

# TRUTHS Update for GSICS



**T**raceable  
**R**adiometry  
**U**nderpinning  
**T**errestrial- &  
**H**elio-  
**S**tudies



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An ESA EarthWatch mission Andrea Marini (ESA)



*A SITSat for  
climate quality  
observations &  
'gold standard'  
reference in  
space*



# TRUTHS: Evolving 150 yrs of the SI



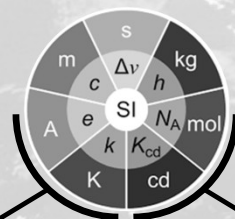
## Metrology lab in space

Absolute  
radiometric anchor

Direct and vicarious  
Satellite intercalibration

Improve EO Agencies & New Space  
data quality and services

Enabling an integrated  
interoperable space climate  
climate quality observing system



## Climate benchmark

Incoming (solar) and reflected energy  
measured at unmatched accuracy

Shorten time-to-detect trends,  
assess climate action impact  
at policy timescales

EO climate records, FCDR  
Calibration beyond lifetime

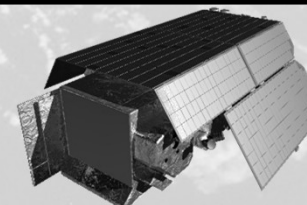
High spatio-spectral observations  
of radiative processes  
for climate models

## The meter

Born 26 March 1791  
in Paris



## SI standard



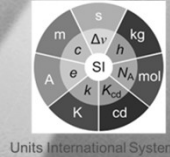
## TRUTHS

Radiometric reference  
in space  
2030



→ THE EUROPEAN SPACE AGENCY

# TRUTHS Mission Objectives



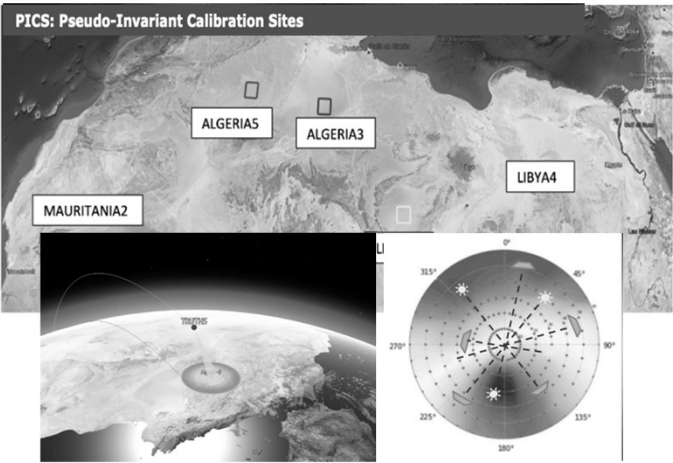
SI-traceable  
measurements of the  
solar spectrum  
addressing direct science  
questions.

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

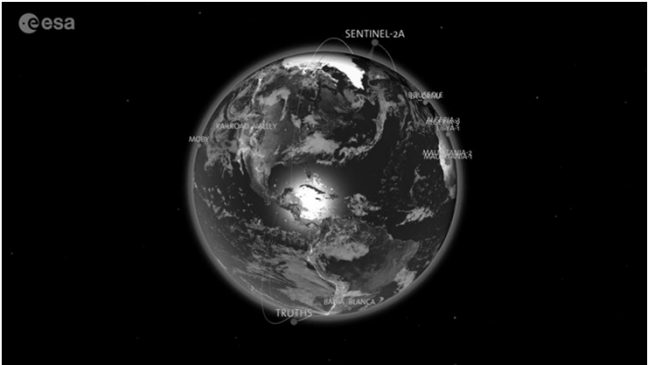
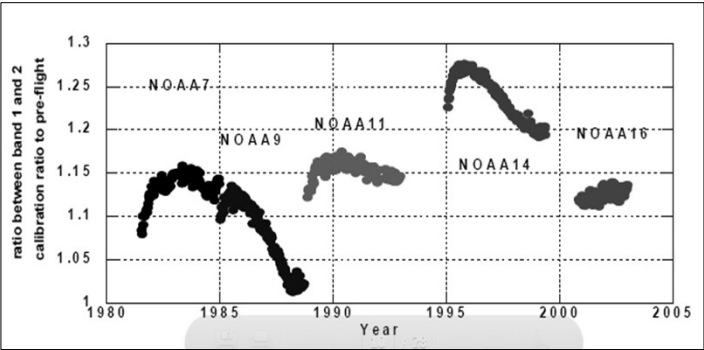
## Satellites cross-calibration

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, an agile pointing hyperspectral benchmark

