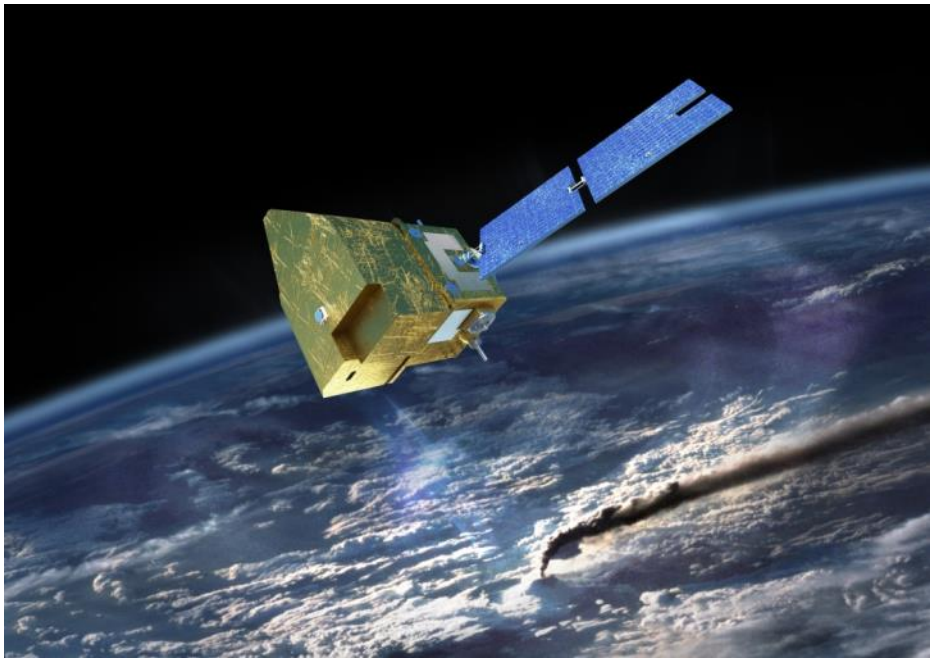
AN UPDATE OF MICROCARB PROJECT PROGRESS AND PERSPECTIVE.



PROJECT STATUS

Francois BUISSON – CNES
Francois-Marie BREON - LSCE

June 8th, 2017

PROJECT IMPLEMENTATION STATUS

Decision milestones

- Dec., 2015 (COP-21): Decision by French government to conduct MicroCarb development
- Jan., 2016: phase B funding completed + kick off
- March, 2017: government decision (Mme ROYAL) to fund phases C-D-E1
- April 2017 Phase B completed successfully
- May 2017: Phase C kick off

France/ UK partnership

- April 19th, 2017: Signature of CNES/UKSA Implementing arrangement
- Partnership involves
  - National agencies: CNES and UKSA
  - Scientific laboratories: LSCE, LMD, LATMOS, IPSL, UoL, UoE, etc
  - Industries: Airbus DS, Thales AS, RAL, NPL, etc

MISSION CHARACTERISTICS

Performance : XCO_2 measurement

- Accuracy < 1 ppm (typical)
- Regional bias (systematic error variation) < 0.2 ppm

Orbit

- SSO – 649 km – 10h30 LTDN or 13h30 LTAN
- 25 days - 7 days sub-cycle

Geometrical characteristics

Parameter	Value
Swath	13,5 km
Size of elementary sounding point	4,5 x 9 km = 40 km²
Number of simultaneous soundings	3
Line of sight agility (scan)	±200 km

