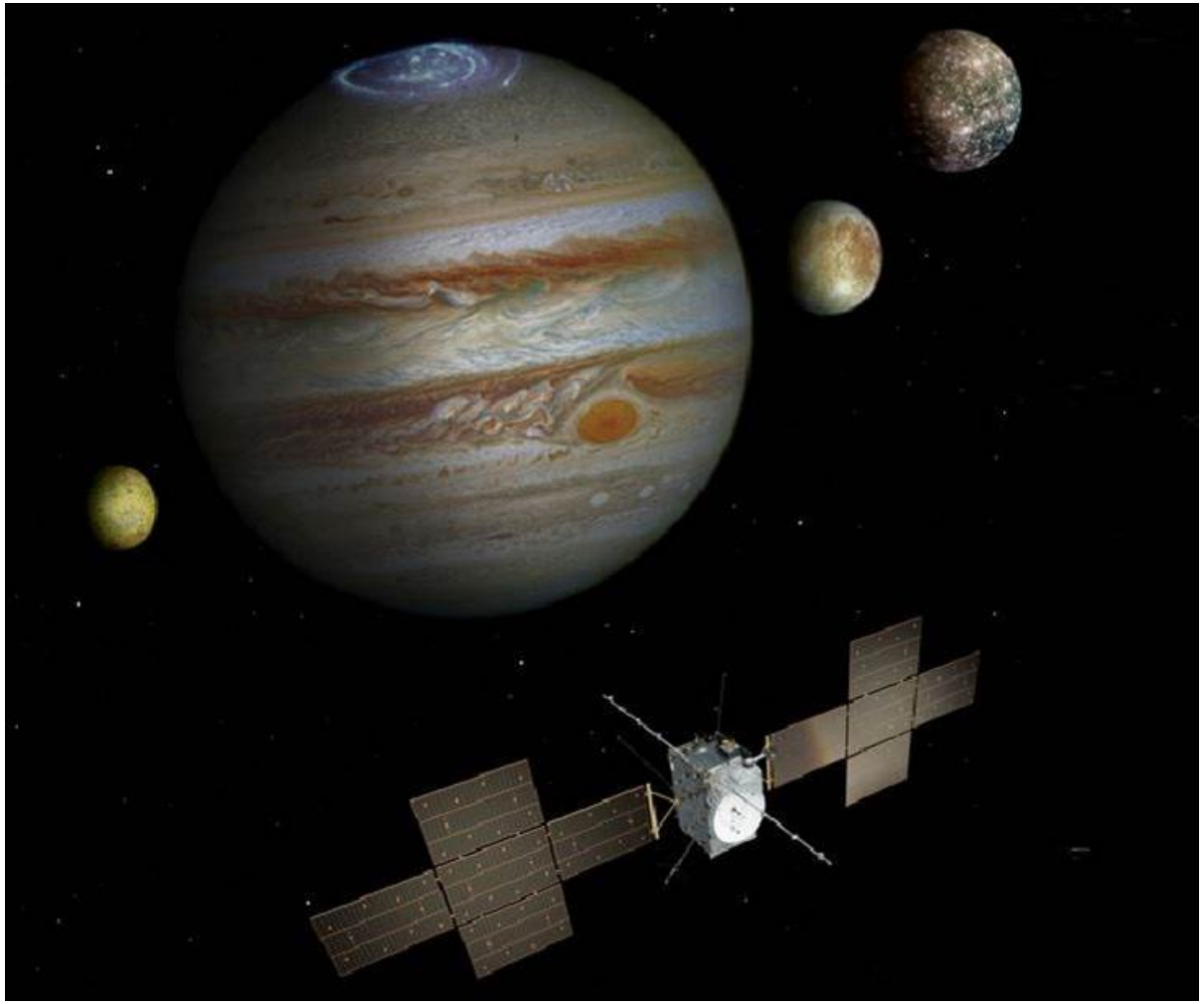
GENERIC

SPECIFIC

- **Applications**
  - Harsh environment, deep space science and exploration, critical functions…
  - Long duration/critical missions in GEO/LEO
  - Low number of spacecraft
- **High RC / High NRC**
  - Specific Technologies & Tools
  - Long developments cycles

Modular products with generic devices

Hardware Integration - Software Partitioning



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COTS-Based fault tolerant computers

- **Processing elements**
  - MP Processors (ARM, PPC, RiscV…)
  - FPGAs (Kintex…) and MPSocs (Zynq…)

  GENERIC
  - Manycores (Low power GPUs, MPPA,…)

  HIGH PERF
- **Applications**
  - "*new space*" constellations, Low Earth Orbit, launchers, non-critical functions, Short missions
  - Very high Performance non critical computers
  - Fast expanding market
- **High NRC / Medium to Low RC**
  - Mitigation of radiation effects
  - Component characterisation and qualification
  - Obsolescence management
  - Low Recurring Cost with large number of units

→ Product lines with Large application range

→ Adoption of COTS standards and oftware

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Thank you for your attention !

Questions ?

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