Orbiting the Edge and Stars: Bridging the gap between Space Avionics and Edge Computing, challenges and space mission's needs

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INNOVATING SOLUTIONS

KEYNOTE

ORBITING THE EDGE AND STARS: BRIDGING THE GAP BETWEEN SPACE AVIONICS AND EDGE COMPUTING, CHALLENGES AND SPACE MISSION'S NEEDS

David González-Arjona, GMV

Abstract: The keynote will bring the space mission processing challenges and opportunities where high-performance computing and architectural designs are pivotal role. The presentation bridges the gap between space avionics and edge computing realities, illustrating how the challenges faced in space are relevant and interconnected with the challenges encountered for other industries edge computing. Space missions are strongly based in remote processing capabilities in autonomous manner. Communications to ground may be costive, not continuous, limited in bandwidth or with big latencies for real-time actuation needs. Earth Observation and space-based sensors are generating and consuming bigger amount of data and edge computing facilitates communication reduction and real-time executions. Exploration missions and landing operations in other solar system celestial bodies autonomously may impose high-performance solution challenges into avionics electronics that must be reliant and enduring harsh environmental conditions. Fault Tolerant HW/SW architectures and technology robust against cosmic radiation, extreme temperature gradients and mechanical vibrations may limit performance capabilities. Last but not least, machine learning applications are entering more and more in the mission's algorithms, including computing challenges to get the functional benefits desired. Continual learning possibilitites will deal with uncertainties in the explored scenario but also expose avionics towards architectural challenges. These topics will be presented and discussed including examples and roadmaps for key technology for the near future in space.

Short bio: David González-Arjona holds the position of Space Equipment section head in GMV Aerospace & Defence SAU, Madrid (Spain), and he is a part-time Associate Professor in the Electronics and Communications Technologies department of Autonoma de Madrid University.

Alignment to :

The HiPEAC conference is the premier European forum for experts in computer architecture, programming models, compilers and operating systems for general-purpose, embedded and cyber-physical systems. Areas of focus and integration include safety-critical dependencies, cybersecurity, energy efficiency and machine learning.

DASIP

Custom embedded, edge and cloud architectures and systems

Machine learning and deep learning architectures for inference and training
Systems for autonomous vehicles: cars, drones, ships and space applications
Image processing and compression architectures
Smart cameras, security systems, behaviour recognition
Edge and cloud processing: special routing, configurable co-processors and low energy considerations
Real-time cryptography, secure computing, financial and personal data processing
Computer arithmetic, approximate computing, probabilistic computing, nanocomputing, bio-inspired computing
Biological data collection and analysis, bioinformatics
Personal digital assistants, natural language processing, wearable computing and implantable devices
Global navigation satellite and inertial navigation systems

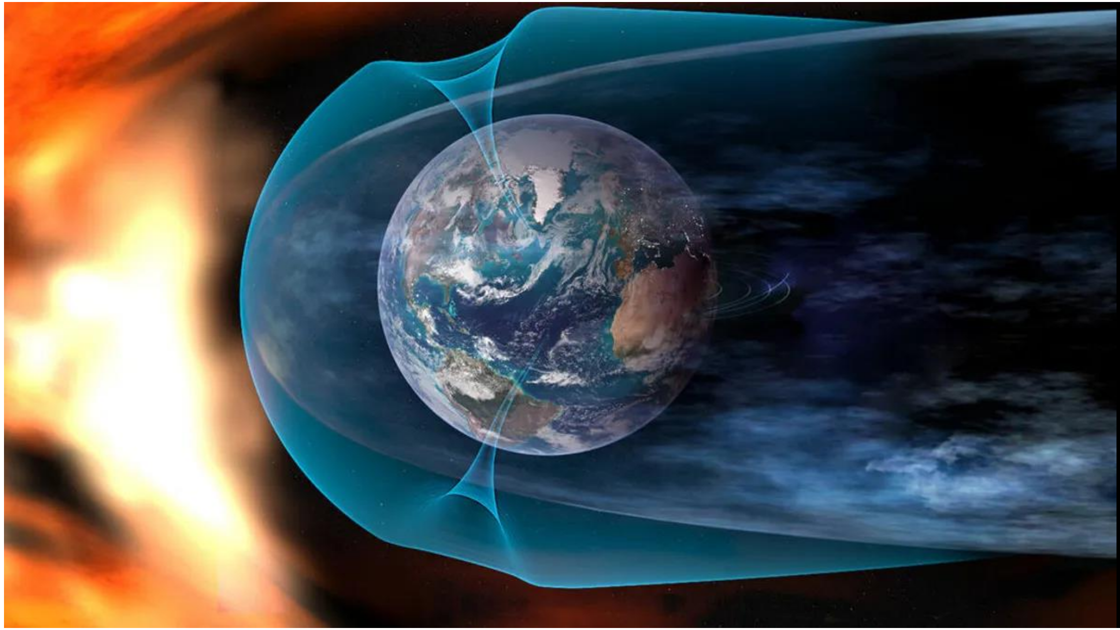
Design Methods and Tools

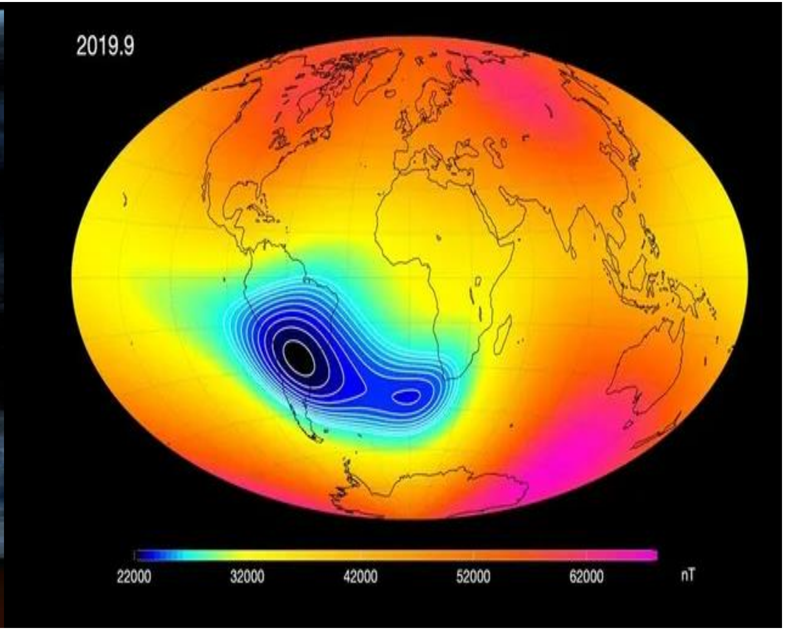
Design verification and fault tolerance
Embedded system security and security validation
System-level design and hardware/software co-design
High-level synthesis, logic synthesis, communication synthesis
Embedded real-time systems and real-time operating systems
Rapid system prototyping, performance analysis and estimation
Formal models, transformations, algorithm transformations and metrics

Development Platforms, Architectures and Technologies

Embedded platforms for multimedia and telecommunication
Many-core and multi-processor systems, SoCs, and NoCs
Reconfigurable ASIPs, FPGAs, and dynamically reconfigurable systems
Memory system and cache management
Asynchronous (self-timed) circuits and analog and mixed-signal circuits

