# The ESA Earth Watch Mission TRUTHS:
## Traceable Radiometry Underpinning Terrestrial- & Helio-Studies
## Status Update

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GSICS, 02 March 2023

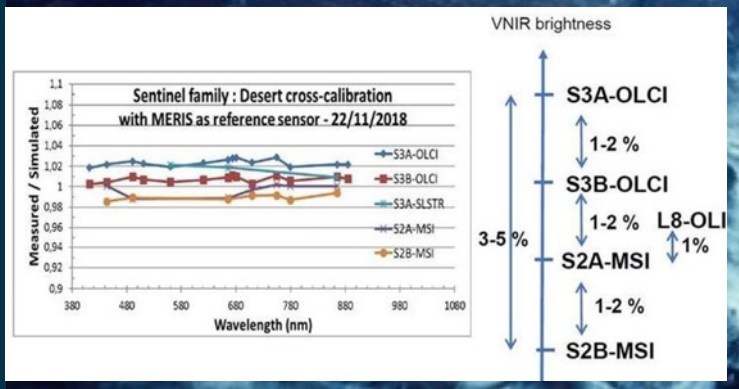
# TRUTHS

provide SI-traceable measurements of the solar spectrum to address direct science questions.

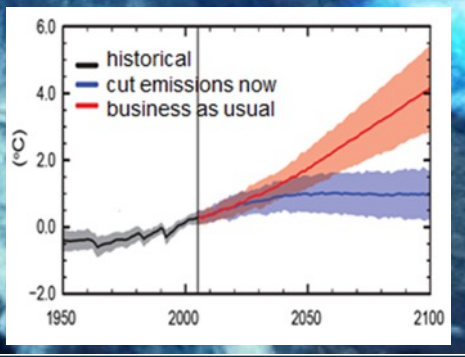
- Optical mission for measuring incoming solar and outgoing reflected radiation
- **Metrology lab in orbit**: flying a primary calibration standard traceable to SI Units

**Satellites cross-calibration**: Establish a 'metrology laboratory in space' to create a fiducial reference data set to cross-calibrate other sensors and improve the quality of their data

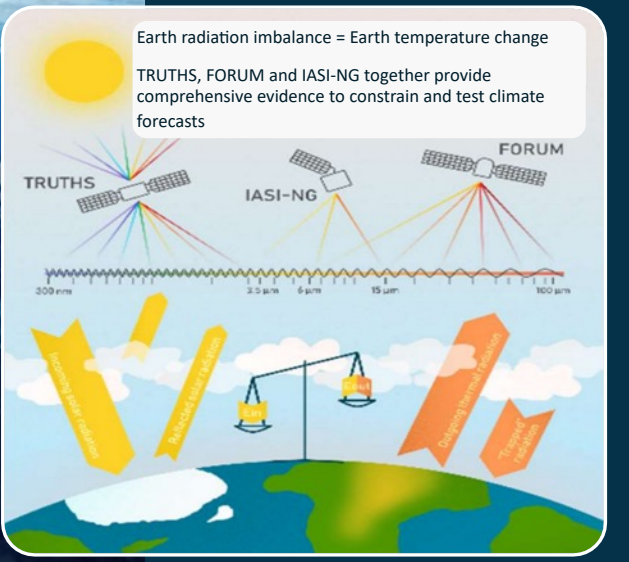
**TRUTHS cross-calibration: bias removal, improving accuracy of other sensors, Datasets re-calibration**




**TRUTHS climate Benchmarking: more precise predictions**




**Climate benchmarking:** enhance by an order-of-magnitude our ability to estimate the **Earth Radiation Budget** through direct measurements of incoming & outgoing energy



# What does TRUTHS do?

**Measures incoming and Earth/Moon reflected radiation from the Sun**

- 320 to 2400 nm @ ~4 nm intervals (1 nm for solar UV)
- Global nadir @ 50 m ground resolution with 100 km swath (capability)
- Target radiometric uncertainty of 0.3% (k=2)

**Establishing a benchmark of the radiation state of the planet at ToA (radiance/reflectance) & BoA surf reflectance to help enable:**

## Observations

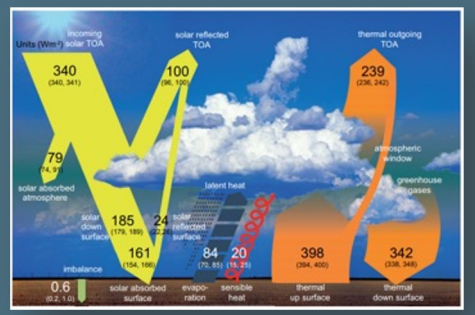
- Benchmark
- monitoring
- Litigation
- algorithm improvement

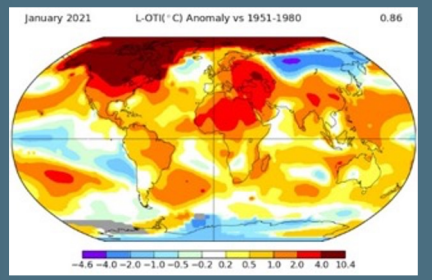
## Calibration

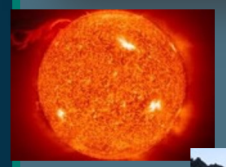
- Interoperability
- data-gaps
- performance
- Utility

## Climate action: Supporting 'Net Zero'

### Climate sensitivity/response



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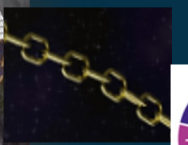
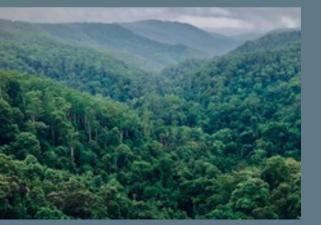



