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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Paris, France
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**

1. Studies + Development
2. 07/02/2008
3. Exploitation
4. 13/02/2017
5. End of Life
6. Scientific exploitation
7. +40 papers

**PICARD**

**SODISM PREMOS SOVAP BOS PGCU**

1. Studies
2. Fin 2004
3. Development
4. 15/06/2010
5. Exploitation
6. 04/04/2014
7. End of Life
8. Scientific exploitation
9. +50 papers

**PICARD-SOL**

**SODISM II MISOLFA CIMEL Pyranometer Caméra**

1. Studies + Development
2. 01/03/2011
3. Exploitation
4. +10 papers
0 – Experience & heritage

- **SoHo** (1995-...): GOLF (IAS) + MDI (Stanford)
- **SORCE** (2003-...): SOLSTICE + SIM + TIM (LASP – Boulder)
- **PROBA 2** (2009-...): LYRA (ORB & PMOD)
- **SDO** (2010-...): HMI (Stanford + Hawaii Universities)
0 – Experience & heritage

MicroCarb 2021-...

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)

<table>
<thead>
<tr>
<th>Essential Climate Variable</th>
<th>Absolute measurement uncertainty at 1σ</th>
<th>Stability per decade at 1σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEI</td>
<td>+/- 1 W.m⁻²</td>
<td>+/- 0.1 W.m⁻²</td>
</tr>
<tr>
<td>SSI (215 nm)</td>
<td>+/-1.7 10⁻⁴ W.m⁻².nm⁻¹</td>
<td>+/-3.4 10⁻⁵ W.m⁻².nm⁻¹</td>
</tr>
<tr>
<td></td>
<td>+/-0.5 %</td>
<td>+/-0.1 %</td>
</tr>
</tbody>
</table>

1 – Scientific objectives

- **Earth Energy Imbalance (EEI)**

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

\[ \text{EEI} = 340.4 - (99.9 + 239.9) > 0 \]

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

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

Global Temperature Relative to 1800-1900 (°C)

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

→ Monitoring with high accuracy 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

- 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.

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), ...).
3 – UVSQ-Sat, a first pathfinder CubeSat

<table>
<thead>
<tr>
<th>Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbit</td>
<td>SSO</td>
</tr>
<tr>
<td>Design life time</td>
<td>1 year for LEO</td>
</tr>
<tr>
<td>Launch date</td>
<td>Q1 2021 / Q2 2021</td>
</tr>
<tr>
<td>Size</td>
<td>1 U</td>
</tr>
<tr>
<td>Mass</td>
<td>1.6 kg</td>
</tr>
<tr>
<td>Solar cells</td>
<td>12</td>
</tr>
<tr>
<td>Batteries</td>
<td>22.5 Wh @ 8 V</td>
</tr>
<tr>
<td>Power generated</td>
<td>2.3 W</td>
</tr>
<tr>
<td>Power consumption</td>
<td>1.6 W</td>
</tr>
<tr>
<td>ADCS</td>
<td>3-axis magnetometer</td>
</tr>
<tr>
<td></td>
<td>6 SLCD-61N8 photodiodes</td>
</tr>
<tr>
<td>CDHS and OBC</td>
<td>400 MHz, 32-bit ARM9</td>
</tr>
<tr>
<td></td>
<td>32 MB SDRAM</td>
</tr>
<tr>
<td></td>
<td>2x2 GB SD-cards</td>
</tr>
<tr>
<td></td>
<td>1 MB NOR flash</td>
</tr>
<tr>
<td></td>
<td>I²C, SPI, UARTs</td>
</tr>
<tr>
<td>Data downlink</td>
<td>1.2/9.6 kbps</td>
</tr>
<tr>
<td>Data uplink</td>
<td>9.6 kbps</td>
</tr>
<tr>
<td>Ground contact station</td>
<td>Less than 1 hour per day</td>
</tr>
<tr>
<td>Downlink UVSQ-SAT data</td>
<td>2 Mbyte per day</td>
</tr>
<tr>
<td>Uplink UVSQ-SAT data</td>
<td>0.3 Mbyte per day</td>
</tr>
<tr>
<td>Transponder</td>
<td>Link with amateur radio</td>
</tr>
<tr>
<td>Payload</td>
<td>12 ERS</td>
</tr>
<tr>
<td></td>
<td>4 DEVINS</td>
</tr>
<tr>
<td></td>
<td>1 TW sensor</td>
</tr>
<tr>
<td>Launch adapter</td>
<td>ISIPOD CubeSat deployer</td>
</tr>
</tbody>
</table>

