NPL
National Physical Laboratory

The STAR-cc-OGSE Family
A Collection of EO Sensor Calibration Facilities

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Radiometric Calibration Equipment, Capabilities, and Facilities session

The Global Earth Observation system

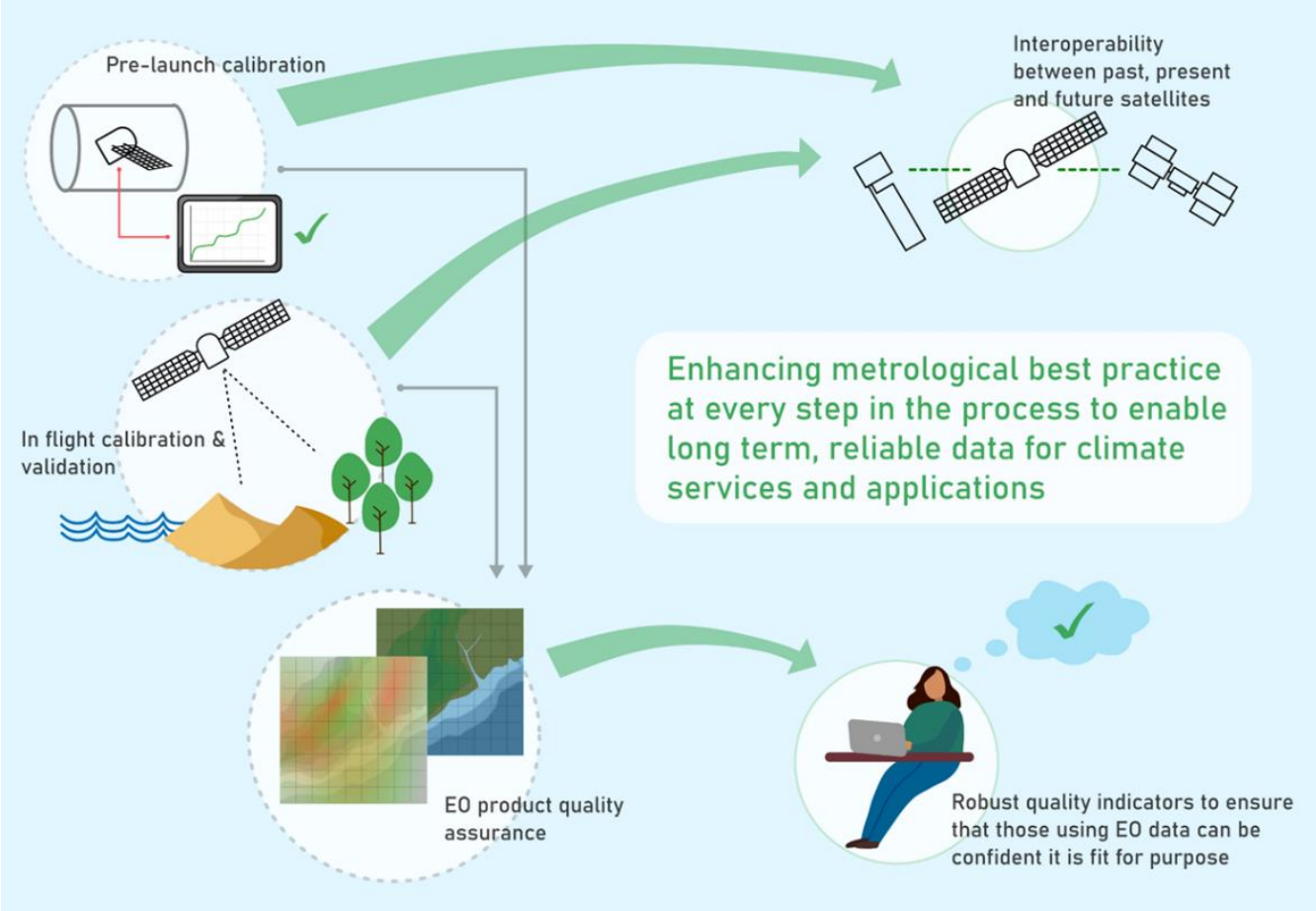
- Reliable characterization and radiometric calibration of satellite sensors are critical to their optimal performance on-orbit.
- Only through a robust understanding of the instrument behavior, performance and degradation mechanisms will the significant effort and expense invested into the flight hardware be fully exploited.
- The uses of satellite sensor data, with their increased use in long-term environmental monitoring and climate studies mean that the performance and data quality provided by a single sensor can no longer be considered in isolation but needs to be considered as a part of the international Earth Observation (EO) infrastructure and referenced to common standard, the SI.

Improved sensor performance drives facility capability

The drive for improved performance, together with the desire for inter-operability between sensors creates increased demands on the pre-flight characterization and radiometric calibration of sensors and the facilities needed to undertake these activities.

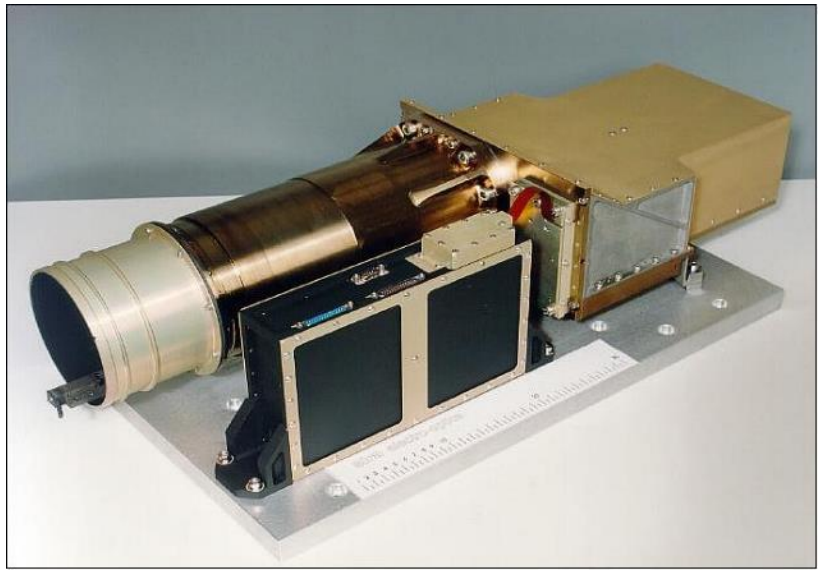
You Need Better Data,

Not More Data!



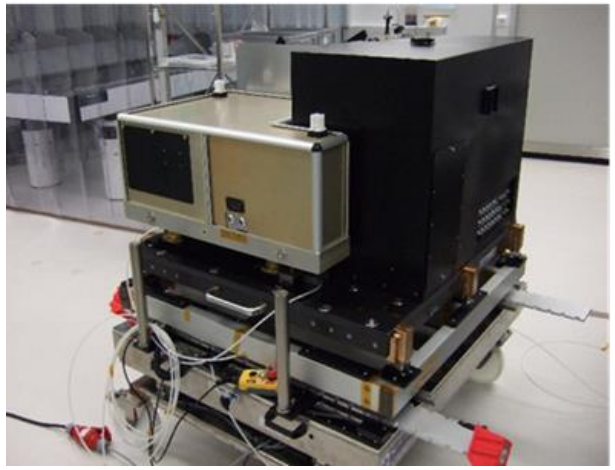
Pre-flight optical sensor calibration

- NPL has worked for many years on the pre-flight calibration of optical sensors
- Characterizing sub-systems e.g. diffuser BRDF
- Provision of SI-traceable sources
- OGSE for AIT and C&C of sensors.
- Innovating new methods and facilities, that utilize technological developments to improve accuracy while reducing time, cost & complexity.



