How mapping greenhouse gas emissions could shape climate change goals

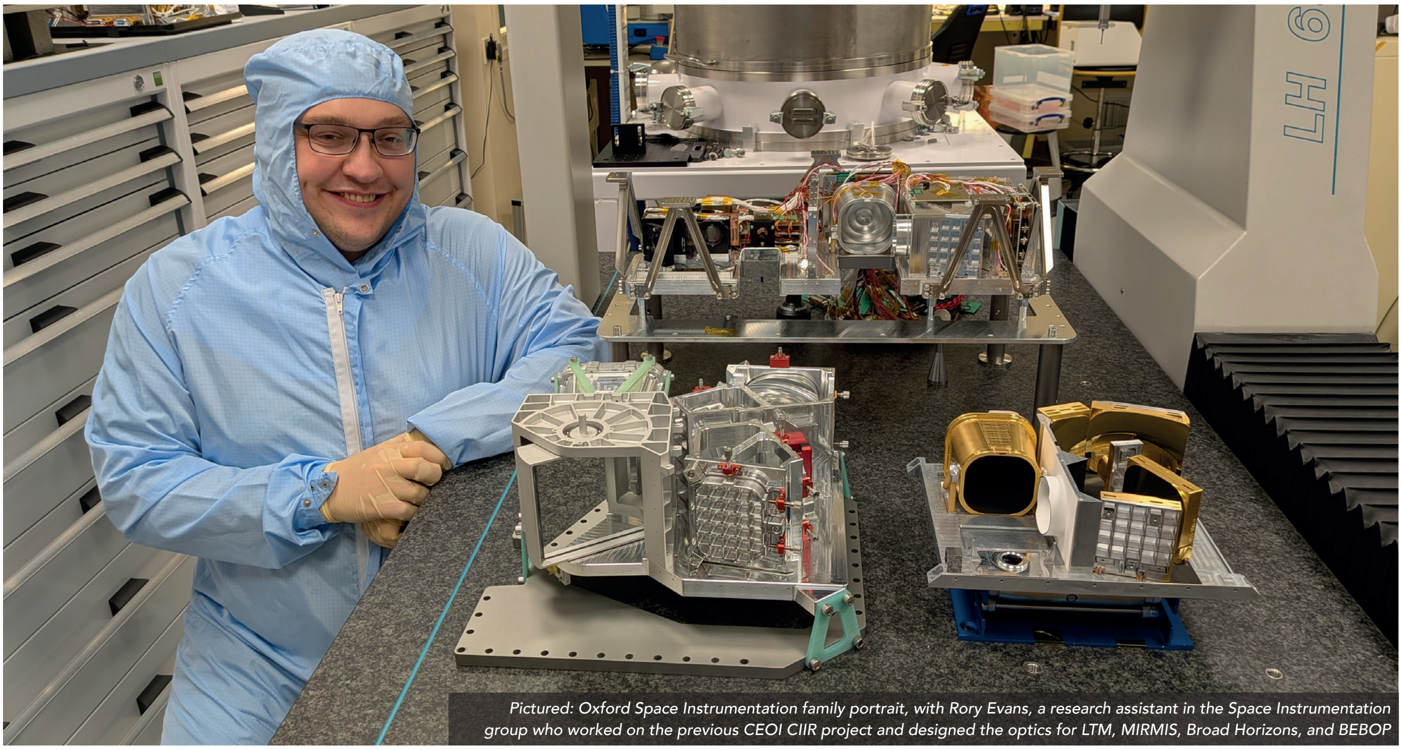
The team behind a space instrument designed to map greenhouse gas emissions has described the technology as "vitally important" in monitoring climate change, particularly for areas of Earth where changes happen seasonally and rapidly.

Broad Horizons, a thermal imaging instrument, is the result of modifications to an existing infrared imager and radiometer, and is designed to make observations of the Earth from a medium orbit.

