NPL
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The STAR-CC-OGSE system for pre-flight sensor calibration

Paul D Green, Sean Devlin, William Kingett and Nigel P Fox
National Physical Laboratory, UK

calcon
www.calcon.sdl.usu.edu

The Global Earth Observation system

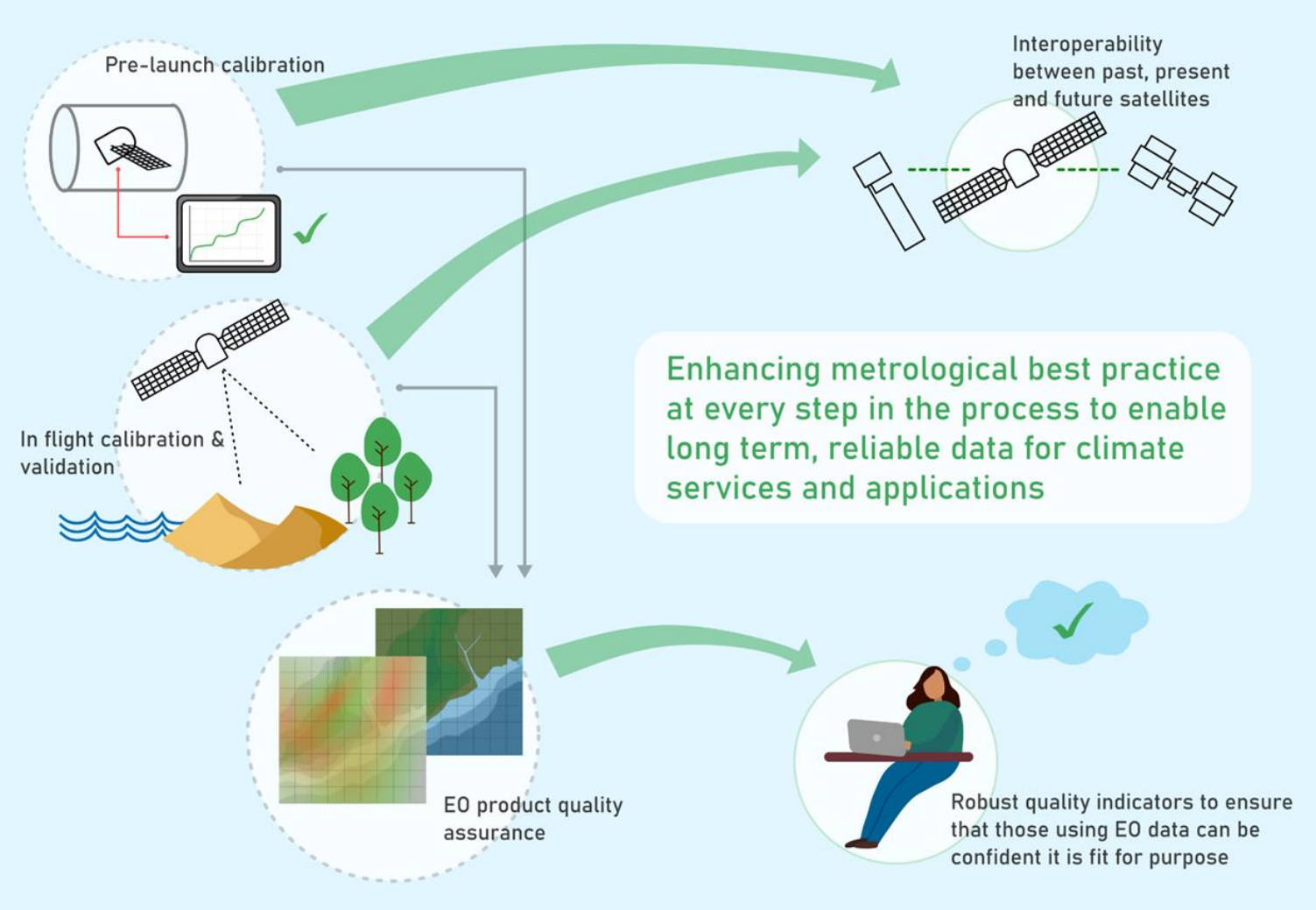
- Reliable characterization and radiometric calibration of satellite sensors are critical to their optimal performance on-orbit.
- Only through a robust understanding of the instrument behavior, performance and degradation mechanisms will the significant effort and expense invested into the flight hardware 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.

