The MicroCarb mission, an innovative pathfinder to CO_2 monitoring

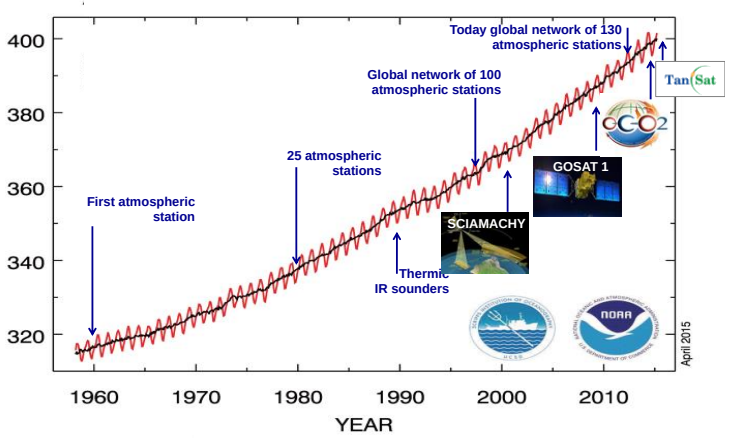
LPS22 23-27 May 2022

MICROCARB

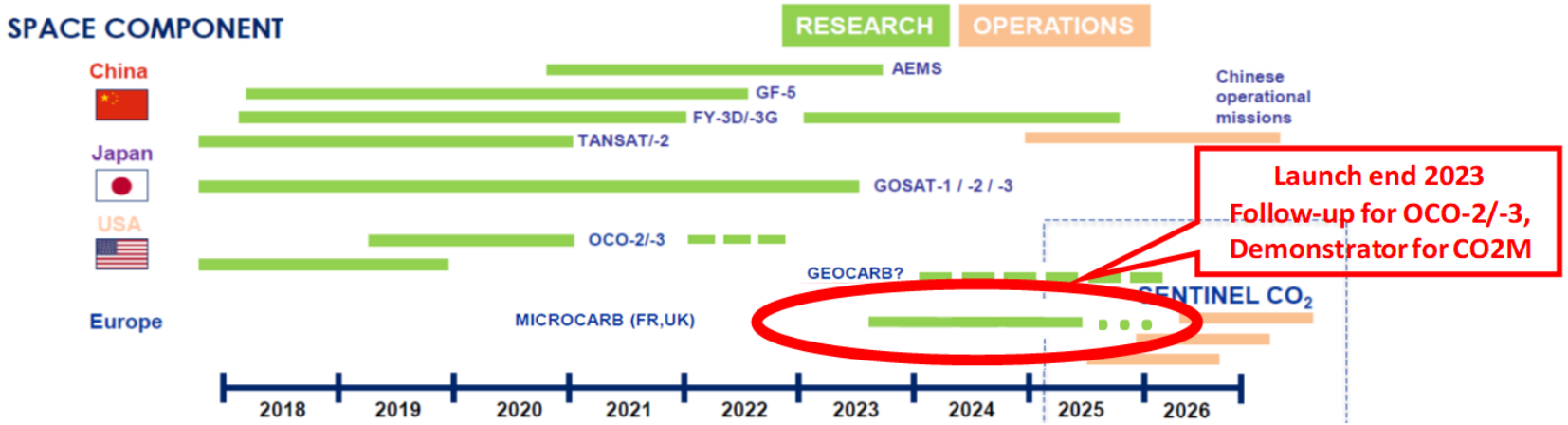
Laurie Pistre on behalf of MicroCarb team

cea cnrs cnes INVESTIR L'AVENIR UK SPACE AGENCY EUMETSAT esa European Space Agency