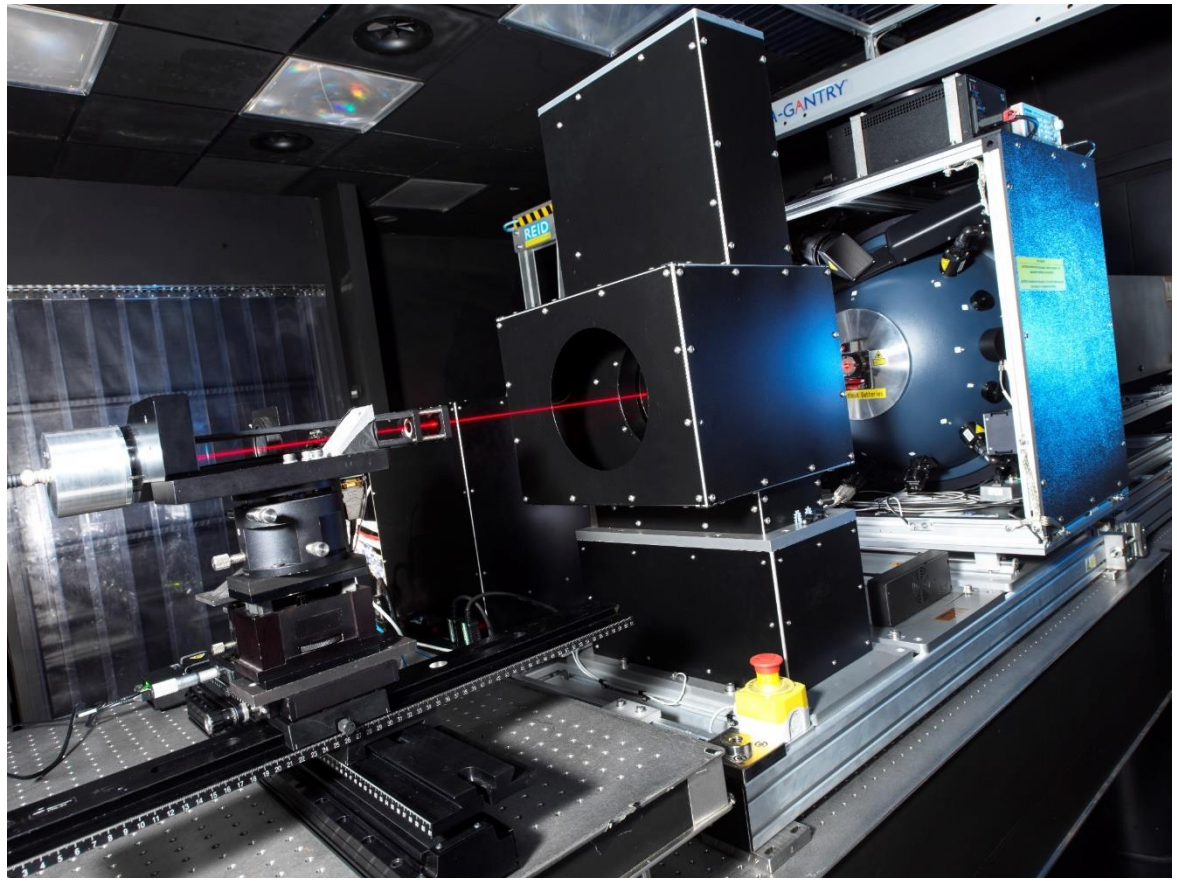
CHRIS on PROBA-V

Copernicus Sentinel 4 OGSE



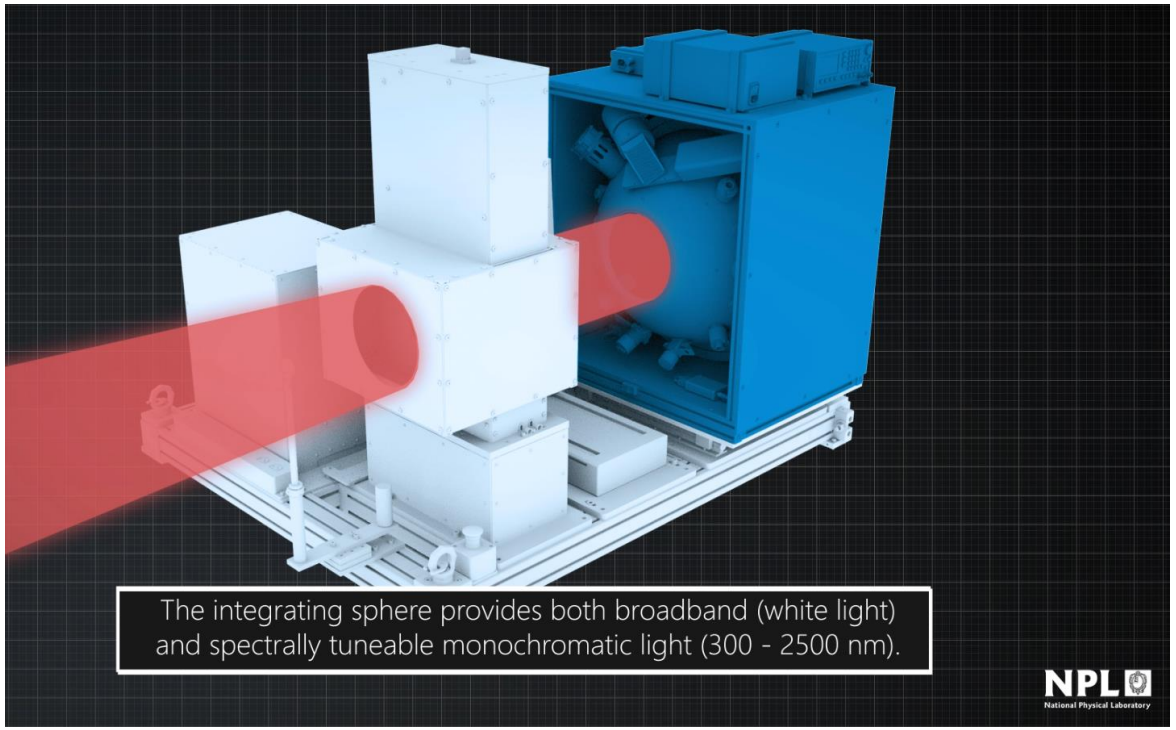
STAR-cc-OGSE Overview

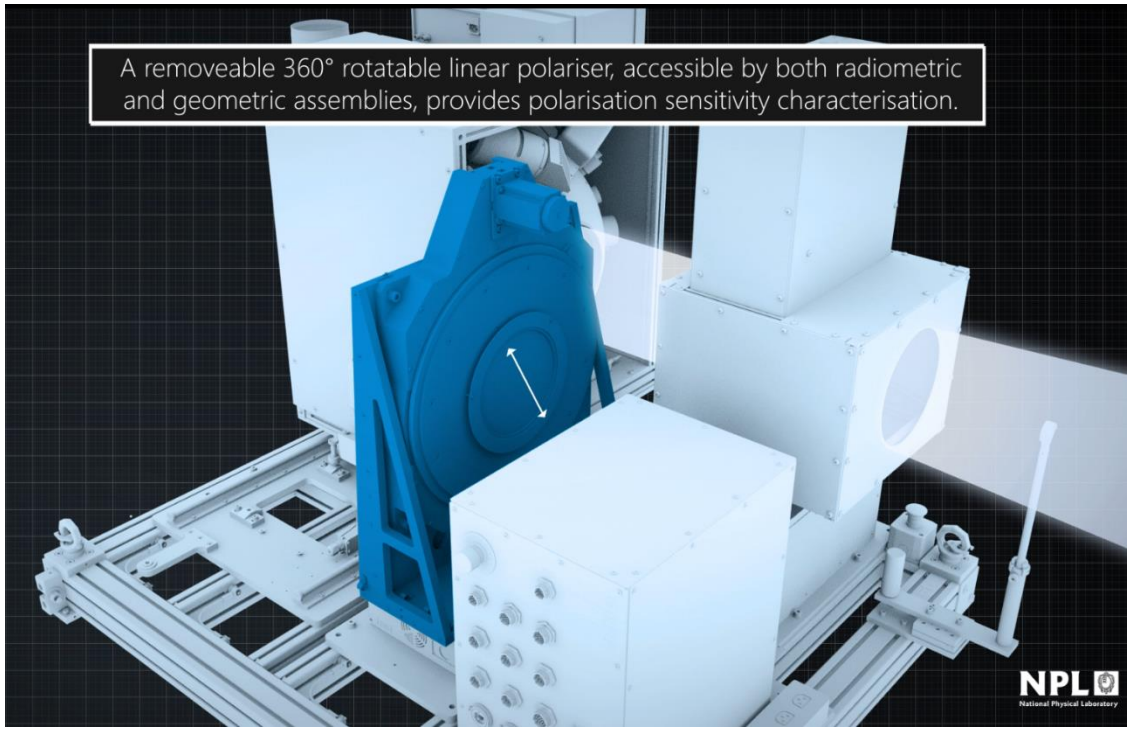
- Cleanroom compatible and transportable system
- Provide geometric and radiometric calibration and characterisation of satellites specifically for earth observation purposes
- Both sources allow for the testing in both broadband and monochromatic modes through use of the white light sources in the sphere and connecting a broadly tuneable pulsed laser* (260 nm to 2700 nm) via a fibre cable
- Detector-based traceability to the Si primary standard cryogenic radiometer.
- Develop to be compliant for the ESA EarthWatch TRUTHS mission pre-flight calibration (<0.3% k=2) in 2028/2029



