Politecnico di Torino

SPEI SATELLES
Hope & Technology in a CubeSat

Sabrina Corpino

con Andrea Notargiacomo - CNR

Workshop *L'impegno italiano nel settore dei CubeSat: tecnologie e missioni future* **June 3rd 2024 – ASI – Roma**

Outline

- SpeiSat Mission
- Design
- Assembly, Integration & Verification
- Launch and Operations
- In orbit results
- Lessons learnt

SpeiSat Mission Overview

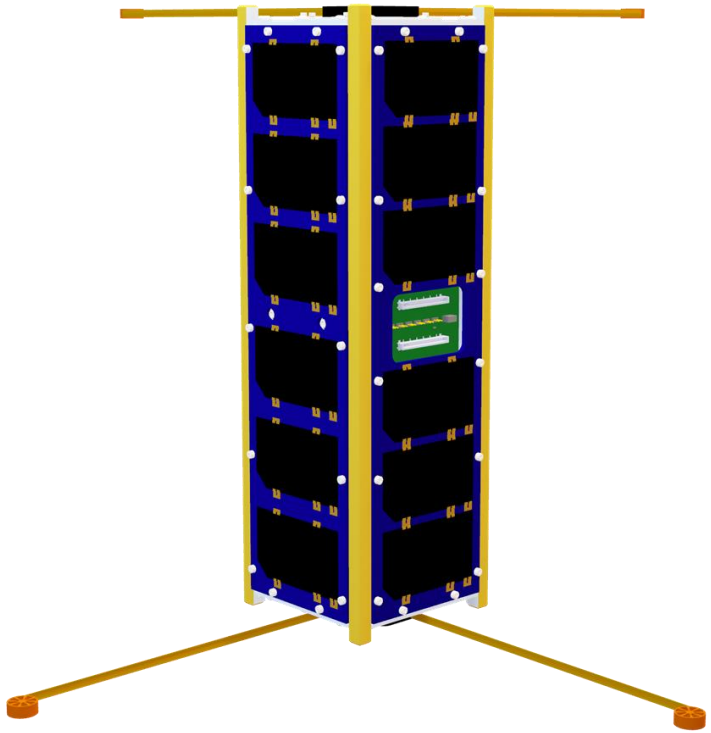
Telecommunications mission, coordinated by **ASI** (**Italian Space Agency**) and promoted by the **Dicastery for Communication** on behalf of **Vatican City**

Secondary mission: collect data to **characterise** the **CubeSat behaviour** and the **space environment**

SpeiSat is a **3U CubeSat** developed at **Politecnico di Torino** by a student team at the STARlab of the Mechanical and Aerospace Eng. Dept.

Successfully **launched** on **June 12th 2023** with **SpaceX Falcon 9 TR8** from **Vandenberg Space Force Base** in **California, USA** and **deployed** by D-Orbit **ION SCV-011** on **June 23rd 2023** in a **SSO** at **550 km**

Ground operations are managed by **Politecnico di Torino**



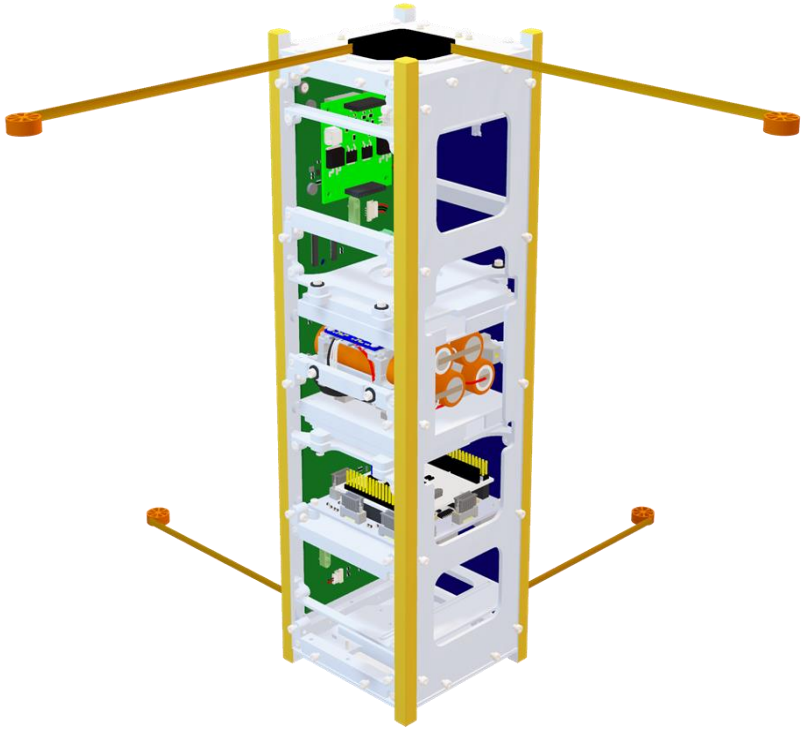
SpeiSat Mission Objectives

Primary mission objectives:

1) To **host** and **bring** to LEO the **Statio Orbis** by Pope Francis in the form of a **nanobook** provided by **CNR**
2) To **transmit text messages of hope** to ground. The messages are sentences collected in a file saved on the onboard computer memory. They are transmitted in three languages: **Italian**, **English** and **Spanish**

Secondary mission objectives:

3) To **characterize** the **internal** and **external thermal environment** of the **spacecraft**
4) To **characterize** the **internal magnetic field** of the **spacecraft** and to **map** the **Earth magnetic field**
5) To **characterize** the **angular motion** of the **spacecraft**

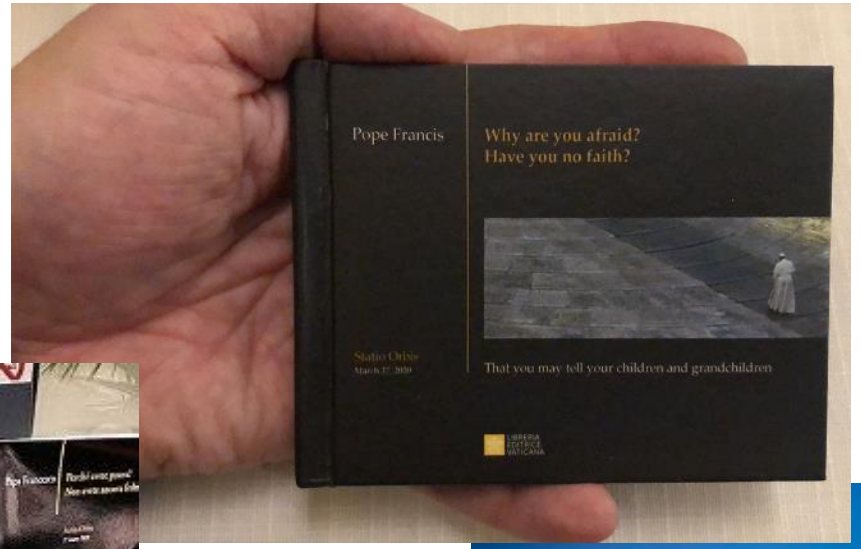


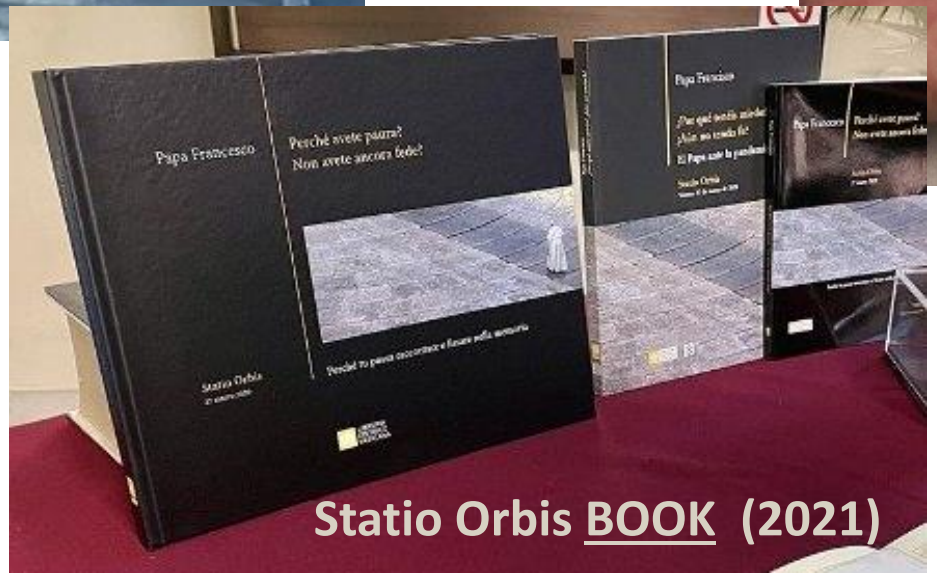
SpeiSat main payload: the nanobook

Consiglio Nazionale delle Ricerche

Politecnico di Torino 1859

Statio Orbis MINI-BOOK (2022)





