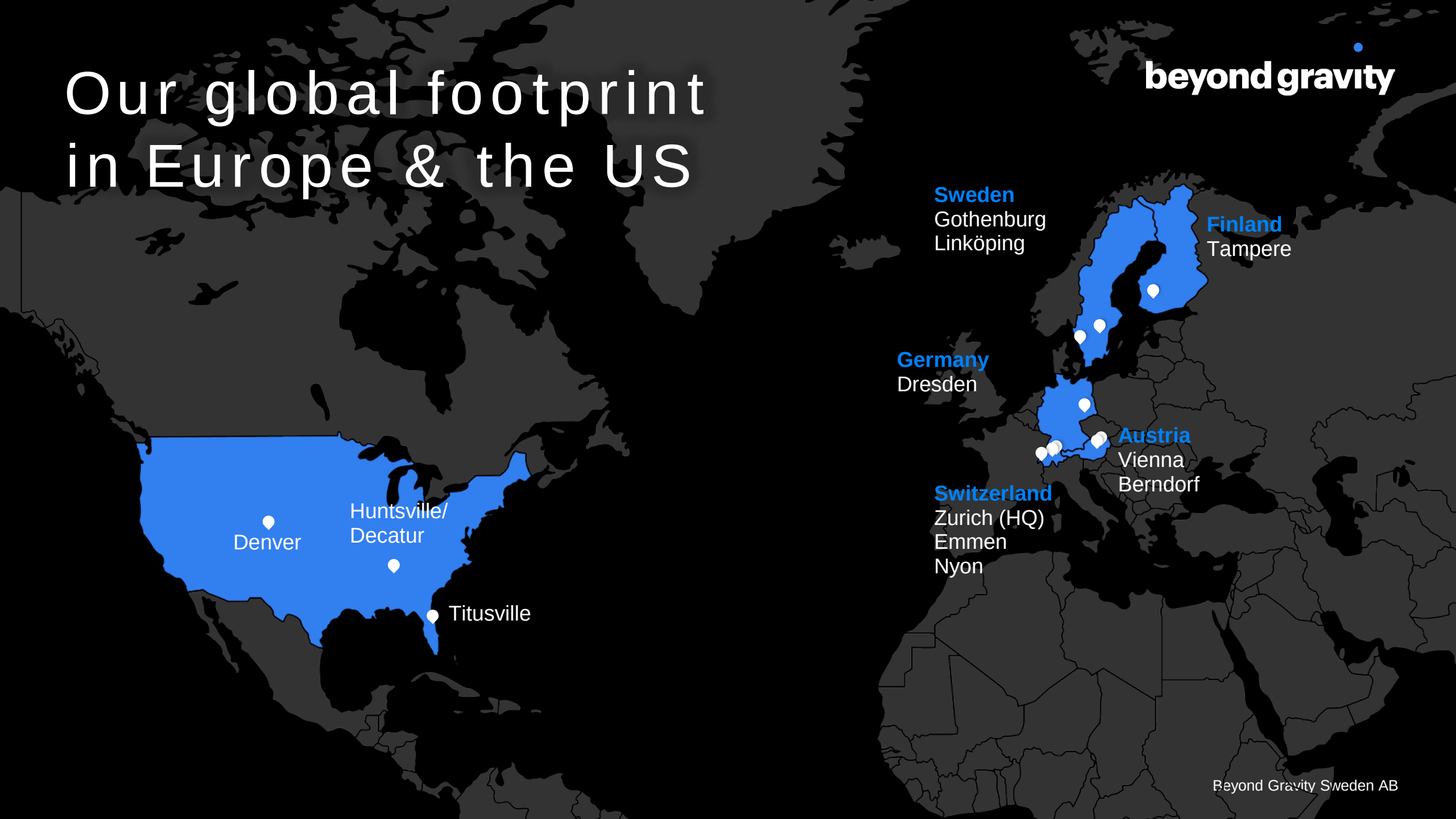
beyond gravity

The High-Performance Single Board Computer for Space Vehicles

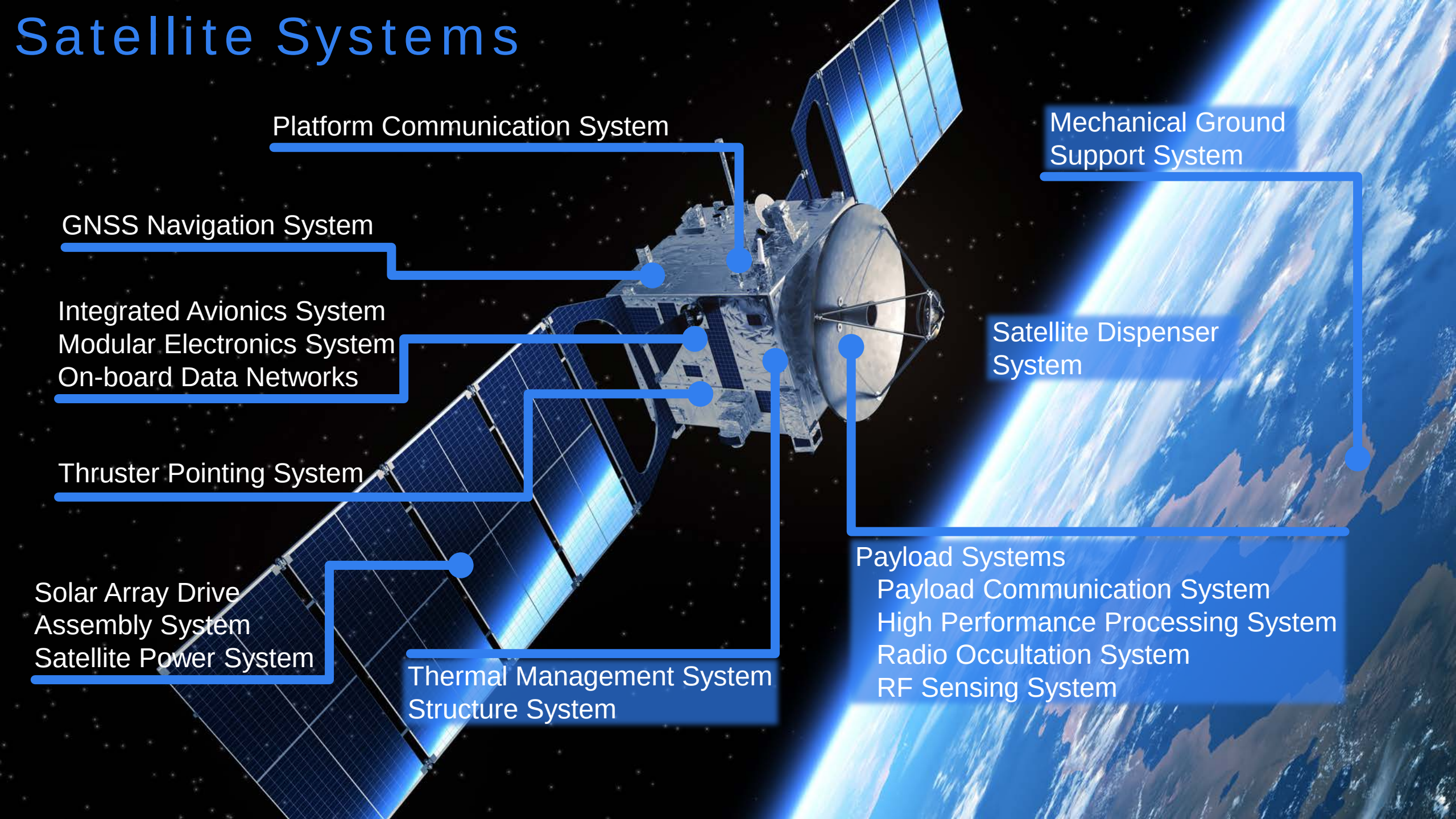
EDHPC2023 Juan-Les-Pins

05 10 2023 | Jonas Lebram – Systems Engineer

Our global footprint in Europe & the US



Satellite Systems



Platform Communication System

GNSS Navigation System

Integrated Avionics System
Modular Electronics System
On-board Data Networks

Thruster Pointing System

Solar Array Drive
Assembly System
Satellite Power System

Thermal Management System
Structure System

Mechanical Ground
Support System

Satellite Dispenser
System

Payload Systems
- Payload Communication System
- High Performance Processing System
- Radio Occultation System
- RF Sensing System

