SIMBA

A CubeSat to measure Sun-Earth Imbalance

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Absolute Radiometry
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Solar-Terrestrial Centre of Excellence (STCE)
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October 12, 2021

RMIB, Laboratory for Absolute Radiometry

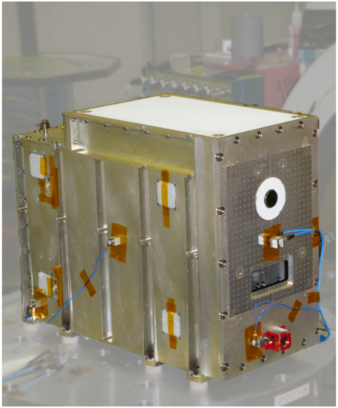
Who are we?

Royal Meteorological Institute of Belgium, south of Brussels

SOLAR : Sun Observation and Laboratory for Absolute Radiometry

Activities

RMIB, Laboratory for Absolute Radiometry

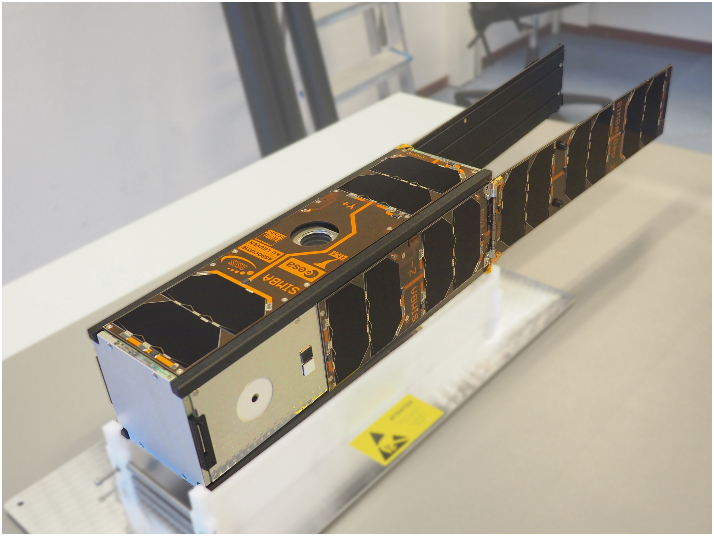


SovaP radiometer during PICARD integration

during a former ICP, Davos, CH

SIMBA : first CubeSat mission

RMIB, Laboratory for Absolute Radiometry



Simba in short

SIMBA : first CubeSat mission

The Satellite

- 3U CubeSat, 4kg, 3.5W, 0.6 MB/day downlink
- Shared-ride proof-of-concept:
  - Payload by RMI
  - ADCS by KUL/Arcsecs
- kicked off 2014, launched 9/2020
- mission duration : 2–3 years

Scientific Payload

Goal : measure and monitor the ERB

Method : Single Absolute radiometer, swivel from Earth to Sun

The BUS

Satellite's features

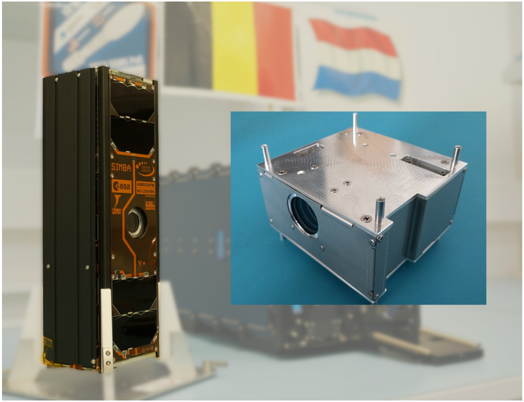
Conception and built : ISISpace, Delft, The Netherlands