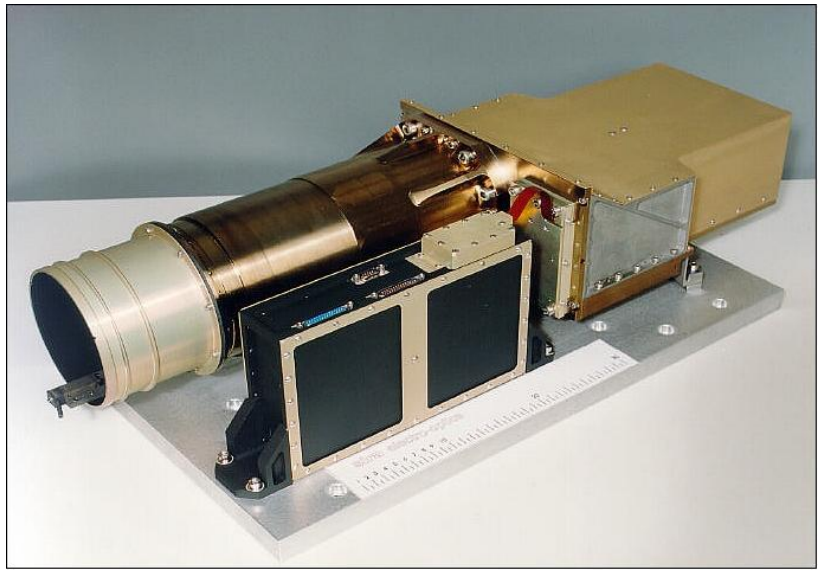
You Need Better Data,

Not More Data!

