NASA – ESA Cooperation on the SBG and CHIME Hyperspectral Satellite Missions

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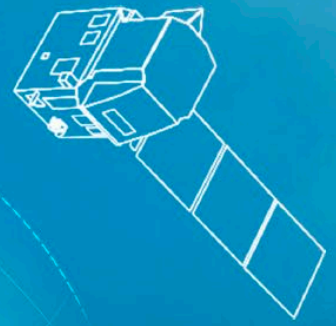
LPS'22
26th May 2022

PROGRAMME OF THE EUROPEAN UNION

opernicus
Europe's eyes on Earth

co-funded with esa

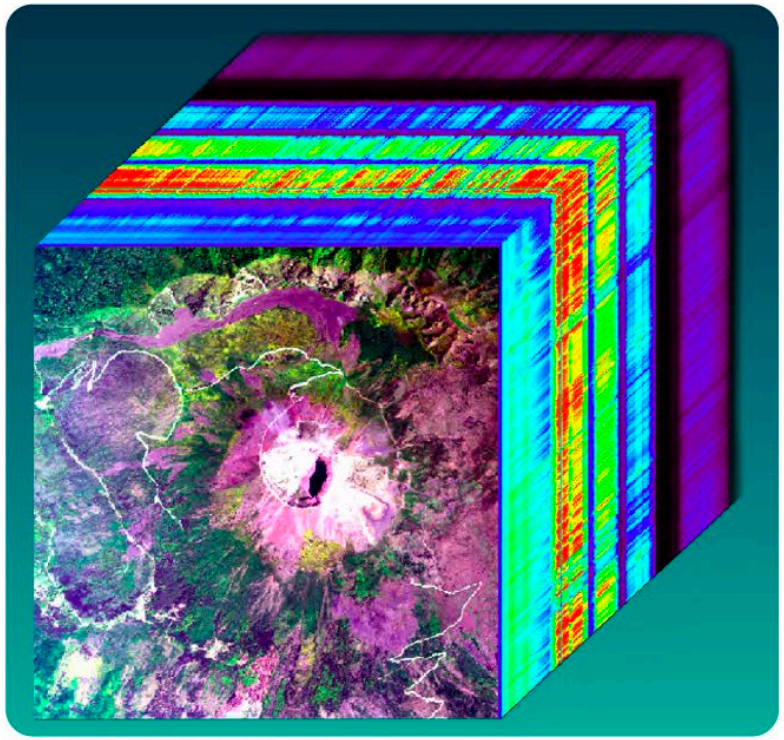


CHIME

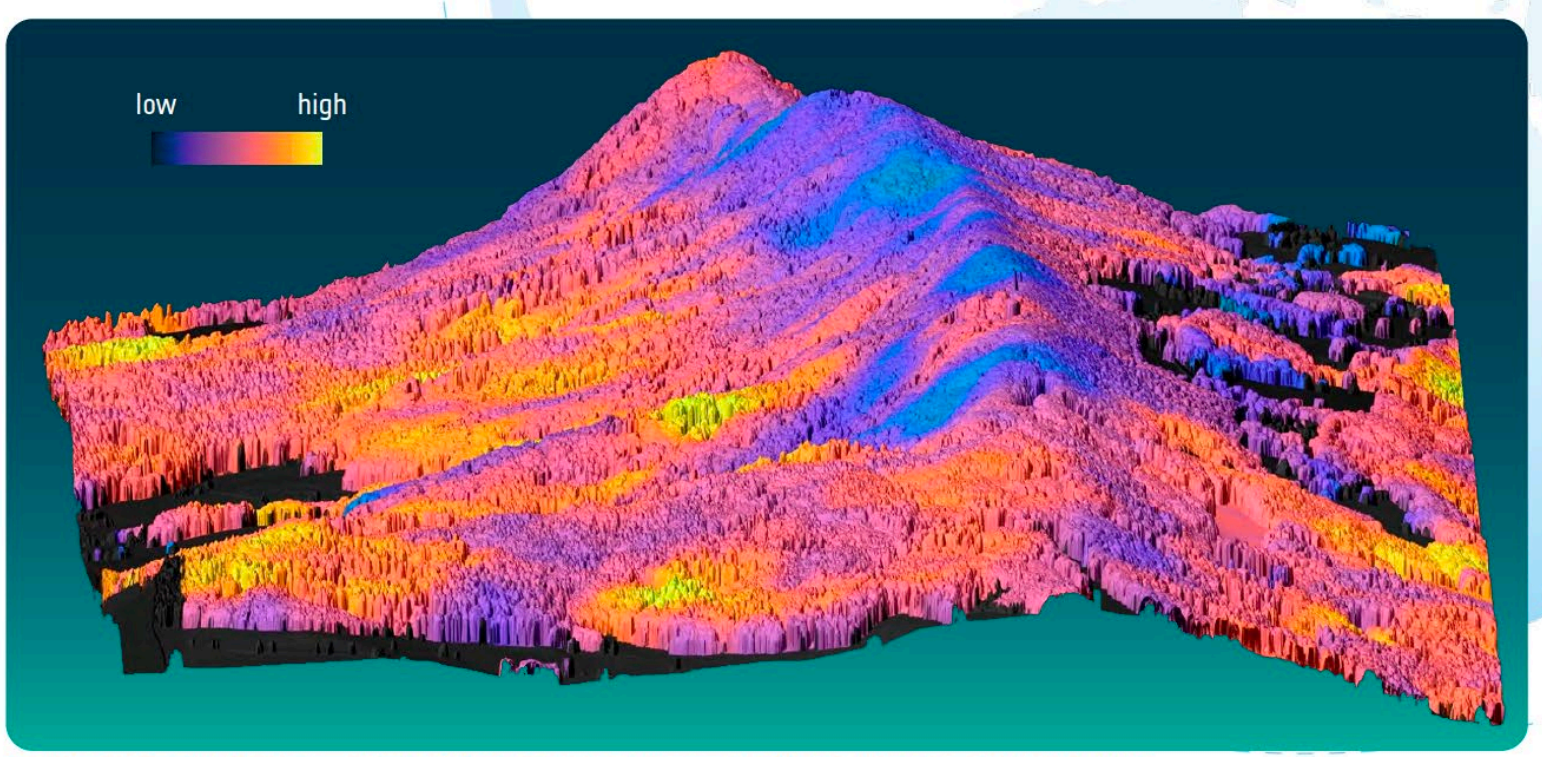
Copernicus Hyperspectral Imaging Mission for the Environment