ISIS

Power, communications, on-board computer

The ADCS

Satellite's features



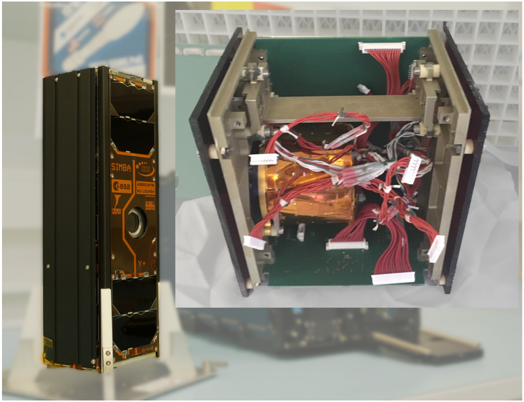
Conception and built : Arcsec, spinned off KULeuven, Belgium

Star tracker, inertial wheels and magnetotorquers

$\delta\angle \approx 0.1\,\mathrm{deg}$

The Payload Bay

Satellite's features



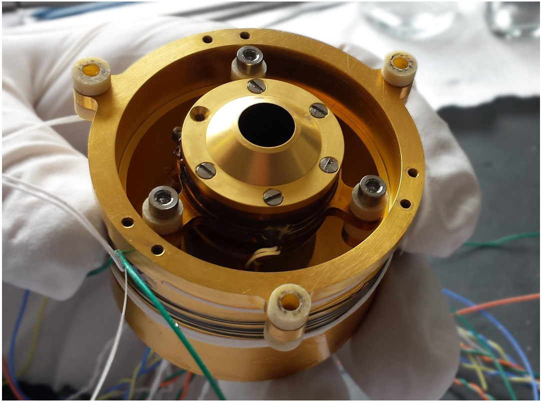
Conception and built : SOLAR group, RMI, Belgium

Cavity + sensors, data acquisition and storage

Bolometric cavity

The Payload Bay

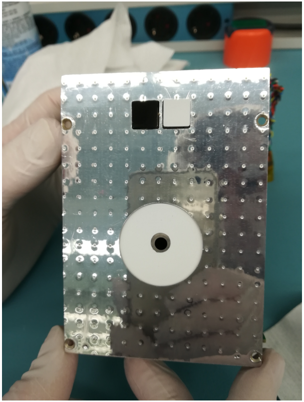
Bolometric cavity, gold plated anodized aluminium, Velvet Black coating



Cavity's aperture

The Payload Bay

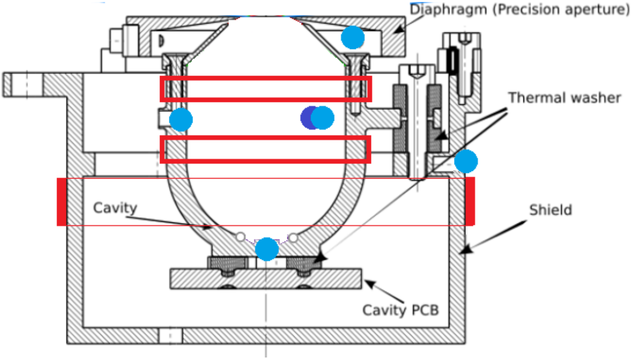
Nadir face of the Sensors bay : cavity precision aperture (Ti + coating), diameter = 5 mm, view angle = 135 deg



Cavity's sensors and heaters

The Payload Bay

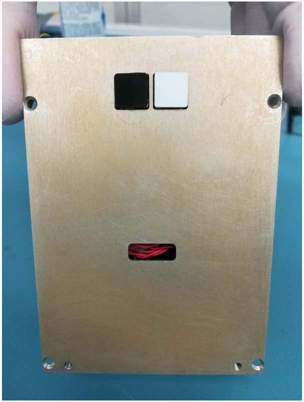
Cavity	2 heating wires + 4 NTC temperature sensors
Shield	1 heating wire + 1 NTC
prec. ap.	1 NTC



Flat Surface Spectral sensors (FSS)

The Payload Bay

1 cm^2, coated with Velvet Black and white paint to discriminate SWR and LWE

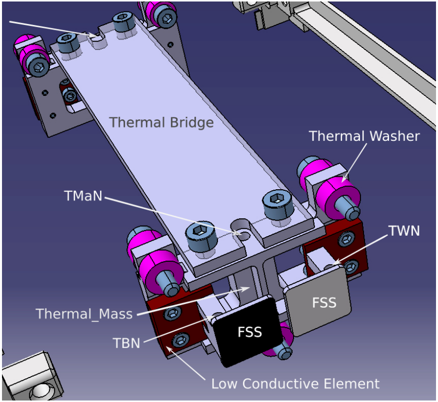


Zenith face with complementary FSS sensors.