Operations

- Launch date: 2020
- Life duration: 5 years

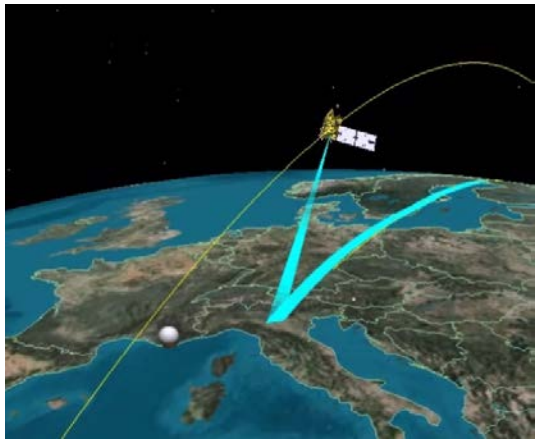
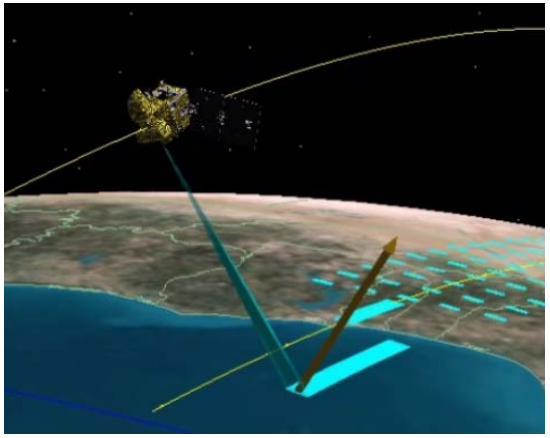
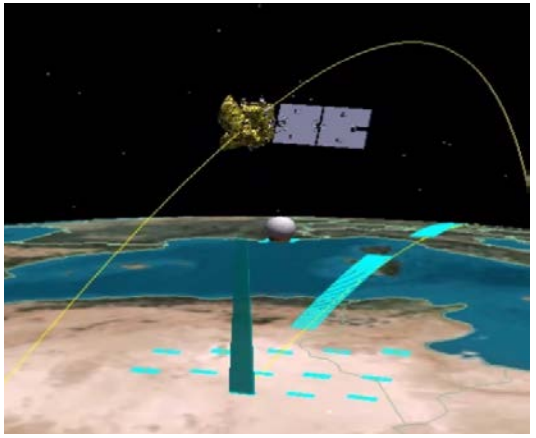
Micro satellite

Launcher

- As an auxiliary payload

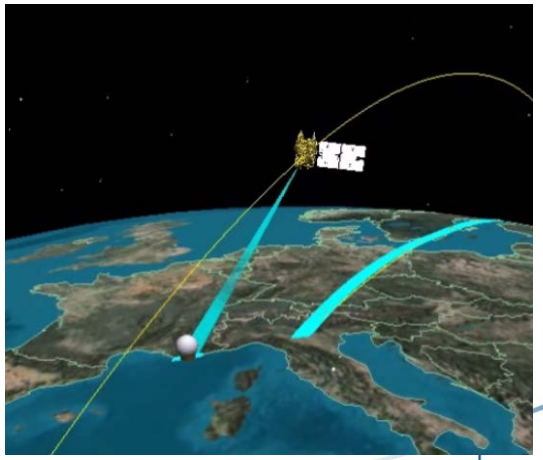
OBSERVATION MODES

Routine modes

Nadir (Over lands)	**Glint** (over oceans)	**Scan**
		

Calibration modes

- Target
  - Over ground stations (TCCON)=> L2
  - Vicarious calibration
- Sun pointing (when satellite over poles) => radiometric and spectral calibration
- Oceans and cold space: => dark signal characterization & airglow



N1 AND N2 PERFORMANCES ASSESSMENT

Spectral characteristics

Performances N1	B1 (O_2)	B4 (O_2)	B2(CO_2)	B3(CO_2)
Central wavelength (nm)	763.5	1273.4	1607.9	2037.1
Bandwidth (nm)	10.5	17.6	22.1	28,1
Spectral Resolution (λ/Δλ)	25 500	25 900	25 800	25 900
Signal to Noise ratio @ Lmean (per channel)	285	378	344	177

