

# The STAR-CC-OGSE\* System For Pre-flight Sensor Calibration

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*\*Spectroscopically Tunable Absolute Radiometric calibration & characterisation OGSE*

# Motivations

- Reliable pre-flight characterisation and radiometric calibration of satellite sensor are critical for their optimal performance on-orbit.
- Drive to compare data from past, present and future satellites for long term climate applications. For this, each satellite should not be treated in isolation but instead part of an EO infrastructure with their uncertainties traceable to a common standard, the SI.
- 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 single/few unit explorer missions and more agile sensor development programs, the expense & post-use redundancy of a bespoke OGSE system may be unnecessary.
- Moving away from 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



Credit: ESA

# What do we need to characterise and calibrate?

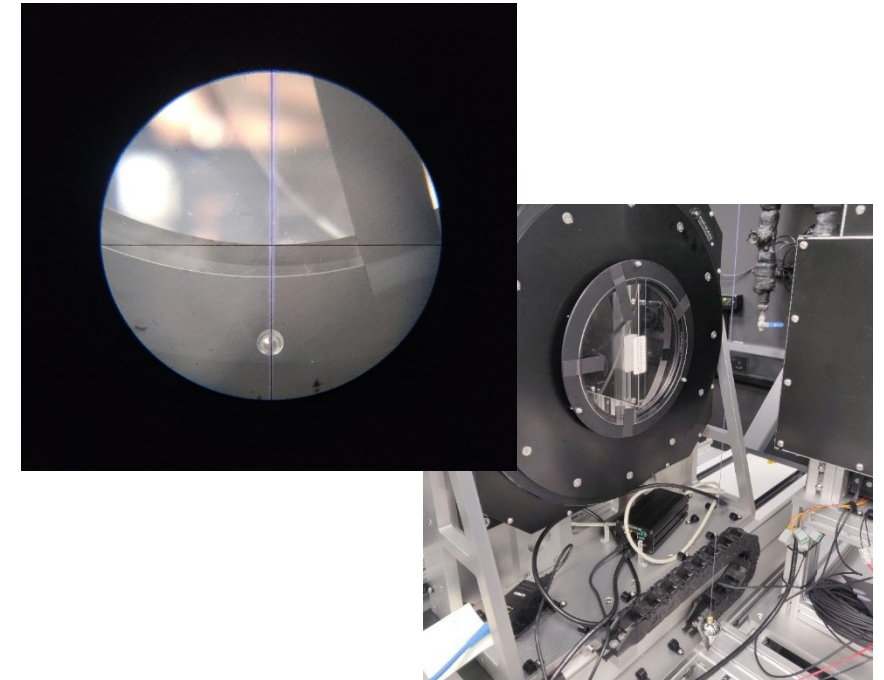
## ■ Geometric characterisation

- 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.

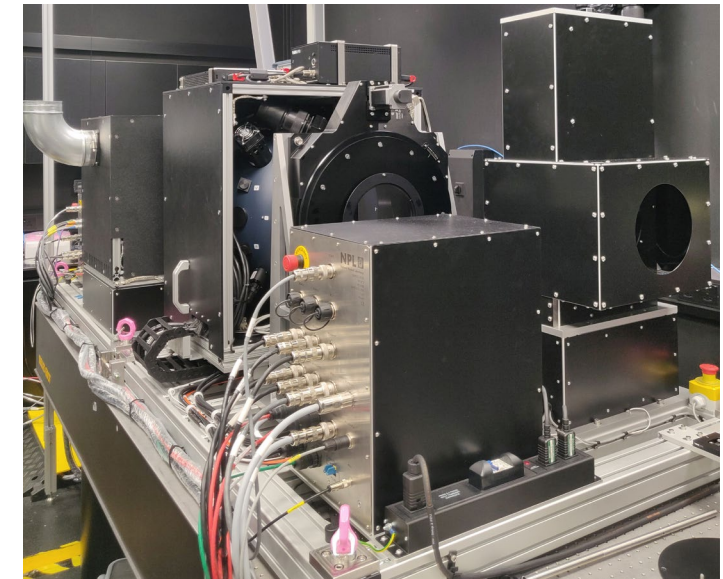
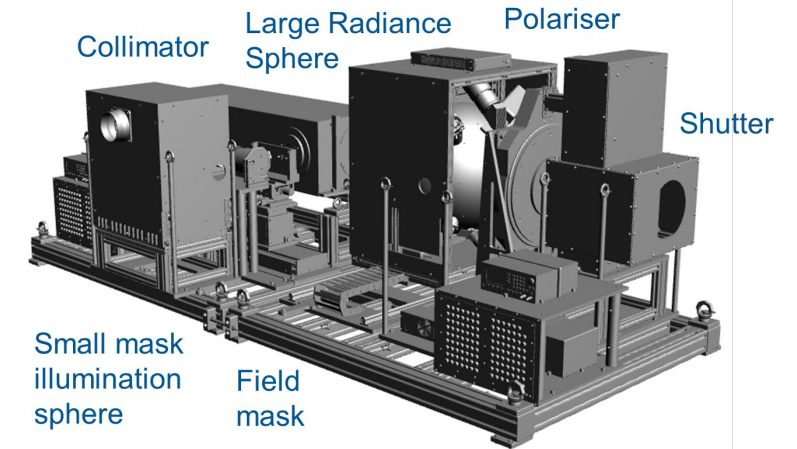
- SNR, ISRF,
- Spectral calibration, out-of-band rejection,
- Radiometric calibration (absolute, relative intra-band/inter-band)
- Non-linearity, dynamic range
- Polarisation sensitivity
- Straylight (spectral & spatial)
- Non-uniformity response ...

