National Physical Laboratory Review

Applying physics to improve the way we live

NPL
National Physical Laboratory

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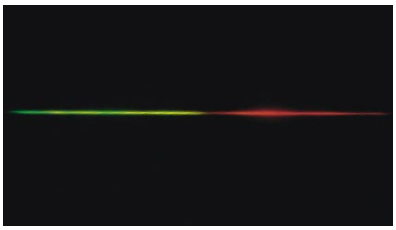

NPL research into optical frequency measurement has significant implications for industry – from telecommunications to satellite navigation. The cover shows part of the wide-span femtosecond comb covering the visible into the mid infrared from 400 nm to 1200 nm. The comb consists of about a million regularly spaced modes.
(See pages 9 and 10)

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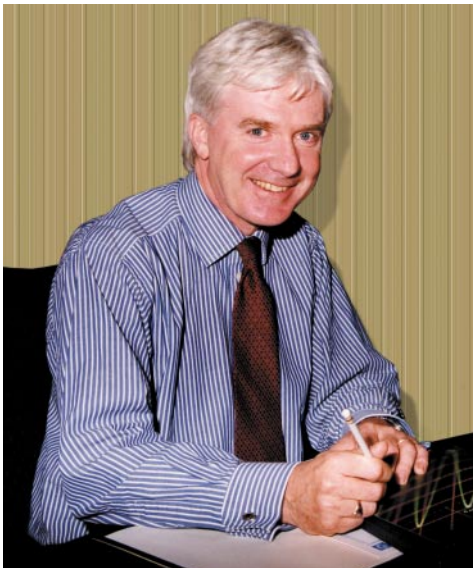


It is my pleasure to introduce this review of the achievements of the National Physical Laboratory in 2001.

For those readers who are not familiar with the Laboratory, I should tell you that NPL is the United Kingdom's national standards laboratory and one of the most admired among fifty or so such organisations in the world.

We provide a unique scientific resource for the nation, focused on developing the measurement technologies and standards vital to trade, competitiveness and the quality of life.

The Laboratory is operated under contract to the Department of Trade and Industry (DTI), by NPL Management Limited, a subsidiary of Serco Group plc.

In 2001 we employed some 670 staff, 85% of whom are graduate specialists in the physical sciences, materials, mathematical software and knowledge transfer. And we manage a suite of unique national facilities, from the atomic clocks that keep the nation's time, to a chamber that can simulate varying ocean conditions for measuring underwater devices, or the calibration facilities vital to safe and effective radiation treatment of cancer.

Government entrusts us with the mission of focusing these powerful human and technical resources on meeting the needs of innovators, regulators, engineers, manufacturers and all others for whom accurate measurement is vital to performance.

Four imperatives form the cornerstones of this mission:

- A commitment to science of unquestionable excellence, generating technologies, methods and data which are trustworthy and valuable to user communities

- High standards of professionalism in knowledge transfer, listening to the real needs of industry and others and ensuring that NPL outputs are readily accessible, exploitable and value adding

- Dedication to the growth of NPL: as a national scientific resource; as a science business (we now secure a third of our funding on a commercial basis); and in international influence for the UK

- A determination to deliver the best possible value for the national investment at NPL in partnership with DTI.

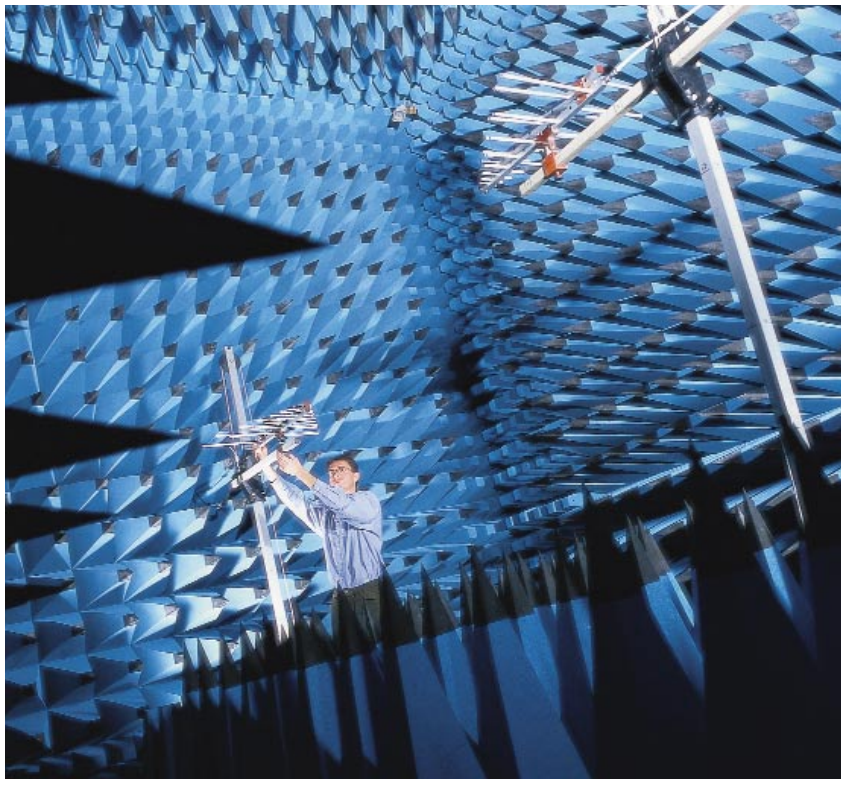
Four imperatives form the cornerstones of our mission

In the following pages we present a wide range of case studies illustrating the activities of the Laboratory and you can judge for yourself how well we are meeting these objectives.

You will find world-leading science, such as our work on materials modelling, our femtocomb spectrum research and our farsighted project on carbon nanotubes.

You will read reports on our latest facilities including NPL's improved anechoic chambers, which offer more accurate calibration and characterisation of radio antennas; or our new hot box technology, which could revolutionise heat transfer standards and the development of more energy efficient building materials.

And you will also find examples of our many successful partnerships with business, such as the technology we have developed in partnership with Fluke and BAE SYSTEMS, using the power of the internet to give rapid access to national measurement resources; or the On-machine Measurement programme, which has produced commercial benefits worth £1 million to a group of small manufacturers in Yorkshire.



We are dedicated to the growth of NPL as a national scientific resource.

If you would like to know more about us, or to comment on this Review and the work it presents, please do not hesitate to contact NPL through one of the access points listed at the end of this Review.

Bob McGuiness
Managing Director

Creating knowledge

Improving measurement accuracy and the technology to deliver it continues to offer fundamental challenges for physics. At the National Physical Laboratory, the national imperative to refine existing measurement standards and develop measurement techniques for new demanding applications is prompting scientific research of the highest quality.

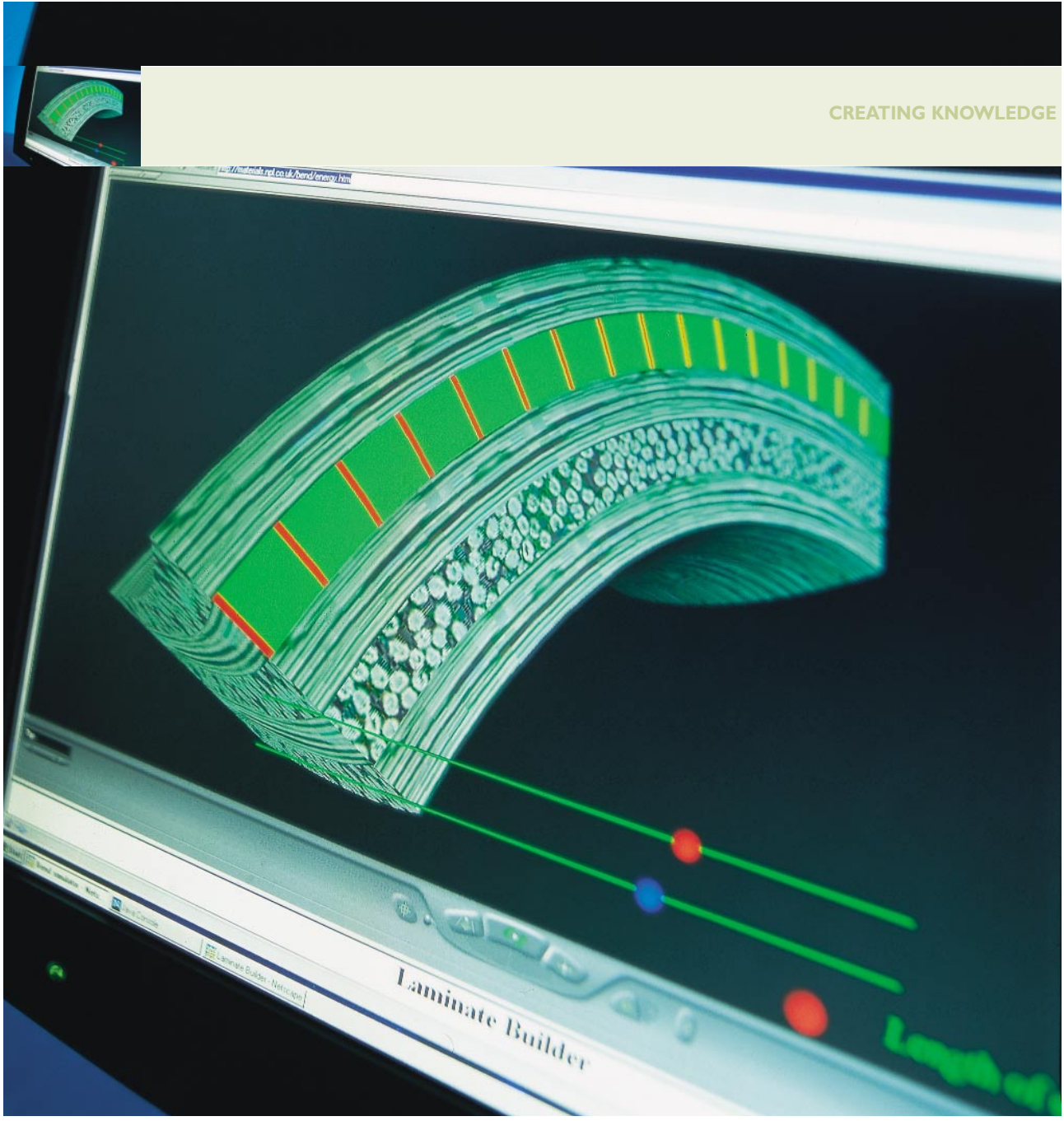
Since the dawn of the industrial era, it has been understood that a developed economy requires a credible measurement infrastructure comprising world-class facilities and associated teams of scientists, eminent in their field. In the UK we recognise that this infrastructure must be adaptable and dynamic, creating an evolving body of knowledge from which to meet national needs.

Today, innovation in industry depends more than ever upon innovation in measurement. Business faces market pressures for continual improvement in product quality, reduction in cost and regulatory compliance. This creates increasing demand for measurements that are more accurate, more stable and more easily usable in practice.

NPL's research agenda is informed by the demands of both the present and the future. It seeks to deliver the ongoing refinement of measurement standards demanded by industry, whilst pursuing the longer-term research and step changes that revolutionise standards and provide a basis for exciting innovations in coming decades.

This mix of the speculative and the pragmatic goes to the heart of NPL's mission: the energetic pursuit of scientific breakthroughs to deliver methodologies and standards that will directly benefit commerce and UK competitiveness.

The following are just four among many case studies illustrating NPL scientific endeavour in 2001.



NPL is pioneering new visualisation techniques designed to make accurate projections of the properties of composite and laminated materials.

Model it, design it, build it

Materials measurement and modelling activity at NPL provides a good example of research that is closely allied to the needs of industry. Innovations can have an immediate effect on the fortunes of a whole host of UK companies – but can equally deliver new understanding with far-reaching implications.

This year a significant breakthrough came with the extension of NPL's materials modelling and simulation expertise into important new areas

The result of this painstaking development work is a model that significantly enhances our understanding of composites, coatings and semiconductor materials

Over the last ten years, NPL has developed mathematical modelling and visualisation techniques designed to make accurate projections of the properties of composite and laminated materials. Principally used to carry out damage simulation and predict the likely response of composite materials under realistic stress conditions, it has obvious industrial applications.

The model developed at NPL is based on a unified set of methodologies, mathematics and software that has been gradually refined to deal with more and more complex composite systems. As a result, it is amongst the finest in the world.

In recent months the model has been adapted to enable the simulation of damage in coatings and the formation of dislocations in semiconductors.

