1. The 3 aims of the webinar - 2 minutes - A. Skidmore
2. Welcome to ITC, new directions, links to ESA – 5 minutes – Freek van der Meer
3. Background to ESA & CHIME mission requirements – 5 minutes – M. Rast **(slides)**
4. Overview of image spectroscopy (hyperspectral remote sensing) – 3 minutes – https://www.youtube.com/watch?v=_sUZ96YZOQU
5. CHIME mission and status – 10 minutes – J. Nieke **(slides)**
6. CHIME calibration and validation activities – 5 minutes – J. Adams **(slides)**
7. Applications with image spectroscopy – 15 minutes – A. Skidmore
8. ESA opportunities for stagiaires and industry placement – 5 minutes – J. Nieke **(slides)**
9. Questions – 10 minutes – A.Skidmore, J. Nieke, J. Adams
10. Close –F. van der Meer – 5 minutes

ITC/UT & ESA Webinar on Image Spectroscopy and the ESA CHIME mission

Wednesday, 4.11.2020, 10-11am

Michael Rast, ESA-ESRIN

CHIM-HO-ESA-PM-0036

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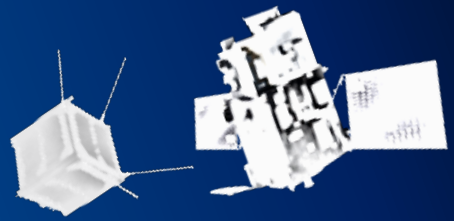
The European Space Agency

esa

for peaceful purposes



Over 80 satellites

developed, tested, and operated **since 1975**

22 Member States

2020 Budget

€ 6.68 billion =

12 per European

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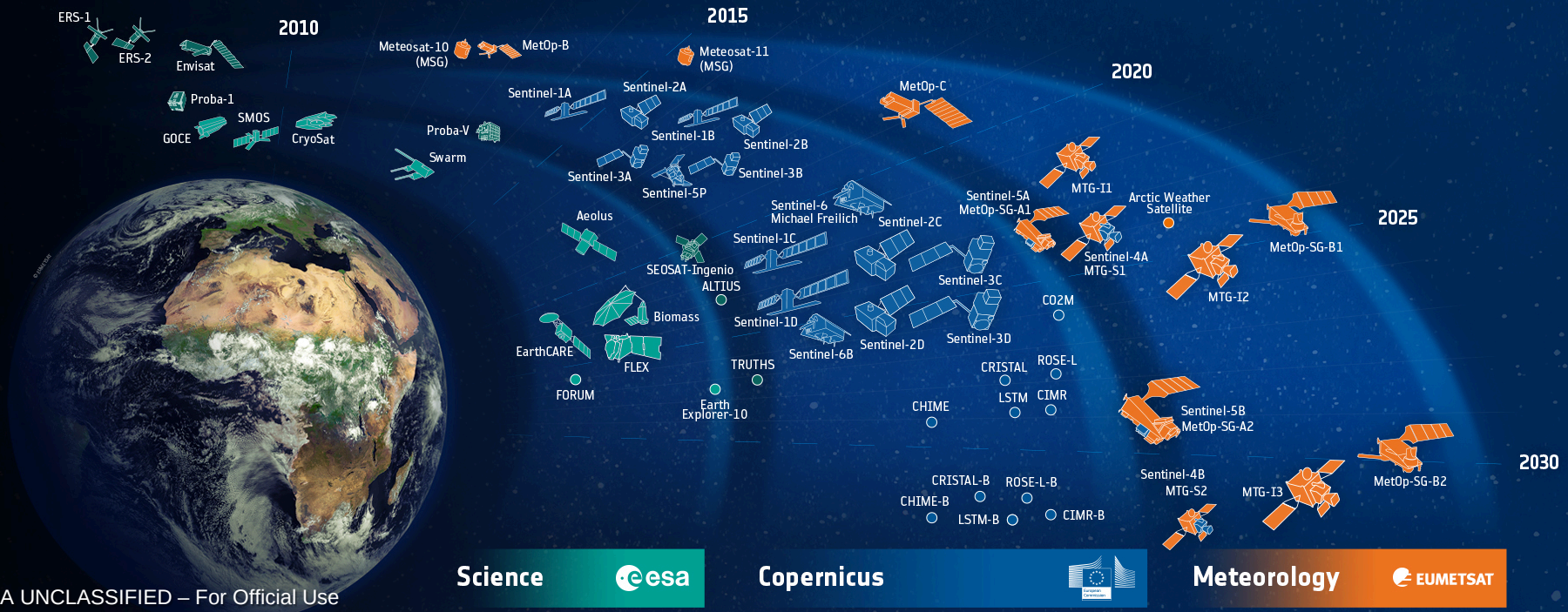
ESA-Developed Earth Observation Satellites

15 in operation
40 under development
13 under preparation



Science esa | Copernicus | Meteorology EUMETSAT

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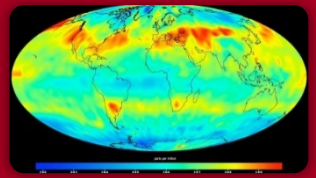
European Space Agency

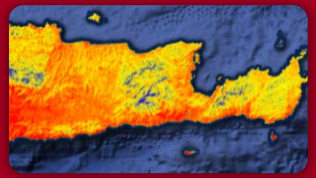
Copernicus 6 HPCM: consortia selected

CO2M - Anthropogenic CO_2 Monitoring



Causes of Climate Change

LST – Land Surface Temperature Mission

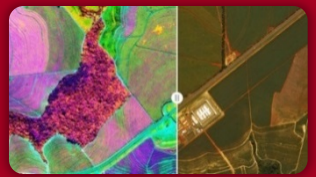


Agriculture & Water Productivity

CRISTAL – Polar Ice & Snow Topography

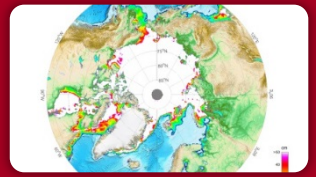
Effects of Climate Change

CHIME – Hyperspectral Imaging Mission



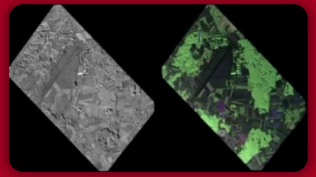
Food Security, Soil, Minerals, Biodiversity

CIMR – Passive Microwave Radiometer



Sea: Surface Temp. & Ice Concentration

ROSE-L – L-band SAR Mission



Vegetation & Ground Motion & Moisture

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Copernicus Hyperspectral Imaging Mission (CHIME)

Provide routine hyperspectral measurements in support of EU- and related policies for the management of natural resources & assets

- **Support food security, agriculture and raw materials, soil properties**
- **Secondary Applications: biodiversity and ecosystem sustainability, forestry management, environmental degradation, lake/coastal ecosystems and water quality, snow grain size/albedo, snow impurities)**

Hyperspectral data cube
(courtesy DLR)

Physiological diversity of a temperate forest

(Airborne imaging spectroscopy APEX data - Schaepman, Jehle et al. 2015)

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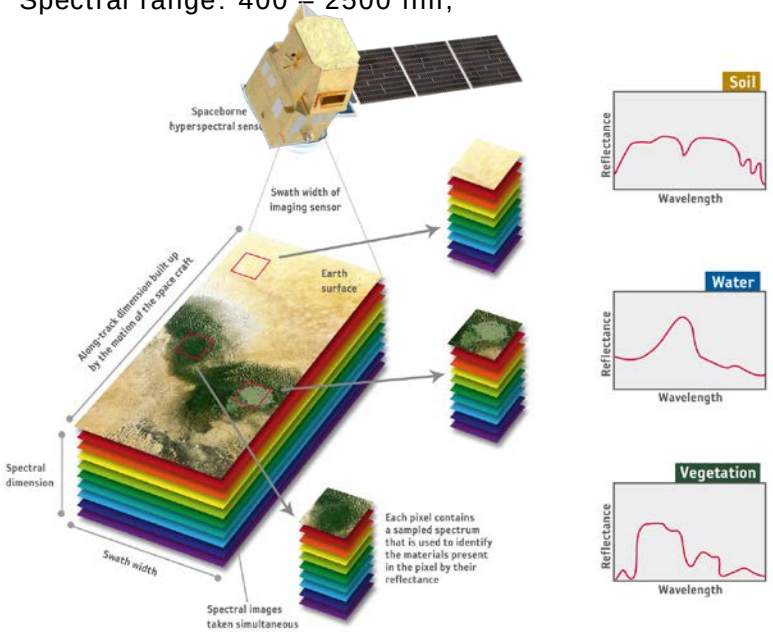
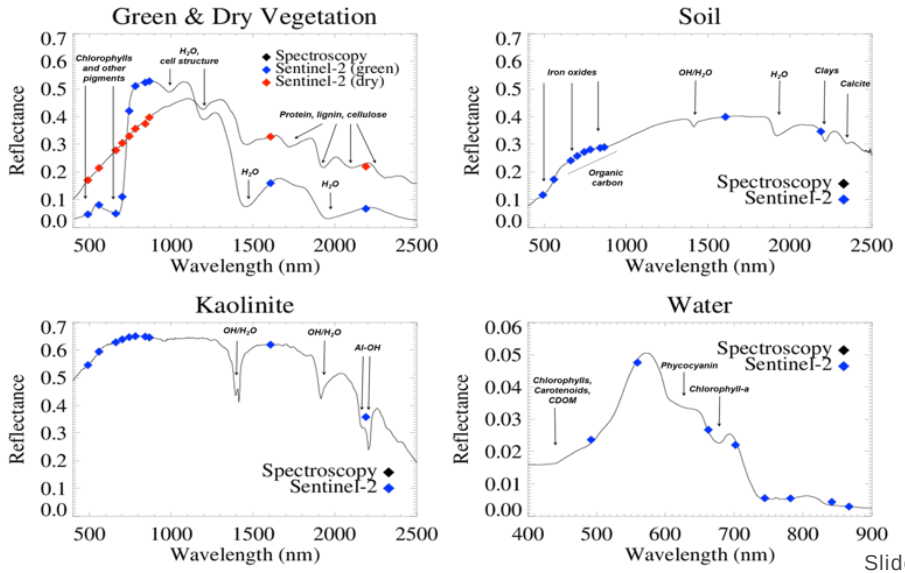
Hyperspectral Imaging Mission(CHIME)

Key Mission requirements (MRD):

- Routine hyperspectral observations
- Sun synchronous orbit (LTDN 10:30 – 11:30)
- Revisit 10-12.5 days
- Nadir view covering land surfaces, inland- and coastal waters
- Spectral range: 400 – 2500 nm,
- Spectral bandwidth ≤ 10nm
- SSD: 20-30m
- High radiometric accuracy, low spectral/spatial mis-registration
- Improved NeDT requirements to match performance of parallel missions (EnMap, PRISMA, etc)

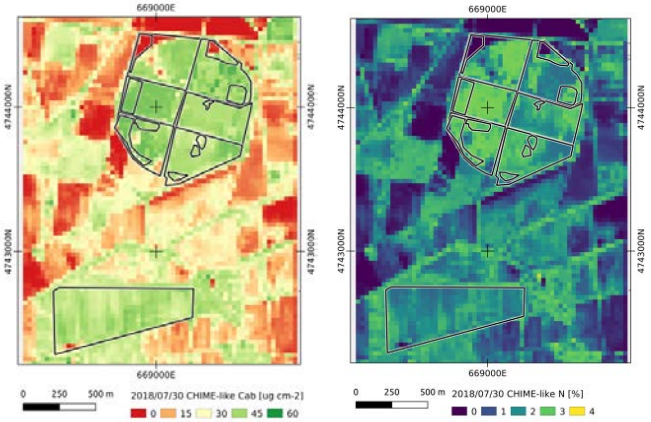




CHIME High Priority Products: Experimental campaign-Grosseto, IT

Leaf Nitrogen Content (LNC % [mg N g^{-1} DM])

