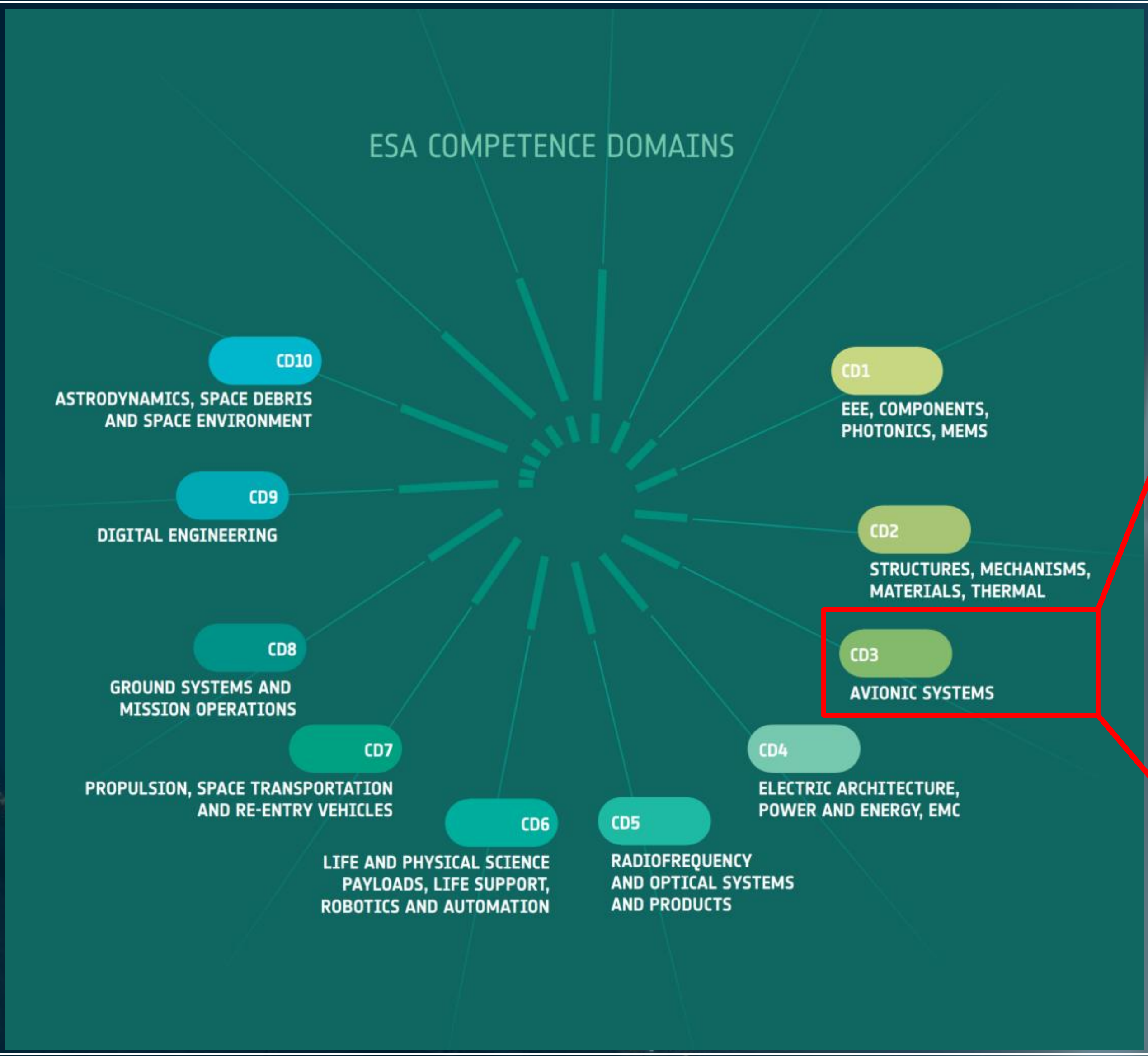
ESA TECHNOLOGY STRATEGY
Competence Domain 3 (AVIONICS)

ADCSS 2021 (16/11/2021)

Prepared by the Competence Domain 3 team

Presented by Olivier Mourra (CDL of CD3)

CD3 perimeter (1/3)



3 2 1 5	AOCS Sensors and Actuators
3	Avionics Embedded Systems
3	Data Systems and On-Board Computers
3 1	Microelectronics: ASIC & FPGA
3	On-Board Payload Data Processing
3 5	On-Board Radio Navigation Receivers
3 9	On-Board Software
3 5	RF & Optical Metrology
3 5 8	TT&C Transponders and Payload Data Transmitters
5 1 3 8	Optical Communication for Space

2020 Report - Implementation of the Harmonised European Space Technology Roadmaps

Main tasks of the Competence Domains

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- *Collection of new R&D ideas and coordination of ESA experts*
- *Formulation of the R&D Technology Strategy with “bottom-up” (strategic lines for specific technologies) and “top-down” (mission/market/industry oriented) approaches.*
- *Coordination with ESA Programmes via the TECNET (future missions and LL)*
- *Definition of Technical Dossiers and Road Maps*
- *Follow the R&D activities implementation and achievements*

…

CD3 perimeter (2/3)

CD03

TT&C E2E systems
Space communication architecture, payload data modulator, transponder, TT&C on-board RF/optical & antenna