This modified design allows it to obtain near-global coverage of greenhouse gas emission and the thermal structure of the atmosphere and heat signatures, along with abundances of key gases including carbon dioxide, ozone and water.

Such findings can pinpoint emission hotspots and smoke outputs, informing the management and reduction strategies of greenhouse gas emissions, shaping climate goals and even measuring reduction performance against climate goals.

Broad Horizons is the result of about eight years of work by the University of Oxford in collaboration with Durham University.



Pictured: Oxford Space Instrumentation family portrait, with Rory Evans, a research assistant in the Space Instrumentation group who worked on the previous CEOI CIIR project and designed the optics for LTM, MIRMIS, Broad Horizons, and BEBOP

The background to Broad Horizons

Broad Horizons is an adaptation to a well-developed space instrument design from the University of Oxford. Its origins can be found in the Compact Infrared Imager and Radiometer (CIIR), a new approach to infrared sensing of the Earth from space to provide calibrated data over hours and years.

Supported by funding from the Centre for Earth Observation Instrumentation (CEOI), CIIR was developed to understand the effects of aerosols, clouds, and the behaviour of stratospheric water vapour on the Earth's radiation budget – the balance between incoming solar energy and outgoing energy.

From there, CIIR was derived into the Lunar Thermal Mapper (LTM), a more refined and more compact version of the instrument that was part of the payload for NASA's Lunar Trailblazer mission to the Moon in February 2025. The aim of LTM was to detect and map water on the Moon's surface.

The LTM design was further refined to become MIRMIS – the Modular InfraRed Molecules and Ices Sensor – which will fly in 2029 on ESA's Comet Interceptor. This mission will intercept and fly past a comet and use MIRMIS to study its thermal structure and determine the composition of its nucleus.

Enter Broad Horizons

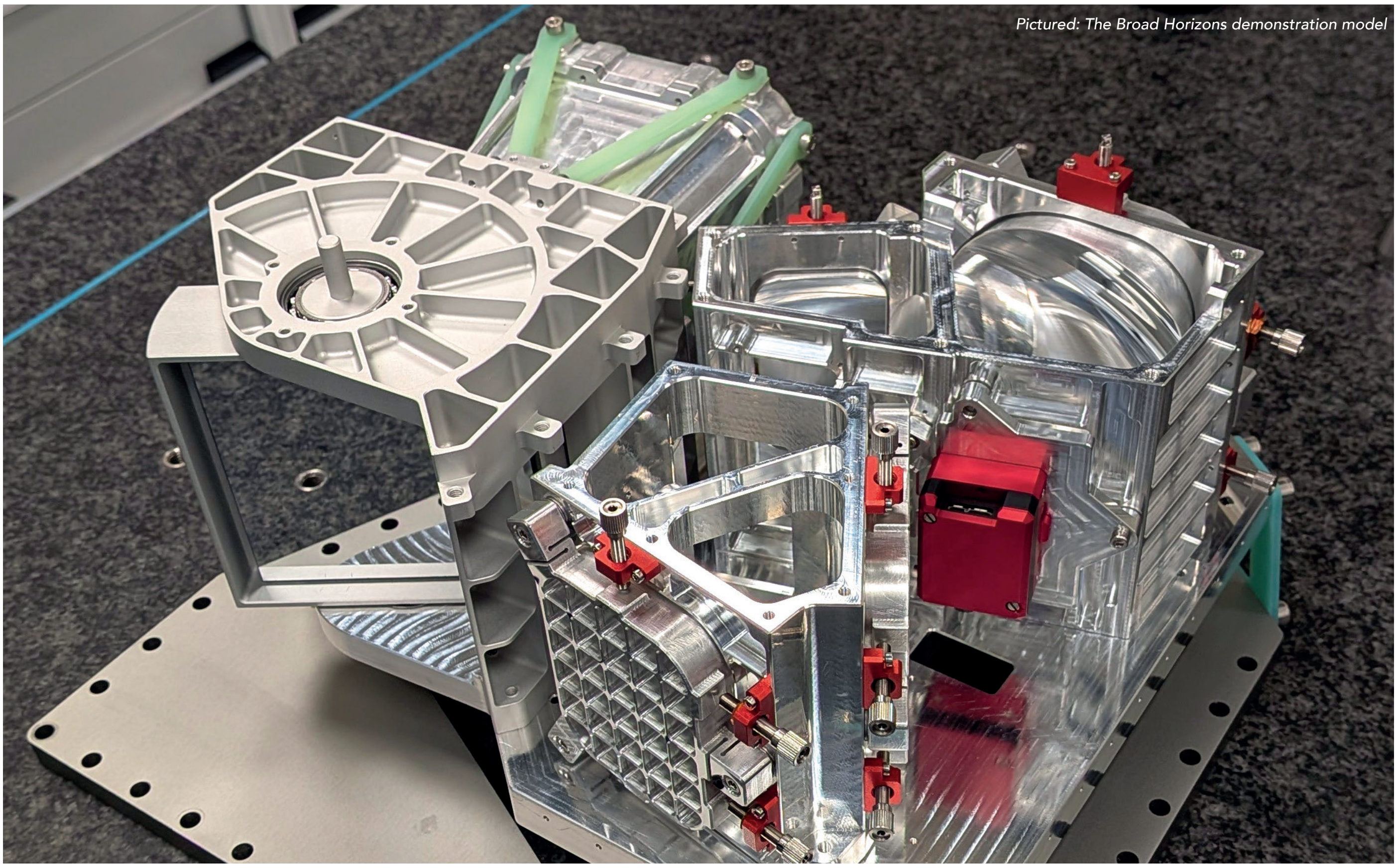
The next chapter in the development of this technology was Broad Horizons, again supported by the Centre for Earth Observation Instrumentation.

