Advanced Manufacturing | Digital | Energy and Environment | Life Sciences and Health

Insights

Beyond Measurement

Ensuring the 5G revolution is a success

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We make your impossible possible

NPL

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AUTUMN 2017

NPL

Foreword

Dr Peter Thompson, CEO of NPL

NPL re-launches to address global challenges and accelerate UK industry

In 1902, the future King George V opened NPL, declaring that it would "bring scientific knowledge to bear practically upon our everyday industrial and commercial life." It was a grand vision, seeking to translate scientific discoveries into economic growth, skilled employment and improved quality of life.

Today we are renewing this vision and re-launching NPL to cultivate growth across areas the UK will most benefit from in the future: advanced manufacturing, digital, energy and environment, and life sciences and health.

We will draw on our century of expertise and world-class facilities to develop new technologies, standards and skills in industries of the future, from Industry 4.0 to the hydrogen economy.

NPL is emblematic of the way research can drive economic and social progress. The impact of the science and engineering that we deliver is felt by everyone, everywhere. The first caesium atomic clock, that led to the redefinition of the second 50 years ago this October and whose descendants now underpin GPS and telecommunications, was created here. Packet switching, the forebear of the internet, which allowed the worldwide exchange of data across digital networks; radar, which revolutionised navigation and defence; and a new chip that brings us a step closer to quantum computing – all were developed at NPL.

By re-launching NPL, we will forge a stronger link between lab and market, creating the measurement standards that support new trade and commercial innovation. We will further our pioneering work helping to save lives, protect the environment and enable citizens to feel secure.

In this magazine, you can read about some of the work taking place at NPL's bases around the UK and our plans for the future, and hopefully be amazed by the quality and impact of what we do.

After a century as the silent partner to industry, helping to deliver now-ubiquitous innovations and advances, the next 100 years will see us continue this crucial role, but in the foreground, delivering ever greater impact to the UK. **We will make your impossible possible. I, for one, cannot wait.**

DIGITALLY ENABLED SUPPLY CHAINS:

WHY DATA CONFIDENCE IS CRITICAL FOR UK MANUFACTURING PRODUCTIVITY

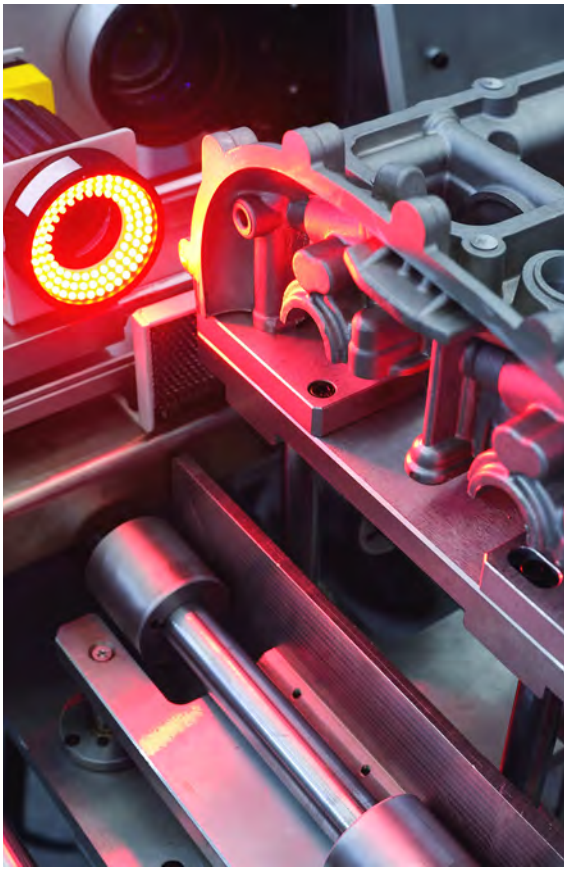
JANINE DE FENCE, STRATEGIC DEVELOPMENT MANAGER FOR ADVANCED MANUFACTURING AT NPL

THE INCREASING AVAILABILITY AND CAPABILITY OF DIGITAL TECHNOLOGIES AND TOOLS ARE CHANGING THE LANDSCAPE FOR MOST BUSINESSES IN A FUNDAMENTAL WAY, CREATING OPPORTUNITIES FOR SIGNIFICANT IMPROVEMENTS IN QUALITY, PRODUCTIVITY AND COMPETITIVENESS.

The increasing availability and capability of digital technologies and tools are changing the landscape for most businesses in a fundamental way, creating opportunities for significant improvements in quality, productivity and competitiveness. Enabling confidence in the data that these digital technologies generate will be critical for consumers, businesses and the UK economy to see the full benefit of the digital age.

Industrial digitalisation describes the application of digital technologies and tools to the manufacturing sector. It is often referred to as Industry 4.0, or digital manufacturing, and will disrupt and change traditional manufacturing and its supply chains, while creating new products, processes, business opportunities and markets. A recent study by the Tech Partnership identified that, by fully applying industrial digital technologies over the next decade, UK industrial production would be up to 30% faster and 25% more efficient.

Within manufacturing, some of the most immediate impacts from digital technology adoption will take place in the factory, allowing organisations to achieve greater machine utilisation and resource efficiency, as well as providing an unprecedented



BY FULLY APPLYING INDUSTRIAL DIGITAL TECHNOLOGIES OVER THE NEXT DECADE, UK INDUSTRIAL PRODUCTION WOULD BE UP TO **30% FASTER AND 25% MORE EFFICIENT.**

level of generated data, allowing for greater process feedback and feed forward. Beyond the digital factory lie opportunities within the supply chain. The creation of digitally-interconnected end-to-end supply chains will enable increased flexibility and responsiveness in the face of changing customer demands and trading conditions through the opportunity to track, trace, monitor and respond in real time. Many companies have already moved in this direction, with a PwC report identifying that a third of more than 2,000 industrial companies, across sectors, have already started the journey to digitalise their supply chains, while nearly three-quarters expect to by 2020.

At the heart of the integration between the physical and digital world sits data. The problem with data is not just about translating it into information, or the risk of cyber-attacks, but there is a significant industrial challenge with data confidence. Without data confidence manufacturers will not be able to use data effectively or make confident decisions based on the data. So what does this mean? This means that efficiency gains, cost and waste reductions, and competitiveness opportunities throughout the supply chain will be lost. By enabling data confidence, data can flow up and down the supply chain and be used to make correct, often critical, decisions, as well as improve the quality of the manufacturing process. ▸

To enable confidence in data the user needs to understand what the data means and how accurate the data is. Solving this challenge will require new and innovative measurement, and data integration techniques, as well as an ability to accurately trace data to primary measurements and internationally-accepted standards; NPL lies at the heart of the UK's primary measurement system and is thus ideally placed to take this concept into the digital realm. NPL's Digitally Enabled Supply Chain (DESC) programme will provide the catalyst to enable data confidence throughout supply chains and establish a world-leading position for the UK .

The DESC programme has been designed to address data challenges through a focus on data collection, data validation, data uncertainty and trust of data as it passes through process and systems, and between organisations. As the UK's National Measurement Institute, NPL will enable data-confident approaches to technology insertion across manufacturing applications and sectors. It will accelerate the capability of the UK supply chain base, particularly SMEs, through regionally-based access to NPL and delivery partners that provide digitally-relevant skills support.

In summary, DESC will ensure that the UK realizes the full benefits of industrial digitisation, and that data flows up and down the supply chain can be used to make the best possible decisions, with confidence. This will position a competitive UK manufacturing sector and supply chains for growth in a global market.

NPL named member of All-Party Parliamentary Manufacturing Group

As part of our re-launch, and four new focus areas, NPL is set to transform the way we support the manufacturing industry. We will deliver the science, technology and engineering that will allow the UK to continue to grow its economic impact across the manufacturing value chain and ensure its continuing competitiveness.

We are currently working with colleagues from across industry, academia and government to identify end-user requirements, support policy-making and enable sustainable growth in the UK. Further to this, we are delighted to confirm our membership of the All-Party Parliamentary Manufacturing Group (APMG).

