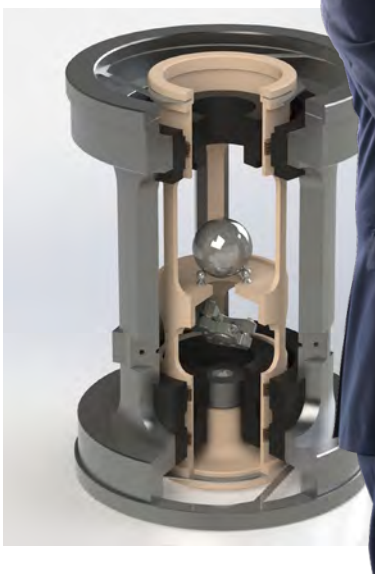
NPL
National Physical Laboratory

CREATING IMPACT FROM SCIENCE

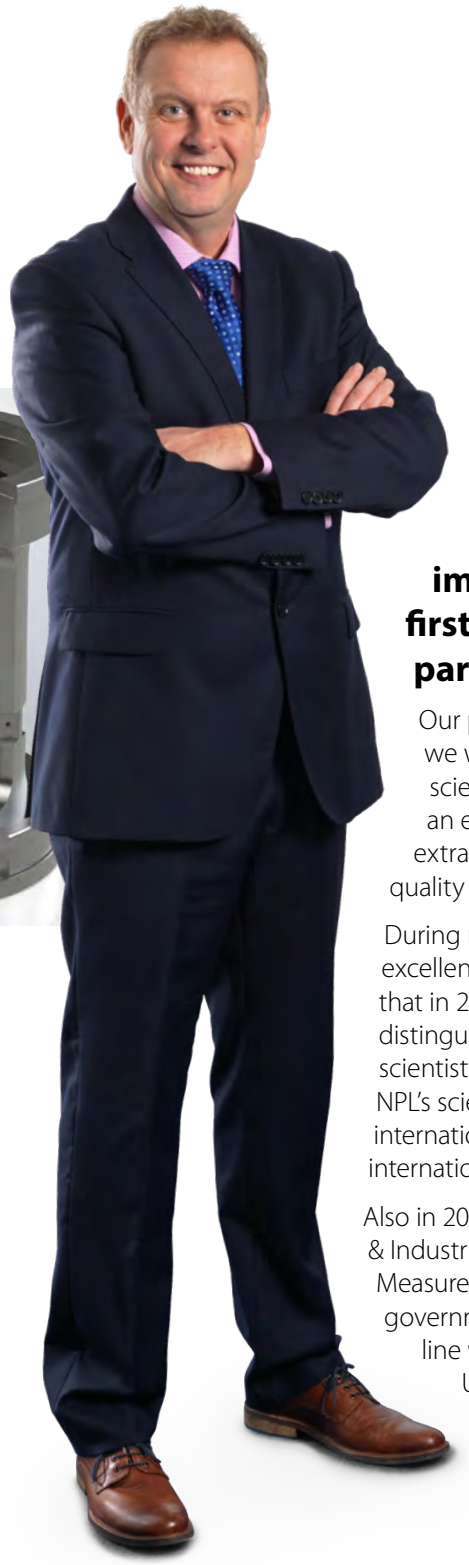
Annual Review

2016

Introduction from Peter Thompson



The Kibble balance (previously watt balance) first proposed in 1975 by Dr Bryan Kibble at NPL and, from 2018, one of the mechanisms that could be used throughout the world to realise the 'new' SI unit of mass.



Every year is exciting at NPL as the work we do is so diverse, the people so amazing and the impact that we create so impressive. But as 2016 was my first full year as CEO, this made it a particularly exciting year for me.

Our people are the heart of our business and together we work towards our vision for excellent measurement science and engineering, to be recognised as an exemplary national laboratory that delivers extraordinary impact and benefits UK prosperity and quality of life.

During my first year I have seen many examples of excellent research, and in recognition of this I was delighted that in 2016, an independent review, carried out by a distinguished committee of independent international scientists and industrialists, concluded that the majority of NPL's science and engineering portfolio is considered to be internationally-leading and all science areas perform at an internationally-competitive level.

Also in 2016, our owner, the Department for Business, Energy & Industrial Strategy (BEIS, formerly BIS) developed the UK Measurement Strategy. Its publication was signalled in the government's recent industrial strategy consultation, and in line with this we are focusing on four key areas for the UK on which measurement can have the biggest impact: advanced manufacturing; digital and quantum technologies; energy and environment; and life sciences and health.

We have had many great successes in these areas, such as the expansion of our support to the UK aerospace industry (*page 06*); the progress we have made in the development and commercialisation of quantum technologies (*page 09*); the techniques we have developed to provide better information for nuclear waste management for the Nuclear Decommissioning Authority and Sellafield (*page 14*); and our world-leading mass spectrometry imaging research, which is helping to tackle some of the healthcare industry's grand challenges (*page 18*).

We deliver impact through our products and services. In 2016, we streamlined these into four key offerings: instruments, training, consultancy and measurement services. During the year, we launched NPL Instruments to improve quality, productivity and efficiency across industry (*page 22*); we grew our training portfolio, launching a new metrology apprenticeship standard to develop the skills of the UK's current and future workforce (*page 24*); we provided tailored consultancy to businesses through our product verification programme – as, for example, with Stone Foundries, a castings company who won a multimillion-pound contract on the back of our support (*page 26*); and we launched 11 new measurement services, designed to give our customers the technical edge (*page 28*).

As a National Measurement Institute, we are part of one of the world's largest international collaborations, working towards the revision of the universal measurement system - the SI units. For example, in 2018, the measurement community is proposing to redefine the unit of mass, doing away with the current definition based on a physical artefact and instead basing the kilogram on a fixed value of the Planck constant, a fundamental constant of nature. In 2016, the watt balance, one of the approaches proposed for this redefinition, was renamed the Kibble balance in honour of its inventor, the late Dr Bryan Kibble who spent 20 years at NPL working on and refining this instrument.

Which brings me to our people. While we will always celebrate the successes of the past, we recognise that our future success is dependent on the quality and commitment of our people and the people we work with across academia, industry and government. We take pride in the diversity of our workforce – 15% of our staff come from outside the UK and speak over 50 different languages. It is great to see so many of the people NPL depends upon receiving recognition at the highest level (*page 32*).

We create impact from science. I hope you enjoy reading about it as much as we enjoy doing it. If you would like to know more, or want to work with us to create an even bigger impact in the future, please call us on: +44 20 8977 3222 or visit www.npl.co.uk

Dr Peter Thompson
Chief Executive Officer

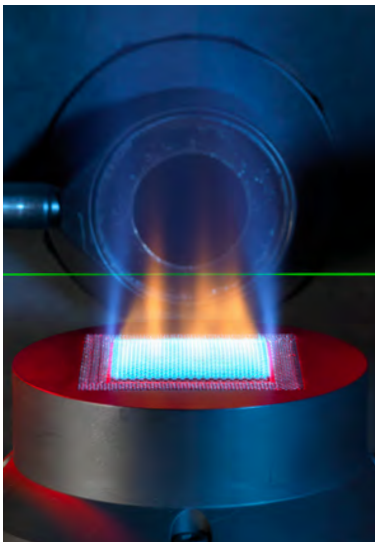
In 2016, an independent review concluded that the majority of NPL's science and engineering portfolio is considered to be internationally-leading and all science areas perform at an internationally-competitive level.

Dr Peter Thompson
Chief Executive Officer, NPL

CREATING IMPACT FROM SCIENCE

ADVANCED MANUFACTURING

Whether it is in the production of advanced things by normal means, or the production of day-to-day things by advanced means, the growth of the UK manufacturing sector is reliant on the increased productivity and value added from advanced manufacturing. All manufacturing is reliant upon measurement, but when it comes to processes that may involve large amounts of automation, machine–machine communication or require precision, then accurate and reliable measurement becomes invaluable. NPL will continue to work with industry across the country to ensure that measurement is considered throughout the manufacturing process, from design to production. We will provide industry with the tools required to raise efficiency and productivity and retain the UK's reputation as a producer of quality products.



The NPL standard flame provides a reproducible region of high temperature gas of known temperature and composition. It is used for the calibration of optical thermometry techniques commonly found in combustion research.

