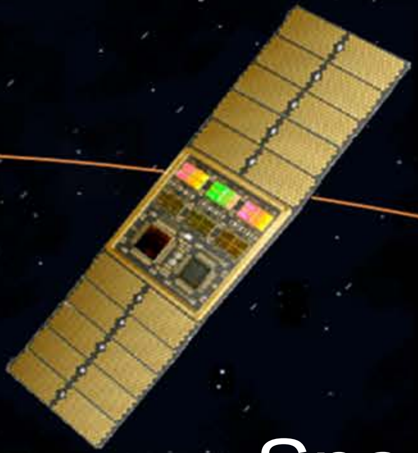

Space Processors

ADCSS 2017
ESTEC, Noordwijk, The Netherlands

DEFENCE AND SPACE

Olivier Notebaert
2017, October 19th

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F P G A S I C P U

Flexibility Performance Green Autonomy Smart Intelligence Communications User

Friendly Products Generic Availability Sustainable Integration Costs Useful

Fast Productivity Global Affordable Simple Innovative COTS Universal

Space Processors

?

needs

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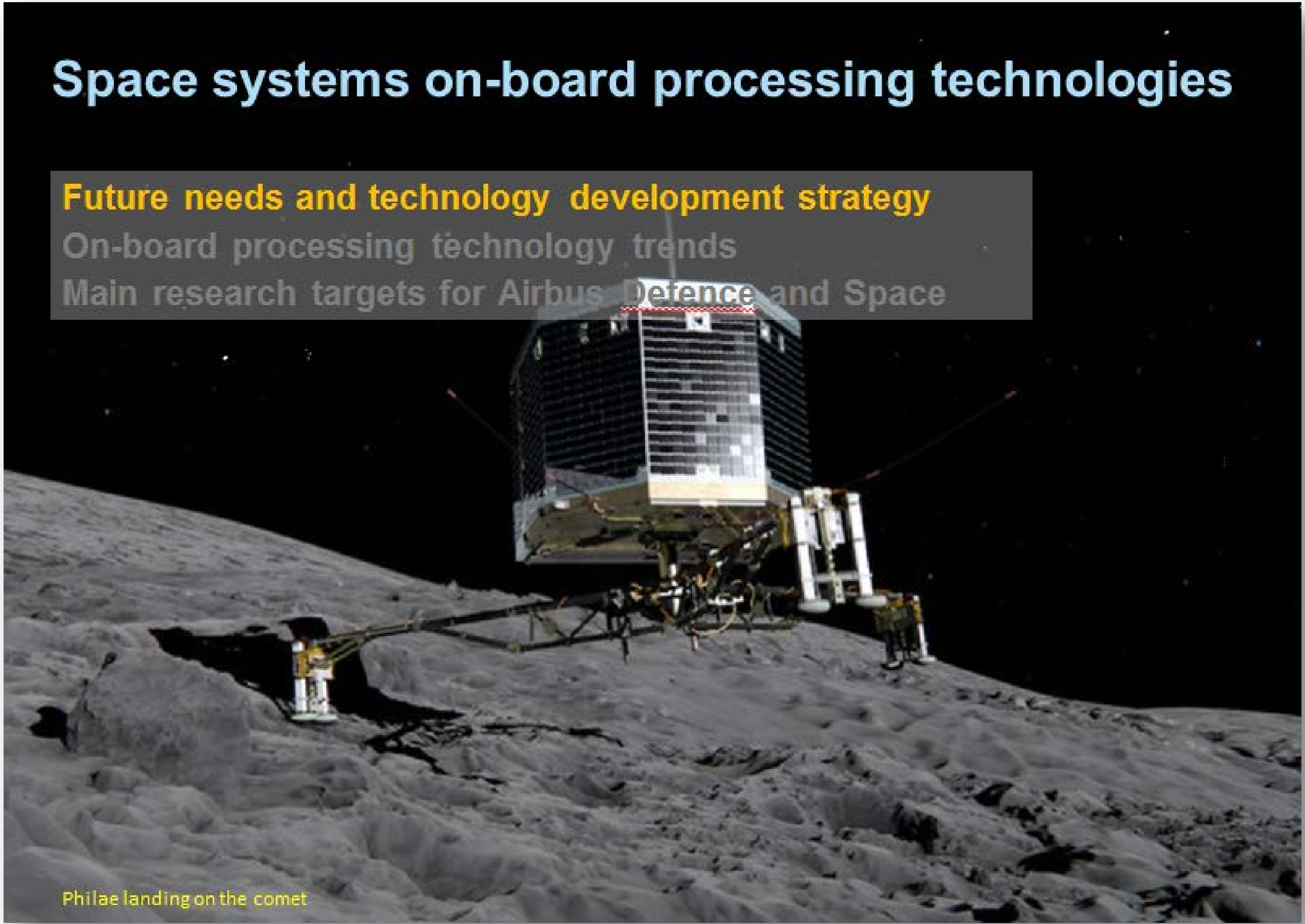
Avionics Technology Trends

@ ADCSS 2015



OPEN

Avionics Technology Trends

@ ADCSS 2015

+ in Orbit Servicing
+ Deep Space Gateway
…

Research & Technology activities in on-board data processing domain

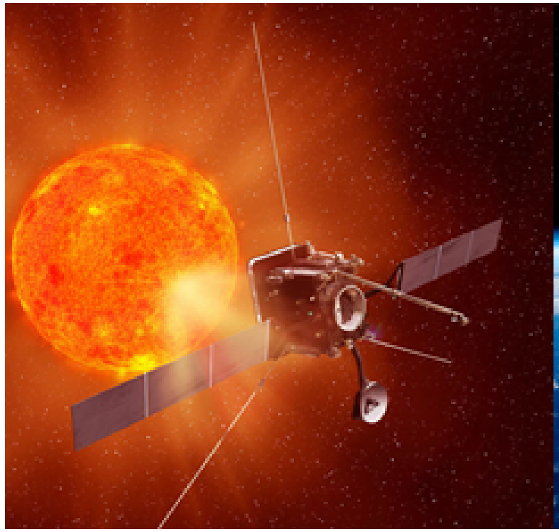
Future missions

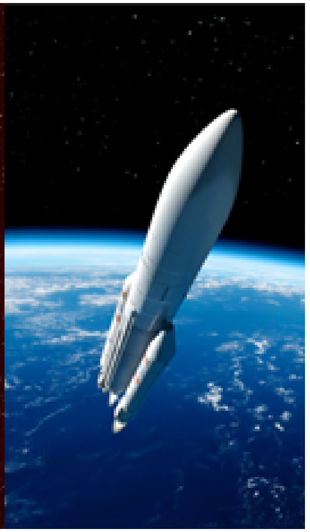
In development

- Space science and exploration program – Bepi-Colombo, Solo, Euclid, Juice…
- Metop-SG
- Next generation telecom
- Ariane 6
- Human Flight: ORION
- Large constellations (OneWeb)

Longer term

- Machine to Machine services
- Multi-service payloads
- Highly flexible and autonomous systems
- Space exploration robotic systems
- Vision based navigation
- Reusable launchers
- Space plane
- …





ADCSS 2015 Workshop on avionics technology trend
October 21st, 2015, ESA/ESTEC, Noordwijk, The Netherlands