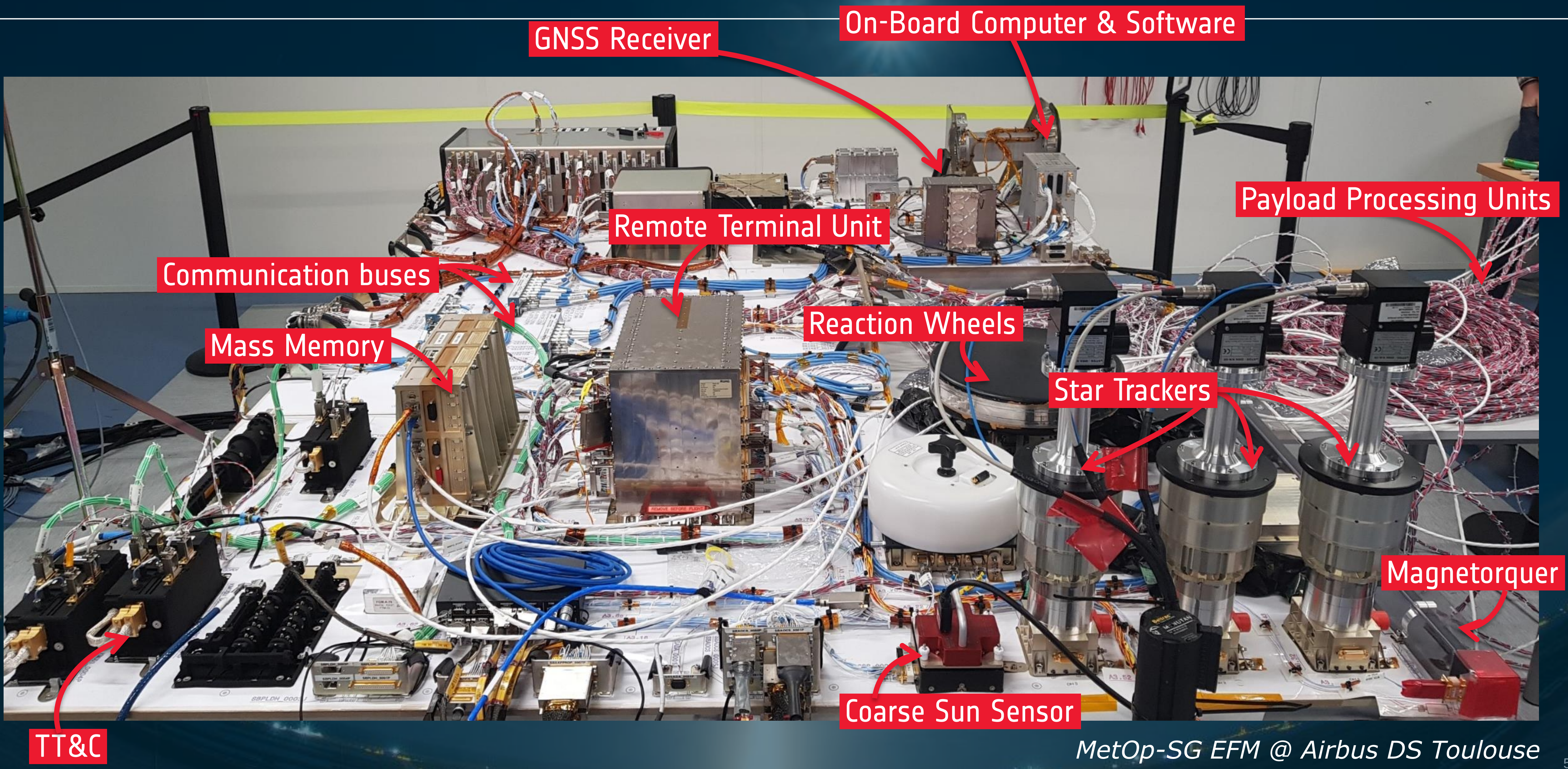
Avionics systems
Avionics Architecture, on-board communication, on-board autonomy, FDIR, operability, on-board security, on-board GNSS receiver

Control systems
AOCS & pointing, GNC, enabling technologies, control techniques, sensors, RF and optical metrology

On-Board Computer - Data Handling Systems & micro electronics
Data Handling Architecture, Data processing and management, platform/payload on-board computers, data storage, on-board networks, and microelectronics (incl. HW-SW co-design)

Software systems
flight software, software quality, dependability & safety

CD3 perimeter (3/3)



MetOp-SG EFM @ Airbus DS Toulouse

CD3 Composition (1/2)

8

TEC Divisions

from TEC-S, TEC-Q, TEC-E & TEC-H

CD03

TEC-SP

TEC-SW
TEC-SWT
TEC-SWF

TEC-SA
TEC-SAG

TEC-QQ
TEC-QQD
TEC-QQS

TEC-H

TEC-ED
TEC-EDD
TEC-EDM

TEC-EF
TEC-EFD

TEC-ES
TEC-ESN
TEC-EST
TEC-ESS

#130

Technical Officers

from 11 sections

SAVOIR
space avionics open interface architecture

CD3 Core Members Composition (2/2)

