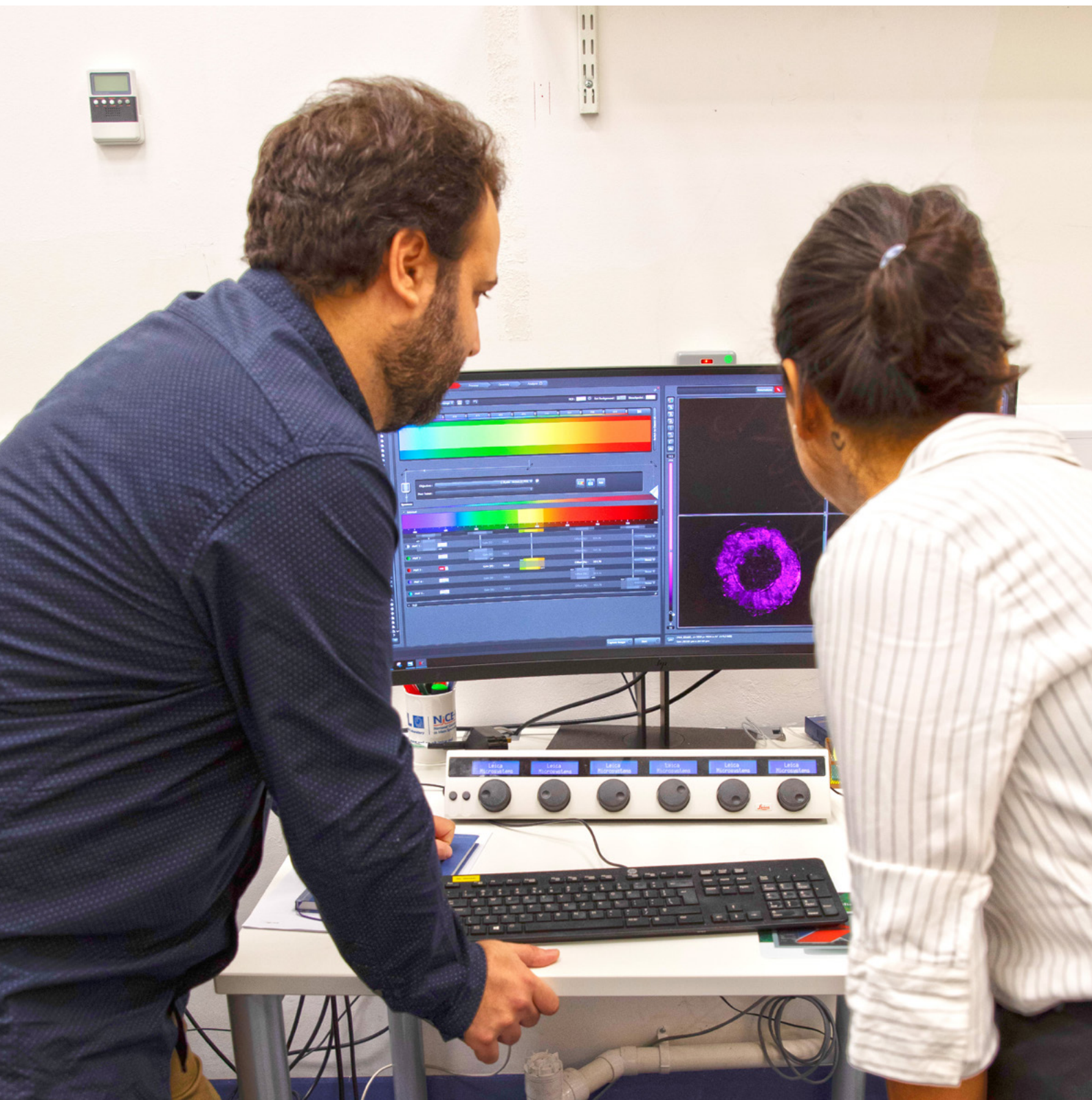


International Science Review 2016-2020 Public Summary



Introduction

The National Physical Laboratory (NPL) is the United Kingdom's National Metrology Institute (NMI), an independent centre of excellence in research, development and innovation in measurement. In 2020, NPL's annual turnover was £104 million. There were over 850 people working in science and engineering teams in 36 000 m² of laboratories, including many unique facilities.

NPL's mission is to provide the measurement capability that underpins the UK's prosperity and quality of life, and key activities include:

- research and development in measurement science to futureproof the national measurement system and accelerate public and private research and innovation
- providing direct support and best practice guidance to end users to improve confidence in measurement via measurement services, training and consultancy
- demonstration of the international equivalence of the UK's national standards
- providing traceability to stakeholders and overseeing the national calibration hierarchy
- national and international engagement and influence to benefit the UK and address national challenges.



