

UK Contributions to the MicroCarb Mission



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CNES MicroCarb team



**National Centre for
Earth Observation**
NATURAL ENVIRONMENT RESEARCH COUNCIL

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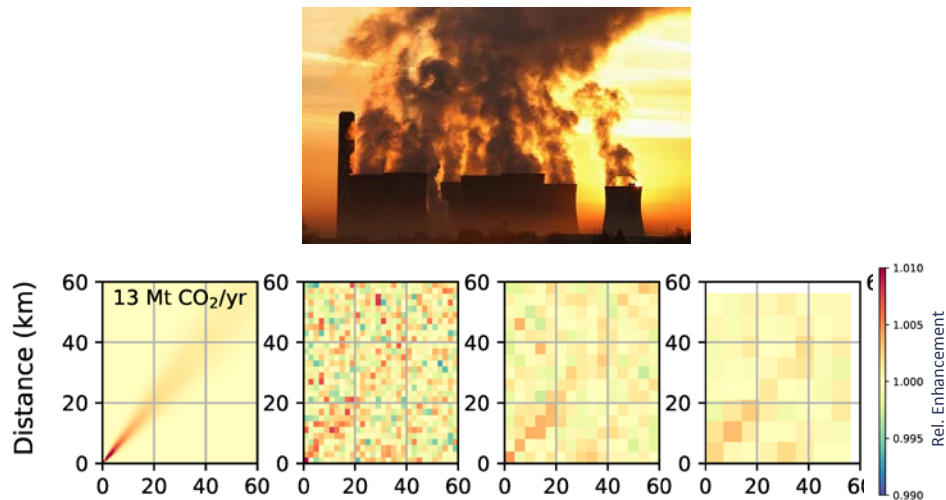


Global Measurements from Space are Essential for Monitoring Atmospheric CO₂

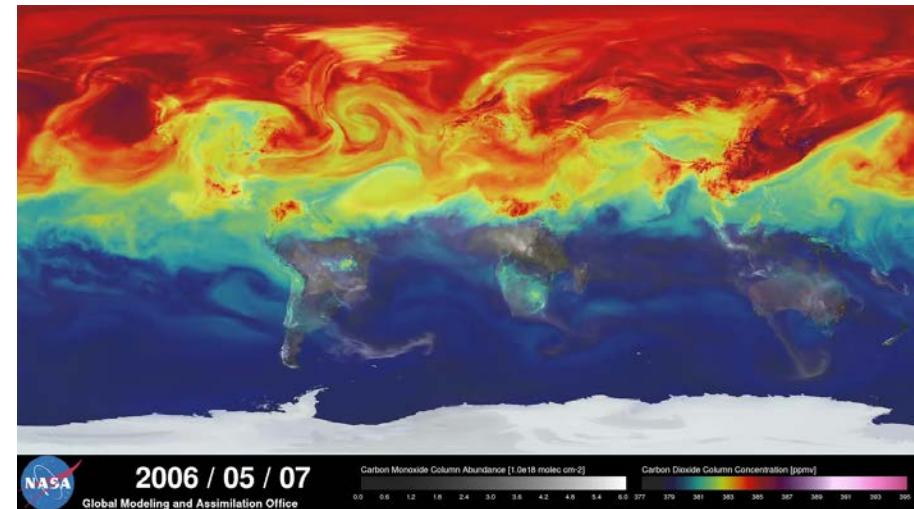
To limit the rate of atmospheric carbon dioxide buildup, we must

- Control emissions associated with human activities
- Understand & exploit natural processes that absorb carbon dioxide

We can only manage what we can measure



Plumes from medium-sized power plant elevates X_{CO_2} by a few ppm for 10's of km downwind [Hill and Nassar, 2019].



These variations are superimposed on a background of “CO₂ weather”

The Pioneers: The first dedicated CO₂ Missions



GOSAT



GOSAT (2009 - ?) – First Japanese GHG satellite - FTS with high spectral resolution optimized for spectral coverage (O₂, CO₂, CH₄)



OCO-2



OCO-2 (2014 - ?) – First NASA satellite designed to measure CO₂ with high sensitivity and resolution with small samples (< 3 km²)



