UVSQ SAT NG : a pathfinder CubeSat for monitoring greenhouse gases and Earth's Outgoing Radiations

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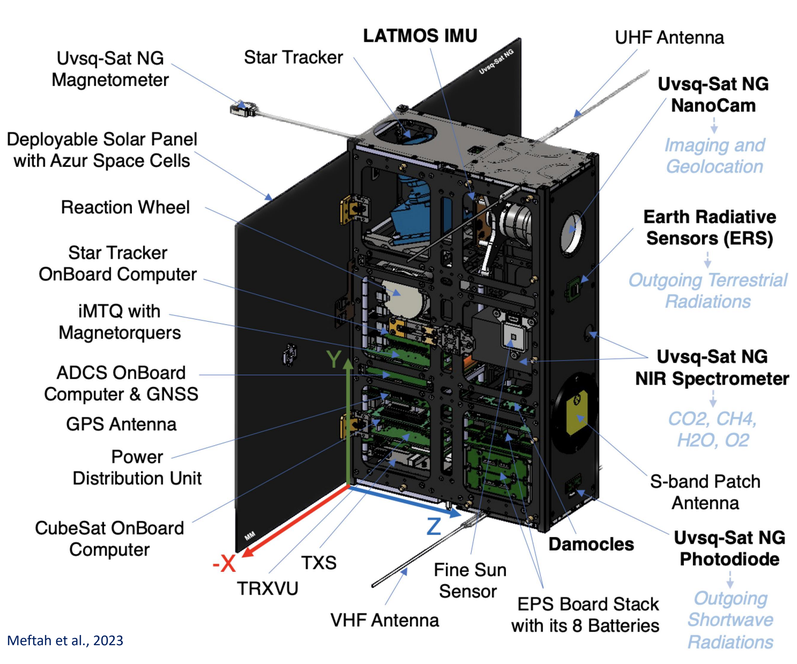
1- Abstract

UVSQ SAT NG is a French CubeSat scheduled for launch in 2025. Conceived and designed at Laboratoire Atmosphère & Observations Spatiales (LATMOS), it follows the path of the laboratory's first two satellites: UVSQ SAT and INSPIRE SAT 7, respectively launched in January 2021 and April 2023 and operational since then. LATMOS is a French laboratory specialized in the study of the Earth and its climate. Climate is a major issue for our century, and CubeSats have the potential to meet the need for data on Earth-Sun relations. These three satellites are designed to study and observe Essential Climate Variables (ECV) such as radiative fluxes at the Top Of the Atmosphere (TOA). Together, the three satellites will form a constellation for observing the Earth's Radiation Imbalance (EEI) using radiometers. In addition, UVSQ SAT NG is an ambitious CubeSat that will use a miniature spectrometer to study greenhouse gases in the atmosphere such as CO_2 and CH_4.

