NPL National Physical Laboratory

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T raceable
R adiometry
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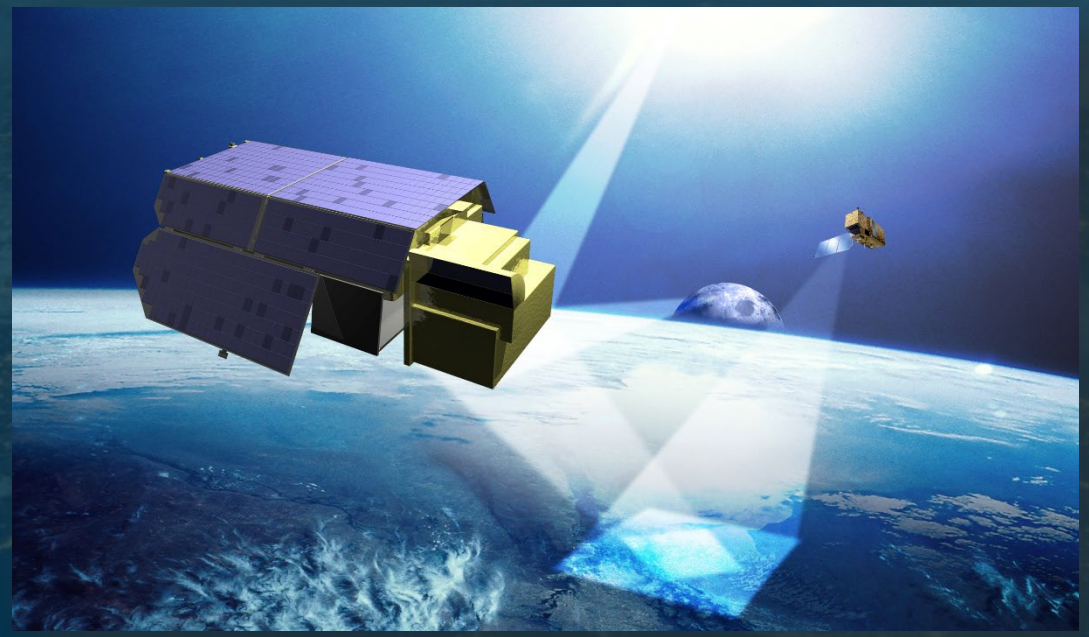
S tudies



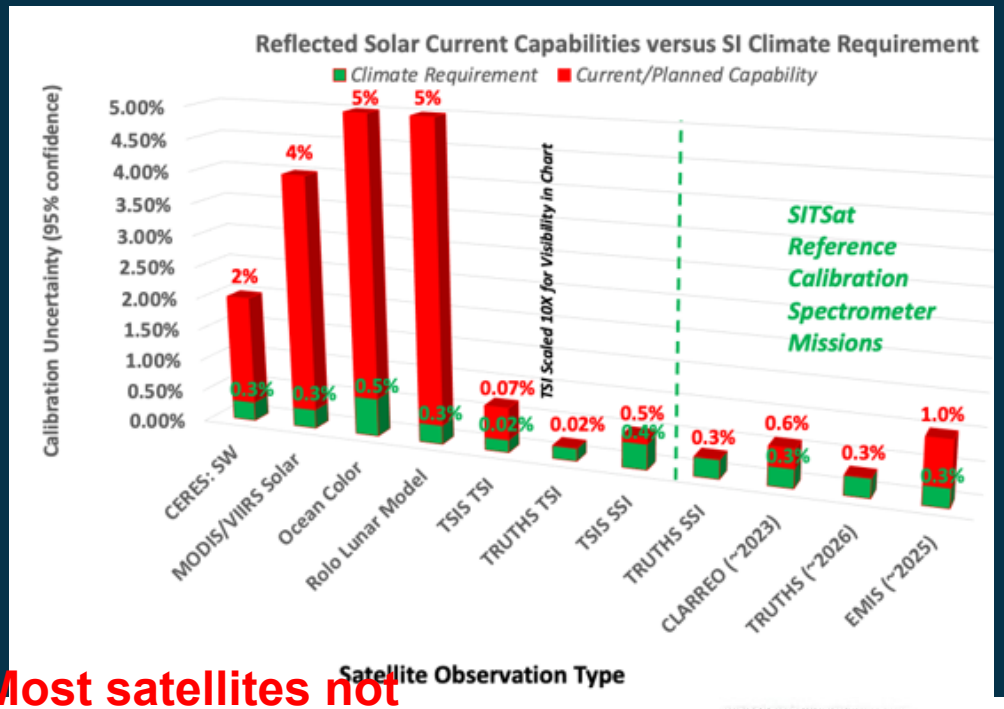
A 'gold standard' reference in space to support climate action

