INSPIRE-5 (UVSQ-SAT), a pathfinder cubesat for observing essential climate variables

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Troisième rencontre spatial Radio Amateur

March 07, 2020

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CNRS/LATMOS/UVSQ/Paris-Saclay/Sorbonne Université/CNES

Paris, France

From INSPIRE to the constellation

0 – Main goals

UVSQ-SAT

An application ranging from science to education.

Three main objectives in:

- **(1) Science** : Earth observation, Solar physics.
- **(3) Technology demonstration** :
  - Instruments miniaturization for solar physics,
  - Instruments validation & satellites constellation validation for Earth observations,
  - Validation of new medical devices that incorporate artificial intelligence on future space flights.
- **(2) Education & outreach** : Satellite, Payload development, Software development, Training material.
  - Enable students to move towards Nanosat via start-ups in creation
  - Foster the emergence and development of start-ups in the Nanosat field
  - Make the space field more accessible to technicians
  - Create new vocations
  - Thinking about tomorrow's jobs

0 – Experience & heritage

SOLAR/SOLSPEC

SOLSPEC

LATMOS

Studies + Development | Exploitation | End of Life | Scientific exploitation

1 – 2 – 07/02/2008 – 3 – 13/02/2017 – 4

+40 papers

PICARD

SODISM
PREMOS
SOVAP
BOS
PGCU

LATMOS

Studies | Development | Exploitation | End of Life | Scientific exploitation

1 – Fin 2004 – 2 – 15/06/2010 – 3 – 04/04/2014 – 4

+50 papers

cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES

PICARD-SOL

SODISM II
MISOLFA
CIMEL
Pyranometer
Caméra

LATMOS

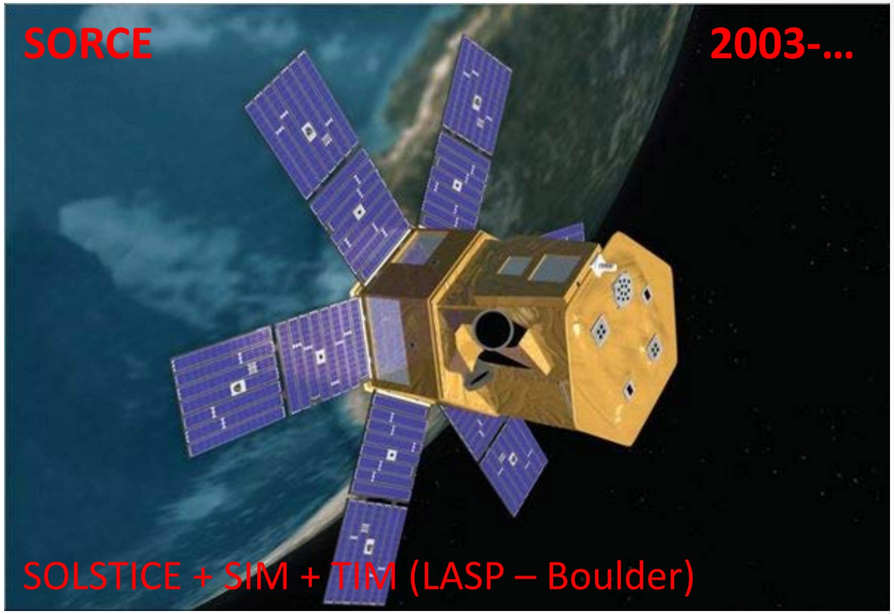
Studies + Development | **Exploitation**

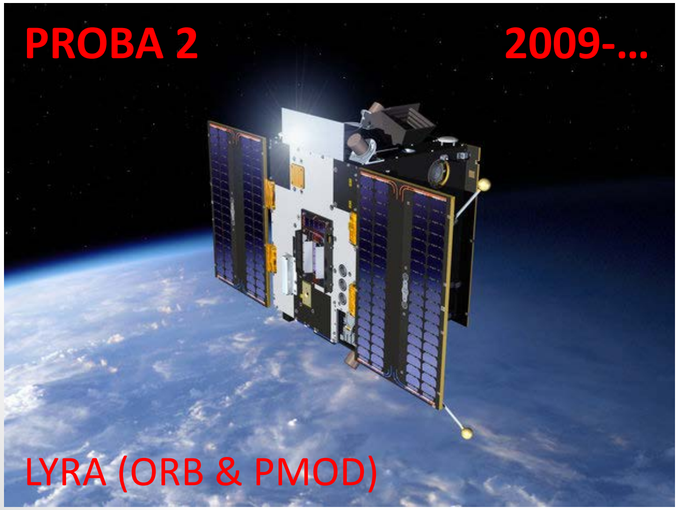
1 – 2 – 01/03/2011 – 3

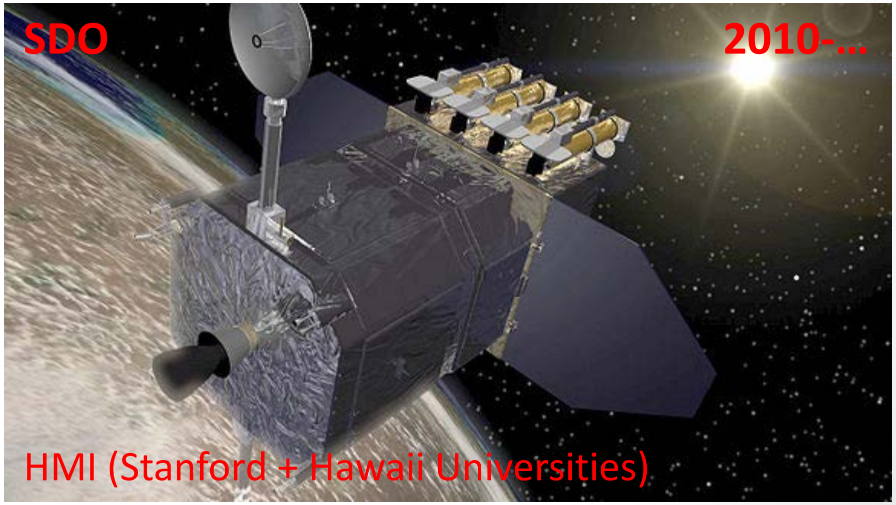
+10 papers

Observatoire de la CÔTE d'AZUR

0 – Experience & heritage

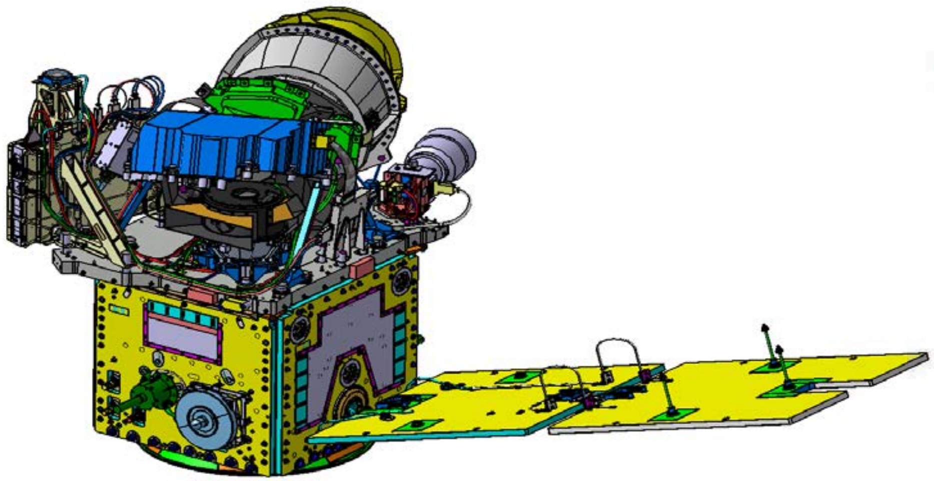


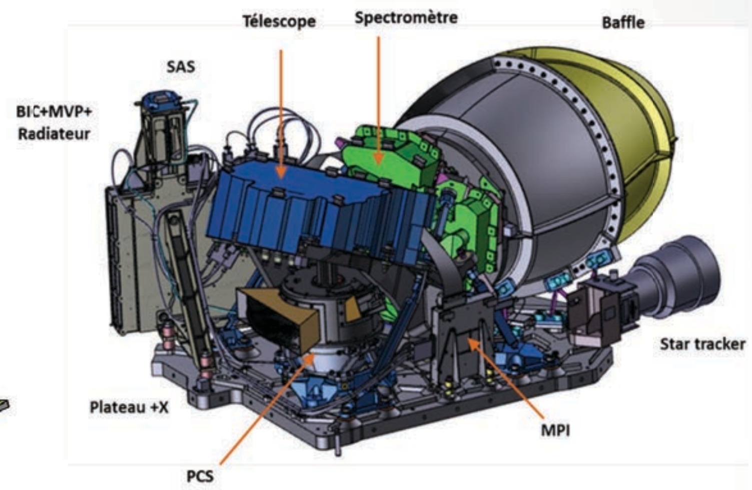


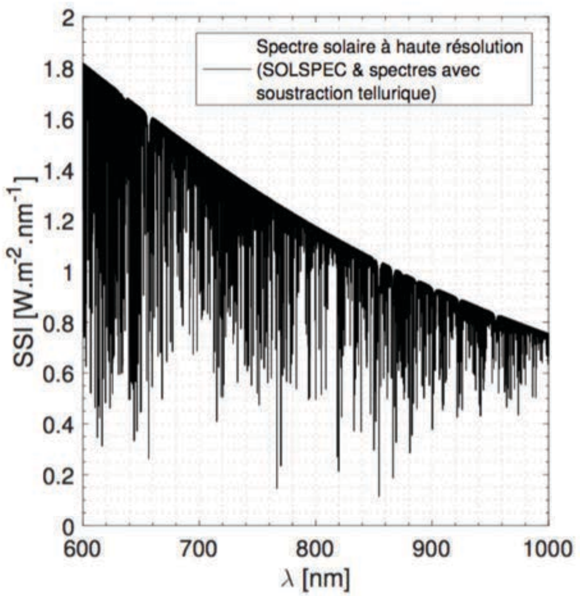


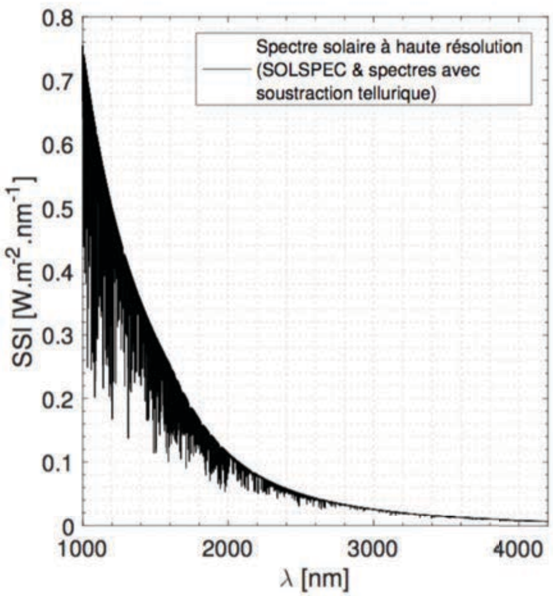
0 – Experience & heritage

MicroCarb **2021-…**









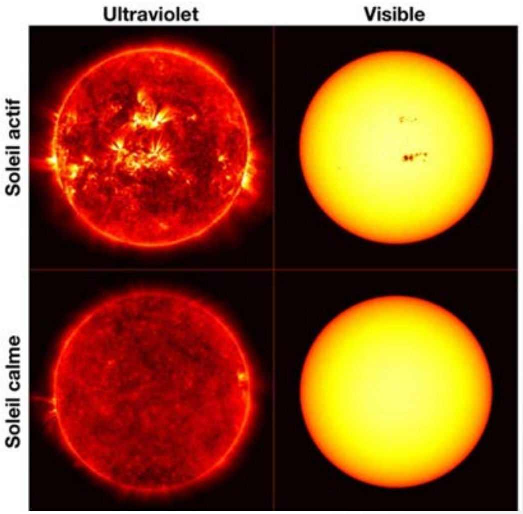
Meftah et al., A New Version of the **SOLAR-ISS Spectrum Covering the 165 – 3000 nm Spectral Region**. ***Solar Physics.* 2020.**

1 – Scientific objectives

The motivation of this project is to implement miniaturized disruptive technologies for remote sensing with compact sensors that could be used in the future for a multi-point & multi-decadal satellites constellation:

- **To observe Essential Climate Variables:**
  - **Earth Energy Imbalance (EEI) with a spatial resolution of few km**
  - **UV Solar spectral irradiance (SSI)**

Essential Climate Variable	Absolute measurement uncertainty at 1σ	Stability per decade at 1σ
EEI	**+/- 1 $W.m^{-2}$**	**+/- 0.1 $W.m^{-2}$**
SSI (215 nm)	+/-1.7 10^{-4} $W.m^{-2}.nm^{-1}$ **+/-0.5 %**	+/-3.4 10^{-5} $W.m^{-2}.nm^{-1}$ **+/-0.1 %**

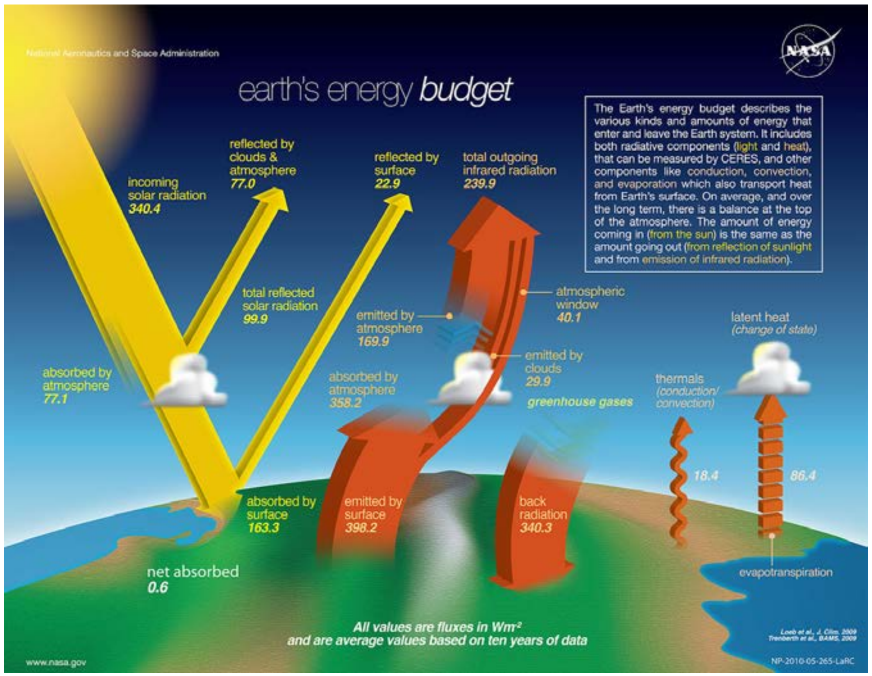


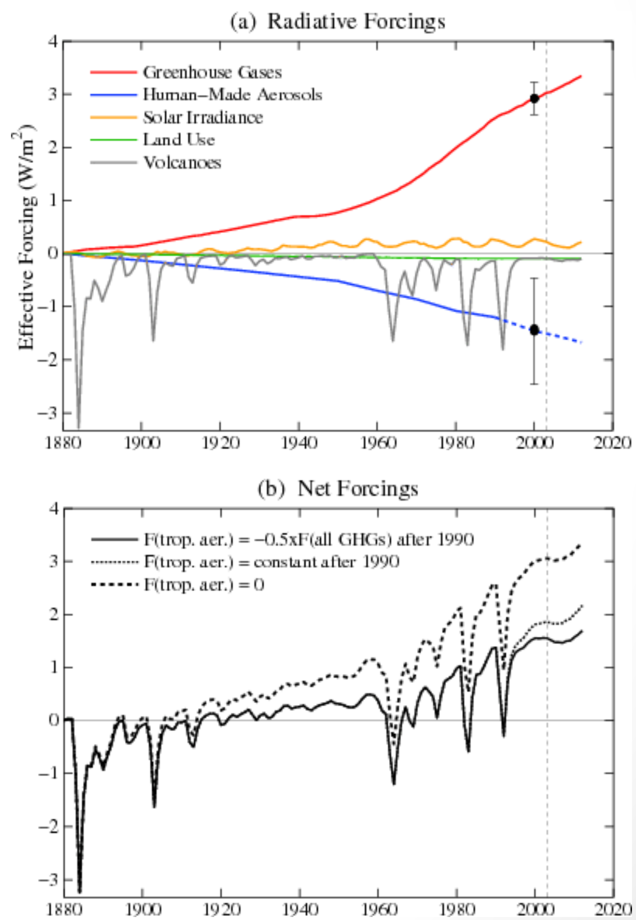
Meftah, M.; Damé, L.; Keckhut, P.; Bekki, S.; Sarkissian, A.; Hauchecorne, A.; Bertran, E.; Carta, J.-P.; Rogers, D.; Abbaki, S.; Dufour, C.; Gilbert, P.; Lapauw, L.; Vieau, A.-J.; Arrateig, X.; Muscat, N.; Bove, P.; Sandana, É.; Teherani, F.; Li, T.; Pradel, G.; Mahé, M.; Mercier, C.; Paskeviciute, A.; Segura, K.; Berciano Alba, A.; Aboulila, A.; Chang, L.; Chandran, A.; Dahoo, P.-R.; Bui, A. UVSQ-SAT, a Pathfinder CubeSat Mission for Observing Essential Climate Variables. *Remote Sens.* **2020**, *12*, 92.