9/25

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Avionics Technology Trends

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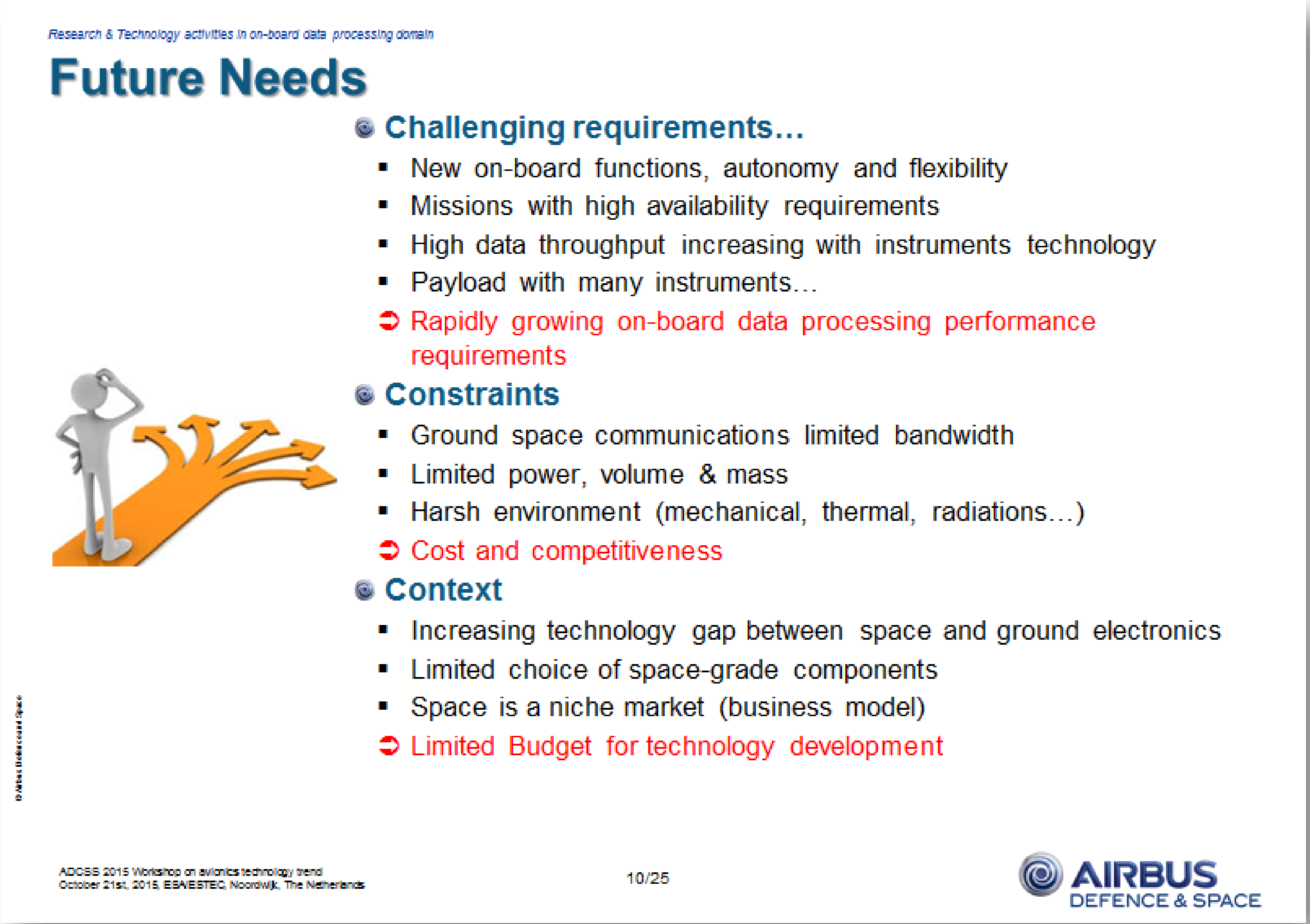

Research & Technology activities in on-board data processing domain

Future Needs

- **Challenging requirements…**
  - New on-board functions, autonomy and flexibility
  - Missions with high availability requirements
  - High data throughput increasing with instruments technology
  - Payload with many instruments…
  - ➲ Rapidly growing on-board data processing performance requirements
- **Constraints**
  - Ground space communications limited bandwidth
  - Limited power, volume & mass
  - Harsh environment (mechanical, thermal, radiations…)
  - ➲ Cost and competitiveness
- **Context**
  - Increasing technology gap between space and ground electronics
  - Limited choice of space-grade components
  - Space is a niche market (business model)
  - ➲ Limited Budget for technology development

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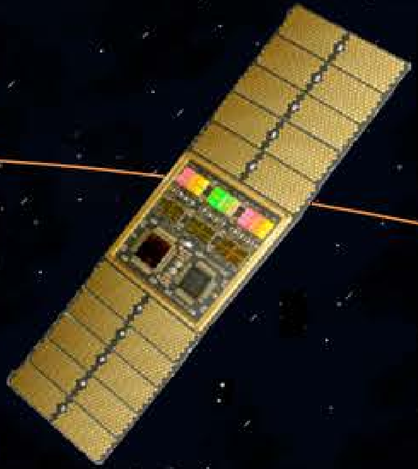
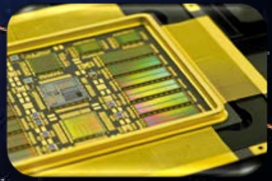
Orbit



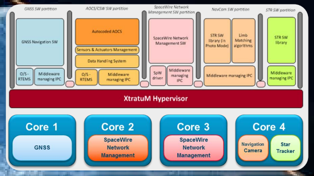
Targets

Technology

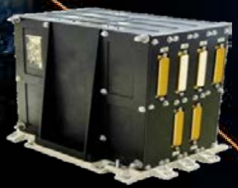


COTS components

Software



Products



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Targets

Technology

COTS components

Software

Products

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Targets

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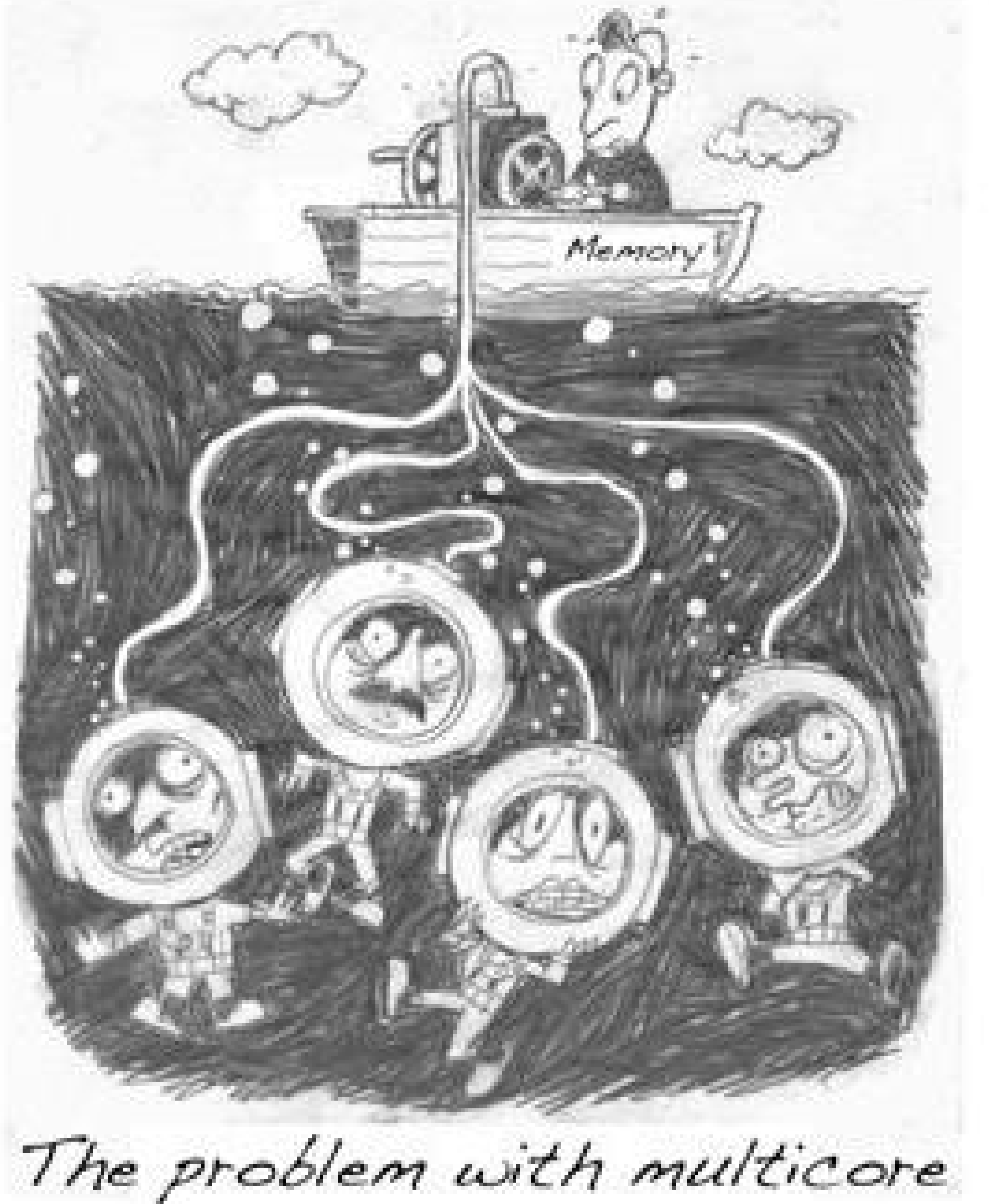
Targets