STAR-cc-OGSE (Radiometric)

- Provides a broadband source of radiance over a 200mm diameter port.
- Broadband and monochromatic radiation covering 300 – 2500nm.
- Sources continuously tuneable in output radiance.
- Removeable linear wire grid polariser to enable polarisation sensitivity characterisation.
- Polariser extinction ratio > 40dB.

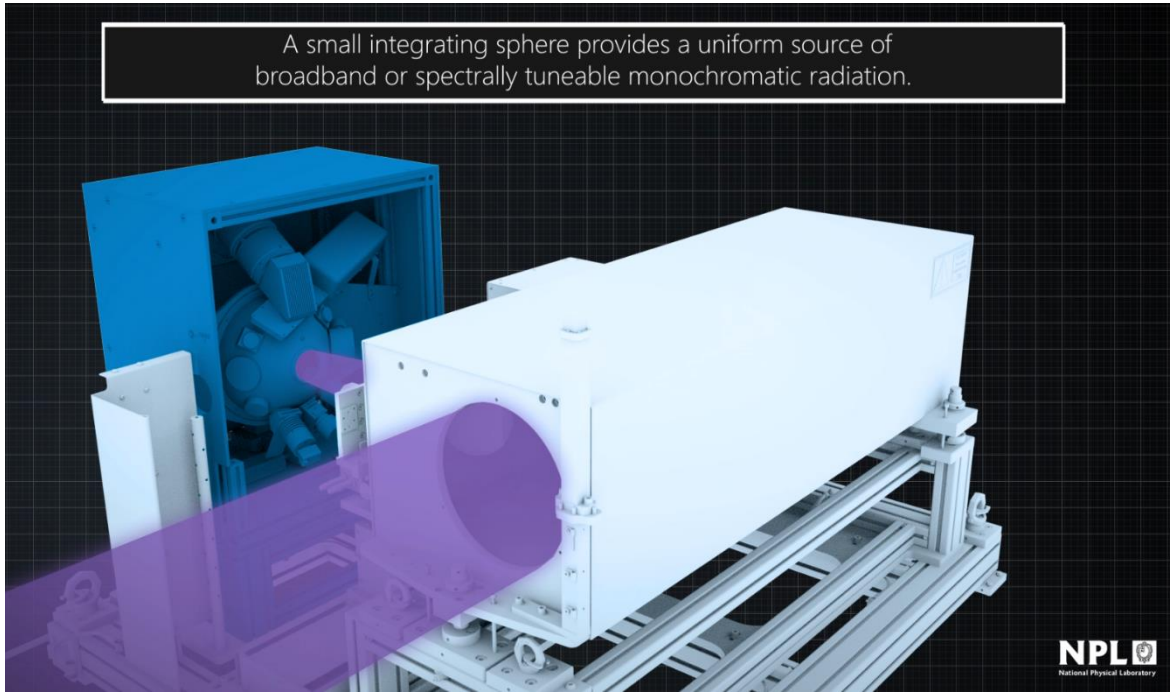


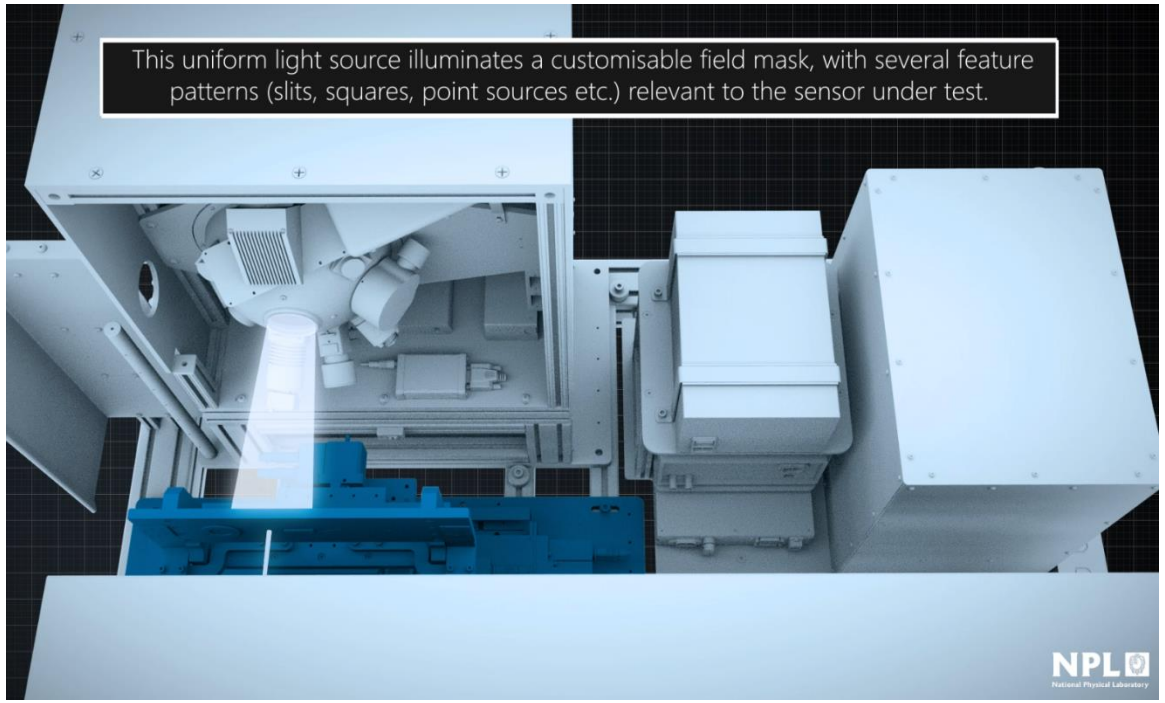


STAR-cc-OGSE (Geometric)

- The geometric assembly consists of a collimated beam source with feature patterns for image quality performance (geometric) characterisation at its focus.

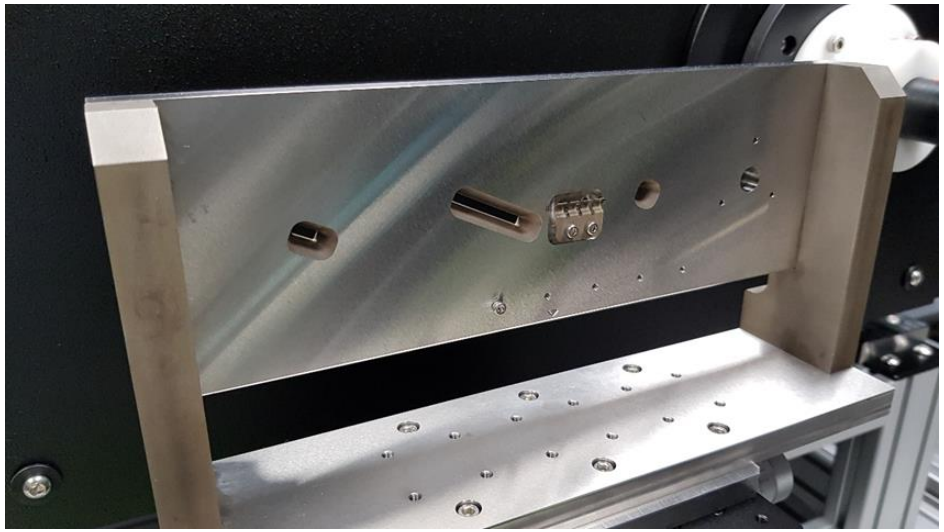
- The field mask sits on a 3-axis precision translation stage to allow feature interchange, precise positioning and focus control.
- The pattern from the mask is projected through a reflective collimator to the sensor under test.