1 – Scientific objectives

- **Earth Energy Imbalance (EEI)**

EEI = Incoming solar radiations –
[outgoing shortwave radiations + outgoing longwave radiations]





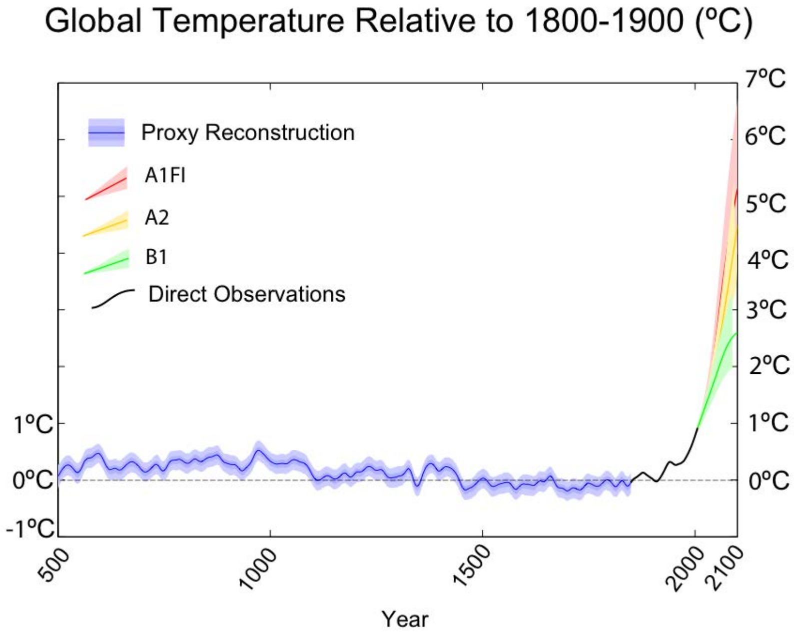
EEI = 340.4 – (99.9 +239.9) > 0

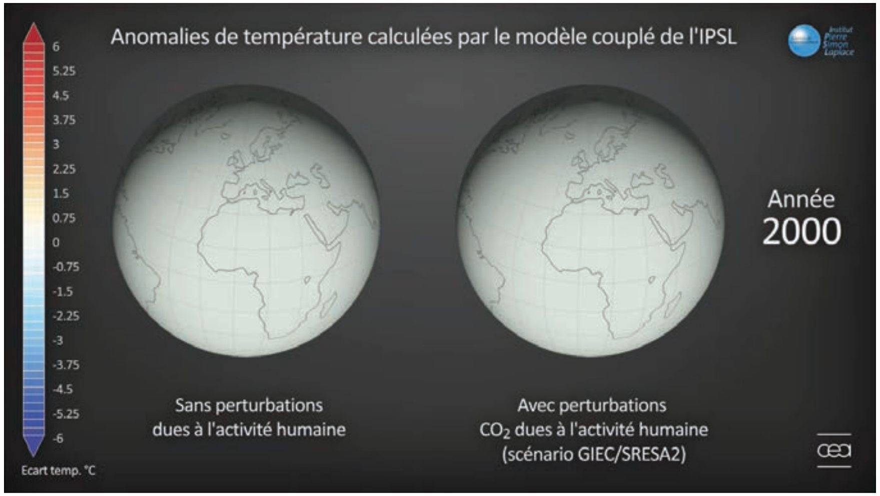
→ *All estimates (OHC and TOA) show that over the past decade the energy imbalance ranges between about 0.5 and 1 Wm^{-2}.*

Hansen et al., 2011

1 – Scientific objectives

- **<u>EEI as a crucial quantity for testing climate models and for predicting the future course of global warming.</u>**





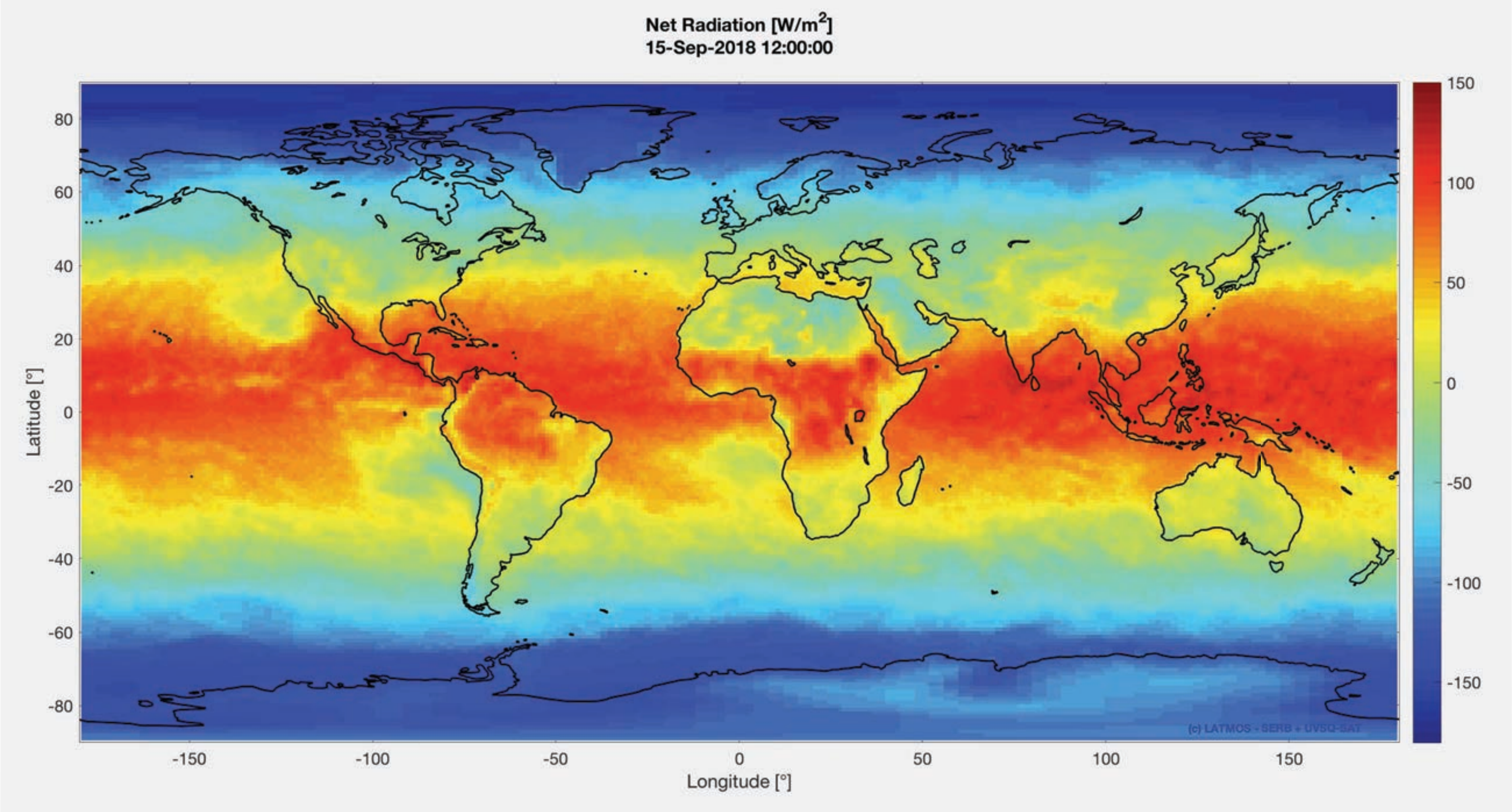
Climate change and global warming pose a severe threat to Humanity.

→ <u>Monitoring with high accuracy</u> the Earth's influx and outflux of both longwave and shortwave radiations from all sources is essential to advance our understanding of climate variability and change, and for developing more accurate climate models and forecasting.

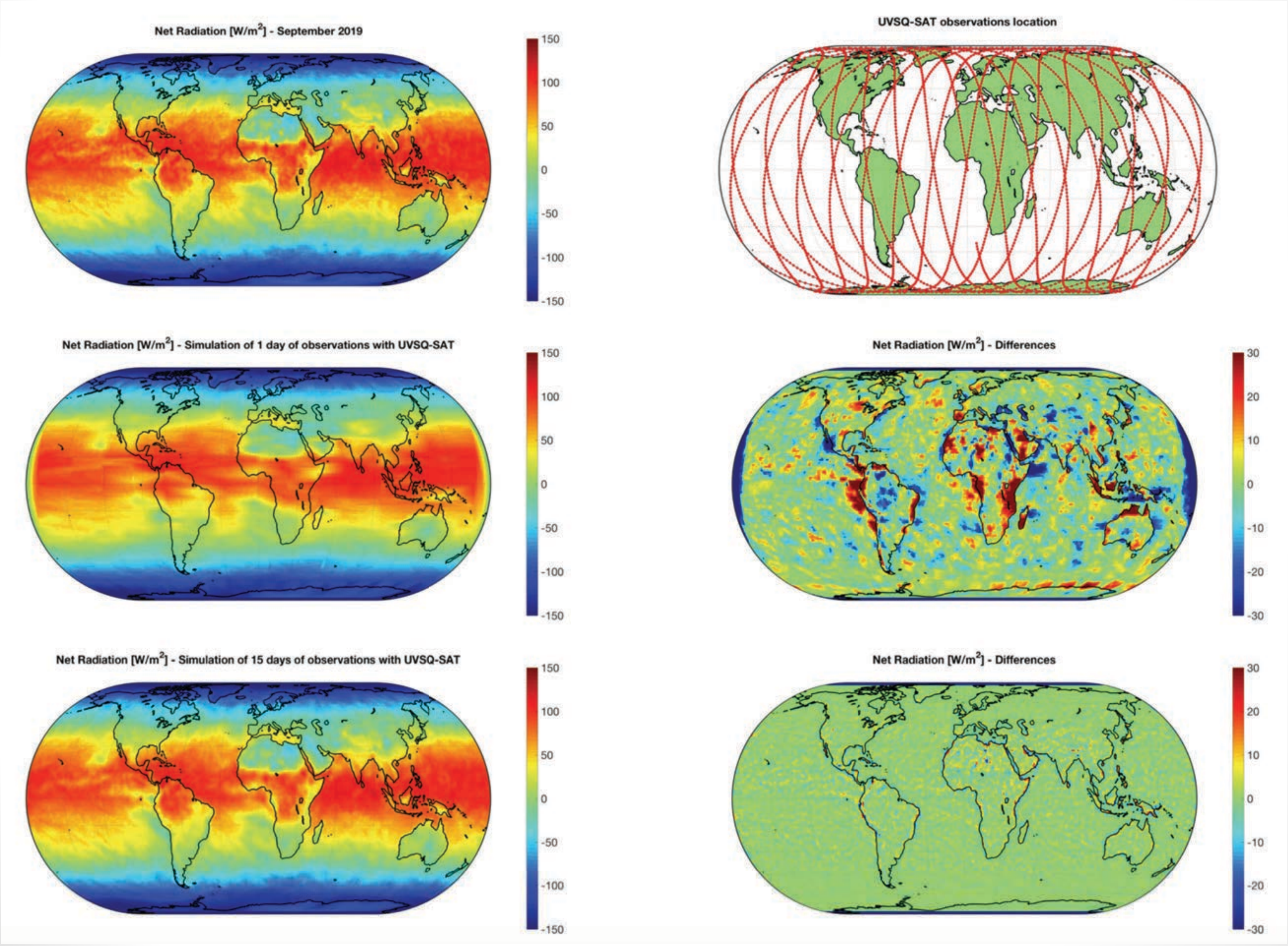
→ EEI can be robustly estimated from changes in ocean heat content on annual and longer timescales, while satellite observations of net radiation flux variability at the top of atmosphere (TOA) can provide information at shorter timescales.

1 – Scientific objectives

Objectives: monitor EEI

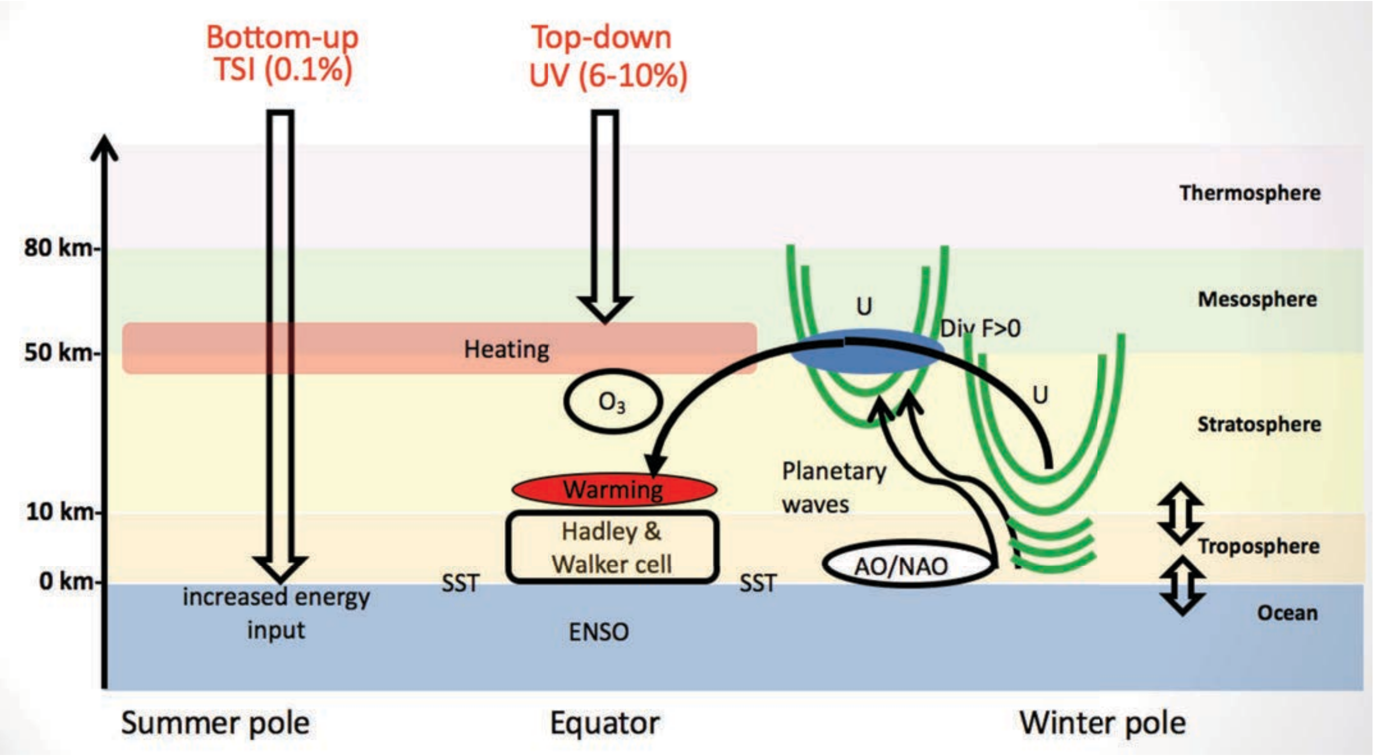


1 – Scientific objectives



1 – Scientific objectives

- **UV SSI in the Herzberg continuum as a crucial quantity for its link with stratospheric ozone and the impact on local climate**

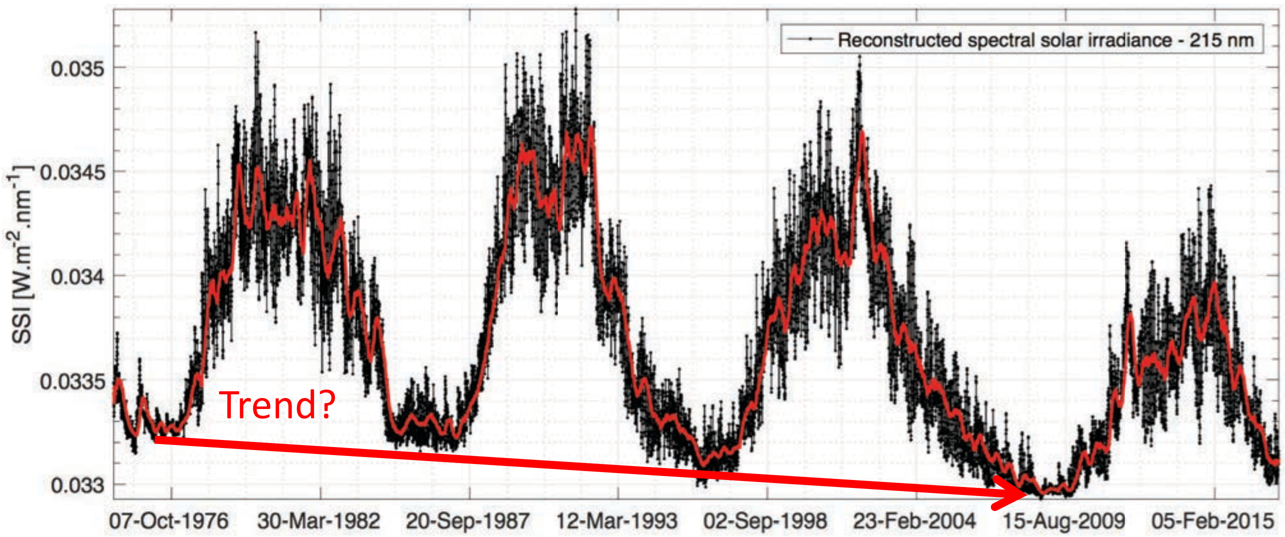


→ Influence of solar variability on Earth climate and regional effects.

→ Dynamical amplification of the stratospheric solar response.

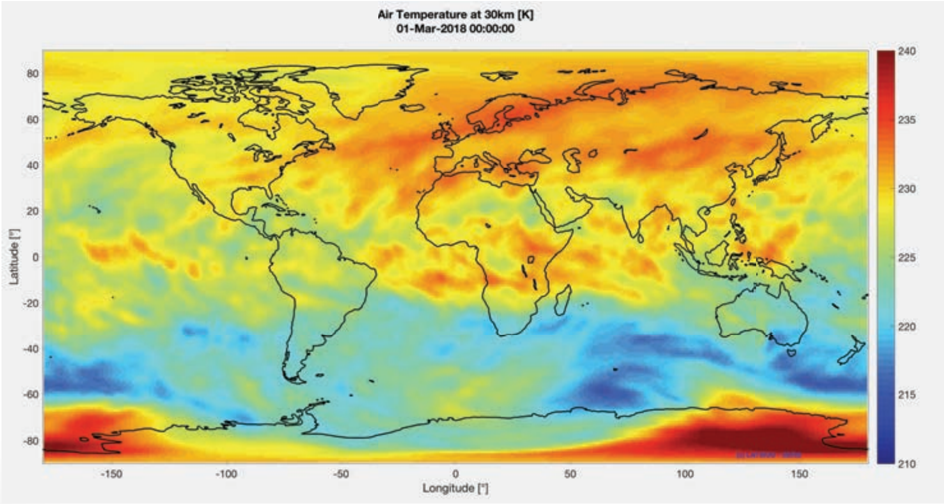
1 – Scientific objectives

Objectives: monitor UV SSI



An approaching Grand Solar Minimum is possible.