MicroCarb will enforce the CO_2 global monitoring continuity

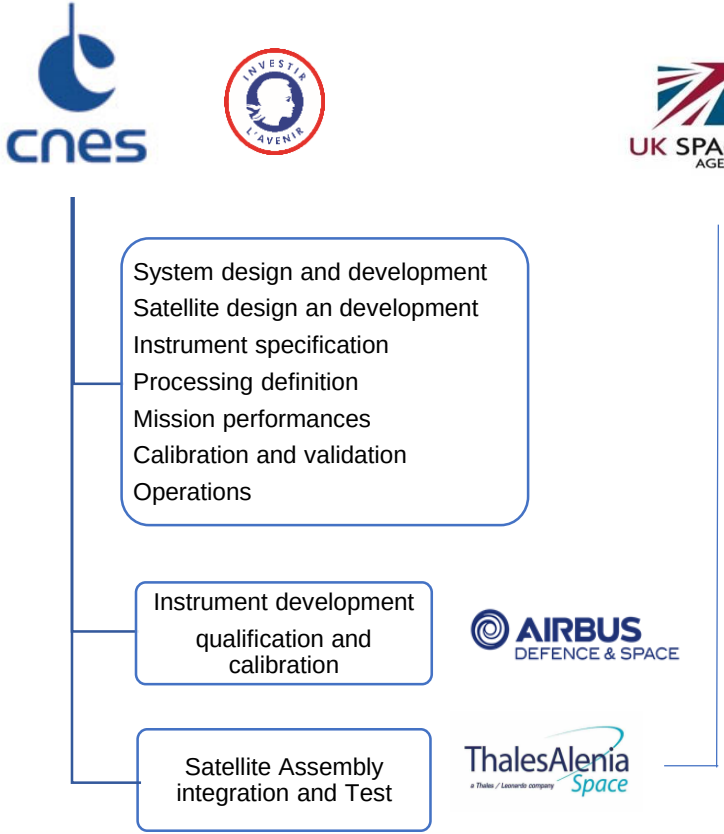


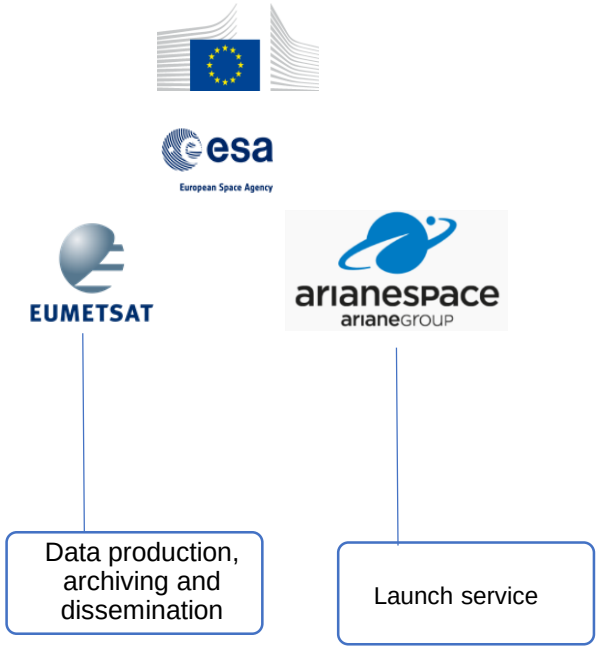
First CO_2 concentration measurements initiated on ground in the 50's. First CO_2 space measurements in the 2000's. Then, surface fluxes estimation is generated from these measurements



Organization

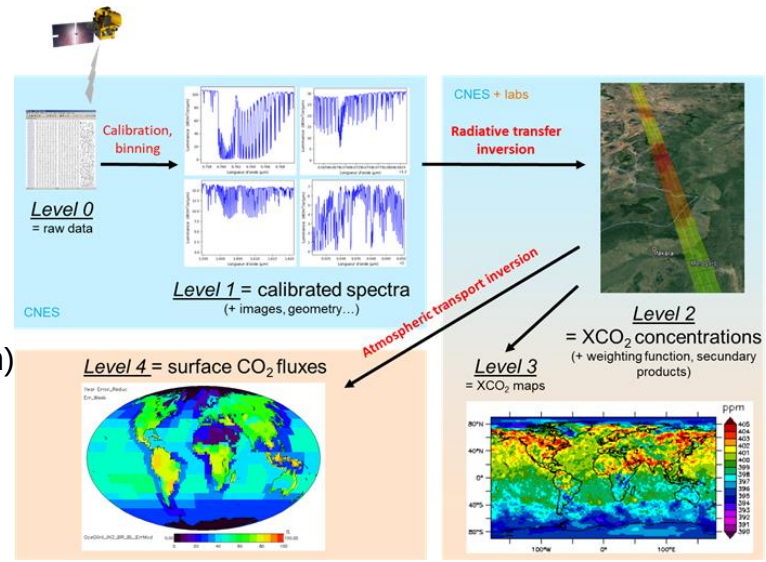
- In the context of the COP21 climate conference, France decided to kick-off the MicroCarb project in 2016
  - ANR (Agence National de la Recherche) and SGPI (Secrétariat Général Pour l'Investissement): PIA (Plan d'Investissement Avenir) funding



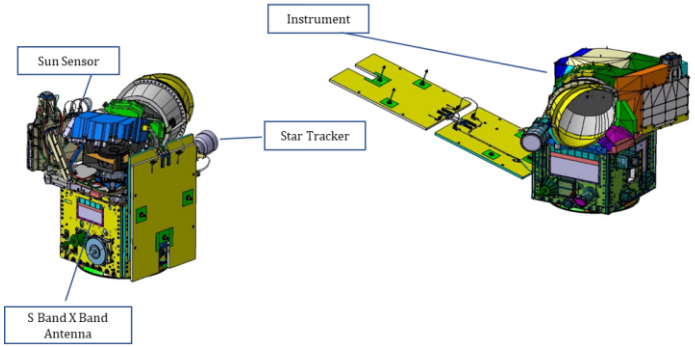


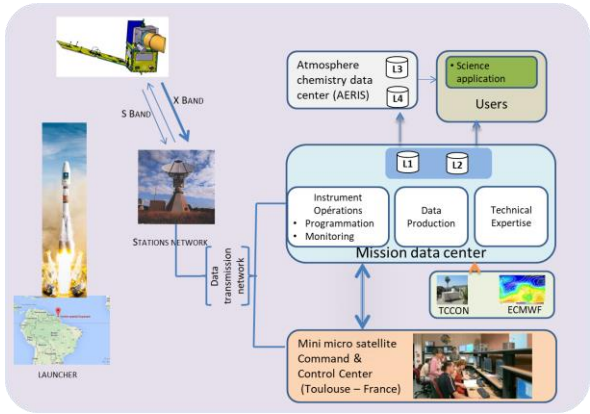
Mission overview

- **Measurement of CO_2 concentration**
  - Sampling mission (not imaging)
    - Swath limited (13 km)
    - Resolution ~ 40 km2 (at nadir)
  - Accuracy (XCO2)
    - Bias < 0,1 ppm (goal), 0.2 ppm (target) (NB: 0,1 ppm = 0.025% as mean is 400ppm)
    - Random < 0,5 ppm (G) , <1,5ppm (T) (NB: 1 ppm = 0.25%)
  - Performances similar to OCO with a more compact (/3) instrument



