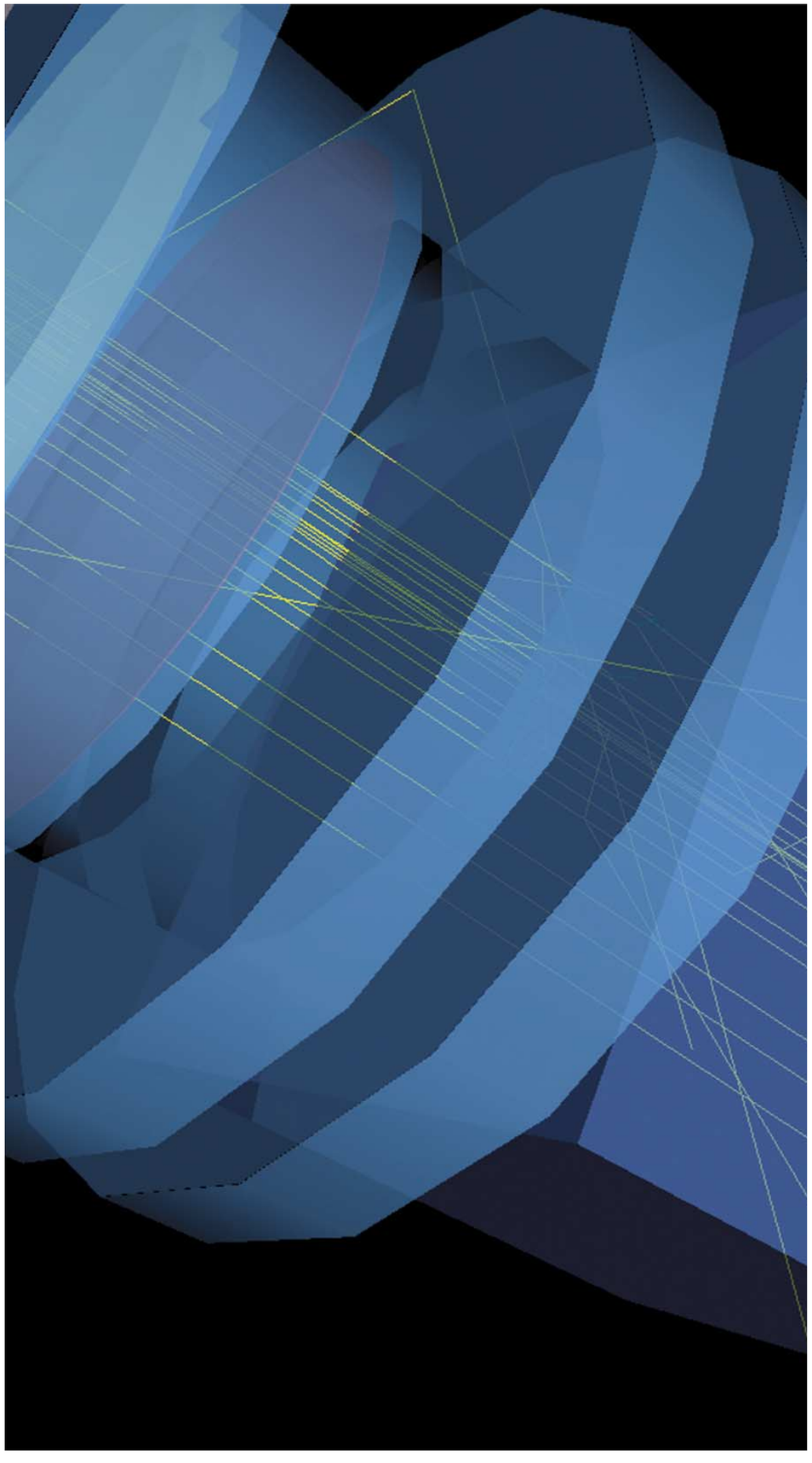
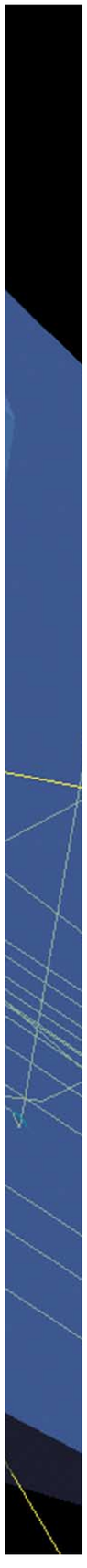
National Physical Laboratory

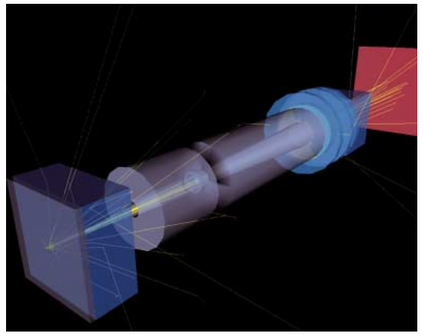
[Review |

2002-03] Contents

NPL is a UKAS-accredited calibration (0478) and testing (0002) Laboratory







[On the cover]

The cover shows a Monte Carlo simulation of the electron linear accelerator (Linac) at the National Physical Laboratory (NPL). This facility is dedicated to providing calibration services where the absorbed electron or X-ray dose needs to be known, or where knowledge is required about the consequences of exposure to these types of radiation. This work impacts on cancer radiotherapy, food irradiation, sterilisation of medical products and the semiconductor industry.

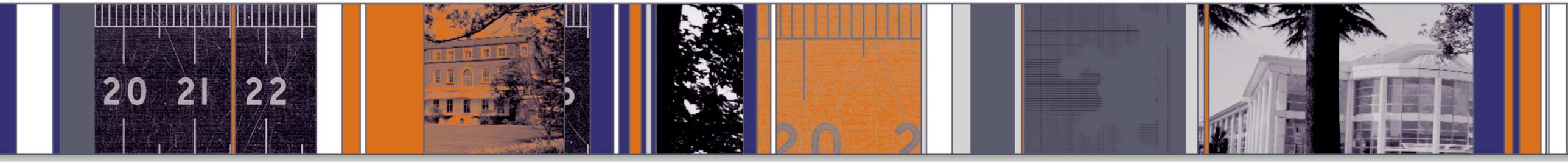
In this case, Monte Carlo simulation is being used to examine the interaction of the electron beam in the Linac with a tungsten target, after passing through various filters and collimators. The simulation models the production of X-rays due to the collision of the electrons in the beam with the target. It predicts the quantity of X-ray photons produced, their energies and their direction of propagation.

One application of this work is to calculate the radiation dose received by cancer patients in radiotherapy units throughout the country. Using the knowledge gained from these techniques, it is possible to provide better services to patients and have greater confidence in the effectiveness of the therapy delivered.

Measurement is fundamental to innovation and sound engineering practice. We can only make progress and understand the progress we are making when we measure with accuracy and confidence. Without a trusted measurement and standards infrastructure our economy and quality of life would quickly falter.

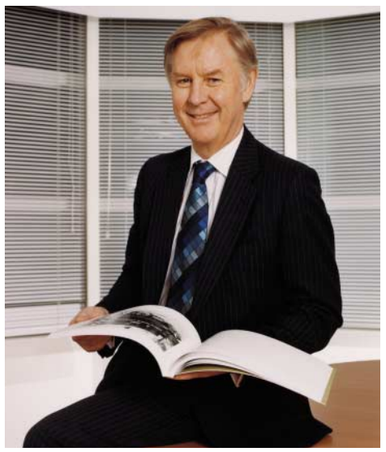
To sustain and build on our position as a world-leading national metrology institute (NMI), NPL continually looks outwards, building bridges with partners in science, industry and Government, to remain relevant and valued.

In this section, the Chairman and the Managing Director of NPL consider the success factors in NPL's performance and the strategy for our future growth and development.



[An ever more active role]

Sir Peter Williams CBE - Chairman



As a scientist with a strong commitment to the translation of scientific research into commercial applications, I have always admired the world-leading measurement science at NPL. The Laboratory is a national asset and the UK can be justly proud of its achievements over the years since its foundation in 1900.

The recognition by the UK Government in the 1990s that such an incubator of knowledge would benefit from change was, in my view, an important turning point for NPL. In 1995, NPL ceased to be a government operated laboratory and became a government owned contractor operated (GOCO) organisation, managed by Serco Group plc on behalf of the Department of Trade Industry (DTI). This business structure means that the Laboratory remains the property of UK Government, but the management of the organisation is now the responsibility of a commercial company.

Embracing change always presents many challenges, but NPL's evolution has been highly successful over the past seven years. By opening its doors and entering into dynamic and innovative collaborations with a diverse range of industries and academic institutions, NPL scientists today seek challenges that will have a positive impact on society's quality of life and on the economy. Devising metrology services and solutions, which will make a technological difference now and in the future, represents a highly motivating goal.

I was therefore delighted to be invited onto the NPL Board in 2002 and honoured to succeed George Gray as its Chairman. Dr Gray, who was one of the founders of Serco Group plc, has made an enormous personal contribution to the recent development of the Laboratory. His commitment to the highest standards of integrity and independence were vital to the smooth transfer from Civil Service to private sector operation of the Laboratory. I will do all I can to uphold the values Dr Gray sustained at NPL. As the new chairman, I also see my role as helping to forge further relationships with industrialists, academics and government representatives, all of whom stand to benefit from a greater understanding of what NPL can do for them.

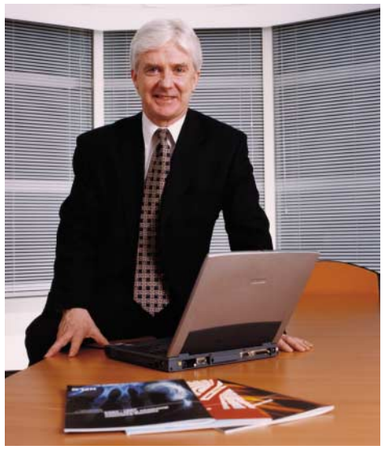
Once our new building is completed, NPL will have one of the finest facilities anywhere in the world. Our internationally regarded scientists continue to work at the frontiers of measurement science across a wide range of disciplines, including chemistry, engineering, materials and the bio-sciences as well as physics - our traditional area of strength.

More challenges lie ahead. NPL must continue to attract and retain bright, dedicated scientists, both from the UK and overseas. In addition, NPL must ensure the seamless re-housing of all its scientific and support staff in the new Laboratory, enabling this asset to realise its full potential. Finally, if our mission is to play an ever more active role in the advancement of the quality of life and wealth creation, this can only be attained by proactively engaging industry. Innovations brought about by measurement science can then benefit the productivity of a higher percentage of UK companies.

I have great confidence that NPL can meet these challenges - and more. I am honoured to be playing a role in the future development of what I consider to be a vital hub of modern science.

[A pattern in the complexity]

Dr Bob McGuiness - Managing Director



As the UK's standards laboratory, our mission is to develop and disseminate the measurement science and technology on which our economy and the quality of our lives depend. It is a national mission, funded mainly by the UK Government within the National Measurement System (NMS); but we have an extending international role, reflecting the vital importance of measurement to trade and globalisation.

I am very pleased to welcome you to this Review of NPL's activities and achievements over the past year.

This has been a year of continued excellence at NPL. Despite tough economic conditions and working alongside a major construction project - which will ensure that NPL has first-class facilities for decades to come - our people have successfully addressed an extraordinary range of scientific, technical and business challenges.

Our achievements are diverse: from leading-edge research in nanosciences to innovation in internet-enabled calibration; from productivity-boosting projects working with small businesses to the creation of a partnership to develop the next generation of global positioning satellite applications. The case studies and highlights we present in this Review are above all testimony to our staff, to their skills, energy and endeavour.

