‘Game changing’ new space instrument set to plug gap in crucial climate change data

The development of an Earth observation instrument could provide “critically needed” climate change data in a key part of the atmosphere that is a driver for the Earth’s climate.

The upper troposphere and lower stratosphere, termed the middle atmosphere, stretches from eight to 50km from the Earth’s surface.

Along with being a poorly observed part of the atmosphere, the middle atmosphere is described as the “canary region” due to its sensitivity. Any changes in the chemical composition in this region causes significant feedback on the Earth’s surface temperature and the evolution of the climate itself.

Scientists are concerned about the large observation gap in this region, with very few instruments monitoring it, at a time when the climate is changing at its fastest pace.

Nadir observation, when a satellite observes by looking down, measures the integrated column of air between the spacecraft and the ground. This dilutes the signal from the middle atmosphere and does not provide the information required by scientists.

Monitoring and understanding the fine vertical distribution of gases in these regions of the atmosphere is essential to improving weather and climate modelling and predictions, improving emissions estimation, and monitoring the impact of human activities on stratospheric ozone recovery.

ENTER SOLSTICE

SOLSTICE: Solar Occultation Limb Sounding Transformative Instruments for Climate Exploration

SOLSTICE evolved from the CubeMAP mission, developed under the ESA Scout programme. These missions were designed to show the capability of small satellites to deliver value-added science, either by miniaturising existing space technologies or by demonstrating new observing techniques.

The technology underpinning CubeMAP was one of the first supported by the Centre for Earth Observation Instrumentation (CEOI) in 2007. CubeMAP aimed to quantify processes in the middle atmosphere to understand how they affect the climate, by measuring fine vertical profiles of water vapour, carbon dioxide, methane, ozone, nitrous oxide and aerosols.

From there, SOLSTICE was developed to create an observing system that was cost effective – aiming to be 20 times cheaper than traditional systems – by leveraging New Space, small satellites and constellation flying to monitor the middle atmosphere with an unprecedented combination of accuracy and coverage.

SOLSTICE will provide a very rich dataset of monthly three-dimensional maps of water vapour, ozone, aerosols and some greenhouse gases in the middle atmosphere. This dataset will be utilised to quantify the impact and feedback of climate change, such as an increase in water vapour content; monitor stratospheric ozone recovery; and understand the impact of greenhouse gas and aerosol injection in this part of the atmosphere.

SOLSTICE will also complement existing nadir sounding infrastructure. Accurate representation of the middle atmosphere from independent SOLSTICE observations will allow improved analysis of nadir measurements from other satellites, for example, leading to better greenhouse gas emissions data products.

HSDI Instrument – 10cm x 10cm Hyperspectral visible camera for accurate sun pointing, and water vapour, aerosols, pressure and temperature data products

The dataset from SOLSTICE will also provide thermal infrared optical information to complement and enhance millimetre wave data, strengthening the prediction capabilities of current Numerical Weather Prediction models.

In addition, SOLSTICE will provide additional data to train AI-based numerical models and digital twinning to derive weather prediction and environmental data products, further enhanced by the scalability of the SOLSTICE constellation.

SOLSTICE has been developed by RAL Space in collaboration with Bright Ascension and Open Cosmos.

The impact of funding from CEOI

£1m of CEOI funding was provided for the underlying technology behind the development of SOLSTICE – the highly innovative laser heterodyne radiometer.

Following this and the development of CubeMAP, RAL Space received a further £2.6m of CEOI grant funding to progress the concept towards space qualification through the development of SOLSTICE.

