Overview of Optical Instrument technologies for Future Earth Observation missions

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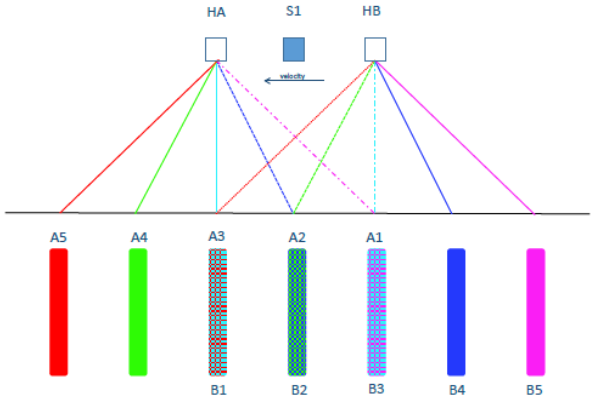
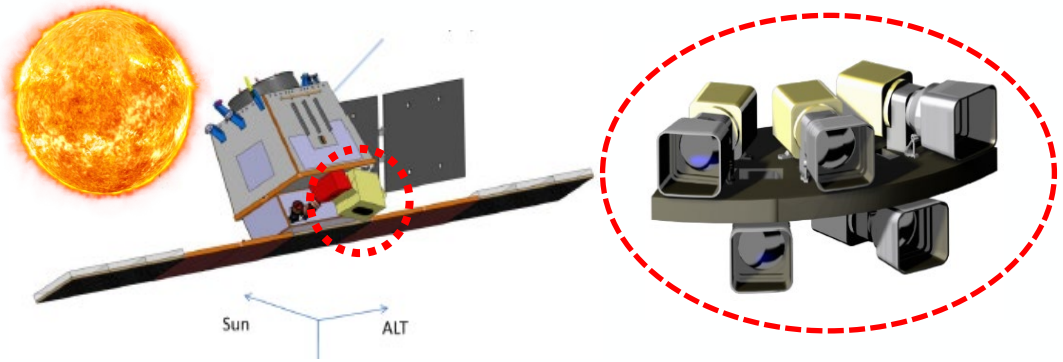
Living Planet Symposium
23-27 May 2022

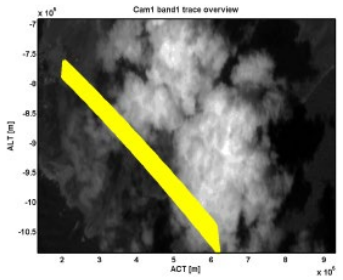
Science driven Missions: Earth Explorers, SCOUT, opportunity missions

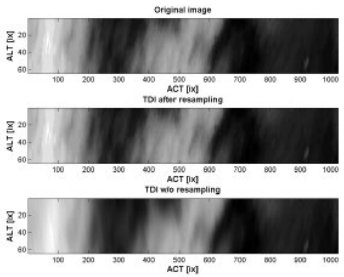
Thermal Infrared payload: up to 5 views/4 bands camera supporting Sea Surface Temperature retrieval and cloud motion vector

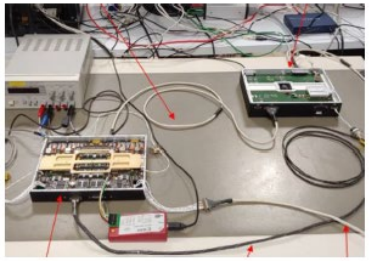


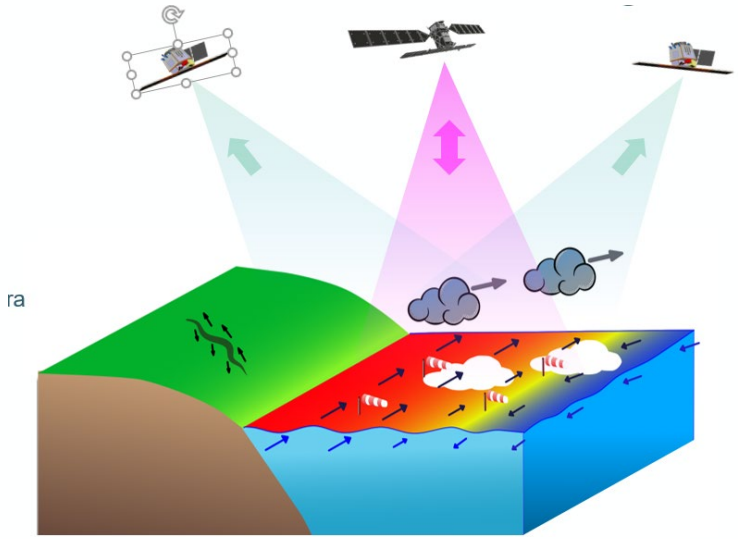


Pre-development with detector testing, filter mounting and processing algorithm







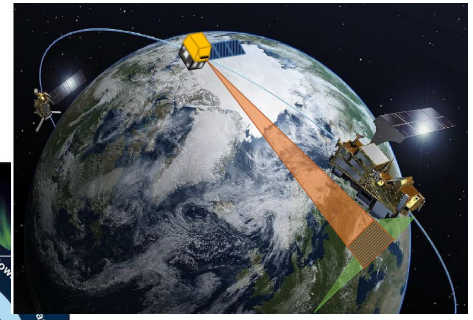


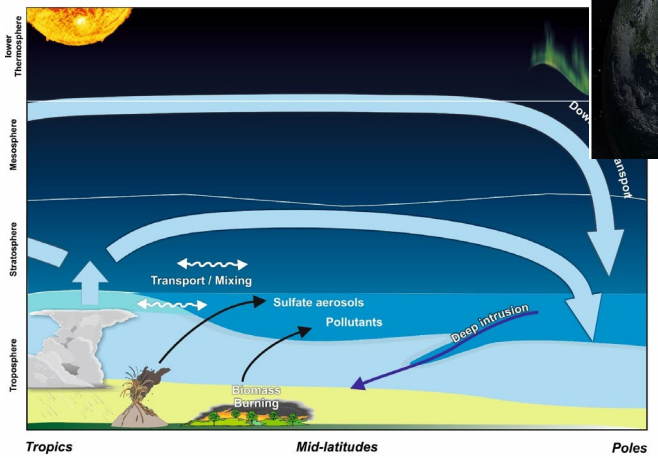
Industrial teams involved: OHB, Leonardo, SSTL, ABB