Chlorophyll (Cab [µg cm^{-2} leaf])

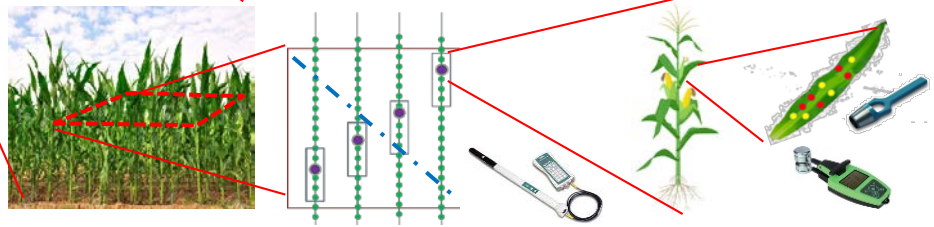


CHIME Product Examples for Grosetto:

Machine learning based algorithm for CHIME-like data products of nitrogen and chlorophyll

Plot Transect

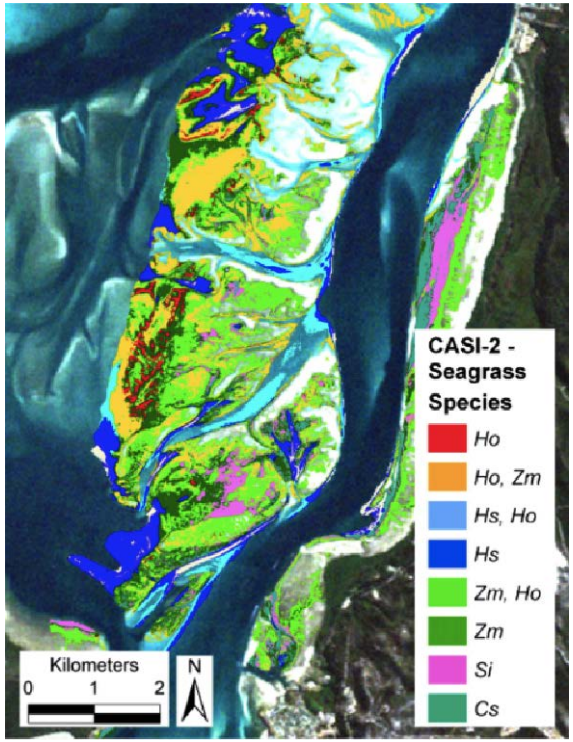
Plant / Leaf sample



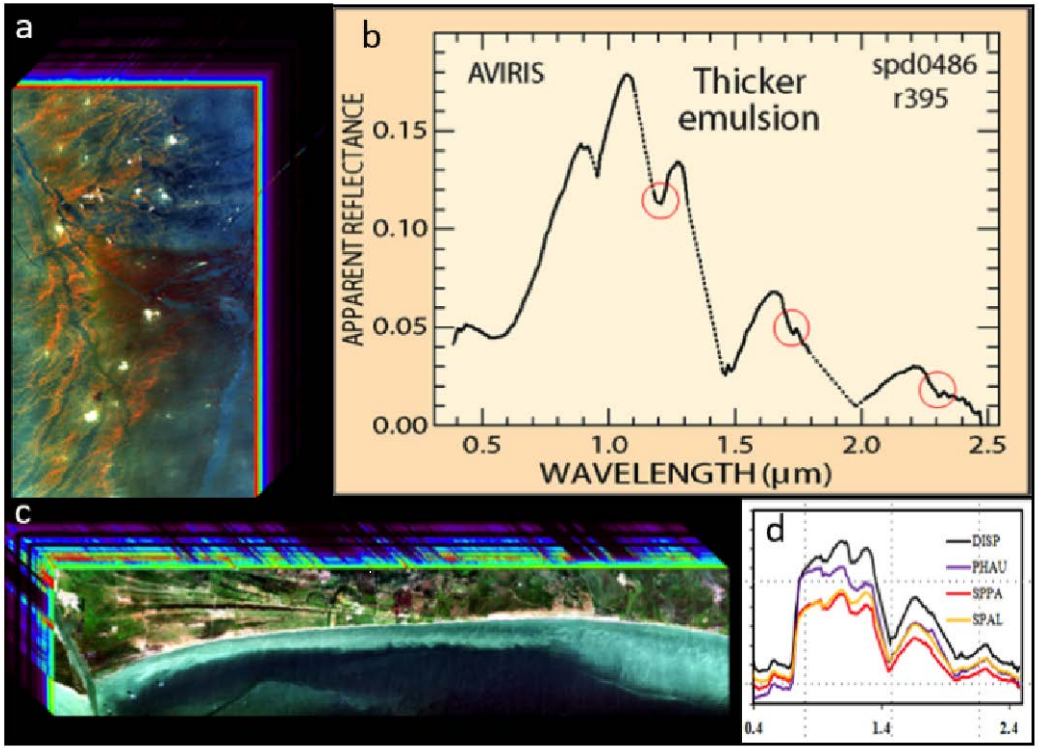
Direct
- Cw
- LMA
- Chl a&b
- Car
- N%

Indirect
- Chlorophyll meter

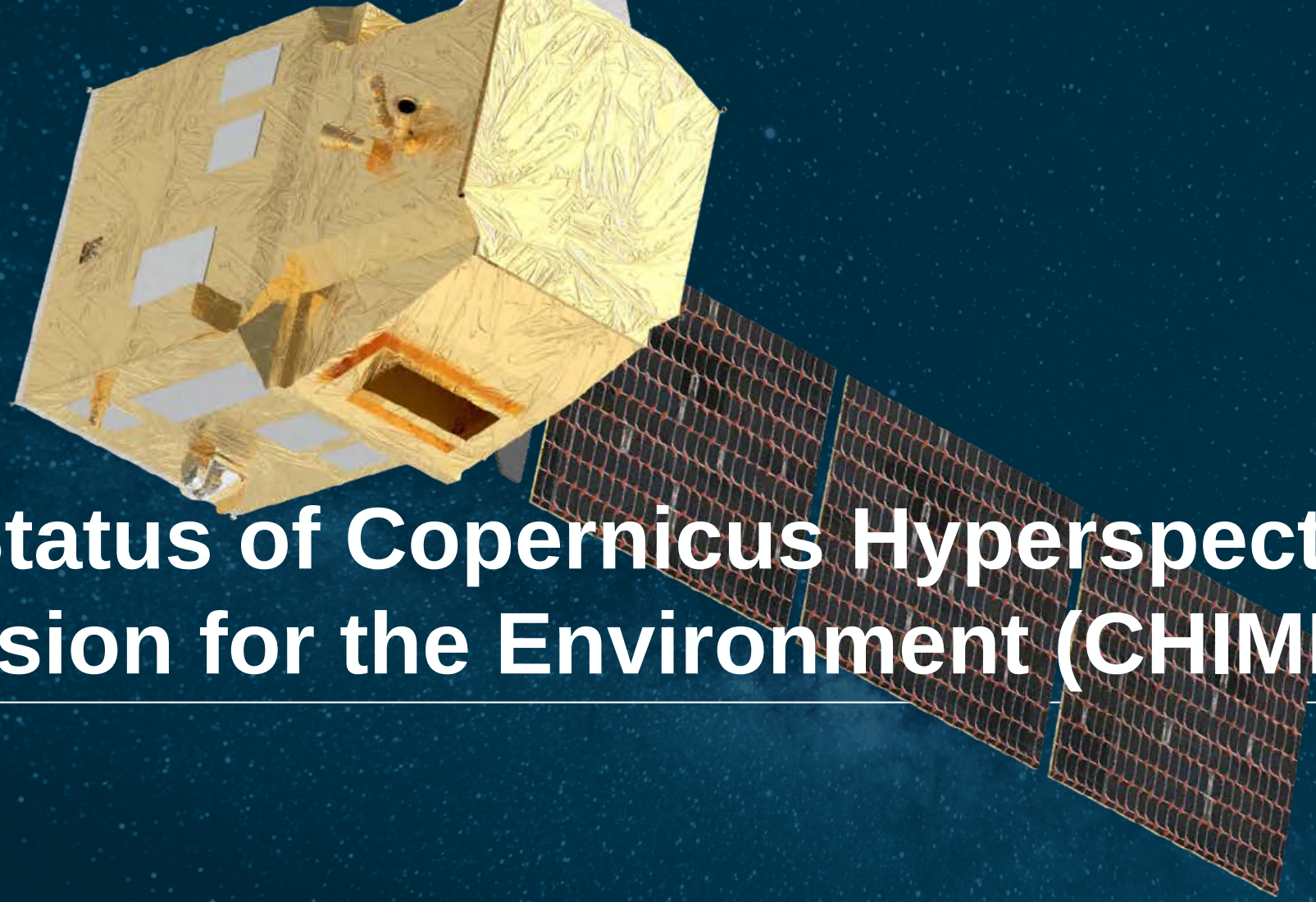
Examples for CHIME-like Coastal Zone observations



Seagrass Species Moreton Bay, Australia

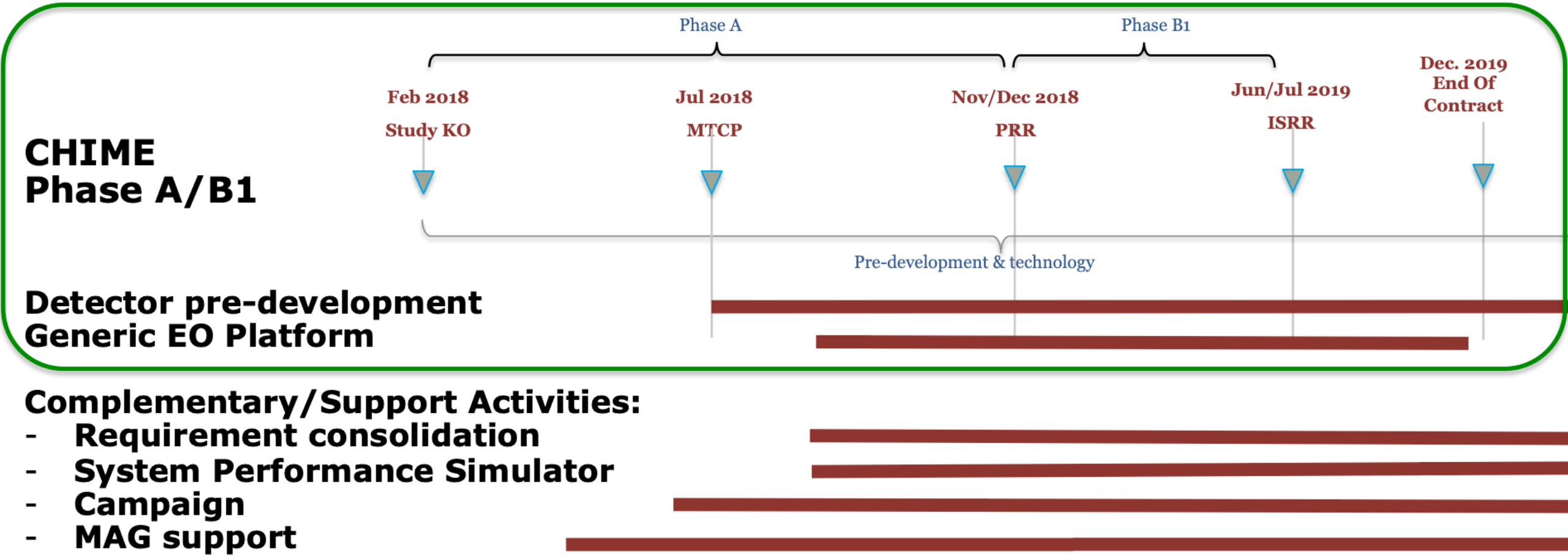


Oil spill mapping with AVIRIS, Gulf of Mexico



5. Status of Copernicus Hyperspectral Imaging Mission for the Environment (CHIME)

CHIME's Combined Schedule (2018-2019)