TanSat

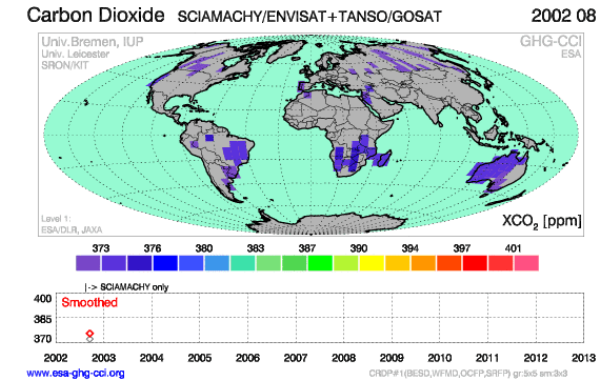


TanSat (2016 - ?) - First Chinese GHG satellite - Uses same O₂ and CO₂ bands and similar orbit as OCO-2

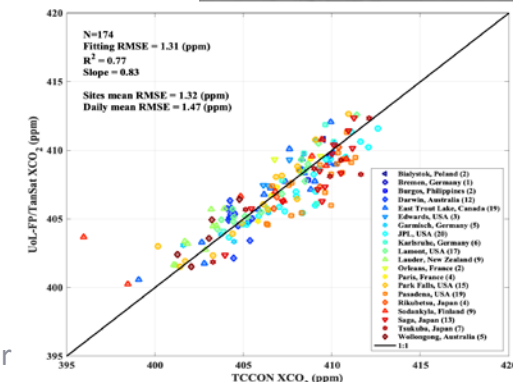
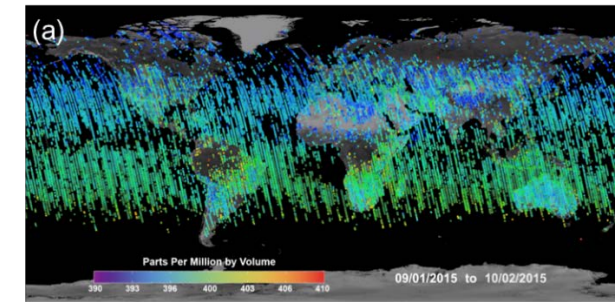


What about Europe?

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(see poster A. Di Noia)

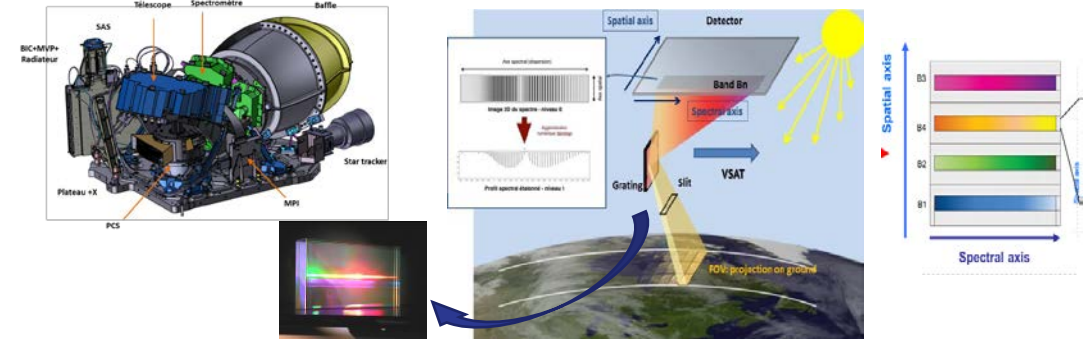


(see poster D. Yang)

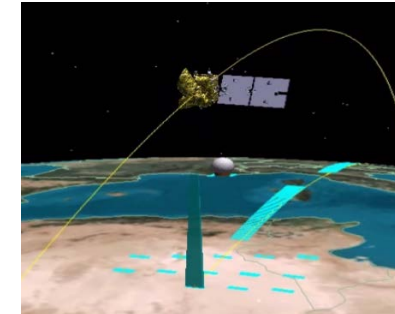
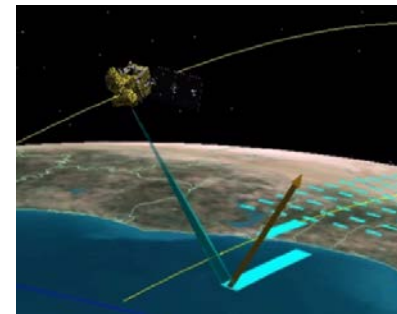
The first dedicated European CO₂ Satellite: MicroCarb



- MicroCarb is a CO₂ mission developed by CNES for in 2021
- Innovative, compact instrument compatible with microsatellite <200kg
 - 4 spectral bands acquired with single spectrometer and detector
 - Very high spectral resolution ($R \sim 25,000$)
 - Extra O₂ band at 1.27 micron to facilitate better aerosol correction
- Similar sampling strategy to OCO-2:
 - Nadir, glint, target with 3 ground pixels each 4.5 x 9 km² (@nadir)