### UVSQ-SAT roadmap

<table>
<thead>
<tr>
<th>Absolute uncertainty</th>
<th>Stability per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pm 15 \text{ Wm}^{-2}$ at $1\sigma$</td>
<td>$\pm 5 \text{ Wm}^{-2}$ at $1\sigma$</td>
</tr>
<tr>
<td>$\pm 8.5 \times 10^{-4} \text{ Wm}^{-2}\text{nm}^{-1}$ at $1\sigma$</td>
<td>$\pm 1.7 \times 10^{-4} \text{ Wm}^{-2}\text{nm}^{-1}$ at $1\sigma$</td>
</tr>
</tbody>
</table>

Follow us on Twitter: @uvsqsat
3 – UVSQ-Sat, a first pathfinder CubeSat

- **Solar panel**
- **Solar cell**
- **Payload Board**
  - **iOBC + DB**
  - **TRXVU**
- **Structure**
- **ERS**
  - Thermopile with carbon nanotubes
  - *Incoming solar radiations + outgoing terrestrial radiations*
- **ERS**
  - Thermopile with optical solar reflector
  - *Outgoing shortwave radiations*
- **DEVINS**
  - UV photodiode
  - *Solar spectral irradiance in the Herzberg continuum*
- **iMTQ**
- **iEPS**

→ Payload Sensors with broad bands Field of View
3 – UVSQ-Sat, a first pathfinder CubeSat

![Project Timeline Diagram]

**Timeline Key Events:**
- **Project Start Date:** 11/2018
- **PDR 10/2019**
- **CDR 02/2020**
- **Launch 12/2020**
- **SC delivery 10/2020**
- **Operations**

**Launch Option Table:**

<table>
<thead>
<tr>
<th></th>
<th>Soyuz / ISILAUNCH 27</th>
<th>Falcon 9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Launch vehicle:</strong></td>
<td>Baikonur/Vostochny</td>
<td>Vandenberg</td>
</tr>
<tr>
<td><strong>Launch site:</strong></td>
<td>From Q1 2021</td>
<td>From Q4 2020</td>
</tr>
<tr>
<td><strong>Launch period:</strong></td>
<td>475-550 km SSO, LTAN 11:00</td>
<td>450-720 km SSO, LTAN 09:30-14:00</td>
</tr>
<tr>
<td><strong>Typical orbit parameters:</strong></td>
<td>QuadPack</td>
<td>QuadPack</td>
</tr>
<tr>
<td><strong>Deployer type:</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3 – UVSQ-Sat, a first pathfinder CubeSat

Falcon 9

Soyuz 2

Payload fairing

Stage 3

RD-0124DR engine

Stage 2

(Core stage)

Stage 1

Four strap-on boosters; two not shown

NK-33-1 engine

RD-107A engine (4)
4 – Development

**Satellite definition & simulations**

Since 2018

**Electrical Design**

**Optical Design**

- ERS → Carbon nanotubes (in green)
- Solar cells (in cyan)
- Machined stainless steel (in red)
- Batteries (in orange)
- Black anodize (in blue)
- ERS → OSR Qioptic (in green)
- FR4 (in magenta)
- DEVINS → black anodize on all faces except the contact face

**CAD Design**

**Finite Element Model Analysis**

**Thermal Analysis**
4 – Development

Software

**SW Modes**

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

*Since November 2019*
4 – Development

Satellite AIV
4 – Development

Satellite AIV
4 – Development

Satellite AIV
4 – Development

Satellite AIV
4 – Development

Satellite AIV
4 – Development

Satellite AIV

MAPSIL® QS1123 THIXO-B
LOW OUTGASSING SILICONE ELASTOMER FOR SPACE APPLICATIONS

PSX primer
ADHESION PRIMER FOR SPACE USE

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
4 – Development

Satellite AIV
4 – Development

Satellite AIV
4 – Development
4 – Development

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical Value</th>
<th>Unit</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>CubeSat category</td>
<td>10</td>
<td>[U]</td>
<td></td>
</tr>
<tr>
<td>Form Factor</td>
<td>11.4 x 11.1 x 11.1</td>
<td>[cm]</td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>1.146</td>
<td>[kg]</td>
<td></td>
</tr>
<tr>
<td>- total mass of the platform</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>1.37</td>
<td>[W]</td>
<td>nominal operation</td>
</tr>
<tr>
<td>- power consumed by the platform</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Storage</td>
<td>2x2</td>
<td>[GB]</td>
<td></td>
</tr>
<tr>
<td>- storage capacity flight control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Downlink - Telecommand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Frequency</td>
<td>437.020</td>
<td>[MHz]</td>
<td>UHF band, amateur range</td>
</tr>
<tr>
<td>- Antenna configuration</td>
<td>Dipole</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Data rate</td>
<td>9.6 (min 1.2)</td>
<td>[kbps]</td>
<td></td>
</tr>
<tr>
<td>Uplink - Telemetry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Frequency</td>
<td>145.830</td>
<td>[MHz]</td>
<td>VHF band, amateur range</td>
</tr>
<tr>
<td>- Antenna configuration</td>
<td>Dipole</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Data rate</td>
<td>9.6</td>
<td>[kbps]</td>
<td></td>
</tr>
<tr>
<td>Architecture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Redundancy level</td>
<td>Single String</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Antenna

