An updated status of MicroCarb Project

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MICROCARB

cnes CENTRE NATIONAL D'ÉTUDES SPATIALES

INVESTISSEMENTS D'AVENIR

UK SPACE AGENCY

Programmatic situation

- Decided in Dec. 2015 (in the frame of COP-21) by French government.
- UK joined the project in April 2017. Partnership set between CNES and UKSA
- Funding completed (development and commissioning)
- CNES conducts the project and develops the system and the satellite
- Airbus Defence and Space develops the instrument
- Thales Alenia space will perform the integration and test of the satellite
- Phase C is on –going => launch in 2021

- UK Scientists
  - ✦ UoL: University of Leicester
  - ✦ UoE: University of Edimbourgh
- Joined the French scientists
  - ✦ LSCE: Laboratoire des Sciences du Climat et de l'Environnement
  - ✦ LMD: Laboratoire de Météorologie Dynamique
  - ✦ IPSL: Institut Pierre Simon Laplace
  - ✦ LATMOS: Laboratoire Atmosphères, Milieux, Observations Spatiales

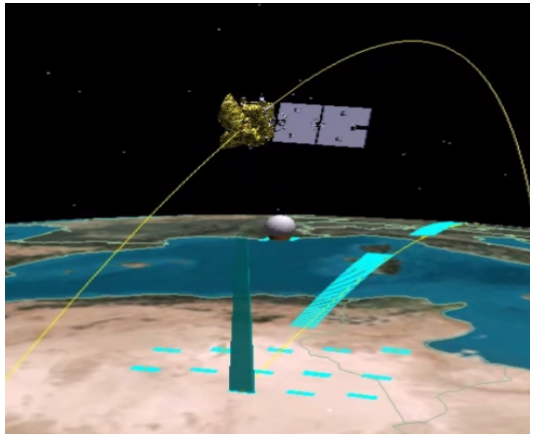
MicroCarb Mission

- Performances: : XCO_2 measurement
  - ✦ Random Noise (goal: 0. 5 ppm Threshold: 1.5 ppm)
  - ✦ Bias (systematic Error variation) < 0.2 ppm
- On ground resolution
  - ✦ Sampling mission: 3 samples every 1.4 s: Footprint 4.5 x 9 km –
  - ✦ Exploratory mode: imaging with higher resolution 2x2 km² over limited area (40x40 km²)
- Compact instrument . Compatible with microsatellite <200kg
- Orbit
  - ✦ SSO – 649 km – 10h30 LTDN or 13h30 LTAN
  - ✦ 25 days - 7 days sub-cycle
- Life time: 5 years
- Launch: as an auxiliary payload