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 ($\lambda/\Delta\lambda$)	25 500	25 900	25 800	25 900
Signal to Noise ratio @ Lmean (per channel)	285	378	344	177

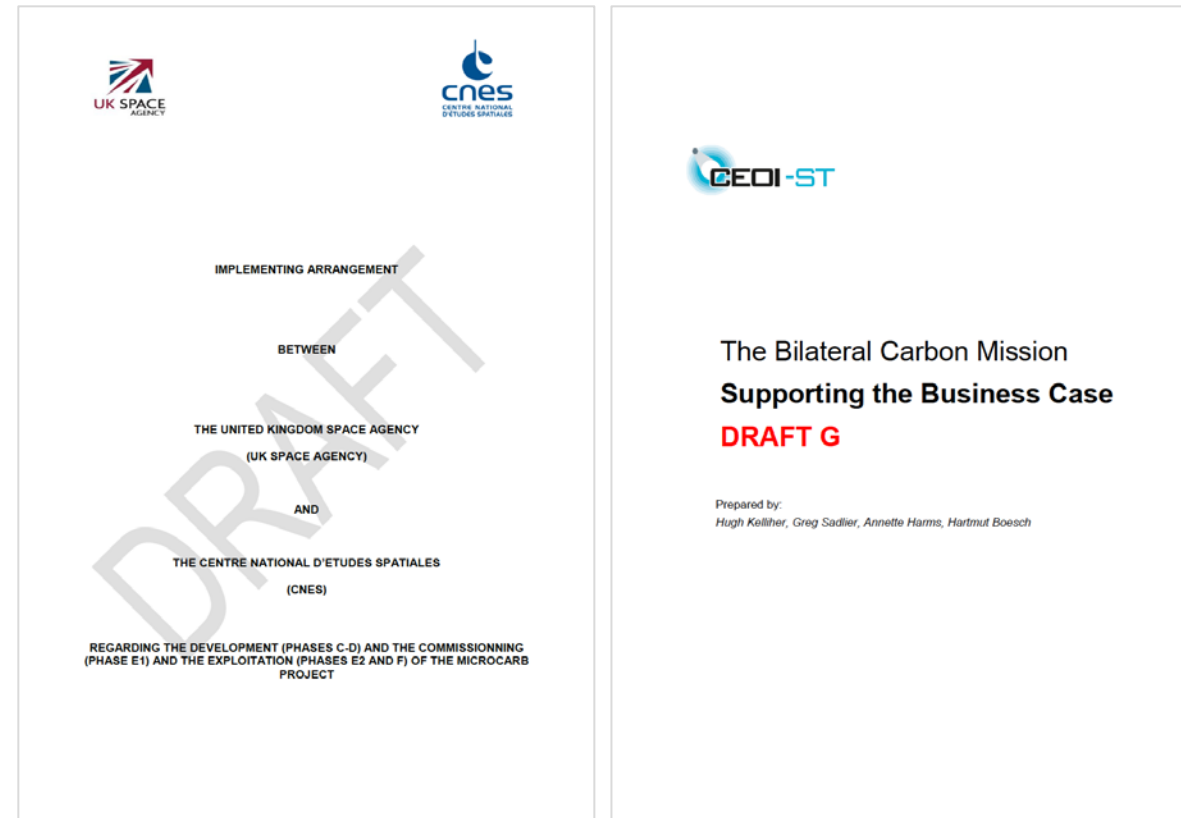


UK Joining MicroCarb Mission

UK Space Agency has joined MicroCarb mission as partner in 2017