Technology

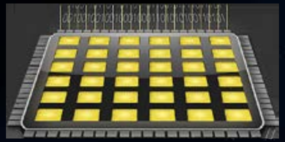
COTS components

Software

Products



Technology



Multicore

Performance

Constraints

Game change

Is not

a
requirement

Is

an
enabling
Technology
for
Performance
&
Integration

Size

180nm
150nm
90nm
65nm
28nm
24nm
16nm

Power

more
GHz
Gbit/s
GFLOPS
per Watt

Resources

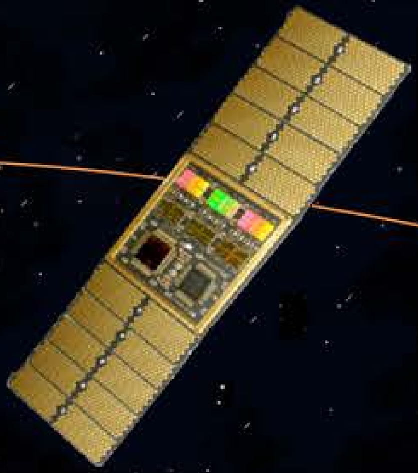
shared
Memory
cache
I/Os
FPU

Software

parallelism
SMP
AMP
MTAPI
OpenMP
OpenCL

Orbit

Targets



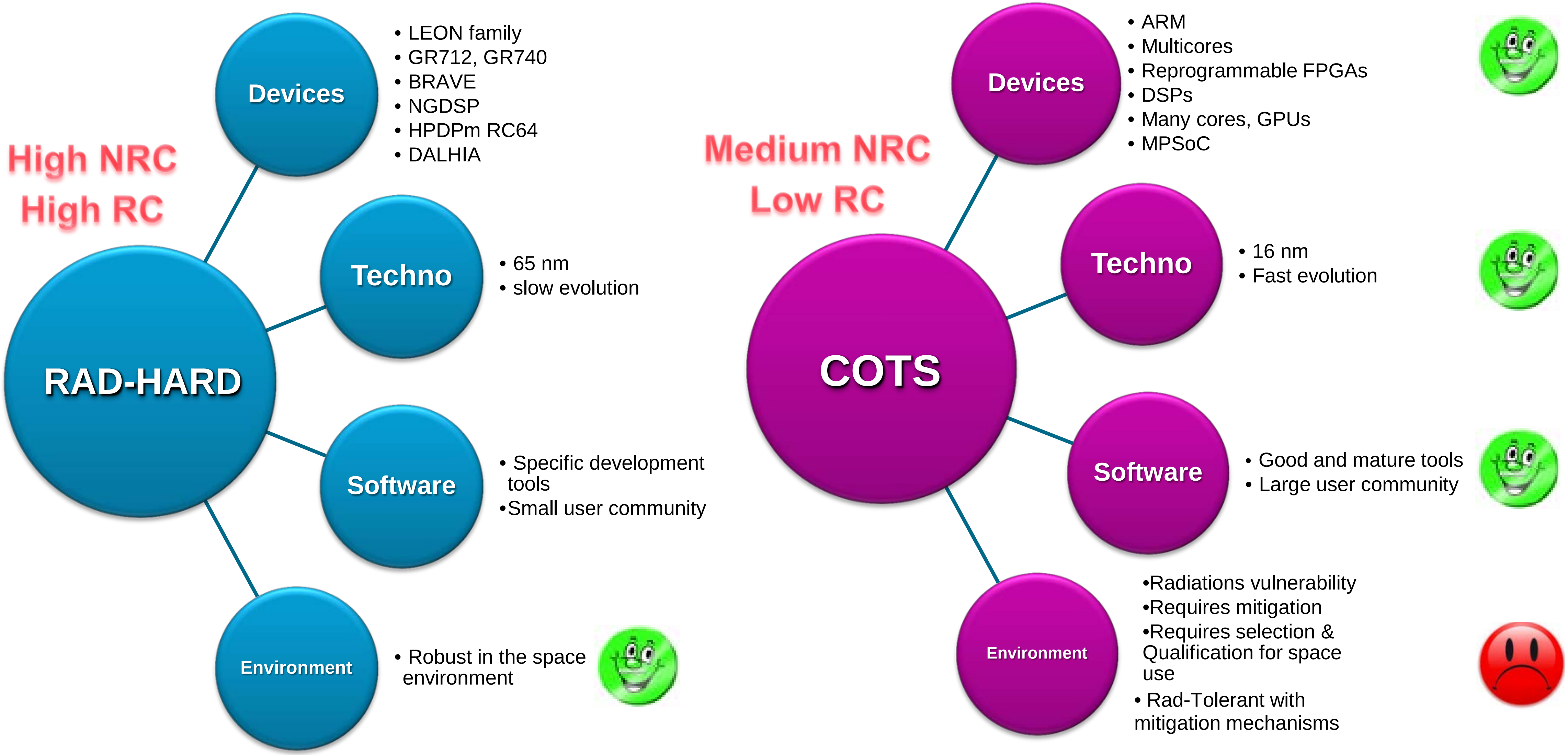
Technology

COTS components

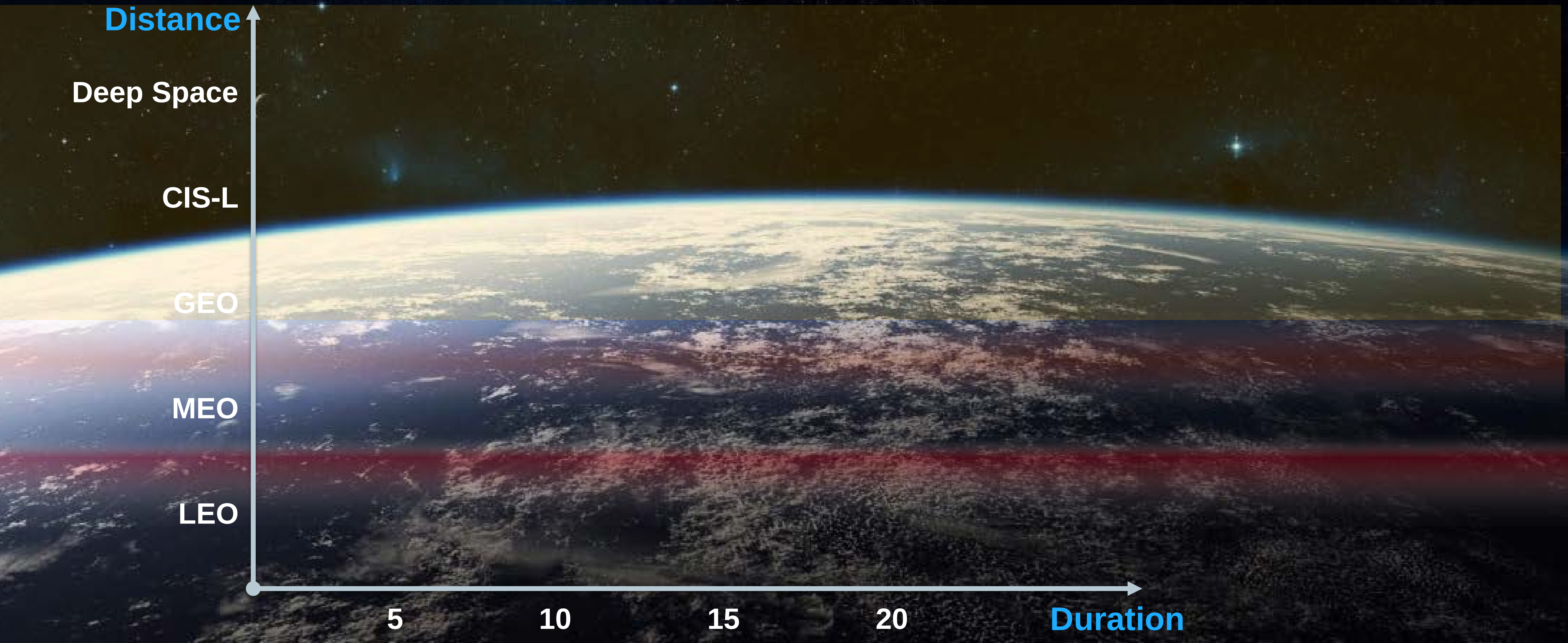
Software

Products

Why COTS ?