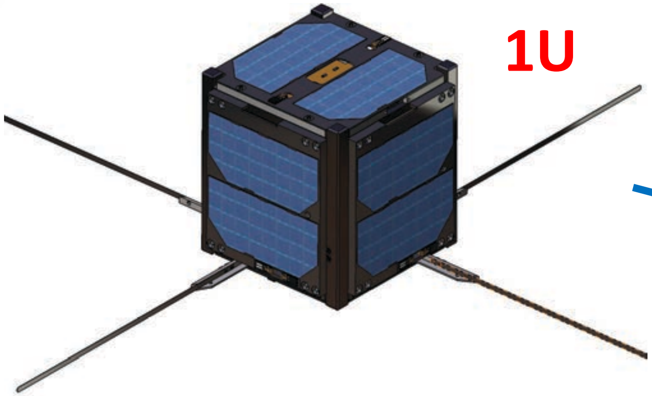
→ NASA's forecast for the next solar cycle (25) reveals it will be the weakest of the last 200 years.



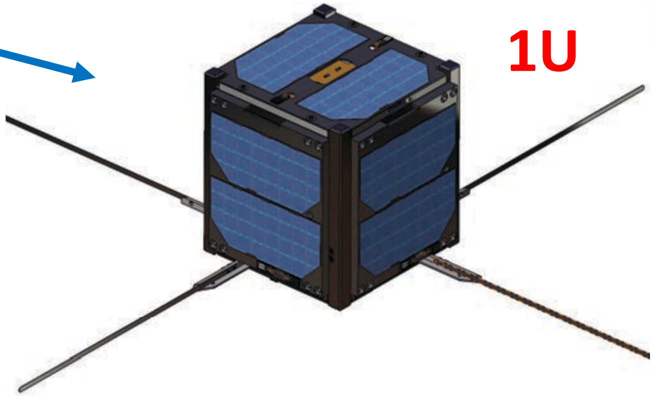
Link with stratospheric ozone and regional effects.

// with temperatures in the stratosphere

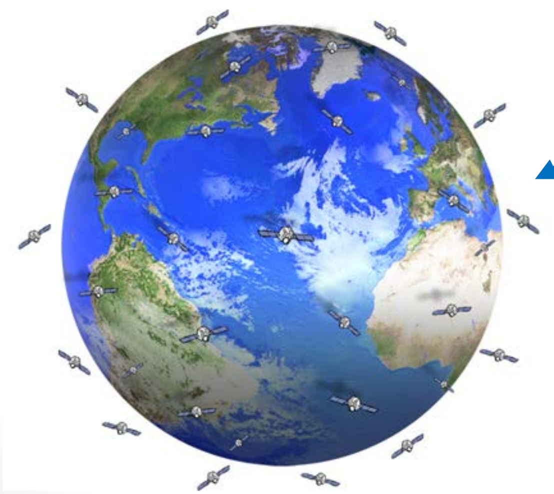
2 – Strategy



INSPIRE 5 → UVSQ-SAT
1.6kg / 1.6W / 10x10x10 cm
Launch in Dec. 2020



UVSQ-SAT+
1.6kg / 1.6W / 10x10x10 cm
Launch in June 2021



Satellites constellation of 100 Cubesats
→ for observing essential climate variables

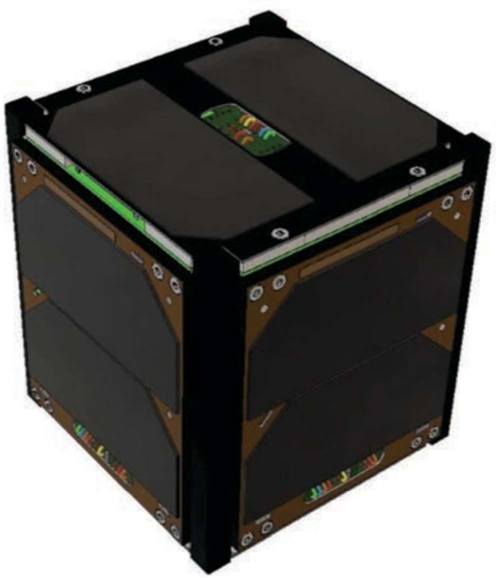
2 – Strategy

The UVSQ-SAT team will provide an availability of the transponder up to 20% (schedule 7 to 15 days in advance with a distribution via the project's website and / or tweeter account, transponder activation/deactivation dates, satellite status information's (battery level, ...), constraints (ex: eclipses), ...).

- International partners: USA, Singapore, Taiwan
- Other international partners: Belgium, Germany, Switzerland, India, Japan, …

As part of the ham radio mission, the UVSQ-SAT one-unit CubeSat embeds a radio transponder which will be accessible to the community in parallel of the other scientific objectives according to the power budget.

3 – UVSQ-Sat, a first pathfinder CubeSat

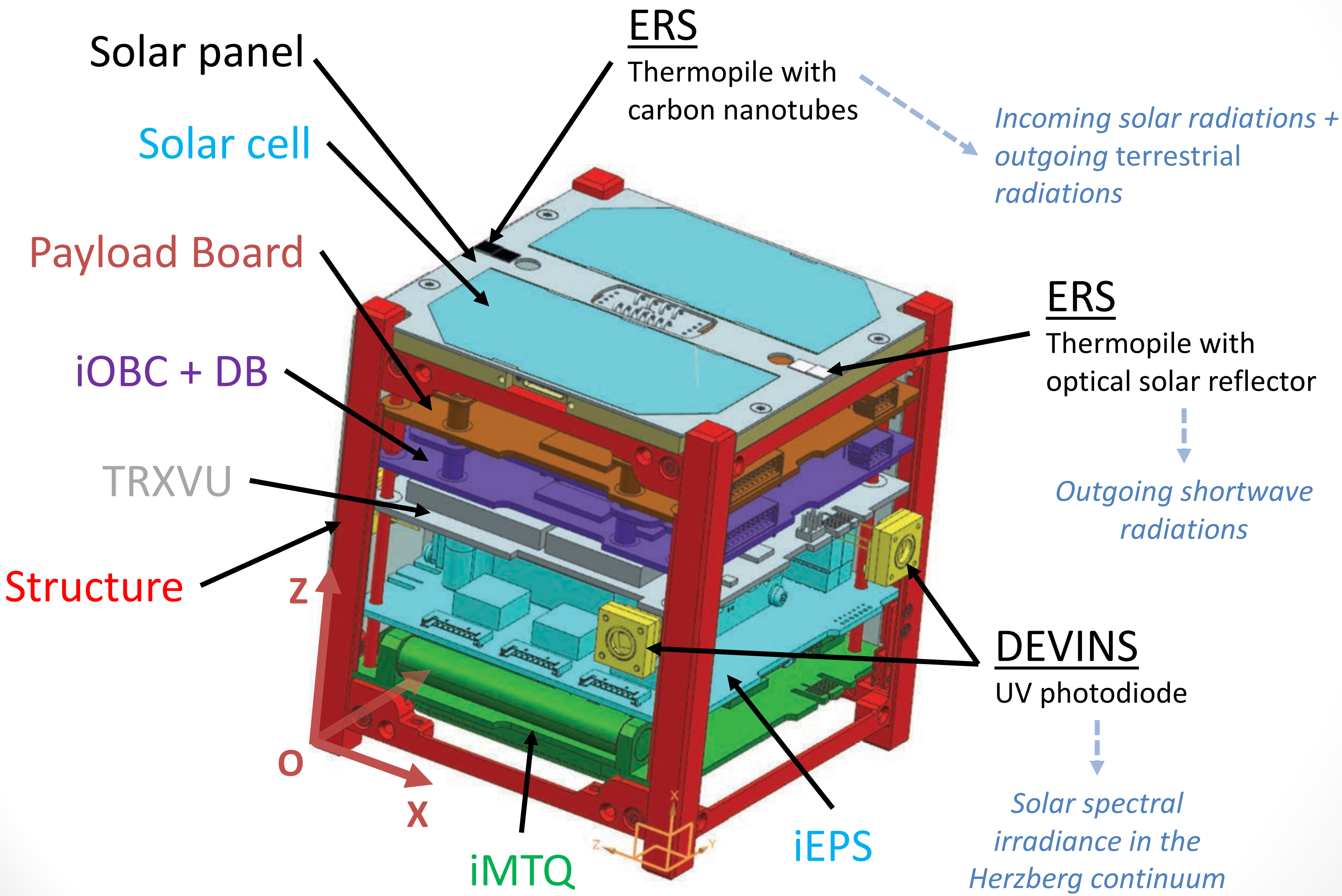


Properties	Value
Orbit	SSO
Design life time	1 year for LEO
Launch date	Q1 2021 / Q2 2021
Size	1 U
Mass	1.6 kg
Solar cells	12
Batteries	22.5 Wh @8 V
Power generated	2.3 W
Power consumption	1.6 W
ADCS	3-axis magnetometer 6 SLCD-61N8 photodiodes
CDHS and OBC	400 MHz, 32-bit ARM9 32 MB SDRAM 2×2 GB SD-cards 1 MB NOR flash I^2C, SPI, UARTs
Data downlink	1.2/9.6 kbps
Data uplink	9.6 kbps
Ground contact station	Less than 1 hour per day
Downlink UVSQ-SAT data	2 Mbyte per day
Uplink UVSQ-SAT data	0.3 Mbyte per day
Transponder	Link with amateur radio
Payload	12 ERS 4 DEVINS 1 TW sensor
Launch adapter	ISIPOD CubeSat deployer

	UVSQ-SAT roadmap	
	Absolute uncertainty	Stability per year
EEI	$\pm 15\ Wm^{-2}$ at 1σ	$\pm 5\ Wm^{-2}$ at 1σ
SSI	$\pm 8.5\ 10^{-4}\ Wm^{-2}nm^{-1}$ ($\pm 2.5\%$ at 1σ)	$\pm 1.7\ 10^{-4}\ Wm^{-2}nm^{-1}$ ($\pm 0.5\%$ at 1σ)

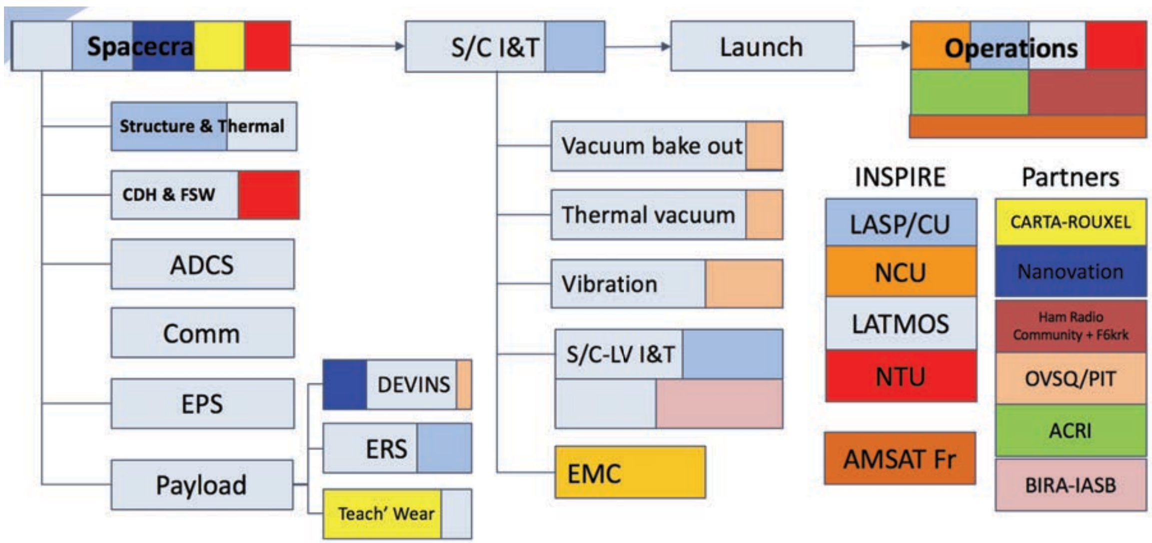
Follow us on Twitter: @uvsqsat

3 – UVSQ-Sat, a first pathfinder CubeSat



→ Payload Sensors with broad bands Field of View

3 – UVSQ-Sat, a first pathfinder CubeSat

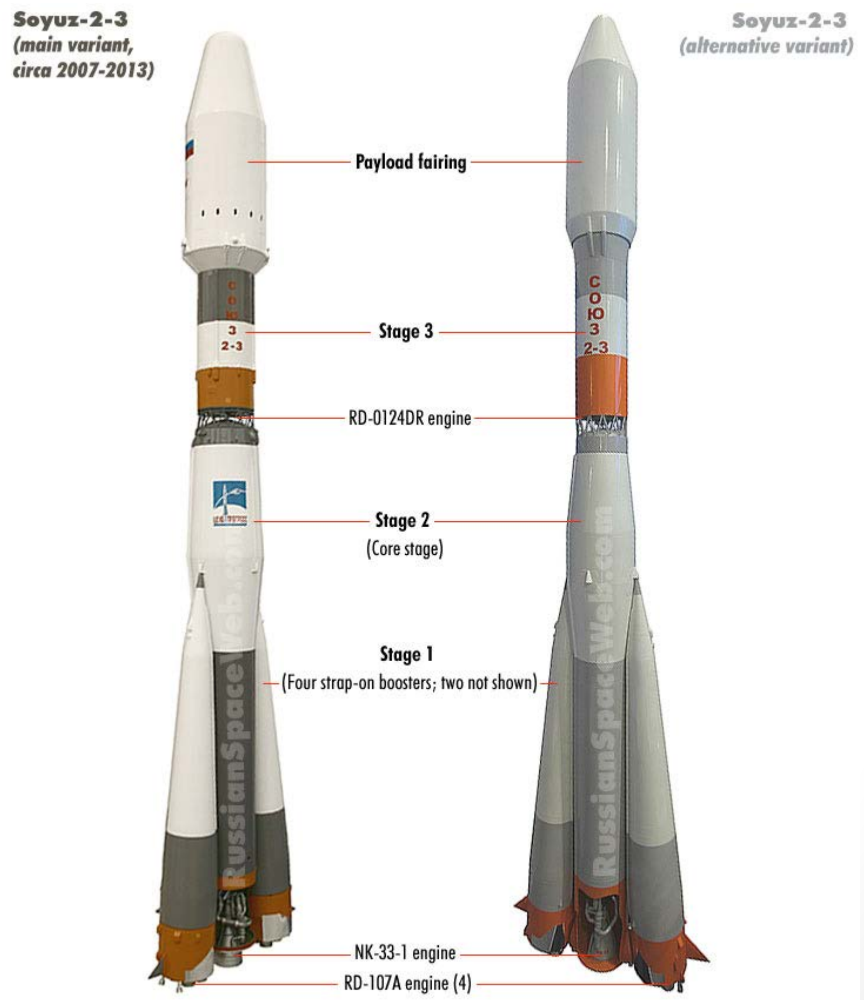


	Launch Option	
Launch vehicle:	Soyuz / ISILAUNCH 27	Falcon 9
Launch site:	Baikonur/Vostochny	Vandenberg
Launch period:	From Q1 2021	From Q4 2020
Typical orbit parameters:	475-550 km SSO, LTAN 11:00	450-720 km SSO, LTAN 09:30-14:00
Deployer type:	QuadPack	QuadPack

3 – UVSQ-Sat, a first pathfinder CubeSat

Falcon 9

Soyuz 2

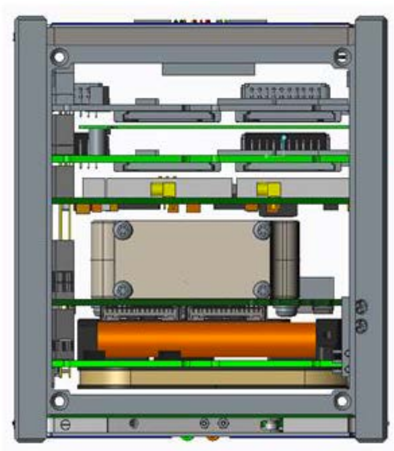


4 – Development

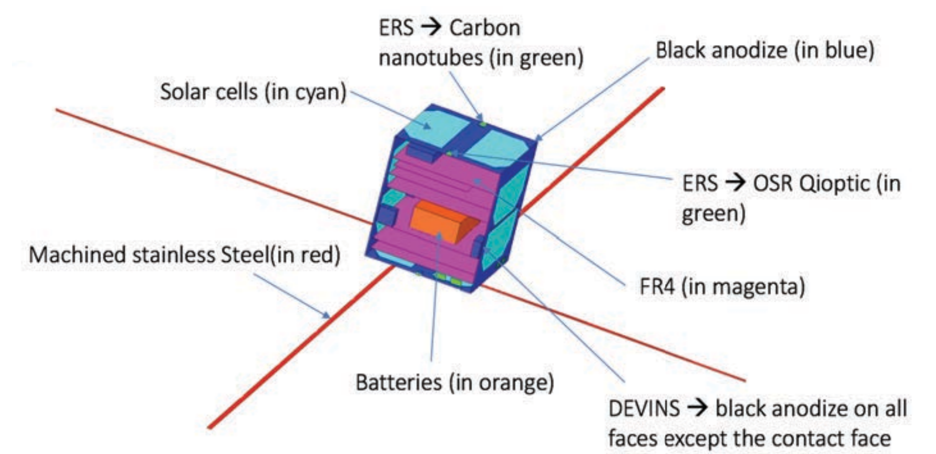
Satellite definition & simulations **Since 2018**

