Technology Market Case Study No. 10

Compact Infrared Imager & Radiometer (CIIR)

The Challenge

The Compact Infrared Imager and Radiometer (CIIR) is a new approach to infrared sensing of the Earth from space that can provide calibrated data over hours and years. Scientific rationale for deployment as a limb sounder is to understand the effects of aerosols, clouds and stratospheric water vapour behaviour on the Earth's radiation budget, key to understanding our climate. The instrument can also be deployed in nadir mode to monitor the Earth's surface in the thermal IR region.

One of the most challenging problems confronting atmospheric science is the understanding and prediction of climate change, especially its anthropogenic component. Quantifying the response of the stratosphere to global warming is an essential part of this problem. In particular, climate initiated changes in stratospheric dynamics and concentrations of radiatively active gases such as ozone and water vapour are key in understanding atmospheric feedbacks. Global, well-calibrated measurements are needed to disentangle long-term changes from natural variations in trace gas concentrations.

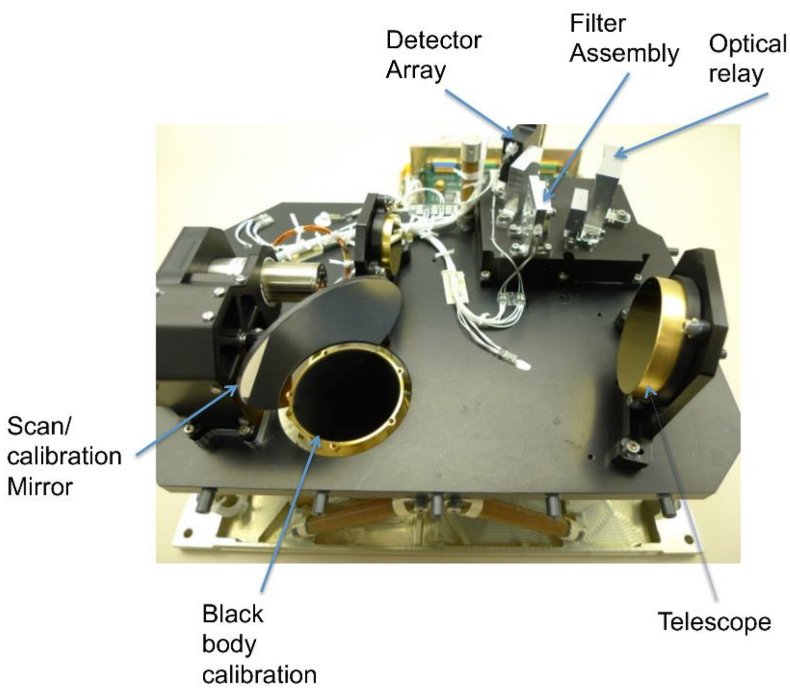
However, since the loss of Envisat in 2012, the Microwave Limb Sounder (MLS) on AURA is the only instrument providing high vertical resolution daily global measurements of water vapour in the middle and upper atmosphere. As MLS was launched in 2004 and has already exceeded its nominal five-year mission there is a very real chance of this key data time series ending.

As a result, a new instrument is required for global water vapour measurements that can maintain the long-term data time series with a level of accuracy that will test model predictions.

The Solution

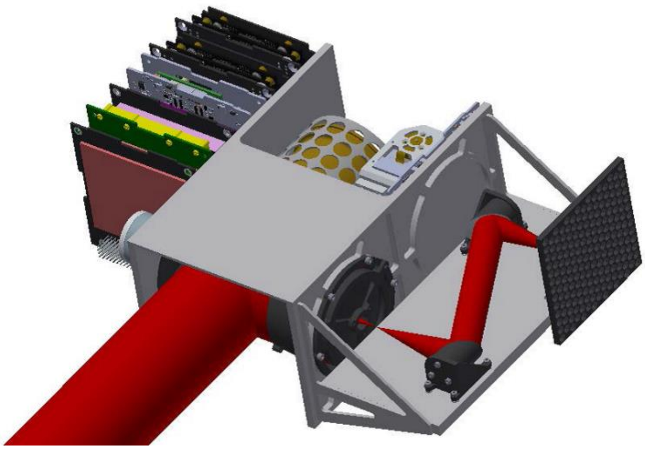
The CIIR concept (Figure 1) builds on the design heritage of the Compact Modular Sounder (CMS) instrument, which was flown on TechDemoSat-1, and adapts it to work on a CubeSat.

The CMS instrument is a modular infrared remote sensing radiometer that is 38 by 32 by 19 centimetres in size with a mass of four kilograms. It consists of a telescope, a scan / calibration mirror, a cold sky calibration target, an optical system comprised of relay and filter optics and an infrared detector array with associated read-out and conversion electronics. The scan mirror selects a field of view of Earth, the limb of



CMS Instrument Design. Source: University of Oxford

Earth or deep space. In standard operations, the instrument switches between the nadir mapping view to the space view and to the cold calibration target.



CIIR Instrument Layout. Source: University of Oxford

CIIR improvements to CMS include two components to ensure it returns data that can reliably complement and enhance existing Earth observation data sets. The first is a traceable radiometric calibration target to guarantee accuracy of <0.2K. The second is an intermediate focus between the input telescope and detector array; this allows a large (>10) number of filters, which provide discrete spectral channels. Finally, the CIIR instrument uses an uncooled microbolometer array to combine medium resolution imaging with atmospheric sounding.