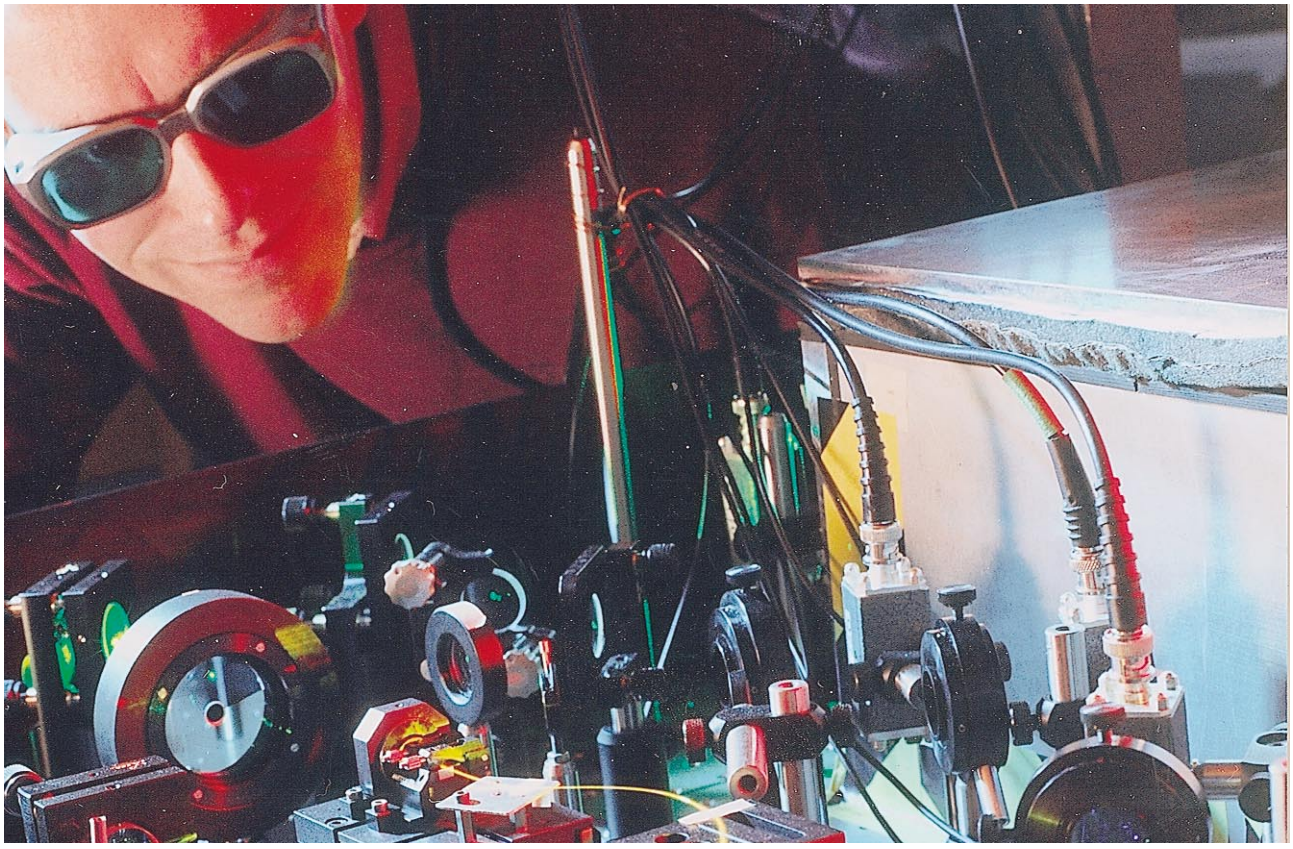
This has necessitated significant development work. The model has been totally recalibrated to work on new length scales – the micrometre level for coatings and the nanometre scale for semiconductors. Another crucial development has been the addition of new loading parameters, for instance to take into account the effect of bending on composites and coatings, and new boundary conditions to deal with strain relaxation in semiconductors. New visualisation techniques have also been developed (see illustration on page 7).

The result of this painstaking development work is a model that significantly enhances our understanding of composites, coatings and semiconductor materials. It provides knowledge that is critical to industrial design and development processes, and will make research and development a far more precise and cost effective process.

Ultimately, this technology could bring an end to the expensive ‘build and test’ design methodology and usher in a new, simpler, more cost effective maxim – ‘model it, design it, build it’.

Combing the spectrum

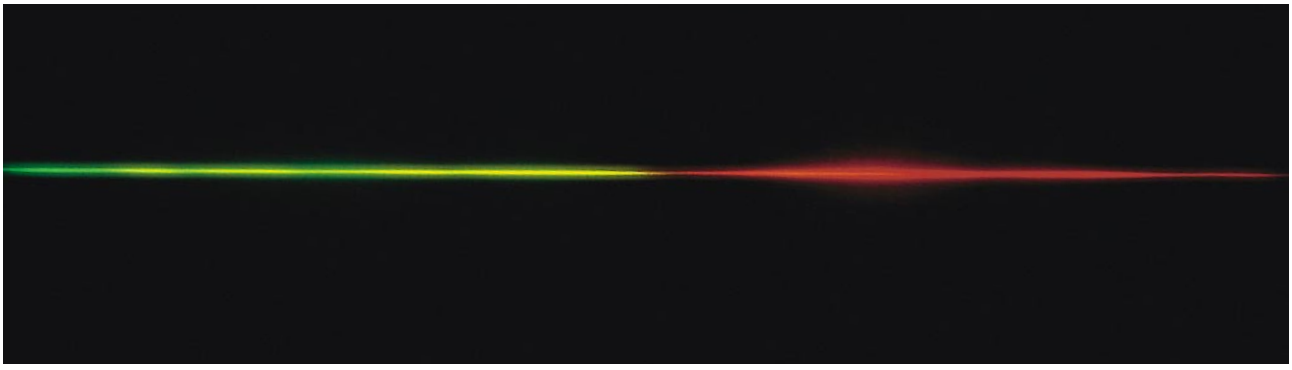
Research into optical frequency measurement also has significant implications for industry – from telecommunications to satellite navigation technology. But recent breakthroughs could have more far-reaching consequences.



Stephen Lea working on the femtosecond wide-span comb technique for measuring optical frequencies.

A technique pioneered in Germany and the US, and built up at NPL, is providing rapid progress towards high accuracy measurement of optical frequency standards and, ultimately, the development of a single ion optical clock.

Measuring optical frequencies in terms of the caesium atomic clock time standard has been possible but problematic for some time. The challenge is in developing the ability to make efficient but high-accuracy frequency comparisons between the optical and microwave frequency regions. Until recently, this was possible only through a complicated and unwieldy process. Finding a simpler, quicker solution is a problem that metrology has wrestled with for 30 years.



Part of the wide-span femtosecond comb covering the visible into the mid infrared from 400 nm to 1200 nm. The comb consists of about a million regularly spaced modes.

NPL research is making rapid progress towards the absolute frequency measurement of trapped ion optical frequency standards

Early indications are that optical standards will eventually be more stable than the caesium clock microwave standard

NPL has applied a new technique, based on femtosecond pulses, to enable direct comparisons between trapped ion optical frequencies and the primary microwave frequency standard provided by the caesium atomic clock.

A 'femtocomb' with spectral bandwidth extending from the blue region at ~400 nm well into the mid infrared region at 1200 nm is generated when a regular stream of very short laser pulses is passed through a novel optical fibre. The fibre provides the medium for the huge expansion of bandwidth of the femtosecond pulses and the resulting spectrum, with a comb-like structure of regular 'teeth', can be manipulated to act as an optical ruler. It allows direct measurement of optical frequencies in terms of a microwave standard, and also the direct comparison of widely-spaced optical frequencies.

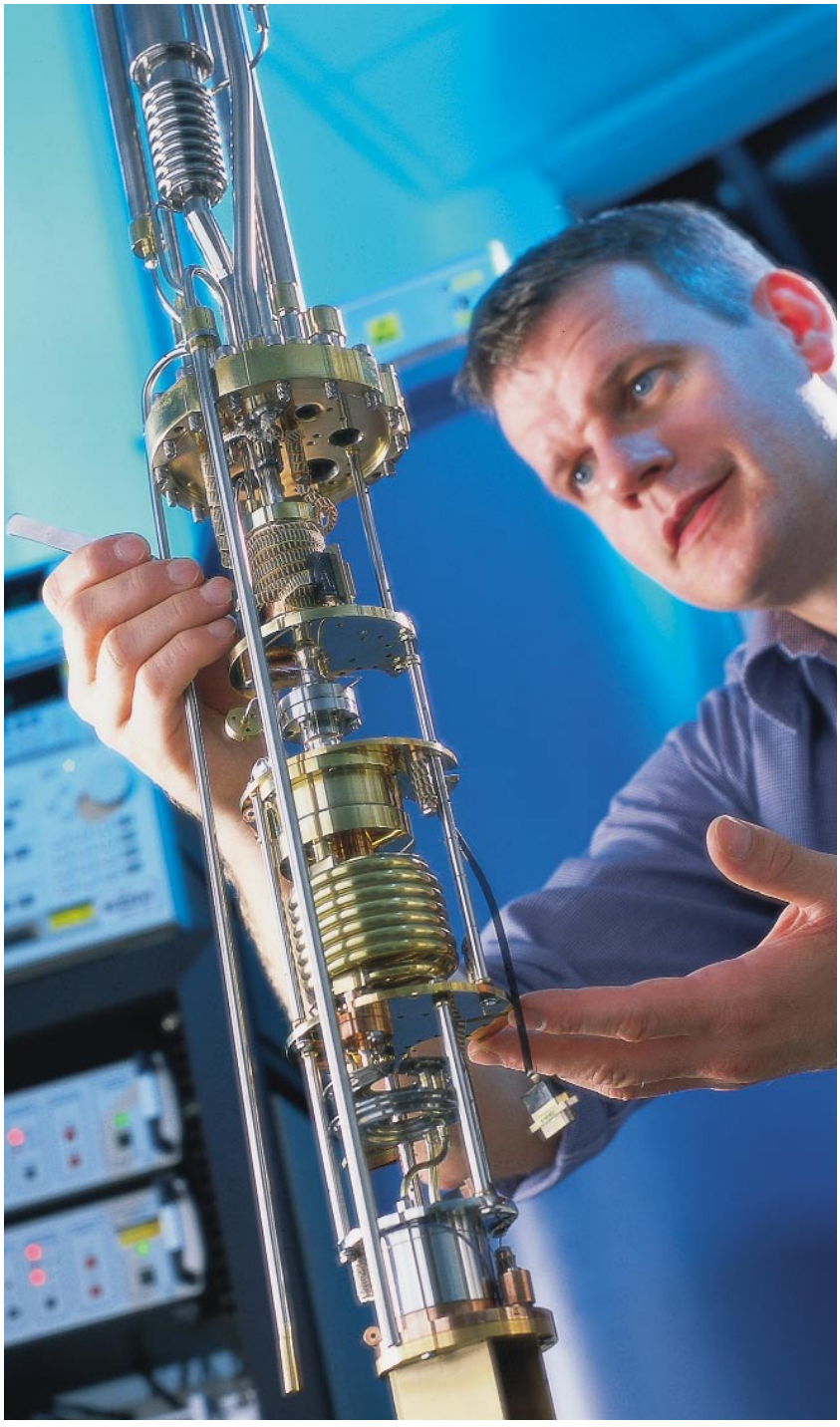
This advance makes the concept of an optical clock a reality. In such an arrangement, the measurement path is reversed, with the femtocomb being referenced to the optical frequency standard. The comb can then provide a low frequency output related to the comb spacing for microwave and RF applications.

Early indications are that optical standards based, for example, on single cold trapped ion techniques will be more stable and accurate than the caesium atomic clock. This in turn is likely to lead to an optical redefinition of the second.

Current affairs

The mixture of speculative and the pragmatic is echoed in NPL's search for a quantum standard of current, and the development of single electron transfer techniques.

The importance of a quantum standard of current is perhaps best understood in terms of the so-called quantum metrological triangle. This relates frequency to voltage, and voltage to current. Deriving a quantum standard of current that relates electrical current to frequency would complete the triangle and allow the internal consistency of the quantum electrical standards to be verified.



Jan-Theodoor Janssen and NPL's helium dilution refrigerator, capable of reaching temperatures as low as 10 mK, which is used for research on single electron transport.