This saw adaptations to the Lunar Thermal Mapper to allow the mapping of large areas to study the Earth's atmosphere.

While there are existing instruments which perform a similar operation, these can weigh more than 300kg and cost more than $1 billion. Broad Horizons achieves the same result at one per cent of the cost.

Taking the form of a small-sat application with two or three telescopes, Broad Horizons can image the entire disk of the Earth at a spatial resolution between 2km and 4km per pixel.

This has been achieved through developing the existing technology: the broadening of the instrument's field-of-view and moving to a larger format detector with a higher pixel density. These adaptations increase the range of coverage and the spatial resolution of the instrument.



Pictured: The Broad Horizons demonstration model

The team behind Broad Horizons

- **Kevin Olsen**
  Instrument Principal Investigator, University of Oxford
- **Rory Evans**
  Designed the optical systems in CIIR, LTM, MIRMIS, Broad Horizons, and BEBOP, University of Oxford
- **Henry Eshbaugh**
  Lead software engineer for LTM, University of Oxford
- **Liam McSherry**
  Principal Engineer for MIMRIS, University of Oxford
- **Cyril Bourgenot**
  Head of the Durham University Precision Optics Lab, Durham University

Critical collaborators also include Simon Calcutt (ret.) and Neil Bowles from the University of Oxford Department of Physics Space Instrumentation group.

