PHASMA: Monitoring the Electromagnetic Spectrum from Above

ISRMM 2025

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Libre Space Foundation

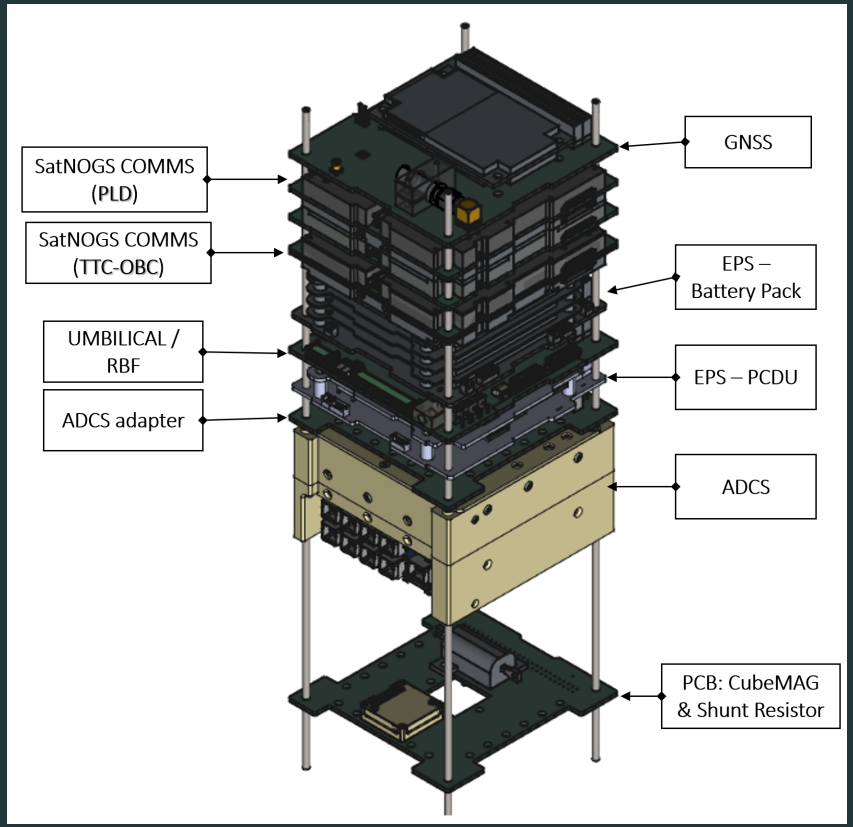
European Space Agency
Agence spatiale européenne

