aerospacelab

October 2023

RHA, COTS & their applications to new space products

Aerospacelab at a glance

~100 M€

VCs, Contracts, R&D over 5 years

A growing team

~200 FTE in Q2, ~350 by Q4 2023

Arthur

Our first satellite launched in June 2021

One operational final assembly line

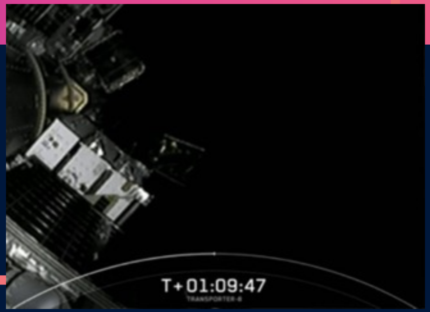
Since July 2022, we produce and assemble satellites internally

8 satellites ready

We launch 5 new R&D and commercial satellites in the next 3 months

European expansion

In 2021, 2022 and 2023 we opened offices in Switzerland, France and the US



Gregoire

Our first satellite VSP platform was launched on June 12th 2023

Mega factory

In 2026, we can produce 500 satellites per year in Charleroi, Belgium.

RT/RH/COTS components strategy

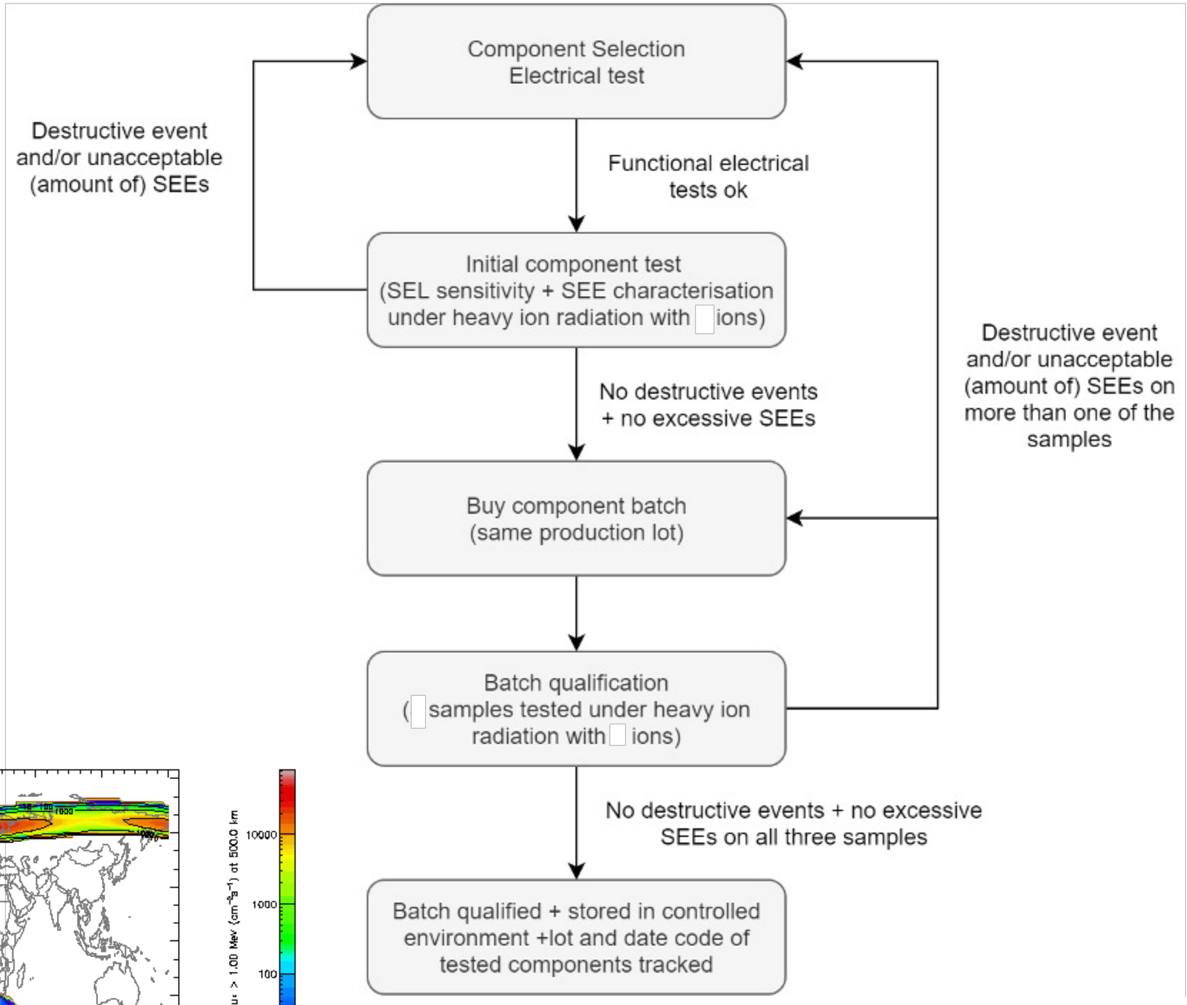
- Blend to meet aggressive price targets of customers
  - **5% RT or RH**: supervisors, watchdogs, GaN Mosfet for DC-DC converters
  - **95% COTS**: everything else

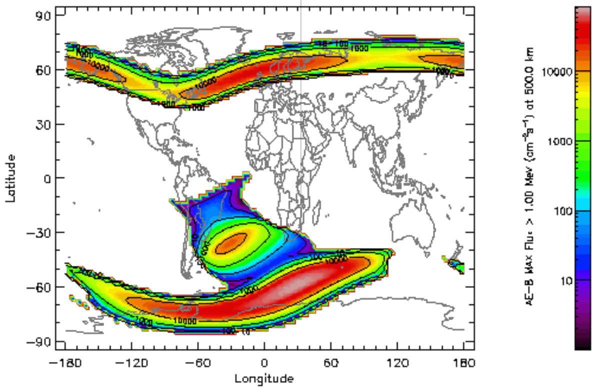
- COTS components selection
  - Mainly military grade / enhanced product / automotive grade components

- SEE radiation test campaign
  - Characterization of COTS components
    - SEL / destructive events sensitivity
    - SEE cross-section
  - Qualification of batches of COTS components for FM units
    - Identical lot code / date code withing a batch
  - Test conditions
    - Heavy Ion in UCLouvain Cyclotron
    - LET up to 62.5 MeV cm²/mg
    - Different ions used to extract the SEE cross-section
    - Board temperature: 85°C