EE 11 candidate missions : CAIRT, NITROSAT

CAIRT Tomography by infra-red limb imaging

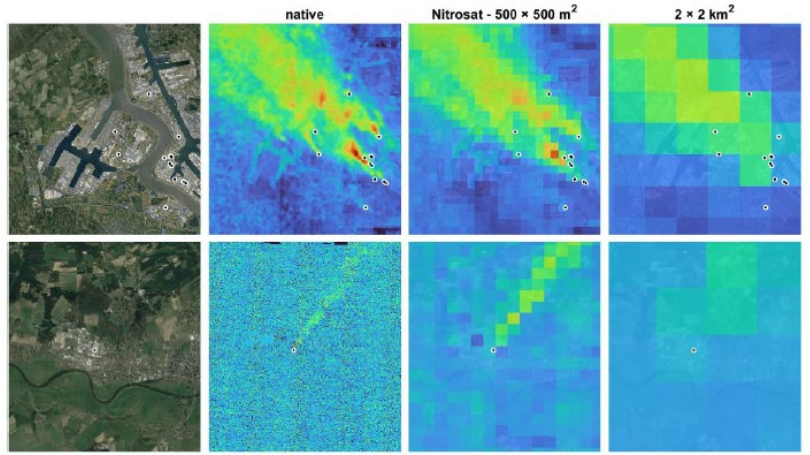
- Quantify atmosphere circulation from the upper troposphere to the lower thermosphere by providing high-resolution observations of temperature and long-lived trace gases
- Limb viewing
- Imaging Fourier-Transform Spectrometer
- Measuring in the mid-thermal IR with high spectral resolution





NITROSAT

- Mapping reactive nitrogen at the landscape scale
- Making measurements of NO2 and NH3 at sub-km resolution
- Monthly seasonal patterns
- NH3: Infrared imaging Fourier Transform Spectrometer (900-1000 cm-1 spectral range)
- NO2 : Visible Imaging Pushbroom Spectrometer NO2 (400-460nm spectral range)

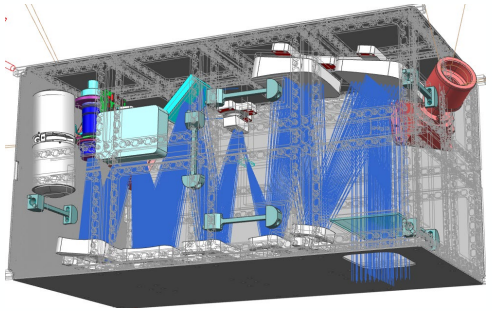


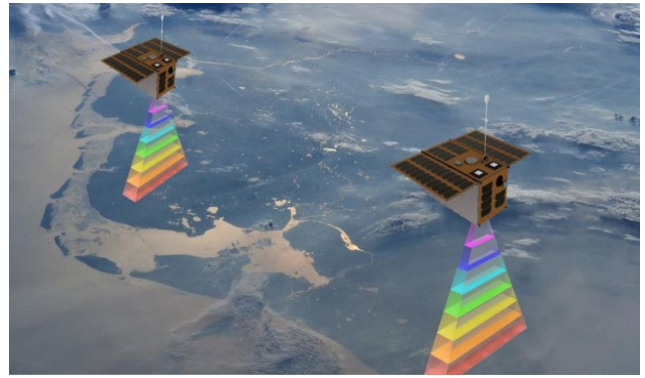
Technologies required: LWIR matrix detectors with fast read-out and large FWC, broad band coatings and dichroics, Inteferometers

SCOUT missions: TANGO and CUBEMAP payloads

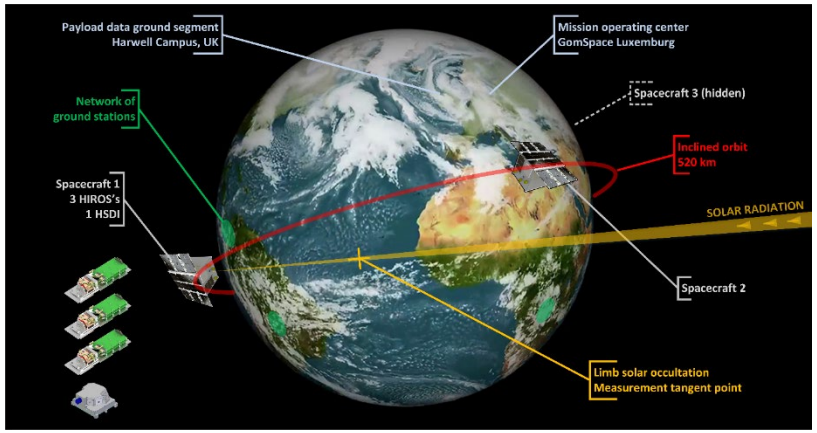
session B7.01.1 Scout: ESA NewSpace Science missions

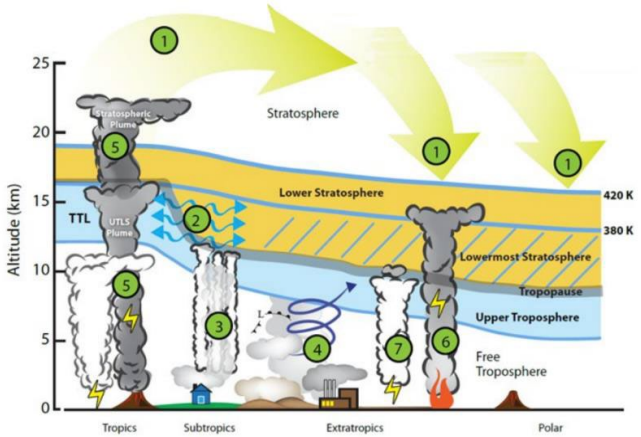
- **TANGO (ISIS/TNO/SRON/KNMI)** risk retirement activities on detector and instrument
  - TANGO-Carbon measures CO2/CH4
  - Imaging spectrometer in the 1.6 µm band
  - TANGO-Nitro measures NO2
  - Imaging spectrometer in the 400-500 nm band

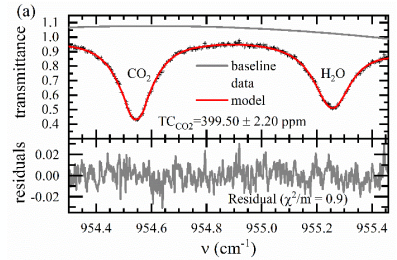


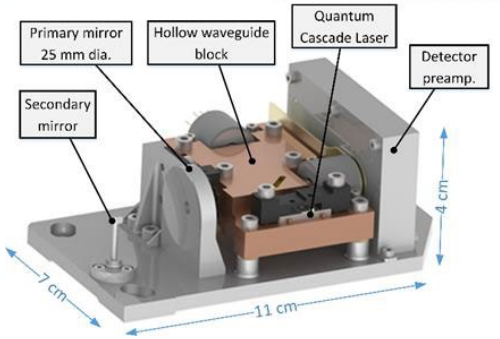


- **CUBEMAP** (GOMSPACE/RAL): first SCOUT mission selected for implementation
  - Thermal infrared laser heterodyne spectro-radiometer (LHR) and Sun disc imager
  - 3 satellites (orbit 28 deg inclination, 520km altitude)