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)

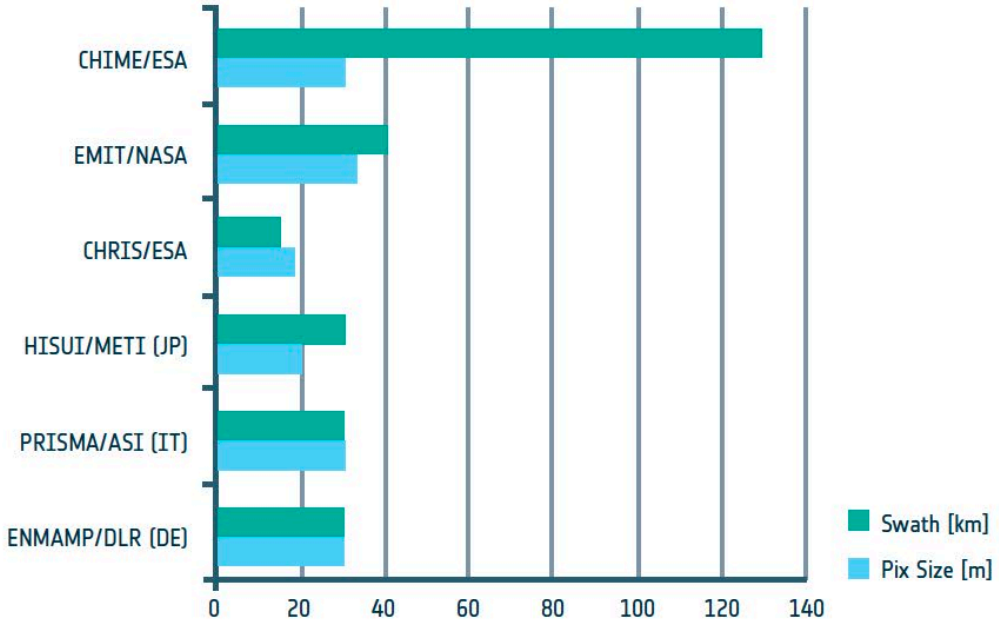


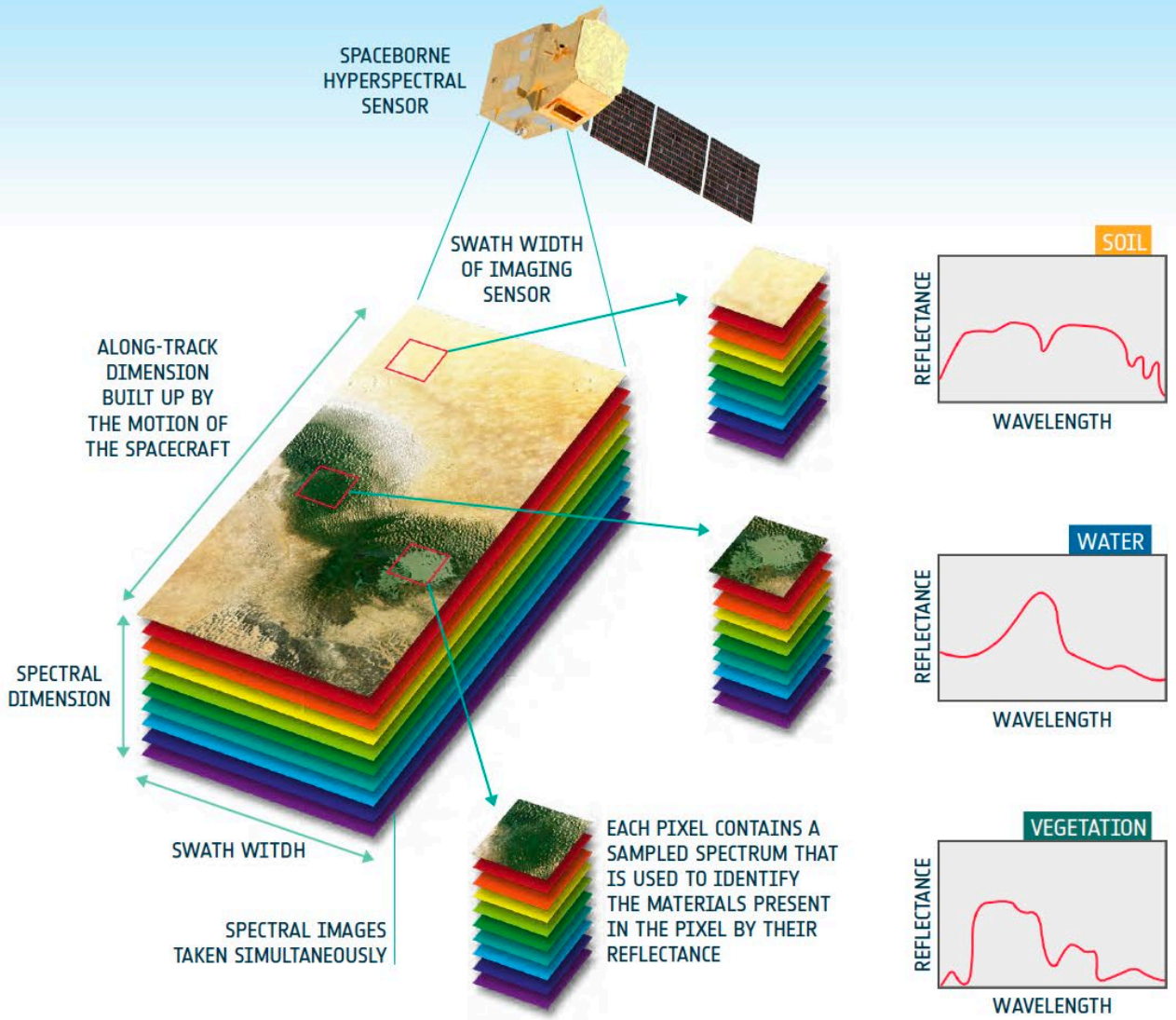
Physiological diversity of a temperate forest (Airborne imaging spectroscopy APEX data - Schaepman, Jehle et al. 2015)