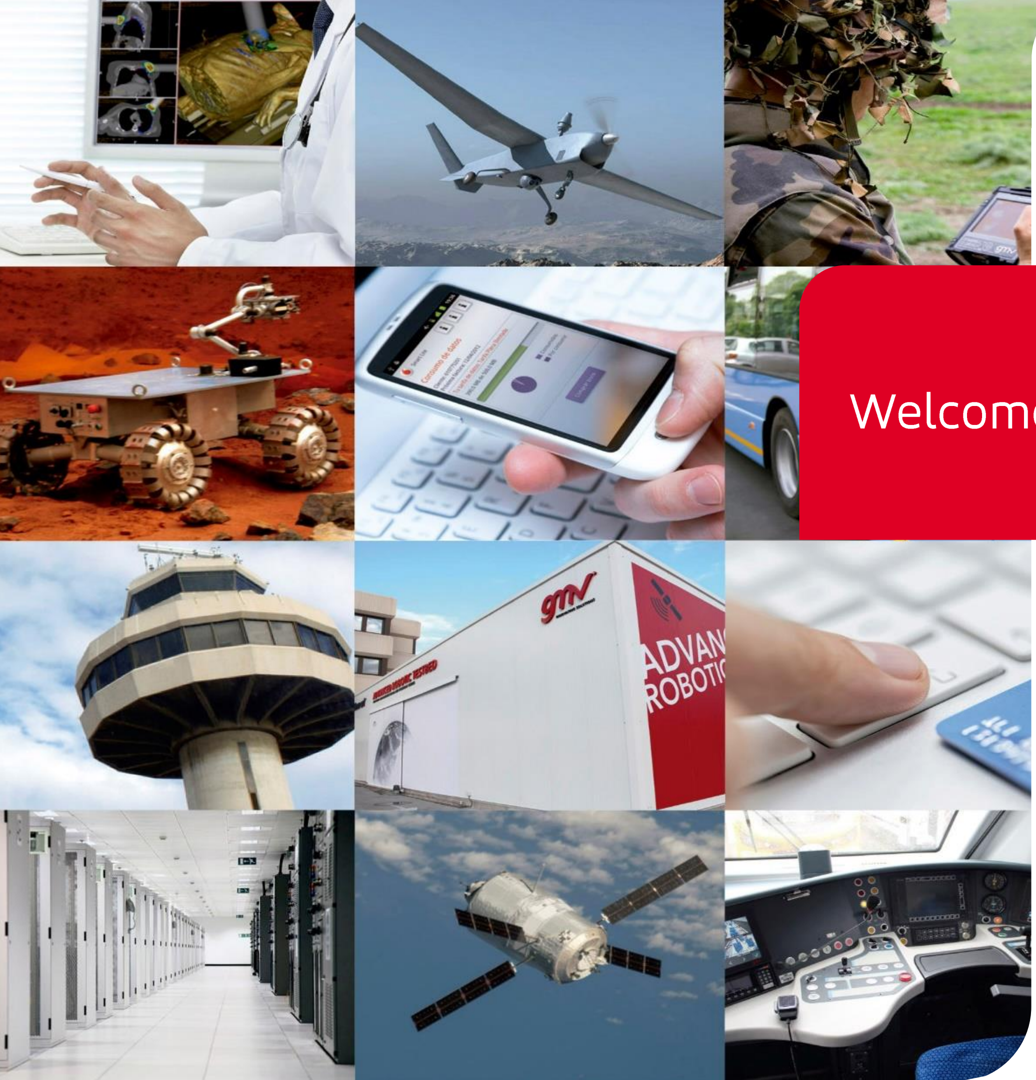
Anomaly Atlantic South





Agenda

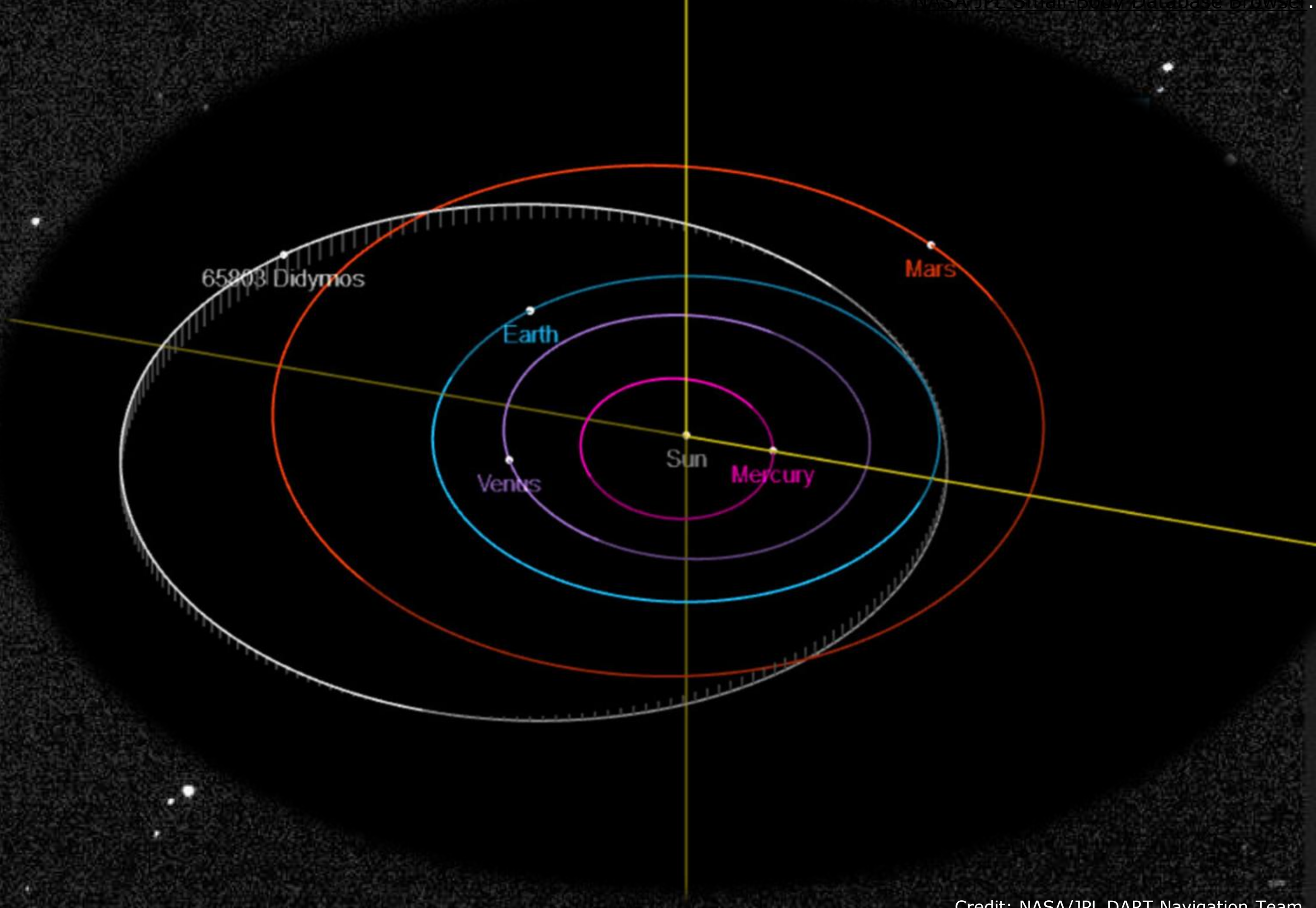
Date: 18/01/2024



Welcome to our units’ offices

Chasing stars?

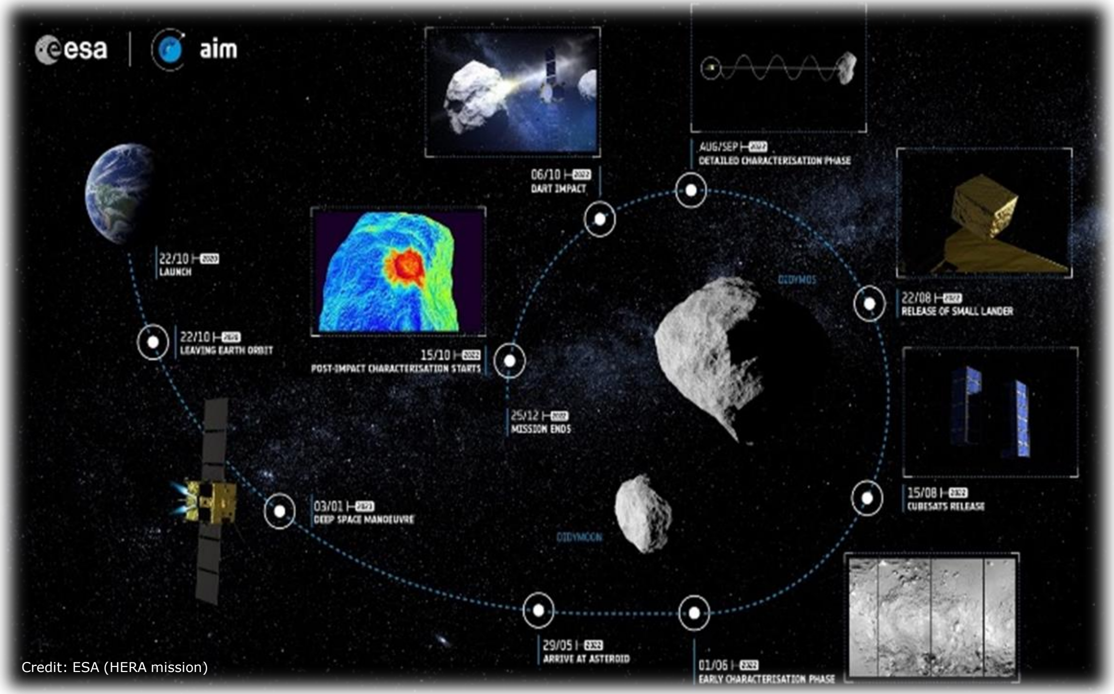
NASA/JPL Small-Body Database Browser.



Didymos' 770-day orbit, which circles from less than 10 million km from Earth to out beyond Mars, at more than double Earth's distance from the Sun

Credit: NASA/JPL DART Navigation Team

Welcome to our units' offices



Credit: ESA (HERA mission)

- **Hardened/Ruggedized** Devices protected versus:
  Radiation
  Solar Pressure
  Electromagnetic Waves
  Vibrations (launching environment)
  Wide temperature range
- Hard/Impossible to repair devices (up there):
  Reliability is a must
- **Autonomy** is a key factor
  Independent Systems
  Huge delay/latency in Ground-Spacecraft communication
- **Limited** power consumption on board
- Mass and volume shall be **minimized**
- Design and implementation of **Fault-Tolerance** systems
- Critical, Precise and **Deterministic** systems in Hard Real-Time applications
- Extensive and intensive **Validation** and Verification

- **Ad-hoc** projects for each mission: Nobody went there before
  → how to create **representative** environment, images, conditions?

GMV: A global technology group

Founded in

1984

Multinational technology group. **Private capital**

Headquarters in Spain (Madrid).

Subsidiaries in 12 countries

(ops in 70+)

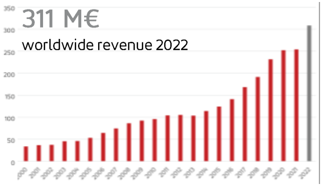
+3,300 employees

Roots tied to the Space and Defence industry

Engineering, development and integration of systems, software, hardware, specialized products and services

CMMI level 5

CMMIDEV/5



Aeronautics, Space, Defense & Security, Cybersecurity, Intelligent Transport Systems, Healthcare, Banking & finances, and ICT industries

Space

Aeronautics

Defense & Security

Telecommunication

Cybersecurity

Intelligent Transport Systems

Healthcare

Public Sector and Corporate ICT

Banking & Finances

Grupo Tecnológico e Industrial GMV, S.A.