Complementary/Support Activities:

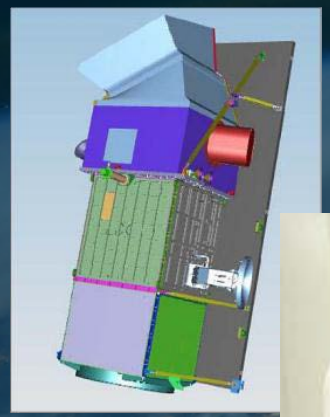
- Requirement consolidation
- System Performance Simulator
- Campaign
- MAG support

Consortium 1

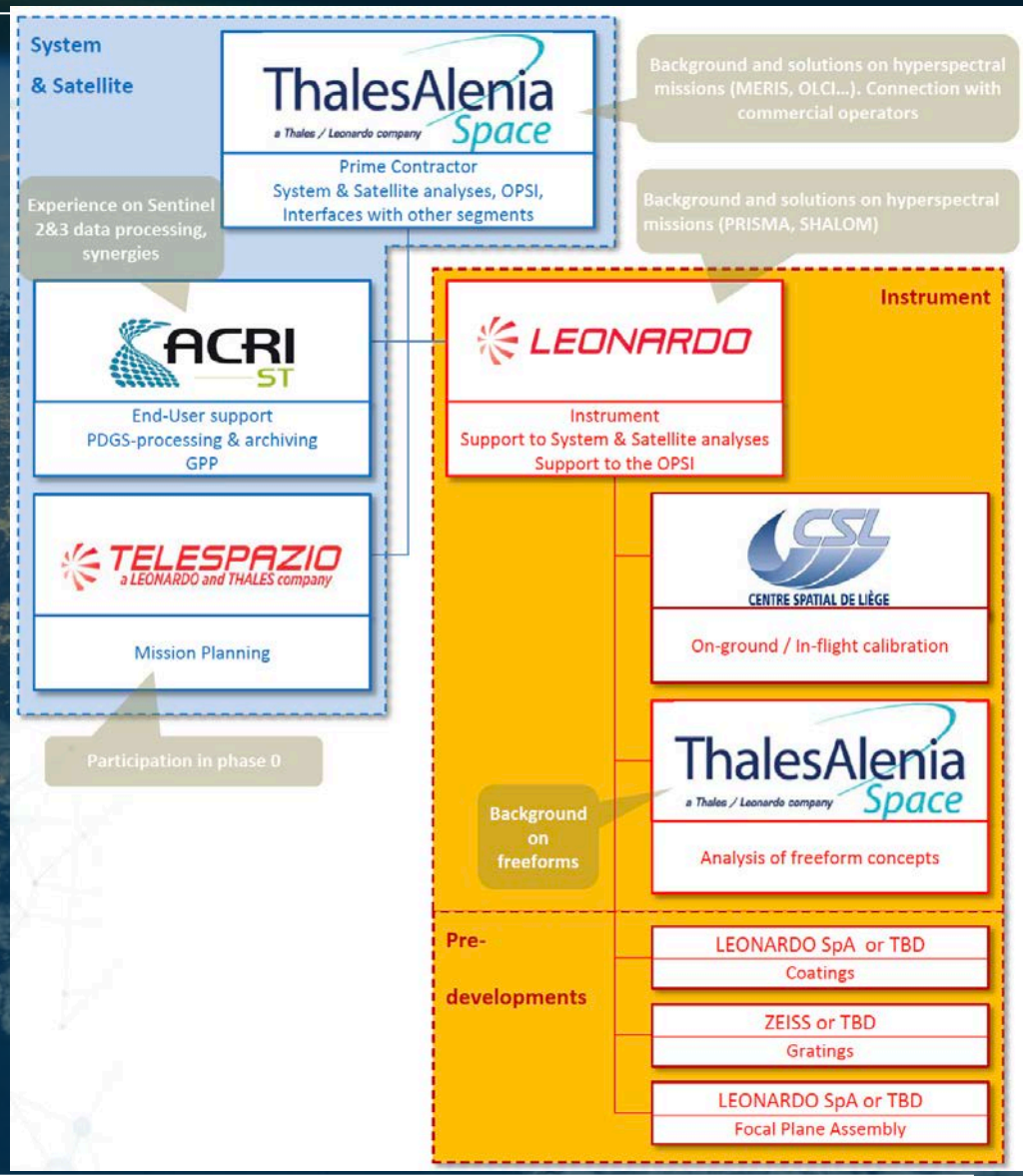
EnMAP platform in the OHB Satellite Integration Facility

- **OHB** — Study Management, Mission & System, Space Segment and Programmatics
  - **TNO** — Calibration System
  - **vito** — Instrument Data Processing and Calibration System
  - **AMOS** (ADVANCED MECHANICAL AND OPTICAL SYSTEMS) — Instrument Optical Engineering Support
  - **OHB ITALIA** — Platform Development
  - **deimos** elecnor group — Mission Analysis and Flight Operations

Consortium 2



Integration of the PRISMA Instrument at Leonardo, Italy



The 3 Main Challenges

The trade space in a typical Phase A/B1 is very large:

- Ground Sampling Distance: 20-30m
- Geometric revisit time: 10 days - 15 days

Challenge 1:

Very high Data Rate (>1Gbps)

Technical solutions:

- On-board Compression (Lossless - Near Lossless)
- On-board Cloud screening (50% reduction)
- On-board Data Processing (to improve compression ratios)
- Improved Data Transmission (X-band 560 Mbps, Ka-band 1.3 Gbps and/or Laser Communication Terminals)

Challenge 2:

Wide spectral range, high spatial resolution, large swath, high throughput Optical Design

Technical solutions:

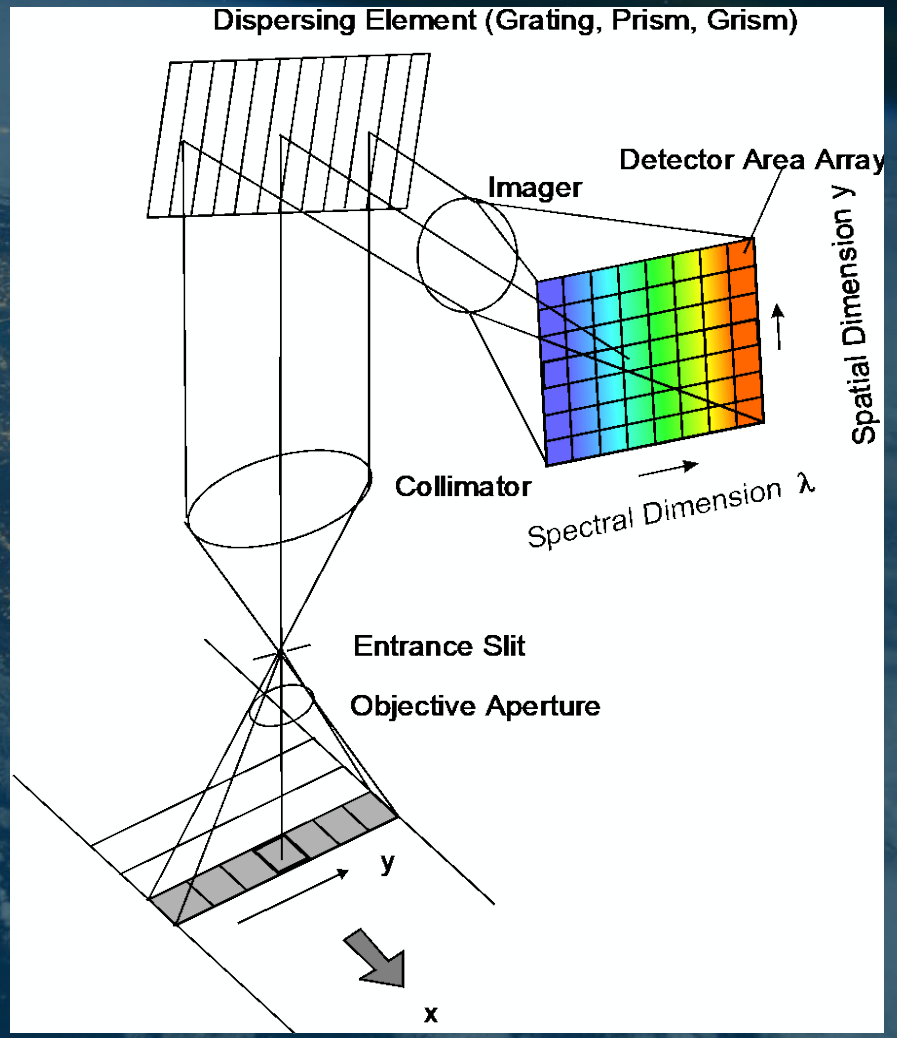
- Develop a Detector (Read-Out rate, large number of pixels)
- Develop a wide range high efficiency VIS-SWIR grating
- High efficiency optical coatings

Challenge 3:

Low Spectral and Spatial Misregistration

Technical solutions:

- Optimized optical design to produce a Uniform Spectral Image



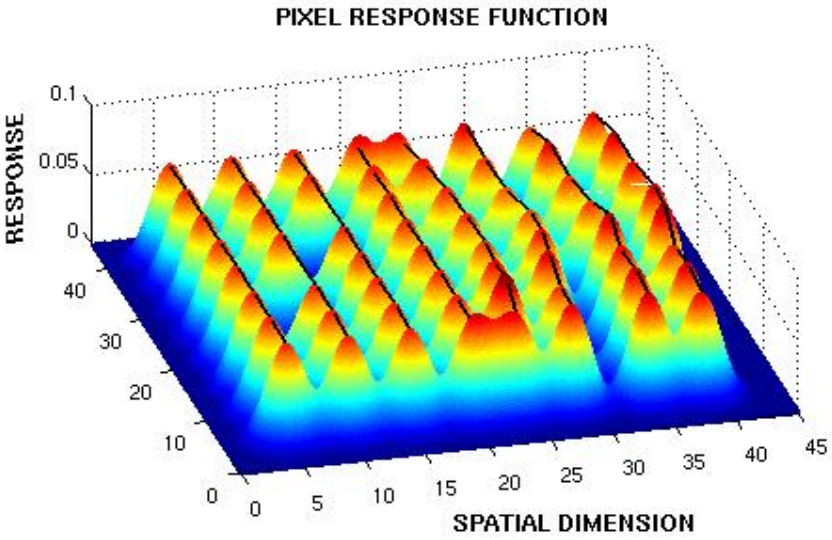
Non-uniformities in imaging spectrometer data