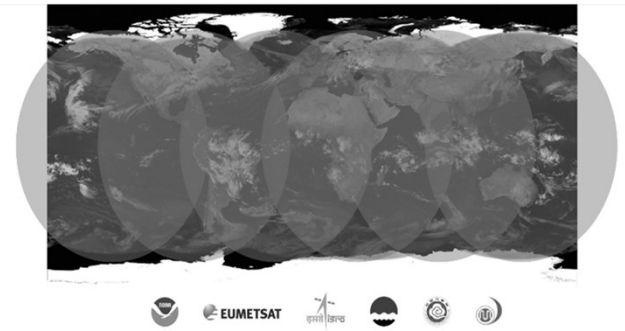


Recalibrate historical FCDRs

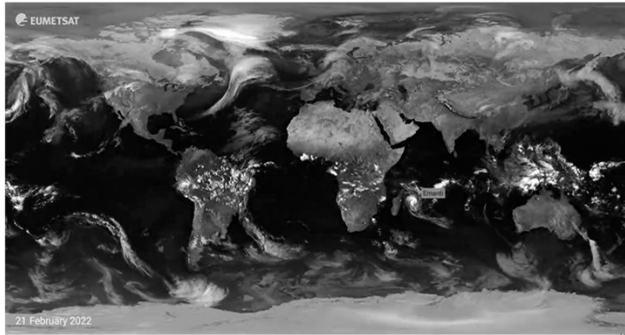


## Operational and Climate Applications

Nadir direct intercalibration  
Slew in pitch & roll (up to  $\pm 40^\circ$ )  
BRDF and vicarious calibration  
Characterise invariant CEOS sites  
Irradiance model of the moon



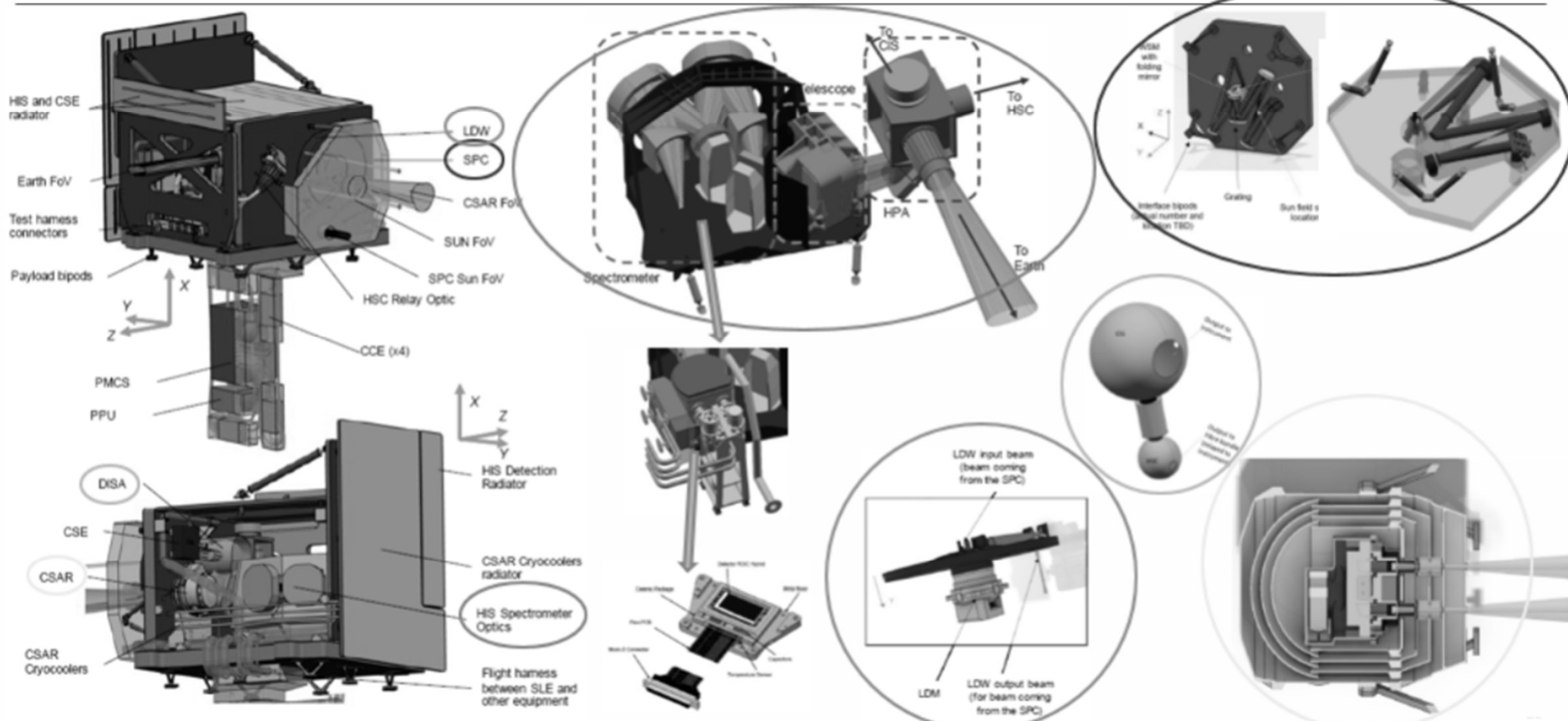
## Direct raymatch Intercalibrate LEO Intercalibrate GEO-ring



