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NPL is a world-leading centre for the development and exploitation of measurement science, technology, related standards, and best practice in a diverse range of technical areas and market sectors. As the UK's National Measurement Institute, our capabilities underpin the UK National Measurement System (NMS), ensuring consistency and traceability of measurements in support of UK and overseas customer interests. We aim to provide world-class science and engineering with economic, social and environmental benefits to the UK.

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Insights

Beyond measurement

The Satellite Applications Catapult

Stuart Martin, CEO, Satellite Applications Catapult

ESA and the role of measurement in space

Dr Constantinos Stavrinidis, Head of the Mechanical Engineering Department, European Space Technology Research Centre (ESTEC)

Astrium Emissions Measurement Service

Christèle Donadini, CTO Innovations Manager, Astrium

Space

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NPL collaborates with people around the world who want to use technology to explore the Universe, monitor the Earth or communicate globally. For over 40 years, NPL has worked with space companies and agencies, providing innovation in measurement research, technology and services.

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NPL's reputation relies on the quality of support we provide, both directly and indirectly, to all who engage with us. Our commitment to scientific excellence is coupled with a determination to offer high quality and affordable services that are of the greatest possible technical and commercial benefit to our customers.

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Foreword

David Willetts,
Minister for Universities and Science

I am pleased to introduce the Space edition of *Insights – Beyond measurement* from the National Physical Laboratory (NPL), who provide vital measurement science and services to thousands of people every year, often 'bridging the gap' between basic research and full commercialisation. This edition highlights the people and organisations that are making the UK space industry a phenomenal success story.

NPL has a unique role in providing space metrology innovation, working in partnership with academia, industry and space agencies to deliver highly competitive and innovative spacecraft and develop pioneering satellite based applications. NPL applies its deep understanding of traceable, quality measurement to the greatest global challenges, including NPL's leadership in international efforts to reduce the uncertainty of data used in generating climate change forecasts.

The Government is now far more committed, coordinated and strategic in its space policy than at any point in the last 50 years. We are proud of our space industry, and British businesses are winning contracts on the world market. Indeed, every Galileo spacecraft, from the first test model, has either been built here in the UK or relies on UK space technology. This is testament to the quality of our satellite manufacturers.

The space industry is an excellent example of public and private investment in innovation and collaboration producing real economic benefit and great technological achievement. The launch of the Satellite Applications Catapult and the development of the Harwell site in Oxford will further ensure that the UK remains at the forefront of space technology and places us a global leader in the provision of space services.

Looking forward, it is important that the entire UK space community continues to maintain its strong position in order to achieve 10% of a global space economy, which is likely to be worth some £400bn by 2030.

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Introducing the Satellite Applications Catapult

Stuart Martin, Chief Executive Officer, Satellite Applications Catapult

The UK space sector is increasingly recognised for its significant contribution to the UK economy, based upon its commitment to excellence and innovation, and sustained high-level growth. It already commands a 7% share of the global space market, and aims to grow significantly to secure an even greater stake as the market swells to a predicted value of £400 billion by 2030.

To support this ambition, the Satellite Applications Catapult was recently established by the Technology Strategy Board. As part of a Government-led programme, the Satellite Applications Catapult exists to support UK businesses, with the aim of becoming a world-class centre for the development and commercial exploitation of space and satellite-based products, services and applications.

We are part of a seven-strong network of world-leading centres of excellence in technology and innovation under the Catapult programme, and Minister for Universities and Science, David Willetts, has expressed his support for our role in stimulating the rapid commercialisation of space technologies in the UK.

A £40bn slice of the global space market

Based in Harwell, Oxford, the Satellite Applications Catapult will be at the forefront of the UK space industry's growth plans, helping the sector to capture 10% of the fast-growing growing global space market, a 3% rise on the current share enjoyed by the UK.

The Catapult programme is a vital element of the UK's strategy to drive economic growth from emerging technologies, and our aim is to make the UK the place to be if you want to do business in space. As part of the Technology Strategy Board's powerful Catapult initiative, we have a great opportunity to put the UK in a premier position developing world-beating applications by joining up our world-class academic base and creative businesses, both small and large.

We offer support to SMEs looking to grow by providing access to expertise and high value facilities end-user organisations, as well as working with academics and individuals to identify the commercial potential in their ideas or research.

Providing in-orbit test facilities means we will also be helping innovative UK organisations to demonstrate new satellite technologies, removing significant cost barriers and shortening the time UK businesses will wait to achieve a first flight demonstration for new equipment and technologies in space.

We are also here to help end-user organisations to understand how satellite applications could help their businesses. Working with many different organisations and individuals throughout the value chain, we will be helping to make connections between them to foster new commercial relationships.

Building on ISIC's success

The International Space Innovation Centre (ISIC) will be incorporated into the Satellite Applications Catapult from April 2013. Since launching nearly two years ago, ISIC has

become a catalyst for space sector growth. The Satellite Applications Catapult will build on the significant achievements of ISIC and take forward a shared vision to accelerate growth in the UK space sector and help simplify and more powerfully direct space innovation activity.

Identifying market opportunities

The Catapult will operate through delivering both market-led and technology-driven programmes, which have been identified following extensive consultation with the community. We based our selection criteria on key factors including growth potential, academic strength, UK capability/interest, and competition.