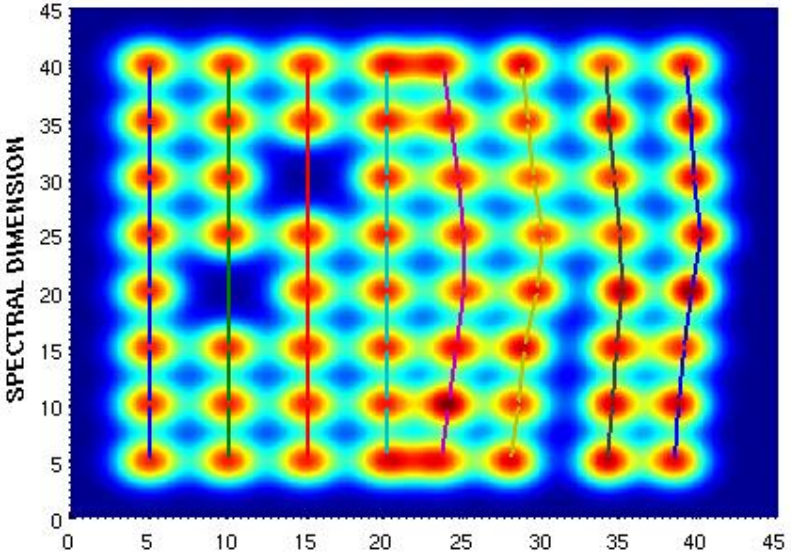
Punctual defects

Linear defects

Areal defects

Stability defects





Schlaepfer et al. IEEE TGARS, Vol. 45, No. 2, 2007
Nieke et al. IEEE TGARS, Vol. 46, No. 10, 2008

Phase A/B1 => Phase B2/C/D/E1

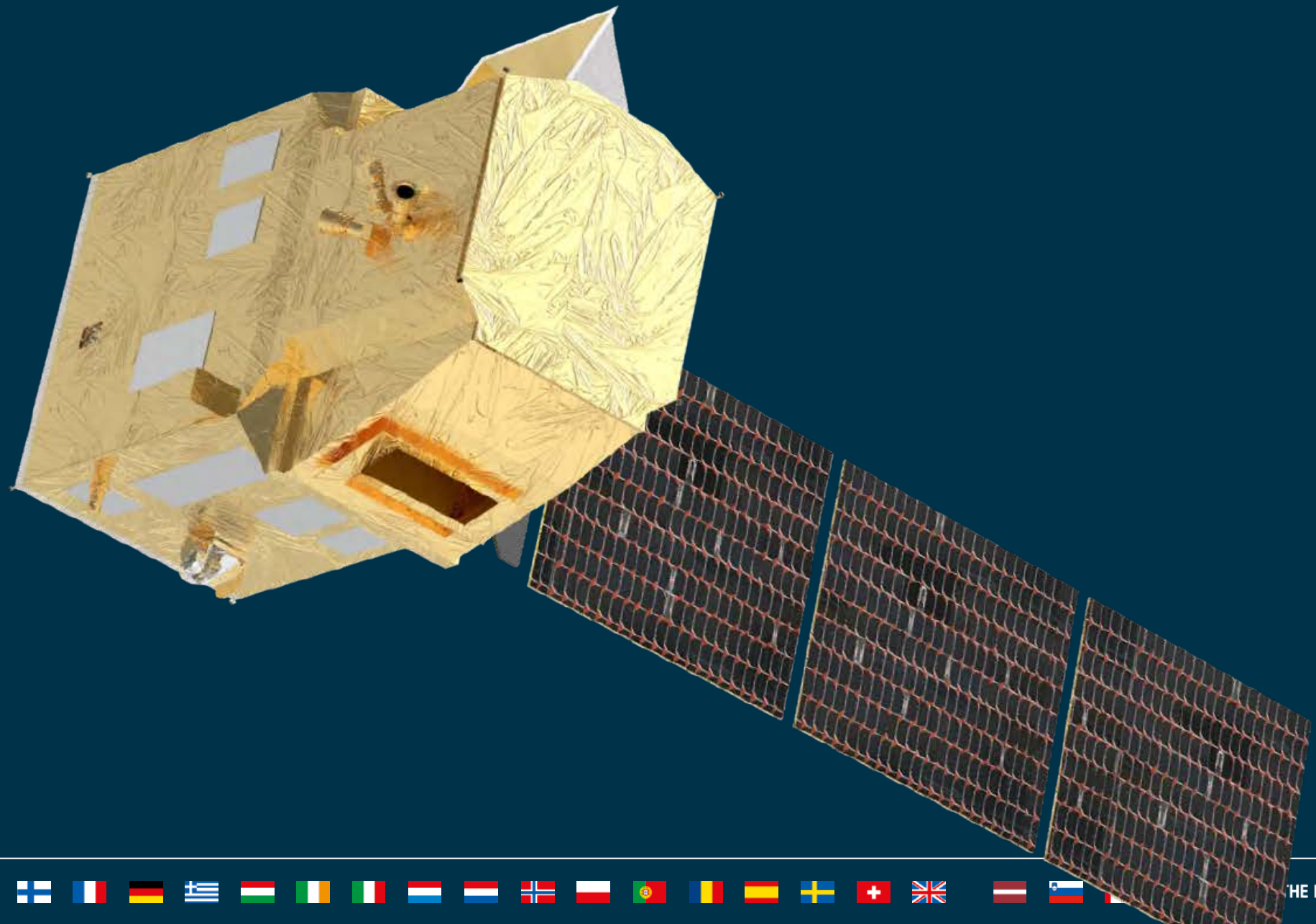
Finalisation of Phase A/B1:

- Both consortia developed various concepts => a final set of requirements/specs

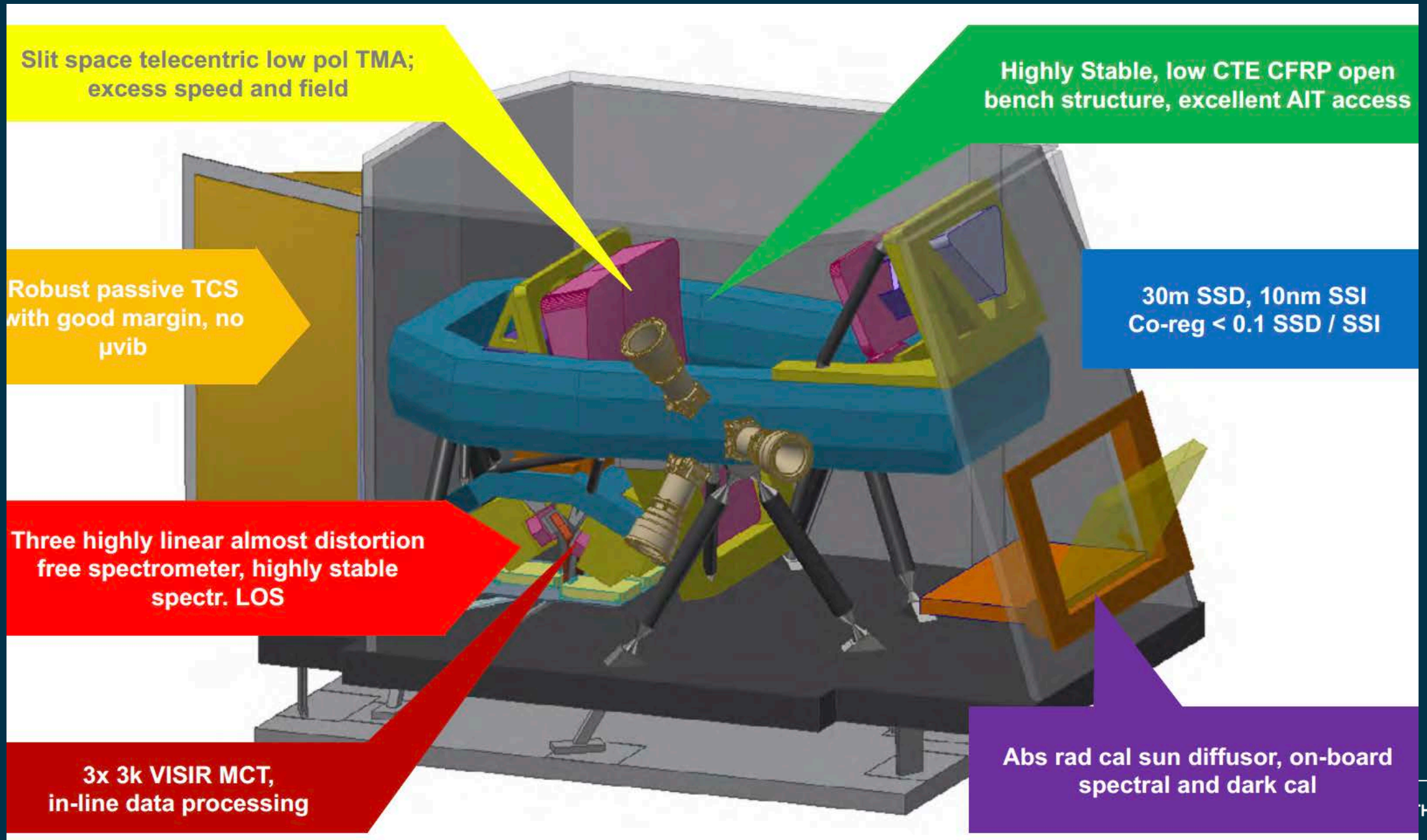
Towards of Phase B2/C/D/E1:

- ESA Released a Request for Proposal: Jul-2019,
- Thales Alenia Space (FR) as Prime and OHB (DE) as Instrument Prime supported by LEONARDO (IT) & AMOS (BE).
- Contract signature: 13-Nov-2020
- Kick-off: 16/19-Nov-2020
- End of Phase B2 (PDR) is planned: Mid 2022
- Launch, planned: 2028

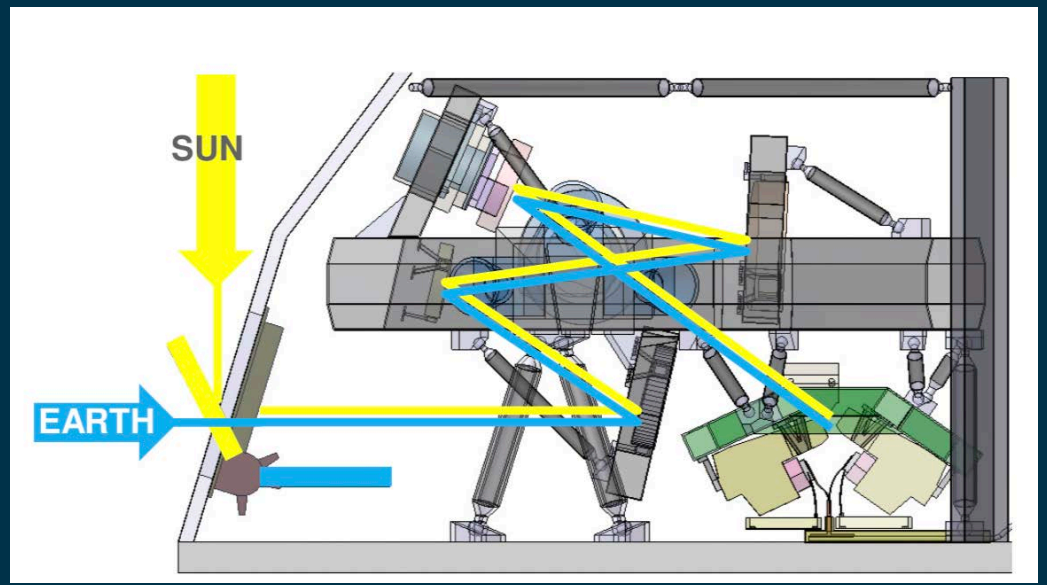
Selected Solution for Phase B2/C/D and E1