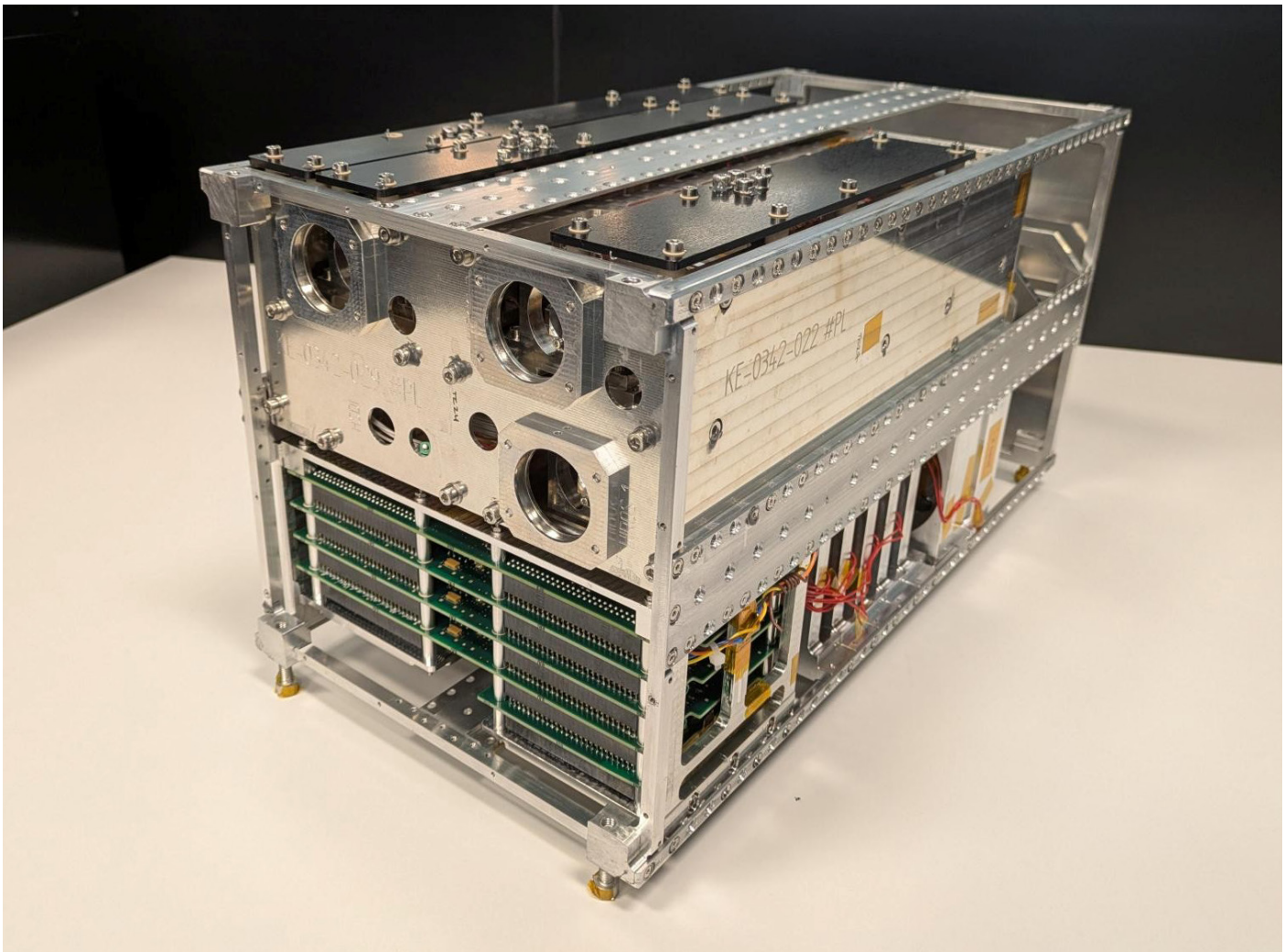
The team used the funding to ensure the instrument is as versatile as possible, adopting a 'plug and play' approach so it is not bound to a specific mission and can be adapted very quickly to ensure SOLSTICE is commercially scalable and suitable for a range of deployment platforms.

