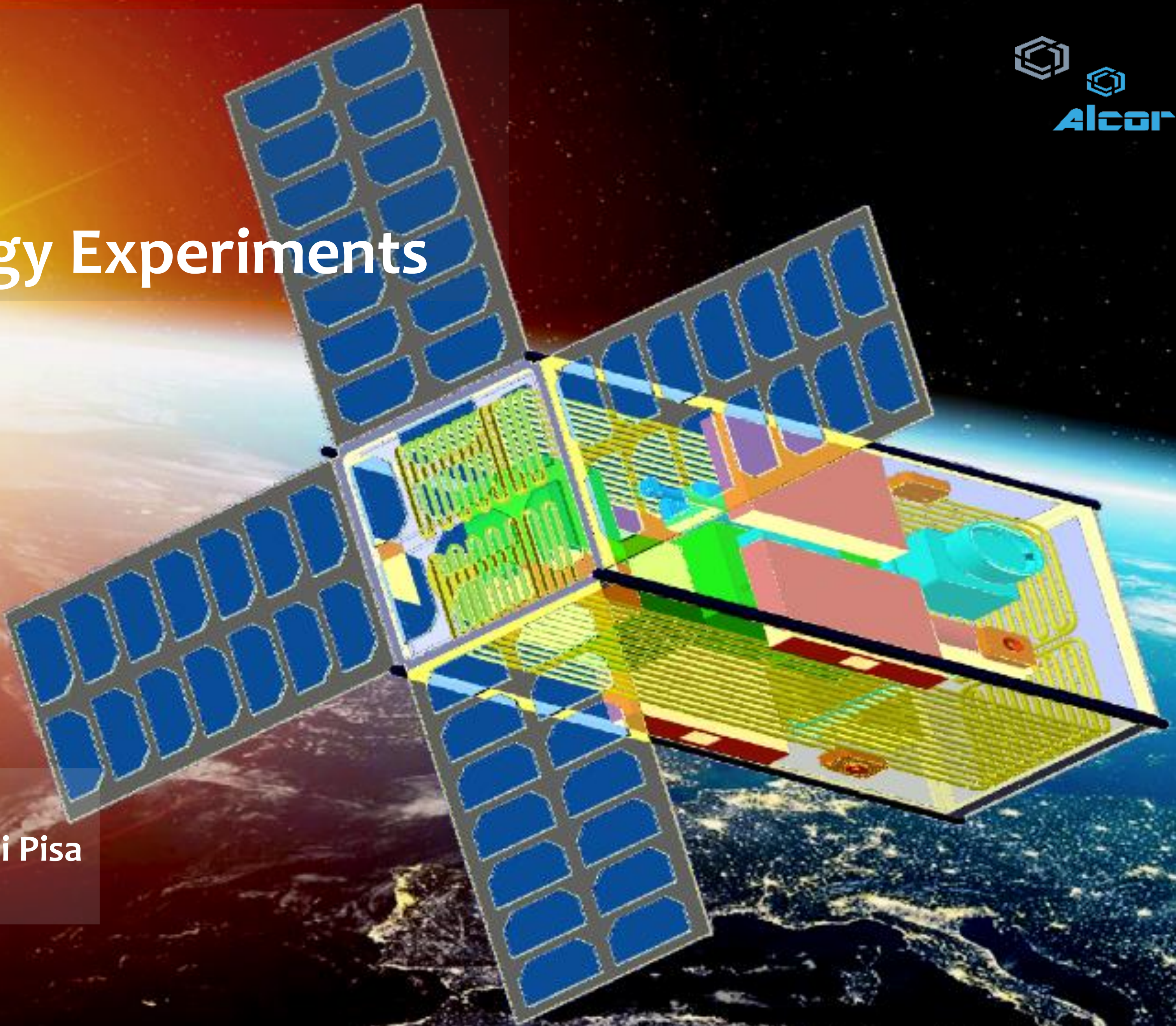
EXCITE

EXtended Cubesat for Innovative Technology Experiments



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Alcor

Università di Pisa · Aerospazio · CRM Compositi · IngeniArs · mbi

EXCITE

EXtended Cubesat for Innovative Technology Experiments

IOD/IOV mission within the *ALCOR* programme by ASI

Proposed by a **regional academic/industrial partnership** located in Tuscany:

- Università di Pisa (prime) through its three Departments of Engineering
- Aerospazio Tecnologie Srl
- CRM Compositi Srl
- IngeniArs Srl
- MBI Srl

Mission objectives

Main goal:

test/validate in orbit a number of small spacecraft technologies developed by UniPi researchers and by local SME's

Secondary objectives:

- implement advanced **bus technologies** developed at UniPi (deployable solar panels, SMA actuators, etc.);
- act as a hands-on **educational laboratory across the engineering disciplines** for graduate students at UniPi.

Technology Demonstration Payloads on EXCITE

PROPULSION

H_2O_2 - Hydrogen Peroxyde Monopropellant Thruster

Green monopropellant thruster, alternative to toxic hydrazine. Microsatellite propulsion system for small to moderate delta-V maneuvers of micro- and small-satellites.

PPT – Pulsed Plasma Thrusters

Miniaturized electric thrusters for high precision, very low impulse bit orbital maneuvers, proximity operations, microsatellite attitude control.

Technology Demonstration Payloads on EXCITE

HEAT MANAGEMENT

PHP – Pulsating Heat Pipe

High throughput heat pipes based on unsteady fluid flow. Specially suited for compact, high heat flux space applications, such as microsatellites with high onboard power.

Technology Demonstration Payloads on EXCITE

OBDH & TELECOM

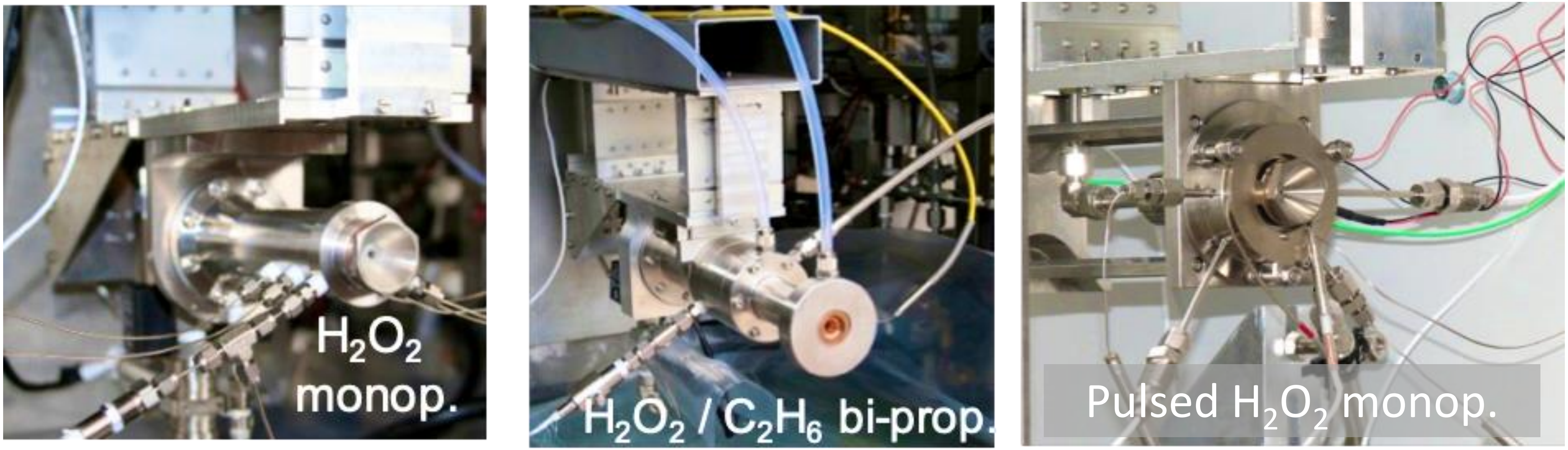
IoT GPU - Internet-of-Things Graphical Processing Unit Demodulator

Demodulator for advanced Internet-of-Things waveforms based on a COTS Graphical Processing Unit.
Low cost, high performance onboard computing.

ReconfAnt - Reconfigurable Integrated S-Band Antenna

Integrated, electronically steerable antenna based on exciters distributed on suitable spacecraft surfaces. Allows for extreme compactness and low mass.

Green Monopropellant Thruster – H_2O_2



Left: hydrogen peroxide nonopropellant prototype; middle: hydrogen peroxide/ethane bipropellant prototype; right: pulsed hydrogen peroxide monopropellant prototype

CubeSAT dedicated hydrogen peroxide propulsion module development at UniPi:

- CubeSat HTP Innovative Propulsion System (CHIPS) project funded by ESA;
- modular unit, **1.5-2U depending on propellant tank size** and total impulse required.