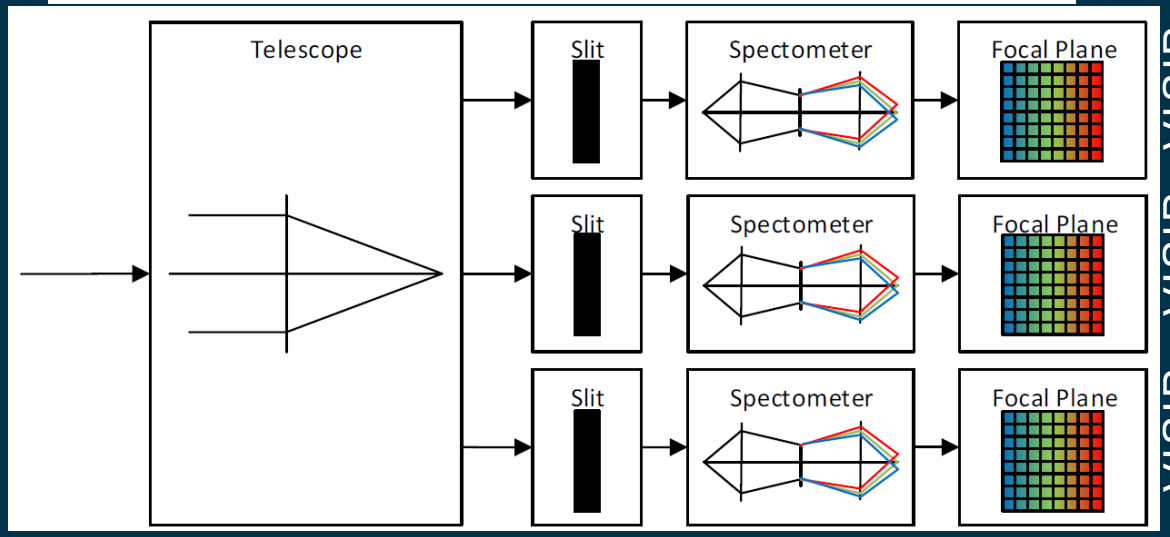


Selected Solution for Phase B2/C/D and E1



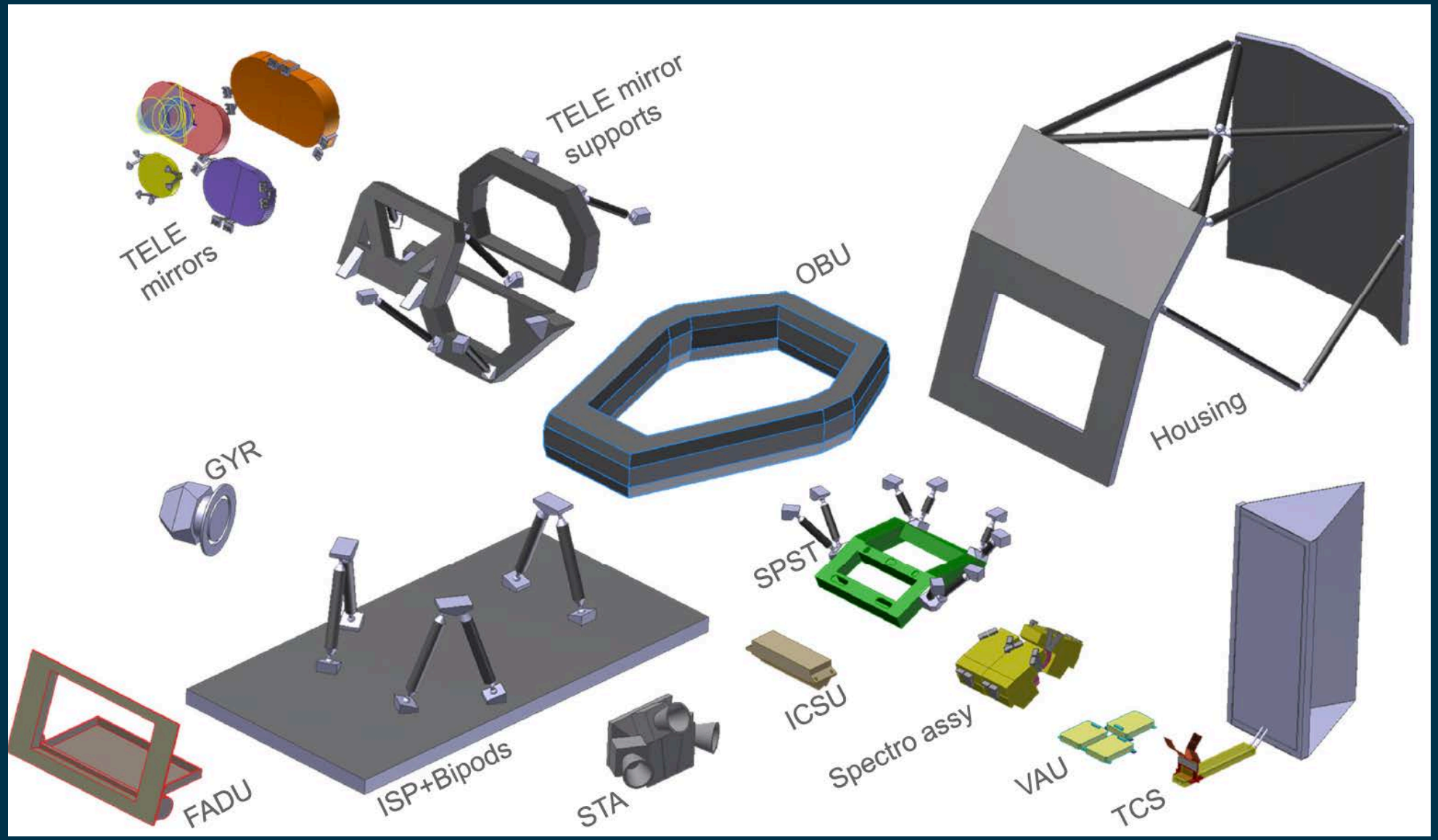
OHB – Instrument Concept





Parameter	Value
GSD	30 m
Effective swath	~130 km
Altitude	632 km
Wavelength coverage	400 nm – 2500 nm
Instrument	1 TMA feeding three spectrometers
Spectral sampling interval	~10nm
Dimensions	1 x 1.6 x 1.2 m3
Payload Mass	445 kg (incl. margin)

Instrument parts overview



Conclusion

- Spectral Range: 400nm to 2500nm with SSI of 8.4nm
- On-ground swath ~130 km (at equator)
- Spatial Sampling Distance 30m
- MTF >0.25 ALT; >0.4 ACT
- Spatial/Spectral co-registration at 0.1 SSD/SSI
- Download: 3.6Gbps through two Ka-Band channels,
- Geometric revisit coverage
    - 22 days with 1 satellite,
    - 11 days with two satellites.

J. Nieke and M. Rast, "Towards the Copernicus Hyperspectral Imaging Mission For The Environment (CHIME)," *IGARSS 2018 - 2018 IEEE International Geoscience and Remote Sensing Symposium*, Valencia, 2018, pp. 157-159, doi: 10.1109/IGARSS.2018.8518384.

6. CHIME Calibration and Validation Activities

Wednesday, 4.11.2020, 10-11am

Jennifer Adams, ESA-ESRIN

CHIM-HO-ESA-PM-0036

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Calibration and Validation Activities

Calibration and Validation (Cal/Val) is used to determine the quality and integrity of imaging spectroscopy data, and is very important in aiding downstream users to confirm the accuracy and reliability of the products generated by the sensor

Cal/Val is an important underpinning need for imaging spectroscopy mission especially post-launch to track sensor performance, and, throughout the life of the mission

CHIME Calibration and Validation

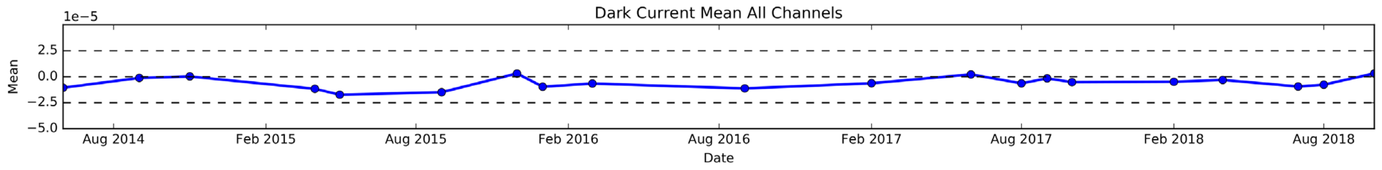
- Pre-launch and onboard calibration for CHIME
    - Absolute radiometric calibration sun diffuser
    - Onboard spectral and dark current calibration
- Post-launch calibration and validation for CHIME
- Validation Campaigns
    - CHIME 2018 Airborne Campaign
    - CHIME 2020 Spaceborne Campaign

CHIME pre-flight and onboard calibration

Onboard spectral and dark current calibration

Spectral fidelity is especially important for the CHIME mission, as the essential properties/variables are heavily reliant on the spectral accuracy of the data

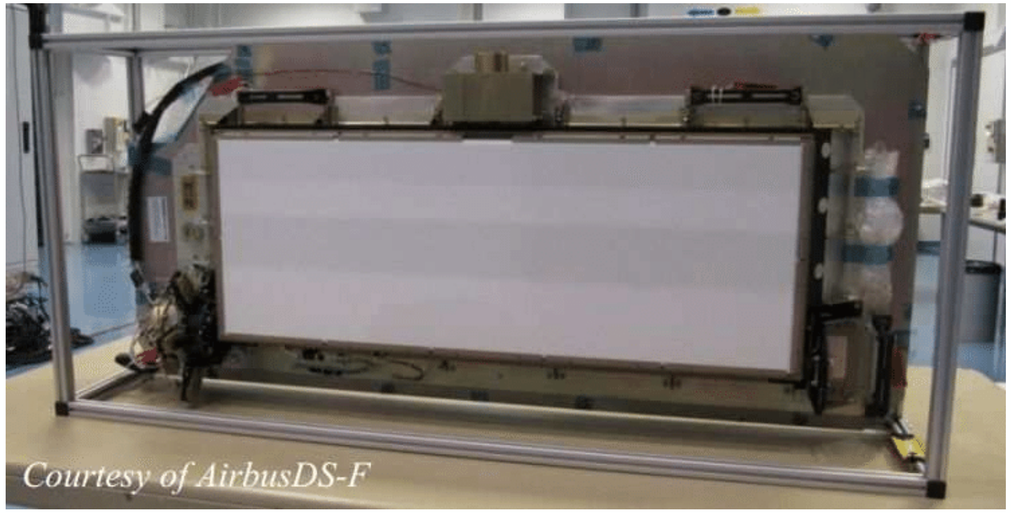
- Comprehensive pre-flight calibration under controlled laboratory conditions to fully characterise sensor characteristics will be performed
- Routine on-board spectral calibration
- Dark current measurements obtained e.g. by closure of the entrance shutter mechanism of the instrument and viewing into deep space will be implemented (e.g. Figure below of dark current measurements by AVIRIS-NG by Chapman et al; 2019)



Absolute radiometric calibration: Sun diffuser

The radiance from a sunlit diffuser is used to illuminate the full aperture and full optical path of the sensor. If certain conditions of the diffuser are known (e.g. incoming solar irradiance), the absolute radiance from the diffuser can be used to determine the absolute radiometric calibration of the sensor.