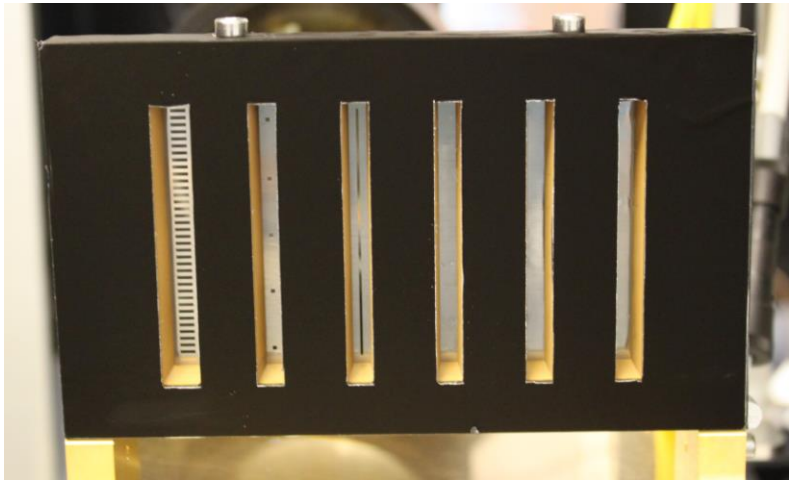




Precision custom field mask

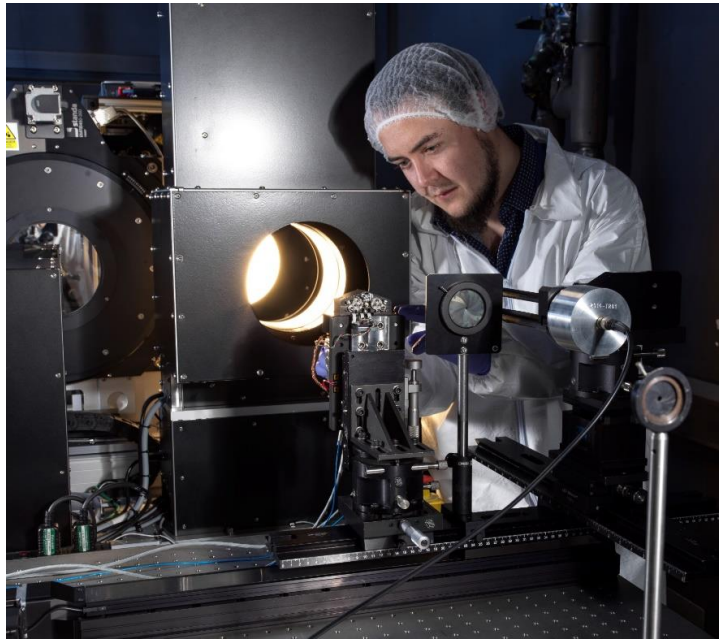
- The field mask at the collimator focus is bespoke for each use, manufactured to fit the customer requirements & sensor input optic geometry.
- Geometric shapes
  - Slit / Edge
  - Square
  - Point sources
- Precision engineering verified by SI-traceable dimensional measurement at NPL.
- Direct fibre feed allows integrated high intensity source for straylight characterisation.





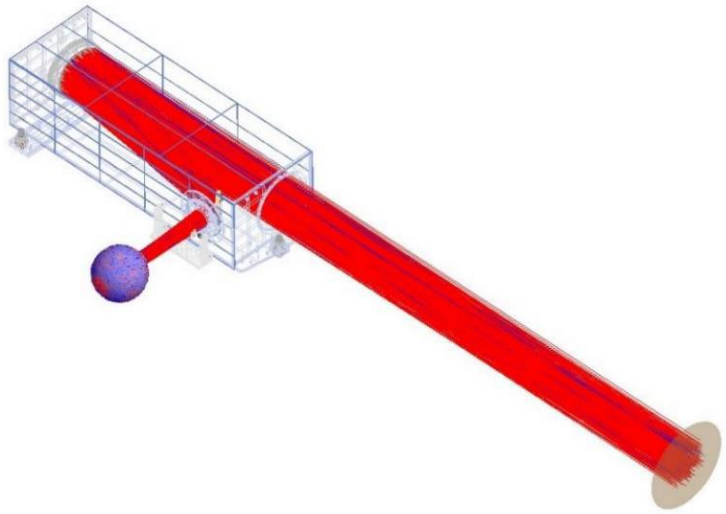
STAR-cc-OGSE (Detector based traceability)

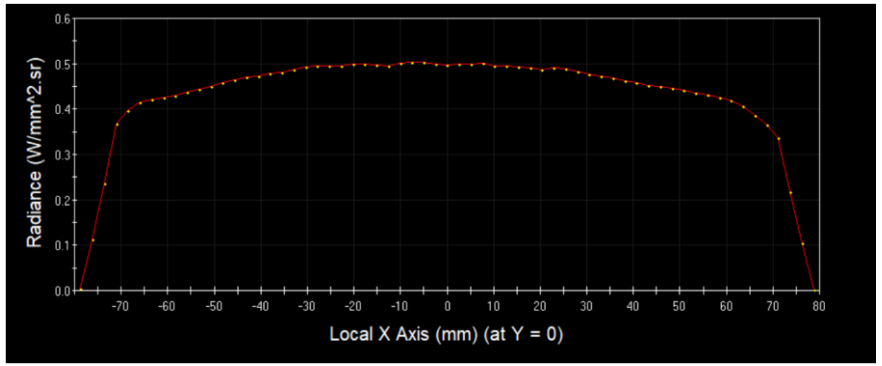
- SI-traceability is achieved using a bespoke vacuum-compatible reference detector, installable at the sensor under-test entrance aperture.
- Target monochromatic accuracy <0.1% (k=1)
- No need to separately determine path absorption, window transmission etc.
- Combination of broadband detectors and fibre-coupled spectrometer give full spectral monitoring.
- SI-traceable to primary standard cryogenic radiometer at NPL.