Background

International Science Reviews of NPL have been performed at roughly five year intervals in recent times. This review was commissioned by NPL's Science and Technology Advisory Council (STAC) to:

- provide an independent and international review of NPL's science and engineering capabilities and outputs against its stated mission and the five key activities listed in the introduction
- benchmark NPL against institutes with similar missions (such as other NMIs from around the world)
- evaluate the capability of the organisation to deliver this mission into the future.

Assessing the quality of NPL's capability in terms of personnel and infrastructure through demonstrable impact was a very important aspect of this review, as well as assessing NPL's foresighting ability, agility and resilience to shocks.

The review spans the period 2016 – 2020 and was delayed due to the COVID-19 pandemic. Input from 18 anonymous Expert Reviewers was fed into a Review Board which then produced the final report. The Expert Reviewers were drawn from appropriate scientific peers in NMIs, industry, academia and other research and technology organisations. Over half were from outside the UK, ensuring that this exercise properly reflected an international perspective. The Review Board made several observations on the level of expertise and impact of each department at NPL during the review period, as well as giving recommendations for the future.

Review Board members

- **Anne Glover** Chair, NPL International Science Review
Special Adviser to the Principal, University of Strathclyde
- **Elizabeth Donley**
Chief of Time and Frequency Department, NIST, USA
- **Judith Hackitt**
Chair, Enginuity, UK
Non-Executive Director, High Value Manufacturing Catapult, UK
Non-Executive Director, HS2 Ltd, UK
- **Martin Milton**
Director, BIPM, France
- **Sheila Rowan**
Professor, University of Glasgow, UK
Director, Institute for Gravitational Research, UK
President, Institute of Physics, UK
- **Jim Smith**
Emeritus Scientist, Francis Crick Institute, UK
- **Ian Walmsley**
Provost, Imperial College London, UK

Observations and recommendations

NPL is an important and iconic institution with a rich history. NPL delivers against a mission that requires both fundamental expertise in laboratory science and the ability to turn that knowledge into societal impact. The International Science Review (ISR) Board valued NPL as part of the national infrastructure, carrying out research in many areas and demonstrating international leadership in many sectors.

NPL has considerable impact with a broad range of stakeholders. It is also clear that much progress has been made over the last few years to raise the profile and understanding of the work of NPL with key UK government departments to underpin its position as an important national asset. Consideration needs to be given to extending this outreach and engagement more broadly to build the case for continued funding and future investment. NPL's people are a major asset and attraction of high-quality scientists is essential for the sustainability of the organisation.

Specific recommendations from the Review Board:

1. **Review funding landscape:** NPL should undertake a review of current funding restrictions to address those that cause unintended barriers to collaboration and efficient sharing of knowledge. In parallel, there should be further engagement with UK-based funding organisations to develop common agendas.
2. **Maintain international influence:** NPL should develop a clear strategy to allow it to maintain its high profile and influence internationally in the new landscape of a post-Brexit and post-COVID world.
3. **Demonstrate national importance:** NPL must continue to provide evidence of positive impact, especially to the UK Government. A clear assessment of the importance of the work and indispensability of the laboratory will support engagement with more Government departments. Demonstrating NPL's unique capabilities and impact on UK commerce and security will support the case for continued funding and future investment, as well as help attract the highest quality staff.
4. **Sustain skills and capabilities:** NPL should recognise the challenges related to recruitment and retention. It should ensure long term plans are embedded within strategies to ensure skills and capabilities can be maintained.
5. **Expand convening power:** NPL should develop its convening power to help shape new opportunities for the UK. NPL is credible, trusted and has an extensive network ranging from academia to business which can be used to influence the research agendas of major funding agencies, spot future opportunities and identify where collaborations will add value for the UK.