NPL's activities reflect the complexity of the technologies we are developing and transferring to industry and the wide range of stakeholders we serve. However, there is a clear pattern in the complexity. Everything we do is part of a continuum, a process by which measurement knowledge is generated, developed and applied, to deliver the maximum possible economic and social value.

The process begins with detailed programme planning. DTI commissions NPL and other contractors to undertake in-depth assessments of future measurement and standards requirements, through a series of market studies, focus groups and public consultations. Typically more than 100 organisations, representative of the user community, are directly involved in the process.

The NMS programmes are the engine room of knowledge generation at NPL. They comprise a portfolio of research, development, facility maintenance and knowledge transfer projects. Our research, generally carried out in close partnership with UK universities, is the basis for continuous, user-driven improvement in the national measurement facilities. This research also generates knowledge in the form of measurement best practice and new technologies for transfer to measurement users.

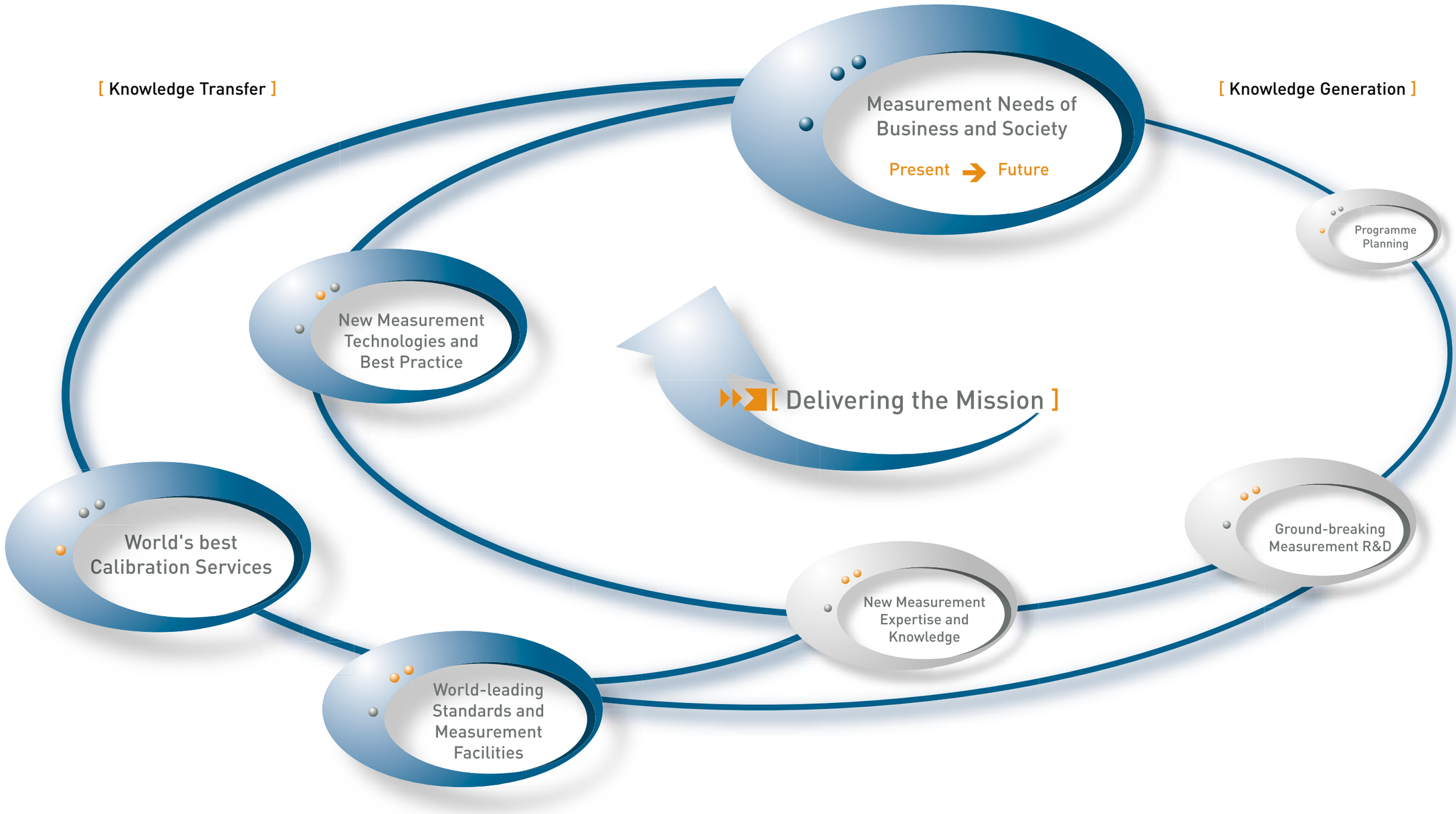
As a result of continuous innovation emerging from our R&D programmes, the UK's national facilities remain at the top of the international system of measurement; and they are the platform for over 200 outstanding calibration services offered by NPL. In order to maximise NPL's value to the economy, we deliver, in parallel, a range of knowledge transfer activities - including best practice dissemination, consultancy and the generation of new technologies for commercialisation. These services and knowledge transfer initiatives are the bonds that tie us to measurement users: NPL must be judged on the extent to which they are relevant and value adding.

→//[www.npl.co.uk/about/vision_and_mission]

NPL is committed to generating and applying data of the highest integrity and quality. This commitment is shared by others within the Serco Science Group, including the safety management consultancy, Serco Assurance, and the Atomic Weapons Establishment (AWE) which maintains the UK's strategic nuclear capability.

In my view, two factors lie at the heart of success for NPL. The first is the professional management of the cycle shown below, recognising and balancing each part of the process. We have the advantage of having developed the model as a product of evolution over 103 years, always with the one consistent goal: to maximise the positive impact of metrology on measurement users.

The second factor is a partnership approach to delivering our goals: partnership with Government, which creates the policy framework for the mission and whose ownership and funding gives NPL its being; partnership between our talented scientists and the UK science base, which provides the fundamental science; partnership with the measurement and instrumentation industry which is the principal medium by which NMS outputs are exploited; and with measurement users, who reap the ultimate benefits of greater accuracy and confidence.



[0.1] The NPL Ionising Radiation Team

> We are what we repeatedly do. Excellence, then, is not an act, but a habit.
>
> Aristotle, Greek philosopher (384-322 BC)

Excellence in research is not achieved by chance. Over its 103 years, NPL has developed the culture and processes that support scientific endeavour of the highest quality. Key elements in sustaining this success include careful pre-project planning and targeting, the capacity to maintain unique scientific facilities and the nurturing of exceptional individuals and teams.

NPL's purpose is to generate and make available knowledge-based products focused on the needs of our society to measure consistently and well. We employ over 500 scientists and engineers, many of them with international reputations in their fields. Each year, NPL undertakes more than £15 million of research and development activity for DTI.

In this section of the Review, we will consider some of these success factors and present case studies from the past year, featuring some of our most exciting research results and talented people.

[Excellence focused on needs]

NMS programmes at NPL:

- Acoustical Metrology
- Electromagnetic Metrology
- Ionising Radiation Metrology
- Length Metrology
- Mass Metrology
- Materials Metrology
- Measurements for Biotechnology
- Measurements for Technology Research
- Optical Radiation Metrology
- Photonics Metrology
- Quantum Metrology
- Software Support for Metrology
- Thermal Metrology
- Time and Frequency Metrology
- Valid Analytical Measurement
- International
- Knowledge Transfer

An independent review undertaken for DTI calculated that the National Measurement System (NMS) adds £5 billion per annum of value to the economy.

NPL is by some margin the largest contractor within the NMS and is currently engaged in a broad portfolio of programmes.

In the next decade, metrology breakthroughs in areas including quantum standards, nanotechnology and biotechnology will help unlock significant business opportunities through new product development and increased productivity. However, it is also vital that we continue to improve measurement support to the UK's manufacturing sector, as the UK seeks to position itself at the high-value end of manufacturing.

NPL is committed to scientific excellence, not for its own sake, but for its exploitation potential. Our research is driven by the analysis of present and future measurement requirements, so that we can bring into being the facilities, services and expertise measurement users need. Each programme is the product of an extensive planning phase lasting around 18 months and overseen by DTI, which involves 'foresight' activity to assess likely future measurement demands, market analysis and industry consultation.

[The right formula]

"Through NPL, and other laboratories, DTI delivers the NMS, providing the UK with the infrastructure and measurement science vital to innovation, productivity and the quality of life. Working in partnership with DTI, NPL plays a key role in the successful delivery of the NMS. We are delighted to see the achievements of the Laboratory's dedicated scientists and staff reflected throughout this Review."

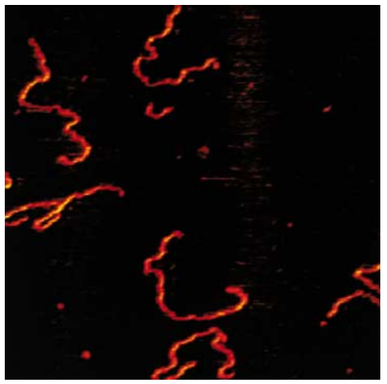
Denis Walker, Director of the NMS, DTI

Programme planning or formulation is an exercise to determine and address the needs of the potential beneficiaries of a programme. Completed in 2002, the Length Metrology formulation provides a good illustration of this. This programme supports and develops dimensional measurement techniques for wavelength, large-scale manufacturing, production engineering, and micro to nanotechnology. In this planning process, we consulted with a wide range of companies from large end-users such as Rolls-Royce and Taylor Hobson Ltd to small and medium-sized enterprises (SMEs) such as Cambridge Optical Sciences and CD Measurements Ltd.

This broad consultation of the end-users and world-leading technical experts was realised through meetings, surveys, studies and site visits, which included:

- Six industry focus groups covering soft gauging, form and 3-D surface topology, conventional and vision based co-ordinate metrology, micro to nanometrology, large-scale measurements/positioning and long-term research requirements.
- A questionnaire-based survey of measurement service users and the Dimensional Metrology Awareness Club (DMAC).
- An in-depth study of metrological requirements for Length in 2002 and beyond commissioned and carried out by Optimat Ltd.
- Extensive consultation of technical experts, project collaborators and colleagues on standards committees.

[0.2]



[0.3]

The Quantum Metrology Programme anticipates and addresses the long-term measurement requirements for business and society. It currently focuses on three themes: Frequency Standards, Fundamental Constants, and Nanoscale Molecular/Particle Detection.

Under the third theme, significant advances have been made in applying surface enhanced Raman spectroscopy (SERS) to understand the structure of biological processes at the molecular level - a good example of how physical techniques can be applied to help solve biological problems. Work includes in-depth analysis of the mechanisms behind SERS, comprising theoretical studies, molecular mechanics and chemical manipulations.