2- Description of the CubeSat



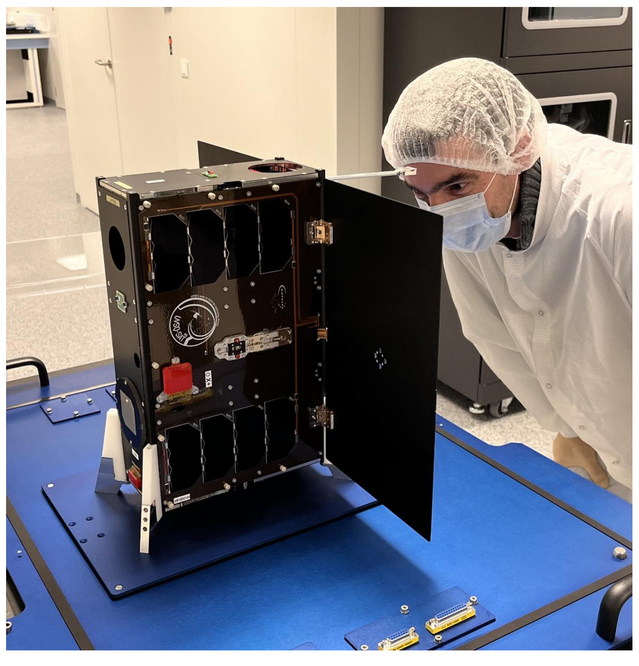

LATMOS credits

Figure 1: UVSQ SAT NG design / Flight model

UVSQ SAT NG is a 6-units CubeSat intended to be placed in low orbit (maximum of 600 km) on a Sun-Synchronous Orbit. The satellite is equipped with two deployable solar panels and a deployable magnetometer which create a satellite of 111.3 × 36.6 × 38.8 cm. The maximum total weight of the whole system is 10 kg.

For communication, UVSQ SAT NG uses UHF (145.8 to 146.0 MHz) and VHF (148 to 150.5 MHz) band thanks to UHF/VHF antennas. To improve telemetry and data downloading with the ground station, the satellite is equipped with an S-band (between 2200 and 2290 MHz). The LATMOS has its own satellite command and control center. UVSQ SAT and INSPIRE SAT 7 are both operated within the laboratory.

In order to fulfill its scientific mission, UVSQ SAT NG requires a fine and precise pointing of its elements. To this end, it is equipped with an Attitude Determination And Control System (ADCS) that can achieve pointing accuracy of up to 0.01°. The ADCS consists of few sensors to determine attitude like a Star Tracker, photodiodes, Fine Sun Sensors, the LATMOS Inertial Measurement Unit (IMU), gyroscopes and magnetometers. All the data from these instruments is used to accurately determine the satellite's attitude, which is then corrected by a servo loop. Attitude correction is performed by two on-board systems: three magnetorquers and three reaction wheels.

3- Scientific objectives of the Uvsq-Sat NG mission

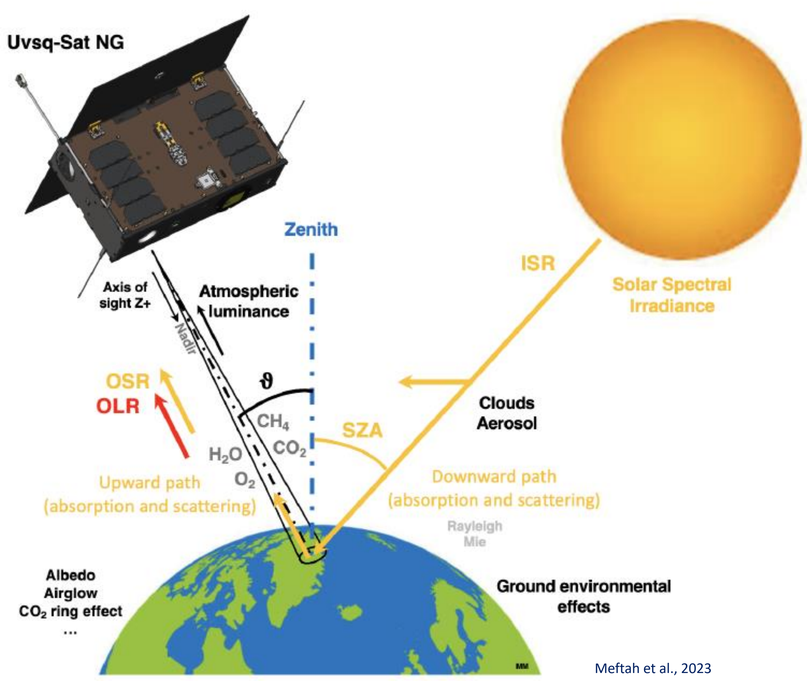


Figure 2: Observation approach used by Uvsq-Sat NG to monitor GHG

UVSQ SAT NG's main mission is the study of greenhouse gases. In particular, CO_2 and CH_4 are the two anthropogenic gases with the greatest impact on climate. The satellite uses a near-infrared spectrometer to observe solar flux backscattered by the atmosphere. The CO_2 and the CH_4 concentrations are determined from the solar spectrum. To achieve scientific requirements, the accuracies must be better than 1 ppm for the CO_2 measurements and better than 10 ppb for the CH_4 ones. Gases are studied with a ground resolution of 2 km.