The first market-led programmes are: transport; security and civil protection; natural resources management, energy and climate; and Internet of Things. Between them, these markets have a global growth potential of over $100bn in the next decade.

These programmes will consist of projects that are clustered around identified sectorial market requirements, and may bring together multiple satellite-based domains (Earth observation, navigation and communications) for addressing these needs.

Capitalising on technology

Our technology-driven programmes will focus on developing and demonstrating the capabilities of existing or new satellite technologies and space-based assets, thereby removing barriers to their commercial application in a range of different market sectors. Further to the Catapult's consultation process, it was identified that we should initially address two technology-driven programmes: space segment technologies, and ground and user segment technologies.

The Catapult programmes will consist of a number of strategic, catalytic, collaborative and commercial projects. The project portfolio will be shaped through consultation fora and using criteria developed to prioritise work. In carrying out projects, we must also be mindful of IPR and state aid issues – and policies have been drafted in both of these areas to provide a baseline position.

Facilitating growth

Through the course of our work, the Satellite Applications Catapult will need a number of facilities to deliver NPL's programmes, and many of these facilities already exist as either public or private assets. We will make use of these through negotiated service level agreements.

In cases where a facility that is integral to the successful delivery of Catapult programmes and projects is not available, however, we plan to develop new facilities through our core grant, subject to a compelling business case. Facilities may be developed to support an individual project, a portfolio of projects within a programme or an entire programme, and we expect these to come under three categories: mission platforms (supporting upstream technology developers), application development and test platforms, and support facilities.

Our aim, as with all of our programmes, is for the development of new facilities to contribute significantly to the UK's growth and competitiveness in the space sector.

ESA and the role of measurement in space

Dr Constantinos Stavrinidis is Head of the Mechanical Engineering Department in the European Space Technology Research Centre (ESTEC), based in Noordwijk, the Netherlands. Here, he describes the valuable role that testing and measurement technologies provide for the space missions.

Image courtesy of ESA

ESTEC is the European Space Agency's (ESA) heart of technical developments. ESTEC's technical work is critical to the performance of space projects currently in operation, and defines the potential of future missions. At any one time there may be up to 50 space missions being undertaken or in the planning stages, encompassing a vast array of projects from planetary exploration through to satellites for next generation weather forecasting.

During the various phases of its development, a spacecraft and all of its parts undergo rigorous and extensive testing. At ESA, the majority of spacecraft are tested in the ESTEC Test Centre - the largest centre of its kind in Europe, and one of the biggest in the world.

The ESTEC Test Centre recreates the launch and space environments a spacecraft will experience. The quality of measurements carried out here is critical in meeting the test standards for spacecraft testing, and the overall success of the mission.

As increasingly challenging space missions are explored and developed, spacecraft testing requirements must also evolve.

New mission BepiColumbo is a great example. Scheduled for launch in 2015 to visit Mercury, the spacecraft will endure temperatures of 350 °C whilst carrying out careful studies of the planet for one year or more. When you consider the cost of the spacecraft will be more than €1bn, it is essential to understand beforehand if it will perform as expected. In order to adequately test the spacecraft, it is of paramount importance that the measurements used are valid and robust.

As such an important factor, the Mechanical Engineering Department and the ESTEC Test Centre are continuously innovating in the way we carry out tests. We do this by working in partnership with metrology experts such as NPL to improve measurement, adopt new innovative measurement technologies to meet new testing requirements, and maintain a sophisticated quality management system. An example of this is the increasing need to understand and suppress weak 'micro-vibrations' on payload instruments during spacecraft operations. NPL worked closely with the ESTEC Test Centre to develop and operate a new test facility dedicated to this, which will allow ESA to confidently measure micro-vibrations on components, traceable to international standards.

In future, as payload instrumentation becomes more complex and more sensitive to its surroundings, the use of validated testing and measurement systems will become even more important than they are now. For this reason, we will continue to work even closer with experts like NPL in order to achieve a greater understanding of how the payload interacts with the satellite and the harsh environment of Space.

"…the Mechanical Engineering Department and the ESTEC Test Centre are continuously innovating in the way we carry out tests. We do this by working in partnership with metrology experts such as NPL to improve measurement…"

The Astrium Emissions Measurement Service

Christèle Donadini, Chief Technical Office Innovations Manager at Astrium Services, explains a new satellite-based service to help combat climate change and develop a low carbon economy.

Monitoring and controlling greenhouse gas (GHG) emissions is crucial at international, national and major city level, to both reduce the level of polluting emissions and to promote the uptake of green, low carbon technologies. This will become even more important as growing populations will make our future cities the primary contribution to man-made global climate change, and countries will need to implement robust strategies to report and reduce their carbon footprint.

Astrium is leading a project with the Centre for Carbon Measurement at NPL, the National Centre for Earth Observation (NCEO), and the Laboratoire des Sciences du Climat et l'Environnement (LSCE) to develop a way of measuring the amount of greenhouse gases in the atmosphere. The project also aims to provide this as a seamless global service to complement current inventories and estimations, which are based on values derived from statistical data that is two years out of date on average.

Great progress has been made in reporting and verifying GHGs through the work of various organisations including the Carbon Disclosure Project, the World Business Council for Sustainable Development, and the World Resources Institute. However, a universal understanding of greenhouse gas emissions measurement has not yet been achieved.