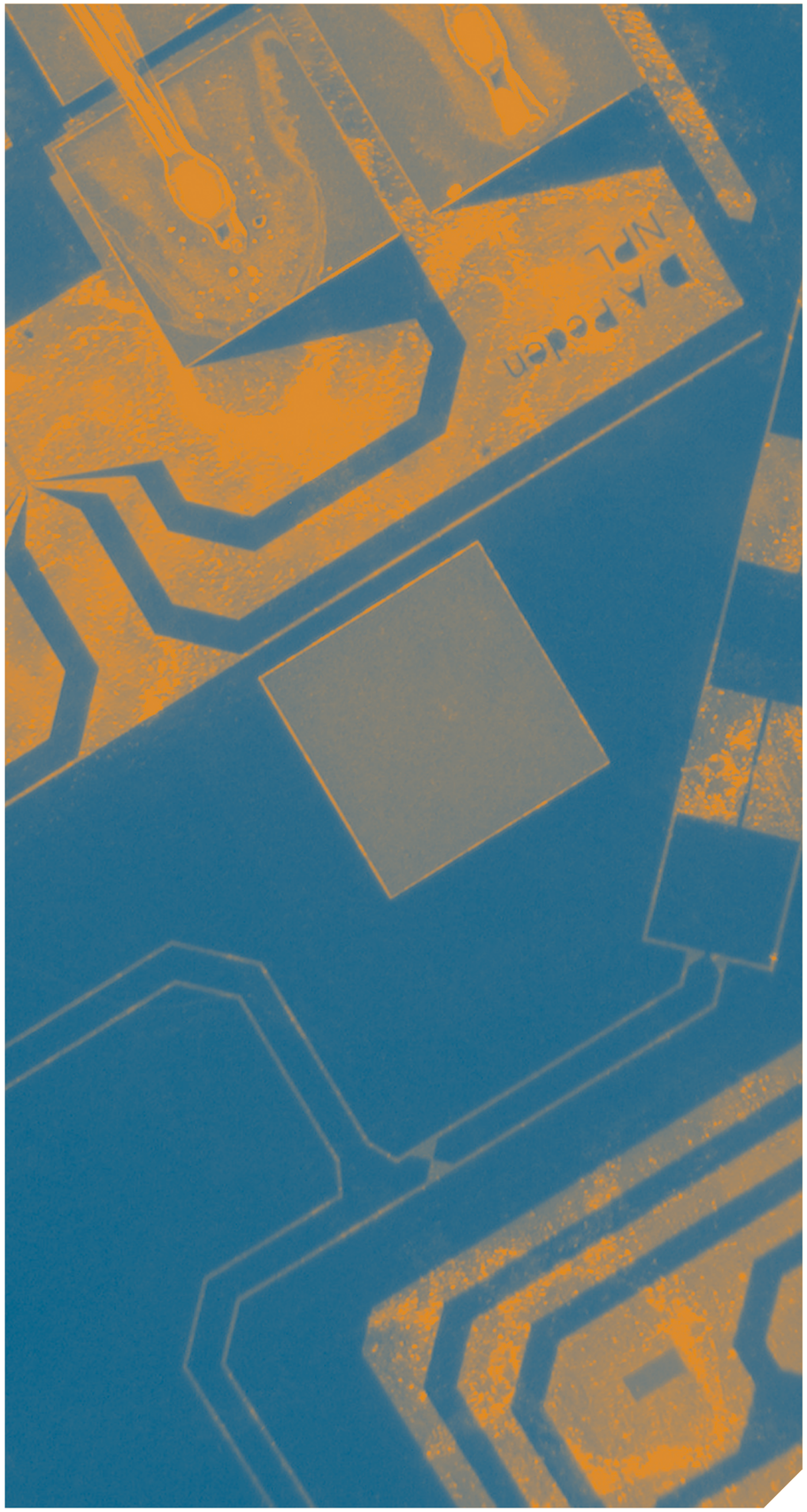
Another project is MOLSWITCH - a molecular magnetic switch that connects the biological and silicon worlds. A nano-switch is being developed, based on a biological molecular motor and a moving magnetic nano-bead, providing a link between the biological sciences and the silicon-based microelectronics industry. This will be used in the development of sensor technologies for detection of biomolecules and could produce a method of single molecule DNA sequencing, which would dramatically change healthcare treatment in the 21st century.

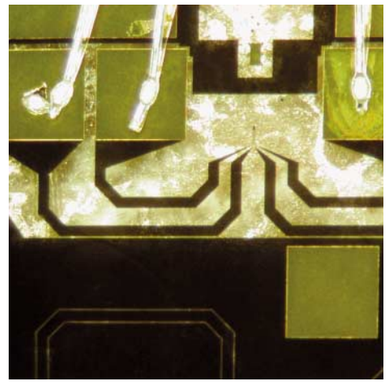
Partnership is vital to our science. In this area, collaborations are being developed with the bio-nanotechnology Interdisciplinary Research Centre in Oxford and a network of universities including Imperial College, Glasgow, Portsmouth and Strathclyde.

[0.2] Atomic force microscope picture of DNA & enzyme scans

[0.3] DNA helix. Model showing the double helix of DNA (deoxyribonucleic acid). The double helix consists of two spiralling strands of sugar phosphates that are linked by nucleotide base pairs.

SCIENCE PHOTOLIBRARY | Alfred Pasieka





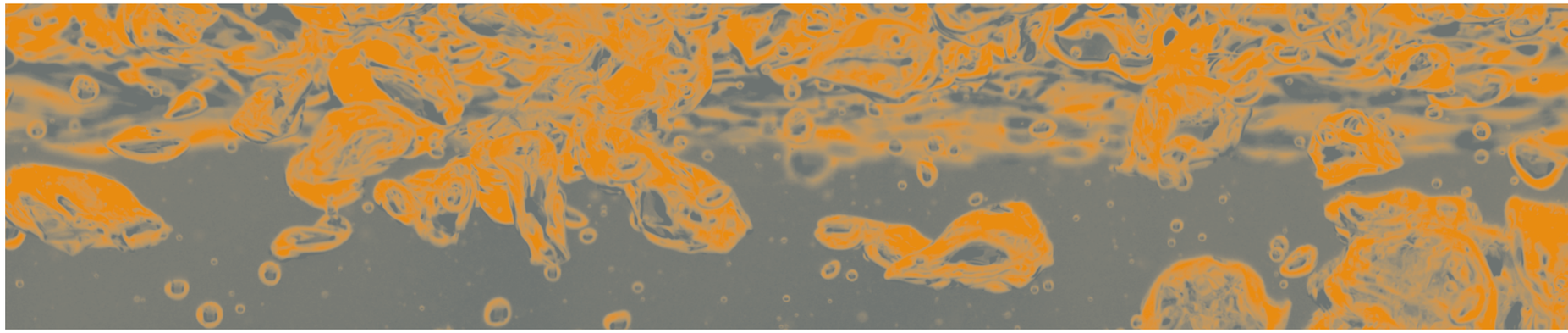
[0.4]

The existence of optical phase conjugation mirrors was proposed in the late 1960s by Russian scientists. They have been widely used since for optical signal processing, spatial image processing, filtering and tracking devices. However, no practical phase conjugation mirror has been demonstrated in the microwave region where its application would have enormous benefits, for example, to improve the performance of mobile phones, radar applications and satellite communications systems.

In collaboration with Strathclyde University, NPL scientists have side-stepped the requirement for highly non-linear materials at microwave frequencies by using discrete element 2-D microwave phase conjugating mirrors based on weakly-coupled superconductors - Josephson junctions. These exhibit extreme non-linearity and may be used in conjunction with other cryogenic materials such as strontium titanate, a ferroelectric insulator. A feasibility study of this novel use of Josephson effects and superconductivity was completed in 2002.

Combining this technique with other unique aspects of superconductivity and oxide functional materials could lead to a very compact realisation of a phase conjugation microwave mirror of a size and simplicity not yet available to the electronics industry. Device design and implementation in a single cell is currently under evaluation. A patent covering the use of superconducting devices for a discrete element microwave phase conjugating reflector has been established. The expectation is that a full 2-D phase conjugating reflector will become a reality in the next five years.

[0.4] Microwave phase conjugation chip

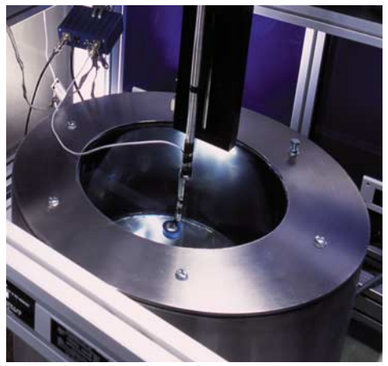


[Taking soundings]

High power ultrasound is used in a large range of applications, from healthcare to aerospace. It is used because of its ability to cause cavitation - the growth, oscillation and collapse of small micron-sized bubbles. There is a long-standing need for reliable cavitation characterisation methods, so that processes ranging from lithotripsy (the ultrasonic destruction of kidney stones) to ultrasonic cleaning and sonochemistry (the use of ultrasound to catalyse chemical reactions) may be optimised and scaled up.

In 2002, NPL commissioned a new ultrasonic cavitation reference facility to increase its research and measurement capabilities. It consists of 30 ultrasonic transducers operating at 25 kHz arranged around a 300 mm diameter and 500 mm high cylindrical cell. It is capable of producing ultrasonic power levels up to 1.8 kW. Once characterised, the new vessel will be established as a high quality test bed, providing reproducible conditions against which NPL's sensor innovations can be evaluated.

[0.5]



[Under pressure]

[0.6]

High-pressure metrology is essential to accurate industrial flow measurement. It is used in industrial process control and in the fiscal monitoring of hydrocarbons which is worth approximately £42,000 per minute to the UK Exchequer. In addition to this, reliable high-pressure measurement is vital to the safe testing of boilers and other pressurised vessels. NPL has long been one of the world's leading laboratories in this field and is building on this reputation.

An innovative method of generating high-pressure standards is being developed in association with an SME. This instrument should offer improvements in the uncertainties with which high-pressure standards are realised as well as allowing the measurements to be carried out more efficiently. In addition to this, NPL has produced a design for a modification to an existing instrument design that has led to a collaborative venture with a leading manufacturer.

[0.5] Nigel Lee setting up the new ultrasonic cavitation facility

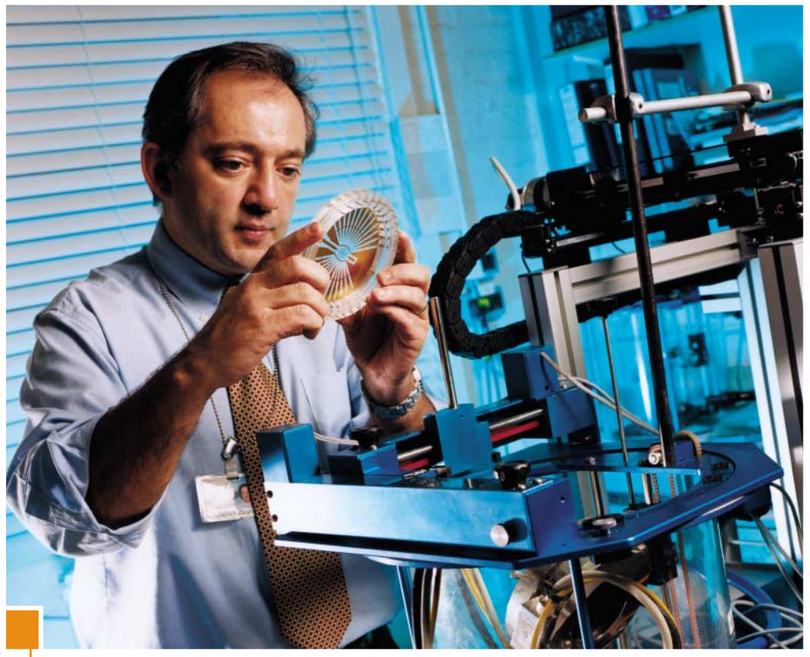
[0.6] Anthony Evenden calibrating a pressure balance

→//[www.npl.co.uk/pressure/high.html]

[Dedication to innovation]

NPL's performance and reputation depend upon the dedication, skills and ingenuity of our staff. We are pleased to record that in 2002 our scientists won more than twenty awards for the quality of their research. A few examples are given below.

Dr Peter Woods received two prizes in 2002: the Chree Medal from the Institute of Physics and the Institute of Measurement and Control's Sir Alec Hough-Grassby Award. Both were in recognition of his innovative research in environmental science, specifically stratospheric ozone depletion and the detection and monitoring of atmospheric trace gases and air pollution.