N2 Performances assessment

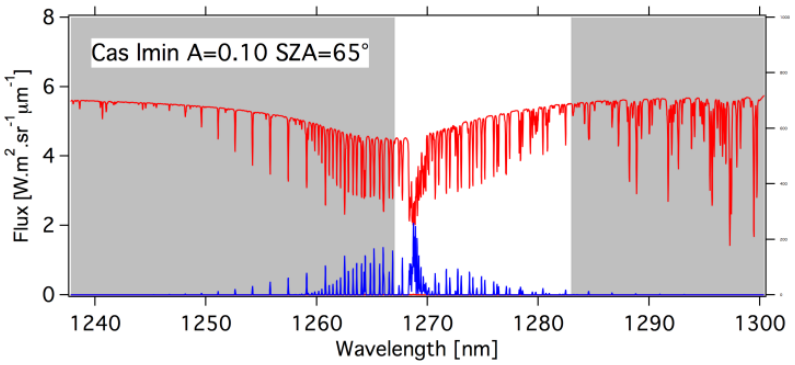
- No pseudo noises nor aerosols considered

X_{CO2} Performances	Random error (ppm)	Random error (ppm) after merging 3 FOV
Prior	16.79	16.79
Mission requirements	< 0.5 (target) , <1.5 (threshold)	
Min. Lum. (SZA=65° , refl = 0.13, 0.1, 0.1, 0.05)	1.5	1.06
Mean Lum. (SZA=36° , refl = 0.25, 0.2, 0.2, 0.1)	0.55	0.39
Max. Lum. (SZA=0° , refl = 0.55, 0.55, 0.55, 0.55)	0.22	0.16

ORIGINAL FEATURES

Use of 1.27 µ band

- O2 absorption band
- 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 and its effects corrected with sufficient accuracy
  - Model Verified with Sciamachy data
  - Airglow will be estimated together with O2
  - Can be measured in flight (eg: over dark ocean)



Intensity of reflected spectrum (L min.)
Intensity of airglow

ORIGINAL FEATURES

Optimization of the mission planning

- The acquisition timeline is an automatic function of :
  - Oceans / lands mask
  - TCCON station visibility opportunities
  - Calibration needs
- A mission planning concept considering meteorological forecasts is currently analysed :
  - Improvement of the ratio of usable data is expected
  - Proved to be efficient on Earth observation missions
  - Will require optimization (acceleration) of the planning loop

ORIGINAL FEATURES

Pointing and calibration system

A scan mirror (one axis) is integrated in the instrument

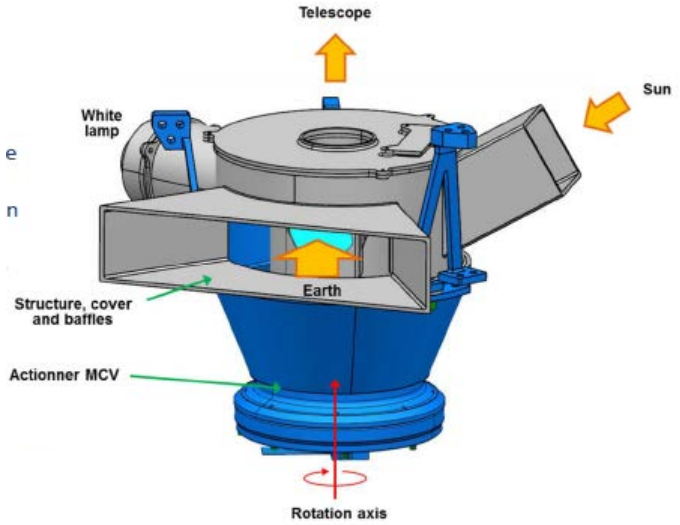
- Releases constraints on satellite agility along roll axis (power, thermal)
- Permits to implement the scan pointing mode over ± 35°

