New in-orbit calibration system set to provide 'unprecedented' accuracy in flight temperature measurements

A miniature calibration system the size of a bottle top is being developed to enable more trusted, accurate in-orbit temperature readings, crucial for measuring climate change and weather behaviour.

TRUST (TRaceability Using STandards) is an embedded calibration system that has been developed to mitigate the drift that thermometers are subject to when in space, and which causes uncertainties in long-term temperature trends.

TRUST will ensure that higher quality Earth observation data is provided for climate science and new space applications, including 24-hour global thermal coverage.

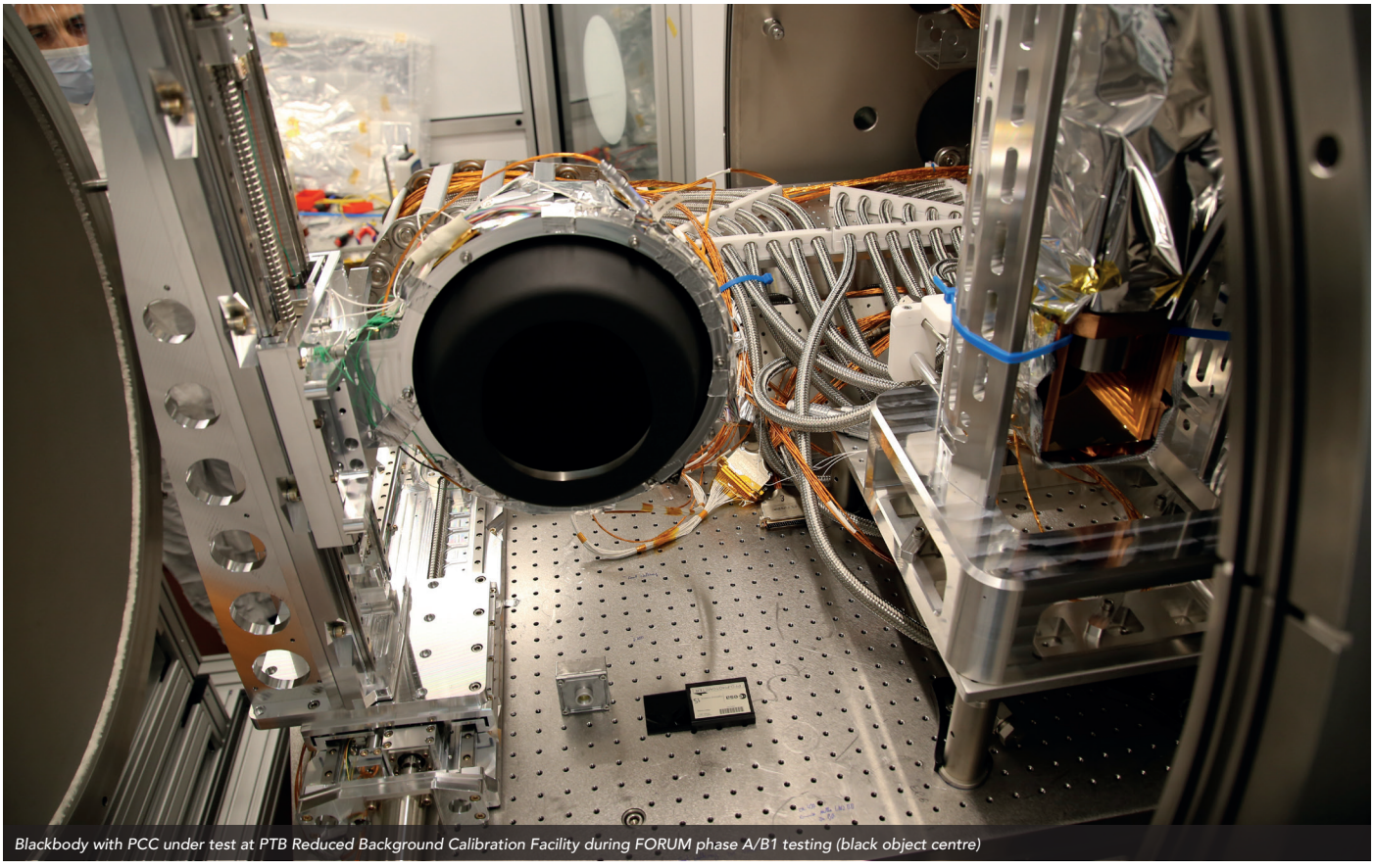
This technology has been described by potential end users as providing "unprecedented level of measurement precision".