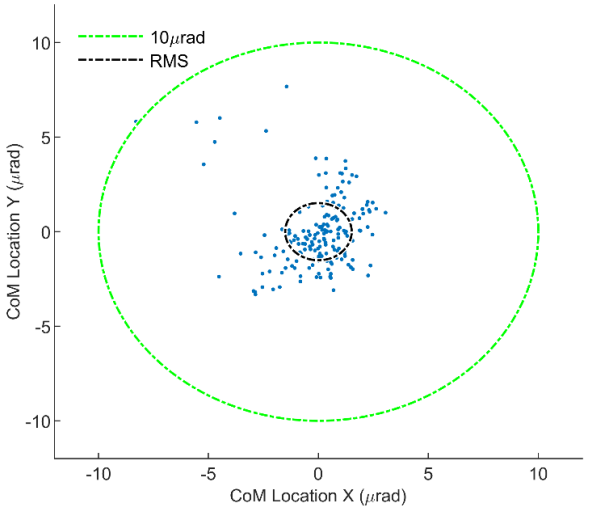
Geometric Characterisation

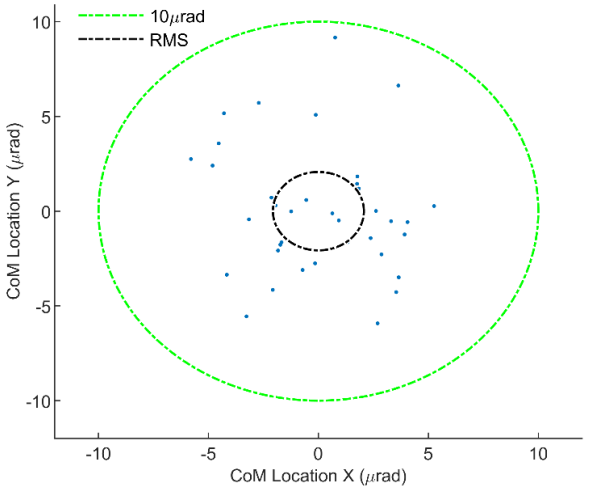
Irradiance distribution modelling



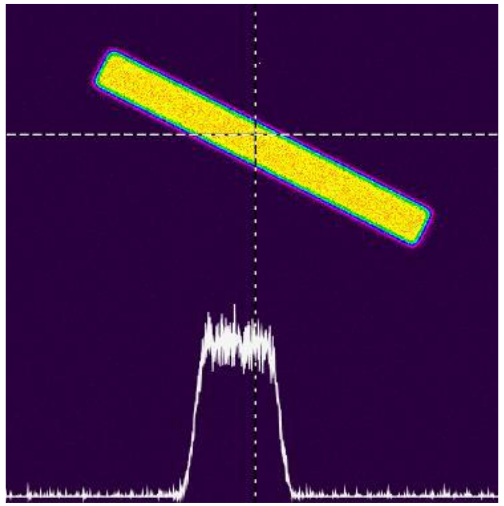


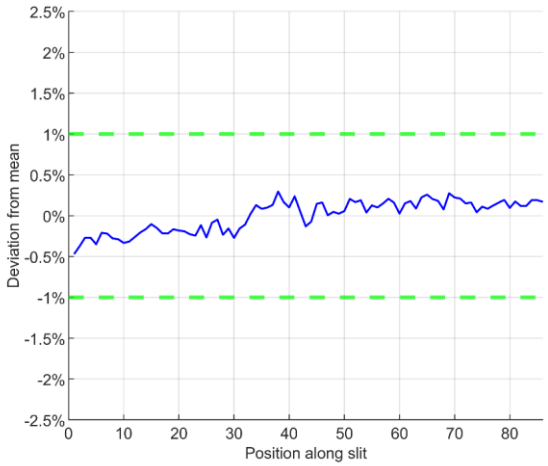
Beam deviation measurements





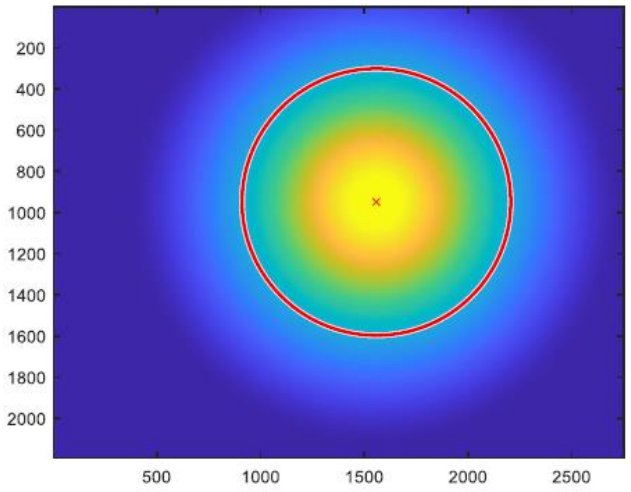
Mask uniformity profiling

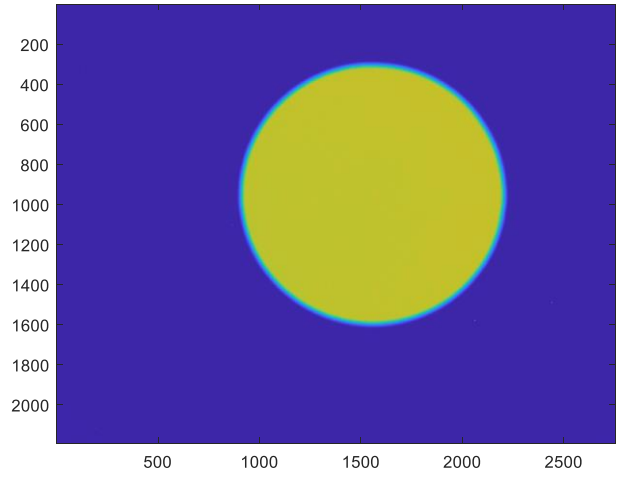




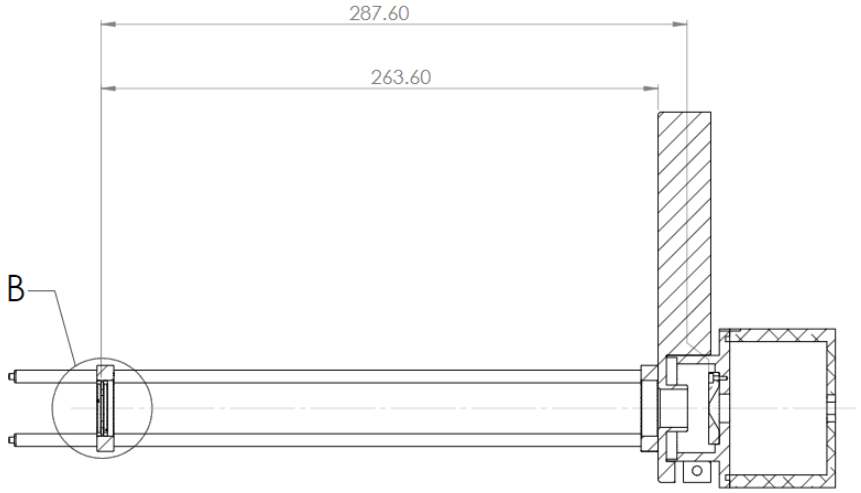
Absolute Radiometric Calibration

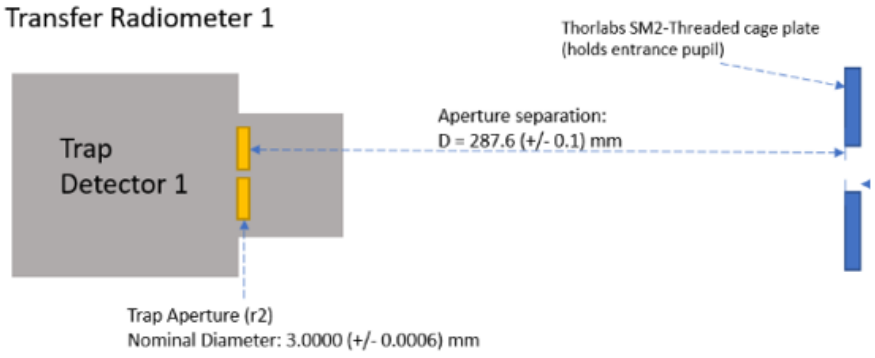
Uniformity characterisation





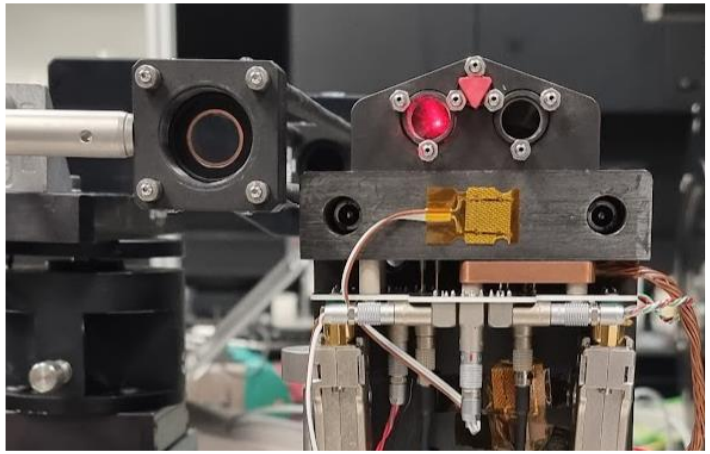
Transfer Radiometer Design

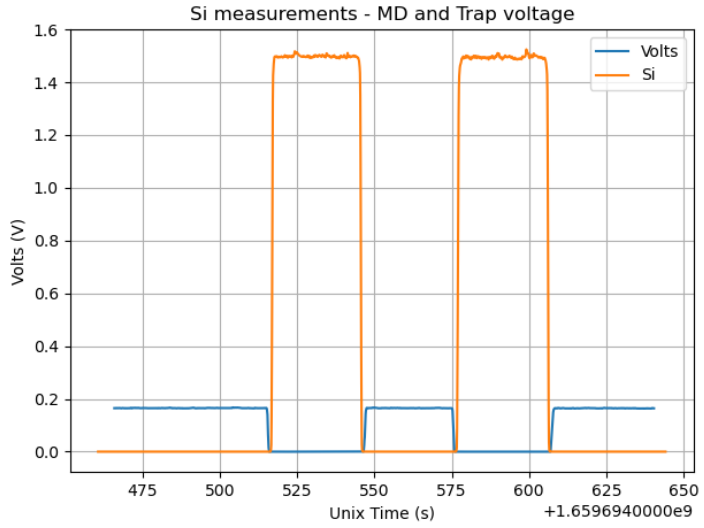




CALCON, SDL Logan, UT - 10 June 2024

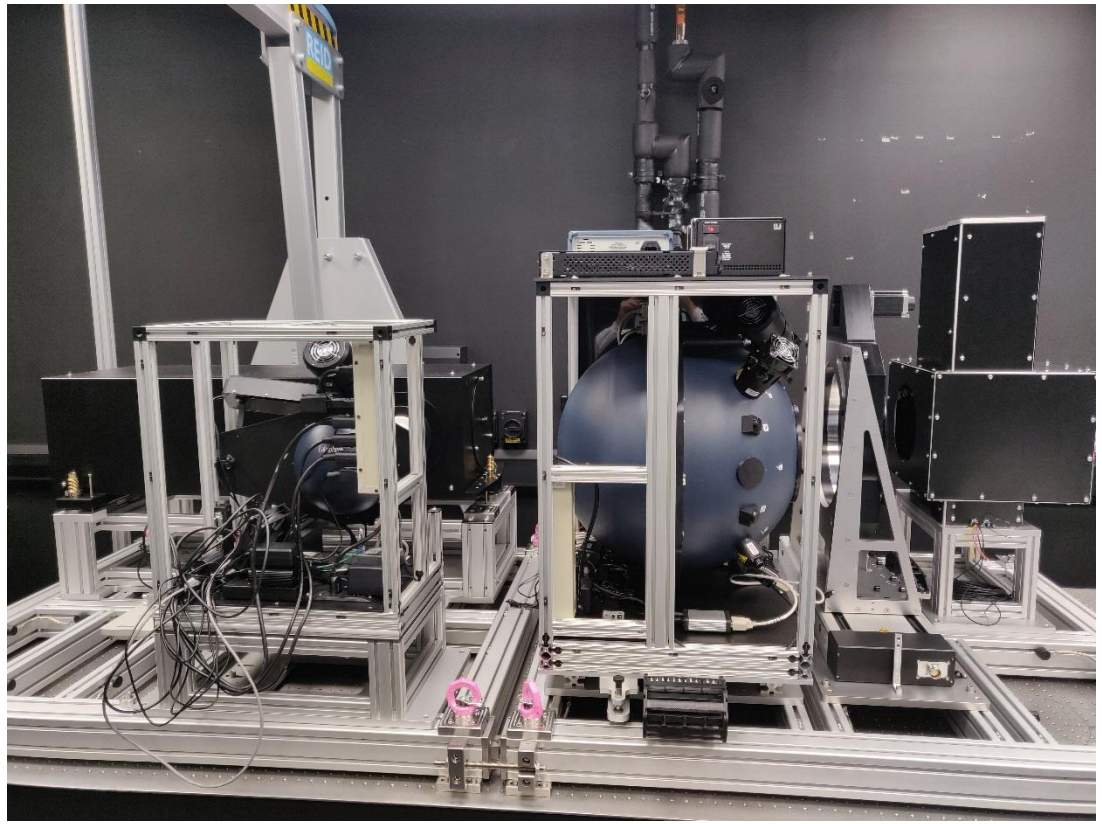
Reference Detector Calibration





Agile approach

- The specific requirements of the sensor, determined by its footprint, FoV, spectral extent & resolution, nominal radiance and required sensitivity typically results in a bespoke OGSE needed to meet the specific sensor requirements.
