Centre for EO Instrumentation

Technology Market Case Study No. 9

Traceable Radiometry Underpinning Terrestrial- and Helio- Studies (TRUTHS)

The Challenge

A key challenge for the international climate science community is to establish an observational climate benchmark data set of sufficient accuracy to enable unequivocal detection of climate change, with the ability to constrain and test climate forecast models on a decadal time scale.

TRUTHS will enhance, by an order of magnitude, our ability to directly measure the Solar-reflective contribution to the earth's radiation budget, establishing an SI-traceable reference data set to cross calibrate other satellites and improve overall data quality from the Earth Observation (EO) system.

The mission objectives are: 1) to detect subtle changes in key indicators of climate change in as short a timescale as possible, in order to critically test climate models and attribute the effects of climate change to geophysical processes; and 2) to upgrade the performance of other EO sensors to near climate quality by 'reference calibration' against TRUTHS.

The Solution

The UK-led TRUTHS (Traceable Radiometry Underpinning Terrestrial- and Helio- Studies) mission, will address this issue, alongside sister satellites from the US and China.

The TRUTHS satellite will carry a Cryogenic Solar Absolute Radiometer (CSAR) to provide an onboard ultra-high accuracy reference standard calibration and hence SI-traceability for the duration of the mission. Inflight re-calibration to the CSAR provides the calibration anchor for the Hyperspectral Imaging Sensor (HIS) instrument, designed to measure the incoming solar radiation, outgoing reflected solar radiation and lunar irradiance to an unprecedented accuracy.

The combination of incoming and reflected solar measurements are key components in understanding the radiative imbalance underlying climate change, with the hyperspectral quality of the data allowing the attribution of effect to specific climate processes. The unprecedented accuracy will shorten the data record length needed to rigorously identify process trends, so critically test climate model predictions and support decision-making on climate adaption strategies.

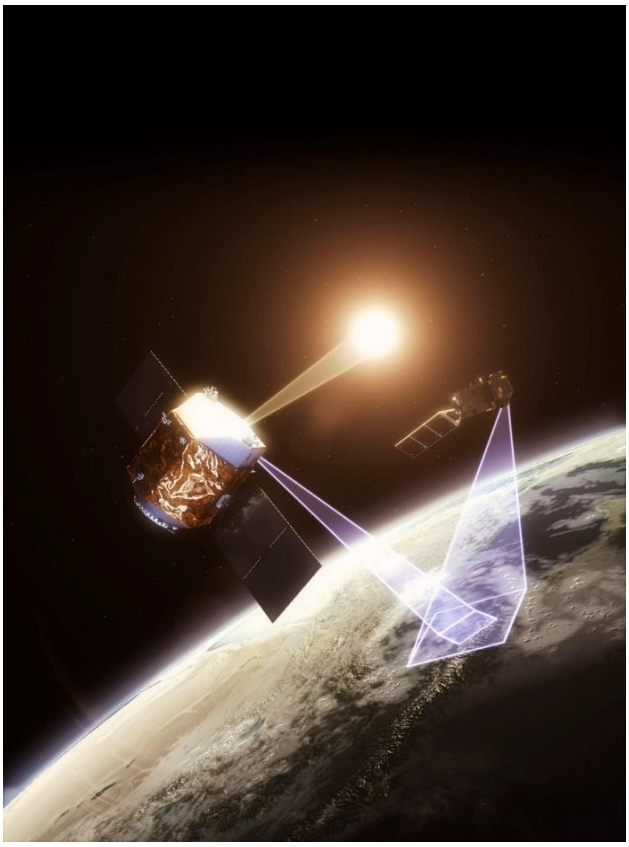

Figure 1: TRUTHS Mission (Credit: NPL)

TRUTHS will additionally serve to calibrate other satellite sensors, such as those carried on the Copernicus missions, through co-imaging operations.