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



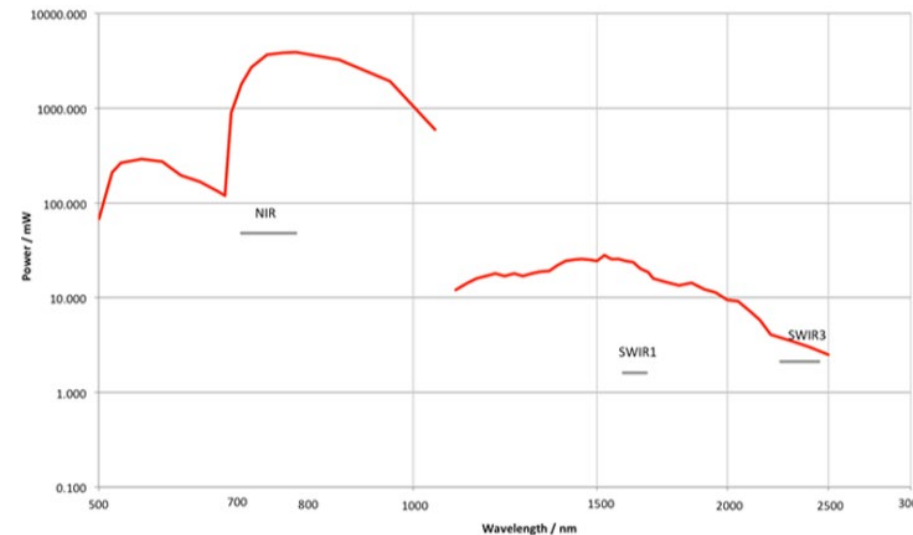
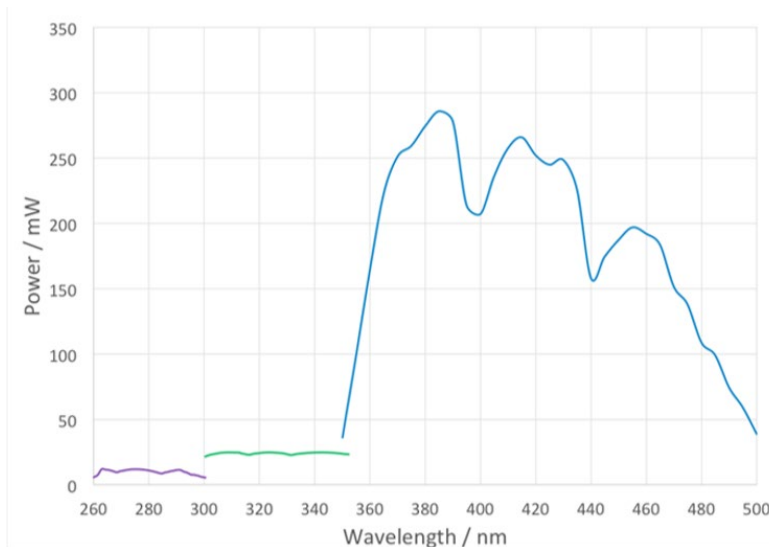
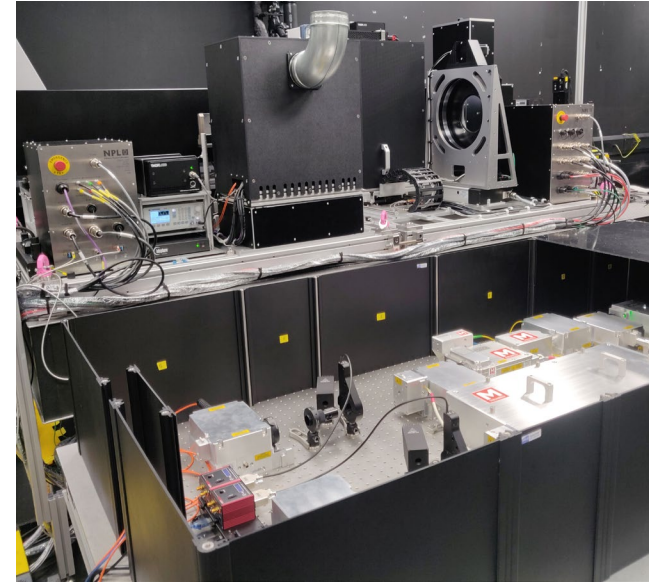
# STAR-CC-OGSE Overview