Satellite Electronics

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- Satellite On-Board Computer
- Remote Interface Units (RIU / RTU)
- Command and Data Handling Subsystems
- Data Processing
- Navigation Receivers
- Frequency Converters & Receivers
- Antennas

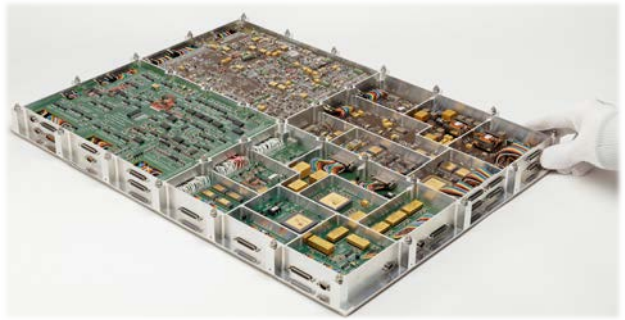








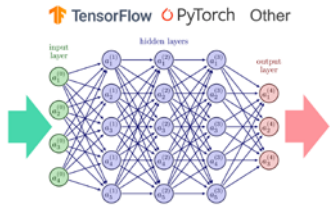





Beyond Gravity Sweden AB

Need for processing power

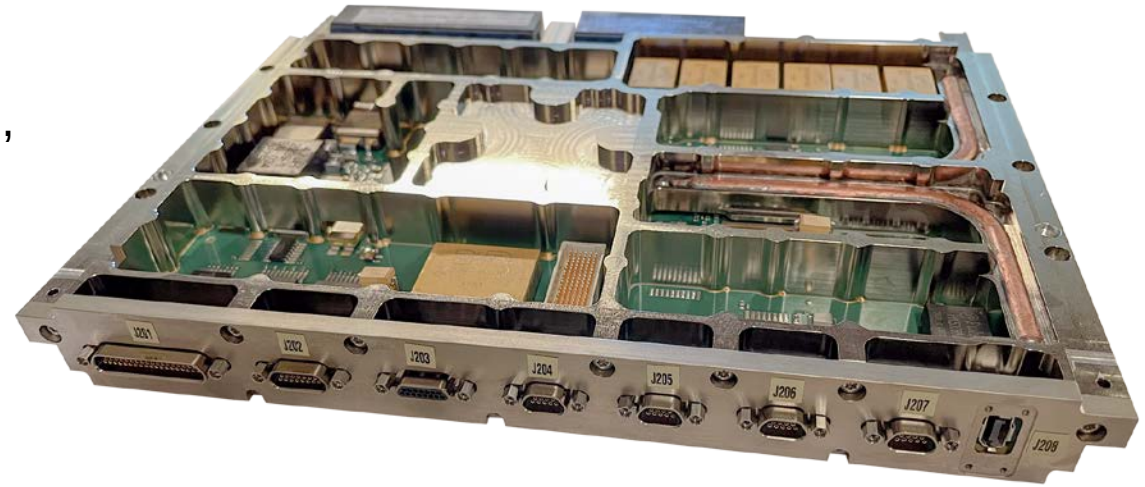
- Modern applications require more and more processing power in flight for e.g.
  - AI/ML model execution
  - Real-time image processing for visual navigation and autonomous control or earth observation and object tracking
  - Edge computing (data processing, compression, filtering) may reduce the need to downlink large amount of data
  - Encryption
  - Software Defined Radio
  - Robotics