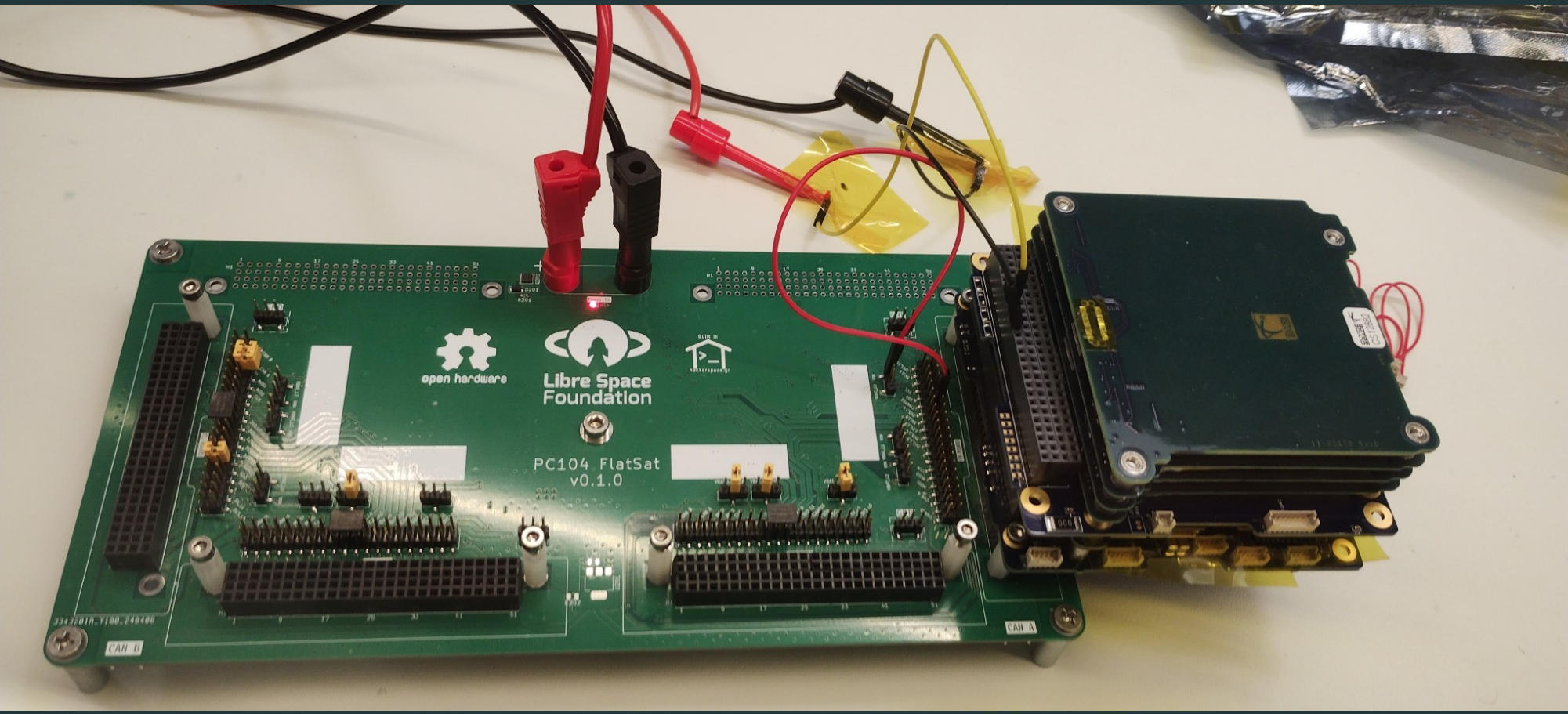
The PHASMA Mission

- **Spacecrafts:** 2 × 3U Cubesats
- **Orbit:** SSO at 510 km altitude
- **Launch:** Q4 2025
- **Objectives:**
  - Spectrum Monitoring on the UHF & S-Band spectrum regions
  - On-board signal detection and classification
  - SatNOGS-COMMS transceiver achieves TRL9 status
- Funded by the European Union–NextGenerationEU, and the Greek National Recovery and Resilience Fund, Greece 2.0.

The satellites

- **Form factor:** 3U
- **Mass:** 3.6 kg
- **COTS subsystems:**
  - ADCS
  - EPS & battery pack
  - Solar Panels
  - GNSS
  - S-Band antennas
- **In-house subsystems:**
  - SatNOGS-COMMS: 1× for COMMS/OBC, 1× for the payload
  - GNSS assisted reference clock
  - UHF antennas and their deployment mechanism