Professor Nigel Fox 'UK mission science lead'
On behalf of TRUTHS mission team
nigel.fox@npl.co.uk

An ESA EarthWatch mission

Photos in presentation courtesy: Airbus, NPL, PMOD, T-E2V, Swissoptics

Climate Need & observation challenges



CEOS GSICS

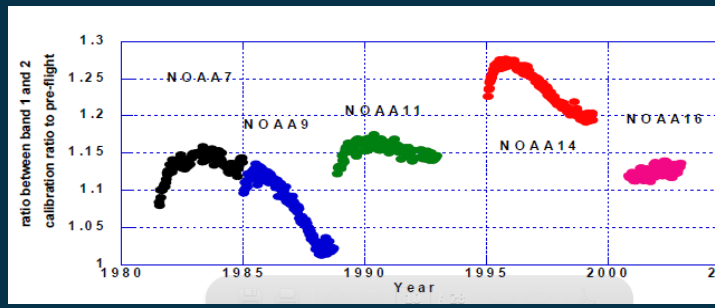
SI-Traceable Space-based Climate Observing System:
a CEOS and GSICS Workshop
National Physical Laboratory, London, UK,
9-11 Sept. 2019

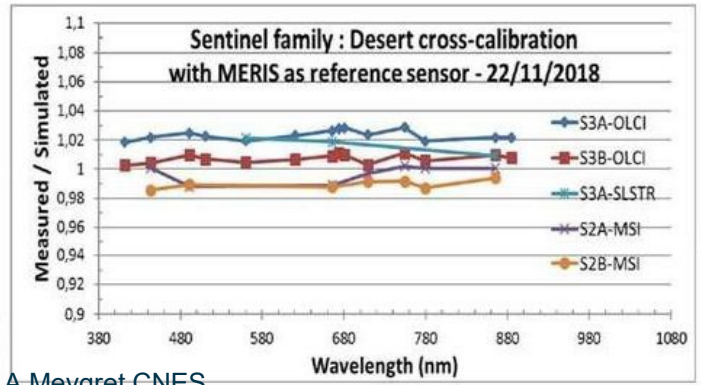
SITSCOS Workshop Report

Editors: Nigel Fox, Tim Hewison, Greg Kopp, Bruce Wielicki

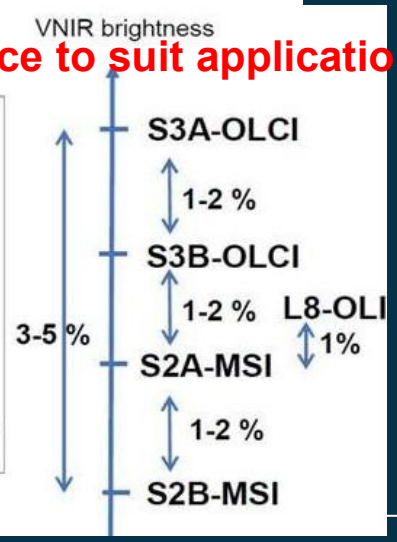
https://doi.org/10.47120/npl.9319

Most satellites not designed for climate: performance to suit application





A Meygret CNES



What is the Truth?

Trustable harmonised time series require stable/understood sensors anchored to invariant references

http://calvalportal.ceos.org/report-and-actions

https://doi.org/10.47120/npl.9319

SI-Traceable anchor for climate action and the Earth system

- Energy imbalance at Top of Atmosphere ultimately source of Earth warming
- Benchmarks of spectral radiation state of planet allow subtle change to be detected and attributed.

TRUTHS unprecedented accuracy across the solar spectrum will speed up the identification of Climate Change processes and help anchor observations used to support the stocktake of emissions and sinks (accessible trustable data for evidence-based policy for ALL nations .

Interoperable observing system

GEO GROUP ON EARTH OBSERVATIONS

CEOS

WMO

GSICS Global Space-based Inter-Calibration System

QA4EO

Maximise utility of data

50% of ECVs requires space observations

Satellites can suffer biases and degradation in performance due to launch and harshness of space.

SITSats such as TRUTHS can help enable a new epoch for space-based Earth Observation

What does TRUTHS do?