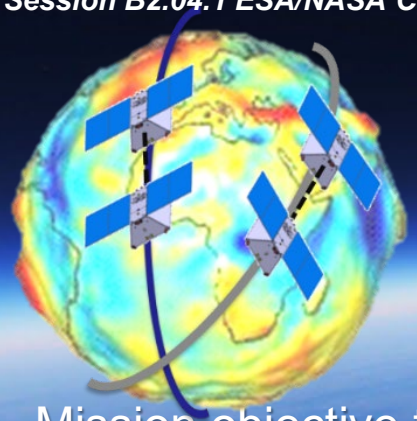


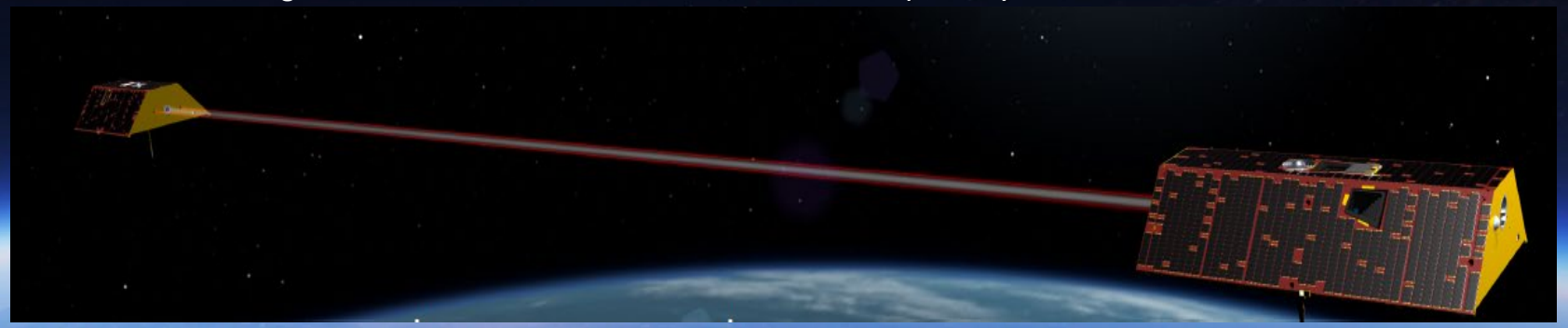




MAGIC

Session B2.04.1 ESA/NASA Cooperation Towards MAss change and Geosciences International Constellation (MAGIC) Mission

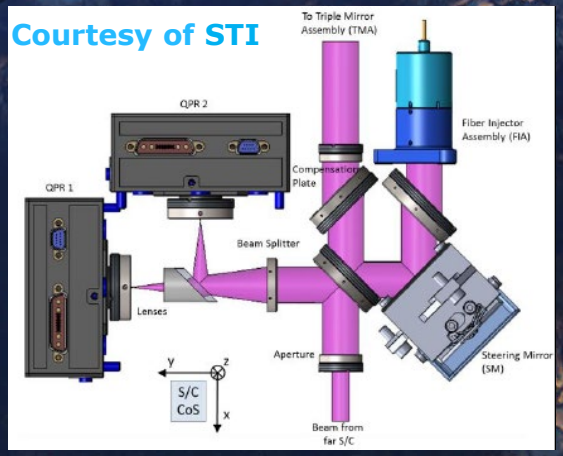




- Mission objective to measure the geoid with 1 mm accuracy at 3-day intervals at <500 km spatial resolution, with 200-km inter-satellite distance, over a time span of 10 years
- Cooperation with DLR and NASA
- Accurate instruments (laser metrology, accelerometers), satellite drag free control
- Pre-development of Laser Tracking Instrument and accelerometers

Courtesy of TESAT

Courtesy of STI



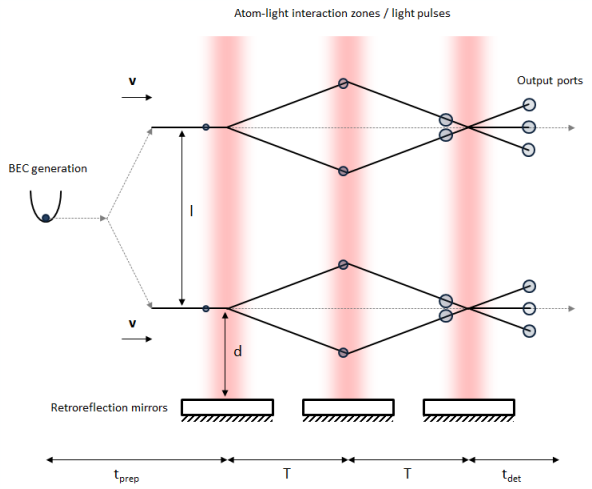
Courtesy of Airbus DS and NPL

Cold Atom Interferometer for Earth Observation

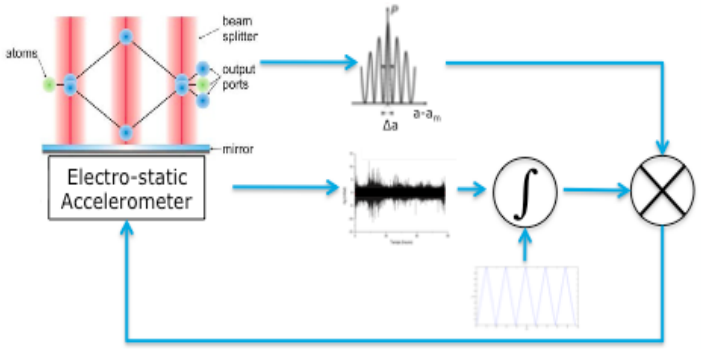
session B9.08.1 Quantum Missions for Climate, ambition for "Space for a Green Future" Accelerator

Concepts for Earth Geodesy

1. CAI interleaved gravity gradiometer

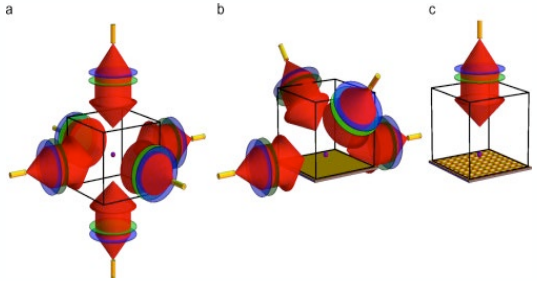


2. Hybridization classical accelerometers/CAI

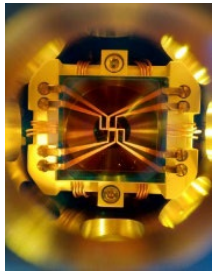


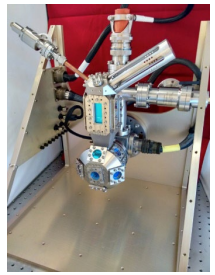
Hardware developments

1. Grating Magneto Optical Trap (MOT)

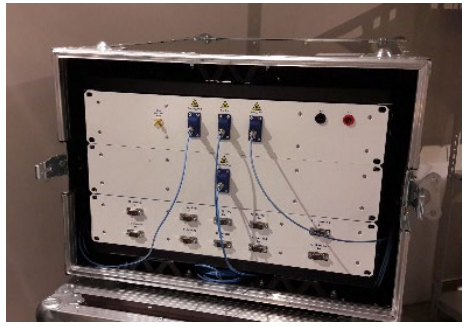


2. Compact Vacuum Chamber for BEC



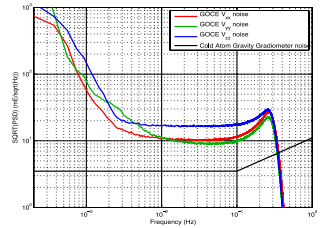


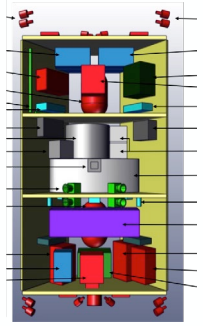
3. Agile and compact laser system for CAI