Also used for calibration

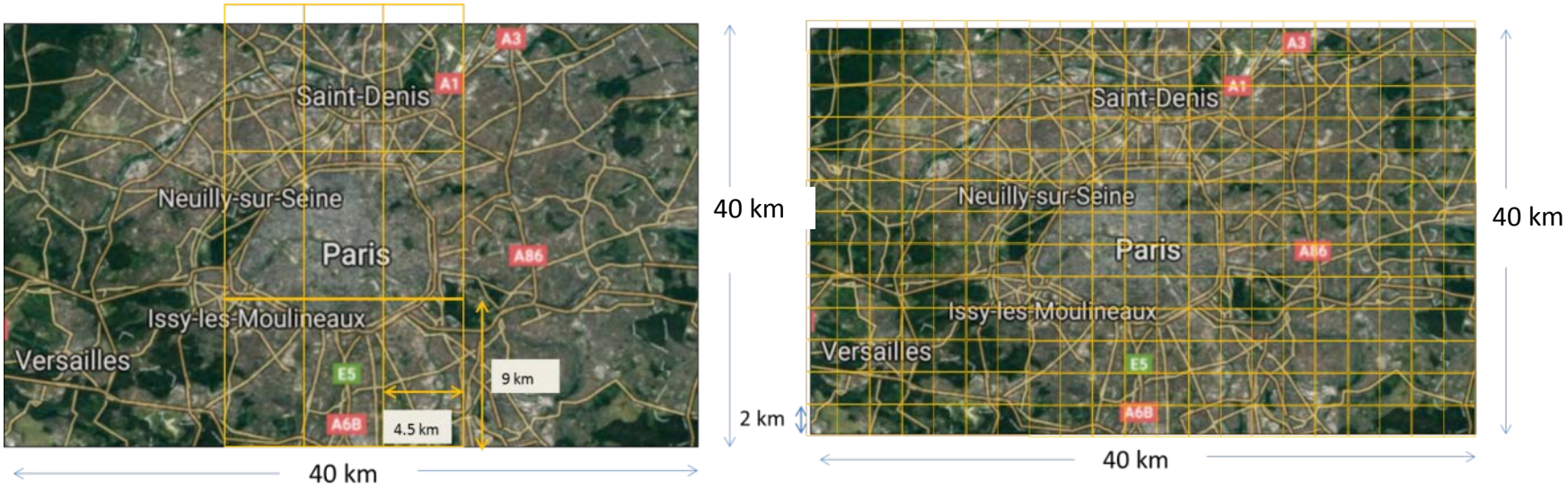
- White lamp
- Solar port with diffuser

And to Shutter

- The instrument entrance
- The solar port (protection of the diffuser vs space)