Green Monopropellant Thruster – H_2O_2

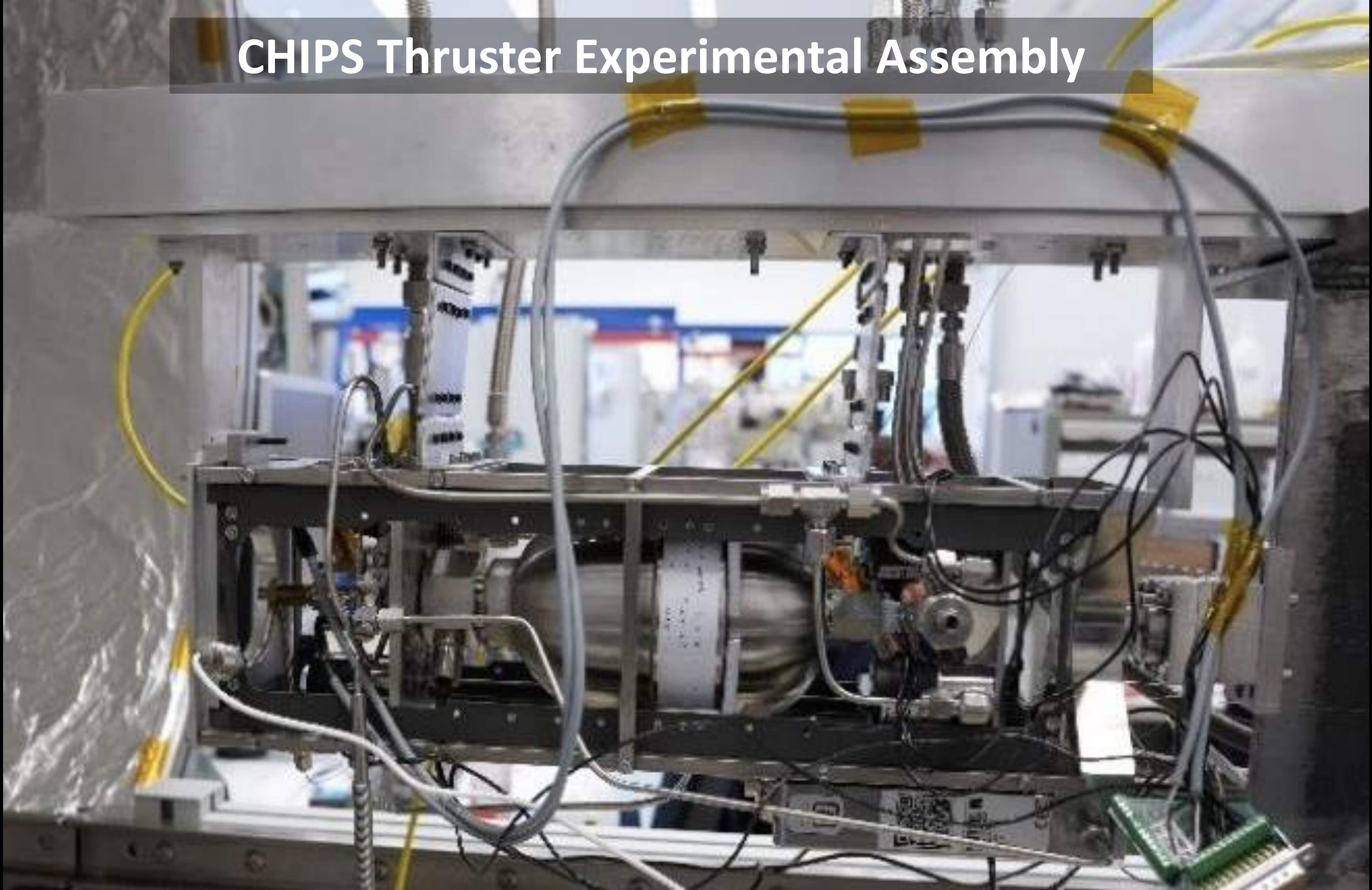
H2O2 Heritage

PulCheR thruster:

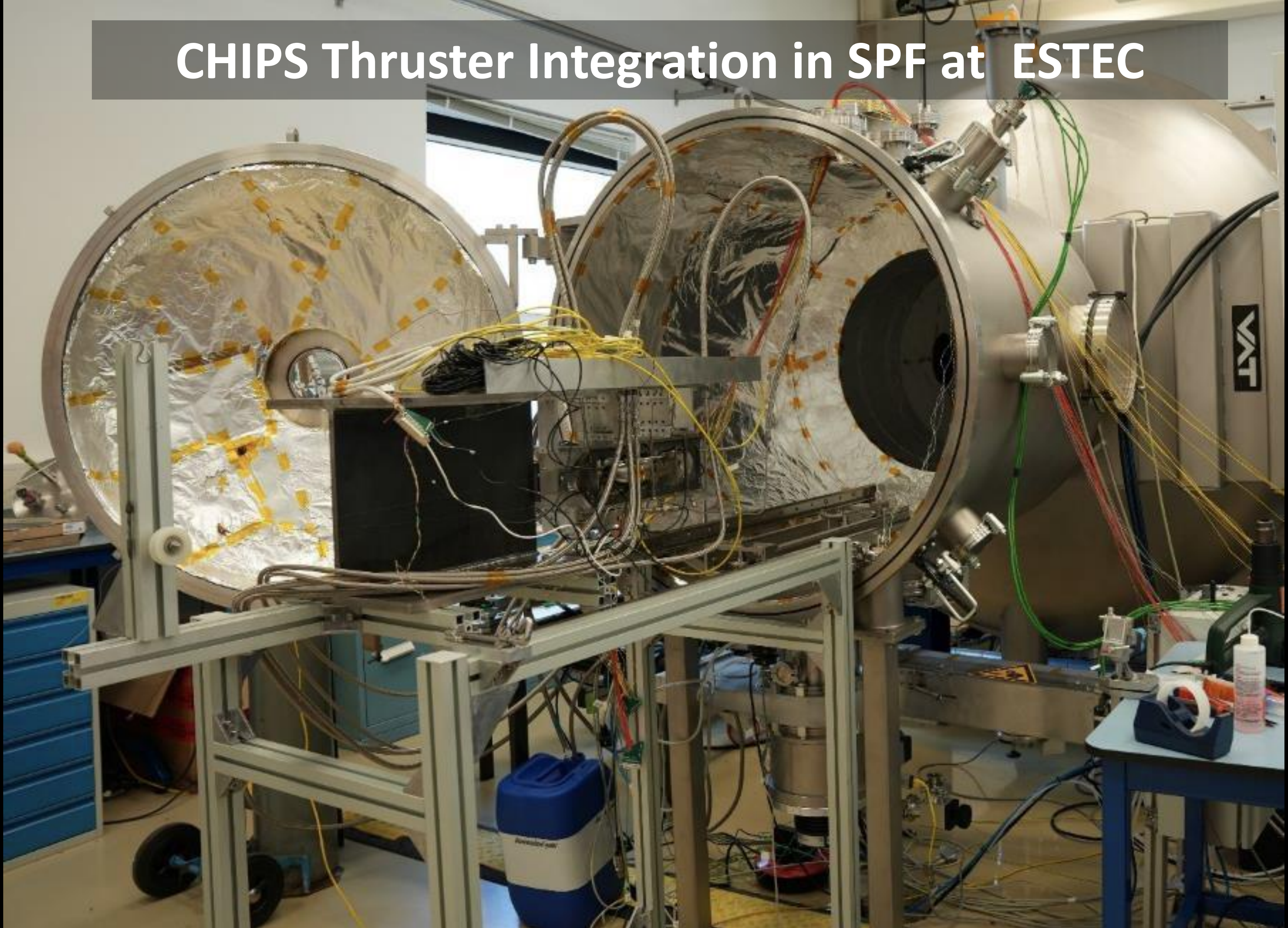
- AISI 310S stainless steel capable of working at high temperatures (> 1000 °C) in oxidative environment;
- platinum catalyst on a α-alumina substrate
- 1 N thrust.

PulCheR project 1N monopropellant thruster	
Thrust	1 N
Expansion Ratio	70
Propellant	98% HTP
Catalytic Bed Volume	≈ 226 mm3
Configuration	Stand-off
Working Chamber Pressure	18 bar
Working Mass Flow Rate	0.55 g/s
Mass	0.2 kg
Size (envelope)	121 mm x 55 mm dia.