Expanding support to UK aerospace manufacturing

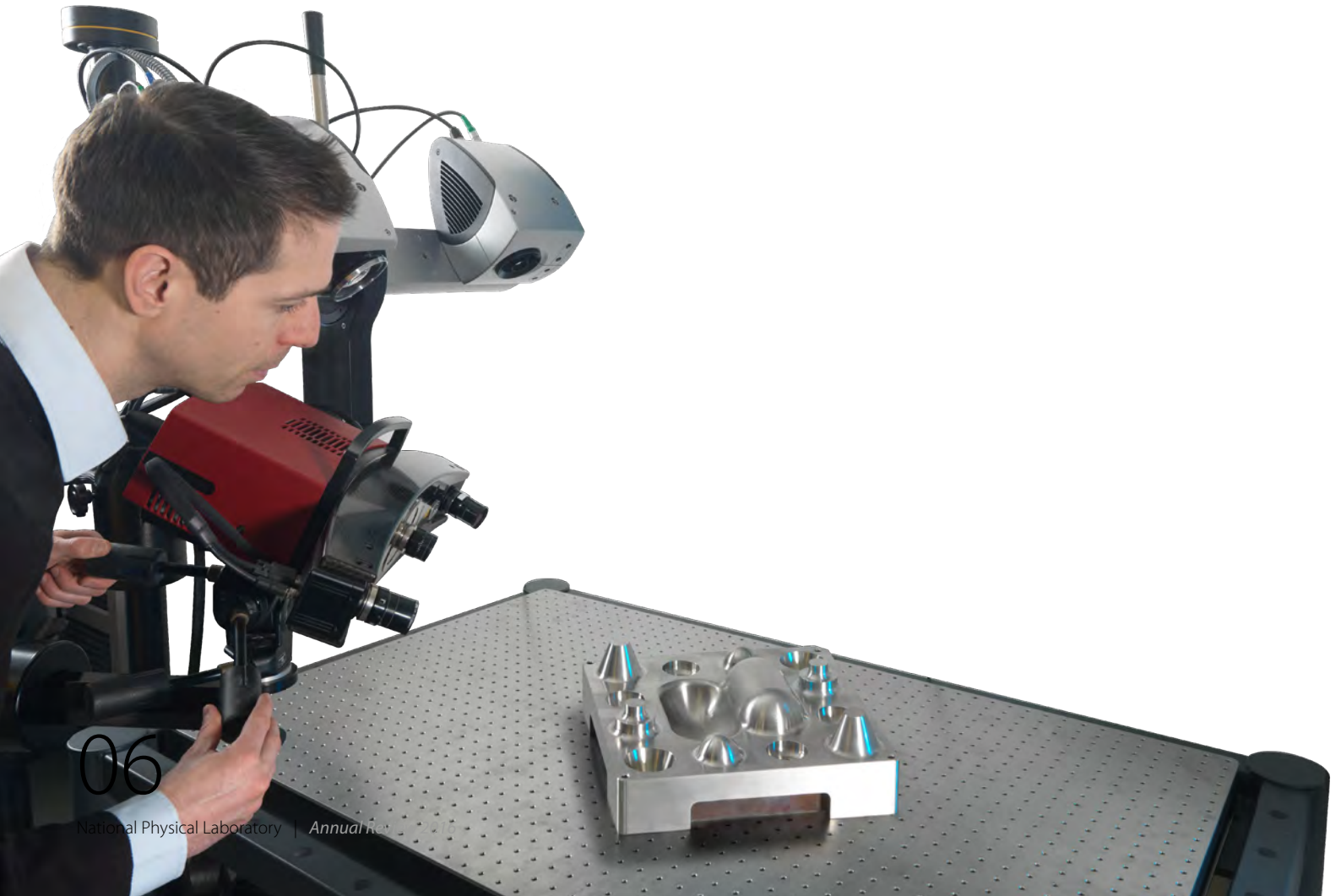
NPL has been awarded a second contract with the Sharing in Growth (SiG) programme to extend its work supporting companies in the aerospace supply chain through its Product Verification Programme. The new contract follows on from a successful partnership with SiG and will allow NPL to extend its services to a further 24 companies within the UK manufacturing sector.

The SiG programme supports UK aerospace companies to increase productivity and competitiveness in international markets. The intense four-year SiG training and development programme is focused on leadership, culture and operational excellence delivered by SiG's own 120-strong team of lean, coaches as well as a bank of experts, including NPL.

NPL was awarded the first contract by SiG in 2013 to work with 40 aerospace manufacturing companies and since then has identified more than £10M in savings for these manufacturers. The NPL team provides the tools, knowledge and training to manage, analyse and improve measurement and inspection processes. One company is saving £75k per year from improved levels of re-work due to better measurement practices.

NPL's CEO Dr Peter Thompson said: "I am delighted that NPL has been chosen to continue to provide state-of-the-art measurement support to UK aerospace manufacturing as part of this important initiative. We look forward to continuing to work with Sharing in Growth as one of their key delivery experts and to supporting the next cohort of SiG beneficiaries."

Andy Page, CEO of Sharing in Growth, said: "The National Physical Laboratory's Product Verification Programme has benefited UK suppliers, allowing them to deliver a competitive performance on the global stage. I am pleased to offer them the opportunity to continue to use this essential skill to benefit the UK economy."



Spray-printed crystals to move forward organic electronics

New technology from a collaboration involving NPL could revolutionise printed electronics by enabling high-quality semiconducting molecular crystals to be directly spray-deposited on any surface.

Organic semiconductors can be grown in a very different way to their conventional inorganic counterparts using solution-based methods at room temperature in air. This opens up the possibility of large-scale production of inexpensive electronics for numerous applications, ranging from field effect transistors and light emitting diodes to medical X-ray detectors and miniature lasers.

The research, from the University of Surrey, NPL, the University of Kentucky and the University of Southampton, demonstrates for the first time a low-cost, scalable spray-printing process to fabricate high-quality isolated organic single crystals. The method is suitable for a wide variety of semiconducting small molecules, which can be dissolved in solvents to make semiconducting inks and deposited on virtually any substrate, and is a powerful, new approach for manufacturing organic semiconductor single crystals.

Product verification beneficiary secures export deal

Sheffield-based precision engineering firm CW Fletcher & Sons Ltd has signed a £7M deal with Japanese firm Kawasaki Heavy Industries (KHI). The deal involves a three-year export contract with KHI involving the supply of unison ring components for use in Rolls-Royce aero engines and comes after CW Fletcher used NPL's Product Verification Service.

NPL worked with CW Fletcher as part of the Sharing in Growth programme, using its Product Verification Service to improve the company's application of measurement techniques and reduce costs. This has allowed the company to alleviate significant cost pressure within an increasingly competitive global market.

Managing Director of CW Fletcher, Steve Kirk, said: "This is a very important contract for us. It demonstrates the quality of our work and the skills of our workforce and it will safeguard Sheffield jobs. We are delighted that the Sharing in Growth programme has helped us win export business for Britain."

Increasing process efficiency through improved thermometry

Alongside its work leading international preparations for the redefinition of the SI unit of temperature, the kelvin, NPL is leading a project to increase process efficiency in high-value manufacturing through improved temperature measurement.

The project, part of the European Metrology Programme for Innovation and Research, will establish a complete traceability chain linking industrial temperature measurements to the SI. Key aspects of the research are the development of: new ultra-low drift thermocouples (the most widely used temperature sensors in high-value manufacturing) and self-validating thermocouples to 1500 °C, both of which will help facilitate autonomous factories; reliable and traceable surface thermometry, solving a long-standing industrial requirement improving, for example, welding processes in marine construction; and the development of a portable standard flame for traceable calibration of users' flame and combustion thermometry systems, which are used widely across manufacturing and transport.

> **The National Physical Laboratory's Product Verification Programme has benefited UK suppliers, allowing them to deliver a competitive performance on the global stage.**
>
> **Andy Page**
> *CEO, Sharing in Growth*

CREATING IMPACT FROM SCIENCE

Image courtesy: iStockPhoto.com/richterfoto

NPL has developed a new high-accuracy coordinate measurement system, an early prototype of the system was successfully demonstrated at Airbus' Filton site.

New measurement system for automated manufacturing

NPL is developing a new class of high-accuracy coordinate measurement system, based on frequency scanning interferometry, for the next generation of automated manufacturing.

Many high-value industries, such as aerospace and large-scale engineering, need to control the position, size and shape of key components with micrometre precision over large volumes (typically hundreds of cubic metres) on the shop floor. The new coordinate measurement system, developed by NPL as part of the European Metrology Research Programme, addresses these requirements, moving beyond the state-of-the-art in terms of its accuracy, traceability to the SI metre and ability to self-calibrate and calculate uncertainties.

Operating in a similar way to global navigation using GPS, the system can precisely calculate position and orientation, and track moving targets in real time, making it ideal for use in automated assembly and manufacture. An early prototype of the system was successfully demonstrated in a live factory environment during a two-week measurement campaign at Airbus' Filton site, performing well even when faced with challenging temperature gradients, vibrations and acoustic noise.

First 3D metrology conference

NPL chaired the first 3D Metrology Conference (3DMC) at RWTH Aachen University, Germany, in November 2016. The pan-European conference was chaired by Ben Hughes from NPL's Dimensional Metrology group and organised with colleagues from PTB (the National Measurement Institute of Germany), the Laboratory for Machine Tools and Production Engineering at RWTH Aachen University, and University College London.

Bringing together internationally-leading expertise, 3DMC is a new conference dedicated to the application and development of 3D measurement technology for industrial, scientific and cultural purposes. The event is aimed at end users of 3D metrology systems, equipment and software suppliers, service providers, researchers and procurement and quality managers. These target audiences operate in a diverse range of sectors, from aerospace and power generation, to the built environment and virtual reality. The event was attended by more than 120 delegates from 20 countries and featured an exhibition of state-of-the-art equipment.