Svalbard Global Seed Vault

SpeiSat main payload: the nanobook

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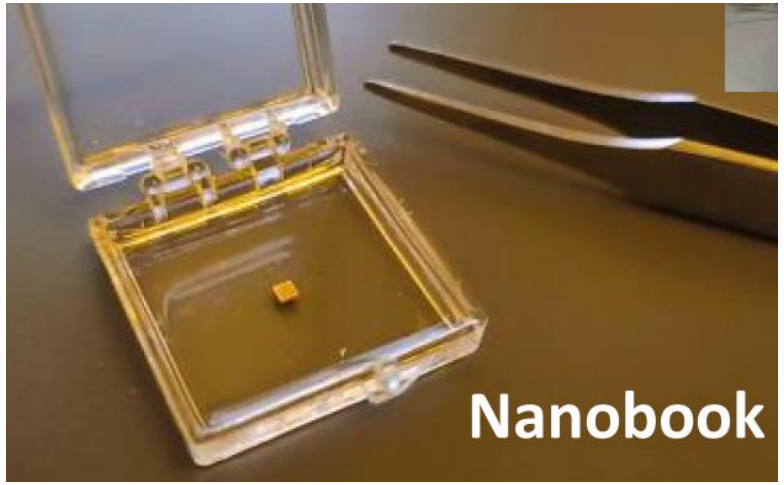
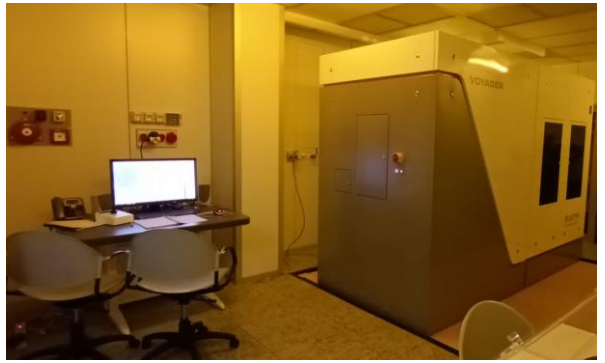
Politecnico di Torino

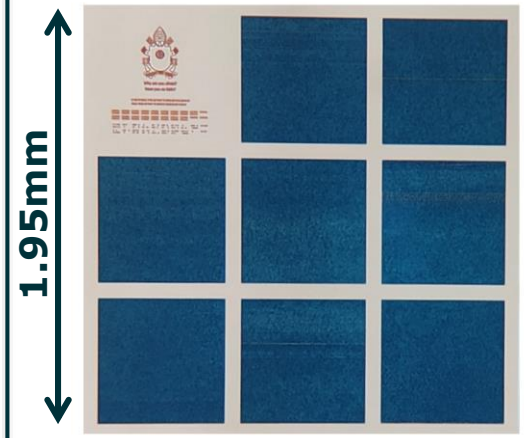
Statio Orbis NANO-BOOK (2023)



"**Nanobook**": nanostructured Silicon chip where the book digital data are encoded as millions of nanoholes.
The Nanoholes are "engraved" by using advanced nanotechnologies used for materials and device nano-fabrication, i.e. electron beam nano-lithography and reactive ion etching.

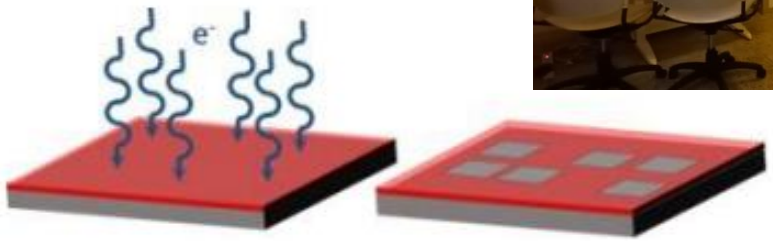
The nanoholes size is ~ 110-130 nm, corresponding to a density of information of ~$5 \cdot 10^8$ bit/in^2.





Optical microscopy image

Materials: Si wafer, Au coating
Size: 1.95 mm x 1.95 mm
Thickness: 0.2 mm
Weight: < 0.01 g.
6 millions of nanoholes



Nanobooks are fabricated by the Institute for Photonics and Nanotechnologies in the NanoMicroFab Research Infrastructure of the CNR

CNR IFN Istituto di Fotonica e Nanotecnologie

NANOMICROFAB ADVANCED LAB

SpeiSat main payload: the nanobook

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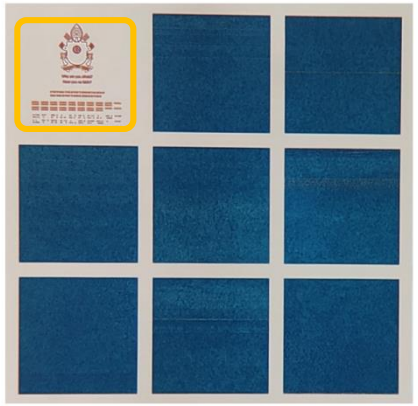
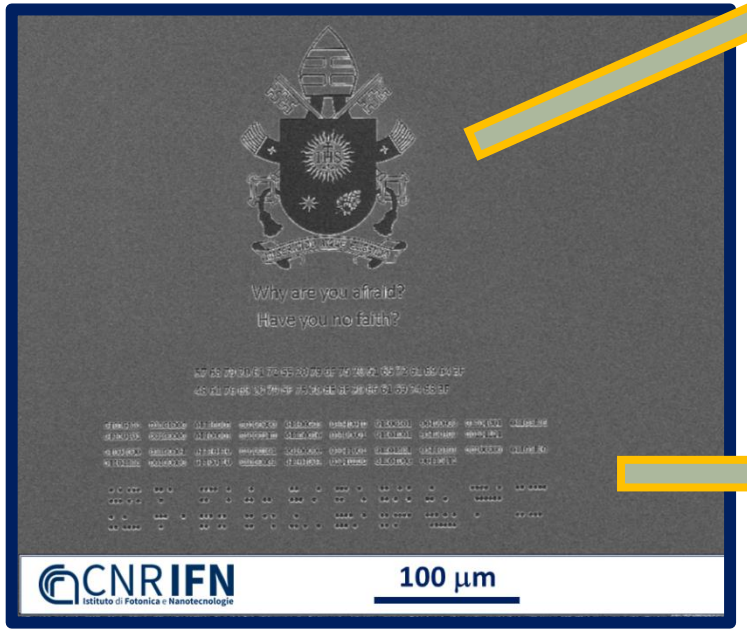
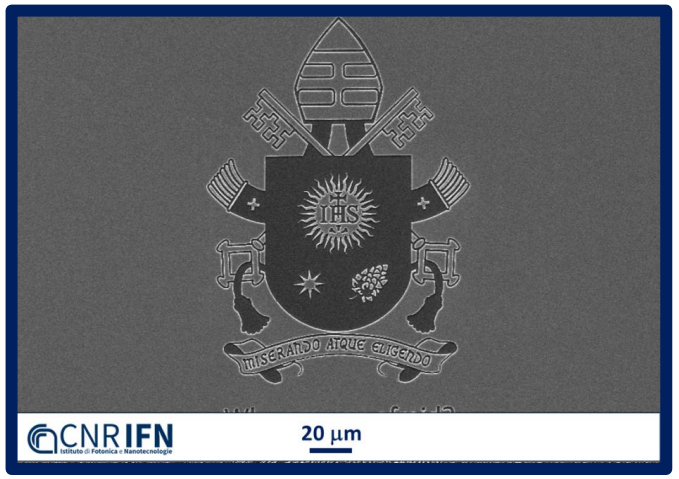
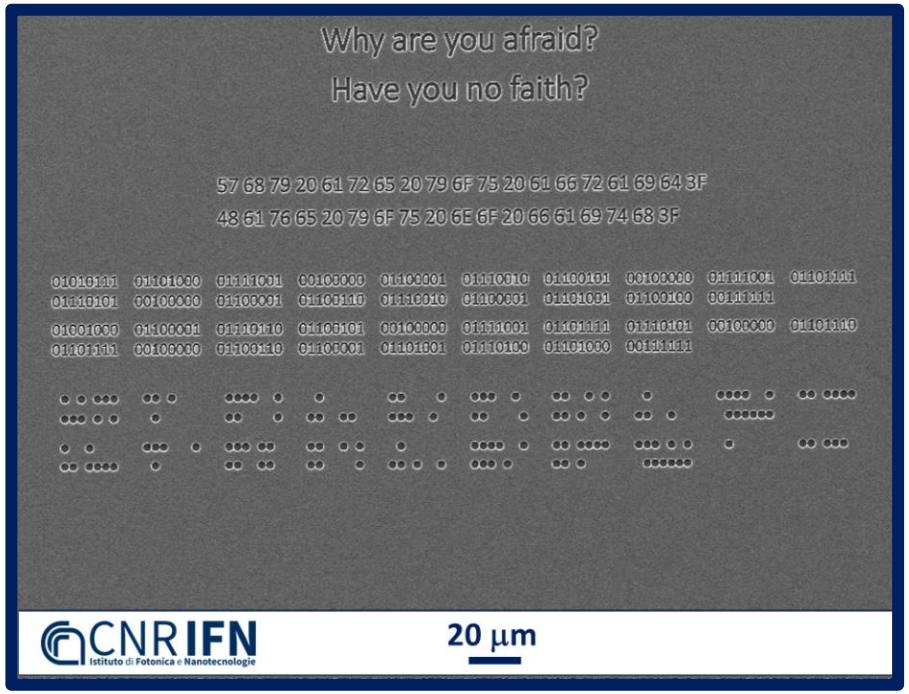
Optical microscopy image