Example of the Sentinel-2 sun diffuser



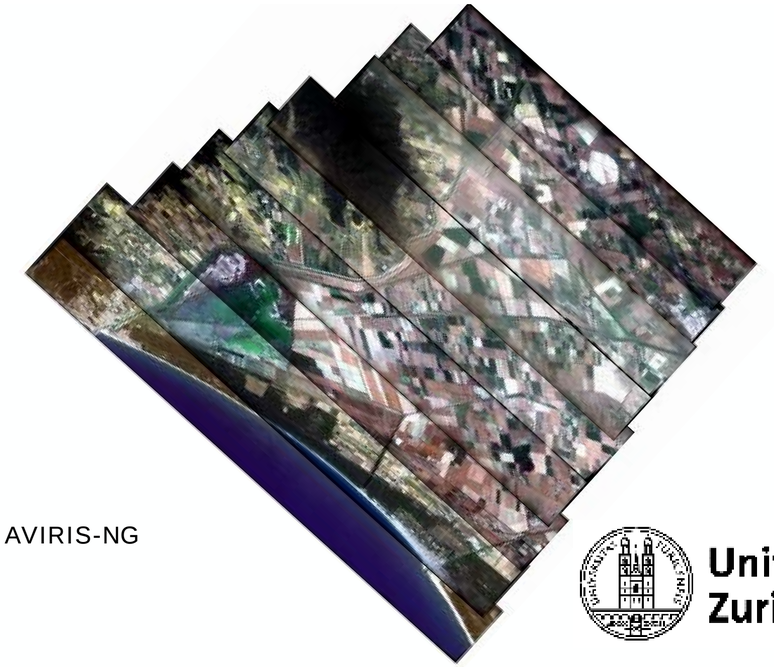
CHIME Airborne Campaign (2018)

Grosseto 2018 dataset

HB-TEN Cessna Caravan 208B EX (APEX)

N53W Beechcraft King Air 200 (AVIRIS NG)

APEX



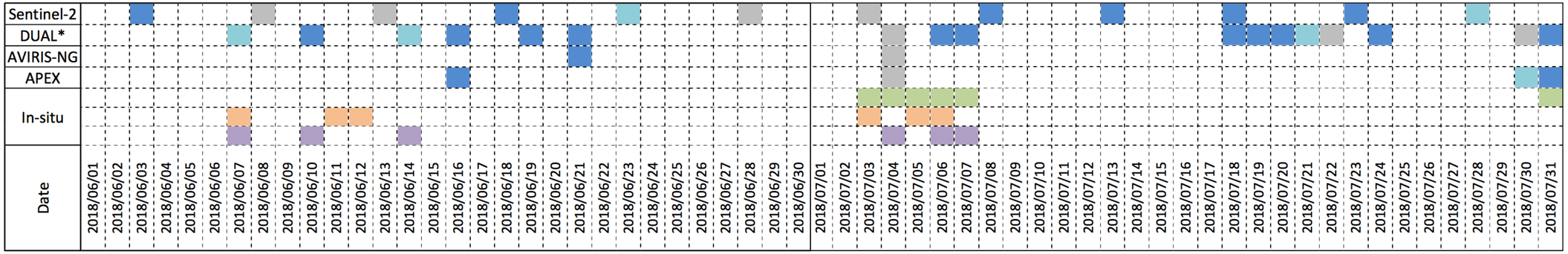
AVIRIS-NG

University of Zurich[UZH]

CHIME Airborne Campaign (2018)

ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

CAL/VAL measurement | Topsoil sampling | Vegetation sampling | Clear sky | Partly cloudy | Cloudy



16/06/2018

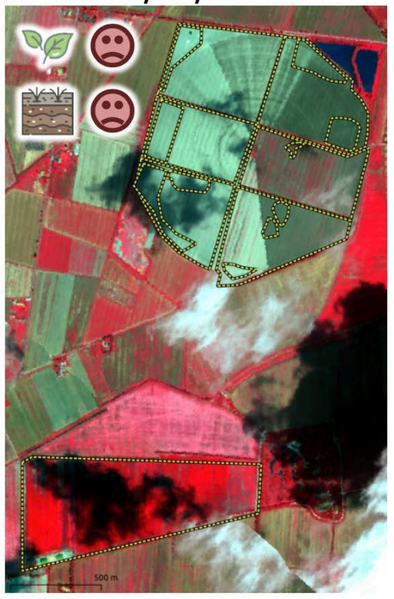
04/07/2018

31/07/2018-A

31/07/2018-B

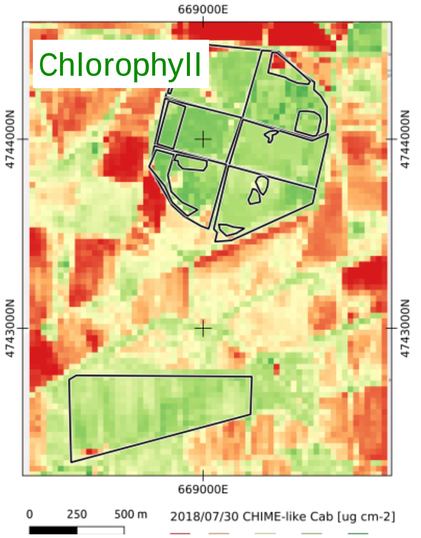
21/06/2018

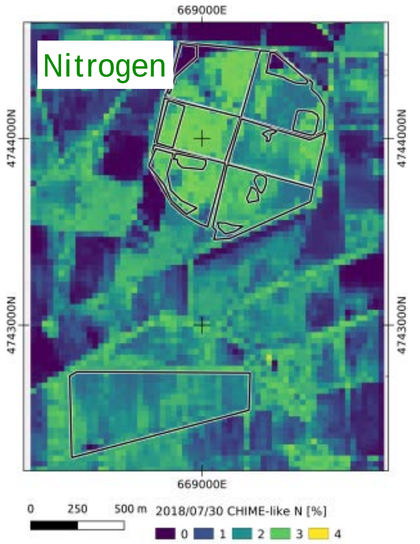
04/07/2018



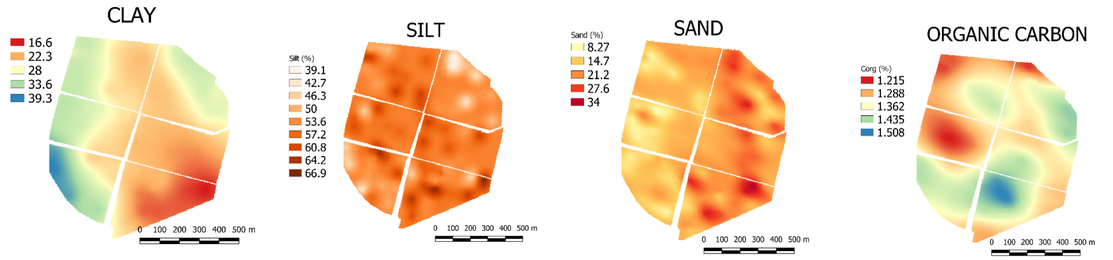
CHIME Airborne Campaign (2018)

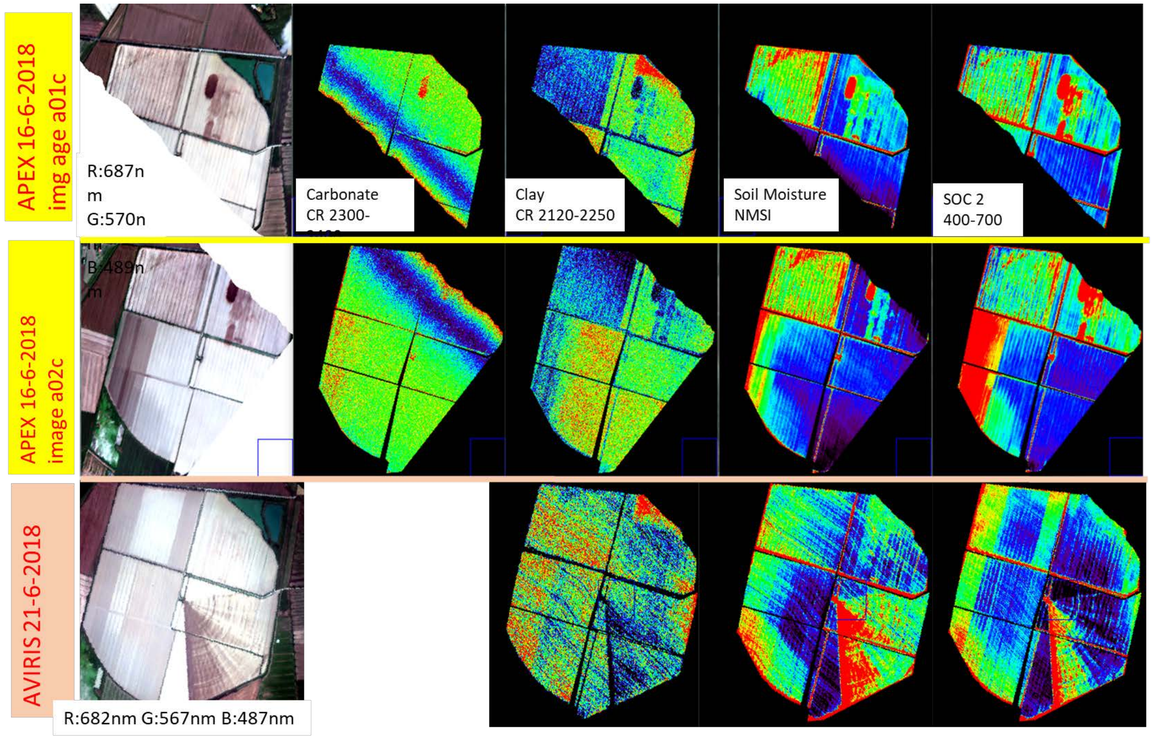
Vegetation





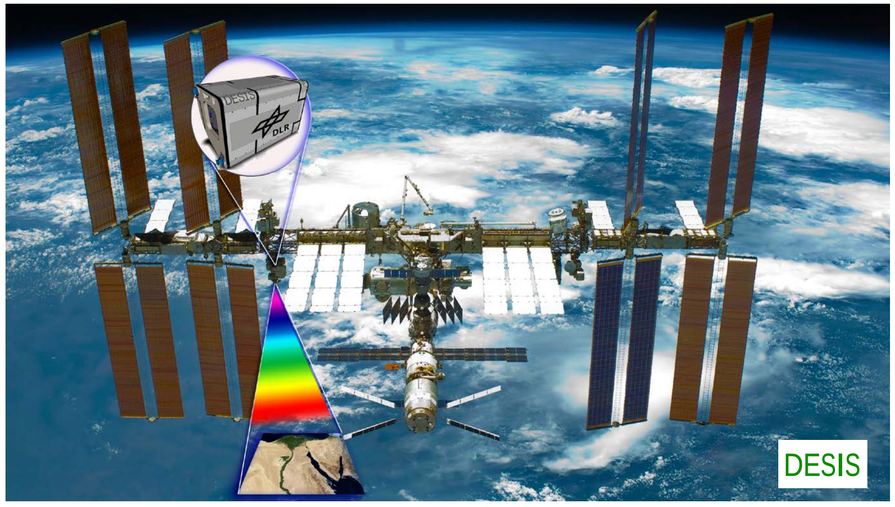
Soils

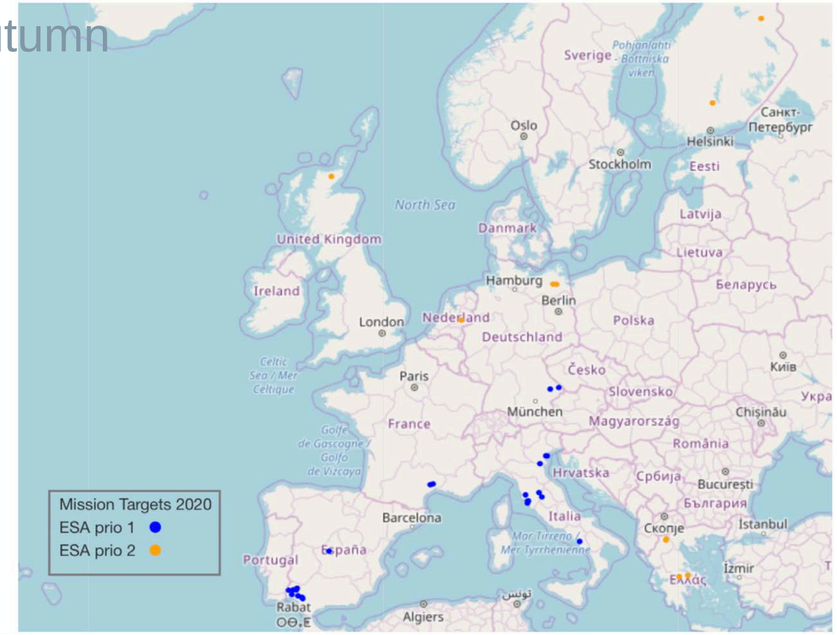




CHIME Spaceborne Campaign (2020)