Observation modes

Routine mode

- Nadir, Glint, Target, Scan
- With footprint: 4.5 x 9 km
- FOV/IFOV= 15

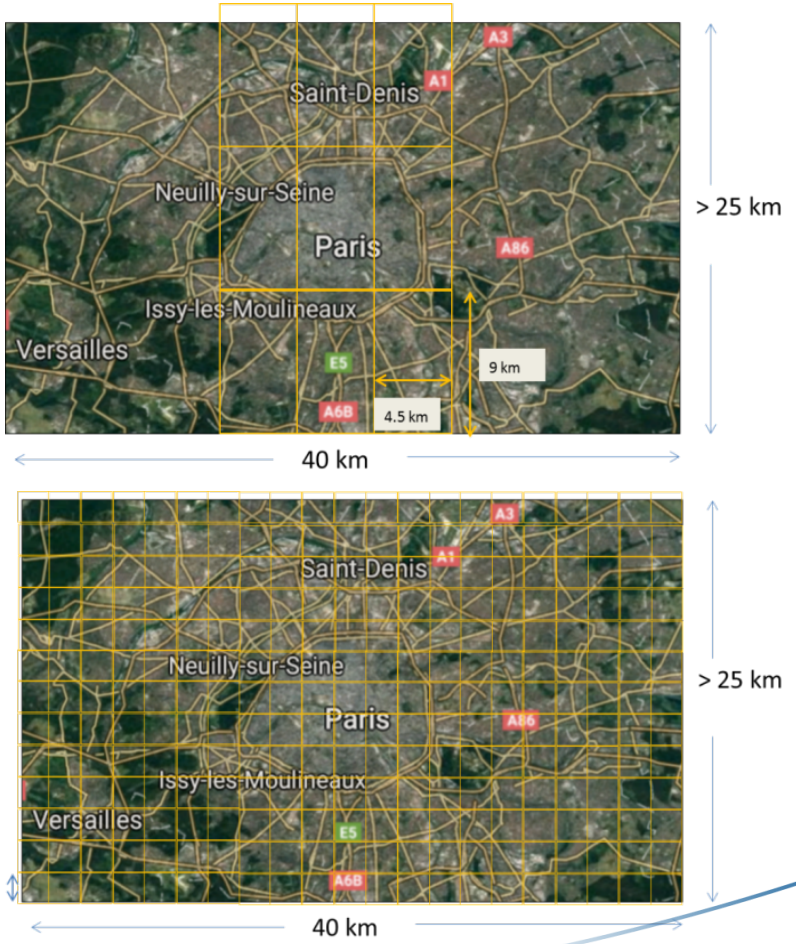


Calibration mode

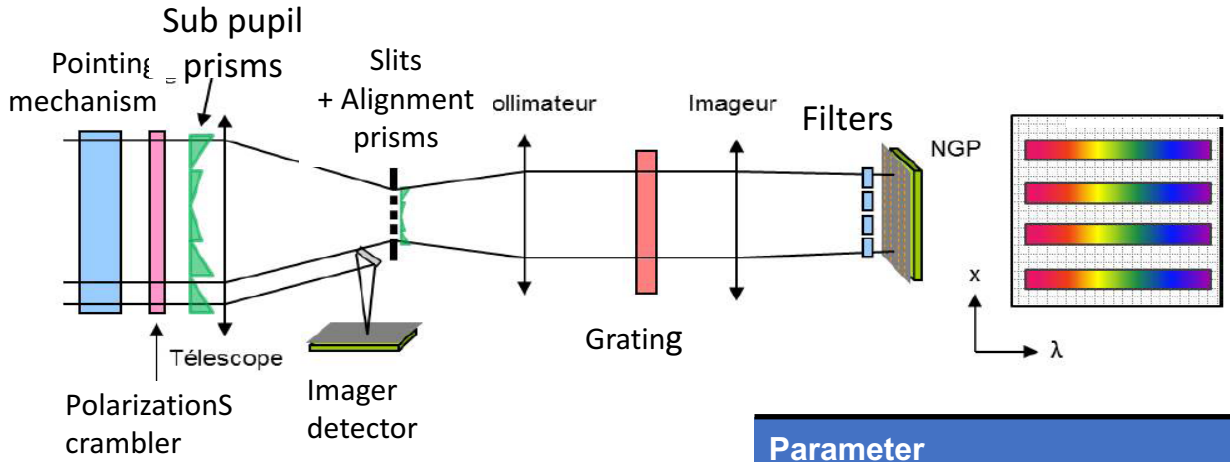
- Sun pointing
- Moon pointing

Exploratory mode: City mode

- Obtained by slowing down the satellite scrolling + scan activation + binning tuning (on ground) + integration time tuning
- No data acquisition before / after (satellite maneuver)
- Typical footprint: 2x2 km
- Typical area surface: 40x40 km²