1.95mm







SpeiSat main payload: the nanobook

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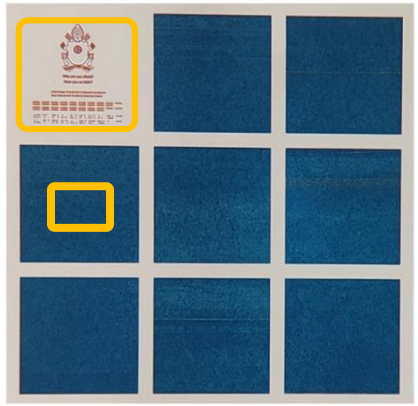
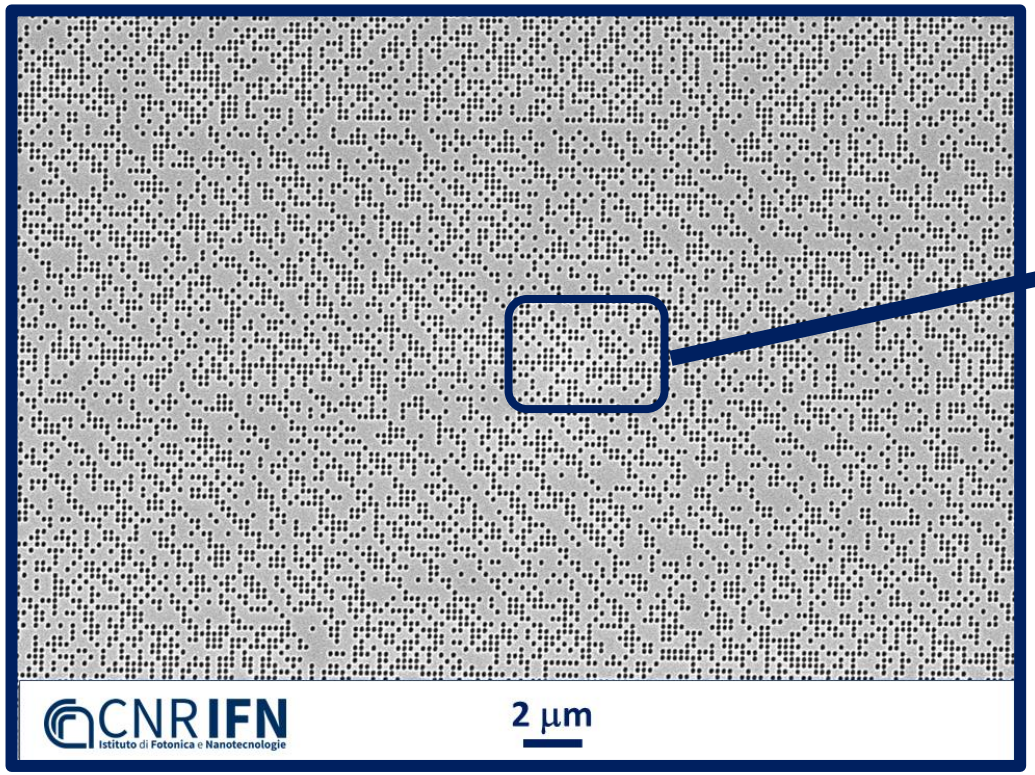
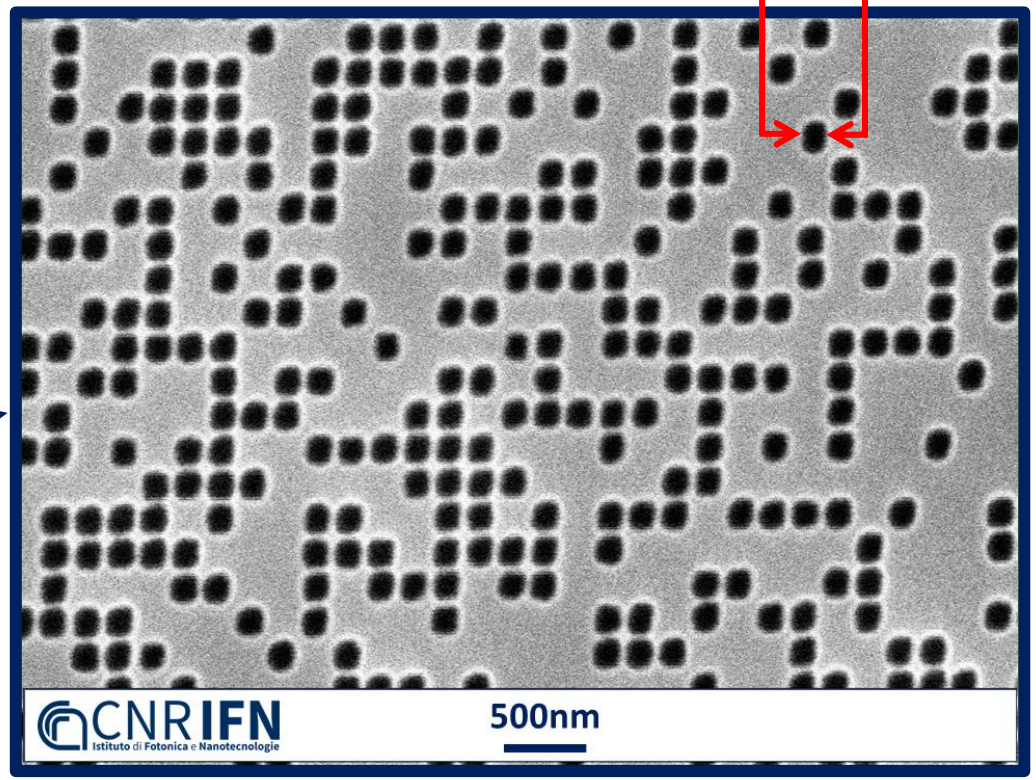
Optical microscopy image



