FORESAIL

An open Satellite Platform beyond LEO

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16.10.2019

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Sustainability in space?

Society, Science and Technology

Sustainability in space?

Society, Science and Technology

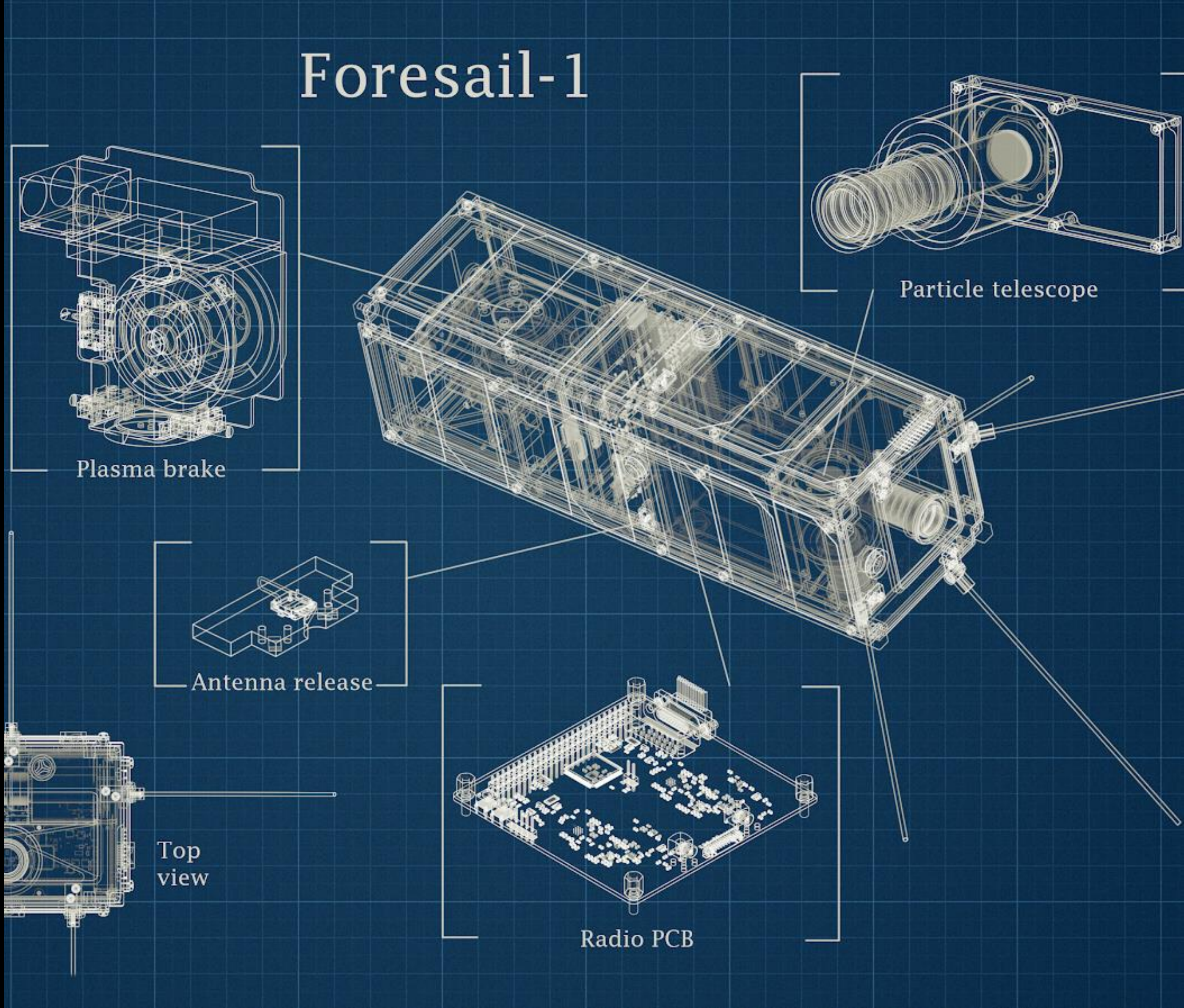
- **Society**
  - Awareness of the global problem. Debris & threats
- **Science**
  - How to survive in solar system with a fusion explosion?
- **Technology**
  - Solutions to space debris problem
  - More robust and mature technologies?