GMV Innovating Solutions, SL

- **GMV Aerospace and Defence, SAU** / Aerospace and Defense markets
  - Grupo Navegación por Satélite Sistemas y Servicios S.L / Galileo development and exploitation
  - Sistemas de Misiles de España, SL / Defense market
  - Satnus Technologies, SL / Defense market
- **GMV Soluciones Globales Internet, SAU** / Telecommunications and e-business markets
- **GMV Sistemas, SAU** / Transportation and Industry markets
- **GMV Innovating Solutions, Inc** / Aerospace, Transportation and Telecommunications markets of USA
- **GMVIS Skysoft, SA** / Aerospace, Defense,Transportation and Telecommunications markets of Portugal
- **GMV Seguridad Integral, SAU** / Security market
- **GMV GmbH** / Aerospace, Defense, Transportation and Telecommunications markets of Germany
- **GMV Innovating Solutions, Sp.z o.o** / Aerospace, Defense,Transportation and Telecommunications markets of Poland
- **GMV Innovating Solutions, SRL** / Aerospace, Defense,Transportation and Telecommunications markets of Romania
- **GMV Innovating Solutions, SARL** / Aerospace, Defense, Transportation and Telecommunications markets of France
- **GMV Innovating Solutions, SAS** / Aerospace, Defense, Transportation, and Telecommunications markets of Colombia
- **GMV Innovating Solutions, Sdn. Bhd** / Aerospace, Defense,Transportation and Telecommunications markets of Malaysia
- **GMV NSL Limited** / Aerospace, Defense, Transportation and Telecommunications markets of United Kingdom
- **GMV Syncromatics Corp** / Intelligent Transport Systems market of USA
- **GMV Innovating Solutions, BV** / Aerospace, Defense, Transportation and Telecommunications markets of the Netherlands
- **GMV Innovating Solutions, SRL** / Aerospace, Defense, Transportation and Telecommunications markets of Belgium
- **Payload Aerospace, SL** / Space market
- **Almefy GmbH** /Telecommunications and e-Business markets of Germany
- **Alén Space, SL** / Space market

GMV Space Technological Leadership

#1 Worldwide Satellite Control Center provider to commercial telecom operators. **Primary SST** technology and Operation Centers

Space Segment GNC technology leader
On-board Autonomy
On-board SW

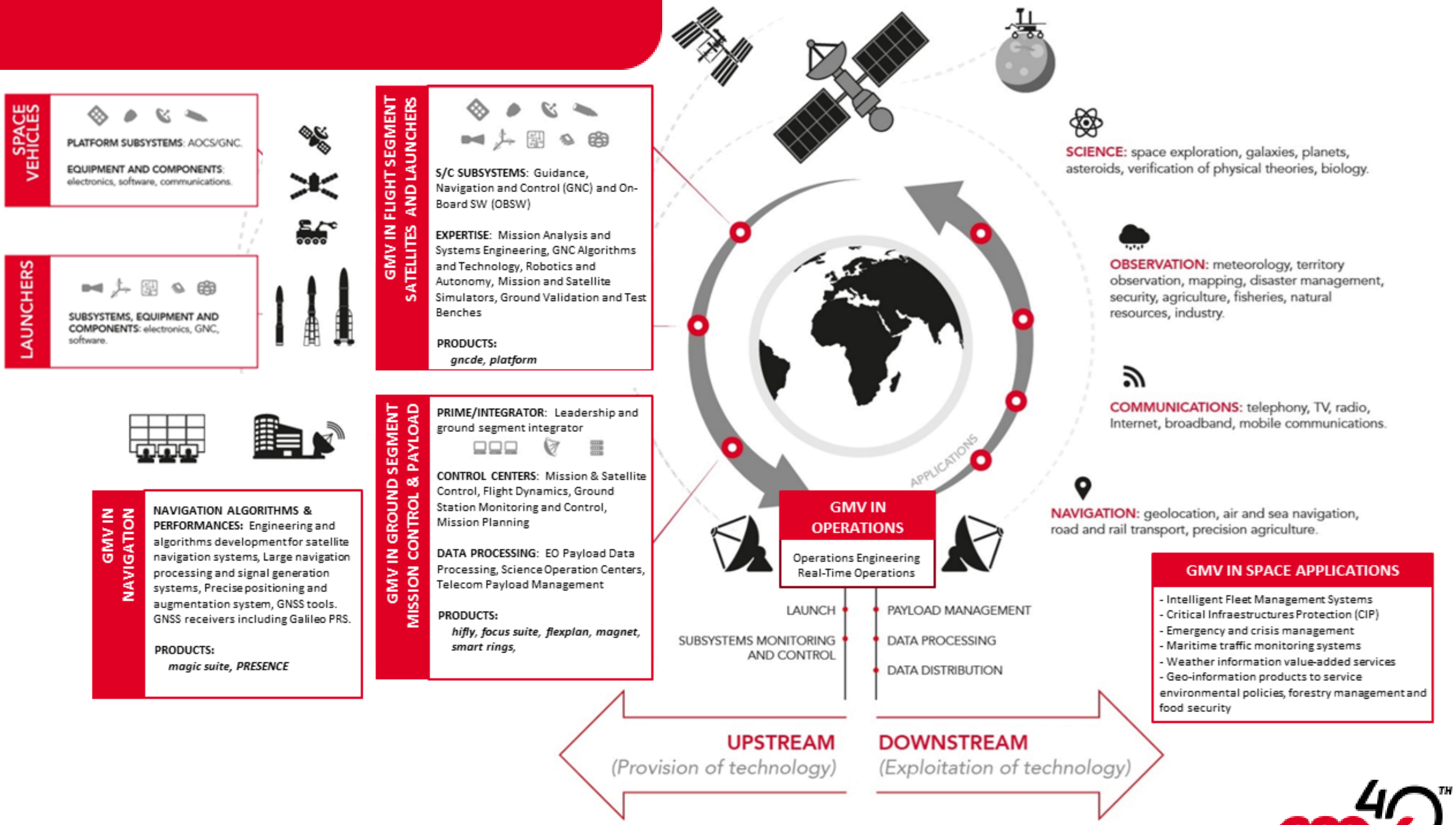
Test Facilities

Prime role in **European GNSS Systems** and its safety critical systems (EGNOS and Galileo)

Leading European Space Robotics technology, growing Microelectronics, HW Avionics and Technology Transfer

Excellence in Flight Dynamics, Mission Analysis, E2E Simulators, EO Data Processing and downstream geospatial services

GMV IN SPACE

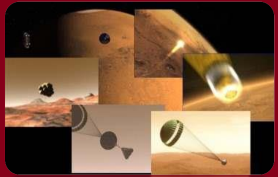


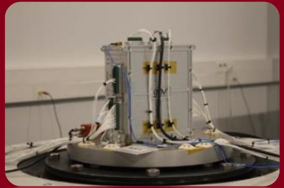
SPACE VEHICLES
PLATFORM SUBSYSTEMS: AOCS/GNC.
EQUIPMENT AND COMPONENTS: electronics, software, communications.
LAUNCHERS
SUBSYSTEMS, EQUIPMENT AND COMPONENTS: electronics, GNC, software.
GMV IN FLIGHT SEGMENT SATELLITES AND LAUNCHERS
S/C SUBSYSTEMS: Guidance, Navigation and Control (GNC) and On-Board SW (OBSW)
EXPERTISE: Mission Analysis and Systems Engineering, GNC Algorithms and Technology, Robotics and Autonomy, Mission and Satellite Simulators, Ground Validation and Test Benches
PRODUCTS:
gncde, platform
GMV IN GROUND SEGMENT MISSION CONTROL & PAYLOAD
PRIME/INTEGRATOR: Leadership and ground segment integrator
CONTROL CENTERS: Mission & Satellite Control, Flight Dynamics, Ground Station Monitoring and Control, Mission Planning
DATA PROCESSING: EO Payload Data Processing, Science Operation Centers, Telecom Payload Management
PRODUCTS:
hifly, focus suite, flexplan, magnet, smart rings,
GMV IN NAVIGATION
NAVIGATION ALGORITHMS & PERFORMANCES: Engineering and algorithms development for satellite navigation systems, Large navigation processing and signal generation systems, Precise positioning and augmentation system, GNSS tools. GNSS receivers including Galileo PRS.
PRODUCTS:
magic suite, PRESENCE
SCIENCE: space exploration, galaxies, planets, asteroids, verification of physical theories, biology.
OBSERVATION: meteorology, territory observation, mapping, disaster management, security, agriculture, fisheries, natural resources, industry.
COMMUNICATIONS: telephony, TV, radio, Internet, broadband, mobile communications.
NAVIGATION: geolocation, air and sea navigation, road and rail transport, precision agriculture.
APPLICATIONS
GMV IN OPERATIONS
Operations Engineering
Real-Time Operations
LAUNCH
SUBSYSTEMS MONITORING AND CONTROL
PAYLOAD MANAGEMENT
DATA PROCESSING
DATA DISTRIBUTION
GMV IN SPACE APPLICATIONS
- Intelligent Fleet Management Systems
- Critical Infraestructures Protection (CIP)
- Emergency and crisis management
- Maritime traffic monitoring systems
- Weather information value-added services
- Geo-information products to service environmental policies, forestry management and food security
UPSTREAM
(Provision of technology)
DOWNSTREAM
(Exploitation of technology)

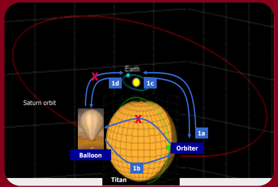
Flight Segment & Robotics

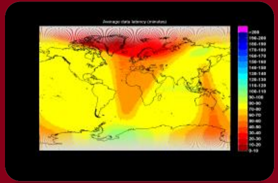
- Mission analysis
- Guidance, Navigation and Control (GNC)
- End-to-end Simulators and HW emulators
- Robotics for Space
  (rovers, instruments, manipulators)
- Critical On-board Software
  (design, development and validation)
- Avionics and Microelectronics
  (processing boards, acquisition, EGSE)
- Instrument prototype processors & equipment
- Test Benches, validation facilities, data processing facilities
- Autonomous Decision Making
- Space assets communications
- Launchers and Access to Space technology









Mission Types and Challenges

NAVIGATION

magic product suite

- Leading GCS (Segment Prime) and main subsystems development: sKMF, SCCF, FDF
- Development of critical GMS subsystems: Orbit Synchr. Processing (**OSPF), Integrity Processing (IPF), Network Monitoring (MNE), Service Products (SPF)**
- **Operations support (15 operations engineers)**
- **PRS receiver development (PRESENCE)**

- Development of EGNOS central processing facility – processing set (CPF-PS)
- Development EGNOS application specific qualification facility (ASQF)
- Development of EGNOS Data Access System (EDAS)
- Development of EURONOTAM

- Development and operation of Galileo's Time & Geodesy Validation Facility (TGVF)
- Development and operation of the Galileo Reference Center (GRC)
- Development of Galileo Service Center (GSC) infrastructure
- Return-Link Service Provider of the Search and Rescue Service (RLSP-SAR)

International market & products:

- **Performance monitoring and SBAS contracts with Roscosmos**
- **SBAS related contracts for OACI, SANSA, ISRO and the Korean ADD**
- **New generation SBAS prototype system for Geoscience Australia**
- **magicPPP Precise Point Positioning Solution**
- **GNSS receivers for niche applications**

TELECOM

273 supported spacecraft

#1 Worldwide Satellite Control Center provider to commercial telecom operators

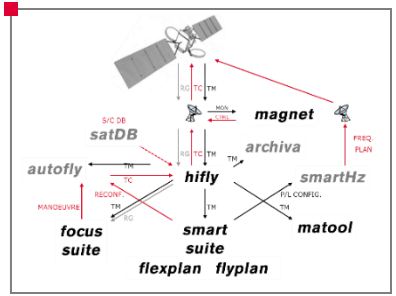
- a total of 40 telecom operators and 273 satellites have selected GMV technology
- 40% of all commercial COMSATs launched in the last 10 years are controlled with GMV technology

Provider to EUTELSAT of a complete solution to the control of the entire heterogeneous fleet of more than 30 spacecraft

GMV solution includes satellite control centre (real-time system), flight dynamics and ground station M&C

Developing for ONEWEB the command and control satellite control centre for the entire OneWeb constellation of more than one thousand satellites.