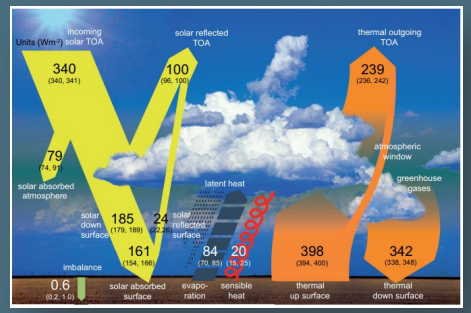
Observations
- Benchmark
- monitoring
- Litigation
- algorithm improvement

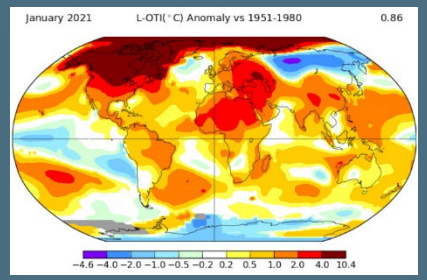
Measures incoming and earth reflected radiation from the sun
- 320 to 2400 nm @ ~4 nm intervals
- Global nadir @ 50 m ground resolution with 100 km swath
- Uncertainty of 0.3% (k=2)

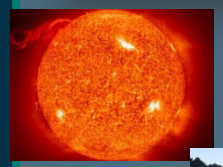
Establishing a benchmark of the state of the planet at ToA & BoA surface reflectance to enable:

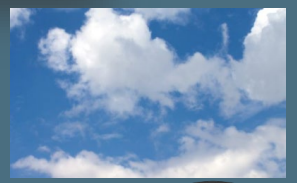
Calibration
- Interoperability
- data-gaps
- performance
- Utility

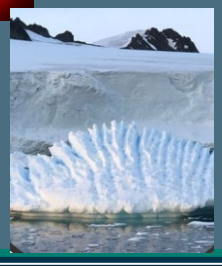
Climate sensitivity/response

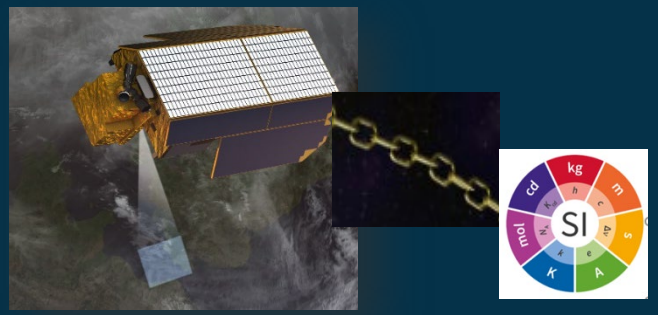






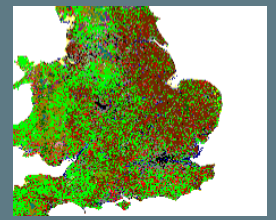


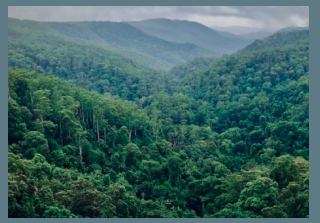




Adaptation/sustainability

Climate action/mitigation



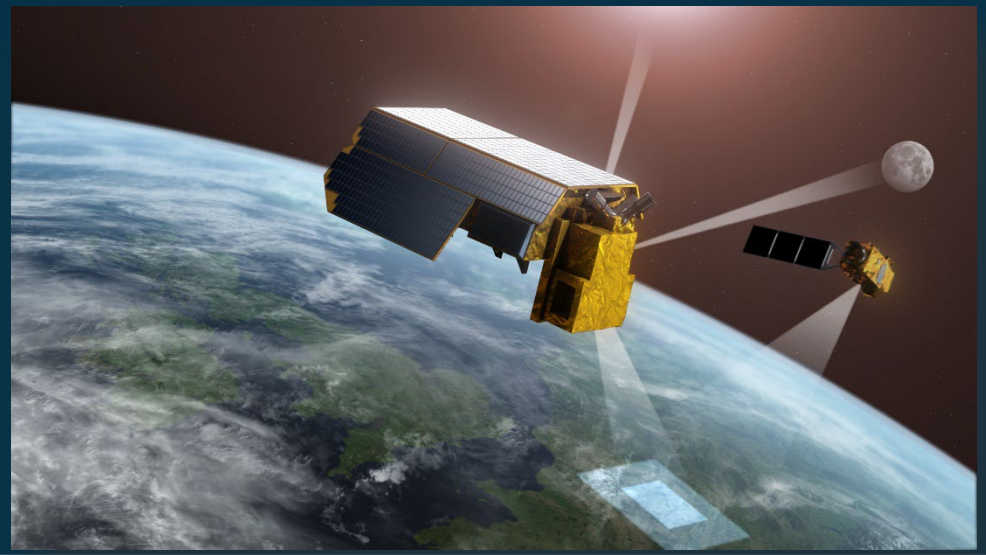


Gold Standard for Satellites observing the Earth, Moon & Sun

TRUTHS will:

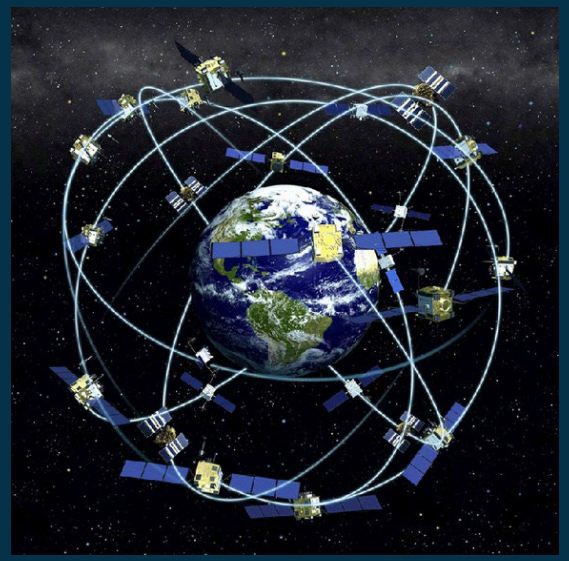
- become a '**Gold Standard Reference**' with free and open 'analysis ready' data
- **transfer its accuracy** to other satellites improving their performance
- characterize special sites on Earth, the moon and the sun's radiation, viewed by other satellites e.g. sentinels and new-space to **assess and improve their data quality**.

TRUTHS will help harmonise and improve the accuracy of data and confidence in derived information from the world's current, historic and future satellites, creating improved 'time-series' of Essential Climate Variables and understanding of the workings of the planet.



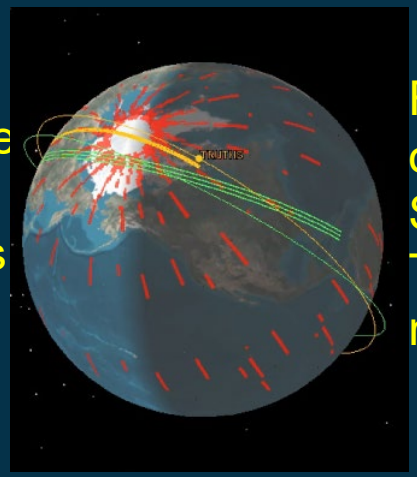
Reference Calibration

- Enables interoperability & Harmonisation
  - Prospect of ‘certified calibration’



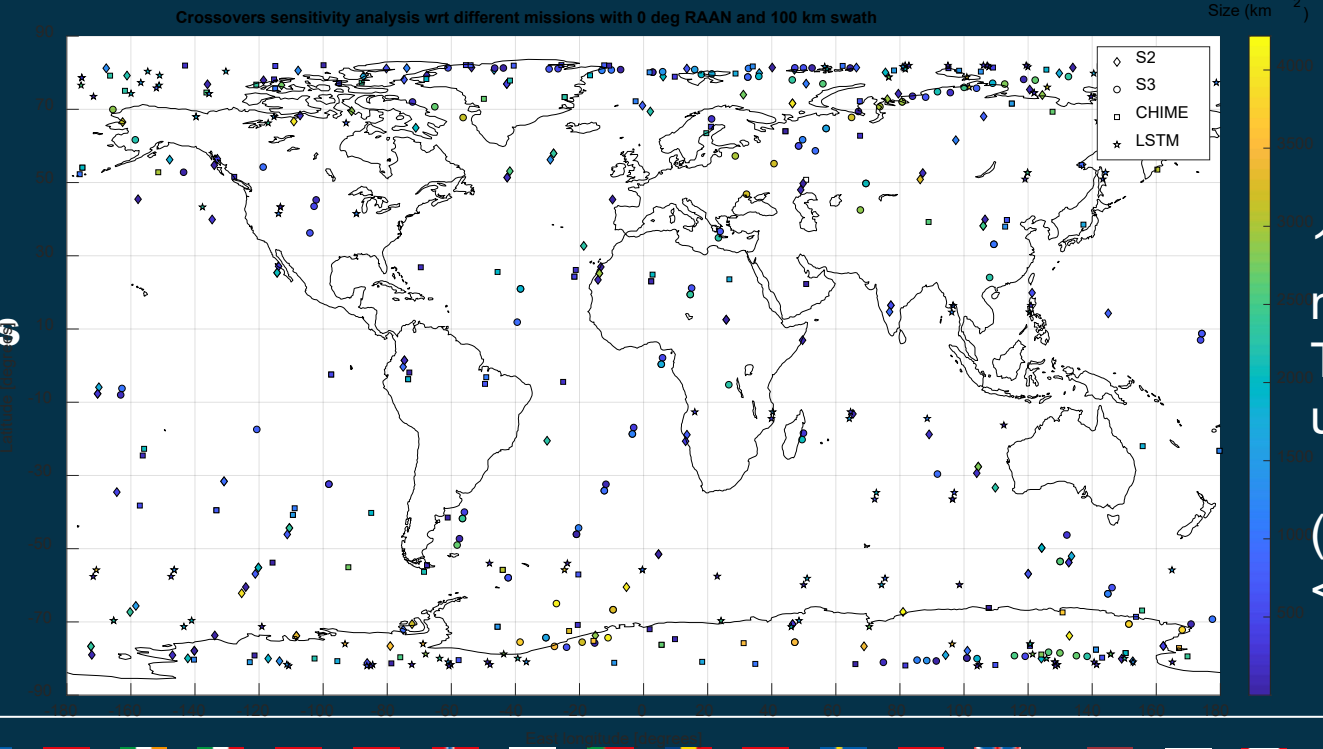
TRUTHS provides the means to transform global EO system, including constellations of micro-sats so they deliver traceable scientific/climate quality observations -