Dr George Dibb, Head of Manufacturing, Design and Innovation at Policy Connect, said: "We're extremely pleased to have NPL join the APMG. The APMG exists to connect MPs and members of the House of Lords interested in putting manufacturing at the heart of the UK's policy agenda with industry experts and manufacturing organisations. With a track record of support for innovation in industry and a new advanced manufacturing strategy, NPL's contribution to the group will be invaluable."

"With a track record of support for innovation in industry and a new advanced manufacturing strategy, NPL's contribution to the group will be invaluable."

Unlocking product verification opportunities for the aerospace industry

NPL and the Aerospace Technology Institute (ATI) have published a new report following a comprehensive consultation that set out to identify the critical measurement needs that will assure performance and quality across aerospace manufacturing. The report identifies a potential £2 billion per year opportunity for the aerospace industry if better product verification practices are adopted.

Product verification processes are used to assess whether a product meets the originally specified requirements. Improvements to these processes generate savings through shorter product development lead times, increased productivity, and greater confidence and trust in the supply chain.

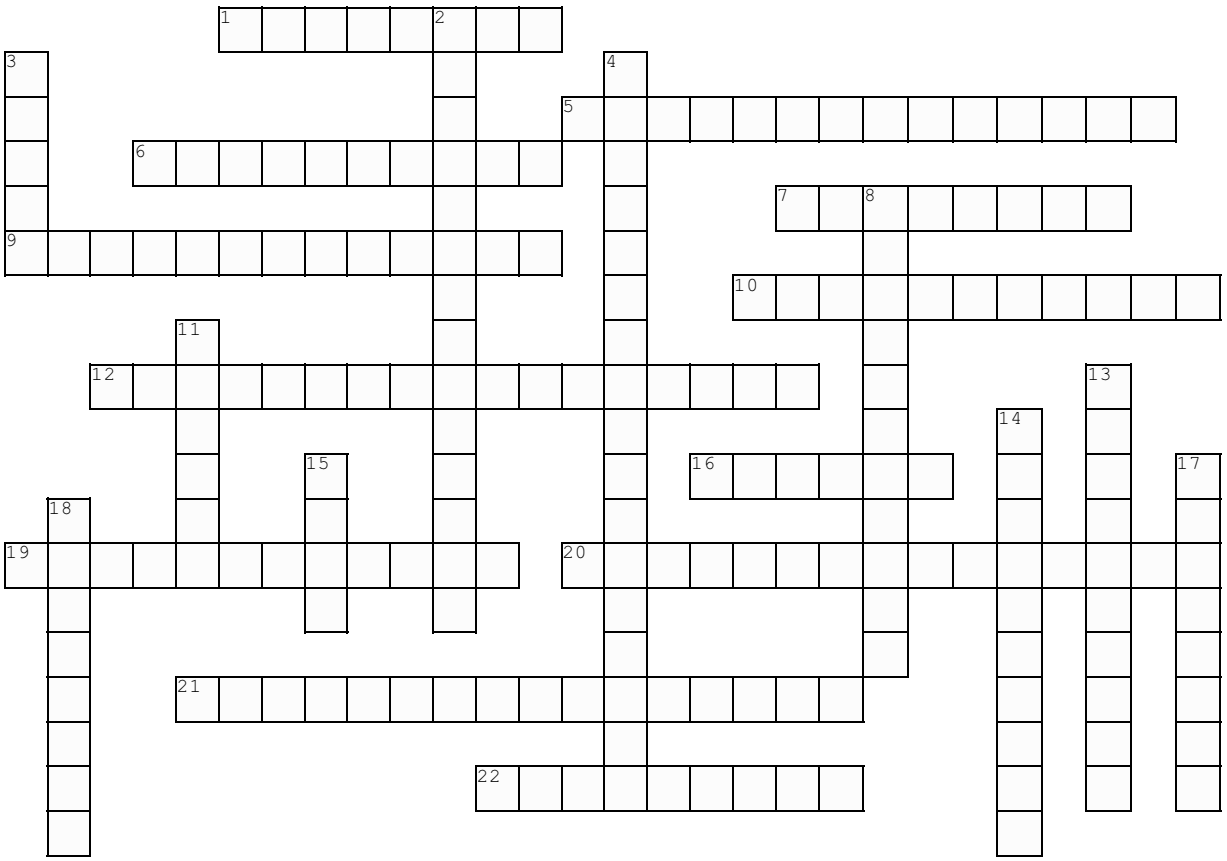
As manufacturing embraces new technology and processes, new measurement challenges are emerging. New manufacturing processes and materials are creating complexity that requires optimal measurement practices to ensure right first-time manufacturing, and digitalisation of supply chains and production lines is driving a need to build confidence in data through measurement.

The report recommends a focus on three areas of product verification, to realise its potential savings: investment into state-of-the-art research, creation of demonstrators, and provision of skills.

NPL's product verification team has identified £10 million of savings across 45 UK manufacturers over three years and will be working closely with industry and partners to progress these areas and ensure NPL's excellent science and engineering supports the UK manufacturing sector to grow.

Complete the crossword to win a prize!

COMPETITION



Across

1 Location in France that is home to the European Synchrotron Radiation Facility
5 Architect of Bushy House, original home of NPL
6 Earth Observation programme named after a Renaissance- and Reformation-era mathematician and astronomer
7 A cylinder made from an alloy of platinum (90%) and iridium (10 %) is used to define this SI unit
9 1955 film with Michael Redgrave, part-filmed at NPL
10 Act of Parliament implemented in 1956 to reduce air pollution
12 This 'Day' falls on 20 May every year
16 Fundamental physical constant that is key to the redefinition of the kilogram
19 NPL scientist who developed packet switching
20 International treaty signed on 20 May 1875
21 Former Superintendent of the Radio Department at NPL, played by Eddie Izzard in BBC drama Castles in the Sky
22 Designed the first caesium atomic clock with Louis Essen

Down

2 2016 review by UK government of quantum technologies
3 Ancient unit of measurement, defined as the length of the arm from the tip of the finger to theelbow
4 First Director of NPL
8 27 of these have been added to Coordinated Universal Time since 1972
11 Country where the 'best blue sky' was measured
13 Type of battery found in mobile devices and cars
14 Designed the Automatic Computing Engine at NPL
15 NPL's remote sensing lab on wheels
17 This weighed 78,700 kg when measured by NPL in 1979
18 Name of the UKs first portable intraoperative radiotherapy machine, used to deliver targeted radiation during surgery