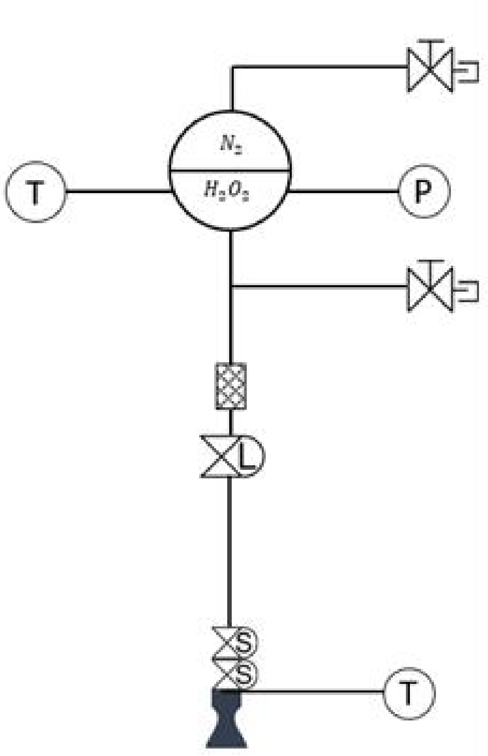
CHIPS Thruster Experimental Assembly



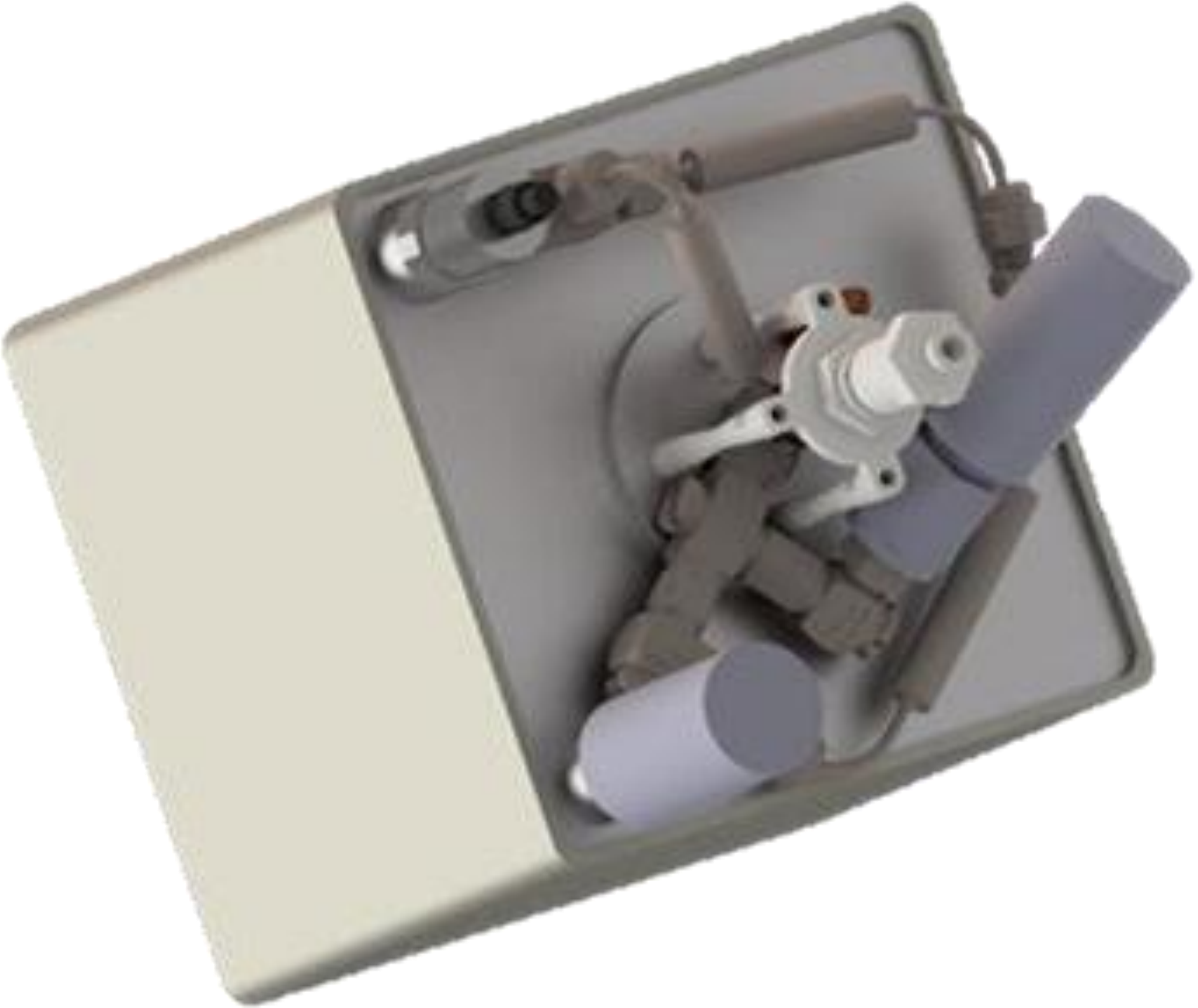
CHIPS Thruster Integration in SPF at ESTEC