Many outstanding questions remain, such as how to categorise emissions, which coefficient to use in calculations, how to express uncertainty in measurement, and how to account for impacts. Underpinning all of this is the question of how to achieve consistency of approach to measurement of greenhouse gas emissions. Current inconsistencies have led to large discrepancies and errors in reporting of GHG estimates, which could ultimately mislead policy makers when determining the effectiveness of GHG reduction measures. The uncertainty in China's emissions, for example, is as large as the total GHG emissions of Japan.

These questions are familiar to measurement scientists, such as those involved in the Centre for Carbon Measurement at NPL, whose work will play a crucial role in providing the consistency, accuracy and traceability of measurement.

Over the coming years, measurement scientists will play a key role in developing the technical methods for business and governments to monitor emissions, which will inform decisions and policy. They will also need to develop neutral and reliable language and international standards to allow effective and coordinated reporting.

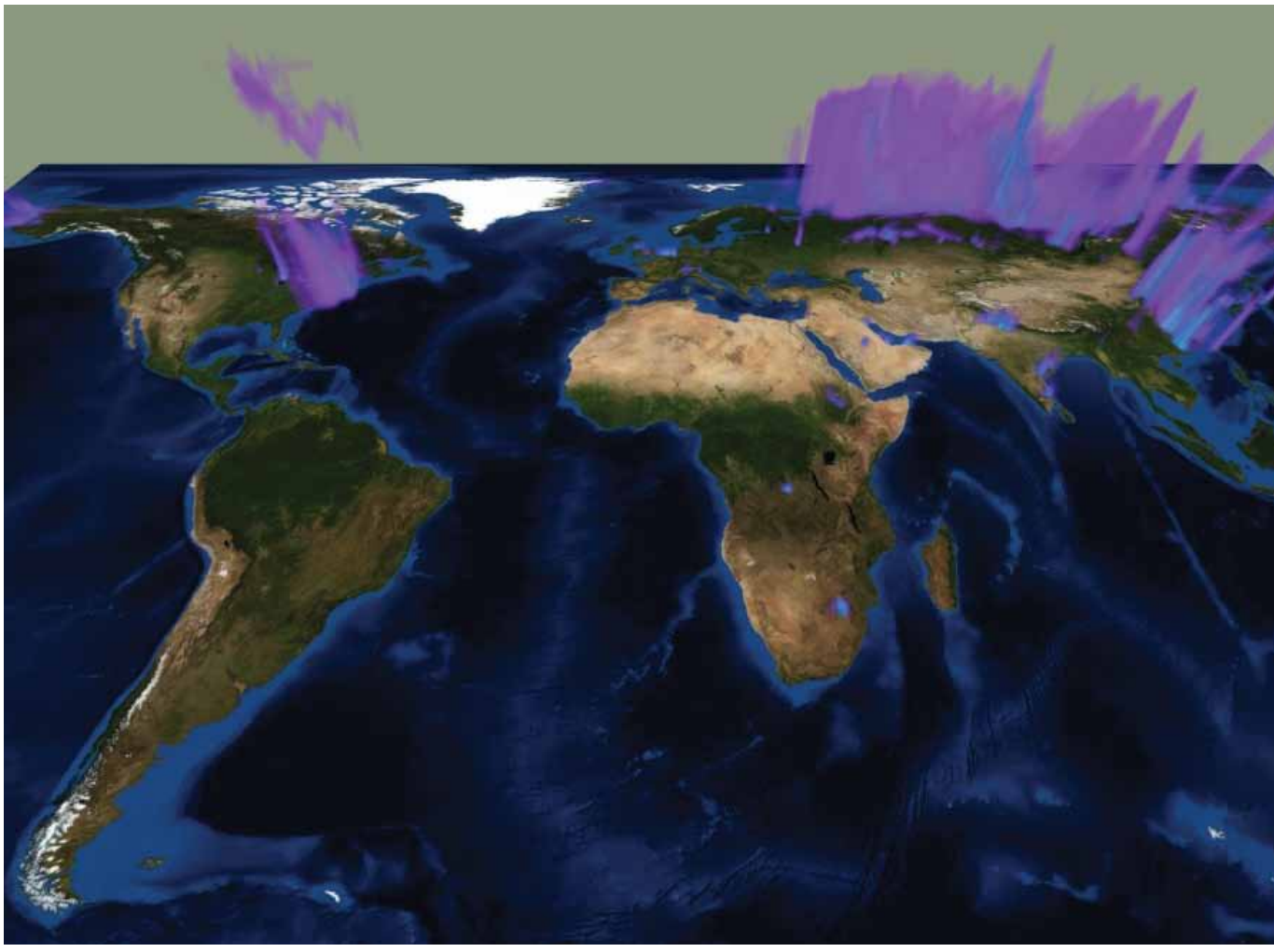
The Astrium Emission Measurement Service will take a central role in providing a way forward based on real and independent measurements, to complement the current inventory/estimation-based method of calculating greenhouse gases. It is essential that the service is cost-efficient, trustworthy, up-to-date, reliable and seamlessly global.

This will be achieved by using an integrated data collection facility. Using innovative sensor technologies to measure real time gas concentrations of carbon dioxide (CO_2), carbon monoxide (CO), and methane (CH_4) from ground stations, aircraft and satellites. With this, we will determine CO_2 equivalent emissions with associated uncertainties and then identify the sources of these emissions. This allows for the full global coverage required, but can be easily and rapidly deployed wherever needed to deliver the service from national down to large city scale.