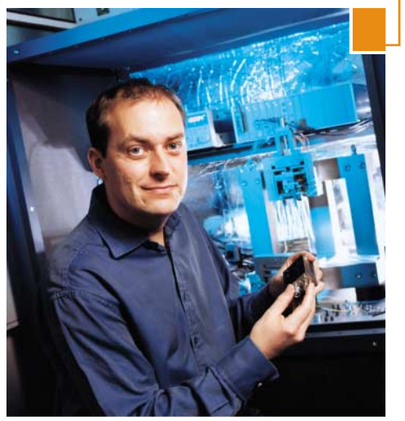


Dr Bajram Zeqiri was acknowledged for his ground-breaking research into techniques for measuring ultrasonic fields used in industry and medicine. Through the development of a number of novel methods, Bajram's work is opening up new areas of measurement, which should ensure that ultrasonic equipment is operated in an optimised, safe and reliable way.

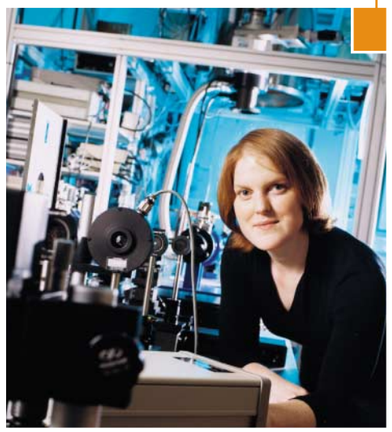
“Often scientific organisations have less than clear career paths for scientists. At NPL, I have been given the opportunity to excel in my field, as well as the chance to develop my business acumen. Over the last year, my hard work has started to pay off.”

Dr Markys Cain

Dr Markys Cain received an award for an Institute of Physics journal paper on magnetic C60 realised in collaboration with Warwick University and the Rutherford Appleton Laboratory. The Engineering and Physical Sciences Research Council (EPSRC) has funded this work and the paper demonstrates the existence of a polymeric form of C60 that exhibits magnetic properties in bulk form. Not only is this of great interest scientifically, but new industrially relevant applications are now under investigation. Dr Cain was also part of a SMART Award-winning team undertaking novel cochlea ear implant research.



As a research scientist and manager of our sensors and functional materials work, Markys has doubled the size of his team and its income, and has directed government and commercial research projects worth more than £2 million. With over 15 years’ experience in the field, he has an acknowledged international reputation in advanced materials science.



During the past year, NPL has welcomed more than 100 new staff. We offer career opportunities ranging from science, technology and engineering to marketing.

We continue to recruit the brightest and best to ensure our future. Dr Hilary Hartigan joined NPL in January 2002. Since then, Hilary has been actively involved in the Quantum Metrology Programme working towards single molecule detection using SERS. This is a collaborative project with Imperial College London and the University of Glasgow. Hilary is also currently working on the optimisation of the Harned cell for highly accurate pH determination.

Hilary has taken opportunities to broaden her contribution to NPL’s business. A keen science communicator and a talented linguist, Hilary has been involved in the development of the NPL website, the organisation of seminars and many other knowledge transfer activities.

“Working on emerging technologies is so satisfying, you really feel that you are contributing to the next generation. In my work in the area of bio-nanotechnology, I have the chance to collaborate with academic and industrial scientists from many disciplines and explore new grounds at the frontiers of physics, chemistry and biology.”

Dr Hilary Hartigan

> To bring scientific knowledge to bear practically upon our everyday industrial and commercial life, to break down the barrier between theory and practice and to effect a union between science and commerce.
>
> HRH the Prince of Wales, later George V, at the opening of NPL

In March 1902, these words underlined NPL's responsibility to focus science and technology on the needs of business. Today more than ever, NPL's relationship with business lies at the heart of our mission. The impact of measurement excellence on the UK Gross Domestic Product is estimated to be in the region of £5 billion annually – an extremely high rate of return on DTI's investment of some £45 million per annum in the National Measurement System (NMS).

The relationship takes many forms: extensive consultation to ensure that our programmes properly address future industrial needs; collaborative R&D; and above all partnership to transfer and exploit the Laboratory's outputs.

In 2002-03, NPL engaged in over 4500 contracts with our clients, ranging from high volume calibration services to high value product development partnerships. We are also one of the UK's largest sources of online technical information. This year has also seen the take-off of e-commerce at NPL, with over 500 transactions processed through our e-Store to date. This section presents just some of our business-focused activities throughout the past year.

[0.7]

[Good working atmosphere]

> Given the importance of the data we collect, NPL's fast and effective service is vital to the prompt analysis of our samples. The quality of the service given and the high level of competence of NPL's scientists allow me to have full confidence in the results which I pass on to the diving industry.
>
> Dr Val Flook, Managing Director at Unimed Scientific Ltd

[0.8]

NPL is working with scientific research company, Unimed Scientific Ltd, to monitor the gases which divers breathe in the living chambers and in the diving bells or in the water.

The normal gas mixture breathed by divers can range up to 30 times normal atmospheric pressure of which 5% to 20% is oxygen and the majority of the remainder helium. Because divers spend weeks continuously in this atmosphere it is important that the potentially toxic contamination, from items in the chambers and from the oil and condensate on the seabed, is kept well below safe exposure levels. The pressure differential between the diving system and the laboratory in which the analysis is carried out means that many components have to be detected at parts per billion levels.

The team at NPL uses sophisticated analytical techniques in parallel, including gas chromatography, mass spectrometry and micro gas chromatography. The most challenging aspects of the analysis are the very low concentrations of some species which require the use of cryogenic pre-concentration, and the similarity of some of the isomeric species.

NPL determines the concentration of more than 50 potentially toxic gas species, with a turnaround time of just 48 hours. The results for each species are compared to the relevant occupational exposure limits, allowing the company to assess potential health risks.

[0.7] SCIENCE PHOTOLIBRARY | Geoff Tompkinson
[0.8] Dr Andrew Brown using a gas chromatograph for complex gas analysis

[0.9]

[10]

[11]

Formula One is as fast moving in technology as on the track.

Behind the excitement and passion of the racetrack the Fédération Internationale de l'Automobile's (FIA's) mobile laboratory ensures that the races are carried out according to a series of clearly designed specifications and that no team gains an unfair advantage.

Materials scientists at NPL have been working closely with the FIA and several Formula One teams to measure the specific modulus – stiffness – of some of the materials being used in this season's cars. Regulations already exist on the maximum allowable specific stiffness, but there are currently no clearly defined test procedures, which has led to some ambiguity in their interpretation.

Series of tests are currently under way, using NPL's knowledge and expertise, to develop suitable tensile and dynamic test procedures and to measure the uncertainties associated with each method. Improved guidelines based on this work will be used to provide more reliable, independent test data for the teams and regulators.

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[Profiting from precision]

> This year NPL and Precise Group have taken the On-Machine Measurement concept to a wider range of sectors. In doing so, we have proved that, as long as we can successfully establish the measurement needs of the industry in question, we can roll out the project and realise significant benefits for a diverse range of manufacturing industries.

Richard Freeman, Chief Executive, Precise Group

In last year's Review we reported how the DTI-backed On-Machine Measurement project was piloted in West Yorkshire. Twenty small companies generated savings totalling £200,000 and created new business worth almost £1 million.

In 2002, NPL secured further funding from DTI to expand the pilot into the aerospace industry around Bristol and the automotive sector around St Helens. Once again, the project had an extremely positive impact on the 20 companies involved. Savings totalled £361,000 and £370,000 worth of new business was generated.

DTI has now agreed the national roll-out of On-Machine and NPL contracted the Precise Group to deliver the programme. In partnership with the Regional Development Agencies, the next phase will target new sectors including print, food and drink, optics and electronics, addressing the needs of key industry clusters. For the printing scheme, supporting companies who have signed up include Meech Static Elimators, GretagMacbeth, Openshaw International, Airedale Rollers and MetalFX. Since the launch, the number of supporter companies has more than doubled from 12 in the initial pilot projects to 26.

[Locating innovations]

PinpointFaraday
Time and position solutions

> The availability of positioning information based largely on Global Navigation Satellite Systems will affect our lives more and more over the next five to ten years. The Pinpoint Faraday will be a catalyst in identifying new applications for positioning system technology and in helping UK companies to develop new products and services that will grow our already substantial reputation in this field of endeavour. This will be done through collaborative research and development projects, training support and knowledge transfer programmes.

Anthony Parish, Executive Chairman, Intellect

Global Navigation Satellite Systems, such as the American Global Positioning System (GPS) and the planned European Galileo project, are creating revolutionary new commercial opportunities in markets such as telecommunications, engineering, retail and transport by their ability to deliver accurate position, velocity and time data. The availability of enhanced navigation information, combined with developments in mobile communications, will have a dramatic impact on our daily lives.

The UK is placing itself at the forefront of innovative positioning application development, fostering the knowledge, skills and resources required. In September 2002, DTI announced the creation of the £1.2 million Pinpoint Faraday Partnership to facilitate the development of the next generation applications and maximise the user benefits of infrastructures such as Galileo.

NPL is managing the Partnership, working in close collaboration with more than 50 founding organisations in industry, government and academia, including Logica, Astrium, Siemens Datatrack, Ordnance Survey, National Air Traffic Services (NATS) and the Highways Agency.

[Turnaround]

NPL offers a choice of off-the-shelf and customised measurement services.

NPL has UKAS accreditation to ISO 17025 and carries out thousands of calibrations each year. In the last year, over 4000 calibration certificates were issued. These services are the principal way NPL promotes the use of traceable measurement and the main entry-point for dialogue about customers' broader measurement problems.

Within the next few years, all of our measurement services will be managed as a virtual business with effective sharing of best practice, ensuring growth, improved services and greater customer satisfaction.

For example, turnaround time in length measurement services such as reference screw calibration have already decreased by 20%, whilst the volume of demand continues to rise.

NPL will continue to offer measurement services to end-users where the highest level of measurement confidence is essential to their business. Working closely with business, NPL is extending its range of internet-enabled calibration and metrology support services. New internet-enabled calibration services are currently being developed. They comprise spectrophotometry for colour management in industries such as textile, paint or automotive and optical time domain reflectometry for the telecommunications industry.

[Next steps in e-metrology]

NPL now offers online high frequency impedance calibration, for applications in the aerospace, defence and other sectors. We will be launching internet-enabled voltage and resistance calibrations - through a service known as iVR, based on multifunction calibration instruments.

These instruments, capable of providing traceability to more than one measurement standard, are now commercially available. NPL has partnered with Adelard and Fluke to develop a facility for the calibration of multi-function transfer devices and explore their potential for disseminating electrical measurements via the internet.