The funding enabled the building and testing of the full payload system within a representative spacecraft structural and thermal model, including the main spectrometer and the electronics associated with the 'plug and play' methodology, to demonstrate its validity for space deployment. The second part of the project involved developing flexible flight software to process captured data and produce the scientific products for future missions.

Ultimately, CEOI funding de-risked the SOSLTICE concept to first level of space qualification, ensuring it can move to the next milestone – flight qualification. It also provided evidence to attract commercial and institutional collaborators and develop mission options including those with other countries. SOLSTICE is now ready for demonstration through a CubeSat demonstration flight.

Current status of this project

The team is currently exploring opportunities to enable the project to move to flight qualification.



SOLSTICE payload with instruments and flight software control unit, integrated within 16U spacecraft Structural Thermal Model

In the words of...

Dr Damien Weidmann

RAL Space Spectroscopy lead

"This project is a unique opportunity to observe this sensitive region of the atmosphere, providing badly missing data for the next couple of decades.

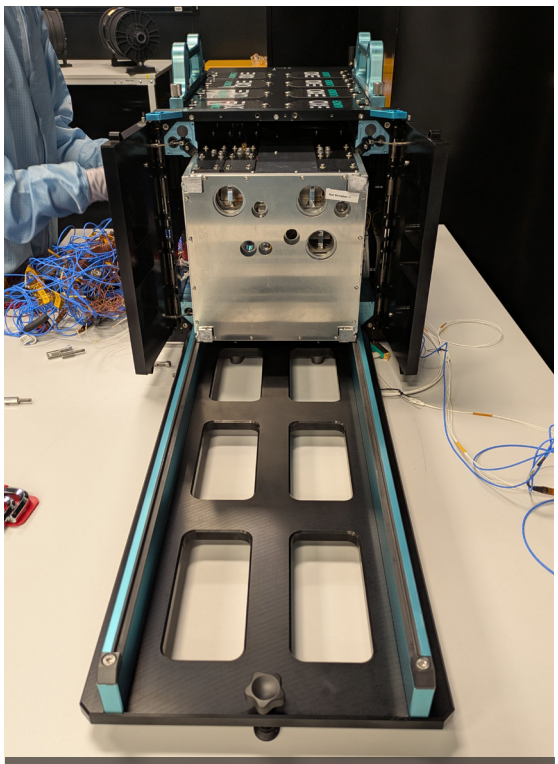
Observing the atmosphere with a very high vertical resolution traditionally cost a lot of money – around £500m – which is why there are so few space systems doing so. SOLSTICE is a game changer because for the first time, it can be done at a reasonable cost.

There is currently no EO mission that will observe this part of the atmosphere for the next 20 to 30 years, at a time when the climate is changing at a very fast pace and when more and more data services need data to train their machine learning and algorithms.

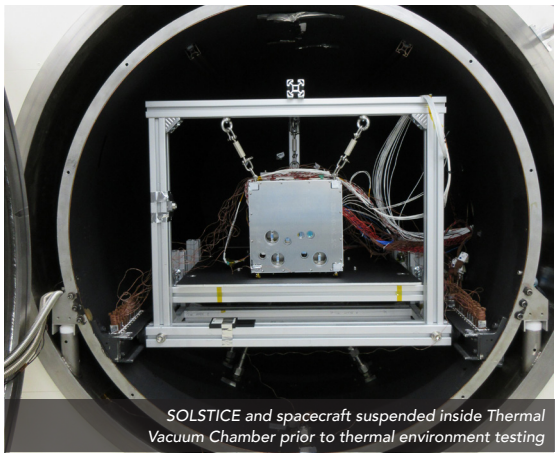
Bringing together high-quality scientific instruments miniaturised to work with CubeSat and using New Space sector approaches enables, for the first time, a cost-effective way to measure the middle atmosphere, and develop scientific and commercial missions offering this dataset.

Funding from CEOI progressed the technology readiness levels of the scientific platforms and ground segments and derisked the mission so we could be in a position to secure the next phase of funding to go for full flight qualification.