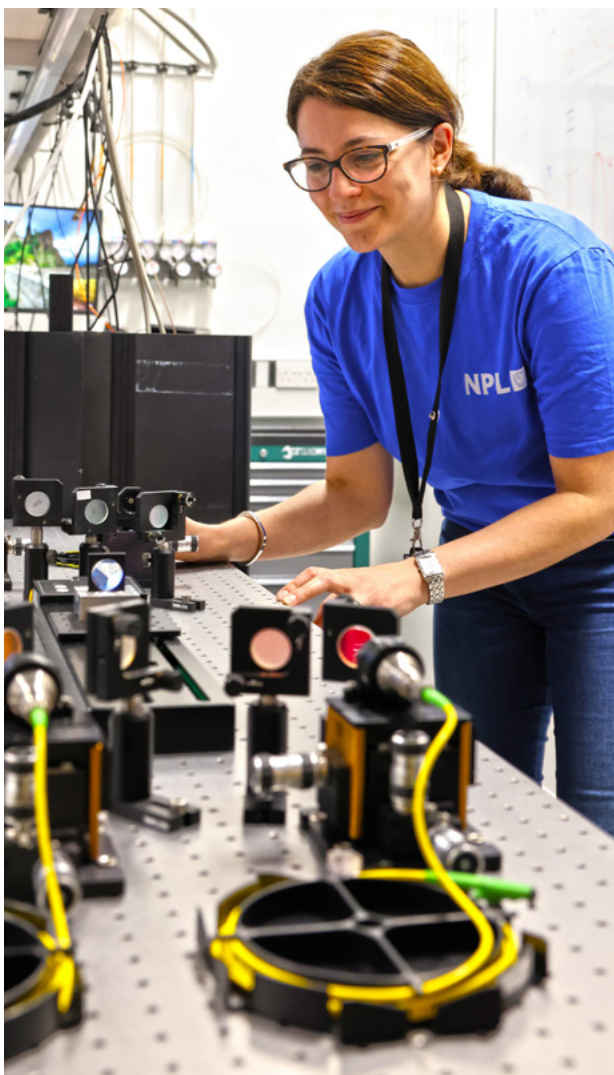
Review Board summary

Chemical & Biological Sciences

This department is dedicated to advancing chemical and biological metrology at the interface between physics, chemistry and the life-sciences with a focus on innovation and healthcare. It transfers research outputs to industry through collaborative projects, VAMAS interlaboratory studies and ISO International Standards. The range of the measurement capabilities spans nanometres to centimetres, providing a wealth of information which is essential to a wide range of industrial sectors. The department produced some of the most highly cited scientific publications at NPL. The work is generally of extremely high quality with repeated excellent testimonies from stakeholders, with expertise predominantly related to reference materials, analytical methods and data handling. To support further development, the department should increase its engagement and collaboration with biologists and strategically important national institutes.

Data Science

The focus of this department is to ensure that we can have confidence in metrology data in a digital world. It covers data analytics, modelling, informatics, digital manufacturing and digital products. Successful digital transformation depends on trust in measured values, data, algorithms, and mathematical and statistical procedures. Generation of trust requires development of procedures and standards that ensure the highest precision, integrity and 'explainability' of algorithms and data analysis methods, and that the chain of traceability back to the International System of Units (SI) be maintained throughout data processing chains. The department enables the effective and intelligent use of data through the development of cross-disciplinary application-independent frameworks and tools to maximise the reliability and value of data throughout the data lifecycle. The department is an important national resource, and it is encouraged to undertake wider communication and public engagement to make itself known to stakeholders.



