

SI-Traceable Pre-flight Calibration of Optical Satellite Sensors

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An SI-Traceable Space-based Climate Observing System

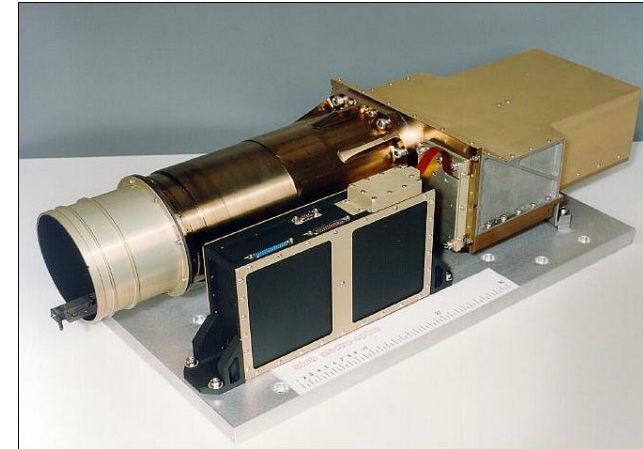
CEOS WMO-GSICS workshop

NPL, UK

9-11 Sept 2019

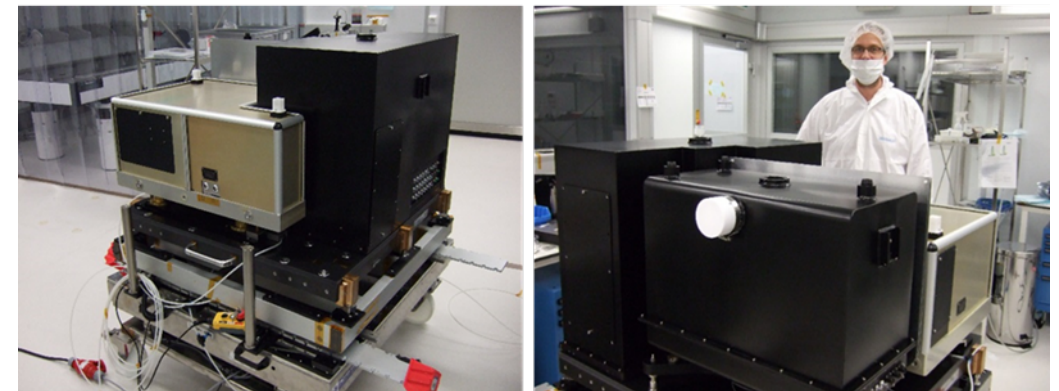
Pre-flight optical sensor calibration

- NPL has worked for many years on the pre-flight calibration of optical sensors
 - Characterising 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 utilise technological developments to:
 - Improve accuracy while reducing time, cost & complexity.



CHRIS on
PROBA-V

Copernicus
Sentinel 4
OGSE



What do we need to characterise and calibrate?

- Geometric characterisation
 - FoV, ILS,
 - Inter-band & Intra-band co-registration,
 - Spatial response function,
 - Smile & tilt, keystone & tilt,
 - Spatial, spectral & temporal registration,
 - MTF, spatial sampling, dazzling ...
- Radiometric calibration & characterisation.
 - SNR, ISRF,
 - Spectral calibration, out-of-band rejection,
 - Radiometric calibration (absolute, relative intra-band/inter-band)
 - Non-linearity, dynamic range
 - Polarisation sensitivity
 - Straylight (spectral & spatial)
 - Non-uniformity response ...