Before that GMV was providing the FDS for Globastar and O3b constellations

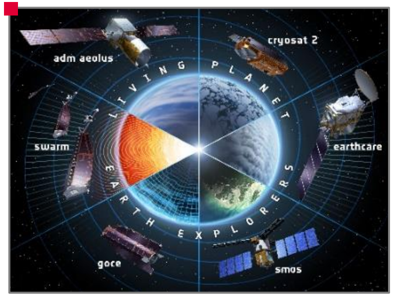


Unique and complete portfolio of products providing off-the-shelf support to 15 different spacecraft buses from 10 satellite manufacturers

- *hifly* (real-time system)
- *focus suite* (flight dynamics)
- *flexplan* (mission planning)
- *magnet* (ground station M&C)
- *smart suite* (payload management)
- ...

EARTH OBSERVATION (upstream)

80
supported
spacecraft



- Mission Analysis and Flight Dynamics for all Earth Explorers through ESOC
- End-to-end simulation for EarthCARE
- Mission Control System of Cryosat-2, GOCE and SMOS
- Mission Planning for Cryosat-2 and SMOS
- Data Processors for SMOS (L0), Swarm L1b, L1b NRT & L2, EarthCARE L0, BBR L1b, MSI L1b and Lidar L1b/L1c

- EPS-SG Mission Control & Operations prime contractor
- EPS-SG Scatterometer Ground Processor Simulator & Tools
- MTG Mission Operations Facility prime contractor
- MTG Instrument Data Processing Facilities
- MTG Instrument Quality Tool development
- Sentinel 3 Flight Operations Segment integration
- On-site consultants (10)

- Sentinel 1 and 5p Satellite Simulator
- Sentinel 3 Ocean and Land Color Instrument software
- Sentinel 2 Instrument Processing Facility
- Satellite Control Center and Flight Dynamics System for all Sentinels
- Mission Planning for Sentinels 1 and 3
- Operational POD service
- Next Generation Space Copernicus EC framework

Ingenio/Paz:

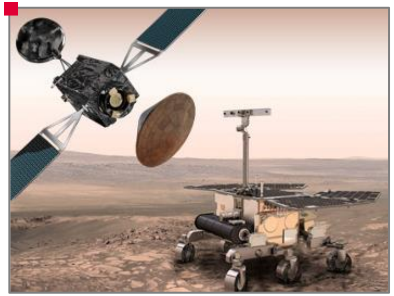
- Mission Analysis
- Satellite Simulator
- Ground Prototype Processor
- Flight Operations Segment: SCC and FDS
- Mission Planning
- User Services

NASA/NOAA:

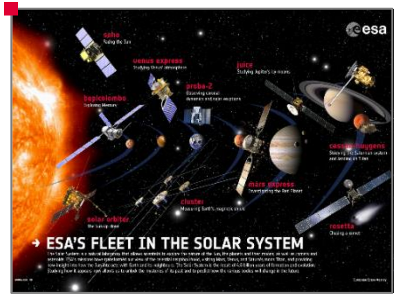
- GOES-R/S Flight Dynamics
- Landsat Mission planning
- OCO/OCO-2 and GLORY FD

SCIENCE & ROBOTIC EXPLORATION

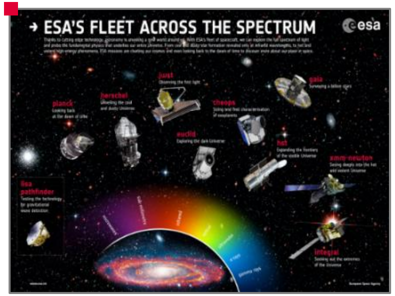
48 supported spacecraft



- ExoMars 2016 Entry Descent and Landing GNC OBSW
- Exomars 2020 on-board software
- Exomars Rover Operations Center
- Phootprint autonomous visual based GNC
- Lunar missions PILOT Absolute and Relative Navigation
- Leading Mars Sample Return ESA's GNC roadmap



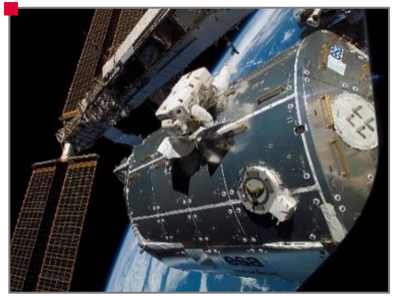
- Bepi-Colombo and SOLO Mission Control System
- ESOC Flight dynamics and operations team (inc. Rosetta mission)
- JUICE AOCS Support
- JUICE Navigation Camera Breadboarding
- ESAC operations staff



- CHEOPS Ground Control Segment and Satellite Simulator
- Gaia Data Processing
- Euclid SVF
- Lisa Pathfinder LTP ISV
- ESOC Flight dynamics and operations team
- ESAC operations staff

- Lunar Reconnaisance Orbiter (LRO) Mission Planning System
- World Space Observatory-Ultraviolet (WSO-UV) Ground Segment

HUMAN SPACEFLIGHT



Columbus Ground Control:

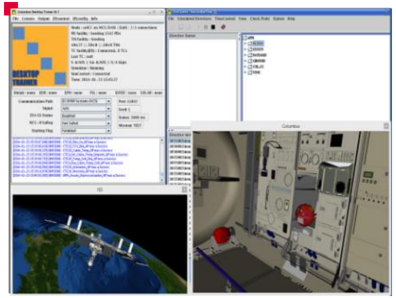
- 24/7 console operations and planning
- Ground subsystems configuration and management
- Upgrades definition and implementation
- New experiments and users support
- Customer PR activities

Columbus Flight Control:

- 24/7 console operations
- Procedures development, verification and validation
- Telemetry and telecommand definition
- Display development
- Training and simulations

ATV:

- Flight dynamics system
- Operations support



Col-CC system engineering:

- Requirements specification
- Design and development
- Integration, verification and validation
- Sustaining engineering
- System level architecture
- Wide area network and LAN
- Monitoring & control system
- TM/TC collection and distribution system
- Video distribution system

Operations Support Tools:

- R/T and off-line ops prep, execution and evaluation
- Issue Tracking, Flight Notes, Voice Loop, Reporting & more

Columbus Desktop Trainer:

- Training & E2E simulation including full ground segment

3D visualisation:

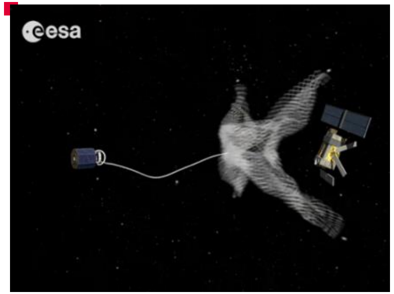
- R/T, simulated or playback data, 3D interaction

SPACE SURVEILLANCE & ACTIVE DEBRIS REMOVAL

Leading provider to ESA SST: original SST activities at ESA (DISCOS, CRASS, ODIN) and major involvement in ESA's SSA/SST (15+ projects) with leadership in SST Integration & Services, Cataloguing, Sensors Tasking & Coordination

Leading provider to CNES SST: SST simulator, re-entry tools and support to studies

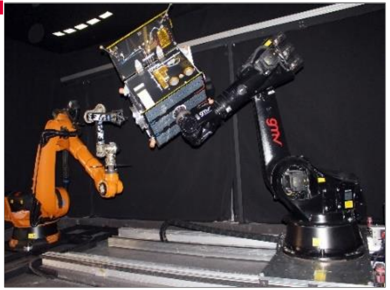
Commercial service (***closeap***, ***focusoc***) for agencies and telecom operators



- Definition of ESA's Space-Based Surveillance (SSBS) Demonstration Mission and SBSS Permanent System
- Leading ANDROID (Active Debris Removal Demonstration Mission) definition Study
- Contribution to e-Deorbit Mission Analysis and GNC design and development

S3TOC: Spanish SST Operations Centre:

- Leadership of the development of S3TOC
- Leadership of S3TOC operations and maintenance
- Support to Spanish SST sensors qualification activities



Test-bed & technology development:

- On ground validation of robotic arm based servicing
- Investigation of Active Detumbling Solutions for Debris Removal
- Net Parametric Characterization Parabolic Test experiment
- Control and Management of Robotics Active Debris removal

LAUNCHERS

IXV:

- Onboard Software
- Software Validation Facility
- Vehicle navigation as part of the GNC system
- Vehicle Model Identification or identification of reentry aerodynamic parameters

TEC:

- Avionics test bench for next generation transportation systems

Space Rider / PRIDE:

- OBSW/SVF Definition and Design
- Contribution to GNC Sub-system Design and Develop.
- Use of Space Rider for Mars Sample Return GNC on-orbit experiment validation

Dream Chaser:

- Collaboration with Sierra Nevada Corp. for the analysis of use for Active Debris Removal purposes