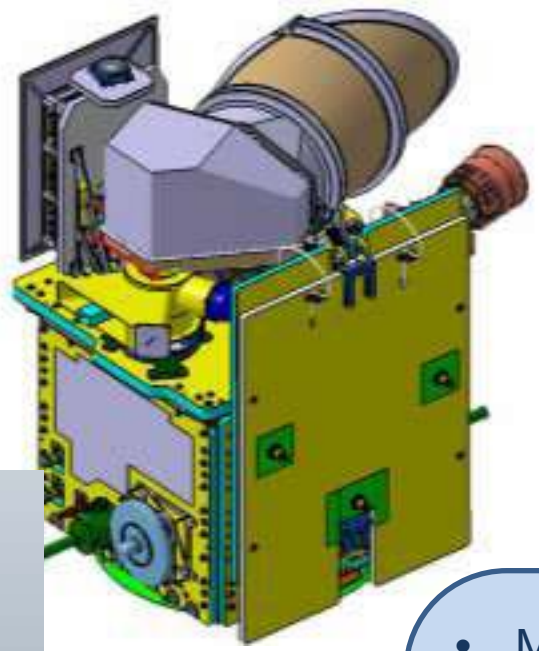
EXPLORATORY MODE

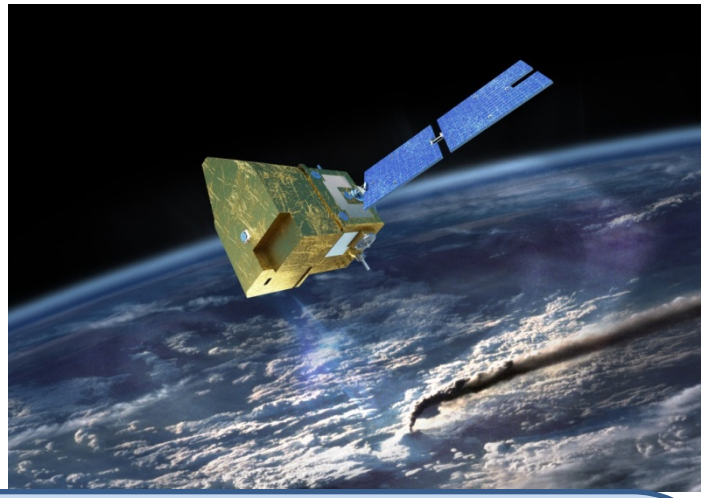


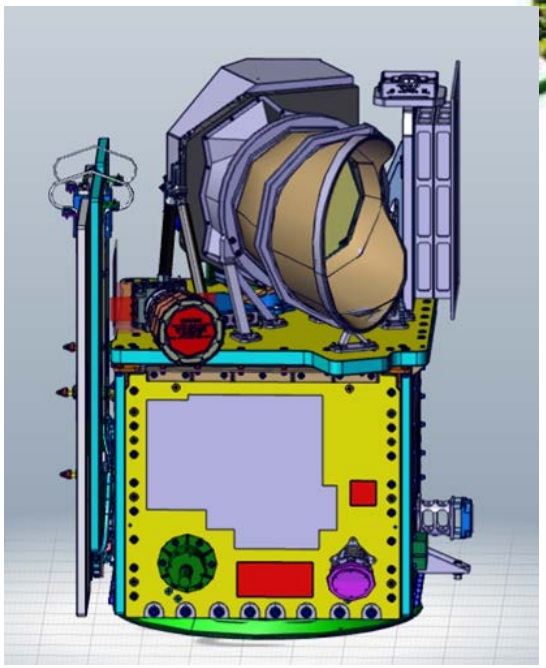
Improved resolution or « City « mode

- Goal:
  - ✦ experiment capacity to characterize local emissions
  - ✦ Support for vicarious validation
- 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

SATELLITE DESCRIPTION







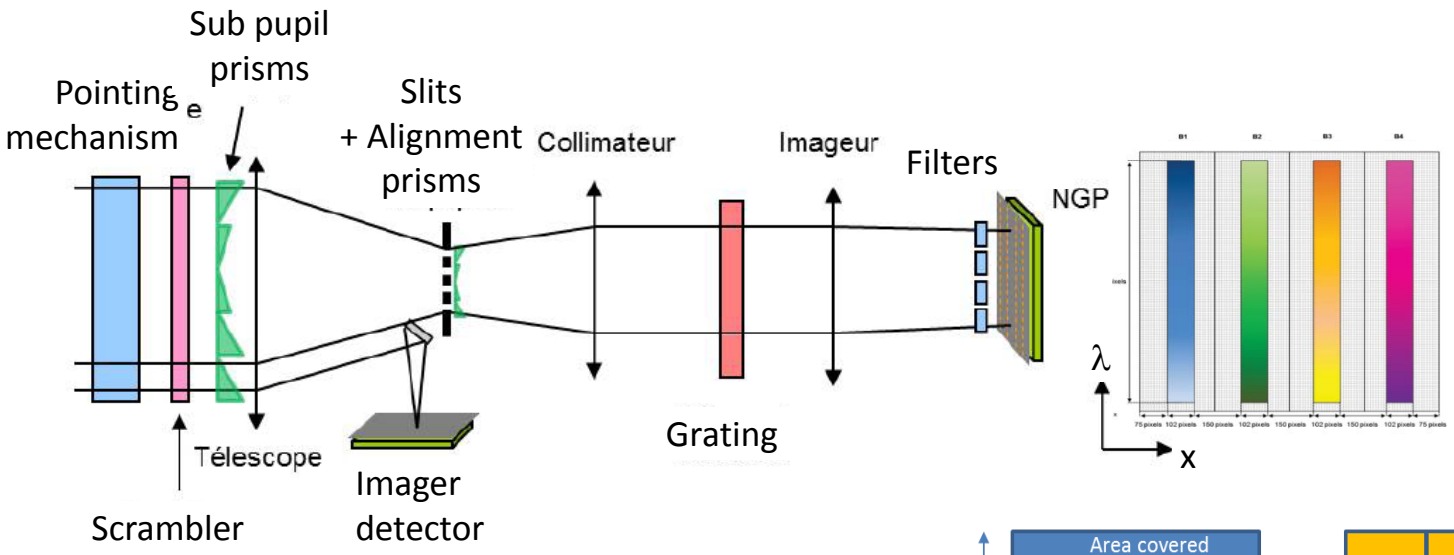
- MicroCarb uses a micro satellite
- Enhanced Myriade family
- Flight proven: used for 19 satellites
- Mass 170 kg. Mean power: 100 W
- Dimensions 80 x 100 x 110 cm
- High rate telemetry: 156 Mbits/s
- On board Data storage: 800 Gbits
- Hydrazine propulsion : 55 m/s
- Steerable solar generator