Eventually, NPL could deliver a quantum standard of sufficient accuracy to enable a represenation of the ampere

Electrons ride each wave rather like a surfer rides waves to the beach

The potential development of consistent, interdependent electrical standards is the basis for huge international interest in a quantum standard of current. NPL and Cambridge University are pioneering research in this area, based on the transfer of single electrons via surface acoustic waves.

The technique relies upon the creation of a two-dimensional electron gas underneath the surface of a semiconductor material. Acoustic waves carry electrons through a variable channel etched into the surface of the semiconductor – electrons riding each wave rather like a surfer rides waves to the beach – to generate a measurable current.

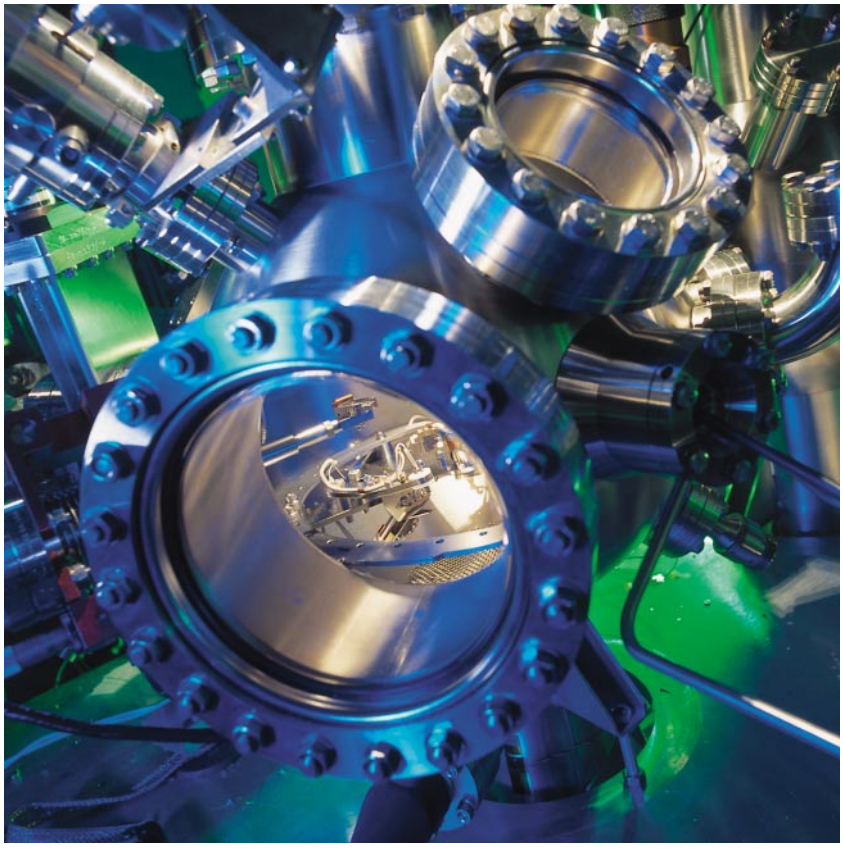
This is the basis for the measurement of a relationship between current and frequency, with a known electron charge. That is, as the width of the channel is increased, the current through the channel reaches a series of plateaux that correspond to the number of electrons passing through the channel with each wave. The transport of electrons is generated by an acoustic wave with a known frequency, so it is clear that the development of a standard of current accurate to a high level is possible.

Ultimately this will enable researchers to use this quantum standard of current as a representation of the ampere – a development that would provide new impetus to the electronics industry.

In the longer term, the transport of single electrons could have a huge range of applications. After all, once the transport of single electrons is under control, quantum communication and quantum computing should not be too far out of reach.

Seeing the future

Perhaps NPL's most forward looking research is its work on carbon nanotubes – a research project designed to deliver new measurement standards applicable across metrology and whose timetable stretches out across the next decade and beyond.



NPL's scanning tunnelling microscope which is crucial to the carbon nanotube project.

Discovered in Japan ten years ago, the nanotube is a new form of carbon – essentially an atom-thick sheet of graphite rolled up to form a tube.

This structure is the basis for incredible elasticity and strength. Carbon nanotubes also have interesting electrical properties. Depending on the level of twist in the tube, they can act as insulators, conductors or semiconductors.

Nanotubes range in diameter from just 0.7 nm to tens of nanometres. This, coupled with their uniquely flexible electrical properties, and status as one-dimensional thermal and electrical conductors, makes them ideal for the creation of nanoscale devices – but this presents real measurement challenges.

Courtesy of Samsung

A prototype five-inch carbon nanotube flat panel display.

NPL research has provided important first steps in the understanding of carbon nanotube structure and behaviour

We aim to develop quantised standards for the measurement of thermal conductivity in carbon nanotubes

Eventually NPL aims to develop quantised standards for the measurement of thermal conductivity in carbon nanotubes. However, the project has already enjoyed significant breakthroughs, specifically in the ability to view and manipulate nanotubes via a scanning tunnelling microscope (STM) and an atomic force microscope (AFM).

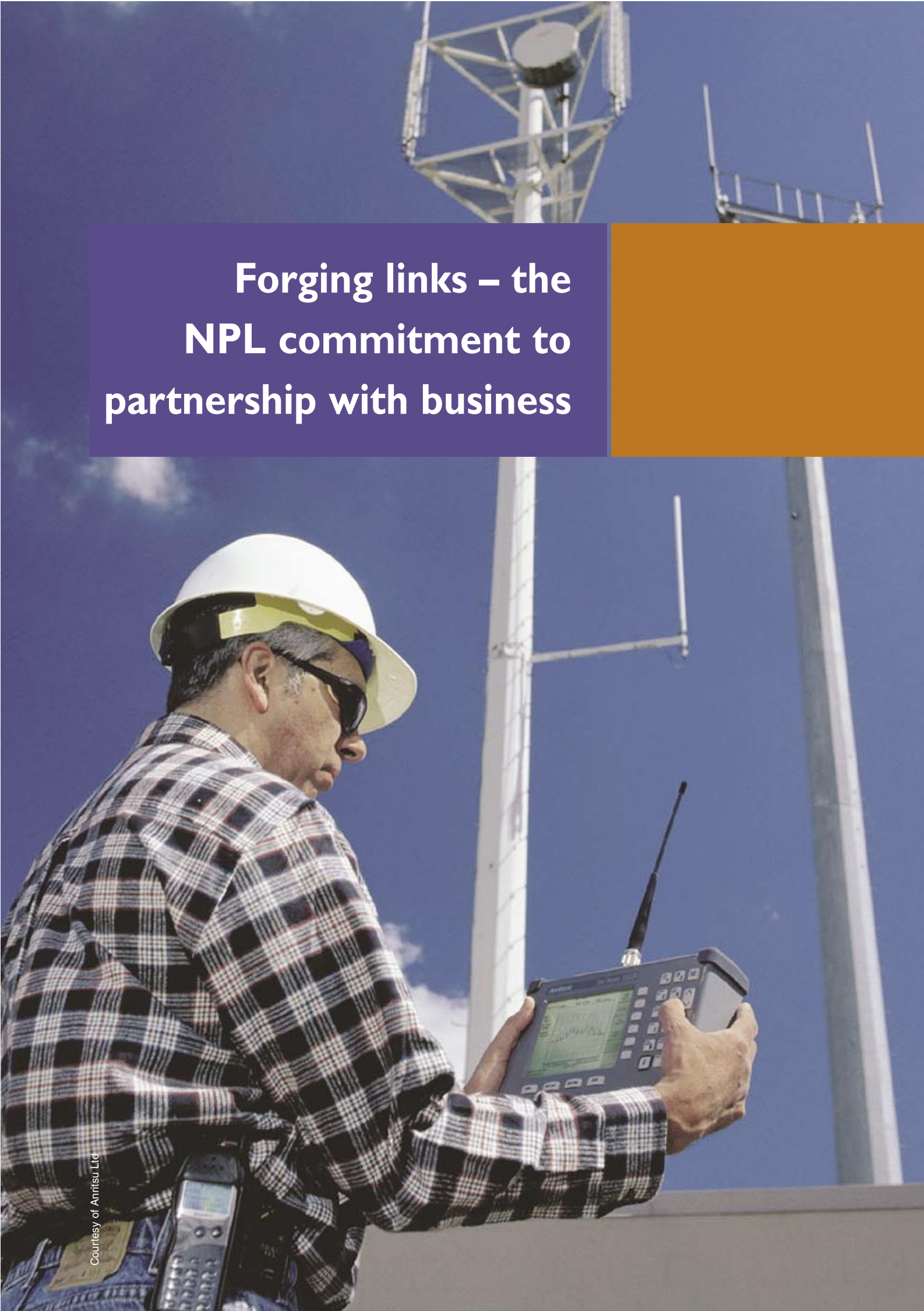
Work with both microscopes has provided a close look at nanotube structure. It has revealed details of rings and junctions between tubes which exist naturally, as well as a map of their surface structure. The AFM meanwhile has enabled initial research into their elastic properties, offering a means by which to bend nanotubes and scan images of their elastic response.

This initial research has provided important first steps in the understanding of nanotube structure and behaviour, and provides a great platform to move the project towards its ultimate goal.

The project has already moved on to begin looking at how nanotube electrical resistance and thermal conductivity is affected by changes in pressure, distortion and differences in state. The AFM has been a key tool in this area and has yielded some interesting results. For instance, electrical resistance reduces as the current across the nanotube is increased, but not in a smooth transition, rather in a series of quantised leaps.

This kind of research into electrical resistance is already being modified to examine thermal conductivity. The results of this, coupled with those already in, will provide the basis for a clear picture of carbon nanotube properties and are a significant step towards NPL's ultimate goal of quantised thermal conductivity measurements.

Forging links – the NPL commitment to partnership with business



Courtesy of Anritsu Ltd

Measurement, management, margins…

In a global, knowledge-driven market place, competitiveness depends upon the ability to measure the parameters of products and processes, as the basis for sound commercial judgements. Businesses face market pressures for simultaneous improvement in product quality, reduction in cost and regulatory compliance. These pressures create, in turn, an increasing demand for measurements that are more accurate, more stable and more easily usable in practice.

The case studies in this section present a cross-section of the wide range of projects NPL undertakes in partnership with business.

The UK has, in NPL, a globally admired scientific institution, with the potential to meet this demand. To ensure this potential is fulfilled, NPL matches scientific endeavour with a commitment to ensuring that our work is valuable, usable and relevant for measurement users. Success, for NPL, is helping UK-based companies convert scientific breakthrough to competitive advantage.

We see this as a cultural issue and are determined that NPL should be an outward facing and market-aware organisation, driven by the need to see excellent science applied for real world benefit.

This can only be achieved through close partnership with industry and other users. Knowledge transfer is not a one-way process. It involves the creation of long-term strategic relationships between scientists, engineers and business people, addressing shared goals.

The NPL proposition to our partners in business

NPL will put you in a position to take business and operational decisions based on technical data of unquestionable quality. We will do this by giving you access to a world-leading, knowledge-based infrastructure, which you can be confident will comprise the best scientists and facilities available. We will provide service focused on your needs, not ours; and at the lowest possible cost.

National standards – local access

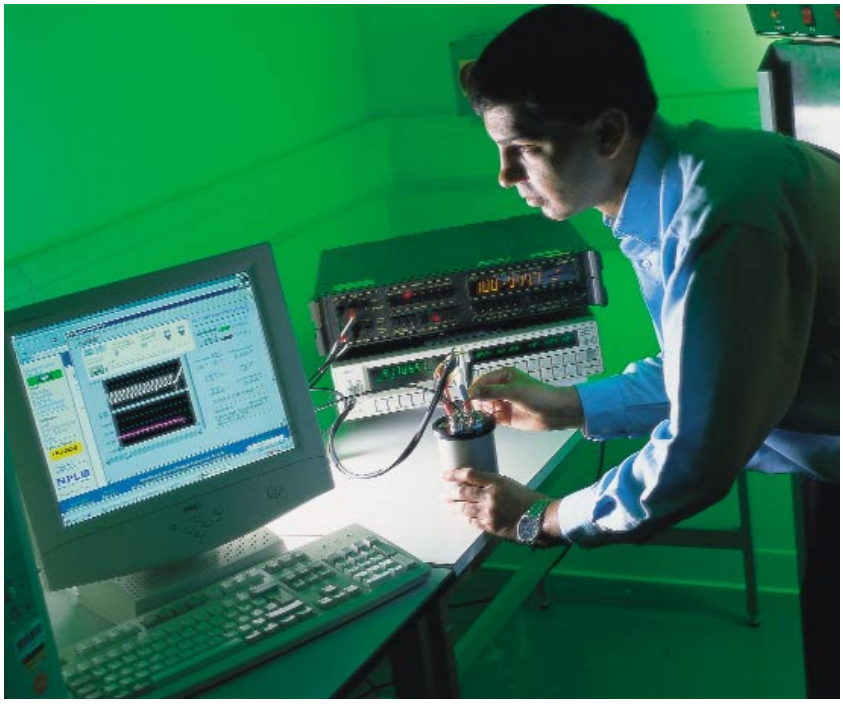
Internet delivery systems are taking national measurement standards closer to industry – making essential calibration and testing simpler, faster and cheaper.