Opening the designs?

- **More open design?**
  → Better understanding of used technologies and solutions
  → More mature designs
  → More successful missions
  → More sustainable space
- **Openness can prevent from making same mistakes**
  - So less in-orbit failures and broken-at-delivery satellites
- **The true way to push the state of the art!**

FORESAIL

Who we are?



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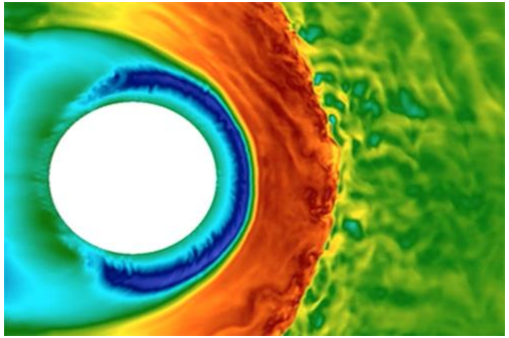
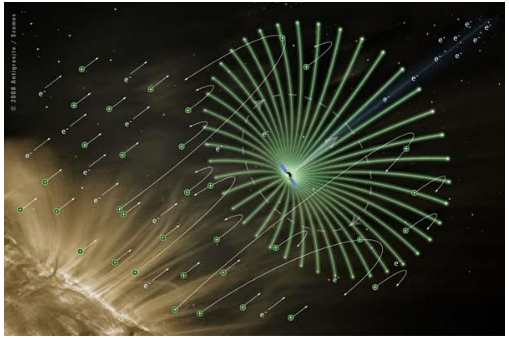
Who we are?

- **FORESAIL: Finnish Centre of Excellence in Sustainable Space**
    - Aalto University: Finnish academic Cubesats
    - University of Helsinki: Space weather
    - University of Turku: Instruments
    - Finnish Meteorological Institute (FMI): Deorbiting systems
- **aka all the top Finnish small space players funded by Finnish Academy**





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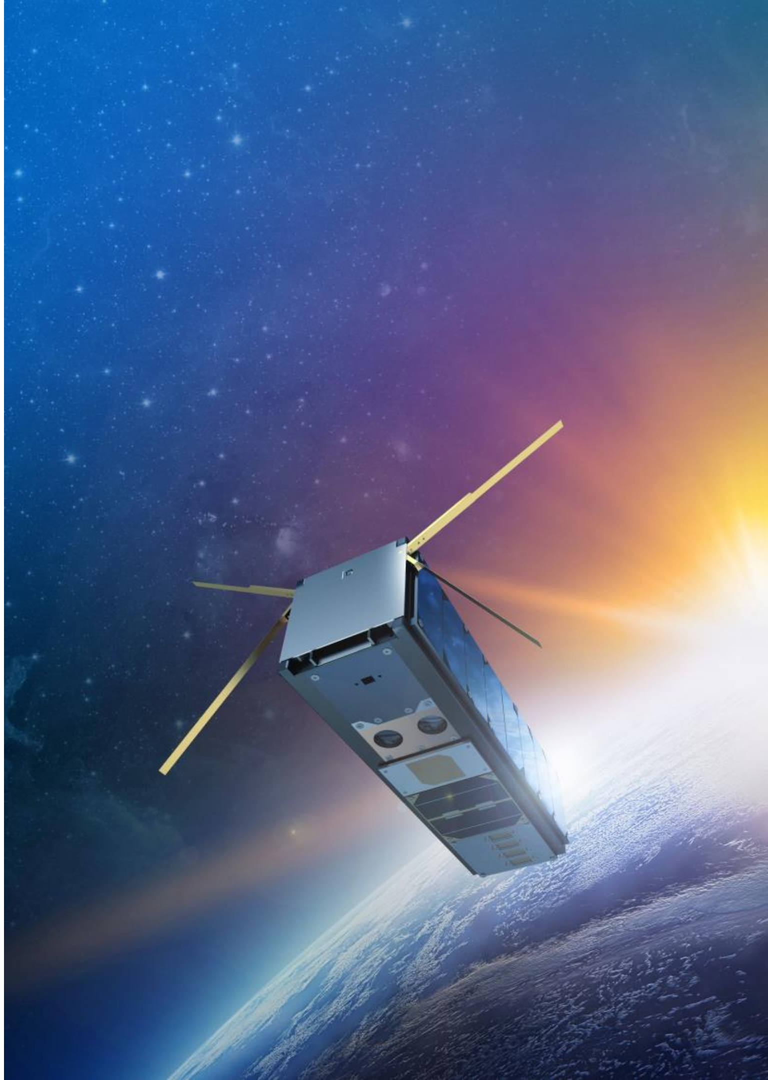
Who I am?

