The HERMES Mission: A CubeSat Constellation For Multi-Messenger Astrophysics

5th IAA on University Satellite Missions and CubeSat Workshop
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HERMES-TP Mission
Mission overview

HERMES-TP stands for

High Energy Rapid Modular Ensemble of Satellites – Technology Pathfinder

Mission objectives:

- **detect** and **locate** high-energy rapid transient in the universe, like **gamma-ray bursts** (GRBs)
- **fast detection** (< 10 s) and **full sky coverage**
- demonstrate the **technological feasibility** for GRBs localisation
- 2-year mission lifetime

Artist impression of a Gamma-Ray Burst. Credits: NASA.

HERMES-TP Mission

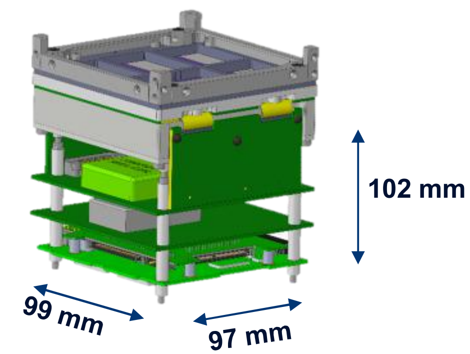
Mission requirements

Scientific Requirements	Value
Accuracy in GRBs localisation	≤ 10 degrees
Number of GRBs detected	short GRBs ≥ 10 per year long GRBs ≥ 70 per year
Triangulation	minimum 3 satellites
Pointing error	≤ 5°
Detection/Localisation delay time	few minutes

Detector Orbital Constraints		Selected Orbit
Altitude	≤ 600 km	**550 km**
Inclination	≤ 20°	**Equatorial**

Scientific payload

Miniaturized detector for GRBs



GRBs detector. Credit: INAF.

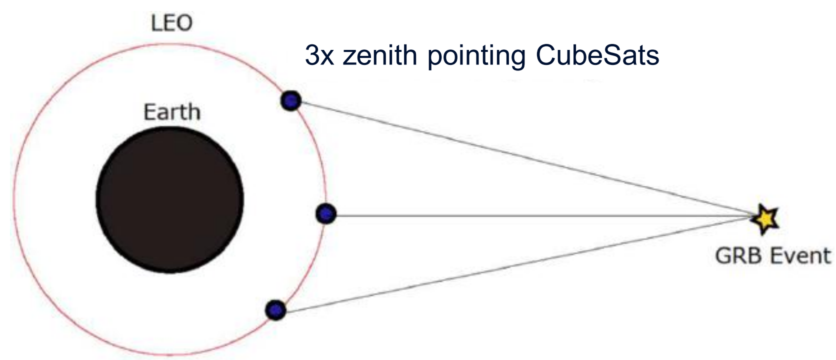
HERMES-TP Mission

Mission challenges

GRBs localisation

Time delay comparison among **detection epochs** of the GRBs event occurred on **at least 3 detectors** spaced on different satellites

→ **Constellation of 3 satellites** in **equatorial LEO**



GRBs triangulation by three zenith pointing CubeSats.

3U CubeSat platform size

- **COTS components** to reduce the mission cost
- **no propulsive system** for attitude control

→ **Passive attitude control** for the **zenith pointing**

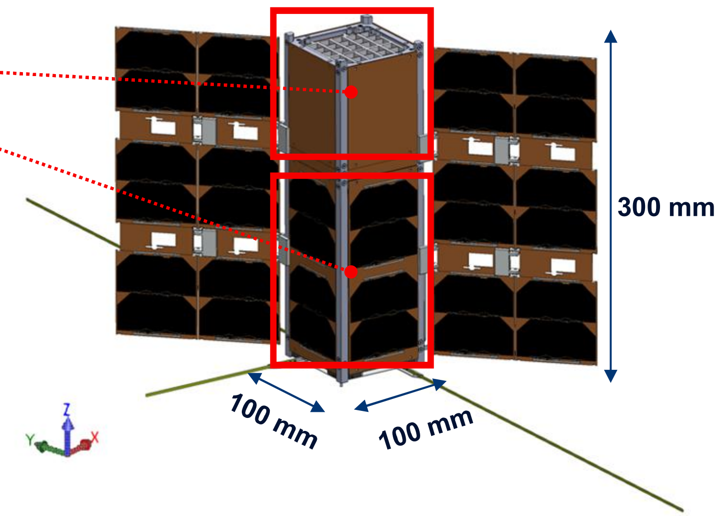
Service module design

Platform overview

Spacecraft configuration

- The **payload** in the top unit
- The **service module** in the bottom part, divided in two sectors
  - The **central part** for **PC104** standard components:
    - → electronics, on-board computer, communication bundle
  - The **bottom part** for **actuator** mounting for attitude control:
    - → reaction wheels