Central to the TRUTHS philosophy is the calibration system which puts SI traceability into orbit. The Onboard Calibration System (OBCS) uses the CSAR to translate power measurements of reference

lasers at discrete wavelengths to the full spectrally resolved radiance calibration of the HIS. TRUTHS utilises techniques developed and routinely implemented in the laboratories at NMIs, but simplified, miniatured and ruggedised for in-orbit operations. The design optimises the number of components, minimises moving parts and where possible uses heritage space components and technologies.

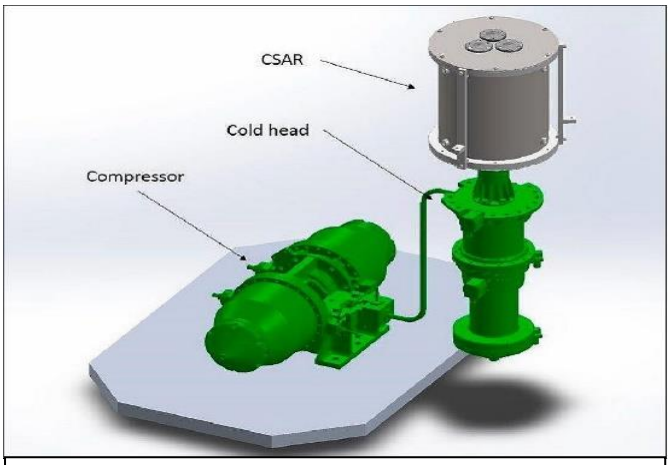

Figure 2: Schematic diagram showing overall layout for the TRUTHS Cryogenic Solar Absolute Radiometer (CSAR), Image credit: TRUTHS collaboration

Spectrally resolved radiance calibration of the HIS is achieved with a set of low power stabilized laser diodes, whose power output is measured by the CSAR. This measurement is used to calibrate a transfer detector (TR), that enables the power to radiance conversion step through geometric calibration of external apertures. A diffuser, illuminated at the same laser diode wavelength is viewed simultaneously and at reciprocal angles by the HIS and TR, allowing the TR to calibrate the HIS viewed radiance, and hence allow calibration coefficients for the HIS to be calculated.

The full OBCS with the CSAR has been demonstrated under vacuum, and all critical technology elements are anticipated to be at or above TRL 5 on completion of the Phase A/B1.

Support from CEOI

CEOI provided several rounds of funding, including:

Open Call 4:	Study to develop the mission and observation requirements.
Open Call 7:	Design study to trade-off complexity/risk/cost against science drivers
Open Call 8:	Flagship project with 3 main components: (1) Increasing TRL of the Cryogenic Solar Absolute Radiometer (CSAR) and the in-flight calibration system to level 5/6; (2) Design and build of a novel calibration system using monochromatic radiation to reach TRL 5/6 for key technologies; (3) Study to establish main parameters of TRUTHS mission (satellite mass, power, orbit, thermal analysis)
Open Call 9:	Study to strengthen science case for TRUTHS as an Earth Explorer mission, including the use of TRUTHS data to further the understanding of clouds and aerosols.

The Results

There were a range of outputs from the work supported by CEOI:

- Fully analysed and prioritised 'Science to Mission' technical requirements document and an optimisation based on technical readiness
- Design for a hyperspectral imager of high but achievable performance with analysis of radiometric and stray light performance
- Updated mission design achievable in space with a reduction in complexity from 5 to 2 instruments and seven to three mechanisms.
- Costed, implementable mission (all elements) in readiness for an opportunity.
- Evidence to prove the viability and performance of both the on-board calibration system and also the ability of TRUTHS to upgrade other sensors e.g Sentinel 2 from 3 to 0.5%.
- Development of a Space Climate observing system.
- A UK led mission concept with sufficient credibility and uniqueness to facilitate the establishment of a bi/multi-national mission on UK defined terms.
- Following the initial proposal by the UK Space Agency, TRUTHS was adopted at ESA's 'Space19+' Council at Ministerial Level as a future Earthwatch Mission.