Electrical Design

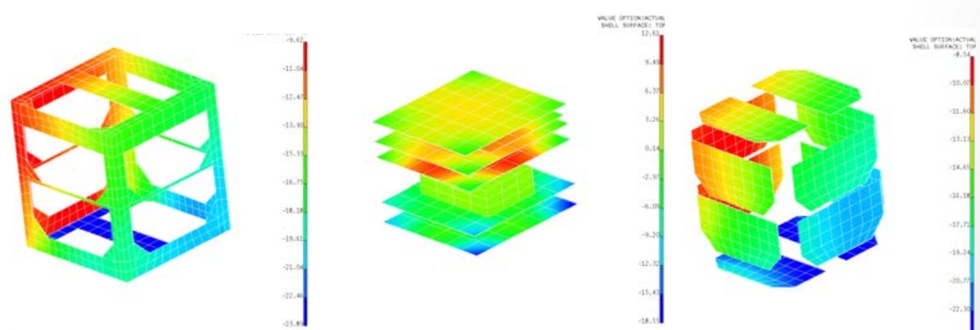
Optical Design



CAD Design



Finite Element Model Analysis



Thermal Analysis

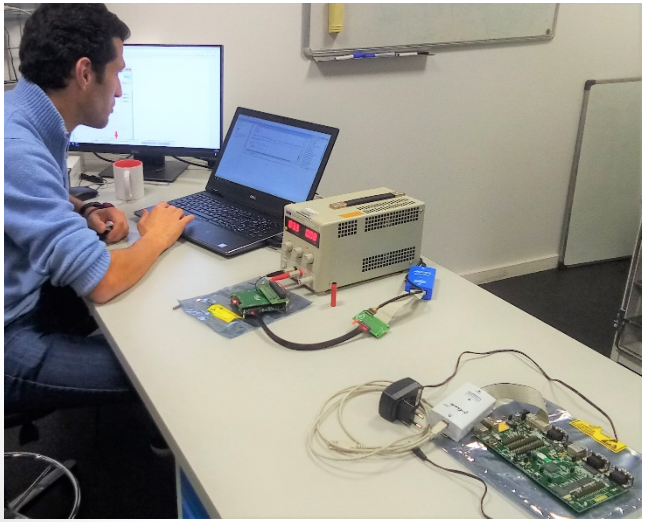
4 – Development

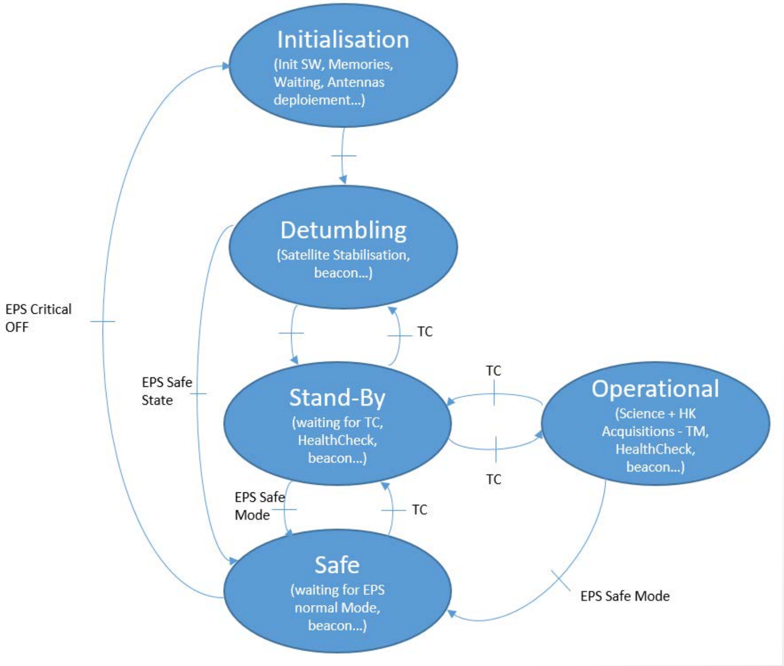
Software

Since November 2019

SW Modes

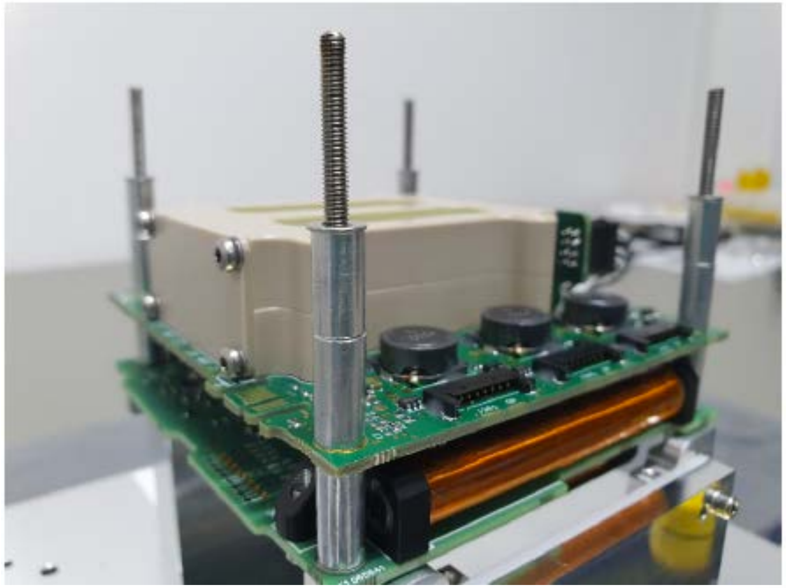
- The Flight SW Modes are:
  - Initialisation
  - Detumbling
  - Stand-by
  - Operational
  - Safe

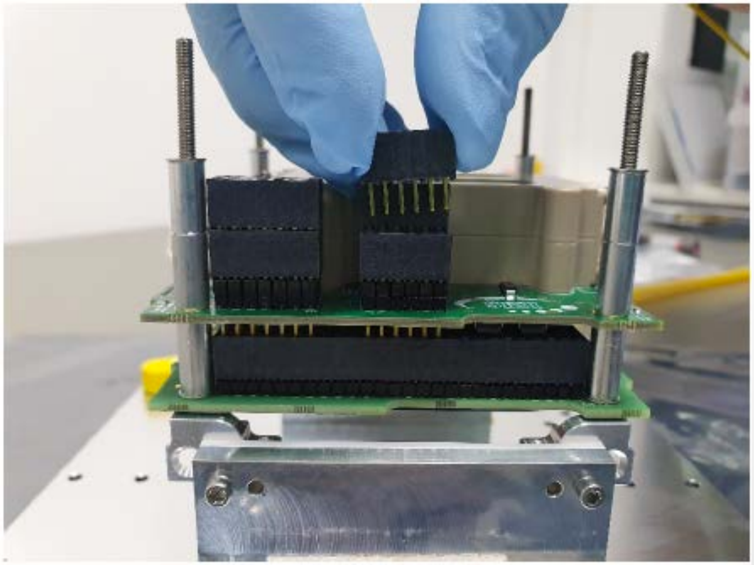




4 – Development

Satellite AIV





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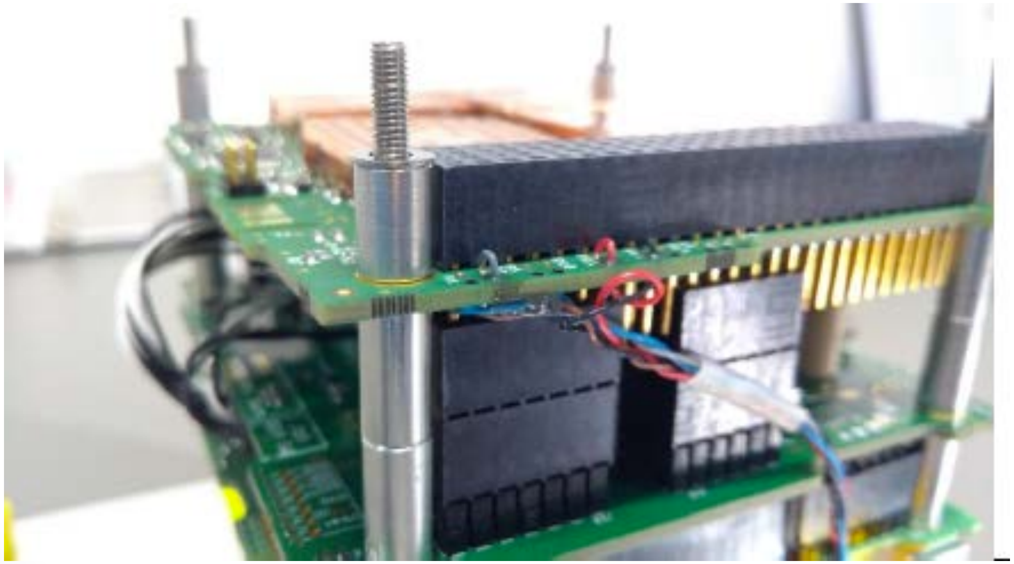
4 – Development

Satellite AIV



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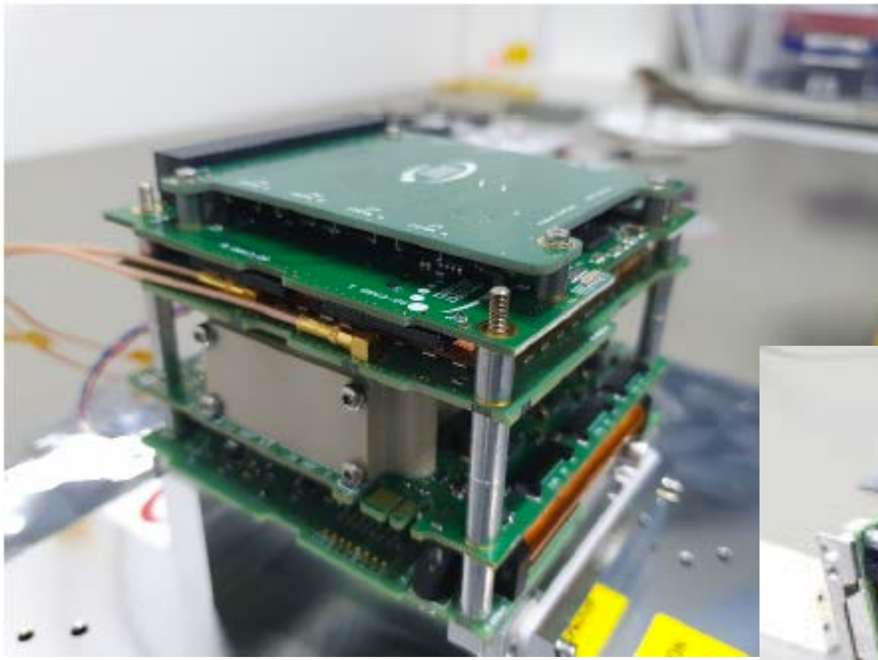

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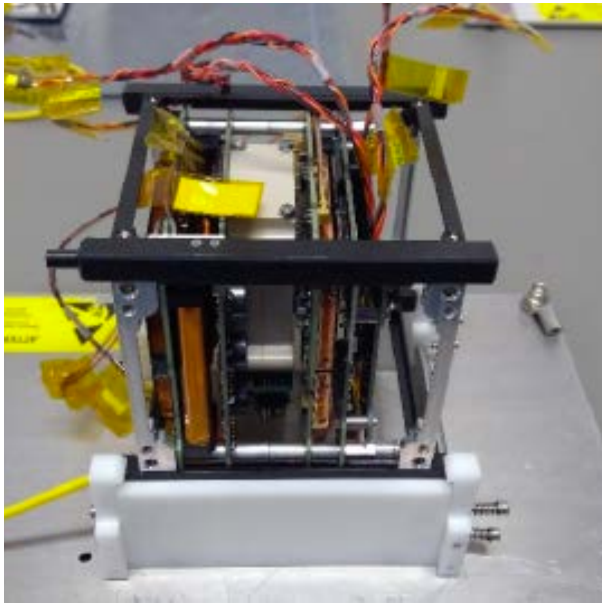

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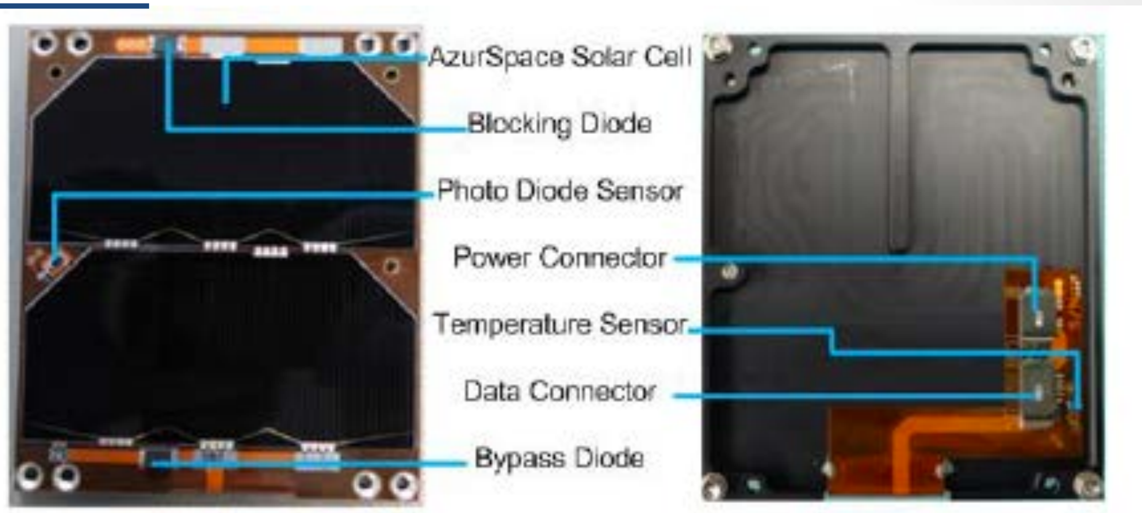

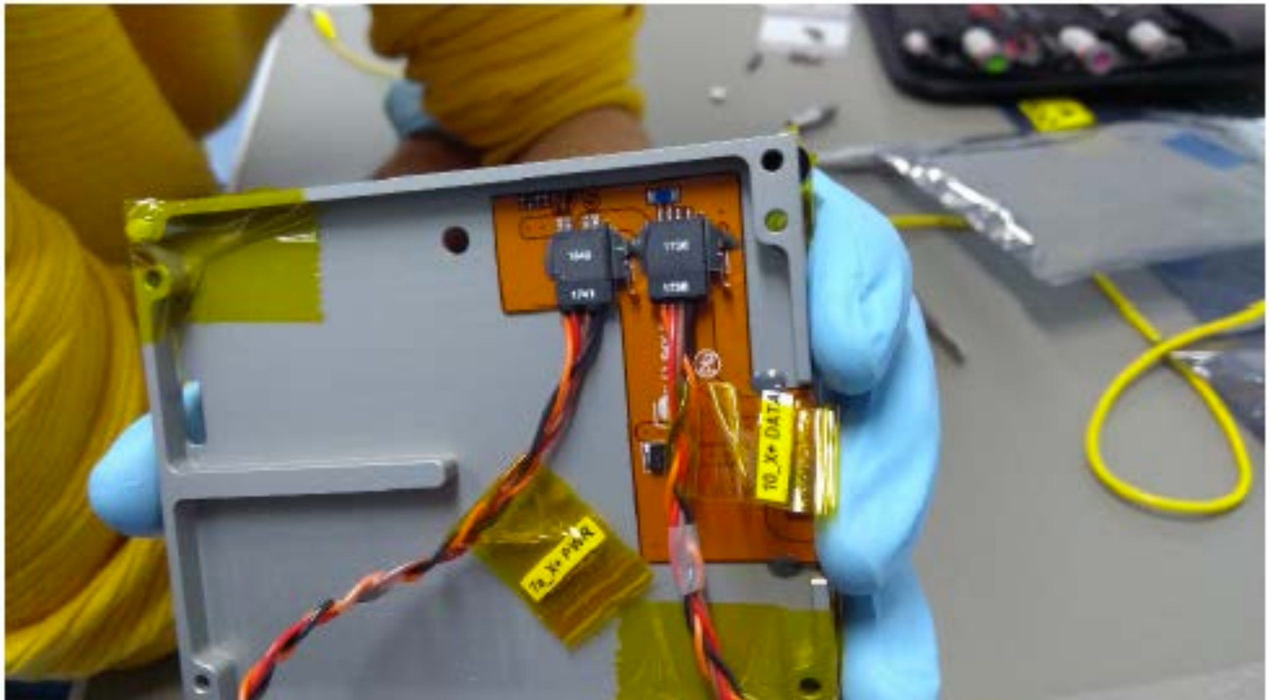

4 – Development

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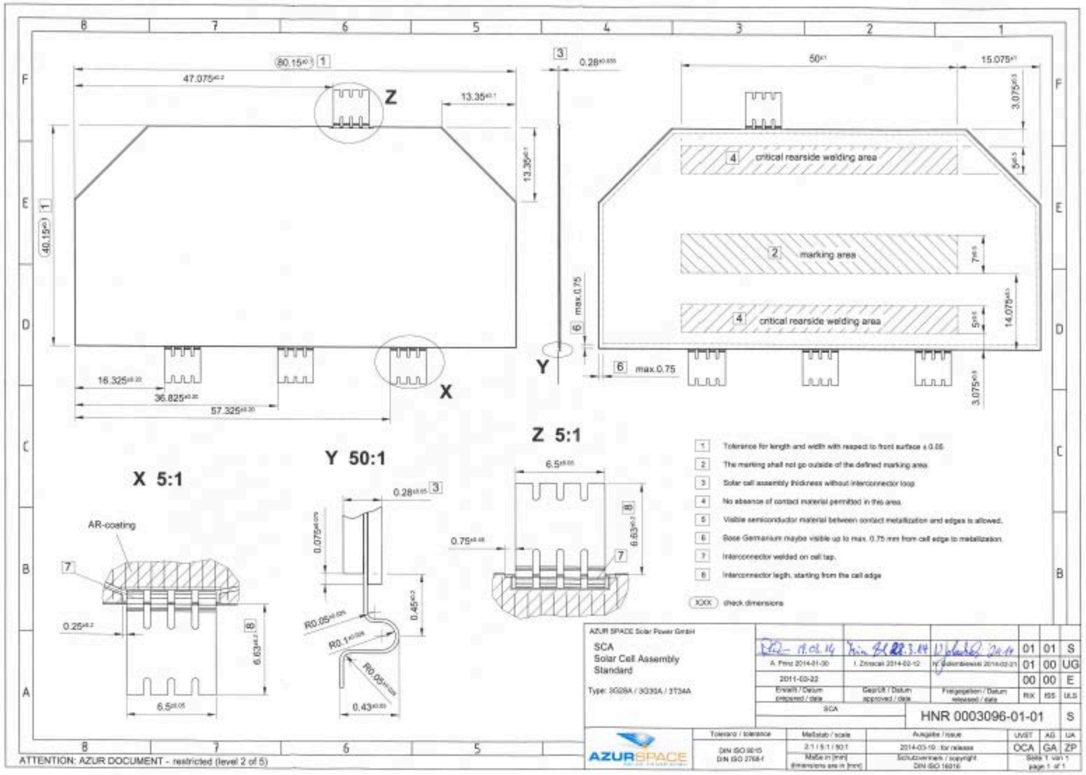