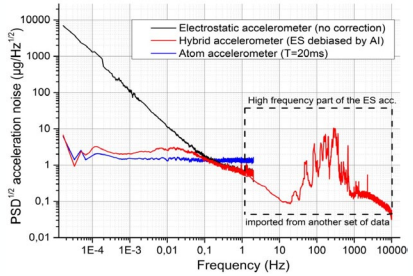


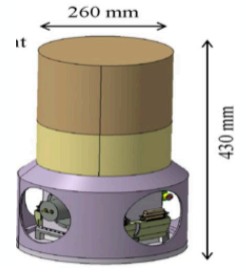
Results

1. Mission and instrument concepts validated



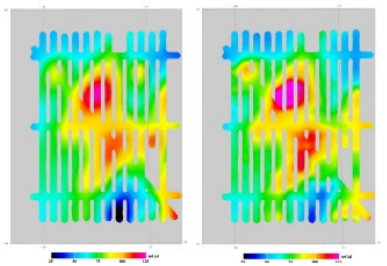




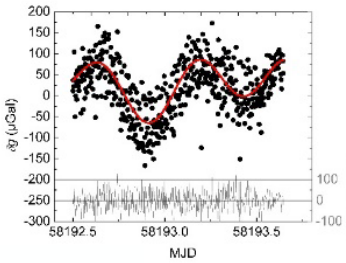


2. On-ground validation

CAI Classical



Laser System



Airborne campaign

Static FTS instrument for CO2, CH4 or O2 detection

Two studies initiated in 2020: Carbon-HIGS (by TNO, NL) and Carbon-CGI (by TAS, FR)

Objectives: assess feasibility of static-FTS concepts, as compact instruments for small satellite for

- GHG concentration at **high spatial resolution** (~200m)
- Quantification of emission from **small sources**
- Working as an **auxiliary instrument** of CO2M, **or stand-alone**.

Carbon HIGS (TNO, NL)
NIR band: for H2O vapour, SWIR1 band for CO2

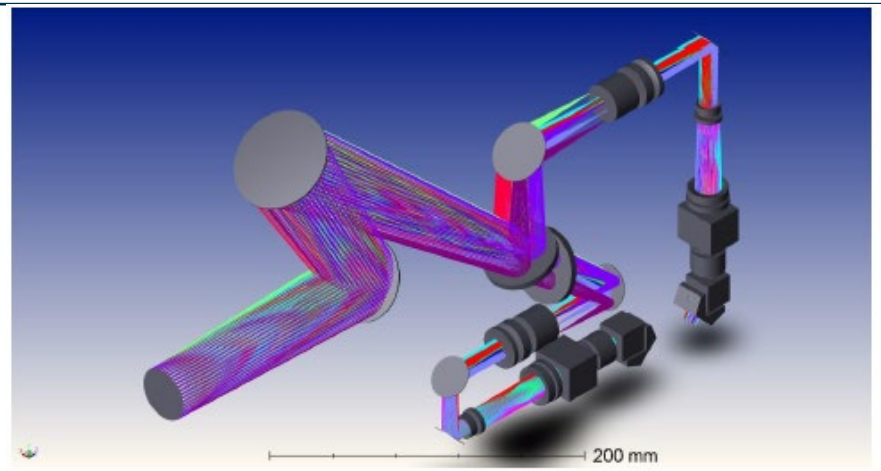


Figure 2, concept optical design with a telescope and two HIGS interferometer channel

Carbon CGI (TAS-FR)
VIS band for NO2 NIR band for O2 surface pressure SWIR1-SWIR2 band for CO2 and CH4

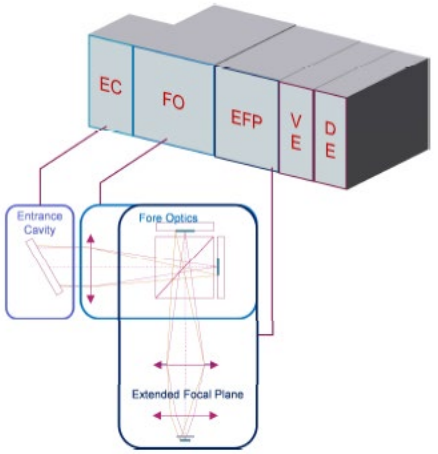
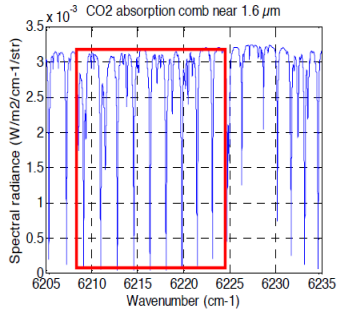
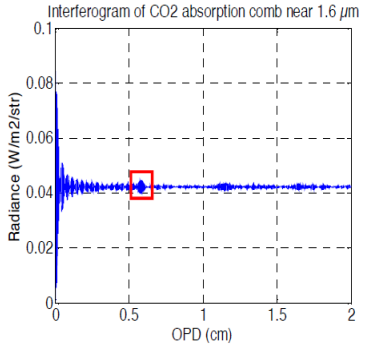


Figure 1: Five volumes architecture concept



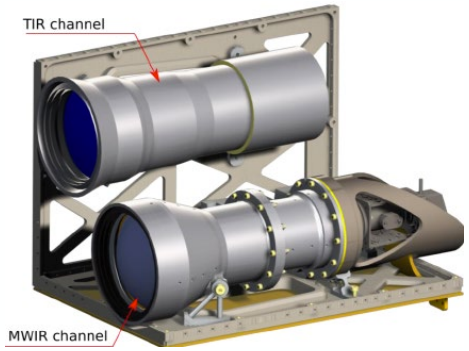


HOW: measuring Partially Scanned interferograms (PSI) using orbital motion to introduce Optical Path Difference

Future EO passive optical missions for small sats

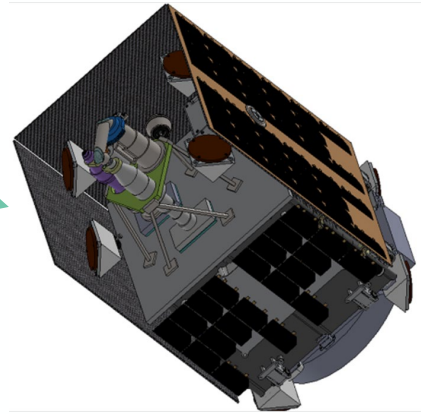
Two studies completed (Q3-2020):