High NRC
High RC
RAD-HARD
Devices
• LEON family
• GR712, GR740
• BRAVE
• NGDSP
• HPDPm RC64
• DALHIA
Techno
• 65 nm
• slow evolution
Software
• Specific development tools
•Small user community
Environment
• Robust in the space environment
Medium NRC
Low RC
COTS
Devices
• ARM
• Multicores
• Reprogrammable FPGAs
• DSPs
• Many cores, GPUs
• MPSoC
Techno
• 16 nm
• Fast evolution
Software
• Good and mature tools
• Large user community
Environment
•Radiations vulnerability
•Requires mitigation
•Requires selection & Qualification for space use
• Rad-Tolerant with mitigation mechanisms

Radiations



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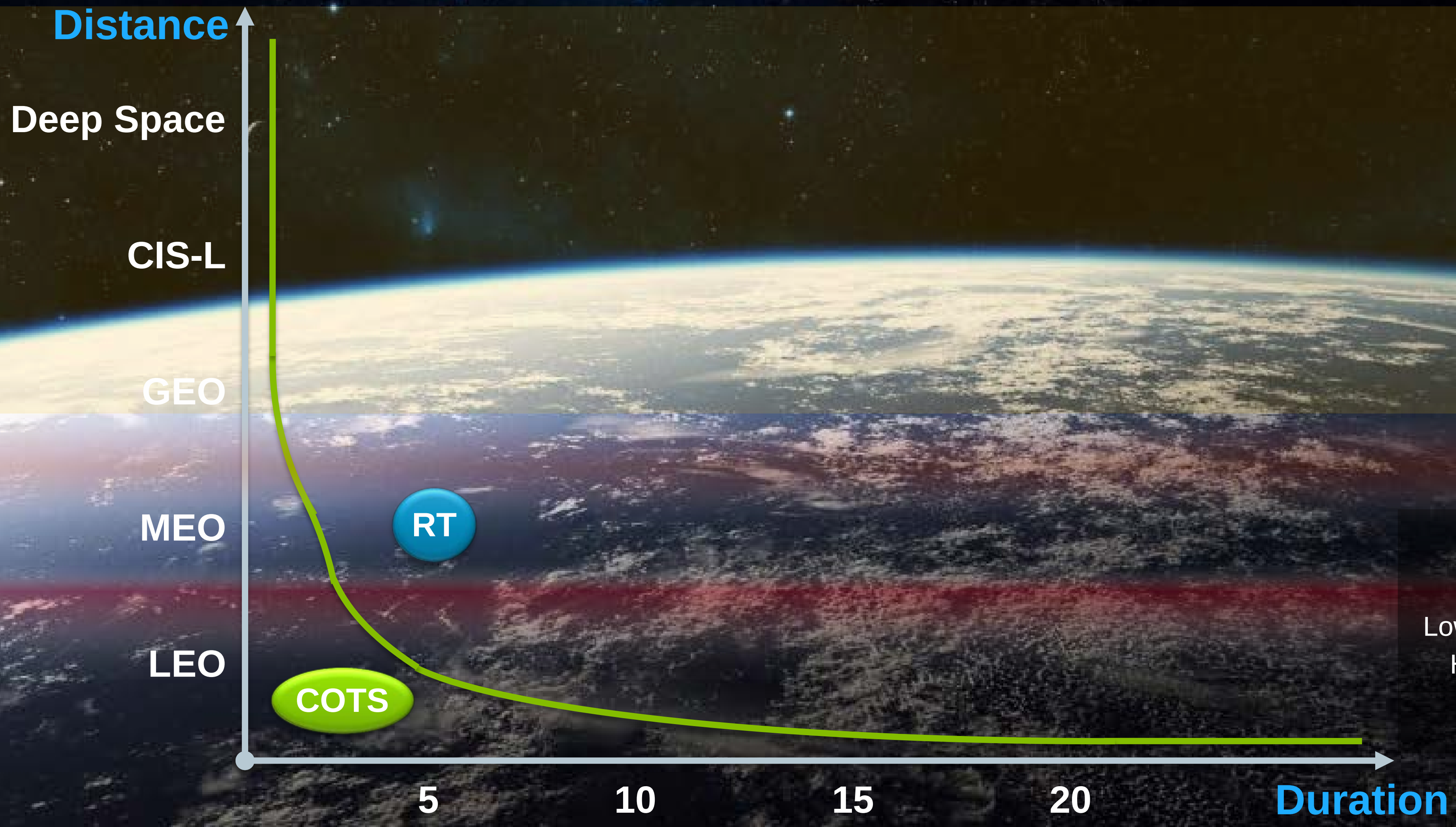
Low Earth Orbit applications



LEO applications

Low to Medium duration

Low to Medium exposure to radiations

High commercial market pressure

→ COTS or Rad-Tolerant

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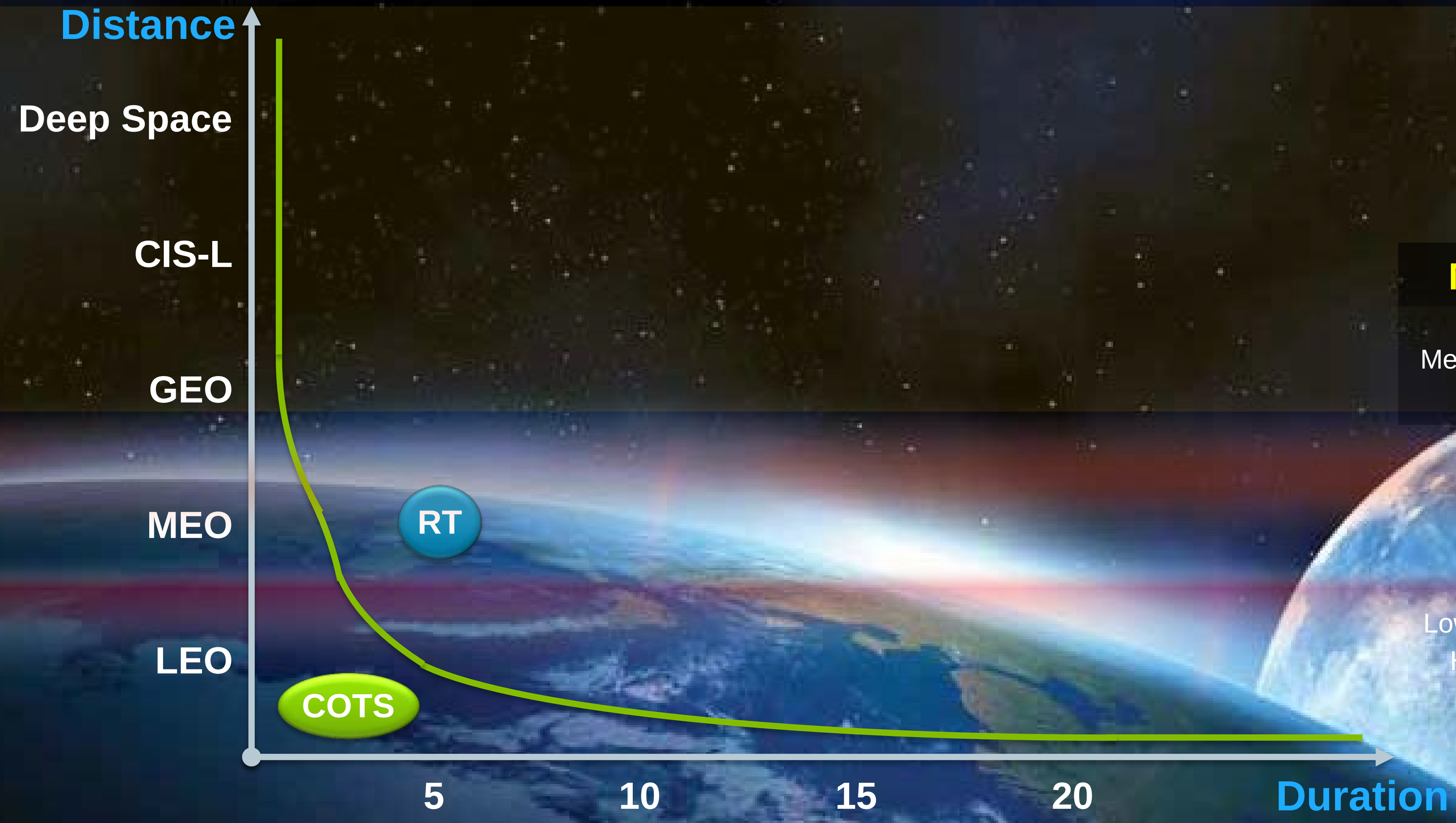
Medium Earth Orbit & Geostationary applications