Flat Surface Spectral sensors (FSS)

The Payload Bay

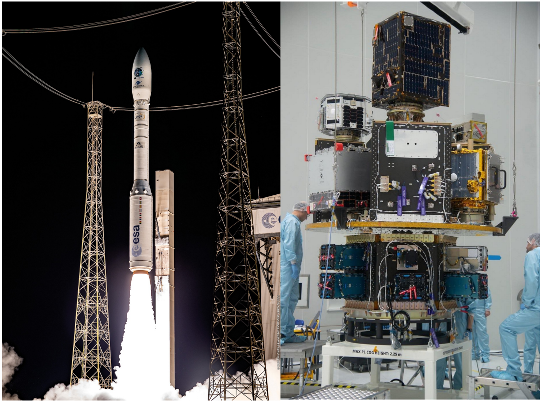
FSS : flux monitored (ΔT betweel surf. and thermal mass), Thermal bridge between the faces



Launch

Early Flight

Launched with Vega VV16, Small Spacecraft Mission Service (SSMS) PoC (53 CubeSats and two small sats on a single platform) on September the 3rd, 2020, from Kourou.



SIMBA in Space

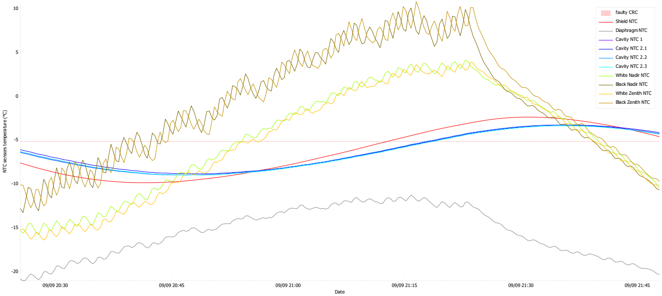
Earl Flight

Orbit	"Sun-synchronous", polar orbit
inclination	97 deg
altitude	550 km
period	$\approx$ 90 min
flight-by	3–5 useful flight-by of ground station in Delft per day

First lights

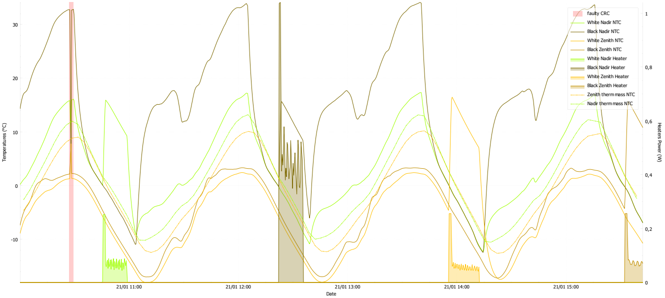
Early Flight

First payload test on sept 9, 2020, passive acquisition, $\approx$ 1 orbit



FSS Heater test

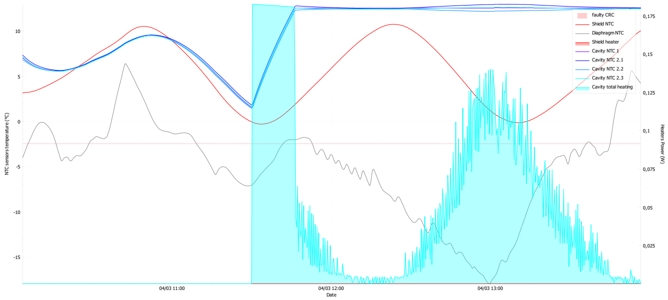
Temperature regulation test



FSS heated to keep a constant temperature difference with their thermal mass.