1.95mm





SpeiSat main payload: the nanobook

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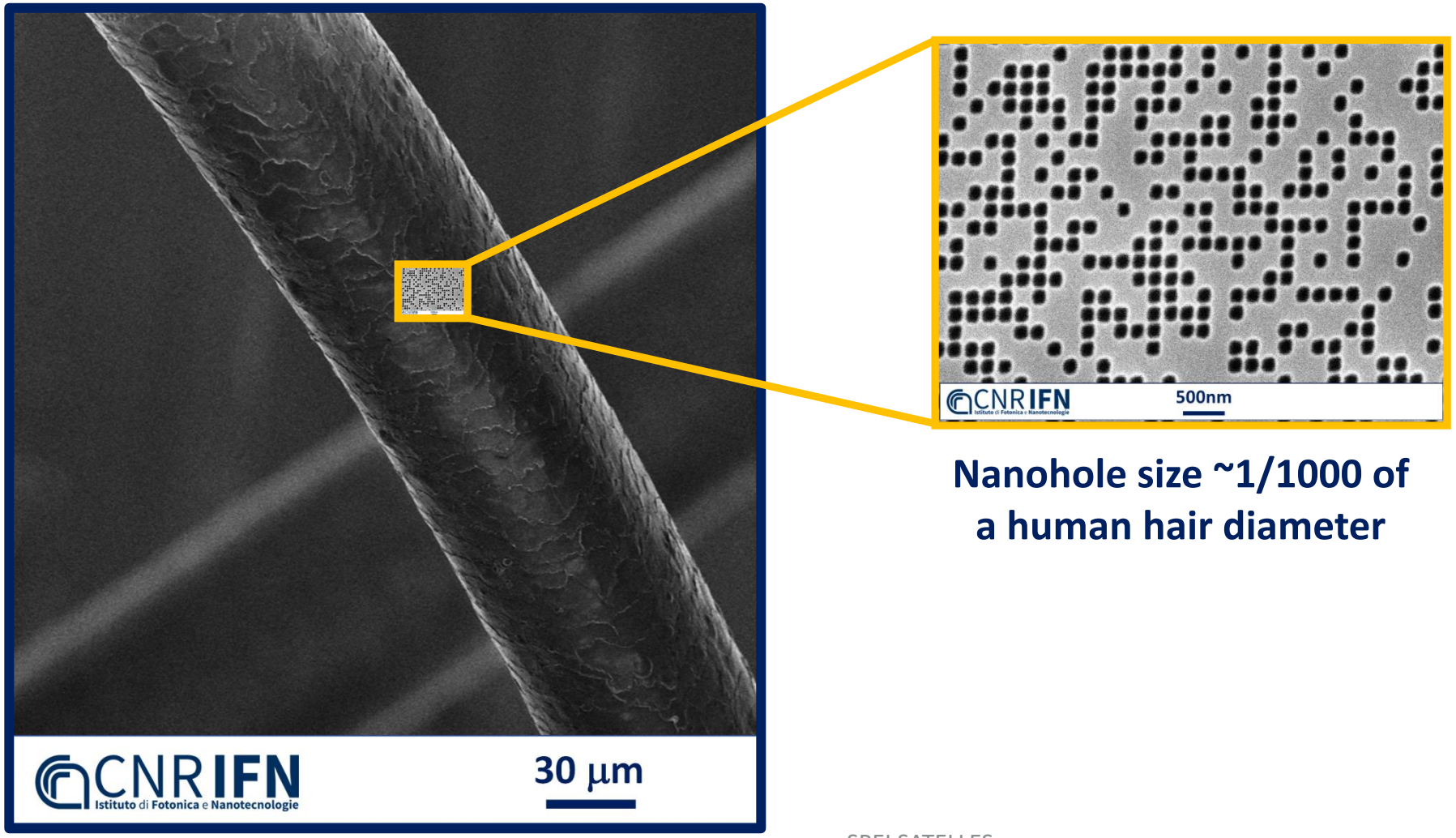
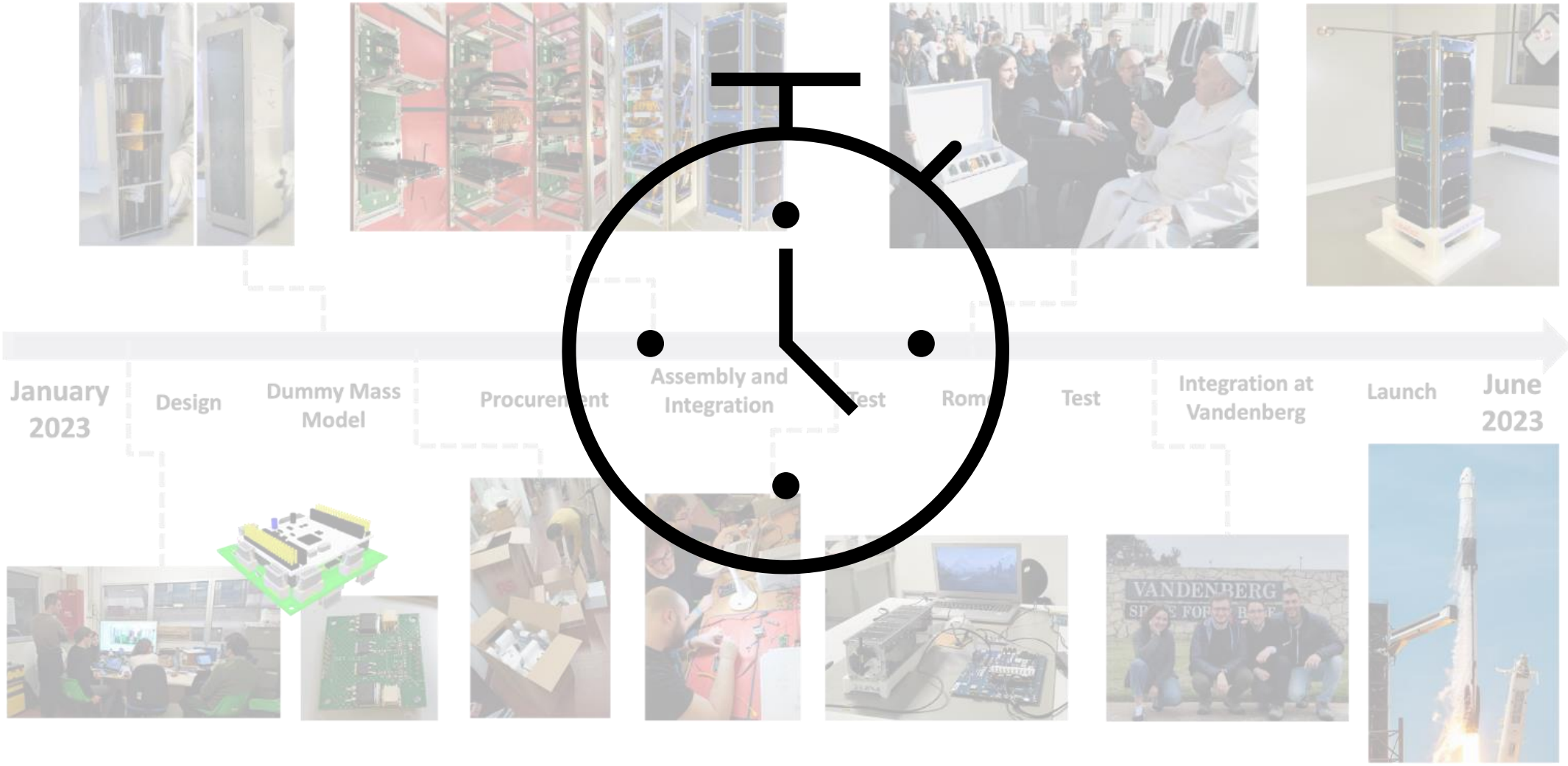
Human hair and Nanoholes on the same scale



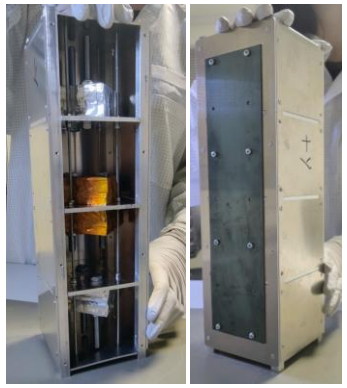
Nanohole size ~1/1000 of a human hair diameter

