NPL
National Physical Laboratory

SCIENCE WITH IMPACT

annual review 06/07

Front cover picture:

The vibrantly coloured object in the front of this year's Annual Review is the 'colorcube', which is used to illustrate the fact that any colour can be expressed in terms of three numbers, represented by the three dimensions of the cube. NPL has a long tradition in measurements of the visual properties of materials: from experiments in the 1920s which underpin the international CIE colour specification system (integral to the reproduction of colours for every computer screen and printer), to current work applying metrology to understand the visual appearance of highly complex materials. This current research will be used to provide new measurement services, including capabilities for real-time monitoring of changes in texture and colour.

Picture opposite from left to right:

Seton Bennett
Deputy Director & Director of International Metrology

Mike Bartlett
Director of Knowledge Transfer and Measurement Services

Susan Evans
Director Industry & Innovation Division

Kamal Hossain
Director Science & Innovation

Ian Licence
Human Resources Director

Steve McQuillan
Managing Director

Martyn Sené
Director Quality of Life Division

Alan Mann
Director of Finance & Support Services

Sally Wilson
Business Development Director *(not pictured)*

SCIENCE WITH IMPACT

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In the last year the National Physical Laboratory (NPL) had a vital impact on industry and society, enhancing its important role as the UK's national measurement institute. As well as our priority research areas, we are expanding our scientific expertise to the service sector, looking at how we can support the financial and creative industries.

Relationships

NPL is forging valuable new relationships across the public and private sectors. Hundreds of large and small companies have benefited from our knowledge in the past year. We are working closely with innovation teams in the regional development agencies, and our scientists support the NHS efficiency agenda with new clinical standards and treatments. NPL scientists and facilities remain at the heart of the Department of Trade and Industry's (DTI's) National Measurement System and undertake around 80% of its research.

Talent and experience

At the heart of NPL are 500 scientists who are passionate about their disciplines and bringing their expertise to applications that have an impact on our economy and quality of life. In the year we have seen our staff rewarded for their work with peer review publications, wider media coverage and numerous personal awards. We have also recruited top scientific and managerial talent including a new knowledge leader for the Quality of Life Division.
(page 7)

Metrology training

One of our most exciting activities was the creation and implementation of a metrology training course designed to develop better measurement practice in the workplace.
(page 16)

Supporting science in schools

The future of UK measurement and standards, and the application of science to commerce and industry, depends on a regular supply of competent physicists from the education system. We are expanding our outreach into schools and universities and are proud to support a new Virtual Physical Laboratory developed with great commitment by Dr John Nunn.
(page 21)

Environmental responsibility

Currently our greatest challenges are climate change and the environment. In its response to the recent Stern Report, NPL outlined the crucial role of measurement science in everything from emissions monitoring to cleaner engines and efficient power generation.
(page 10)

The transfer of knowledge

NPL has spent years developing expertise in the transfer of knowledge between researchers and industry, and we are professionals in the application of experience from one sector to other areas with similar challenges. NPL is now capitalising on this expertise in a market for knowledge transfer, providing services to a number of customers.

We are also exploiting the knowledge and intellectual property developed by NPL's leading scientists.
(page 14)

The following pages outline not only some of the most notable scientific achievements, but also what NPL is doing for the UK's key economic sectors, including aerospace, engineering, and healthcare, and our contribution to emerging technology areas like nanotechnology.

The next year holds many opportunities for NPL and we are facing it with confidence.

Steve McQuillan

Managing Director

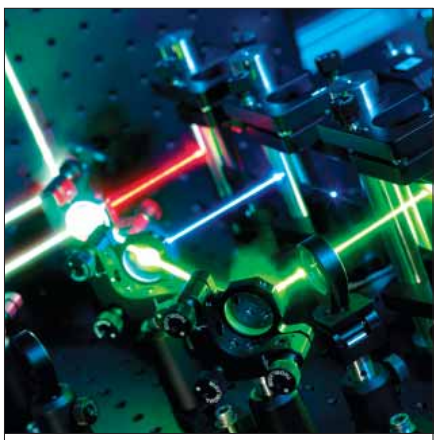
Excellence in Science

Critical to NPL's remit to improve the economy and quality of life in the UK is the world-class science delivered by over 500 scientists. In the last year we have maintained our reputation for excellence through 150 published papers in leading science journals and 50 intellectual property ideas being assessed. Individuals were also recognised for their work, most notably Dr Seton Bennett, NPL's Deputy Director, who was awarded a CBE for his services to International Metrology.

We believe that our research must be relevant and to ensure this we run 'road mapping' sessions based on science and technology challenges such as environmentally friendly transport, bioscience and security. These sessions encourage industry, government departments and other organisations to outline their needs and applications for the future, thereby enabling NPL to develop responsive and relevant research programmes of the highest calibre. Fundamental to our mission is to deliver science with impact. Therefore we need to transform our research into applications that enable others to make use of them; this transfer of knowledge is supported by a dedicated team highlighted on pages 14 to 17 of this review.

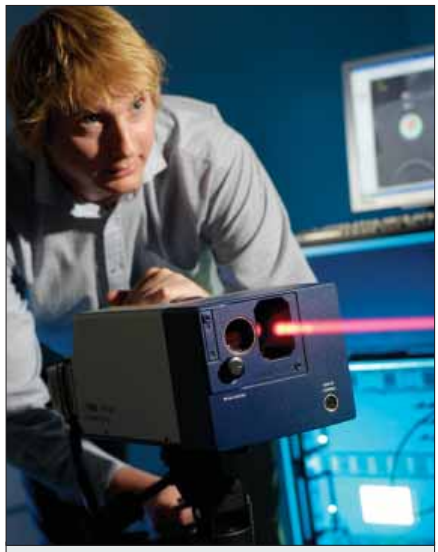
Much of our work underpins the national measurement infrastructure in the UK and is funded by the DTI. NPL is involved with projects under the European Framework Programme and Government Technology Programme. NPL also invests in far reaching and cutting edge research, pushing the boundaries of measurement science and beyond. Our Strategic Research Programme funds a number of projects including our work in single molecule fluorescence.