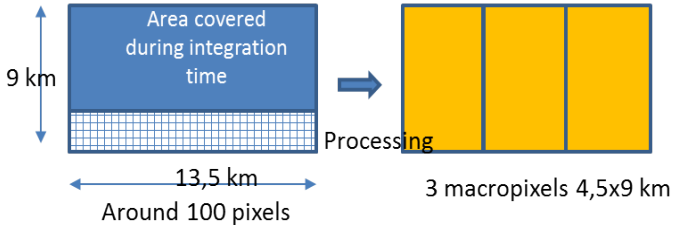
INSTRUMENT - DESCRIPTION

- CNES selected Airbus Defence and Space for the development and qualification of the instrument

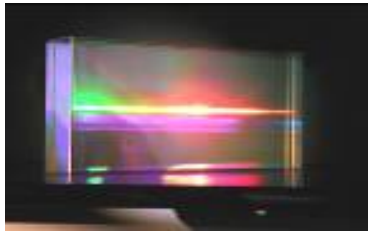
Type	Unique spectrometer with a Grating element
Mass	< 70 kg
Power	< 55 W
Detector	NGP Sofradir (HgCdTe) 1024 x 1024
Imager	Integrated. Cloud detection. 0.625 µm 120 m SSD. FOV=2 x Spectrometer FOV
Data processing	No processing on board : all data are downloaded with lossless compression. Data rate: 300 G bits/day
Cooling	Passive : detector (150K), spectrometer : 220 K
Calibration	Calibration devices on board (diffuser, calibration lamps)
Polarization	Scrambler
Pointing:	Scan mechanism 1 axis ±200 km
Structure mirrors	Made of SiC. Free form mirrors

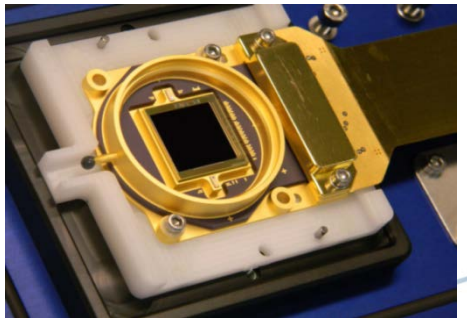
INSTRUMENT - PRINCIPLE





- Innovative concept permitting the acquisition of the 4 spectral bands with a single telescope, spectrometer and detector (NGP Sofradir)
- Enables to implement a higher number of bands (5- 6)





OPTICAL PRINCIPLE

Telescope Principle

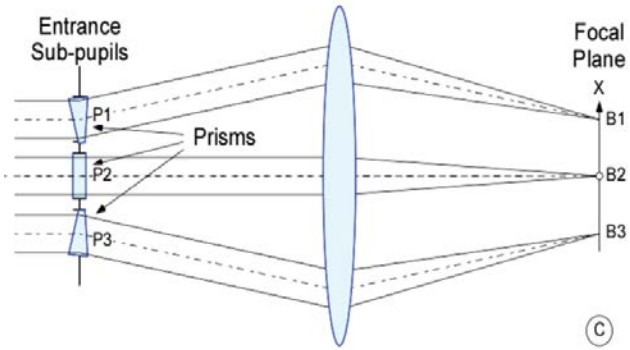
- Split-pupil telescope: Alignment of the spectrometer slits on the same Earth point by 4 Pupil Separation Prisms (PSP), placed at the telescope entrance pupil