Name	Entity	CD3 role
Mourra O.	TEC-EDD - On-Board Comp. & Data Handling Section	CD3 Lead – Interface (Main) to TECNET GEN
Honvault C.	TEC-SWT - Software Technology Section	CD3 Co-Lead - Interface (Deputy) to TECNET GEN
Zdybski S.	TEC-H - Technology Coordination & Planning Office	TEC-H interface to CD3
Fuchs J.	TEC-SW - Software Systems Division	Core Member
Casasco M.	TEC-SAG - Guidance, Navigation & Control Section	Core Member - Interface (Main) to TECNET ST & EXP
Girouart B.	TEC-SA - GNC, AOCS & Pointing Division	Core Member - Interface (Main) to TECNET EO and deputy Interface to TECNET TEL
Bennani S.	TEC-SA - GNC, AOCS & Pointing Division, Systems Department	Core Member
Mellab K.	TEC-SP - Projects Office	TEC-S Nominated Member
Jung A.	TEC-SWF - Flight Software Systems Section	Core Member – Interface (Main) to TECNET SCI
Zadeh A.	TEC-ED - Data Syst, Microelectr. & Comp.Tech.Division	Core Member - Interface (Deputy) to TECNET SCI
Marinis K.	TEC-EDD - On-Board Comp. & Data Handling Section	Core Member - Interface (Main) to TECNET TEL
Giordano P.	TEC-ESN - Radio Nav. Systems & Techn. Section	Core Member – Interface (Main) to TECNET NAV
Morgan-Owen R.	TEC-EST - TT&C & PDT Systems & Techniques Section	Core Member - Interface (Deputy) to TECNET EO
Camarero R.	TEC-EFD - RF Digital Equip. & Payl. Data Proc. Section	Core Member
Fernandez-Leon A.	TEC-EDM - Electrical Department	Core Member
Aguilar Sanchez I.	TEC-ESS - Systems Security Engineering Section	Core Member
Fedi-Casas M.	TEC-QQS - Software Product Assurance Section	TEC-Q Nominated Member Main
Cosson F.	TEC-QQD - RAMS Section	TEC-Q Nominated Member Deputy
Radu S.	TEC-QQD - RAMS Section	TEC-Q Nominated expert

CD3 Technology Pillars

1. Avionics Engineering Methods
2. On-board Platform & Payload Data Processing Solutions
3. Miniaturized / Integrated Solutions
4. Modular and Reference Architectures
5. Interface Solutions
6. On-board Autonomy
7. On-board Security
8. TT&C and Payload Data Transmission
9. AOCS/GNC Systems

P1- Avionics Engineering Methods

Challenges to be addressed

- Promote the simplification, reuse, spin-in of development, operations and development tools in order to favour product lines, improve consistency, ensure independent evolution of sub-systems, and reduce system level testing.

Objectives

- Pursue the effort for having generic requirements documents for spacecraft avionics.
- Deploy model-based (functional) avionics for digital continuity from requirements to design and to software, to support functional analysis, traceability, coverage, verification, modification of the system while taking into account product lines (e.g. avionics architectural models, functional models, Electronic Data Sheet).
- Develop the SW/HW techniques and tools for supporting the avionics engineering methods (e.g. model based software engineering, reference architecture, automatic code generation and integration, etc.).

Key future activities

- **A04** SAVOIR avionic model consolidation and exploitation; **C07** Automating the transition from System to Model Based Avionics Engineering; **C09** Multidisciplinary Design Optimization (MDO) for Avionics Systems; **C13b** Development of an automated HW/SW generation test tool; **C14** Definition, analysis and demonstration of the next generation Avionic System; **C15** Hardware Software co-design methods and tools; **C20** Avionics Verification and Validation; **C27** Model Based AOCS/GNC engineering; **C28** Avionics Digital Twin for Verification.

P1- Avionics Engineering Methods

State of the art: What did we achieve? Where do we stand?

- SAVOIR Reference Architecture and Generic Specifications, generic requirements for spacecraft avionics in relation with operations (e.g. generic OIRD)
- POWER and AVIONICS models in CAPELLA, digital continuity demonstrator
- CORA activities on GR740+BRAVE Medium and CoRA-MBAD for Zynq 7000 programming
- AOCS software code generation is now used in several ESA Projects, process could be further optimised in the SAVOIR working group
- New development/production lines for Avionics hardware development of 'New Space' constellation (e.g. OneWeb)

What are the system impacts?

- Favor Avionics products allowing to redirect the resources on new and challenging technology developments
- Guarantee consistency and coherence of avionics sub-systems development
- Promote multi-domain activities and therefore system optimization
- Reduce system level testing
- Improve the communication between stakeholders through "digital continuity"
- Enable twins of equipment for a more flexible V&V functional validation
- Optimise the Avionics V&V schedule
- Enhance integration of full Avionics supply chain in the V&V process

P2- On-board Platform & Payload Data Processing Solutions

Challenges to be addressed

Provide and enhance End-to-End On-Board data processing solutions (Algorithms, HW, SW and IP Cores) and their engineering tools for future platform and payloads applications.

Objectives

Increase On-Board Processing capability (Processing Modules (HW/SW) & tools).

Develop on-board Data Management and disruptive data analysis technologies (AI/ML) for supporting avionics and payload applications (incl. data compression and reduction).

Key Futures activities

HW Processing Modules based on rad-hard Microelectronics (HPDP, new European multi-core [re-]programmable System-on-Chip based on RISC-V, LEON and ARM) and COTS (selection, characterization).

Design and validation (algorithms and HW/SW implementation) of State of the Art payload processing techniques for data compression/reduction and payload performance.

HW/SW co-engineering (reference designs with development tools ecosystems).