- **Petri Niemelä**
    - Master in Automation and Electrical Engineering
    - Doctoral Candidate in Space Science and Technology
    - Worked with Cubesats since 2013
- **Foresail-1's systems engineer, chief engineer, developer….**
- **Expertises:**
    - Software, embedded systems, electronics, RF, communication…
    - Everything from ground to space

Our previous work

- **Aalto-1: The first Finnish satellite**
  - 3U with 3 payload
  - Launched June 2017, still operating
- **Aalto-2: QB50 satellite**
  - Failure after 5 days
  - Deorbited after 20 months
- **Suomi-100**
  - "Jubilee" satellite to celebrate Finland's 100th year anniversary
  - Commercial platform with own payload



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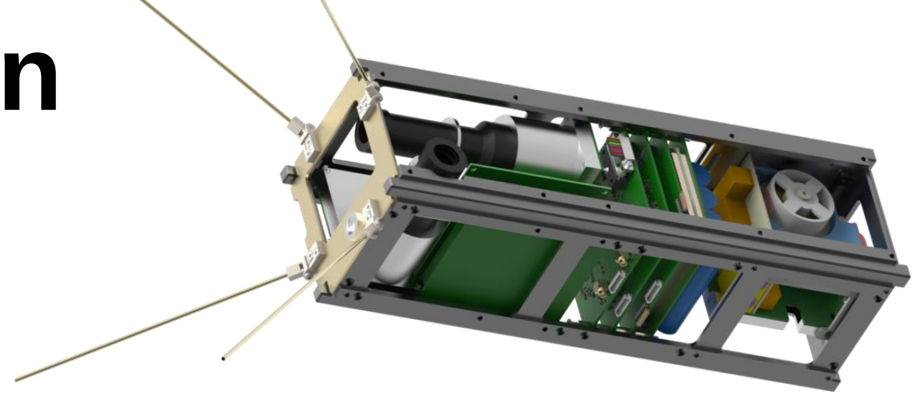
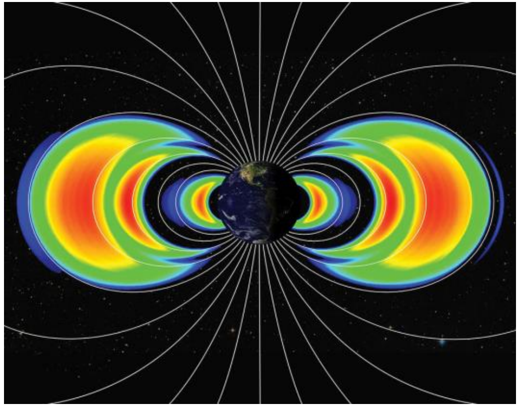
FORESAIL-mission



- **FORESAIL-1: 3U Cubesat to LEO**
  - “The first Finnish scientific satellite:”
    - Particle Telescope to observe energetic particles in upper ionosphere and their interactions
    - Plasma Brake to demonstrate Coulomb drag deorbiting method
  - How to built a satellite for harsh environment?
  - Launch: Summer 2020?
  - Mission paper: *“FORESAIL-1 CubeSat Mission to Measure Radiation Belt Losses and Demonstrate Deorbiting”,* Palmroth et al.
- **FORESAIL-2: 6U Cubesat to GTO**
  - “Lets dive to solar wind to make scientific observations!”
  - On paper but building hasn’t started yet