This service architecture was piloted last year in London. Astrium deployed a GHG sensor network and converted a London bus to host a mobile GHG sensor, which was then driven around a fixed London route every day to detect GHG concentrations and variations at street level. The whole system was calibrated and maintained using NPL high quality gas standards, and potential end-users were invited to demonstrations organised on-board the bus, showcasing the service in action.

Airborne and satellite observations were made over London at the same time, and the team combined the various measurements to produce a real-time cityscape video of carbon dioxide and methane concentrations around central London. 3D visualisations of modelled emission sources over London, the UK and the world show how natural sources and sinks of carbon dioxide compare with man-made emissions over a cycle of days and weeks.

The London measurement campaign demonstrated the viability of the GHG Emissions Measurement Service being developed by Astrium and its partners, who will increase further their capabilities by participating in similar initiative in Paris and Rotterdam.



Future optical clock technologies for space

Leon Lobo, Time & Frequency
Business Development Manager, NPL

NPL is playing a prominent role in a Europe-wide effort that aims to advance optical clock and optical frequency comb technologies, with a view to incorporating them in relevant space missions and spacecraft infrastructures within a decade.

The combination of state-of-the-art cold atom and ion optical frequency standards with optical frequency combs provides the capability for optical clocks to outperform the best available microwave clocks by more than an order of magnitude. The underlying clock technology allows accurate comparison of widely different optical frequencies, leading-edge down conversion to microwave frequencies, and follow-on capability to make time interval, distance and gravitational potential measurements.

However, this technology is not yet mature enough for integration into space missions. NPL scientists, along with other European research teams, are actively working on a number of projects to accelerate its development to a technology readiness level suitable for use in future space missions.

Optical clock sub-component development

NPL is part of a European consortium involved in an ESA technology project targeting the development of space-qualifiable reduced-payload optical clock sub-component technologies. These include the cold atom or ion physics reference package, the optical local oscillator (the 'clock' laser), the clock system control unit and subsidiary cooling lasers.

High stability lasers using force-insensitive optical cavities

NPL has produced a stable optical reference cavity that is a vital component of very high frequency optical oscillators for use in diverse ESA application areas such as Earth observation, satellite communications, and future fundamental physics missions involving optical atomic clocks.

The cavity is designed to survive a launch and operate in the harsh environment of space. It is insensitive to inertial forces acting in any direction and to the compressive force used to constrain it. The design is based on a cubic geometry with four supports placed symmetrically about the optical axis in a tetrahedral configuration. It achieves the lowest passive sensitivity to vibration reported for an optical cavity.

Frequency combs

NPL were part of an ESA high accuracy absolute long distance measurement study that considered opportunities offered by femtosecond combs for accurate measurement of inter-satellite distances in formation flying space missions. Such missions involve multiple spacecraft flying between tens and hundreds of metres apart in order to gather more data by effectively acting as one large sensor. Comb measurements are one of the techniques that can be used to make accurate measurements of these inter-satellite distances.

Atmospheric trace gas analysis from space

Knowledge of the level and distribution of contaminants such as carbon dioxide within the atmosphere is critical to our understanding of global warming, and satellite-based time-resolved backscatter measurements of trace gas absorption provide a versatile method to gather such data. NPL is involved in an ESA activity to develop frequency-stabilised spectroscopic references to provide high resolution wavelength calibration for such satellite monitoring.

STE-QUEST

We are also contributing to the ESA Cosmic Vision Space-Time Explorer and Quantum Test of the Equivalence (STE-QUEST) mission proposal, which is devoted to a precise measurement of the effect of gravity on time and matter using an atomic clock and an atom interferometer.

If selected, this international project will test a fundamental prediction of Einstein's theory of general relativity with high precision. STE-QUEST combines matter-wave interferometry and clock timing in one mission, testing aspects of Einstein's equivalence principle in the search for a unifying theory of quantum mechanics and gravity.

One of the primary goals of the mission will be to measure gravitational redshifts to improved accuracies over ESA's ACES (Atomic Clock Ensemble in Space) mission on the International Space Station (ISS), by making use of elliptical orbits and advanced atomic clocks. The second goal is a quantum test of the universality of free-fall by interferometrically tracking the propagation of matter waves in the Earth's gravity field. For the ACES mission, NPL will be hosting one of the microwave ground terminals, contributing ground clock referencing and analysis.

SOC2

NPL also has an important role in the European Framework 7 project Space Optical Clock, SOC2, which will demonstrate high-performance transportable neutral atom optical lattice clocks, leading to a future mission deployment on the ISS. Project developments include the necessary laser systems, and atomic packages that make use of novel solutions with reduced space, power and mass requirements, such as NPL's permanent magnet Zeeman slower for pre-cooling the atoms, and monolithic multiple cavity structures for stabilising the auxiliary lasers.

In summary, a range of new applications will be enabled by ultra-precise optical clocks deployed in space. This includes the fields of fundamental physics for testing general relativity; time and frequency metrology for the comparison of remote terrestrial clocks, perhaps with future operation of master clocks in space; geophysics to map the gravitational potential of the Earth; deep space navigation, and potential applications in astronomy, such as local oscillators for radio ranging and interferometry in space. NPL's team, led by Prof Patrick Gill, has considerable expertise in the field of optical frequency standards and metrology, and is contributing significantly to making this technology a reality.