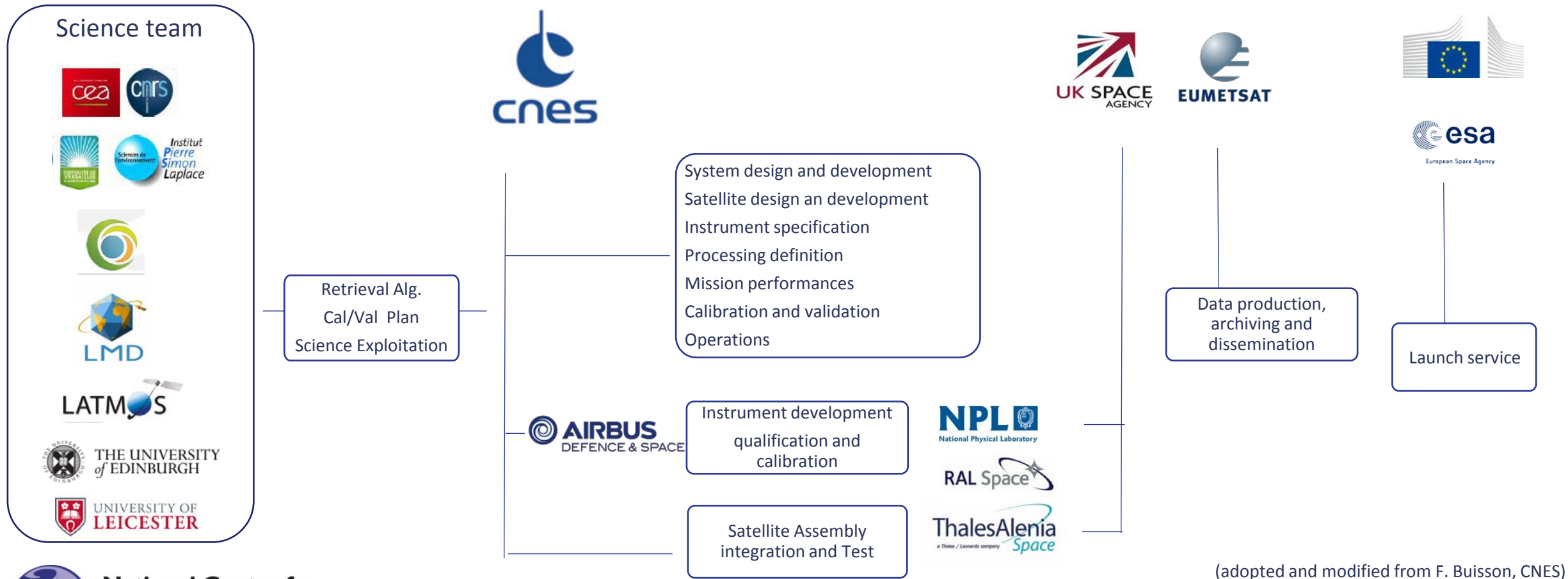
UKSA-CNES Signing Ceremony, April 2017



(CEIO Bilateral Carbon Mission Project, 2014 - 2015)

MicroCarb Organisation

UK contributions in key areas: Calibration, AIT, algorithms and science



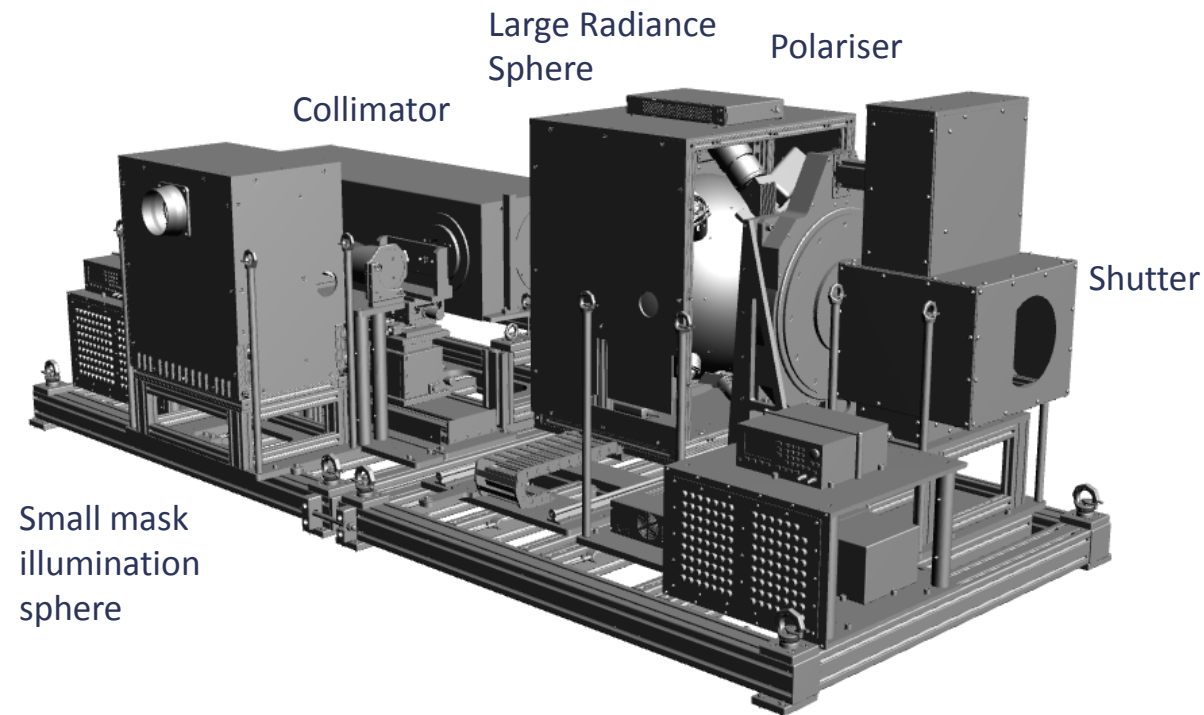
(adopted and modified from F. Buisson, CNES)