# Showcase Anchored Missions (SAMs)

|   | Mission                                                    | Instrument /Orbit                                              | Provider                                                                                                                                     |                                                                                       |
|---|------------------------------------------------------------|----------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| 1 | S3 / S3-NGO                                                | Multispectral imager<br>LEO                                    | Operational service<br>Global (land/sea) and dynamic range                                                                                   |    |
| 2 | S2 / S2-NG                                                 | Multispectral imager<br>LEO                                    | Operational service <a href="#">TRUTHS</a> <a href="#">S2A VIDEO</a><br>Land - spatial resolution superior to TRUTHS                         |    |
| 3 | MTG-FCI                                                    | Multispectral imager<br>GEO                                    | Operational MET service<br>Showcase GEO-TRUTHS                                                                                               |    |
| 4 | CO2M                                                       | Hyperspectral mission<br>LEO                                   | Operational AC/AQ service<br>Ambitious radiometric requirements (aerosols, formation)<br>Coarser footprint but higher spectral resolution    |    |
| 5 | VIIRS<br>(Visible Infrared<br>Imaging Radiometer<br>Suite) | Multispectral imager<br>Afternoon orbit                        | Climate profile.<br>Libera/VIIRS.<br>CLARREO-VIIRS<br>VIIRS-TRUTHS                                                                           |   |
| 6 | Landsat-9 / NG                                             | S2-NG like<br>LEO<br>Quasi-constellation<br>with S2 → intercal | Support US colleagues in calibrating Landsat-10.<br>Strong ESA-NASA collaboration on S2-Landsat.<br>Strong support expected at Agency level. |  |

# Payload accommodation overview



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## Indicative products



## ESA open data policy



**L1B TOA radiances (0.32-2.40  $\mu\text{m}$ , 0.3%) + full uncertainties, on demand (Continuous)**



land 100m  $\beta$  bandwidth constraints, User requests (some applications) for 50 m?



ocean 200m



special observation events (calibration) 50m  $\beta$  1 min/day (43k km<sup>2</sup>) bandwidth constraints



## L1C TOA radiances, re-gridded spatially (UTM/WGS84)



## Annual average TOA radiances, re-gridded



## L1B Total (0.3-30 $\mu$ m, 0.02%) and Spectral (0.3%) Solar Irradiance



### L1B Lunar Spectral Irradiance (0.3%)

**(Daily)**

**(2 to 3/week)**

build model of libration/phase



**L2 BOA spectral reflectance land/ocean (0.38-2.40  $\mu\text{m}$ , ~1%)**



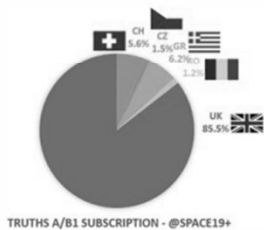
## Simultaneous overpass catalogue for identified target missions



## Intercalibration tools è match-ups and calibration coefficients

# Timeline

- 2019: **UKSA** proposed **TRUTHS** as **ESA Earth Watch mission**
- 2019: Cmin-19, phase A/B1 fully subscribed by **UK, GR, CH, CZ, RO**. Kicked-off Oct'20
- 2022: Successful ISSR, independent science review June'22, **SRL-5 achieved**
- 2022: Cmin-22, phase B2/adv.C subscribed by **UK, GR, CH, CZ, RO + ES**. Kicked-off Nov'23



Mission Advisory Group:  
14 scientists from MS  
3 observers from C3S, EUM, NASA

Support science studies:  
Procurement ongoing, Kick-Off 09/2024  
Ground Segment ITT imminent, Kick-Off Q2-2025

**Major funding milestone CMin 25 (Nov 2025)**





# NPL - STAR-cc-OGSE: Preparing Ground Cal/Val

(Spectroscopically Tuneable Absolute Radiometric calibration & characterisation OGSE)

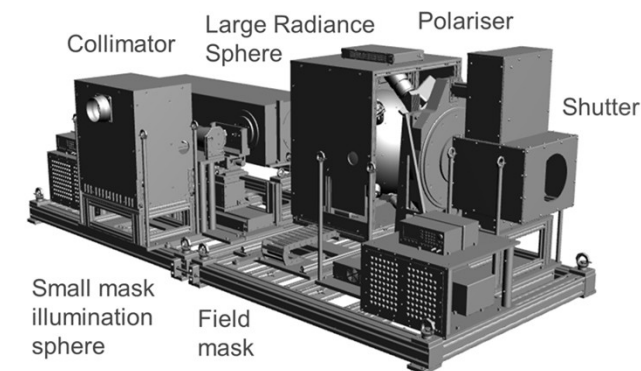


STAR-CC-OGSE provides radiometric calibration & characterization of satellite sensors.