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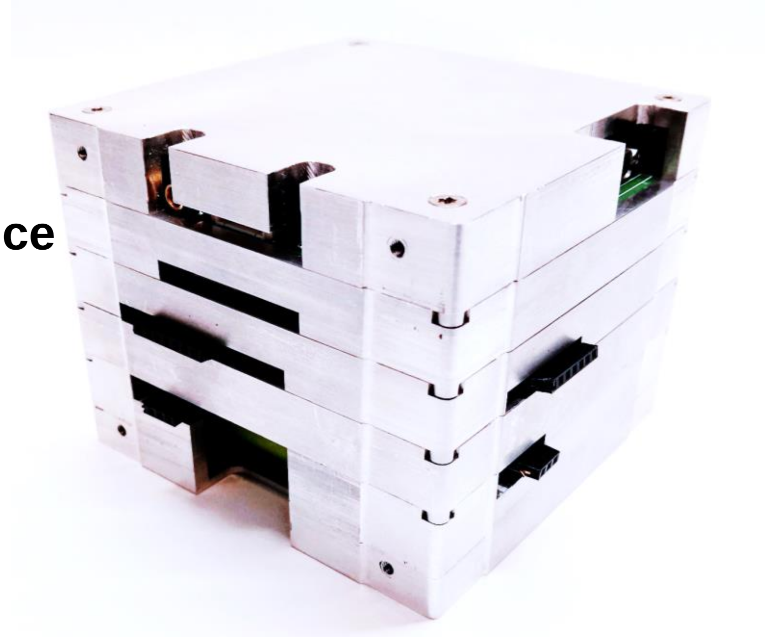
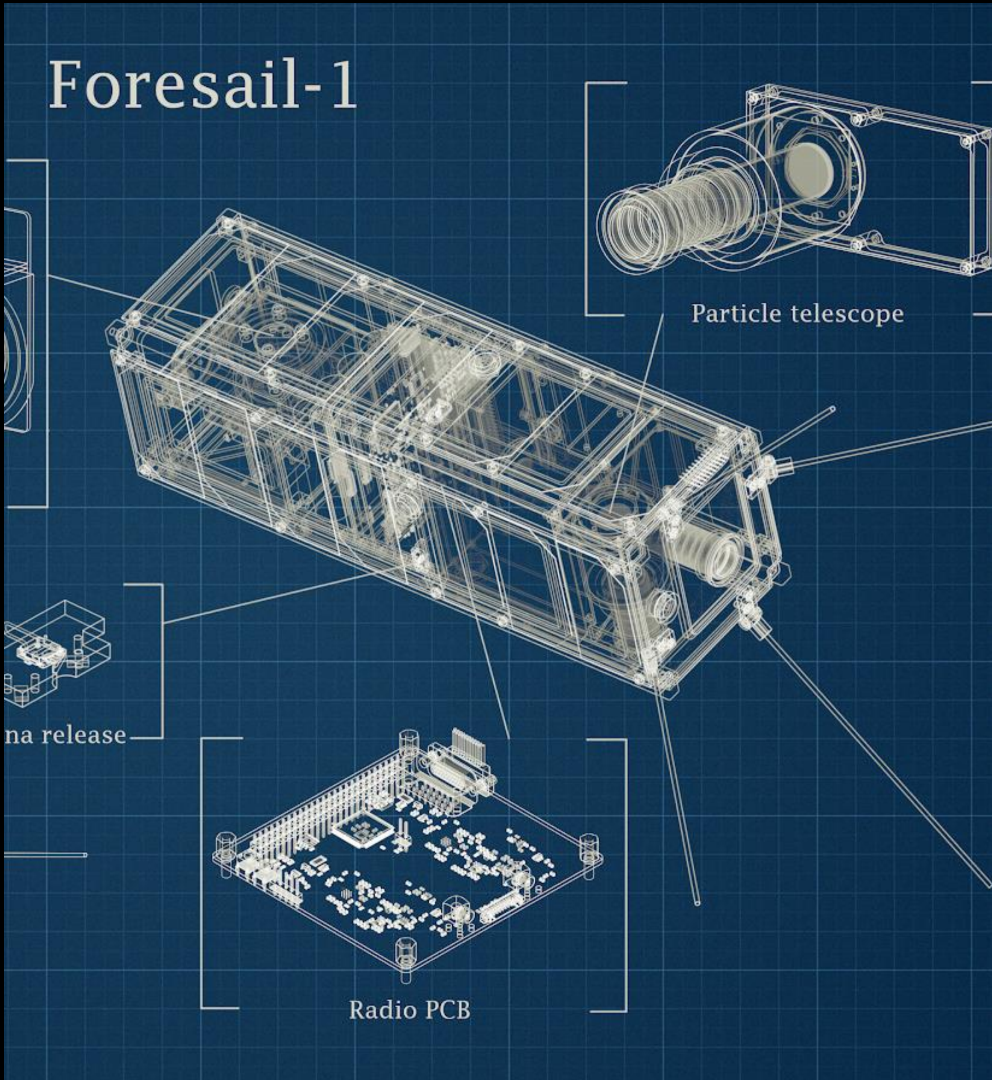
Foresail platform