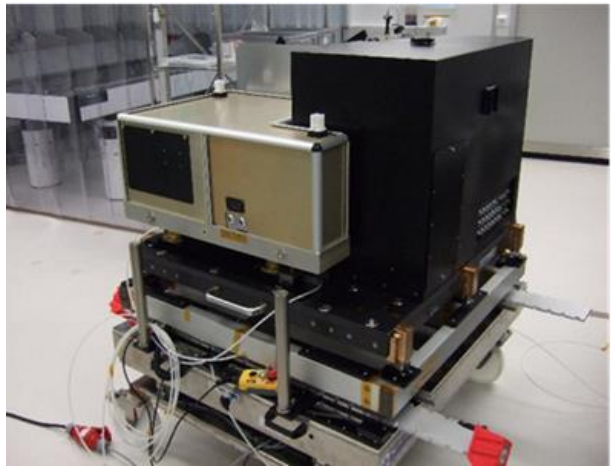


Pre-flight optical sensor calibration

- 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

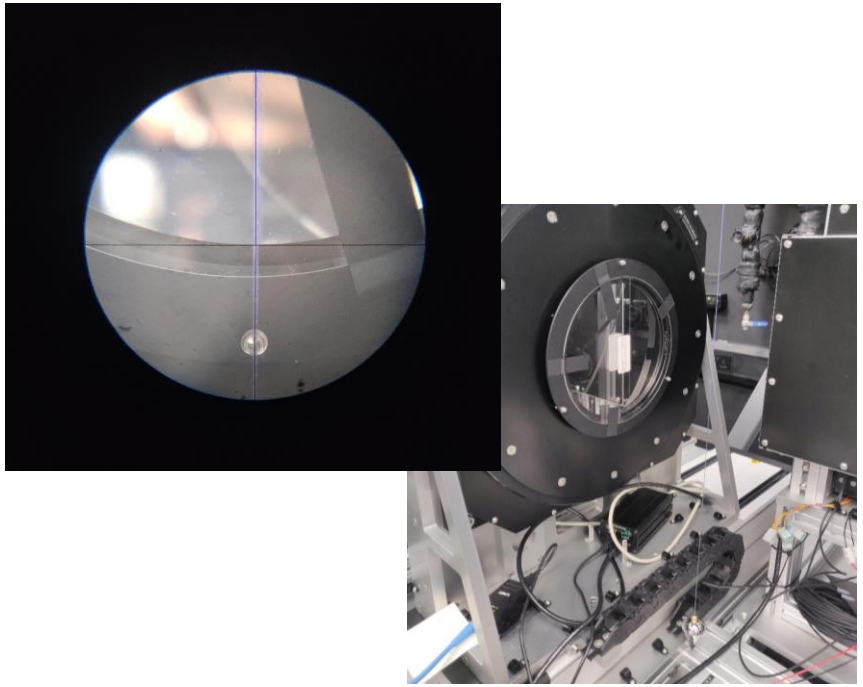


Copernicus Sentinel 4 OGSE

What do we need to characterise and calibrate?

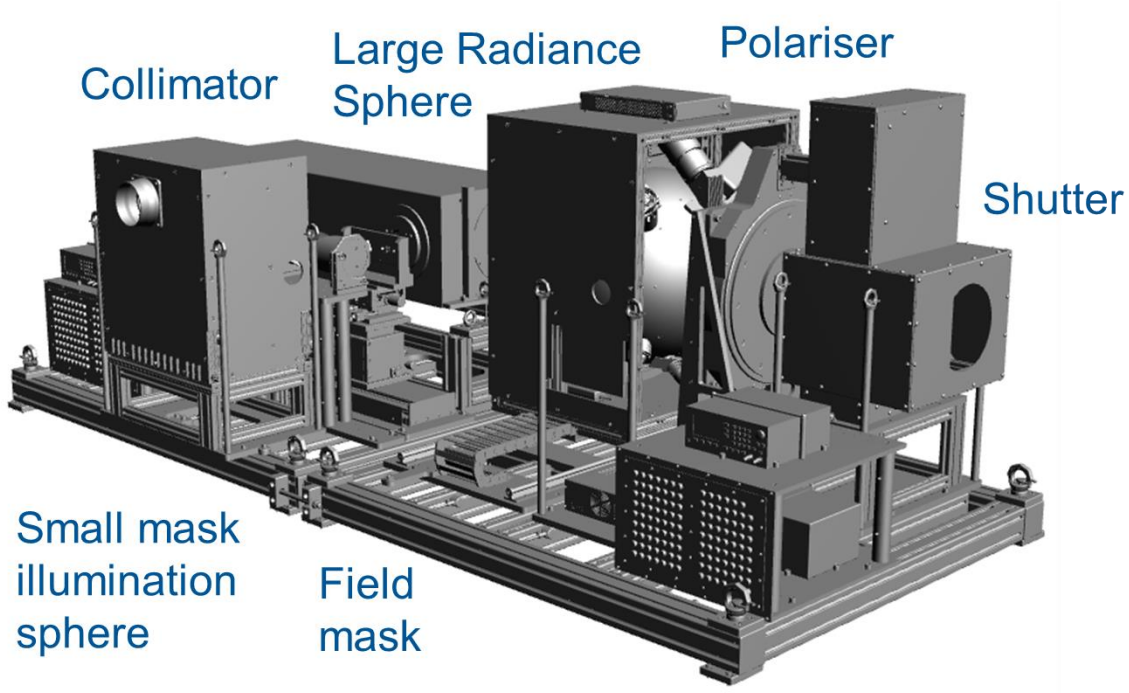
- Geometric characterisation
  - FoV, ILS,
  - Inter-band & Intra-band co-registration,
  - Spatial response function,
  - Smile & tilt, keystone & tilt,
  - Spatial, spectral & temporal registration,
  - MTF, spatial sampling, dazzling …
- Radiometric calibration & characterisation.
  - SNR, ISRF,
  - 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 …

Sensor pre-flight characterization and calibration facilities, or optical ground support equipment (OGSE) test sensor performance over a few broad categories