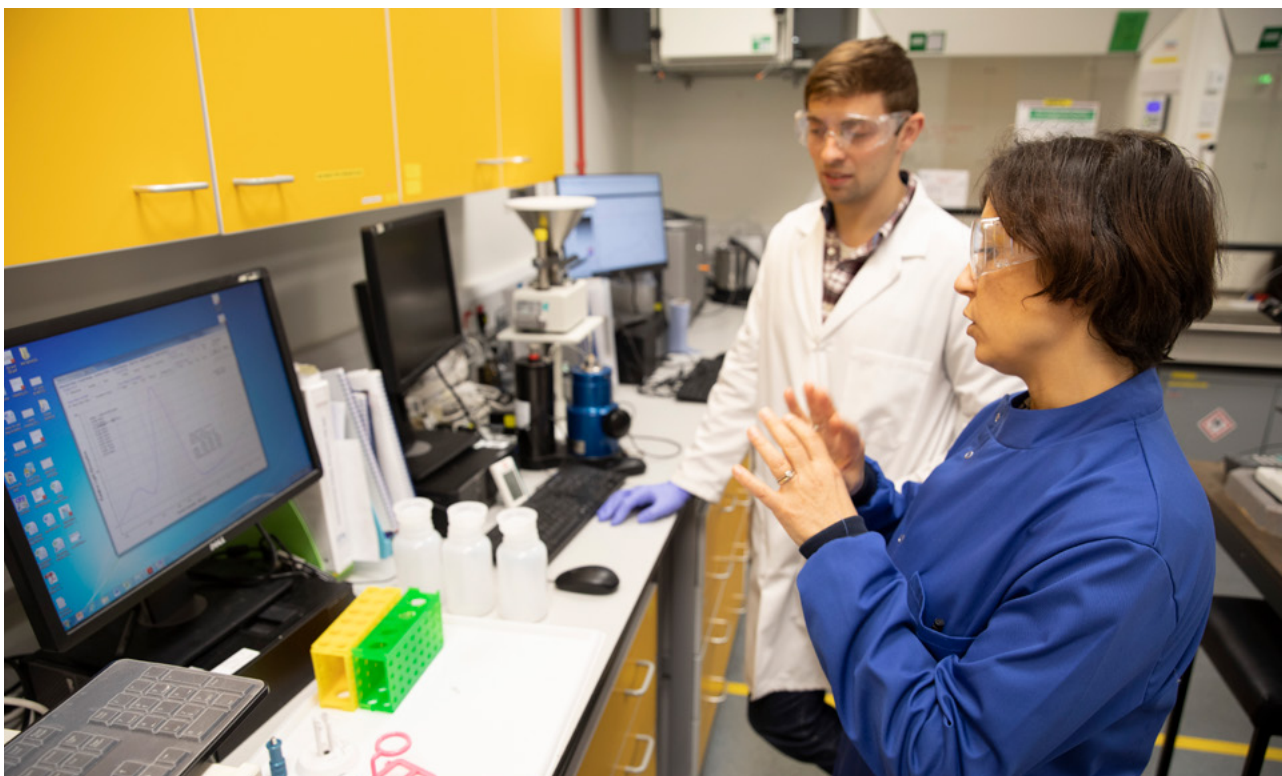
Atmospheric Environmental Science

Directly supporting UK science strengths and business capabilities, this department underpins and provides the scientific evidence and intervention to manage the impact of climate change and improve air quality for the protection of human health. It has a world-class metrology capability, providing the highest point of reference for gas composition and airborne particle properties for industrial, regulatory, government and academic stakeholders. The department responds to the measurement challenges from government and industry. It addresses the market shortfall in the UK quality infrastructure with unique facilities and expertise in the application of metrological methods in the field. It also provides scientific impartiality to inform decisions. The department delivers high quality scientific outputs, and ensures NPL holds a leading position amongst NMIs in this area. To maintain this position, the department is encouraged to review their measurement services portfolio to ensure strategic alignment with their research plans and vision.

Electromagnetic & Electrochemical Technologies

This department covers electromagnetic technologies and measurements, electrochemistry, and electronic and magnetic materials. The metrology capability is wide ranging and delivers particular impact on the UK strategy challenges of national security and resilience and the Green Recovery. Priorities for the department include work on assured autonomy, 6G communications, electrification and renewable energy. It also leads on the increasing digital focus within NMIs, and throughout industry and society. The work of the department is diverse yet well-integrated and the enthusiasm of the team for their work and its impact was demonstrated clearly. The department has a high profile and significant levels of international influence, and needs to develop a plan to maintain this.





Medical, Marine & Nuclear

This department develops, maintains and disseminates the metrological infrastructure to enable people to live longer, healthier and more prosperous lives. It covers medical radiation physics and science, nuclear metrology, ultrasound and underwater acoustics. It is responsible for developing and maintaining primary and secondary standard measurement capabilities traceable to the realisation of the derived SI units of the becquerel, the gray and the acoustic pascal. It aims to provide confidence in data and reproducible and reliable measurements. This is important for early diagnosis and precision in medicine, to develop the bioeconomy, to deliver net zero and a sustainable future, and to underpin sovereign defence capability. The department's current strength lies in its well-connected, very respected and highly qualified staff, as well as its excellent facilities. The department should continue to ensure that it engages fully with the user community through appropriate Impact Advisory Groups. This would help it reflect on the level of impact NPL wanted to achieve in each area and ensure that it retains core capability and strategic direction.

Engineering

NPL provides the underpinning metrology to UK industry to support prosperity and innovation. This department is responsible for realising and disseminating the UK's length and mass units, as well as derived units for force, pressure and density. It also develops metrology to establish the international materials measurement standards that support innovation and trade. NPL's main laboratories at Teddington and its regional centre at Huddersfield offer a range of high specification measurement and calibration services and consultancy. The department provides support to the science teams across NPL to develop instrumentation, taking particular care to ensure relevant legislation is satisfied. It also provides direct support for industrial processes, engineering and manufacturing. The departmental outputs are used throughout many sectors, such as aerospace, defence, advanced manufacturing, transport, energy and nanotechnology, either through measurement services or direct third-party contract work for industrial, academic, regulatory and government customers. The department is encouraged to consider different ways to collaborate more widely with other partners in the UK and increase its geographic reach.