- **Build for the FS1 mission**
- **<1U for avionics: OBC, ADCS, EPS, UHF**
- **Build for high reliability and radiation tolerance**
    - Redundant subsystem designs
    - Most of the components will be radiation tested
    - Shielded with 4mm aluminum to decrease TID
- **3-axis stabilized**
- **Status: Building of the flight model starting now**



How are we contributing for more ~~sustain~~ open space community?



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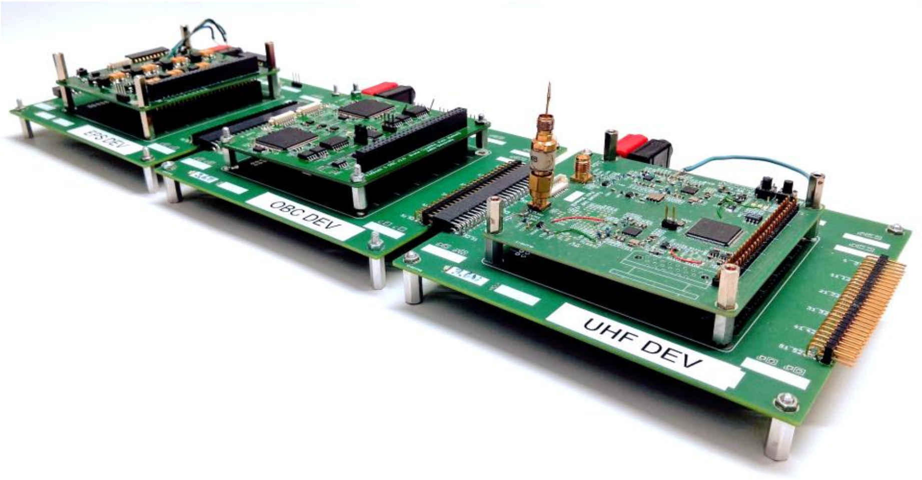
By open sourcing design

- **Open subsystem can be valuable for the community but…**
- **FORESAIL is not just a subsystem…**
  - but the whole satellite bus
  - and the stack from ground to orbit!
- **It's a full platform for a scientific mission**
- **But it's not a new standard**
  - Not generic
- **Only future shows it**



Being totally open is difficult!

- **Opening everything in your project is troublesome:**
  - Decision processes?
  - Branching of the design?
- **In worst case can kill the open project**
  - Too ambitious
  - Too generic
  - Too much overhead…
- **BUT this should not stop you from publishing!**

Being totally open is difficult!