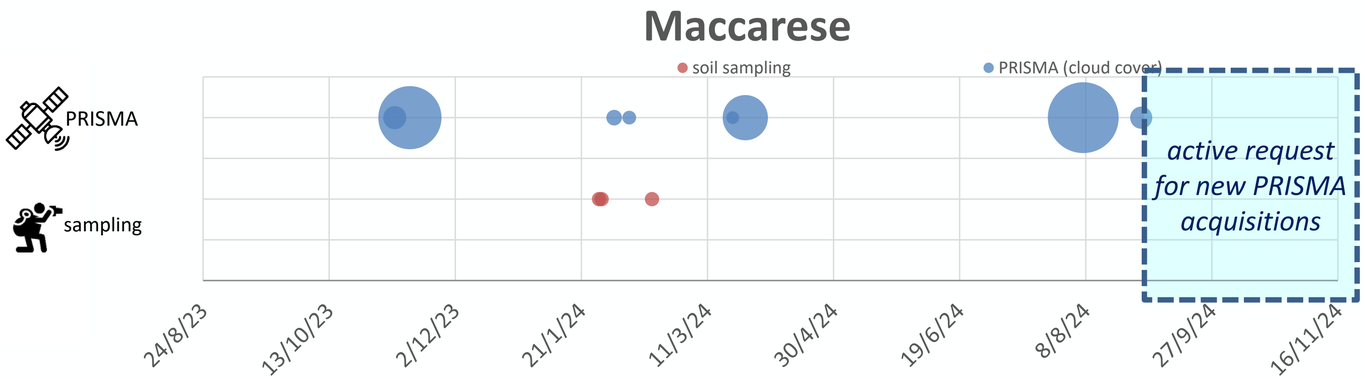
- Due to Covid-19, a planned 2020 Airborne campaign with the NASA-AVIRIS NG airborne imaging spectrometer was delayed until May-June-July 2021.
- Instead, a Spaceborne campaign using 2 currently flying imaging spectrometer missions took place:
  - The Italian Space Agency (ASI)'s PRISMA mission
  - The German Space Agency (DLR)'s DESIS mission, onboard the International Space Station (ISS)
- 22 European sites were identified, covering the major objectives of the CHIME mission
- Field campaigns conducted over some sites during the Summer and early Autumn

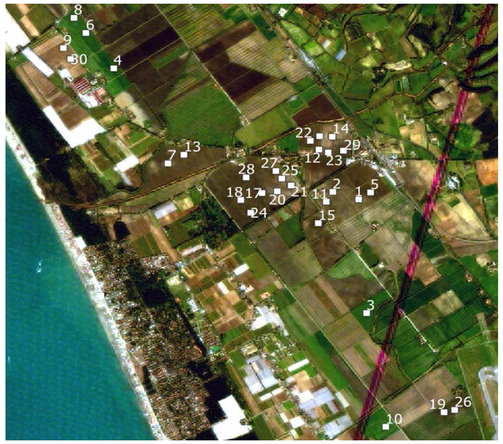




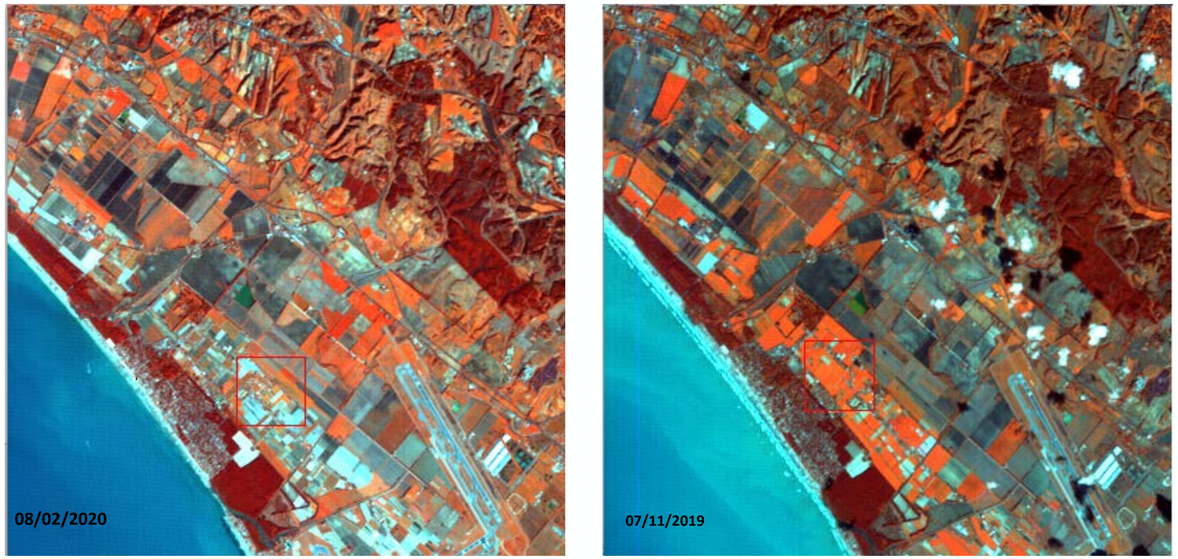
CHIME Spaceborne Campaign (2020): Soils

Field measurements

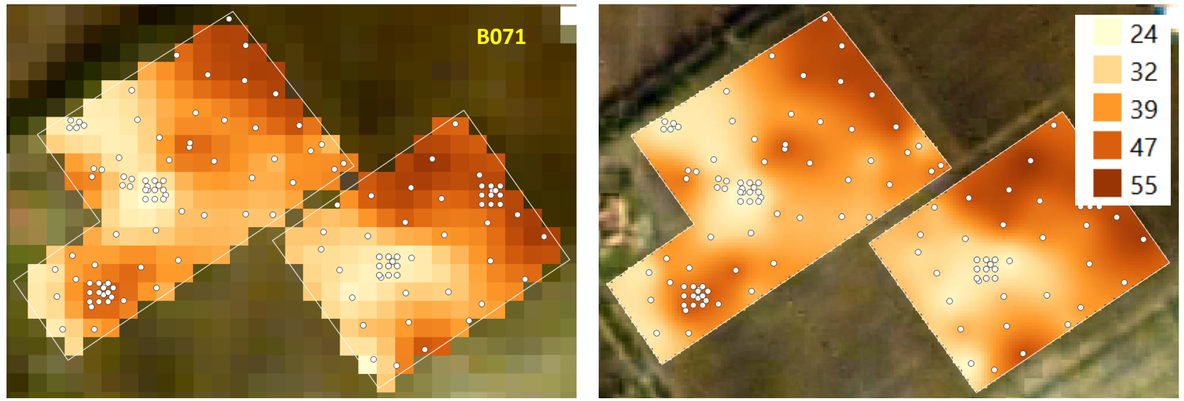




PRISMA images over Maccarese in Feb. and Nov. 2019

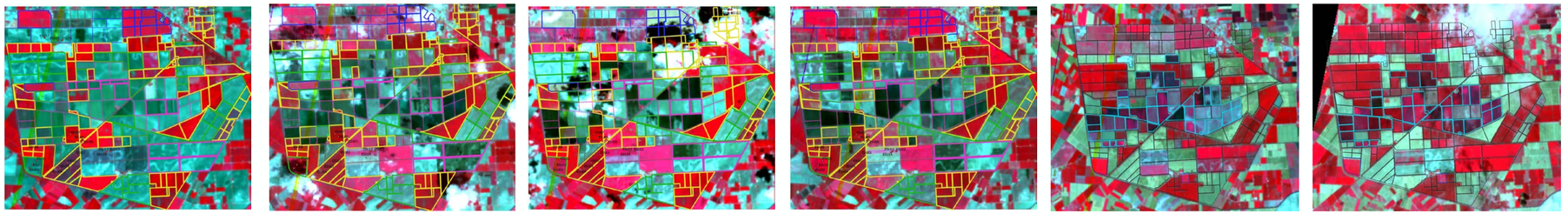


Example of Clay soil retrieval over field in Maccarese site using PRISMA imagery at 30m resolution (left) and sharpened 5m resolution (right)

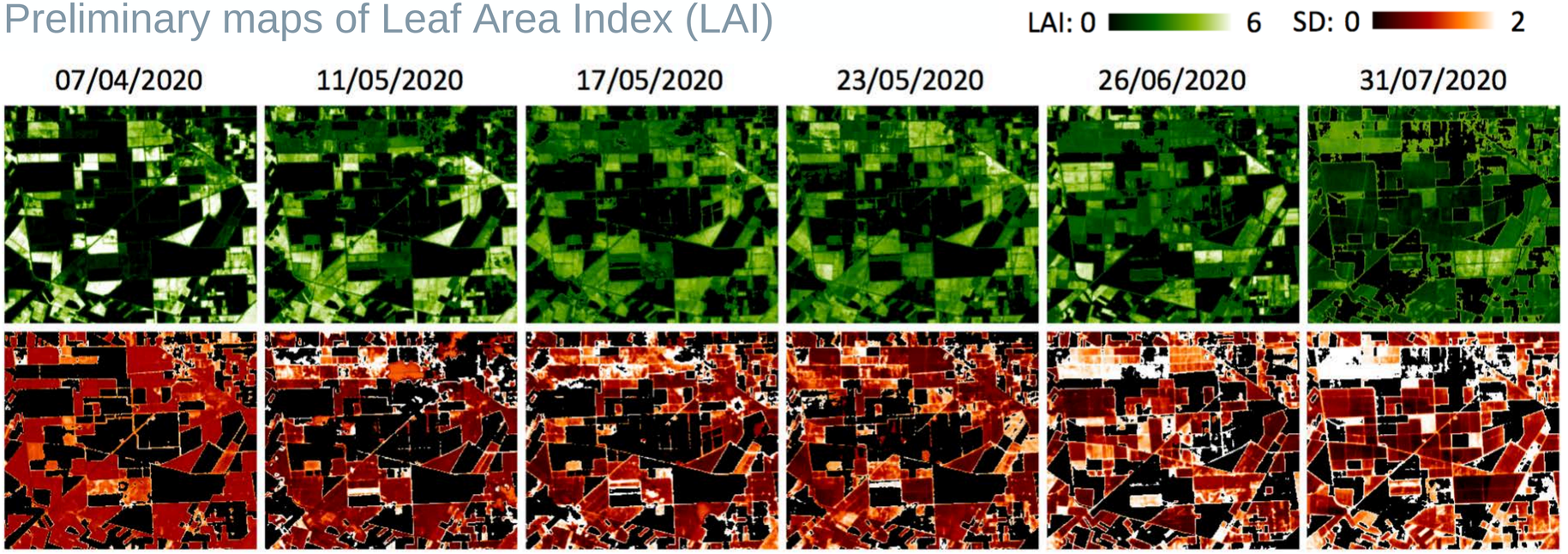


CHIME Spaceborne Campaign (2020): Vegetation

Spaceborne PRISMA images over Grosseto during May/June/July 2020



Preliminary maps of Leaf Area Index (LAI)