Although molecules are too small to be seen directly, by attaching fluorescent probes to them we can detect them and monitor where they are and what they are doing. We are doing this using a specially modified microscope and a sensitive camera. We can learn a lot about the properties of molecules from studying how they behave individually that we cannot learn from studying them as a population. We are looking at potential applications to metrology of biomolecules, genomics and drug discovery.



The NPL apparatus for single molecule imaging. By using three lasers (red, green and blue) we can use three different colours of fluorescence, enabling us to monitor up to three different types of molecule in the same experiment.

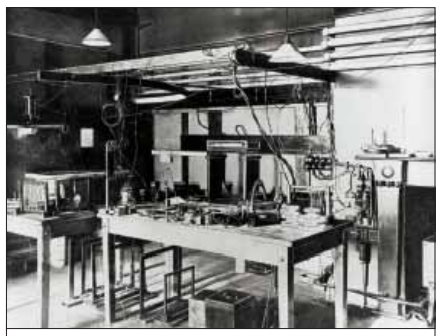
During the last year NPL has been working on new test methods to demonstrate the usability and reliability of electronic components made from recycled materials. Legislation is encouraging all circuit manufacturers to use materials that can be reused or are themselves recycled. The flexible circuit (pictured opposite) is made in conjunction with CIT (Conductive Inkjet Technology) from thermoplastic which can be reused and is interconnected by conductive adhesive rather than traditional solder.



Seeing sound

Pictured is NPL's laser scanning vibrometer, capable of scanning the surface velocity of acoustic devices such as loudspeakers or underwater sonar arrays and mapping the field in front of these devices using the acousto-optic effect.

Two-dimensional images of acoustic pressure fields have been obtained in air, exploiting a phenomenon known as the acousto-optic effect. This has, for the first time, allowed the perturbing effects of commonly used measurement devices such as microphones and sound level meters to be directly visualised. This work was published in a Institute of Acoustics conference paper 'Mapping of scattered acoustic fields in air using the acousto-optic effect' and reported in The Engineer.



This is where it all began, one of the earliest pictures of the first electrical measurement laboratory in Bushy House, 1906.

- A team including Nick Ridler, Andrew Morgan, and Richard Dudley from NPL has been awarded the IEE (Institute of Electrical Engineers) Measurement Prize for their work on 'Internet-enabled traceability for high precision measurements using microwave network analysers'.
- Angela Dawson was awarded the European Rubber Journal Award and also the TJ Drakely Prize for her MSc project work with the London Metropolitan Polymer Centre. She was also awarded the prestigious James Walker Institute of Materials Award. These awards recognize the high quality of work carried out by more junior staff at NPL.
- Paul Tomlins won an American Society for Testing of Materials Award for diligent and sustained efforts contributing to the standards development and related activities of the Committee for Medical and Surgical Materials and Devices.
- NPL's first Royal Society Incoming Foreign Fellowship was awarded to In-Mook Choi from KRISS (Korean Research Institute for Standards and Specifications) for work on the Watt Balance re-definition of the kilogram.

Excellence in Science

NPL had over 150 papers published in leading scientific journals in the past year.

Picking up on a very popular topic in the atomic physics community, Yuri Ovchinnikov of the Quantum Frequency Standards Group published a paper in the international peer-reviewed journal Physical Review A; 'Coherent manipulation of atoms by co-propagating laser beams'. This novel method for trapping atoms can be exploited for example to build small portable clocks or atom interferometers. While measuring and analysing pulsed random radio-frequency (RF) fields, an NPL team led by Luk Arnaut discovered a previously unknown aspect of the coherence properties of random fields. Their findings are published in Physical Review Letters: 'Observation of coherent precursors in pulsed mode-stirred reverberation fields'. The findings help us, for example, to understand and control the way wireless signals get distorted within buildings.

Some of the papers have received considerable on-line success such as, 'A review of accelerated ageing of polymeric material', by Tony Maxwell, Graham Sims, Greg Dean and Bill Broughton, which has been downloaded from NPL's internet site more than 2,000 times. Also the Analytical Science Team had two key publications in the Royal Society of Chemistry's Faraday Discussion Volume on Surface Enhancement Raman Spectroscopy (SERS): 'Electromagnetic modelling of Raman enhancement from nanoscale substrates: a route to estimation of the magnitude of the chemical enhancement mechanism in SERS' and 'Nanoscale imaging of carbon nanotubes using tip enhanced Raman spectroscopy in reflection mode'. Both of these papers have been ranked in the top 1% of all Faraday Discussion papers downloaded last year.

A paper by Rob Brooks, Alan Dinsdale and Peter Quested, 'The measurement of viscosity of alloys – a review of methods, data and models', published in the journal Measurement Science and Technology and on their website was identified as one the top 50 papers published in 2006.

Intellectual property

NPL's intellectual property often manifests itself in technological products or processes that are for sale or available to license. Many companies benefit from NPL knowledge inside their own products, processes and services.

This year a new management system was put in place to capture, evaluate, exploit and track the progress of individual IP opportunities and we are currently assessing and progressing more than 50 ideas. A number of products have progressed into full licensing arrangements during the year, such as the Secondary Standard Radio Nuclide Calibrator, licensed to Southern Scientific.

To aid their research and improve the accuracy of their measurements, the Medical Ultrasound Team at NPL has developed a special polymer lining material to coat water tanks. These tanks are used to measure the energy produced by medical equipment to ensure it complies with standards. This technology has been licensed and commercialised by a partner company and has proved successful, being widely sold to other medical equipment manufacturers and users. Feedback from this community has prompted NPL to develop a new tank lining for sonar applications working at lower frequencies. Using DTI proof of concept funding, last year a new contoured acoustic tile was developed which will be licensed later this year.