Fully automated, transportable and SI-Traceable

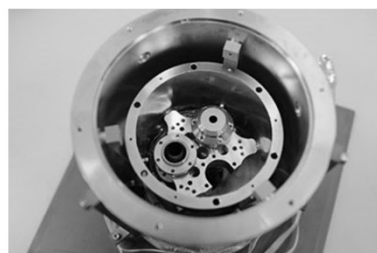
The main components of the STAR-CC-OGSE system are:

- A collimated beam source, with field mask for optical performance (geometric) characterization & 200 mm diameter exit port integrating sphere for flat-field radiometric calibration (with or without polarizer).
- A CW laser monochromatic continuous tuneability from 260 nm to 2700 nm (pm resolution) plus a broadband (white light) source extending over the same spectral extent (for both illuminations). **Simultaneous spectral, straylight, radiometric Caln**
- A vacuum-compatible detector module installable in TVAC at the sensor-under-test entrance aperture containing SI-traceable photodiodes and fibre to spectrometer



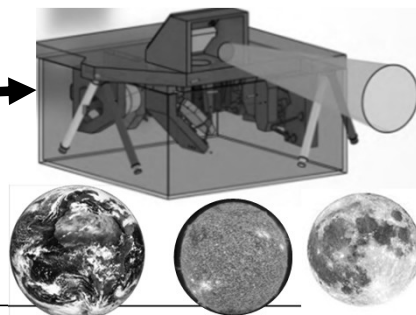
Green, Baker et al

| Symbol | Source of Uncertainty                    | Probability Distribution | Si    |       | InGaAs |       |
|--------|------------------------------------------|--------------------------|-------|-------|--------|-------|
|        |                                          |                          | Value | ui    | Value  | ui    |
| uAbs   | Photodiode Absolute Calibration          | Normal                   | 0.05% | 0.05% | 0.05%  | 0.05% |
| uRel   | Photodiode Spectral Response Calibration | Normal                   | 0.08% | 0.08% | 0.10%  | 0.10% |
| uSp    | Spectrometer                             | Uniform                  | 0.05% | 0.03% | 0.05%  | 0.03% |
| UC     | Combined Uncertainty (k=1)               |                          |       | 0.10% |        | 0.11% |
| U95    | Expanded Undertainty (k=2)               |                          |       | 0.19% |        | 0.23% |
|        | Photodiode Abs + Rel only (k=1)          |                          |       | 0.09% |        | 0.11% |
|        | Photodiode Abs + Rel only (k=2)          |                          |       | 0.19% |        | 0.22% |

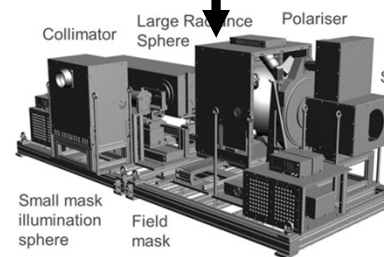
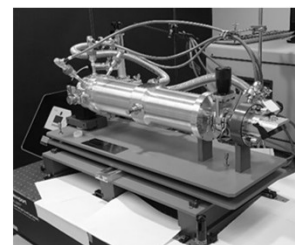


## COMPARISON

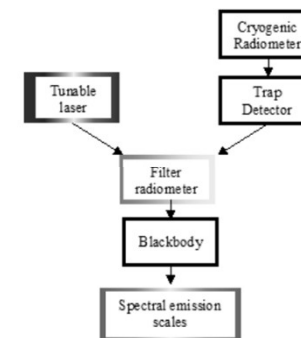
**HIS**



## Pre-flight (Ground) Cryogenic Radiometer (Lab)



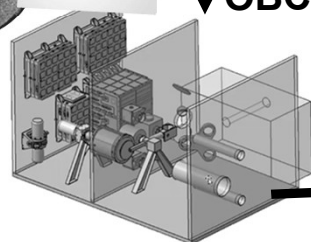
**STAR**



## Laser radiation

## Solar with SMC

**↓ OBCS**



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