DIGITAL & QUANTUM TECHNOLOGIES

The world is becoming increasingly connected, people to people and devices to devices. This explosion of interconnectivity brings a host of challenges along with its many opportunities. The blending of the real and digital worlds in social life, industry, healthcare, transport and government all present exciting new possibilities for increasing industrial growth and quality of life for citizens. All of this is based on fundamental computer-based technology, including components, devices, sensors, communications and the materials used to create them. Intrinsic to taking advantage of these possibilities is a detailed understanding and confidence in the workings of this technology, and the data it gathers, within complex systems. In the future, new devices based on quantum physics will add further to the range of technological developments enhancing the modern world.

Image courtesy iStockPhoto.com/Yuri 2015

NPL has established a fully-functional fibre link between optical clocks based in the UK and France.

Showcasing advances in quantum technology

The second National Quantum Technologies Showcase, held at the QEII Centre in London in November, was an opportunity for the organisations involved, including NPL, to display the world-leading research and technological development that they have been undertaking.

As a partner in the UK National Quantum Technologies Programme, NPL is applying its capabilities to help the UK become the world leader in the development and commercialisation of quantum technologies. NPL's Quantum Metrology Institute (QMI) put on a number of displays at the Showcase, ranging from miniature atomic clocks and other quantum devices, to a table-top quantum Hall system, which can provide a primary resistance standard in a relatively simple package. These potential new products and services will have an impact in areas as wide-ranging as communications, healthcare and quantum computing.

A number of successful bids for funding from the Quantum Technologies Innovation Fund were announced on the day, including a project led by technology company e2v, to work with NPL to further develop and commercialise the NPL MINAC miniature atomic clock. The compact nature of this clock will allow for stable and accurate timescales to be held locally across the world, reducing the problems of potential interference and disruption to GPS/GNSS timescales.

The Blackett review on quantum technologies, developed by Sir Mark Walport, the Government Chief Scientific Adviser, and Sir Peter Knight, the Chair of the QMI, was also launched at the Showcase. The report puts forward 11 recommendations to help make the most of recent government investments, many of which highlight the need for the QMI's expertise in metrology and standards to encourage the development of quantum technologies in the UK.

A planning application for an Advanced Quantum Metrology Laboratory (AQML) at NPL was also accepted. The AQML will provide a unique scientific environment, enabling frontier research in the field and enhancing NPL's reputation as a world-leading centre of excellence in developing and applying the most accurate measurement standards, science and technology available.

New facility supports ultra-efficient communications

A new joint facility – the Nonlinear Microwave Measurements and Modelling Laboratories (n3m-labs) – has been launched at NPL and the University of Surrey's Advanced Technology Institute to help develop the next generation of super-efficient electronic devices.

The n3m-labs facility will be the world's first multi-physics enabled laboratory dedicated to nonlinear microwave measurements and modelling, and comprises shared laboratories which will build on the strategic partnership between NPL and the University of Surrey. Research at n3m-labs will involve close collaboration with the 5G Innovation Centre at Surrey to ensure the next generation of wireless technology is highly energy efficient.

Professor Nick Ridler, the n3m-labs Director at NPL, said: "Through n3m-labs, we will be able to focus on major research areas that will underpin next-generation information and communications technology. This technology is necessary to establish an effective Internet of Things, machine-to-machine communications, and other multi-sensor dependent applications, including smart cities."

The new facility will provide an outstanding platform for strategic, high-quality, joint research into the next generation of scientific and engineering innovation.

Dr Peter Aaen
n3m-labs Director, University of Surrey

Optical fibre connects clocks in London and Paris

NPL, in collaboration with LPL (Laboratoire de Physique des Lasers) and LNE-SYRTE in Paris (part of the French National Measurement Institute), has established a fully-functional fibre link between optical clocks based in the UK and France. The international fibre link, only the second of its kind in the world, will allow optical clocks developed independently in the two countries to be characterised and compared, and will be used to help change the way we measure the second, the fundamental unit of time.

The 800 km long fibre link allows signals from a strontium optical lattice clock housed at NPL (and operated for the first time in 2016) to be compared against signals from similar optical clocks housed in Paris. As the most accurate clocks in the world, the only way to ensure optical clocks are working correctly is by comparison against other clocks of similar accuracy. Such international comparisons will be essential in the preparations for any future redefinition of the SI second in terms of an optical transition frequency.

CREATING IMPACT FROM SCIENCE

Record speed and accuracy from single-electron pumps

NPL, in collaboration with NTT (Nippon Telegraph and Telephone Corporation) in Japan, has measured silicon single-electron pumps with the highest speed and accuracy ever achieved, paving the way towards practical primary standards for electric current.

Single-electron pumps are tiny electronic devices that generate an electric current by moving large numbers of individual electrons around a circuit. These devices could be used as primary standards for the SI unit of electric current, the ampere. Highly-accurate techniques to verify the performance of single-electron pumps, such as those being developed at NPL, are crucial in the international effort to prepare for the new SI ampere.

The two key requirements of single-electron pumps are high accuracy and high speed. NTT's silicon nanodevice technology pushed the operating speed of the single-electron pumping frequency over 1 gigahertz (a billion cycles per second), while the accuracy was verified to be better than one part per million using NPL's high-precision small-electric-current measurement system. This is the first time that silicon single-electron pumps have been tested at such accuracy levels.

Image courtesy: iStockPhoto.com/alengo

NPL scientists have helped draft the first quantum technology standard, which includes standards for the next frontier of data.

First standard for quantum technologies

Scientists from NPL's Quantum Metrology Institute led the drafting of the first quantum technology standard, which covers the characterisation of components used in quantum key distribution (QKD) systems, the next frontier of data encryption technology.

Providing an additional layer of security over and above standard encryption methods, QKD shares an encryption key between two users that is made completely secure using quantum mechanics. The provision of standards for validation and certification is essential to enable the wider commercialisation of this new technology.

The new international (pre-)standard from the European Telecommunications Standards Institute (ETSI) marks a significant step forward in the standardisation of quantum technologies, outlining specifications and procedures for the characterisation of optical components used in QKD systems, such as single-photon sources and detectors. Measurement techniques for these components were developed at NPL, and tested in collaboration with Toshiba Research Europe Ltd, BT and ADVA, giving NPL the expertise which enabled it to lead the drafting of the new standard.

New device produces tuneable photons on demand

A collaboration including researchers at NPL has developed a tuneable, high-efficiency, single-photon microwave source. The technology has great potential for applications in quantum computing and quantum information technology, as well as in studying the fundamental reactions between light and matter in quantum circuits.

Circuits which produce single photons are a vital component in quantum computers. They usually consist of a quantum bit, or 'qubit', coupled to a resonance circuit. The resonance circuit limits the photon output to specific frequencies depending on the design of the circuit, meaning that researchers have to rebuild them each time a different frequency is required – this is both time and labour intensive. To overcome the problem, NPL, in collaboration with RIKEN in Japan, the Moscow Institute of Physics and Technology and Royal Holloway, University of London, created a new device which is tuneable and able to produce single photons over a wide range of frequencies on demand.

Data Metrology and Standards Workshop held at the University of Cambridge

NPL organised an industry workshop with the Universities of Cambridge and Huddersfield aimed at engaging and connecting with UK industrial users of data to understand their data science and data assurance needs. Over 100 delegates heard the keynote speaker Bob Hanisch, Director of the Office of Data and Informatics at NIST, provide an overview of the current development of data management initiatives. The workshop was facilitated by the Institute for Manufacturing, with the focus of the day on understanding current state of the art in UK industrial data capabilities, and data science requirements through road mapping and project prioritisation activities.

ENERGY & ENVIRONMENT

With national and international agreements in place to limit our impact on the planet, it's becoming increasingly important that the UK takes a leading role in the development of new technologies to both build a thriving economy from emerging opportunities, as well as retain our status on the world stage. At the same time, we must ensure the security of energy supply and its affordability to every member of our society. NPL will be working with government, regulators, innovators, power generators and researchers to ensure that the best possible technologies are being developed and implemented based on the best possible understanding of our environment.

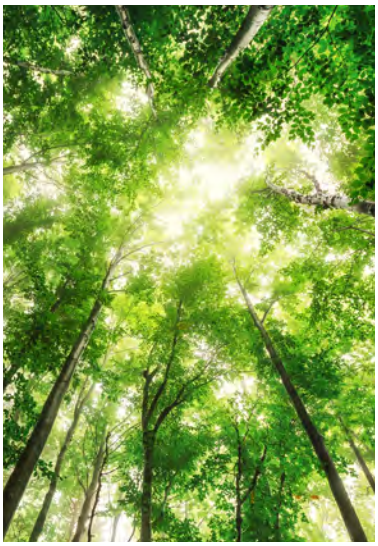


Image courtesy iStockPhoto.com/kallio886

Collaborative research involving NPL is using lasers to accurately 'weigh' trees to help take stock of how much carbon is locked within forests.

Fast, effective management of nuclear waste

A new technique developed by NPL for the Nuclear Decommissioning Authority (NDA) improves the speed and accuracy of strontium-90 analysis to provide better information for nuclear waste management plans.