Hyperspectral Imaging Mission (CHIME)

Key Mission Requirements:

- Routine hyperspectral observations of land and coastal areas
- Revisit 12.5 days (2 satellites)
- Spectral range: 400 – 2500 nm, bandwidth ≤ 10nm
- Ground Resolution: 30 m
- High radiometric accuracy, low spectral/spatial mis-registration
- Spectral bandwidth ≤ 10nm
- High SNR requirements to match performance of international missions (PRISMA, EnMap, SBG, etc.)

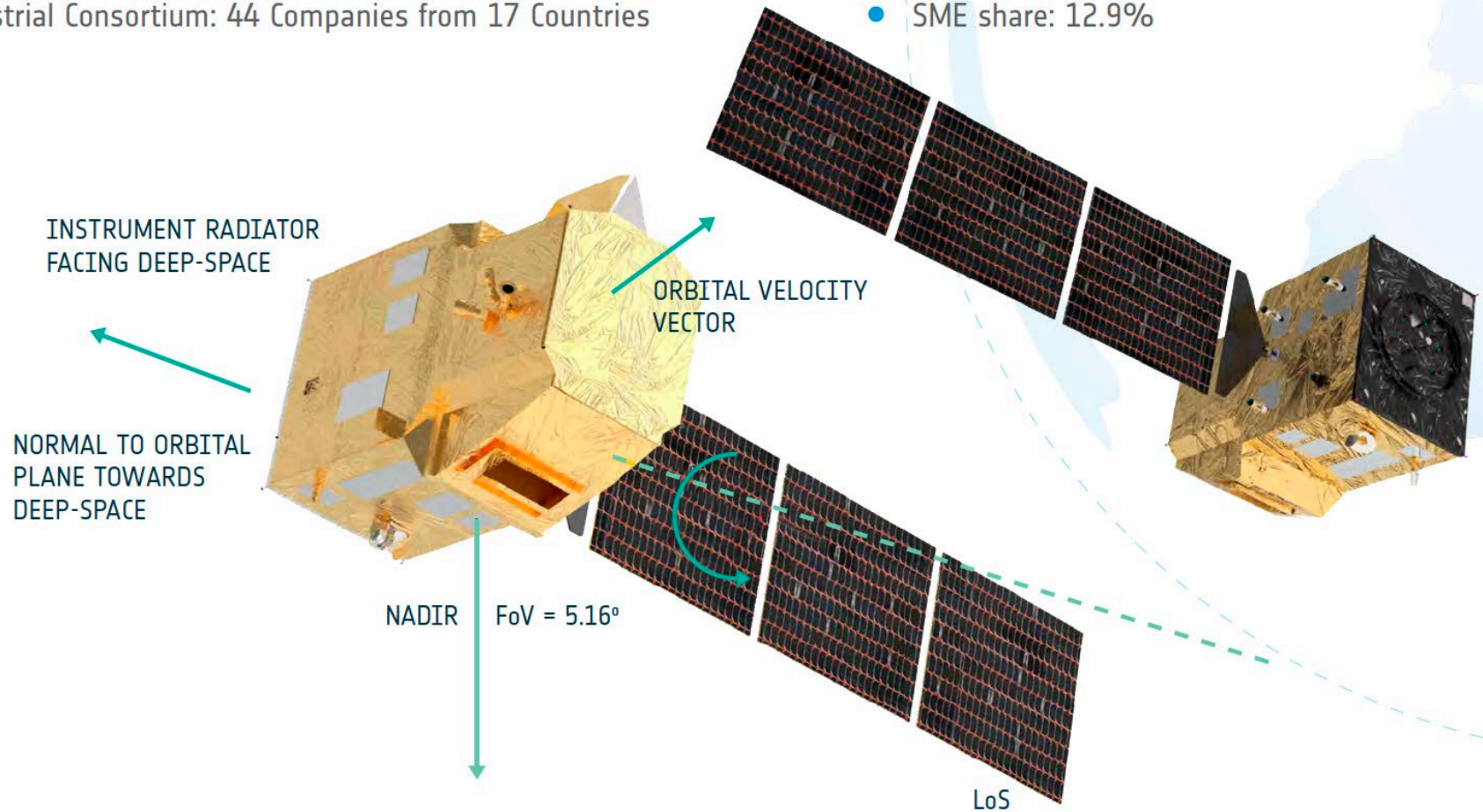




CHIME Space Segment

Full Consortium Established for Space segment Development B2/CD (for PFM + FM2)

- Prime Contractor: Thales Alenia Space France (TAS-F)
- Industrial Consortium: 44 Companies from 17 Countries
- Instrument Prime: OHB (DE) with
  - LEONARDO (IT) for Focal Planes & E2E Calibration
  - AMOS (BE) for 3 x spectrometer, gratings and slits
- SME share: 12.9%



CHIME System – External Framework

Cooperation with ASI, DLR and NASA | Focus: Satellite Constellation and Data Fusion | No exchange of funds and/or hardware

Agenzia Spaziale Italiana

PRISMA

- CHIME Campaign
- advancement of algorithm development
- new retrieval techniques such as AI and machine learning are examined

DLR

EnMAP and DESIS

- End to end simulator combined usage
- Exchange of ATBDs at different product levels
- Cooperation on retrieval toolbox and operational processors

NASA

US decadal plan priority Mission SBG (Surface Biology Geology)

- established Joint Working Groups consolidating an End-Product harmonisation, Retrieval Simulations and Orbit definitions and CalVal

NASA's SBG Mission

- In May 2021, NASA reported that it will create a new set of Earth-focused missions. The satellites in the Earth System Observatory (ESO) are designed to complement one another to create a holistic view of the Earth.
- Surface Biology and Geology (SBG) will enable improved understanding of climate changes that impact food and agriculture, habitation, and natural resources, by answering open questions about the fluxes of carbon, water, nutrients, and energy within and between ecosystems and the atmosphere, the ocean, and the Earth.
- The SBG architecture will be centered around two free-flying spacecraft, one hosting a wide-swath global mapping VSWIR-IS instrument, and the other hosting a wide-swath global mapping Thermal Infrared (TIR) instrument paired with a multi-band Visible to Near-Infrared (VNIR) instrument contributed by a foreign space agency.
- The National Academies 2017 decadal survey has identified five (5) Most Important and seven (7) Very Important objectives for SBG.