Instrument Optical design



Unique Spectrometer

Unique detector

Imager

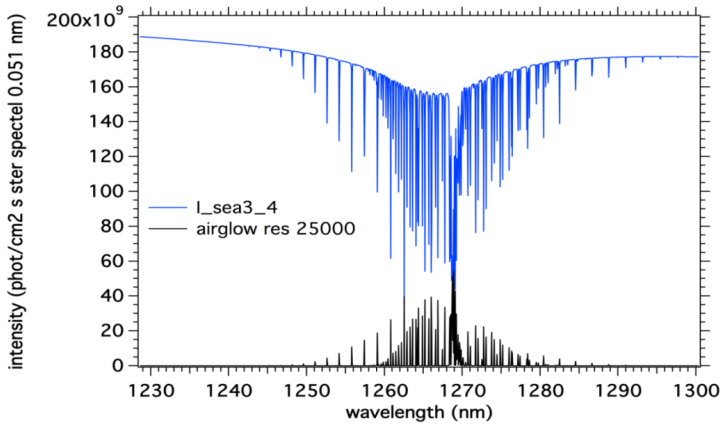
❖ Detection of sparse clouds

Parameter	Value
Central Wavelength	0.625 µ
FOV	18 x 26 km²
Resolution	140 m

Parameter	B1 (O_2)	B4 (O_2)	B2(CO_2)	B3(CO_2)
Center wavelength (nm)	763	1269	1607	2037
Bandwidth(nm)	10	17	22	27
Mean spectral resolution	24 872	24 996	24 967	24 829
Signal to Noise Ratio per channel (@mean radiance)	285	378	344	177

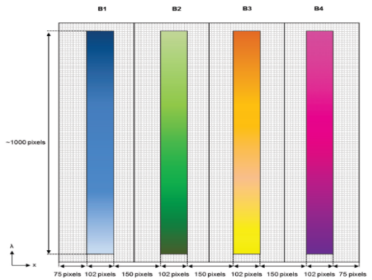
Use of 1.27 µ band O2

- Aerosols properties depends on wavelength => interest to have characterization in λ close to CO2 bands
- Band used by TCCON
- A reduction of the uncertainty on X_{CO2} is expected:
  - ✦ Better assessment of the spectral impact of aerosols and of $N_{dry\ air}$ at CO_2 wavelengths
  - ✦ Reduction of the impact of uncertainty in spectroscopy
- Affected by air glow phenomena in high stratosphere
  - ✦ Analysis has demonstrated that air glow could be modeled (Reprobus) and its effects corrected with sufficient accuracy
  - ✦ Model was verified with Sciamachy data
  - ✦ Airglow will be estimated together with O2 (as an element in 4A RTIC state vector)
- Work is in progress to improve O2 spectroscopy in this band



Focal Plane

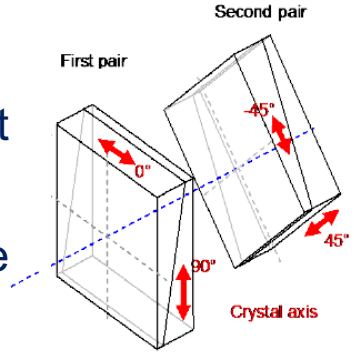
- NGP Detector(1024 x 1024). Sofradir
- Cooled down to 150 K by Passive cooling: radiator directed towards cold space
- Each band covers 100 x 1024 pixels
- Multi reading (10 Hz) mode implemented



- No processing aboard: all useful pixels downloaded => data compression implemented.