- **Compatibility with a microsatellite**
  - Use of Myriade classique
  - Satellite < 200 kg
- **Orbit**
  - SSO, 650 km, 22h30
- **Operations**
  - Launch date: 2023
  - Life duration: 5 years

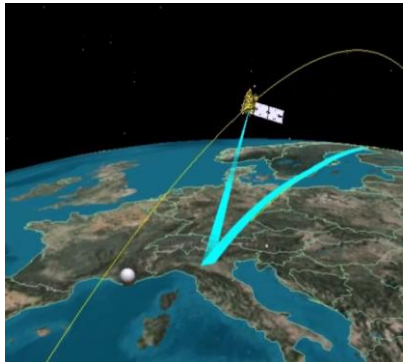
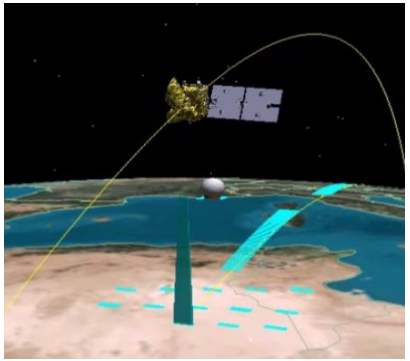
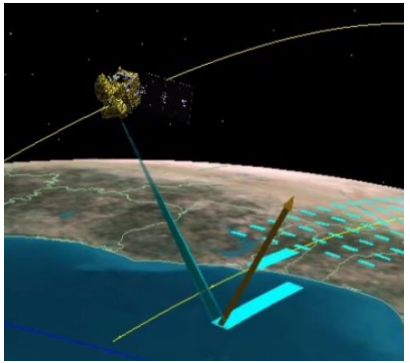


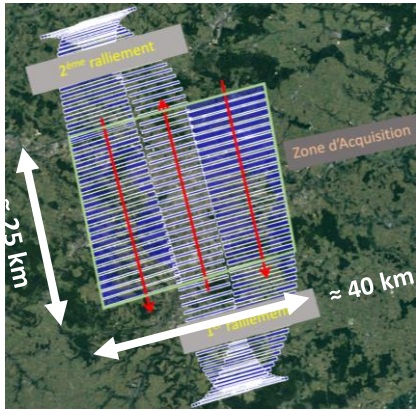
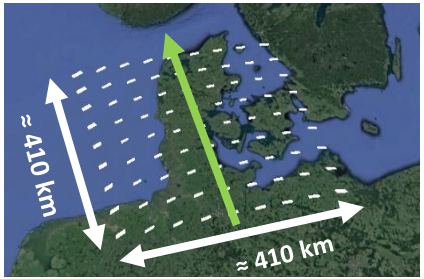
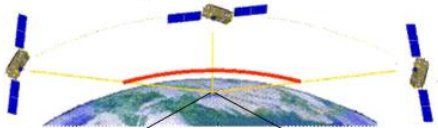


Operating modes

Pointing and Calibration System (PCS): 1-axis scanning capability in the ACT direction of ±35° and calibration lamps

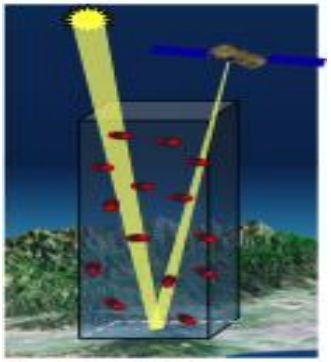
- Science nominal modes
  - Nadir (lands)
  - Scan (lands to decorrelate footprints)
  - Glint (ocean)
  - Offnadir target
- Probatory modes
  - City
  - Region
- Calibration modes
  - Target (L2 validation)
  - Calibration : sun, lamp, shutter, cold space, moon, ground laser…
  - Limb for 1.27µm airglow

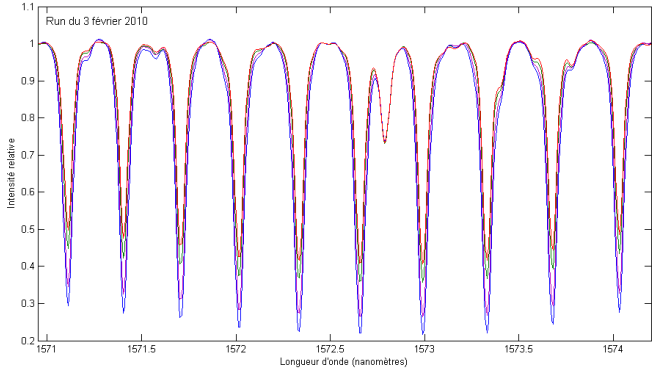
Nadir	Scan	Glint
		

City	Region	Target
		Target Mode observes surface zenith angles between ±75° 

MicroCarb measurement

- MicroCarb principle: retrieval by measurement of the CO_2 absorption of reflected sunlight using several highly resolved spectra in visible and near-infrared region (several spectral bands)
  - CO_2 : 1.6 µm & 2.04 µm
  - O_2 : 0.76 µm & 1.27 µm