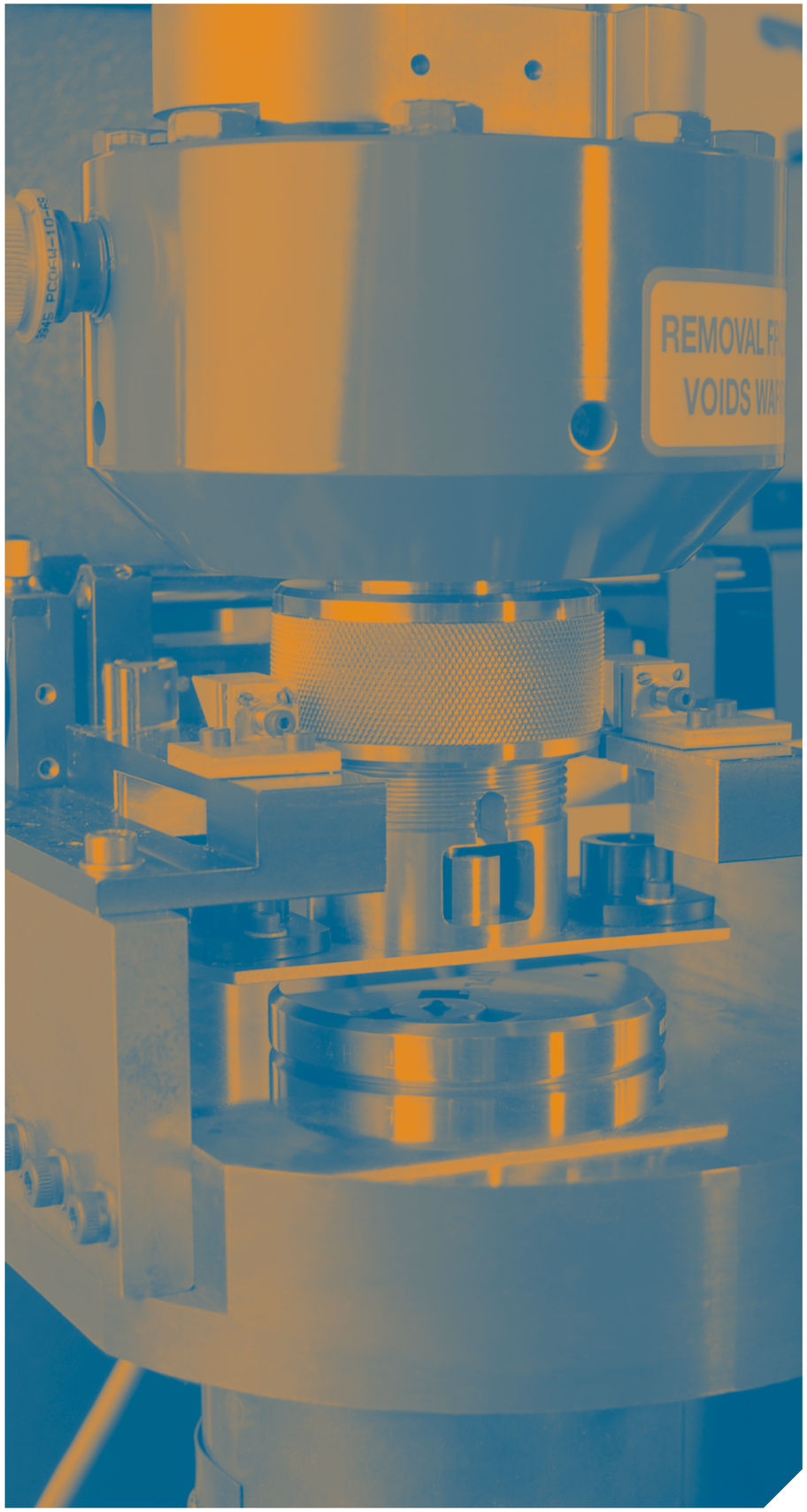
The iVR system has called upon a broad range of expertise including software design, development and integration. The software development programme was challenging and required a unique collaboration between the three partners.

"From the start of the iVR project, we aimed to develop generic software - iCal - that could form part of many e-metrology applications. Within the next few years, iCal will make a wider range of measurements services quickly and easily accessible to industry through the internet."

Dr George Cleland, project manager for iCal at Adelard.

An initial trial of the prototype system was carried out at Fluke between August and September 2002. This demonstrated that all components of the system worked correctly and that the software was user-friendly. It also identified areas for improvement such as higher quality web-cam pictures and the verification of algorithms.

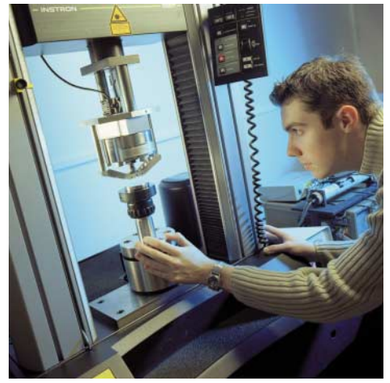
This new service will provide direct traceability to national primary standards. It will reduce downtime of instruments, require minimal transportation of artefacts, and offer access to NPL's software, Quality Assurance system and online consultancy support. The partnership is very pleased with the results to date and aims to launch the service in the last quarter of 2003.



[A hard standard is good to find]

“The new centre of excellence extends NPL’s unique range of measurement facilities for materials testing. The new national standards will increase the competitiveness of engineering industries, especially those involved in metal cutting and forming such as aerospace, automotive and materials processing; those involved in oil and gas exploration and extraction and those in mining, mineral winning and quarrying by enabling them to access highly accurate hardness measurements.”

Bill Coles, Marshalls Hardmetals



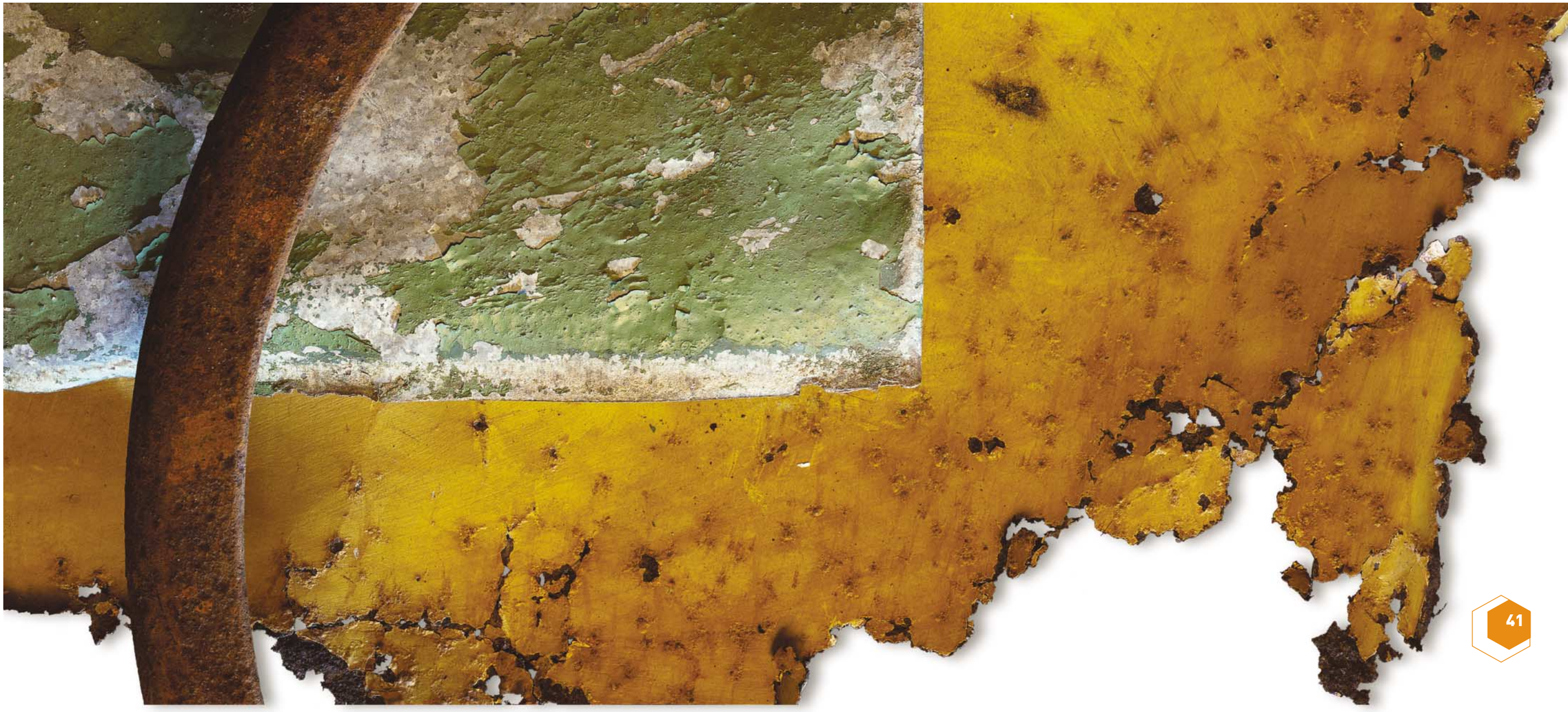
This year, NPL introduced a calibration service for hardness blocks used to verify the performance of hardness testing machines and this service is traceable to UK national standards.

The new centre of excellence offers a source of advice and consultancy to industry and will help to re-establish the UK’s influence in the development of international hardness standards. With ever increasing demands on industry to export, the need to ensure that our measurements compare favourably with those of other countries also increases and it is a great help to have available an independent arbiter in the event of dispute.

Funded by DTI, the fast on-demand calibration service complements the range of hardness testing services and facilities for Vickers, Brinell and Rockwell scales.

By extending the range of state-of-the-art measurement facilities for materials testing, NPL can attract more manufacturing collaborators to make use of its facilities and measurement techniques. The overall aim is to solve industrial problems and enhance the quality and competitiveness of manufacturing.

[12] Laurence Brice adjusting a 1.5 kN hardness standard machine



[Don't be worn down]

Engineers, teachers, environmental managers and many others will benefit from this new web-based corrosion resource which provides quick and easy access to expert technical advice. The range of information is clear, well presented and comprehensive, resulting from the high quality of corrosion research expertise at NPL.

David Deacon,
President, Institute of Corrosion
- the professional body for all corrosion engineers, scientists and teachers.

Corrosion not only damages physical structures, but also erodes the commercial, environmental and safety performance of products. The economic impact is significant - corrosion damage is estimated to cost the UK £30 billion every year. It affects plant efficiency, availability, product quality, safety and environmental impact, all of which eat away at the bottom line. However, the use of existing expertise could easily prevent a quarter of all corrosion problems.

NPL has been the UK's centre of excellence in the measurement and application of materials properties for 100 years and is home to the National Corrosion Service (NCS). It provides a 'gateway to corrosion expertise' for organisations throughout the UK to an international corrosion knowledge base, so that the phenomenon can be prevented or controlled.

A telephone helpline linked to a web-based information system allows users to talk directly to an expert who will provide impartial advice.

The website also provides a focal point from which worldwide expertise on corrosion can be accessed quickly. It provides technical materials and online guides.

Over the past year, the service helped over 500 companies to reduce cost, improve safety and reduce environmental impact through corrosion control.

The advice is underpinned by ongoing research projects undertaken by NPL in collaboration with industry. Information on the current corrosion and oxidation programme is available from the helpline on 020 8943 6142.

[Shedding light on regulation]

> We were very pleased with the calibration service provided by NPL. As we operate two UKAS accredited laboratories, it was very important to us that our new Harmonics and Flicker Generator product, the HFG01, should have a calibration traceable to NPL with its international reputation for precision measurement, independence and a high quality service. We can now with assurance market our HFG01 to other test laboratories.
>
> Chris Marshman, York EMC Services Ltd

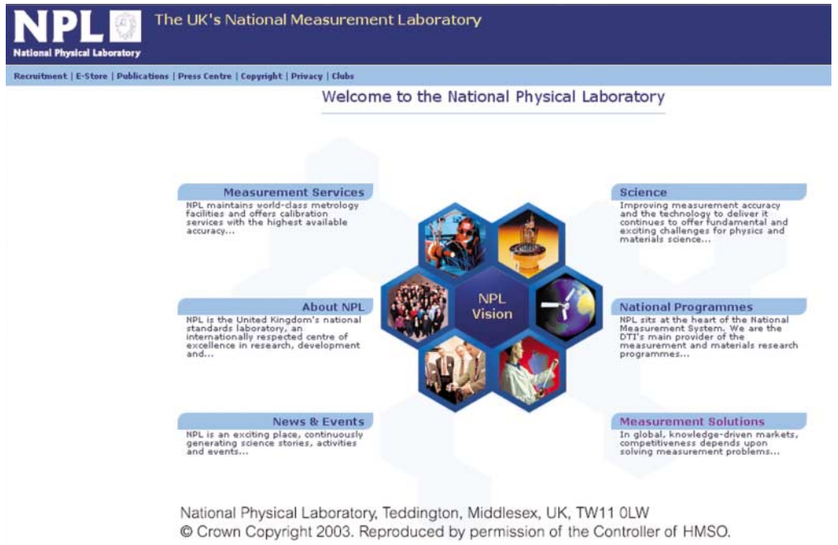
To enhance confidence in the testing of electrical appliances, traceable calibration for harmonic and flicker analysers is essential. NPL offers UKAS accredited calibration services for these analysers.

