

# Measuring the changing environment from space

The technology to monitor the Earth from space is growing ever more sophisticated, letting scientists do research that would once have been impossible. Mick Johnson describes the latest developments.



## Building the next generation of instruments

'In early 2008 the optical designer for this project, Dan Lobb of SSTL produced a fantastic design, which could move the field of atmospheric remote sensing forwards significantly. It fell to my colleague Christopher Whyte and me to build a prototype and demonstrate its potential.

Finding suppliers for the beautifully shaped mirrors, lenses and gratings was a huge challenge. It is these components that make this design so elegant and effective, but it was only after carrying out global searches and fact-finding missions that we found one or two potential suppliers of some of the most intricate parts. The compact nature of the instrument is a fantastic attribute for space missions, but it also causes really difficult practical problems when you're trying to fit components into a small volume.

However, the trials of construction were worth the reward. The finished spectrometer provided its first atmospheric measurements in late 2008 and is now incorporated into a highly novel system of air quality and emission monitoring instruments, CityScan. This uses a number of CompAQS-like units mounted on tall buildings or towers around the periphery of an urban area and sophisticated data analysis to build a 3D picture of the distribution of pollution. We also have plans to see it on a satellite where the true capabilities of all those beautiful bits of glass can be appreciated.'

*Dr Roland Leigh  
CompAQS project manager at the University of Leicester*

Since the beginning of the space race, we have been sending instruments into space to help improve our understanding of the planet. Over the last 20 years, observing the Earth from space has become increasingly sophisticated, but also increasingly necessary to monitor the impact people are having on the global environment.

The Earth system is in a dynamic balance. The sun supplies huge amounts of energy to the oceans and atmosphere. The Earth absorbs some of this energy, but also reflects and radiates energy into space. The recent UN Copenhagen climate conference highlighted the ways in which man's industrial and other activities are shifting this balance, by changing the composition of the atmosphere through emissions of carbon dioxide and other greenhouse gases.

Observations from space provide global and consistent measurements of the Earth at daily intervals or better – measurements which are not available by any other means. We use a sophisticated array of instruments, operating at all wavelengths of the electromagnetic spectrum that can penetrate the atmosphere, including

visible light, and ultraviolet, infrared and microwave radiation.

These instruments can work passively, by detecting reflected sunlight and radiated energy using imagers and spectrometers, or they can use an artificial source mounted on the satellite, such as a radar or lidar, to illuminate an area of interest and detect the radiation that is reflected back.

At the Centre for Earth Observation Instrumentation (CEOI), we are developing new instruments and technologies using the combined expertise of universities and industry. The technologies build on existing UK strengths in space instrumentation – see the examples below. British groups have significant experience of building advanced systems, with world-class instruments already flying on major ESA and NASA satellites.

### Spectrometers for monitoring air quality

A CEOI team at the University of Leicester, in cooperation with Surrey Satellite Technology Ltd (SSTL) of Guildford, is developing a prototype instrument called CompAQS which

monitors air quality. It is a novel compact spectrometer – an instrument which measures the properties of light by splitting it into its different wavelengths. This one operates in the visible part of the spectrum, analysing the sunlight reflected and scattered back into space.

Each gas absorbs light at characteristic wavelengths, letting scientists calculate their concentration in the air. The challenge for the design team is to make the spectrometer as small and light as possible without compromising its performance, since a larger instrument requires a larger spacecraft, leading to a costlier launch and mission.

### Using lidars in space

A laser flying on a satellite together with a sensitive detector pointing in the same direction provides a system collectively known as a lidar. This works a bit like a radar, except it uses laser light rather than radio waves to sense information about far-off objects.

Applications include determining the height of a forest canopy – the tree-top height – by

measuring how long it takes the laser light to be reflected back to the receiver; measurement of the speed of the wind using the signal reflected from airborne particles, by detecting the Doppler shift – similar to the way the pitch of an ambulance's siren seems to change as it drives past – or monitoring atmospheric composition by measuring how it absorbs the laser light.

But there are significant problems in putting these ideas into action, both because of the spacecraft's speed relative to the Earth's surface – typically 7km a second – and because of the laser power needed to ensure enough of the light is reflected back to the spacecraft. The resulting system is very complex, and the first few minutes of a satellite's journey into space provide a hard test of the mechanical design of a delicate instrument: there are no second chances.

This means instruments must be designed to be robust enough to survive the very severe acoustic noise, mechanical vibrations and shock associated with being launched on a rocket. CEOI has funded projects to look at how to

build these instruments so they can survive the launch and achieve their objectives.

### GNSS Reflectometry

Engineers and scientists at Surrey Satellites are developing a new method of Earth observation, making use of the signals which are continuously broadcast by the constellations of navigation satellites such as the US GPS system and in the future the European Galileo system. Whilst some of the signal these satellites broadcast is picked up by sat-nav receivers on Earth, much of it is reflected back into space from the Earth's surface.

By using dedicated, sensitive receivers mounted on another satellite, we can investigate the reflecting surface – be it land, ocean or ice – and the atmosphere above it. Because there are so many navigation satellites in operation – each constellation has about 30 – very frequent measurements are possible, providing wide coverage of the Earth's surface.

### The future

The UK currently funds much of its Earth observation through the European Space

Agency (ESA), with UK industry and academia competing with others in Europe to supply the instruments.

The work being carried out at CEOI will give UK teams a significant technological advantage in these competitions and help retain the UK's capabilities in space technology. But as well as technology we need the next generation of instrument designers. Therefore the CEOI supports NERC PhD studentships and runs training workshops.

There is a new space race under way to build the Earth observation satellites and provide the data we need to understand our changing environment. This is a vital component of the global monitoring systems required to understand the causes and consequences of climate change, and the Centre for Earth Observation Instrumentation is determined to play its part.

### MORE INFORMATION

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