The system uses a modular approach designed to easily mix subsystems to fly different versions on multiple spacecraft platforms at low cost by tailoring the instrument to specific mission requirements. The CIIR/CubeSat combination studied under CEOI provides a proof of concept for future low-cost constellations of spacecraft, to allow multiple local times to be sampled.

Support from CEOI

CEOI provided two phases of funding to a consortium of the University of Oxford (project lead), RAL Space, and Clyde Space. The first was to investigate the capabilities of a 6U CubeSat-type spacecraft to fly the Compact Infrared Imager and Radiometer (CIIR). The second was to bring the design of the CIIR to a level of maturity suitable for implementation as a flight CubeSat payload, and address concerns raised during the earlier phase regarding radiometric calibration accuracy and pointing stability.

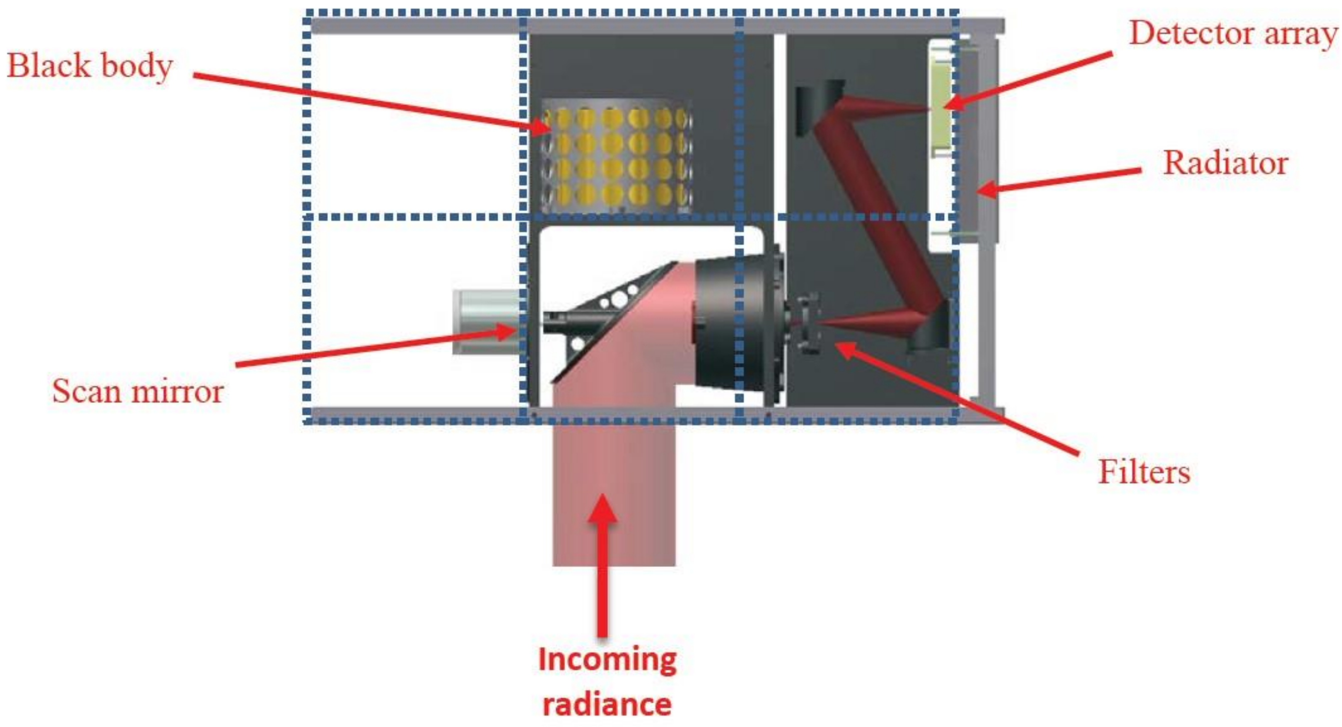
The Results

The results from the two studies showed:

- Scientifically useful data on stratospheric aerosols are achievable with the baseline design.
- Trace gas abundances such as water vapour and ozone are more challenging using existing infrared filter designs, but further optimisation is possible.
- A significant additional source of error in limb sounding is the pointing performance of the platform, this is limiting the ability to retrieve trace gas abundances but technology development is rapid and further improvements are expected in this area.
- Nadir viewing at moderate spatial resolution (~150 m) is achievable in the thermal-IR region.
- The integrated CubeSat/instrument concept is viable for low cost Earth system science where global coverage is a requirement.
- Absolute accuracy of the radiometric calibration easily met the target of ±0.5K. The accuracy was limited by systematic errors in test equipment and further improvements are anticipated.
- The design of the CubeSat structure and most sub-systems is now mature and fabrication of the majority of a flight unit would be straightforward.

Two major issues were still outstanding at the end of the CEOI funded projects:

- Demonstration of the viability of in-orbit pointing correction
- Improvements in the CIIR optical design to accommodate the large detector arrays now available.



CIIR Radiometer Configuration   Source: University of Oxford

Wider Deployment

The CIIR instrument has been specified for flight on NASA's Lunar Trailblazer mission, which will investigate the presence and form of water on the Moon.

It has also been specified for flight on ESA's Comet Interceptor F-Class Mission, a three spacecraft mission which will perform simultaneous observations from multiple points around the comet, creating a 3D profile of a 'dynamically new' object that contains unprocessed material surviving from the dawn of the Solar System..

The Future

The University of Oxford is considering setting up a spin-out company to commercialise the instrumentation technology. The radiometric calibration target developed as part of the programme has also been specified into a future commercial constellation of near infrared satellites that will provide highest resolution thermal imagery.

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.