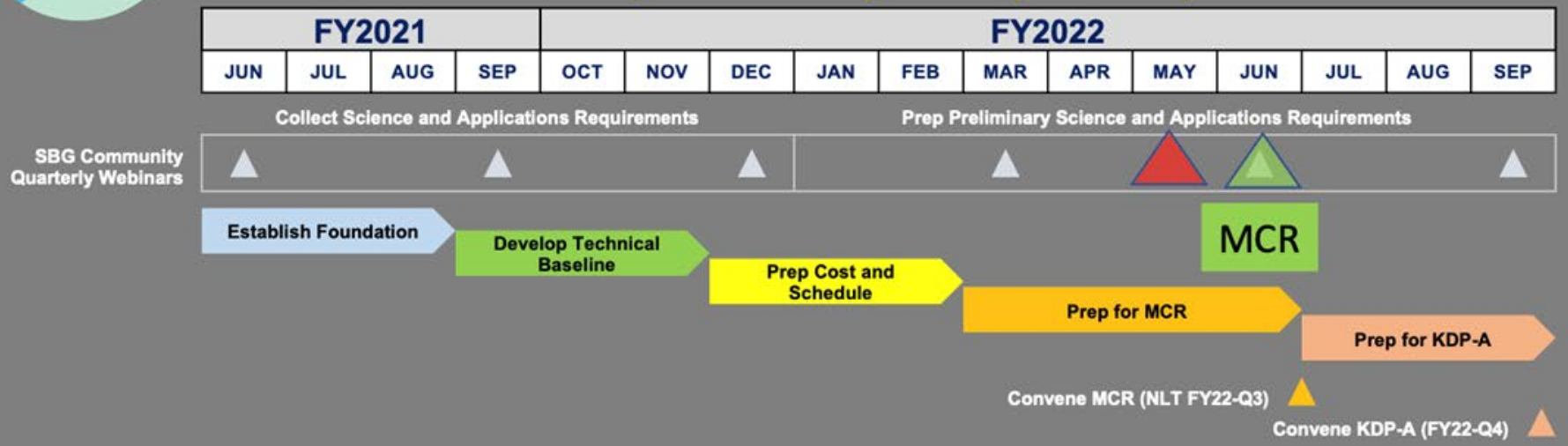
SBG Status (2/2)

Preliminary Specification of the SBG VSWIR Imaging Spectroscopy Instrument are:

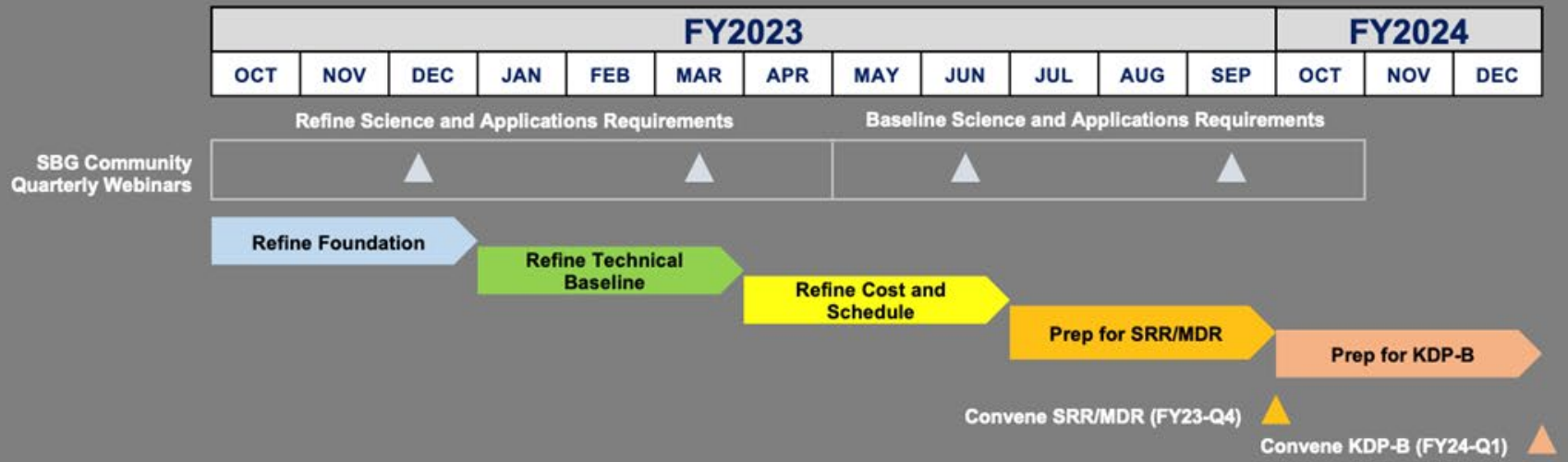
- Spectral Range: 400-2500 nm
- Spectral Bands: ≤10 nm with continuous spectral coverage, 210+ bands
- Radiometric and Signal to noise (SNR) performance: SNR ≥400 VNIR and SNR ≥250 SWIR at 25% reflectance, <5% absolute radiometric uncertainty with high uniformity, low stray-light, and low polarization sensitivity needed to meet key science objectives
- Ground Sampling Distance (GSD) at nadir: 30 m
- Revisit Period: ≤16 days at the equator
- Coverage: All global land, inland waters, and coastal oceans
- Local Time for Acquisition: Between 10:30 to 11:30 AM
- Stability and duration: Measurements must be able to detect long term changes for addressing dynamics of the Earth System over the prime mission lifetime of 3 years with possible extensions