### Adaptation/sustainability

### Climate action/mitigation

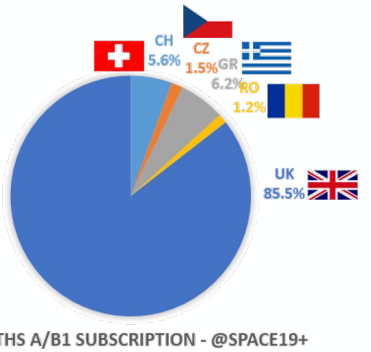


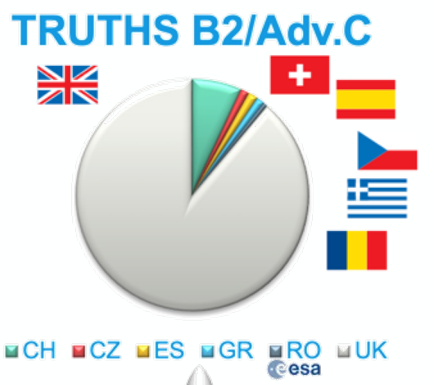
# TRUTHS - an ESA Earth Watch element

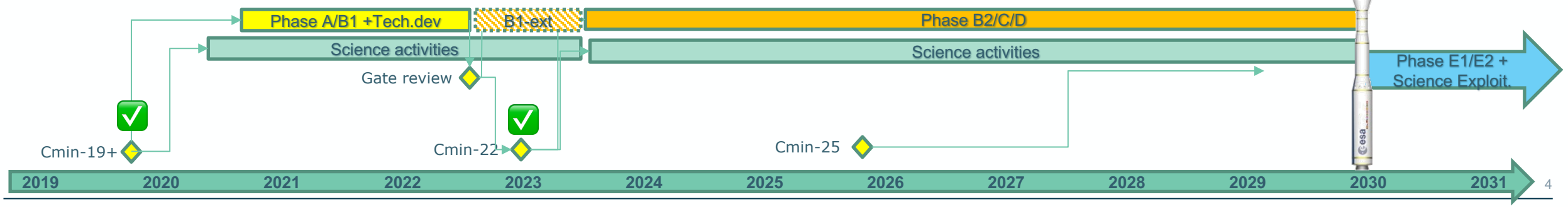
- TRUTHS was proposed by UKSA to ESA in May 2019 as a **Earth Watch** Element

  **“Climate and Calibration Observatory in Space”**

- TRUTHS was included and fully funded as an **operational mission** in the ESA EO programme proposals at the ESA Ministerial Council “Space19”+ in Nov. 2019 covering the development **Phase A/B1**
- Successful Intermediate **System Requirements, Independent Science and Gate Review** closing Phase A/B1 (continued by Phase B1 Extension/Bridging)
- The TRUTHS Programme continuation was approved for **Phase B2/Advance C** at the ESA Ministerial Council in Nov. 2022

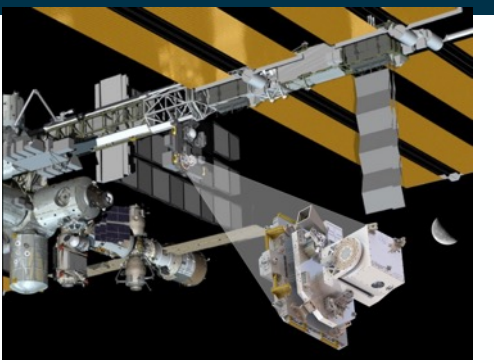


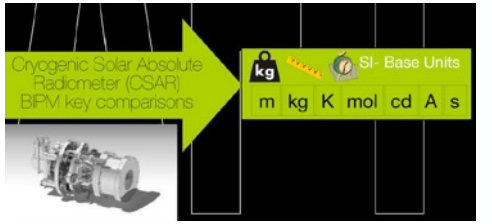



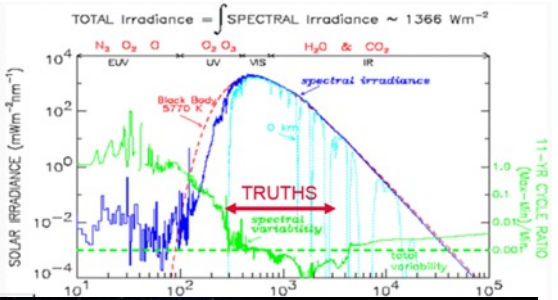



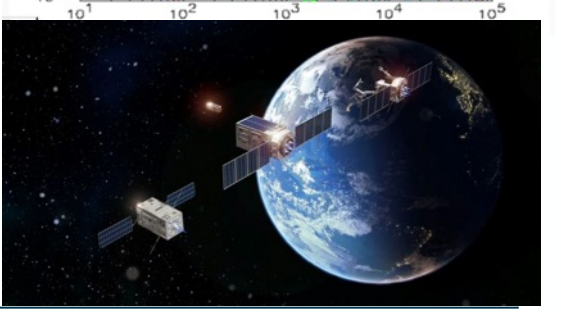
# TRUTHS Vision: mission assets and perspectives

- **An international climate Observatory**
  - The need to cover long time series and many solar cycles calls for long-term operation. Once TRUTHS will be operational, international cooperation and data interoperability among different missions worldwide will be implemented (SITSats constellation). NASA already agreed to a TRUTHS/CLARREO-Pathfinder framework. Initiating CEOS WGCV (& GSICS hopefully) task group on SITSats in general.
- **An operational service for institutional and commercial satellites**
  - The capability to cross-calibrate other satellites opens up to an operational service for improving the quality of other optical satellites, either institutional (e.g., Copernicus and Eumetsat series) and commercial (new space). The traceability to SI units and rigorous uncertainty tracing makes the measurements unambiguous and trustworthy
- **A new concept for next generation optical missions**
  - Once proven, TRUTHS unique calibration system might be optimized / miniaturized and become a novel package for optical instruments calibration. In alternative, smaller satellites might opt to fully rely on calibration from TRUTHS data service and optical payload can be conceived lighter and simpler,
- **A step towards a System of Systems**
  - TRUTHS opens up to an efficient use of space and data assets: one satellite improves the performance of many others and the TRUTHS data on calibration sites permit to improve new and existing datasets, even taken in the past. TRUTHS concepts fits in the strategic view of making space assets interconnected and result of a distributed effort