Lynx Single Board Computer

A high-performance space grade computer module

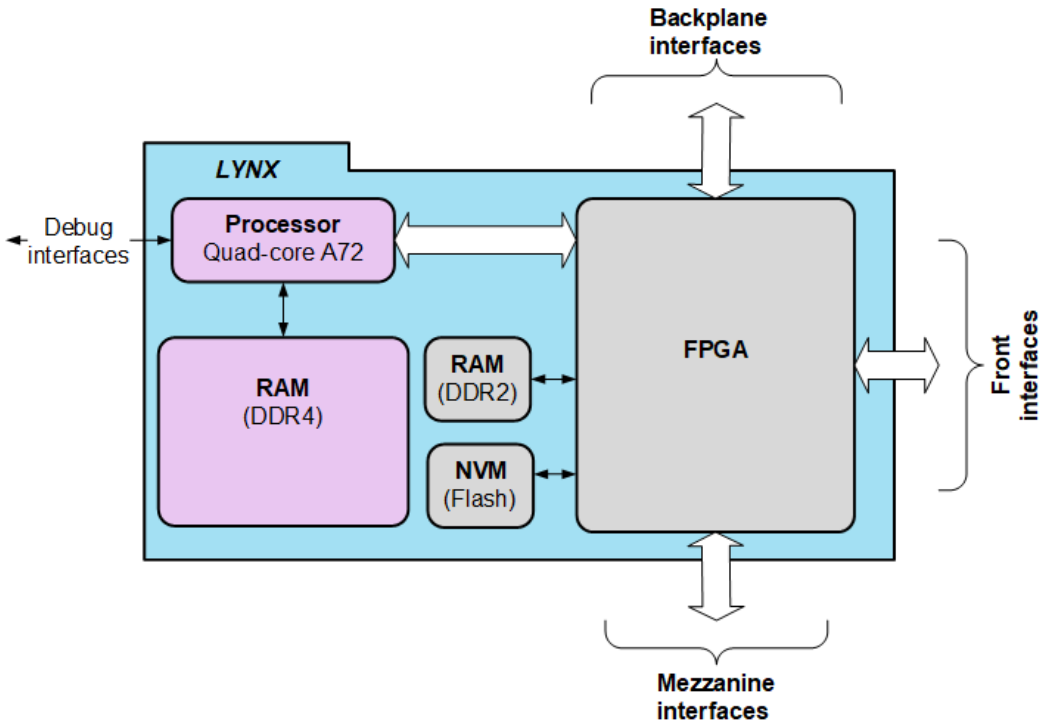
- High-performance general purpose single board computer
- Mass storage capabilities
- Means for project specific FPGA implementations /add-ons, reprogrammable in flight
- Powerful quad core ARM processor, delivering > 30,000 DMIPS
- Very fast DDR4 memory
- Lots of general purpose IO (Static and High-Speed)
- Designed for critical tasks in a harsh radiation environment including LEO, MEO, GEO and Deep Space