A snapshot of NPL's work in space

Turn left at the next pulsar

Setnam Shemar, Time & Frequency Group

The Time & Frequency Group at NPL is tasked with the development and operation of the UK's national time scale. This defines civil time in the UK, to the extent that you could say all time is traced back to NPL and its atomic clocks. Our work involves developing and applying the very latest time measurement techniques and analysis methods.

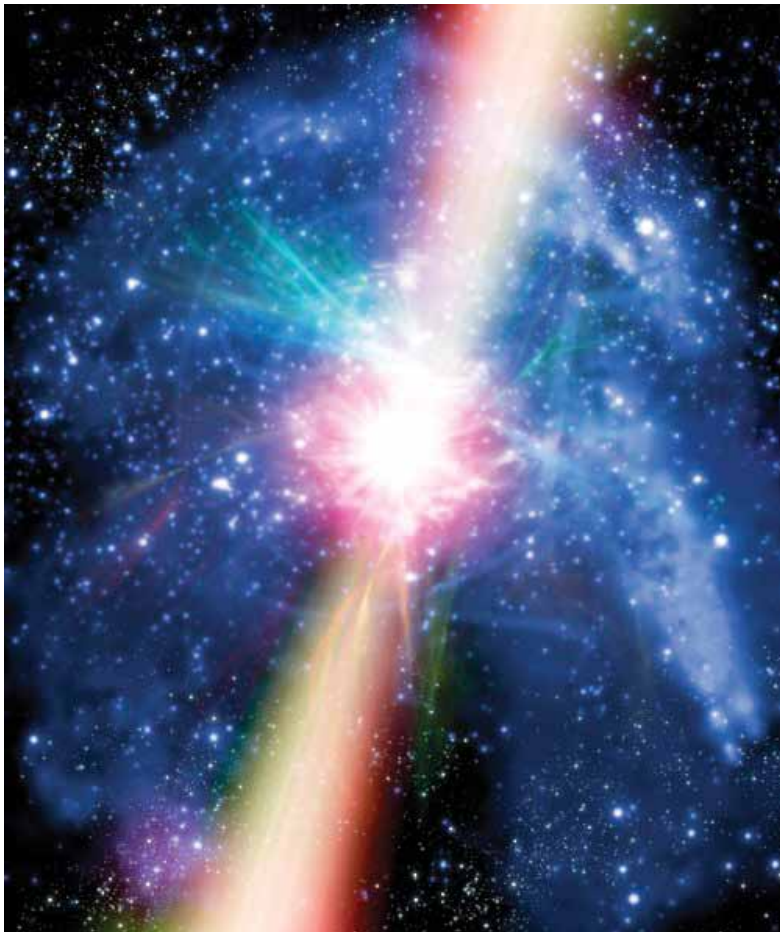
We are encouraged to apply our knowledge and understanding of time and timing techniques to new applications of benefit to the wider industry and society in general, and recently we have become involved in spacecraft navigation.

Together with the University of Leicester, we are carrying out a feasibility study to determine whether X-ray pulsars, which are exotic stars observed as pulsating X-ray beacons in space, could be used to speed up and improve navigation data for spacecraft, on behalf of the European Space Agency (ESA).

Currently, a spacecraft on an interplanetary mission needs to communicate with Earth to determine its location and confirm that it is on the correct trajectory. The process of receiving, analysing and returning data, however, can take several hours, which means that a spacecraft faces a significant delay before it can react.

The hope of our research is that, in the future, a spacecraft will instead be able to locate itself based on its relative position to known X-ray pulsars, using a concept similar to existing sat-nav systems. This idea originated in the 1980s and since then, particularly in the last decade, a small number of studies have been carried out by different space agencies. It is clear that extremely sensitive X-ray detectors are needed, but if it is achievable to use even a single pulsar, this could be beneficial for a mission to the outer Solar System or even a future manned mission to Mars.

The project I am leading at NPL is one of a small number of its kind in the world and is still at concept stage. We are evaluating the timing and navigation potential and developing algorithms, whilst our colleagues at Leicester University are advising on X-ray instrumentation and X-ray astronomy. The output will advise ESA on its technical strategy and whether or not it will be viable to use pulsars for deep space navigation.



Putting the heat into space power

Laurie Winkless, Functional Materials Group

Our work focuses on the characterisation of thermoelectric generators (TEGs), which are semiconductor-based heat engines that use temperature difference to produce electricity. These devices are used to harvest waste heat in many terrestrial applications, but they also have proven history in space.

Radioisotope Thermoelectric Generators (RTGs) have been used in the space industry since the Apollo era. At its heart, an RTG has an encapsulated radioisotope source which produces heat. This is then surrounded by thermoelectric generators which are cooled on the opposite side by the low temperatures of deep space. Although this technology has been used since the 1960s, the research has continued to evolve, so that even recent missions like the Mars Curiosity Rover depend on these nuclear batteries for power.

The UK is the lead investor in the Mars Robotic Exploration Preparation Programme, part of which is the development of the first European RTG. A consortium of UK universities and companies has already developed a prototype system based on commercial TEGs. At NPL, we are working on the required test system necessary for the next stage of this work, which will characterise the performance of these TEGs under specific conditions.

We can currently characterise the performance of thermoelectric generators and materials over a wide range of temperatures (liquid nitrogen to 700 °C), and we are also leading the UK effort to produce the first measurement standard for these devices.