MEO/GEO applications

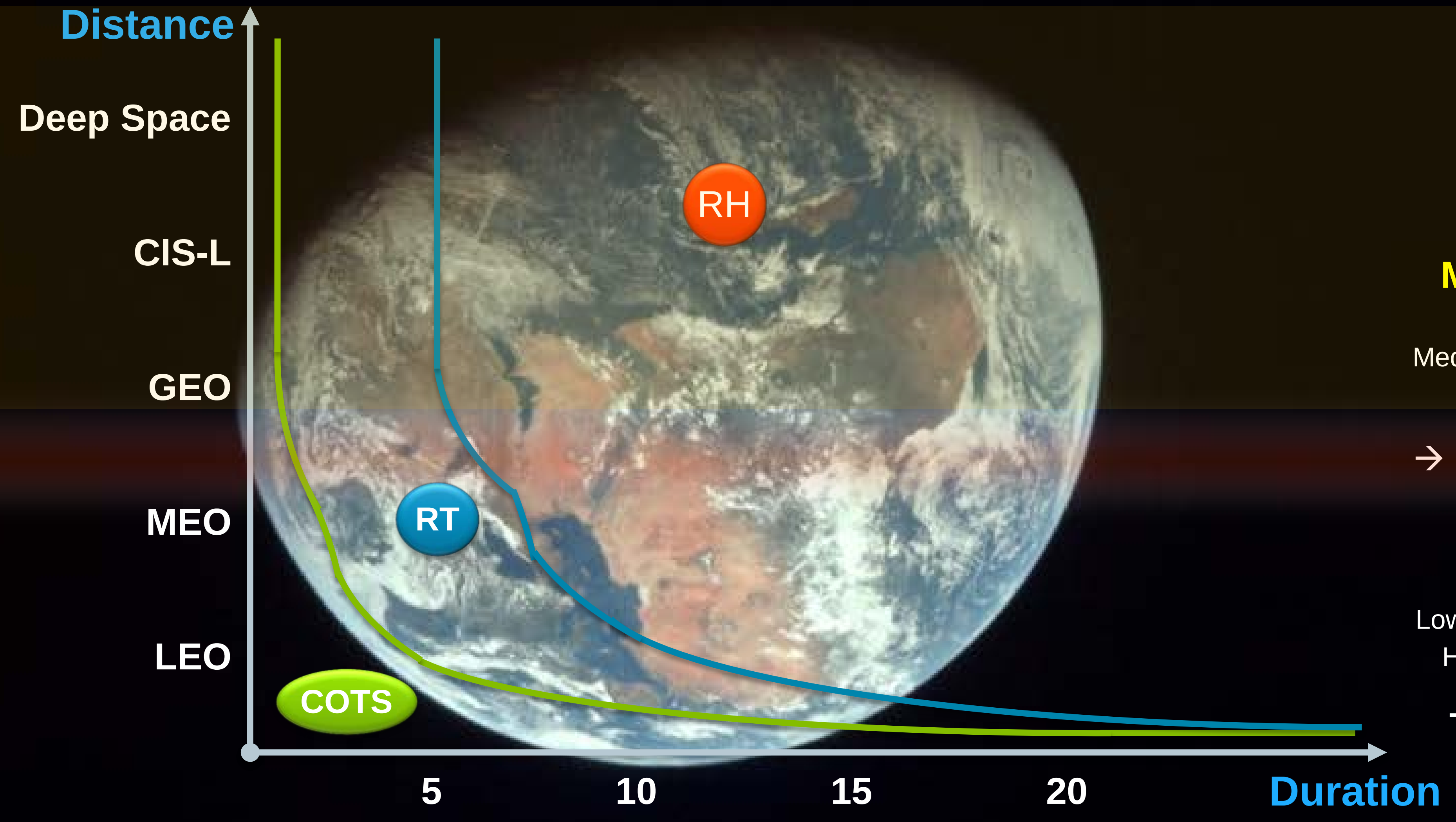
Medium to Long duration
Medium to High exposure to radiations
Commercial market pressure

LEO applications

Low to Medium duration
Low to Medium exposure to radiations
High commercial market pressure

→ COTS or Rad-Tolerant

Medium Earth Orbit & Geostationary applications



MEO/GEO applications

Medium to Long duration
Medium to High exposure to radiations
Commercial market pressure

→ Rad-Tolerant or Rad-Hard

LEO applications

Low to Medium duration
Low to Medium exposure to radiations
High commercial market pressure