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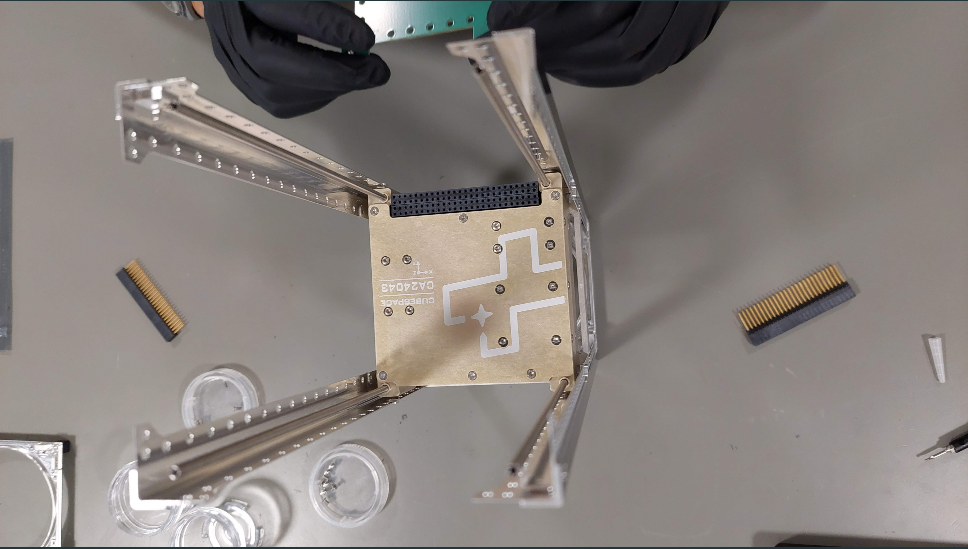
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