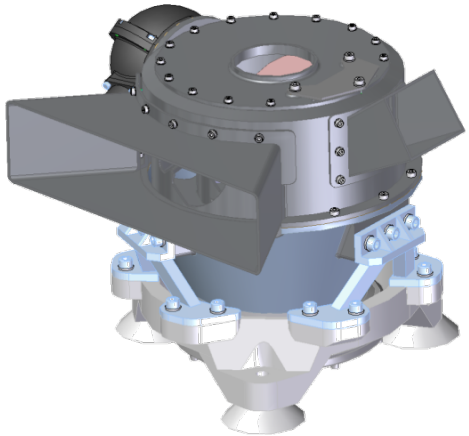
Polarization scrambler

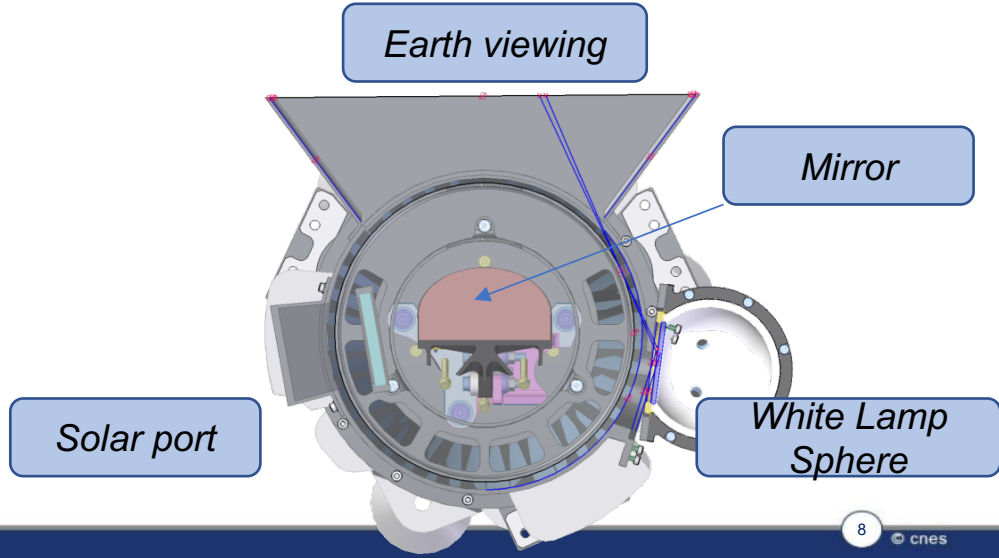
- Goal: eliminate any bias due to polarization (and in particular unknown polarization due to aerosols)
- Based on Dual Babinet
- Creates a diamond effect
- Performances: residual polarization rate
  - Glint < 0.1 %
  - Nadir < 0.5%
- Polarization will be measured at instrument level