External view of HERMES-TP CubeSat



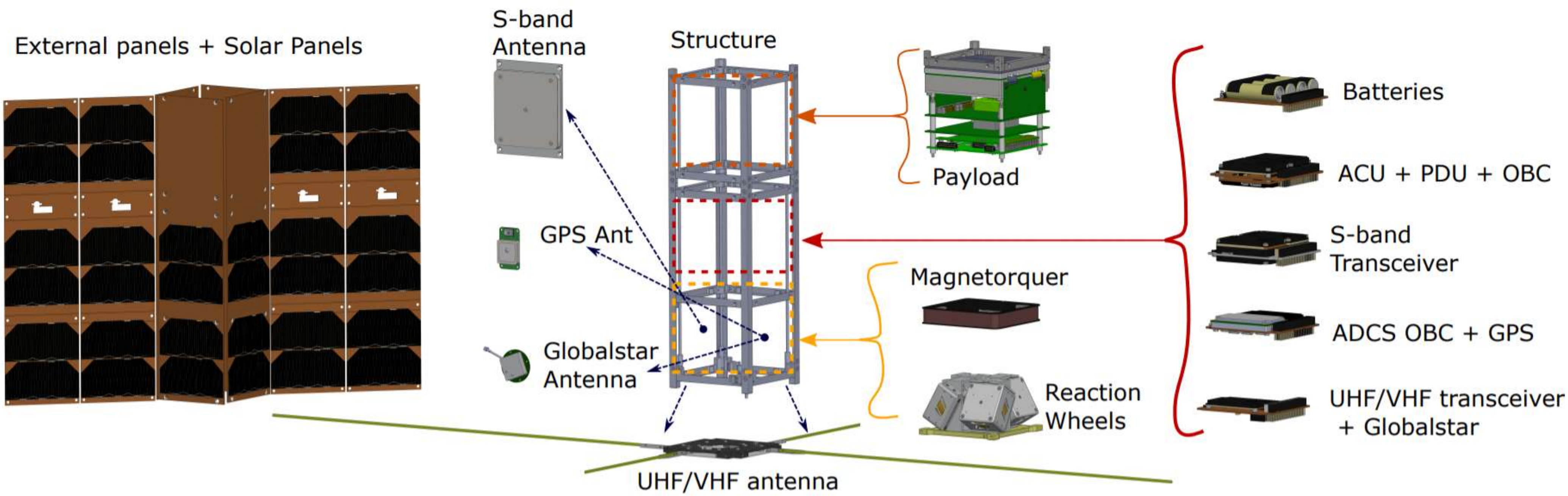
Design strategy

- **Compactness** of PC104 stack for **space optimisation**
- Components rationale disposition for **harness length minimisation**
- **Avoid electrical and mechanical interference** of service module components.

Service module design

Platform overview

HERMES-TP internal configuration



Service module design

TT&C architecture

TT&C Functions

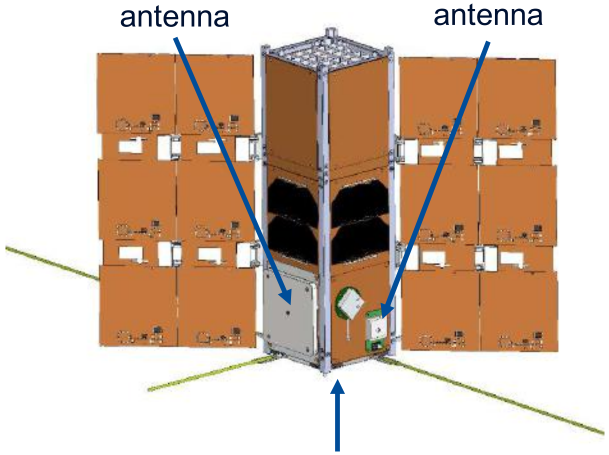
- **Telemetry and telecommand** from/to the ground segment
- **GRB early warning** transmission of a trigger message within 30 min
- **Scientific observation data** downlink(1 Gbit per day)