NPL has worked closely with industry partners to develop remote calibration systems in two areas: DC and LF measurements; and high frequency electrical measurements. The systems have been developed in partnership with Fluke and BAE SYSTEMS, and use the power of the internet to give rapid access to NPL resources.

Calibration procedures developed jointly with BAE and Fluke are used to take local measurements, and the internet link enables instant calculation of results for measurements which are traceable to primary national standards.

The systems deliver significant benefits. They enable measurement devices and components to be calibrated under their conditions of use, to a level of accuracy only previously attainable on the NPL site. Delicate instruments and components no longer need to be transported to NPL, so a source of potential error and expense is eliminated.

Most importantly, the internet link means that calibrations can be completed in a matter of hours rather than weeks. This enables users to simplify the calibration phase of manufacturing, and calibrate a range of components and instruments at one time. The result is a streamlined manufacturing process in which reduced downtime and cost effective calibration deliver real productivity gains.



Shakil Awan demonstrating NPL's internet calibration system for resistance measurement.

The system developed in partnership with BAE SYSTEMS was launched this year by the Minister for Science and Innovation, Lord Sainsbury of Turville, and is already in use at the UK's two largest high frequency electrical instrument makers. The DC and LF measurement system is expected be launched early in 2002 and is already generating huge industry interest.

The internet link means that calibrations can be completed in a matter of hours rather than weeks

Marketability from metrology

Harwell Dosimeters' close collaboration with NPL puts metrology at the heart of the company's manufacturing process.

Harwell Dosimeters Ltd, a small Oxfordshire-based business, is the UK's only manufacturer of routine dosimeters for the radiation processing industry. Its products are used to verify that the correct dose of radiation is used in the sterilisation of up to 15 million disposable medical items made in the UK every year.

Accurate dose measurements are crucial, so the company's competitiveness is enhanced by calibration against the most accurate standards available. The market demands streamlined process management, but the company's success depends above all on its ability to prove the accuracy of its dosimeters, which must conform to stringent product safety regulations.

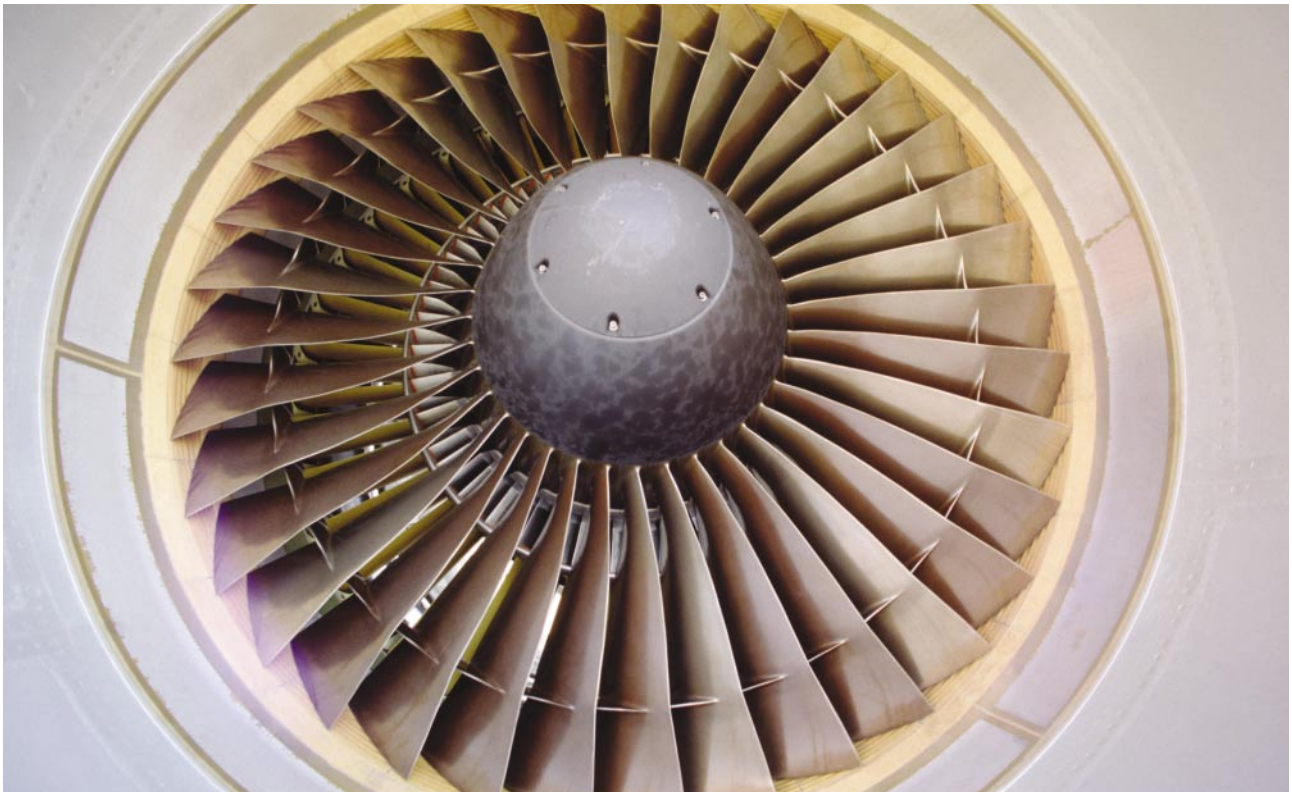
NPL provides a flexible, accurate calibration service based on primary national standards – and the service has been integrated with Harwell Dosimeters' manufacturing operations.

The company uses a batch manufacturing process, and has worked closely with NPL to include an extra step for verification of the calibration of each batch. This integration allows accurate calibration to be carried out without disruption to product delivery and without manufacturing downtime.

The calibrations delivered by NPL provide Harwell Dosimeters with valuable competitive advantage. They prove the accuracy of its products and lend them the credibility associated with NPL measurements. At the same time, they provide explicit information on measurement uncertainty that enables customers to configure radiation-processing operations more efficiently, and provide Harwell Dosimeters' products with an important additional selling point.

Good metrology is vital in the healthcare applications of ionising radiation; three types of dosimeter manufactured by Harwell Dosimeters Ltd are shown with typical radiation sterilised medical devices.

The company's competitiveness is enhanced by calibration against the most accurate standards available



Aerospace is a key potential beneficiary of the INTErSECT project.

Where science and industry intersect

A Faraday Partnership managed by NPL and Sira has facilitated 13 industry-university research partnerships and is helping to get three new ventures off the ground.

The Faraday Partnerships' scheme is designed to build relationships between researchers and industry. The INTErSECT partnership managed by NPL and Sira focuses primarily on intelligent sensors and control, and facilitates the development of technologies and relationships that enable UK companies to take new products to market.

During the last twelve months, INTErSECT has grown at a remarkable rate. The partnership now brings together ten major end user companies – including Rolls-Royce, Glaxo SmithKline, Unilever and ICI – numerous smaller companies and nine university research departments.

This growth has been fuelled by the development of a comprehensive business support network. The partnership provides access to research funding and puts companies in touch with research specialists and venture capitalists, to help them convert a good idea into a viable commercial product.

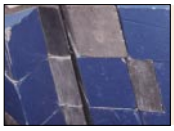
The partnership has already resulted in plans for three new ventures that will take innovative products to market

The impact of this approach has been immediate. INTErSECT has established 13 research projects involving 24 large companies, 28 SMEs and nine research partners. Its total funding has increased to £3 million, whilst research projects have attracted a further £4.2 million in industry co-funding.

The increased focus on network building has also highlighted areas of opportunity for the future. Work has already begun to address instrumentation supply chain problems that are impeding innovation and growth, whilst continued collaboration with INTErSECT will further increase small business involvement.

Most importantly, the partnership has already resulted in plans for three new ventures that will take innovative products to market as a direct consequence of collaboration facilitated by INTErSECT.

An aluminium test block and source transducer for determining the frequency response of acoustic emission transducers. These devices are used for monitoring structural integrity, for example in aircraft wings and engines.

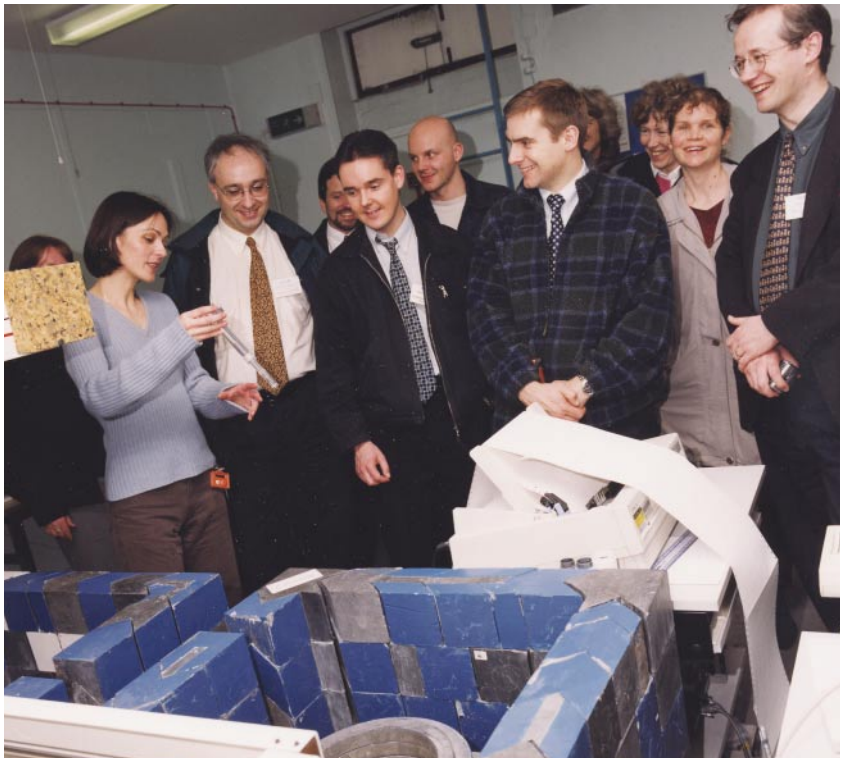


Clubbing the competition?

The National Measurement System's (NMS) relaunched electrical metrology clubs bridge the worlds of electromagnetic science and industry – to provide early access to new knowledge and keep researchers in touch with the needs of business.

Three successful industry metrology clubs run by NPL have been refocused to address business issues more directly. The DC and LF, Freemet and Communications Clubs have a reduced focus on pure metrology, but look closely at measurement issues in product development, quality assurance and design.