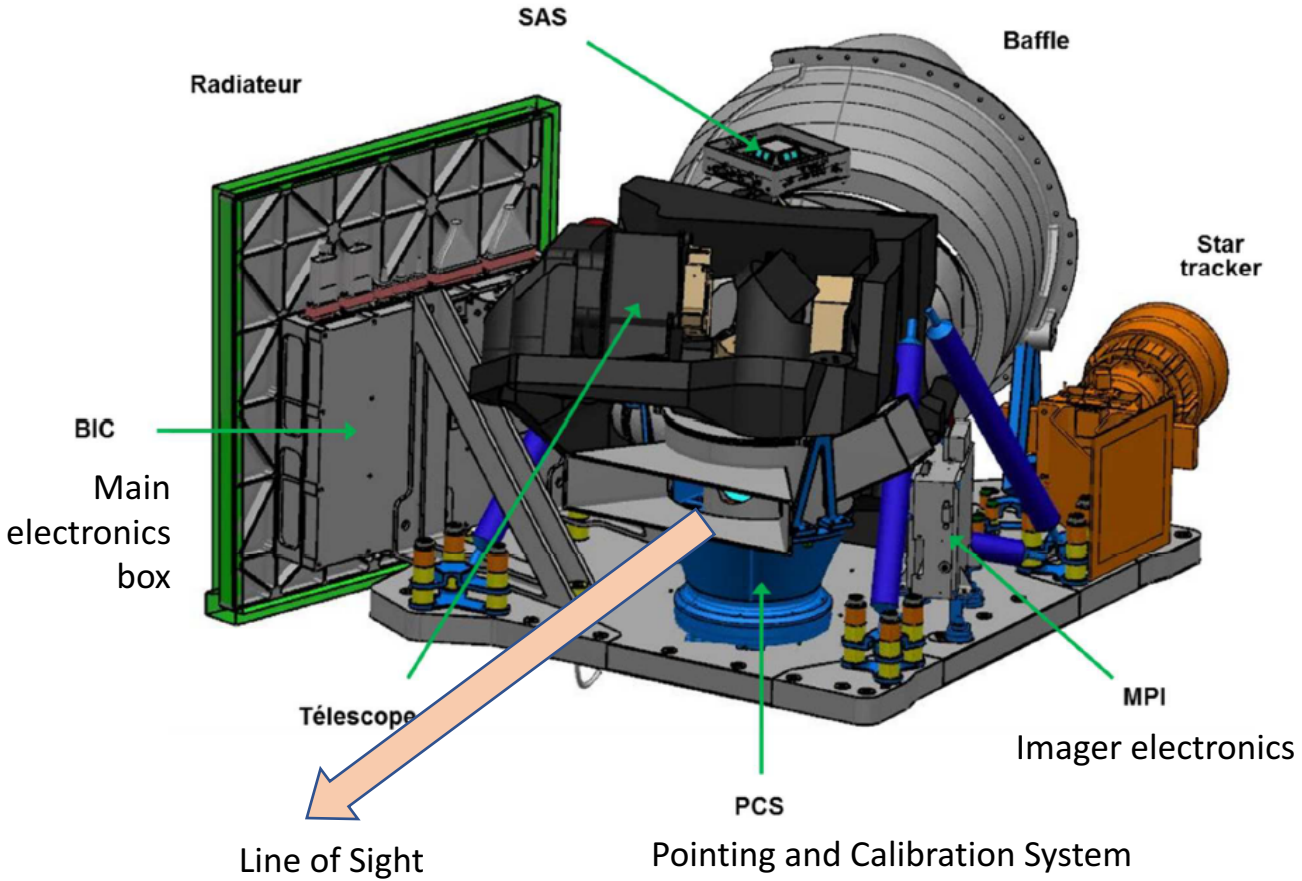
Pointing and calibration system

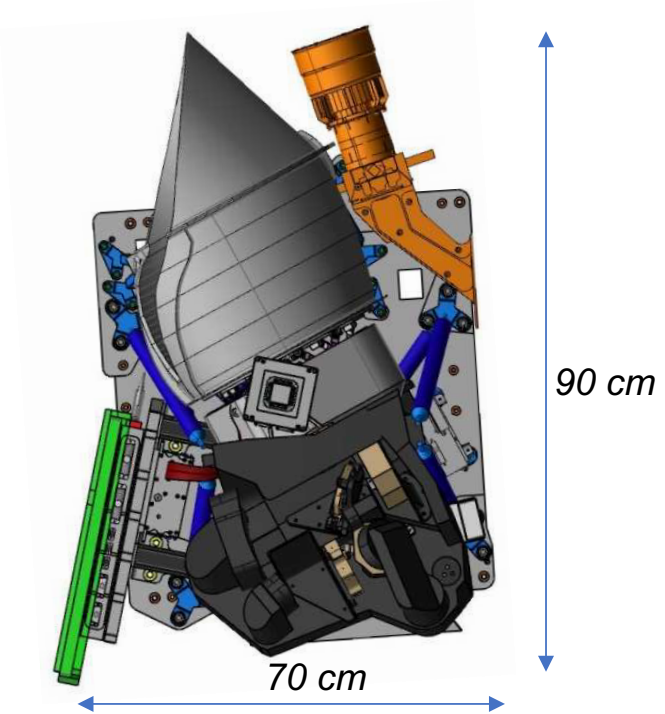
- **A scan mirror (one axis) is integrated in the instrument**
  - Releases constraints on satellite depointing capacity along roll axis (power, thermal) for target, glint, etc
  - Permits to implement the scan pointing mode over ± 35°
  - Pointing towards area without cloud (as far as possible) will be considered
- **Also used for calibration**
  - White lamp
  - Solar port with diffuser
  - And to Shutter
    - The instrument entrance
    - The solar port (protection of the diffuser vs space)