Surface Biology and Geology (SBG)

Pre-Phase A (Pre-Concept Study Phase) Schedule

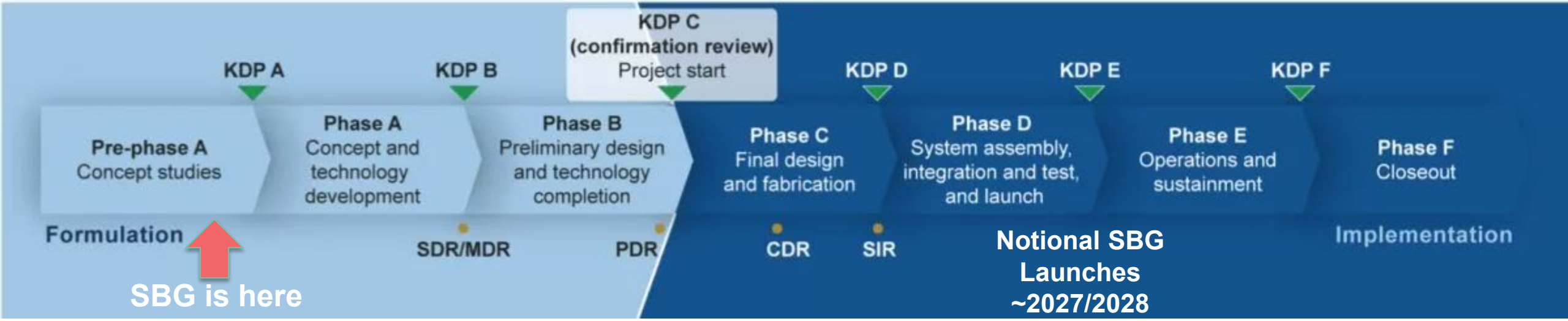


Phase A (Concept Study Phase) Schedule - Notional

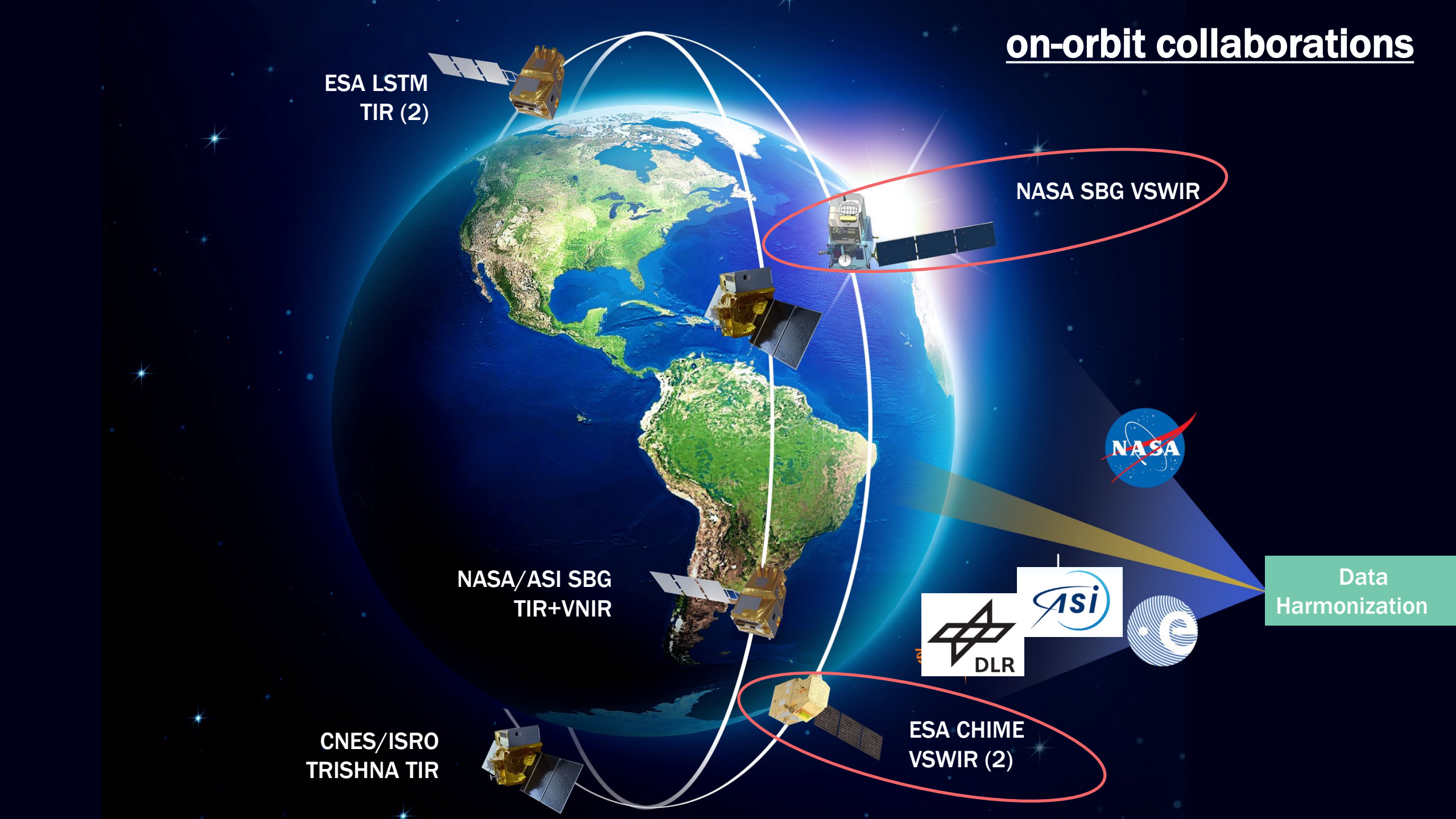


Pre-Decisional Draft: For planning and discussion purposes only.