- TID radiation campaign
  - Done at unit level / component level

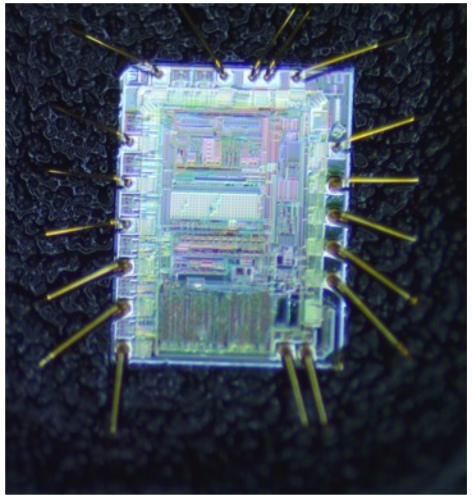
- Spenvis used to extract radiation environment of mission
  - Computation of error rate



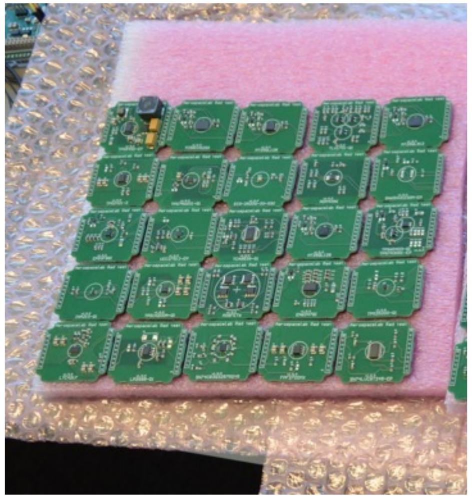


Radiation test setup: overview

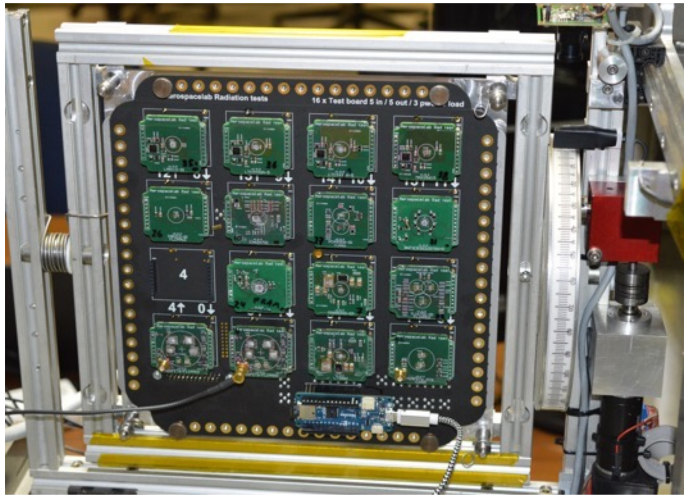
- Radiation test setup developed internally
  - Goal: to run cost effective radiation test campaigns
- Hardware
  - Motherboard
  - Daughterboards (for each component)
- Software
  - Logging software
  - SEE analysis software
- Features
  - Temperature control up to 85°C
  - Support of analog, power, digital and RF components
- Decapsulation
  - Etching process optimized by Aerospacelab + University
  - Suitable for gold, copper, aluminum bonding wire, flip-chip.



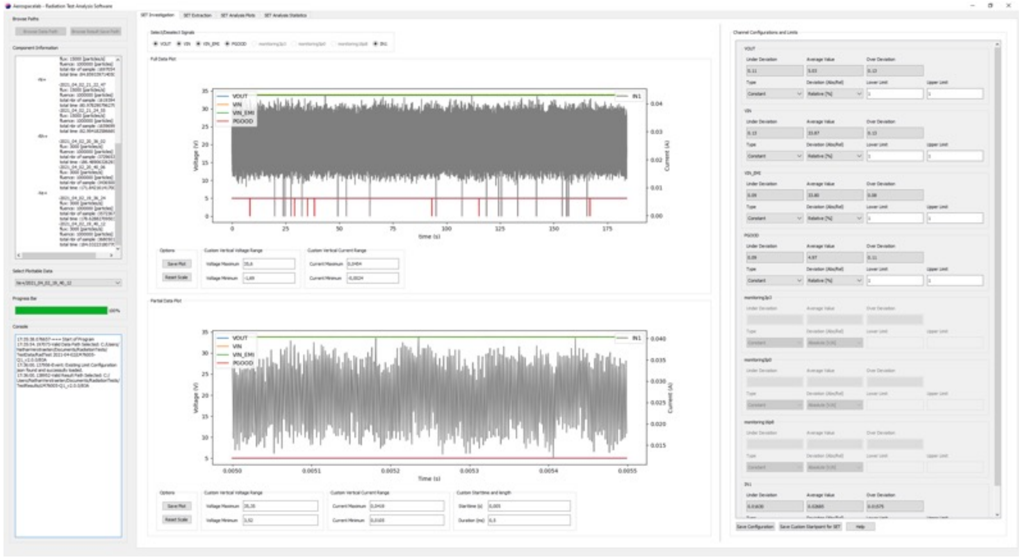
Decapsulation



Daughterboards



Daughterboards on Motherboard

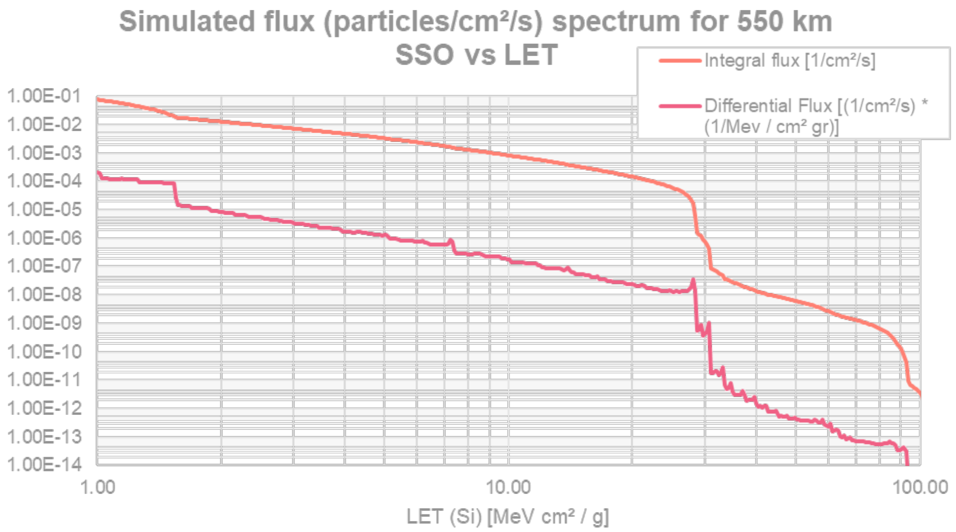


Postprocessing software

Radiation testing: outcome

Components tested

- 10 campaigns conducted (~ every 3 months now)
  - 400 components tested in total
  - 150 unique components tested, about 80 suitable for space applications
- 50 batches of components fully qualified for FM units