In July 2006, the Metrologia special issue on Statistical and Probabilistic Methods for Metrology was jointly edited by NPL and contained six NPL authored or co-authored papers. Following the publication of this edition the number of downloads from the site doubled to 10,000 in the month.

1954 - The Royal Commission on the Civil Service visits NPL, photographed on the steps of Bushy House. Today NPL is visited four times a year by the Royal Society and the Royal Academy of Engineering to peer review the science that we are undertaking on behalf of the Department of Trade and Industry.

- John Gallop, Ling Hao, Patrick Joseph-Franks and John Macfarlane won the best paper at the 9th World Multi-conference on Systemics, Cybernetics and Informatics for 'Sensor-based on nano-scale SQUIDs'.
- Alan Brewin, Chris Hunt and Ling Zou received the IPC Distinguished Service Award for NPL's work for the global electronics interconnection industry.
- Chris Hunt and Martin Wickham won best international conference paper - 2006 IPC Printed Circuits Exposition for 'Impact of Lead Contamination on Reliability of Lead-Free Alloys'.
- Dr Jason Crain joined NPL as the Quality of Life knowledge leader on full time secondment from Edinburgh University, where Jason is a Condensed Matter physicist. He brings experience in running interdisciplinary research, bridging physical and life sciences and a track record of forging research relationships with leading international companies including IBM and Nikon.
- Tobias Lindström won the European Science Foundation Prize for Excellence of Research in 2006 for contribution to understanding d-wave Josephson Junctions and SQUIDs.
- Graham Sims was recognised for his leadership in composite materials science, technology and standardisation, receiving the 2006 Holiday Prize from the Institute of Materials, Minerals & Mining.

Advanced Manufacturing

NPL has provided precision metrology, technology research and consultancy to a diverse range of engineering and manufacturing issues for more than a hundred years. In the last year we have provided measurement and testing solutions from automotive and wind power to electronics and medical devices.

We continue to be challenged to deliver solutions that need to withstand extreme temperatures, pressures and vibrations in demanding applications such as providing materials expertise to the Federation Internationale de l'Automobile (FIA). NPL helps to ensure that teams respect the rules of F1 racing without compromising the safety and competitiveness of the sport.

Many measurement issues are transferable across sectors and we see sharing our knowledge and skills as critical to NPL's mission. This year we developed a non-destructive testing method to monitor the life of thermal barrier coatings that protect power plant turbine blades. This will be a great development for power plants that have to take their turbines off line to replace coatings. This is also an issue for coatings on jet engines, as aerospace companies regularly take engines out of service to replace coatings.

It is often the case that small knowledge-intensive companies reach a barrier in the process of development of their products due to lack of resources and technical facilities. In the micro- and nanotechnology sphere, measurement plays a more significant role in this development process than in conventional technologies. CEMMNT – The Centre of Excellence in Metrology for Micro and NanoTechnologies was launched in 2006. This is DTI part-funded to provide companies with access to know-how and facilities from the partners: NPL, the Systems Engineering Innovation Centre (SEIC), QinetiQ, Taylor Hobson, and Coventor.

Display technology

Display technology is a key component of highly engineered devices in everything from cars to mobile phones. Standards for the readability and reliability of modern displays don't yet exist, so NPL's measurement scientists are extending and improving techniques originating from the aerospace industry to specify display legibility in sunlight.

NPL's new Ambient Illumination Laboratory (AIL) became operational in 2006. It is the only commercial facility of its kind in Europe, providing specialist lighting, software and measurement devices to simulate different illumination scenarios.

Jaguar Cars Limited are the first company to make full use of our new facilities; NPL scientists have provided valuable feedback on the sunlight legibility of automotive displays. The Ambient Illumination Laboratory (AIL) has been pivotal in creating a method for quantitatively specifying the visual performance of electronic displays that can be easily passed on to suppliers. It also provides the means of establishing fitness for purpose of new display systems.

Biological glue for micro-manufacturing

NPL has started a project to develop ways for biological recognition to bond hundreds of tiny components into a mechanical device the size of a full stop.

Instead of the painstaking manual assembly of a MEMS device, an emerging biomimetic technique gives each silicon component a set of DNA strands with a particular code. Each set has a matching partner on another component. The components are mixed together till they find each other and bond.

This project is in partnership with eleven Europe-wide partners. The nanomaterials group is undertaking a critical review of biomolecular attachment mechanisms already found in nature.

These mechanisms will be assessed for their compatibility with existing surface functionalisation processes. Defining the metrology of these bio-inspired objects is of the highest importance; measurement techniques must be developed to assess and define the interaction forces between the components on the objects.

NPL testing gauges used in the manufacture of fuses and shells during the First World War.

- NPL visited Agilent's manufacturing and R&D site in Scotland to see how low-uncertainty measurement methods and calibrations developed and supplied by NPL underpinned their whole production process. The mobile phone handset tester was only the second product in the history of Agilent to have achieved over $1 billion of sales.
- In 2006 the materials team at NPL won research and development contracts to support the UK's naval fleet with fibre optic sensing systems for structural health monitoring.
- NPL is developing highly sensitive instruments to address the absence of reliable, affordable and standardised tools for measuring the size and shape of nanoparticles and to characterise their composition and surface behaviour.

Environment and Transport

The Stern Review highlighted the importance of high quality climate change data. However there is significant debate over the reliability of existing data. Reducing uncertainty will lead to reduced economic risk and facilitate wider international participation in any mitigation strategy.

NPL has developed a range of optional sensing technologies which are world leading in the direct detection and measurement of fugitive emission from industry, including the Differential Absorption Lidar (DIAL) system which is able to remotely map concentrations of compounds in the atmosphere. NPL is currently working with the US Environmental Protection Agency to assess the use of DIAL and other optical technologies for use in improving the quantification of greenhouse gas emissions. This is one way in which measurements can help future carbon pricing to be based on robust, scientifically sound, consistent and internationally accepted measurements.