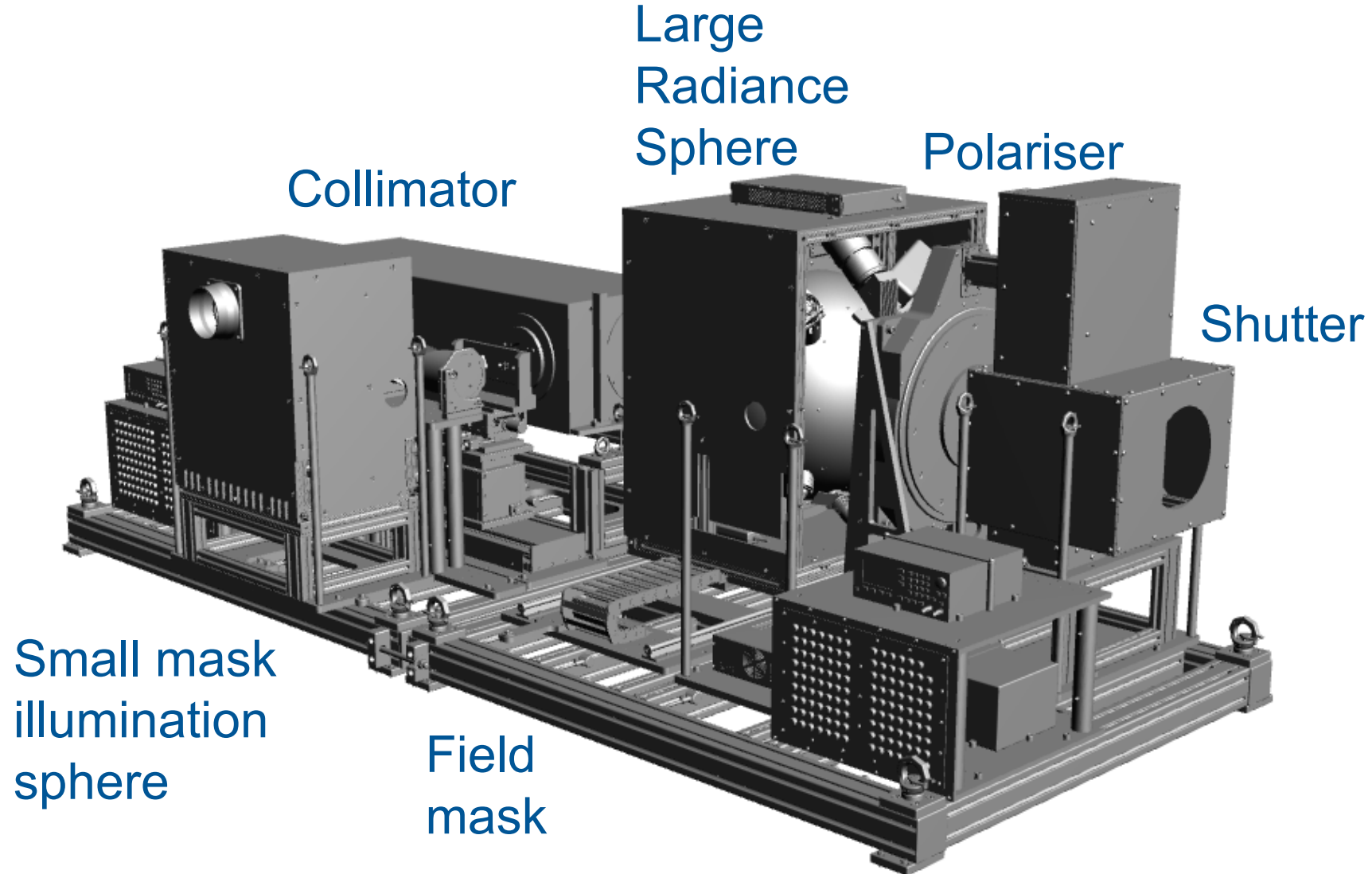
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 - Non-uniformity response ...
- What do we need to consider?
 - Interfacing to the test facility
 - Alignment
 - Thermal cycling
 - FoV rastering
 - ...

STAR-CC-OGSE overview

- The Spectroscopically Tuneable Absolute Radiometric calibration & characterisation OGSE (STAR-CC-OGSE) is a versatile facility for the radiometric calibration and calibration of satellite sensors.
- The laser allows monochromatic continuous tuneability from 270 nm to 2700 nm, with a broadband (white light) source extending over the same spectral extent.
- The STAR-CC-OGSE has two components,
 - a large aperture SI-traceable calibrated integrating sphere source for radiometric calibration
 - a collimated beam source, equipped with an interchangeable, position fine-tuneable feature mask for optical performance characterisation.