Instrument view

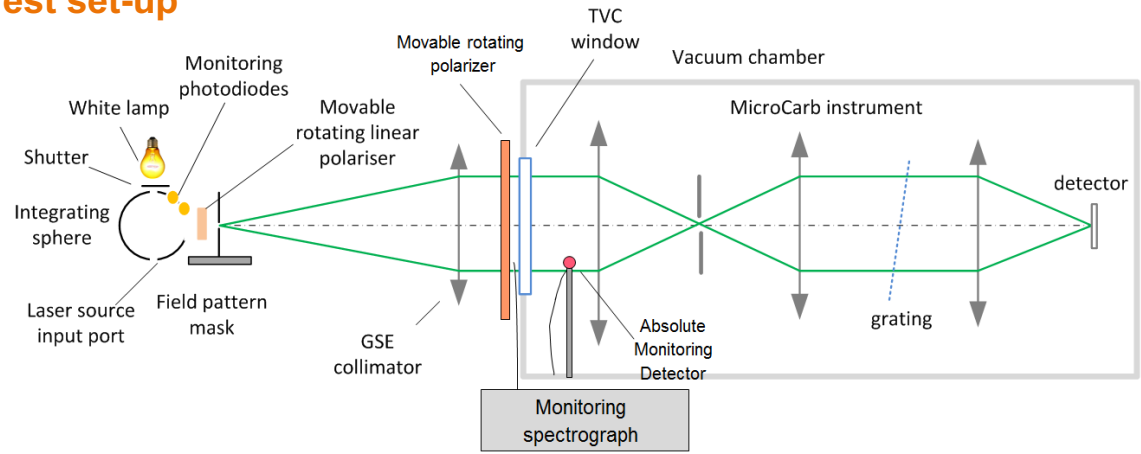




Parameter	Value
Mass	< 70 kg
Power	< 54 W
Data rate (compression) per day	339 Gbits

Instrument calibration. On Ground

Test set-up



Optical devices

- Tunable laser source,
- Wide band source
- Integrating sphere,
- Collimator,
- Polarizer

Radiometric performances

- Dark signal: offset and stability
- Non linearity
- Absolute and relative gain
- Verification straylight model
- Verification polarization model

Spectral performances

- Dispersion law parameters
- Keystone
- ISRF Shape

Spatial performances

Test with heliostat under analysis

In orbit calibration and validation

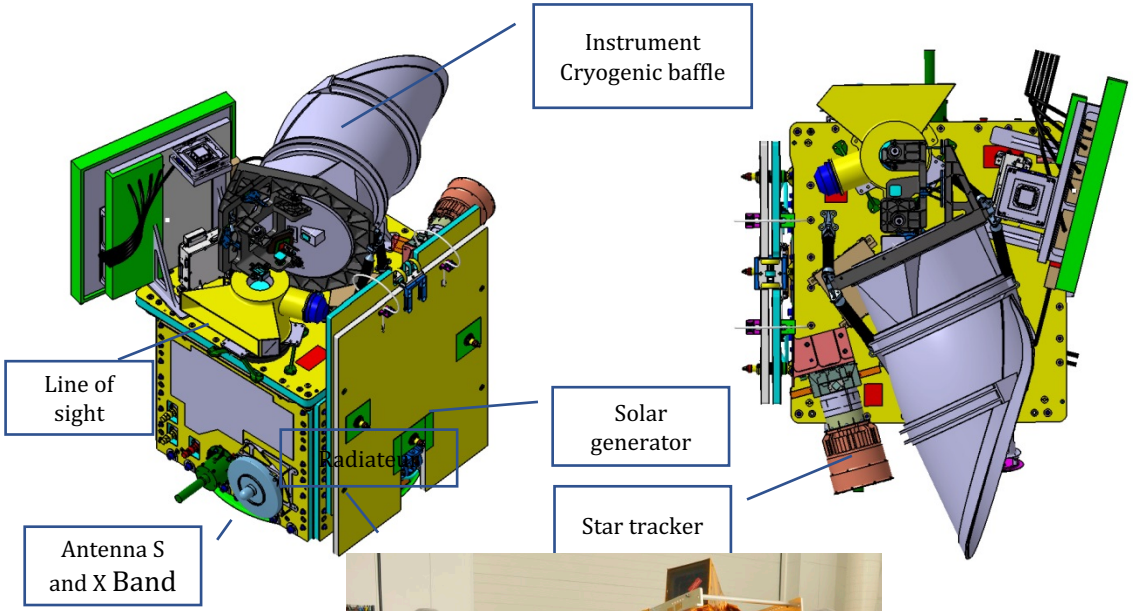
Instrument calibration

- **Closed shutter**
  - Dark signal: offset and stability
- **White lamp**
  - relative radiometric gain
  - Keystone
- **Sun Pointing**
  - Absolute radiometric gain
  - Reference solar spectrum
  - Dispersion law parameters
- **Moon pointing**
  - Co registration, etc