NASA Project Lifecycle



on-orbit collaborations



CHIME – SBG collaboration opportunity in a nutshell

Programmatics

- How to implement the collaboration
- Working Groups on Cal/Val, Product Harmonisation and Modelling/e2e Simulation
- Identify added value to Decadal Survey and EO programmes
- Harmonisation of Practices and procedures for coordinated operations and exploitation

Science Goals

- Decadal Survey
- ESA Living Planet Strategy
- CHIME Sust. Agri./Food security

Applications and services

- Copernicus Services
- EU Directives/Policies/Green Deal
- NOAA, USGS, US EPA, USDA

Improved Observations

- Revisit
- Coverage
- Continuity
- Core and Priority Products
- Atmospheric Correction
- Information Content (ATBD/algorithm development)

Implementation

- Orbit definition
- Tandem flight manoeuvres
- Schedule
- Joint Campaigns
- End-to-End Simulator/Observation Simulation System Experiments
- Common ground data system elements

Cooperation NASA SBG (VSWIR) and ESA CHIME

- Cooperation based on the heritage of hyper-spectral candidate missions of NASA (HIRIS, FloraSat, ECOSAT) and ESA (HRIS, LSPIM, SPECTRA), and of Hyperspectral Campaign deployment in Europe (1991, 2018, 2021)

- Between SBG and CHIME highly compatible **mission objectives**, **parameters** and **procedures/practices**

- Cooperation based on **'no exchange of funds'** and **'no exchange of hardware'**

- The cooperation should follow the successful 'cooperation model' Landsat-8 and Sentinel-2 under the **Europe-US Copernicus Coordination Group (CCG)**

- **Three joint NASA-ESA Working Groups** established and working on:
  - **'Data Products and Algorithms',**
  - **'End-to-End Simulation and Modeling',**
  - **'Calibration/Validation'.**

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Short-Term Planning

- ***Monthly*** **CHIME-SBG cooperation meetings**
- ***October-2022*** **2nd Workshop on International Cooperation in Spaceborne Imaging Spectroscopy**

Joint NASA-ESA WGs - Status

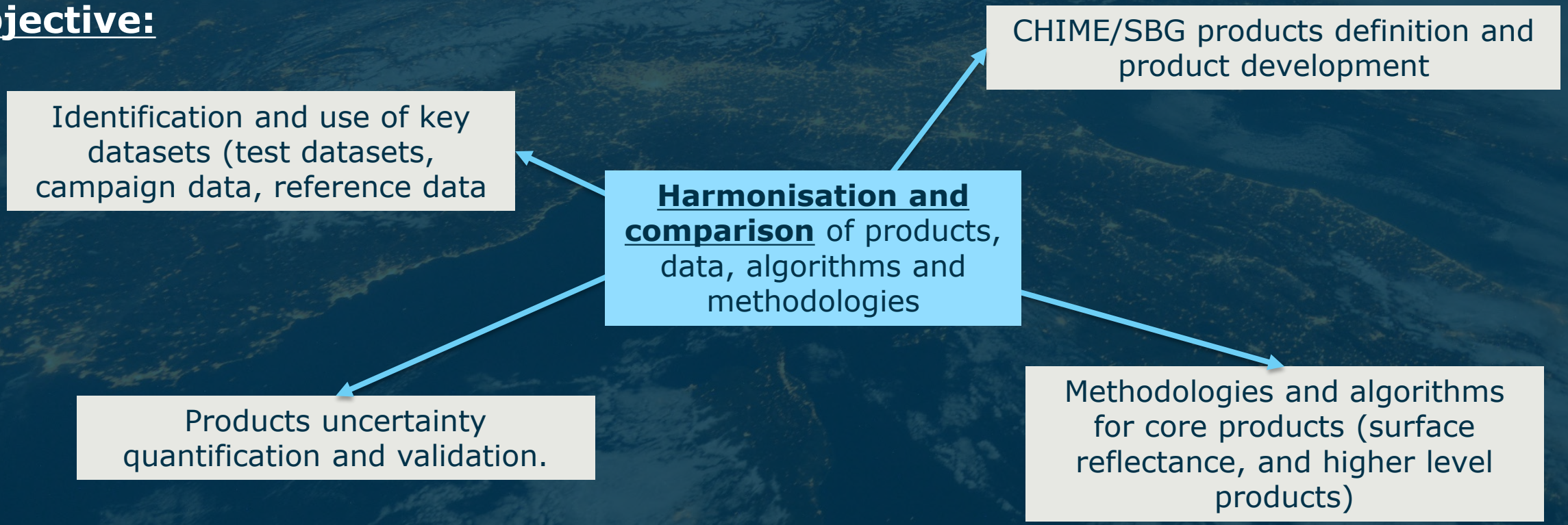
- **3 joint NASA-ESA Working Groups** established and working on:
  - 'Data Products and Algorithms',
  - 'End-to-End Simulation and Modeling',
  - 'Calibration/Validation'.

WG: Data Products and Algorithms (1/2)

Co-leads: Phil Townsend (NASA), Marco Celesti (ESA)

WG Members: Claudia Isola (ESA), David Thompson (NASA), Ferran Gascon (ESA), Kerry Cawse-Nicholson (NASA), Valentina Boccia (ESA)

Objective:



WG: Data Products and Algorithms (2/2)

Roadmap for Cooperation:

- **Exchange of early science results from precursor or airborne missions**, with a focus on results from the CHIME Requirements Consolidation Study (RCS) and NASA Pathfinder Studies, as well as the NASA-ESA Joint Hypersense Campaign
- **Crosswalking of CHIME and SBG core products (L2A, L2B)** and identify products that are operationally equivalent
- **Intercomparison exercises on key common products**, focusing on their dependencies, categories of harmonization practices and common datasets
- **Identify needs of the Ground Segment** for each mission to generate harmonized products, and compatibility and coordination in the archiving, distributing and sharing of L0 to L2 data
- Identify the types, needs and characteristics of **reference datasets for harmonization**, as well as the inter-dependencies between referance datasets and mission/system requirements,.
- **Comparison of Atmospheric correction** procedures and atmospheric radiative transfer, and coordination with intercomparison exercises such as ACIX-III and RAMI4ATM
- Identifying the needs and recommendations for **interoperable data formats and metadata for data product harmonization**
- **Coordination on sharing of algorithms and test-datasets** (and methodologies) through mission exploitation programmes (software development, training, education activities), open source and common algorithms and identify a formal framework for data sharing
- Share methodologies and approaches for **validation and end-to-end traceable uncertainties**