→ COTS or Rad-Tolerant

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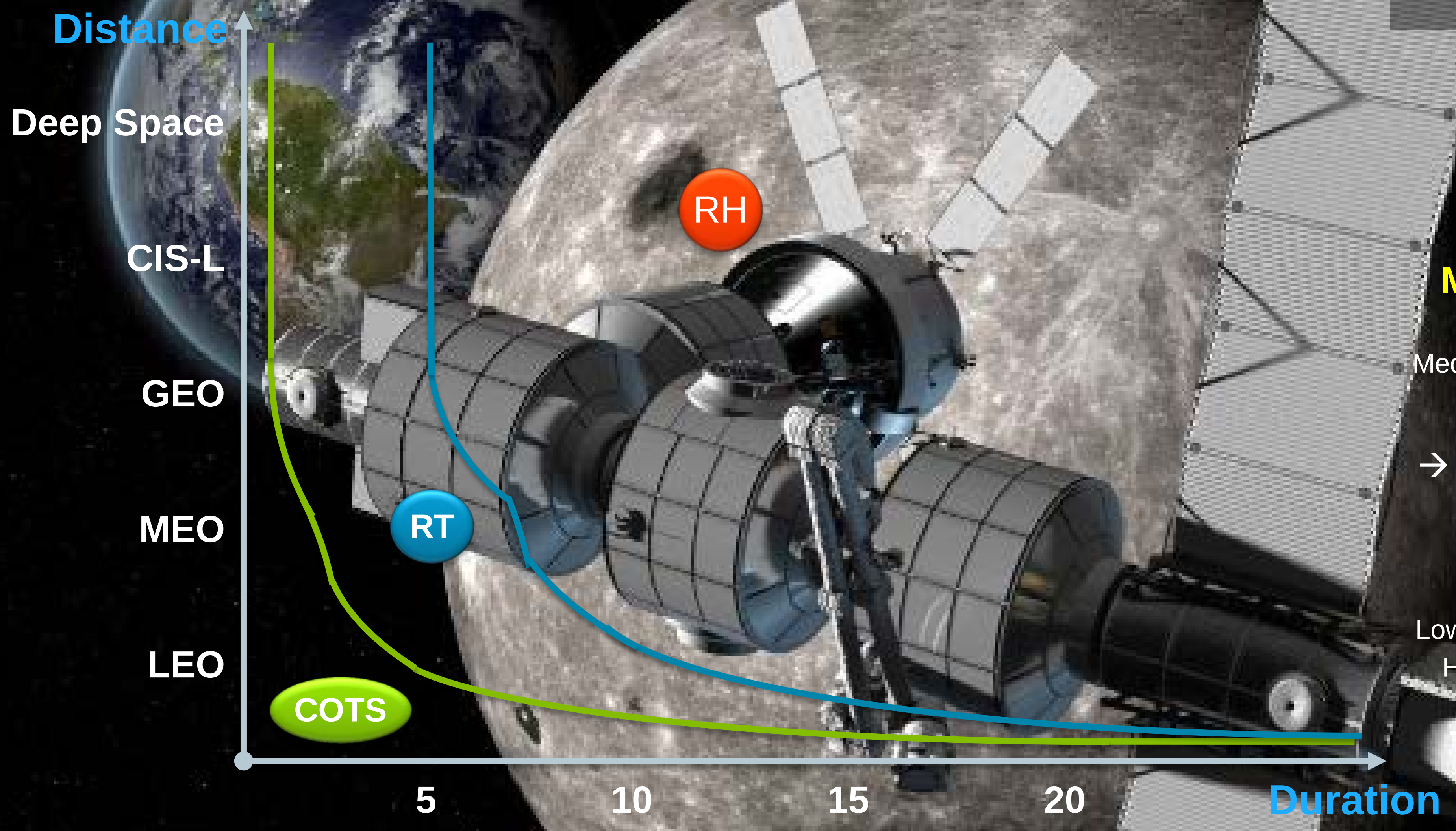
Deep Space applications



Deep Space

MEO/GEO applications

Medium to Long duration
Medium to High exposure to radiations
Commercial market pressure

→ **Rad-Tolerant** or **Rad-Hard**

LEO applications

Low to Medium duration
Low to Medium exposure to radiations
High commercial market pressure

COTS or **Rad-Tolerant**

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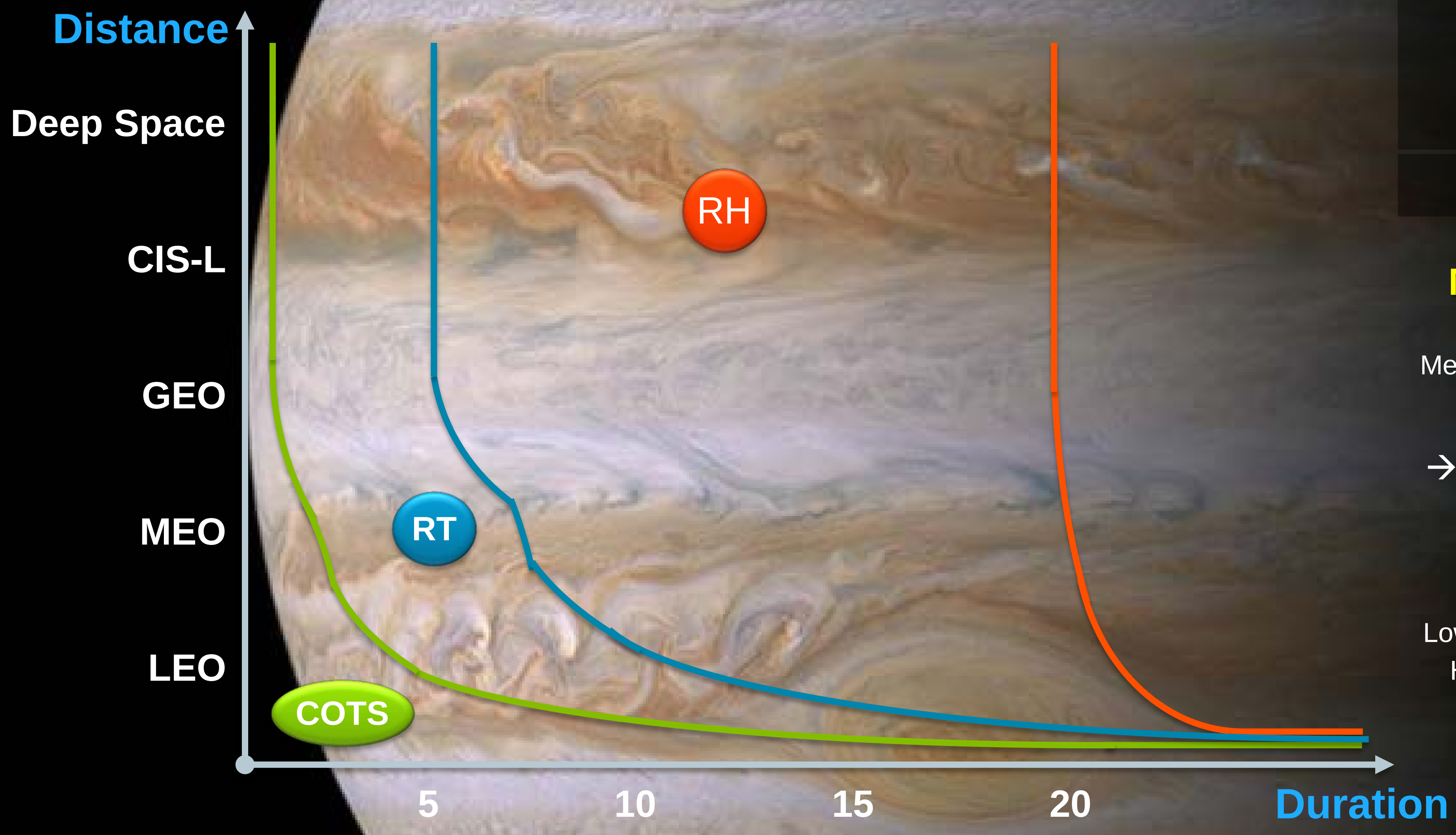
Deep Space applications



Deep Space

Medium to Very Long duration
High exposure to radiations
Mostly institutional

→ Rad-Hard

MEO/GEO applications

Medium to Long duration
Medium to High exposure to radiations
Commercial market pressure

→ Rad-Tolerant or Rad-Hard

LEO applications

Low to Medium duration
Low to Medium exposure to radiations
High commercial market pressure

→ COTS or Rad-Tolerant

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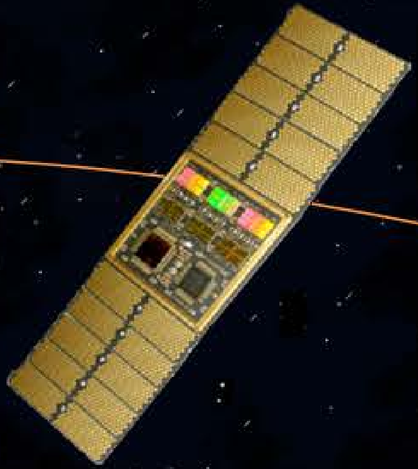