- **Opening everything in your project is troublesome:**
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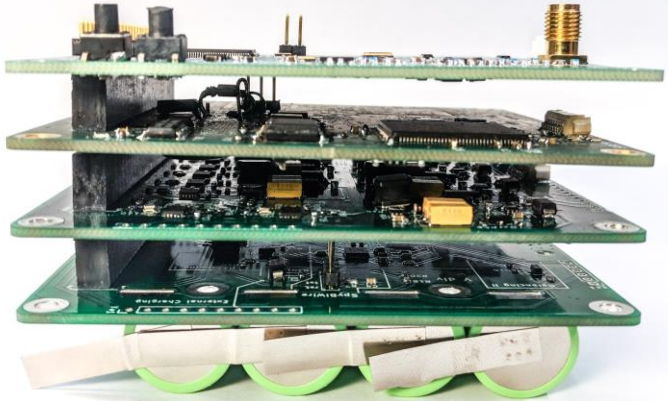
- **BUT this should not stop you from publishing!**

- **Not an open mission but a open platform**
- **Not openly managed project**
- **More like a high quality reference design**

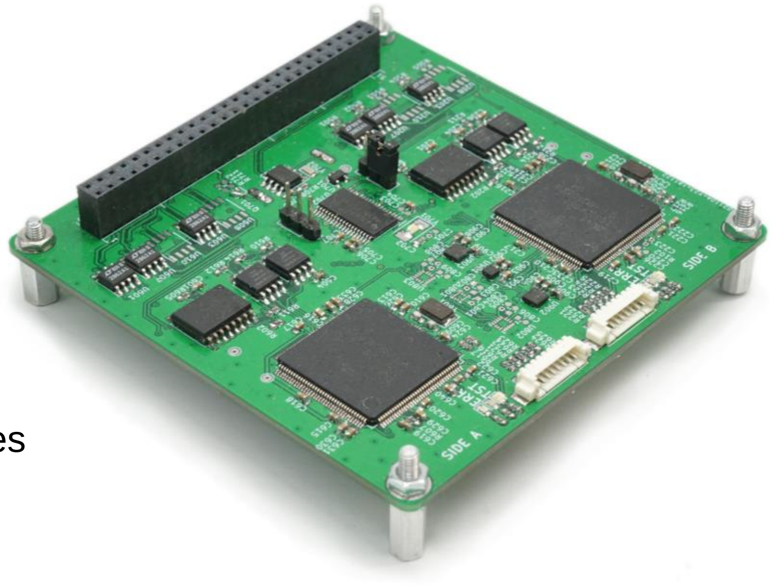
Technically…

- **Not a "standard" PC/104-format**
    - Smaller PCB and only 52-pin stack connector
- **Communication using redundant RS-485 buses**
    - Custom protocol on top for frame formatting, medium access control and reliability
    - Simple enough for any platform: Low-power MCU, FPGA, Linux..
- **The bus offers multiple 3.6V and battery lines**
- **EPS, OBC, ADCS, TTC, MTQ, SS...**