SW (development environments, operating systems, libraries)

P2- On-board Platform & Payload Data Processing Solutions

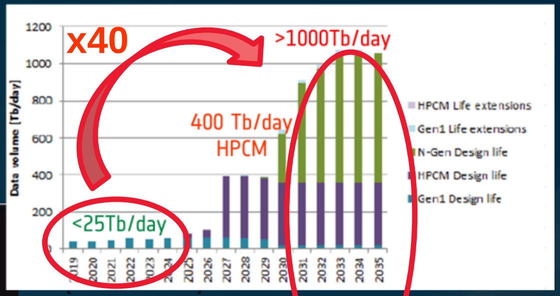
State of the art - What did we achieve? Where do we stand?

- HW Processing Modules based on rad-hard Microelectronics (under development by primes with European processors and FPGAs from C.Gaisler and NanoXplore)
- HW Processing Modules based on COTS (Myriad 2 VPU (AI on Φ-sat-1), Chimera (GomX-4B), Unibap ix5 AMD GPU SoC (D-Orbit ION), etc). *See relevant paper "Commercial Off the Shelf Components in Space Avionics and Payload Data Handling".*

What are the system impacts?

- Reduction of space-to-ground transmission and ground data processing/storage costs
- Transfer of ground operation tasks to on-board autonomous tasks
- Enable more performant payloads through processing techniques (e.g. computational imagery)
- Support new on-board security technologies
- Support "Cognitive Cloud & Edge Computing in Space" vision
- Support new EOP near-real time services in support of Terrestrial Applications

[1]from 10's to >1000 Tb/day



35-40M€/year for downlink only

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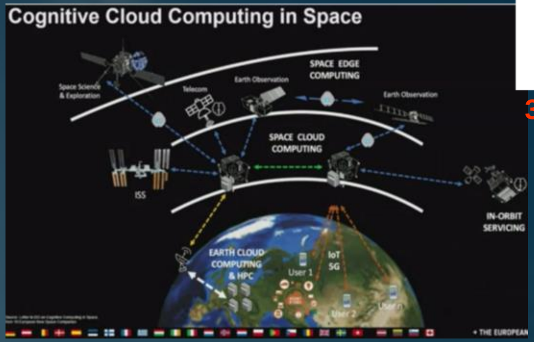
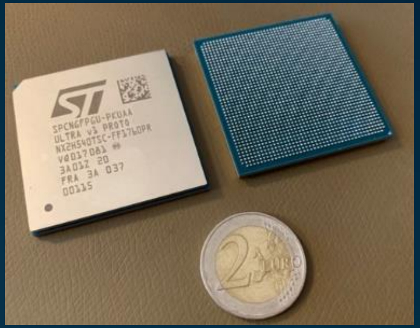


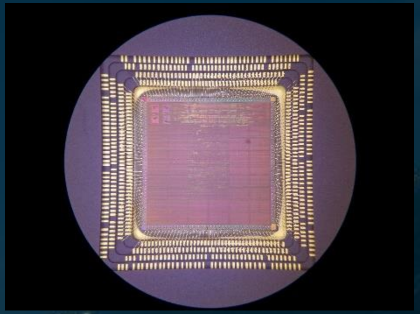
[1]EOP-8MT_TECNET-EO
[2]ESA/PB-EO(2020)55 Paris, 10 November 2020 - LTS Cost analysis for Ground Segment, Data Management and Contributing Missions

P3- Miniaturized – Integrated solutions

Challenges to be addressed

- miniaturise equipment: more functions in less hardware by exploiting multi-core System On Chip (digital and mixed-signal ASSPs, ASICs, FPGAs and System-in-Package).
- Reduce HW module interfaces and interconnect sizes to make better use of available cable bandwidth, reduce harness mass and volume
- Cubesat modules based on competitive space components, offering good radiation tolerance at reduced cost





Objectives

- provide physical architecture solutions related to Miniaturisation and Integration **for** spacecraft **in order to** adapt cost, mass, and size to a range of mission classes for 2025
- facilitate use and safe adoption of new rad-hard, COTS SoC and reprogrammable devices, associated to the development of new IP Cores as building blocks of key OBC/DHS functions
- facilitate development and adoption of AOCS/GNC sensors for nano and micro platforms
- IOD of new architectures and technologies that reduce mass and size of satellite avionics.

P3- Miniaturized – Integrated solutions

- **Key Future Activities**
- provide physical architecture solutions related to Miniaturisation and Integration **for** spacecraft **in order to** adapt cost, mass, and size to a range of mission classes (ex: ADHA compact modules (3U) / Units)

- facilitate use and safe adoption of new rad-hard and COTS SoC and reprogrammable devices:
  - European latest rad-hard devices: GR740 (4xLEON4), NanoXplore NG-Medium/Large/Ultra FPGAs, HPDP, GR716, Microchip SAMRH707
  - Non European COTS and rad-tol: Xilinx KU060, Microchip PolarFire and RTG4 FPGAs

- development of new IP Cores as building blocks of key OBC/DHS, and porting to new ASIC/FPGA technologies:
  - Instruction set architecture (ISA) extensions for RISC-V for GNSS, AI/ML, etc. ; data compression, security, optical communication coding, AXI bus, COTS FPGA memory scrubbing, TSN, TTethernet, etc.