Many nanostructured materials have potential for use within the space industry. Nanostructured thermoelectric materials have demonstrated high efficiencies, but a lack of metrology and low Technology Readiness Level (TRL) has also limited their development so far. In 2010, my team at NPL developed a Nanomaterials Roadmap for ESA, which has helped to providing a realistic path-to-market for nano-enhanced materials.

Isolating the issue

Dan Veal, Mass & Dimensional Group

The Mass & Dimensional Group at NPL is tasked with solving various metrology problems related to force and vibration. As part of this, I work on mechanical microvibration projects to develop new satellite component test equipment for ESA for their ESTEC Test Centre in the Netherlands. This is the largest facility of its kind in Europe and one of the largest in the world, and its primary role is to evaluate prototypes and verify that instruments and equipment will operate as intended.

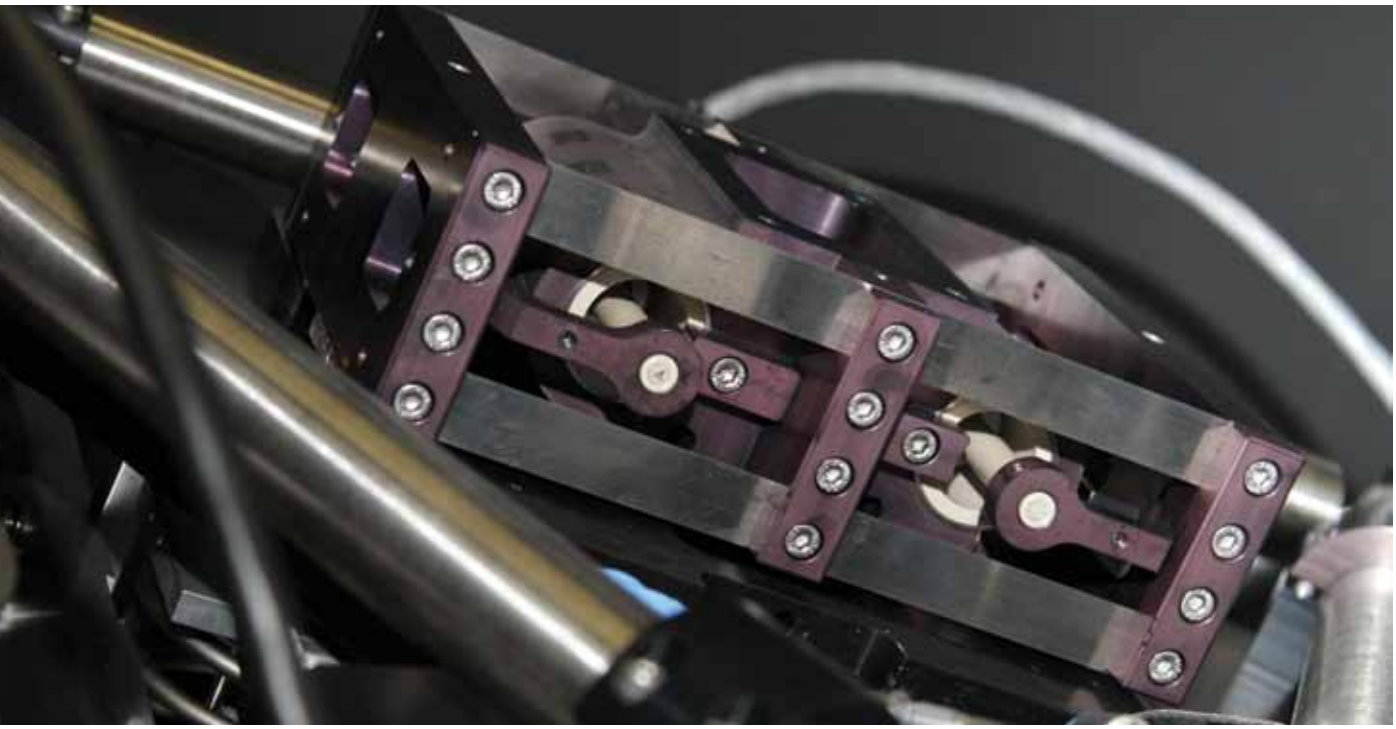
If a spacecraft component is producing unwanted vibration, perhaps because of a worn-out bearing or slight manufacturing flaw, it is critical that this vibration pollution is measured. Even very small microvibrations can affect other components and instruments on the spacecraft, and how well they are characterised can directly influence the success of a mission.

The work we are doing at NPL improves ESA's measurement capability, and therefore its ability to support future missions, in two ways. Firstly, we are developing an active vibration isolation system which uses low-noise sensors and actuators in order to isolate existing equipment from external noise more effectively than traditional passive systems. Secondly, we are supporting ESA by building new, innovative measurement equipment that works at much lower frequencies and is sensitive to much lower forces than the equipment they currently have.

The breadth of our group's experience in force, as well as dimensional and mass measurement, is a huge benefit to our work in this area as we are able to draw on multi-disciplinary expertise to inform our research.

These particular mechanical microvibration projects are still in their relatively early stages, but we expect our work to play an important role in ensuring the success of ESA's space missions in the future. For example, our equipment could support future proposed missions such as the New Gravitational wave Observatory (NGO, formerly LISA), which is based on formation flying requiring very tight relative position control of three satellites and would therefore be very sensitive to any uncharacterised vibrations.