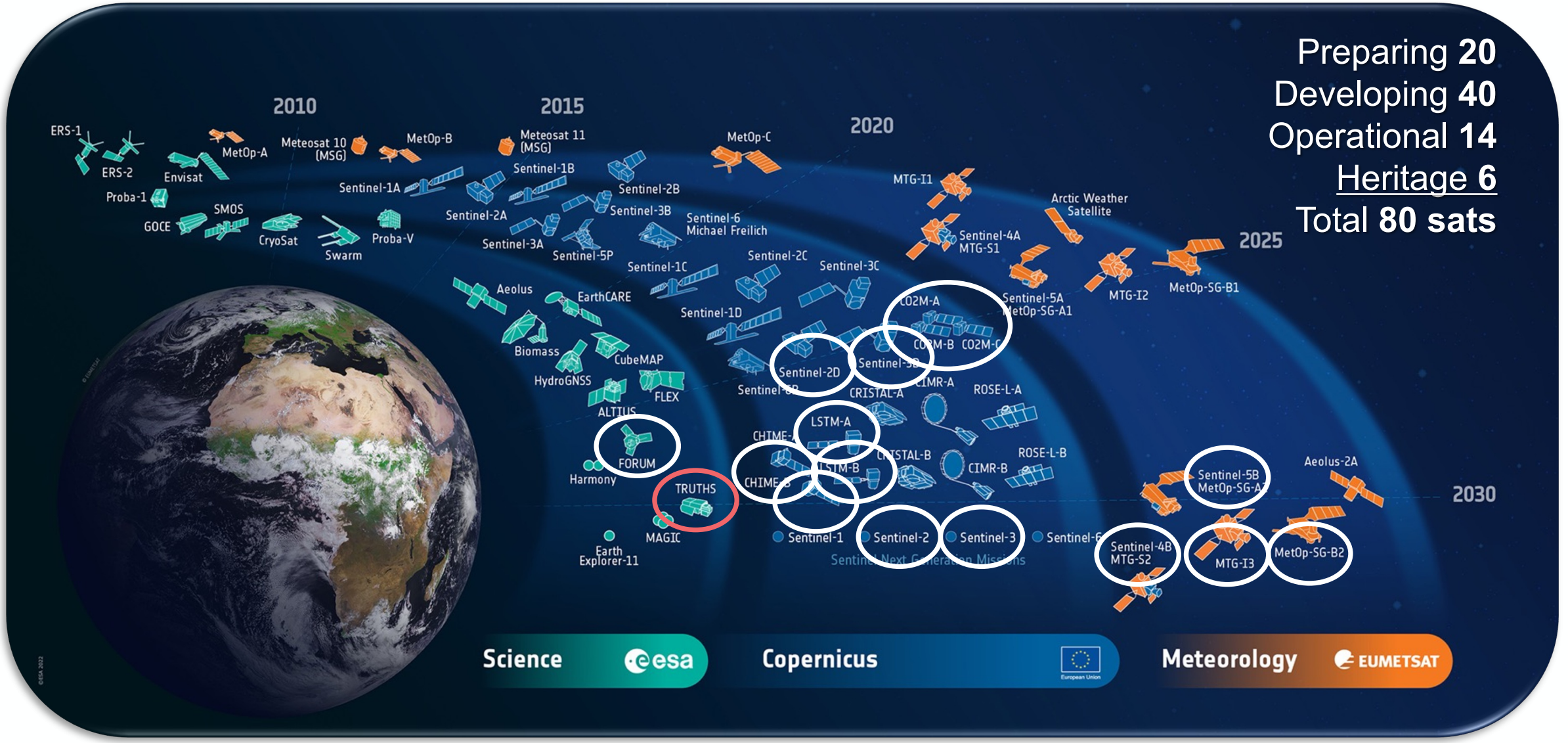




# ESA-developed Earth Observation Missions



# TRUTHS Phase A/B1 Accomplishments (2020-2022)

## Industrial study

- **System study**
  - Phase A/B1 in ~18 months
  - Agile reviews / sprint-scrums co-engineering
  - Science interactions with TMAC
- **System simulators**
  - OPSI/E2EMS/S2SC
  - Scenes inputs by TMAC for geometric calibration and
- **Technology pre-developments**
  - TRL-raising activities
  - Additional de-risking activities and industry up-skilling

## Science activities

**Independent User reqs. Study**

- User needs identification and "Traceable Mission Req.s Review"

**TMAC (Science) Study**

- Mission requirements and calibration performance
- L2 algorithm definition
- Reference scenes generation
- Rigorous uncertainty simulator (FIDUCEO methodology)
- S2SC image match-up analysis