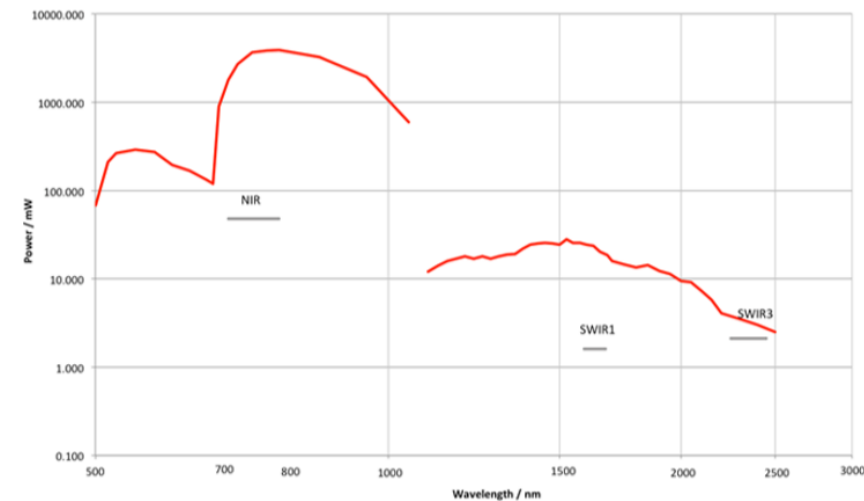
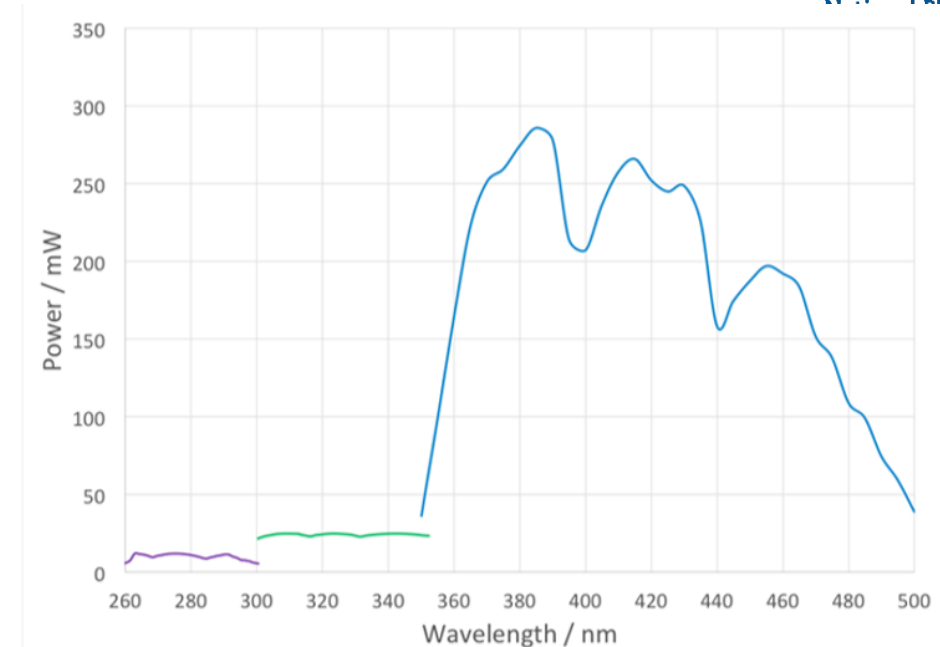
STAR-CC-OGSE system