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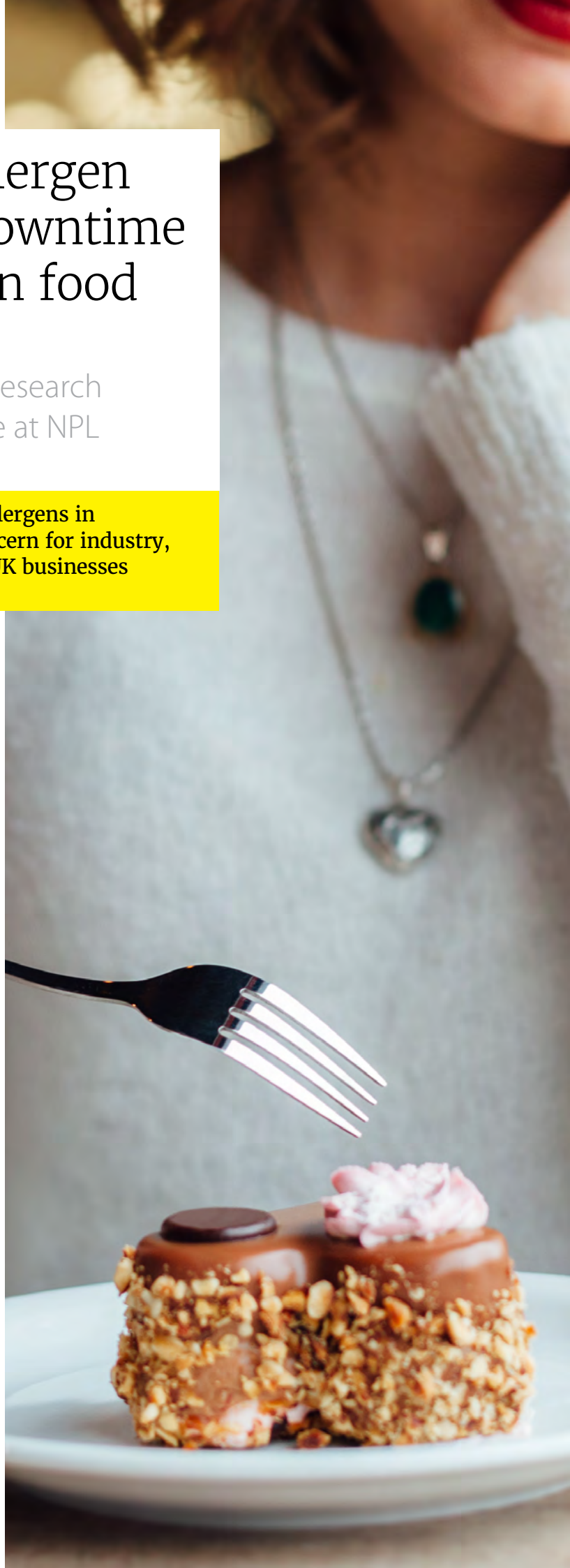
Scan and submit your completed crossword to **communications@npl.co.uk** to be in with a chance of winning an **NPL goody bag!**

Visit **npl.co.uk/terms-conditions** to view the full terms and conditions

New graphene allergen sensor reduces downtime and safety risks in food manufacturing

Dr Olga Kazakova, Principal Research Scientist in Quantum Science at NPL

Today, the effective management of allergens in manufacturing operations is a key concern for industry, and one that can prove very costly to UK businesses through increased downtime.



The UK has some of the highest prevalence rates of allergic conditions in the world. It is estimated that 1-2% of adults and 5-8% of children in the UK have some sort of food allergy – this equates to around two million people. Often, trace quantities of allergens, such as milk, can be found in food processing plants at very low concentrations and can trigger an immune response in allergic individuals, ranging from hives to severe gastrointestinal and respiratory symptoms, and, in serious cases, anaphylactic shock. As a result, where there is a possibility of cross-contamination, food producers are obliged to label products or recall incorrectly-labelled products and refund customers, costing millions for businesses.

Such recalls are a clear public health concern, but, moreover, they pose a significant economic challenge for the UK's manufacturing industry, requiring product retrieval, storage and destruction, and leading to unsaleable product, as well as potential legal costs and damage to brand reputation. This is a growing issue for businesses, principally due to the lack of monitoring systems capable of rapid and accurate measurement of allergen levels in foods. Currently, manufacturers must send off samples for testing, meaning production must be halted and increasing switchover times between products.

A recent Innovate UK project, delivered by NPL, Unilever, ProGnomics (a spin-out of Swansea University) and the University of Cambridge, has developed an in-situ graphene allergen sensor to solve this issue. This sensor will help ensure that milk allergens are removed after production, to ensure the safety of other products and help manufacturers become more productive and efficient.

This was achieved by exploiting the exceptional electronic properties and surface sensitivity of graphene, which allow it to work as an effective sensor. The detection mechanism works by using chemically-modified graphene that includes antibodies specific to the allergen being detected. The antibody on the sensor will bind with the antigen of the allergen present. This process results in the transfer of the electrical carriers between the biological molecule and graphene that increases the device resistance and gives a reading of the allergen level. This simple, yet effective, field setup is capable of detecting binding events down to parts-per-million level and doing so in real-time on the factory floor, providing a quick, comprehensive and accurate indication of even a small quantity of allergen residue in production plants. ▸

By reducing cleaning times and waste, as well as energy and water consumption, the sensor could significantly increase manufacturing efficiency for food producers.

NPL provided unique access to state-of-the-art facilities for the project, to monitor the microstructure and electrical properties of the various sensor prototypes to identify the industrial promise and effectiveness of them. The project has provided a real glimpse into the future and shows what could be possible with the development of an easy-to-use sensor capable of monitoring allergen levels. Chemical modification of graphene means that such a biosensor could be used to identify the presence of other allergens in food manufacturing in the future.

The sensor offers significant benefits to the manufacturing industry. By reducing cleaning times and waste, as well as energy and water consumption, the sensor could significantly increase manufacturing efficiency for food producers. What's more, it will also improve process monitoring with specific in-situ measurement that will provide improved quality assurance, enabling potential issues to be predicted and rectified before they halt production or cause a safety risk for consumers.

Manufacturing is critical to the UK, accounting for 45% of our exports and employing 2.7 million people, with more in food and drink manufacturing than anywhere else. This importance will only increase as the country becomes independent of the EU, so it is essential that our world-leading research in fields such as graphene is harnessed to protect and grow the productivity of this industry.

The UK has some of the highest prevalence rates of allergic conditions in the world.

New composites test facility to open

NPL is working closely with UK company Instron to open a new facility in 2018 to provide a world-leading mechanical testing capability. From metals to ceramics, the facility's state-of-the-art equipment will provide comprehensive testing of a vast range of materials over a wide temperature range, but will in particular help UK industry to better take advantage of new composite materials.

Advances in composites promise significant advantages for infrastructure such as bridges and products such as cars, offering desirable properties like reduced weight or increased strength for lower cost. The opportunity for the UK is significant, with the potential to grow its current £2.3 billion composite product market to £12 billion or more by 2030. Yet uptake of these exciting new materials is limited due to a lack of standard data and thorough testing capabilities, which prevent industry from having the confidence that they will perform as claimed.

NPL's expertise in material characterisation and evaluation will ensure that testing is traceable and reproducible, providing industry with full confidence and assurance in the suitability and performance of new composite materials and enabling their real-world application. NPL will also help to develop ever-more comprehensive testing techniques and lay the groundwork for new regulations, codes and standards, ensuring that the benefits these materials offer are realised as soon as possible.