- IOD of new technologies that reduce mass and size of satellite avionics:
  - Cubesat and other first flying opportunities for new SoC components, and new ADHA compact modules
  - Software defined functions

P3- Miniaturized – Integrated solutions

State of the art: What did we achieved? Where do we stand?

- Star tracker processing function and GNSS receivers have been already integrated in the OBC.
- TT&C subsystems are integrating more functionalities, e.g. encoder, buffering in the modulators.
- Reprogrammable FPGA (e.g. NanoXplore, Xilinx) enable reprogramming (updating or swapping) functions in-flight, along with changing missions needs.
- European SoC devices embedding processor and communication cores: GR740, HPDP, NX Large and Ultra FPGAs; Non European COTS and RT devices from Xilinx and Microchip.
- Digital and Mixed-signal rad-hard ASIC libraries for full-custom highly integrated ASIC solutions: STM (65nm), Microchip (150 nm), IMEC DARE (180, 65, 22 nm).
- European IP Cores: SpaceWire/Fiber, CCSDS data compression, SPARC/LEON and RISC-V, TMTC, etc.

What are the system impact?

- STR/GNSS integrated in OBC: cost/mass reduction, better integration in V&V process, ease operations
- Lower harness
- Lower unit mass
- lower power consumption
- Higher performance

P4- Modular and Reference Architectures

Challenges to be addressed

Provide modular and standardized HW and SW architectures for avionics and payload data handling in order to improve interoperability, flexibility, scalability, competitiveness and ease the procurement.

Objectives

ADHA Unit

- Incremental building approach with Advanced Data Handling Architecture (unit and modules): HW, HW/SW and then enlarge ADHA to other CD3 domains and applications.
- Build the ADHA portfolio with new modules based on advanced technologies (rad-hard / COTS microelectronics, algorithms, SW, IP cores) to target new applications (incl.AI.ML).
- Consolidation of the On-Board Software Reference Architecture and integration of security features.

Key Future Activities

- Advanced Data Handling Architecture (*see dedicated paper*) study 2; Development of new ADHA modules and ADHA unit Application SW. De-centralised Architectures based on microcontrollers. Build MBSE and digital twins for ADHA products.
- Develop a generic modular execution platform supporting fast configuration to missions.

P4- Modular and Reference Architectures

State of the art: What did we achieve? Where do we stand?

- Advanced Data Handling Architecture study 1: form factor 6U and “cPCI-ss” standard endorsed by industry at large.
- On-Board SW Reference Architecture
- Time and Space Partitioning
- Payload Execution Platform Software

What are the system impacts?

- ADHA meets three technology targets (reduction of cost and development time, quicker adoption of new technology).
- ADHA federates innovation with the contributions from prime, LSI, unit suppliers and PME across Europe.
- ADHA opens the door to SME to participate to large (ESA) programs.
- ADHA orients the resources on production quality control for recurrent modules (as automotive and Aeronautics industry do), and on the engineering effort for new innovative modules development targeting new applications.
- OSRA and TSP ease the integration and qualification of software developed by different suppliers.

P5- Interface solutions

Challenges to be addressed

Develop functional/physical interface and protocols for spacecraft avionics in order to improve integration and interoperability while reducing harness mass and complexity.

Objectives

- Provide E2E communication solutions (components, IP cores, connectors, cables, protocols) and EGSEs (including simulators).
- Make equipment interoperable (at physical and functional level) between several platforms/payloads/ground processing (e.g. sensors, GNSS receivers, TT&C).
- Improve performances and robustness of on-board links between equipment.
- Use mixed criticality network solutions to reduce harness & connector count.
- Reduce the different types of satellite electrical interfaces.

P5- Interface solutions

Key future activities

- Development of new interface ASIC components (bridges, routers etc.).
- Improve quality of testing of interconnects with test handbooks / standards.
- Increase data rates and power efficiency of protocols, e.g. through improved encoding schemes.
- Increase reliability, determinism, and management capabilities by developing new additional protocol layers.

State of the art: What did we achieve? Where do we stand?

- SpaceWire: Worldwide de-facto standard for payload data handling, ECSS standardized since 2003.
- SpaceFibre: Successor of SpaceWire with much higher data rates (multiple Gigabits/s) and improved reliability over copper or optical fibre, ECSS standardized since 2019.
- TTEthernet: For space transportation and human space flight, allows mixed-criticality networks for a large number of nodes and over long distances, ECSS standardized since 2021.
- Time-Sensitive Networking (TSN): Set of IEEE standards currently evaluated for space applications as potential alternative to TTEthernet.
- CCSDS Protocols: Protocols integrated in mass memories for data downlink - new trends including CFDP (File Delivery Protocol) and Bundle Protocol (Delay Tolerant Networking).