CHIPS Flight Model Configuration

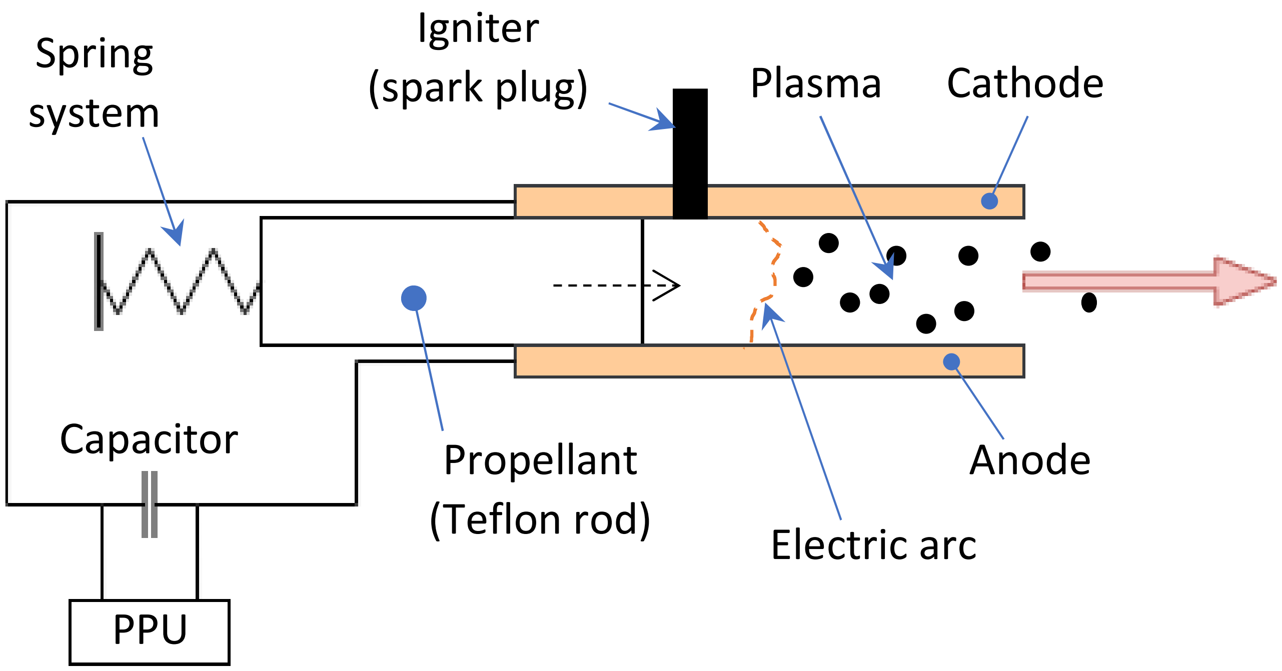


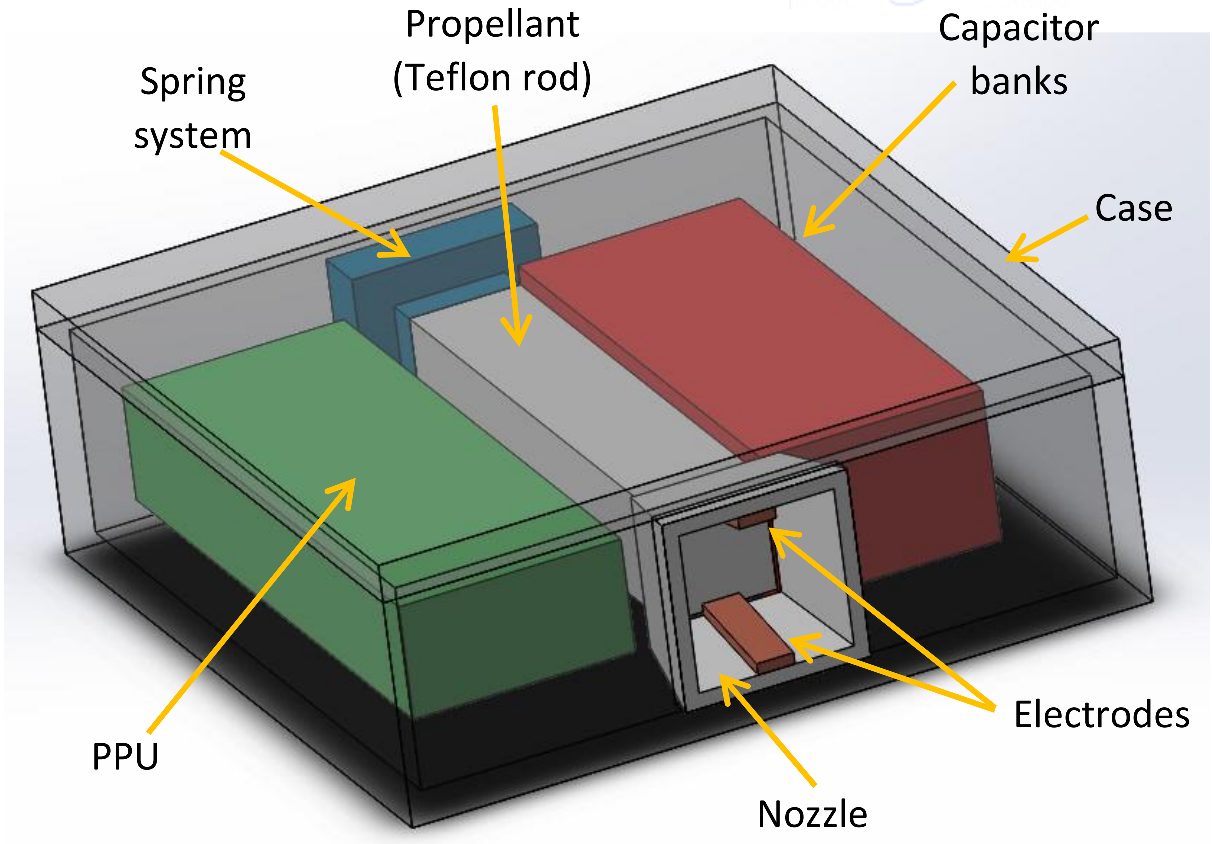
LEGEND	
	Tank
	Fill & Drain / Vent Valve
	Pressure Transducer
	Temperature Sensor
	Filter
	Isolation Valve
	Solenoid Valve
	Catalyst bed and Thruster



- Thrust: 500 mN
- Isp: 160 s (vacuum)

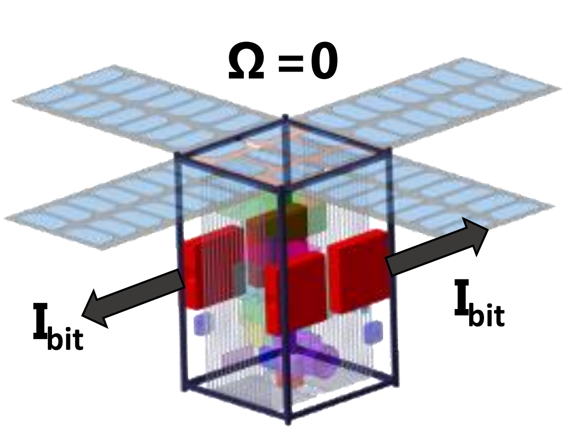
Pulsed Plasma Thrusters – PPT



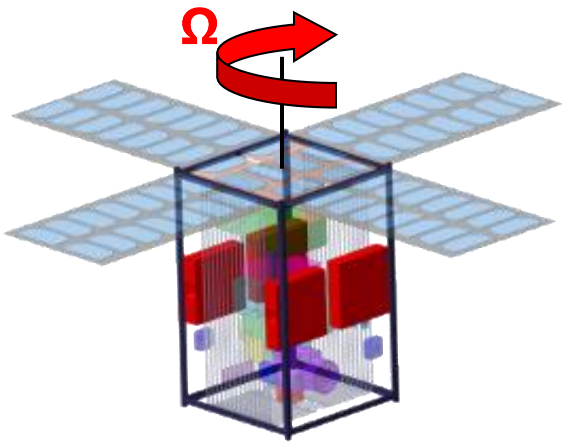


- Mass: 280 g per thruster (including the EMI shielding box);
- Power: 0.01 - 2 W nominal - can be throttled down continuously;
- Nominal stored energy: 2 J;
- Thrust - 40 μN @ 2 W ; nominal firing frequency: 1 Hz; **min. impulse bit: 40 μNs**;
- Specific Impulse: 600 s ; total impulse: 44 Ns;
- Overall dimensions: 100 x 100 x 33 mm^3 **(0.3 U)**.