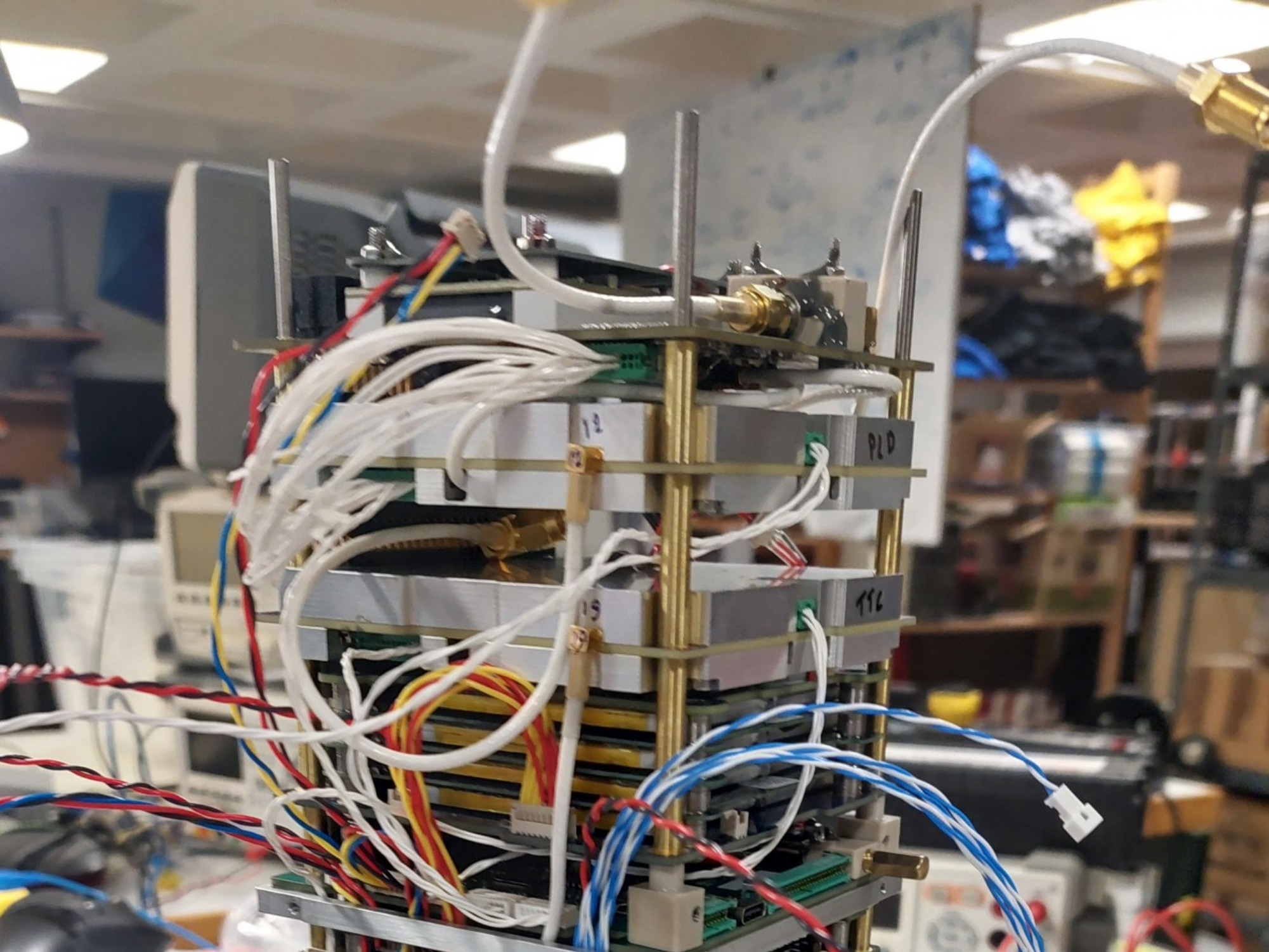
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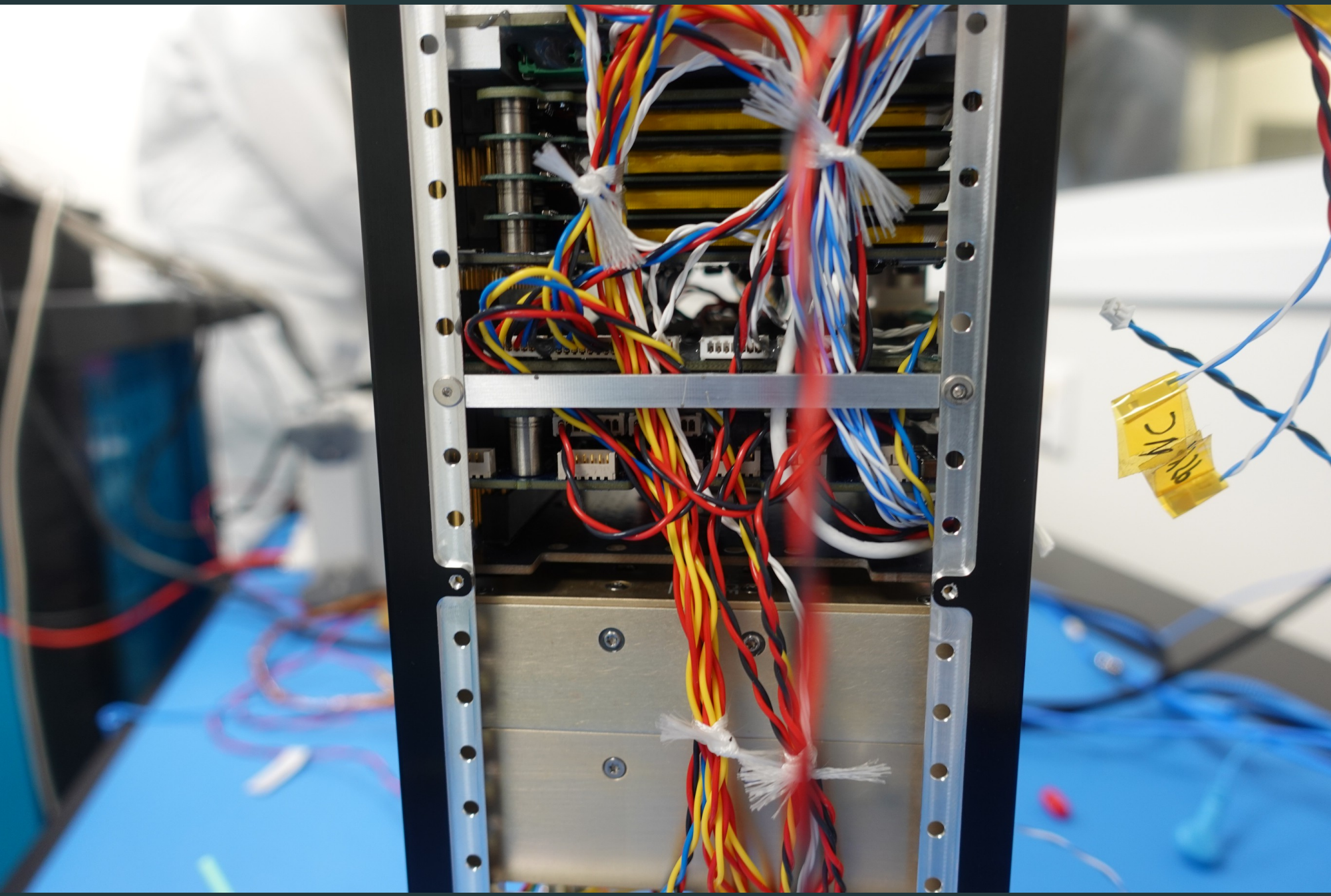