Electrical manufacturers can now access online information and guidance on harmonics and flicker testing of electrical products. These tests, as defined in International Electrotechnical Commission (IEC) standards, impose limits on the harmonic and flicker generated by electrical appliances.

The new web pages on NPL's website give guidelines for adhering to these new standards and explains the sampling systems used to analyse and measure non-sinusoidal waveforms. It also describes the methods developed at NPL to provide accurate traceable calibration for power analysers used in flicker and harmonics measurements.

The harmonics and flicker online information has a strong commercial role, as failure to meet the harmonic standard can prevent manufacturers from gaining access to new markets and can lead to delays in the production and marketing of new products.

[NPL's website is a hit!]



With the changing nature of business and the internet-based culture, it is vital that the NPL website moves with the times. After a review and consultation with internal and external customers, a complete redesign of the NPL website was proposed.

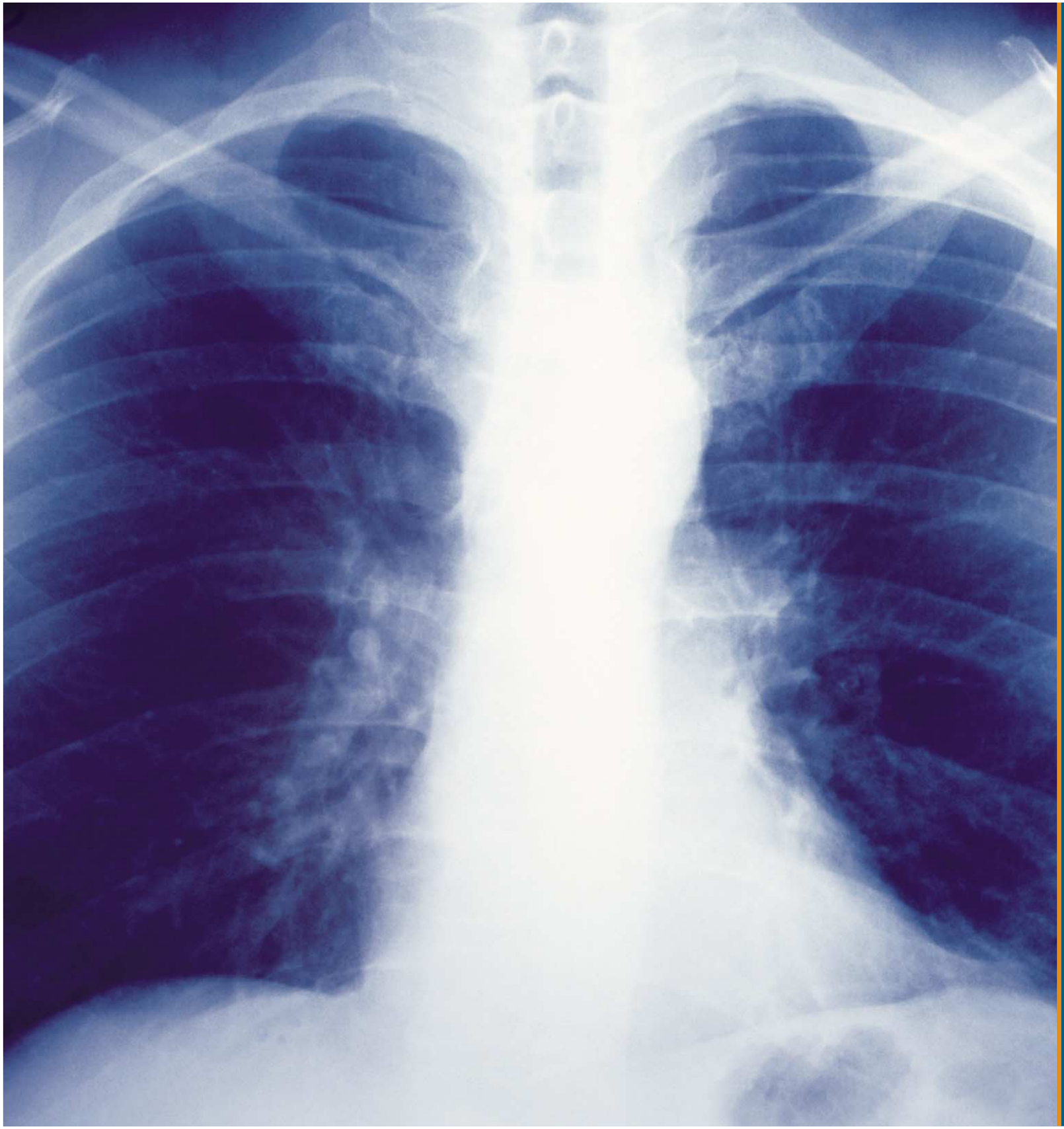
www.npl.co.uk is now designed to give consistency, quality and style, as well as a quicker and easier navigation system.

The new website is a huge success and on average receives over 600,000 hits per month, 80% of which are from business.

This year saw the arrival of the e-Press Centre which holds the latest good news stories, mini case-studies and press releases, as well as providing a point of contact for the media.

The NPL website is now a streamlined functional tool that reflects and aids NPL's mission to disseminate scientific knowledge to the wider community.

→//[www.npl.co.uk/electromagnetic/dclf] →//[www.npl.co.uk/press_centre]



[Services to society]

> Il n'y a pas de sciences appliquées, seulement des applications de la science.
>
> There is no such thing as applied science, only the applications of science.
>
> Louis Pasteur, French biologist (1822-1895)

NPL was created with a primary mission to support UK industry and this Review has presented a range of case studies from 2002-03, illustrating our services and their benefit to business. However, a substantial part of our work addresses the wider needs of society, as quality of life grows increasingly dependent upon technology.

The national measurement infrastructure costs the UK about £1 per citizen per year. In our view, this represents excellent value when you consider that both the economy and our very social fabric rely upon a trustworthy system of measurement. It would be simply unacceptable, for example, to base healthcare provision, environmental monitoring and health and safety regulations upon inaccurate measurements.

As technology advances, new methods of measurement also need to be developed. NPL is involved in the refinement of these new measurement methods and continually pursues their validation and implementation. For instance, the next generation of drug treatment will rely on our ability to determine the structure of drug-related proteins and on new systems of precise drug delivery at the nanoscale. These crucial technological advances will positively impact on the effectiveness of patient treatment and consequently their quality of life.

In this section, we will present some of the many areas in which NPL's work impacts on our life in the UK.

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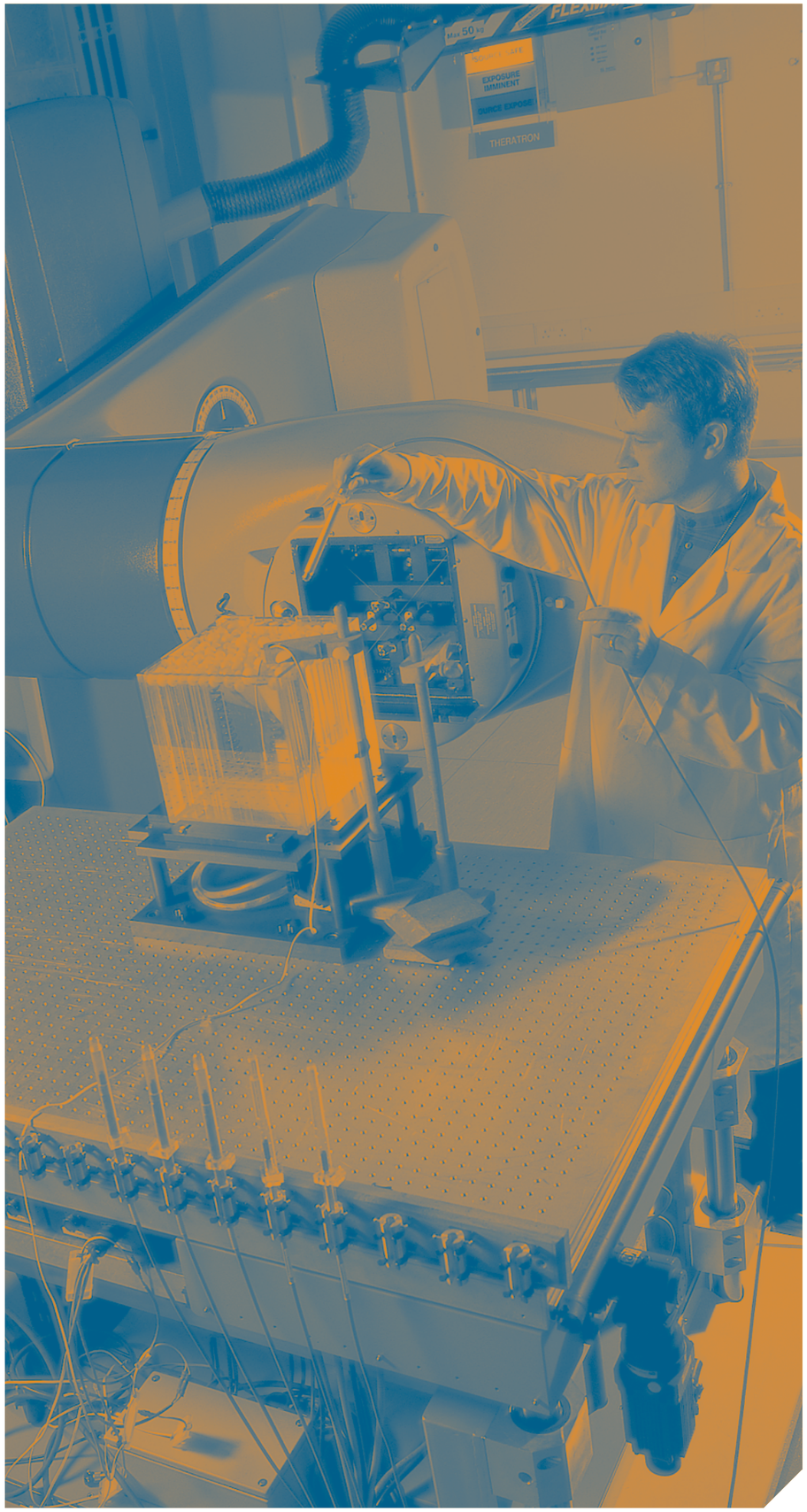

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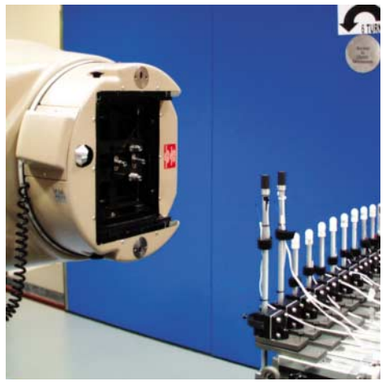


Each year around 150,000 cancer patients receive radiotherapy treatment in the UK.

Accuracy in dose delivery can be a life and death matter, so the ionising radiation measurement facilities at NPL, which provide measurement traceability to the best available international standards, are a vital component of the UK's radiotherapy infrastructure.