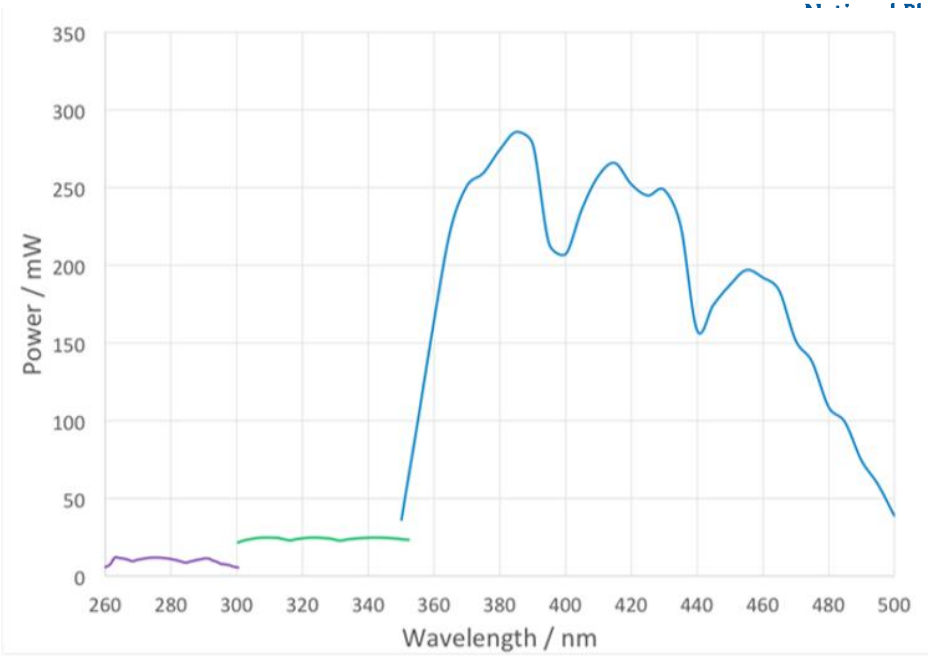
STAR-CC-OGSE overview

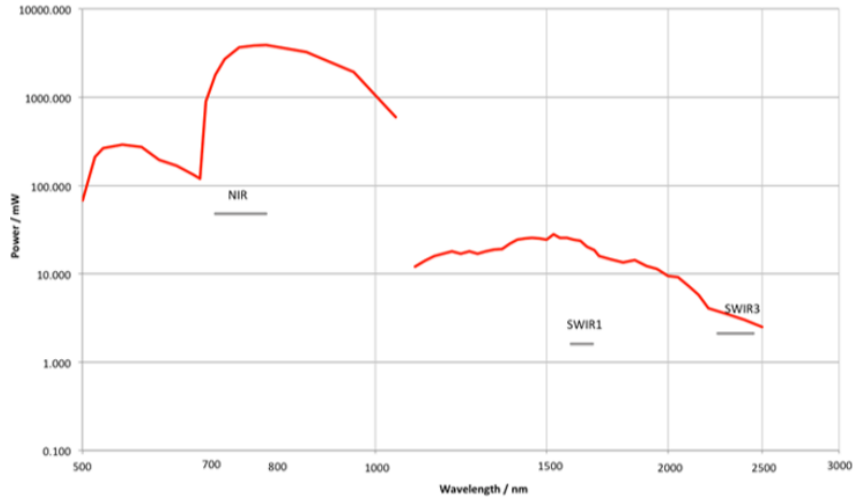
- The Spectroscopically Tuneable Absolute Radiometric calibration & characterisation OGSE (STAR-CC-OGSE) is a versatile facility for the radiometric calibration and characterisation of satellite sensors.
- The laser allows monochromatic continuous tuneability from 270 nm to 2700 nm, with a broadband (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.