The NDA expects to spend more than £3 billion ensuring the safe and efficient clean-up of the UK's nuclear legacy in the 2016/17 financial year. To understand how best to manage the increasing amount of waste, UK nuclear sites (managed by the NDA) need to be able to accurately measure the distribution and concentration of the radioactive isotopes (radionuclides) present. However, for many radionuclides, existing measurement procedures are time and labour-intensive and in some cases non-existent.

Strontium-90 is a radionuclide of significant interest in decommissioning, produced by nuclear fission during reactor operation. Current measurement techniques are labour-intensive and lengthy, as strontium-90 needs to be chemically separated from waste material before it can be analysed, and often requires long counting times in order to reach the desired detection limits relevant to waste characterisation limits.

NPL's Radioactivity group was commissioned by the NDA to investigate the possibility of a faster, alternative method using the latest-generation triple-quadrupole inductively coupled plasma-mass spectrometry (ICP-QQQ-MS). The optimised methodology developed by NPL enables the selective removal of interfering isotopes, leaving the strontium-90 behind so it can be accurately measured, and significantly reduces the procedural time and labour required for analysis. This results in higher sample throughput, potentially reducing site clean-up time and therefore offering significant economic benefits to nuclear sites.

The success of this project accelerated the start of another project for Sellafield Ltd, investigating the capability of ICP-QQQ-MS as a rapid and cost-effective alternative for measuring multiple radionuclides in aqueous discharge samples. NPL's ultimate aim is to develop the methods from these projects into accredited procedures, enabling the UK's nuclear industry to realise the benefits.

Taking stock of carbon in forests

Dr Kim Calders has won the Robert May Prize for the best paper submitted by an early-career researcher. The prestigious prize, awarded each year by the British Ecological Society (BES), was given to Kim for his research in collaboration with UCL and Wageningen University, Netherlands, on using lasers to accurately 'weigh' trees.

Measuring the mass of trees allows climate scientists to take stock of how much carbon is locked within forests, in turn supporting policy-makers and scientists to make essential decisions about the mitigation of climate change. Using accurate laser-scanning technology to measure each tree's volume, Kim's team used sophisticated mathematical modelling and remote-sensing methods to make accurate estimates of biomass. The technique builds upon the existing density database, adding information without felling trees, and makes measurements of carbon content much more accurate.

The BES praised both the scope and promising nature of Dr Calders' work, noting its potential for monitoring the world's carbon reserves and developing new climate-based policy.

Confidence in climate data

NPL is providing broad-based support to ensure the quality of data from a newly-launched European Space Agency (ESA) satellite.

The Sentinel-3A satellite, the latest in the EU Copernicus programme, aims to provide long-term data for ocean characteristics such as temperature, height and colour. NPL's Earth Observation, Climate and Optical group was initially involved in providing standards for the pre-flight calibration and will now be actively involved in supporting the science from Sentinel-3A's data, including being formally included on the validation team for its ocean colour and temperature sensors.

The Centre for Carbon Measurement at NPL, in collaboration with the University of Reading and Telespazio France, has also launched a two-year project to ensure the Copernicus Climate Change Service – the world's largest store of climate information – delivers climate-quality data products with clear and robust assessments of their accuracy, allowing its users to assess the 'fitness for purpose' of the data for their applications.

Supporting uptake of green gas

Lucy Culleton has won the first European Biogas Association Poster Award for her work supporting the introduction of biogas into Europe's gas networks.

Biogas, produced from decomposing organic matter such as municipal or agricultural waste, can be mixed with natural gas and introduced into existing pipelines, or even used to power vehicles, but impurities introduced by the initial waste material can lead to problems. Lucy and her colleagues at NPL have been developing methods capable of detecting extremely low levels of impurities in biogas, to support its use as an alternative, renewable energy source.

Using a gas chromatograph, which separates the biogas components, together with a highly-sensitive detector, NPL is establishing a facility that will measure the total silicon content of a biogas sample with unprecedented accuracy – at low parts-per-billion level. This will provide confidence in quality control for biogas and support its safe and effective introduction into Europe's gas networks.

For more than a decade NPL has been a reliable partner of the ESA test centre, helping us to safeguard traceability of measurement results and investigate advanced environmental testing concepts.

Mark Wagner
Head of Test Facilities at ESA

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Image courtesy: iStockPhoto.com/sankai

NPL is the sole provider of nitrogen monoxide reference standards to WMO Global Atmosphere Watch, helping to provide a better understanding of changes to the Earth's atmosphere and their impact on human health and the environment.

Setting standards in atmospheric monitoring

NPL has been appointed the Central Calibration Laboratory for nitrogen monoxide by the World Meteorological Organization (WMO), as part of a programme to better understand changes to the Earth's atmosphere and their impact on human health and the environment.

The role will see NPL supporting the WMO Global Atmosphere Watch (GAW) programme as the sole provider of nitrogen monoxide reference standards to monitoring stations across the world. The GAW monitoring network, made up of over 500 stations spanning 80 countries, provides long-term observations of the chemical composition of the atmosphere, to improve our understanding of the increasing influence of human activity on the Earth's atmosphere.

Accurate monitoring of nitrogen monoxide levels is critical to effective air quality research and policy-making, as it reacts with oxygen in the air to form nitrogen dioxide, a major pollutant known to detrimentally affect both human health and the environment.

Hydrogen refuelling station opens

A new public hydrogen refuelling station, opened at NPL by Transport Minister Andrew Jones, will serve drivers of fuel cell powered vehicles. The station is one of several being installed in the London area as part of the HyFIVE project, an EU-funded initiative designed to kick-start electrification of transport. Hydrogen-fuelled cars produce no harmful exhaust emissions, only water vapour, and hydrogen is set to become a crucial part of the UK's future energy mix as the government strives to create a low carbon economy and meet challenging climate change and air quality targets.

In addition to hosting the refuelling station for ITM Power, NPL is supporting the development of a hydrogen economy through its cutting-edge research on fuel cells, electrolysers and hydrogen purity. A novel reference electrode invented by NPL is helping electrolyser manufacturers identify more durable and cost-effective water-splitting catalysts, and NPL's hydrogen purity laboratory is supporting the rollout of hydrogen vehicles by providing quality assurance to refuelling stations.

LIFE SCIENCES & HEALTH

Work in life sciences and healthcare is being spurred by an ageing population and an increase in chronic and lifestyle diseases such as cancer, dementia and obesity. Meeting these challenges and maintaining the UK's world-leading status in healthcare will require a convergence of the physical sciences with existing work in life sciences. From personalised medicine to smart surgeries, from advanced therapeutics to synthetic biology, an accurate understanding of the measurements involved in working with biological systems is crucial to success. Whether in delivering the exact dose of radiation to treat a tumour, or improving processes for drug discovery, NPL is working with researchers, regulators and charities to ensure that the UK has a healthier, happier future.

Image courtesy iStockPhoto.com/tudemm

NPL is applying its world-leading expertise in mass spectrometry imaging to support the development of improved treatments for cancer, and help reduce late-stage drug failure through early measurement of exactly where drugs are distributed.

Mass spectrometry imaging in cancer research

NPL is applying its world-leading expertise in mass spectrometry imaging (MSI) to support the development of improved treatments for cancer. The National Centre of Excellence in Mass Spectrometry Imaging (NiCE-MSI) at NPL is one of the world's leading MSI centres, with a focus on advancing measurement capabilities, establishing metrology for reliability and standardisation, supporting UK industry and training the next generation of scientists and engineers.

MSI offers unique opportunities in cancer treatment for measuring disease markers, drug distribution and the molecular changes occurring within tumours throughout treatment. These attributes highlight MSI's excellent potential to inform treatment decisions and monitor treatment responses, to help the development and delivery of therapies that are effective for particular groups of patients.

NiCE-MSI is leading a multi-disciplinary consortium, shortlisted for Cancer Research UK's Grand Challenge award, that aims to bring MSI techniques together in an ambitious programme for multi-scale imaging of tumour metabolism inside and outside the body, down to sub-cellular measurements. If successful, this project will use the revolutionary 3D OrbiSIMS instrument, conceived by NPL to address a grand challenge in the pharmaceutical industry: reducing late-stage drug failure through early measurement of exactly where drugs go within sub-cellular compartments, known as 'organelles'.

This innovative instrument, the only one worldwide, is a powerful UK capability and was launched by Sir Colin Dollery, Senior Consultant at GSK, in November 2016. In addition to the pharmaceutical challenge, the instrument has incredible potential for cancer research owing to its ability to accurately identify tissue constituents and the presence of chemicals, such as those metabolised by a tumour, that are otherwise obscured in other state-of-the-art instruments.

As the UK's National Measurement Institute, NPL is well poised to deliver reliable and validated protocols which will provide meaningful results and be widely adopted by other researchers. Globally, NPL has the strongest track record and coverage of international standardisation in MSI. Such standardisation is essential in cancer research and the life sciences because of the need to improve reproducibility in biomedical research, the interdisciplinary nature, the complexity of the techniques themselves, and the portfolio of evidence and validation required for regulatory approval of new treatments and diagnostic tests.