**Mission Advisory Group**

- 12 scientists from ESA MS
- Observers from NASA, EUMETSAT, ECMWF/C3S

**Independent Science Review**

**Outreach**

- COP-26, Glasgow, UK, 2021
- LPS22, Bonn, Germany, 2022
- …

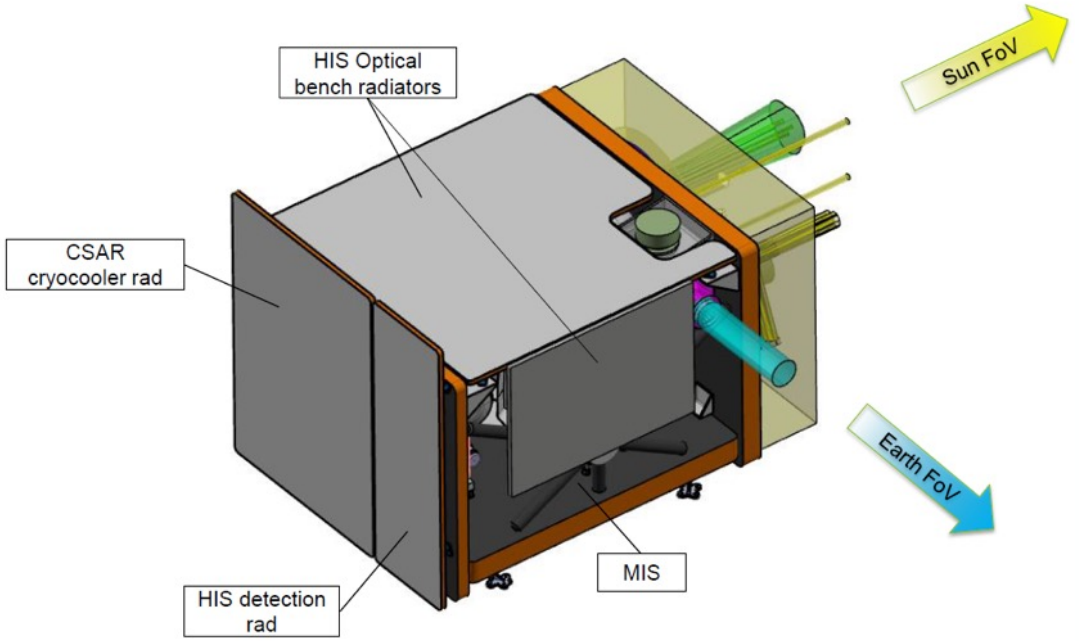
## ESA

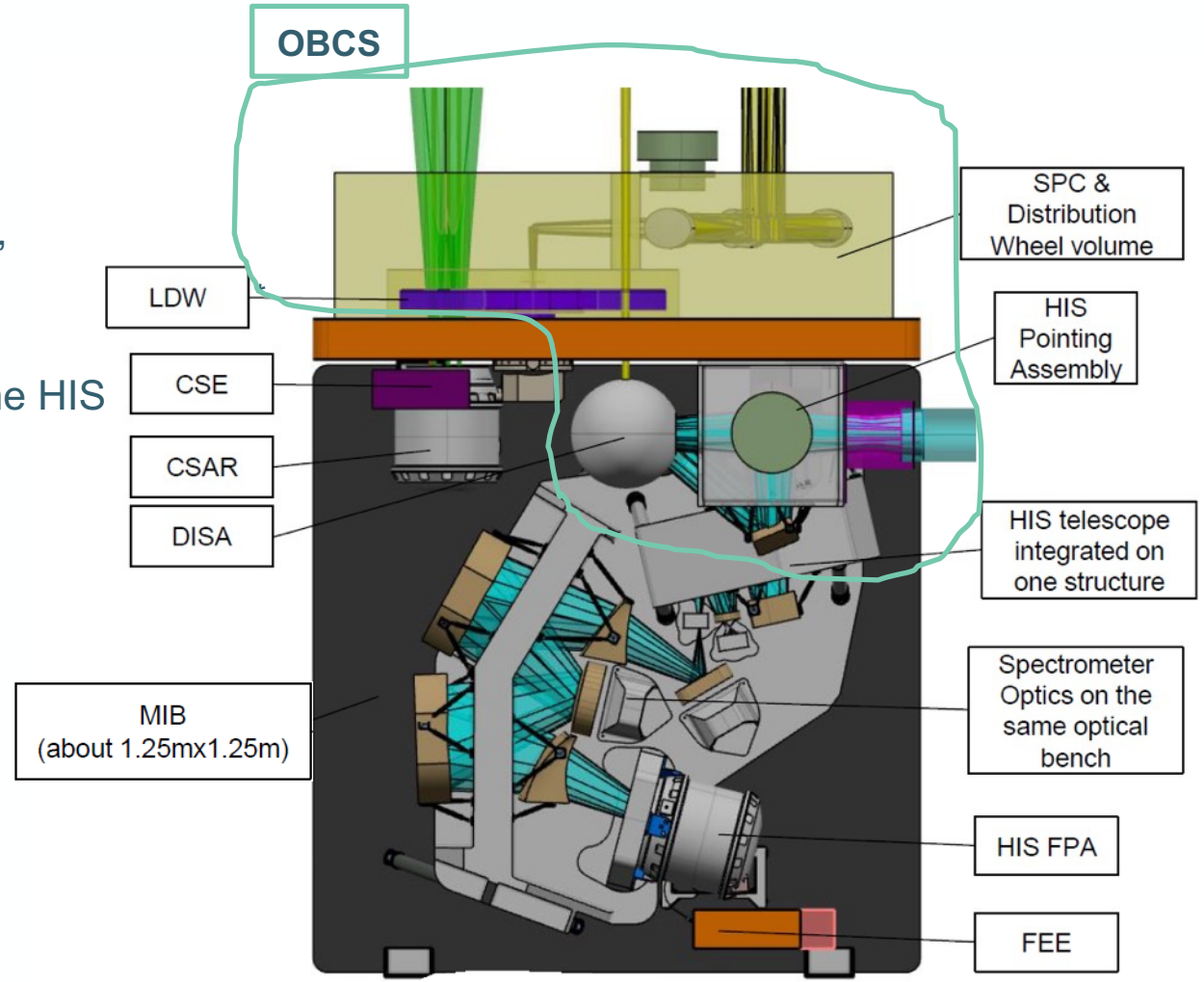
- Launcher trajectory and accommodation study
- Support to pre-development (component analysis, material testing)

# Payload Overview

Payload, composed of three elements:

- **CSAR** (Cryogenic Solar Absolute Radiometer) – operated at 60 K (cryocooler*), the "**primary standard**"
- **HIS (**Hyperspectral Imaging Spectrometer) – UV to SWIR (320-2400 nm), single detector, 50 m resolution, 100 km swath. Detector actively cooled at 150 K
- **OBCS** (On-Board Calibration System) – transferring the CSAR solar absolute (SI) measurement to the HIS




*Cryo-cooler Assembly – recurrent from THRISHNA mission at ISRR baseline

# TRUTHS in-orbit calibration philosophy

1. **CSAR measures optical power in SPC output**

*SPC generates beams of 'monochromatic' radiation from sun, which can be distributed to different parts of the calibration system.*

2. **The "new" DISA (2 Integrating Spheres) replaces the old Transfer Radiometer**