New technology – new approach
CW tuneable laser system

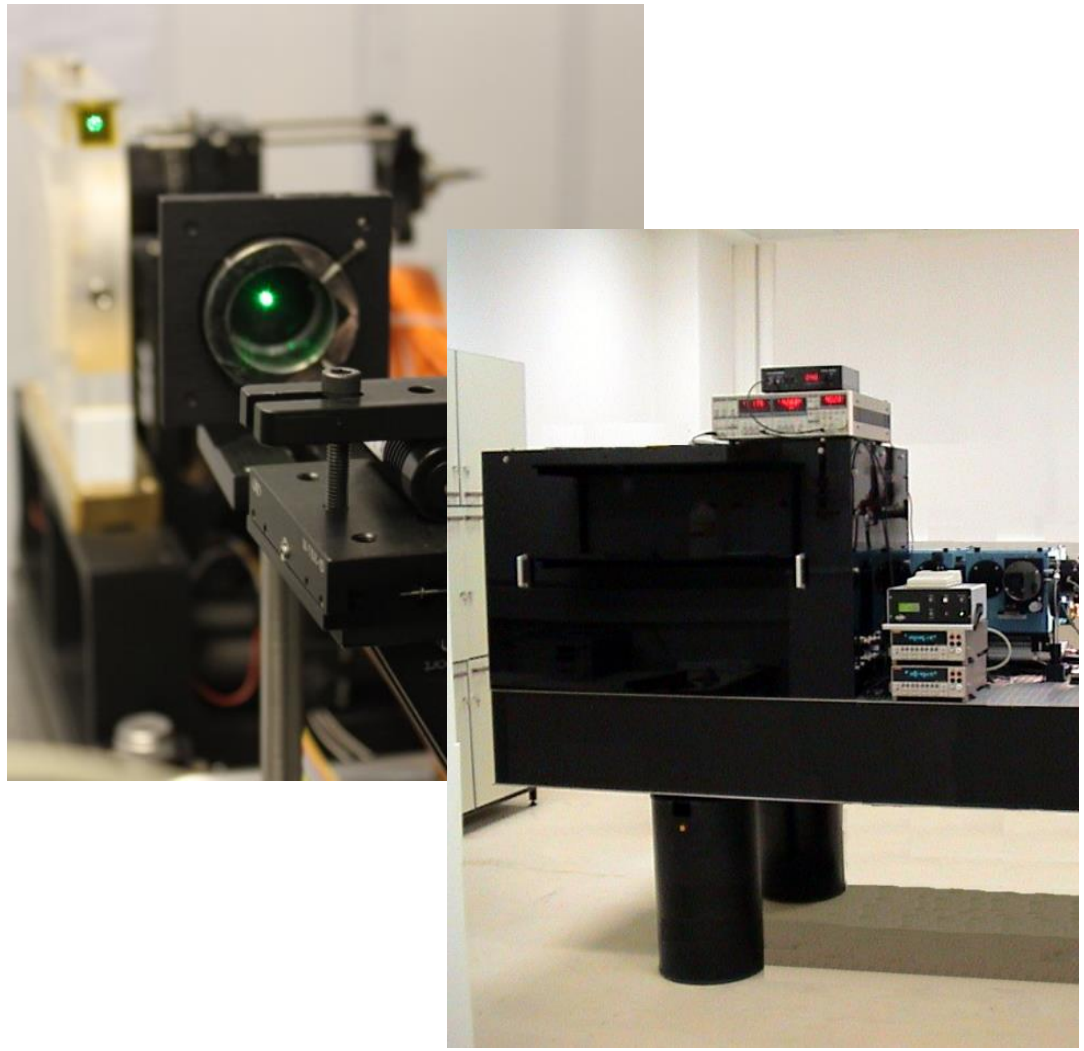
- Fully tuneable CW laser systems from the UV to the NIR
  - High power (5 mW to 2 W)
  - Wide spectral range (260 nm – 2700 nm)
  - Small tuning step (few pm)
  - Narrow line-width (<0.1 pm)
  - Fully automated
- From a single facility allows:
  - monochromatic radiance calibration
  - spectral response characterisation
  - straylight characterisation