In the words of Dr Kevin Olsen

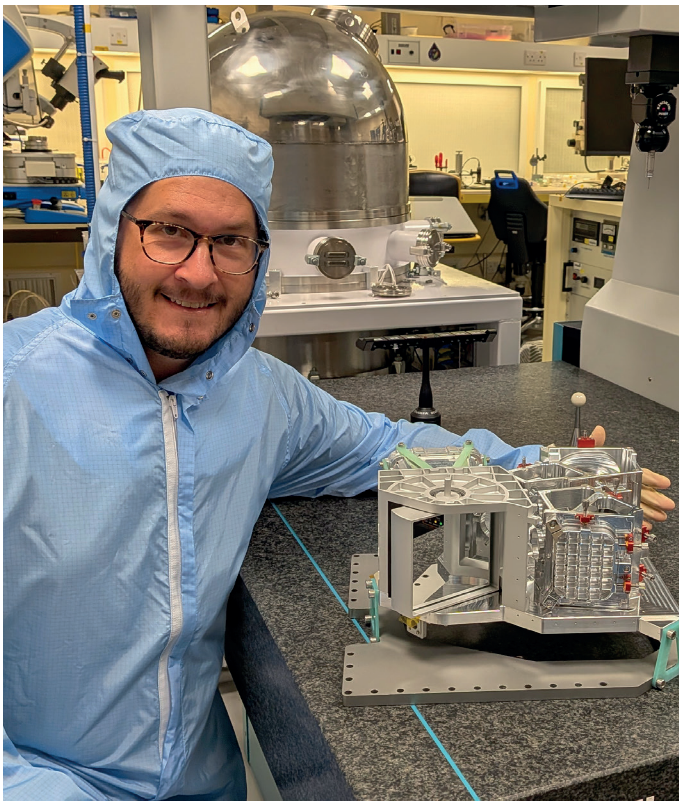
Instrument Principal Investigator, University of Oxford

"Broad Horizons, as its name suggests, enables us to see a much larger area, with excellent spatial resolution and sensitivity. By imaging wide swaths of the Earth we would be able to map pollutant emissions and find hot spots, like wildfires.

With our satellite, you'd be able to monitor – on a regular basis, several times a day – the entire Greenland ice sheet and the ice around it. You can monitor how fast it is melting, what the heat signature is, and study how heat is being transferred from the ground through the ice into the atmosphere. You can also monitor greenhouse gases so it's a really important instrument for keeping track of climate change, especially things that change seasonally and rapidly.

The Arctic is a really important application for this satellite because other satellites that make these type of measurements are in geostationary orbit, and they can't see that far north.

Broad Horizons could be used to map ice coverage and forecast weather over the Arctic region where we have increased shipping and commerce."



Pictured above: Dr Kevin S Olsen with the Broad Horizons demonstration model built with a CEOI Pathfinder Grant

Current status of this project – Introducing BEBOP

While the team looks for opportunities to launch Broad Horizons, their concept directly led to BEBOP (Broadband Exploration with Bolometric Optics), a thermal imaging system tasked with accurate weather forecasting on Mars in order to improve the safety of robotic or human explorers on the Mars surface.

The primary scientific objective is to characterise the contemporary climate of Mars, to determine the origin of large dust storms, and to learn how to predict these storms.

In order to move from the Moon-observing Lunar Thermal Mapper design to the Mars-facing BEBOP, the telescope field-of-view needed to be widened, employing detectors with a higher density of pixels – exactly what the Broad Horizons development provided.

The European Space Agency (ESA) recently announced that BEBOP is among its preliminary selection of payloads for its future missions to Mars, the ESA LightShips.