Cavity first regulation test

Temperature regulation test



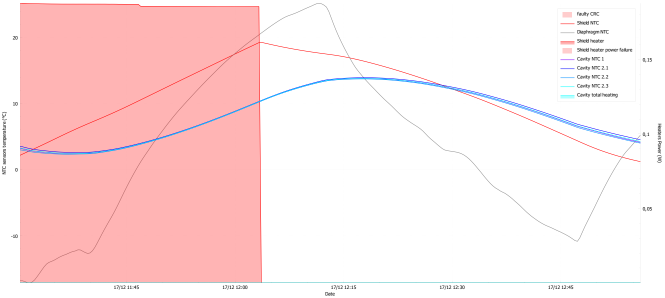
Cavity can be regulated at a constant temperature with a st. dev as low as 0.01 °C on the feedback-providing NTC

but

anisotropy with st. dev. on other NTC up to 0.2 °C

Cavity heater malfunction

Temperature regulation test



Shield's heater always at nominal power, probably short-circuited, cannot set at desired temperature.

Thermal equilibrium in the cavity

Characterisation of the Cavity

Thermal equilibrium in the cavity

$$C^{\theta} \underbrace{\frac{\partial T}{\partial t}}_{=0} = P_{opt}^{in} + P_{opt}^{out} + \Delta R_{dia}^{in} + \Delta R_{dia} + \Delta R_{sh} + \Delta P_{cond} + P_{elec}$$

with

P_{opt}^{in} : the incoming radiation (what we search)

$P_{opt}^{out} = -A_{out}^{*}\sigma T_{cav}^{4}$: thermal radiation escaping the cavity

$\Delta R_{dia}^{in} = A_{dia,in}^{*}\sigma(T_{dia}^{4} - T_{cav}^{4})$: radiation exchange between the precision aperture and the cavity's inside

$\Delta R_{dia} = A_{dia}^{*}\sigma(T_{dia}^{4} - T_{cav}^{4})$: radiation exch. between the prec. ap. and the cavity's outer walls

$\Delta R_{sh} = A_{sh}^{*}\sigma(T_{sh}^{4} - T_{cav}^{4})$: radiation exch. between the shield and the cavity's outer walls

$\Delta P_{cond} = S^{\theta}(T_{sh} - T_{cav})$: conductive exch. between the shield and the cavity

$P_{elec} = V^{2}/R$: the electrical power input

Thermal equilibrium in the cavity

Characterisation of the Cavity

in a perfect world

T_{cav}, T_{sh}, T_{dia} being constant, thermal equilibrium becomes

$$P_{opt}^{in} + P_{elec} = Cst$$

and thus

$$P_{elec}^{\star} - P_{elec}^{\odot} = TSI, \quad P_{elec}^{\star} - P_{elec}^{\otimes} = EOR$$

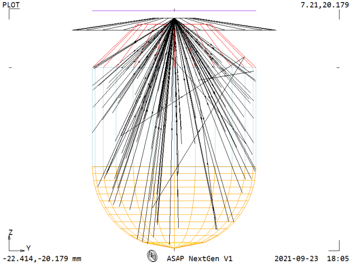
BUT

without the shield's regulation and with a precision aperture's temperature varying greatly, all the aforementioned terms must be evaluated.

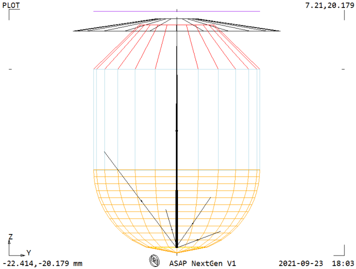
Absorption of the cavity

Characterisation of the Cavity

The absorption of the cavity was evaluated by mean of Ray-Tracing



source at aperture, Earth-like irradiation
absorption of the cavity : 98,93%



source at infinity, sun-like irradiation
absorption of the cavity : 98,958%

Work and figures by Luca Schifano, 2021

Radiative exchange with the cavity

Characterisation of the Cavity

Thermal exchange between two grey-body surfaces i & j :

$$\Delta R_{ij} = A^*_{ij}\sigma(T_i^4 - T_j^4)$$

with a fictive equivalent surface

$$A^*_{ij} = \frac{1}{\frac{1-\varepsilon_i}{\varepsilon_i A_i} + \frac{1}{A_i f_{i\to j}} + \frac{1-\varepsilon_j}{\varepsilon_j A_j}}$$