We have completed our initial studies and are now working on building it into commercial-grade equipment which aims to be deployed at ESTEC within the next couple of years.



Keeping an accurate eye on Earth

Dr Nigel Fox, Earth Observation & Climate Change Group

In recent years there has been increasing demand for improved accuracy and reliability of Earth Observation (EO) data, stimulated not only by our desire to understand better the workings of our planet and the cause and impact of climate change, but also because improvements in models allow us to discriminate better between data.

The Climate Data theme of the Centre for Carbon Measurement at NPL is, amongst other things, developing techniques to improve calibration of satellites before they are launched. As technical leader, I lead our European project to coordinate the activities of a number of national metrology institutes in Europe, researching new capabilities for pre-flight, in-flight and post-launch calibration, and validation of satellite data. I also coordinate the efforts of the international space community (optical domain) as chair of the IVOS sub-group of Committee on Earth Observation Satellites Working group on Calibration and Validation.

At NPL, we are the independent provider of quality information for both deliverers and users of satellite data, and our role is to understand it and assess quality metrics in collaboration with the wider industry. We have calibrated satellites that are currently flying, and are providing calibrations for a number of instruments due to fly on satellites in the next few years.

One of the most exciting things I am working on now is the design and leadership of a proposed satellite mission called TRUTHS (Traceable Radiometry Underpinning Terrestrial- and Helio- Studies). The novel mission concept provides fully SI traceable measurements from orbit at uncertainties a factor ten lower than any other, sufficient to make benchmark measurements suitable for the detection of decadal climate change. This is based on a new standard we developed in collaboration with Swiss colleagues to replace the world radio metric reference for solar irradiance measurements.

Our work also looks at the intercomparison of satellite data over common targets such as the snowfields of Antarctica, and a member of my team is currently in the Arctic at present. Other projects look at how to evaluate and assign quality indicators on Earth observation data, all the way through to applications quantifying amount of carbon in forests.

Within the wider international Earth Observation community, we have also run a number of comparisons to harmonise the measurement of ocean colour, land surface reflectance, and sea surface temperature.

Going forward, our aim is to build on our expertise and expand our work establishing quality indicators to support climate applications and climate services.

More information on NPL's work in the space industry - www.npl.co.uk/commercial-services/sectors/space/

One giant leap for the UK economy

As the global space market continues to grow, the UK is in a prime position to capitalise on the opportunity. Robert Elliott, Space Business Development Manager at NPL, explains where the UK's strengths lie in the space sector and considers future growth potential.

Amongst a backdrop of nationwide economic struggle, one sector bucking the trend is the UK's space industry, which continues to go from strength to strength. Generally speaking, UK space companies have grown significantly year-on-year and, as such, the sector is one of the quiet success stories of the British economy in recent years.

Five decades since the UK became the third space-faring nation with the launch of satellite Ariel 1, the industry now contributes £9.1bn per year to the UK economy and employs 29,000 people. The last few years particularly have seen considerable activity in the UK space scene, from the establishment of the Space Leadership Council and UK Space Agency, to the launch of the brand new Satellite Applications Catapult.

The Government continues to look to the space sector as an important part of the engine for economic growth and most recently, in late 2012, Chancellor George Osborne announced an additional £60bn annual investment for the next two years. This represented a strong statement of recognition for the UK's achievements and potential in this sector, and it came accompanied by ambitious growth targets. By 2030, the Government wants to increase the UK's market share from 6% to 10%, which would be equivalent to £40bn. Similarly, the move aims to create 100,000 high-value jobs in the UK.

Focusing the funds

The Government's investment will help UK industry to diversify its industrial technical capabilities, but the industry must also innovate in the ways that it does business and seize this as an opportunity to explore avenues for growth. The Technology Strategy Board's Satellite Applications Catapult will play an important role in facilitating new commercial relationships and supporting fledgling projects with the expertise and facilities to help get them off the ground.

We are still in an important period of identifying the UK's strengths and correlating them with market opportunities. The UK already has considerable expertise in many aspects of the industry, such as processing satellite data and managing communications systems on the ground, but it is also important to be investing in new areas of future growth as they begin to emerge.

Technological progress in the future will be driven and constrained by the need to achieve a sustainable low carbon economy, new scientific discoveries and innovation, and the wellbeing and security of citizens. Space will play a crucial role in the advancement of these areas and, as such, technologies supporting these areas hold the most potential.

Telecommunications

First and foremost, there is ripe opportunity for growth in those areas where the UK is already successful, such as satellite communications. According to the UK Space Agency, by the end of 2013 every UK satellite TV channel will be delivered via UK-built spacecraft, which is a significant achievement.

The UK's involvement in the ESA's Advanced Research in Telecommunications Systems (ARTES) programme has been notably successful, previously generating £750 million of private investment and sales, and the most recent investment announcement increased UK funding by 60%.

Much of the new involvement is through the Integrated Applications Programme, which provides some or all of the funding to develop user-led commercial services that incorporate the use of satellites. This programme provides many exciting prospects to deliver a high level of innovation into new and existing areas. Farming, global trade, our future cities, natural resource exploration are all examples of areas with existing challenges that could benefit enormously from Integrated Space Applications.