- For large-scale multi-sensor series programs, a bespoke solution may remain the preferred solution.
- However, for single/few unit explorer missions, commercial constellations and more agile sensor development programs, the expense & post-use redundancy of a bespoke OGSE system may be prohibitive.

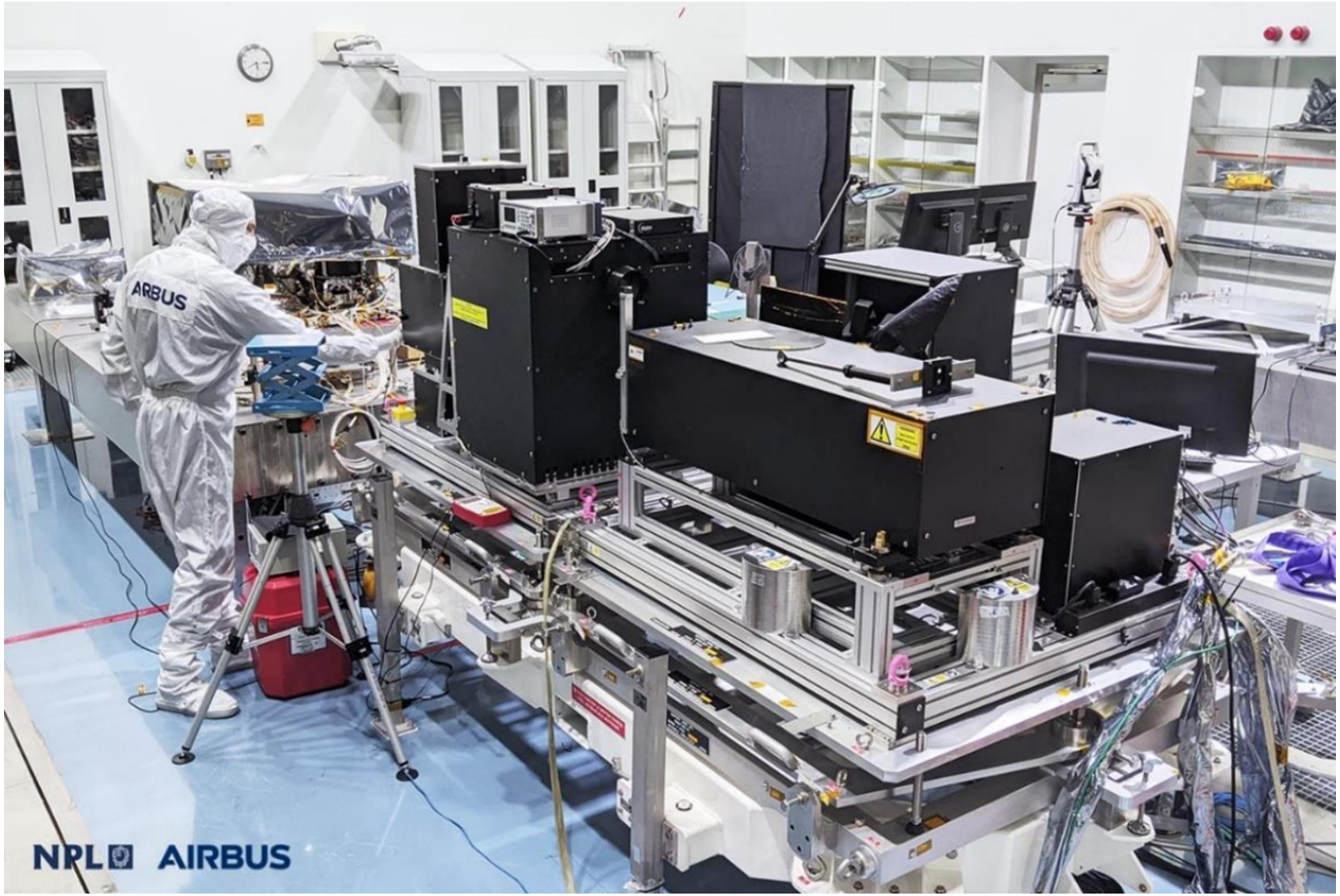


Adaptable & pragmatic model

- Designed to be transportable to customer sites. Crane-able & transported in sections with repeatable inter-connections.
- Approx. 2.5m x 1m x 1m + laser, rack & interface electronics and ~500kg
- ISO 6 compliant. (ISO 5 possible)
- Adaptable S/W interface with customer EGSE.
- Includes mechanical alignment infrastructure
- Advocate a lease model – moving away for a bespoke system for each sensor.
  - lower cost
  - state-of-the-art (facility evolves over time)
  - SI-traceable calibration at NPL (before & after use)