NPL is also addressing the challenge of environmentally friendly aviation in an industry which depends on metrology for its success. The industry's commitment to reducing its impact on the environment demands lighter airframes and more fuel-efficient engines. NPL applies its knowledge of composites to help leading aerospace manufacturers such as Boeing and Airbus to test and measure advanced materials, and predict the lifetime of critical components.

NPL's newly developed 'virtual chimney' which provides a controlled environment where manufacturers can hone their measurement skills and test pollution monitoring equipment over a range of operating conditions.

NPL's optical radiation scientists helped a local science college to build and fly a remote controlled helicopter which supports equipment taking spectral measurements of the earth's surface.

Breathe easy

Nanoparticles are of major societal importance but raise health concerns about airborne particle pollution. NPL has made a significant investment to develop the urgently needed metrology in this area, which has many challenges, not least that particles can evaporate after they are collected.

EU legislation puts limits on the amount of PM_{10} (particles less than 10 microns in diameter) in the air to minimise risk to public health. To extend the range of reliable air quality monitoring, NPL is developing valid analytical methods for measuring ambient airborne particle size distributions in the 20 nm to 200 nm range.

NPL has established an important capability for measuring airborne nanoparticles and producing reference nanoparticles. During 2006, a new instrument was delivered and tested, which is capable of measuring airborne particle-size distributions with good size resolution in the range 0.9 nm to 400 nm. Other systems typically cannot operate below 5 nm. This will greatly expand NPL's abilities to calibrate other particle counting instruments and determine their limitations at low particle sizes, as well as being an important experimental tool for looking at clusters of molecules at the 1 nm to 2 nm scale that have been reported in the atmosphere.

NPL testing car horns in 1929; today noise levels in the UK are predicted on the basis of traffic flow estimates. NPL is working on low cost acoustic sensors which could combine prediction with actual measurements.

- NPL won the contract to deliver its fourth air-quality monitoring network, for black smoke, for the Department for Environment, Food and Rural Affairs (Defra). NPL ensures the data obtained by the networks are of the highest quality to comply with UK and EU regulations.
- During 2006 we undertook a trial of 16 instruments used for automatic air quality monitoring and found the different measurement methods provided significantly different results.
- NPL has been working with Land Rover to predict the effect of accidents on car interiors, to help inform the choice of materials used.
- NPL and partners won a project to develop a framework for assessing the integrity of advanced composite structures over their complete life cycle, through an integrated approach to structural health management. Advanced composites are used successfully in many industries including construction and renewable energy.

Healthcare & Bioscience

Longer lives and the expectation of a higher quality of life puts pressure on the National Health Service and other medical providers. Standards and measurement from NPL are supporting new medical technologies and the drive for innovation and greater efficiencies in healthcare.

In 2006, NPL launched the London Bio Nano Centre (BNC) in partnership with Imperial College and University College London. The centre will offer specialist nano and bio measurement equipment and expertise with a focus on early stage product development in small and medium sized companies to aid getting products to market. The centre has invested in new capabilities at NPL including nano analysis - measuring biological molecules on surfaces - and bio molecule structure and interaction analysis, both of which are key in a wide range of areas including drug delivery, biosensors and drug discovery.

Many new advances come from small medical engineering firms. Our scientists are supporting a number of companies, such as Southern Scientific Ltd which, using NPL technology, has developed a new PC-based readout for an instrument used by medical physicists to check radioactive drugs before injection into the patient. We also assisted Lein Applied Diagnostics, which has developed the hardware and data processing for a technique to shine laser light onto the eye to monitor insulin levels through changes in refractive index.

Thermometer testing in the 1920s.

Remote monitoring

Efforts are underway to ensure citizens of ageing populations can enjoy life and treatment at home rather than in hospital. The government's desire to shift from centralised to community healthcare is driving the development of 'assisted living platforms' - wireless sensor systems that let clinicians and carers remotely monitor a patient's condition.

NPL is developing a range of techniques that will allow the users of these systems to quantify the confidence they can have in the information the system is providing. In order to properly understand the system it is essential to consider the physical wireless system, the data processing and the readout, which NPL is uniquely placed to do.

Faster drugs

It can take up to 15 years to develop a biopharmaceutical drug from original patent to mass market but NPL is helping the pharmaceutical industry to get better drugs to market more quickly by using good measurement practice to reduce the time and cost of testing.

Biopharmaceuticals are manufactured to extremely high specifications set by regulatory bodies such as the Medicines and Healthcare products Regulatory Agency (MHRA) and the Food and Drug Administration (FDA) in the US.

Regulatory approval requires extensive testing including biological activity testing which the industry finds can give imprecise results. In a trial of one characterisation technique with 27 different laboratories NPL demonstrated that better results could be given by improving calibration and operating procedures.