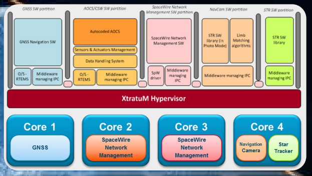
Targets

Technology

COTS components

Software

Products



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Software with Multicores

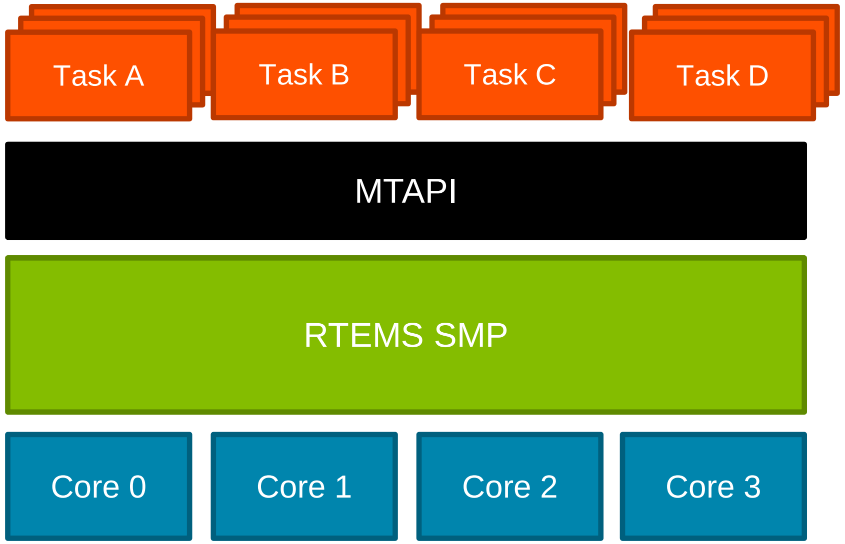
Efficient programming of a multicore processor is tricky
- Performance is actually limited by our ability to effectively load all processing cores
- applies both for RTOS and at application level
- hard real time and deterministic execution is difficult to achieve

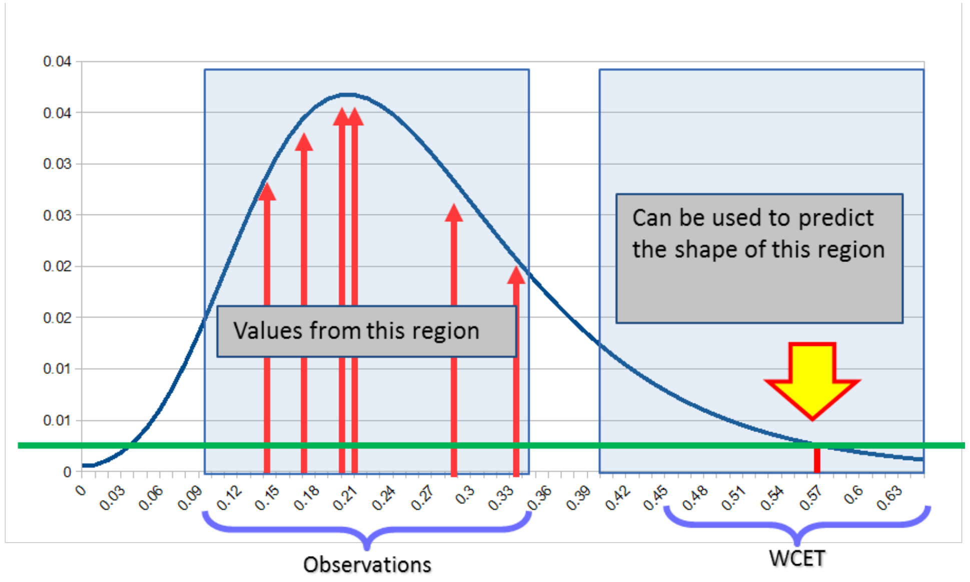
Adaptation of methodology, engineering tools, development environment, Software Execution Platform
- Operating Systems and Hypervisors
- Methods and tools to facilitate and optimise software parallelisation on several cores
- Development of runtime libraries for parallel programming
- Schedulability and timing analysis, WCET estimation vs. proof

Support by EU, ESA and National Agencies R&T programs

PROARTIS PROXIMA Embedded With RTEMS www.rtems.com

SAVOIR space avionics open interface architecture P4S XtratuM





Software

Instrument Data Processing Performance

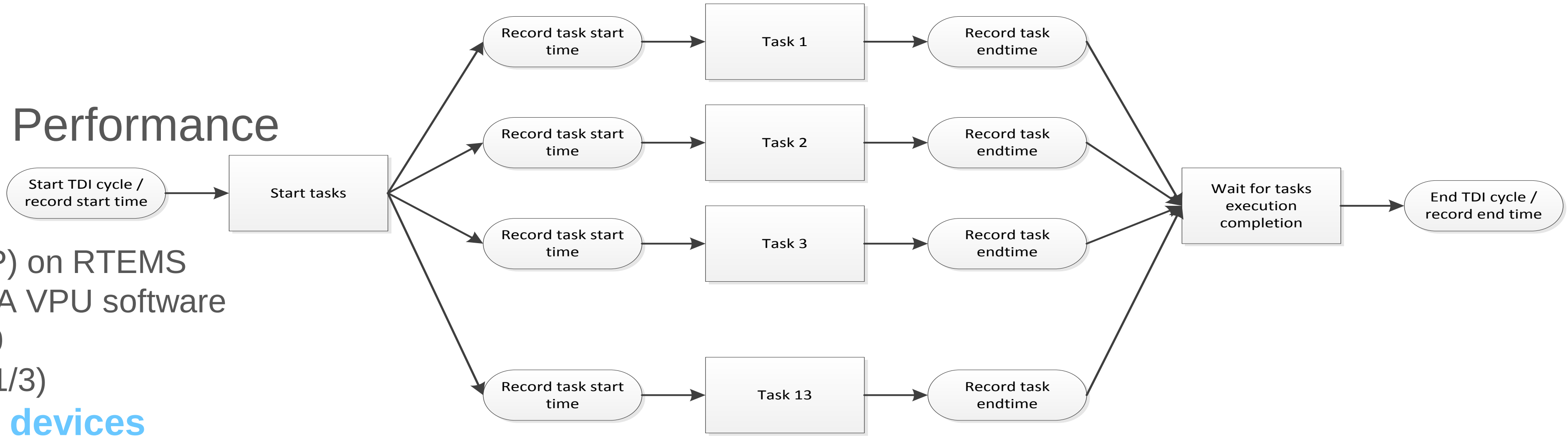
➢ Software parallelization

GR740: GAIA VPU benchmark

– Symmetrical Multi Processing (SMP) on RTEMS
– With a GR740 @ 250 MHz the GAIA VPU software runs as fast as on Maxwell SCS750 with much better power efficiency (1/3)

Data processing on many core devices

– Use of OpenMP, OpenCL with
  – HPDP
  – RC64
  – GPUs
  – SPDP

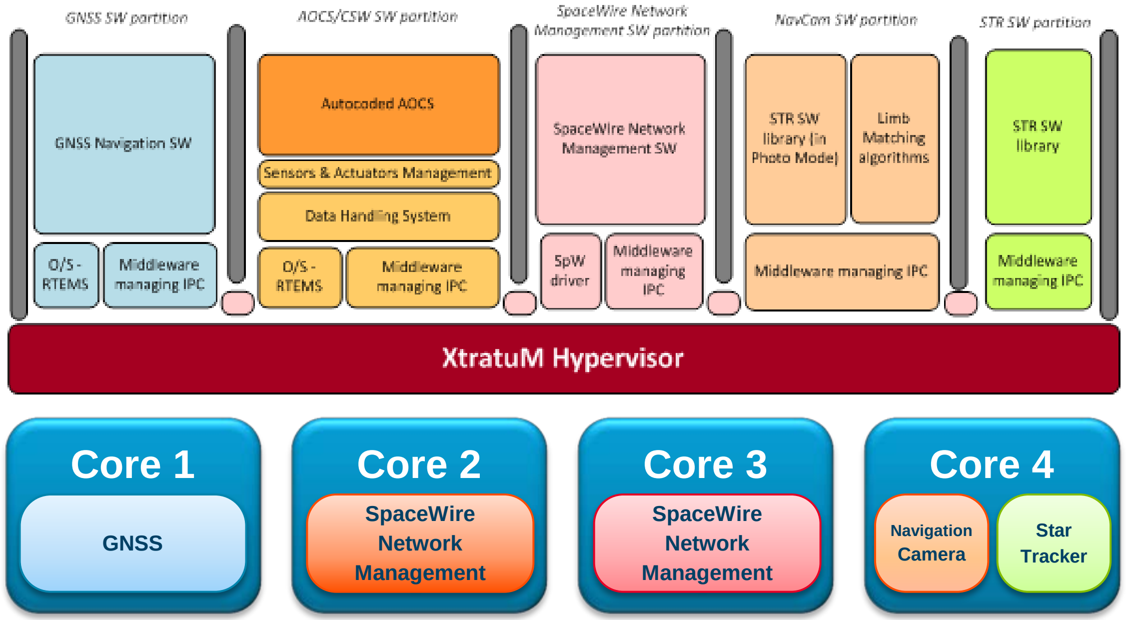


Satellite Avionics Integration

➢ Functional integration in the central computer

esa study « AOCS SpaceWire Prototyping »