The new Theratron ^{60}Co irradiation facility is part of a multimillion-pound ionising radiation suite of facilities. It provides a world-leading absorbed dose to water and air kerma calibration service for radiotherapy centres across the UK.

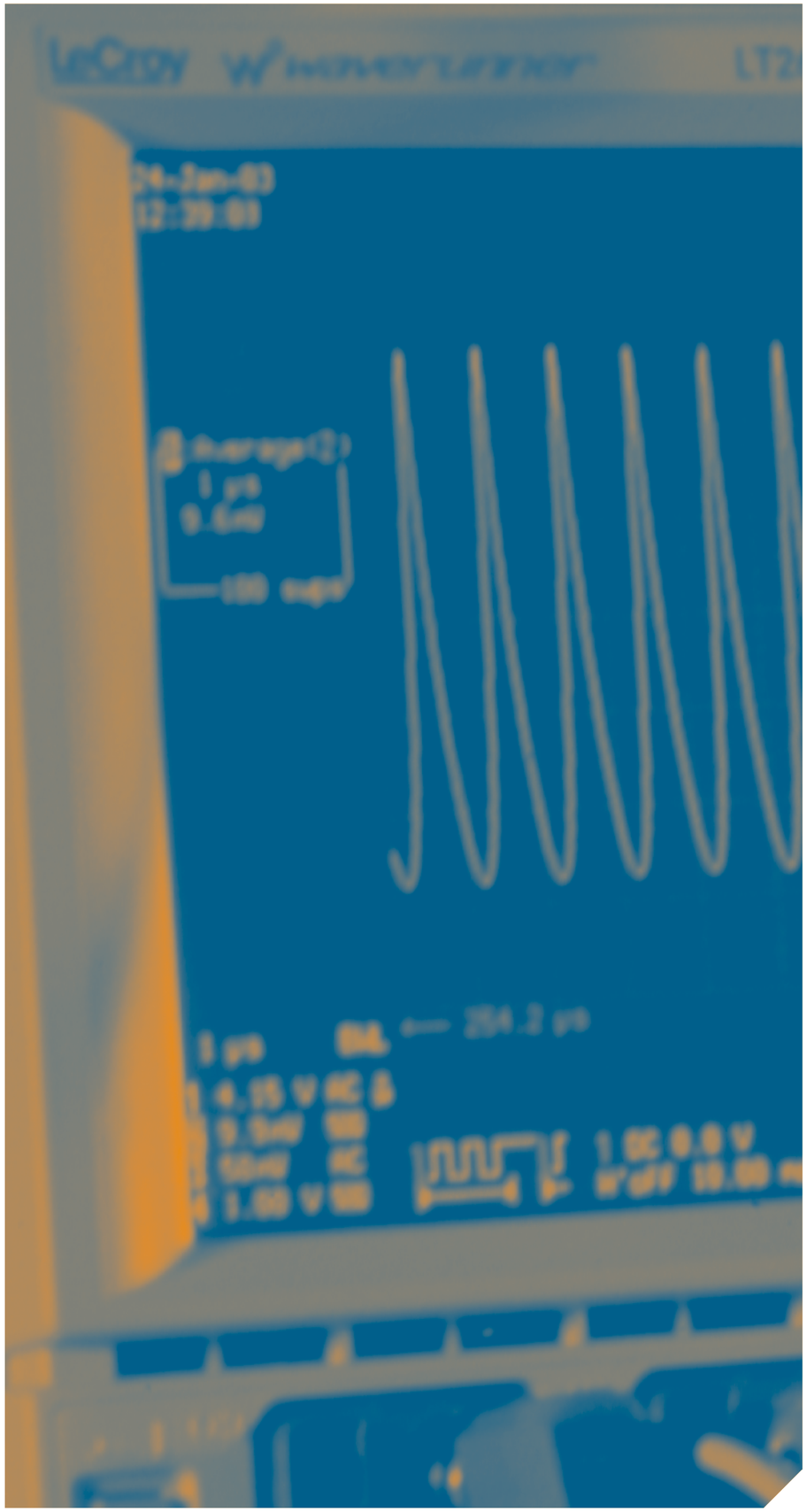
In every radiotherapy clinic, the calibration of treatment equipment is maintained and monitored with reference to a secondary standard ionisation chamber. From across the UK, each one of these instruments, originally designed by NPL, is returned every three years for re-calibration and operational checks.

The calibration of the secondary standard instruments used for photon radiotherapy is carried out in batches twice a year. These are major exercises involving up to 15 scientists and using our electron linear accelerator (Linac) and X-ray exposure facilities as well as the Theratron.

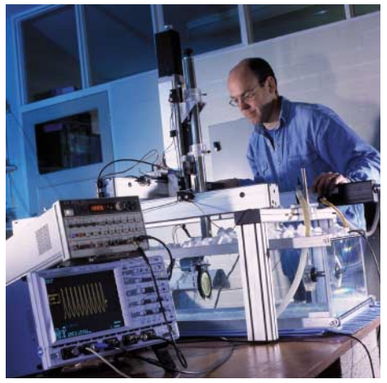
Furthermore, the Theratron facility underpins continuing research in radiation measurement for this essential area of medical science. For example, work is under way at present on 3-D dosimetry systems (Gels) that can be used to monitor advanced radiotherapy techniques that tailor radiation beams to the shape of a tumour in the patient.

The facility has also been used to develop the portable calorimeter – a device that enables NPL staff to carry out on-site dose delivery checks on treatment equipment in radiotherapy clinics, with an accuracy approaching that of a primary standard.

[13] Ian Stoker performing absorbed dose calibrations in the Theratron facility
[14] View from outside the Theratron facility
[15] The primary standard of air kerma for ^{60}Co radiation



> The new device will enable physiotherapists and patients to have greater confidence in the ultrasound equipment. The close working relationship between NPL and Precision Acoustics is bringing new ultrasound quality assurance products to the medical community in the shortest possible time.
>
> Terri Gill, Managing Director
> Precision Acoustics



[16]

Every year millions of patients across Europe receive ultrasound treatment in hospitals. In the UK alone, there are over 10,000 physiotherapy units relying on ultrasonic instruments. Ultrasound is widely used to treat soft tissue injuries and accelerate healing.

However, there is currently no simple way for physiotherapists to check the sound energy being delivered to their patients or to check whether equipment calibration is drifting or not working at all.

To address this, NPL, in partnership with Precision Acoustics (PA) Limited, has created an easy-to-use measuring device to give physiotherapists a cost effective and quick method of checking the output of their equipment. Based on a novel idea developed at NPL, a prototype system has now been manufactured by PA. A commercial system should be available to hospitals and manufacturers in mid-2003.

[16] David Bell from Precision Acoustics testing a hydrophone

[Biotechnology - a new measurement frontier]

For the past two years, NPL has been building up biotechnology expertise to meet the emerging demand for measurement services in this area. In September 2002, a new laboratory facility was opened, and the biometrology team has more than quadrupled in size this year.

DTI recognised the potential of NPL's emerging biotechnology metrology capabilities, awarding the laboratory six biotechnology R&D contracts with a combined value of £1.3 million. NPL will focus on the links between physical and chemical measurements and biological activity. The structures of new biopharmaceutical products will also be examined. Better physical measurement in the field of biology should lead to more cost-effective pharmaceutical drugs and reduce the need for animal testing.

Working with LGC, NPL will be investigating the performance and comparability of microarrays used for gene expression and transcript profiling studies, which are used in the discovery process for pharmaceutical developments. This work is of particular importance in the pharmaceutical and clinical diagnostics sectors. It could dramatically alter the way scientists use microarrays, establishing more reliable research and development processes and helping researchers to discover new molecules and unravel the way the human genome functions.

[On beam]

[17]

[18]

NPL plays a critical role in determining the radiation doses for X-ray procedures. With over 40 million taken each year in the UK, it is imperative that when patients have an X-ray examination, they are exposed to the lowest radiation doses consistent with obtaining vital diagnostic information.

The new diagnostic and mammographic X-ray exposure facility at NPL is furnished with two clinical machines, so that for the first time NPL can simulate the beam qualities used in clinical practice.

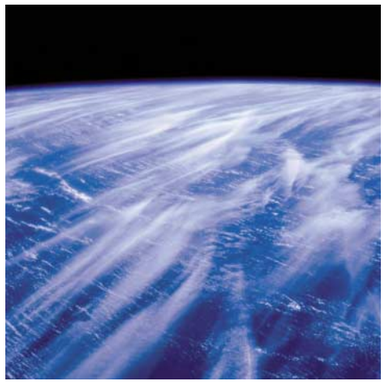
Over the past few years, our radiation dosimetry scientists have been working with practitioners in hospitals and clinics, providing an improved calibration service that will enable compliance with new legislation - the Ionising Radiation (Medical Exposure) Regulations 2000.

[17] James Manning in the mammographic and diagnostic X-ray facility
[18] Martin Palmer adjusting equipment in the γ–ray multisource exposure facility

→//[www.npl.co.uk/biotech] →//[www.npl.co.uk/rad]

[19]

[Telling TRUTHS]



[20]

Environmental commitments, such as the Kyoto Protocol, highlight the importance and reliance that European governments are placing on Earth Observation (EO) data from space.

This results in an increased demand for accuracy and quality assurance from both the satellite instruments and the ground-based validation activities. Although tremendous efforts are put into the development of EO instrumentation, the harsh conditions of launch and space make it difficult to achieve improvement in data accuracy and often lead to discrepancies between instruments.

As we move towards the establishment of 'operational services' for monitoring the environment and security in Europe, as envisaged in the new initiative Global Monitoring for Environment and Security (GMES), data from many sources will need to be integrated and combined making such discrepancies unacceptable.

For many years NPL has advocated the case for higher accuracy and improved traceability in EO data. In 2002, Dr Nigel Fox, head of science for the optical radiation team, developed a concept for a revolutionary satellite-based mission to establish a 'calibration laboratory' in space - Traceable Radiometry to Underpin Terrestrial and Helio Studies (TRUTHS).

The TRUTHS concept has generated strong scientific and media interest. It proposes a tenfold increase in the measurement accuracy of both its on-board instrumentation and that of other EO satellites. Such an increase in measurement accuracy would significantly boost confidence in data, helping governments and scientists at national and international levels to make informed decisions on global warming and climate change.

[19] Envisat in the cleanroom | ESA/A.Van Der Geest
[20] EO satellite Envisat | ESA/Denmann production

The scheme gives confidence to our members' customers that equipment that is being fitted to their process is fit for purpose. Coupled with testing carried out by MCERTS approved organisations and personnel, the on-going quality is assured.

Dave Curtis of the Source Testing Association. The STA is committed to improving quality in emission monitoring.

The Environment Agency has established a rigorous Monitoring Certification Scheme (MCERTS) for pollution control equipment.

Environmental scientists at NPL have played a key role in developing these new performance standards. The scheme, based on internationally accepted principles, includes continuous emission monitoring systems. Manufacturers of continuous emission monitors can submit their instruments to be tested under the MCERTS scheme, with tests involving key aspects of performance and accuracy.

The scheme gives confidence to regulatory authorities that instrumentation is fit for purpose and gives confidence to users that the instruments are robust and conform to recognised standards.

NPL is also involved in another facet of the Environment Agency's MCERTS scheme, which covers performance standards for ambient air quality monitors. These are designed to be compatible with new (CEN) standards being drafted to support new EU Directives. Ultimately, all these aspects of monitoring support the supply of accurate, reliable environmental data to the public.

NPL has developed a dedicated suite of test and calibration facilities that are accredited under ISO 17025 for carrying out instrument tests to the MCERTS standards. These include a variable temperature test cell that can produce accurate concentrations of stack gases and water vapour in simulated stack conditions, and an environmental chamber for testing those parts of the monitoring system exposed to outdoor conditions.