MicroCarb Pre-flight Calibration & Characterisation

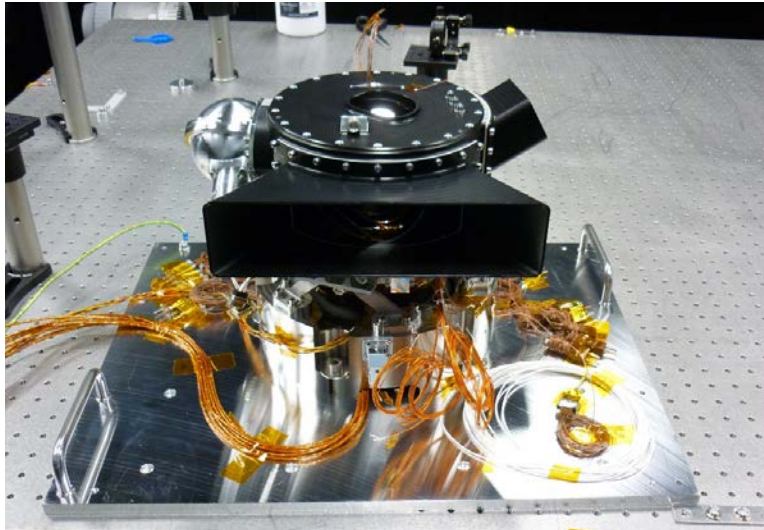
- NPL is providing the MicroCarb instrument pre-flight calibration facility:
 - NPL Spectroscopically Tuneable Absolute Radiometric calibration & characterisation OGSE (STAR-CC-OGSE)
- MicroCarb instrument 4x spectrometer bands and imager performance needs to be verified for parameters including:
 - SNR, ISRF, ILS, smile/tilt, keystone/tilt, dazzling, FoV, SRF, spectral calibration, absolute radiometric calibration, non-linearity, polarisation-dependence, inter/intra-band, spatial, spectral & temporal registration...
- This is provided by an effective optical test card of projected geometric features and uniform radiance fields in both broadband and monochromatic wavelengths

The STAR-CC-OGSE system

- STAR-CC-OGSE - a versatile facility for radiometric calibration and calibration of satellite sensors
- Laser allows monochromatic continuous tuneability from 380 nm to 2500 nm, with broadband (white light) source extending over same spectral extent
- STAR-CC-OGSE has two components:
 - large aperture SI-traceable calibrated integrating sphere source for radiometric calibration
 - collimated beam source, equipped with interchangeable, position fine-tuneable feature mask for optical performance characterisation

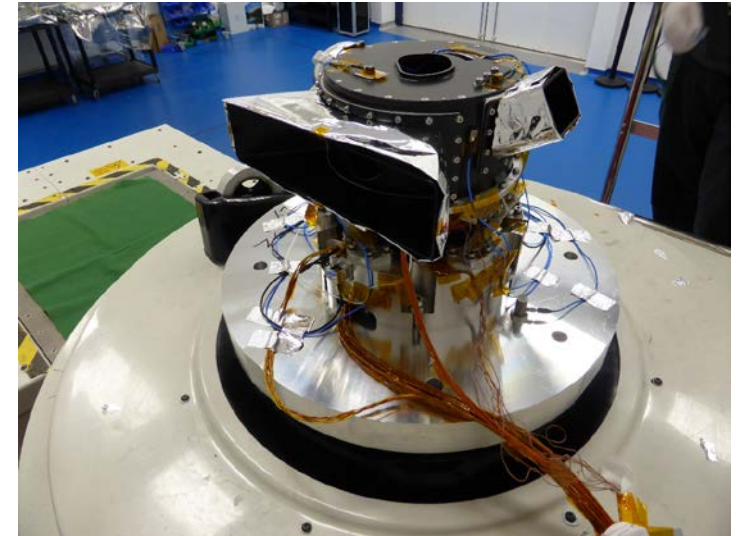


Pointing and Calibration Subsystem (PCS)