The project in pictures

Project driver



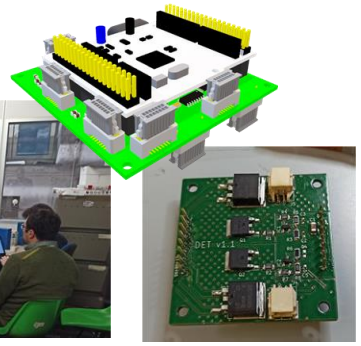
Project timeline



January 2023

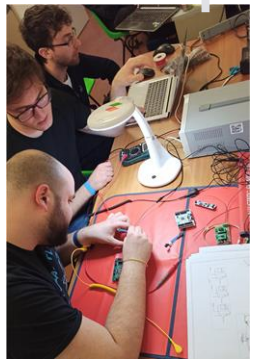
Design

Dummy Mass Model

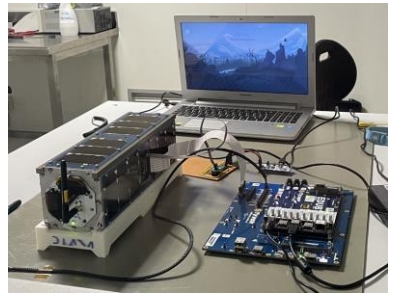


Procurement

Assembly and Integration



Test



Rome

Test

Integration at Vandenberg

Launch

June 2023

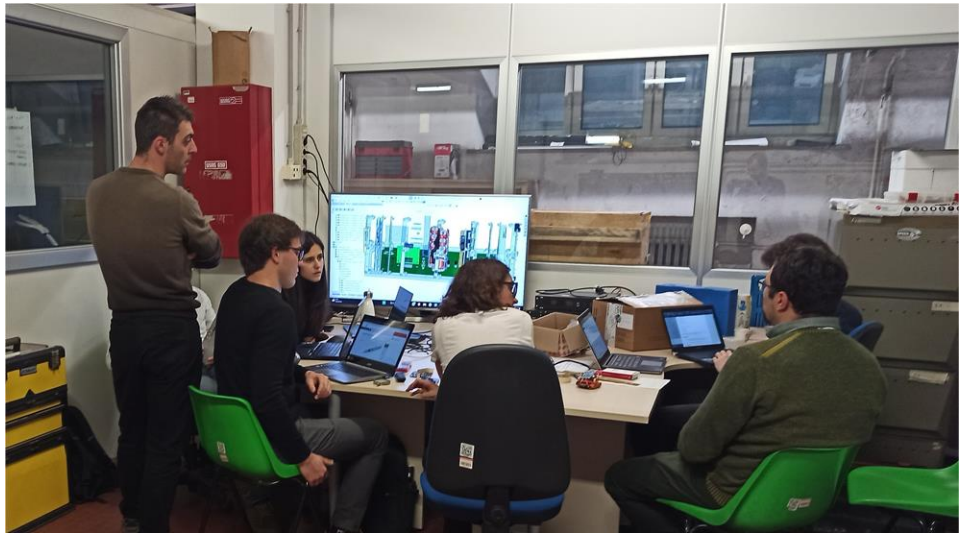
Design highlights

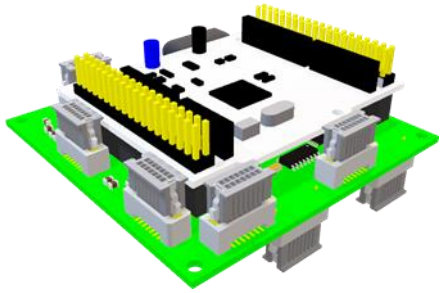
Design drivers – 3Rs:

- **Reliability: redundancy of C&DH and TT&C system, simple design (e.g. DET, passive stabilization), verification approach**
- **Robustness: modular structure, margins**
- **Reuse: design heritage, ground segment**

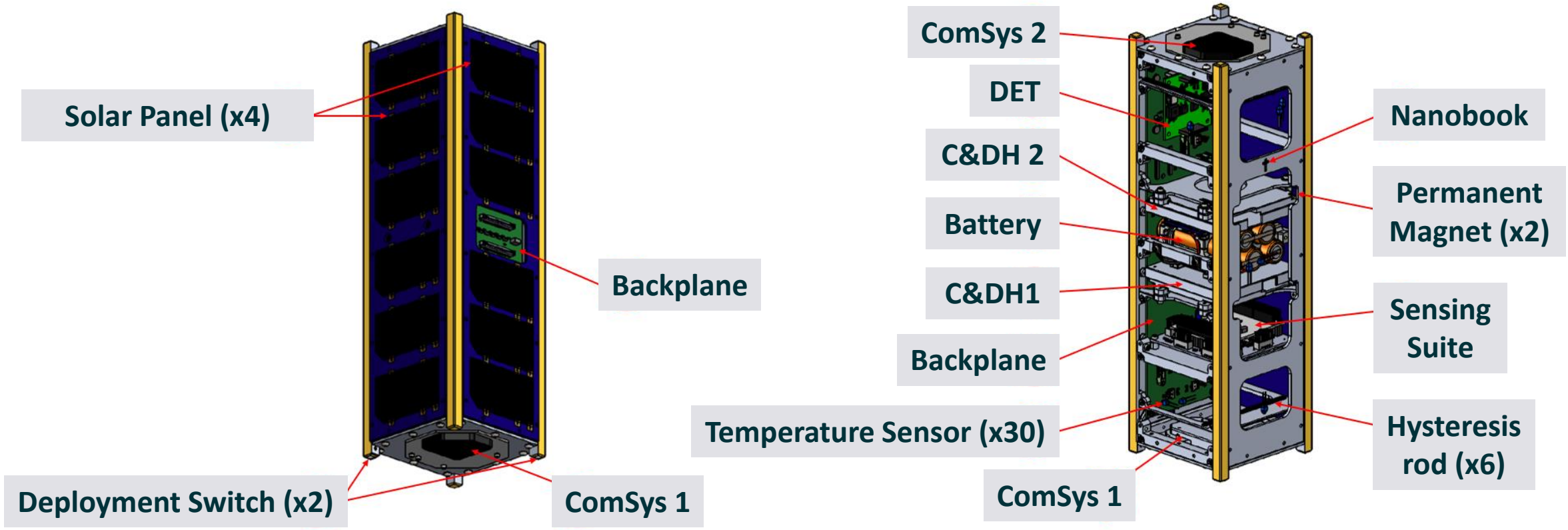
New Developments:

- **Direct Energy Transfer Board**
- **Sensing Suite Board**
- **Backplane Board**