New technology – new approach

CW tuneable laser system

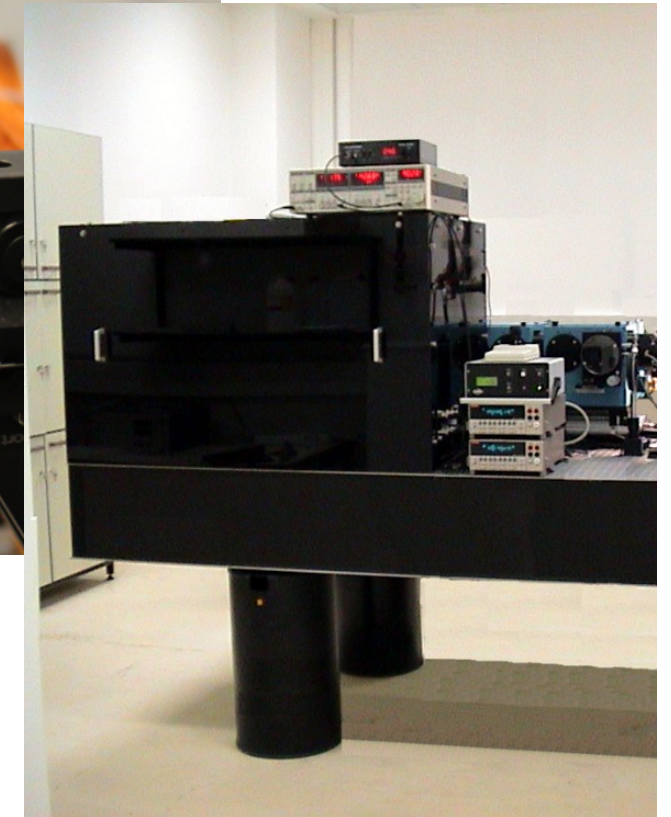
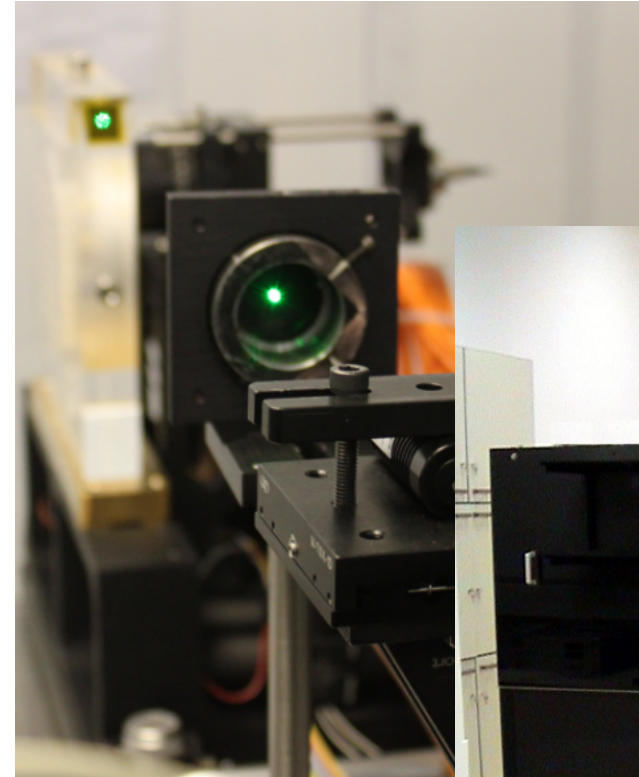
- Fully tuneable CW laser systems from the UV to the NIR
 - High power (5 mW to 2 W)
 - Wide spectral range (260 nm – 2700 nm)
 - Narrow line-width
 - Fully automated
- Allows monochromatic radiance calibration and straylight characterisation with a single facility.