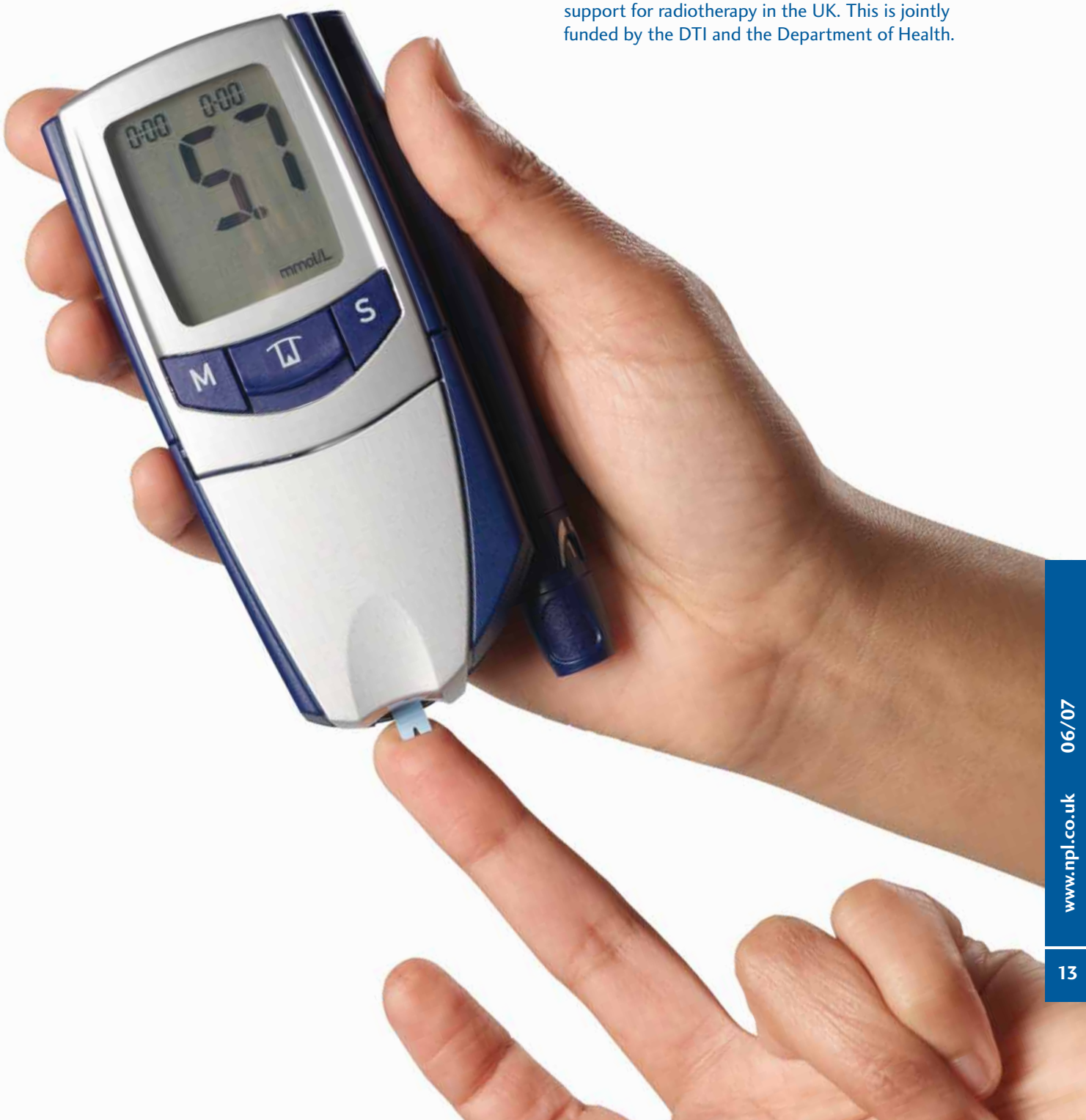
Supporting OCT

NPL has established itself as an expert in optical coherence technology (OCT), a new non-invasive medical technique for looking at the internal structure of biological tissue.

NPL is using OCT to investigate the properties of tissue scaffolds. These structures are used as the frame upon which to grow tissue formations, such as arterial tissue for vascular grafts. Knowing the wall thickness changes in these tissues is critical to their design.

In 2006, Pete Tomlins (pictured above) spent time at the Oregon Health and Science University in Portland, USA, developing an OCT-based measurement technique for monitoring the curing process in dental polymers. Other applications of OCT include quantitative measurement of the optical properties of biological tissues to link the measurements with disease.

- NPL has teamed up with Guy's & St Thomas' Hospital and Cranfield University in a joint research project to improve the traceability of Continuous Cardiac Output (CCO) measurements. The project aims to develop a device for generating traceable pressure waveforms and to improve the cardiovascular model used to predict the cardiac output.
- New visual display standards developed by NPL are supporting an initiative by primary care trusts to reduce reliance on film-based X-rays. NPL is ensuring screen-based clinical images look the same no matter where they are viewed.
- Work began at NPL on a new clinical linear accelerator facility to provide calibration services and R&D support for radiotherapy in the UK. This is jointly funded by the DTI and the Department of Health.



Knowledge Transfer & Innovation Support

NPL treats the communication of science and transfer of knowledge as a critical part of our mission and has a dedicated team working in this field. Measurement expertise supports the development of new products and processes from demonstrating compliance to legislation and proving new concepts. NPL's unrivalled network of companies, research organisations, government departments and universities provides access to the vast range of innovation players in the UK.

Within the NPL team, specialist staff are deployed with expertise in technical writing, technology 'road-mapping', exploitation of intellectual property and the management of specialist events.

The key role for the Knowledge Transfer team is to ensure that NPL's expertise is disseminated in a way that users can obtain the greatest benefit. This could be as simple as attending an NPL training course or reading one of our many freely available best practice guides. NPL also likes to be innovative in its approach to sharing knowledge and making good use of technology.

NPL is leading the use of online networks to share information about measurement and standards. We host online forums to act as focal point for measurement or standards discussions and information. Each has their own specialist mentor who is able to facilitate discussions, signpost resources and share best practice. Each forum holds monthly online meetings on topical issues and the outcome of these meetings and other physical meetings held by NPL are made available online. NPL is one of the first national research laboratories to exist in Second Life®, an online three-dimensional world, where we have built a number of exhibits and given presentations.

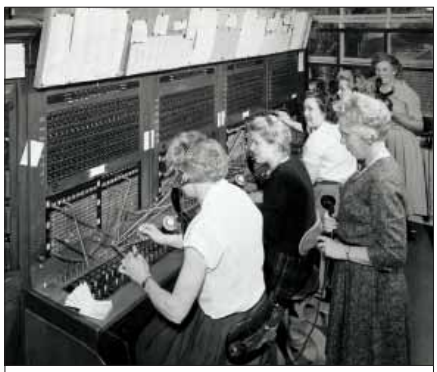
Second health

Imperial College London has commissioned NPL to help the medical community engage with patients - before they even need care.

'Second Health' is a knowledge transfer project that will help patients and clinicians to visualise their journeys through current and future medical procedures.

A hospital is being built in the 3D virtual world of Second Life®, where people interact as online avatars. Several storylines are being filmed inside Second Life® to show what people can expect when they access health care, such as emergency services, or scheduled surgery.