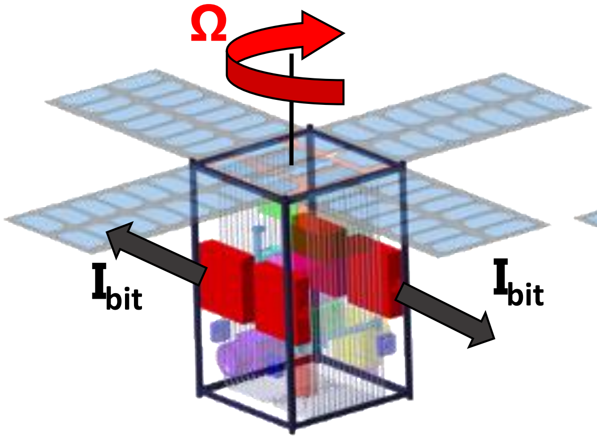
Pulsed Plasma Thruster Testing Sequence



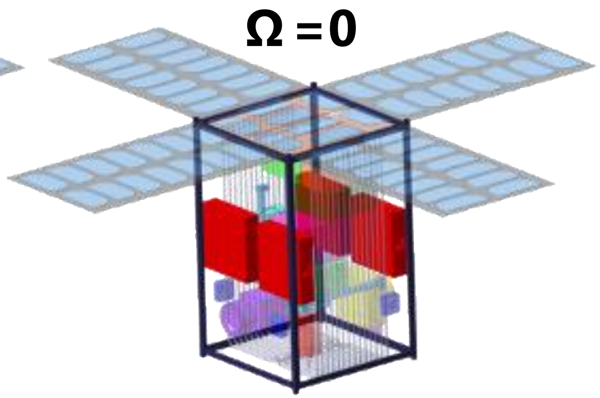
1. CW 15 min burn



2. Z-Spinning rate measurement

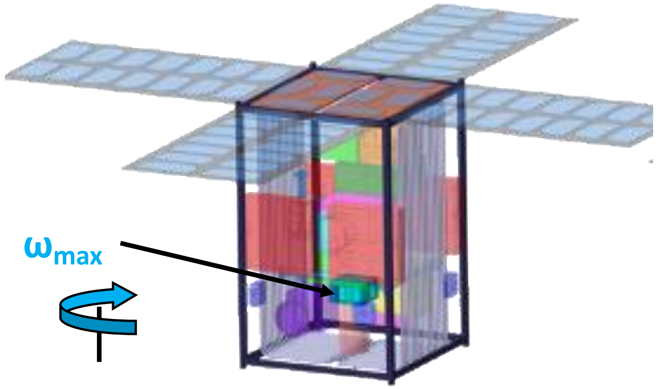


3. CCW 15 min burn

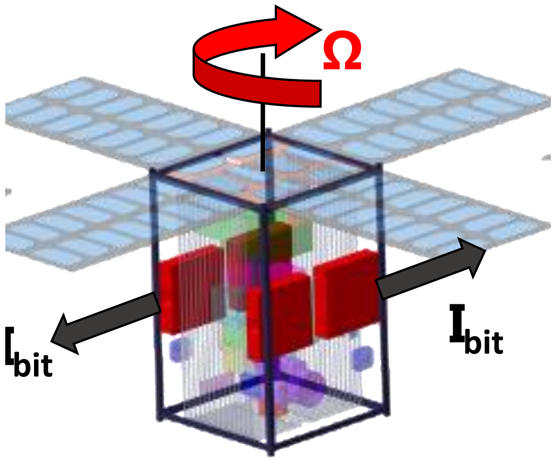


4. Z-Spinning rate measurement

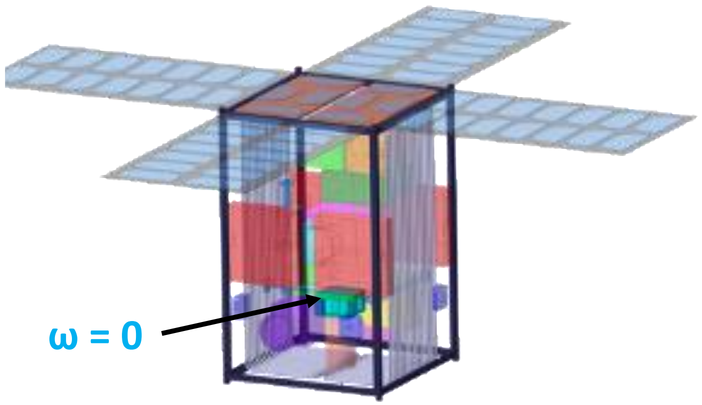
1. Spin-up / spin-down



1. Saturated Z-RW



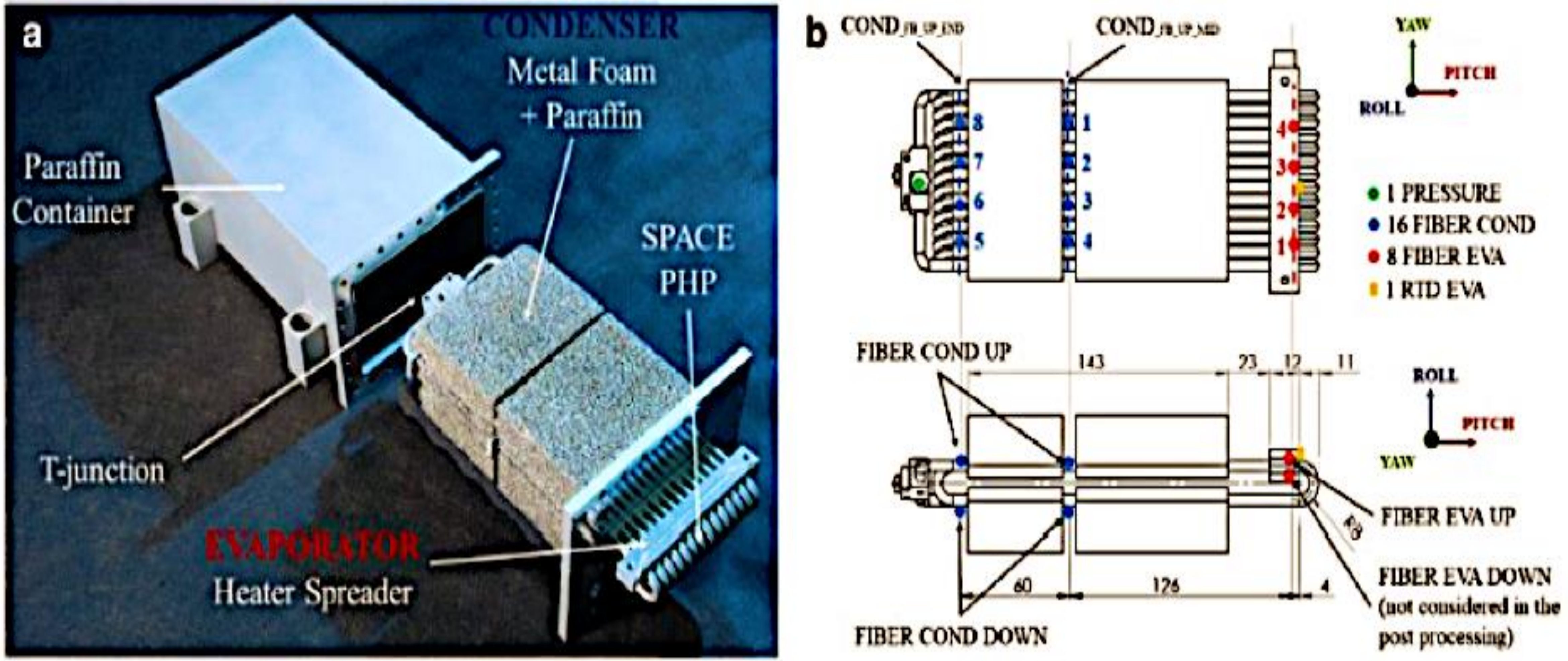
2. Burn start



3. Ending burn

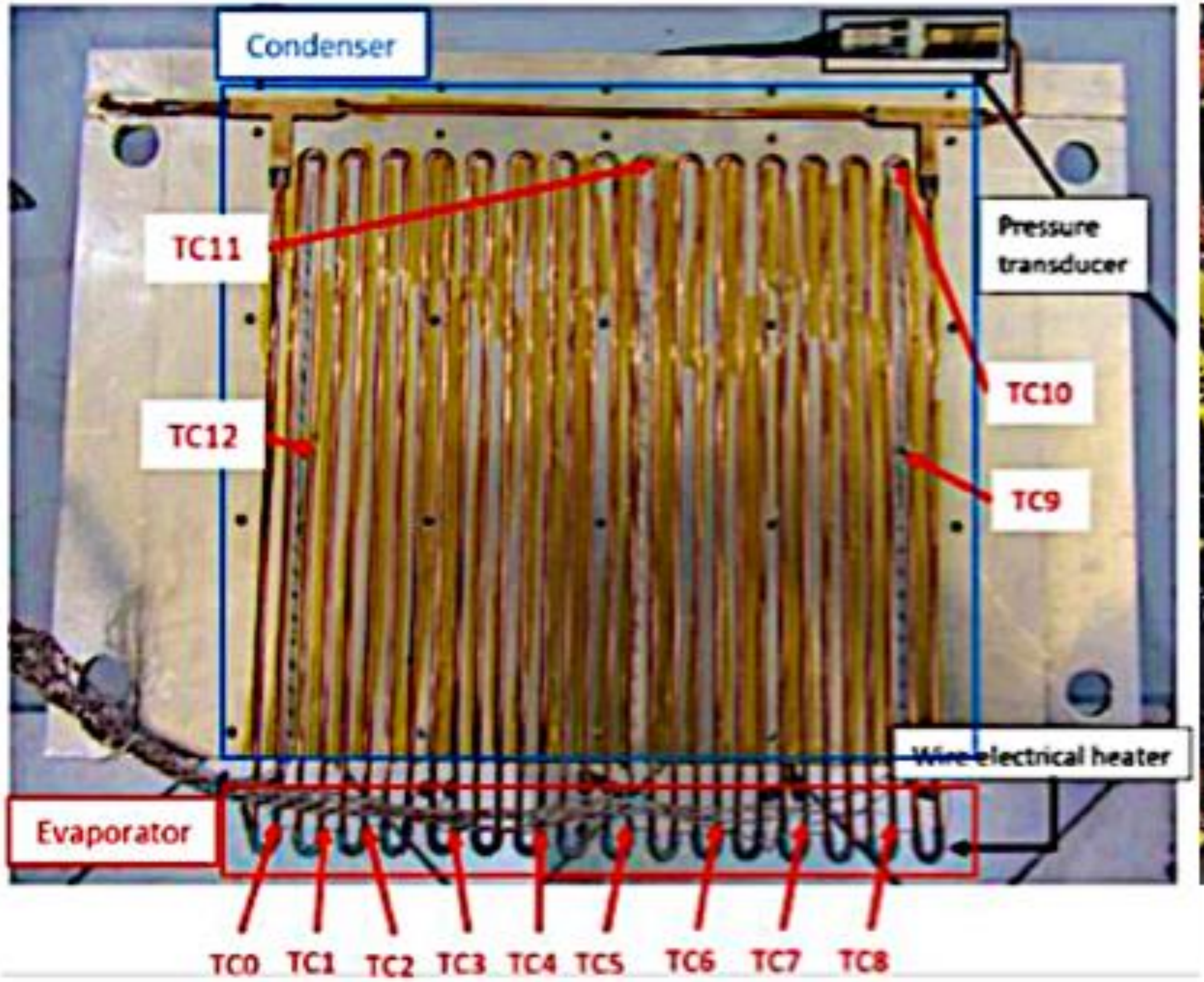
2. Reaction wheel de-saturation

UniPi’s Pulsating Heat Pipe Technology



UniPi’s Pulsating Heat Pipe
Tested on board the REXUS 22 sounding rocket

UniPi's Pulsating Heat Pipe Technology



UniPi's PHP tested on board two Parabolic Flight Campaigns

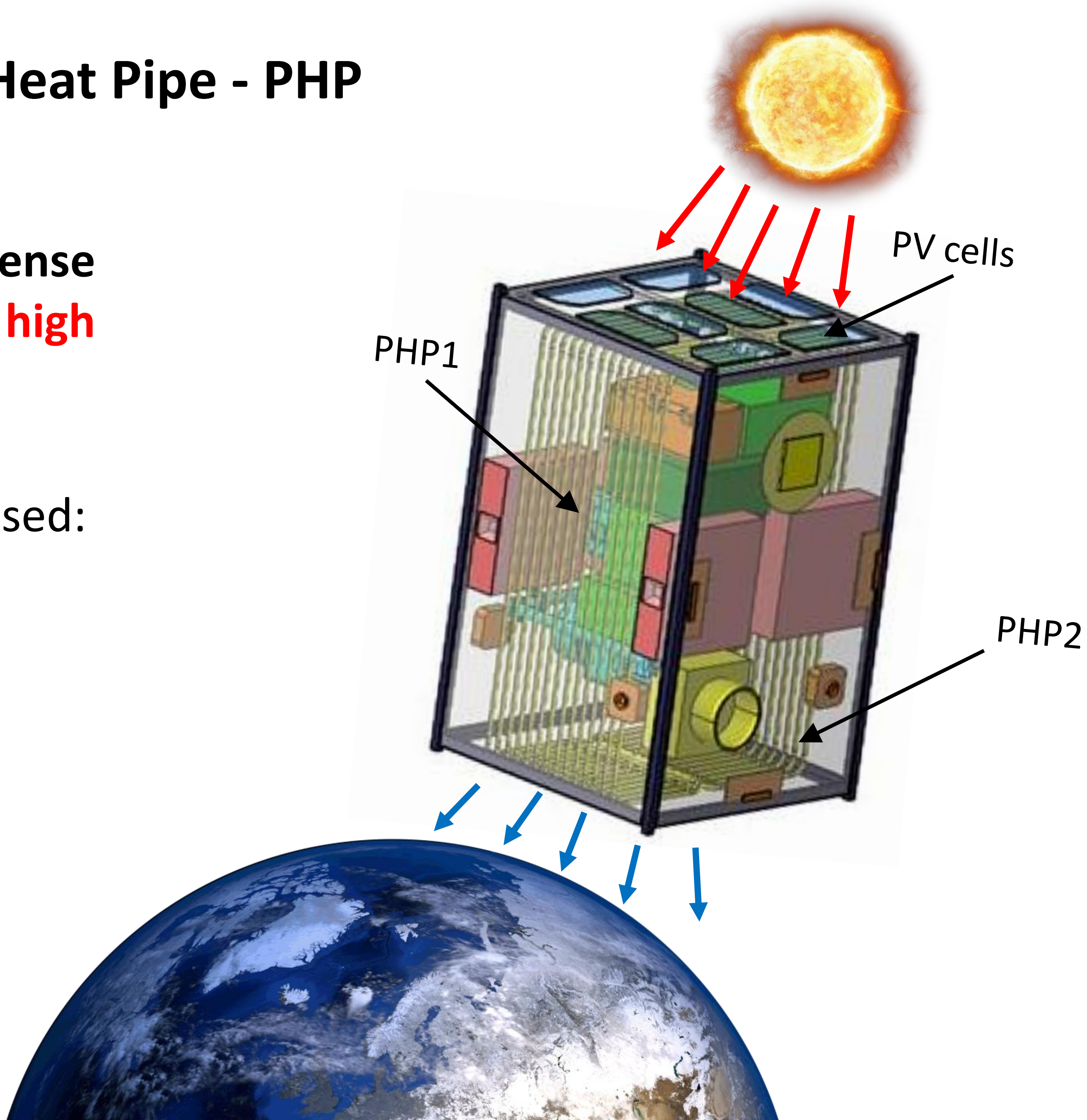