- Review optical technology (optics, detectors, Cal/Val) usable in small sats and commercial space
- Derive instruments and non-commercial mission concepts (operational, scientific, detection applications)
- Several promising concepts defined, needing further system and prototyping work

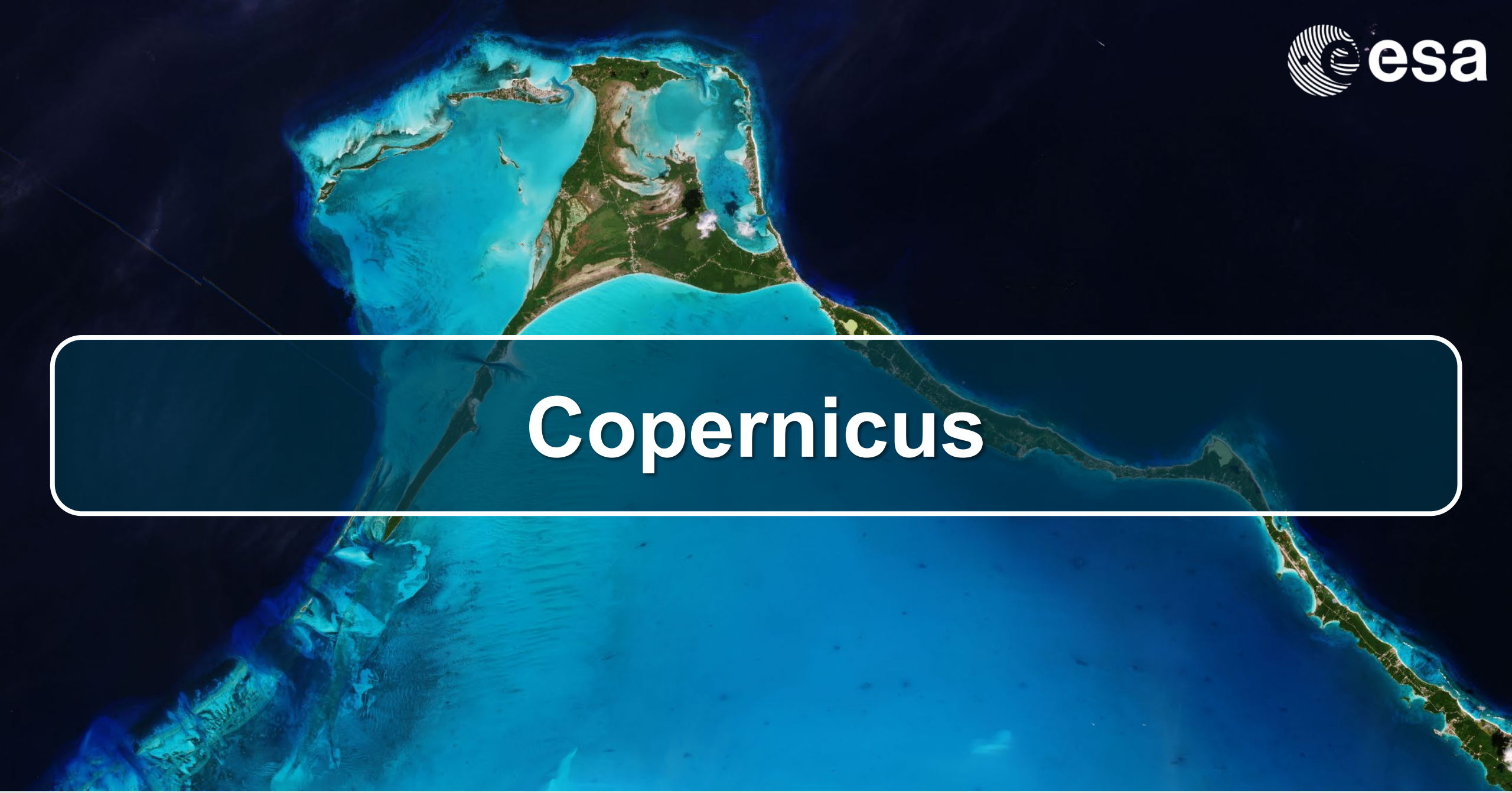


Cosine TIR instrument for multi-angular LST

Cosine, ISIS, TuDelft (NL) study	SSTL, Univ. Leicester (UK) study
Multi-angular LST MWIR+TIR, 3x 26 kg nanosat	Subdaily ocean colour VNIR, 16x 36 kg microsat
Aerosol Properties VNIR Polarimeter, 4x 8 kg Cubesat	Subdaily Aerosol PM2.5/AOD VNIR polarimeter, 16x 36 kg microsat
Atmospheric Ammonia (NH3) (TIR HS, 1 x 68 kg microsat)	Subdaily SST/LST TIR, 16x 36 kg microsat



VNIR+Satellite for subdaily ocean colour (SSTL)