The challenges of thermometry

Measuring temperature is vital for understanding climate change and weather, with satellites using reference thermometers. However, thermometry is notoriously unstable – on Earth, recalibration can be carried out each year to remove the drift that these systems inherently experience over time, and are calibrated against the standard measurements system Système international d'unités (SI).

Such recalibration is currently not possible in space, where drift can affect thermometers due to satellite launch vibration, the radiation environment and long mission life.

In climate change studies, where long term temperature trends provide vital information, these uncertainties in temperature can be problematic if Earth observation data is found to be unreliable.



Blackbody with PCC under test at PTB Reduced Background Calibration Facility during FORUM phase A/B1 testing (black object centre)

The background to TRUST

For more than 20 years, RAL Space has played a key role in developing the calibration systems for the Sea and Land Surface Temperature Radiometer (SLSTR) for the European Space Agency's (ESA) Sentinel-3 mission, designed to monitor the Earth's oceans, land, ice and atmosphere.

Currently, there is no way of calibrating, in orbit, mid-wave infrared (MWIR) and thermal infrared (TIR) Earth observation instruments to SI. To improve the capabilities of the technology underpinning SLSTR, RAL Space teamed up with the National Physical Laboratory (NPL).

The team began exploring the concept of flying a miniature, lightweight standards laboratory on board a blackbody to provide an 'absolute reference' in terms of temperature.

Supported by £275,000 in funding from the Centre for Earth Observation Instrumentation (CEOI), the concept was developed through the TRUST project, a 22mm-tall phase change calibration system. It works by warming the system's sensor, causing a material in the calibration system to melt. This means a phase change has occurred, with energy absorbed at a precise, repeatable temperature. The energy absorption can be observed and analysed to provide a known temperature for thermometer calibration. Ultimately, it means that thermometer and electronics drift can be corrected using this known temperature, providing an SI-traceable reference on orbit.

The technology was demonstrated using Gallium, Gallium-indium, and water cells, achieving high accuracy and establishing RAL Space and NPL as European technology leaders in miniature temperature reference.

The TRUST technology was later adopted by ESA for the FORUM (Far-infrared Outgoing Radiation Understanding and Monitoring) Phase A/B1 pre-development activities, showing strong recognition of its potential. Two instrument concepts were taken forward, including one using TRUST. Although the TRUST-equipped instrument was not selected for flight—and the alternative design was chosen—the decision was unrelated to the TRUST technology. The pre-development work clearly demonstrated that TRUST is robust, capable, and mature, strengthening its prospects for future Earth-observation missions.

Current status of the project – TRUST II

The team received further funding from CEOI, £158,000, for TRUST II, a project that was established after it was found that some cells in the calibration system were undercooling, meaning they would not freeze repeatably.

TRUST II is developing the technology from Technology Readiness Level (TRL) 4 to TRL 5, by testing in a representative thermal environment while mitigating against undercool.