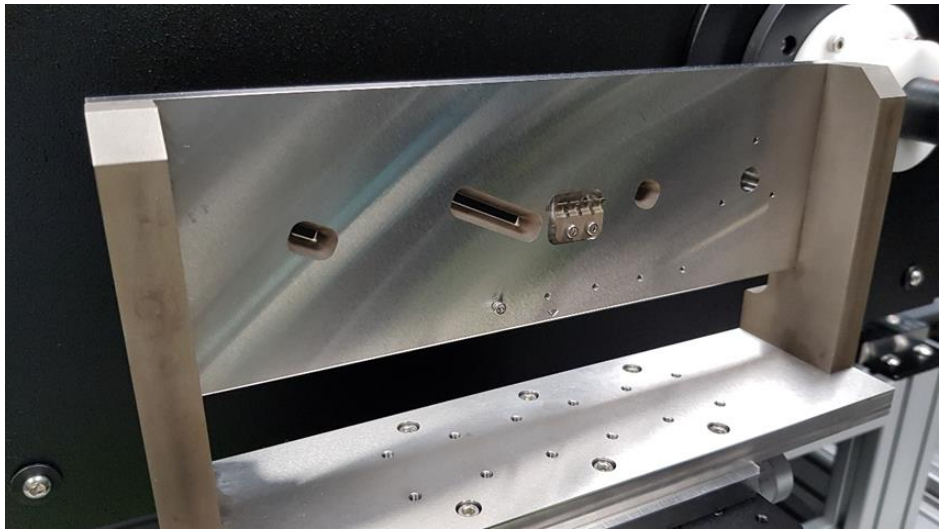
New technology – new approach
Detector-based SI-traceability

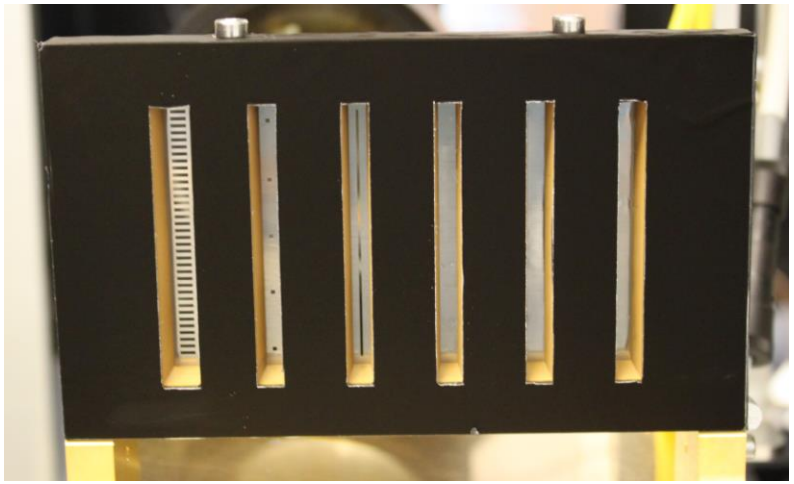
- Traceability via detector system mounted at the instrument input port (in vacuum).
- Monochromatic accuracy ~0.5% (k=1)
- No need to separately determine path absorption, window transmission etc.
- Combination of broadband detectors and fibre-coupled spectrometer give full spectral monitoring.
- Spectrometer calibrated in-use via the tuneable laser source accounting for transmission/installation contributions.
- SI-traceable to primary standard cryogenic radiometer at NPL



New technology – new approach
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.