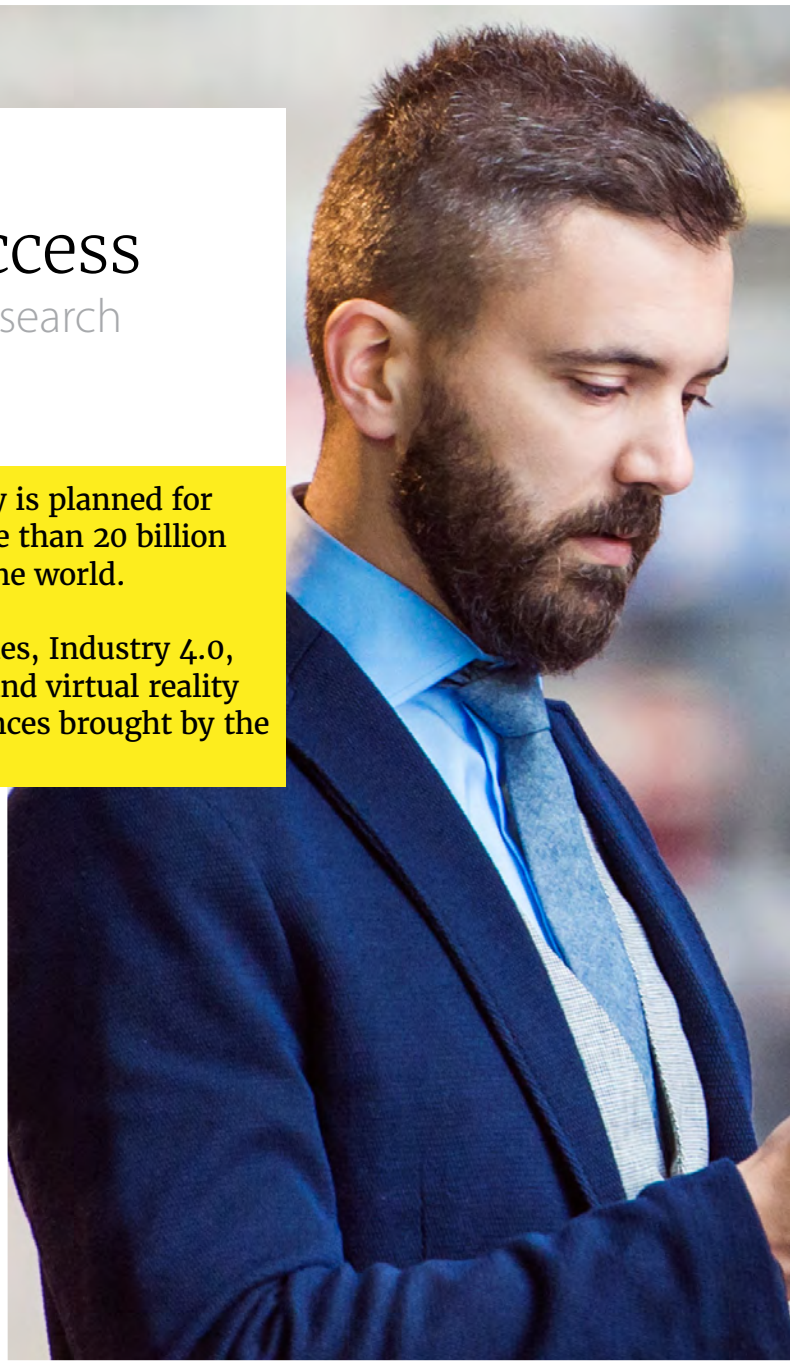
The opportunity for the UK is significant, with the potential to grow its current £2.3 billion composite product market to £12 billion or more by 2030.

Ensuring the 5G revolution is a success

Dr Tian Hong Loh, Principal Research Scientist at NPL

Fifth generation or 5G mobile technology is planned for deployment in 2020, by which time more than 20 billion connected devices will be in use across the world.

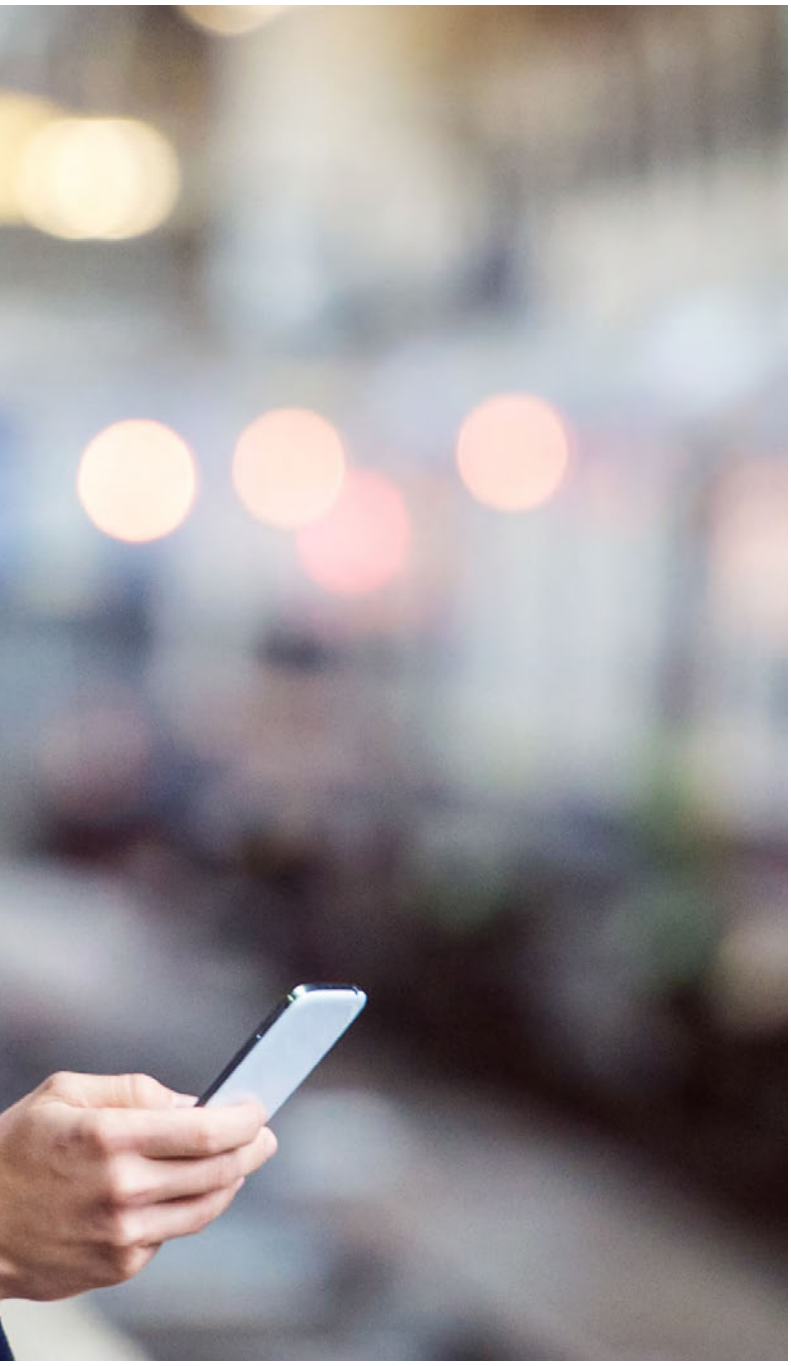
Emerging applications such as smart cities, Industry 4.0, autonomous cars, precision agriculture and virtual reality will all rely upon the technological advances brought by the 5G network.



The 5G network won't just deliver a much higher data capacity and faster mobile internet connection. It will also allow for 90% less energy consumption and provide more reliable coverage, forming the basis on which the UK will implement its digital economy. Digital technology is predicted to boost the UK economy by £55 billion by 2020 and, with a significant proportion of components in smart devices designed in the UK, we need to maintain our competitive edge and ensure the technology we manufacture in the UK is easily exportable to other markets.

The timing of 5G's rollout is apt, as technological innovation and rising demand for data means that industry and society desperately require a communication network tailored to our data-hungry needs. Existing 3G and 4G networks were introduced without the relevant measurement infrastructure and standards in place, and there are still discrepancies in measurement. This meant that even when a device claimed to be fully connected to a 4G network, there was no traceable means of proving it – which might explain why those emails were never sent on the train home. This led to increases in cost for consumers and problems when exporting technology, stifling innovation and damaging trade. If we are to unlock the full potential of 5G, this cannot happen again.

To ensure that the 5G vision is realised, new supporting metrology needs to be developed alongside product development. There is a shortage of available frequency spectrum below 6 GHz meaning that millimetre-wave frequency bands are a good candidate to explore for 5G smart device applications, but shifting to these frequencies presents problems such as loss of signal without line of sight. To tackle these challenges, NPL is at the forefront of an array of cutting-edge projects to develop new antennas that can operate at millimetre-wave frequencies and provide a reliable signal when integrated into a smart device.