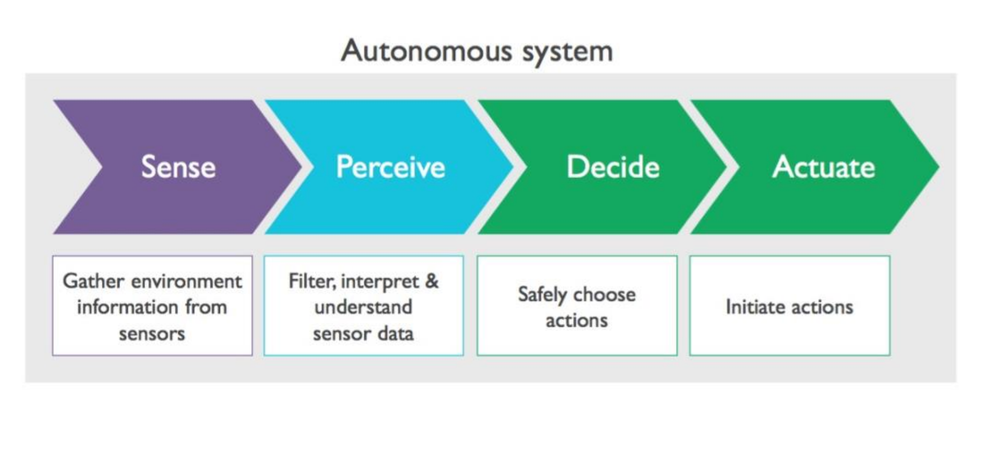
P6- On-board Autonomy

Challenges to be addressed

Increase autonomy, robustness, cost efficiency, performance while maintaining the reliability of space systems for 2025.

Objectives

- Reduce the cost of operations by transferring on-board (e.g. in AOCS/GNC subsystem) functions traditionally performed on ground.
- Enable new, reliable and safe missions by developing advanced on-board processing technologies as well as advanced FDIR techniques.
- Improve performance of missions by increasing availability though dynamic re-planning and FDIR diagnosis and recovery.



State of the art

- Thanks to the research performed in past years, the new techniques developed may lead to an increase in on-board autonomy.
- Activities regarding the use of advanced on-board processing for guidance, navigation and FDIR algorithms are ongoing and show promising results with implementations emerging in some missions under development (e.g. Hera, ADRIOS, EL3, Space Rider).
- Activities with regards to increasing on-board autonomy for systems using COTS are emerging as well, especially in the area of complex missions performed with CubeSats such as deep-space, close proximity operations, constellations (e.g. Lumio, Margo, e.inspector, etc.).

P6- On-board Autonomy- Future Key activities

- Reduce the cost of operations by **transferring on-board functions** traditionally performed on ground

Functions	Technologies
Sensing and perception	Intelligent image processing advanced on-board product generation/processing (e.g. through AI/ML); Sensing data fusion, sensor hybridization
Planning and decision	Dynamic re-planning through implementation of on-board real-time planning and re-planning

Functions	Technologies
Monitoring, Diagnosis, Surveillance	On-board trend analysis and failure prognostics (w/o AI/ML)
AOCS/GNC	Autonomous collision avoidance
Recovery	Intelligent FDIR autonomous recovery

- Enable new, reliable and safe missions by developing **advanced on-board processing** technologies as well as advanced FDIR techniques

Functions	Technologies
Detection, isolation and recovery	Intelligent FDIR diagnosis and recovery On-board trend analysis and failure prognostics
Mission/ Resource/ Fault management	Artificial intelligence as enabling technology for avionics

Functions	Technologies
AOCS/GNC	Advanced technology for estimation & control; Neural Networks for navigation and control; Vision-based navigation, including multi-spectral navigation; Autonomous collision avoidance

- Improve performance of missions by increasing availability through **dynamic re-planning** and **FDIR diagnosis and recovery**

Functions	Technologies
Human-system interface	Implementation of R/T operations and reduction of delays and reaction time
Availability	reduce outage through optimized RAMS budgets/planning and advanced FDIR techniques (AI)

Functions	Technologies
Dynamic planning	Implementation of on-board real-time planning and re-planning capabilities
Reliability (AI/ML)	Increase of reliability characterization through return of experience Optimize redundancy management; Decide for satellite life extension prediction based on trend analysis

P6- On-board Autonomy - System Impacts

Specific application	System impact	Potential mission benefiting from implementation
• FDIR • GNC/AOCS	• More reliable and safe autonomous operations; • Risk of increased complexity	• Close Proximity Operations missions (rendezvous, capture, in-orbit servicing, etc.).
• Advanced technology for estimation & control • Vision-based navigation, including multi-spectral navigation • Autonomous collision avoidance • On-board real time planning and re-planning • Use of AI/ML • FDIR techniques enabling on-board autonomy • Estimation, data-fusion, sensor hybridization	• More reliable and safe autonomous operations • Reduces cost of operations • Improve mission performance • Risk of increased complexity during design and testing	All mission types and in particular the following: • Close Proximity Operations missions • Science and exploration missions • Mega constellations • Flying formations
• On-board trend analysis and failure prognostics (w/o AI/ML) • In-orbit return of experience assessment • Mission and resource fault management	• Improve mission performance • May lead to more balanced technical budgets while still ensuring safety and mission success => Optimization of redundancy • Outage optimization • Increase of reliability characterization through return of experience contributing to life extension decision	All mission types

P7- On-board Security

Challenges to be addressed

The area of security is becoming increasingly important in order to make sure that missions are not compromised by malicious events. Security is vital in both the space and ground segments assets as well as their interconnections.

New actors, not necessarily security-aware and/or competent, are proliferating and becoming potential threats to others in a shared outer space.

Objectives

1. Build a solid and complete portfolio of security countermeasures for future space missions in order to effectively protect their assets as well as their space communications, navigation and sensing.
2. Support the development and deployment of adequate Spacecraft On-board HW and SW Security Technologies for new actors in the shared space environment.