CO_2 absorption lines spectrum, near 1.6 µm

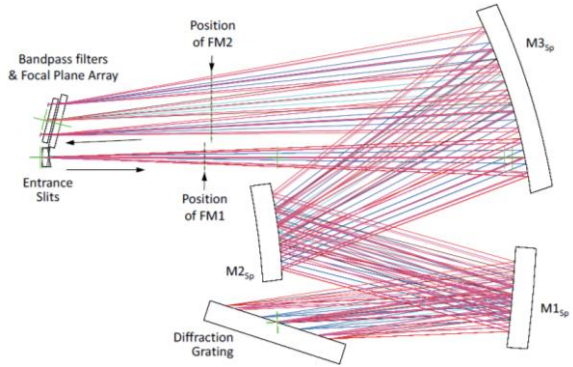
- Imager
  - Imager FOV > 2 * Sounder FOV
  - Resolution ~120m x 150m
  - Band 550 – 700 nm

- High spectral and radiometric accuracies, with low signal levels, calling for accurate on-ground calibration and high in-flight stabilities
  - Figure of merit p is a combination of:
    - Signal to Noise Ratio (SNR)
    - Spectral Resolution (R)
    - BandWidth (BW)
  - Detector temperature 150K, spectrometer temperature 240K, passive cooling

Figure of Merit (p)	0.31
R	~26000
FWHM	>2.7pixels
SNR	Btw 230 (B3) and 500

Instrument compact design: only one detector

The instrument is based on an innovative concept permitting the acquisition of the spectral bands using a single telescope, spectrometer and detector, covered by an **Airbus Defence & Space** (ADS) patent.

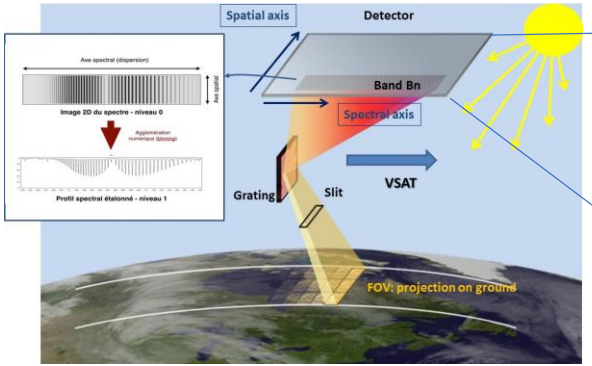


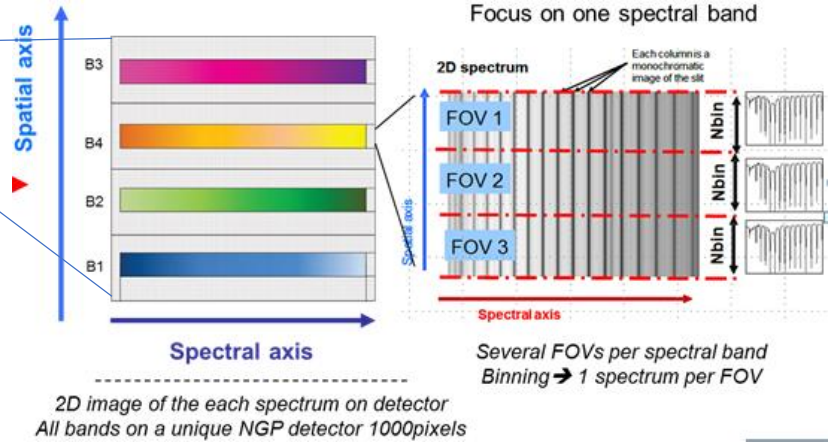
Spectrometer principle

- Spectral bands multiplexing by the grating, each band corresponding to a different diffraction order, between 15 and 40
- Echelle grating of ~60 grooves/mm in near-Littrow configuration
- Double-pass TMA compact spectrometer with **4 slits**

Configuration at detector level

- One spectrum: about 1000 pixels in λ direction
- ACT field: ~100 pixels in the x direction
- Band separation: ~150 pixels in the x direction
- On-ground slit instantaneous: 13.5km ACT * 0.65km ALT
- Integration time of 1.3s : 13.5km * 8.9km, separated into 3 FOV of 4.5 km * 8.9 km ~40 km^2