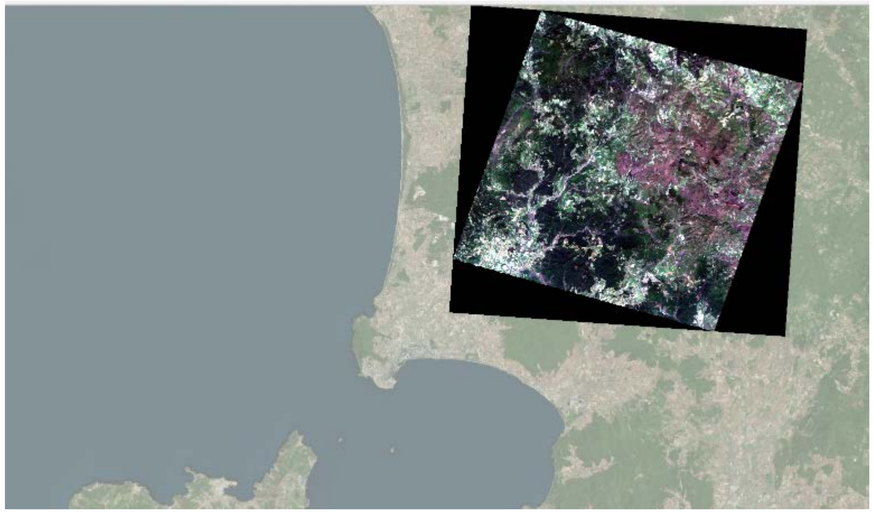


- PRISMA spaceborne data and field measurements of vegetation health used to derived maps of vegetation Leaf Area Index (LAI)

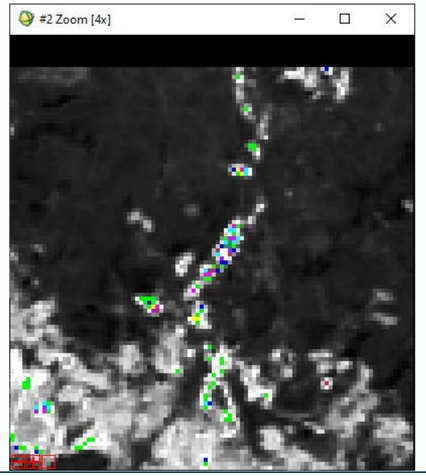
- **LAI: is important for assessing growth and vigour of vegetation on the planet.** It represents the amount of leaf material in ecosystems and controls the links between biosphere and atmosphere

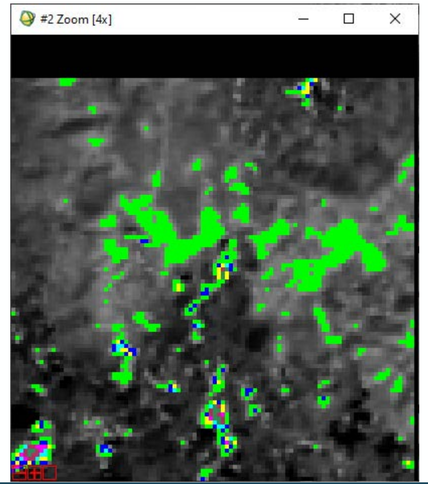
CHIME Spaceborne Campaign (2020): Raw Materials

Biancane (Italy) Campaign



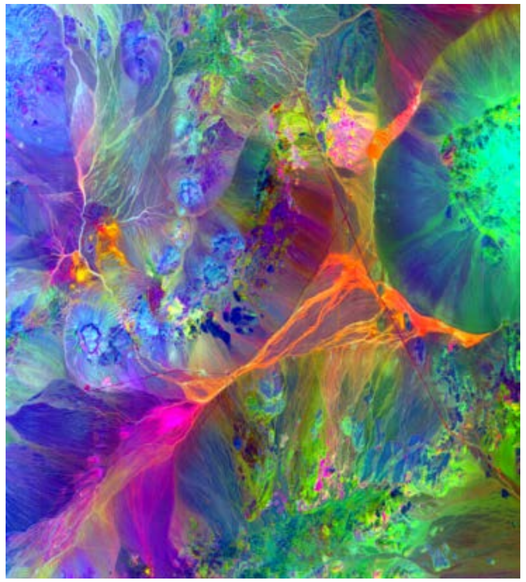
Minerals retrievals over Biancane





Cuprite (Nevada, US) Campaign

Example of “Spectral Unmixing”



VNIR

SWIR

8. CAREERS AT ESA

ENGINEERING DISCIPLINES

Mechanical engineering
(optical, propulsion, thermal, mechanisms, structures, materials, robotics)

Electrical engineering
(RF, power & data systems, antennas, microelectronics, EMC, components)

System engineering

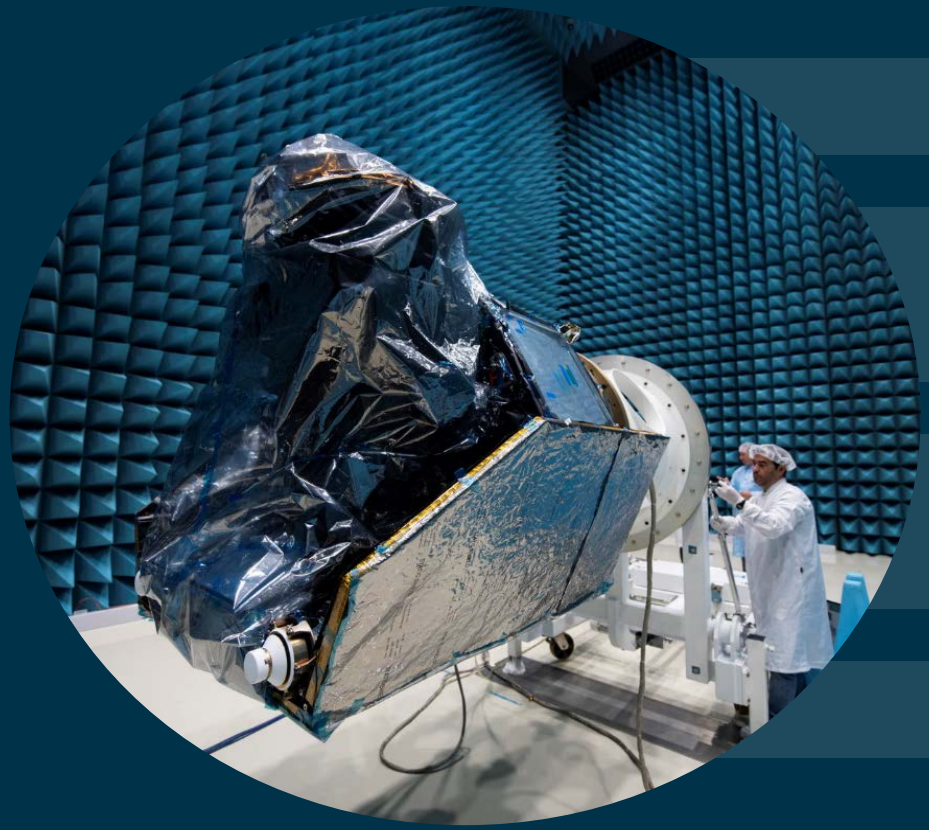
Telecom & integrated applications

Software engineering

Ground segment systems & operations

Product/quality assurance & safety

SCIENTIFIC DISCIPLINES



Applied mathematics

Earth observation & **environmental science**
(geophysics, meteorology, climatology)

Planetary & **space science**
(astronomy, astrophysics, solar physics)

Life & **material sciences**

BUSINESS AND ADMINISTRATION

Law
(contracts, procurement, international public law)

Finance
(project control, cost analysis, auditing)

Communications & public relations

Human resources

Information technology

Facility management

ENTRY-LEVEL AND RESEARCH PROGRAMMES

STUDENT INTERNSHIPS PROGRAMME

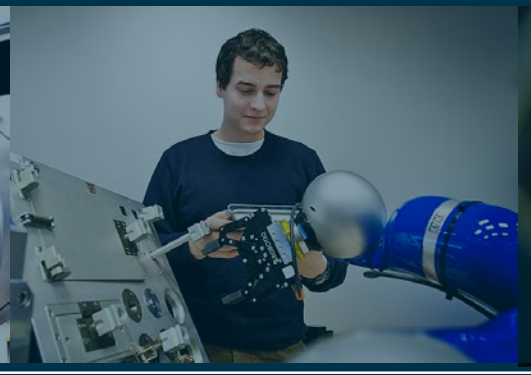
YOUNG GRADUATE TRAINEE PROGRAMME

NATIONAL TRAINEE PROGRAMMES

RESEARCH FELLOWSHIP PROGRAMME (post-docs)

ESA CO-FUNDED RESEARCH (for PhDs and post-docs)




STUDENT PLACEMENTS (INTERNSHIPS)

Students in their **last** years of a Master's degree or equivalent

Space Sector experience as part of the studies; fulfilling **internship requirements** for graduation; Final **Thesis contribution**

3 – 6 months placement

Applications are accepted from nationals of ESA Member States and European Cooperating States, together with Latvia and Slovenia as an Associated Member States and Canada as a Cooperating State.

More than **100 topics** published beginning of November on our website

YOUNG GRADUATE TRAINEE (YGT) PROGRAMME

Recent **Masters Degree** graduates

Preparation for a job in **Europe's space industry/research institutes**

1 year contract, a second year extension may be granted

YGT opportunities published in February 2021 in engineering, science, IT, natural/social science, business and administration

Applications are accepted from nationals of ESA Member States and European Cooperating States, together with Latvia and Slovenia as Associated Member States and Canada as a Cooperating State

NATIONAL TRAINEE PROGRAMME

Masters graduates

Bilateral agreements: ESA – national space entities (e.g. DLR, Swiss Space Office, BELSPO, …)

On-the-job training – tutor supervision and guidance

One-year contract, with a possible extension for an additional year

National Trainees are nationals of Belgium, Estonia, Germany, Ireland, Luxemburg, Portugal, Switzerland

The annual recruitment procedure is run by the national agencies and ESA's HR.

RESEARCH FELLOWSHIP (RF) PROGRAMME

Recently attained doctorate **(PhD) in a relevant field**

Carry out advanced **research related to space** science, space applications and technology

2 year contract, with the possibility of renewal for a third year

Applications are accepted from nationals of ESA Member States and European Cooperating States, together with Latvia and Slovenia as Associated Member States and Canada as a Cooperating State.

Publication of opportunities throughout the year on ESA recruiting site. Go to Careers at www.esa.int

ESA CO-FUNDED RESEARCH

PhD or **post-docs**

ESA is looking for **novel ideas** related to **space activities**, and novelty is the differentiator.

Research on advanced technologies **related to space activities** carried out by universities or research institutes

ESA co-funds **up to 50% and up to €90K** research at PhD or post-doc level, **Access to ESTEC** laboratories;
Technical support by **ESA experts**; **Networking through ESA** links to identify industrial partners for further cooperation or to build ”innovative networks”

Apply any time of the year via **ideas.esa.int**

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