- Quad-Core LEON4FT processor (GR740)
- XtratuM Hypervisor for Time and Space Partitioning
- Asymmetrical Multi Processing with static mapping of the partitions on the 4 processing cores



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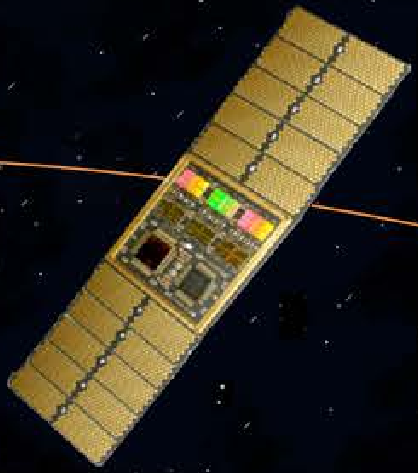


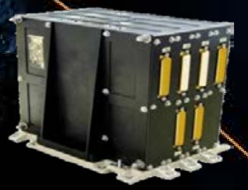
Targets

Technology

COTS components

Software

Products



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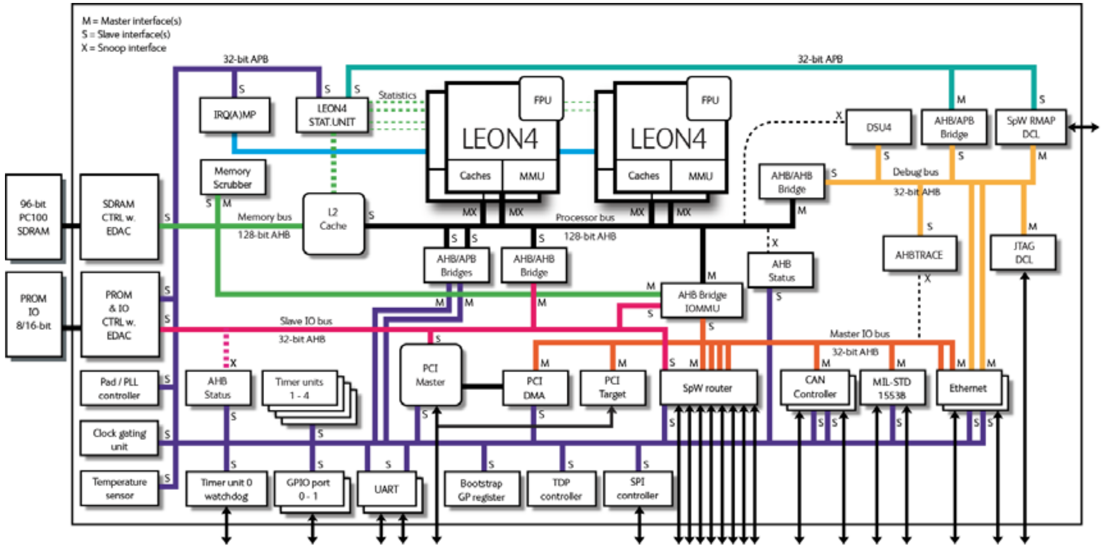
Processor Products

Existing devices (RH, RT or COTS)

- GR712 – Dual-core Leon3FT, 180nm → Juice
- GR740 – Quad-core Leon4FT, 65nm → IOS
- Several ARM® devices, including RT and RH
- ARM® dual-cores used in dual-core lock step
  → Ariane 6 + "new space" in LEO



Devices in development (not exhaustive)

- **Computer systems**
  - JUICE DPU (GR712)
  - OMACS4S (GR740, ARM)
  - Compact Reconfigurable Avionics Data Handling Core (GR740 and BRAVE)
- **Demonstrators**
  - AOCS SpaceWire Prototype (GR740)
  - Compact Reconfigurable Avionics
- **Processing devices based on ARM® processor cores**
  - TCLS ARM® 4 Space
  - DAHLIA
  - COTS MPSOCs with embedded FPGA (e.g. Zynq® Ultrascale™)

\+ **Many-cores / NoC / Arrays of processors**
(for high performance digital signal processing)
  - HPDP
  - MPPB/SSDP
  - RC64
  - MPPA 256, MPPA 64 (Kalray)

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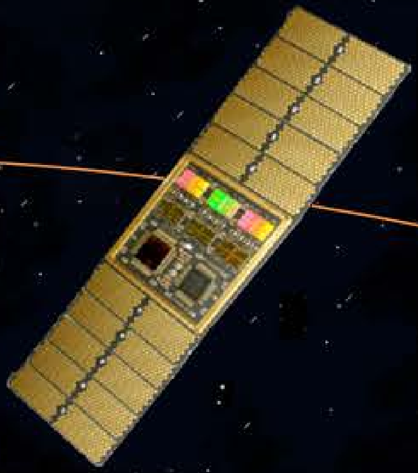
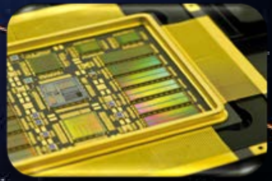
Conclusion



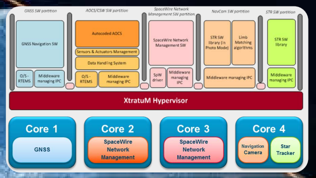
- Targets

- Technology

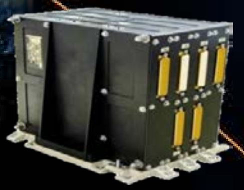


- COTS components

- Software



- Products



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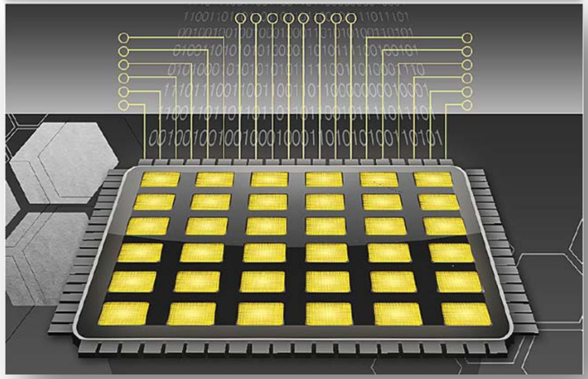
OPEN

Detailed Summary

On-board processing



opportunities

- **High flexibility and data processing performance for instruments**
  - enabling new advanced space missions
- **Overall reduction of cost, mass, volume and energy consumption through**
  - high integration of on-board computing functions
  - increased development of ARM based products
  - evolution towards Integrated Modular Avionics

challenges

- **Development of generic products (multicore or not)**
  - compact and reconfigurable on-board computers
    - Spacecraft Controllers and Payload Data Processing Units
    - Including reconfigurable FPGA's with efficient Support Software
  - Rad-Hard for deep space / missions with harsh radiation conditions
  - COTS based at very low recurring cost for new space markets
    - Selection Process
    - radiation mitigation techniques
- **Development/adaptation of software engineering framework**
  - Efficient use and control of Multi Core Processing resources
  - Support for efficient software parallelisation
  - Low level software execution platform products
  - Adapted software engineering methods and tools

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Check list

Performance	• Multi/Many-cores • Technology shrink • COTS components
Cost	• COTS and RT components • ARM • Integration / T&SP
Flexibility	• Processors • Reconfigurable FPGAs • Modular architecture
Non Dependency	• GR740 • BRAVE • DAHLIA

Thank you for your attention

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