INNOVATIVE COATINGS
FOR YOUR TECHNOLOGY
Company Certified ISO 9001 and Evaluated EN9100

Product Information

CNES Licence n°90542

MAPSIL® QS1123 THIXO-B

LOW OUTGASSING SILICONE ELASTOMER FOR SPACE APPLICATIONS

INNOVATIVE COATINGS
FOR YOUR TECHNOLOGY
Company Certified ISO 9001/EN9100

PSX primer

ADHESION PRIMER FOR SPACE USE

Product Information

cnes Licence N°80473

:ed on MAPSIL ® QS1123 technology.

lastomer dedicated to room temperature bonding in thin layer, :lose contact between electronic equipment and satellite walls. ition. This product could find applications in aerospace and high

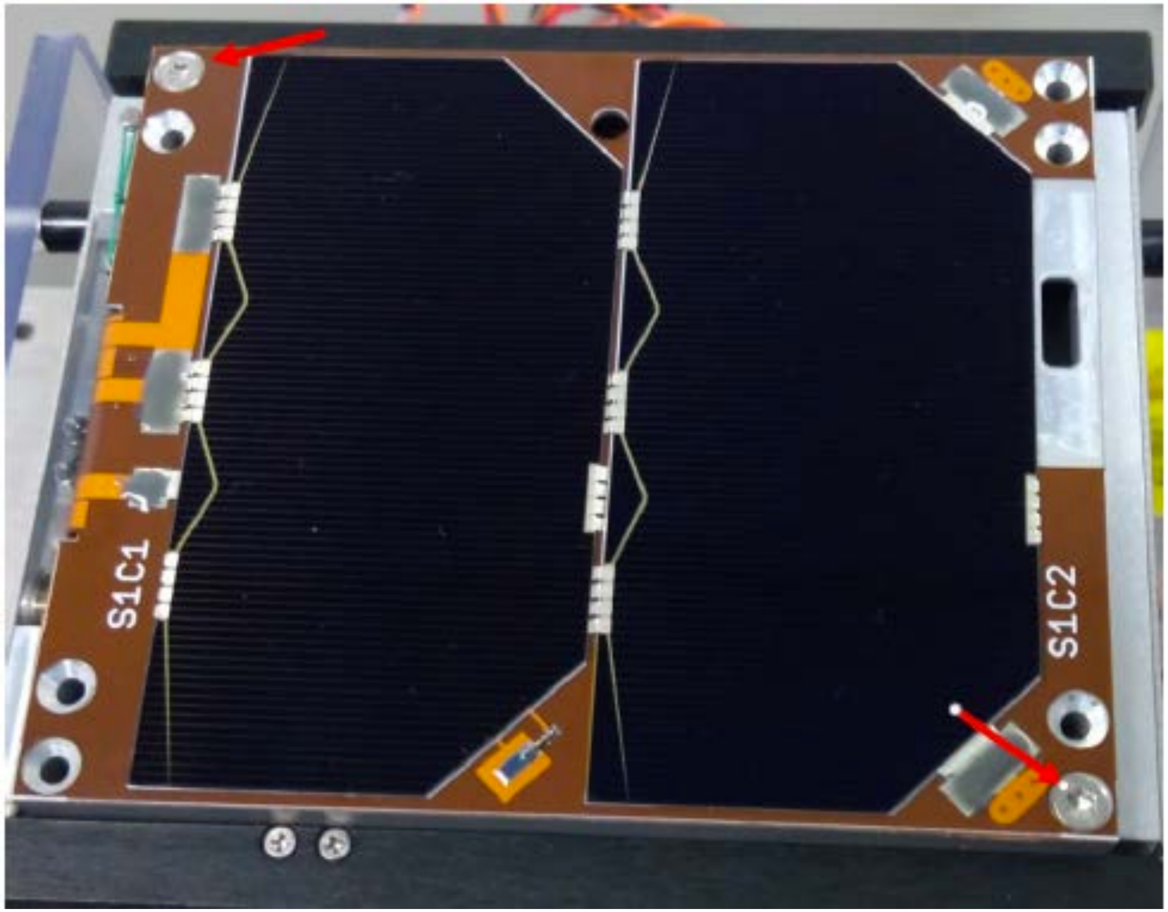
DESCRIPTION

PSX primer is an adhesion primer for silicone paints and resins.

TYPICAL PROPERTIES *(Technical data are indicative and non-contractual)*

4 – Development

Satellite AIV



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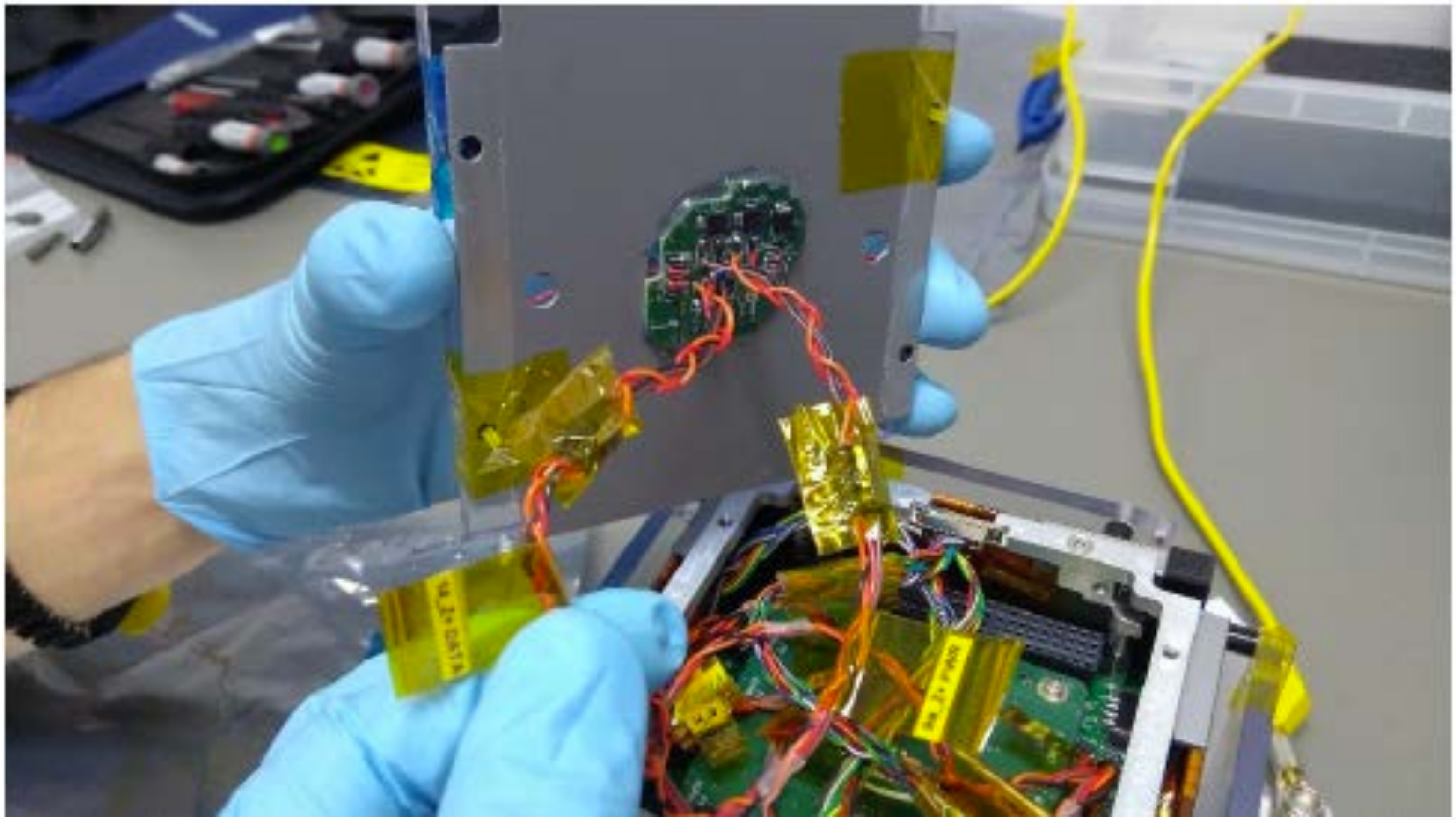

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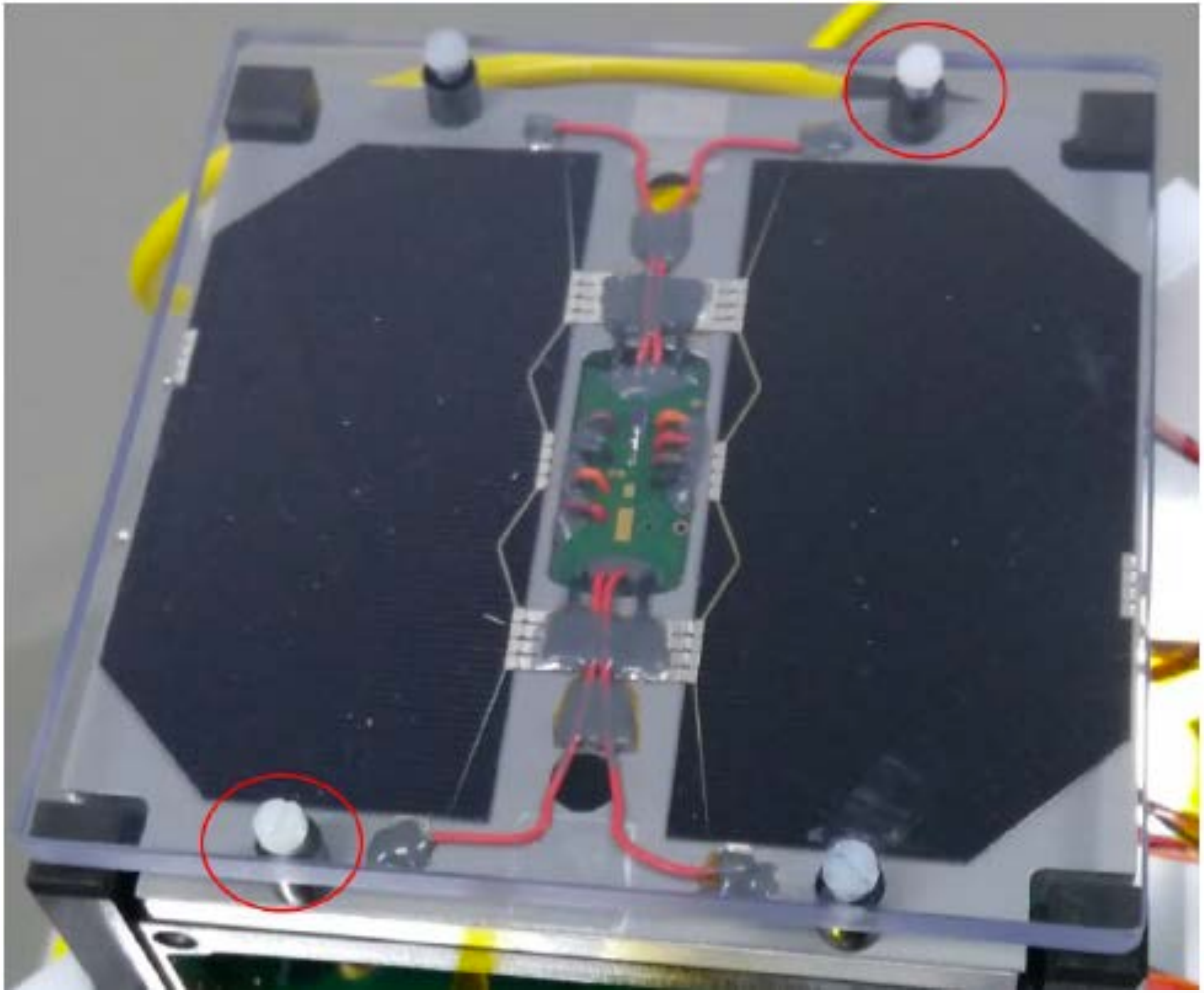

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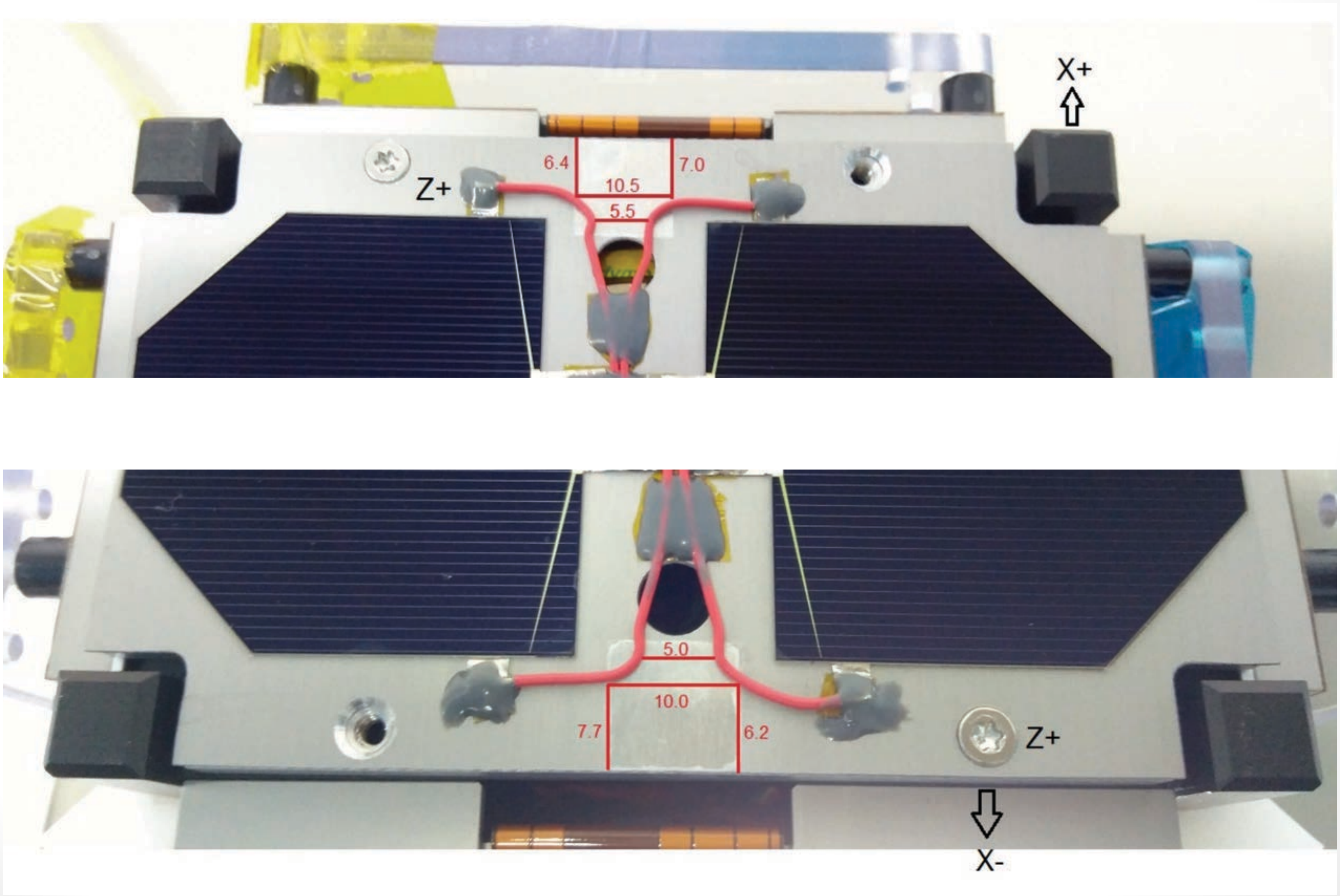