Physical	
Physical size	2.6m (L) x 1.2m (W) x 1.0m (H)
Mass	<500Kg
Transport	Crane-able & transported in sections
Beam diameter	200 mm
Field mask features	Slit, squares, MTF, high intensity point source.
Field mask rotation stage	±5°
Cleanliness	ISO6 (external surfaces compliant to ISO5)
Shutter response time	< 5 seconds
Operations	Completely remote controlled, interfaced to customer control systems.
Data management	Customer-tailored data interfacing system.
Environmental (operations)	Temp: 18° C ± 2° C, Pressure: 900 hPa -1084 hPa, humidity: 40 %rh – 70 %rh
Environmental (transport/storage)	Temp: 0° C - 40° C, Pressure: 900 hPa - 1084 hPa, humidity: 40 %rh – 70 %rh
Compliance	CE & ROHS

CNES/UKSA MicroCarb mission

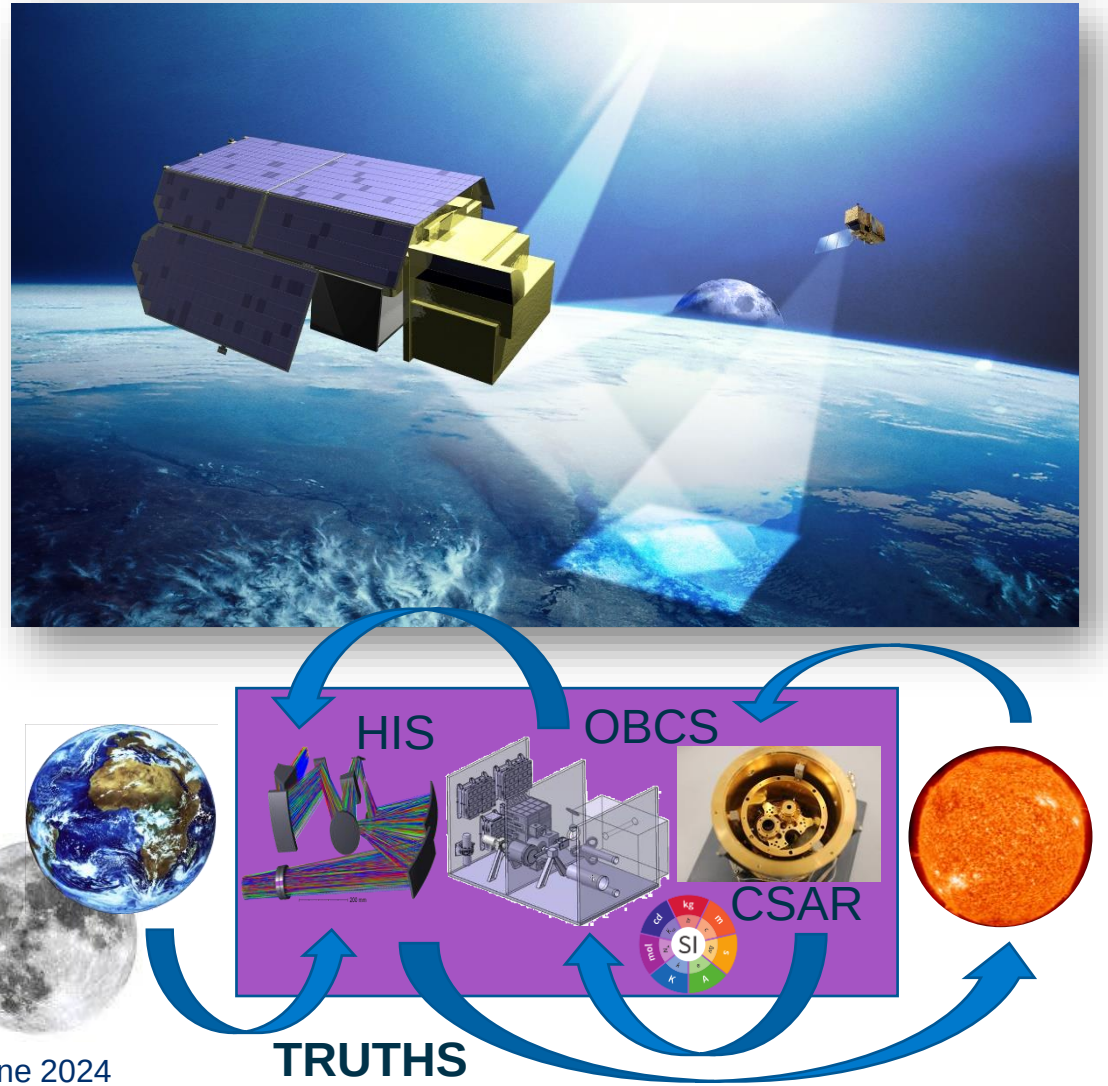


TRUTHS mission

NPL

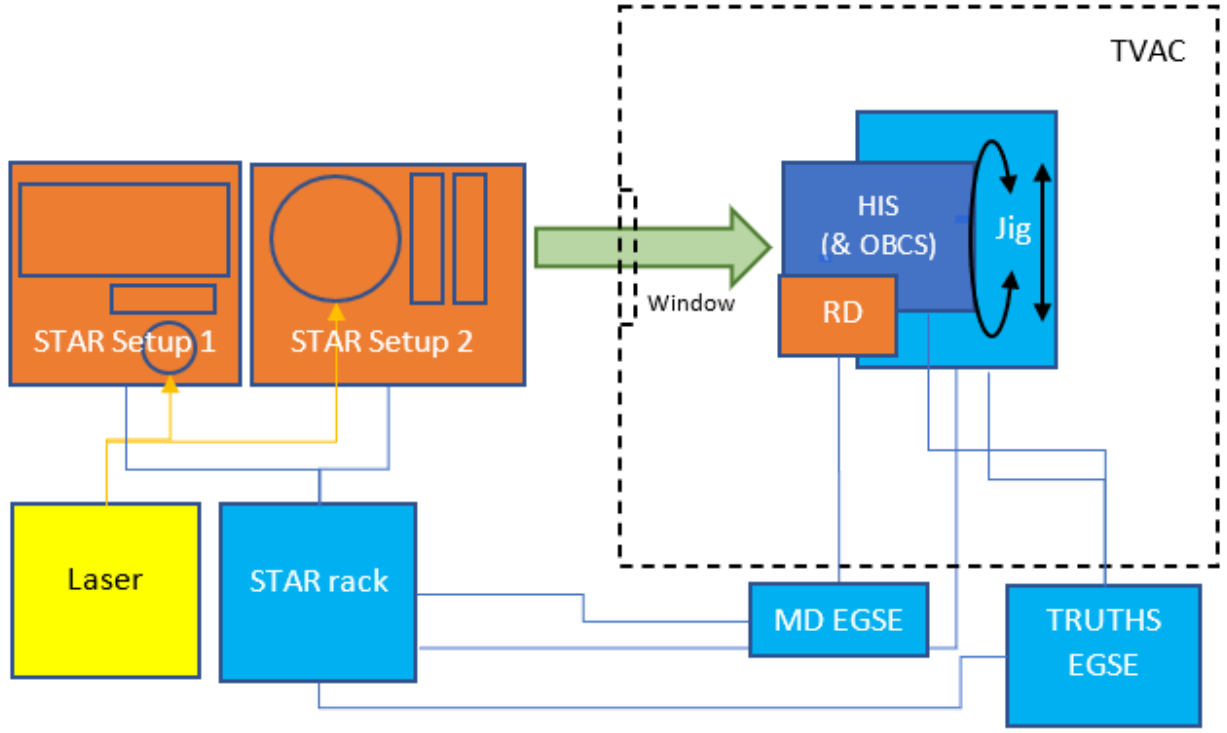
- TRUTHS is a UK-led ESA EarthWatch operational Earth Observation mission that will initiate a **space based climate & calibration observatory**.
- TRUTHS will measure incoming and reflected solar radiation **10 times more accurately (traceable, in-space, to SI units)** than is currently possible.
- On-board calibration system **mimics ORM terrestrial methods**.
- This enables TRUTHS to **increase confidence in data** from other EO satellites through in-flight cross-calibration.
- More trustworthy data will **accelerate climate model predictions** and reduce their uncertainty, thus enabling policymakers to make **better and earlier strategic investment decisions**
- In addition**, hyperspectral data** from TRUTHS will address **challenges across all Earth science disciplines**