UniPi's PHP selected to be hosted on board of the ISS

Pulsating Heat Pipe - PHP

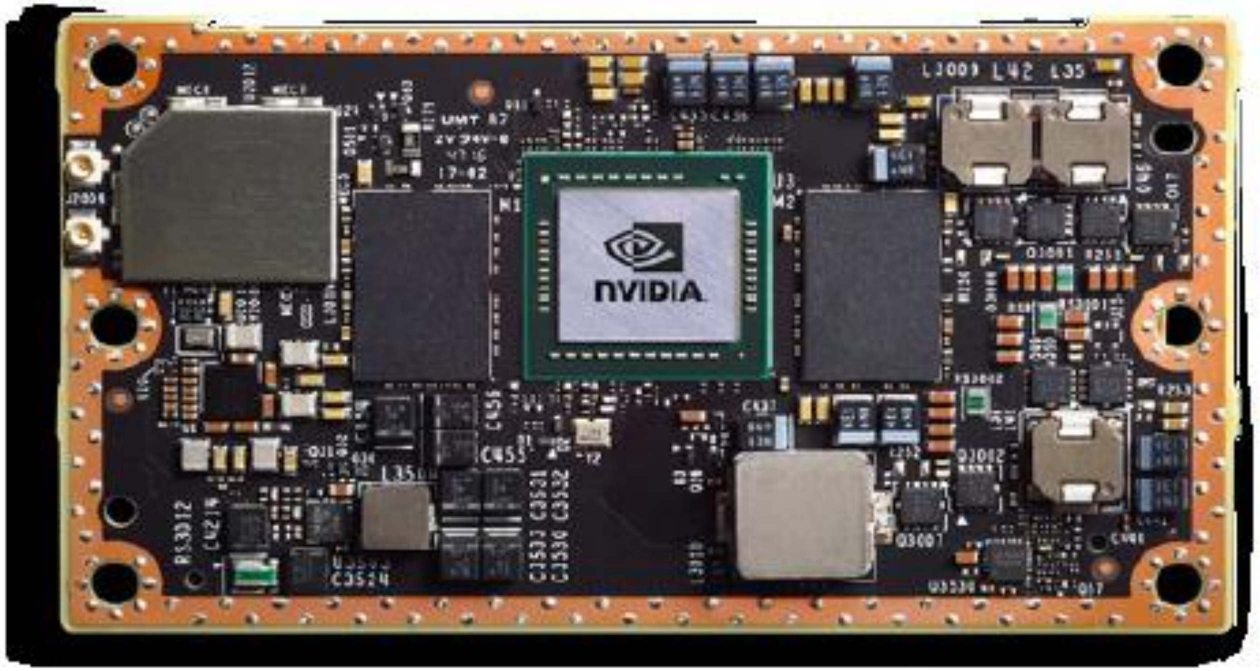
Pulse removal of **highly localized, intense heat fluxes** - **thermal management of high power microsatellites**

Open issues – **absolute firsts** to be addressed:

- performance with highly customized geometry;
- characterization at low working fluid temperature (<290 K);
- long run duration testing in real environment.



IoT GPU Experiment



The Jetson TX2 module (credit card size) (left) and Jetson AGX Xavier (right)

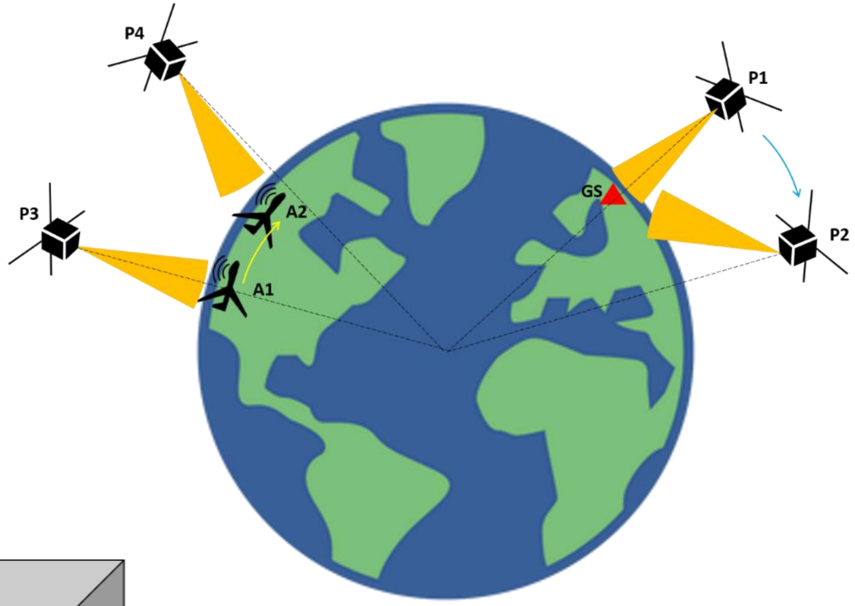
- Validation of a **COTS CPU-GPU** - Better performance w.r.t FPGA, microchip or PC currently used in the SmallSat ecosystem
- innovative applications: on-board demodulation, enhanced image processing, high precision autonomous navigation and formation flying, etc.