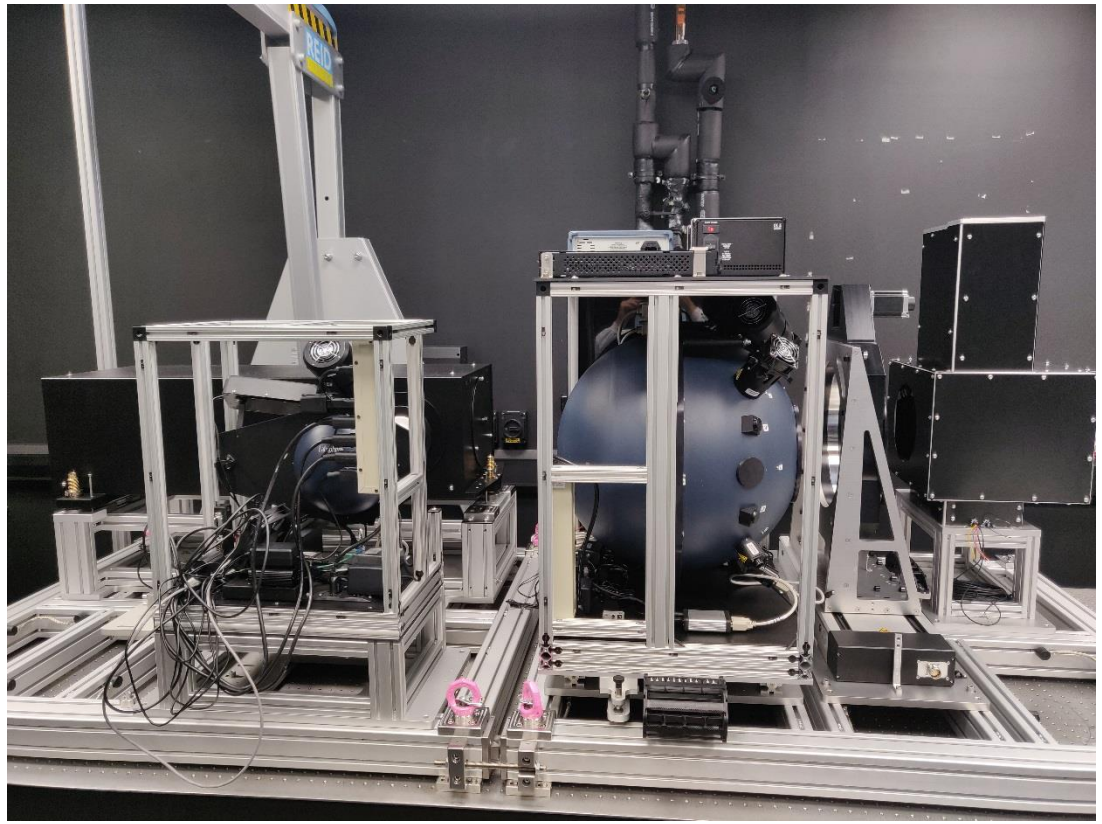
New technology – new approach
Transportable

- 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	±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