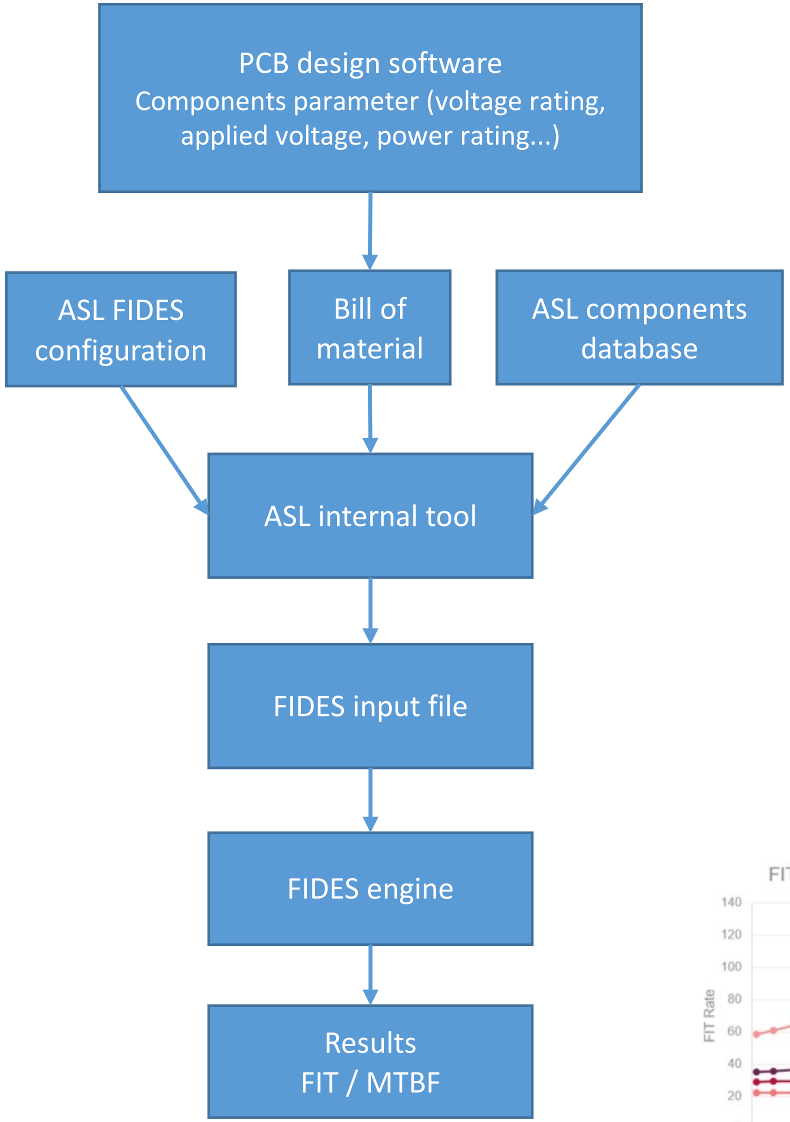
Mitigations put in placed based on results

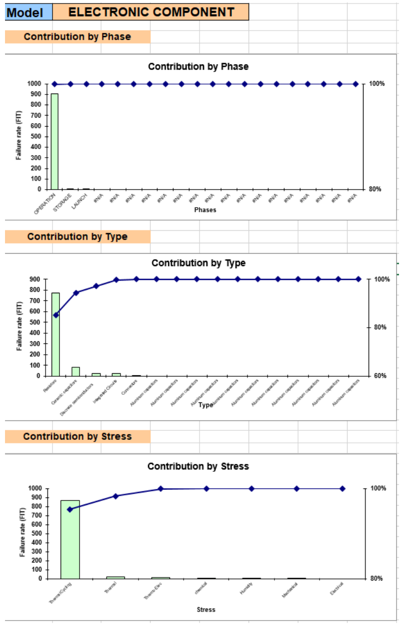
- SET characterized:
  - Max / min output voltage on DC-DC converter
  - Software mitigation for sensing (ADC, opamp, Vref)
- SEU
  - Characterized in all memories
    - Mitigated with ECC and/or scrubbing.
  - Characterized in FPGA
    - Mitigated with scrubbing and TMR.
- SEFI
  - Monitoring of peripherals, clocks, etc by micro-controllers and processors.
  - Watchdog for micro-controllers and processors.
- SEL
  - Current limiter and current measurement for components sensitive to SEL.
  - All power supplies (DC-DC converter, LDO) and current limiters: LCL free.

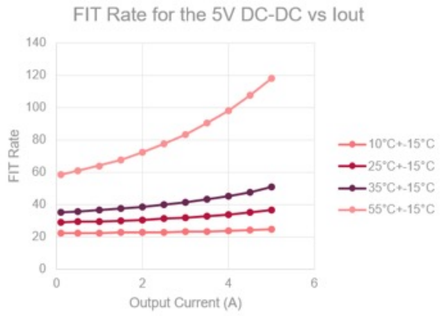
FIDES flow

- FIDES used to:
  - Compute MTBF / FIT rate of functionality in a unit => design trade-off
  - Compute MTBF / FIT rate of electronics units => satellite reliability and system trade-off
  - Sensitivity of board temperature and temp cycles
- Smooth FIDES flow developed at ASL
  - Internal tool developed to make the bridge between PCB design software and FIDES
  - FIDES fully configured
    - Components (passive, active, RF, connectors)
    - PCB technology and PCB assembly
    - Process from Aerospacelab and subcontractors
    - Life cycle (launch, temperature, thermal cycling)
  - Allowing quick and easy usage of FIDES

- Check it out: https://www.fides-reliability.org/







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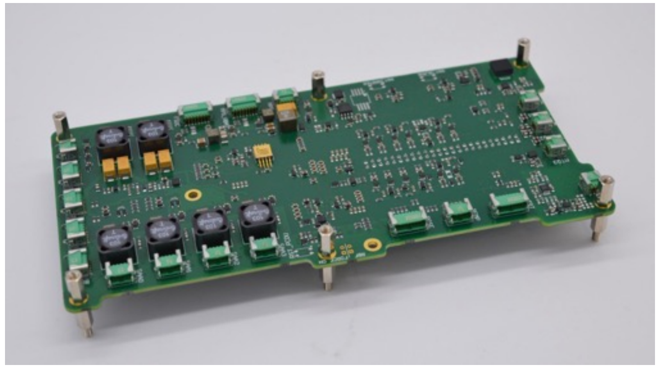
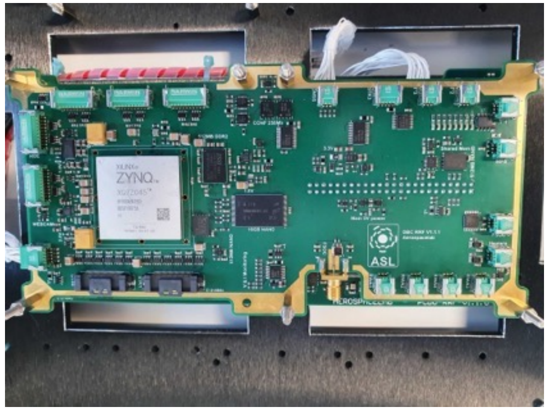
12U/16U cubesat products (TRL9 since June 2021)