Schedule

February 17th 2021 - Kick off meeting between co-leads to discuss coordination

March 5th 2021 - First WG Meeting

March 30th 2021 - Second WG Meeting

June 1st 2021 - Discussion and development of WG Roadmap

June 29th 2021 – Finalisation of draft WP roadmap

WG: End-to-End Simulation and Modeling (1/2)

Co-Leads: Marco Celesti (ESA) and Ben Poulter (NASA)

Contributors: Antonio Gabriele (ESA), Claudia Isola (ESA), Alexey Shiklomanov (NASA), Ann Raiho (NASA), Jennifer Dungan (NASA), Shawn Serbin (BNL), Phil Townsend (UW)

Objectives:

To address synergies between end-to-end traceability needs and develop and evaluate tools supporting the CHIME and SBG missions. The Working Group meets to exchange ideas, methodologies, data (i.e., simulated or observed hyperspectral reflectance and top-of-atmosphere radiance data), and instrument models (to the extent possible).

Synthetic Hyperspectral Top-of-Atmosphere Data for June 1, 2018 Wang et al.,

WG: End-to-End Simulation and Modeling (2/2)

Following activities are planned:

- **Exchange core scenes and early science results**, comprised of 'true' or synthetic data,
- Extend 'E2E' frameworks to enable cross-comparison on same L2b algorithms (synergies with WG#1), potentially using same test data system (TDS) from airborne 'truth' data or synthetic scenes.
- **Compare and evaluate atmospheric-correction procedures** (CHIME=ATCOR and SBG=OE) **and atmospheric radiative transfer models** by coordinating with ACIX intercomparison
- **Compare simulation performance of instrument models**, e.g., instrument noise, including spectral fidelity/smile, keystone, etc. and use to inform cal/val working group activities.
- Enable, evaluate and improve existing (i.e., ERADIATE, DIRSIG, SCOPE, DART, Hydrolite), or develop new (i.e., LSM), canopy, soil, geology radiative transfer models to simulate hyperspectral reflectances and to provide basis for new inversion activities and algorithms.
- **Contribute**, with WGI, **to concepts and test data and sharing of code for Open Science Data System development**, i.e, the joint NASA-ESA Multi-mission algorithm and analysis platform (i.e., expanding MAAP beyond biomass, exploring opendatacube, esatoolbox, Copernicus-toolkit, NASA-Harmony API, NASA-EOSDS etc.).

Schedule

Dec. 12, 2020 - Kick off meeting to discussion coordination, meeting #1

Jan. 19, 2021 - Recognition of the Data Modelling and Simulators Working Group

Apr. 8, 2021 – Discussion of WG charter and Common products, meeting #2

Sept.16,2021- Finalization of WG charter , meeting #3

Feb 22, 2022 – Cloud-based science data systems

WG: Cal / Val (1/2)

Co-Leads: Valentina Boccia (ESA), Kurtis J. Thome (NASA)

Members: Kevin Alonso (DLR/ESA), Kevin Turpie (NASA), Ray Kokaly (USGS)

Why?:

Cal/Val determines the **quality and integrity** of the data provided by the spectrometers, thus impacting the **accuracy and reliability** of the products

- fundamental while the satellites are in-orbit and operating
- even more crucial when data from different satellites, carrying different imaging sensors, are used by users worldwide in a complementary and synergetic manner
- facilitates cross-calibration and interoperability

Objective:

Establishing a **roadmap** and **strategy** for future SBG-CHIME coordination activities and collaborative studies

WG: Cal / Val (2/2)

Roadmap focus areas:

Measurement Networks and commonly recognized Cal/Val reference sites

Atmospheric radiative transfer and atmospheric–correction procedures

Joint airborne spectroscopy campaigns to simulate both missions and exercise the capabilities for interoperability (data collection, calibration, data product production, etc.)

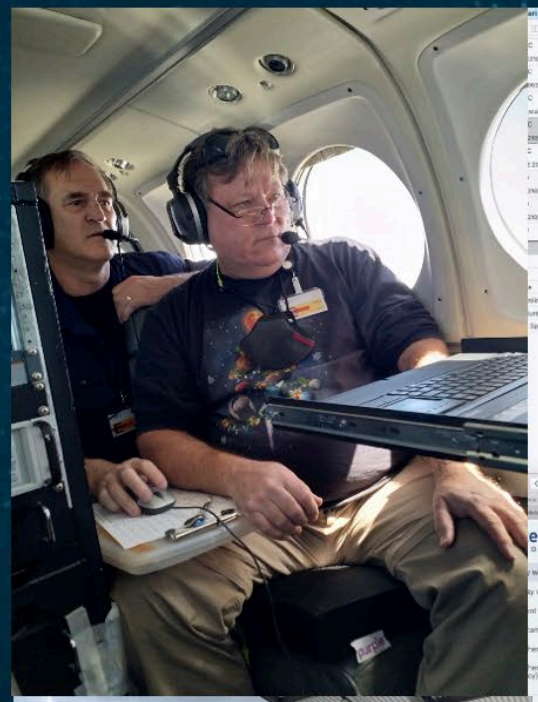
Continuous validation throughout the lifetime of products