Later on, people will be able to visit the virtual hospital themselves, explore the facilities, and ask questions of online health staff. This could help to alleviate patient anxiety before treatment.



The NPL telephone exchange in 1962. Today the NPL Helpline takes over 600 enquiries every month on a wide range of measurement related topics.

Road mapping for the future

We believe that our research must be relevant; to ensure this we run road mapping workshops. These workshops are focused on science and technology challenges highlighted by the Government Technology Strategy Board as their priorities. They cover areas such as environmentally friendly transport, bioscience and healthcare, intelligent connected world and a secure environment.

The workshops are run in conjunction with the Institute of Manufacturing at Cambridge University and invite industry, Government departments and other organisations to share their expectations of the future and capture barriers to the innovation needed to achieve them. From these, we outline the measurement and standards requirements enabling NPL to develop responsive and relevant research programmes of the highest calibre.

Last year we held eight workshops. The output of these is now available as a technology roadmap via Technology Sector Industry Knowledge Transfer Networks. These online forums enable us to keep these roadmaps alive and responsive to wider feedback. Discussions around these roadmaps are supported by a 'wiki' allowing visitors to add, remove, edit and change content; linking among many pages of information. This enables us to record comments, validate our findings and monitor any changing views.

- The Measurement for Innovators programme enables companies to work directly with the experts and facilities contained within the UK's National Measurement Institutes. NPL led 23 collaborative research projects in 2006, with 71 companies including BAE Systems, Dyson, IBM and Unilever.
- NPL and QinetiQ hosted a high-profile event in 2006 to raise the profile of privacy issues associated with sensing and location technologies.
- NPL manages two successful Knowledge Transfer Networks on behalf of DTI. Together they represent more than a thousand member companies and organisations interested in sensors and location technologies.

Knowledge Transfer & Innovation Support

Helping the regions

NPL's Peter Haycocks is one of 14 innovation advisors for the South East England Development Agency's recently formed Innovation Advisory Service. Although Peter's expertise is in finding measurement solutions for companies to assist with problem solving and enabling innovation, he often finds himself helping companies with diverse tasks such as applying for R&D funding or preparing business development plans.

For example he helped swimming pool covering specialist, Plastipack, with advice on suitable test techniques to obtain the Australian 'Smart Approved WaterMark' thus enabling the company to dramatically increase sales. He is now helping the company develop new products exploiting their technology to the construction and water facilities management sectors.

Taking tea at an event at NPL in 1911. Last year over 2000 delegates attended NPL events or training courses.

Metrology training

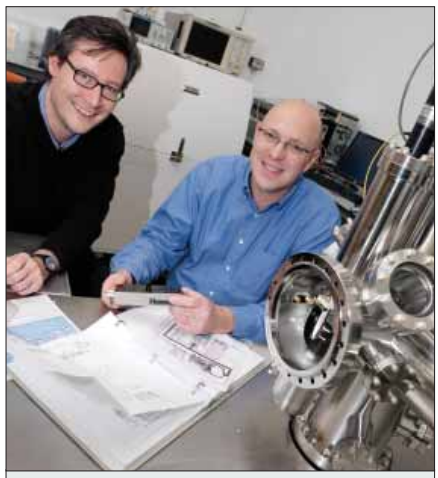
In 2006 NPL launched its pioneering metrology training scheme, NPL Training Framework, which brings together the measurement community into an accredited framework ensuring a consistent, credible measurement qualification applicable across industries.

The quality of measurement skills within companies is fundamental to engineering and manufacturing. If employees understand the importance of quality measurements and can spot issues early in the production process they can save companies time and money.

The framework offers practical application-based training courses, supported by workshops and seminars, designed to improve skills and competencies in measurement and related areas. The modular framework enables the training to be completed alongside existing work commitments.

Rolls-Royce was the first to adopt the new NPL Training Framework, which it believes will increase staff efficiency by applying the principles of measurement to product development and manufacturing. Rolls-Royce believes it will enable effective decision making by more employees through the development of a questioning culture.

Companies including Hexagon, Nikon, Siemens as well as Rolls-Royce have put employees through this new training course. In feedback 96% of delegates rated the training as good or excellent. NPL training is independent and supported by industry and it is hoped this will become the national standard for measurement competency in the UK.



Nano sensors

Applied Nanodetectors, a small company with significant intellectual property in the field of nanotechnology-based sensors for environmental and medical applications, last year approached NPL for support. Dr Victor Higgs, their MD, was able to gain first hand experience of how specialised measurement of nanomaterials could be used to accelerate the development of new products and intellectual property. They accessed a range of measurement facilities including the new Atomic Force Microscope at NPL under the guidance of Dr Alex Cuenat, a nano-functional materials specialist. This understanding of the measurement techniques, how they can be applied and which are the most effective has enabled Victor to make use of funding opportunities that support the further development of sensors using NPL as the collaborating metrology partner.

- CEMMNT – The Centre of Excellence in Metrology for Micro and NanoTechnologies was launched in 2006. DTI part-funded this scheme to provide companies with access to know-how and facilities from the partners: NPL, the Systems Engineering Innovation Centre (SEIC), QinetiQ, Taylor Hobson and Coventor.
- In the last year NPL produced 18 new Measurement Best Practice Guides. Many of our guides are available for free download from www.npl.co.uk/publications and are downloaded thousands of times each year. Currently the two most popular guides cover dimensional metrology and design and interpretation of engineering drawings for measurement processes.
- NPL undertook or received over 50 secondments in the year between other institutes, universities and large companies both in the UK and abroad – further sharing scientific knowledge and enabling the transfer of skills.

Defence, Security & Nuclear

Security technology has had to adapt to terrorism threats in urban environments where it is required to be non-intrusive and avoid disruption to civilians and daily life. NPL is applying its metrology skills to these defence and security challenges.