TRUTHS 90°pole to pole orbit, observing through the diurnal cycle, allows many opportunities to overpass orbit of sun-synchronous sensors



Red shows nadir overlap between Sentinel 2 GSD and TRUTHS within ±5 minute window

Summary after 6 months

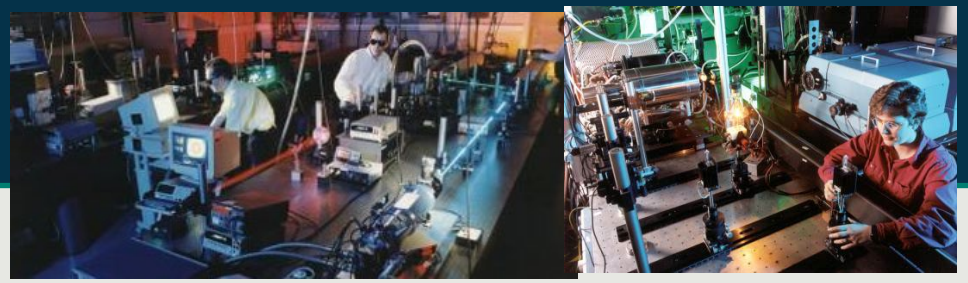


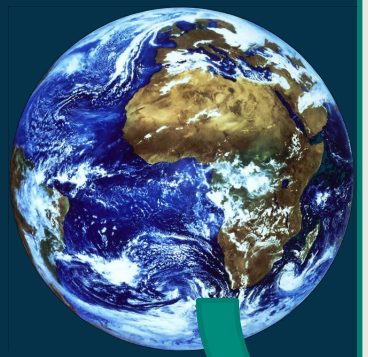
1 year of near perfect nadir overlaps for TRUTHS & satellite under test