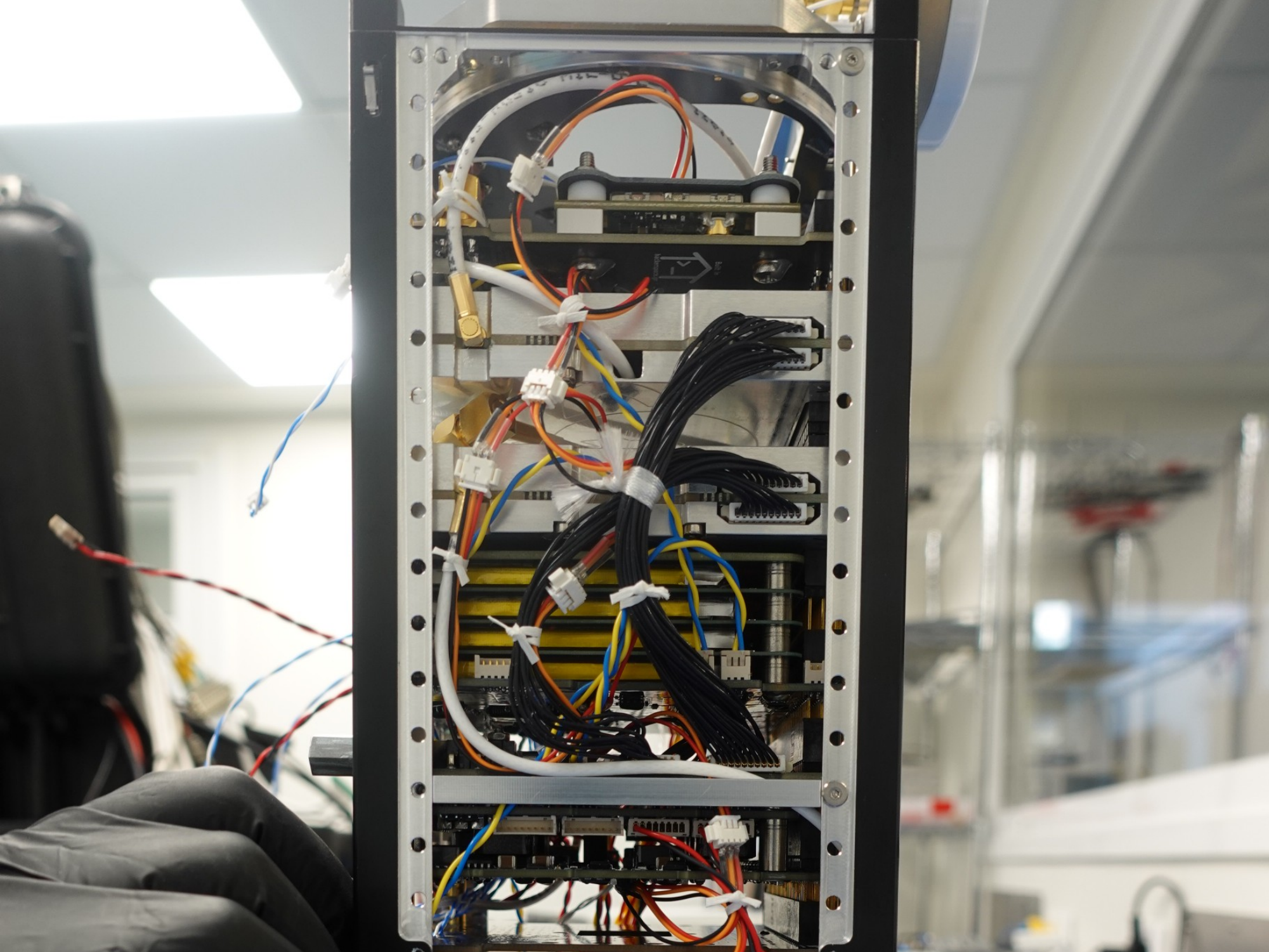

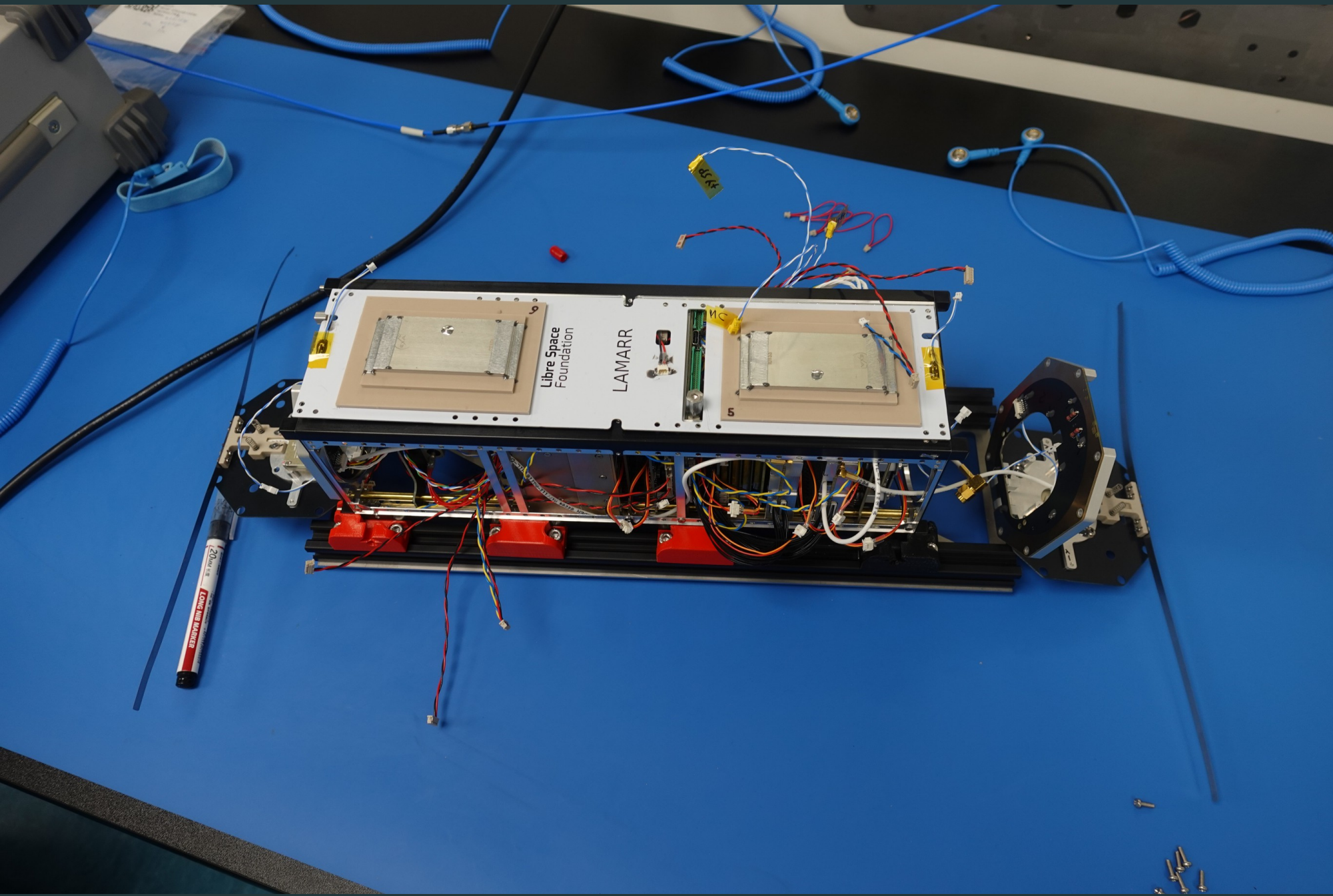
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EXO LAUNCH
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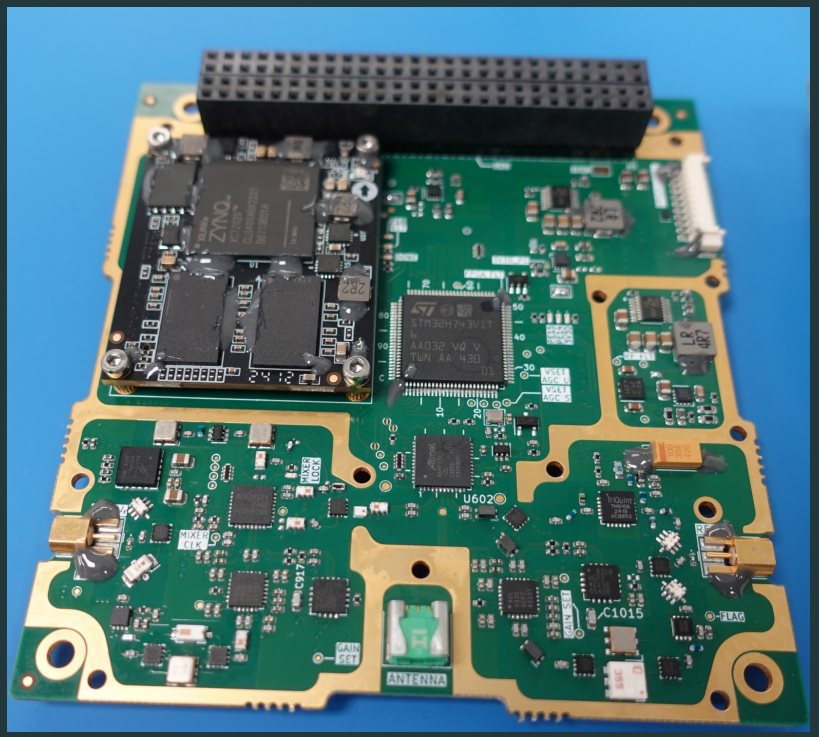
PHASMA Powertrain: SatNOGS-COMMS

- Co-funded by LSF and ESA
- UHF and S-Band dedicated transceivers
- STM32H7 main MCU
- ZYNQ-7020 FPGA
- Suitable for LEO up to 600 km
- Fully open software and hardware



PHASMA Powertrain: SatNOGS-COMMS

- **SDR capability operating at 4 MSPS**
- In-flight reconfiguration for both MCU and FPGA firmware
- On-board 32 GB storage for experiment results

PHASMA Powertrain: SatNOGS-COMMS

SDR characteristics:

- up to 4 MSPS
- up to 2 MHz IF hardware filter
- User selectable wide-band and narrow-band RF pass-band filters
- 13-bit IQ resolution
- GNSS assisted reference clock input
- GNSS PPS timestamping on the IQ stream
- **HUGE** dynamic range based our custom hardware AGC mechanism
- Quite low noise figure ($\approx$ 1.4 dB)

PHASMA Powertrain: SatNOGS-COMMS

- PHASMA uses two SatNOGS-COMMS trasnceivers per satellite
- One for OBC + COMMS
- One for the spectrum monitoring payload utilizing the SDR capability and the ZYNQ-7020 co-processor for the DSP tasks

Spectrum Monitoring

Major challenges:

- We are limited by the small maximum observable bandwidth of the transceiver (2 MHz)
- Sweeping is necessary
- S-Band antenna is quite wideband (150 MHz)
- UHF antenna is a simple dipole, compensation should be performed

Spectrum Monitoring

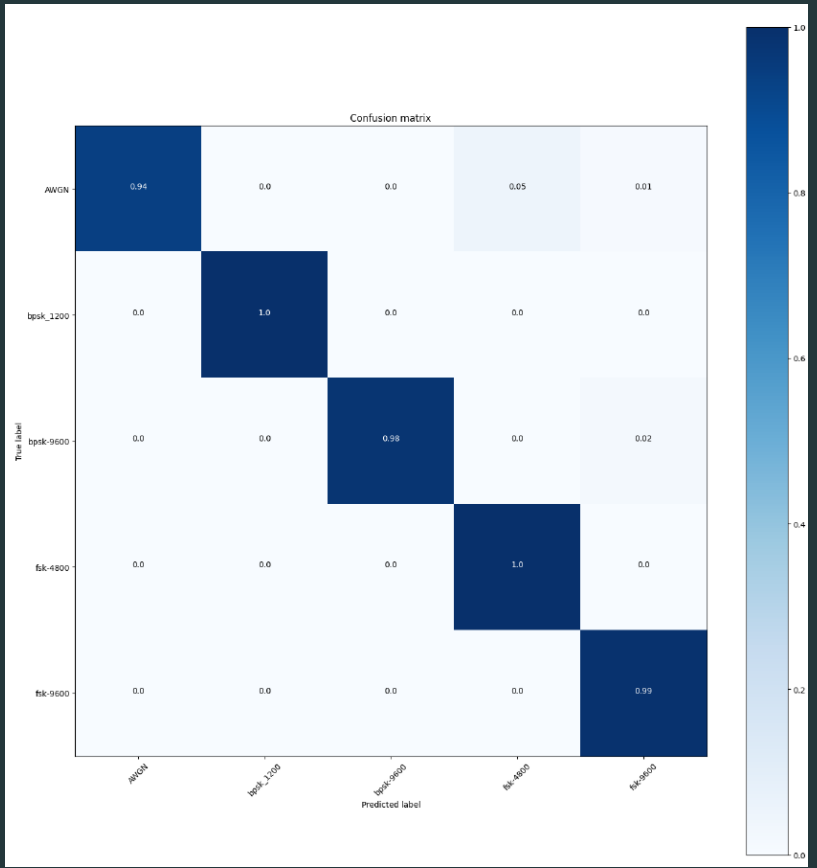
Parameter	Description
Channel Distribution	Defines monotonically the channel assignment, their bandwidth and the duration of each channel observation based on the GPS time.
FFT size	Defines the resolution bandwidth of the spectrum monitoring.
Overlapping percentage	Defines the percentage of the FFT overlap. It can be used to reveal in more detail RF emissions with a small duration.
Characterized noise floor	Contains a characterized noise floor for each channel. The characterization will be done on the ground before launch but can be amended afterwards.

Spectrum Monitoring

Result	Description
Spectrum usage heatmap	A heatmap describing the spectrum utilization of the channel for the duration of the observation.
Time	GPS time on which the observation started.
Location	A pair of locations containing the satellite location when the observation started and when it ended. Combined with the known orbit at a particular time and the antenna characteristics, the field of view of the satellite can be estimated.
Channel	The observation channel.
Estimated noise floor	This is an optional metric, indicating the on-spacecraft estimated noise floor of the channel.
Observation Parameters	Contains the parameters used for the channel observation (FFT size, overlapping, duration).