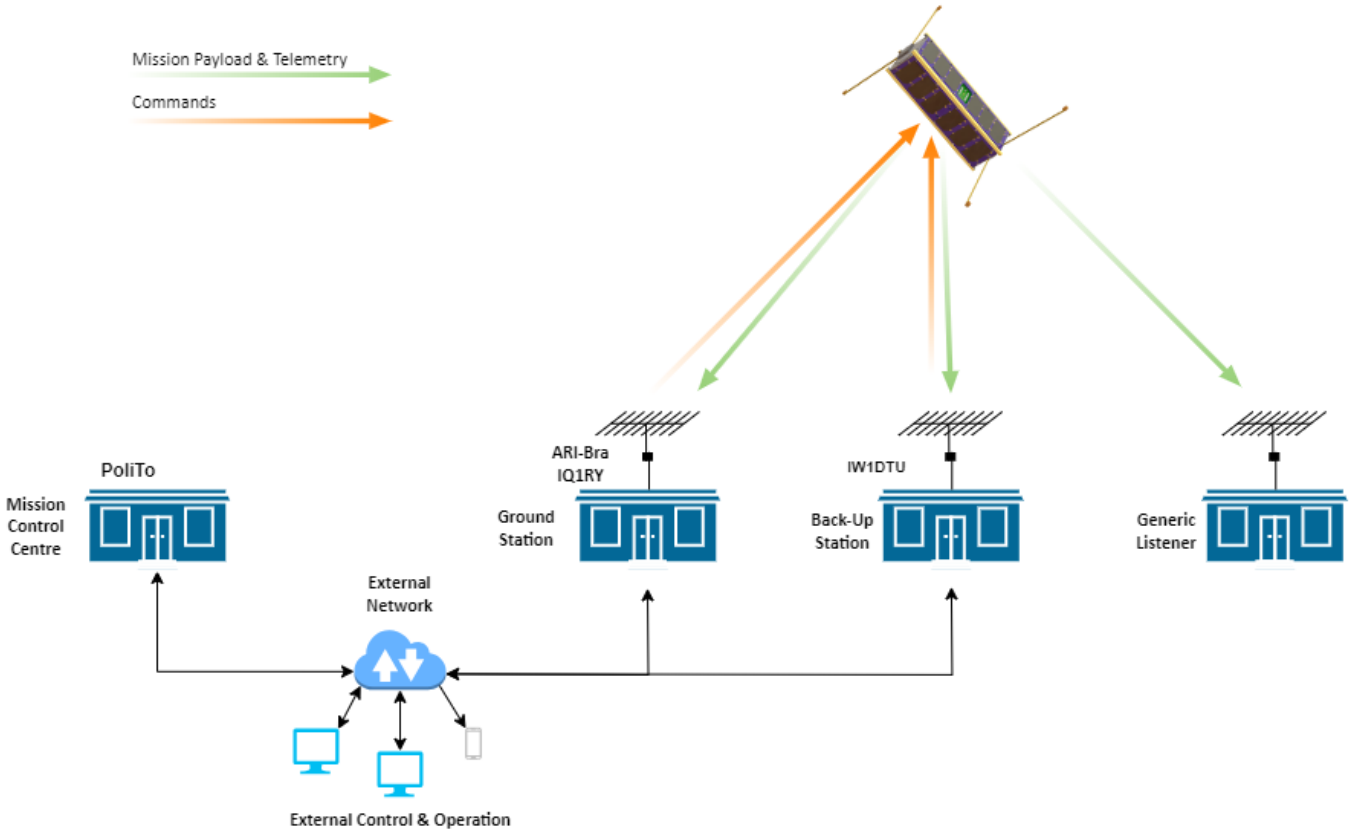


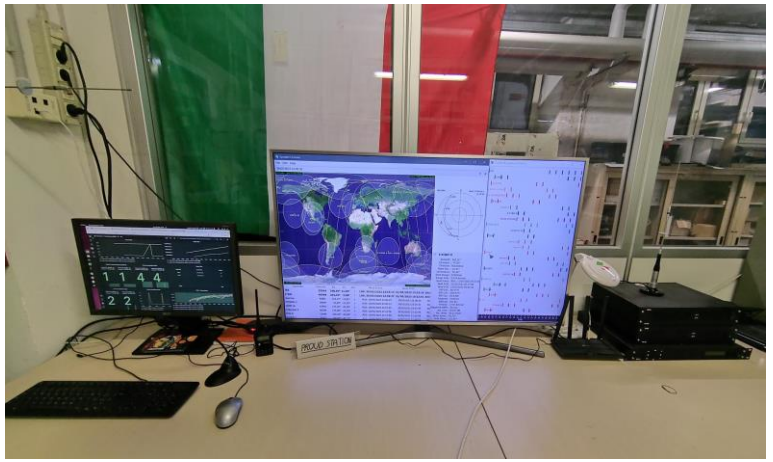


The Space Segment

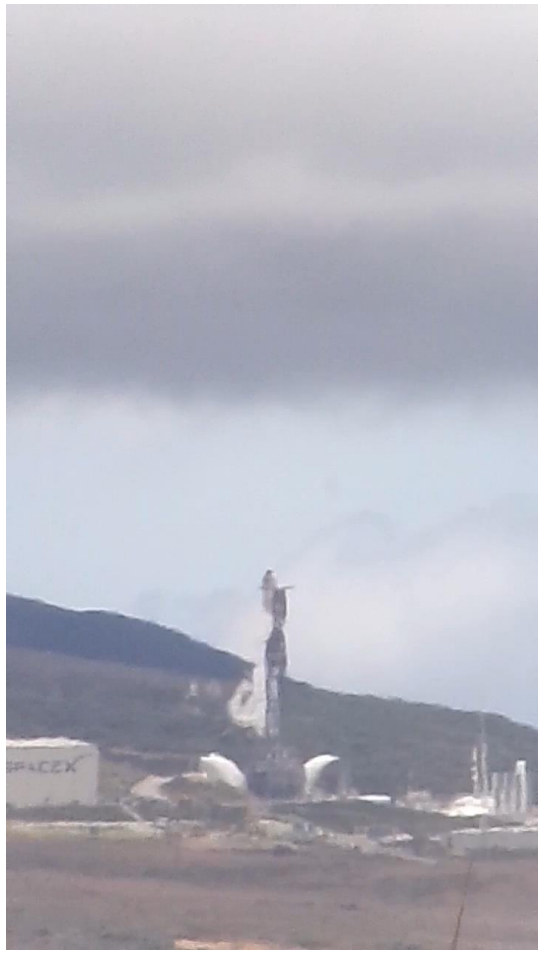


The Ground Segment



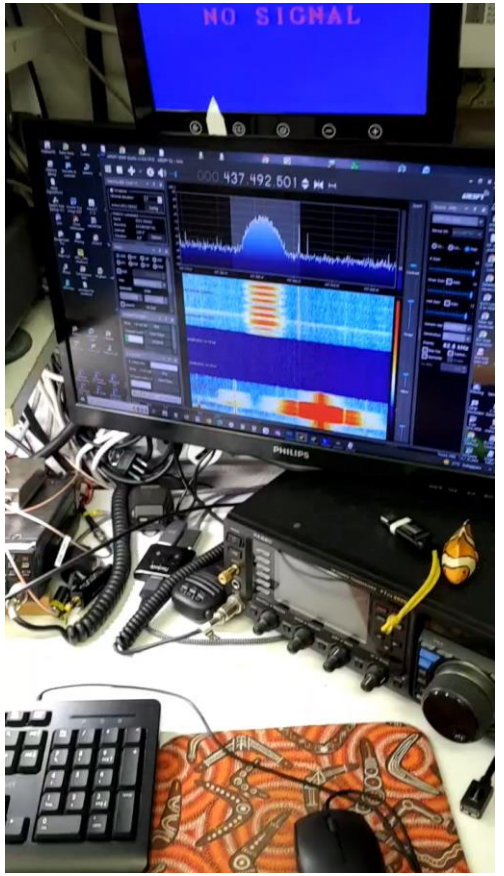


Launch and Operations

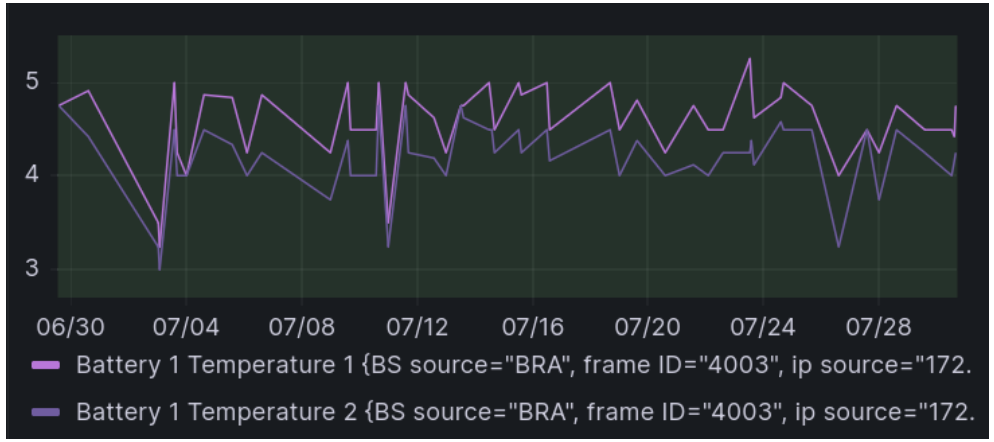


June 12, 2023

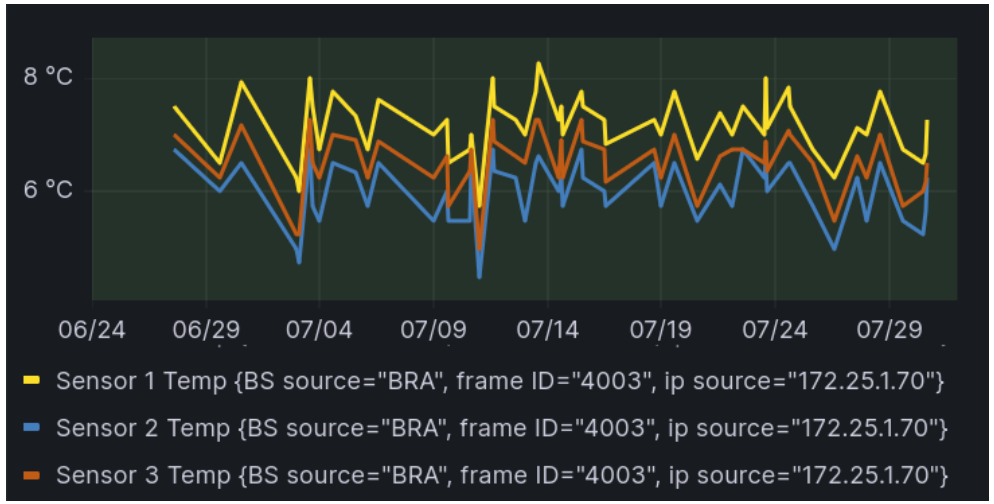
June 23, 2023

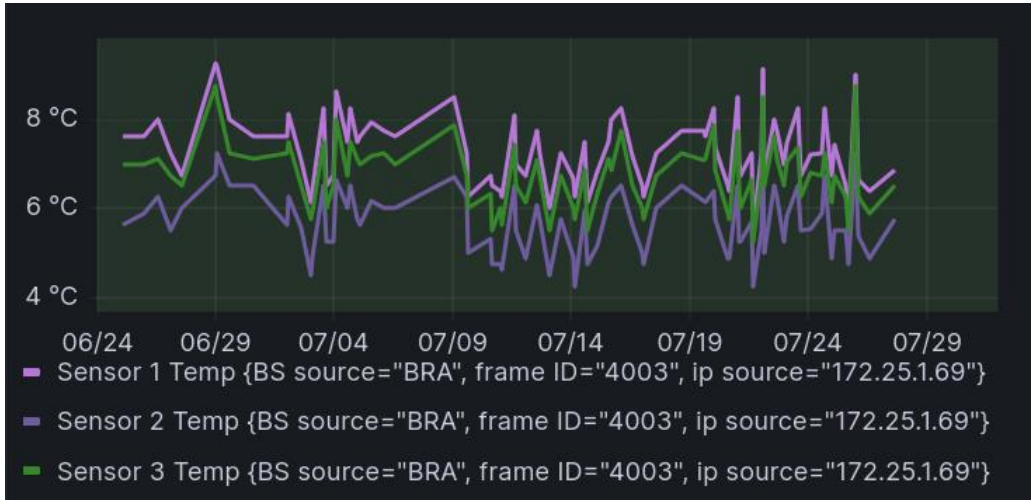


Operations – In-Orbit Data



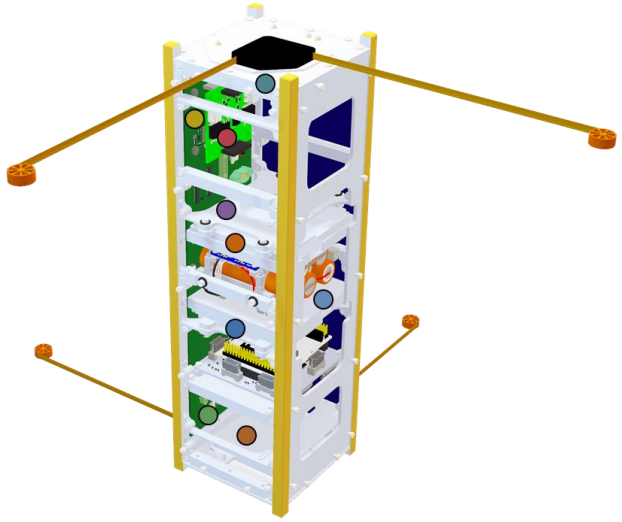
- Nominal battery temperature values: [3, 5.25] degC
- Nominal C&DHs temperature range:
  - C&DH 1 temperature range [4.5, 8.25] degC
  - C&DH 2 temperature range [4.2, 9.25] degC





Operations – In-Orbit Data

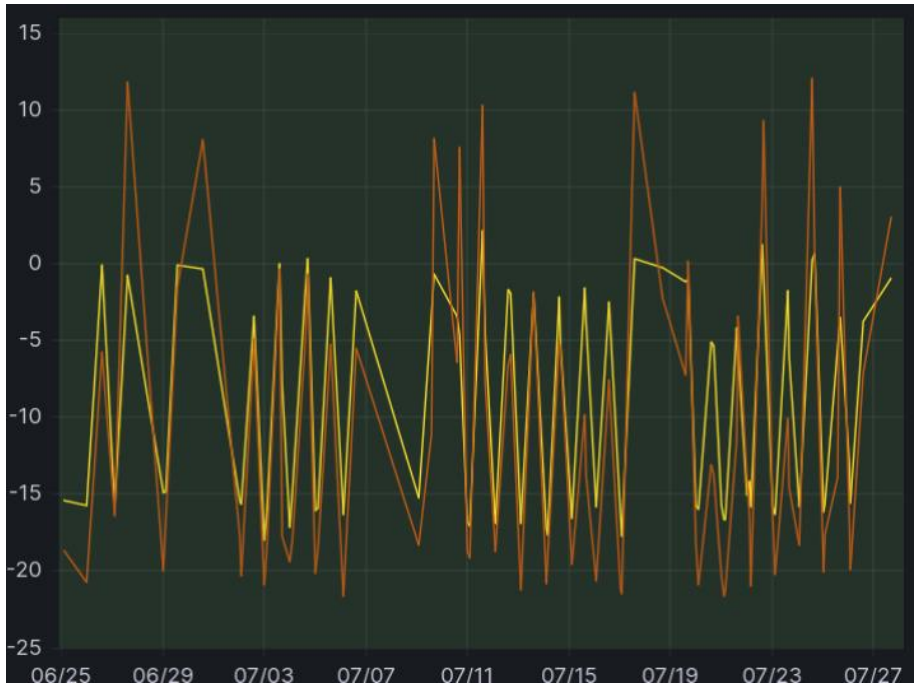
- Temperatures acquired by the **Sensing Suite** (30 temperature sensors)