Bringing revolutionary cancer treatment to the UK

NPL has made measurements of the UK's first portable intraoperative radiotherapy machine, used to deliver targeted radiation during surgery. The machine, called the 'Mobetron' (mobile electron accelerator), will be used to treat tissue around tumours as they are surgically removed, allowing high doses of radiation to be delivered to precise areas and reducing the chances of recurrence.

To guarantee the Mobetron could be used with the desired degree of precision, accurate measurements needed to be made of its properties and performance. In recognition of its expertise, NPL's Radiation Dosimetry group was commissioned to make these measurements, including the assessment of different electron applicators, used to target the beams of electron radiation. NPL's measurements precisely defined the properties and performance of the machine, allowing its operators to deliver high doses of radiation with a high degree of accuracy. The first bowel cancer patient in the UK was treated using the Mobetron at Southampton General Hospital in January 2017.

Engineering more effective antibiotics

An international team of researchers, led by NPL, has engineered an antimicrobial mechanism that kills bacteria within minutes by peeling their membranes. The findings could provide a new physical basis for designing more effective antibiotics.

Our immune systems use host defence peptides that recognise and destroy the membranes of harmful bacteria. Exploiting this natural defence mechanism, the team predicted and engineered a molecular-scale motif that thins and exfoliates the membranes of bacterial cells – the process, termed 'monolayer poration', 'nibbles' bacterial membranes to expose their oily part to water, which leads to irreparable ulcers and invariably to bacterial cell death.

This research was carried out in collaboration with researchers from UCL, the Universities of Oxford, Edinburgh and Western Australia, the European Commission Joint Research Centre, Physikalisch-Technische Bundesanstalt and the IBM Thomas J Watson Research Center. The findings are now being explored to enhance our defences against the growing threat of increasingly-sophisticated bacteria.

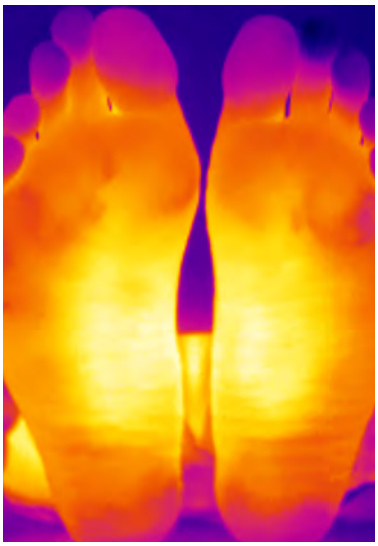
Improved detection of breast cancer using ultrasound

A collaboration including researchers from NPL has devised a prototype clinical system for a new ultrasound imaging technique for potential use in breast cancer diagnosis. The development was shortlisted for the prestigious Collaborate to Innovate award run by *The Engineer* and given for work which displays high-level collaboration to produce innovative technology.

The concept behind the ultrasound imaging technique originated at NPL and is currently being developed through Innovate UK funding in collaboration with industry partners Precision Acoustics Ltd and Designworks, along with University Hospitals Bristol (UHB). The novel detection method uses pyroelectric sensors and should produce images with fewer imaging artefacts, which are easier for clinicians to interpret than current techniques.

Gary Livingstone, Managing Director of Precision Acoustics, said: "We are very proud to be involved with NPL on such a ground-breaking project. The collaboration made possible by Innovate UK brings together scientific discovery and engineering ingenuity to produce an exceptional advancement of cancer imaging and potential future treatment."

> **Our role, working with medical device manufacturers like Mobetron and the NHS, is key to ensuring that the most cutting-edge technology is available for the treatment of cancer in the UK.**
>
> **Rebecca Nutbrown**
> *Head of Metrology for Medical Physics*



NPL is working with health experts to develop a portable thermal imaging device to identify pre-ulcerous sites on feet by detecting temperature anomalies.

The world's smallest virus

NPL, in collaboration with the Universities of Brighton, Bristol and Reading, has engineered an artificial virus able to encapsulate and safely transfer genes into human cells.

Instead of using large complex proteins that typically make up viral shells, the team designed very short protein fragments that assembled into the world's smallest virus, just 12 nanometres in diameter. In addition, the virus was shown to be structurally plastic, with the ability to adapt its size to that of genes it encapsulates.

Recognising the potential applications of the work, the American Chemical Society highlighted the impact the virus could have in genetic medicine, explaining that it could someday carry potentially therapeutic DNA or RNA and transfer it to human cells. With their uniform sizes and morphology, the virus shells provide a solid platform for developing candidate reference materials as suitable standards for gene transfer products, in support of NPL's work producing reference standards, methods and materials to ensure the safe and reliable use of synthetic biology.

Thermal imaging for better diabetes care

Diabetic foot ulceration (DFU) is a serious and rapidly-growing issue, estimated to cost the NHS in England and Wales more than £1 billion each year. Early detection is critical to improving patient outcomes, enabling doctors to take prompt preventative action that could reduce the number of amputations needed by 80%.

NPL, working with Pennine Acute, Newcastle upon Tyne and King's College Hospital NHS Trusts, the University of South Wales and Photometrix Imaging Ltd, has developed a portable and easy-to-use thermal imaging device, which identifies pre-ulcerous sites on feet by detecting temperature anomalies, before any visible signs of skin damage arise. Early identification of vulnerable skin and appropriate preventative action is key to stopping ulcers developing. After performing well in an initial trial on healthy volunteers, the device is now being assessed as part of a clinical trial involving patients at high risk of DFU.

The research was funded by the National Institute for Health Research (NIHR) II-LA-0813-20007 programme. The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR or the Department of Health.

PRODUCTS & SERVICES

- Instruments
- Training
- Consultancy
- Measurement services

Instruments

NPL provides confidence through traceability by developing highly-accurate measurement instruments, sensors and artefacts. The range of instruments we can provide extends from bespoke systems designed to meet specific measurement requirements to standard artefacts and complete metrology systems based on those operated at NPL.

www.npl.co.uk/instruments

NPL's Differential Absorption Lidar (DIAL), a remote sensing lab-on-wheels, has been used by Defra to provide reliable methane monitoring at landfill sites across the UK.

NPL Instruments launched to help accelerate industrial innovation

NPL announced the launch of NPL Instruments, bringing its world-class measurement instruments and expertise still closer to industry, improving quality, productivity and efficiency.

In launching NPL Instruments, NPL is furthering its commitment to ensuring business and commerce benefit from its measurement expertise. It does this by providing confidence that their products and processes perform as they should and to the highest quality, and by maximising the reliability and efficiency of their systems.

Organisations like NASA, the Ministry of Defence (MOD), the Department for Environment, Food and Rural Affairs (Defra) and the European Space Agency (ESA) are already benefiting from this expertise. NASA, for example, uses the most accurate machines in the world to craft the mirrors in its space telescopes. NPL was uniquely placed to create the laser systems that control and operate these machines. Defra has made use of new environmental monitoring techniques from NPL that track greenhouse gas emissions in 3D over large areas, allowing it to manage sites such as landfills much more effectively.

To support the continued growth of this relationship with industry, NPL Instruments will be putting £1.5M towards new machining centres and state-of-the-art laboratories, as well as the recruitment of new engineering specialists and advanced engineering apprentices.

Professor Ian Boyd, Chief Scientific Adviser, Defra, said: "Accurate monitoring of atmospheric gas emissions is a key input to sound policy decisions. NPL's sophisticated remote sensing lab-on-wheels, DIAL, is an example of a unique instrument which has been used by Defra as a tool to provide reliable methane monitoring at landfill sites across the UK."

Professor Jeremy Watson CBE, IET President, said: "NPL prides itself on improving technology and providing precision through a long history of making novel instruments, which has been invaluable to all areas of engineering: from advanced manufacturing to medical, to environment to space."

Micro-vibration device tests ESA satellites

The European Space Agency (ESA) has added a micro-vibration test instrument developed by NPL to its satellite testing facilities. ESA needs to be able to test and correct for vibrations caused by satellite subsystems to improve the accuracy of its Earth observation measurements. NPL developed a micro-vibration platform for ESA that can measure vibrations made by subsystems to an unprecedented degree of accuracy – so sensitive it can measure the force of a single dropped feather. The platform also generates small, controlled forces and torques to shake satellite instruments and components in six degrees of freedom.

Mark Wagner, Head of Test Facilities at ESA, said: "Based on the scientific knowledge and profound excellence in measurement techniques at NPL, ESA entrusted the development of its new micro-vibration test facility to them. This new facility exhibits unprecedented measurement performance and will help us characterize spacecraft units on the ground with the aim of understanding their contribution to overall performance in orbit."

NANA offers new opportunities in radioactivity metrology

A new gamma-ray spectrometer at NPL is set to significantly extend capabilities in radioactivity measurement, from the standardisation of radiopharmaceuticals for medical treatment, to our understanding of the rarest isotopes ever discovered. Developed in collaboration with the University of Surrey, the new instrument, known as the National Nuclear Array or 'NANA', can be used to analyse complex radioactive samples with incredible speed and accuracy, identifying exactly which radioisotopes are in a sample, and in what quantity, within a matter of nanoseconds.