Engineering Qualification Model of Pointing and Calibration Sub-system of MicroCarb Instrument

- during integration and functional test (left)
- in Qual Vibration Test (right)



On-Board Pointing and Calibration Sub-system of MicroCarb will:

- 1) Ensure telescope Line of Sight de-pointing in one direction of $\pm 35^\circ$ around Nadir
- 2) Calibrate instrument radiometric response in absolute terms and spectral dispersion using Sunlight through a diffuser
- 3) Calibrate instrument radiometric response in spatial and spectral relative terms using white lamp
- 4) Close instrument entrance at launch, for dark calibration and in safe modes

MicroCarb Satellite Assembly, Integration and Test (AIT)

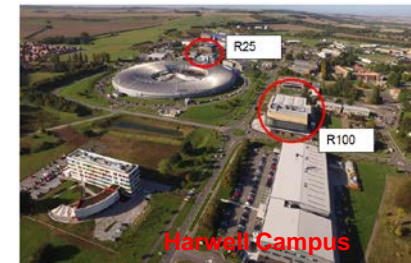
- MicroCarb Satellite integration is being performed by TAS in UK in cleanroom at RAL Space
- Platform, FM units and Instrument are supplied by CNES: “Myriade” Platform designed for small EO missions
- Bespoke Satellite MLI blankets/Active Thermal Control are developed by TAS in partnership with RAL Space
- Bespoke EGSE are being developed by TAS to support MicroCarb AIT
- Propulsion retrofit of existing Myriade Propulsion unit is performed in Thales Belfast to comply with French Space Law



TAS Bristol



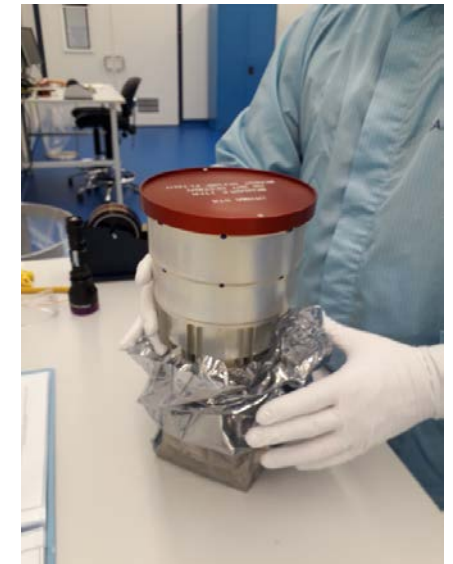
RAL Space R100



Harwell Campus

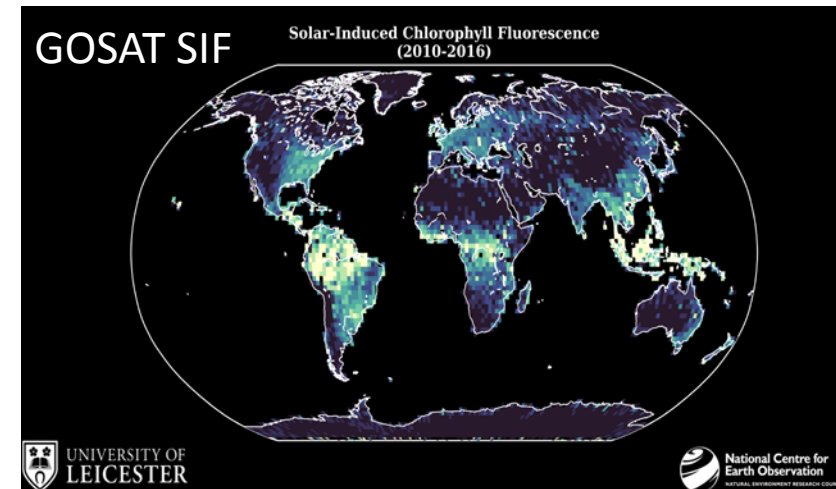
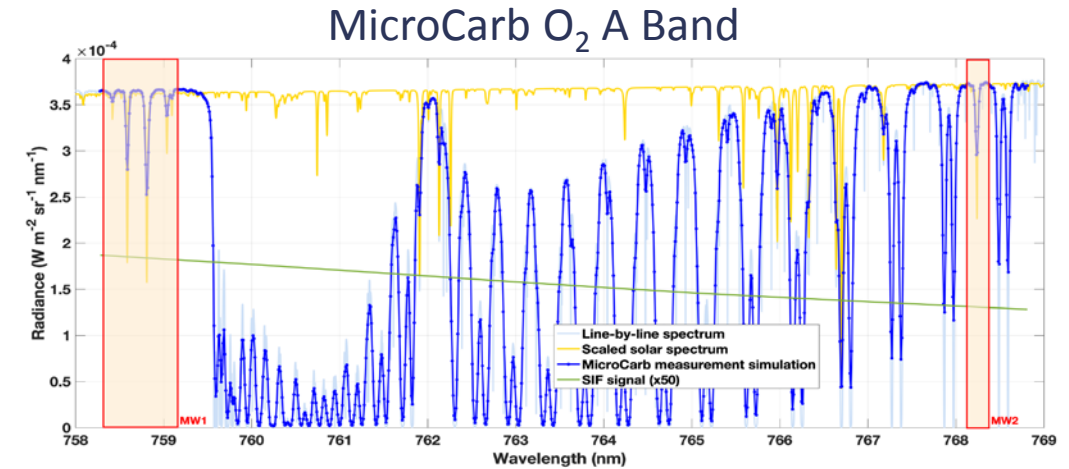
MicroCarb AIT - Four Major Project Phases