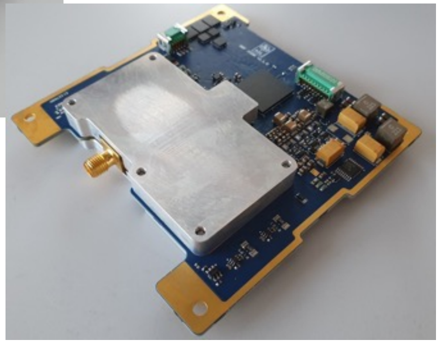
PCDU



OBC

SBT

SBA & XBA



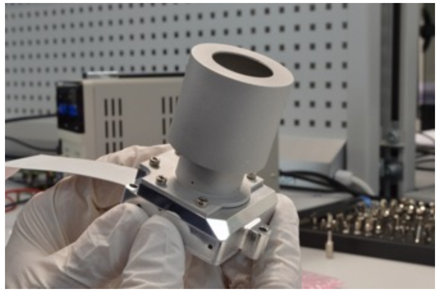
XBT

SAA

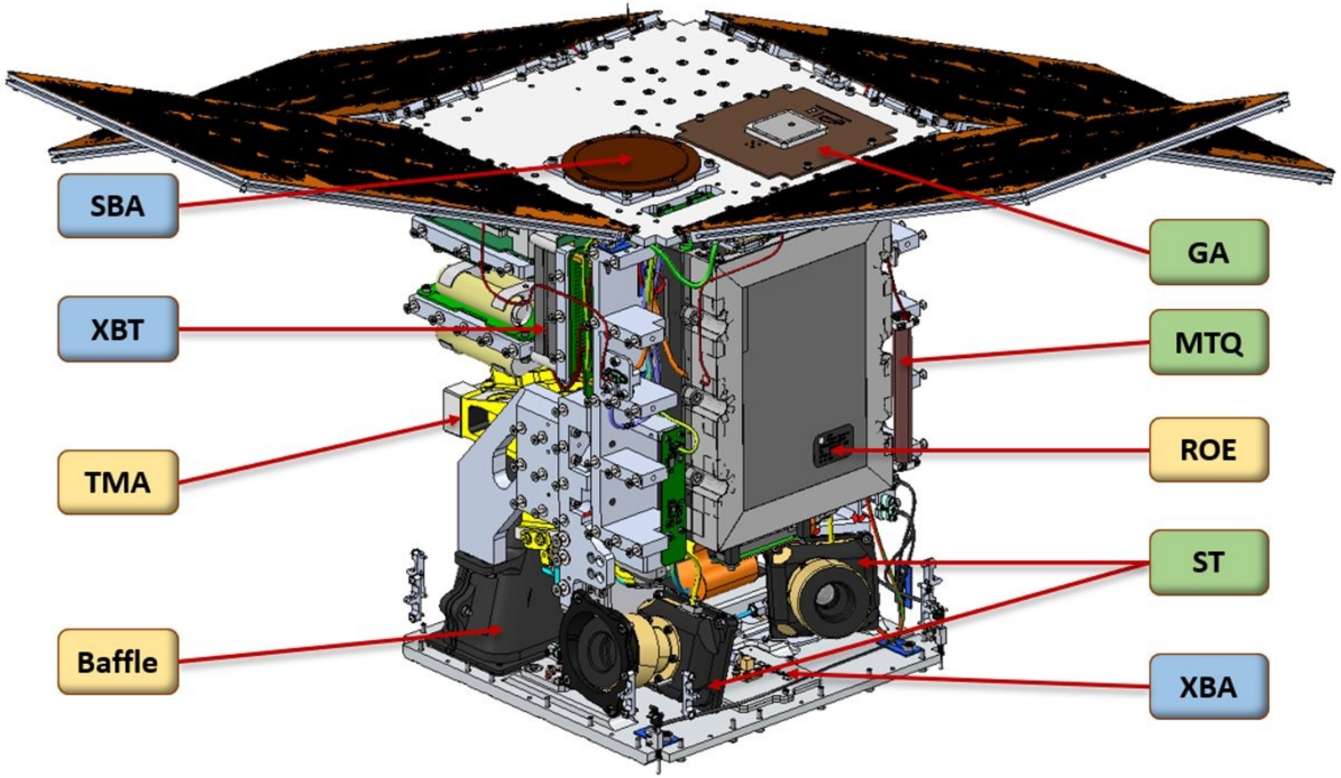
BPA

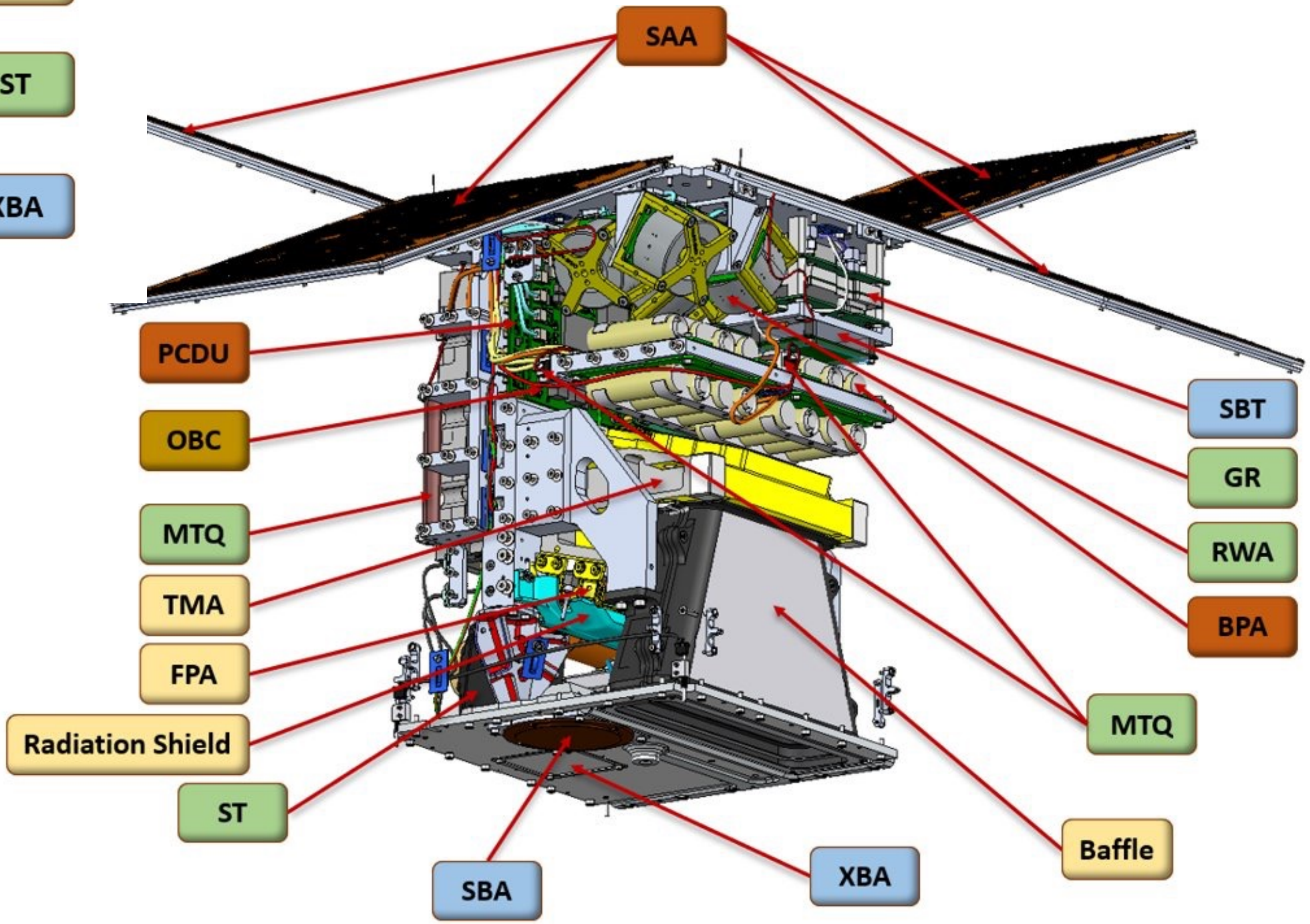
ROE

MTM



ST





PVCC satellite for ESA

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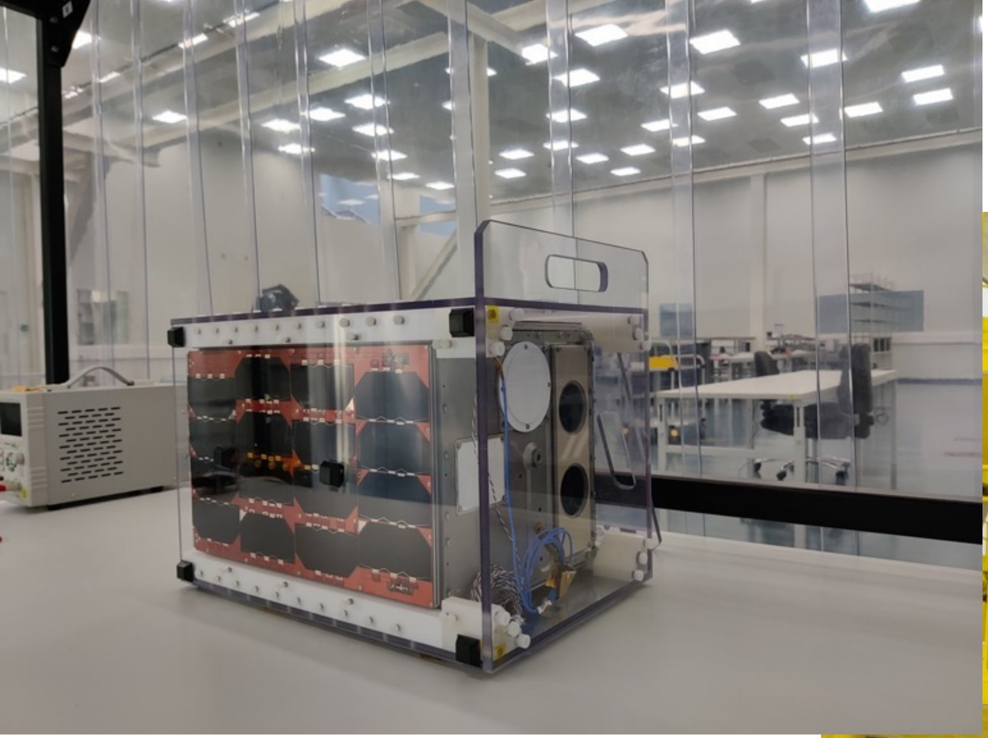
VV23 launching October 6



In Aerospacelab’s cleanroom (ISO 5)