IoT GPU Experiment

Five different experiments, including testing/demonstration of key Internet-of-Things (**IoT**) functionality:

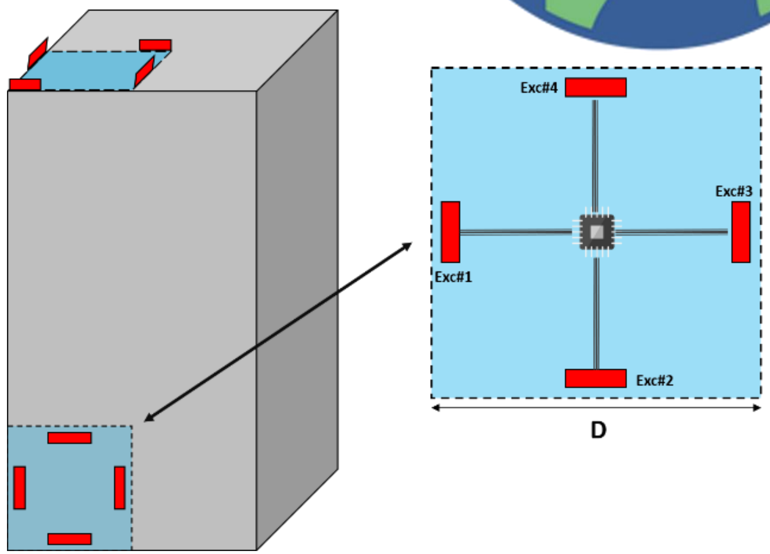
1. **COTS use in LEO environment**;
2. **innovative spread-spectrum IoT waveform** - IURA (IoT Universal Radio Access). IoT signal on ISM 2.4 GHz band will be de-modulated onboard;
3. **recording of I+Q incoming samples**;
4. **S-band Digital Spectrum Analyzer** to characterize the level of noise plus interference;
5. **Continuous Wave S-band downlink beacon** for analysis of doppler shift , power level, antenna beam-steering, etc.

ReconfAnt - Reconfigurable antennas for Space



- A reconfigurable-pattern antenna can be useful for improving data transfer by offering the chance to have **longer connection with a ground station**;

- A radiation pattern able to scan the main beam **saves energy consumed for changing the attitude** of the satellite thus increasing the satellite operational life.