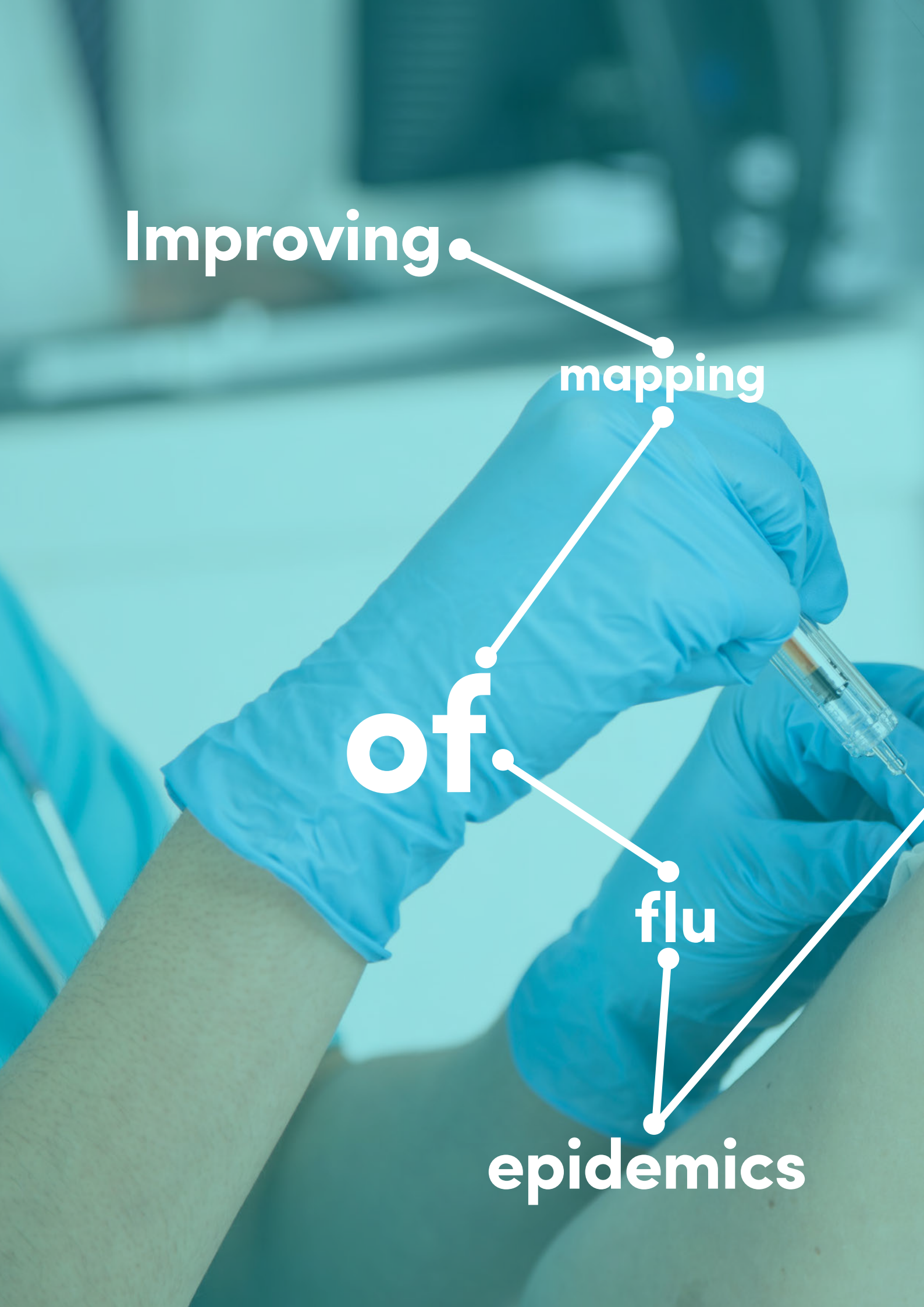


We need to maintain our competitive edge and ensure the technology we manufacture in the UK is easily exportable to other markets.

Digital technology is predicted to boost the UK economy by £55 billion by 2020.

In addition to developing and testing new hardware, we are working on developing standards for 5G to ensure it is interoperable globally, leading a European project, MET5G, on the measurements underpinning 5G, with input from researchers and key industrial stakeholders. Through this project, our world-class scientists and facilities are testing technology, signals and the real-world environmental factors affecting 5G performance. As part of our strategic partnership with the University of Surrey, we are also a member of the 5G Innovation Centre (5GIC), now the largest UK academic research centre dedicated to the development of the next generation of mobile and wireless communications, and we jointly run the Nonlinear Microwave Measurements and Modelling Laboratories (n3m-labs), which help develop the next generation of super-efficient electronic devices.

For industry and society to be able to benefit from this step change in connectivity, we need to provide measurement support to underpin all aspects of 5G – the signals, devices, systems and test environments. NPL's work is key to making this happen – it will help to provide a competitive edge for industry in the UK, improve the speed to market for 5G products, and ultimately improve engagement between consumers and the latest cutting-edge technology.


Improving
mapping
of
flu
epidemics

through data science

In the UK, the seasonal flu epidemic kills an average of 600 people each year, but this can fluctuate enormously, especially in pandemic years. However, capturing enough data to predict an outbreak is difficult due to the unpredictable nature of the influenza virus.

Prof Simon de Lusignan, Professor of Primary Care and Clinical Informatics, and Head of Department of Clinical and Experimental Medicine, University of Surrey

Many factors can influence the length and severity of an outbreak. These can vary from what type of influenza viruses are spreading and the peak times of an outbreak, to whether scientists can offer a vaccine compatible with the right virus. Furthermore, as the influenza virus adapts and mutates, every solution must be provided on a case-by-case basis. For example, the outbreak of swine flu in 2009 was an irregular strain in that it did not severely affect the age groups who are usually most vulnerable. While seasonal flu often has its greatest impact on older people, the worst affected by swine flu were adults under 65 years old.

Since 1967, the Royal College of General Practitioners Research and Surveillance Centre (RCGP RSC) network has been actively monitoring incidents of influenza, alongside other diseases, in a long-standing surveillance and research partnership with Public Health England (PHE) and its predecessor organisations. The network is the principal surveillance system for England. It extracts data from around 200 volunteer GP practices, collecting anonymised data. This data enables the NHS to find spikes of outbreaks during the different seasons of the year, to assess their effectiveness and support vaccination programmes. The network played an important role in reporting the swine flu epidemic. (The RCGP RSC secure data and analytics hub moved to Surrey in 2015.)

The quality and accuracy of the UK's medical records is high, but factors such as the structure of GP appointments and human input can lead to inconsistencies. Most GP appointments are 10-minutes long and a GP can see as many as 40 people a day. These constraints can limit data quality in computerised records. Any inconsistencies in data or reports recorded limit the knowledge we can glean from the

"As we improve our ability to analyse and utilise big data, such as through our partnership with NPL, we will unlock exciting new opportunities to improve and innovate healthcare in the UK."

retrospective data. We, at the University of Surrey, usually run weekly data quality checks to ensure the data received is coherent. However, due to data quality issues or incomplete extraction, we have to exclude around 10% of recorded data as they do not meet the required standards.

We have recently started work with NPL, using their data mining expertise to study the data monitored by RCGP RSC and correct missing or mis-coded incidents not properly tracked by the network – in particular, differentiating a new incident case of an influenza-like illness from a follow-up. NPL's algorithm will enable us to analyse the corrected data weekly and historical data will be analysed retrospectively. This level of accuracy should provide us a clearer and more comprehensive picture of peaks in different influenza epidemics, and allow us to include data we currently discard. Such visibility will allow us to easily identify trends over time, and ultimately improve the accuracy of epidemic early warnings, and increase our understanding of the impact of infection on certain demographics. It will also give us a new perspective on the efficacy of new vaccines and other treatments, and improve our ability to plan for and treat flu epidemics.

This opens many avenues to how we can better utilise this data in the future. For example, there is the potential to combine current data sets with other information, such as data from social media. We have researched this possibility in conjunction with University College London and PHE. The findings found a correlation between our data sets and data from Twitter. It is best to be cautious about social media in the context of predicting epidemics, given the self-reported and unverified nature of the data. However, it is certainly true that as we improve our ability to analyse and utilise big data, such as through our partnership with NPL, we will unlock exciting new opportunities to improve and innovate healthcare in the UK.

Improving lithium-ion battery safety

The lithium-ion battery is a staple of modern life, used in applications from smartphones and tablets to vehicles and medical devices. In certain conditions, however, they can overheat and explode, causing significant safety issues that have been well documented in recent times.