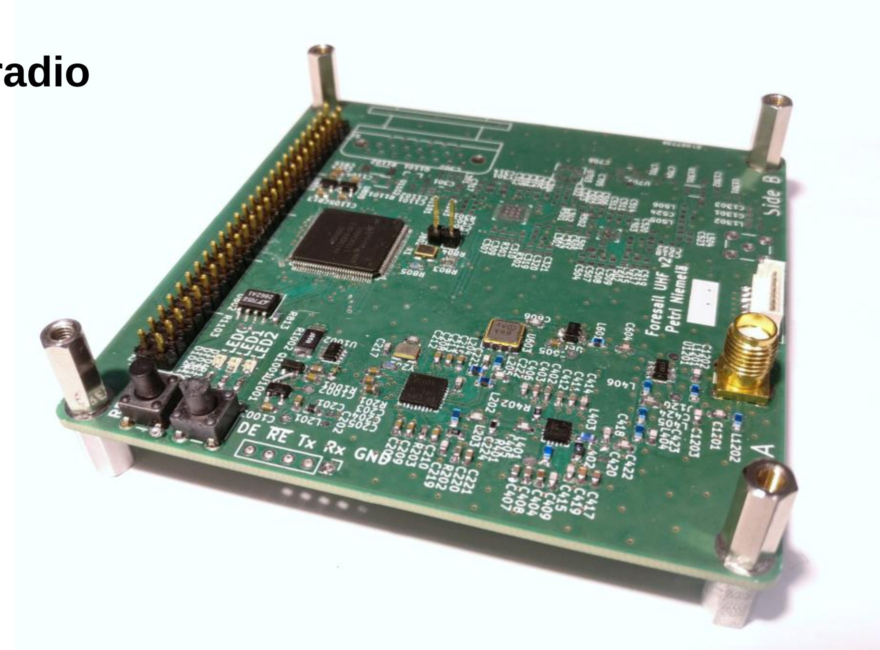
On-Board Computer

- **Two identical cold redundant sides with safety critical Cortex-R4 cores**
- **1 MB FRAM:** For logs, housekeeping, firmware images and configuration values
- **128MB SLC-NAND:** With YAFFS file system
- **The on-board software!**
    - FREERTOS based modular design
    - Build around ECSS PUS-style communication
    - All base software housekeeping and event databases
    - Attitude Control and Determination
    - + Ground commanding system



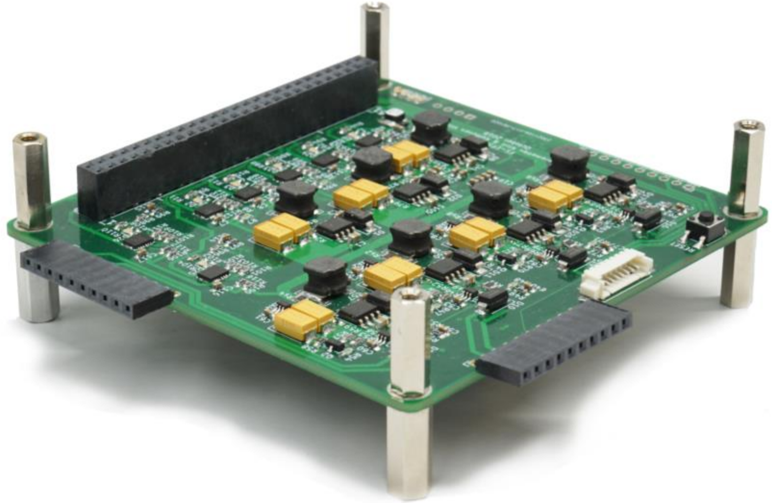
TT&C: UHF-radio

- **Not just a RF radio but a telecomunication radio**
- **437.125MHz, 20kHz, TDD**
- **100krad tolerant Cortex-M0**
- **Cold redundant transceiver and RF chains**
- **Simple reliable space protocol:**
    - True Time Division Duplex
    - Virtual Channel
    - Reliable Data Transfer protocol
    - Amateur repeater channel
- **+ SDR modem libraries for GS**

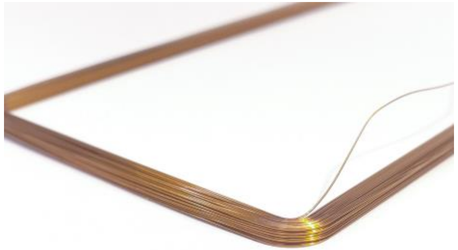


Electrical Power System

- Built for 3U Cubesat
- 4x battery chargers with MPPT
- Controlled by rad-tolerant Cortex-M0
- 8x latching OCP+OVP switches (3.6V and batt)
- 3.6V bucks for easier voltage
- 2S2P Battery board design