NANA's capabilities could provide support to a huge range of applications, including the safe storage and disposal of nuclear waste, reliable monitoring of radioactivity levels in the environment, and the safe, effective use of radiopharmaceuticals for the diagnosis and treatment of cancer. NANA's radiation detectors have also taken part in fundamental physics experiments around the world, from the Argonne National Laboratory in the US, to RIKEN in Japan, and even to the home of particle physics, CERN.

Primary attenuation standard delivered to South Africa

NPL has installed a primary radio frequency (RF) attenuation measurement system at the National Metrology Institute of South Africa (NMISA). Attenuation standards, together with those for noise, impedance and power, underpin almost all reliable microwave measurements made today. Reliable microwave measurements are essential to the performance and advancement of a range of technologies, from smartphones and wireless networks to GPS and remote sensing.

Based on the state-of-the-art system at NPL, the new system at NMISA was constructed using both commercially-available equipment and bespoke hardware designed by NPL and built by Ultratest. The system was installed at NMISA by experts from NPL's Electromagnetics group, who also provided specialised training for the system's users and instrument control software. The new capability puts NMISA among the world-leading microwave standards laboratories using a bespoke attenuation measurement facility to underpin their microwave metrology.

NPL prides itself on improving technology and providing precision through a long history of making novel instruments, which has been invaluable to all areas of engineering: from advanced manufacturing to medical, to environment to space.

Professor Jeremy Watson CBE
IET President

CREATING IMPACT FROM SCIENCE

Training

NPL sets the standards for metrology training in the UK, helping customers gain maximum value from their measurement systems. NPL Training encourages learners to make a difference within their workplaces, giving them the opportunity to generate a return on investment for their employers while simultaneously improving corporate measurement capability.

www.npl.co.uk/training

NPL is offering a new Diploma in Metrology and Calibration, the first approved qualification in the UK that offers technical education leading to skilled employment, as an alternative to the academic route.

Metrology apprenticeship standard approved by government

The Department for Education (DfE) approved a new NPL-led trailblazer apprenticeship standard for Metrology Technician. The trailblazer programme sees groups of employers join to design apprenticeships that develop the skills of their current and future workforce, in support of the government's ambition to increase the number of quality apprenticeships in England.

The new Level 3 standard was developed by the metrology trailblazer group, which includes over 30 employers and key stakeholders. This group is led and chaired by NPL and supported by Kapow Learning Solutions. The new standard sets out the knowledge, skills and behaviours required by Metrology Technicians across a wide range of industries.

As the first nationally-recognised apprenticeship standard in metrology, it will ensure apprenticeship training is relevant and beneficial to the future of the metrology industry. It will also help boost opportunities for people starting out in the metrology industry and will help support the growth of the metrology workforce nationwide.

The Minister of State for Apprenticeships and Skills, Robert Halfon, said: "Apprenticeships offer young people a ladder of opportunity to gain the vital skills they and businesses need to succeed. By putting more control in the hands of employers, we are ensuring apprenticeships are high quality and address skills shortages facing industry. Congratulations to the metrology trailblazer for publishing their Metrology Technician apprenticeship standard, and for playing an active role in developing the workforce of the future."

Suzanne Loftus, Chair of the metrology trailblazer group and Operations Manager for NPL Training, added: "Metrology is key to UK companies and currently there are no specific vocational routes into skilled roles. The new apprenticeship standard is a game changer for employers, providing an alternative route into skilled employment and valuable recognition of the metrology profession. The standard will ensure individuals have relevant technical skills and knowledge that are valued by industry, contributing to the long-term success of the economy."

Students master the fundamentals of metrology

A new one-week training course in the Fundamentals of Metrology has been delivered by NPL to students from the University of Cambridge, Cranfield University and CERN. The series of 22 lectures, devised and delivered by NPL staff, is offered as a Master's-level module by the EPSRC Centre for Doctoral Training in Ultra Precision Engineering, based at Cambridge and Cranfield.

Designed to introduce students to practical and theoretical aspects of engineering metrology, the course covers subjects ranging from uncertainty analysis, the worldwide basis for metrology and the SI and its forthcoming revision, to the latest research and provision of services in dimensional, thermal and mass metrology. The course was first delivered in January 2016 and, as well as the formal series of lectures and laboratory demonstrations and tours, now features an assessed assignment, which is submitted to NPL for marking after the lectures have concluded.

First diploma in metrology

NPL is offering a new Diploma in Metrology and Calibration, the first approved diploma in the UK that offers technical education leading to skilled employment, as an alternative to the academic route.

The Level 3 Diploma provides students with the knowledge and skills required to become proficient Metrology and Calibration Technicians. The flexible modular structure ensures it can target specific industry sectors, meeting continuing professional development requirements, while delivering formal qualifications.

Students study core modules, providing a general foundation in metrology, and are then led to field-specific learning pathways, constructed from 14 optional modules. These pathways can focus on fields such as electrical or dimensional measurement, or take a more generalist approach combining these with additional topics such as force, pressure or temperature and humidity measurement. The Diploma is approved by EAL, a skills partner and awarding organisation for industry which provides a robust quality framework, enabling NPL to work with training providers and industrial training schools to roll out these courses across the UK.

New postgraduate training programme

NPL has introduced a new measurement science training programme for students in the Postgraduate Institute for Measurement Science (PGI). The new series of training courses, created by the PGI and NPL, provides a foundation for good measurement practice that will support students during their doctoral research and beyond.

The PGI, established following a strategic partnership between the Department for Business, Energy and Industrial Strategy (BEIS), the Universities of Strathclyde and Surrey, and NPL, aims to be the leading UK and international centre for doctoral training and skills development in metrology and its applications. One year on from its inauguration, the first annual PGI conference was held at NPL in November. The two-day conference was attended by 150 delegates, comprising postgraduate researchers based both at NPL and partner universities, their supervisors, invited guests and speakers, including Dr Tania Mathias MP.

Congratulations to the metrology trailblazer for publishing their Metrology Technician apprenticeship standard, and for playing an active role in developing the workforce of the future.

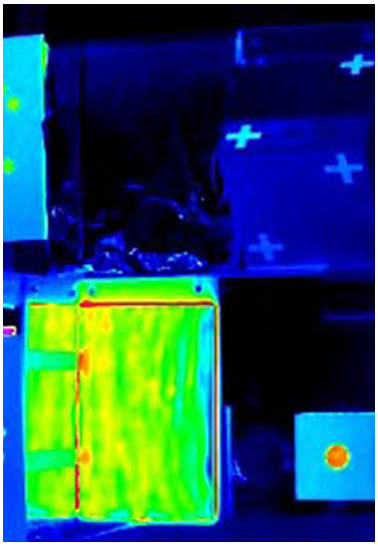
Robert Halfon:
The Minister of State for Apprenticeships and Skills

CREATING IMPACT FROM SCIENCE

Consultancy

NPL's knowledge is regularly used by our global client base to help to solve business-critical problems. We also provide responsive and affordable tailored consultancy solutions to help identify measurement needs and issues within organisations.

www.npl.co.uk/consultancy



Researchers at NPL have developed a new technique for taking 3D thermal images of satellites, allowing developers to better model and validate satellite behaviour prior to launch.

Confidence in data helps castings company secure contract

Castings company Stone Foundries has secured a multimillion-pound contract as a result of product verification support from NPL. The new business paves the way for further investment in plant equipment and technology at Stone Foundries' facility in south-east London, which produces high-integrity aluminium and magnesium castings for the aerospace and defence industries.

NPL's Product Verification team has been working closely with Stone Foundries under the Sharing in Growth programme, and identified an opportunity to bring in NPL's expertise in laser scanning measurement and casting modelling and simulation. Access to this expert knowledge greatly increased Stone Foundries' confidence in the use of casting modelling process data. As a result, the company was able to demonstrate its capability to a potential new customer and secured a substantial new contract on the strength of NPL's work.

Stone Foundries' Quality Director, Dr Simon Butler, said: "Through NPL's support the customer recognised that we now have the capability to manufacture this complex part in a difficult magnesium alloy. The subsequent production is likely to have a life of many years to come."

Demonstrating this technical capability was a major factor in Stone Foundries' success. Managing Director, John Townsend, said: "The market is tough but we are winning on innovation, speed, quality and efficiency and this will help Stone Foundries fulfil the growth ambitions set out when we joined the Sharing in Growth programme in 2013.

"At that time we were seeing light alloy castings work transferring from the UK and the USA to Eastern Europe and Asia. With the support of the Sharing in Growth programme our capability and competitiveness have reached new levels, resulting in major long-term global opportunities and investment in class-leading new technologies in line with customer needs."

New 3D thermal imaging capability for satellites

Researchers at NPL have developed a new technique for taking 3D thermal images of satellites, which is being developed for prospective use at the European Space Agency's (ESA) largest vacuum facility, the Large Space Simulator.

Historically, when measuring temperature, space scientists use thermocouples. However, for an accurate, high-resolution measurement, many thousands of thermocouples need to be attached to each satellite, which is often impractical. A solution comes in the form of thermal imaging – 3D thermal pictures taken on the ground provide supplementary information, allowing satellite developers to model and validate satellite behaviour prior to launch.