Key Future Activities

- Reference System Architecture
- Spacecraft Cybersecurity
- Spacecraft On-board Situational Awareness
- Secured In-flight Re-programmability
- CCSDS Security Building Blocks: SDLS evolution, Secure Delay Tolerant Networking (DTN) and Secure IP-over-CCSDS
- Configurable Space Security Module
- GNSS RF Firewall

P7- On-board Security

State of the art: What did we achieve? Where do we stand?

Protected spacecraft with sound remote access control and monitoring (e.g. CCSDS Space Data Link Security),

- employing quantum-resistant symmetric cryptography (Advanced Encryption Standard-256)
- for TC and TM data security services (authentication, encryption, authenticated encryption)

Anti-jamming protection for TC signal

Standards:

- CCSDS Security (various) as well as
- ongoing update of ECSS Software Engineering and Software Product Assurance standards taking into account security related requirements

Unknown supply chain risk, potentially impacting all Avionics HW/SW/FW, new ECSS on Security in space systems lifecycles in preparation.

What are the system impacts?

+ Effective solution for simple mission topologies (e.g. one space link)
+ Strong dependability and recovery capabilities
+ Interoperable (CCSDS Space Link Extension)
- Lifecycle inflexibility → early design & development decisions with long-term risk exposure against threat evolutions (e.g. computing power, novel attacks)
- Limited scalability (not well-adapted to large constellations with space networks)
- Satellite secret(s) shall be well kept before launch
- Unknown residual risks

P8- TT&C and payload data transmission

Challenges to be addressed

Develop new TT&C systems for all applications in order to increase the uplink and downlink data capacity and improve communications availability, efficiency and performances. Add new functions for Deep Space Science and Exploration.

Objectives

- Reduced SWAP of TT&C & PDT systems
- Increased TM/TC rates and optimised link efficiency
- Improved Deep Space communications at all stages including emergency modes
- Improved proximity communications using European qualified equipment
- Fulfilling specific Deep Space nano / cubesat needs for their links with earth and Intersatellite/ proximity links
- Improved availability and data rates for Launchers TT&C
- Protect TC and TM links for critical applications (see also P7- On-board Security)

P8- TT&C and payload data transmission

Objectives (cont'd)

Objectives 2025	Future work (refer to TT&C THD /Roadmap for details*)
Reduced SWAP/cost of TT&C & PDT	Development of Transponder Standard IP core; implementation of X-Band only TT&C/PDT; Miniaturisation of Deep Space Transponder (THD Aim A)
Increased TM/TC rates and optimised efficiency	Development and qualification of onboard TT&C/PDT equipment to support: -> Earth Observation:: 10Gbit/sec (TM) (THD Aim D) -> Science/Exploration: 100s of Mbit/sec (TM/TC) (THD Aim D) -> Debris/Space Safety missions: 10s of Mbit/sec (TM/TC) (THD Aim B) -> link optimization using variable/adaptive coding and modulation combined with DTN/CFDP
Improved Deep Space communications and autonomy at all stages in all conditions including emergency modes	Development/qualification of new/improved TT&C link functions (THD Aim A): autonomous link acquisition, controlling multiple spacecraft simultaneously; improved ranging/location and radioscience; specific design/modulations for emergency modes at very large distances
Improved proximity communications using European qualified equipment (recovering obsolescence)	orbiter/lander new equipment development/ qualification (UHF/X/K-Bands) (THD Aim C) implementation of RF direction finding (THD Aim F)
Fulfilling specific Deep Space nano/ cubesat needs for their links with earth and Intersatellite/ proximity links	Addition of communications in new frequency bands (e.g. UHF and Ka-Band) to nanosat Deep Space Transponders (THD Aim A)
Improved availability and data rates for Launchers TT&C	Development of TT&C communications architectures via data relay satellites for re-entry vehicles and launchers (e.g. K-Band via EDRS). (THD Aim D)
Protect TC and TM links for critical applications	Development of Secure TT&C: Protection measures at radio level (spread spectrum modulations, enhanced with cryptographic sequences; protection of the data)

*Reference Harmonisation (THD): https://tec.esa.int/sites/act-Axv8LB/Harmonisation%20Topics/Forms/All%20Topics.aspx,
Then select "TT&C Transponders and Payload Data Transmitters"

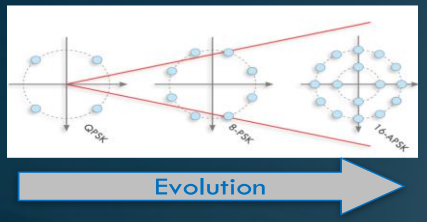
P8- TT&C and payload data transmission

State of the Art

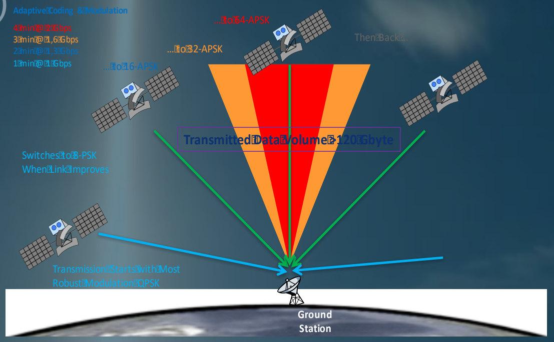
What did we achieve / Where do we stand?