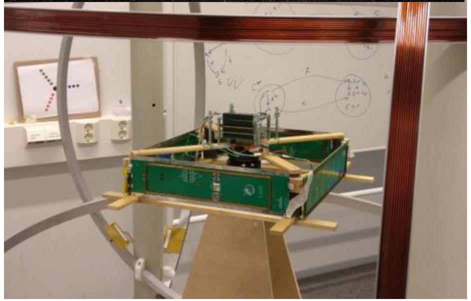


Attitude Determination and Control System



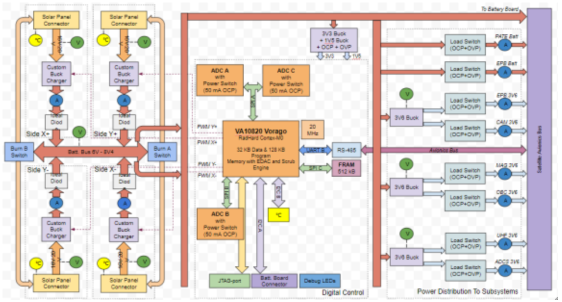
- **Mostly integrated to OBC**
- **UKH, PD-control, Spin Control etc.**
    - Verified algorithm in HIL simulators and Helmhotlz + air bearing setup

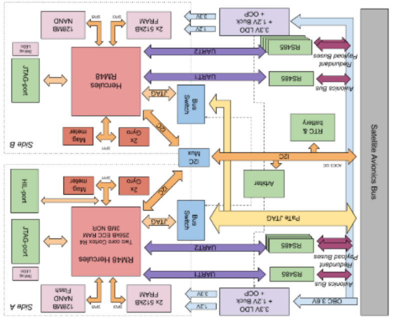
- **Hardware**
    - Low power “analog” PSD sensor
    - “Digital” profile sensor
    - Magnetorquer driver
    - Air coils winded by a 3D printer



+ The documentation

- **Designs are nothing with the documentation!**
  - Design documents,
  - Test plans + hopefully results
- **Not text books but they include all the important technical information**





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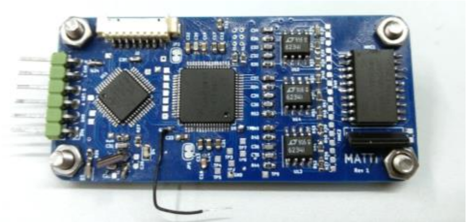
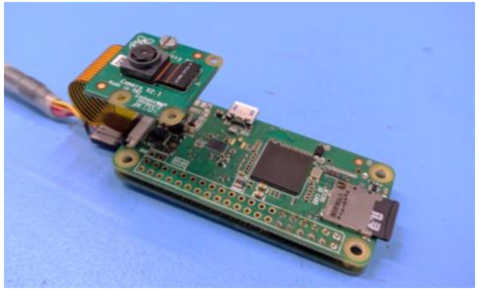
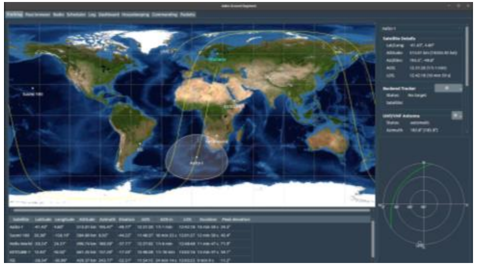
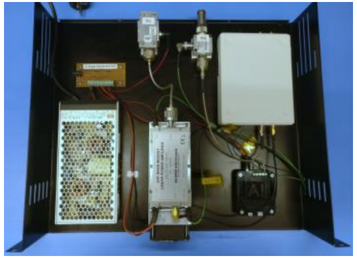
More…

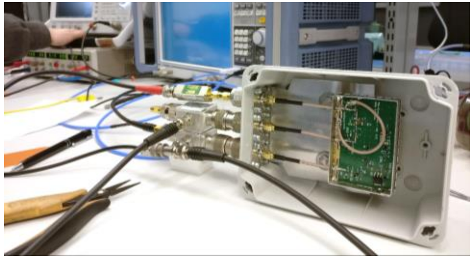
- **Payloads:**
    - Low-power embedded SDR platform
    - Scientific magnetometer
    - Cheap and dirty RPi Camera payload
- **Ground segment designs:**
    - Ground stations control software
    - Mission control software
    - RF-designs (LNA/switch, SDR-setup)
    - Rotator controller
    - ….











Conclusion

- **Not an open mission/project but open designs**
- **Hopefully publishing first designs sooon!**
  - ✔ Designs
  - ✔ Licenses: University layers working with them
  - Schedule: We should also finish the flight model

Thank you

Questions?

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