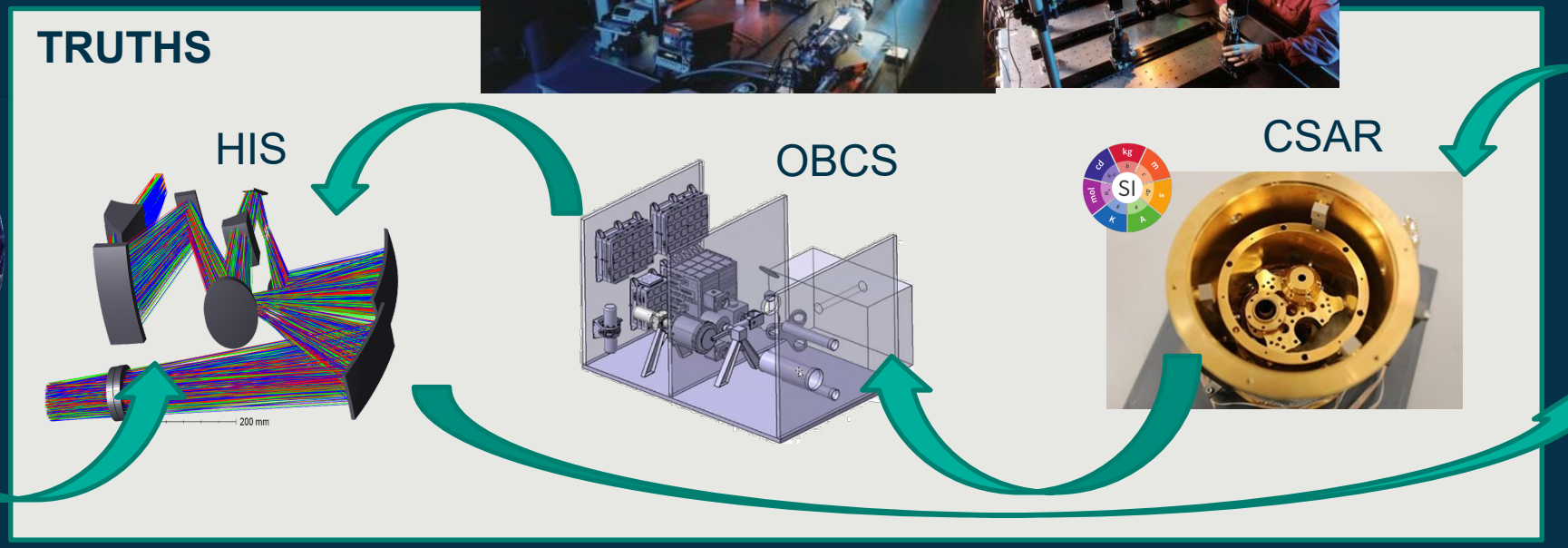
(<1° (no pointing) <30 s time difference

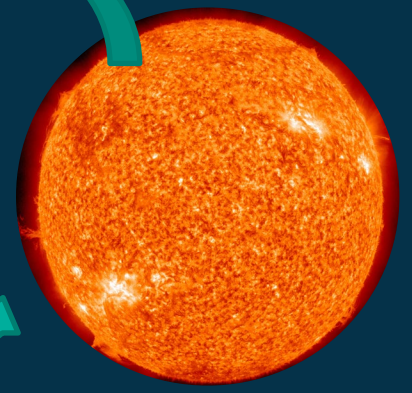
Metrology laboratory in-space

- Measuring energy from the sun, providing the direct traceability to International Standards (CSAR)
- ‘Camera’ (Hyperspectral Imaging Spectrometer, HIS) observing the direct incoming and Earth reflected sunlight at high spectral and spatial resolution
- Novel on-board calibration system (OBCS) ensuring traceability to the absolute reference (CSAR) (mimicking terrestrial methods)







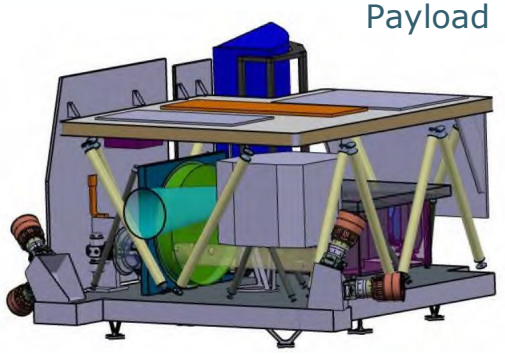


Phase A/B1 running to provide a mature concept

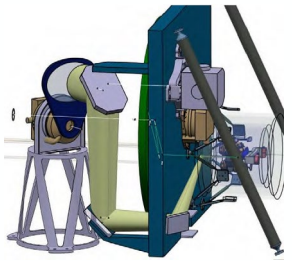
- Platform recurrent from **CRISTAL**
- Payload key technical features:
  - ✓ **HIS:** Four-mirror anastigmatic telescope, Offner (two-prisms) spectrometer, single MCT detector at 150 K, thermally stable optical bench. Airbus design
  - ✓ **CSAR**– three high-absorbance cavities, operated at 60 K with cryocooler, design heritage of NPL (UK) and PMOD/WRC (CH)
  - ✓ **OBCS** (On-Board Calibration System) – traceable set of absolute wavelength anchors (solar monochromator + TBD filter), high-dynamics transfer radiometer, precise and stable wavelength scanning mechanism, relay optics, diffuser to HIS
  - ✓ **Calibration process:** novel methodology, heritage of metrology lab (NPL), rigorous traceability of uncertainties, need for complex on-ground calibration
- Pre-developments running for all critical items (detector, coating, CSAR, mirror, calibration detectors…)
- Phase A/B1 led by Airbus UK progressing as planned with final review, the ISRR, to start mid-April 22.
- Gate review (as defined in the EW element) by summer 22 to confirm technical, scientific and programmatic maturity of the proposed solution