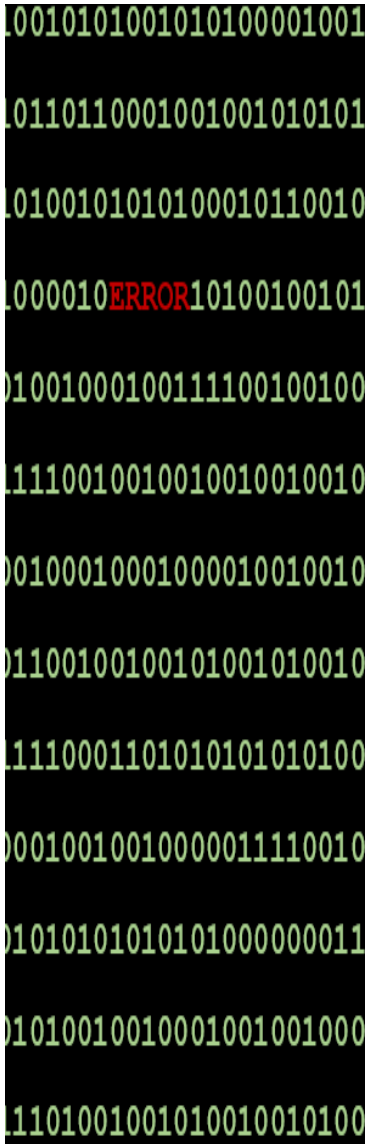
Radiation susceptibility regions

- High performance CPU Core, radiation characterized and screened, but still susceptible to SEU / SEFI
  - The quad core ARM processor
  - 4/8 GiByte DDR4 RAM
  - Ethernet, JTAG and debug UART for full integration in software environments
  - PCIe for fast memory mapped connection to FPGA Core

- Radiation tolerant FPGA Core
  - Supervises the CPU core
  - Provides high-speed serial links and signals
  - Allows custom/project specific FPGA implementations
  - Provides mass memory
  - DMA to/from Processor DDR4 RAM
  - Dedicated DDR2 RAM



Error handling



The CPU Core may encounter un-correctable errors due to SEE, both from the processor and from the processor DDR4 RAM.

- Some disappears in the next access, some requires a reset, and some needs a power cycle
- 1 restart in 500 days GEO quiet conditions, 1 restart per day during worst week in GEO

The **CPU Core** is separated from the **FPGA Core** to allow resets and power-switching of CPU Core only

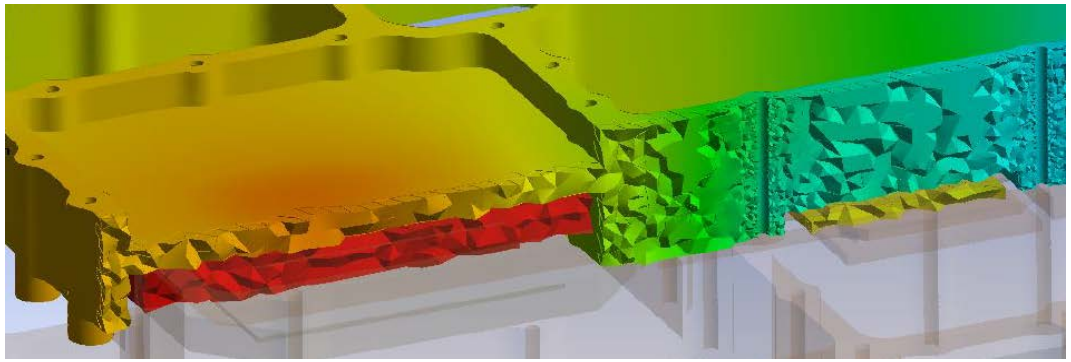
The FPGA Core implements TMR and ECC such that is becomes Rad-Hard.

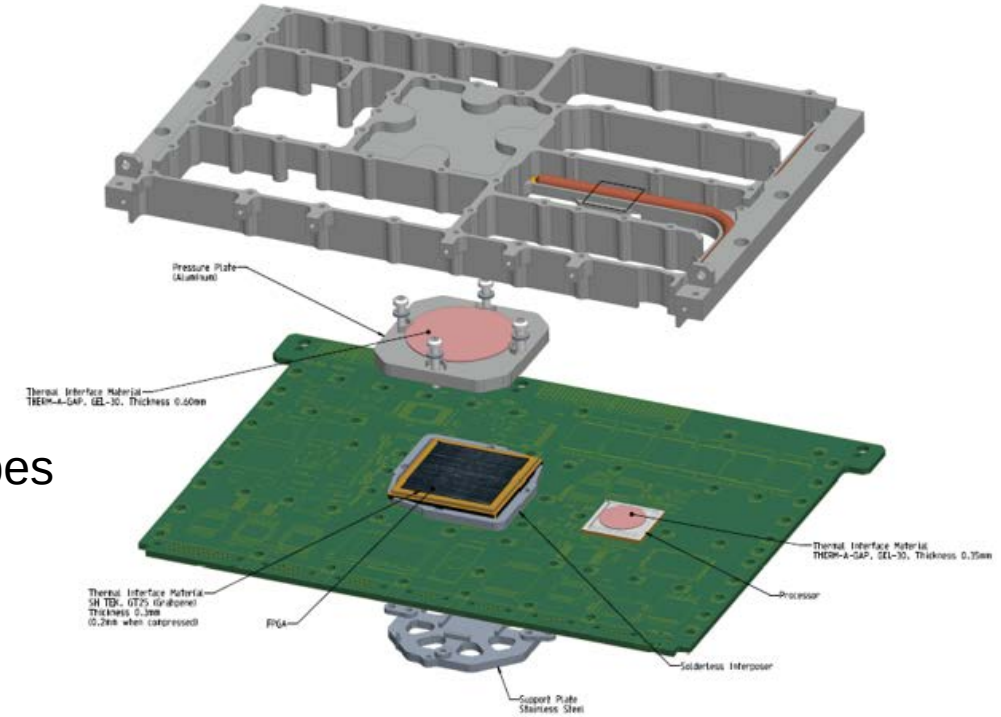
- FDIR Manager, providing watchdogs and alarms for CPU Core fault detection,
- CPU Core restart and power-cycle means for recovery
- Massive error correction in Flash virtually eliminating failing blocks
- Multiple software images for boot and ASW in Flash