Modulation Classification

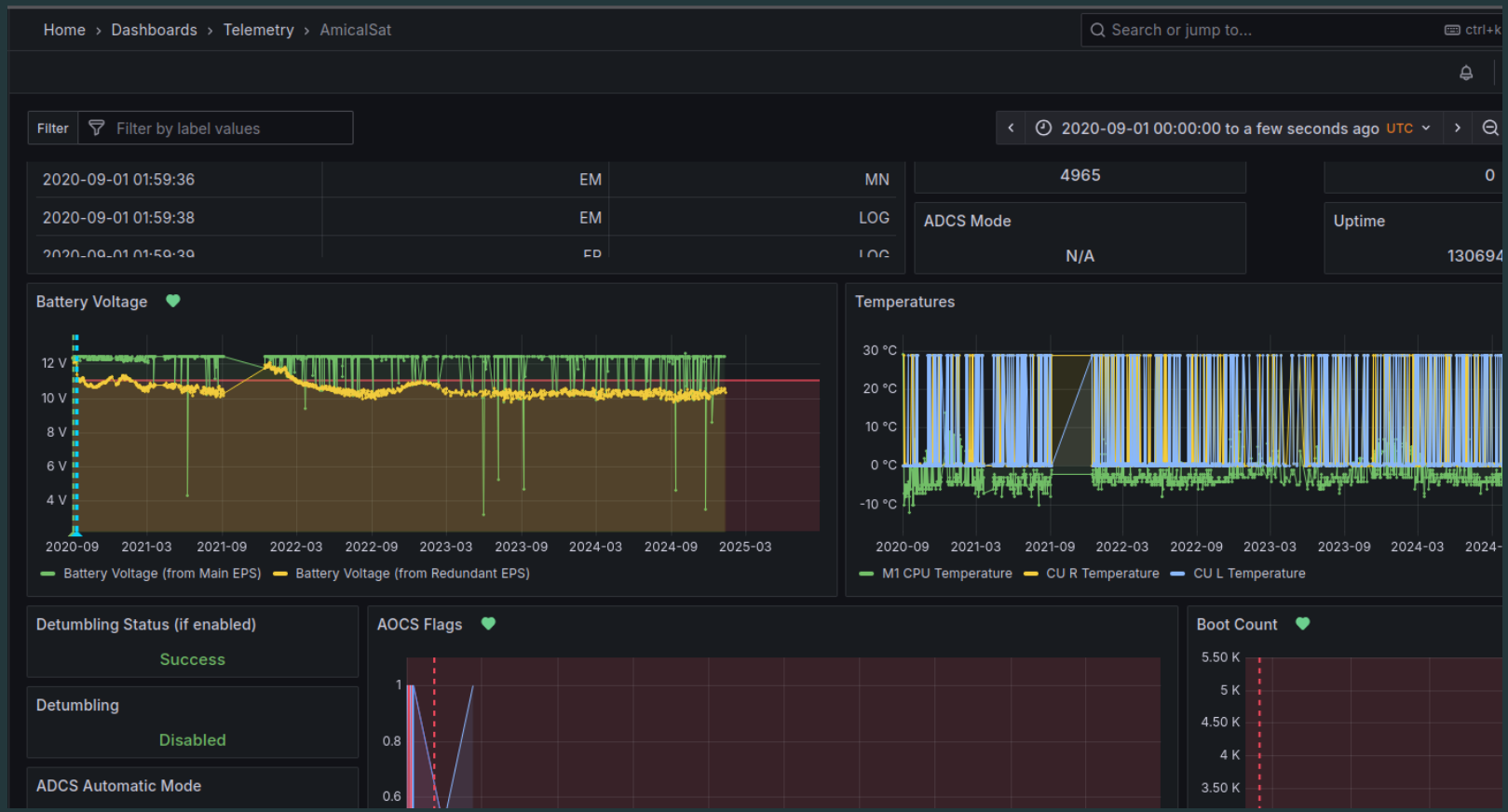
- Classify received signals using ML
- During the ESA SDR Makerspace program an activity revealed quite promising results
- Processing was performed on received signals from SatNOGS ground stations
- Real decoded satellite frames were used to train the ML models



Open in every possible way!

- All the telemetry data as well as the spectrum monitoring measurements will be publicly available though the SatNOGS infrastructure

- `https://dashboard.satnogs.org`



PHASMA: An RF laboratory

- LSF is open for collaborations that may extend the capability of PHASMA
- The fully re-programmable payload can act as an experimentation platform
- A third identical satellite is waiting also for a mission!

More info

- #phasma:matrix.org
- gitlab.com/librespacefoundation/phasma
- https://libre.space
- info@libre.space