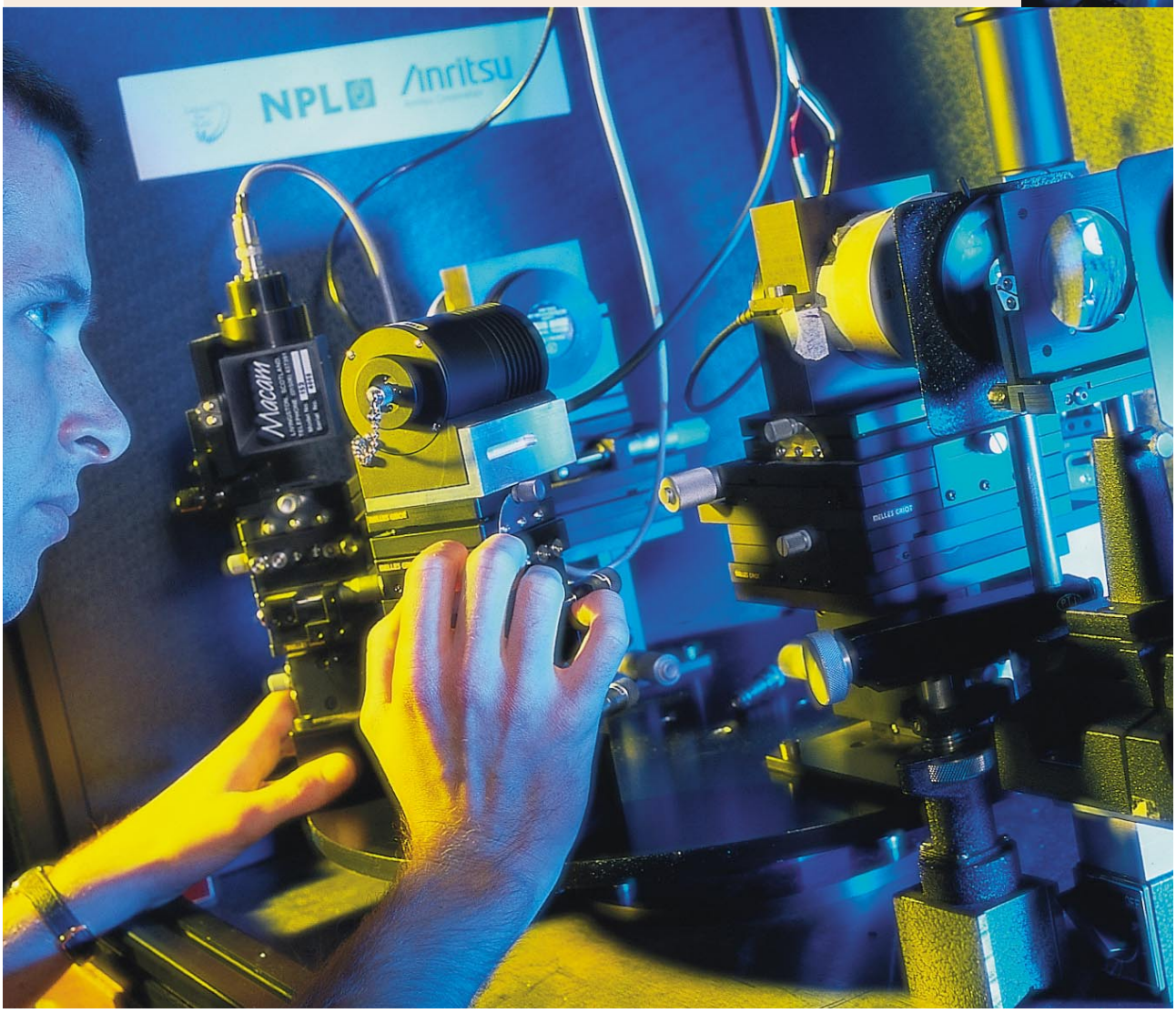
The relaunch of the clubs followed an extensive consultation process carried out in collaboration with industry partners, Fluke, Link Microtek and the EMC Test Laboratories Association. It provided an in-depth understanding of the key measurement issues facing industry, as well as those to which metrology could offer new solutions. NPL also worked with the Institution of Electrical Engineers and TCD to ensure the clubs' relevance and accessibility for small businesses.



Dagmara Tyler with members of an intercomparison workshop. NPL clubs and workshops are vital to successful knowledge transfer.

This knowledge was a crucial guide in the development of club content, planning speakers and targeting new members. For instance, the clubs now provide an opportunity to gain hands-on experience of metrology techniques and equipment – to give companies a chance to see the business benefits for themselves.

The refocused clubs offer a unique opportunity to network with industry colleagues, share best practice and meet leading researchers. They will help to ensure that scientific breakthroughs in the NMS electrical programme are applied rapidly to boost UK competitiveness.



Andrew Deadman working in NPL's high power fibre optic power meter calibration facility. NPL is currently the only laboratory worldwide that provides traceability and standards for the high optical powers that are used in the latest telecommunication links and networks.

Seeing the light

NPL has become a trusted research and development partner for Japanese inward investor, Anritsu, and has developed new standards in fibre optic measurement in the process.

Anritsu is a world-leading telecoms equipment maker, specialising in measurement equipment, and an inward investor in the UK. In 1998, the company approached NPL for help in the development of a fibre optic power meter. The meter needed to deal with the spectral range and more powerful signals demanded by heavier telecoms traffic – and deliver highly accurate, traceable measurements. Anritsu saw NPL as a one-stop shop for fibre and photonics measurements, with unrivalled expertise in fibre measurements and standards and unique technical capabilities. All of this was the result of far-sighted investment by DTI a decade earlier.

NPL provided an advanced research and development facility for Anritsu. It developed

Courtesy of Anritsu Ltd

NPL works in partnership with measurement, test and instrumentation companies to ensure that field test equipment is accurate.

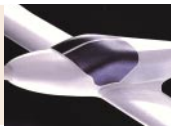
NPL is now seen as the research and development partner of choice for Anritsu worldwide

technology to deal with the demands of wider spectral range and broke new ground in metrology by originating a measurement system capable of dealing with increased signal power, traceable to primary standards.

A prototype sensor was developed in collaboration with Anritsu, but based on research and development work carried out at NPL. The finished product was delivered in January 2001, calibrated with reference to primary standards held at NPL.

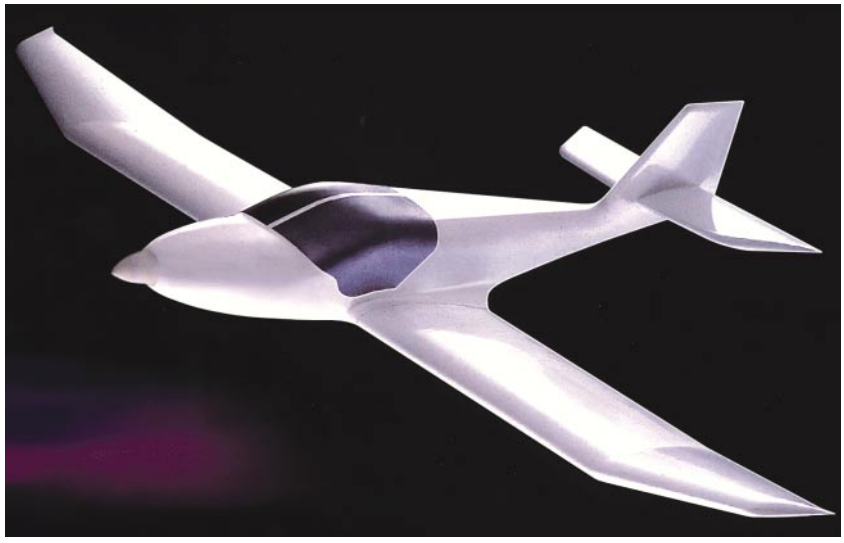
The benefits of NPL's collaboration with Anritsu are clear. There has been significant industrial co-funding for the development of the UK's national capability in measurement adding value to the DTI's investment. These new capabilities are available to all. Anritsu has drawn on world-leading expertise and highly accurate standards in the development of an innovative, credible product, whilst the project has given NPL added commercial credibility and third party investment.

NPL is now seen as the research and development partner of choice for Anritsu worldwide and joint projects in the UK and the US are already under way.



Heavy impact on light aircraft

This year, NPL was one of the first non-academic research organisations to participate in a TCS Programme.



Through TCS, NPL's composite material expertise is helping Aviation Enterprises Ltd obtain CAA approval for its new Magnum VLA two-seater aircraft.

TCS is a UK Government scheme that enables firms of all types to access the wide range of expertise available in higher education institutions and in public and private research institutes and organisations. Through the scheme partnerships are formed between UK companies and groups of staff, often from different disciplines, in UK knowledge base organisations. At the heart of all TCS Programmes are innovation projects that are central to the strategic development of the company. The projects are implemented by teams comprising senior staff from both the companies and the knowledge base partners and graduates (referred to as TCS Associates).

For three years, NPL has had responsibility for managing the entire scheme, under contract with DTI. However, this year the Laboratory also became one of the first non-academic organisations to be involved as a knowledge base partner. It has recruited a recent aeronautical engineering graduate, Geoff Nunn, on to a TCS Programme with industrial partner Aviation Enterprises Ltd.

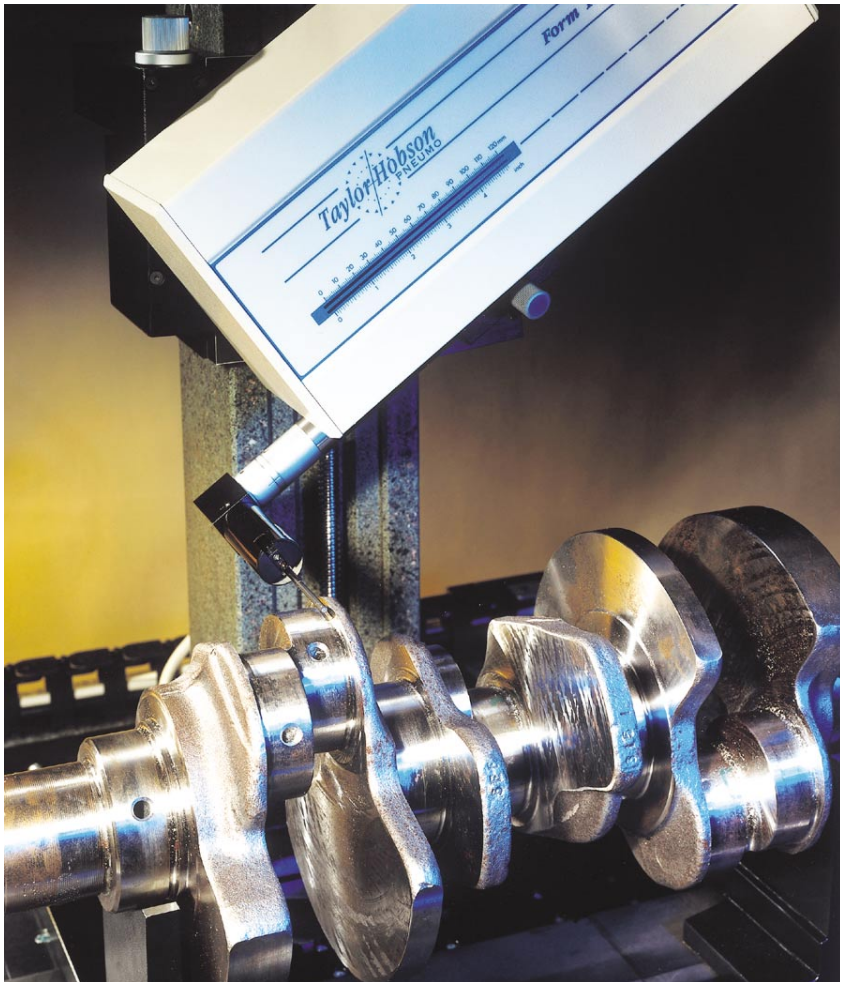
The company designs and builds light aircraft and is currently in the process of seeking Civil Aviation Authority (CAA) approval for a new two-man aircraft. The recruitment of a recent graduate and access to the technology and expertise of NPL's Composites Group through TCS, is important to achieving this aim.

In a project led at NPL by Graham Sims, NPL's composite material expertise is providing Aviation Enterprises with the evidence it needs to supply to the CAA. In liaison with the team at NPL, Geoff Nunn is using the latest tools and techniques to analyse every aspect of the design – from testing materials and components to stress analysis.

TCS offers benefits to all involved. Aviation Enterprises is able permanently to improve its capabilities by implementing leading expertise and technology that would otherwise be beyond its reach, whilst NPL gains valuable insight into the application of previous work and into future industrial measurement needs. For Geoff, TCS provides valuable commercial experience and the potential for further qualifications, and offers a prospect of employment at the end of his project.

Metrology to make the Finance Director smile

A scheme designed to introduce the benefits of measurement is helping small manufacturers increase productivity and win new business.



Courtesy of Taylor Hobson

Taylor Hobson is one of the UK's instrumentation companies whose participation is vital to the success of the On-machine Measurement Programme.

In manufacturing industries, minimising scrap and downtime is essential to maximise output and efficiency. Effective measurement is a critical, but often overlooked, aspect of manufacturing process control that contributes significantly to realising these objectives.

NPL is running the On-machine Measurement Programme, a DTI pilot scheme that helps small manufacturers increase yields from machining processes. Launched early in 2001, the scheme is based in West Yorkshire and run in partnership with the University of Huddersfield, Leeds College of Technology and Kirkdale Industrial Training Services. Participating companies receive a capability and needs audit, to assess manufacturing processes and identify areas in which measurement technology could deliver efficiencies and bottom line benefits.