Working with Swiss 3D measurement company PhotoCore and London-based management consultancy PSI-tran, NPL implemented new, state-of-the-art features which produce accurate, traceable geometrical and thermal information from the satellite structure. The new technique will be used in satellite testing by ESA at its European Space Research and Technology Centre, as part of its ongoing work to enhance measurement data.

Measurement support leads to significant savings

Support from NPL has helped precision engineering company Anglia CNC Engineering (ACE) improve its manufacturing processes and is expected to save the company at least £50k a year.

NPL's team of Product Verification specialists visited the company to identify opportunities to optimise manufacturing and inspection processes through improved measurement practices, before providing the necessary support to address them. The first involved developing ACE's capability to perform in-house calibrations of measurement equipment, which will significantly reduce subcontracting costs. The second involved helping ACE collect and apply appropriate measurement data to better understand its machines' capabilities and improve performance – this should reduce the cost of non-conformance in machining operations by at least £50k a year.

Graham Fenn, Managing Director of ACE, said: "The NPL team quickly understood my company's challenges. They were flexible to my business' needs, which really impressed me, and made an immediate, tangible difference to my business."

Autonomous space travel moves closer to reality

An accurate method for spacecraft navigation took a leap forward as NPL and the University of Leicester revealed a spacecraft's position in space, in the direction of a particular pulsar, can be calculated autonomously, using a small X-ray telescope on board the craft, to an accuracy of 2 km.

The technique, evaluated for a European Space Agency feasibility study, uses X-rays emitted from pulsars (dead stars that emit X-ray and other electromagnetic radiation) to work out the position of a craft in space. For a certain type of pulsar, called a 'millisecond pulsar', the pulses of radiation occur with the regularity and precision of an atomic clock and could be used much like GPS in space.

Traditional ground-based space navigation can only support a limited number of spacecraft at any one time. This new technique could allow a greater number of complex space missions to take place simultaneously in deep space as craft become capable of navigating themselves.

> **Through NPL's support the customer recognised that we now have the capability to manufacture this complex part in a difficult magnesium alloy. The subsequent production is likely to have a life of many years to come.**
>
> **Dr Simon Butler**
> *Stone Foundries' Quality Director*

CREATING IMPACT FROM SCIENCE

Measurement services

NPL's services are built on 100 years of leadership in accuracy, innovation and scientific research. These services are designed to meet the most challenging measurement requirements and provide our customers with the technical edge needed to be truly world-class.

www.npl.co.uk/measurement-services

*NPL*Time*® is a precise time signal directly traceable to Coordinated Universal Time (UTC) and provides a highly-accurate time standard to ensure that financial transactions completed in microseconds can be easily certified.*

NPL signs agreement with UBS and TMX Atrium to provide NPL*Time*®

NPL has signed an agreement with UBS and TMX Atrium to provide NPL*Time*®, a certified and precise time signal that will offer trusted time for trading infrastructures.

NPL*Time*® provides a precise time signal directly traceable to Coordinated Universal Time (UTC) and independent of GPS. The service provides the end user with a distributed solution that is certified at their premises via TMX Atrium infrastructure. Having traceability back to such a highly-accurate time standard will ensure that transactions completed in microseconds can be easily certified.

Dr Leon Lobo, Strategic Business Development Manager at NPL, said: "Our remit is to manage and disseminate the UK's timescale, UTC(NPL). NPL*Time*® is an extension of many decades of time dissemination expertise. We operate two of the world's most accurate atomic clocks, the caesium fountains NPL-CsF2 and NPL-CsF3, which are accurate to one second every 158 million years, and are developing the next generation of optical atomic clocks, which will be accurate to one second in 14 billion years. By launching this new solution, with a direct connection to UTC, we are able to provide users of NPL*Time*® with a trusted and traceable distribution service that completely eliminates reliance on GPS."

Eric Sinclair, President, TMX Market Insights, and Group Head of Information Services, TMX Group, said: "The global demand for higher degrees of timestamp accuracy continues to grow. The provision of NPL*Time*® on the TMX Atrium network enables our community to receive a highly-accurate time signal that cannot be disrupted by outside interference and can be implemented using existing infrastructure. The system removes the need for time synchronisation between various locations, and will better equip our clients with the ability to comply with regulatory obligations around the world."

Chris McConville, Global Co-Head of Equity Electronic Agency Trading at UBS, said: "The NPL*Time*® solution will provide UBS infrastructure with a stable, accurate and resilient time signal, whilst simplifying the MiFID II time synchronisation traceability requirements."

NPL also installed the first of two caesium fountains, based on the design of NPL's own primary frequency standards, at the Space Research Centre of the Polish Academy of Sciences in December 2016.

Independent testing builds consumer confidence for Tech21

NPL has worked with phone case manufacturer Tech21 to deliver a rigorous testing methodology, ensuring Tech21 phone and tablet cases are tested under the supervision of independent experts.

NPL and Impact Tech Labs (ITL), the research and development arm of Tech21, began a partnership in 2015 with the aim of developing a measurement procedure for independently assessing the quality of phone cases. Tech21 is based in Twickenham and one of the top two phone case manufacturers in the world, producing high-quality and durable cases for a range of smartphones. The collaboration with NPL has since grown, with NPL now housing three visiting researchers on site.

The independent measurement procedure established by NPL and ITL is a first-of-its-kind collaboration, allowing each phone case to be quality tested using methodologies co-developed with experts at NPL. This has provided customer confidence and assured the quality of the products.

Precision measurement brings new products to market

Measurement expertise from NPL has provided UK developer Arden Photonics with the confidence to launch a significant new product for the optical communications industry.

Arden recently developed a new high-magnification system for optical fibre manufacturers and users to measure the diameter of fibre cladding. Having worked with NPL previously, Arden sought the expertise of the Electromagnetics group, to verify its new measurement system could meet the industry's exacting requirements. NPL provided Arden with measurements using calibrated reference fibres, allowing the company to compare the new system's performance against those produced by NPL's well-established, high-precision microscope system.

The results confirmed that Arden's new measurement system was capable of meeting the strict tolerances required by the optical communications industry. David Robinson, Managing Director at Arden Photonics, said: "This work has allowed us to launch a significant new product with great confidence that we can match or exceed the current [commercial] state-of-the-art in terms of optical fibre geometry."

New measurement services online

A key part of NPL's remit it so to carry out research into innovative new measurement techniques, technology and best practice. In 2016, 11 new measurement services were introduced from field measurement of neutron dose quantities and underwater acoustic recorder calibration to MRI compatibility testing and a quadrupole mass spectrometry service.

This work has allowed us to launch a significant new product with great confidence that we can match or exceed the current [commercial] state-of-the-art in terms of optical fibre geometry.

David Robinson
Managing Director at Arden Photonics

Image courtesy: iStockPhoto.com/Factory7h

Publications

The following NPL publications have been highlighted for their scientific contribution in 2016.

www.npl.co.uk/publications

At time of publication, NPL had published an estimated 322 papers in peer-reviewed scientific journals in 2016.

Modified hyper-Ramsey methods for the elimination of probe shifts in optical clocks

Physical Review A

Richard Hobson, William Bowden, Steven King, Ian Hill and Patrick Gill (with University of Oxford)

Chemical intervention in plant sugar signalling increases yield and resilience

Nature

Melissa Passarelli, Ian Gilmore, Rory Steven, Josephine Bunch (with Rothamsted Research, University of Oxford, University of Nottingham)

A de novo virus-like topology for synthetic virions

Journal of the American Chemical Society

James Noble, Emiliana De Santis, Jascindra Ravi, Baptiste Lamarre and Max Ryadnov (with University of Reading, University of Bristol and University of Brighton)

Tuneable on-demand single-photon source in the microwave range

Nature Communications

Sebastian de Graaf and Oleg Astafiev (with Royal Holloway, University of London, RIKEN, Tokyo University of Science and Moscow Institute of Physics and Technology)

The range of options for handling plane angle and solid angle within a system of units

Metrologia

Paul Quincey

Precise characterisation of molecular orientation in a single crystal field-effect transistor using polarised Raman spectroscopy

Scientific Reports

Sebastian Wood, Grigorios-Panagiotis Rigas, Alina Zoladek-Lemanczyk, James Blakesley and Fernando Castro (with University of Surrey and Institute of Materials Science of Barcelona)

A Bregman-proximal point algorithm for robust non-negative matrix factorization with possible missing values and outliers - application to gene expression analysis

BMC Bioinformatics

Stéphane Chrétien (with FEMTO-ST Institute, ISIFC, UFR Sciences et Techniques, ABC&T and Centre Hospitalier Lyon Sud)

Development of a primary standard for absorbed dose from unsealed radionuclide solutions

Metrologia

Ilias Billas, David Shipley, Seb Galer, Graham Bass, Thorsten Sander, Andrew Fenwick and Vere Smyth

Air–vacuum transfer; establishing traceability to the new kilogram

Metrologia

Stuart Davidson and James Berry (with National Institute of Standards and Technology, Swiss Federal Institute of Metrology, National Research Council Canada, Istituto Nazionale di Ricerca Metrologica and Danish National Metrology Institute)

Towards Implementing the new kelvin

Philosophical Transactions of the Royal Society A

Guest edited by Graham Machin

Thermodynamic temperature assignment to the point of inflection of the melting curve of high-temperature fixed points

Philosophical Transactions of the Royal Society A

Emma Woolliams, Maurice Cox, Martin Dury, Dave Lowe, Graham Machin, Helen McEvoy and Aaron Whittam (with Physikalisch-Technische Bundesanstalt (PTB), National Measurement Institute Australia (NMIA), National Institute of Advanced Industrial Science and Technology (AIST), Laboratoire commun de métrologie (LNE-Cnam), Spanish National Research Council (CSIC), Centro Español de Metrologia, National Institute of Metrology (NIM), All-Russian Research Institute for Optical and Physical Measurements (VNIIOFI), National Institute of Standards and Technology (NIST) and National Research Council Canada.