- **Preparation Phase (Phase A) :** Complete
- **Platform AIT Phase (Phase B) :** In Progress.
 - Phase commenced with reception of Structure Panels in July 2019.
 - Panel preparation and bake-out currently underway alongside receipt of Flight Equipment prior to mechanical & electrical integration.
- **Satellite AIT Phase (Phase C) :** Phase commences with reception of flight instrument in Summer 2020. Instrument is mechanically and electrically installed, prior to Satellite qualification campaign.
- **Launch Campaign (Phase D):** Six week launch campaign at Kourou launch site (French Guiana) in Summer 2021. Thales Alenia Space team from UK shall be on-site to perform final launch preparations



MicroCarb Retrieval Development: Solar-Induced Fluorescence SIF Retrieval

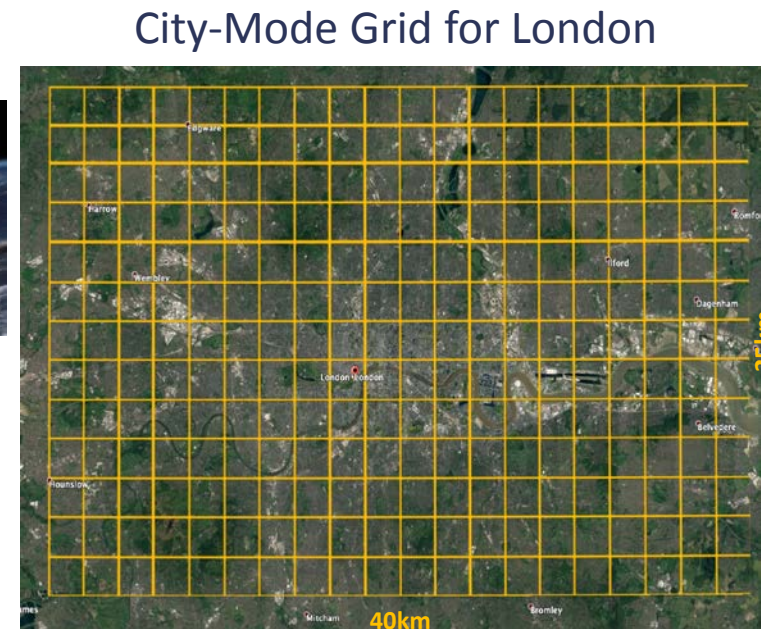
- In addition to supporting MicroCarb CO₂ retrieval development, we will provide SIF retrieval processor
- Solar Induced Fluorescence SIF is a NIR signal emitted by plants during photosynthesis
- SIF can be retrieved from filling-in of solar lines (eg GOSAT)
 - SIF product allows observation of plant productivity GPP from space
 - Synergistic use with CO₂



Focus on Cities

- 'City-Mode' of MicroCarb:
 - Experimental capacity with locally improvement of spatial resolution of 2x2 km²
 - Obtained by slowing down satellite scrolling + scan + binning tuning
 - Allows mapping of cities to study CO₂ emissions
- Development of Models and Flux Inversions for MicroCarb City-Mode
- London as reference city