- STAR-CC-OGSE is a versatile facility for the radiometric calibration and characterisation of satellite sensors.
- The system is provided fully characterized, calibrated and performance verified, with an easy-to-use software interface that allows fully automated remote operation.
- The main components of the STAR-CC-OGSE system are:
  - A collimated beam source, equipped with an interchangeable, position fine-tuneable feature field mask for optical performance characterisation
  - An M Squared CW laser allowing monochromatic continuous tuneability from 260 – 2700 nm. A broadband (white light) source extending over the same spectral extent.
  - A vacuum-compatible SI-traceable radiance detector module containing both broadband photodiodes & a spectrometer, installable in TVAC at the sensor-under-test entrance aperture



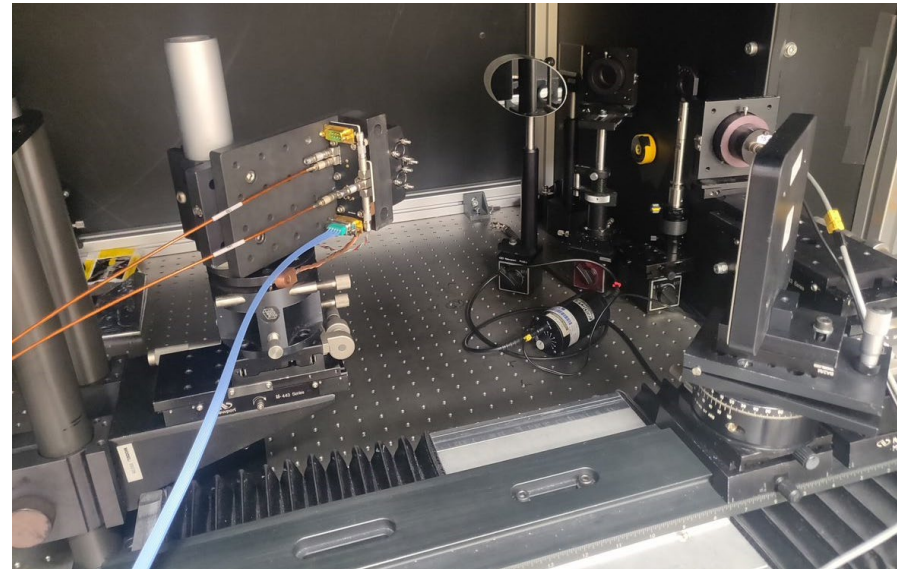
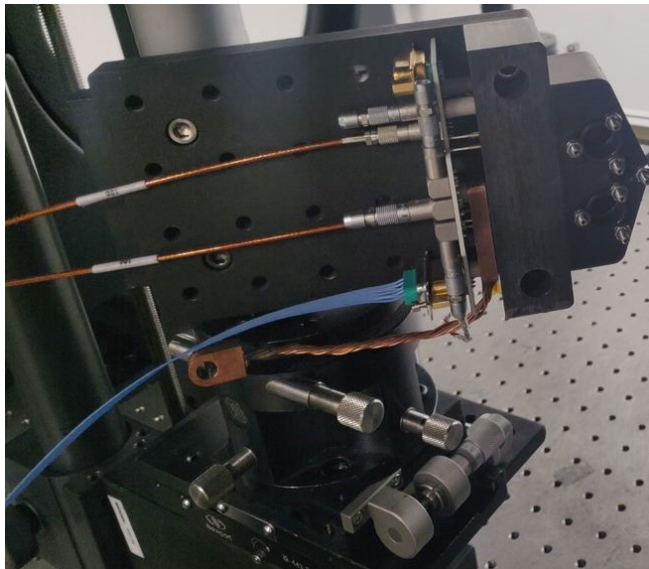
# Tuneable CW Laser System