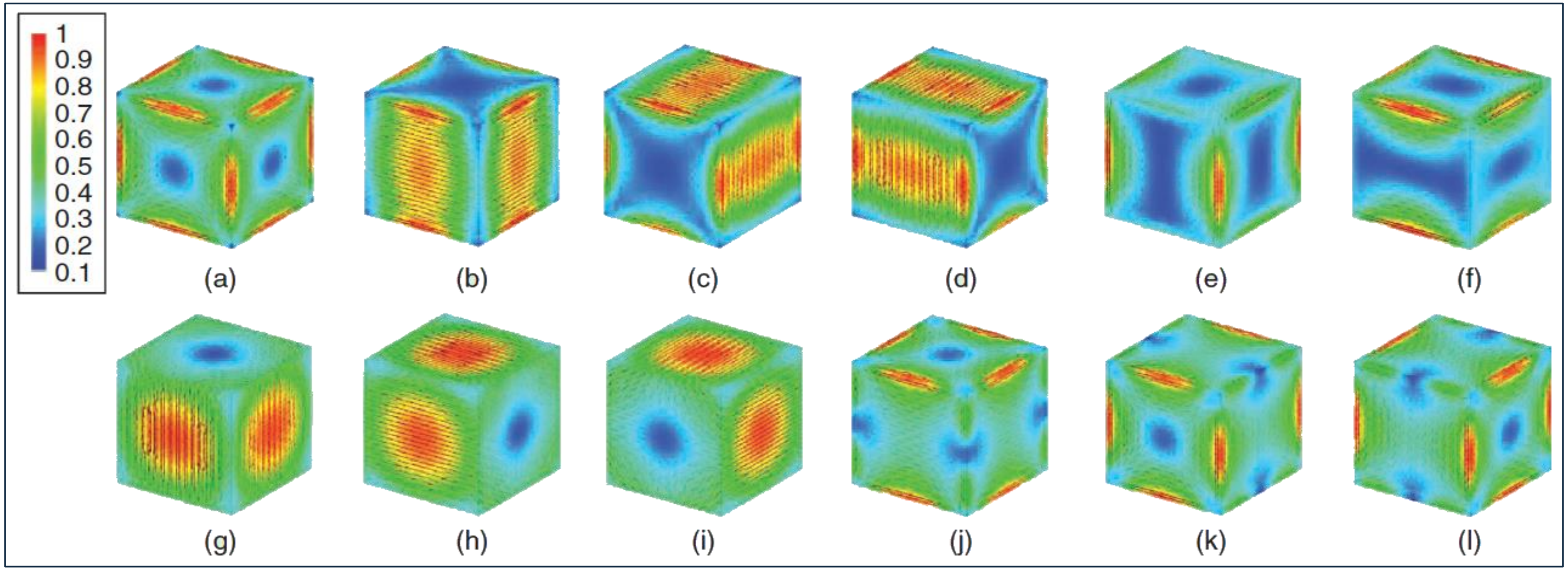


✓ **No need of any deployment system**

✓ **Great area saving**

✓ **Adopted excitation requires only phase control**

Reconfigurable Integrated S-Band Antenna

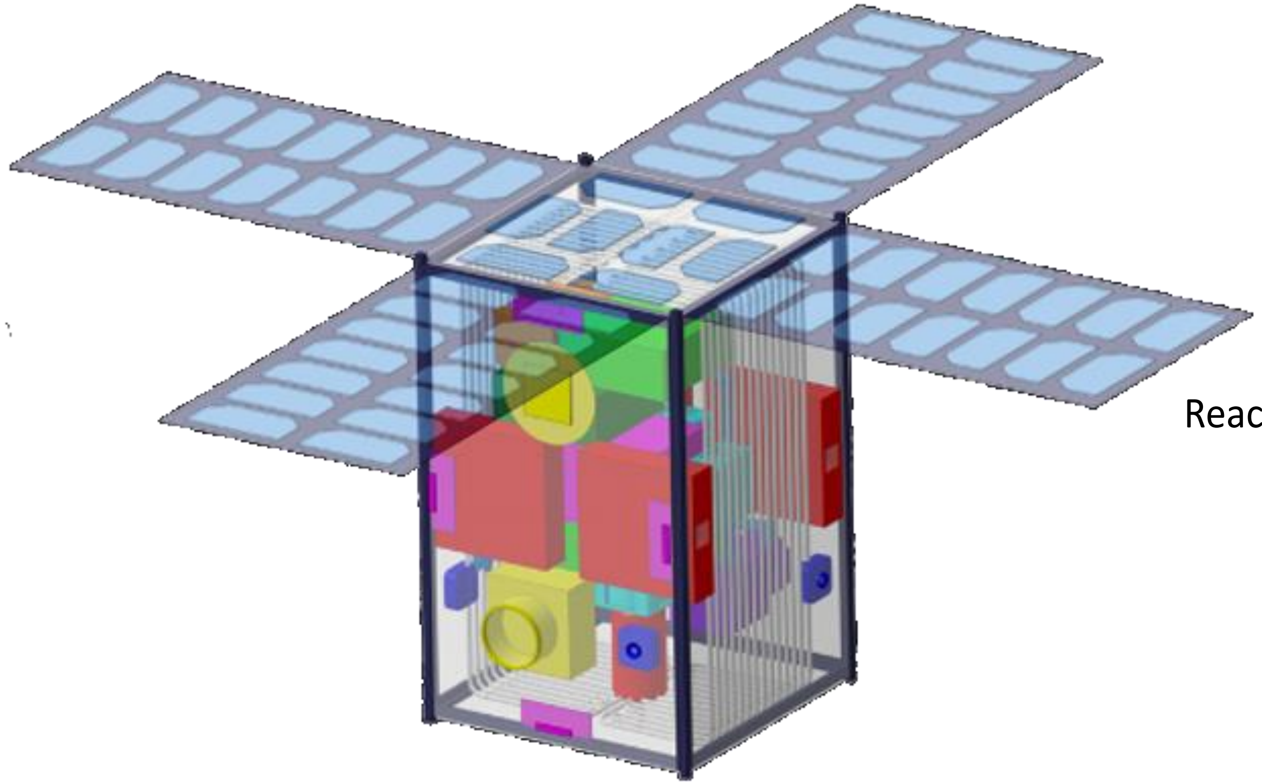


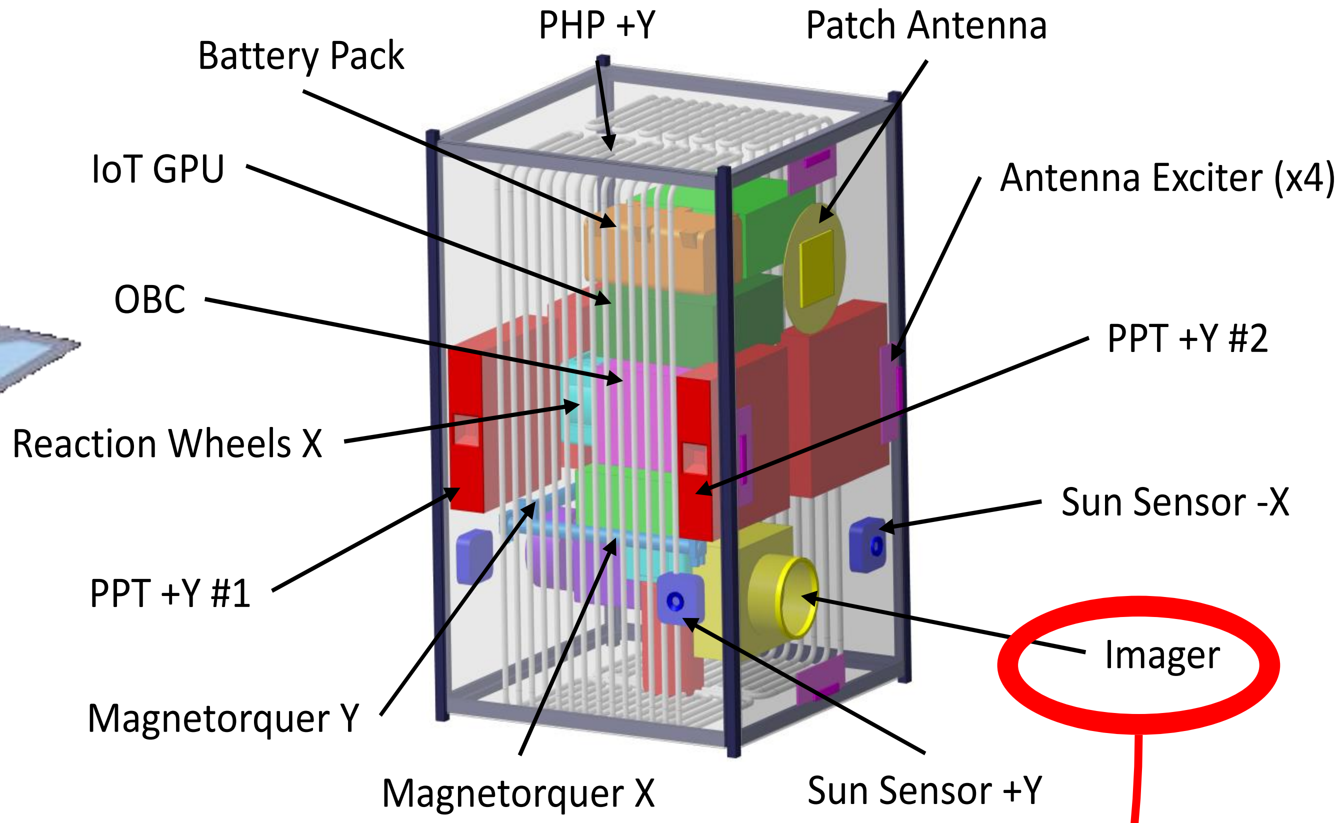
Current modes distribution at 2.425 GHz on a 1U Cubesat structure

ReconfAnt main design steps:

1. characterization of the **properties of the composite materials** employed for the Cubesat structure to correctly plan the exciter placement and configuration
2. integration of the antenna system in accordance to the other payload needs
3. design of the single non-resonant exciter

EXCITE – Platform Configuration

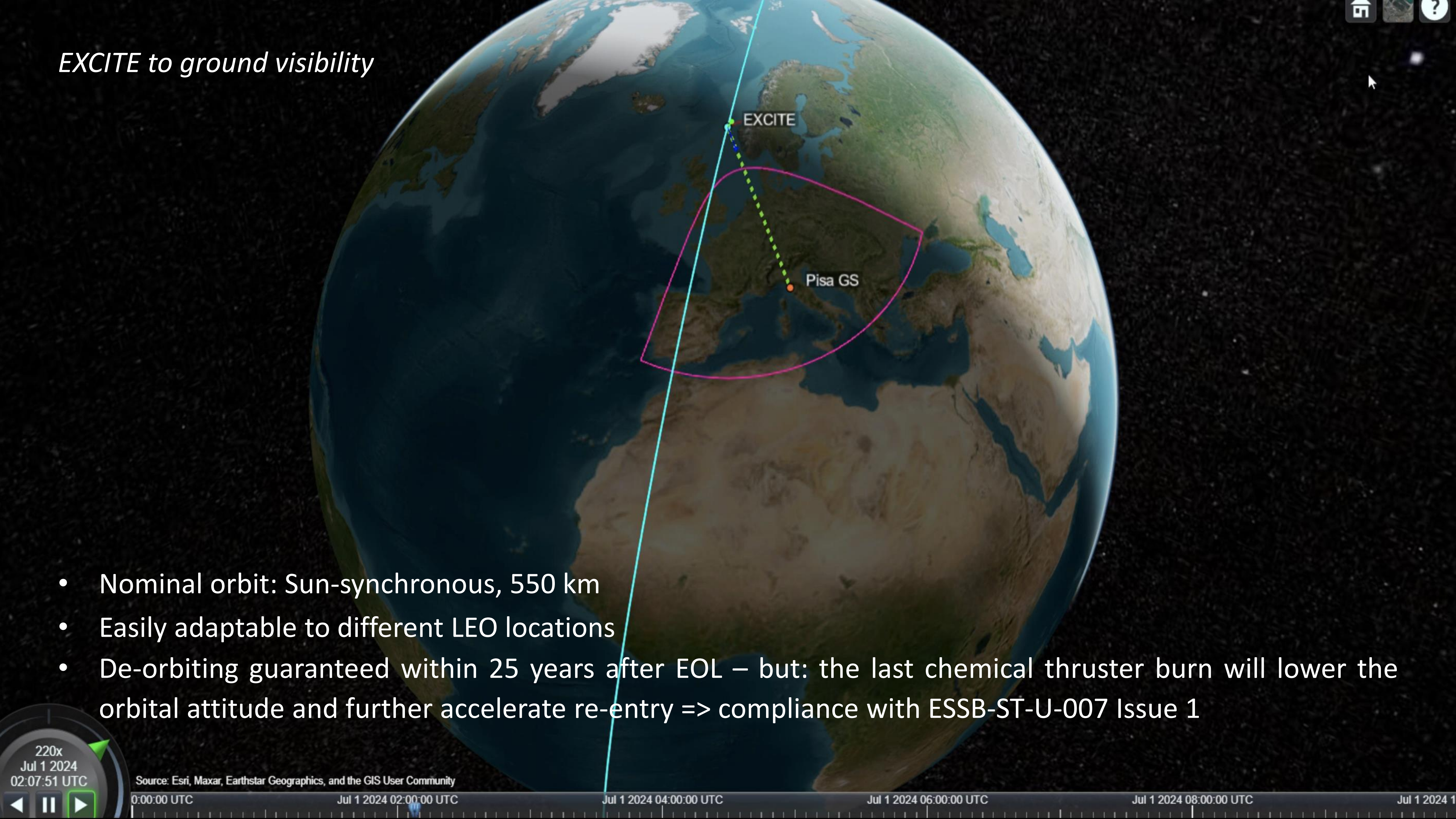




- 12 U Cubesat form factor (16 U also under consideration)
- 4 deployable + 1 fixed solar panels
- Full composite structure
- 3-axis attitude stabilization
- Non-constrained internal volume

1.5 U volume available for a commercial optical sensor or other hosted payload

EXCITE to ground visibility



- Nominal orbit: Sun-synchronous, 550 km
- Easily adaptable to different LEO locations
- De-orbiting guaranteed within 25 years after EOL – but: the last chemical thruster burn will lower the orbital attitude and further accelerate re-entry => compliance with ESSB-ST-U-007 Issue 1

Challenges

TECHNICAL

- EXCITE is a **dedicated platform**
- Push the boundaries of Cubesat platform technology: Thermal, Propulsion, Telecom, Data processing

PROGRAMMATIC

- Mixed academic/industrial environment - calibrate student involvement in the programme vs. project continuity
- Strike the proper balance between agile management (truly cubesat-like) and a more structured, PA-conscious approach