NPL is part of a collaboration with University College London, the European Synchrotron Radiation Facility, NASA's Johnson Space Center, the US Department of Energy's National Renewable Energy Laboratory, the University of Warwick and Diamond Light Source, researching how lithium-ion batteries behave under short-circuit conditions.

For the research, short circuits were initiated inside the batteries at pre-determined locations and monitored using high-speed X-ray imaging, to assess the damage in real time and see how thermal runaway spread throughout the battery cells. The cells went from being completely intact to being completely destroyed within around one second. The findings show the importance of isolating failing cells to prevent dangerous chain reactions of battery failures, and will help to improve reliability and safety of lithium-ion batteries in the future.

NPL*Time*® expands to meet demand ahead of MiFID II implementation

NPL is expanding its precise timing network, NPL*Time*®, through a distribution agreement with QuantHouse, an end-to-end systematic trading solutions provider. The agreement comes ahead of the implementation of the European Securities and Markets Authority (ESMA) update to the Markets in Financial Instruments Directive (MiFID II), which will require financial organisations to achieve up to 100 microsecond level traceability of trading events by 3 January 2018.

NPL*Time*® provides a certified precise time signal traceable to Coordinated Universal Time (UTC) and accurate to within one microsecond. It enables users to be fully compliant with MiFID II requirements and eliminate their reliance on GPS, removing susceptibility to jamming, spoofing, urban canyon effects and space weather. The agreement with QuantHouse will provide its customers with the underpinning timing capability for traceable timestamping, latency monitoring and synchronisation. The service is also available through ICE:NYSE and Intergence.

"In today's markets, timing is everything; precise timing offers competitive advantage and ensures regulatory compliance."

Leon Lobo, Strategic Business Development Manager at NPL

INTERVIEW

An apprentice with a need for speed

Joshua Schofield is an engineering apprentice at NPL. He is leading the F1 in Schools English Champions team to design, manufacture, market and race a car powered by compressed air. After beating the competition to finish second in the UK Finals, Joshua's team is heading to Malaysia to compete in the World Finals in September 2017. We caught up with him to hear about his apprenticeship experience so far, and his ambitions to race for gold.

Why did you decide to pursue an apprenticeship?
I grew up in Kent and attended a grammar school. From early on, I chose STEM subjects, including engineering GCSE and maths, physics, biology and systems and control AS Levels. After those, I decided to pursue something more practical to gain more skills and experience, which is why I considered an apprenticeship. I told myself that I'd only go for an apprenticeship if I found the right one. Fortunately, the opportunity at NPL caught my eye, and here I am!

What has been your experience so far?
It's been great. Most of our first year was spent full time at Kingston College, learning the ropes. Since the end of June we've been at NPL – and the apprentices have even been given our own office! I'm currently working with the NPL Instruments business, which overlooks the vast engineering workshop, working on a laser testing system which calculates the reflectance and transmittance of samples. Then, from Christmas, I'll move to the workshop itself and then to the design office. I'm already using a lot of the skills we learned at college in practice here, like CAD and machining. The calibre of people at NPL is incredible and I'm amazed every day by the work that goes on here.

Tell us about your F1 in Schools team
I first got involved in the competition as a young kid. It was a really exciting way to apply normal classroom work into something practical, and made a change from coursework. The competition is huge, with 20 million people involved from 50 countries. It's also comprehensive, testing not only engineering skills, but also business-related activity such as sponsorship success and marketing – just like running a real F1 team! This year, our team, Tiro Racing, are all junior engineering apprentices, and includes Toby Thompson, who is also at NPL. Tiro (pronounced Tie-ro) means apprentice in Latin, so we felt this would be an appropriate name!

We are now the first team of apprentices to ever reach the World Finals in the competition's 14-year history!

What gives you the competitive edge?
Having people that have already made an engineering career choice has definitely helped. The competition involves a lot of work when everyone else is enjoying their time off, and requires high-accuracy parts, so having people who are both really interested and skilled has been vital. Kingston College and NPL have also been a major factor in our success, giving us access to outstanding training and facilities. Thankfully, the hard work has paid off, and we are now the first team of apprentices to ever reach the World Finals in the competition's 14-year history. Competing at a global level is a once-in-a-lifetime experience and something we will never forget – becoming World Champions would be incredible, but we'd love to come away with an award.

Where next?
While I can't enter the competition next year, I will definitely be involved in one way or another, such as through mentorship or judging. As for my career, I'm considering doing a degree apprenticeship, to get a degree in engineering or instrumentation. For now, I'm excited to see what the next few years will hold, and can't wait to get involved with more projects at NPL.

Follow Tiro Racing's progress:
@TiroRacing on Twitter
and **Facebook**

Jane Burston, Head of Energy and Environment at NPL

THE FUTURE OF METHANE MONITORING

DO SATELLITES HOLD THE ANSWER?

The amount of methane in the atmosphere today is higher than at any point in at least 800,000 years. Concentrations have grown by 150% since the Industrial Revolution, with levels surging particularly fast in the past decade. This is a big problem for climate change, as methane is a much more powerful greenhouse gas than carbon dioxide (CO_2), causing 28 times more warming compared to CO_2 over a 100-year timeframe.

To reduce methane emissions we first need to understand where the methane is coming from. Current technologies for monitoring methane emissions are largely ground or aircraft based. NPL leads in the development of some of these technologies, such as the DIAL system: a portable lab that can accurately map emissions sources from individual sites. While techniques like this are very accurate, deploying these at the scale needed and having the resources to maintain and interpret the data, are commercially unviable and practically impossible.

Could a new generation of satellites help to solve the problem? Certainly, taking measurements from space provides global coverage, giving ready access to sites that account for significant methane emissions but are hard to access or measure, such as industrial sites or vast areas of farmland.

Satellite measurements could also add a level of scrutiny to each country's self-reported inventories that is impossible to achieve from the ground. Currently, inventories are inferred by multiplying the amount of polluting activities each country does with a standardised factor for how much methane each of those activities emits. This method is uncertain, with calculations of methane potentially off by as much as 50% for India and between 30% and 40% for Russia. Effective satellite measurements could verify and improve the calculations used for the inventories and provide repeat measurements to monitor trends over time.

Indeed, satellites have measured methane from space for the last 15 years, but these were designed to monitor regional scale concentrations and are not intended to detect individual point-sources of emissions. Therefore, current satellites can't be used by, for example, industrial operators who want to be able to fix leaks or governments who want to ensure the right policies across the right sectors are in place to reduce them.

What's more, existing satellite instruments use reflected sunlight to make the measurements, so can't operate at night or measure through clouds, limiting the amount of usable measurements.

THERE IS CLEARLY NO SILVER BULLET FOR ACCURATELY MONITORING SOURCES OF METHANE. WHAT'S NEEDED IS A HOLISTIC APPROACH, COMBINING THE GLOBAL COVERAGE OF SATELLITES WITH THE ROBUSTNESS OF GROUND-BASED MEASUREMENTS AND VALIDATION.

Another option is to use an instrument which produces its own source of light instead. The French–German MERLIN satellite will be the first mission to use this technology and is planned for launch around 2020. This is intended to give 24-hour coverage but spatial resolution will be around 50 km, which is only useful for measuring the average methane concentration over large areas.

Satellites have several other limitations too. They produce vast amounts of data requiring huge data servers and powerful computers to process. If they break, expensive replacements have to be launched, taking years to build and resulting in gaps in the data. What's more, winds and jet streams cause gases in the atmosphere to mix together. Satellite measurements therefore have to be combined with weather models to calculate where the methane has come from.

Despite this, satellite technology is improving with every new launch and resolutions are beginning to demonstrate the possibility of detecting individual methane sources from space. Nations recognise the need to improve capabilities, and more than 60 of the world's space agencies signed the New Delhi Declaration in May 2016, which acknowledges the need to develop new technologies and models and establish an international, independent system for estimating and curbing emissions based on accepted data.