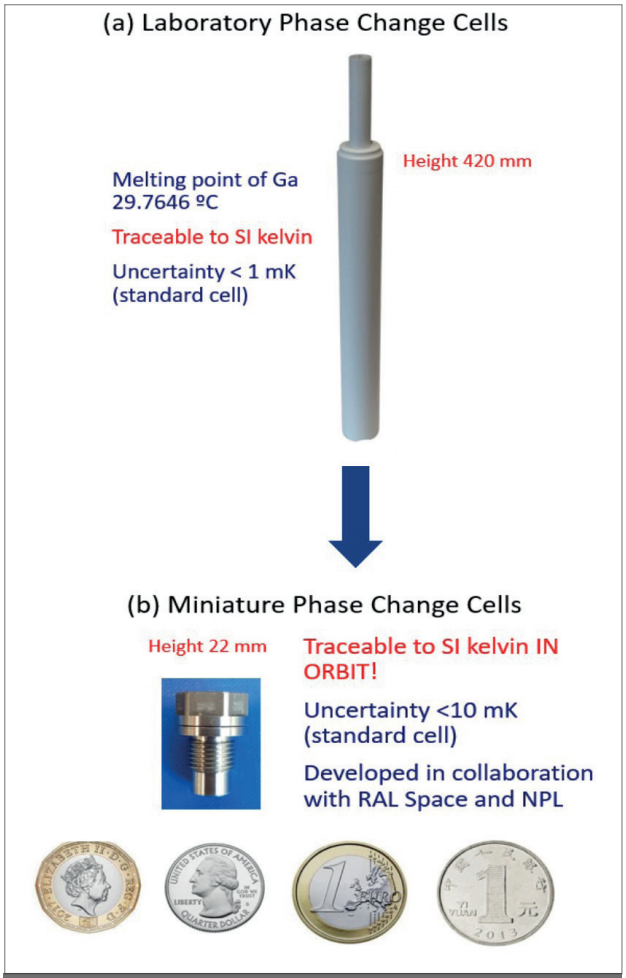
Controlling the cycle and phase changes is vital to demonstrating the feasibility of this technology for use on orbit.

What's next?

The TRUST technology, and the potential it offers, has attracted significant interest from the space industry. This includes Leonardo Space, which has identified the miniature phase change cell technology as a key area of interest, and is looking to adapt this technology into the next generation SLSTR on ESA's Sentinel-3 mission. RAL is on contract as part of the phase B1 pre-development including this technology.

The TRUST team is looking to target the TIR and MWIR supply chain, which has been identified as a key growth area in the coming decade, and are actively targeting climate, environment, meteorology, and defence-based markets.

Public and private funding avenues are being explored to move to higher TRLs, with a view to developing bread board and full-scale models according to customers' individual needs.



Miniaturisation of PCC from Ga laboratory standard (a) to RAL/NPL Ga miniature cells (b)

In the words of Dr Dan Peters

Section lead, InfraRed calibration technology, RAL Space

"For those interested in climate measurements, it is vital that the measurements made from space remain stable over time. If you are interested in slow changes in temperature and the changes in degrees over decades, you require a very stable calibration system. For these bigger missions encompassing climate studies, TRUST enables you to have standard re-calibration on orbit.

For New Space constellations, where you have many different instruments, thermal infrared is becoming a hot topic. In-roads are being made but it's still relatively new, and there are not many instruments on orbit that are taking meaningful thermal measurements.