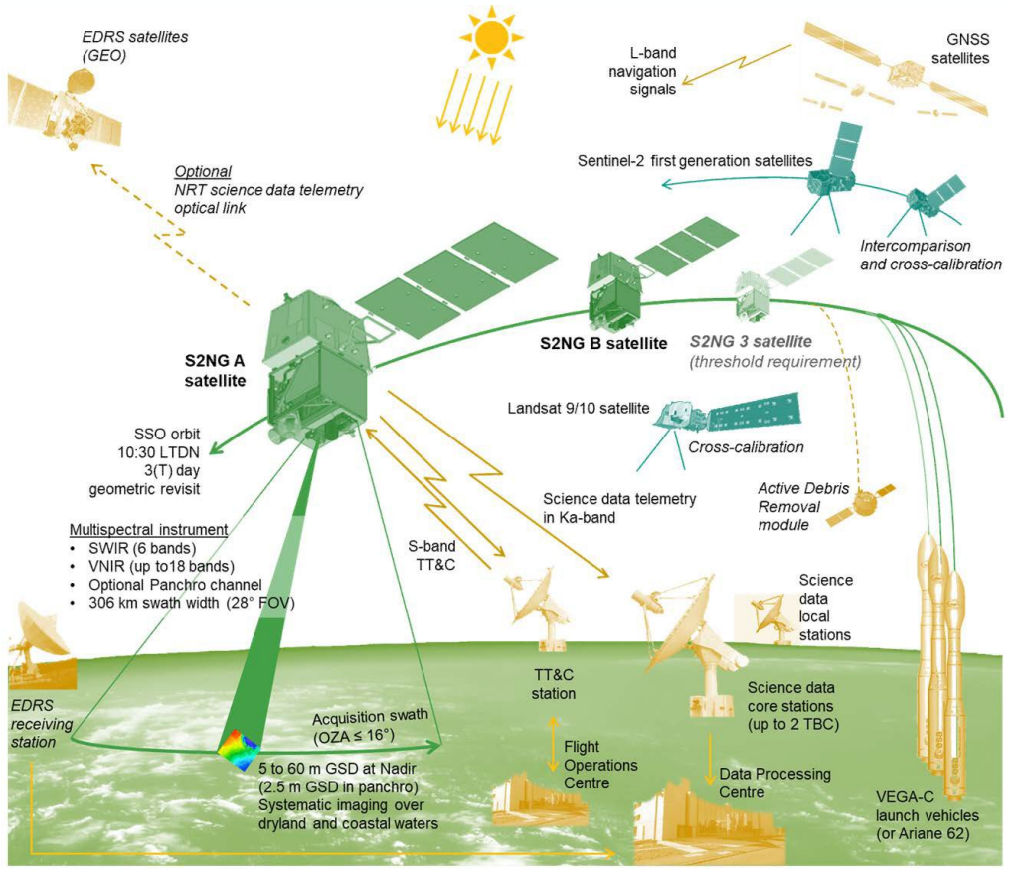
Copernicus

Sentinel 2 NG phase 0

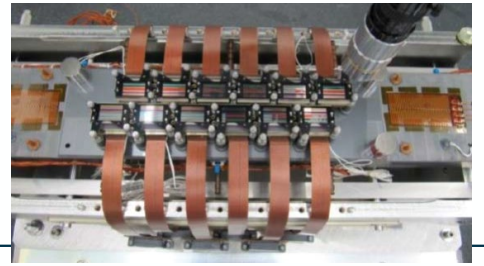
Session B8.09.2 Copernicus Sentinel Extension Missions/Next Generation

- Phase 0 running with OHB and ADS
- Significant increase in requirements (spatial resolution *2 - up to 24 spectral bands)

Band	SSD Goal	SSD Threshold	Center Wavelength	Bandwidth	L_{min}	L_{ref}	L_{high}	L_{max}	SNR@Lref Goal	SNR@Lref Threshold
	@ SSP [m]	@ SSP [m]	λ [nm]	Δλ [nm]		$Wm^{-2}sr^{-1}\mu m^{-1}$				
0 (G)	10	10	410/412	15		45,00		501,00	100	(TBD)
1 (T)	30	60	443	20	15,79	129,11	n/a	587,87	894	129
1a (G)	5	10	470/473	20	14,29/13,99	137,5/137,04	n/a	643,10/643,53	(TBD)	(TBD)
2 (T)	5	10	490	65	11,70	128,00	n/a	615,48	162	154
2 new	10	20	510	10	17.45	44.39	449.60	562.0		
2a (G)	10	10	531	10	8,11	110,00		572,00	(TBD)	(TBD)
3 (T)	5	10	560	35	6,49	128,00	n/a	559,01	189	168
3a (G)	5	10	620	20	4,17	21,50	n/a	397,00	(TBD)	100
3b (G)	5	10	650	20		23,00		380,00	100	(TBD)
4 (T)	5	10	665	30	3,31	108,00	n/a	484,13	175	142
5 (T)	10	10	705	15	2,61	74,60	n/a	449,55	192	117
6 (T)	10	10	740	15	2,06	68,23	n/a	412,92	169	89
6a (G)	10	10	763	10	1,39	36,00		284,00	(TBD)	(TBD)
7 (T)	10	10	783	20	1,67	66,70	n/a	387,08	161	105
8 (T)	5	10	842	115	0,95	103,00	n/a	307,80	174	174
8a (T)	5	10	865	20	0,95	52,39	n/a	307,80	117	72
9 (T)	30	60	945	20	0,51	8,77	n/a	232,91	135	114
9a (G)	10	10	985	20		14,10		220,00	100	
10 (T)	30	60	1375	30	0,06	6,00	n/a	45,00	301	50
11 (T)	10	10	1610	90	0,40	4,00	32,00	69,78	133	100
12a (G)	10	20	2130	50	0,16	2,12	(TBD)	23,97	(TBD)	132
12b (G)	10	20	2210	50	0,13	1,79	(TBD)	20,77	(TBD)	132
12c (G)	10	20	2260	50	0,12	1,65	(TBD)	18,71	(TBD)	132
12 (T)	10	10	2190	180	0,10	1,70	11,00	24,60	141	100



- Technology pre-development: telescope, free form mirrors (TDE in 2022/23), detectors (both VIS and SWIR), filters



Sentinel 3 NG phase 0

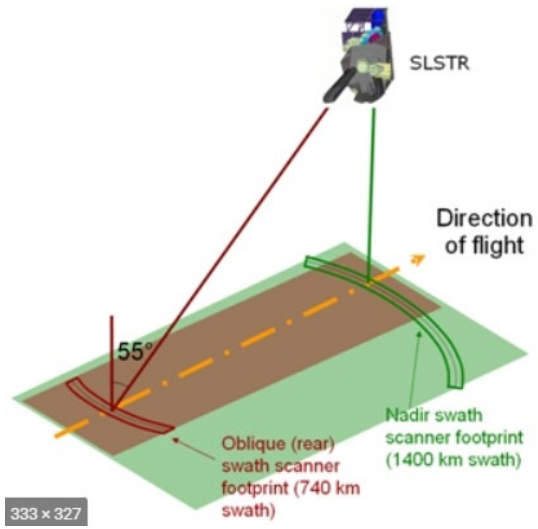
- Phase 0 running with OHB/ADS and TAS/Leonardo

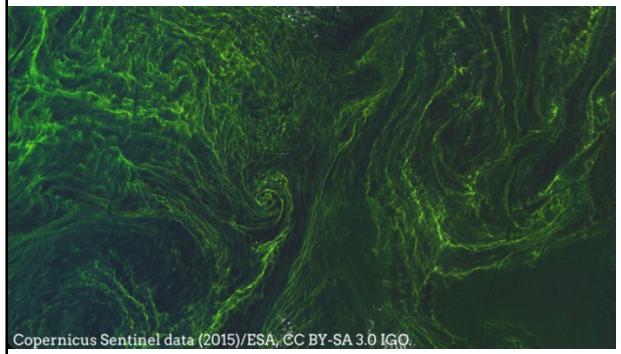
AOLCI

- Spatial resolution improved by at least factor 2 (150m and target 100m)
- Additional bands in VIS/UV (detection of Algae blooms) and SWIR bands (atm. correction)
- SNR > current generation in-orbit