There is clearly no silver bullet for accurately monitoring sources of methane. What's needed is a holistic approach, combining the global coverage of satellites with the robustness of ground-based measurements and validation. The emerging era of big data and advances in computing power and modelling provide exciting opportunities to combine data sources into a comprehensive service to improve on the current inventory method.

With methane emissions rising as quickly as they are, progress can't come soon enough.

The importance of understanding limitations of low-cost air quality sensors

Dr Richard Brown, Fellow in Chemical Metrology at NPL

Poor air quality is an increasing concern in urban areas. The Royal College of Physicians states that, annually, "inhaling particulates causes around 29,000 deaths in the UK, which … may rise to around 40,000 deaths when also considering nitrogen dioxide exposure."

These associated health effects have led members of the public to take action to reduce air pollution, through initiatives such as Clean Air Day, as well as monitor air quality and their exposure for themselves.

While government-run monitoring stations provide valuable data on the air we breathe on busy streets, it is impossible to have them on every corner. Therefore, entrepreneurs are working to cater to this market, offering consumers the ability to track their exposure to air pollution wherever they go with portable air quality sensors. These low-cost sensors are increasingly heralded as a way for governments to add to their existing network of data points and assess what difference their policies are having on the environment.

However, different sensors often give different readings in the same location, even if they're manufactured by the same provider. Moreover, the sensor data quality can deteriorate over time. Unlike traditional air quality monitoring stations that contain large, expensive instrumentation, these sensors are not subject to any ongoing checks of their performance and accuracy once they are in use, meaning users cannot determine whether they are still working.

NPL is a key organisation in the UK with the knowledge of sensors and data quality able to advise government, academia, industry and the public about how to draw conclusions from the data produced by air quality sensors. As such, we are working to highlight the importance of the public understanding the limitations and benefits of using low-cost sensors to monitor their exposure to air pollution, and subsequently make decisions or alter their behaviour. There is currently no compelling scientific evidence that these sensors are able to give absolute

measures of concentration over extended time periods that could be used, for instance, to predict health effects.

With NPL's expertise in calibration, we are also highlighting the issues that arise with air quality sensors not being regularly checked or re-calibrated. However, they are not the only piece of equipment used by consumers that fall in this realm. So, you may ask why the public should believe their bathroom scales, for instance, but exercise caution with air quality sensors?

Firstly, air quality sensors are new compared to bathroom scales, so their technology is less well understood. Secondly, bathroom scales are not affected by interferences, while air quality sensors can give different readings of the same pollution levels if, for example, the weather conditions are different. Thirdly, while we can judge whether our bathroom scales are starting to give the wrong result, sanity checking air quality sensors is incredibly difficult, as the quantity of pollution being measured is very small. Even in urban areas, sensors are measuring around one unit of pollution to 100,000 units of clean air. Relative to our weight, this is like trying to detect a difference of one gram on bathroom scales. The job of sanity checking is made even more difficult with pollution being mostly invisible to the naked eye.

There is currently no compelling scientific evidence that these sensors are able to give absolute measures of concentration over extended time periods that could be used, for instance, to predict health effects.

Low-cost air quality sensors may have the potential to help consumers measure personal exposure, increase the data we have about air quality in many different locations, and help us better understand the links between pollution and health impacts. However, until crucial issues with them are resolved, the use of the data produced by them should be restricted to applications where research has demonstrated that they are fit-for-purpose. NPL is working closely with industry to overcome these challenges and introduce standardisation, which will ultimately help low-cost sensors to meet their potential in accurately monitoring air quality.

Investigating the use of graphene in nuclear decommissioning

The Nuclear Decommissioning Authority (NDA) recently published a report identifying graphene technology as a promising area that could help to deliver safe, sustainable solutions to the challenge of nuclear clean-up and waste management.

The unique properties of graphene enable its use in a wide range of applications for nuclear decommissioning. NPL has collaborated with the University of Manchester, where graphene was first isolated, and NSG Environmental Ltd, under contract to the NDA, to review the potential of this material for water decontamination in nuclear power plants, sensors for radiation detectors, and as part of new composite materials to build safer and more resilient facilities.

Paving the way to a hydrogen economy

The use of hydrogen as an energy carrier in the UK is beginning to shift from hypothetical debates to practical demonstration projects, but has yet to have wide commercial uptake. To accelerate the shift towards a hydrogen economy in the UK, NPL has published a report, 'Energy transition: Measurement needs within the hydrogen industry', which highlights and prioritises the current measurement challenges facing the industry.

These challenges were identified through an industry-wide workshop and in-depth interviews and consultation with key stakeholders within the hydrogen industry, and include: materials development for fuel cells and electrolysers; measurement of the combustion properties of hydrogen and validated techniques for hydrogen storage.

Understanding these challenges fully is an important step towards addressing them and will pave the way for hydrogen to play a significant role as we move to a decarbonised energy system.

To read the report, visit:
npl.co.uk/hydrogenreport

New paradigms for antibiotic discovery and production

Dr Ian Fotheringham, Managing Director at Ingenza

Currently, it is estimated that around 700,000 deaths worldwide result from antimicrobial resistance each year. Unless action is taken, this is projected to rise to 10 million deaths each year by 2050, with the added impact of a cumulative $100 trillion of economic output at risk due to the rise of drug-resistant infections.

Antibiotics underpin modern medicine as we know it: if they lose their effectiveness, key medical procedures (such as caesarean sections, joint replacements and treatments that depress the immune system, such as chemotherapy for cancer) could become too dangerous to perform.

There are various recommendations on how to tackle this problem, including enhancing public awareness and promoting new, rapid diagnostics in order to cut unnecessary or inappropriate use of antibiotics. One solution on which NPL is working is to increase the number of effective antimicrobial drugs to defeat infections that have become resistant to existing medicines.

In response to the challenge, NPL is working to discover, screen and validate new classes of antimicrobials that exhibit effective mechanisms against pathogens. Combining this world-class measurement expertise with Ingenza's experience as the UK's premier industrial biotechnology company to engineer efficient and adaptable biomanufacturing systems is a natural fit.

The success of the first antibiotics, such as penicillin, was based on their ability to not only combat infection, but also be redesigned to enhance effectiveness, resulting in longevity and sustainability of useful antibiotics. NPL and Ingenza are therefore creating a new family of antibiotics, by enhancing the design and measurement of antibiotics that selectively attack microbial cells.

This August, Ingenza and NPL kicked off a three-year collaboration with Dr Mathew Upton's group at the University of Plymouth, thanks to a grant from Innovate UK. Dr Upton's group is internationally recognised for the discovery and development of epidermicins, a novel class of antibiotics.

The epidermicin class of bacteriocins are naturally-occurring toxins produced by bacteria to kill other, closely-related strains. The specific range of bacteria that epidermicins naturally target already offers an initial clinical application to combat hospital-derived MRSA infections (commonly known as 'superbugs' as they are drug-resistant). However, if a systematic approach can be found to adapt these bacteriocins into more broadly effective or even more potent antibiotics, they could increasingly challenge the growing problem of antibiotic resistance and the threat this poses to human health.

This unique consortium is extremely well-placed to take forward joined-up discovery, development and manufacture in ways which have never been done before.

NPL's experimental approach will help establish the critical performance criteria for selected epidermicins, their derivatives and related bacteriocins. This should in turn enhance the range of bacteria they can kill, as well as the potency at which they can do this. The goal is to generate a pipeline of candidate molecules to deliver the most effective treatment, while minimising any potential side effects. Within the same project, the team will also work to optimise the efficiency and adaptability of Ingenza's fermentation-based manufacturing platform to scale up production of each promising new antimicrobial candidate for further testing and clinical trials.

The collaborative effort also includes machine learning approaches for antimicrobial discovery developed in collaboration with IBM and the Science and Technology Facilities Council's Hartree Centre. No such combined capability currently exists in the development of new antibiotics and antimicrobials.

This isn't the first time NPL's expertise has been critical in tackling this huge global health challenge – just last year they worked with UCL to convert a breast milk protein into an artificial virus that kills bacteria on contact. The collaborative nature of the project was again the winning ingredient – funded by EPSRC, BBSRC and the Department for Business, Energy and Industrial Strategy, measurements were also performed at Diamond Light Source.