During launcher integration in Kourou

12U/16U cubesat products

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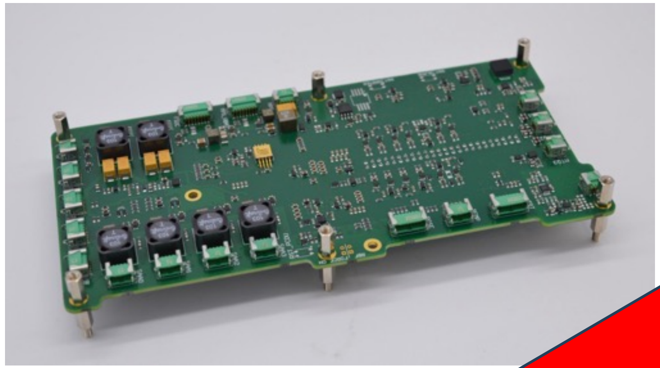
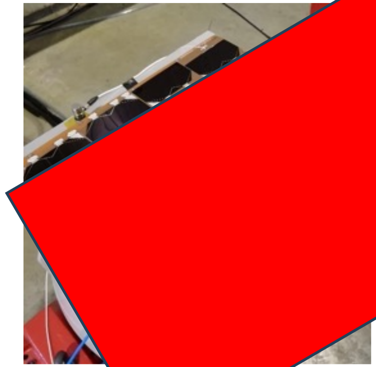


PCDU

OBC

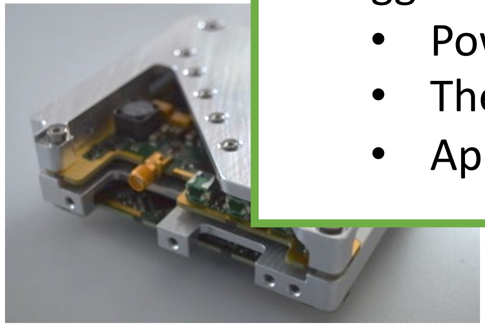
SBA & XBA

- High performance cubesat = custom
- NRE costs >> Launch costs
- Bigger is (almost) always better:
    - Power
    - Thermal
    - Aperture