- Trend of 9 **temperatures in relevant/critical points** of the satellite
- SPEISAT is a **cold satellite**: most internal components below 0 degC
- C&DH1 and C&DH2 boards maintain 5 degC constant trend
- DET circuit temperature: some spikes due to shunt resistors where the surplus of energy from solar panels is dissipated
- Z+ and Z- faces temperature represent ComSys1 and ComSys2, respectively. The coldest one values, but within expected range

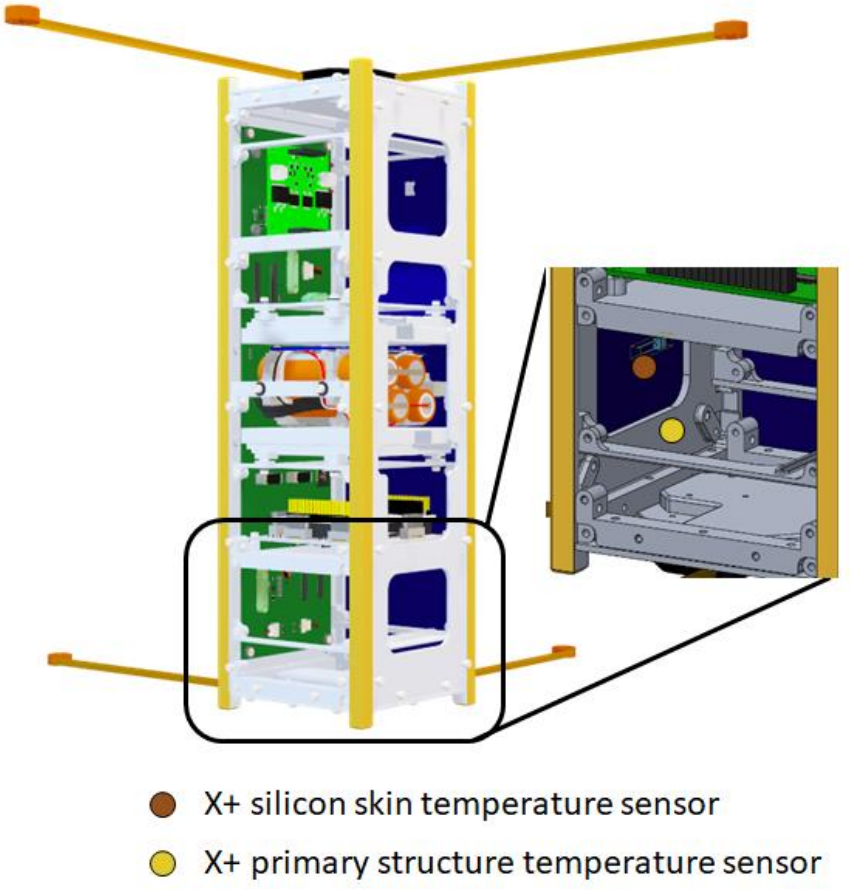


- Z+ ComSys2 temperature sensor
- DET temperature sensor
- Backplane up temperature sensor
- C&DH2 shelf temperature sensor
- C&DH2 case temperature sensor
- C&DH1 case temperature sensor
- C&DH1 shelf temperature sensor
- Backplane down temperature sensor
- Z- ComSys1 temperature sensor