One of the most pressing demands is the swift detection of explosives. There is a delicate balance between the limited official and public tolerance of false alarms generated by an over-sensitive system and system failures which could have devastating consequences.

NPL won a joint project with broadcast and IT visualisation companies to fuse data to improve the users understanding of complex systems or dynamic environments, such as crowd management and security incidents.

Best biometrics

To help ensure that fingerprints stored on travel documents can be used the world over, NPL has successfully concluded a project to look at the interoperability of fingerprint systems. With many nations choosing different vendors to supply systems for their border officials, it is vital that these systems interoperate.

Working with the international standards community and four of the world's largest fingerprint system suppliers, NPL has developed methods for checking that such systems will work together.

NPL has internationally recognised credentials in performance testing, measurement and calibration of biometric systems. It is project editor for the ISO global standards for biometrics performance testing and contributes to the UK's Biometrics Working Group.

Nuclear clean up

NPL works with experts in the nuclear industry to develop protocols for the correct identification and measurement of nuclear materials. These help users to consign waste more cost effectively while maintaining safety standards.

Correct identification of nuclear material is a major challenge in site decommissioning. Waste on a typical site ranges widely, both in activity level and physical form. This leads to measurement problems with major cost implications for the industry.

NPL has developed a mock radioactive waste drum so nuclear decommissioning teams can test their procedures for characterising radioactive waste. The NPL drum is currently being used to test the accuracy of these detectors in the UK. It will help identify any problems with current measurement systems, standards and procedures.

In 1933, sextants were tested at NPL for the Admiralty and the mercantile marines.

- The NPL acoustic pressure vessel provides a unique facility within Europe to simulate underwater conditions. New acoustic stealth panels were tested in this facility for their absorbing properties, with depth and temperature between 1 kHz and 5 kHz. This frequency range had previously been extremely challenging and is a first for NPL.
- Radioactivity in the environment and the food chain is monitored in the UK by a network of analytical laboratories. NPL plays a key role helping the laboratories demonstrate that their measurements are accurate, consistent and independent of the nuclear industry. In 2006 NPL completed a successful proficiency test exercise for these laboratories, distributing radioactive samples based upon our primary radioactivity standards for them to measure.
- NPL colorimetry expertise was used to ensure military camouflage matches its surroundings. Modern camouflage must be disguised not just from soldiers' eyes, but should also evade detection by infrared, ultraviolet and thermal imagers.

Space & Communication

NPL is helping the space community to develop better satellites to monitor climate change, support communication networks, increase economic performance and save lives.

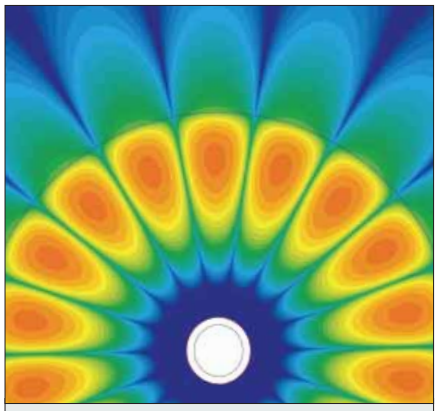
NPL provides the measurement tools to build satellites with more sophisticated timing systems and precise positioning in space. It enables robust and accurate antennae, better tools for data analysis, traceable calibrations for improved data quality and more resilient materials to increase life expectancy.

Improved satellite-based earth observation and imaging will give policy makers more accurate and reliable information about climate change. It will also assist with weather forecasting and disaster mitigation.

Precise time in space

Stringent demands on atomic timekeeping have given NPL a role in several ESA projects looking for more precise time signals in space. Better timing helps improve the precision of satellite signals, which are the basis of location-enhanced services on mobile phones and global positioning systems.

In 2006, NPL and partners won three contracts to assess the potential of optical clock and comb technologies for future ESA ground-station and space-borne metrology, and a separate contract to develop a prototype high-performance microwave oscillator for supplying each ESA ground station with an improved frequency reference.



Accurate earth monitoring

NPL is supporting the European Space Agency's (ESA) Global Monitoring for Environment and Security (GMES) project, which gives policy makers and European industries more accurate and user-friendly data from satellites.

GMES will deliver more advanced satellites and generate flexible data products from those already in orbit. NPL is leading a consortium to develop a strategy to assure the quality of data and set standards for GMES. Last year, the first stage of this, a review of the current systems, was completed and delivered to ESA.

NPL has developed a design for an ultra-stable microwave oscillator offering fractional frequency stabilities that remain constant to a few parts in a million billion, over the course of a quarter of an hour. The oscillator's 'whispering gallery' mode (pictured above) is an electromagnetic standing wave that goes around in circles, following the curve of sapphire rings outer cylindrical wall. The frequency at which the mode vibrates, and hence that of the microwave oscillator, is better than one part in 10^{14} over time intervals of 1 s to 1000 s.

1920s chronograph for comparing time signals.

- In 2006 tests were successfully undertaken on the first satellite in the Galileo constellation. NPL had previously tested the antennae, which proved all the communications worked.
- NPL's optical radiation team completed the first phase of tests on an instrument that will fly on the James Webb telescope and measure the 'redshift' of galaxies at the end of the universe.
- In 2006 NPL successful re-bid for the contract to manage the Location and Timing Knowledge Transfer Network, a group of more than 800 academics and companies working on current and future applications for positioning information.
- The NPL MSF time signal moved location from Rugby to Anthorn, following a re-tendering for the contract. This hand over followed a significant testing period and investment in new equipment. There is now a 10-year contract in place to provide this signal throughout the UK.

International Measurement

NPL continues to support global trade and technology through its role as the UK's National Measurement Institute (NMI). It is responsible for developing and maintaining primary measurement standards while developing innovative metrology to support new technologies.

As part of an international network of NMIs, NPL helps ensure measurement standards are accepted across the world and that metrology is developed to support national and European legislation.