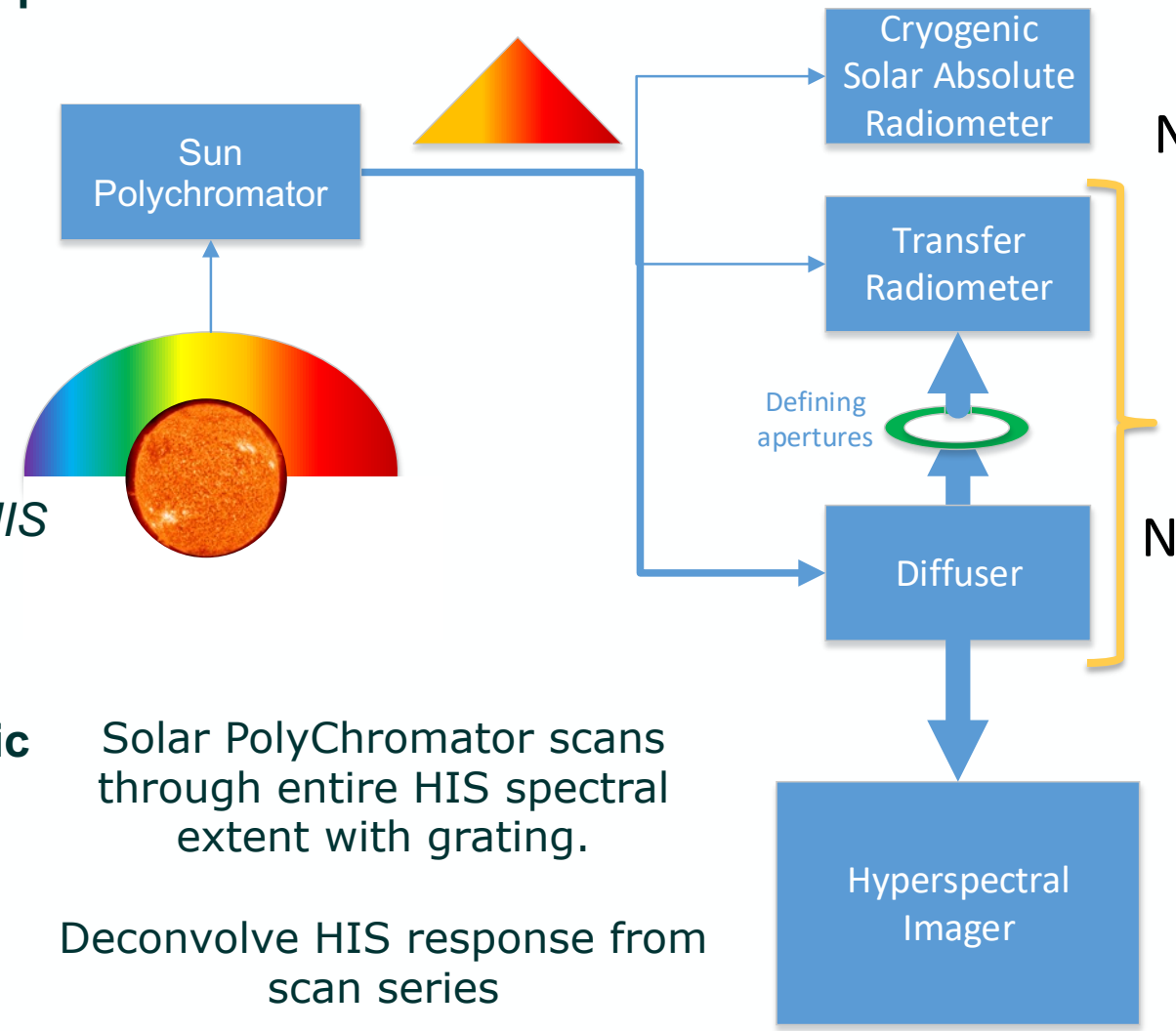
*Conversion from power to radiance.*

*It is calibrated, relative mode, via direct sun + HIS measurement.*

Calibrates *HIS gain via SPC output.*

3. **Concept of Operations based on geometric knowledge & stability**

*Calibrating out in-flight degradation only. Repeatability assumptions based on mechanical and thermal control.*