With the view factors between surface i & j :

$$A_i f_{i\to j} = A_j f_{j\to i} = \iint \frac{cos\theta_i \ \cos\theta_j}{r_{ij}^2} dA_i dA_j.$$

(view factors between geometric forms often have parametric solutions)

view factors from the cavity

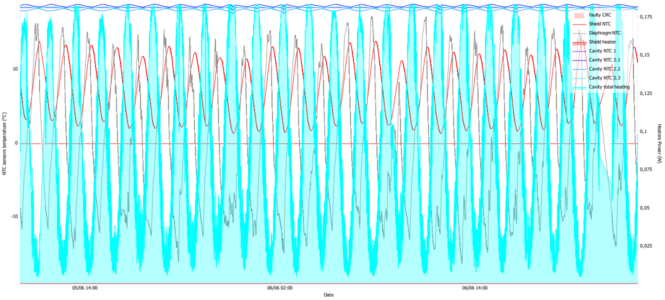
Characterisation of the Cavity

View
factors from the cavity to the shield and the precision aperture

Cavity	Shield		Diaphragm (precisio	
	base (a)	wall (b)	pierced disk (c)	rim inner wall (d)
conical top (1)			0.7487	0.1684
flat top (2)			0.8125	0.092
cylinder (3)	0.0411	0.645	0.0502	0.2173
hemisphere (4)	0.3037	0.3219		
PCB top (5)		0.0407		
PCB sides (6)	0.2271	0.7357		
PCB bottom (7)	0.9425	0.0575		

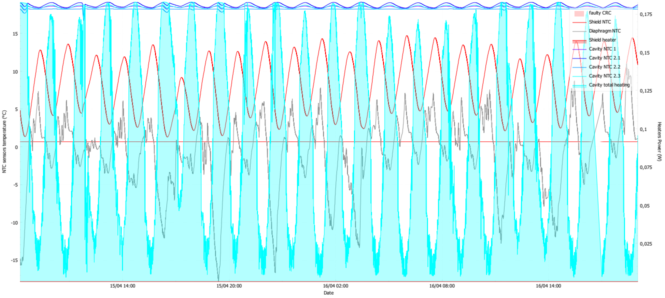
Pointing to Deep Space

Active measures



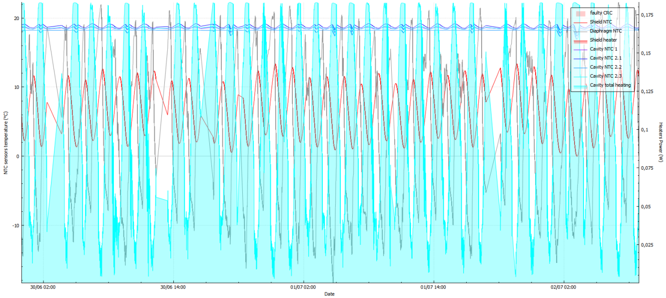
Pointing Earthwards

Active measures



Pointing Sunwards

Active measures



Discussions

Active measures

- the characterisation of the cavity as for now does not allow yet to balance the equations
- the pointing inaccuracies (the ADCS took a long time to improve)
- the minimalist design increases the cost of post treatment

Lessons learnt

Looking forward

- share-riding two PoCs brings a lot of uncertainties
- redundancy!
- updating the software in orbit might help go around the problem
- traditional designs are more cumbersome but at least more sturdy
- cavities should better be tested on the ground before in orbit