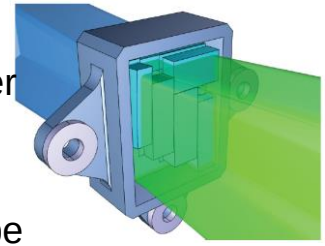


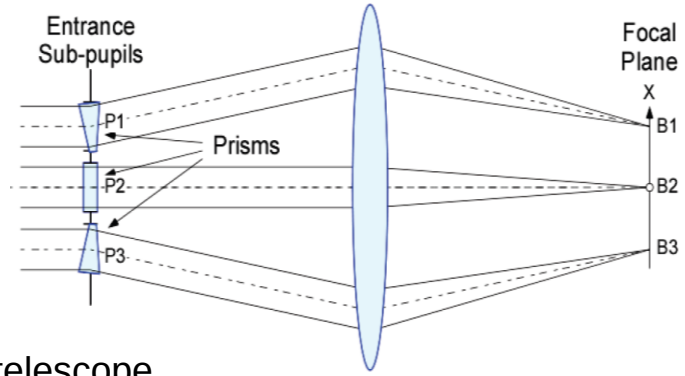


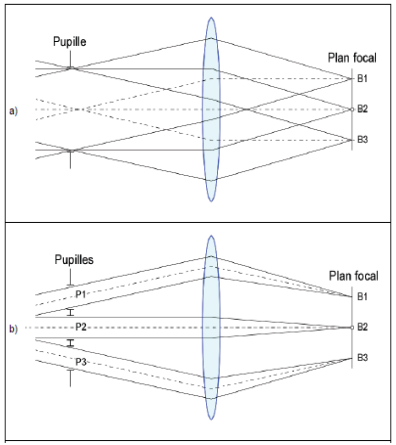
Instrument compact design: only one detector

Split-pupil telescope

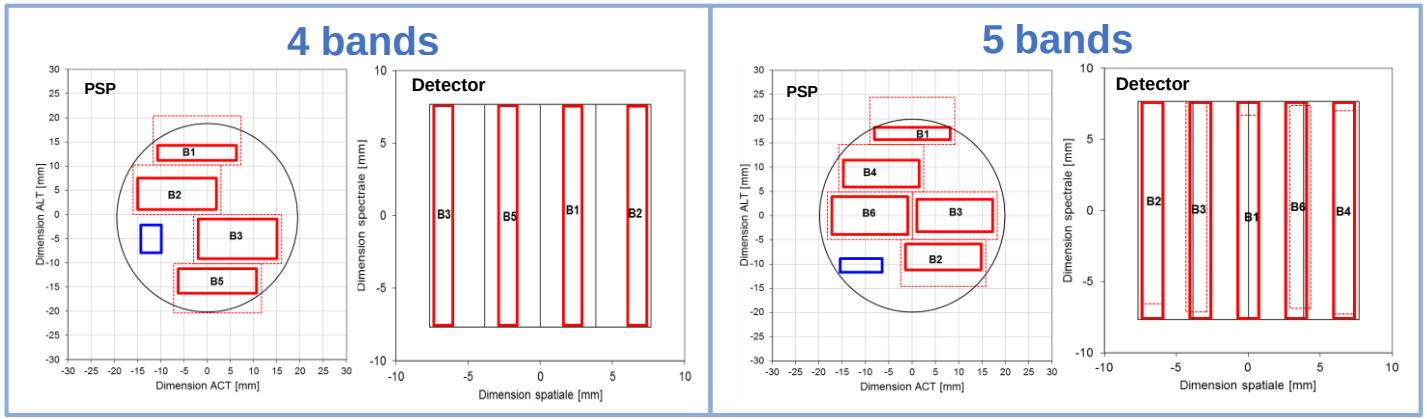
- Alignment of the spectrometer slits on the same Earth point by 4 Pupil Separation Prisms (PSP), placed at the telescope entrance pupil







- Possible only with multi-pupil configuration of the telescope
- Principle applicable to any number of spectral bands, with large flexibility on sub-pupil shape and dimensions



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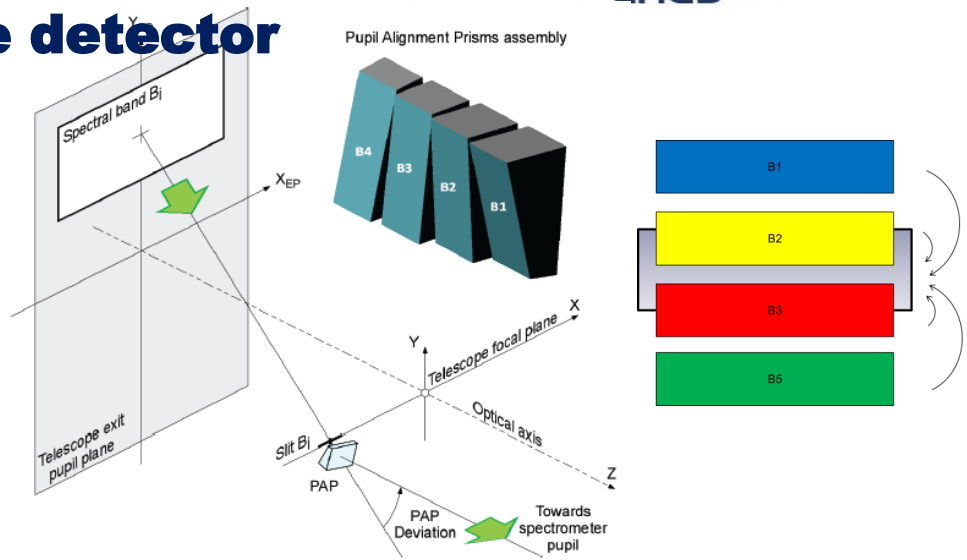
Instrument compact design: only one detector