TT&C Components

UHF/VHF antenna & transceiver
- dipole antenna
- up to 35 kbps

GlobalStar antenna & transceiver
- passive patch antenna
- up to 72 bps
- alert in less than 3 min

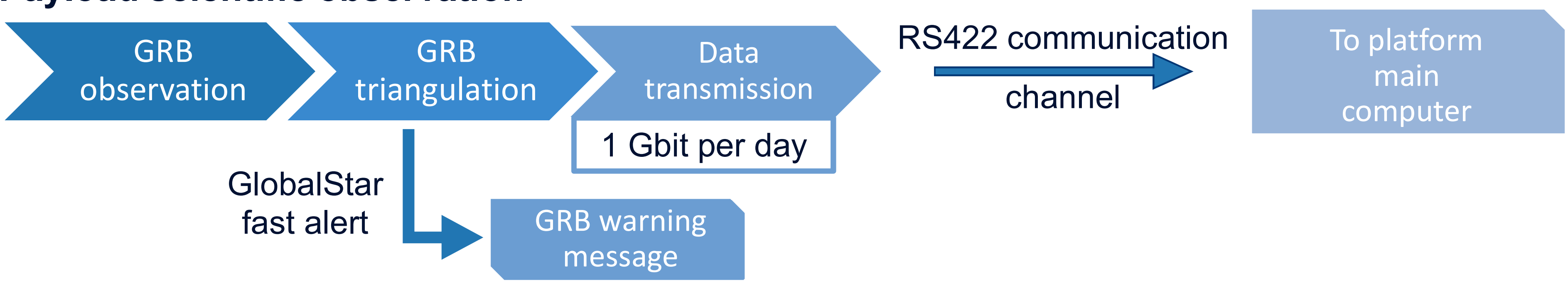
S-band antenna & transceiver
- active patch antenna
- 8 dBi gain
- up to 700 kbps



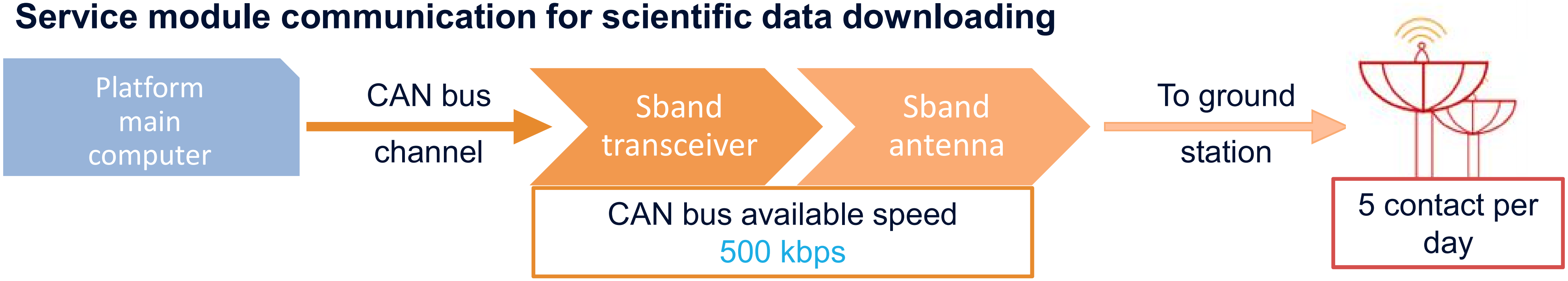
Service module design

Telecommunication strategy

Payload scientific observation



Service module communication for scientific data downloading



Service module design

On-board computer software design

Requirements

- Large **flight-proven driver** library available
- **ECSS compliant**
- **Off-line test and simulation**

Bright Ascension libraries and tools

- **Licensing** is per-satellite
- One license for both **main and AOCS OBCs**
- Development is under **Eclipse**
- **CCSDS** Packet Protocol