- Fully tuneable CW laser systems from M Squared Lasers (MSL)
- High power (up to 2 W)
- Wide spectral range (260 nm – 2700 nm)
- Small tuning step (few pm)
- Narrow line-width (<0.1 pm)
- Fully automated and controlled remotely
- From a single facility allows:
  - Monochromatic radiance calibration
  - Spectral response characterization
  - Straylight characterisation



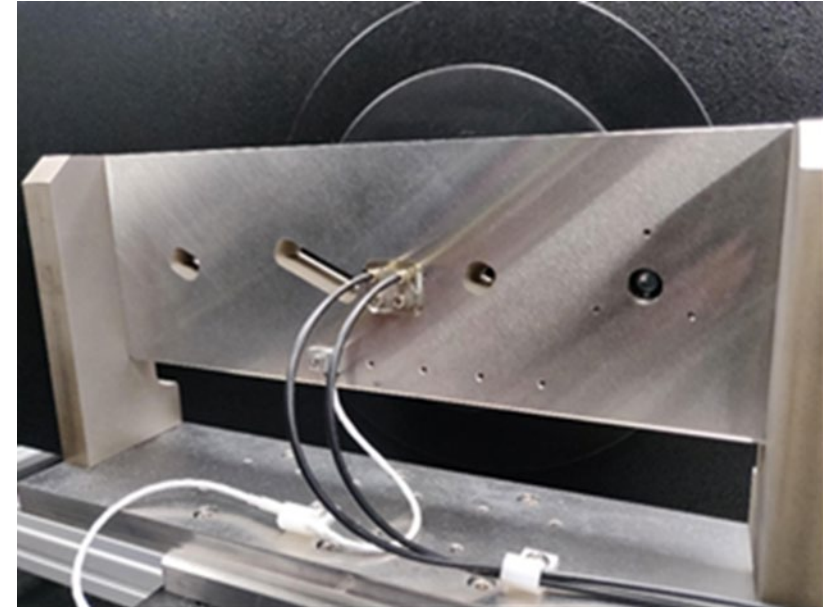
# Detector-Based SI-Traceability

- Traceability via detector system mounted at the instrument input port (in vacuum).
- Monochromatic accuracy  $\sim 0.5\%$  ( $k=1$ )
- 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



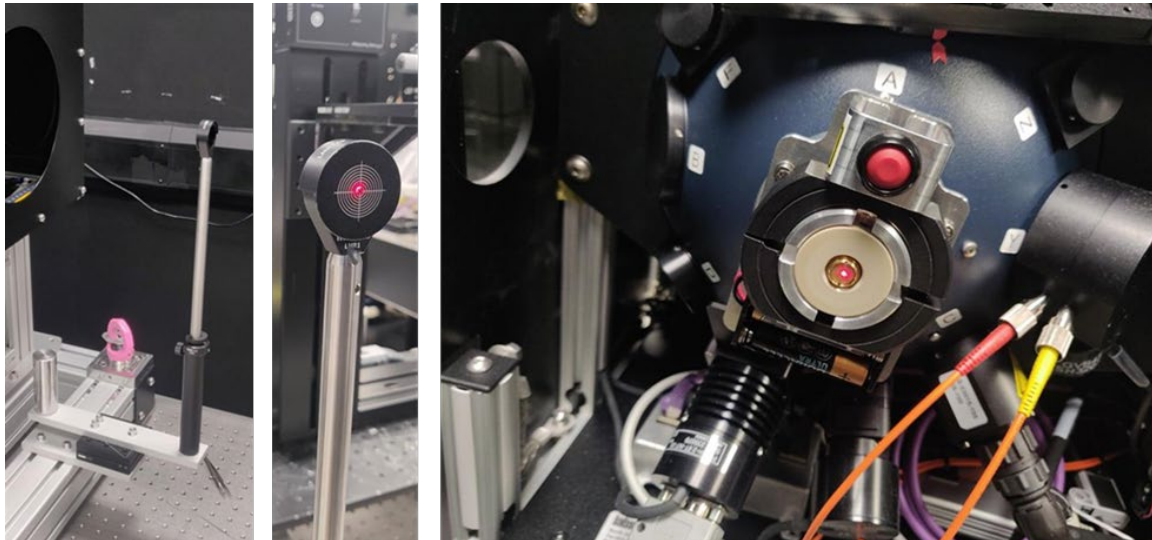
# Custom-Made Field Mask

- The field mask at the collimator focus is bespoke for each use, manufactured to fit the customer requirements & sensor input optic geometry.
- Precision engineering verified by SI-traceable dimensional measurements at NPL.
- Feature patterns include:
  - Slit / Edge
  - Pinholes
  - Square
  - High intensity point sources