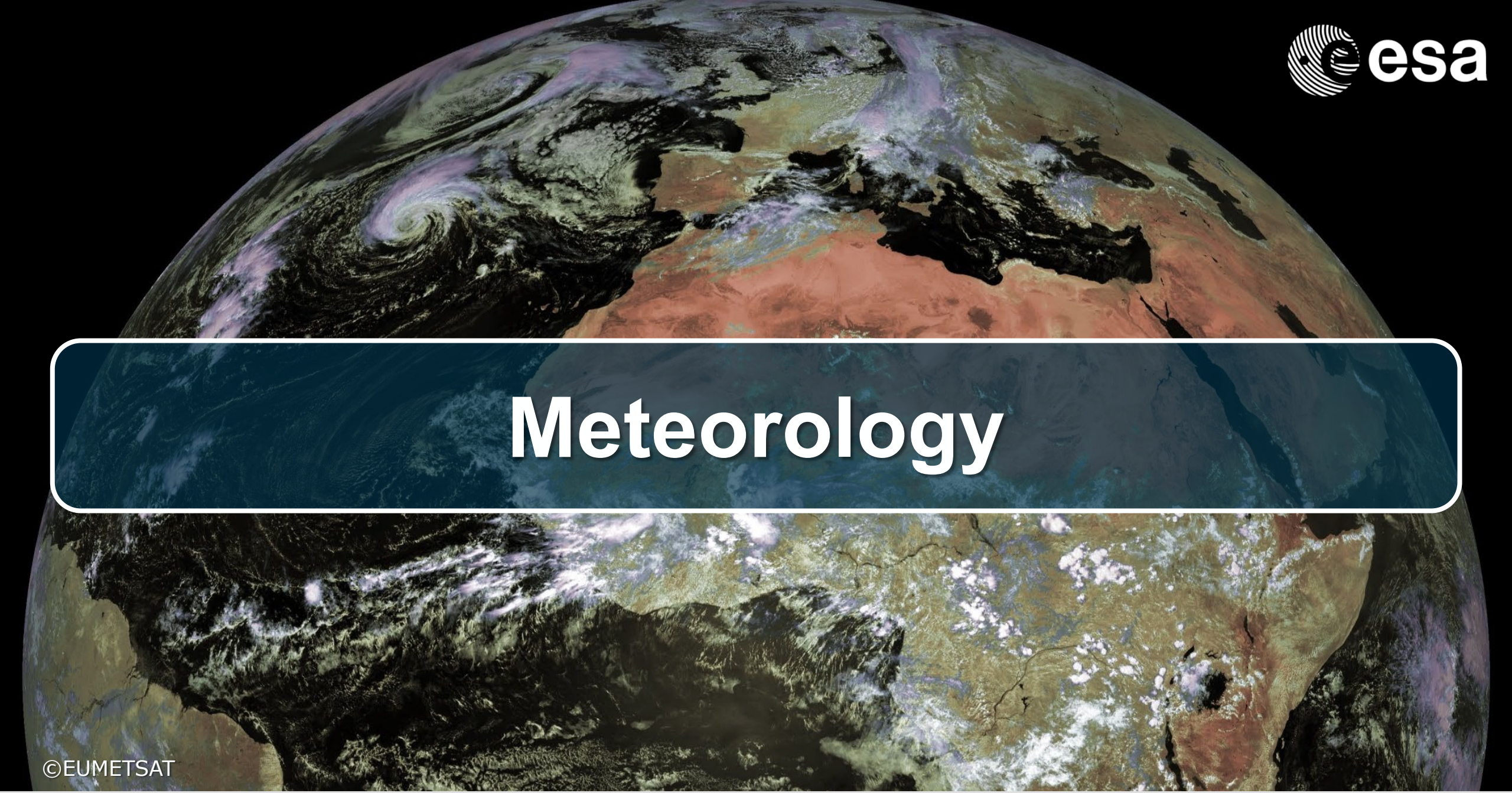
ASLSTSR

- Spatial resolution improved by factor >2





- Technology pre-development foreseen: telescope, detectors, filters


esa
Meteorology
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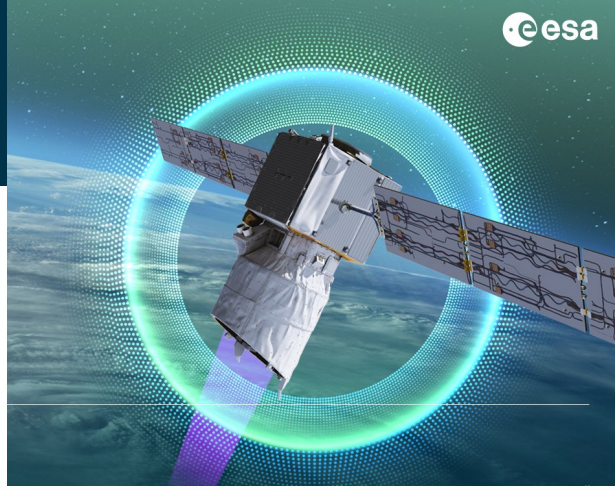
Aeolus 2

session B5.01.4 Future Meteorological Missions : AWS & Aeolus-2

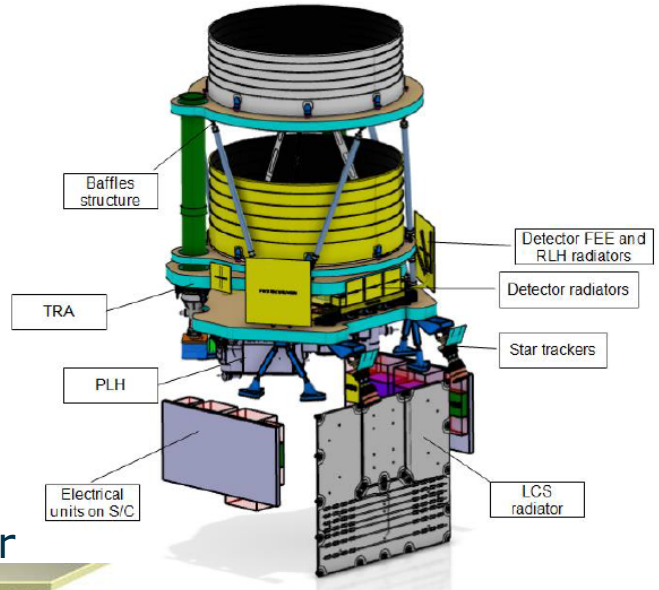


Building on the success of the Aeolus mission utilising the heritage and lessons learned from both the Aeolus development and in-orbit operations and performance;

Having a mission lifetime of 10-15 years utilising 2 spacecrafts;

Increasing robustness and operability required for an operational mission;

Incorporating recommendations on observational requirements for future DWL missions from the Aeolus Scientific Advisory Group



- ✓ Instrument Consolidation study with Airbus DS-SAS
- ✓ 2 Transmitter Engineering model developments with Fraunhofer Institute for Laser Technology and Leonardo
- ✓ Detector Engineering model development with Teledyne E2V

Commercially driven optical payloads and smallsats

Incubed: some examples of upstream projects with payload development

session E1.05.1 New Space missions in InCubed

mantis

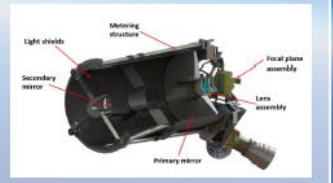
Mission and Agile Nanosatellite for Terrestrial Imagery Services

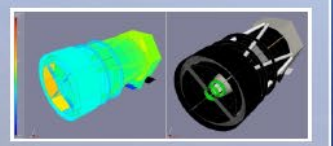
Specific focus on Oil and Gas applications
3m GSD (SR)
12U Cubesat with
VIS-NIR Push broom Multispectral 4 bands Dual Telescope - Onboard Super Resolution and Cloud Detection