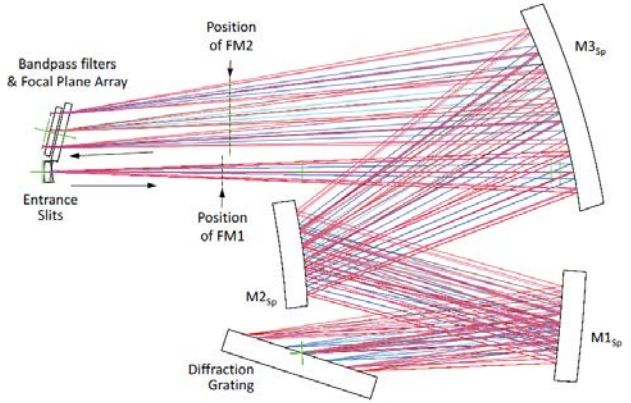
Spectrometer principle

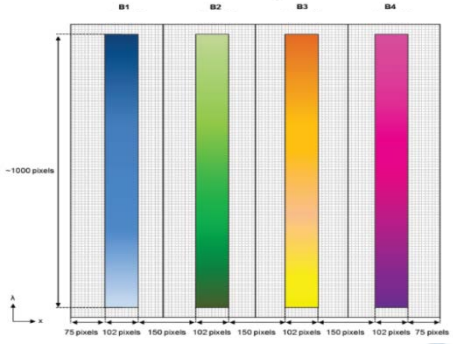
- Spectral bands multiplexing by the grating,
- Echelle grating of ~60 grooves/mm in near-Littrow configuration
- Double-pass TMA compact spectrometer with 4 slits

Configuration at detector level

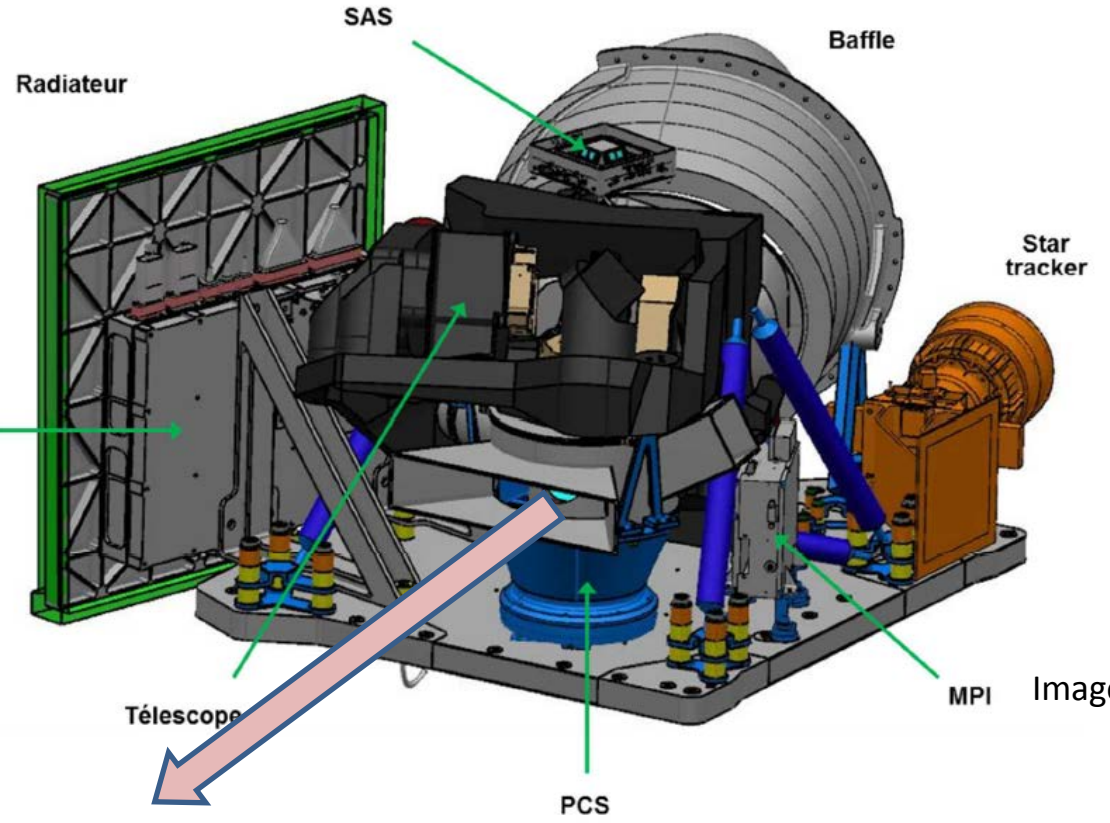
- One spectrum: about 1000 pixels in λ direction
- ACT field: ~100 pixels in the x direction
- Band separation: ~150 pixels in the x direction