Rapid – COTS library

Flexible – component based

Robust – tested and proven code

Ease-of-use – API reference doc

Service module design

Power generation

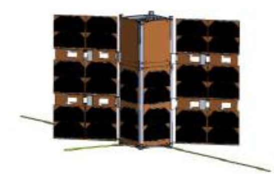
Power Budget

Scientific Requirements	Mean Power demand [W]	Peak Power demand [W]	Power generation source
Scientific observation phase	12.2	22.7	Solar panels & Batteries
S-band data download phase	16.2	28.8	Battery only (in eclipse)

Solar Panels Architecture selection

- **Deployable** solar panels
- Azur Space solar cell (**30% efficiency**)
- Maximum peak power ≥ **30 W**

➡ **Trade-off analysis** in **zenith pointing**

	Petals Solar Panels	Wing Solar Panels
		
Mean Generated Power in light [W]	17.2	25.0
EOL batteries DoD [%]	40	40

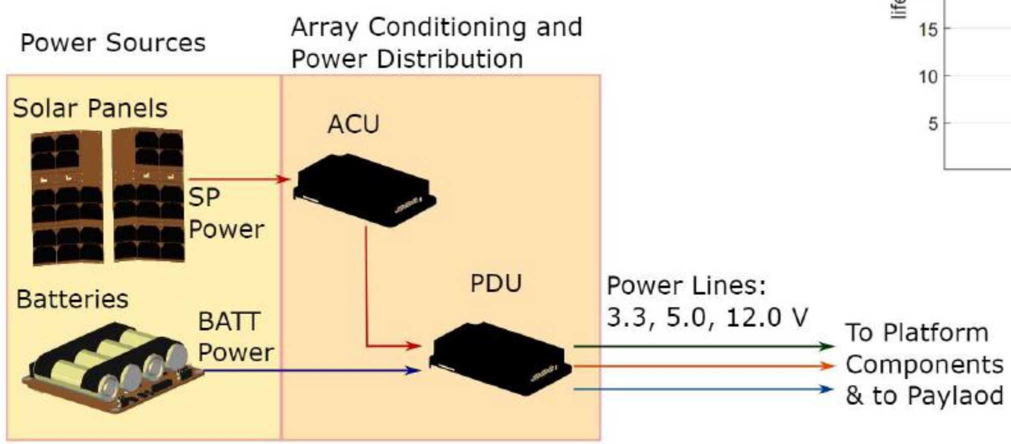
Service module design

Power generation

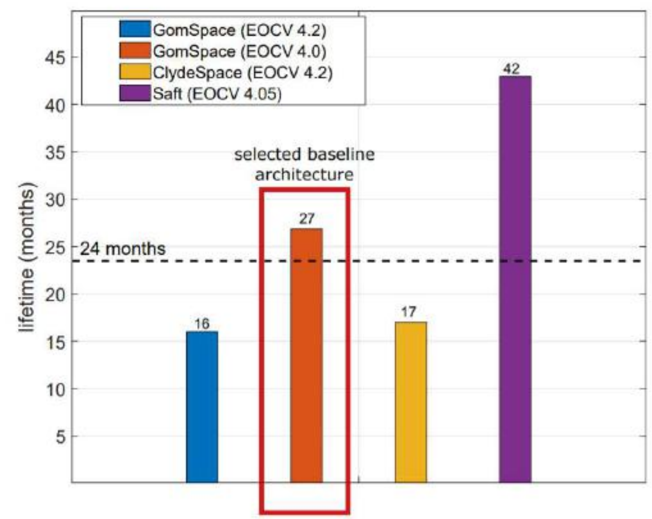
Battery pack selection

- **11000 eclipse cycles** in 2-year mission
- **40 Wh capacity**
- Space qualified product (**TRL 9**)

Final EPS Architecture



Battery pack analysis



Up to 30% DoD at EOL

Service module design

Thermal control

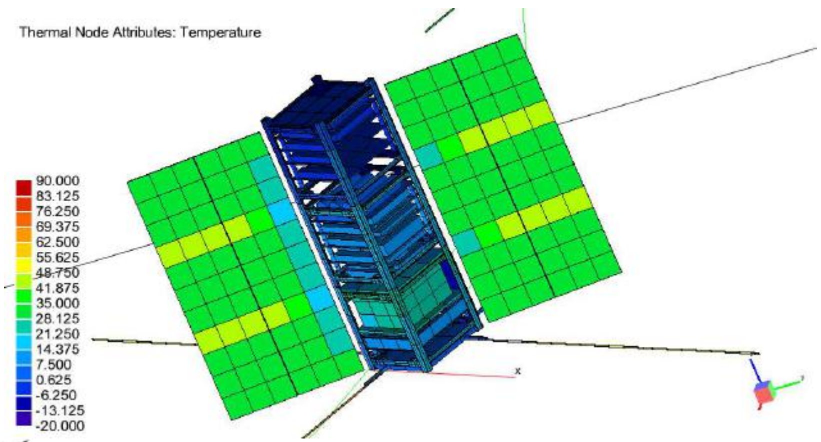
Thermal control design:

- **FEP tape** on payload side panels
- **Thermal sensor** for temperature monitoring

P/L operative T ranges: **-30°C / +10°C**

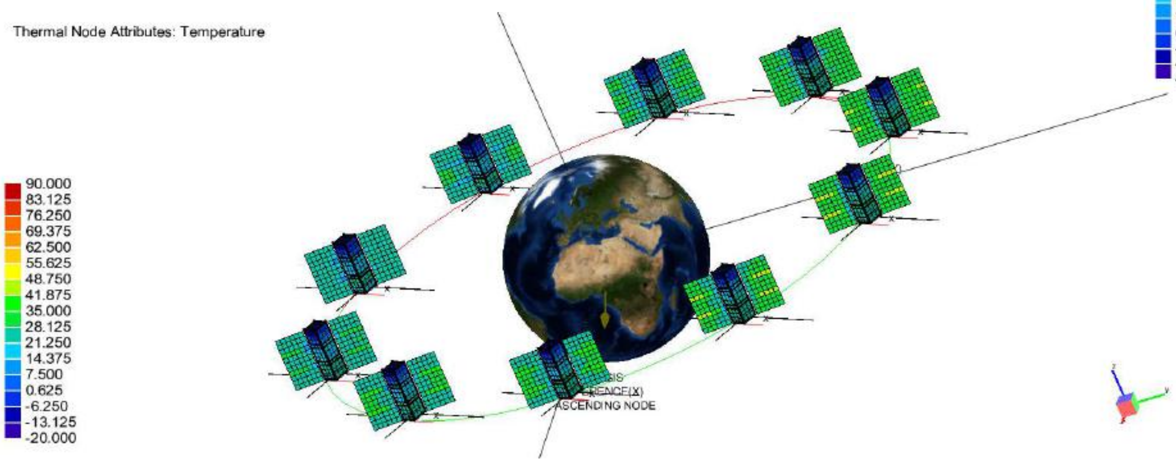
Platform operative T ranges: **-40°C / +80°C**

T(°C)



Components stay within the **correct temperature ranges**

T(°C)



Conclusions

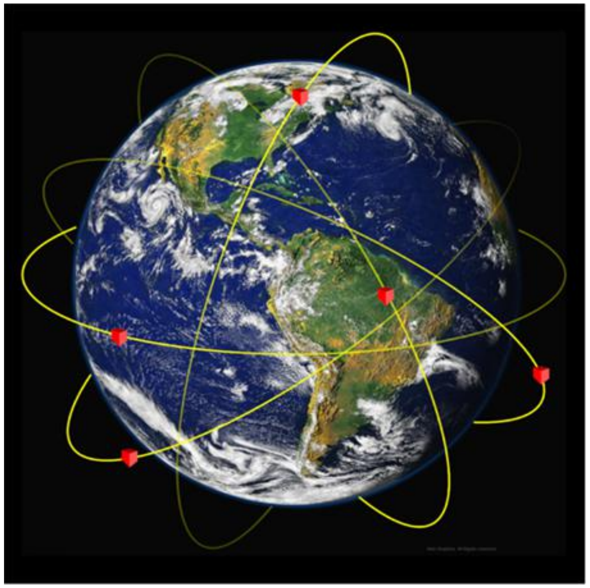
HERMES-TP mission future developments

HERMES-TP has just closed its **PDR** (dec 2019)

- **Service module design** respects the mission **requirements**
- **Final design refinement**
- **Procurement** of the components on-going
- Preparing to the **CDR** for end of April 2020

Future developments

- **Assembly, Integration and Verification Plan** for the **service module** and the **payload**
- Hardware and Software **Tests procedure**
- Delivery of the **protoflight model** of the CubeSat
- Extension to a **3+3 Constellation** in **HERMES-SP**



HERMES-SP Constellation. Credit: INAF

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