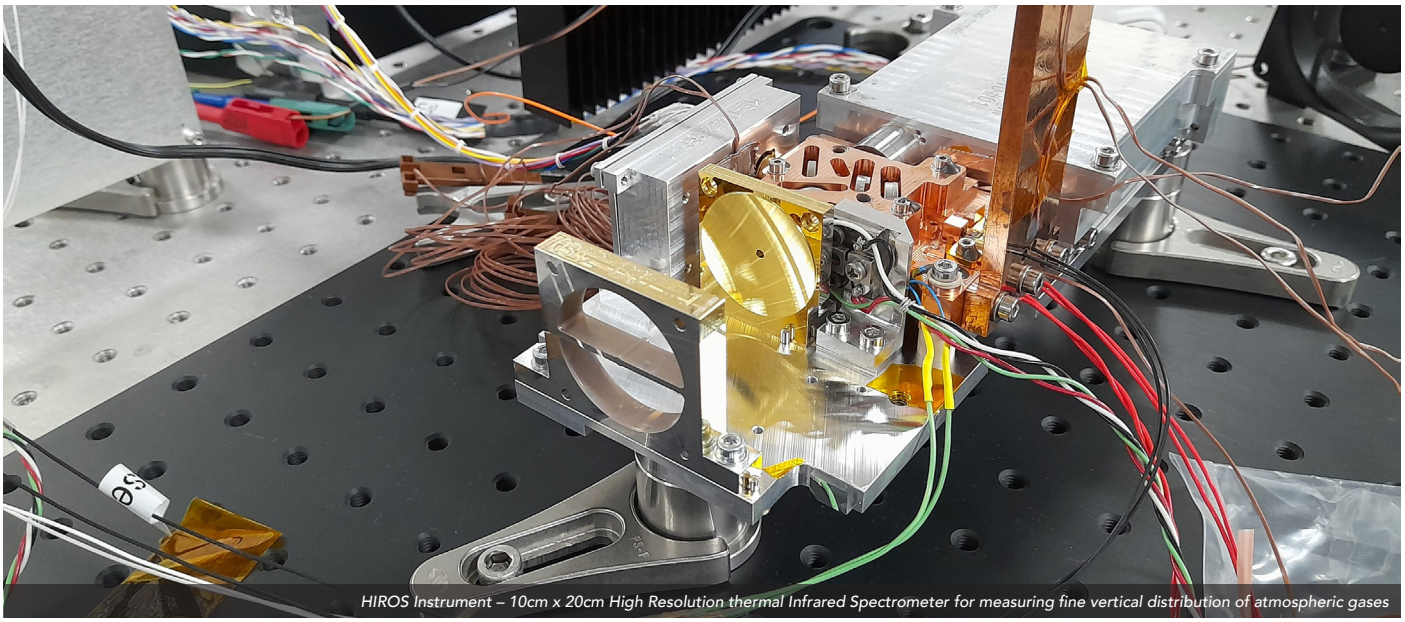
SOLSTICE provides important advances in UK strategic goals for Space, delivering completely new Earth observation instruments, leveraging UK strengths and providing novel UK scientific capabilities."



SOLSTICE and spacecraft loaded into launcher pod, prior to vibration and shock testing



SOLSTICE and spacecraft suspended inside Thermal Vacuum Chamber prior to thermal environment testing



HIROS Instrument – 10cm x 20cm High Resolution thermal Infrared Spectrometer for measuring fine vertical distribution of atmospheric gases

At a glance

- Other funding streams: **ESA – £4m**
- Total cost of the project to orbit demonstration: **£15m**
- Number of people involved in the project: **More than 50** over its lifetime
- Number of jobs SOLSTICE could create in the first 12 months of launch to market: **10**

SOLSTICE and spacecraft in launcher pod on vibration table, prior to launch loads test