Like UVSQ SAT and INSPIRE SAT 7, UVSQ SAT NG studies the Earth's Energy Imbalance. The expected resolutions for measurements of variations in Outgoing Shortwave Radiation (OSR) and Outgoing Longwave Radiation (OLR) at the TOA are 1.00 W/m².

On-board Instruments and Payloads

To carry out its scientific missions, UVSQ SAT NG is equipped with various payloads:

- Two Earth Radiative Sensors, one able to measure OSR and the other OLR at the TOA. This technology is already being used and validated by UVSQ SAT and INSPIRE SAT 7 missions. The spatial resolution of such sensors is 2500 km.
- A NanoCamera used for geolocation and for Solar flux observations between 390-690 nm. With a field of view of 13° and an entrance aperture of 32 mm, the ground footprint is about 77 km. The spatial resolution will be better than 30 m on the ground. This high-resolution miniaturized camera in a visible range will provide Earth observations.
- A miniaturized low resolution spectrometer which will analyze near-infrared fluxes in the atmosphere (1200-2000 nm) to measure CO_2 and CH_4 concentrations. The ground resolution of this instrument is 2 km. The NIR Spectrometer consists of a 300 gr/mm blazed grating and a parabolic mirror. For detection, the instrument uses an InGaAs linear image sensor. The detector is cooled by a Peltier thermoelectric cooler, which keeps the temperature below -5°C. Measurement resolution is limited by the miniaturization of optics and the SNR received by the sensor.

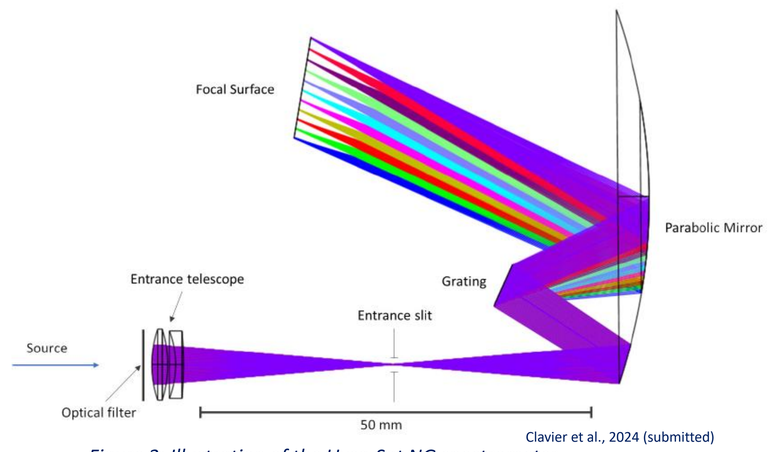


Figure 3: Illustration of the Uvsq-Sat NG spectrometer

Conclusions and perspectives

Studying the Earth's Energy Imbalance (EEI) at the TOA is fundamental to understand climate change. Similarly, the study of greenhouse gases such as CO2 and CH4 with a spatial resolution of a few kilometers and a temporal dynamic of a few hours enables near-real-time monitoring of emissions. Following the success of the UVSQ SAT and INPIRE SAT 7 missions, UVSQ SAT NG will initiate its own constellation to study greenhouse gases. A constellation of CubeSats for climate is a key prospect for a dynamic study of GHG emissions. CubeSats are a major asset for space science, enabling the development of new technologies to benefit climate research.

References :
- UVSQ-SAT, a Pathfinder CubeSat Mission for Observing Essential Climate Variables, M. Meftah, L. Damé, P. Keckhut 2020
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- Uvsq-Sat NG, a New CubeSat Pathfinder for Monitoring Earth Outgoing Energy and Greenhouse Gases, M. Meftah, C. Clavier, A. Sarkissian et al. 2023

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