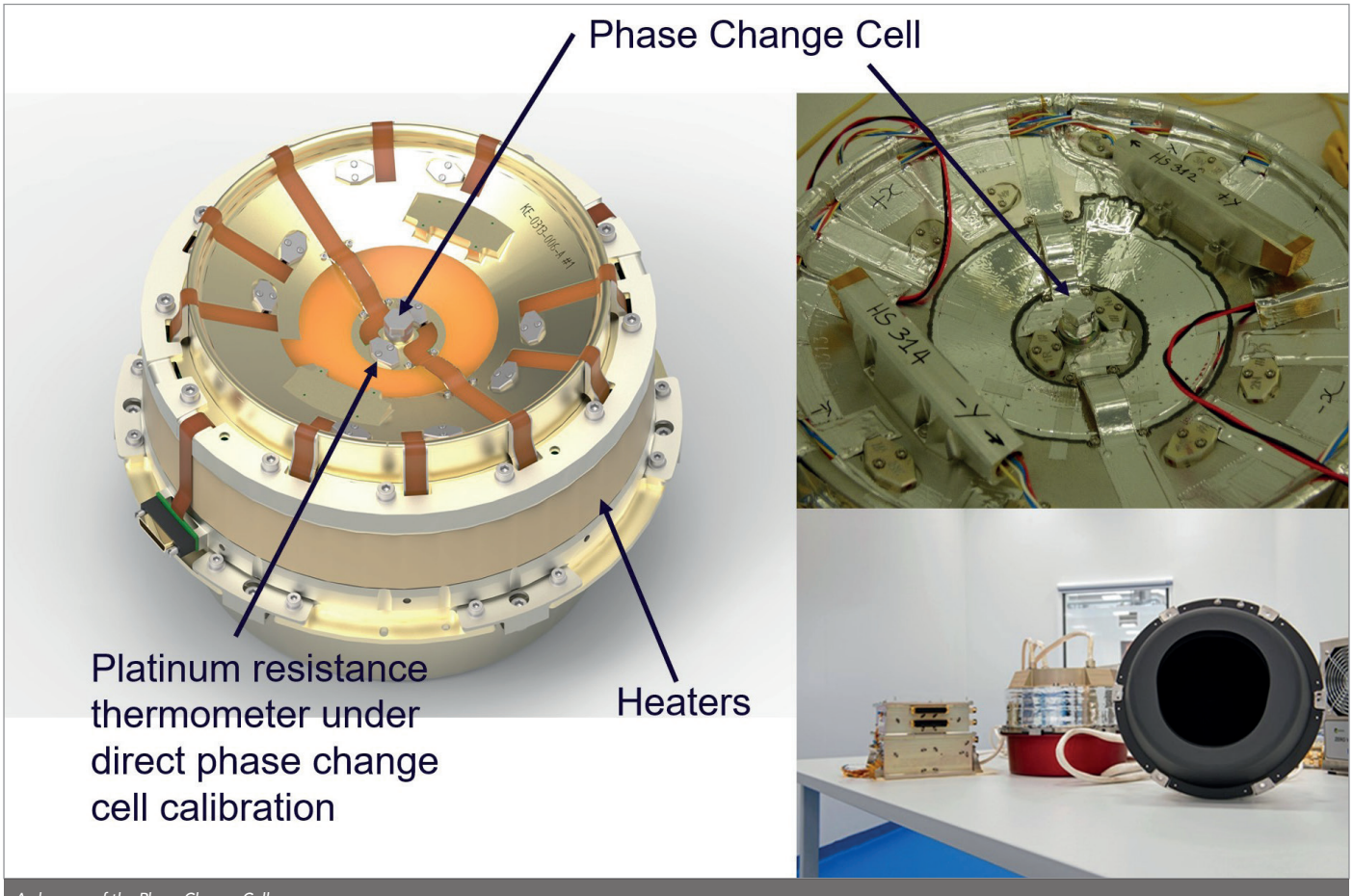
Having standard re-calibration on board is useful when you have many instruments and you need to compare them – it's about inter-instrument calibration. It could also be that some of the expensive calibration you do on the ground could be done on orbit, as this technology flies with the instrument.

As the name suggests, it's about trust in the measurements and trust in the quality of the data coming out of the spacecraft, and that it's comparable between instruments and comparable over time.

We need to have the critical technologies to be leading in this field and to enable the UK to be competitive in this arena. The UK has a long history in thermal infrared imaging, radiometry and spectroscopy, and this is part of that story – to remain a leader we need to keep our expertise.

This project helps to maintain and strengthen the UK's capability in thermal infrared by providing the necessary calibration technology, enabling access to the growing commercial, operational and scientific markets.

Crucially, thermal infrared is also important for the defence industry – we need that capability in-house."