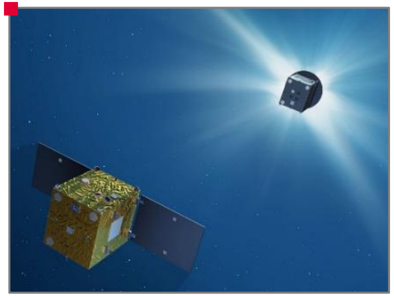
VEGA:

- Contribution to Guidance, Navigation and Control design and validation, QA and RAMS
- Support to VEGA-C New Avionic Definition

PLD SPACE:

- Complete avionics of MIURA 1, including guidance, navigation and control, telemetry and onboard software of both launchers
- Participation jointly with PLD Space in MIURA 1 integration, qualification and launching-support operations

TECHNOLOGY DEMONSTRATION MISSIONS



aim

OPS-SAT

EGS-CC EUROPEAN GROUND SYSTEMS COMMON CORE

cnes SIRIUS FLIGHT DYNAMICS

PERASPERA

SPACE ROBOTICS TECHNOLOGIES

PROBA-3

- Full responsibility over the Formation Flying System, which is the major mission innovation
- Responsible for the Formation Flying on-board guidance, navigation and control subsystem
- Developer of the on-ground flight dynamics system and formation flying monitoring system

AIM/HERA

- Responsible of the guidance, navigation and control on-board system

OPS-SAT:

- Key partner of OPS-SAT nanosat flying laboratory to test new techniques in mission control and on-board

ASSIST:

- On-orbit servicing fuel transfer study on interfaces and standardisation

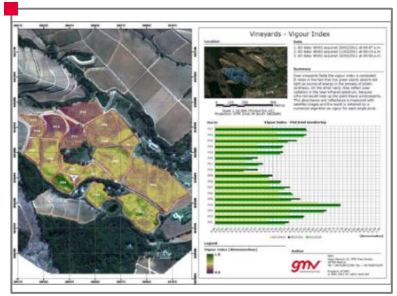
- Core partner and key developer of the European Ground Systems Common Core
- GOF9 Frame Contractor for Astrodynamics, Data Systems and Operations
- Developer of CNES SIRIUS Flight Dynamics System for new CNES missions
- CNES Frame Contractor for flight dynamics, operations and on-board software

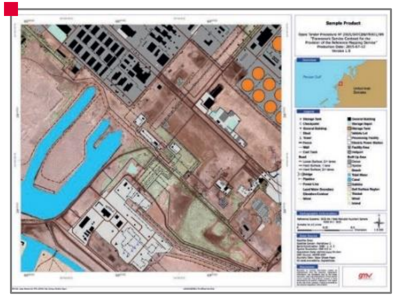
Leading role in PERASPERA (Strategic Research Cluster on Space Robotics Technologies):

- ESROCOS: development of the operating system for control of space robots
- ERGO: Autonomy or artificial intelligence system
- FACILITATORS: Validation test phase in diverse European laboratories

GEOSPATIAL SERVICES (downstream)

WORLD CLASS
SUPPLIER OF
INTELLIGENT FLEET MANAGEMENT SYSTEMS





SATNAV applications for integral solutions:

- Intelligent Transportation Management Systems
- Fare Collection Systems
- Scheduling and Rostering
- Passenger Information Systems
- Moviloc

World class supplier with more than **400 customers** in **35 countries** from **4 continents**

Agriculture:

- Crop growth models for Food security across Africa (AfriCultuReS)

Forests:

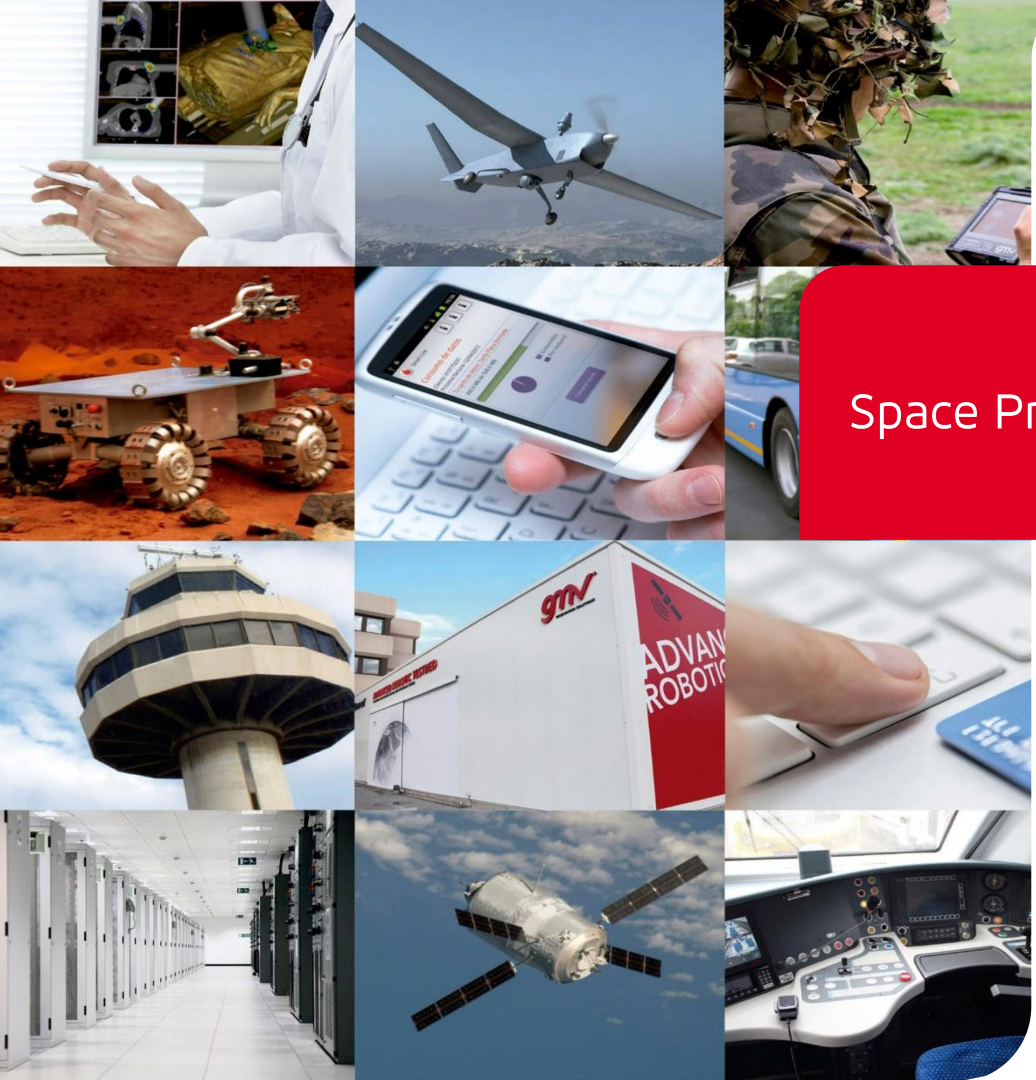
- Mozambique mosaic generation to support REDD+
- Forest Biomass Estimations by means of multisource data in Spain
- Operational sustainable forestry (MySustainableForest)

Land characterization:

- Forest Geo-information for Monitoring Tree-dominated areas in Abu Dhabi Emirate
- Land use / Land Cover map for habitat conservation policies in Abu Dhabi Emirate
- Monitoring of Oil & gas pipelines fields in Iraq
- Urban green areas characterization (UrbanGreenUp)

Emergency and Security:

- Support to External Actions operational service provision FWC for the SATCEN
- Reference mapping FWC for the SATCEN
- Maritime surveillance for Guardia Civil
- Earthquake post-impact assessment for the International Red Cross



Space Processing Solutions

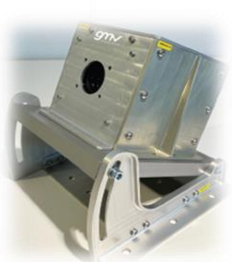
SPACE PROCESSOR & CO-PROCESSOR

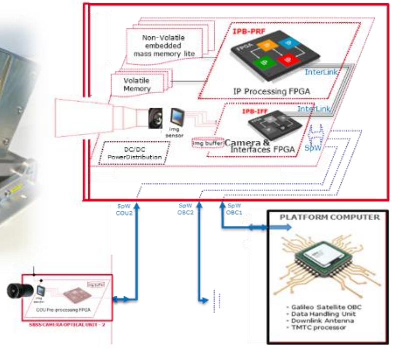
High-Performance On-Board Co-processors: HERA-IPU, GMVision

- Computer-Vision HW acceleration, spaceWire PUS, camera images correction
- Reconfigurable in-flight to accomodate other VBN IPs or CNN experiments
- HERA-IPU o fly on HERA mission supporting autonomous VBN. GMVISION using full European components (rad-hard FPGAs and DC/DC)
- Evolution to miniaturization and integrated OBC+Accelerators

G-Theia1 Smart On-Board Camera + Processing

- Embedded all in 1: sensor, optics, proximity logic electronics, pre-processing images and HW accelerated processing on-board
- Validated for Space-based Surveillance and Tracking based on optical images processed on-board, re-used for Vision-Based Navigation (proposed in Leopard, CAT)
- Second external camera connection for 2 Optical Heads with same processor
- Evolution to maturization, Optics, SoC and Deep-Learning exploitation