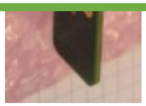


A

BPA



ROE



MTM

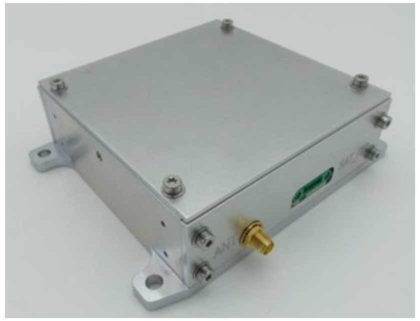
ST

Let’s go bigger: microsatellites products

PCDU

OBC

MTM



GNSS Rec

BM

SSDR

SBA

ROE

XSDR

XBA

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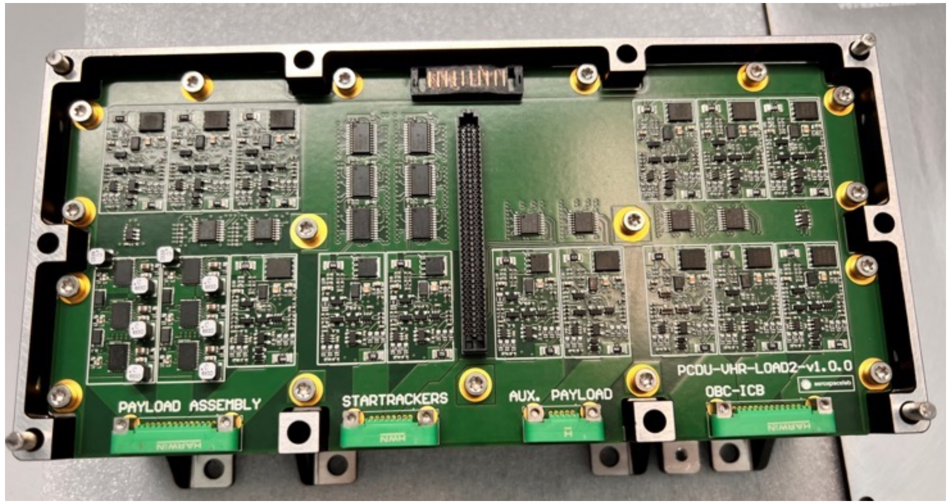
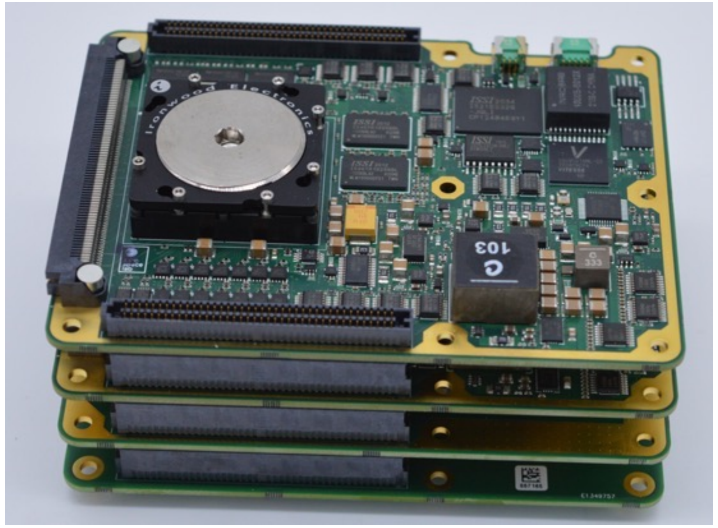
VSP 150 PCDU

- Stackable modules based architecture: PCDU easily tailored to the mission
- Module “Main”
  - Radiation hardened micro-controller and watchdog
  - Interfaces: CAN, RS-485
- Module “SAA”: **360W power generation** per module (max 2 modules per PCDU)
  - 4x MPPT channels with buck-boost converter per module (360W power generation)
  - Deployment circuit and telemetry
- Module “Battery”: **800Wh storage** per module (max 2 modules per PCDU)
  - Interfacing to 2x BM-28V for energy storage
  - BM monitoring done by the PCDU: under- / over-voltage protection, over-current protection, temperature monitoring, heaters, balancing
- Module “Distribution”: up to **750W**
  - Module tailored for each mission (16 loads per module, up to 3 modules per PCDU)
  - Unregulated 28V battery bus, 12V regulated bus, 5V regulated bus
  - LCL with fault reporting and current measurement for each line
    - Design compliant with ECSS-E-ST&HB-20-20C.
- Radiation
  - **Rad-hard MCU and rad-hard watchdog**
  - Other components: SEE tested COTS automotive
  - FRAM memory for micro-controller with image recovery
- Local redundancy: **99.5% reliability on 5 years mission**



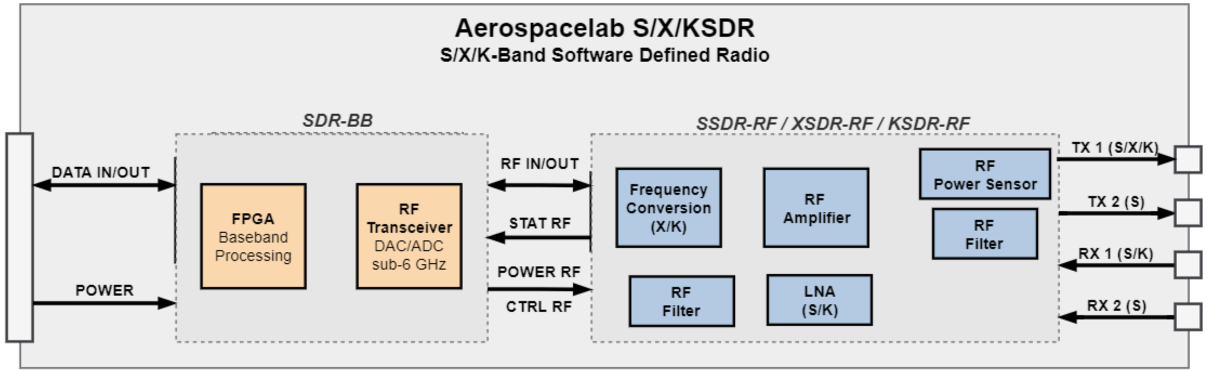
VSP 150 OBC

- Stackable modules-based architecture: redundancy + OBC tailored to the mission
- Module “Computing”
  - Zynq-7000 FPGA with 2x ARM CPU
  - 512MB DDR with ECC, 64GB storage with ECC
  - Radiation hardened micro-controller and watchdog
  - FPGA and MCU supplies and peripherals (memories, telemetry)
  - Interfaces: 4x CAN, 26x RS-485, 5x SpaceWire, 2x diff-I2C, ethernet, several GPIOs
  - Cold redundancy by having 2 computing modules in the OBC
- Module “MTQ, Heaters, Analog”
  - Fully redundant interfaces for 3x MTQ, 12x Heaters, 12x temp sensors, 1x sun sensors
- Module “Inter-connection”
  - Inter-connection for the harness
  - Customized for the mission
- Module “Extension”
  - Interfaces: 5V supply, PCIe x4, 24x LVDS, I2C, 24x GPIO
  - Mission based
- Reliability
  - **Rad-hard supervisor MCU and rad-hard watchdog**
  - Other components: SEE tested COTS automotive
  - Fully redundant architecture by stacking 2 identical boards => **99.7% reliability on 5 years**