A close up of the Phase Change Cell

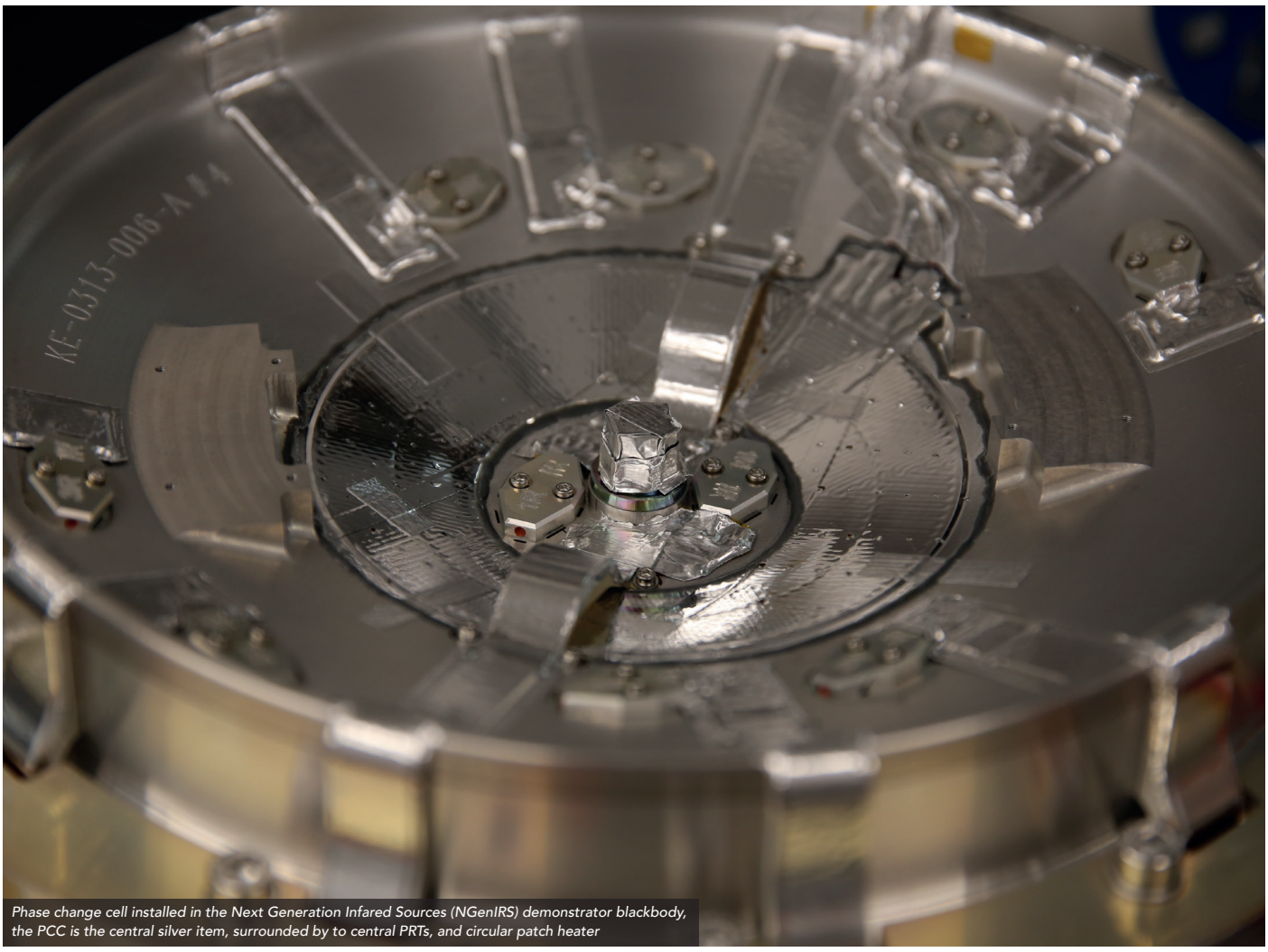
The impact of funding from CEOI

The tranches of funding from CEOI allowed the team to continue to develop the TRUST project and overcome initial setbacks. The development of the different elements to this technology has already led to the team securing more than £1m in commercial contracts.

The funding has provided training and upskilling opportunities too – two graduate engineers joined the project, allowing key skills to be passed on so that projects can continue to be developed. This is particularly important in climate science where programme duration can range from 10 to 30 years.

At a glance

- Funding from CEOI: **£433,000**
- Other funding steams: On contract for ASLSTR phase A/B1 study with ESA – this technology allowed the team to **win** this contract
- Number of people involved in TRUST: **6**
- Years in development: **2 years to date**
- Capability of TRUST: Aiming for **10mK accuracy** traceable to the SI over mission lifetime
- Training opportunities: The project provided training for **two graduates** from RAL and NPL



Phase change cell installed in the Next Generation Infared Sources (NGenIRS) demonstrator blackbody, the PCC is the central silver item, surrounded by to central PRTs, and circular patch heater