MLA-OBC Microlauncher Avionics set

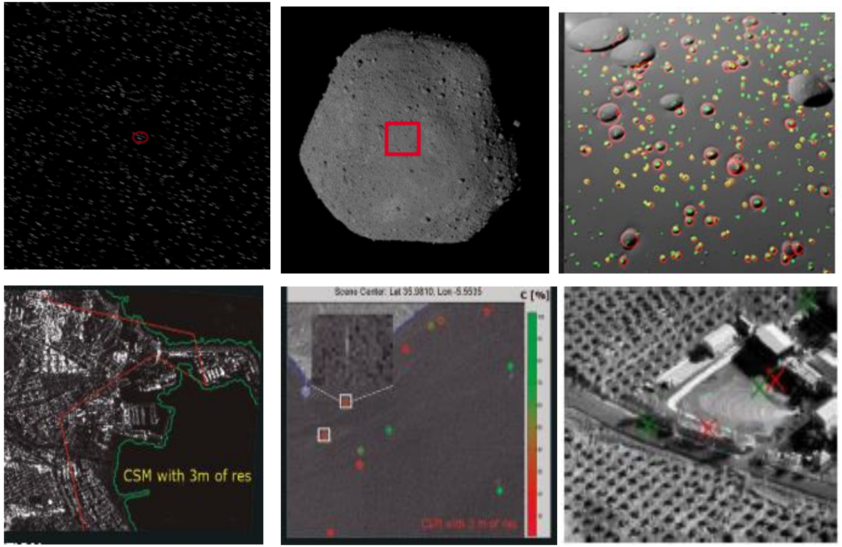
- System-on-chip Processor + FPGA. >TRL7
- Main OBC devoted to GNC and DH.
- Distributed nodes for sensors, actuators and TVC computer
- Redundant Time-Sensitive Network gigabit ethernet on FPGA side
- Evolution to orbit requirements

On-board AI deployment

- Autonomy AI → Deep Learning DNN/CNN → SNN Neuromorphic (event-based ←→ power consumption)

Heritage ESA/EDA projects with focus on replacing computer-vision (Optical SAR) and edge-computing to reduce downlink cost

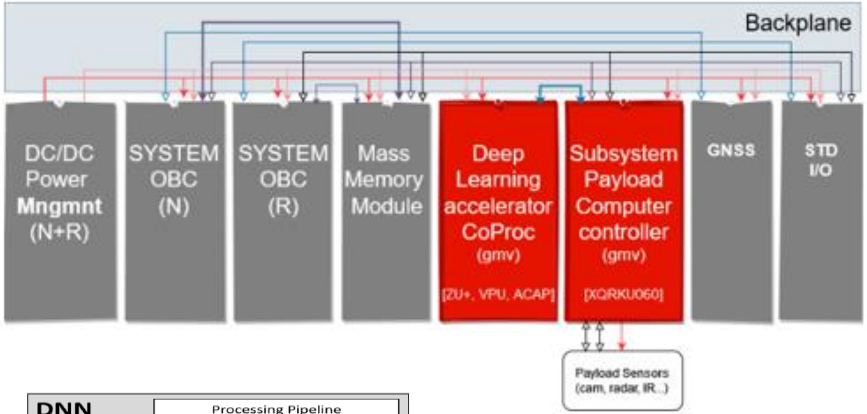
- EO classification and detection problems,
- Space-based Surveillance Debris Detection,
- Asteroid Patch pinpointing
- Vision-Based Navigation
- Built-in-test ML classifier BIT
- Safe Autonomous Flight Termination
- Ship/Vessels Detection and tracking
- Coastline Detection

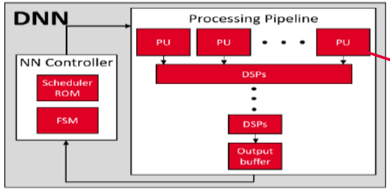


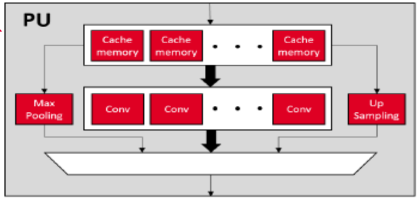
- Laboratory testbench representative HW and Image Generation

DL Accelerator Development and Analysis

- Processor, tools, deployment, architetcure
- Flight-segment AI accelerator compatible with new standard ADHA architecture
  - High-Performance dedicated Processing Unit
  - COTS, Ruggedized, Rad-Tol, Rad-Hard
- Different approaches being developed
  - (A) FPGA hand-written RTL DL processor
  - (B) Model-based Design to HW/SW FPGA SoC
    - (C) Dedicated AI cores:
      - Ubotica's Myriad2 VPU + Controller FPGA
      - [bonus-track] Versal ACAP AI core
- AI Demonstrators Use-Cases
  - Moon Landing Crater Detection
  - Space Exploration Asteroid patch pinpointing
  - Space-Based Surveillance Debris Detection








ESA test of Intel Myriad 2 AI chip at SPS North Area

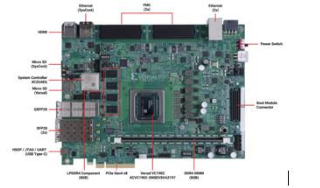
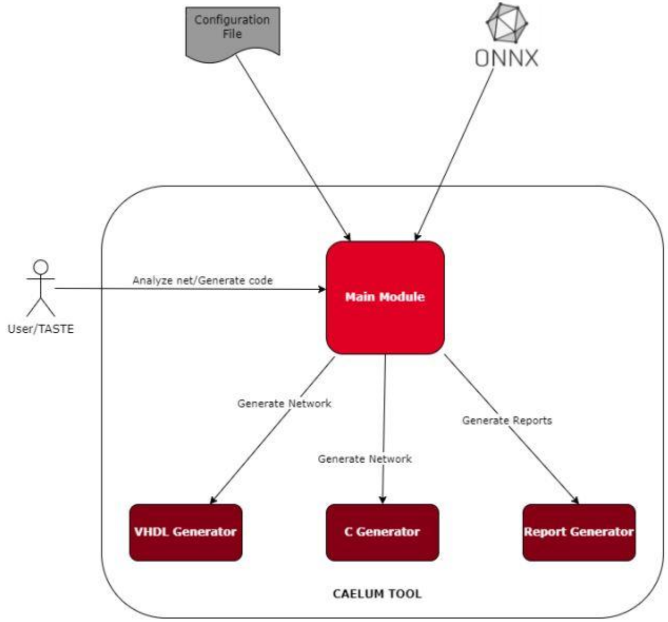


Fig. 7. Board Features of the Versal AI Core VCK190 Evaluation kit

Tools and framewors for on-board AI deployment

- Edge-Computing of inferred CNN or a whole Continual Learning application imposes high performance processing requirements for autonomous real-time execution in space avionics
- We get models and implement on-board
- Hand-written using different languages for HW targets
- We developed CAELUM tool framework to accomplish different HW deployment target solutions end2end
- Analysis on embedded processing and memory for feasibility checks on HW targets
- Solutions on:
  - ➢ Zynq, ZU+, ku060, V5QV, ngultra, ARM, Leon
  - ➢ Myriad VPU, Coral TPU, Jetson Nano, Versal

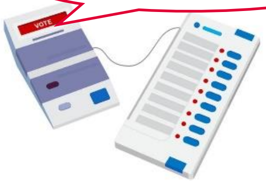
```
Network done.
Max in memory variables (input not included): 2
Max memory allocated for outputs (dynamic allocation) (input not included): 86528 bytes
Variable pool size: 93704 bytes
Variable pool size: [40, 2000, 2000, 3136, 43264, 43264] bytes
Variable pool maximum used size: [40, 2000, 2000, 3136, 43264, 43264] bytes
Maximum pool usage in a cycle (Theoretical best): 89664
Total output memory (fully static allocation): 149321 bytes
Parameter size : 1651680
Status: OK
```



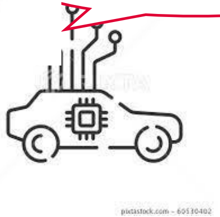
Fill de Gap between space avionics and edge computing realities

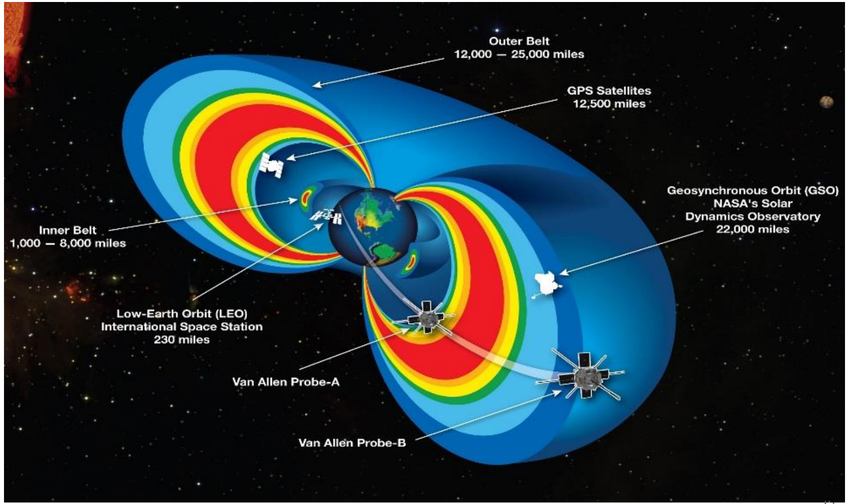
- A quick story:
- May 18th 2003, 22:30
  - What is radiation?
- Schaerbeek district, Belgium

+4096 votes?



+4096 m/s?