- Implementation of **X/Ka-Band Deep Space Transponder** and **Ka-Band Radioscience Transponder** brings step forward in TT&C functions and performance for Deep Space science missions (Bepicolombo/Juice)
- Integration of **Deep Space Transponder with Radio Science Transponder functions** allows BepiColombo/Juice-like TT&C functions inside one onboard unit and additional functions (IDST EM 2022)
- Development of **nanosat Deep Space X-Band Transponder** (DST) adopted by M-ARGO Deep Space mission (EM 2022)
- **Payload Transmitter (TETRA)** with Variable Coding and Modulation (VCM) up to >2.5Gbit/sec per unit adopted by HPCM Copernicus missions. TETRA also allows implementation of Adaptive Coding and Modulation (ACM). (EQM now available)

PDT Building Blocks



VCM / ACM



Satellite Pass with VCM

What are the system impacts?

- IDST will allow Bepicolombo/Juice type TT&C /radioscience with single unit
- **Autonomy** of some functions (e.g. IDST implements autonomous acquisition of different TC data rates)
- Nanosat DST will provide M-ARGO with **low cost low SWaP unit** (1kg)
- VCM transmitter (TETRA) will allow very **high data volume of HPCM** missions imaging data with optimised Ground Station passes
- For highest rate HPCM mission (ROSE-L), **4x TETRA transmitters are required to reach the multi-Gbit/sec Payload TM rate**

P9- AOCS/GNC Systems

Challenges to be addressed

Create AOCS/GNC Systems more performant, more robust, more autonomous, more cost-effective to enable ambitious missions within challenging economical ecosystem

Develop diverse AOCS/GNC products and equipment serving full range of Space missions, from high end Science missions to New Space platforms, as well as AOCS/GNC engineering processes and tools to steer industrialization of the AOCS/GNC products, while fostering fast innovation adoption for successful challenging missions and competition in 2025

Objectives

- Enable new categories or phases of Space missions via AOCS/GNC capabilities
- Enhance Space systems GNC and AOCS performance and autonomy
- Accompany and harmonise transition towards leaner and more AOCS/GNC digital processes
- Support standardization and missionisation of AOCS/GNC product lines,
- Factor disruptive innovation in the AOCS/GNC systems to prepare future missions and products

P9- AOCS/GNC Systems

Objectives (cont'd)

Objectives 2025	Future work
Enable new categories or phases of Space missions via AOCS/GNC capabilities	Close Proximity Operations -for rendez-vous, in-orbit servicing, active debris removal-, Autonomous navigation and optimal guidance, Data fusion & sensing hybridation, New Space AOCS/GNC systems with COTS-based equipment, European non dependency in AOCS/GNC sensors and actuators
Enhance Space systems GNC and AOCS performance and autonomy	High accuracy/stability pointing, Vision-Based navigation and GNC for Exploration missions, Launcher GNC performance enhancement
Accompany and harmonise transition towards leaner and more digital AOCS/GNC processes	Embedding of digital AOCS/GNC development process beyond automated code generation, Model based AOCS/GNC engineering incl. evolution of AOCS/GNC testing philosophy and modelling approaches Multi-physic modelling
Support standardization and missionisation of AOCS/GNC product lines,	Auto calibration along the AOCS/GNC supply chain Functional AOCS architecture based on modular building blocks (instead of AOCS modes) Embedded in modular Avionics architectures
Factor disruptive innovation in the AOCS/GNC systems to prepare future missions and products	Use of AI/ML on board AOCS/GNC systems Re-usable / evolvable launchers Autonomous decision making On board use of non deterministic AOCS/GNC algorithms

P9- AOCS/GNC Systems

State of the Art

What did we achieve?

- Increasing **productisation / industrialization** (e.g. AOCS in Copernicus standard platforms, SatCom AOCS,…)
- **European non dependency** in sensors/actuators (e.g. towards qualification of European inertial sensors)
- **New exploration missions** (GNC enabling subsystem for some phases of Exploration missions)
- Towards **autonomous Navigation** (e.g. PILOT)

Where do we stand?

- **Advanced core techniques** (data fusion, control and estimation, robust, e.g. use of advanced robust control on JUICE GNC,…)
- **Autonomy** (e.g. ADAMP GSTP, autonomous guidance studies for Comet Interceptor,…)
- New Space **sensors** (e.g. Innalabs ARIETIS NS, SODERN Auriga upgrade,…)
- **Cost-effective Performance / Productisation** of AOCS (for LEO orbit, for SatCom, Navigation,…)
- **MBSE** for AOCS/GNC systems and V&V (MB4SE WG and related group of studies)
- Use of **AI/ML on-board**: hybridation and verification aspects (e.g. TDE for use of AI/ML in GNC systems, study on AI verification for AOCS system)

What are the system impacts?

- **Autonomy** (ground/board sharing, on board intelligence and decision making, fault tolerant architectures) and reactivity/adaptation
- **Re-usability** of AOCS system in platform **product lines**
- **Re-usability of launcher**
- **Debris policy** (ADR, CPO,…)
- **More capabilities to Space missions** (entry descent landing, close proximity operations, collision avoidance, cost-effective design and testing, faster development)

Conclusion

The CD3 is large group of experts, working on Avionics systems, Control systems, TT&C E2E systems, On-Board Computer - Data Handling Systems & micro electronics, and Software.

MetOp-SG EFM @ Airbus DS Toulouse

The CD3 recently defined 9 technology pillars to be included in the ESA Technology Strategy.

This presentation gave an overview of these pillars and the targeted objectives for the next years.

For more details, do not hesitate to contact the CD3 team.

Q/A Session