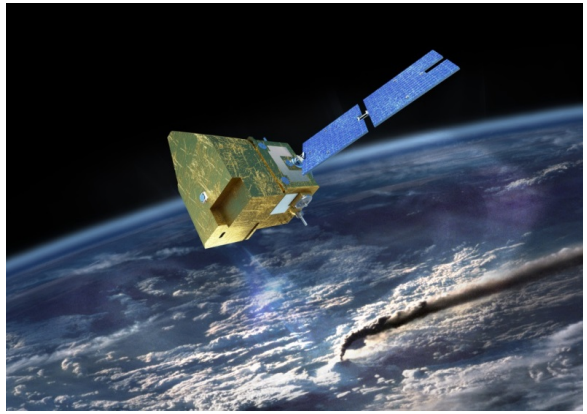
Data validation

- The following is considered
  - Comparison to TCCON station (+ COCCOON)
  - Aircore (balloon flight)
  - Vicarious campaign
  - Cross validation with other projects (OCO, GoSat, Tansat, etc)

Satellite Description



Myriade
class micro
satellite



- MicroCarb uses a micro satellite
- Enhanced Myriade family
- Flight proven: used for 19 satellites
- Mass 170 kg. Mean power: 100 W
- Dimensions 80 x 100 x 110 cm
- High rate telemetry: 156 Mbits/s
- On board Data storage: 800 Gbits
- Hydrazine propulsion : 55 m/s
- Steerable solar generator

Data processing

Processing tools under development

- Radiative transfer : 4A-OP (by LMD)
- Inversion algorithm: 4A RTIC (optimal estimation)
- Implementation of B4 on -going
- Spectroscopy data base: based on improved existing GEISA + addition of O2 @1. 27 µ
- Solar model: based on
  - SOLSPEC (by LATMOS) for the continuum
  - And Toon for absorption lines
- Scattering modelization. VLIDORT SOS

Other products

- SIF, airglow

Validation

- Processing applied to OCO-2 L1 data and comparison to OCO-2 L2
- Step 1: clear sky, nadir: completed
- Step 2: comparison to TCCON , scenes with aerosol , estimation of SIF, glint mode

Data latency

- Products will be available within 48 hours in compliance with CAMS (Copernicus) requirements

Performances

See poster C6.8 **The MicroCarb L1 & L2 algorithms and performances -**Denis Jouglet (CNES, France)

X_{CO2} Performances	Random error (ppm)
Prior	16.79
Mission requirements	< 0.5 (target) , <1.5 (threshold)
Min. Radiance (SZA=65°, refl = 0.13, 0.1, 0.1, 0.05)	1.5
Mean Radiance (SZA=36°, refl = 0.25, 0.2, 0.2, 0.1)	0.55
Max. Radiance (SZA=0°, refl = 0.55, 0.55, 0.55, 0.55)	0.22

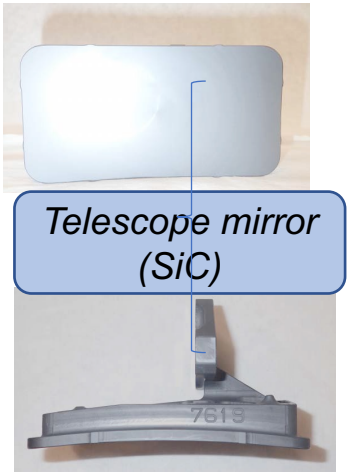
Bias

- Under construction

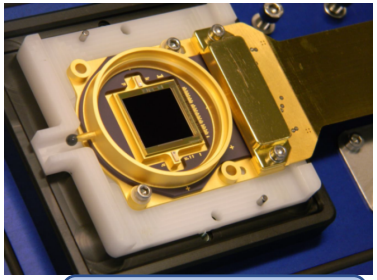
Status

- Instrument realization in progress

Scan mirror (SiC)



Telescope mirror (SiC)



NGP Detector

Echelle grating

Baffle

- Instrument integration and calibration: Jan to Dec 2019
- Satellite integration and test: Jan to Dec 2020
- Launch: 2021

Thank you for your attention !