New technology – new approach

Detector-based SI-traceability

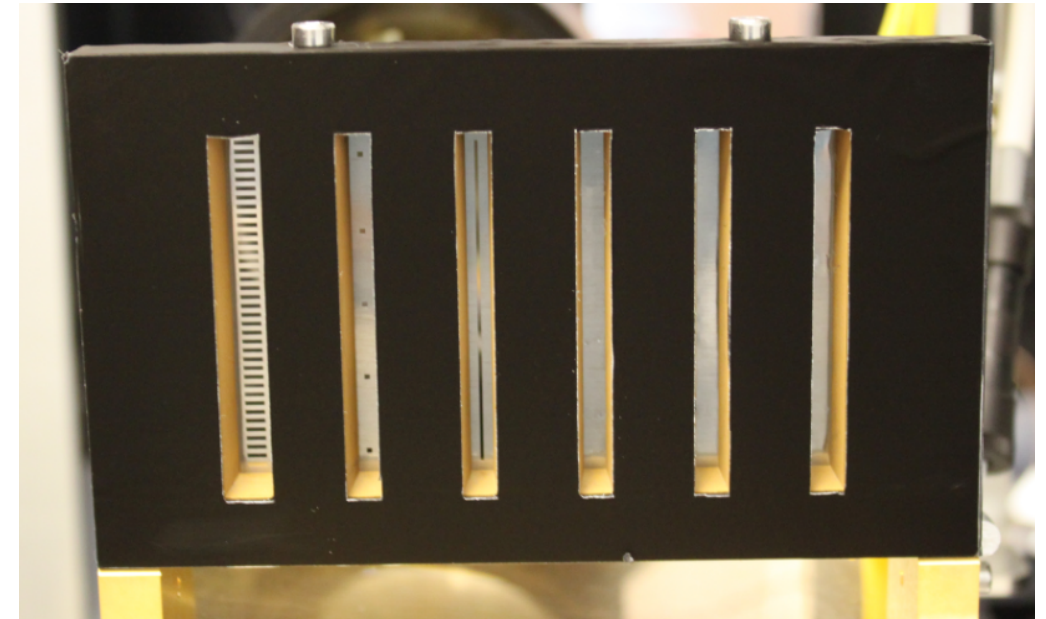
- Traceability via detector system mounted at the instrument input port (in vacuum).
- No need to separately determine path absorption, window transmission etc.
- Combination of broadband detectors and fibre-coupled spectrometer give full spectral monitoring.
- Spectrometer calibrated in-use via the tuneable laser source accounting for transmission/installation contributions.
- SI-traceable to primary standard CR



New technology – new approach

Custom field mask

- Collimator field mask bespoke to customer need.
- Geometric shapes
 - Slit / Edge
 - Square
 - Point sources
- Precision engineering verified by SI-traceable dimensional meas.
- Direct fibre feed allows integrated high intensity source for straylight characterisation.



New technology – new approach

Transportable

- 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
- ~500kg
- ISO 6 compliant. (ISO 5 adaptable)
- Adaptable S/W interface with customer EGSE.
- Includes alignment infrastructure

| 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 | $\pm 5^\circ$ |
| 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 \pm 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 |

New Space – new approach

- 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)
- Yet adaptable to user need, particularly in:
 - the geometric characterisation (field mask design)
 - laser wavelength range
- First customer – CNES/UKSA MicroCarb mission (Q2 2020)
- Future uses are in discussion.
- Low cost & flexibility allows potential small satellite / constellation applications

STAR-CC-OGSE specification

| Radiometric | |
|---|---|
| Monochromatic spectral range | 260 nm to 2700 nm. |
| Broadband spectral range | 250 nm to 2500 nm (eqv. to 3000K blackbody). Can be extended into UV |
| Monochromatic typical radiance | Max. 0.5 W.m ⁻² .sr ⁻¹ (@800nm) |
| Broadband typical radiance | Max. 2000 W.m ⁻² .sr ⁻¹ .nm ⁻¹ (@1200nm) |
| Radiance spatial uniformity | Typically <0.15% PV (application dependant) |
| Radiance temporal uniformity | Mono (0.2% PV), BB (0.02% rms) |
| Monochromatic source line width | <0.1 pm |
| Monochromatic source tuning step size | ~few pm |
| Monochromatic source wavelength calibration | <0.2 pm (PV) |
| Calibrated TVAC-compatible radiance monitor | <0.5% (k=1) [TBC] |
| Collimator focal length & F/# | 1000 mm & F/5 |
| Polarisation | |
| Contrast ratio | >1:10 ⁴ |
| Rotation extent, resolution & accuracy | >360° , <0.1° , <0.2° |

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