Attenuator
4 – Development

Payload

Work in Progress since January 2020

Earth radiative sensors
4 – Development

Payload

UV photodiodes

Work in Progress since January 2020

Rogers et al. (2018)
4 – Development

Payload

Teach’ Wear

Work in Progress since August 2019

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

Payload main board plugged on CSKB connector (PC104, two rows H1 & H2)

Daughterboard

GND

I2C bus

3V3 Switchable

5V Switchable

Mechanical fastening

iOBC

J3 (GPIO)

J2 (SPI)
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.

- ...
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

- Shock

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Qualification</th>
<th>Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>Recommended</td>
<td>Required</td>
</tr>
<tr>
<td>Directions</td>
<td>{BRF}</td>
<td>X, Y, Z</td>
</tr>
<tr>
<td>Profile</td>
<td>Frequency [Hz]</td>
<td>Amplitude [g/Hz]</td>
</tr>
<tr>
<td></td>
<td>LV stages</td>
<td>Fregat</td>
</tr>
<tr>
<td>20 – 50</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>50 – 100</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>100 – 200</td>
<td>0.02 – 0.05</td>
<td>0.02</td>
</tr>
<tr>
<td>200 – 500</td>
<td>0.03</td>
<td>0.02 – 0.008</td>
</tr>
<tr>
<td>500 – 1000</td>
<td>0.05 – 0.025</td>
<td>0.008 – 0.004</td>
</tr>
<tr>
<td>1000 – 2000</td>
<td>0.025 – 0.013</td>
<td>0.002 – 0.002</td>
</tr>
</tbody>
</table>

Shock spectrum corresponds to Q = 10.
<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-system</th>
<th>Tmin off</th>
<th>Tmin operational</th>
<th>Tmax operational</th>
<th>Tmax off</th>
<th>Heritage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td>Structure (STS-1U)</td>
<td>-40</td>
<td>80</td>
<td>80</td>
<td>2013</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Communication board (TRXVU)</td>
<td>-40</td>
<td>60</td>
<td>80</td>
<td>2016</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Antennas (AntS)</td>
<td>-50</td>
<td>70</td>
<td>85</td>
<td>2010</td>
<td></td>
</tr>
<tr>
<td>CDHS</td>
<td>On-Board Computer (iOBC + DB)</td>
<td>-40</td>
<td>65</td>
<td>80</td>
<td>2013</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>Electrical Power System (iEPS – type A – 22.5 WH)</td>
<td>-40</td>
<td>70</td>
<td>85</td>
<td>2017</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Battery Cells on iEPS In charge</td>
<td>-40 N/A</td>
<td>85</td>
<td>45</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Solar panels (SPA 3G30A)</td>
<td>-40</td>
<td>125</td>
<td>125</td>
<td>2017</td>
<td></td>
</tr>
<tr>
<td>ADCS</td>
<td>Magnetorquers board (iMTQ)</td>
<td>-40</td>
<td>70</td>
<td>70</td>
<td>2016</td>
<td></td>
</tr>
<tr>
<td>Payload</td>
<td>UV detectors (DEVINS)</td>
<td>-50</td>
<td>90</td>
<td>100</td>
<td>New</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IR detectors (ERS)</td>
<td>-50</td>
<td>90</td>
<td>100</td>
<td>New</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Physiologic detectors (Teach-Wear)</td>
<td>-50</td>
<td>60</td>
<td>70</td>
<td>New</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Payload board (PB)</td>
<td>-50</td>
<td>60</td>
<td>70</td>
<td>New</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Harness &amp; other</td>
<td>-50</td>
<td>60</td>
<td>70</td>
<td>New</td>
<td></td>
</tr>
</tbody>
</table>

**Thermic**

**PFM tests recommendations:**

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

<table>
<thead>
<tr>
<th>Frequency band</th>
<th>Electric field strength maximum recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>140-150MHz</td>
<td>3 V/m</td>
</tr>
<tr>
<td>400-450MHz</td>
<td>6 V/m</td>
</tr>
</tbody>
</table>

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

\[ R_{\text{TOT}}(\theta_i, \phi_i) = \int \text{BRDF}(\theta_d, \phi_d, \theta_i, \phi_i) \, d\Omega = \int \int \text{BRDF}(\theta_d, \phi_d, \theta_i, \phi_i) \cos(\theta_d) \, |\sin(\theta_d)| \, d\theta_d \, d\phi_d \]
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

Mission operations center

Operational since January 2020
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
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

CERTIFICATE of PUBLICATION

Certificate of publication for the article titled:
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