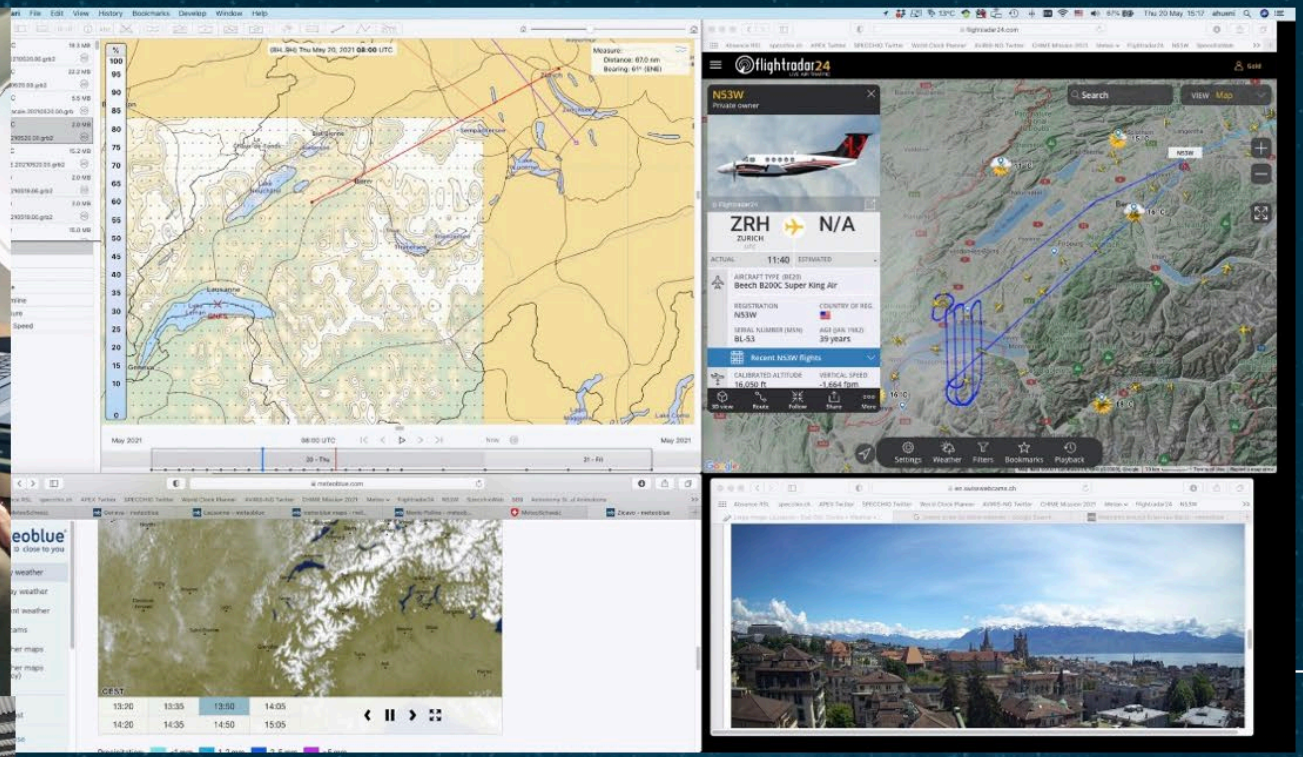
Opportunities for efficiency and success through cooperation on cal/val, downlink capabilities and shared algorithms (e.g. compression and on-board data reduction)

Main Milestones so far:

- 1st WG meeting: 22nd of February 2021
- 5 WG meetings already held
- Draft Roadmap presented at EGU 2021
- Current presentation at the LPS'22

‘Hypersense’ Campaign with AVIRIS-NG in 2021

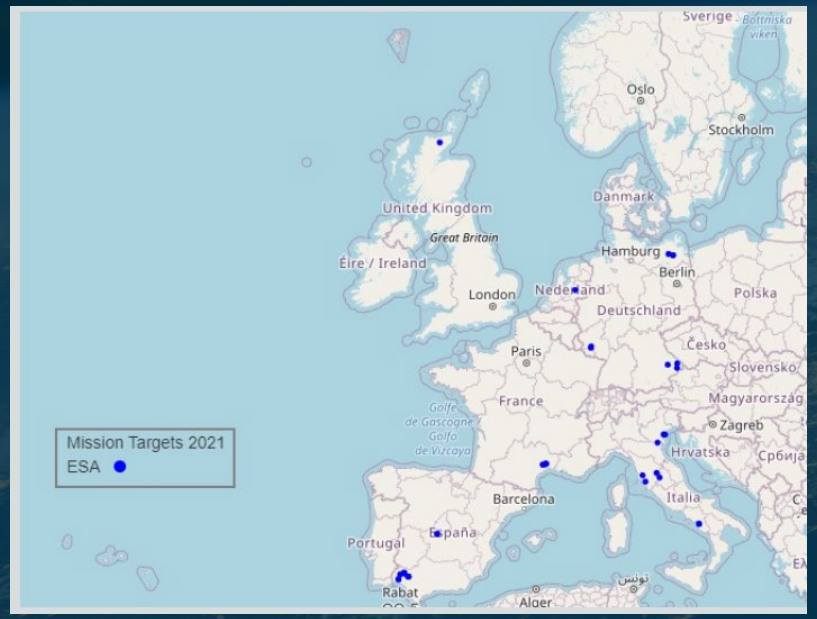




- Demonstrate key algorithms (Ecosystems, Agriculture, Soils, Geology, Hazards, Snow/Ice, etc.) for the science and applications objectives of CHIME and SBG.
- Collect a diverse set of large data sets in Europe that can be used in preparation for CHIME and SBG (e.g. Western Diversity Time Series, California).
- Test and evaluate new state-of-the-art science algorithms: atmospheric correction, etc.
- Grow international science collaboration in support of ESA CHIME and NASA SBG.
- Test/Demonstrate calibration, validation, and uncertainty quantification approaches.
- Strategic cross comparison under flights of space missions: DESIS, PRISMA, Sentinels, etc.

https://ares-observatory.ch/esa_chime_mission_2021/
https://twitter.com/AVIRIS_NG_RSL

‘Hypersense’ Campaign with AVIRIS-NG in 2021



- 17 fully successful sites across Europe
- Exceptional coordination between all teams (including PRISMA and DESIS)
- Concurrent ground / airborne / satellite acquisitions over 8 sites
- Open data policy fostering community exploitation

AVIRIS-NG Surface Reflectance (RBG)
22nd June 2021 - Jolanda di Savoia (IT)


Thank you for your attention!