TRUTHS satellite

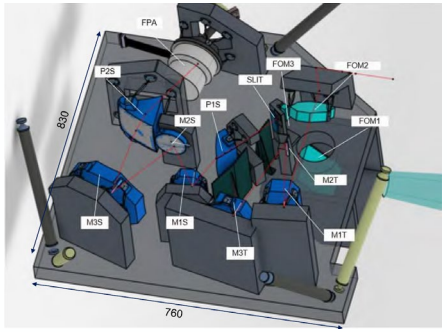
TRUTHS Payload



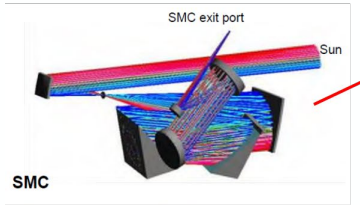
CSAR layout/OBCS I/F

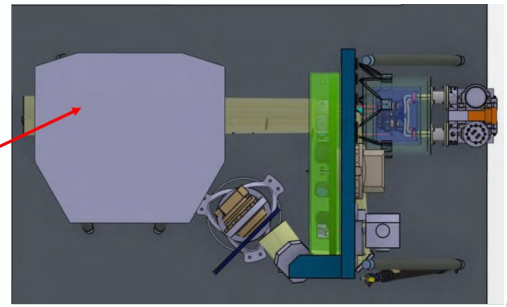


HIS layout



SMC - OBCS layout

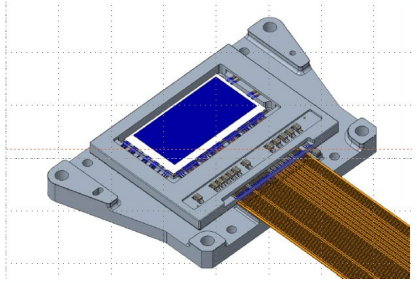


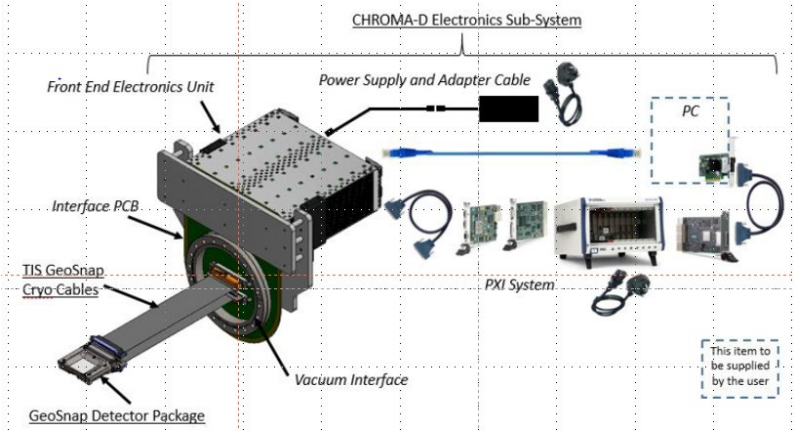


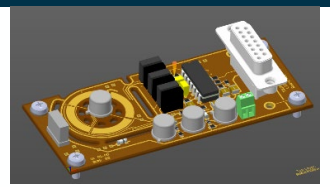
All images courtesy of Airbus, PMOD, NPL