Intensive Measurement Study for London



Ground-based
4 x portable FTS



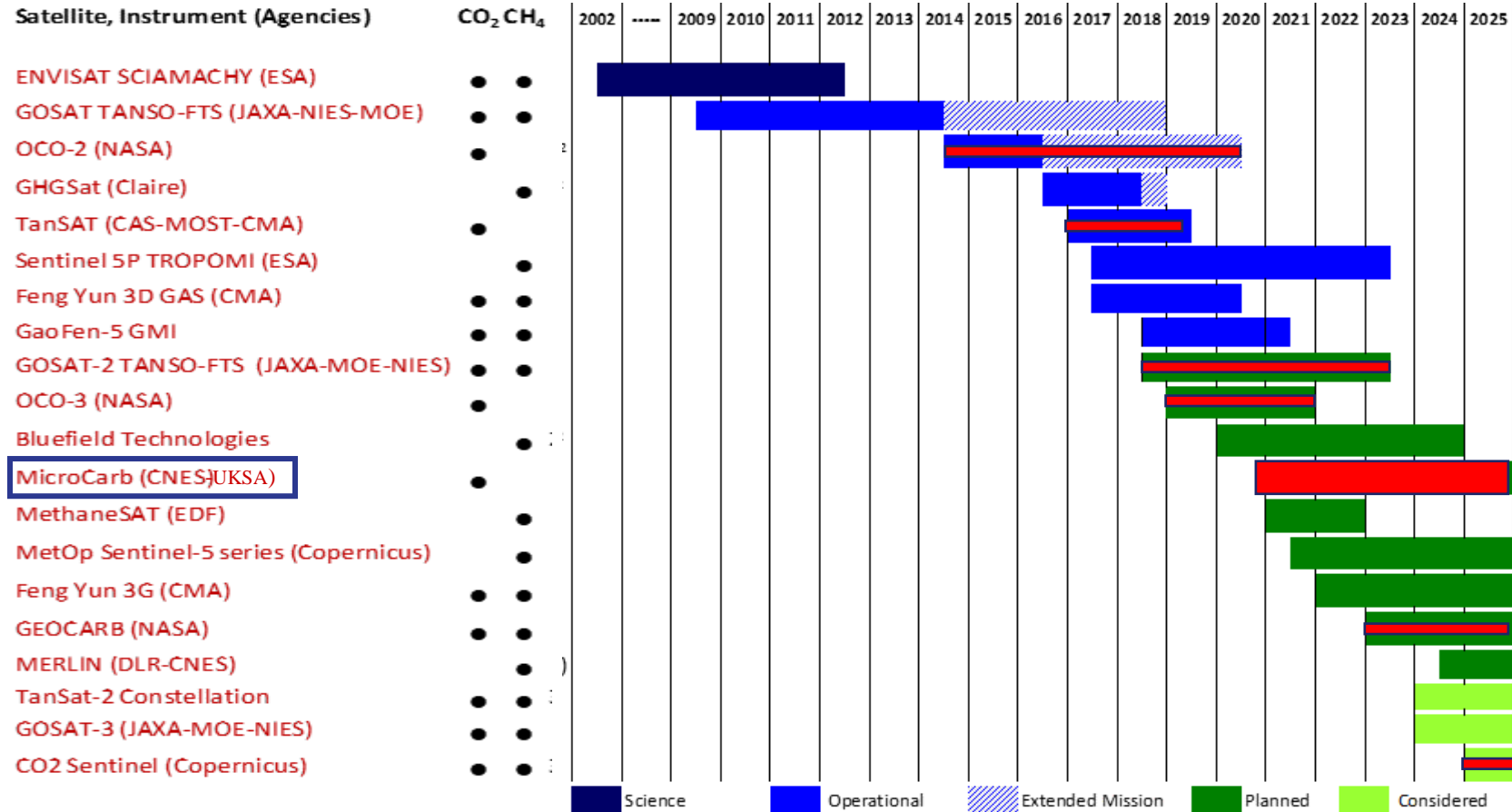
3 x DOAS (NO₂)



TCCON (Harwell)



MicroCarb - Part of the International GHG Constellation



- MicroCarb is critical mission for continuous presence in space - Launch 2021 is important
- Cross-validation and coordination with OCO-2/-3, GOSAT/-2 and Tansat
- Play part in preparation of global stocktake 2023/2028
- Contribute to preparation of future CO2M (Copernicus)

- MicroCarb will be the first dedicated, European CO₂ mission which will be an important contribution to the international GHG constellation and be an important step toward a space-based capacity for monitoring anthropogenic carbon emission
- UK has strong involvement in MicroCarb in key areas from space-hardware, cal/val to ground-segment/algorithms
- MicroCarb will provide great opportunities for science exploitation and help to strengthen the role of UK for future carbon missions