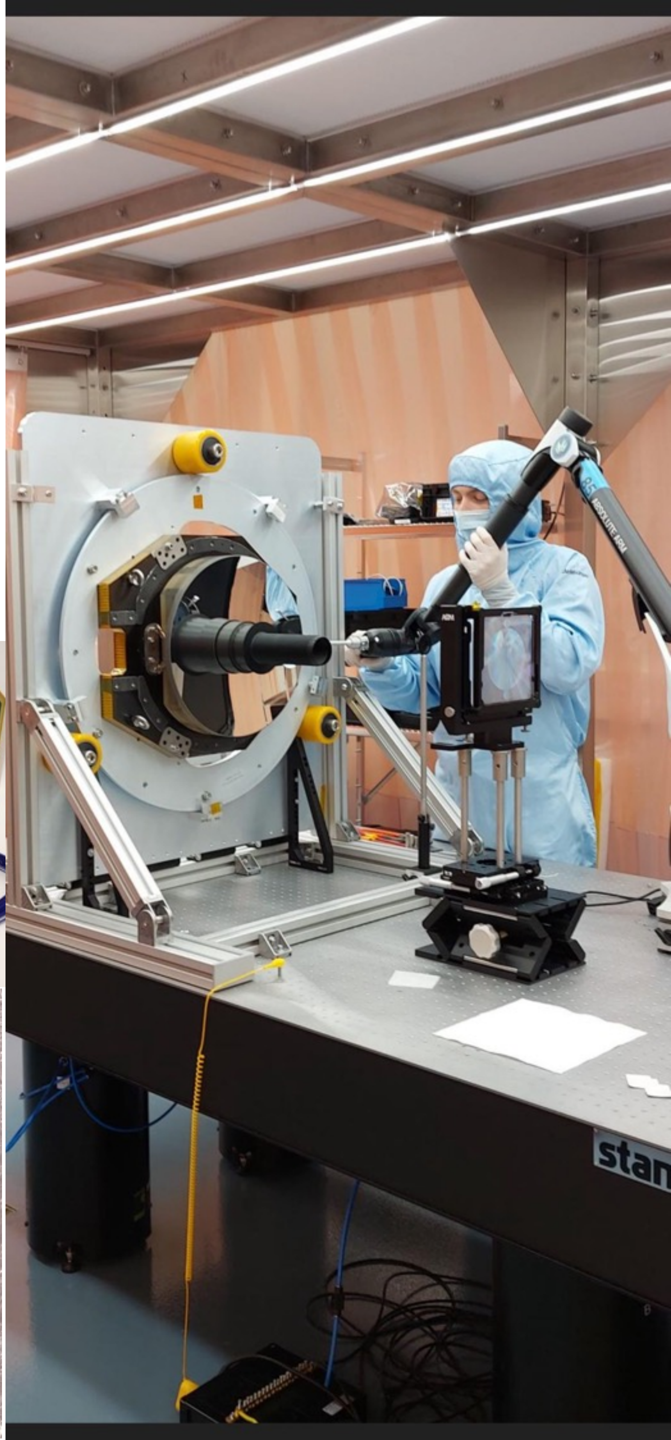
VSP 150 SDR platform

- SDR platform based on 2 boards:
  - Baseband board common to all the radios
    - Power supplies, FPGA, RF transceiver
    - Interfaces: full duplex RS-485, CAN, high-speed PCIe (for X/K)
    - Galvanic isolation from PCDU ground
  - RF board: specific design for each radio
    - S-band Tx / Rx
    - X-band Tx
    - K-band Tx / Rx
- Mechanical casing common to all the radio products
- Radiation
  - SEL protection and detection
  - SEU: ECC, TMR, scrubbing



Payload processing

- **Processing board**
  - Xilinx KU060 FPGA
  - 2x 4GB DDR4 memory 64bits
  - 2x 1TB NVMe SSD for storage
- **Control / telemetry board**
  - Rad-hard micro-controller
  - Payload thermal control
  - FPGA monitoring
  - FPGA reconfiguration
  - 16x temperature sensors and heaters
- **Payload interface board**
  - Custom interfaces and power supplies for payload
- Spacecraft interfaces
  - 1Gbps Ethernet (1000BASE-T)
  - 10Gbps Ethernet (10GBASE-R)
  - CAN
  - RS-485
  - PPS input



Gigabit Ethernet switch

- 9 Copper Ethernet interfaces at 10/100/1000 Mbps
- 2 high-speed interfaces (SGMII 2500Mbps)
- Energy Efficient Ethernet standard (IEEE 802.3az)
- Additional features available on each Ethernet connector for easy payload integration
  - PPS propagation
  - Power delivery
  - CAN bus

- Developed in < 6 months due to pivot in architecture. We needed to have 6 ROEs on the same spacecraft → daisy chain nightmare → Ethernet switch