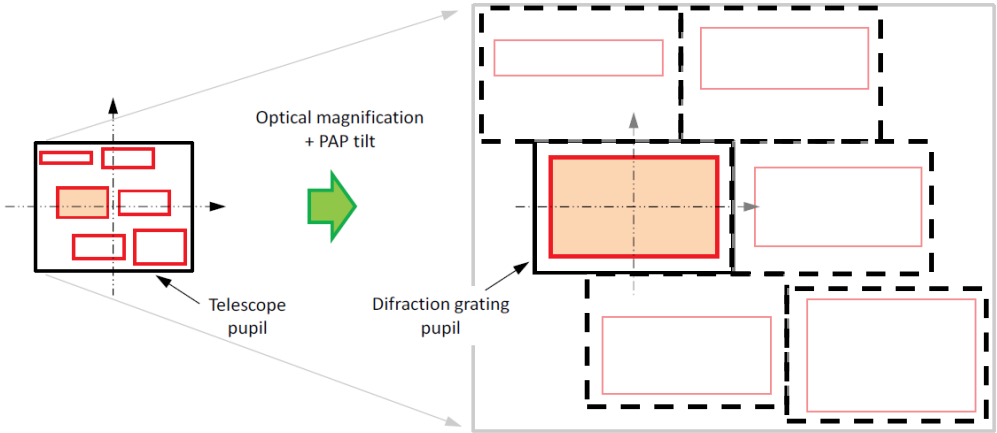
Co-alignment of the band sub-pupils in the spectrometer

- At slits level thanks to Pupil Alignment Prisms (PAP) which superimpose the various pupils on the grating
- Spectrometer size imposed by the largest band sub-pupil

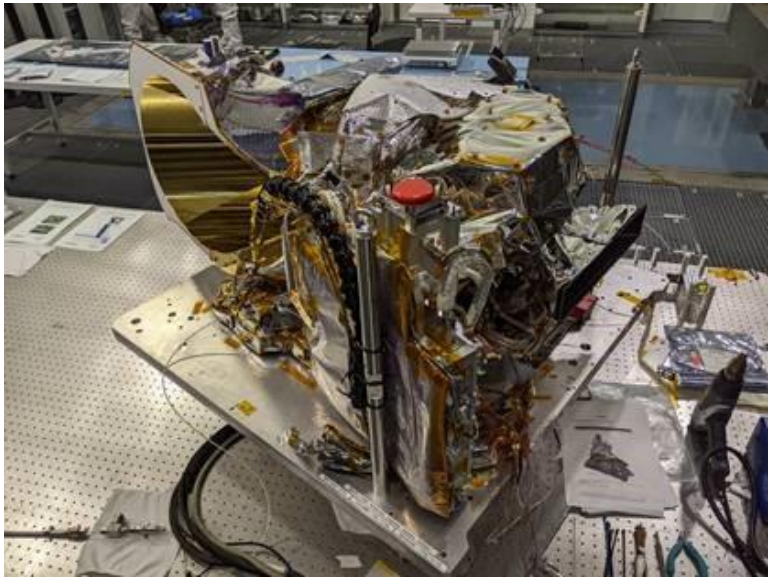


Straylight minimization

- At telescope level, grating image for band Bi outside sub-pupil of band Bj, avoiding inter-band direct straylight
- Use of several field masks at telescope and spectrometer levels
- Bandpass filters with high rejection on PSP and detector filters



Overall instrument architecture



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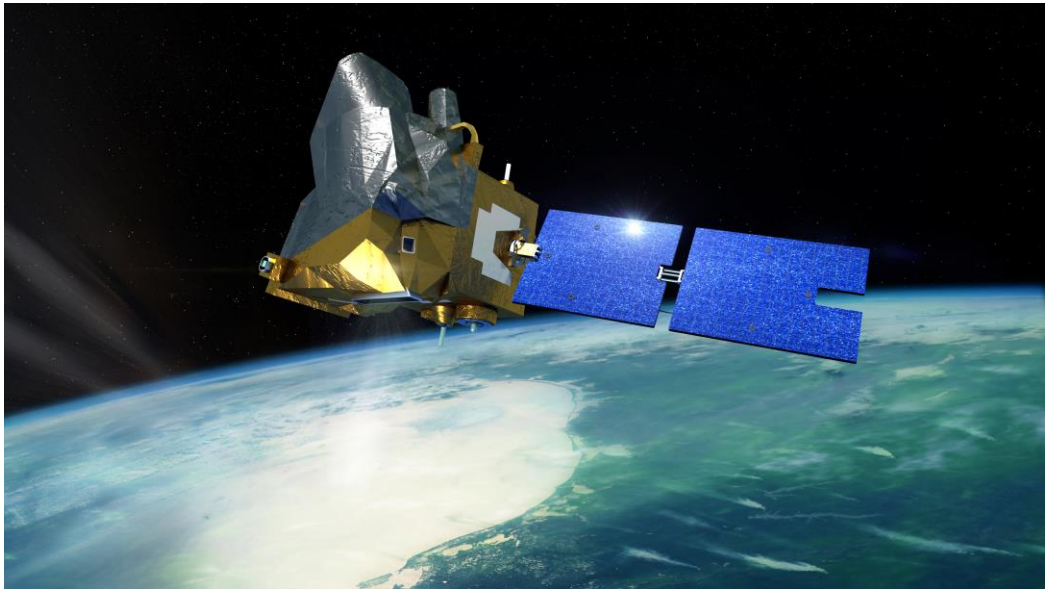