Open Cosmos- SATLANTIS

SAT4EO

AOCS and Instrument for
Very High Resolution imagery from state of the art small satellite platform



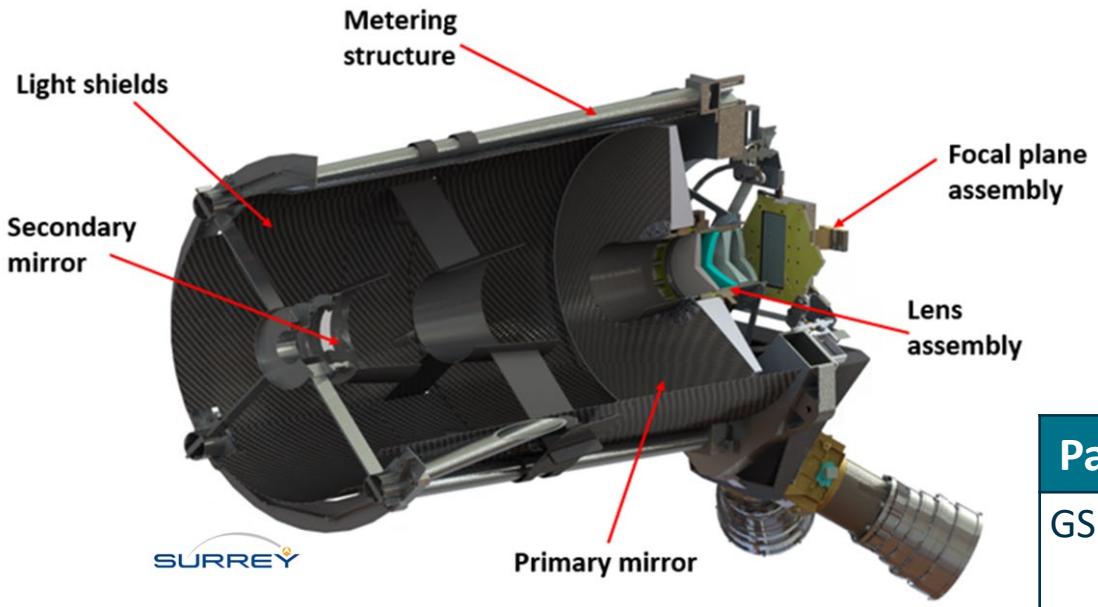


VHR System, 0.6 m native GSD with Super Resolution capabilities (0.3 m), Enhanced AOCS
100-200 Kg S/C AOCS Suite – Compact VIS-NIR VHR Telescope (new Sensor Development) – Dedicated ground Exploitation Platform

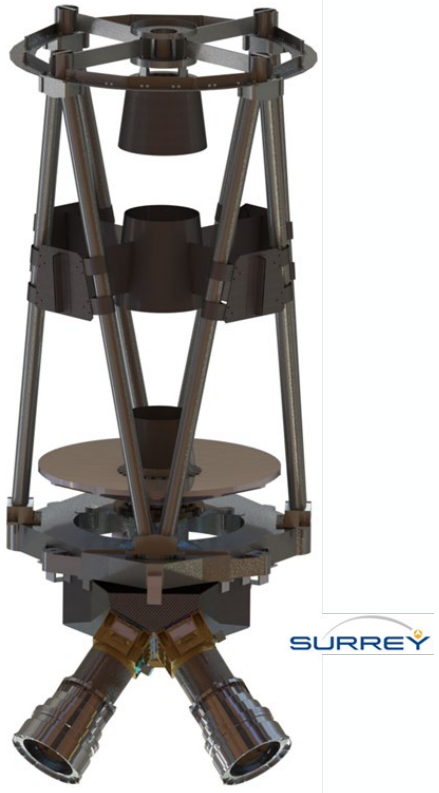
Deimos- SSTL

Incubed: SAT4 EO Precision payload

Precision is a very high resolution multispectral imager which utilizes a novel CCD-in-CMOS time delay and integration (TDI) line scan detector and innovative opto-mechanical techniques to achieve cutting edge performance at a market-leading size, weight and power.



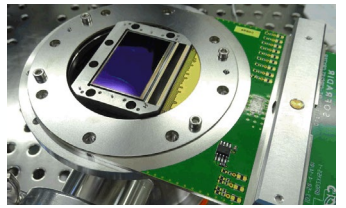
Parameter	Specification
GSD	0.6 m PAN (< 0.5 m with ½ pixel shift) 1.2 m multispectral
Swath	9.5 km
Bands	PAN, R, G, B, NIR
Sensor Type	CCD-in-CMOS TDI detector
SNR	>100



Other Technologies needs for future EO

Future meteo missions both in LEO and GEO

- new IR detectors based on Superlattice technologies (MWIR->TIR)
- improved MCT detectors,
- IR coatings/dichroics,

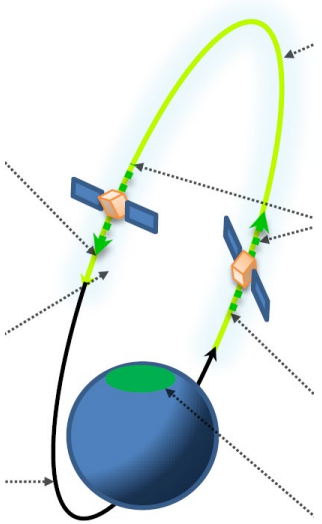


Risk retirement activities **for Night Light Remote Sensing** following non selected proposals such as N8 or Galene, but also addressing needs for Nordic Arctic Imaging

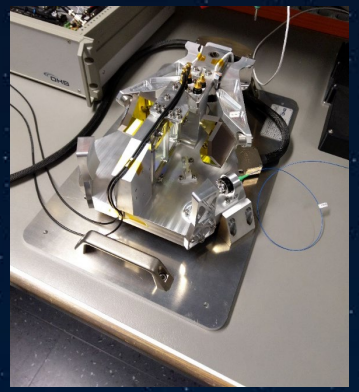
- Day and Night Band imager
- High dynamic, high sensitivity VIS detector

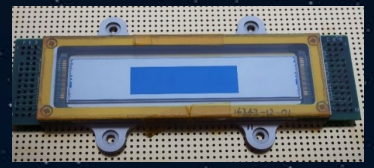
Enabling technologies for **compact instruments**

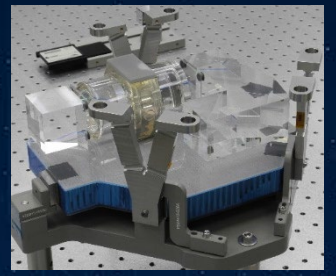
- Deployable telescopes,
- Active pointing and WFE corrections,
- Digital LOS stabilisation
- Miniaturising instrument concepts



➢ **Activities to be funded through Future EO and TDE/GSTP**







Thank you.

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