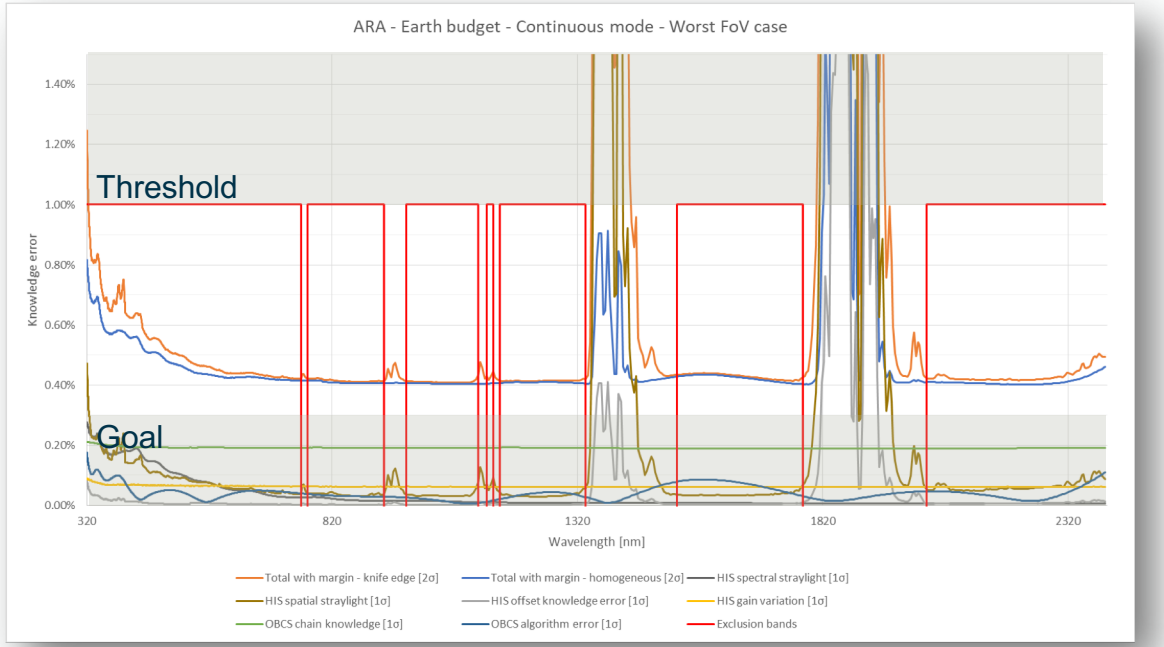


# Absolute Radiometric Accuracy (ARA)

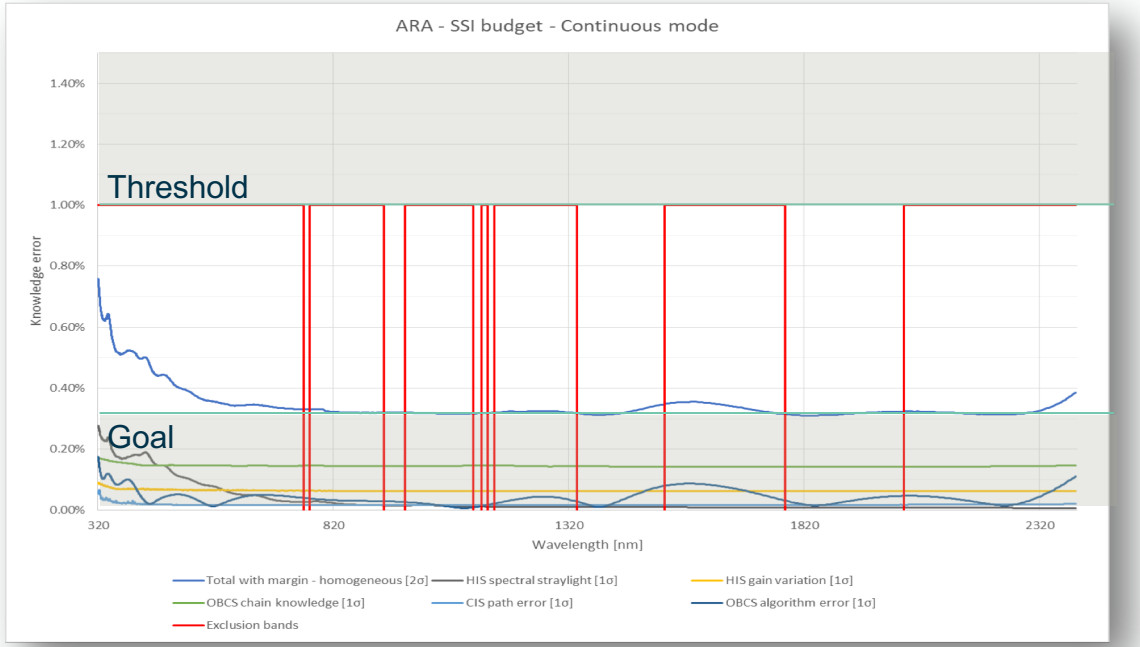
Mission requirement:

| MRD-ID | Type | Value |
|---|---|---|
| MRD-OBS-310 | ERU ERSR, SSI, LSI | The Expanded Radiometric Uncertainty for ERSR, SSI and LSI measurements shall be better than 0.3% (G) / 1% (T). |

## Earth Reflected Solar Radiance



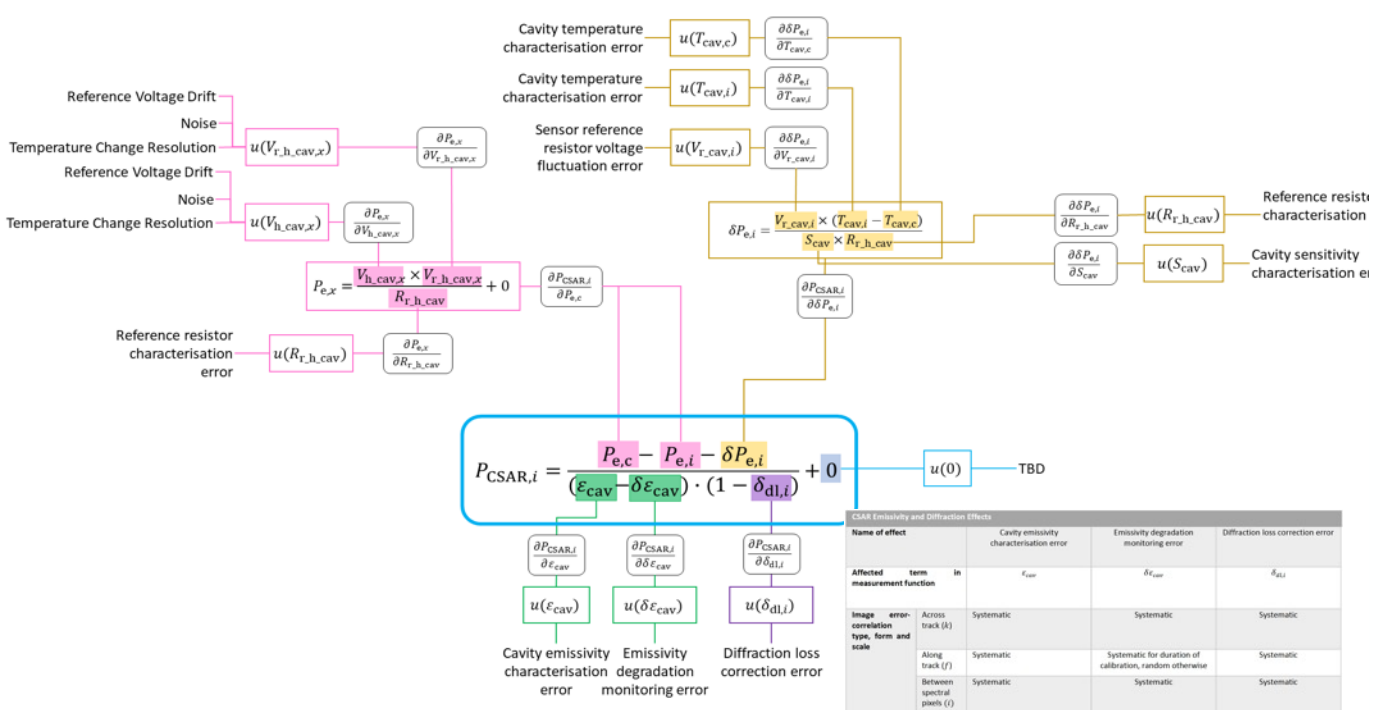

## Spectral Solar Irradiance



# Application of Metrological principles

FIDUCEO like analysis of end to end traceability and uncertainties establishing measurement equation and errors sources together with associated uncertainties for the end to end measurement.