Mechanical Challenges

- New PCB and new mounting methods
  - Solderless mounting of the Ceramic 1657 pin FPGA

- Advanced thermal design
  - The module is designed for a max dissipation of > 50 W
  - 25 % of the dissipation is from the processor, requiring heat pipes





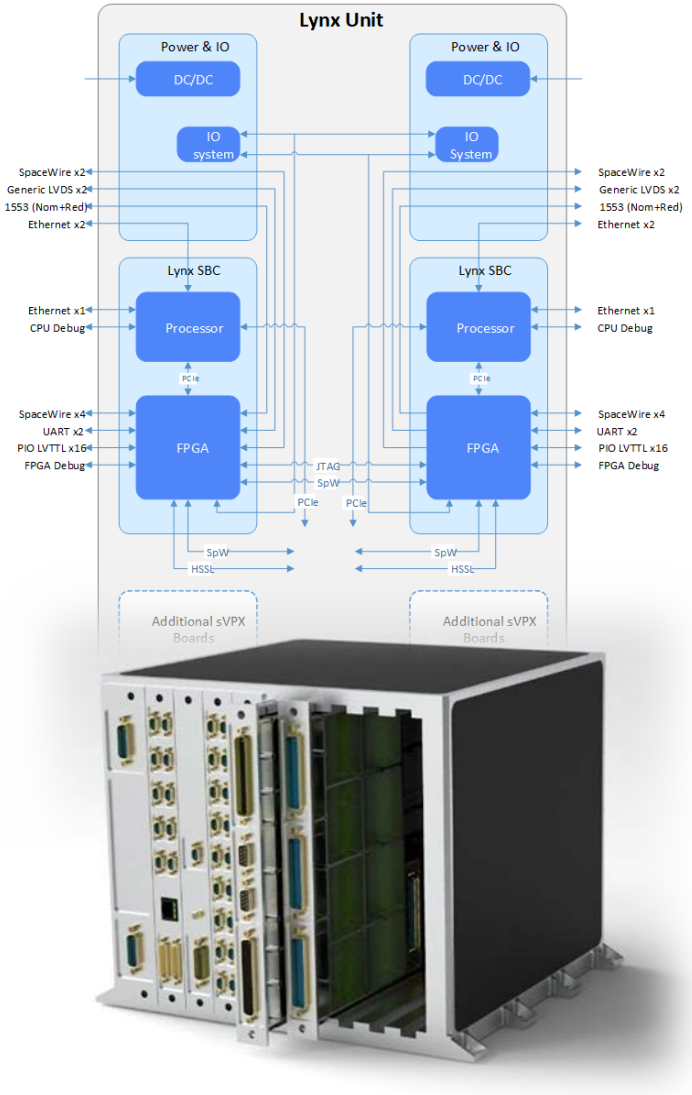
The computer module in a unit

- The standard 6U SpaceVPX module allows easy integration in units

- In a unit, the processing module is typically redundant with interconnection for
  - sharing state and health information (both for warm and cold redundancy schemes)
  - sharing FPGA resources (for semi-cold redundancy schemes)