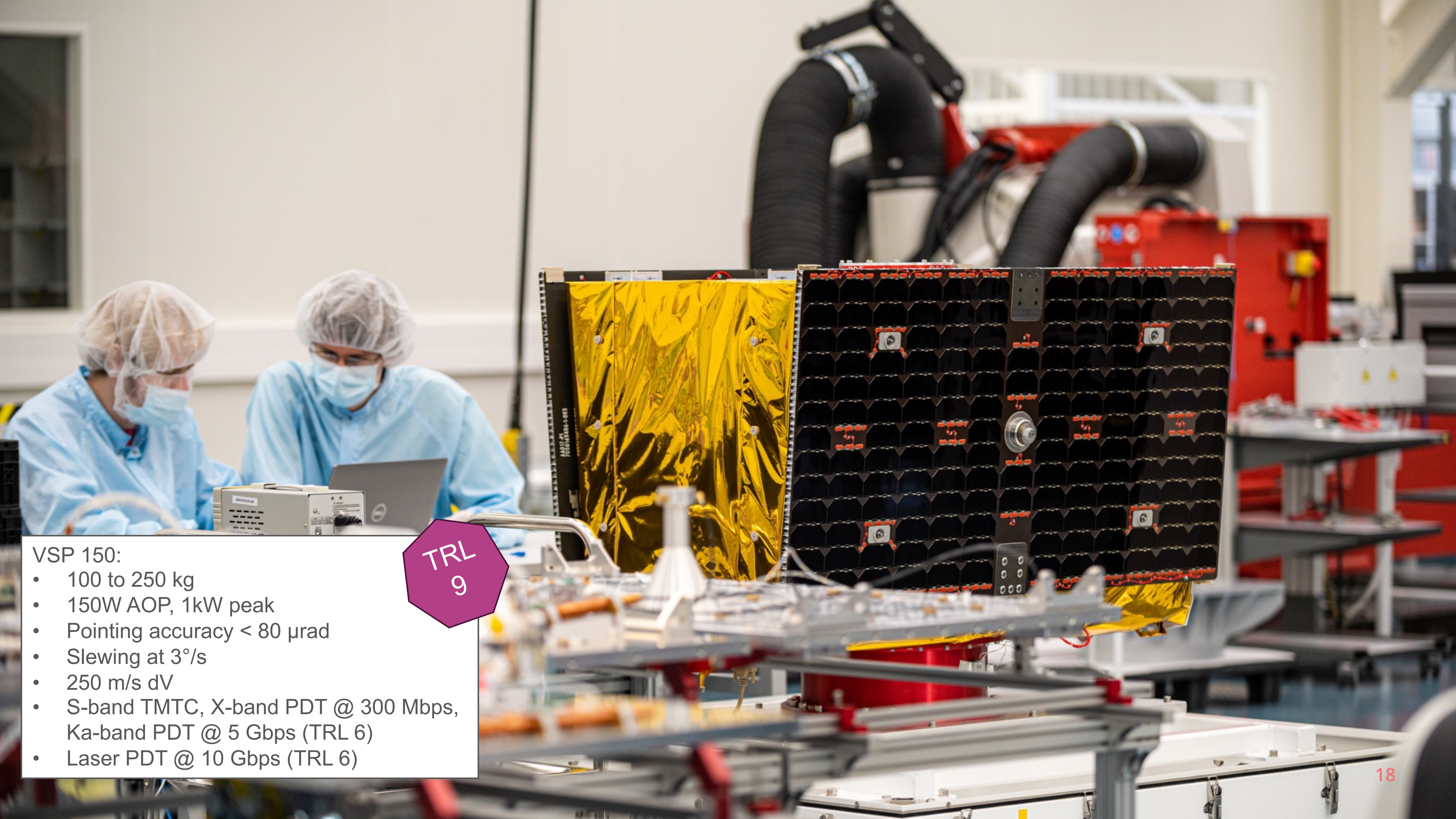
Optical communications

- OOK/DPSK
- 1W optical output (qualified), upgrading to …W (in house EDFA)
- Up to 4 optical bands simultaneously (4*10 Gbps)
- ~5 kg

- Iterative development
  - Version 0 in space since June 2021 (1 Gbps)
  - Version 1.0 in space since June 2023
  - Incremental updates 1.x to be flown every 3 to 6 months

Space Tx chain

Ground Rx early prototype in sunny* Belgium



VSP 150:

- 100 to 250 kg
- 150W AOP, 1kW peak
- Pointing accuracy < 80 µrad
- Slewing at 3°/s
- 250 m/s dV
- S-band TMTC, X-band PDT @ 300 Mbps, Ka-band PDT @ 5 Gbps (TRL 6)
- Laser PDT @ 10 Gbps (TRL 6)

TRL 9

Launch with SpaceX T9
(Nov 2023)

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Launch with SpaceX T10
(Jan 2024)

What’s next for us

- We need more **power**: demand driven by LEO telecom constellations ~ 3 to 5 kW. **Thermal management** identified as key challenge.

- Optimize for (mass) **manufacturability**
  - Reduce harness
  - Reduce number of parts (more centralization of functions)
  - Push EGSE automation

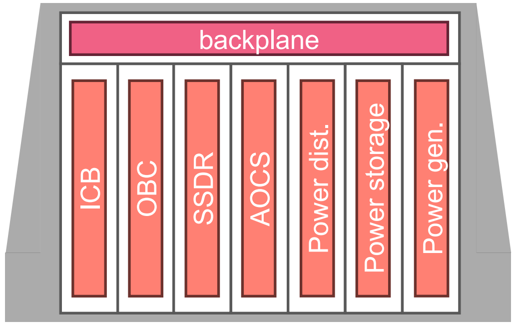
- Push **hardening** to cope with telecom availability requirements and MEO/GEO orbits

- “**Standardized Customization**”: full custom is expensive, full standardized is not flexible enough. Find the middle ground.

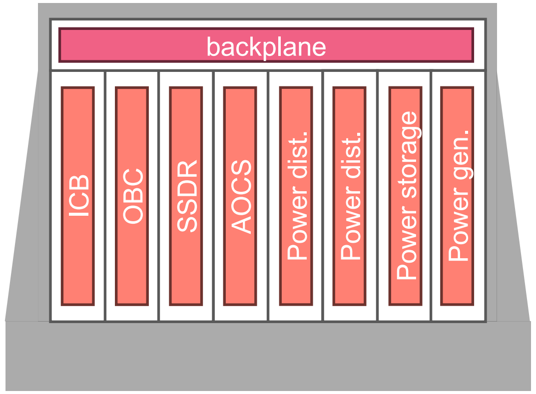
New satellite platform aiming at 750 kg – 5kW
18 months from KO to IOD

Modular “Avionics Centralized Unit”

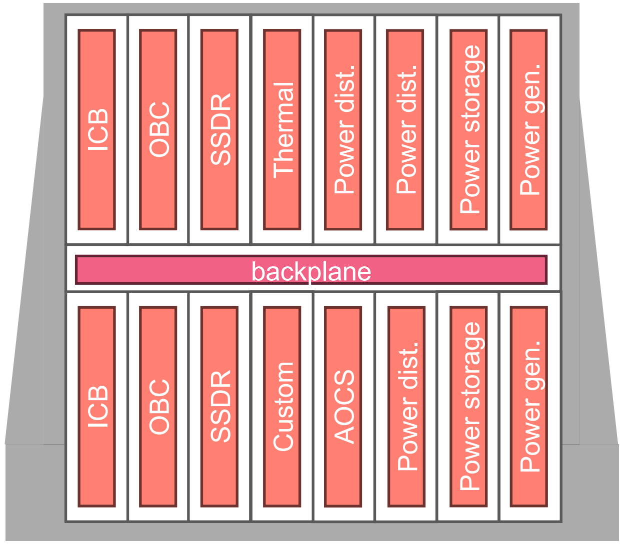
- Minimal ACU:
  - 7 modules
  - 500 W of power gen.
  - No redundancy
  - 2x Battery Modules
  - 16x LCLs
  - 12x heaters and temp sensors



- Typical EO mission example:
  - 7 modules
  - 500 W of power gen.
  - No redundancy
  - 2x Battery Modules
  - 32x LCLs
  - 12x heaters and temp sensors



- Big ACU:
  - 16 modules
  - 1kW of power gen.
  - Double redundancy
  - 4x Battery Modules
  - 32x LCLs
  - 2 high power LCL
  - 34x heaters and temp. sensors



Work in progress:
- Custom form factor + ADHA + VPX compatibility
- External PCDU for higher power
- **RC = BoM + ε with ε → 0 when # of units go large**

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Thank you for your attention

Captured by Arthur-1 during moon calibration routine

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We are hiring (a lot!):

- Power/Analog
- Digital/FPGA
- Embedded software
- …

- Full remote, flex remote, on-site
- Offices in BE, FR, CH, US

benoit.deper@aerospacelab.com with EDHPC2023 in subject line