Leeds West MP John Battle (second from right) presents a special award to the Yorkshire-based railway parts engineering company, Pickersgill Kaye. Also shown, left to right: Peter Murphy, Pickersgill Kaye; Mick Capps, Leeds College of Technology; David Wilcock, Pickersgill Kaye; Jerry Benson, NPL.

A number of leading UK instrumentation companies (including Renishaw, Taylor Hobson, Moore and Wright/Bowers Group Ltd and 600 Lathes Ltd) are giving invaluable support. Participating companies benefit from a one-month free trial of the measuring equipment most relevant to their business as well as access to specialised training facilities so they can see for themselves how measurement could improve process control and impact on the bottom line. The scheme has delivered huge benefits to a wide range of small manufacturers. Significant process savings have resulted from reduced scrap, increased machine life and more effective machine maintenance, whilst effective process control and 24-hour running have increased output and productivity.

The benefits of the scheme, however, do not end there. Access to measurement equipment has provided extra competitive edge – one participating company recently won a European contract worth £200 000 per year, based on a £15 000 measurement investment. And so far the total financial benefit to the companies is estimated at £900 000.

So far the total financial benefit to the companies is estimated at £900 000

Standards for living

NPL's mission is to bring scientific breakthrough to bear on commerce, but its research and innovation also helps improve quality of life for thousands of people.

Throughout its history, NPL has recognised an important social role for measurement and national standards. It has consistently undertaken projects with that end in mind, be it through consumer protection and trading standards or via the broader societal benefits of environmental measurement programmes.

This year has been no different. A range of safety and security, environment and health projects have accounted for some 15% of NPL's activity and are helping to make lives better across the UK. The following case studies provide a taste of this activity.

NPL offers a service to quantify the environmental impact of industrial processes.

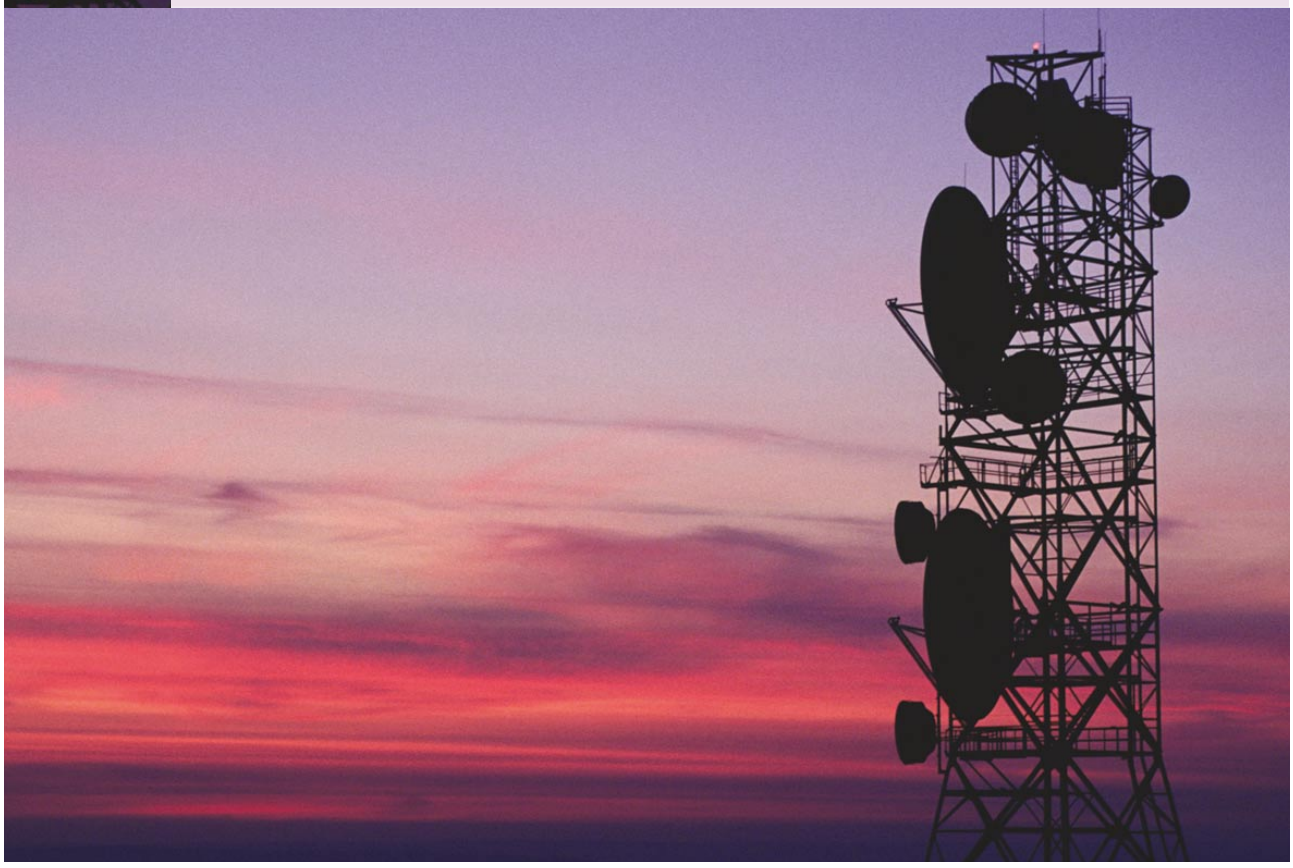
Breathe easier

NPL services and expertise are helping to deliver better air quality for everyone.

According to a recent study in Austria, France and Sweden, air pollution caused 6% of total mortality and contributed to 290 000 episodes of bronchitis in children and half a million asthma attacks within those countries.

NPL plays a significant role in monitoring air pollution in the UK. Its calibration facilities underpin measurements of ozone, carbon monoxide, sulphur dioxide, nitrogen dioxide and hydrocarbon pollution levels. They are critical to monitoring air pollution in a range of settings, minimising its impact on both the local population and the wider environment, and are applied in a variety of ways:

- NPL staff check and calibrate many of DEFRA's air quality measurement sites and turn their raw data into reliable information on local and national air quality
- NPL provides BP, and others, with accurate measurement of ambient hydrocarbon levels around refinery sites, enabling the adoption of more efficient practices and protecting the interests of the local population
- The development of pioneering infrared spectroscopy techniques at NPL has provided a more versatile method for measuring air pollution and emissions from industrial chimneys



Telecommunications issues present demanding challenges for NPL.

Is it safe to talk?

Reliable measurements from NPL support mobile phone safety studies and device testing.

Mobile telephones are very much part of modern society, but doubt over the long-term health implications of exposure to electromagnetic radiation persists.

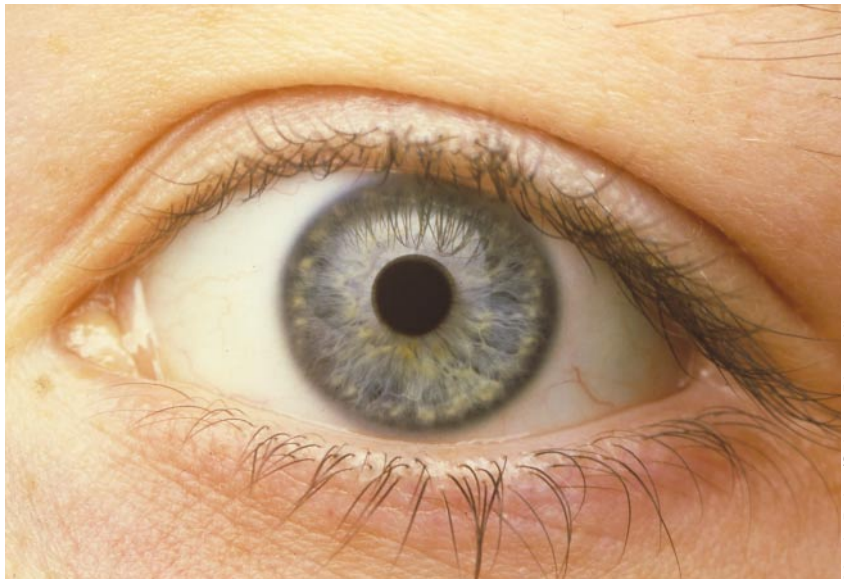
These concerns have led to the development of mobile phone emissions standards to which all handsets must conform. NPL is helping manufacturers to comply with these regulations by calibrating field strength measurement probes and characterising test materials traceably to national standards. This helps manufacturers to measure the Specific Absorption Rate of electromagnetic radiation emitted from handsets operating in the 900 MHz and 1800 MHz frequency bands which are used by most mobile phones in the UK.

This work is being significantly extended with the development of facilities to enable more comprehensive measurements across a wider range of devices – this will include handsets operating in the 380 MHz to 430 MHz range using the TETRA system, which is intended for use by the emergency services.

The RF and Microwave Group is also providing metrology consultancy to the Mobile Telecommunications and Health Research Programme sponsored by DTI and the Department of Health. As part of this work, it is intended to embark upon a new research project for quantifying the magnitude of magnetic pulses generated by mobile phone handsets – an essential prerequisite for assessing the impact of such pulses upon the health of mobile phone users.

Looking for recognition

NPL is helping to make biometric recognition and enhanced security a reality.



Martin Dohrn/Science Photo Library

The unique pattern in an individual's iris can be used as the basis for recognition technology.

In a world where sensitive information is increasingly held electronically, effective security technology is paramount. NPL is working with biometric recognition device makers to help test the effectiveness of their security technology based on recognition of such features as fingerprints, faces, irises and voices.

NPL's statistical analysis expertise and independence is proving crucial in testing and reporting the effectiveness of different recognition technologies and their suitability for a range of applications.

NPL has assessed a range of biometric devices by measuring their false acceptance and false rejection rates. Different applications give different weights to these criteria and the results are helping manufacturers to develop better systems, and providing potential users with information on which technologies are most effective in a particular application.

Ultimately, NPL's work on biometric device testing could have far-reaching social benefits. It could bring peace of mind by helping to secure personal information, for instance using iris recognition at ATMs or voice recognition for telephone banking. Equally, it can have applications in crime detection and immigration, where reliable face recognition could be used to pick individuals out from video footage.

Global positioning

Trading on standards

It may seem a contradiction, but NPL can only truly fulfil its role as the UK's national standards laboratory by operating effectively on the international stage.

Internationalism is a vital element both in the demand for and the supply of accurate measurement. Measurement standards were first created to facilitate trade. In today's global economy, where regulations abound and products are assembled from components sourced in many countries, trade remains at the heart of global demand for consistent, traceable measurements.

On the supply side, few NPL programmes are undertaken without involvement from international partners. Each of the pioneering research projects outlined elsewhere in this review relies to some extent on overseas partners – whether NPL research is building on work begun by international colleagues elsewhere, depends on technologies developed overseas or is being carried out in partnership with other national metrology centres.

Internationalism is a vital element both in the demand for and the supply of accurate measurement

Regulation and safety issues are key drivers for international collaboration in metrology.

Negotiate to collaborate

The growing internationalisation of metrology means that moves to formalise cross-border co-operation are inevitable. Collaboration between national metrology institutes is increasingly the basis for real advances in metrology; and a collective strategy can only enhance this effect. At the same time, co-operation on standards removes technical barriers to trade and will be good news for British business and competitiveness abroad.

The reality of this international collaboration in metrology has been formally recognised with the establishment of NPL's International Office.

The team seeks to make sure that UK interests are represented at the international negotiating table. It aims to guarantee that the strategic development of international metrology benefits the UK, and that the UK end user measurement community is in a position to take advantage of developments as they happen.

NPL's International Office is responsible for a wide variety of activities. The following short case studies illustrate their activities in the past year.

The growing internationalisation of metrology means that moves to formalise cross-border co-operation are inevitable

UK – centre stage

In the context of the growing internationalisation of metrology, maintaining the UK's high profile is critical.

Maintaining a high profile in both the metrology and the end user community has become essential

NPL's position as a world-leading metrology centre and its reputation for innovation and expertise ensures it is able to represent the UK position in international negotiations affecting UK business, and NPL provides representatives to many international committees and working groups. With greater collaboration and an increasing emphasis on business partnership, maintaining a high profile in both the metrology and the end user community has become essential.

Cross-border collaboration and NPL participation at metrology conferences are raising the profile of UK standards and expertise in the international metrology community. This year for example, NPL sent a strong delegation to the National Conference of Standards Laboratories (NCSLI) conference in the US, recognised as one of the premier events in metrology worldwide. It is industry rather than research driven and is attended by metrology laboratories and end user companies from around the world, providing a great opportunity to build partnerships and enhance reputations. In the past two years four of our papers have won awards at NCSLI, including a 'Best Paper' award (see page 39).