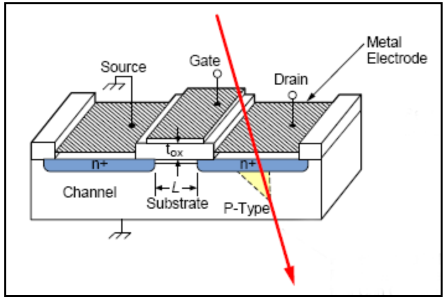


esa credits

- ENERGY in form of accelerated particles (protons, electrons, neutrons, ions, photons…)

- Sun: Solar flares and solar wind
- Milky Way: Supernovas and high-energy events

- Radiation Effects
  - TID, SEU (see, sel, set , sefi..)
  - Destructive Latch-up

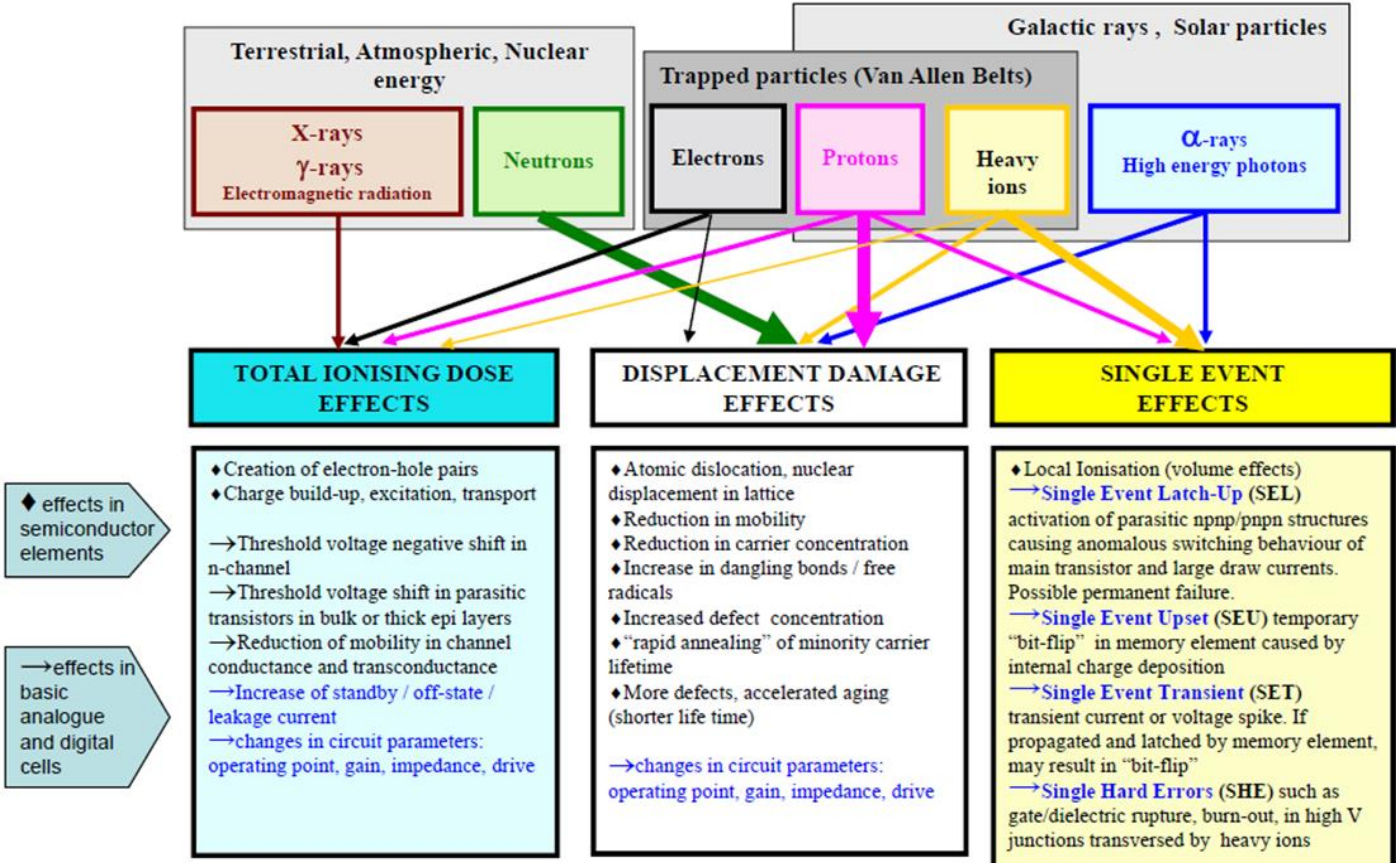


DON'T FORGET:

- Launch Environment
  - Shock and Vibration

- Thermal Environment (Vacuum)
  - Surviving Extremes
  - Getting the Heat Out

Radiation Effects in semiconductor devices



esa credits

Level	Radiation effect mitigation technique	TID	SEE		
			SEL	SEU (or sampled SET)	SET
System	Temporarily remove and re-apply power supply ("**power cycling** ") to eliminate "microlatch" or non-destructive latch-up condition.		X		
System	Apply **reset** to "persistently flipped" memory elements			X	
System	External leakage **current detection and protection** (current limiters) for latch-up in sensitive devices	X	X		
System	**Fault detection and Reconfiguration / systematic scrubbing** (RAM based architectures)			X	
System	**HW or time redundancy at system level** (for voting or reconfiguring)		X	X	
System	**Cold-sparing & Hot swap**	X	X		
Structure	**Aluminium Shielding**	X	X	X	X
Wafer process	**SOI** processes	X	X	X	X
Wafer process	**thin epi over heavily doped substrates**	X	X		
Wafer process	**trench isolation / p+ guard rings around NMOS transistors**	X	X		
Cell Layout (RHBD)	Hardened libraries: **edgeless transistors, capacitive and resistive hardening; guard bands or equipotential source and/or drain regions**, Part parameters de-rating to reach immunity to expected degradation (i.e. drain-to-source voltage), **redundancy and feedback** at transistor level	X	X	X	X
Netlist design	EDAC: **parity, checksums, codes** ; fault masking: **TMR, Hamming/cyclic codes**, dead-lock-free **FSM /Counter hardening**			X	X

esa credits

Cost of rad protection:

- More silicon área, less integration
- Lower speed
- More weight
- Higher power consumption
- Higher design complexity, longer development times
- Export constraints dependencies
- Higher techonology prices (special= expensive components, tests and tools

Radiation protection can have a high Price, but the cost of loosing on-board experiments on the entire satellite is much higher

Design Metrics

- Trade-off analysis
  - The best solution is not the most complex, is the one that optimizes the tradeoff between all the different design metrics

Cost
- Recurring cost: The cost of manufacturing a unit
- NRE (Non-Recurring Engineering Cost): The one-time cost of designing the system (includes prototyping)

Performance
- Real time?
- Latency/Frequency

Physical & Environmental Constraints
- Mass, Volume, Weight
- Volume
- Power consumption
- Thermal endurance
- Vibration endurance

Interfaces and Communication Requirements
- Speed links
- Protocols
- Integration other units

Development time
- Time-to-protoype: The time needed to build a first working version of the system
- Time-to-market: The latter time, plus the time to manufacture the product and distribute it to the resellers

Radiation/Fault Tolerance
- Rad-hard components
- Mitigation techniques
- Fault-tolerant designs

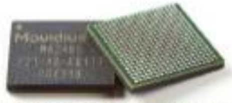
Other design issues
- Flexibility: the system can be used for different tasks without significantly increasing the NRE or the unit costs
- Maintainability: the system can easily be updated and/or repaired
- Fail-safe operation: Necessary in mission-critical systems, like life support

Understanding technology fabric

- Specific space radiation protection
  - RHBD Radiation hardened by design devices; qualified (MIL/ECSS) packages
    - – Requires only little additional system radiation hardening
  - RT Not hardened devices; but radiation tested; qualified (MIL/ECSS) packages
  - – Requires dedicated system radiation hardening
  - COTS Commercial devices; hopefully radiation tested; not qualified package
    - – Requires dedicated system radiation hardening and possibly radiation test
    - – Otherwise: could compromise on mission lifetime, availability and reliability

RHBD example: GR740 (CAES Cobham Gaisler)

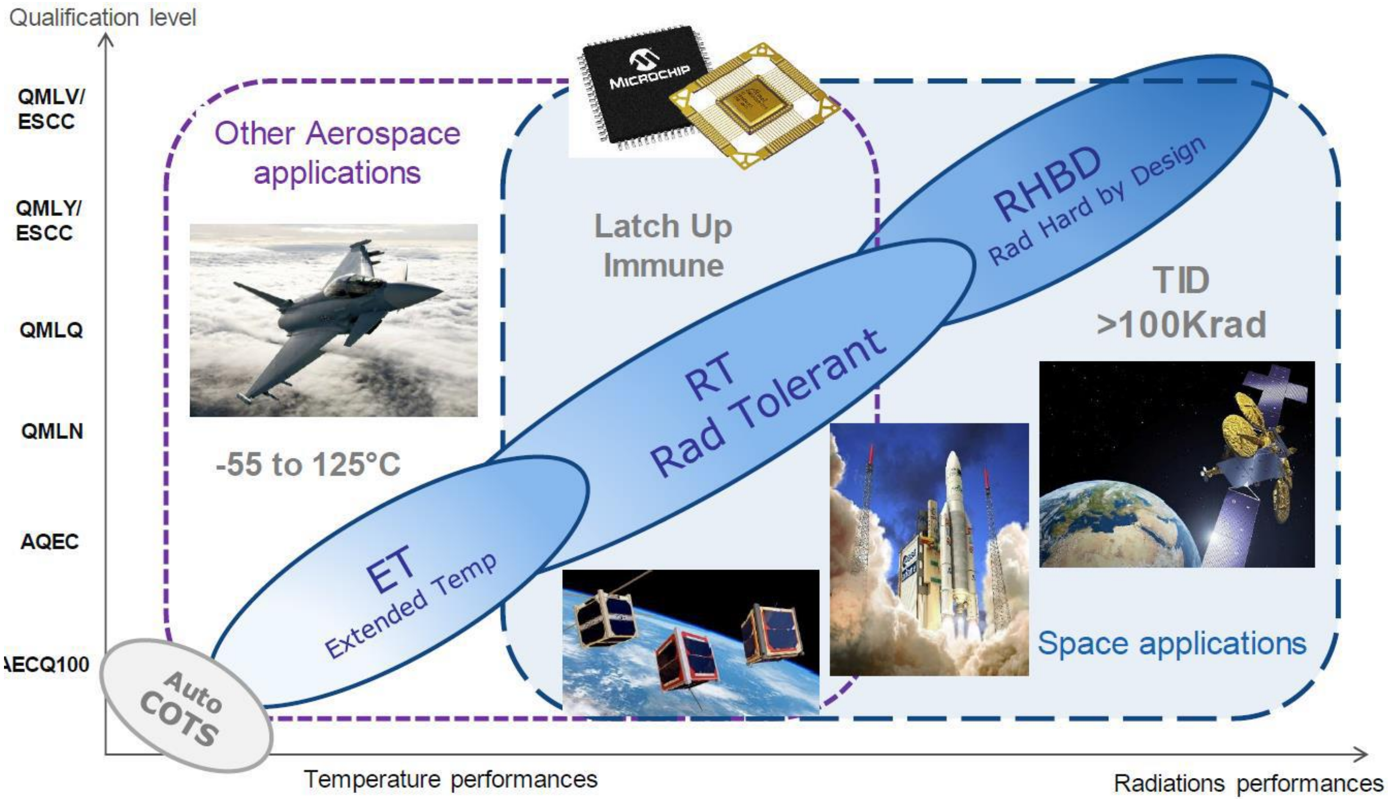
RT example: XQRKU060 (Xilinx)