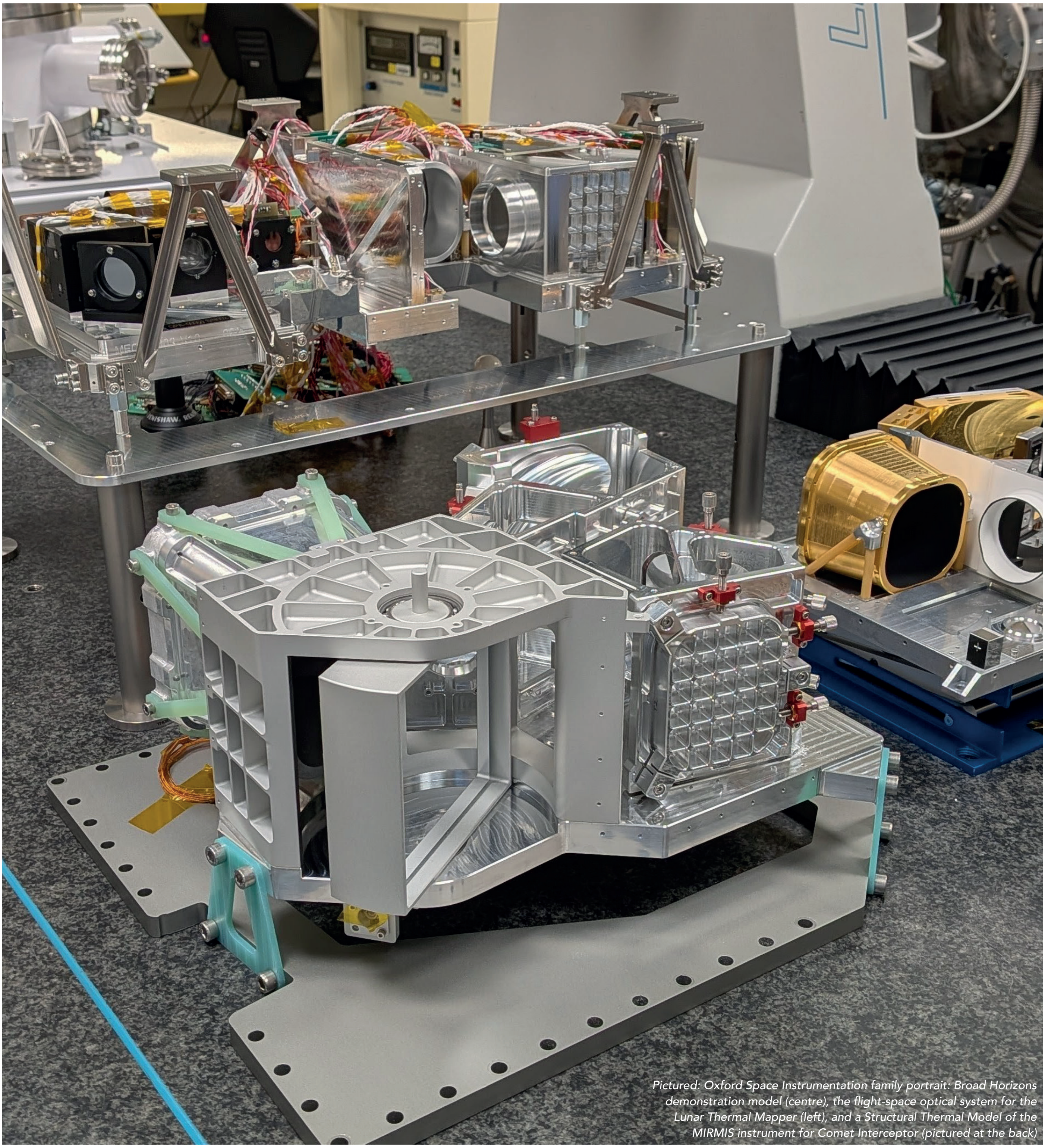
The impact of funding from CEOI

Two grants from CEOI allowed the team to prove it could build an optical system that performed in the way they wanted, raising the Technology Readiness Level and proving that Broad Horizons works in the lab.

Not only that, the funding gave the team the time to iron out the details and write a technically sound proposal, in time to respond to the European Space Agency's call for instrument proposals for the LightShip missions to Mars. This included a completed design to demonstrate exactly how the optics work and how data is captured.

At a glance

- **£143,000** provided by the Centre of Earth Observation Instrumentation for the CIIR breadboard study and the development of Broad Horizons
- Capability of Broad Horizons: 16 channel infrared images with a **spatial resolution of 2km – 4km**
- Number of people involved in the project: **5**



Pictured: Oxford Space Instrumentation family portrait: Broad Horizons demonstration model (centre), the flight-space optical system for the Lunar Thermal Mapper (left), and a Structural Thermal Model of the MIRMIS instrument for Comet Interceptor (pictured at the back)