David Nunuk/Science Photo Library

International measurement standards are vital for trade in today's global economy.

Opening the door to co-operation

In October 1999 the directors of national metrology institutes (NMIs) from across the industrialised world signed a Mutual Recognition Arrangement (MRA) for national measurement standards and calibration and measurement certificates. The agreement was signed by NPL on behalf of the UK. The MRA, which is in its implementation phase, underpins wider agreements related to international commerce and regulation and the removal of technical barriers to trade.

Courtesy of BIPM

The International Bureau of Weights and Measures (BIPM) at Sèvres, near Paris.

The development of this international co-operation has come as a result of painstaking work behind the scenes, in which NPL's International Office has played a leading role. The calibration and measurement capabilities (CMCs) of the participating NMIs are undergoing extensive peer review, supported by scientific comparisons and the implementation of comprehensive quality assurance systems to ensure confidence in the process. NPL's Scientific Business Centres have been heavily involved in this activity.

The CMCs are described and laid out in a common format enabling end users to compare the calibration and measurement capabilities of the NMIs. Results from the scientific key comparisons are already being included in a database of mutual equivalence available via the BIPM website (www.bipm.org). NPL's performance ranks at the very highest level.

This is an important development. It will encourage greater international collaboration between NMIs in the future and provides a technical foundation for wider agreements between governments.

NPL's performance ranks at the very highest level

Courtesy of BIPM

In 2002 NPL's Andrew Wallard (left) will take over from Terry Quinn as Director of BIPM.

Share the mission, reap the benefits

NPL is representing UK national interests in discussions over a comprehensive strategy for international collaboration in metrology.

The Airy vase after recent restoration by the National Maritime Museum.

In a recent National Measurement System policy review, the DTI found that the demand for the development of diverse measurement standards was putting strain on research budgets.

These findings echoed a growing feeling throughout the international metrology community that, over the next few years, the demand for new measurement standards will outstrip national research funding. Recently, this concern has been the focus of considerable international dialogue.

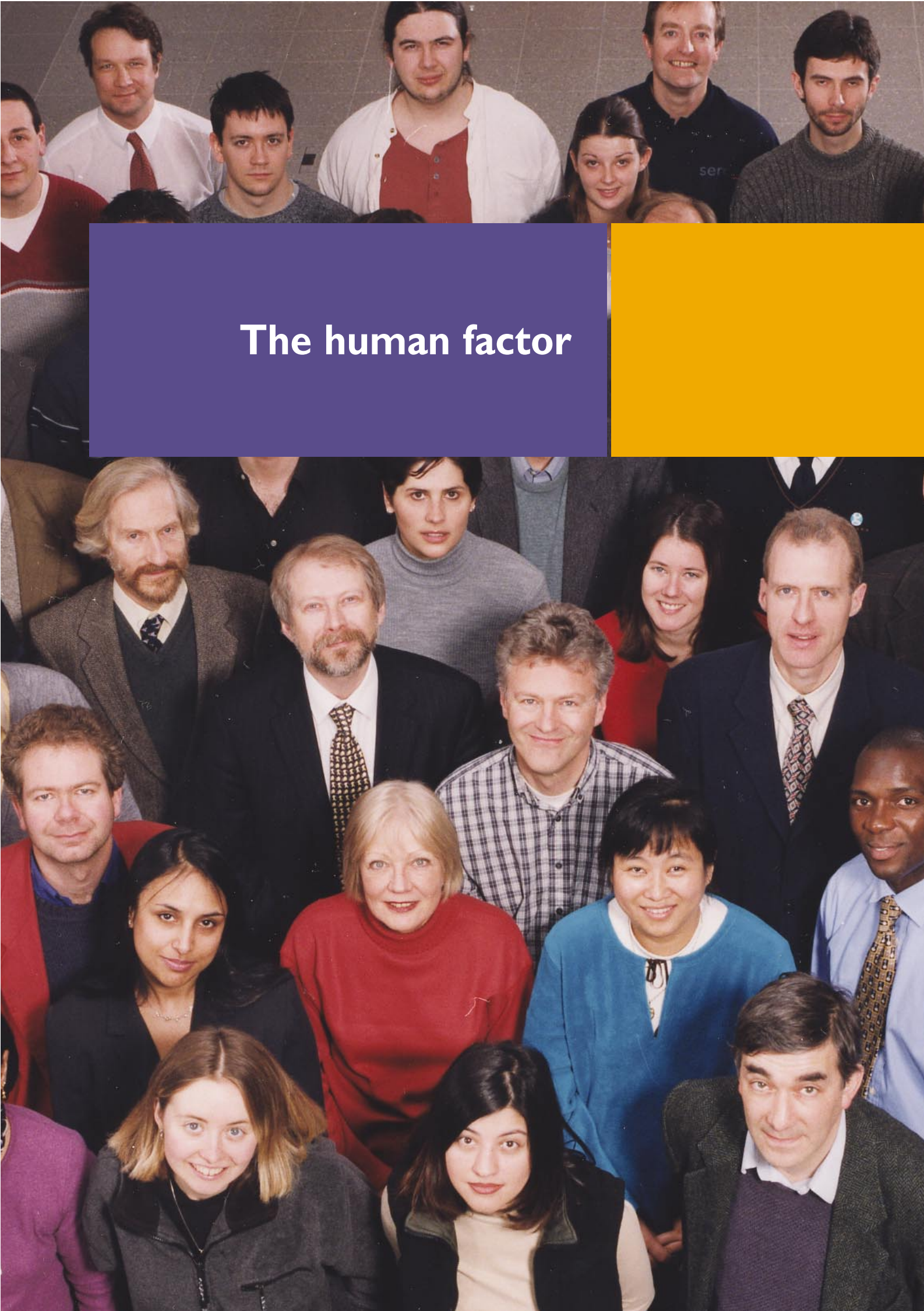
The outcome of these discussions has been a recognition that metrology centres need to look more closely at the allocation of resources – to ensure that they are efficiently targeted to meet national requirements whilst contributing to the development of metrology and standards in new areas.

In order to best represent UK interests in future negotiations, NPL is, in partnership with the DTI, developing tools that provide a comprehensive picture of the demands of businesses in the UK. It is mapping these against the metrology strategy being developed at an international level to see where interests overlap and where there is clear potential for formalised collaborative research.

Essentially, this is a strategy of interdependence, allowing a more effective allocation of resources and defining national and international research priorities. In future, national laboratories will have no choice but to work more closely together in researching standards in new areas of metrology.

NPL's focus is on making this happen whilst fully supporting the needs of UK business and national competitiveness.

International collaboration in metrology is not a new phenomenon. In the 1870s members of the International Commission of the Metre were presented with a Sèvres vase by the French government. Representing the UK government was Sir George Airy who at the time was President of the Royal Society and Astronomer Royal. This marked the start of formal worldwide collaborations in metrology and led to the establishment of BIPM.



The human factor

A national laboratory's product is knowledge, generated by virtue of a powerful blend of people and facilities. Within this formula, the people factor is by far the most important. The extraordinary expertise of NPL's people, and their commitment to innovation and quality, touch every aspect of the organisation.

NPL's ability to attract, retain and support the best people is vital to our success. We are working hard to create the right environment for innovation – to provide new people with an opportunity to do their best work, and work together to realise new possibilities.

Julie Taylor, Photonics Programme Manager, briefing members of her team – left to right: front: Rob Ferguson, Subrena Harris, David Ives back: Martin Wicks, Joan Smith, Julie Taylor and Colin Campbell.

Playing for the team

An innovative team structure has been designed to promote cross-discipline collaboration and the acquisition of new skills.

The structure means research projects are now grouped under specialist areas such as Photonics or DC/LF Measurement, with teams hand picked to include the right mix of skills and experience to deliver them.

As such, researchers have an opportunity to work across a broad range of research projects. The team structure ensures that skills development is in line with the demands of NPL's science strategy, and provides people with the opportunity to broaden skills and tackle new areas.

Cross-discipline collaboration inevitably breeds a greater awareness of research being carried out across NPL. It promotes greater communication, provides a basis for innovative research projects and is encouraging the development of a community of science leaders at NPL.

The team structure provides people with the opportunity to broaden skills and tackle new areas

Looking to the future: Gordon Rodger measuring the height of a visiting student during an open day for NPL Junior Metrology Awards finalists.

Glittering prizes

The quality of NPL's work continues to be recognised by external organisations, both national and international. Just some examples of these awards are given below.

The Worshipful Company of Scientific Instrument Makers announced that their year 2000 Achievement Award would go to Andrew Wallard for his outstanding contribution to metrology. Andrew also received this year's Lifetime achievement award from the Metrology for World Class Manufacturing Awards' panel.

Peter Woods, leader of NPL's environmental standards team was awarded one of the Institute of Physics' premier medals – the Charles Chree medal for 'his contributions to environmental metrology'.

NPL staff have won best paper awards at a series of international conferences: one of these was the world's largest metrology event, the National Conference of Standards Laboratories International (NCSLI) this year in Washington, USA. Five members of staff presented papers and Paul Wright won the NCSLI Best Paper award in the applied category for 'Methods for the calibration of flickermeters'.

The year ended with the news that the Institution of Electrical Engineers had awarded the prestigious IEE Measurement Prize to Martin Alexander, Wenlie Liang, Benjamin Loader and Andrew Gregory from NPL, together with Shinegori Torihata and Ryuiji Osawa from Tokin Corporation, Japan, for their work on a new generation of electro-optic field probes.

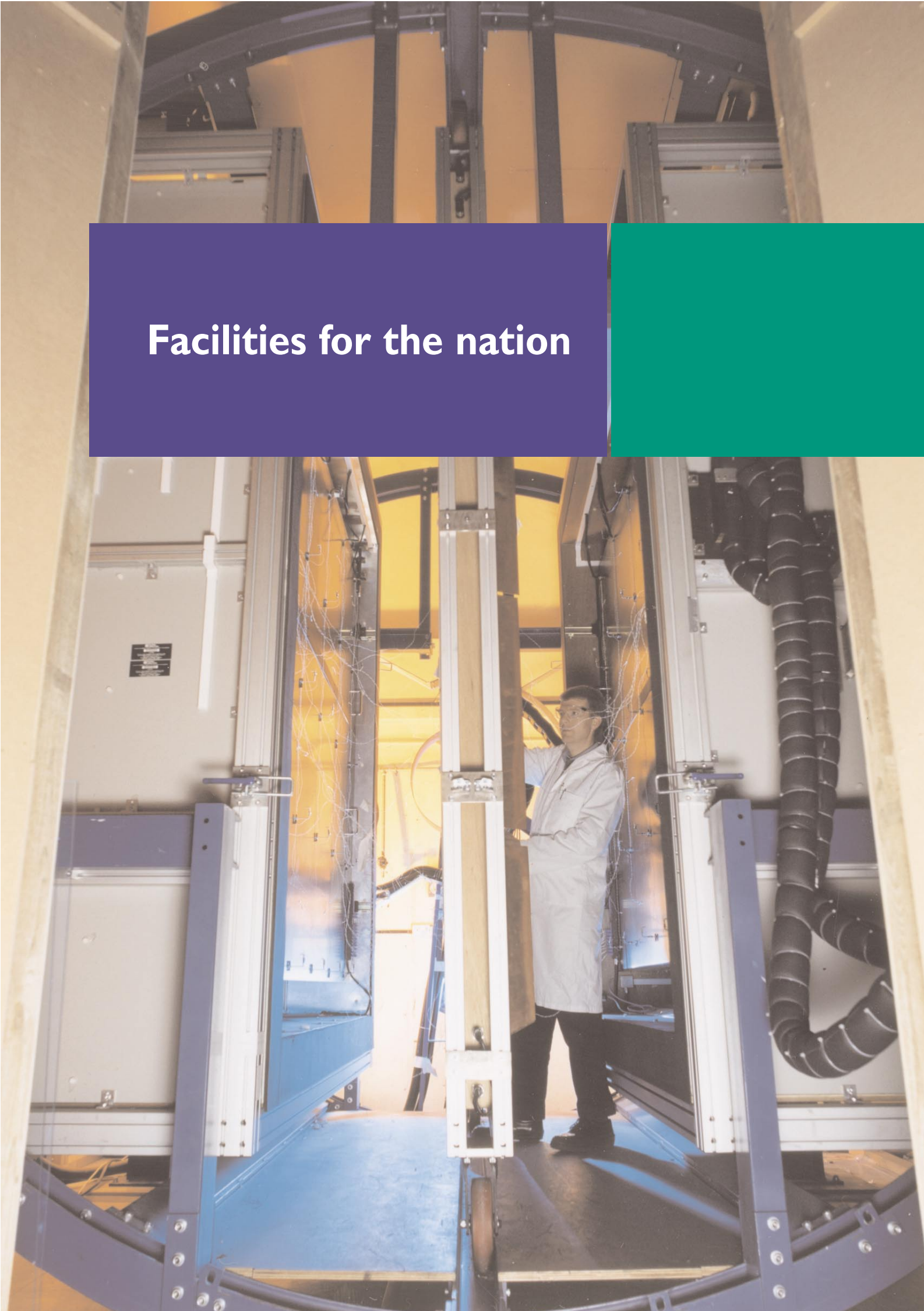
Many functions – one mission

A successful national laboratory depends completely upon the commitment and professionalism of staff in a wide range of disciplines, not just in science but in vital support and infrastructure roles.