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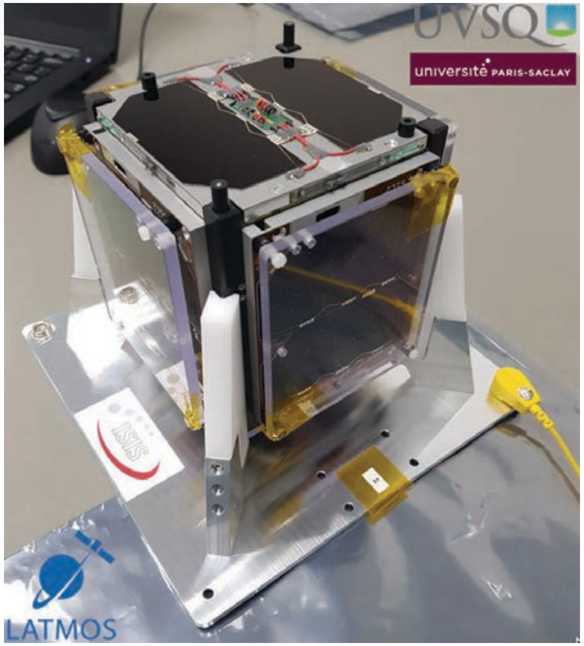
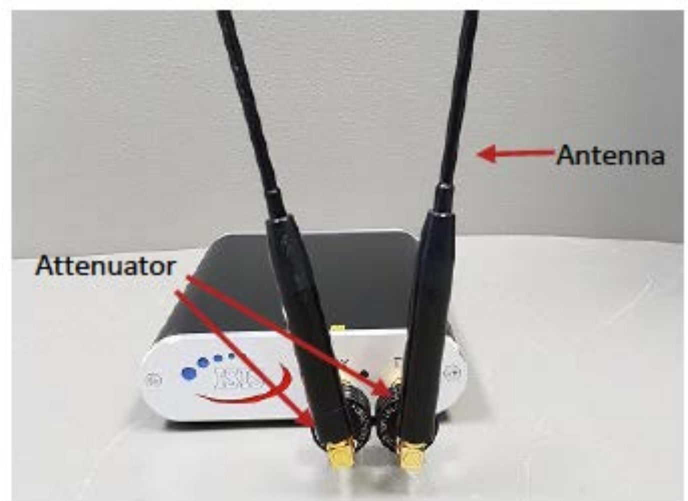


Parameter	Typical Value	Unit	Comments
CubeSat category	1U	[U]	
Form Factor	11.4 x 11.1 x 11.1	[cm]	
Mass			
- total mass of the platform	1.146	[kg]	
Power			
- power consumed by the platform	1.37	[W]	nominal operation
Data Storage			
- storage capacity flight control	2x2	[GB]	
Downlink - Telecommand			
- Frequency	437.020	[MHz]	UHF band, amateur
- Antenna configuration	Dipole		range
- Data rate	9.6 (min 1.2)	[kbps]	
Uplink - Telemetry			
- Frequency	145.830	[MHz]	VHF band, amateur
- Antenna configuration	Dipole		range
- Data rate	9.6	[kbps]	
Architecture			
- Redundancy level	Single String		

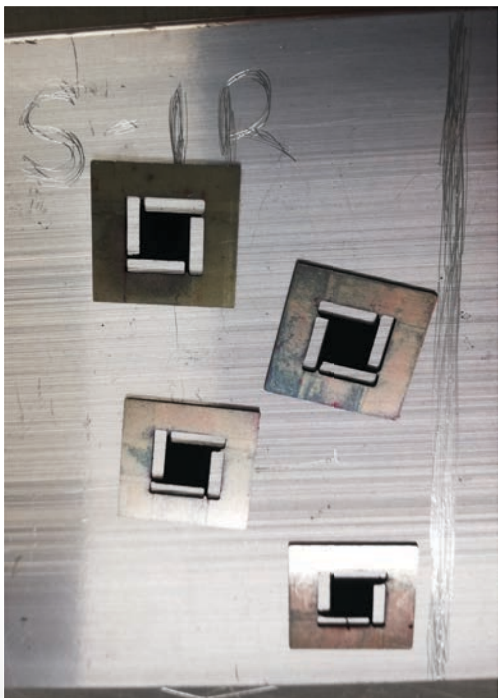


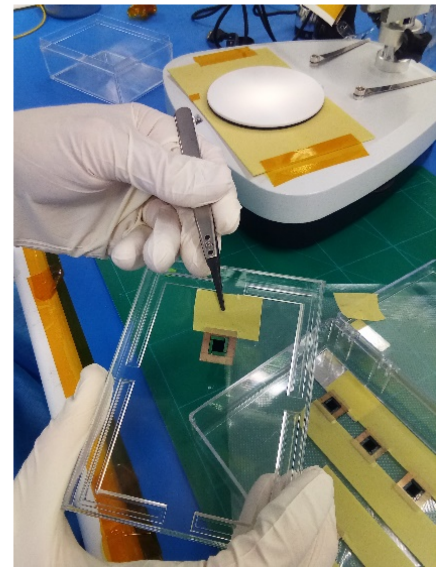
4 – Development

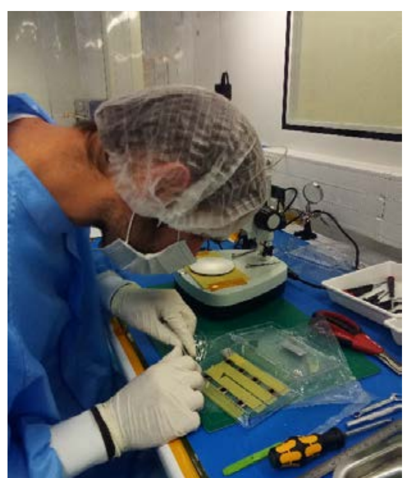
Payload

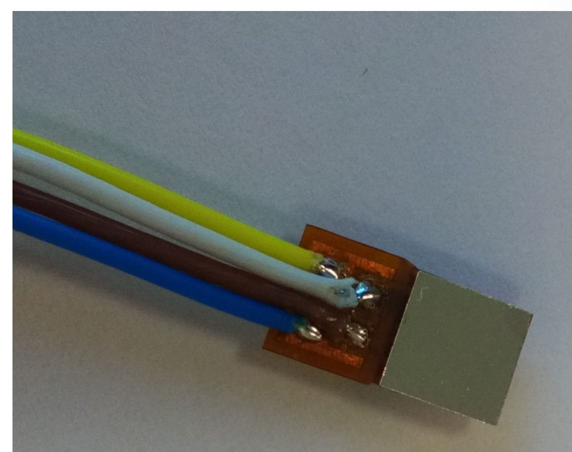
Work in Progress since January 2020

Earth radiative sensors







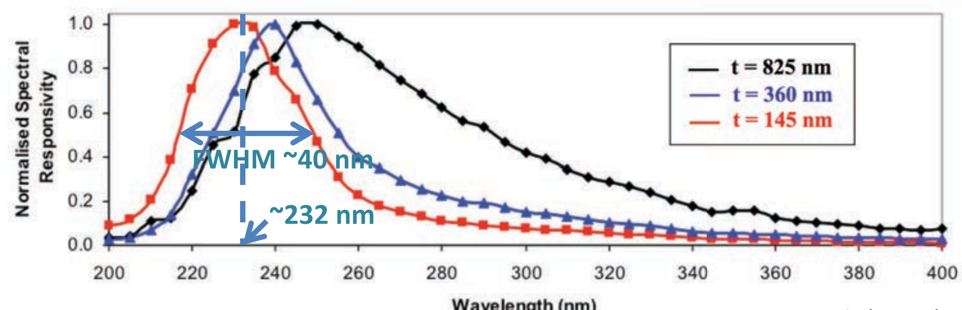


4 – Development

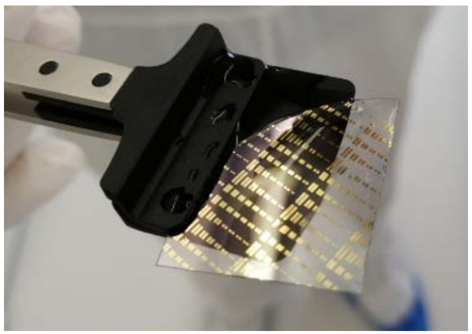
Payload

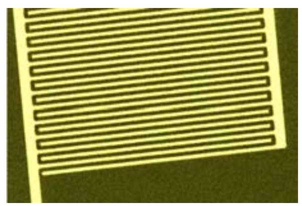
Work in Progress since January 2020

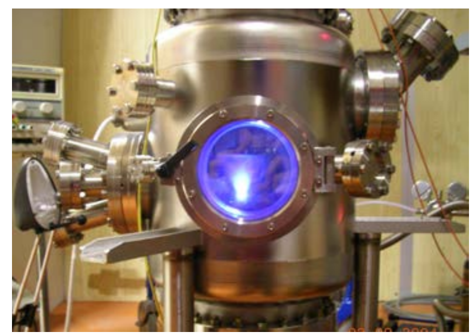
UV photodiodes

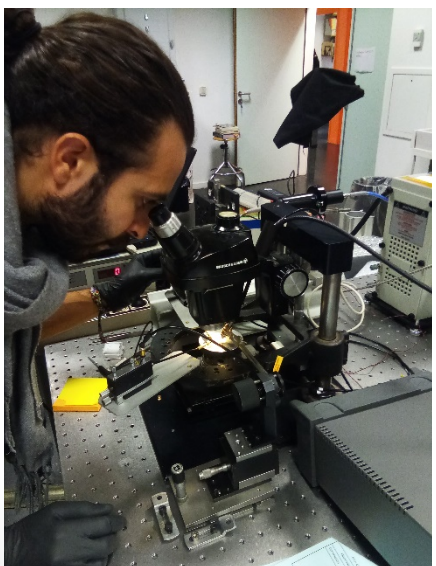


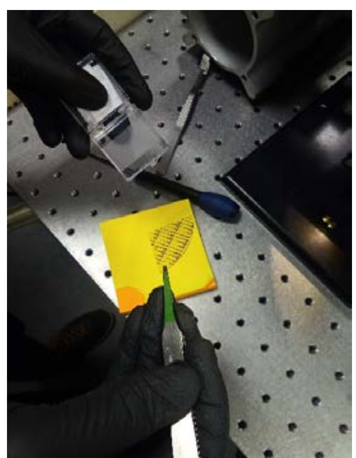
Rogers et al. (2018)











4 – Development

Payload

Work in Progress since August 2019

Teach' Wear

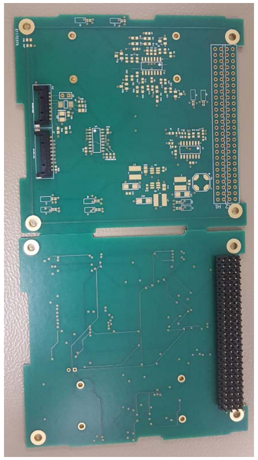
The TW sensor will be used
in the future as medical devices to prevent health problems for astronauts in space.

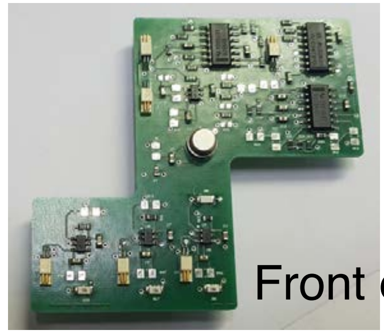
→ Discussions with Thomas Pesquet.