Quantum Technologies

With unique expertise and knowledge of the application of quantum effects, the department has a strong base to accelerate innovation. It covers quantum electrical metrology, quantum information processing, quantum materials and quantum sensors. The department has doubled in size since 2016, reflecting research advances and metrology needs driven by worldwide quantum research and development. The department underpins UK science and business through world-leading metrology, test and evaluation expertise, and facilities. It supports UK economic growth driven by the successful development and sale of new products and services based on quantum technologies. It also leads the UK on internationally accepted quantum standards. Quantum electrical metrology provides the UK's primary point of reference linking the SI electrical units to industrial processes and customer products through UK traceability chains. The department produces work of high quality, including new science, measurement capabilities for users, and services for industry. It has a strong national and international position, and it is critical that NPL is able to continue to recruit and attract high calibre people.

Time & Frequency

Time is sometimes called an “invisible utility”, underpinning many of the technologies we depend on in our daily lives, such as digital communications, satellite navigation systems, the energy grid and high-frequency trading. The department operates the national time scale UTC(NPL) and maintains the primary frequency standards used to realise the SI second, ensuring international equivalence through participation in Coordinated Universal Time (UTC). The department uses this infrastructure to provide customers and partners with access to trusted and reliable time and frequency. It also undertakes a wide-ranging programme of research that pushes the boundaries of timing technologies, including optical frequency metrology towards a redefinition of the SI second and compact atomic clocks and sensors for end

user applications. There are many linkages between the different areas and as a result crossdepartment working is common. The quality of science in the department is outstanding. The department has contributed ground-breaking research and has also been a key contributor to broad European collaborations. NPL should consider having an independent economic impact analysis performed to evidence the value of the infrastructure protection and commercial impact of the department's services.

Thermal & Radiometric Metrology

This department realises and disseminates primary capability in thermometry, humidity measurement and radiometry, including the SI units the kelvin and candela. It has a strong focus on the impact metrology can have on societal challenges, with an emphasis on industry, environment variables and earth observation. Its measurement infrastructure underpins traceability for a very wide range of applications. The work on Earth observation and optical radiometric metrology are focused on environmental monitoring challenges, in particular, enabling accurate, traceable measurements which can be demonstrated to be equivalent. This is crucial for reliably informing climate policy. The scientists have significant international influence, bringing metrological principles to the heart of satellite-based Earth observation through research and international collaborations, and by embedding metrological principles in key influential institutions. The research on temperature metrology has been fundamental to the redefinition of the kelvin and the department continues to provide global leadership in the resulting applications across government, industry and academia. The department could consider refreshing its underpinning measurement infrastructure capability to support future work.


Looking forward

I would like to give my sincere thanks to Professor Dame Anne Glover and the Review Board for their work in carrying out this International Science Review. Despite the review being delayed due to the pandemic, we welcome the recommendations and are using them to shape our future research strategy.

NPL has continued to grow over the past few years, and we now have approximately 950 people working in our science and engineering teams. Our recently launched graduate scheme demonstrates our continued investment in people and skills, and complements our established apprenticeship programme. We were proud to publish our new Diversity and Inclusion Strategy in 2022 and annually issue a research integrity statement.

The International Science Review provided NPL with a thorough review of its science and engineering capabilities, as well as benchmarking it against similar organisations. We are constantly examining how we can maximise our impact, and the focus of the review on foresighting, agility and resilience continues to be extremely useful. All these activities contribute to NPL being a world class laboratory and an excellent place to do science.

We look forward to continuing to evolve and respond to national challenges, as well as boosting prosperity and quality of life in the UK.



JT Janssen, NPL's Chief Scientist
May 2023





NPL

National Physical Laboratory

www.npl.co.uk

National Physical Laboratory, Hampton Road, Teddington, Middlesex, TW11 0LW

Disclaimer: Although every effort is made to ensure that the information contained in this document is accurate and up-to-date, NPL does not make any representations or warranties, whether express, implied by law or by statute, as to its accuracy, completeness or reliability. NPL excludes all liabilities arising from the use of this document to the fullest extent permissible by law. NPL reserves the right at any time to make changes to the material, or discontinue the leaflet, without notice. The NPL name and logo are owned by NPL Management Limited. Any use of any logos must be authorised in writing.