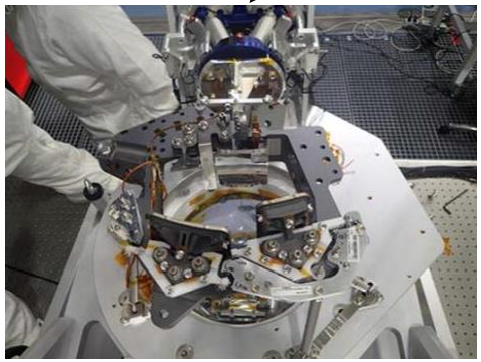
- Compact instrument:

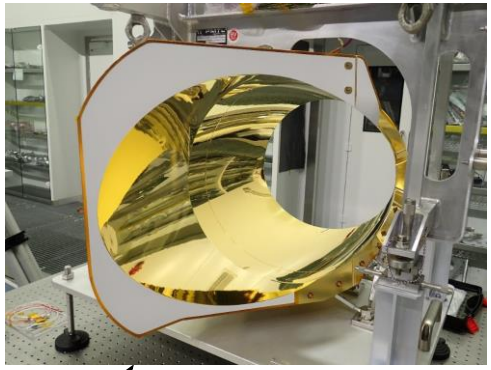
Mass	<80kg
Power	50W
Volume	600 x 500 x 1100 mm^3

Instrument AIT Activities

- Integration considering very compact instrument was a success
- Instrument final alignement in between telescope, spectrometer and detector achieved
- EMC and mechanical tests on-going

Spectro

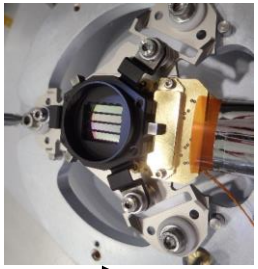




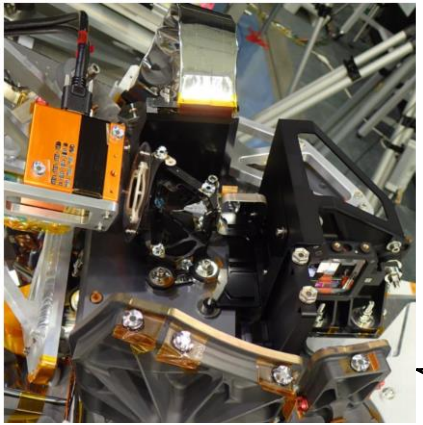
Baffle Therm.

Archi MLI

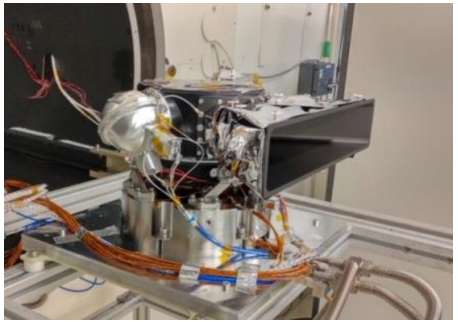
PCS



NGP detector FM and filters



Telescope



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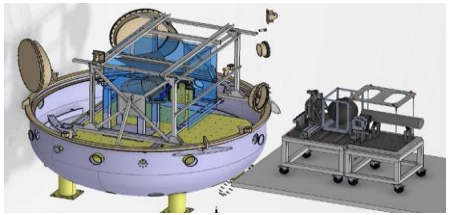
On Ground Instrument calibration: Instrument AIT conclusion

Tests performed under thermal vacuum condition (~40 days) are foreseen this summer

Optical devices

- Tunable laser source & Broad band source
- Integrating sphere & Collimator
- Polarizer
- Theodolite



Other tests

- Gas cell => characterization in absorption (B2 only)
- **Test with actual sun**

  Sunlight brought by telescope + fiber into the TV chamber

  - Acquisition in the 4 bands
  - Comparison with EM27, AirCore, Aircraft, …
  - Detection of instrumental defects and processing defect at L1 or L2 level
  - Link ground - flight

Radiometric performances

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

Spectral performances

- Dispersion law parameters
- Smile and keystone
- ISRF Shape

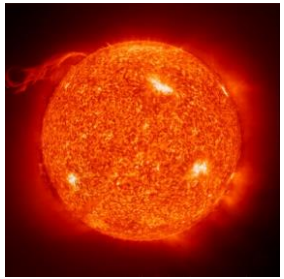
Geometric performances

- LOS alignment
- Imager – sounder registration
- Band registration
- FOV spread Function

Cross calibration With GoSat TANSO (common radiometer): under investigation

Notional Cal/Val Plan (1/2)

- Typical expected duration : 1 year
  - Launch ➔ Launch + 6 months
    - L1 calibration
    - L2 production starting and parameter definition
- Many sources for L1 calibration