4 – Development

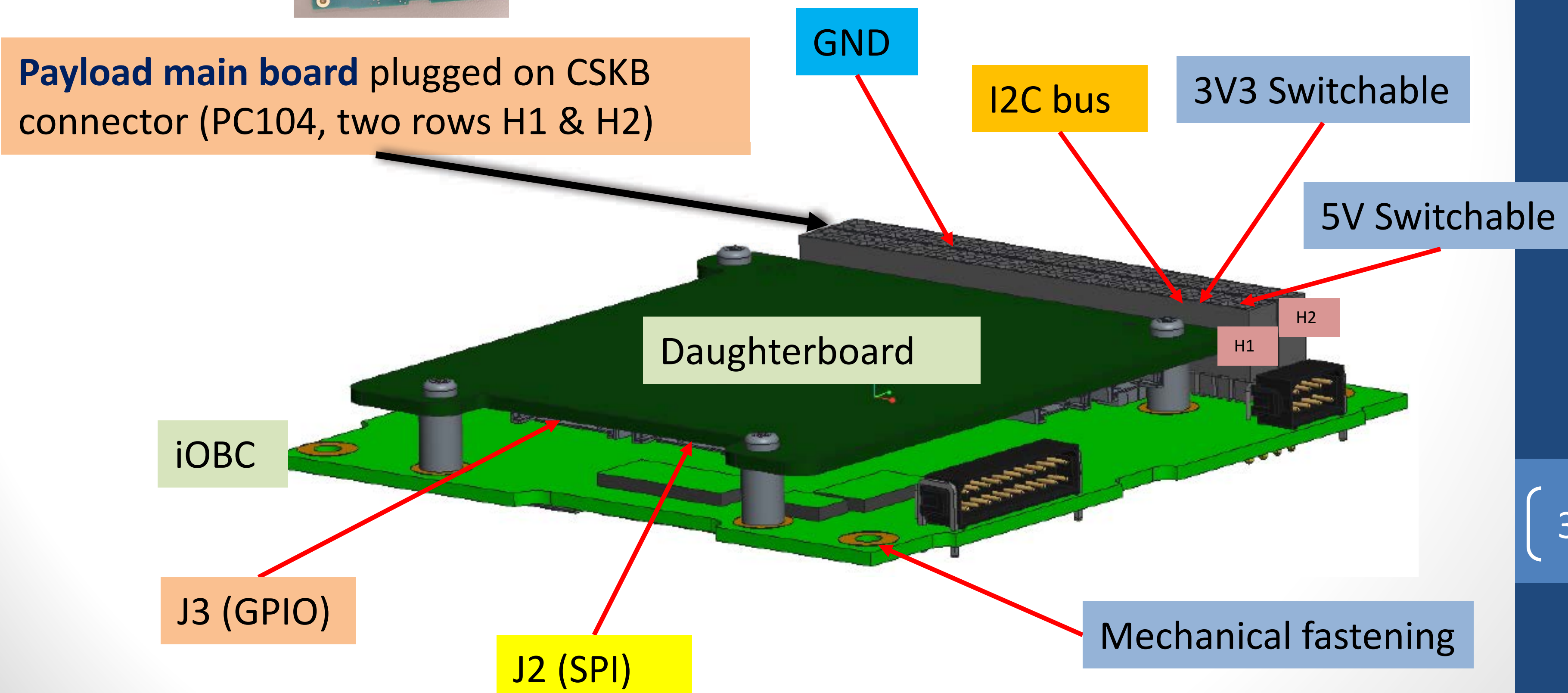
Payload

Electronic



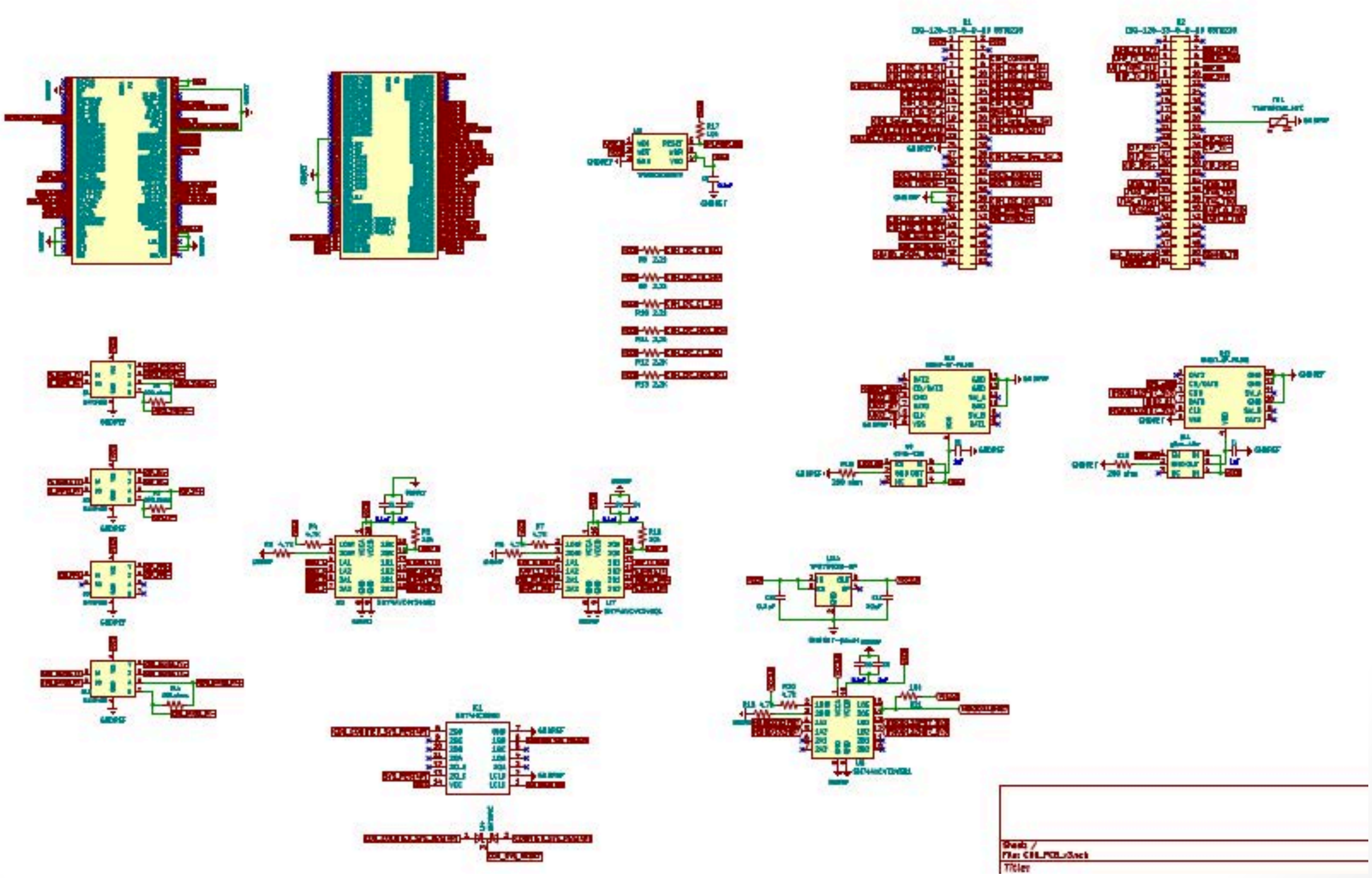


Front end Electronic



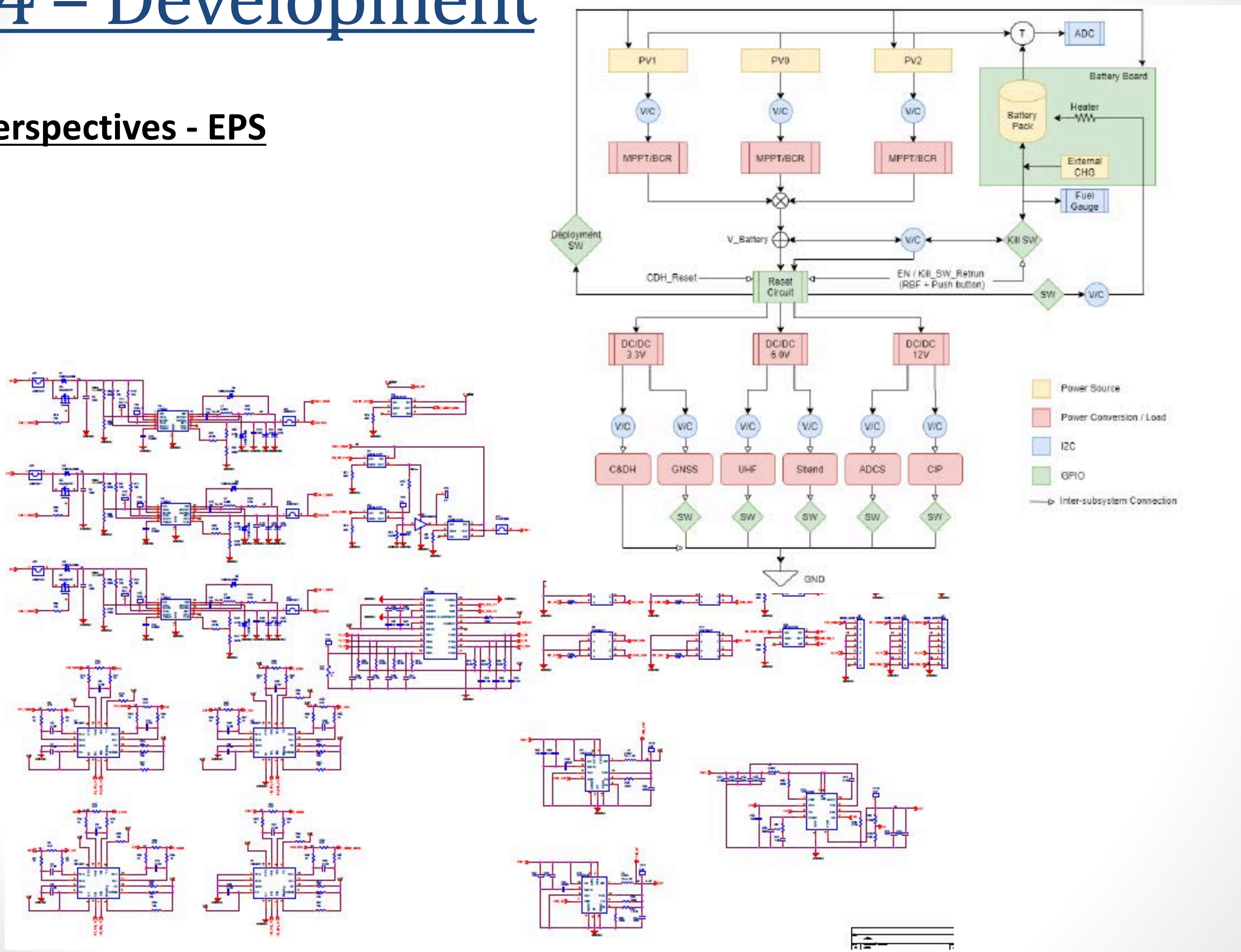
4 – Development

Perspectives - OBC



4 – Development

Perspectives - EPS



4 – Development

Satellite tests **Starting in August 2020**

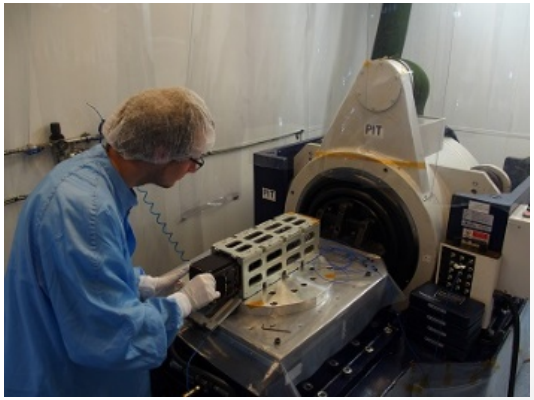
Main LATMOS/OVSQ facilities for UVSQ-SAT:

- **270 m² of ISO5, ISO7 and ISO8 clean rooms**, equipped with permanent temperature and hygrometry monitoring, daily particles counting measurements. Several tools to facilitate the integration phases are available: space electrical components storage and packing, 3D and 2D mechanical metrology, clean soldering and gluing stations, trinocular visual inspection etc.

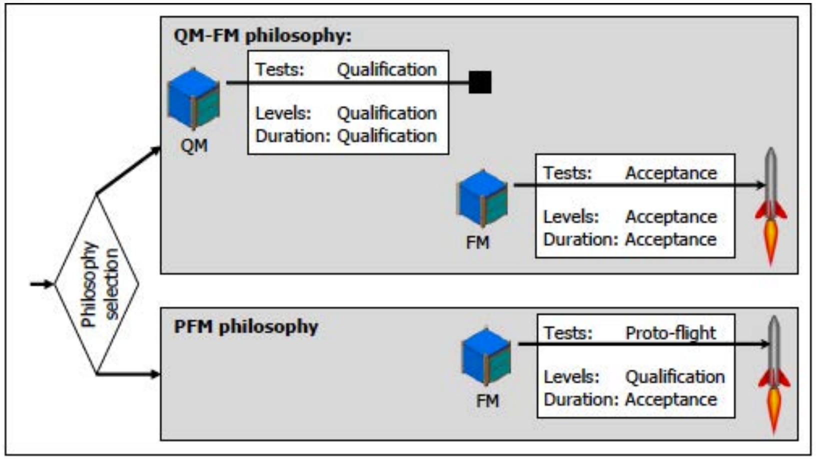
- **A 40 kN shaker installed under an ISO5 laminar flux**. This equipment is used for all prototypes mechanical validation as well as qualification and acceptance tests. Classical quasi-static, sine and random vibrations are achieved using this equipment.

- **A 3 m3 thermal and optical vacuum chamber, installed in an ISO8 clean room**. This chamber is able to simulate the Martian environment (regulated pressure steps between 5 and 20 mbar under CO2 atmosphere), as well as nominal space thermal vacuum environment below 10-5 mbar. Instruments up to 600x600x1600mm (50kg, 100W) fit into this chamber, also equipped with a cryogenic decontamination finger, a 300 amu mass spectrometer and a high spectral resolution McPherson type 225 monochromator allowing optical calibration within the 30-1200 nm range.

- …

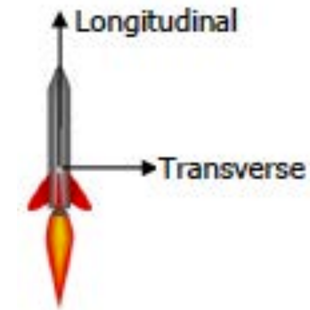


4 – Development



Mechanic

PFM tests recommendations:



- Acceleration (quasi-static)
  - Axial: +10 g – 600 sec.
  - Lateral: +9g – 600 sec.

- Resonance survey
  - +0.4g – 5 to 2000 Hz – 2 octave/mn
  - PFM fundamental frequency > 40 Hz

- Sine vibration

If natural frequencies > 40 Hz and quasi-static qualification tests were performed, it is allowed to omit the sine vibe tests

- Random vibration

Characteristic		Qualification			Acceptance		
Test		Recommended			Recommended		
Directions	{BRF}	X, Y, Z			X, Y, Z		
Profile	Frequency range [Hz]	Amplitude [g²/Hz]			Amplitude [g²/Hz]		
	See Notes, 11	LV stages		Fregat	LV stages		Fregat
	20 – 50	0.02	0.02	0.004	0.01	0.01	0.002
	50 – 100	0.02	0.02	0.004	0.01	0.01	0.002
	100 – 200	0.02 – 0.05	0.02	0.004	0.01 – 0.025	0.01	0.002
	200 – 500	0.05	0.02 – 0.008	0.004	0.025	0.01 – 0.004	0.002
	500 – 1000	0.05 – 0.025	0.008 – 0.004	0.004	0.025 – 0.013	0.004 – 0.002	0.002
	1000 – 2000	0.025 – 0.013	0.004 – 0.002	0.004 – 0.002	0.013 – 0.006	0.002 – 0.001	0.002 – 0.001
Duration		120 [sec]	480 [sec]	875 [sec]	60 [sec]	240 [sec]	437½ [sec]

- Shock

Characteristic		Qualification	Acceptance
Test		Recommended	Not required
Directions	{BRF}	X, Y, Z	X, Y, Z
Profile	Frequency [Hz]	Amplitude [g]	Amplitude [g]
	100 – 200	30 – 60	20 – 40
	200 – 500	60 – 255	40 – 170
	500 – 1000	255 – 750	170 – 500
	1000 – 2000	750	500
	2000 – 5000	750 – 1500	500 – 1000
# of shocks			5 [/axis]

Shock spectrum corresponds to Q =10.

Category	Sub-system	Tmin off	Tmin operational	Tmax operational	Tmax off	Heritage
Mechanical	Structure (STS-1U)		-40	80		2013
Communication	Communication board (TRXVU)	-40	-40	60	80	2016
	Antennas (AntS)	-50	-30	70	85	2010
CDHS	On-Board Computer (iOBC + DB)	-40	-25	65	80	2013
Power	Electrical Power System (iEPS – type A – 22.5 WH) Battery Cells on iEPS In charge	-40 -40 N/A	-40 -40 -5	70 85 45	85 85 N/A	2017
	Solar panels (SPA 3G30A)	-40	-40	125	125	2017
ADCS	Magnetorquers board (iMTQ)	-40	-40	70	70	2016
Payload	UV detectors (DEVINS)	-50	-40	90	100	New
	IR detectors (ERS)	-50	-40	90	100	New
	Physiologic detectors (Teach-Wear)	-50	-40	60	70	New
	Payload board (PB)	-50	-40	60	70	New
	Harness & other	-50	-40	60	70	New

Thermic

PFM tests recommendations:

Number of test cycles	- PFM 8 cycles: 1 non-op plus 7 operational
Chamber pressure	- Ultra vacuum - <= 10^{-5} mbar
Chamber cleanliness	- No outgassing materials allowed inside the chamber - Cleanliness measurements prior to test
Thermal I/F to device under tests (DUT) (Chamber baseplate)	- Thermally controlled baseplate - Baseplate electrically conductive - Baseplate flatness: <= 0.1mm over 100mm - Surface finish: <= 3.2 microns center line average at one I/F point - Estimated baseplate temperature range:-55°C to 75°C
Thermal I/F to DUT (Chamber baseplate)	- LATMOS provides four thermal washers made of Al 6082 (Alodine 1200) for thermal cycling
Radiative thermal I/F to DUT (Shroud)	- The DUT shall be exposed to controlled shroud surfaces in all directions, except the mounting surface.
Temperature control	- I/F temperature shall be measured at TRP - Gradients on the instrument I/F points shall be <= 1K
Temperature control	- Temp set points at TRP shall be within +/- 1K - Dwell time is >= 2h - Max. temperature slope shall be <= 20K/minute
Acceptance temp. ranges (Baseplate & Shroud)	- Non-operational: -50°C / +70°C - Operational: -40°C / +60°C

4 – Development

Electromagnetic compatibility (EMC) tests / Electromagnetic interferences (EMI)
During prelaunch processing and launch, the spacecraft onboard equipment and ground support equipment (GSE) shall sustain the electromagnetic fields of up to 10V/m within 10 kHz to 40 GHz.

→ ***We need an EMC test. CNES support.***

Frequency band	Electric field strength maximum recommended
140-150MHz	3 V/m
400-450MHz	6 V/m

Radiation susceptibility

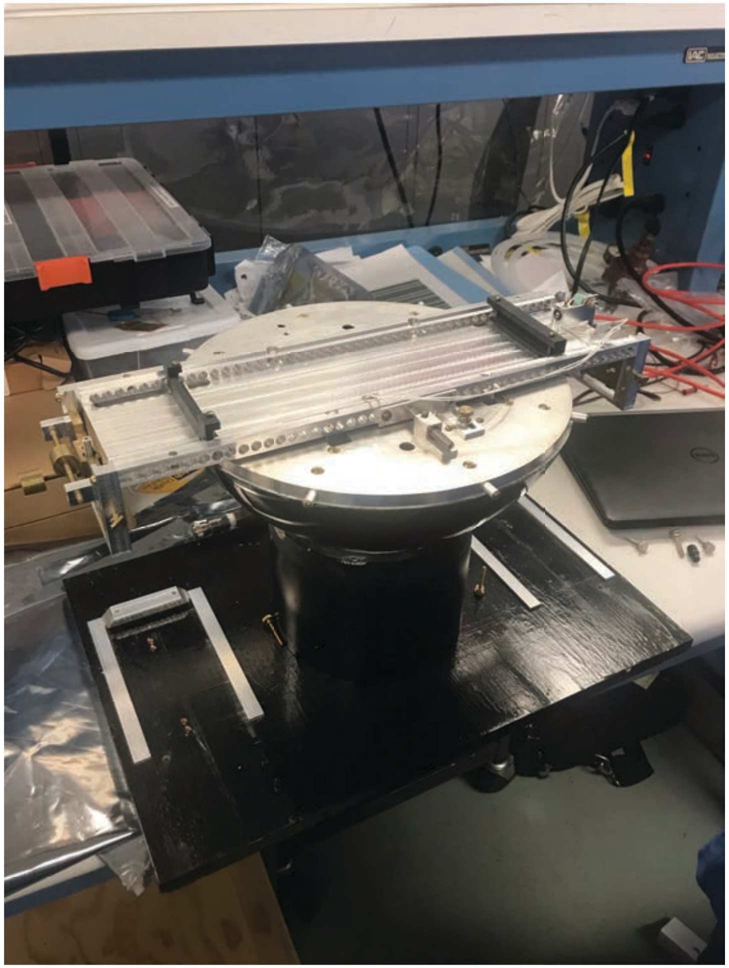
Magnetic cleanliness
Take special care to ensure that the payload magnetization is reduced as much as possible. Hard and soft magnetic materials are source of stray magnetic field and could start spinning the satellite. In order to ensure magnetic cleanliness, the following considerations are proposed:
- Identify the components that have magnetic properties, mind the location of the magnetic components, …

The remnant magnetic dipole of the satellite (to which the payload magnetization contributes) will interact with the Earth magnetic field; therefore, generating torques that can unexpectedly spin the satellite.

→ ***We need a test to obtain a magnetic cleanliness. CNES support.***

4 – Development

ADCS tests – Detumbling mode
Development of an air bearing table.



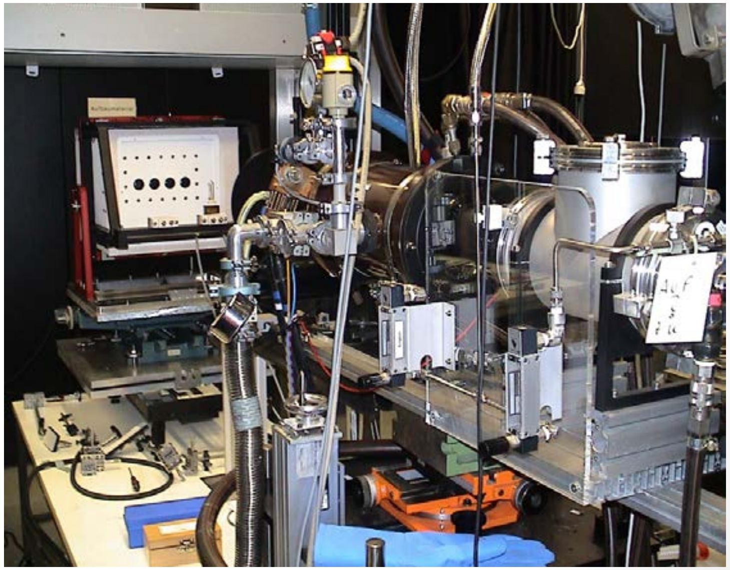
4 – Development

Satellite calibrations **Starting in October 2020**

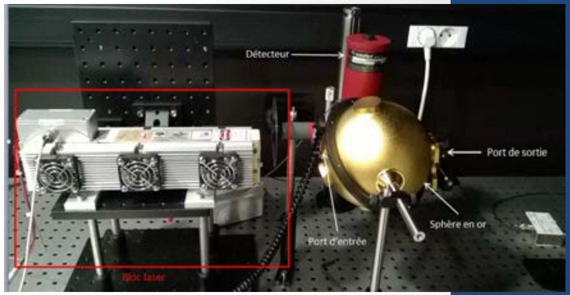
Calibration with SI standard

- Use of the blackbody BB3200pg as primary standard for spectral irradiance to calibrate the sensors. The blackbody will be operated at several temperatures between 2800 K and 3150 K and we will calculate the spectral irradiance at the sight-limiting input optics of the sensors.
- Additionally we can do auxiliary measurements like distance variation.
- We need a vacuum chamber for the sensors tests with the satellite.