Advances in large-scale metrology – Review and future trends

CIRP Annals - Manufacturing Technology

Ben Hughes and Alistair Forbes (with RWTH Aachen University, University of North Carolina, ETH Zürich, Politecnico di Torino, Physikalisch-Technische Bundesanstalt and National Institute of Standards and Technology)

NPL guides aim to improve measurement understanding and technical abilities across the UK and the rest of the world. NPL published five new guides in 2016:

Introduction to temperature measurement
Good practice guide for miniature ETMT tests
Strategic planning for coordinate metrology
Guide to the storage of primary mass standards
Guide to weighing in vacuum

In 2016, the Consultative Committee for Units unanimously voted to rename the watt balance, the Kibble balance, in honour of the late Dr Bryan Kibble.

Our people & life at NPL

Metrology community honours Bryan Kibble

The global metrology community paid tribute to the late Dr Bryan Peter Kibble, who passed away on 28 April 2016. Dr Kibble's famous invention, the watt balance, was renamed the Kibble balance in a unanimous decision by the Consultative Committee for Units (CCU). Invented at NPL in the 1970s, the instrument is used for making extremely accurate measurements of the Planck constant, as part of the effort to redefine the SI unit of mass, the kilogram, in terms of a fundamental physical constant. Dr Kibble will be dearly missed by the international measurement community.

Alan Turnbull awarded in New Year's Honours

Dr Alan Turnbull, Senior NPL Fellow in Electrochemistry and Corrosion, was awarded an OBE in the New Year's Honours list 2016 for services to science and industry. Alan leads NPL's Electrochemistry team and, since joining NPL in 1973, has produced more than 200 publications on the measurement and modelling of environment-assisted cracking and the localised corrosion of metals. By reducing the risk of such failure mechanisms, the impact of Alan's research has been substantial across the energy, marine and chemical sectors.

Patrick Gill elected Fellow of the Royal Society

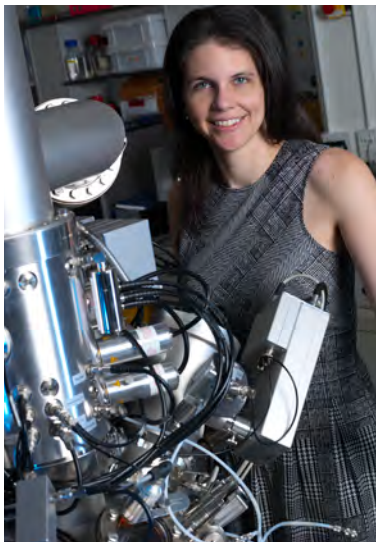
Prof Patrick Gill MBE, Senior NPL Fellow in Optical Frequency Standards and Metrology, was elected Fellow of the Royal Society. Patrick is co-Director of NPL's Quantum Metrology Institute and leads the Time & Frequency group's research. The Fellowship of the Royal Society is made up of the most eminent scientists, engineers and technologists from the UK and the Commonwealth. Fellows are elected for life through a rigorous and highly-competitive peer review process based on excellence in science and in recognition of their "substantial contribution to the improvement of natural knowledge."

New NPL Fellow

Prof Alexander Tzalenchuk was made an NPL Fellow in Solid State Quantum Technologies. Alexander has over 30 years' experience in solid-state physics, nanotechnology and quantum metrology, and currently leads NPL's graphene research. Alexander's early work on graphene was cited in the scientific background on the Nobel Prize in Physics 2010 and led to NPL being recognised as a key player in the field. NPL Fellowship is a recognition of individual merit awarded to researchers who make significant contributions to NPL's scientific achievement and standing.

Melissa K Passarelli awarded Vickerman Prize

Dr Melissa K Passarelli has received the UK Surface Analysis Forum's prestigious Vickerman Prize. The prize is awarded for work carried out by early-career researchers, which is expected to have a major impact on the field of surface analysis. Dr Passarelli won the award for her work on secondary ion mass spectrometry (SIMS), developing a revolutionary new instrument, the 3D OrbiSIMS, for high mass resolution imaging. Improved mass resolution allows for clearer molecular specificity, meaning more information can be observed within the imaged sample. The 3D OrbiSIMS has the potential to make vast improvements in subcellular imaging, which could lead to breakthroughs in drug treatments and the battle against antimicrobial resistance.



Dr Melissa K Passarelli, recipient of the Vickerman Prize for her work on secondary ion mass spectrometry.

SET for BRITAIN 2016

Flaviu Cipcigan and Grigorios Rigas, PhD students studying at NPL, were shortlisted from hundreds of applicants to present their research at the House of Commons, as part of SET for BRITAIN 2016. Flaviu, from the University of Edinburgh, presented on 'A model of the water molecule using electrons on a spring' and Grigorios from the University of Surrey, had a poster on 'Ink-jet printed inorganic electronics for biosensing and energy harvesting applications'.

A fond farewell to Susan Martin

Susan Martin, one of NPL's longest-serving members of staff, retired after nearly 60 years at NPL. After joining in 1957, Susan's first work involved preparing tables of figures using a hand-operated desk machine. Later, Susan moved on to punched card machines, programming both the DEUCE, one of the world's first automatic electronic digital computers, and its greatly enhanced successor, the ACE, designed by Alan Turing. Susan went on to specialise in numerical optimization, developing algorithms and library software, and applying her expertise to materials modelling software.

NPL Chair knighted in Queen's Birthday Honours

Sir David Grant, Chair of the NPL Board, was awarded a knighthood in the Queen's Birthday Honours 2016 for his wide-ranging contribution to engineering, technology and education. David joined the NPL Board in 2015 following NPL's return to government ownership. In addition to his role at NPL, David is a non-executive director of the Defence Science and Technology Laboratory (Dstl) and senior independent director of Renishaw Plc and IQE Plc. He is also Chair of the educational charity STEMNET.

New regional directors appointed

NPL has established two new regional bases at the Universities of Surrey and Strathclyde, which join the existing base at the University of Huddersfield. As part of this expansion, NPL was delighted to announce the appointment of Dr Peter Aaen as regional director at Surrey and Dr Matthew Maynard at Strathclyde. Through collaboration with the partner universities, NPL's regional bases will substantially increase both the volume of measurement research in the UK and the impact of the national measurement infrastructure on the UK's prosperity and quality of life.

NPL's latest intake of apprentices has been expanded to offer IT Apprenticeships, alongside the already established Junior Scientist and Business Administration roles.

NPL Open House

NPL staff opened their laboratories to over 3,000 customers and members of the public to celebrate World Metrology Day (20 May each year) commemorating the anniversary of the signing of the Metre Convention in 1875. In September 2016 NPL also opened Bushy House for a day, where NPL's first laboratory was based in 1900, receiving over 2,500 visitors.

Providing a perspective on Earth and climate change

NPL attended Cheltenham Science Festival and New Scientist Live, with an exhibit that demonstrated how satellites can be used to observe the Earth's surface. These prestigious and popular science festivals were an ideal setting to explain the work of NPL, and to give the public the opportunity to see the Earth from a new perspective.

NPL's award winning apprentices

Becky King, a Junior Scientist apprentice at NPL has been announced as a winner at the London National Apprenticeship Awards 2016 regional ceremony and her colleague Arthur Vie received the CSR Group Advanced Apprentice of the Year award at a graduation ceremony at the Royal Society of Chemistry.

The latest intake of apprentices joined NPL in September 2016 and the programme has been expanded to offer an IT Apprenticeship for the first time, alongside the already established Junior Scientist and Business Administration Apprenticeships.

NPL Outreach and Water Rockets

By our reckoning nearly 51,000 people were involved in over 260 events, educational equipment loans or other activities delivered by the extended NPL Outreach team. This included 350 water rockets constructed at 14 events, including the annual NPL Water Challenge. We also had 33,000 educational posters mailed and downloaded from our website, and gave out 3,000 copies of the *Little Big Book of Metrology*.

National Physical Laboratory

The National Physical Laboratory (NPL) is the UK's National Measurement Institute. At the heart of our mission is delivering impact by disseminating research and measurement best practice and traceability for the economic and social benefit of the nation.

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