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

Paul D Green[1], Sean Devlin[1], William Kingett[1] and Nigel P Fox[1]

[1]*The National Physical Laboratory, Teddington, United Kingdom*
Corresponding e-mail address: paul.green@npl.co.uk

A robust SI-traceable pre-flight characterisation and radiometric calibration of satellite Earth Observation sensors is critical to maximising the value obtained from the data provided by our on-orbit environmental monitoring infrastructure. The NPL STAR-CC-OGSE pre-flight satellite sensor calibration and characterisation system has been designed as a generic OGSE facility capable of meeting the needs of the next generation of sensors. The STAR-CC-OGSE incorporates a fully automated tuneable CW laser system and is available on a lease basis to provide a cost-effective OGSE solution to the EO community.

INTRODUCTION

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

The evolution of 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. Sensor data is increasingly used synergistically; across individual platforms & constellations, across space agency providers and across spectral domains and measurement techniques.

The drive for improved performance, increased sensitivity to geophysical phenomena, together with the desire for inter-operability between sensors creates increased demands on the pre-flight characterisation and radiometric calibration of sensors and the facilities needed to undertake these activities. This paper describes the developments made at NPL to create the facilities needed to service the next generation of optical band and hyperspectral satellite sensors.

OPTICAL GROUND SUPPORT EQUIPMENT REQUIREMENTS

Sensor pre-flight characterisation and calibration facilities are better known as optical ground support equipment (OGSE). The purpose of an OGSE is to determine the sensor performance over a few broad categories including:

- Geometric performance / Image quality
- Channel/Band co-registration
- Spectral calibration / Out-of-band rejection
- Radiometric calibration
- Polarisation sensitivity
- Non-linearity, non-uniformity response etc.

The methods employed have advanced over time but routinely use broadband white light and emission lamp sources projected through an optical test card providing a known illumination against which to test the sensor performance. 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 programmes, a bespoke solution may remain the preferred solution. However, for single/few unit explorer missions, commercial constellations and more agile sensor development programmes, the expense & post-use redundancy of a bespoke OGSE system may be prohibitive.

THE STAR-CC-OGSE SYSTEM

NPL has developed a generic OGSE system, the Spectroscopically Tuneable Absolute Radiometric calibration & characterisation OGSE (STAR-CC-OGSE), a versatile facility for the radiometric calibration and calibration of satellite sensors, available through a cost-effective lease arrangement.

The system is provided fully characterised, calibrated and performance verified, with an easy to

use software interface that allows fully automated remote operation from the customer interface. The system can be installed at a customer cleanroom facility or operated at NPL with a customer-supplied sensor. The main components of the STAR-CC-OGSE system are:

- A large aperture integrating sphere source for radiometric calibration
- A collimated beam source, equipped with an interchangeable, position fine-tuneable feature field mask for optical performance characterisation
- A CW laser allowing monochromatic continuous tuneability from 270 nm to 2700 nm, with 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.

The laser illumination interface to either the small mask illumination sphere, large radiance sphere or direct to the field mask allows fully tuneable monochromatic illumination for all characterisation and calibration modes. Figure 1 shows a CAD model of the on-table assemblies.

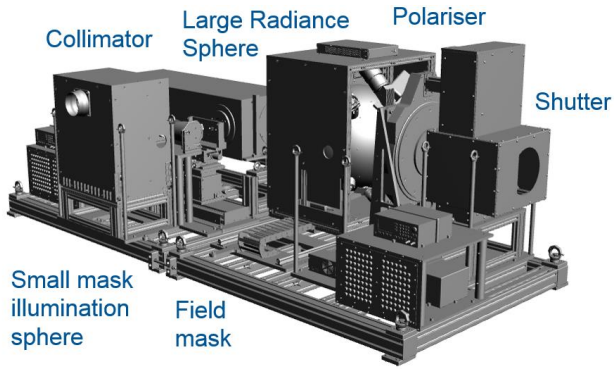

Figure 1. A CAD rendering of the STAR-CC-OGSE system. The collimator setup is to the left, the large sphere radiance source to the right, together with the polariser and shutter assemblies. The laser system and electronics rack (not shown) are connected to the on-table assembly via fibre & cable links.

SI-traceability via a vacuum-compatible detector-based module, that can be installed at the sensor-under-test entrance aperture, ensures the radiance at the sensor-under-test is directly measured with an uncertainty far superior to a source-derived calibration reliant on additional transmission measurements and modelling. Some of the system performance parameters are given in Figure 2 & Figure 3

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°

Figure 2. The STAR-CC-OGSE system radiometric and polarisation performance parameters.

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

Figure 3 The STAR-CC-OGSE physical performance parameters.

SYSTEM STATUS

At the time of writing the STAR-CC-OGSE is undergoing final performance testing, with delivery to the initial lease customer in Spring 2020. This paper will describe the STAR-CC-OGSE system, the outcome of the verification testing and system performance.