## CSAR power calibration

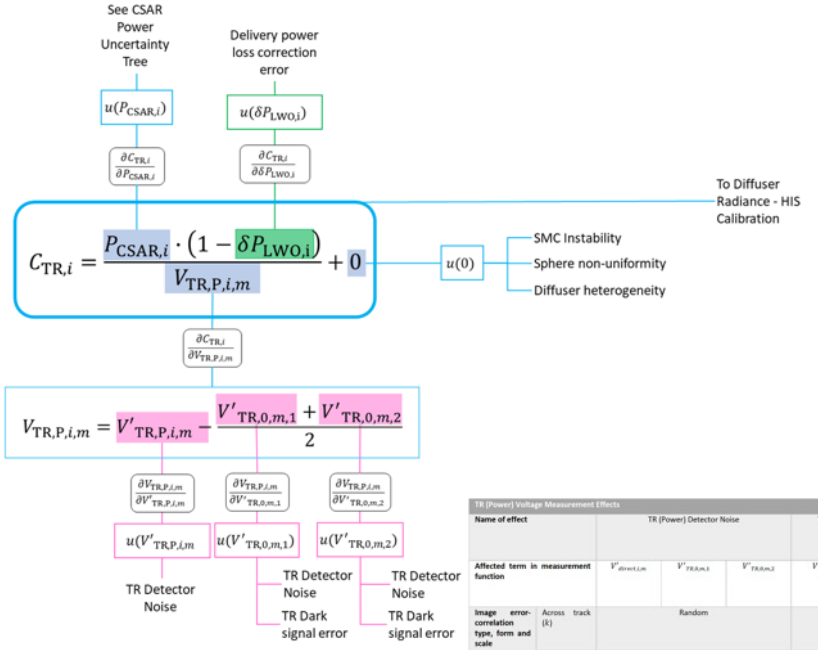


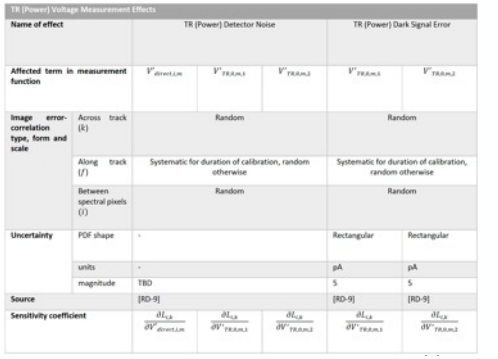



Hunt and Fahy, NPL, 2022

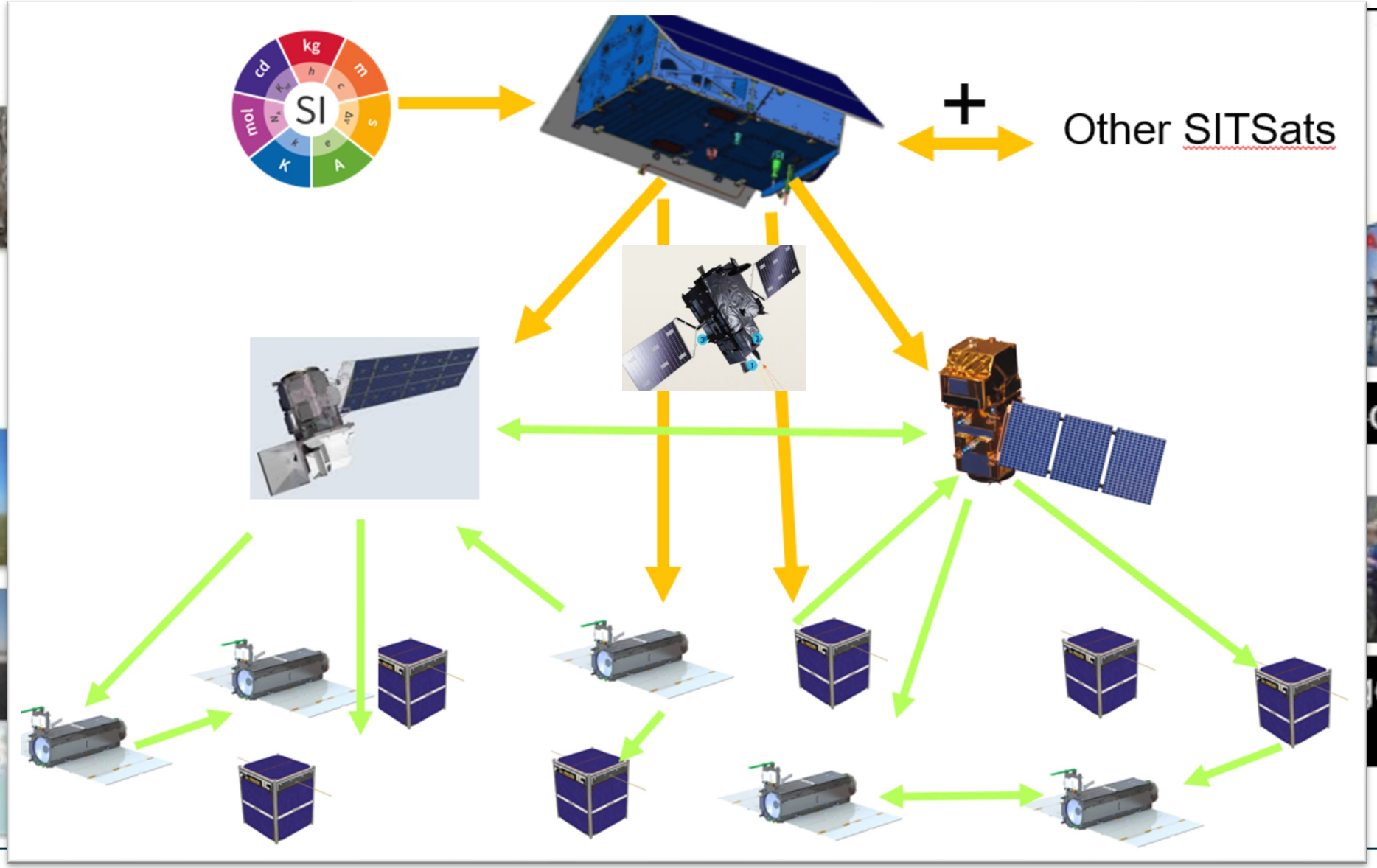
## Transfer Radiometer power transfer

(to be updated)