Blackbody BB 3200pg (PTB)



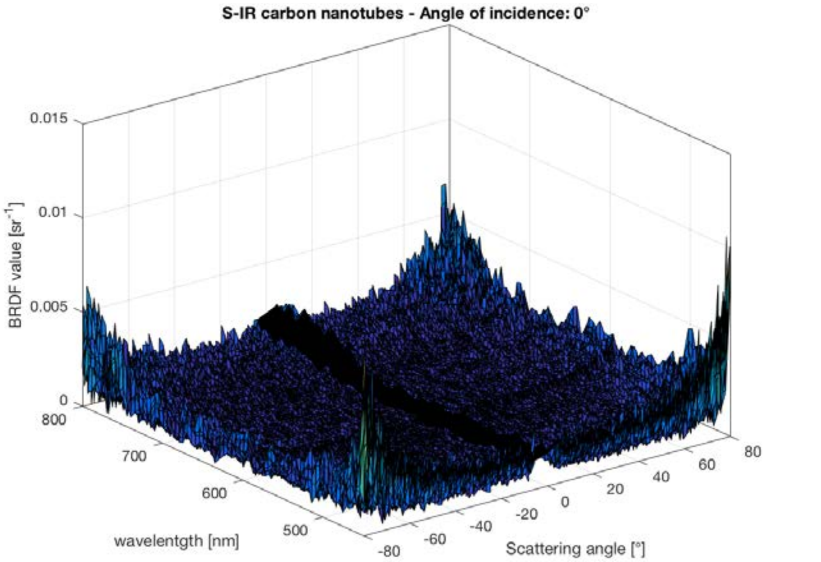
4 – Development

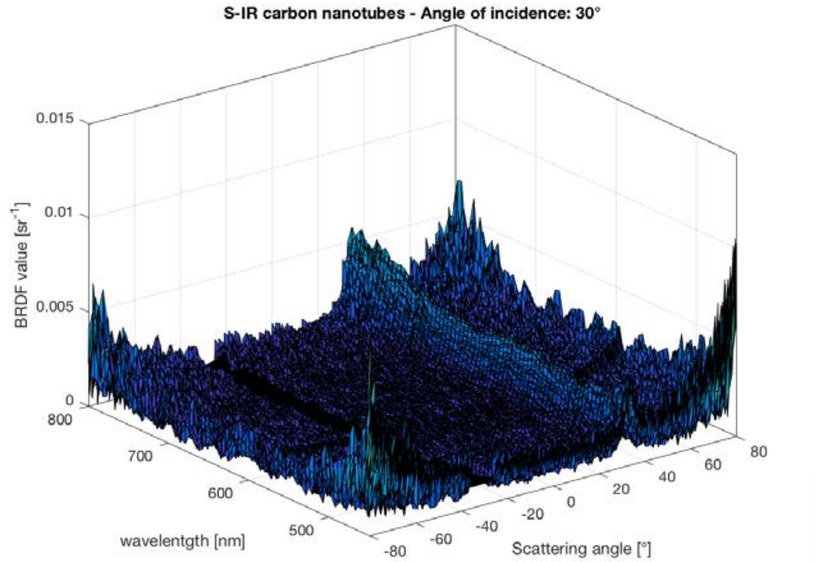


Payload calibrations

Starting in January 2020

BRDF characterization



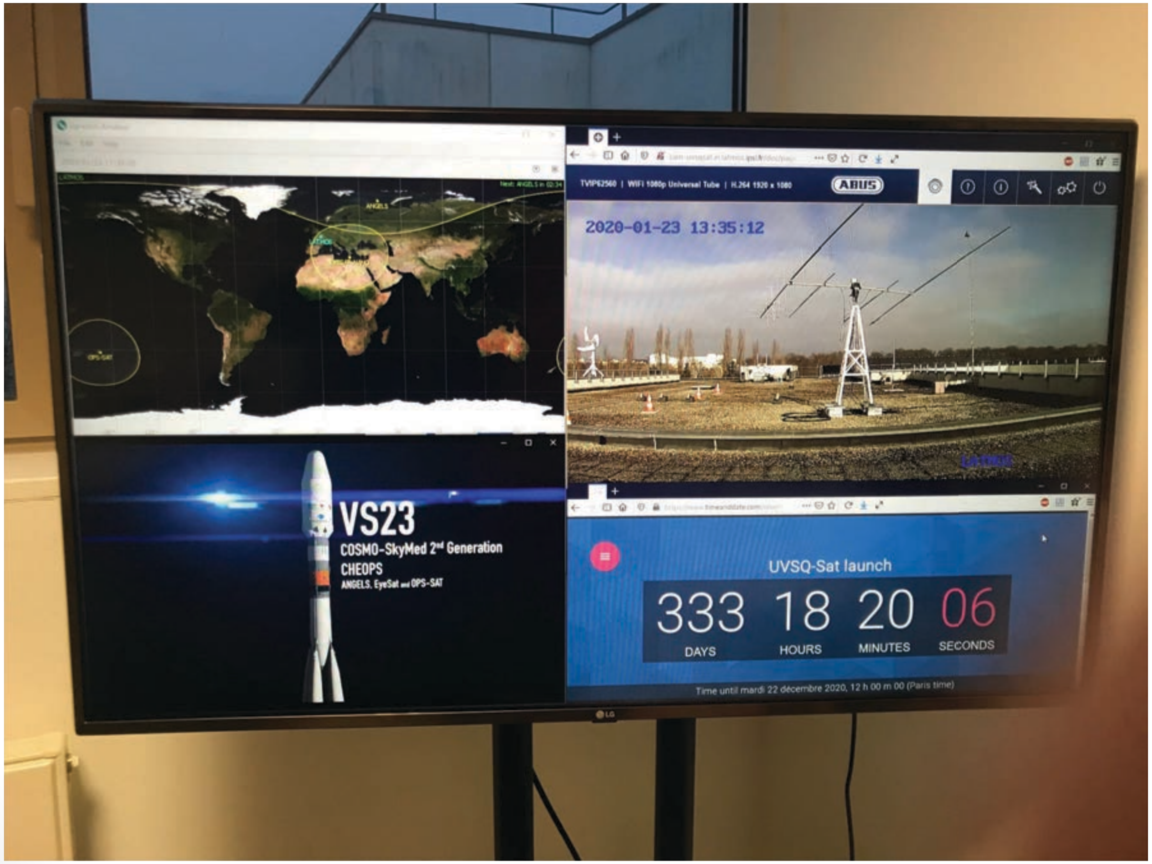


Total reflectivity

$$R_{TOT}(\theta_i,\varphi_i) = \int BRDF(\theta_d,\varphi_d,\theta_i,\varphi_i)\, d\Omega = \iint BRDF(\theta_d,\varphi_d,\theta_i,\varphi_i) \cos(\theta_d)\, |\sin(\theta_d)|\, d\theta_d\, d\varphi_d$$

4 – Development

Launch (Soyuz2, PSLV, or Falcon 9) December 2020



- ODAR → In progress
- LOS → In progress (new law in January 2021)
- Satellite declaration → In progress
- ICD with launcher → ok
- End User statement → ok
- IARU frequency coordination request → ok
- Insurance (SPACE THIRD PARTY LEGAL LIABILITY) → ok

4 – Development

UHF Satellite (for telemetry)
Frequency segment: 435-438 MHz

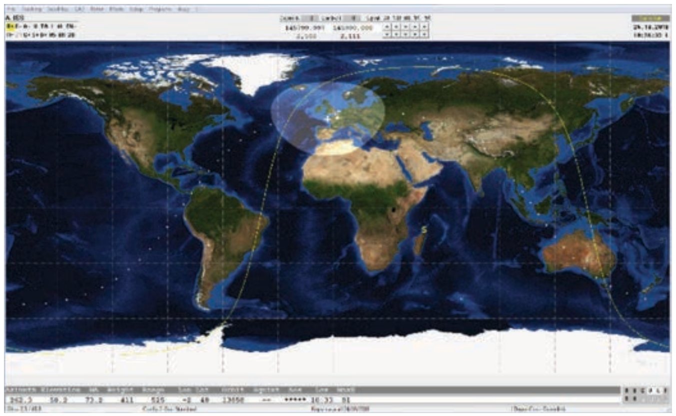
⇨ Requested downlink frequency: **437.020 MHz**

VHF Satellite (for telecommand)
Frequency segment: 145,800-146,000 MHz

⇨ Requested uplink frequency: **145.830 MHz**

Mission operations center

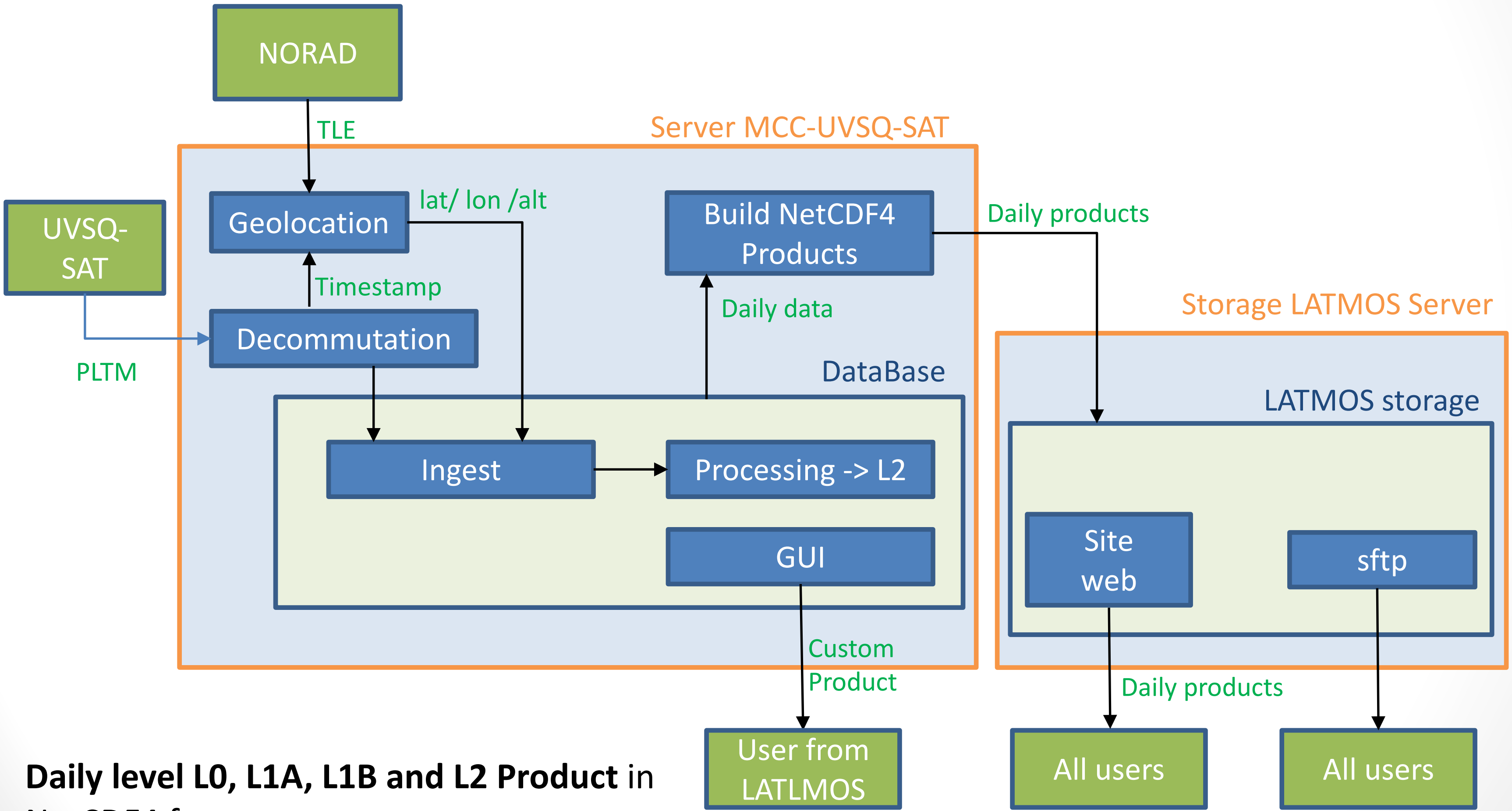
Operational since January 2020



4 – Development

Operational in November 2020

Mission Center



Daily level L0, L1A, L1B and L2 Product in NetCDF4 format

- Sftp: user@sftp.latmos.ipsl.fr
- Website: http://bdap.ipsl.fr/uvsqsat/

4 – Development

Exploitation → PhD student

Feb 2020 to Feb 2023

Analysis → Master M1/2 students

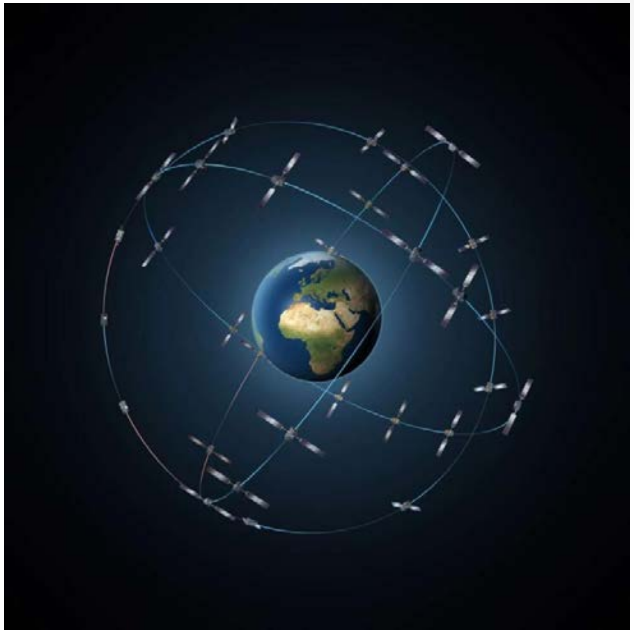
Operations → Master M1/2 students

The students can use tools located at the control/command centre to predict satellite overpasses. They prepare an optimum observational program for the day or the period.

Conclusions

This UVSQ-SAT project aims scientific objectives in connection with the observations of the Earth and the Sun. Scientific requirements are established.

The first step of our program is to develop two innovative proof-of-concept nano-satellites (UVSQ-SAT and UVSQ-SAT+). The second step is to launch 100 "UVSQ-SAT" nano-satellites to obtain a global distribution of Earth fluxes, would allow accurate measurements of the Earth's energy imbalance with the diurnal and multi-directional sampling, which are a prerequisite to capture spatio-temporal variations.



Long term: EEI measurements reveal the future direction of climate change.

Short term: EEI measurements allow to constrain poorly known radiative forcings (aerosols, aerosol interactions, total solar irradiance and UV, etc.). EEI measurements allow to provide albedo accurate measurements. The reduction of albedo due to the disappearance of polar ice accelerates warming. This melt exposes the permafrost that releases a large amount of methane, a GHG 28 times more harmful than carbon dioxide.

These measurements would also greatly strengthen the scientific basis for climate change mitigation, notably the magnitude of reduction in GHG emissions required to stabilize the climate system at a defined benchmark of global warming (e.g. 2°C).

Conclusions

- Earth's surface temperatures have been rising by about 0.2K per decade since 1981.
- It is now well established (beyond doubt) that the climate is changing and that greenhouse gas concentrations have reached record levels and will continue to increase rapidly.
- These changes are unprecedented, for more than half a million years, in their amplitude but especially in their speed. Climate change and global warming pose a severe threat to humanity.

Observe, understand, act and preserve the planet!

Spatio-temporal resolution with high accuracy measurements →

Thank you for your attention

Conclusions

• **Année 2019 : Mise en œuvre de la mission UVSQ-SAT**
- Nicolas Muscat – 4 mois (100%) – Ecole d'ingénieurs ESTACA.
- Guillaume Leon-Henri – 1 an (100%) – CNAM.
- Ahmed Aboulila – 4 mois (100%) – IUT Ville d'Avray.
- Etudiants de la Licence Professionnelle SIMIS (Systèmes Intelligents Mécatroniques pour l'Industrie et le Spatial).

• **Année 2018 : Plan de mission**
- Roxane MORICE – 3 mois (100%) – Master M2 (Outils et Systèmes de l'Astronomie et de l'Espace).
- Bastien BEAUMONT – 3 mois (100%) – Master M2 (Outils et Systèmes de l'Astronomie et de l'Espace).
- Etudiants de la Licence Professionnelle SIMIS (Systèmes Intelligents Mécatroniques pour l'Industrie et le Spatial).

• **Avant 2018 : Période Pre-Mission**
- Georges Giakoumakis – 3 mois (100%) – Master M2 (Outils et Systèmes de l'Astronomie et de l'Espace).
- Alexandre Malecot – 3 mois (100%) – Master M2 (Outils et Systèmes de l'Astronomie et de l'Espace).
- Guillaume Stankowiak – 3 mois (100%) – Master M2 (Outils et Systèmes de l'Astronomie et de l'Espace).
- Maxime Quesnel – 3 mois (100%) – Master M2 (Outils et Systèmes de l'Astronomie et de l'Espace).
- Marine Brand – 4 mois (100%) – Ecole d'ingénieurs ESTACA.
- Loïc Wauquiez – 4 mois (100%) – Ecole d'ingénieurs ESTACA.
- Helix Osabuohien Aideyan – 2.5 mois (100%) – Master M2 (Eco-innovation).
- Thibault Bonnit – 3 mois (100%) – Ecole d'ingénieurs ESTACA.
- 34 étudiants de l'école Polytechnique (projet tutoré de 80 heures par an)

+ 50 étudiants formés aux sciences spatiales

→ Climat, Physique solaire, relations Soleil-Terre, véhicules spatiaux, instrumentation spatiale, télédétection, analyse et traitement de données, optique, thermique, outils de simulation en physique et mécanique (SIEMENS NX, Matlab), production et consommation énergétique, …

Conclusions

remote sensing

IMPACT FACTOR 4.118

CERTIFICATE of PUBLICATION

Certificate of publication for the article titled:

UVSQ-SAT, a Pathfinder CubeSat Mission for Observing Essential Climate Variables

Authored by:

Mustapha Meftah; Luc Damé; Philippe Keckhut; Slimane Bekki; Alain Sarkissian; Alain Hauchecorne; Emmanuel Bertran; Jean-Paul Carta; David Rogers; Sadok Abbaki; Christophe Dufour; Pierre Gilbert; Laurent Lapauw; André-Jean Vieau; Xavier Arrateig; Nicolas Muscat; Philippe Bove; Éric Sandana; Ferechteh Teherani; Tong Li; Gilbert Pradel; Michel Mahé; Christophe Mercier; Agne Paskeviciute; Kevin Segura; Alicia Berciano Alba; Ahmed Aboulila; Loren Chang; Amal Chandran; Pierre-Richard Dahoo; Alain Bui

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