TRUTHS technology gallery

Detector layout and FEE test assembly

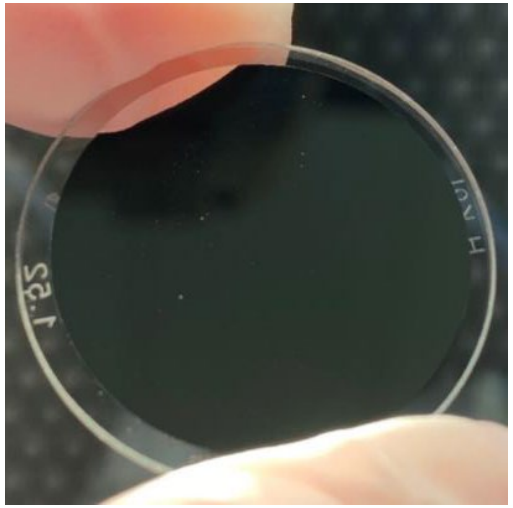




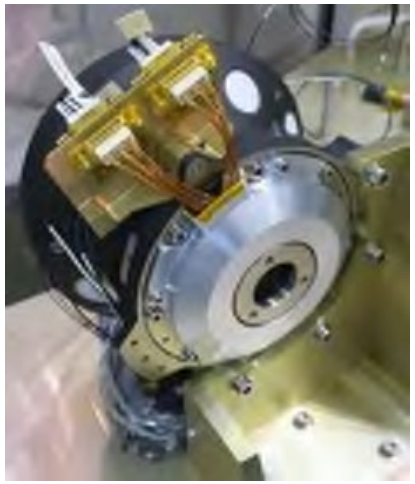


CSAR Voltage Ref: LTZ1000 Board

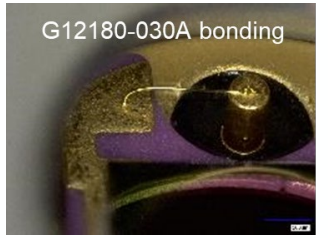
Mirror coatings



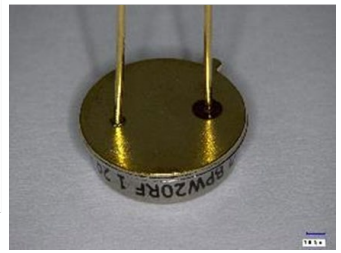
WSM actuator: TRISHNA EM



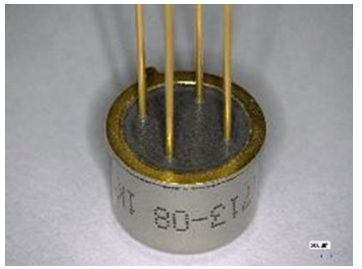
CA OBCS TR photodiodes



Visual Inspection



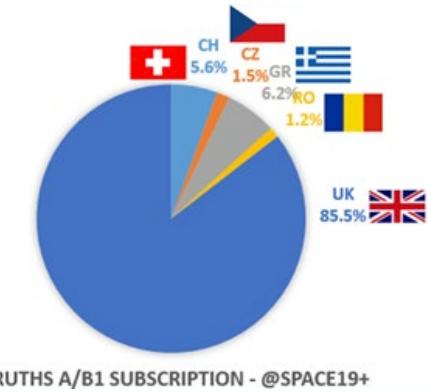
X-ray



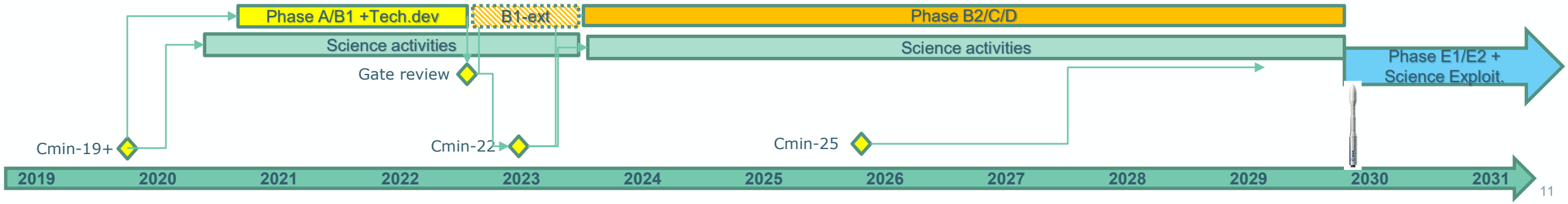
K -1713-08 dual-colour

TRUTHS Program context

- TRUTHS was proposed by UKSA in May 2019 as a new Earth Watch (EW) Element.
- TRUTHS Phase A/B1 has been fully subscribed at Space19+ by 5 Participating Countries: UK (85.5%), GR (6.2%), CH (5.6%), CZ (1.5%), RO (1.2%)
- Industrial Phase A/B1 system studies and technology predevelopments initiated in Oct-20.
  - Phase-A kicked-off in Oct-20 and completed at end-July 2021
  - Phase B1 on-going, to be completed in Q2-2022.
- Mission Advisory Group (MAG): Science/Engineering/User expertise primarily from Europe (not limited to funding nations) inc NASA CLARREO Pathfinder
- TRL and SRL assessments in May/June 2022
- Programmatic "Gate Review": go/no-go decision, in July-22, to submit program to CM-22
- Phase B2/C/D/E to be funded at CM-22/-25 -> Program plan being currently prepared



TRUTHS A/B1 SUBSCRIPTION - @SPACE19+



International (CEOS?) climate & calibration Observatory

- TRUTHS ~ 2029 will become a founding element of an international climate & calibration observatory
  - A 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 Chinese Libra

TRUTHS will provide unique and critical information for understanding and monitoring Climate and environmental change from space and support climate action – A resource for ALL nations