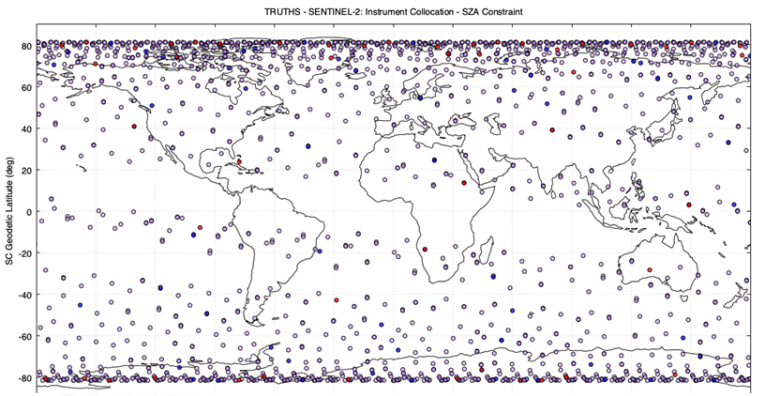



# SI-Traceability to Cal/Val infrastructure

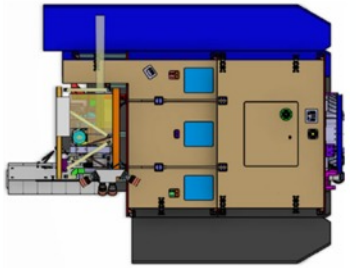


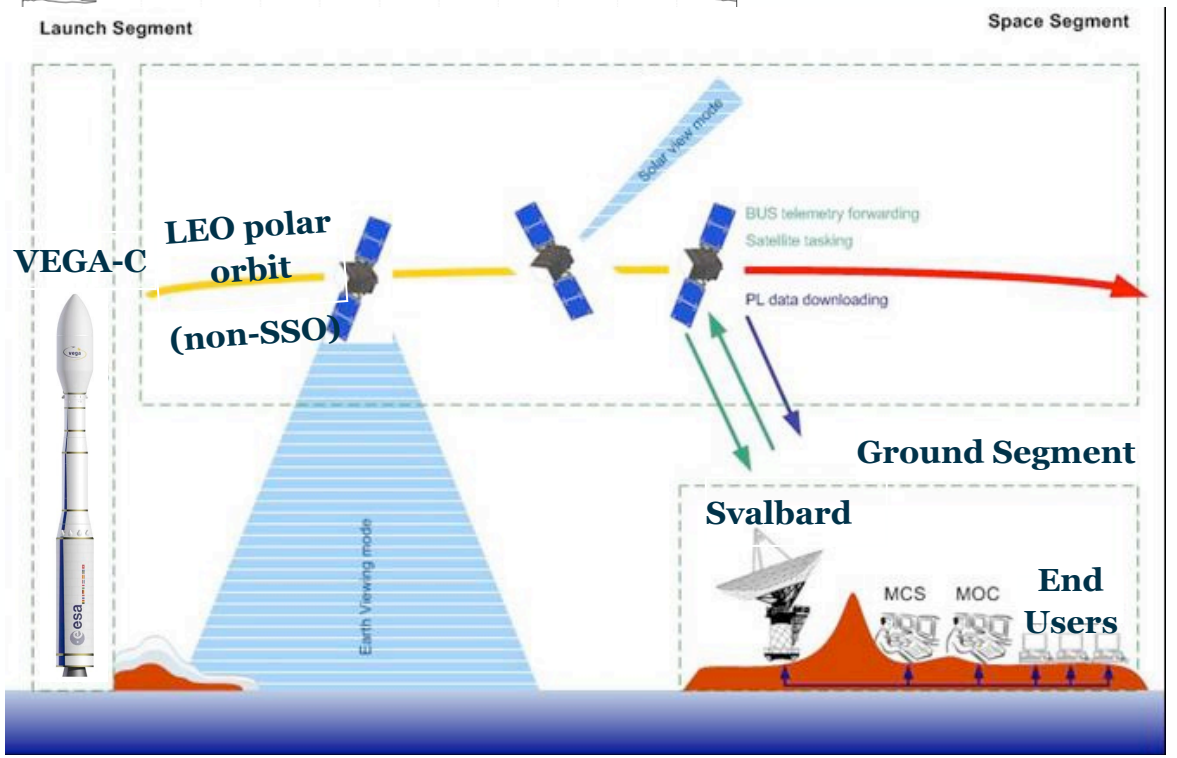
# System Architecture Overview

- Lifetime 5 years + 3 extension
- Launch foreseen in 2030
- Space Segment:
  - Orbit 614 km, polar (90º) non-SSO
  - 1 satellite – agile, design for non-SSO
  - Novel Payload (CSAR, OBCS, HIS)
- Launch Segment:
  - Vega-C (-E) single launch
- Ground Segment
  - 1 polar station (baseline)
  - lossless compression 9baseline)
  - Routine FOS in UK
  - PDGS in UK + data access at ESRIN
  - **ESA free and open data access policy**

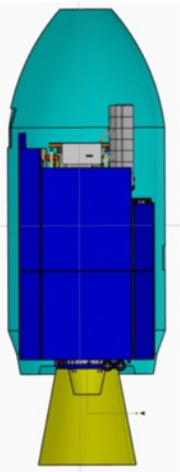



Space Segment






Launch Segment



# International Climate & Calibration Observatory

TRUTHS ~ 30 will help initiate a sustainable long-term international climate & calibration observatory as direct response to international requests

NASA CLARREO-Pathfinder 'sister mission' which will be launched to the ISS in 2023/24.

- Hope for overlap!
- Also potential overlap with Chinese Libra

Guaranteeing the future of space activities by protecting the environment

**TRUTHS & CPF SITSats will provide unique and critical information for understanding and monitoring Climate and environmental change from space and support climate action**