Dispersion law & smile

Dark signal

ISRF shape

Absolute radiometric gain

Polarization

ISRF on heteregenous scenes

Imager & Band coregistration

Geolocation

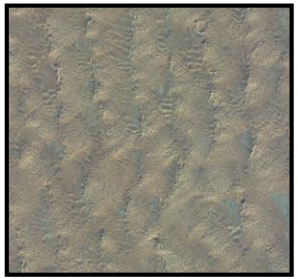
Intra-band relative gains

Straylight & lag

Non-linearity

Internal lamp

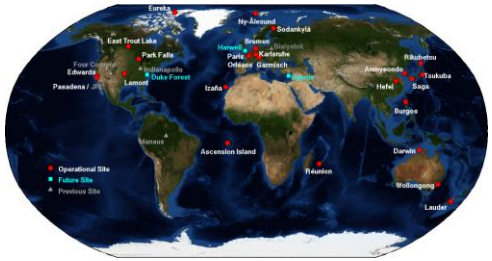
Radiometric noise

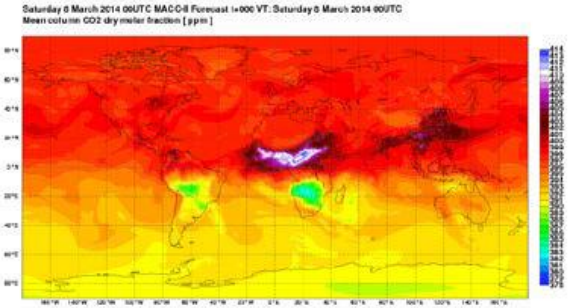


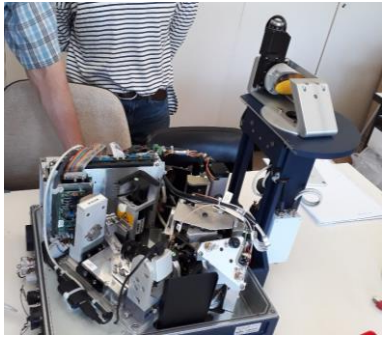
ACT relative gains

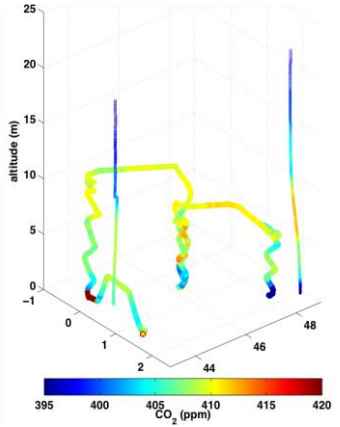
Notional Cal/Val Plan (2/2)

- ❖ Typical expected duration : 1 year
- ➢ Launch + 6 months ➔ Launch + 12 months
  - Data delivered to MAG
  - L2 validation and bias charaterization (CNES + MAG)
- ❖ Operational comparisons for massive statistics
  - To TCCON network (target and offnadir modes)
  - To CAMS CO2 model
  - Inter-comparison to other missions
- ❖ Regular measurements
  - EM27
  - AirCores on ballons
- ❖ Campaigns
- ➢ Currently one MAGIC campaign per year which combines on-ground, ballons and airplanes measurements
- ➢ Instruments:
  - EM27
  - AirCores on balloons
  - AMULSE on balloons
  - Aircraft (Picarro on Falcon)
  - CHRIS
  - If possible : ICOS and TCCON

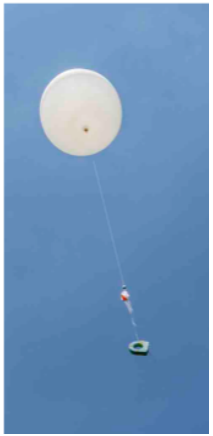






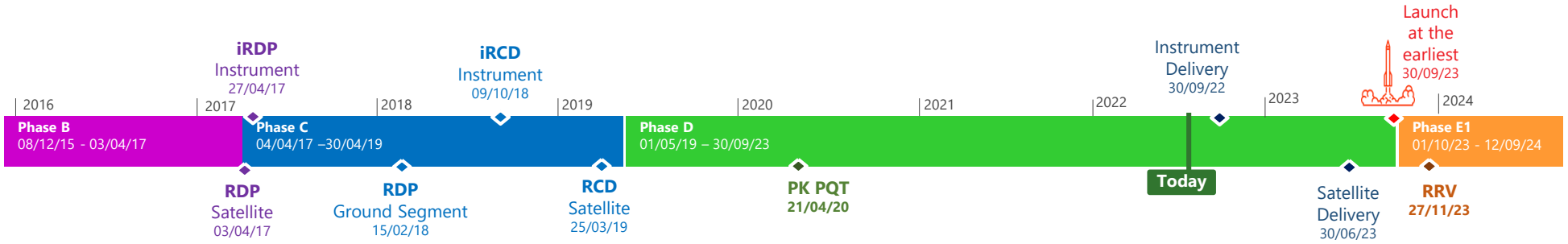


Results of Falcon and AirCore from MAGIC 2018



AirCore

Progress



- Next challenges:
  - Instrument performances tests in thermal vacuum conditions
  - Satellite AIT
  - Wait for co-passenger on Vega-C end 23 or beginning 24
  - Cal/Val

Thank you for your attention !