COTS example: Myriad 2 (Intel)

* Currently only RHBD and RT are possible for most ESA (high risk) missions. RT requires dedicated analysis for target orbits. COTS only possible through up screening campaign (>1MEUR)

- Microchip (company) view



New Space – COTS devices

High performance the main driver for COTS devices, but also:

- **Radiation tolerance**
  - _ TID minimum requirements –driven by technology node
  - _ SEL/SEU/SEFI mitigation on system-level and/or software –driven by design
- **Fault-detection**
  - _ Correcting codes (ECC) on caches and external memory interfaces –EDAC
  - _ Duplication or Triplication of functionalities (TMR)
  - _ Time repetition (3 consecutive executions)
- **Packaging and power**
  - _ Single-point thermal load,
    generally not designed for operating conditions vacuum
    (maximum 10W components – otherwise complex thermal design)
- **Product and market aspects**
  - _ Long-term support for device
  - _ Availability of device lot tracability(Single Controlled Baseline)

Other qualitative aspects must also be taken into account:

- Availability of **development, verification and debugging tools**
- Size of user community –adoption of tools
- Support for reliable real-time operating systems
- Access to open-source APIs and drivers for inspection

Conclusion –**Selection of processor devices requires coordination of experts in multiple domains**

- Electronics system experts; components experts; environmental experts; quality experts; software experts; etc.

Credit: Alén Space

European guidelines for the use of COTS components already exist:
ECSS-Q-ST-60-13C "Commercial electrical, electronic and electromechanical (EEE) components" being expanded with COTS guidelines,

TECHNOLOGY PROCESSING AVIONICS DESIGN OPTIONS

Identify the most suitable platform for the requirements and specification

Single and multicore processors
- GR740 – RHBD quadcore LEON4
- Teledyne e2v – RT (qualified COTS) quadcore ARM Cortex A
- HPSC – heterogenous ARM Cortex-A and Cortex-R processor

DSPs and manycore processors
- HPDP – 40x core RHBD stochastic grid-array, 2x VLIW cores
- RC64 – 64x core VLIW DSP processor with hardware scheduler
- SX4000 – Quad ARM A53 and DSPs (optimized for SDR processing)
- Kalray MPPA – manycore processor

Embedded GPUs
- NVIDIA TX2 and Xavier
- AMD "Steppe Eagle", Embedded Ryzen V1000 and V2000
- Low-power softcore GPU in FPGA

FPGAs (and "MPSoc"/"ACAP"/"Heterogenous FPGA-based SoCs)
- Xilinx Virtex5QV, XQRKU060, ZUS+, Versal AI, Versal AI Edge (just released)
- NG-LARGE, NG-ULTRA, ULTRA-7
- RTG4, PolarFire-RT, PolarFire-SoC
- Front-Grade Lattice Certus

Image/Video Processing
- HERA-IPU
- Myriad2 VPU

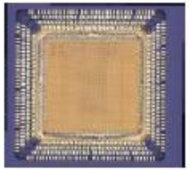

HERA-IPU (GMV)

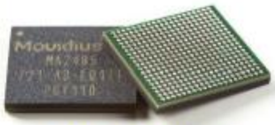
GR740 (Gaisler)


TX2 (NVIDIA)

ZUS+ (Xilinx)

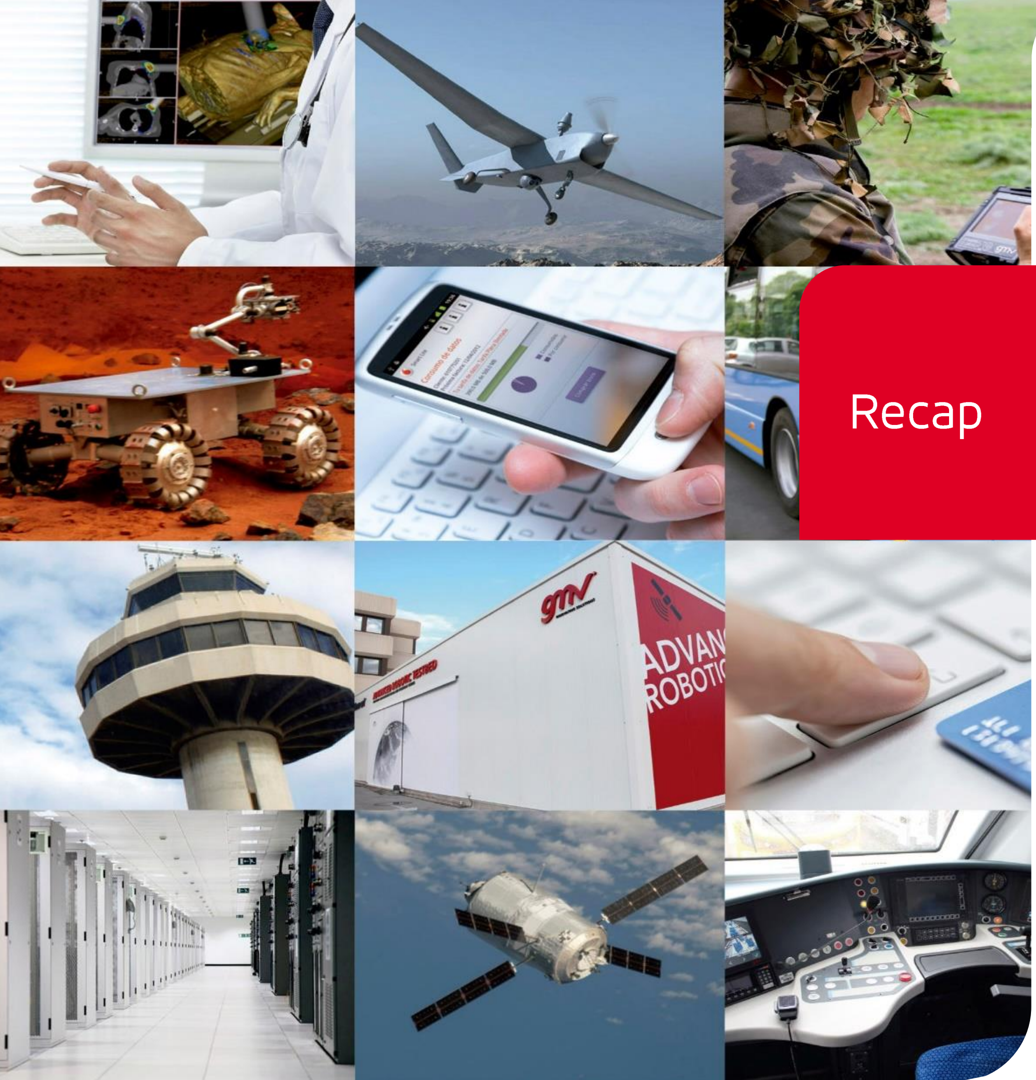
Kalray (MPPA)


HPDP (ISD)



Myriad 2 (Intel)


NG-MED (NanoXplore)

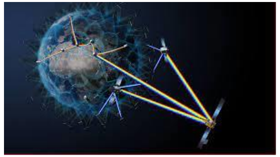


Recap

ENABLING TECHNOLOGIES

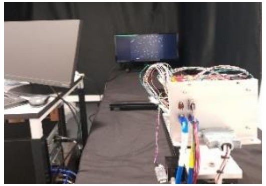
AGENDA 2024+

• High-Speed Data communication



- hydRON optical communication network for boradband in space
- 4SSTB

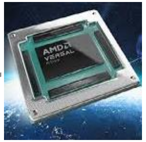
• Advanced Sensors



- Edge Computing
- Smart Sensors
- G-Theia:
  camera & co-processor
- VigIA concept for EO artificial intelligence on Edge

• Low-Power Electronics

RISC-V

¿ 

?

LPGPU

• Autonomous Systems & AI:

ERGO, ESROCOS, FACILITATORS, ADE, PERASPERA.
Very long traverses with autonomy decisión making goals

Deep Learning

Event-based Neuromorphic

• Radiation-Hardened Electronics (radiation-tolerant) (ruggedized COTS)

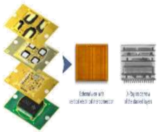
HERA-IPU
GMVISION
AVIOAR
IFMSOC
GNSSW-HS

- AITAG, AUTONN-SW

European guidelines for the use of COTS components already exist:
ECSS-Q-ST-60-13C "Commercial electrical, electronic and electromechanical (EEE) components" being expanded with COTS guidelines,

• Miniaturized Electronics

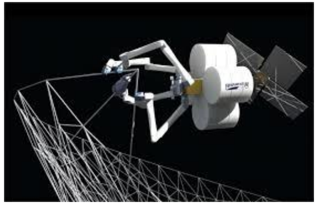
- Shrinking fabric node & technology
- Mems, System-in-Package
- Smaller instruments, cameras…



• Quantum Technologies

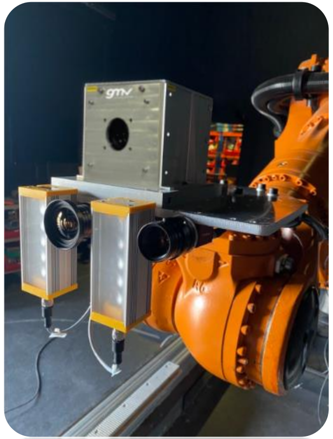
Quantum Communication,
QKD & PQC security
TPM for Space
Quantum TRNG

• Additive Manufacturing



SpiderFab: 3D Printing Robots Construct Structures in Space

Glad to get questions or coffee chats!



Thanks