Wider Deployment

The vision of an ultra-high accuracy reference standard in space has enabled NPL to promote SI traceability and data quality assurance to the Earth Observation community. It has also led to buy-in by the international community and particularly ESA of its importance. It is anticipated this will lead to further significant growth opportunities for the UK EO sector with 'trustable' data as a key differentiator.

Development during the project of a higher performance cryocooler which will enable improved performance of a range of technical and scientific equipment.

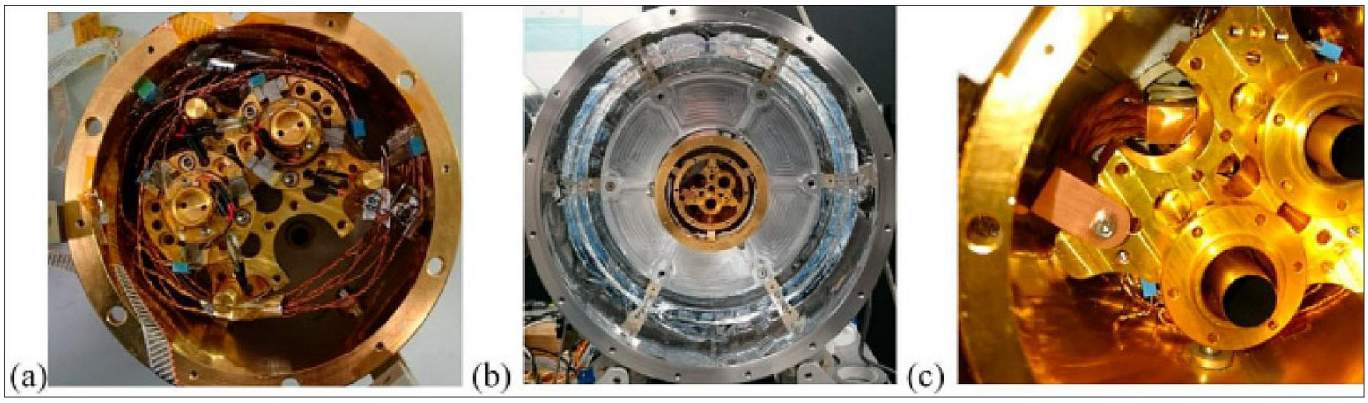

Figure 3. The TRUTHS CSAR laboratory demonstrator instrument, showing a) triple cavity detail (2 or 3 installed) b) the CSAR radiometric head (gold) with its vacuum housing (grey) and c) a detail of the cavity thermal-mechanical mounting.

Development of a carbon nano-tube black will open up new applications for blackbodies in lighting, heating, security, thermal imaging, space, and test & measurement applications.

TRUTHS data product will also underpin future UK climate service initiatives.

The Future

Airbus DS Ltd in Stevenage has been awarded the lead in the European Space Agency (ESA) contract for the TRUTHS A/B1 system feasibility study and pre-development activities as part of ESA's Earth Observation Earth Watch programme. The study is defining the TRUTHS mission system implementation concept as well as focusing on the preparation of critical technologies ahead of the planned implementation of the mission from 2023.

The TRUTHS study and pre-developments are funded by the UK Space Agency and supported by key UK space organisations including Teledyne e2v UK, National Physical Laboratory (NPL), RAL, University of Leicester, Thales Alenia Space UK, CGI IT UK, Telespazio-UK and Goonhilly Satellite Earth Station as well as important contributions from companies and institutes from the participating nations, which together with the UK are the Czech Republic, Greece, Romania and Switzerland. The overall A/B1 contract is worth approximately €16 million, including significant technology developments.

CEOI

Centre for Earth Observation Instrumentation (CEOI) works with UK academia and industry. Its objective is to develop a world leading, internationally competitive, UK Earth Observation (EO) instrument and technology R&D capability, enhanced through teaming of scientists & industrialists. CEOI is funded by the UK Space Agency with parallel technology investment from industry.

Further information on this & other technologies funded by CEOI can be found at ceoi.ac.uk, or contact: CEOI Director, Prof Mick Johnson: Tel: +44 (0)1438 774421 email mick.johnson@airbus.com.