Operations – In-Orbit Data

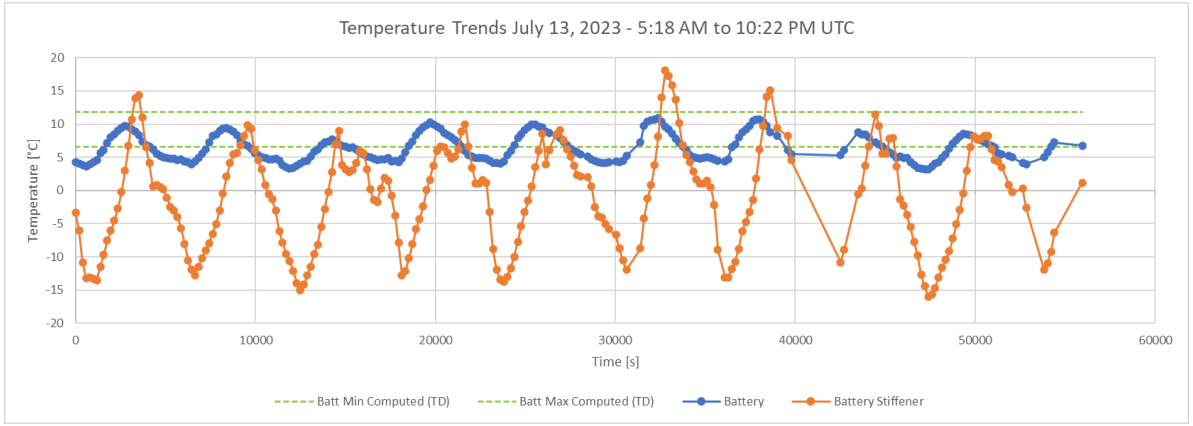
- Two sensors on the aluminum of structure and the FR4 of the solar panel, both mounted on the +X face
- Gap filler between the aluminum and the FR4:
  - Isolate internal parts
  - Reduce minimum and maximum temperature values

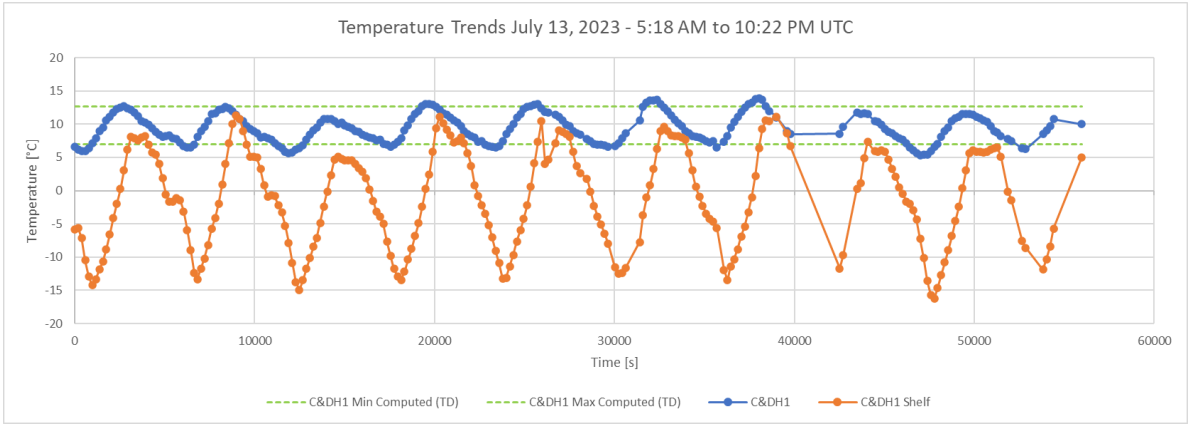


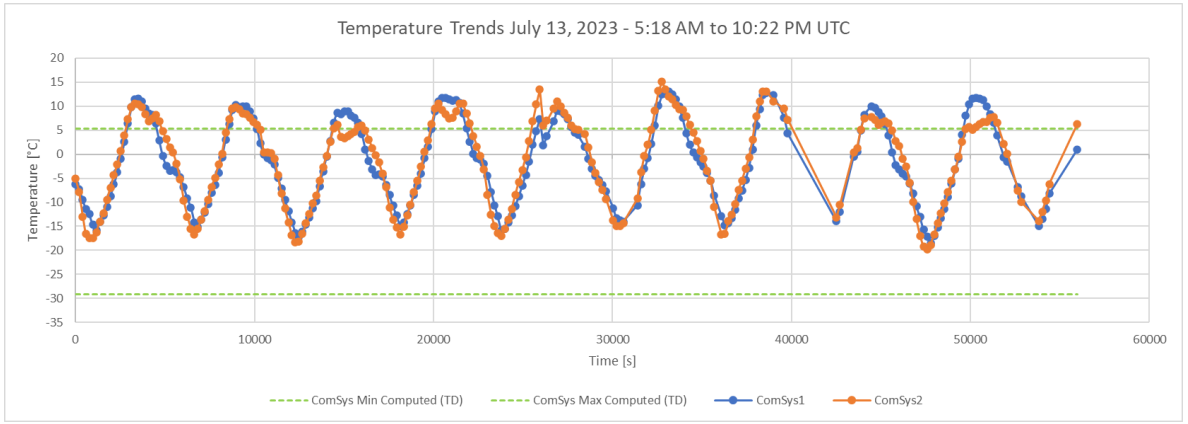


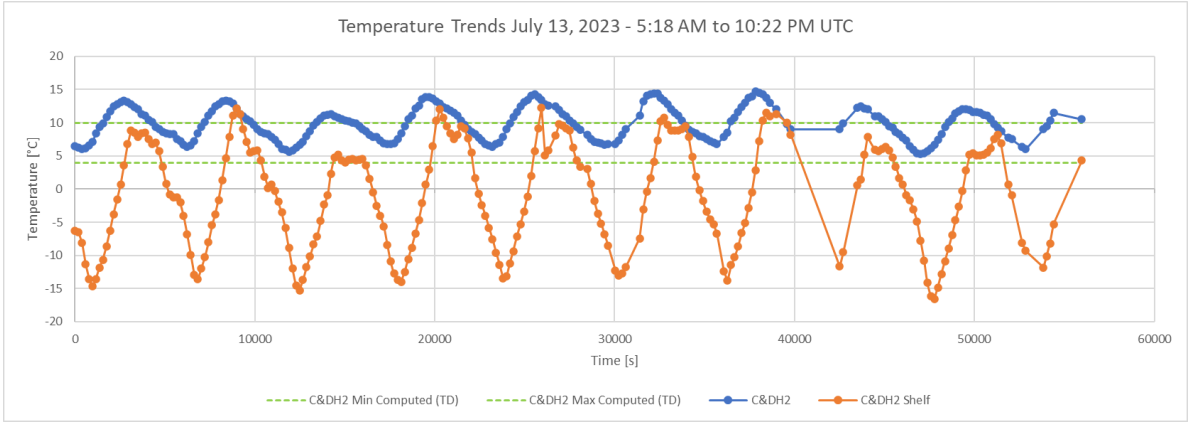
Operations – In-Orbit Data

- Trend shape similar to the numerical simulation prediction
- Different minimum and maximum temperature, due to attitude discrepancies of the model compared to the real situation and different operative mode considered for the cold case in the simulation









Lessons learnt

- Doing a CubeSat in 6 months requires new approaches in all phases of the lifecycle
  - Concurrent engineering has proven to be the key for mission success
  - *Keep it simple* is the golden rule
  - Functional test as soon as possible
- Doing a CubeSat in 6 months requires that an ecosystem is there
  - Well established hands-on educational programmes on space engineering
  - Strong connection and collaboration between all the stakeholders: the Agency, the University, and the relevant industrial entities

A special thank to:

- Silvia Natalucci with Giuseppe Leccese and Alberto Fedele, and all ASI staff who supported the project
- D-Orbit for the perfect piggyback to orbit
- Tyvak International for providing vital items, useful advice and unvaluable time
- The ARI-BRA staff and Supertrack IW1DTU for tracking SpeiSat and supporting the operations
- Luca Peyron and Lucio Adrian Ruiz for the idea (and the name) of the mission Spei Satelles
- Giorgio Saccoccia for trusting us
- and the amazing students of Politecnico di Torino who made it!