# Usage

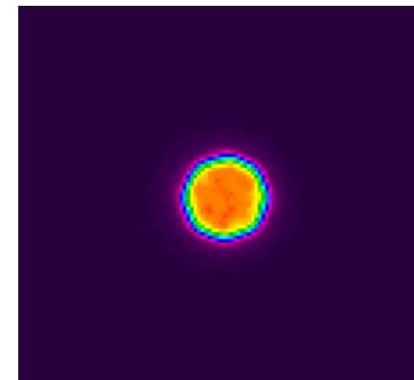
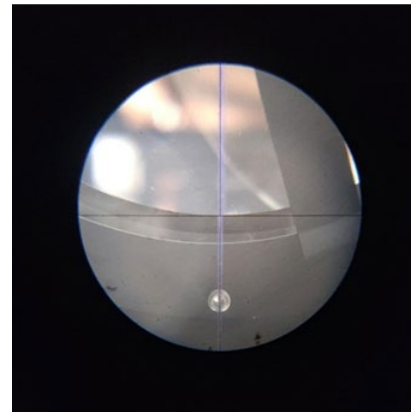
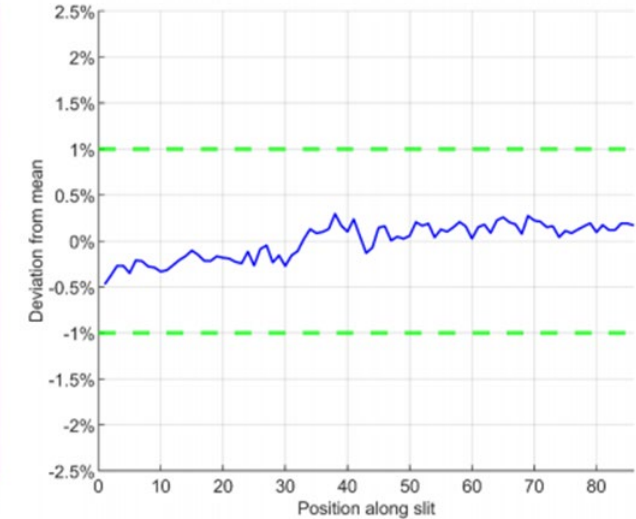
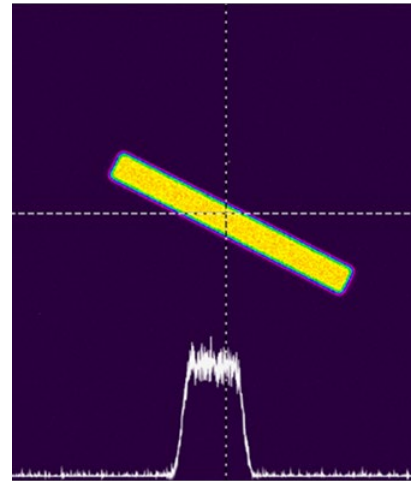
- Easily transportable to customer sites
- Crane-able in sections
- Repeatable interconnections
- ~500 Kg
- ISO 6 compliant (ISO 5 adaptable)
- Includes alignment infrastructure





# Verification and Performance Testing

- Field mask stage alignment
- Polarizer alignment
- Polarizer beam deviation testing
- Source spatial uniformity
- Source temporal stability
- System transmission
- Software operational testing
- CE marking and safety testing



# 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 <sup>-2</sup> .sr <sup>-1</sup> (@800nm)
Broadband typical radiance	Max. 2000 W.m <sup>-2</sup> .sr <sup>-1</sup> .nm <sup>-1</sup> (@1200nm)
Radiance spatial uniformity	Typically <0.15% PV (application dependant)
Radiance temporal uniformity	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 <sup>4</sup>
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.
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

# Conclusions

- STAR is available for hire
- Suitable for atmosphere, land and ocean missions
- Deployable to customer sites or measurements can be done at NPL
- Currently being used to calibrate and characterise the CNES/UKSA MicroCarb satellite
- For more details, contact me at [sean.devlin@npl.co.uk](mailto:sean.devlin@npl.co.uk)
- Any questions??