A small cross-section of the scientists and support staff who make NPL a globally-respected Laboratory: Ian Stoker, Matthew Maddock, David Dadswell, Stephen Protheroe, Keith Walker, Jamie Vogel, Laura Kelly, Jeremy Stirling, Jacque Dowdall, Ben Lorkin, Simon Bellwood, Mike Wiltshire, Alan Green, Chris Lewis, David Adamson, Irene Paxton, Gareth Jones, Stephen Farrant, Richard Stevens, Tunde Adeaga, Janet Belliss, Alan DuSautoy, John Macfarlane, Mike Stevens, Diane Beauvais, Karen Hood, Martin Seah, Graham Torr, Tony Hartland, David Robinson, Mark Baxendale, Jonathan Williams, Shakil Awan, Richard Rusby, Andrew Hanson, Baljit Sidhu, Pamela Croft, Ling Hao, Denis Byarugaba, Martin Keene, Surinder Bagal, Lizzie Inglessi, Nikki Gill, Hugh Klein.

Scientific Centres – Information Technology Support Unit – Reprographics – International Office – Finance & Business Information Systems – Communications – Library – Quality, Health & Safety and Environment – Engineering Services – Human Resources – Knowledge Transfer – Graphic Design – Marketing & Sales – Reception – Switchboard – Helpdesk – Cleaning – Security – Catering – Conferencing – Integrated Logistic Services – Technical and Site Maintenance

Facilities for the nation



Facilities for the nation

NPL's mission could be described as a continuum of groundbreaking research, converted to innovative measurement technologies and services, which are in turn made available to industry and other users. This process depends critically upon the development and maintenance of special scientific facilities.

Continuous investment in NPL's equipment base is vital to breakthroughs in metrology

Our facilities are part of a national measurement infrastructure essential to national competitiveness, but whose development and maintenance is beyond the means of individual companies. This unique facility base is a key factor in defining what it means to be a national laboratory, as opposed to a commercial scientific consultancy or research organisation.

Continuous investment in NPL's equipment base is vital to breakthroughs in metrology and to making techniques and expertise accessible to others in a practical form. The move to NPL's new building offers a unique opportunity to reassess and update facilities throughout NPL. It is enabling the development of bigger, better facilities that are a basis for extending knowledge and delivering improved services.

Some of the important developments of the last twelve months are outlined on the following pages.

Spanning the spectrum

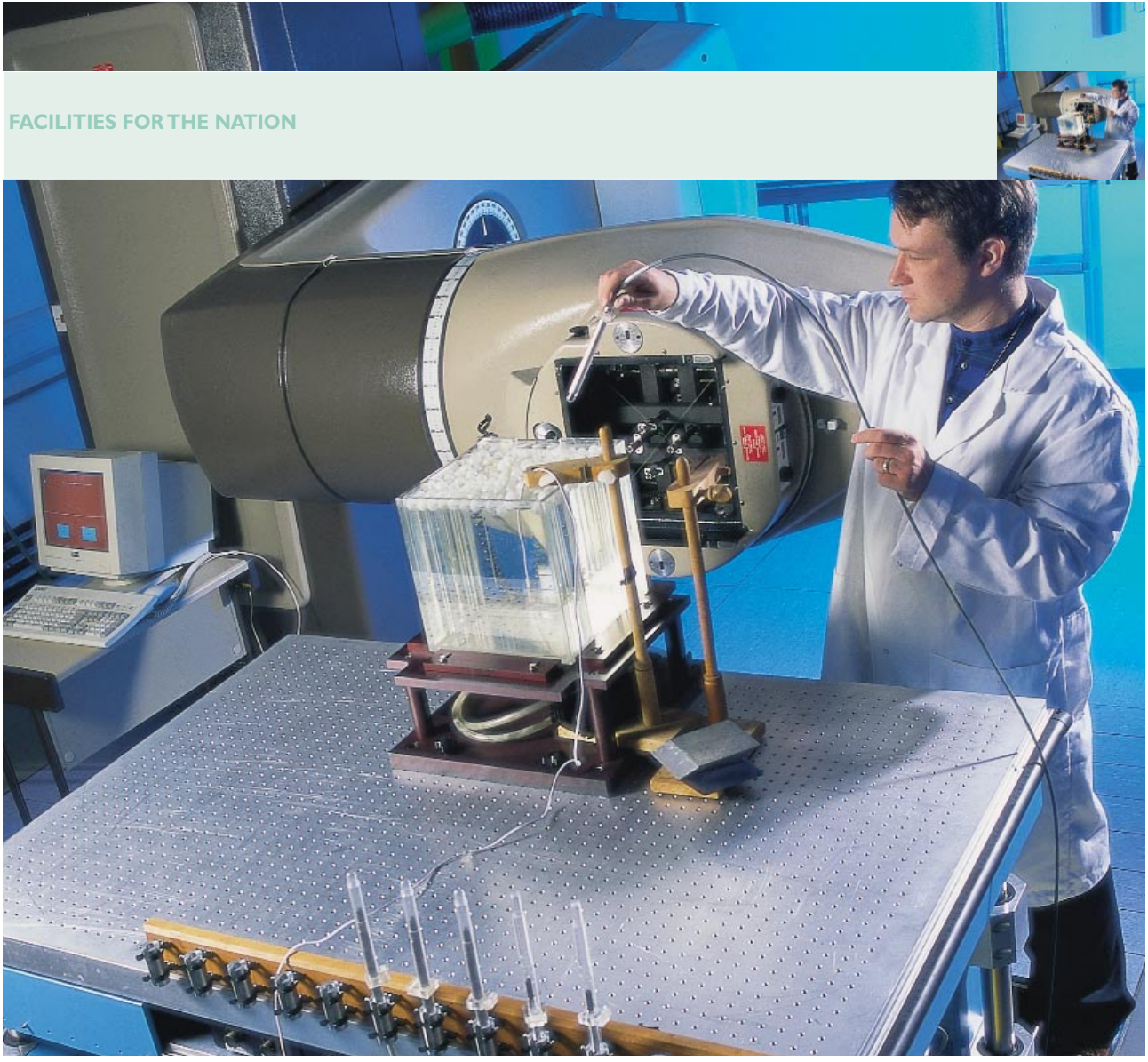
NPL's new extrapolation range offers improved calibration and characterisation services for radio antennas.

At 15 metres in length and aligned to 100 micrometres, the new extrapolation range offers a wider range of services for the accurate calibration and characterisation of antenna to a broad cross-section of industry including telecoms, defence and space.

The characteristics of antennas are determined from measurements made as two antennas are moved apart along the accurately aligned tracks of the extrapolation range. The range is housed in a gigantic 735 cubic metre anechoic chamber to provide a 'quiet' environment for the measurements.

The characterisation of antennas is particularly important to the telecoms industry. As demand for mobile internet access and other broadband services grows, telecom companies are seeking to make better use of the electromagnetic spectrum. Antennas are a critical part of this and the availability of world-class calibration services is essential to support these developments.

David Knight characterising radio-frequency antennas in one of NPL's new anechoic chambers.



Ian Stoker undertaking dosimetry measurements in NPL's new Theratron irradiator facility.

Healthy developments

NPL's new Cobalt-60 irradiator facilities represent a significant step forward in measurement support for radiation dosimetry.

The safety and effectiveness of every one of the hundreds of thousands of radiotherapy cancer treatments undertaken in the UK each year depend upon this facility

The new facilities, housed in purpose-built laboratories, began offering calibration services to health service and industrial customers in 2000 and offer significant benefits over their predecessors.

The installation of a Theratron irradiator typical of Cobalt-60 units found in hospitals, together with improved temperature control, reduces uncertainties in dose measurement and enables NPL to deliver even more accurate radiation dosimetry services, traceable to national standards.

These services are critical to both health service and industrial users. The more accurate calibration of health service radiotherapy equipment contributes to more effective cancer treatments whilst well calibrated radiation protection instrumentation helps to protect those working with radioactive material.

Larger exposure rooms contribute to the ongoing development of accurate measurement standards and are enabling new dosimetry services to be introduced. An example is radiation hardness testing. The Theratron is being used to assess damage caused by extended exposure to low-level radiation, a service which has applications in the telecoms and space industries.

Box clever

NPL's new hot box apparatus (see photograph on page 41) will contribute to the development of heat transfer measurement and calculation standards that are an essential tool in the evaluation of more energy efficient building materials and structures.

The measurement of heat transfer through building structures is traditionally carried out in a hot box apparatus in which the test element is mounted vertically between a hot environmental chamber and a cold one. U-values are then derived from the energy required to maintain a constant temperature gradient across the test element.

However the progressive tightening of heat transfer requirements of building regulations means that demand for more accurate measurement is growing. The new hot box developed at NPL can be rotated to measure heat transfer across test elements held in any position, which allows the measurement of heat transfer across building structures in realistic orientations. This is essential for precise measurements of structures such as roof lights and roof panels – because convection is an important part of the heat transfer process and it is affected by orientation.

This new apparatus provides an opportunity to develop EU measurement and calculation standards. These should be sufficiently precise to facilitate the development, evaluation, sale and regulation of the complex building products that are an essential part of our efforts to reduce carbon dioxide emissions and meet our commitments to the Kyoto Protocol.

Elizabeth Whiting & Associates

NPL's new hot box facility will help to ensure that heat loss from buildings is kept to a minimum.

The potential to deliver substantial energy conservation and environmental benefits

Seeing the big picture

NPL is developing a database of all the major DTI measurement facilities at UK laboratories.

The database is designed to give a clear view of DTI-funded national measurement resources and capabilities, and is delivering a range of other benefits. It is thought to be the first of its kind.

The National Measurement Facilities Database already includes comprehensive details of 50 major facilities held at NPL and is available to DTI and NPL staff. Parts of the database will also be made available to the public. Entries provide details of facility specifications and cost, supported standards, legislation and obligations as well as information about how they deliver NPL measurement research and commercial services.

The final database will include details of around 700 facilities and provide a unique view of the research capabilities used in the delivery of the DTI's National Measurement System and materials metrology programmes. It will provide a clear understanding of the dependencies between facilities and the commercial and research services they deliver. The database will also include DTI facilities at other UK measurement laboratories.

NPL's national laser radiometry facility – a unique suite of lasers underpinning optical radiation measurements.

This development has integrated a wide range of disparate information about facilities into one centralised view. It will include the benefits to industry of each facility, how it is ranked worldwide, the expertise required to run it and information on the types of industry that make use of it. It delivers a tool to manage national measurement facilities more cost effectively.

This unique facilities database is a key factor in defining what it means to be a national laboratory

Contacting NPL

The NPL website has a wealth of information and is a good starting point for those wanting to know more about NPL services and publications. There are sections on NPL's scientific areas, research programmes and commercial services as well as articles of more general interest, for example the history of length measurement and reference details of SI Units.

Some teams have already moved into the new NPL building – a state-of-the-art facility vital to NPL's future as a world-leading measurement science laboratory.

This year has seen the launch of the NPL e-Store where many of our goods and services (from Measurement Good Practice Guides to training courses) may be purchased online: www.npl.co.uk/e-store/

The *NPL Points of Contact* booklet lists NPL contacts for various areas of technical expertise and Clubs. A new edition will be available in 2002. If you know which scientist you wish to speak to but not the extension number, please use the switchboard number.

The NPL Helpline will be happy to help you with any measurement-related scientific enquiries. The staff will either answer your questions directly or put you through to an NPL expert for advice. Contact the Helpline by e-mail, fax, telephone, letter or via the internet.

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