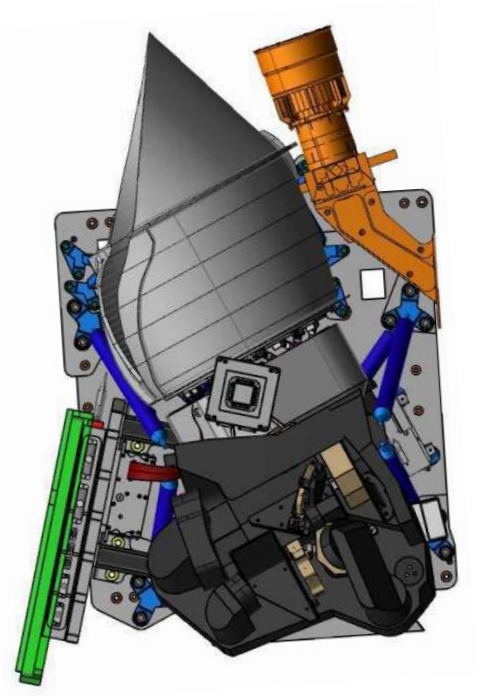






LAYOUT





Imager electronics

INSTRUMENT CALIBRATION

Category	Parameter	G	O	Method
Radiometry	Dark signal, offset	X	X	Ocean (night) or cold space
	Dark signal, stability (temperature)	X	X	Ocean (night) or cold space
	Non linearity	X	X	
	Relative Gain (pixel)	X	X	White source (lamp)
	Absolute characterization (gain)	X	X	Sun (through diffuser)
	Stray light	x		
	Polarization (model)	x		
Spectral	Reference solar spectrum		X	Sun (through diffuser)
	Parameters of the dispersion law	X	X	Sun (through diffuser)
	Keystone	X	X	White source
	ISRF shape	X	X	Sun
Geometry	Alignment imager / sounder	x		
	Detectors lines	X		
	FOV Spread function	x		
Other	Sun diffuser stability	X	X	Moon pointing

DATA PROCESSING – DATA VALIDATION

Data processing

- MIcroCarb will use specific tools
  - Spectroscopy Data base: GEISA
  - 4AOP for simulation of the radiative transfer (Source: LMD)
  - 4A-RTIC for the inversion (based on Rodgers Optimal estimation)
- Improvement and optimization is on going
  - Addition of Band B4, addition of physical processes (Vegetation fluorescence, ..)
  - Acceleration of the code (simplified scattering calculation, parallelism)
  - Import of exogenous data (CAM aerosols data, etc)
  - Benchmark with OCO data is conducted : comparison with TCCON data

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)

CONCLUSION

- CNES and UKSA have concluded a Partnership agreement for the development of MicroCarb
- Funding for project implementation is completed
- Phase C has been kicked off
- MicroCarb takes advantage of the experience gained by former projects: to be continued in order to improve the quality of the data and make them profitable to the community (eg instrument calibration)
- MicroCarb introduces original features (instrument concept, 1.27 µ band, up the ramp, …) which may be profitable to future missions
- Launch targeted as soon as possible (satellite ready for launch in 2020) in order to
  - Ensure continuity of the data
  - Be able to perform cross calibration with former projects
  - Contribute to the preparation of future missions