- The Lynx may be bundled with a power converter module, routing internal links to external connectors

- The FPGA may be re-programmed in-flight by another module in the unit (e.g. the redundant Lynx)

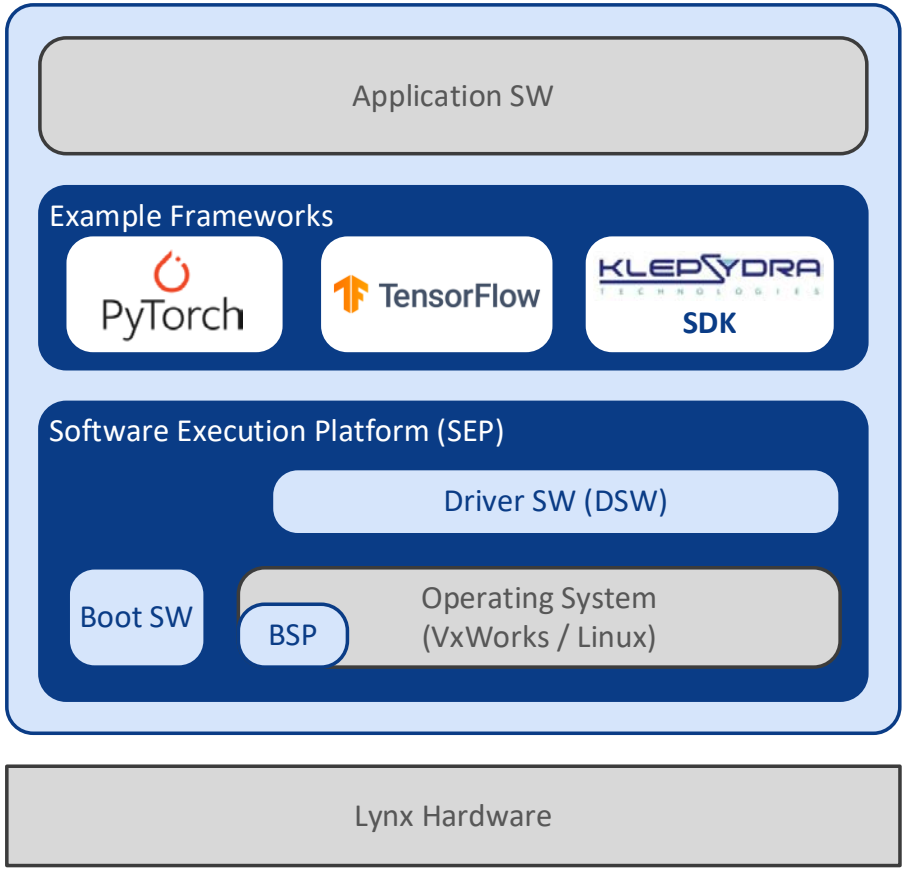


Software Environment

- High-performance processor boards like Lynx SBC may provide modern, well-known software development environments

- Operating system
  - VxWorks version 7
  - Linux (support is coming)

- Example Frameworks
  - Klepsydra SDK (edge computing, robotics, collision avoidance)
  - PyTorch, TensorFlow and others



Development background

- Development in the ESA ARTES Technology phase was completed in 2021. It covered
  - Functional design including critical interfaces, and
  - BB/EM available including basic FPGA core and SW framework

- The ESA ARTES Product phase continued with
  - HPPCM (i.e. Lynx) Engineering Qualification Model (EQM) design
  - Radiation and screening process of key components

  ESA main contact for this project has been
  King Lam, as Technical Officer, and
  David Steenari, as On-Board PL Data Processing Engineer

  At the time of writing, HPPCM TRR/CDR has been held, and review closure is ongoing.

Thanks for listening!