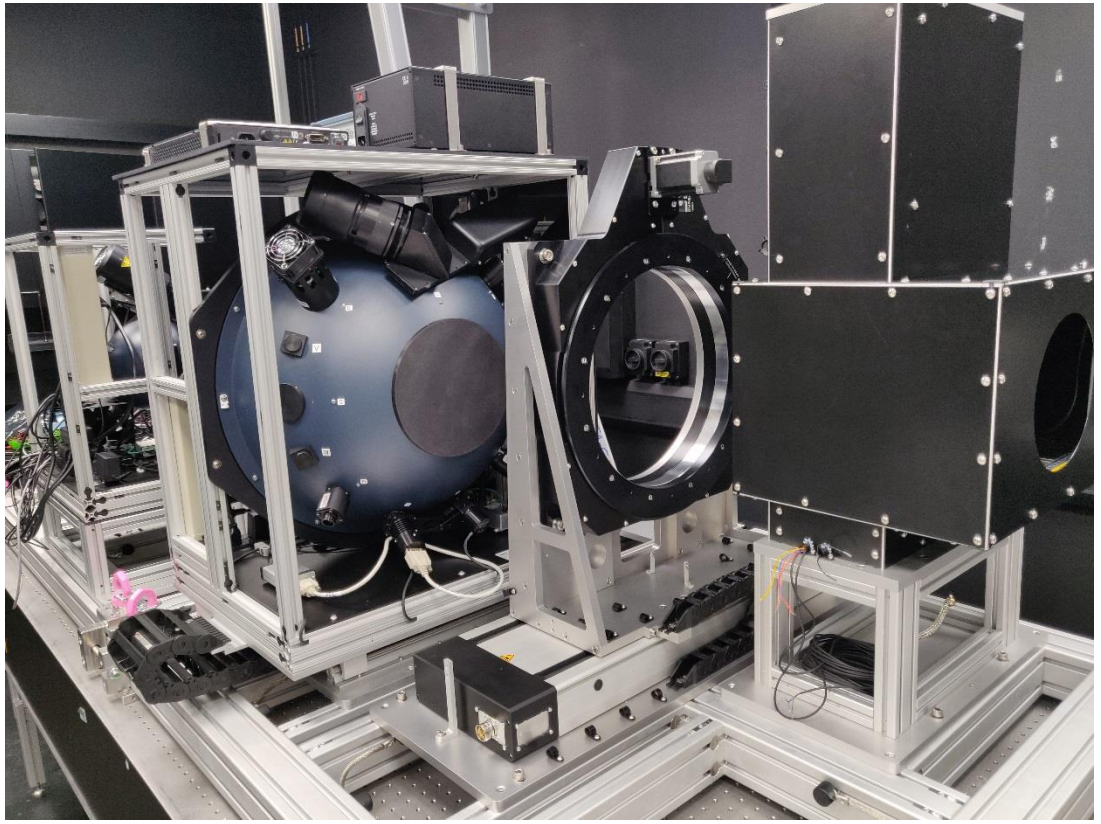
New Space – new approach

- 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.



New Space – new approach

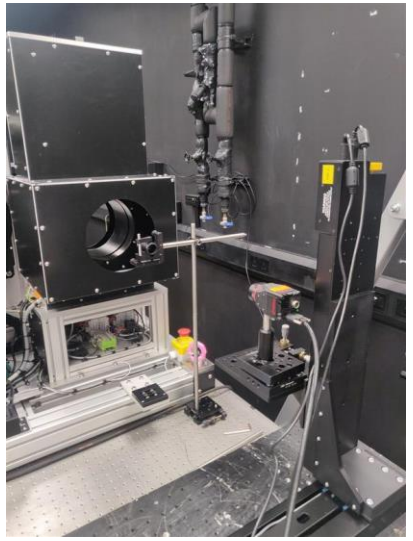
- Advocate a lease model – moving away for a bespoke system for each sensor.
  - lower cost
  - state-of-the-art (facility evolves over time)
  - SI-traceable calibration at NPL (before & after use)
- Yet adaptable to user need, particularly in:
  - the geometric characterisation (field mask design)
  - laser wavelength range
- First customer – CNES/UKSA MicroCarb mission (Q3 2020)
- Future uses are in discussion.
- Low cost & flexibility allows potential small satellite / constellation applications

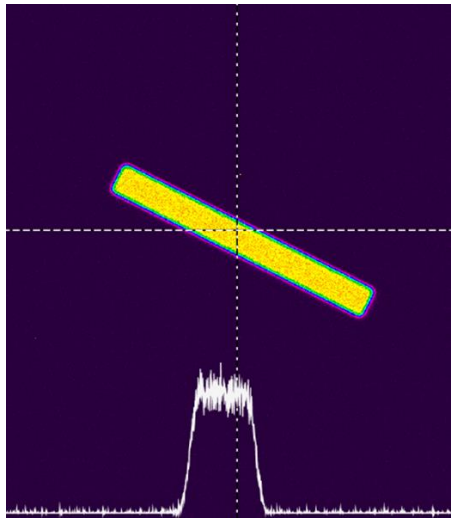


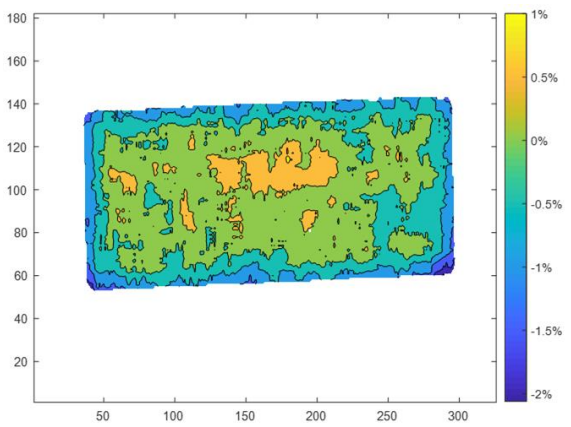
Verification testing

- Verification testing is now complete
  - Field mask stage alignment
  - Polariser alignment
  - Polariser beam deviation testing
  - Source spatial uniformity
  - Source temporal stability
  - Overall system transmission
  - Safety system testing
  - Software operational testing

- The STAR system is in a final performance testing phase, before shipment to the customer site







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°

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.
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