Earth observation

Earth observation is increasingly recognised for its importance in managing major challenges such as climate change and natural disasters, and the UK has a solid role in ESA's Earth Observation Envelope Programme (EOEP).

As climate change moves up the agenda, the demand for accurate and detailed satellite data is growing in order to help our understanding of just how fast the Earth's climate is changing, and what the implications will be. Our most reliable models rely on data acquired through a range of complex measurements, many of which must be taken from space, but current measurement capabilities are nowhere near sufficient as yet.

Presenting a solution to this issue would be an excellent investment for the UK, not only in terms of addressing climate change but also in business terms. NPL has put forward such a solution in the form of its TRUTHS (Traceable Radiometry Underpinning Terrestrial- and Helio- Studies) mission. This would see a satellite launched into orbit with the ability to make accurate traceable measurements of climate variables and to calibrate and upgrade the performance of other Earth Observation (EO) satellites in space, allowing for a harmonised global climate observing system. The project, which would be led by NPL, is under consideration by various major organisations.

Similarly, UK industry is developing technology to deliver long term, reliable Earth observation data sets for the Global Monitoring of the Environment and Security (GMES) programme, and EU backing suggests that this project could present promising opportunities for future growth. More promising still, commercial applications for using the data is likely to spark innovation in the UK, particularly within the Harwell space cluster.

Another promising new endeavour in this area is the UK Space Agency's significant investment in the Meteorological Operational (MetOp) satellite programme, which is replacing the current satellites fundamental to the Met Office's service. The £81 million funding announced in 2012 means the UK's role in developing the prototype satellite will be sufficient to secure guaranteed repeat orders from EUMETSAT.

Navigation

Navigation presents a huge area of opportunity for the UK, which is already a world leader in making small satellites. Surrey Satellite Technology (SSTL), for example, cut the price of access to space by creating cost-effective small satellites, and in July 2012 won an €80m contract to build eight satellites for the Galileo global navigation project funded by the EU and ESA.

The European GNSS Evolution Programme (EGEP) is targeted at future generations of European navigation satellites, offering reduced costs and higher performance over the current Galileo satellite platforms. The UK is already involved in building all of the current 22 satellites and there is an opportunity for further involvement that would help maintain our competitive edge when the EU takes over full responsibility and funding in 2014.

Looking further ahead to burgeoning technologies, the UK is also playing an important role in determining the use of X-ray pulsars for faster and more accurate navigation data for spacecraft. A joint project between NPL and the University of Leicester exploring this is one of a small number of its kind in the world which will advise ESA on its technical strategy and whether or not it will be viable to use pulsars for deep space navigation in the future.

Commercial space travel

Once the stuff of dreams, commercial space travel is set to become a reality by the end of 2013 with the first passenger flight of Virgin Galactic. The craft's maiden voyage is planned to take passengers 100 km to the very edge of space and, although the exact timeline for this trip is yet to be finalised, it will be a landmark event.

The UK is already involved in Virgin Galactic's commercial flight plans, with SSTL lined up to optimise payloads for the new rocket system. However, these short flights could be just the beginning of a huge market opportunity as the long-term benefits could be on a much wider scale.

One notable opportunity where the UK is currently trying to get a foothold is in the provision of our own spaceport. Scotland's burgeoning space sector is vying to build the UK's first spaceport, which would enable us to launch more satellites and potentially capitalise on space tourism. With Science Minister David Willetts having expressed his support for the UK to "seize the advantage", this could be an area of investment in the near future.

Space science and exploration

The UK contribution to scientific studies in space and the exploration and discovery of stars and planets is staggering. UK research laboratories such as the Astronomy Technology Centre delivered major components to Hubble's successor, the James Webb Space Telescope (JWST), which will allow us to understand how the first stars and galaxies were formed.

The UK has many scientists and technologies contributing to planetary exploration studies, including the current Mars Curiosity mission and future studies such as ESA's ExoMars mission. We will also be much more involved in activities on-board the International Space Station in future, including a £12 million contribution to the European programme for Life and Physical Sciences (ELIPS).

The UK space industry is one of the nation's most promising and fastest growing sectors. Already a successful element of the world economy, the industry is bursting with potential and, with significant government backing and a sharp focus on expanding our existing expertise in core areas, we are well positioned to capitalise on the wealth of opportunity before us.

Case Study

NPL, together with the Satellite Applications Catapult, is driving Space growth in the public sector by establishing the National Space Applications Programme (NSAP), on behalf of the UK Space Agency.

NSAP will act as a trusted first port of call for advice on space applications, from Earth Observation to Navigation and Telecommunications. Crucially it will also be able to collate issues or technical challenges faced by the public sector in the use of space applications. NSAP will focus particularly on leading government to government talks to enable neutral identification of public sector requirements. NSAP will therefore have a particular role to play in the neutral brokerage of ideas between users and suppliers of space products and services. NSAP will take account of related applications work happening in the UK and internationally, and will be both flexible in responding to user needs and aligned with UK strategic priorities.

NPL's Bob Cockshott is the Programme Manager for NSAP. He will work with expert sector facilitators to allow public sector requirements to be identified and followed through. Bob, who also manages the Location and Timing Knowledge Network for the TSB, says:

"Starting up the National Space Applications Programme provides NPL and the Catapult with an exciting, timely opportunity to maximise the impact and exploitation of our satellite industry. Even in its early stages of creation, NSAP is generating a lot of interest from public sector departments across Britain."