Traceable Radiometry Underpinning Terrestrial- & Helio- Studies



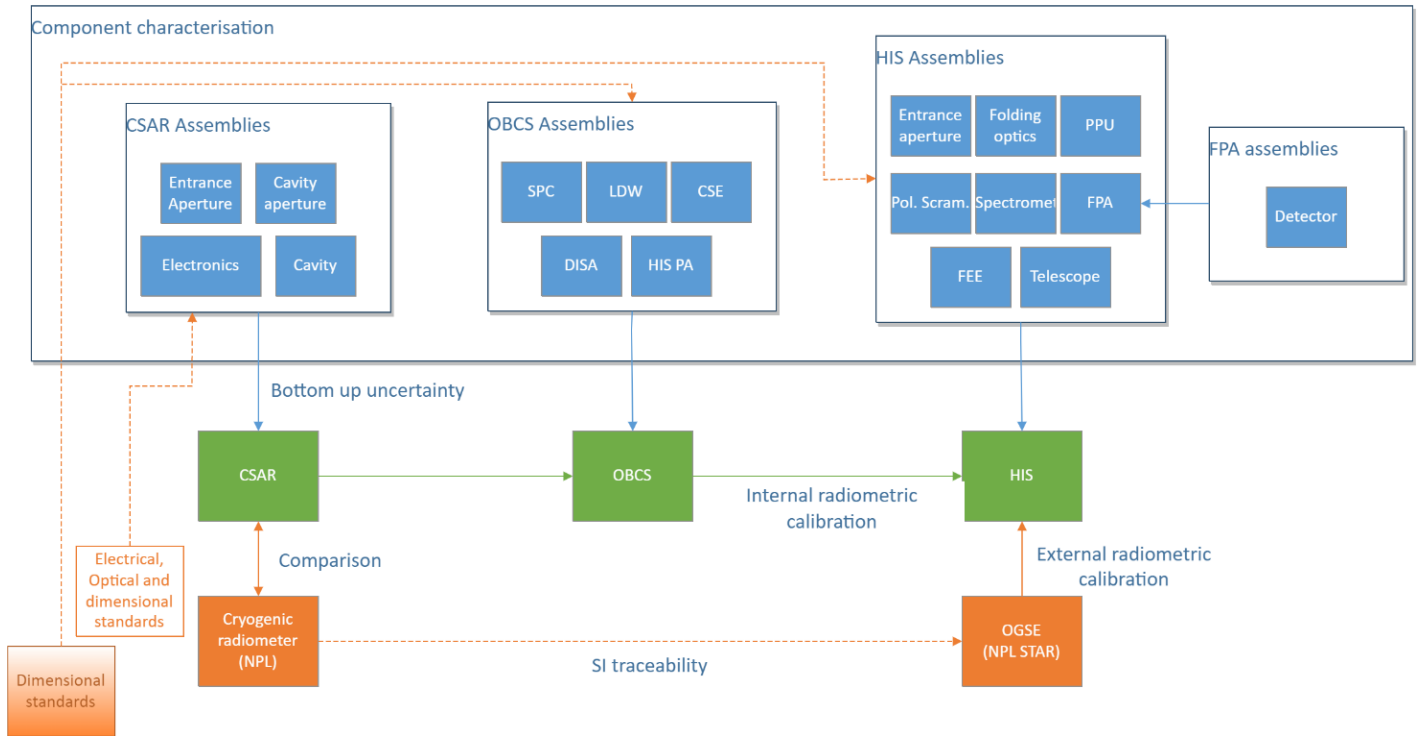
TRUTHS External Calibration Principle

- Validate calibration of HIS with internal primary standard (CSAR) and on-board calibration system (OBCS)
- External radiometric calibration of HIS using STAR-cc-OGSE
- STAR RD will be co-mounted with TRUTHS payload, measuring radiance field incident of the HIS entrance aperture.



TRUTHS (pre-flight radiometric calibration)

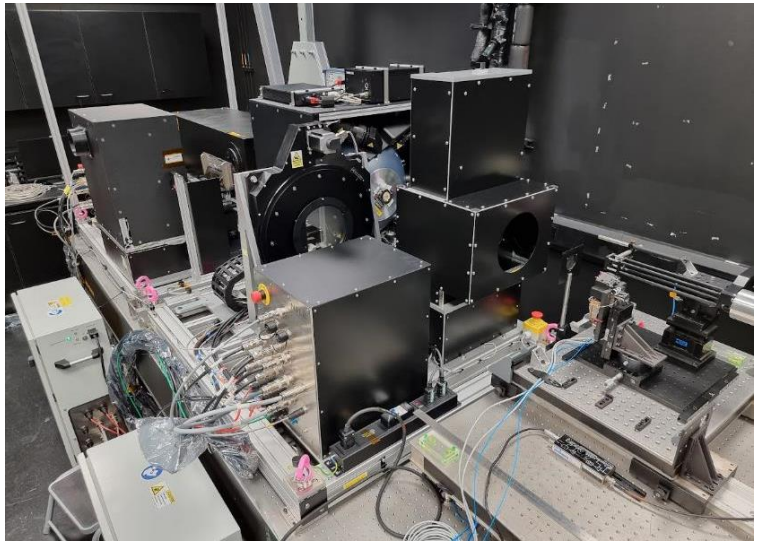
- Core system suitable for TRUTHS
- Planned developments
  - In vacuum detectors (extend to 2.5 µm)
  - Shorten traceability chain to cryogenic radiometer to meet 0.1% (k=1) across full TRUTHS spectral range
  - Upgrade NPL CR facility
  - CPD incorporation for >1000 nm transfer reference from CR to STAR-cc-OGSE detector.
  - Demonstrate full end-to-end process



STAR-cc-OGSE capability expansion

STAR-cc-OGSE

- Vacuum compatible detector
- Up to ISO 5
- Transportable to customer clean rooms and vacuum chamber facilities

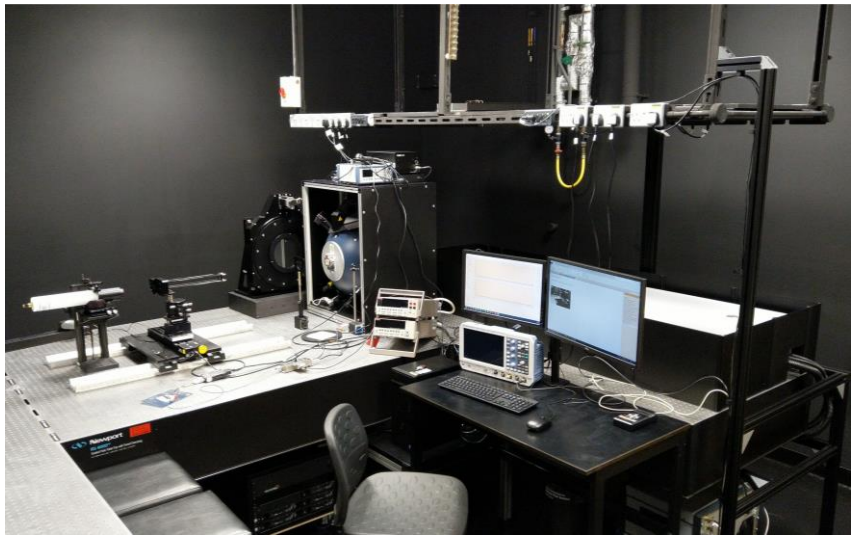


STARWELL

- Up to ISO 7 (ISO 5 with addition cleaning)
- Located at RAL Space in Harwell
- Designed for small-satellite sensors & component characterisation

CARES

- No clean room requirements
- Located permanently at NPL
- Designed for ‘terrestrial’ cameras & spectrometers -. i.e drone-mounted and hand-held field instruments



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