The test facilities are also being used for the benefit of UK export companies developing the latest environmental monitoring devices.

→//[www.npl.co.uk/environment/mcerts.html]

[Time to celebrate]

[21]

[22]

As part of the Jubilant Trust's Celebration of Time in September 2002, John Laverty, NPL's head of time measurement, travelled down the Thames on a royal shallop, the 'Jubilant', with an atomic clock. On arrival at the Royal Observatory Greenwich (ROG), he presented the clock to Jonathan Betts, Horology Curator, and Kirsten Lipincott, Deputy Director at ROG.

NPL's Louis Essen constructed the first working caesium atomic clock in 1955, a development that led to the redefinition of the second in 1967. The example that played centre stage in the Celebration of Time is a modern-day caesium atomic clock, one of those used at NPL to help keep the UK's time signal. The atomic clock is now on public display as part of the Observatory's famous timekeeping exhibition.

21st century clocks promise even greater accuracy. NPL is currently developing ion traps, using the element ytterbium. These devices have the potential to improve time standards by a factor of 1000 relative to the best atomic clocks today.

Such accuracy may not matter to the train timetable, but plays a key role in measuring frequencies and other physical phenomena vital to the future of science.

[21] Satirist Alan Coren playing King George III
[22] Prince Andrew commissioning the shallop

[Rockets shoot local charity sky high]

[23]

The physical sciences and engineering underpin much of the wealth creation in the UK. However, since 1994, the number of young people choosing to study these subjects at university has fallen by 12% and 19% respectively. NPL is working to help reverse this worrying trend, with a programme of activities aimed specifically at engaging young people's interest in science.

As part of the programme the Annual Water Rocket Challenge took place in June 2002. Competition was tough with fourteen school teams from across the country taking part. Their challenge was to design rockets that would remain in the air for as long as possible.

Kingston Grammar School won the schools competition with a rocket that spent 18.1 seconds in the air. The celebrated scientist and TV personality, Heinz Wolff, attended the event and presented the prizes.

With the help of the NPL Sports Club, the event raised over £1000 in aid of the Middlesex-based charity, the Shooting Star Trust. The money will contribute towards a children's hospice to serve terminally ill children.

[23] Heinz Wolff congratulating the winning team

[Global influence]

> Science is a thoroughly globalised endeavour, one in which Britain can and must play a key role. [...] Science is both internationally competitive and internationally collaborative. If we are to remain an innovative, forward-looking nation, we need to retain the capacity to do this work, both on our own and in collaboration with scientists in other nations.
>
> Tony Blair, Prime Minister, from a speech delivered at the Royal Society on 23 May 2002

As one of the world's leading national metrology institutes (NMIs), NPL works to sustain the global influence of UK measurement science.

Our work directly supports much of the UK instrumentation sector that generates exports of around £6.6 billion each year. However, we also play a much wider infrastructural role, working with other NMIs worldwide. These international partnerships are the basis for collaborative research to keep the UK at the forefront of science and promote our approach to metrology.

In 2002-03, our scientists presented papers at more than 60 international conferences and represented the UK on 500 standards committees worldwide. We are active participants in the global system of standards that ensures confidence and facilitates international trade.

[Measured once, accepted everywhere]

Since the 1960s, the world has witnessed an increasing need for a consistent global measurement infrastructure to support growing international trade.

Measurement intercomparisons are therefore a crucial part of NPL's work, ensuring that the UK national standards are equivalent to comparable standards in other NMIs around the world.

This equivalence is enshrined in a Mutual Recognition Arrangement (MRA), overseen by the Comité International des Poids et Mesures (CIPM). It is a vital requirement for international trade.

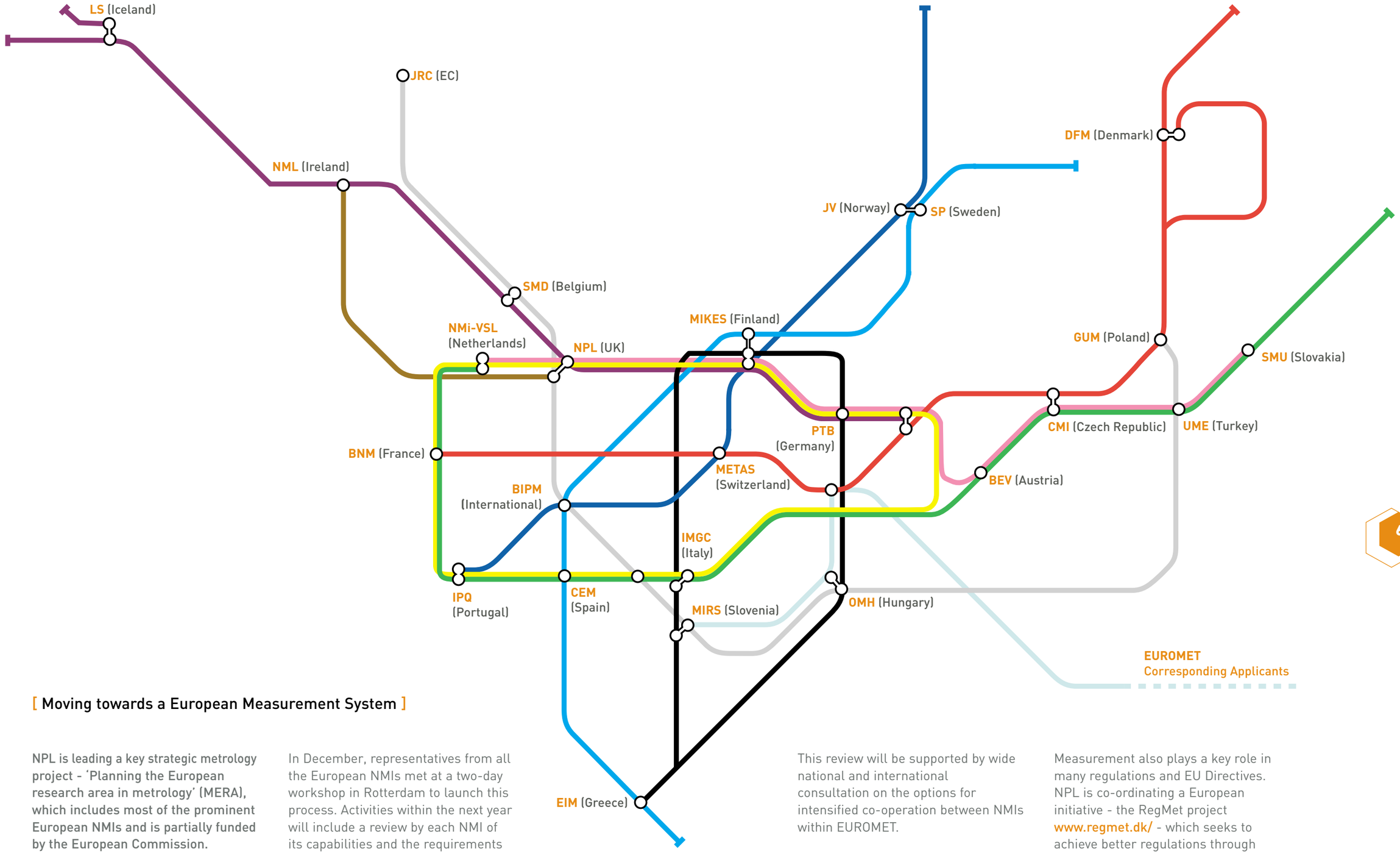
The MRA supports trade by preventing and removing the technical barriers that can arise from measurement discrepancies. The MRA will help to ensure fair trade and competition by providing mutually recognised and reliable measurements.

In 1999, following several years of work, the CIPM MRA was signed by the NMIs in the major trading nations worldwide. Over 50 NMIs have now signed the Arrangement, which commits them to fulfilling three crucial elements: the implementation of an appropriate Quality Assurance system, regular participation in international comparisons of measurement standards and peer review of the capabilities the NMIs claim.

This rigorous process is producing a trusted and transparent service for measurement end-users. NMIs' calibration and measurement capabilities (CMCs) are published in an international database - accessible at www.bipm.org

In May 2002, NPL completed a research project, on behalf of DTI, to benchmark the UK CMCs with those of other prominent NMIs from both Europe and the USA. This exercise confirmed that NPL is sustaining its position as a leading NMI. It also revealed that many NMIs tend to specialise in specific areas, relying on agreements with other laboratories to deliver a full range of calibration services to end-users.

→//[www.npl.co.uk/international_office]



[Moving towards a European Measurement System]

NPL is leading a key strategic metrology project - 'Planning the European research area in metrology' (MERA), which includes most of the prominent European NMIs and is partially funded by the European Commission.

The project started in September 2002 and it is examining the way forward for the development of a more integrated European measurement system, through increased collaboration.

In December, representatives from all the European NMIs met at a two-day workshop in Rotterdam to launch this process. Activities within the next year will include a review by each NMI of its capabilities and the requirements of its end-users with a view to identifying potential areas for future collaboration and rationalisation.

This review will be supported by wide national and international consultation on the options for intensified co-operation between NMIs within EUROMET.

The options being examined under MERA include opportunities for greater collaboration in research, the shared use of facilities, and increased mobility of researchers, as well as looking for more effective ways of exploiting metrological research.

Measurement also plays a key role in many regulations and EU Directives. NPL is co-ordinating a European initiative - the RegMet project www.regmet.dk/ - which seeks to achieve better regulations through improved dialogue between NMIs in Europe and the European regulatory bodies.

[Fair exchange]

[24]

Nothing does more to promote effective international collaboration than secondments and mobility of scientists.

Glazebrook Fellowships are funded by DTI to facilitate closer links between NPL (and the other UK NMIs) and other overseas NMIs by supporting strategic scientific placements. NPL and others across the world are now benefiting from the scheme.

Four NPL scientists have already been accepted for placements at other NMIs in 2003. Andrew Yacoot will be going to PTB in Germany; Andrew Morgan to METAS in Switzerland; Nigel Jennett to NIST (USA) and Michael Shaw to NRC (Canada). A PTB scientist, Heinrich Schwenke, began a secondment to NPL in January 2003. The high level of interest in placements demonstrates their importance and more placements are already planned for 2003.

[24] Dr Nigel Jennett, Michael Shaw, Dr Heinrich Schwenke, Dr Andrew Yacoot and Andrew Morgan mapping out their trip

[In the frame for FP6]

NPL is preparing for the European Union's new framework programme of support for technological research and development. The sixth four-year Framework Programme (FP6) will run until 2006, with a total budget of €17.5 billion. Throughout Europe, industrial companies, research organisations, universities, users, and other stakeholders will be able to take part and receive support, with SMEs receiving specific incentives.

With no dedicated measurement and testing theme, NPL and other NMIs will address the numerous areas where measurement will be a key element in the wider objectives. These include biotechnology, the information society, nanotechnology and nanoscience, multifunctional materials and production processes, aeronautics and space, food quality and safety and sustainable development.

NPL provides a national source of information and advice to participants in various technology areas. It is also the UK framework programme contact point for industrial technologies, covering nanotechnologies, materials and production processes, and surface transport research and policy.

[Contacting NPL]

The NPL website provides comprehensive information on our activities and services. A direct web link for each of the case-studies featured in this Review is provided at the foot of the relevant page.

The NPL Helpline staff will be pleased to answer your queries and will put you in touch with appropriate scientific staff. We receive an average of 600 enquiries each month. The Helpline can be contacted by telephone, e-mail, fax or post.

Available from the Helpline, the NPL Points of Contact is a directory which gives details of all our key measurement services, training, clubs and areas of research. Updated yearly, it provides direct contact details for our measurement experts.

The NPL's e-Store www.npl.co.uk/e-store offers a wide range of goods and services, available for purchase online, from measurement good practice guides to training courses.

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