For hundreds of years the standardisation of weights and measures has kept pace with the development of international trade. Today many EU directives in fields as diverse as food safety and environmental monitoring provide measurable limits as part of their legal definitions. Informed advice to lawmakers can ensure these limits are measurable, so industry can prove it is complying with directives and meeting targets.

NPL's role in international metrology projects gives the UK a strong and coherent voice on the world stage and contributes to the removal of technical barriers to trade by championing enforceable regulations.

The original caesium atomic clock (designed in 1955) in-situ in the standards division. This methodology still forms the basis of the definition of the second throughout the world today.

Leading light

NPL is working with other research institutes and the International Commission on Illumination (CIE) to address an absence of internationally recognised standards for the most effective illumination under twilight lighting levels. NPL's research into performance of the eye in low-light could lead to new lighting standards being adopted by highways agencies, road lighting designers, lighting manufacturers, legislators and regulators.

European metrology leadership

NPL is leading a European-wide network of national measurement institutes (iMERA) with the aim of ensuring metrology resources are shared and deployed for economic and social benefit. The EU spends 1% of GDP on measurement each year. The 20 iMERA partners from 14 countries are supporting this investment through closer collaboration that will benefit manufacturing, trade and the quality of life.

A major achievement of iMERA has been to secure € 21 million from the European Commission to support a long-term collaborative metrology research programme. This will be launched under NPL leadership during 2007.

- Dr Markys Cain, knowledge leader for NPL's Materials Team, is helping a European Network of Excellence to establish the European Institute of Piezoelectric Materials and Devices.
- NPL is at the forefront of international activities for standardisation of measurements at the nanoscale, especially in the development of clear and consistent terminology, international standards for scanning probe microscopy, and surface chemical analysis for use by industry.
- NPL is leading an international working group established by CIPM - International Committee for Weights and Measures - to assess the need for increased metrology in the measurement of material properties.

Outreach – Inspiring the Future Generation

For over 100 years NPL's world-leading reputation has relied upon exceptional scientists and passionate communicators. As we see the decline in the number of students choosing to study science or pursue scientific careers, NPL is committed, as part of its Corporate Social Responsibility Mission, using its innovative science outreach team, to bring science to life and inspire thousands of children, students and teachers.

NPL works in partnership with schools and local education departments to deliver a campaign that is core to our corporate responsibility strategy, undertaking activities as diverse as school visits, on-site science based competitions, teacher training days and evening classes all of which are supported by a range of resources.

Protons for Breakfast – in the evening

In the last year NPL twice held the Protons for Breakfast evening course. In its third year it consists of a two hour evening session over six weeks, numbers have grown with each course, with over 70 people enjoying the last one. The course introduces some simple science concepts and then uses these to allow people to understand and debate topical issues such as climate change and nuclear power.

Interactive learning

In 2006 NPL launched the 'Virtual Physical Laboratory', a comprehensive interactive software resource, containing 170 interactive experiments, which brings physics to life in schools. NPL has partnered with the Institute of Physics to make it available free of charge to schools. The package was developed by Dr John Nunn to fill a serious lack of teaching resources, especially for practical demonstrations, a fundamental requirement in the learning process.

It is the only IT package to be recommended by Cambridge International Examinations, the world's largest provider of international qualifications for 14 – 19 year-olds and received a five-star rating from the UK's leading Physics Education journal. The freely available package is currently used in over 450 schools in 10 countries, with requests arriving daily.

A Dalek at the children's Christmas Party 1967.

- NPL inspires over 1200 children, parents and teachers each year through 25 active Science Ambassadors.
- 2500 new visitors a month visit our online learning room of resources.
- NPL sent out over 2000 science poster packs to schools.
- NPL, as part of Serco Science, was cited as an exemplar company in 2006 for promoting Women in Science by the Women in Work Foundation. NPL has seen a rise in both recruitment and progression of female scientists.
- NPL has been invited to advise the Government's Chief Scientist on expanding outreach campaigns.
- NPL held Water Rocket Workshops at the Royal Armouries education centre at the Tower of London, as part of Science Week.

Commercial Services from NPL

We help all UK industry, research organisations, institutions and government departments to use our knowledge to support their business. Working with NPL opens the door to 500 passionate scientists and world-class facilities through DTI-backed research programmes. NPL provides a range of services to solve your problems by applying measurement advice to lever and compliment your skill base. NPL experts give up to two hours of free advice and have many guides and dissemination events available.

Technical research and development

NPL can support your business by undertaking bespoke measurement research, working in collaboration with your team to ensure the sharing of knowledge.

NPL has been providing R&D project management services for government, research organisations and industry for many years and can use this expertise to project manage contract research or science-based collaborations on behalf of your stakeholders.

Professional services

If you have a specific problem or opportunity we can work with you to tailor an appropriate measurement solution.

This might include consultancy, training, or a tailored measurement service. To help you verify a new process or take a product to market, NPL can undertake a measurement audit or validate performance. NPL is sometimes in the position to offer DTI-funded research for consortia of companies and secondment programmes, and consultancy for companies meeting the Government's SME criteria.

Technology exploitation

NPL's expertise often manifests itself in technology processes, software or instrumentation products to support its research work. NPL can be commissioned to design instrumentation and also has a number of instruments and software for sale and license.

Many companies' own products and services benefit from the 'NPL Technology Inside' scheme.

Measurement services

NPL provides over 200 standard calibrations, routine tests, reference artifacts and materials. As the pinnacle of measurement in the UK, our services are often unique in accuracy and availability.

NPL is accredited by UKAS as a calibration laboratory No. 0478 and testing laboratory No. 0002 to ISO17025:2005 and as a reference material producer No. 4002 to ISO Guide 34:2000.

Knowledge transfer

NPL is a research organisation that excels in sharing its knowledge, developing methodologies and making use of innovative technology. NPL can manage the exploitation of your knowledge, developing and implementing strategies that encompass policy support, network management and impact assessment.

Contact the NPL Helpline staff, who will be happy to advise you and find the correct person with the right know-how for your enquiry.

Helpline: **020 8943 6880**
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