The advance of antimicrobial resistance is relentless and well-documented. There is a clear need to develop new antibiotics, but in doing so we must ensure that these new antibiotics can be adapted to keep pace with changing resistance. This unique consortium is extremely well-placed to take forward joined-up discovery, development and manufacture in ways which have never been done before.

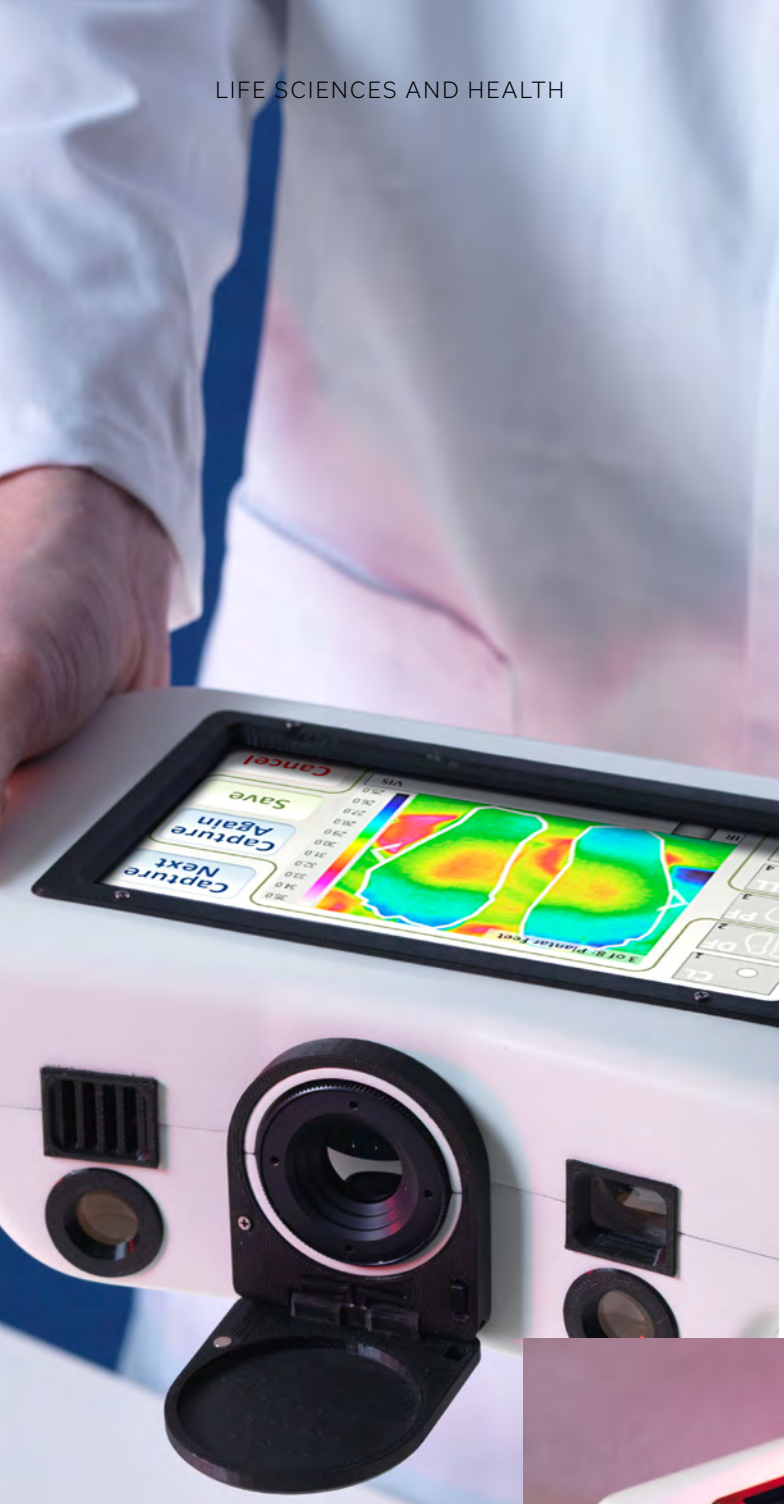
Improving quality of life and life expectancy in diabetes

Prof Graham Machin,
Fellow in Temperature Measurement at NPL

There are at least 3.3 million people with diabetes in the UK, a number projected to rise to more than five million by 2025. In addition to complications with their eyes, people with diabetes are prone to serious, slow-to-heal ulcers in their feet (diabetic foot ulceration or DFU), which can become infected and lead to amputation. Mortality rates after DFU and amputation are high: up to 70% of people die within five years of an amputation and around 50% die within five years of developing an ulcer.

Besides the adverse effect on patients, it has been estimated that DFU and related complications currently cost the NHS between £972 million and £1.13 billion per year.

These sobering statistics highlight that avoiding amputations is key to increasing the quality of life for diabetics and improving survival rates.



Detection of potential ulcer sites on the foot is critical to improving patient outcomes with DFU, enabling doctors to intervene to protect the foot before ulceration occurs. If DFUs are not prevented, there is significant danger of serious infection, which, if not rapidly treated, can lead to gangrene and amputation. Before any visible signs on the foot of possible ulceration, it has been found that, in the vulnerable skin area, temperatures can rise by more than 1 °C. NPL has exploited this knowledge and our world-leading expertise in thermal imaging metrology to produce a breakthrough medical imaging device, called DFIRST, that generates temperature maps (thermography) of patients' feet, to provide early alerts of potential problems. Such early detection would give more than a week's extra time to take preventative action, reducing or even eliminating the ulceration and associated risk of infection.

The research is the outcome of a £1.2 million project funded by the National Institute for Health Research (NIHR) Invention for Innovation (i4i) programme in 2012. Since the project's inception we've gone on to develop four prototypes of the device and conducted two clinical trials, recording the data of hundreds of patients.

Such early detection would give more than a week's extra time to take preventative action, reducing or even eliminating the ulceration.

Most modern clinical decisions, from diagnoses, to treatments, are based on advanced pieces of technology which take patient readings. To provide meaningful data on which life-saving decisions are made, these have to be reliable and trustworthy in their readings. Performance testing of the DFIRST device was conducted at NPL; our expertise in the field of quantitative thermal imaging means that the device has been tested against rigorous standards, ensuring it is as trustworthy as possible. Aligning with the trend in home monitoring, NPL's DFIRST works fast and in a similar way to an ordinary camera, meaning it is potentially suitable for home use, empowering patients in their own care and monitoring risk throughout the treatment pathway.

NPL is also working to make sure this breakthrough in medical thermography can benefit other healthcare sectors. The technology could be deployed in many areas where monitoring and mapping temperature is key, such as Charcot foot (another serious and potentially limb-threatening lower-extremity complication of diabetes), reconstructive surgery, gauging an organ's viability for transplant and tackling chronic wounds.

The value of the global wound care market is expected to reach $20.4 billion by 2021. Using its innovation in DFU, a common chronic wound, as a starting block, NPL is now looking to transform this market and the lives of those that live with chronic conditions.

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

Accelerating hepatitis diagnosis in high-incidence regions

NPL is part of a UK–China collaborative project developing a sensor made from graphene to provide an easy, low-cost method of diagnosing hepatitis on the spot. This will be the first sensor to simultaneously test for three types of hepatitis – A, B and C – out of the five types that exist, and will provide an alternative to blood tests.

Hepatitis is a huge global health problem, with nearly 400 million people worldwide affected, resulting in over 1.4 million deaths per year. The project aims to develop a prototype and establish the reliability, stability and sensitivity of the sensor in preparation for its commercialisation. It is estimated that if the sensor is produced in large quantities, each device could cost as little as £1.

Supported by the UK's Newton Fund and led by Biovici, the multi-partner project brings together NPL, the University of Chongqing, Swansea University and CTN to develop this new diagnostic technology.

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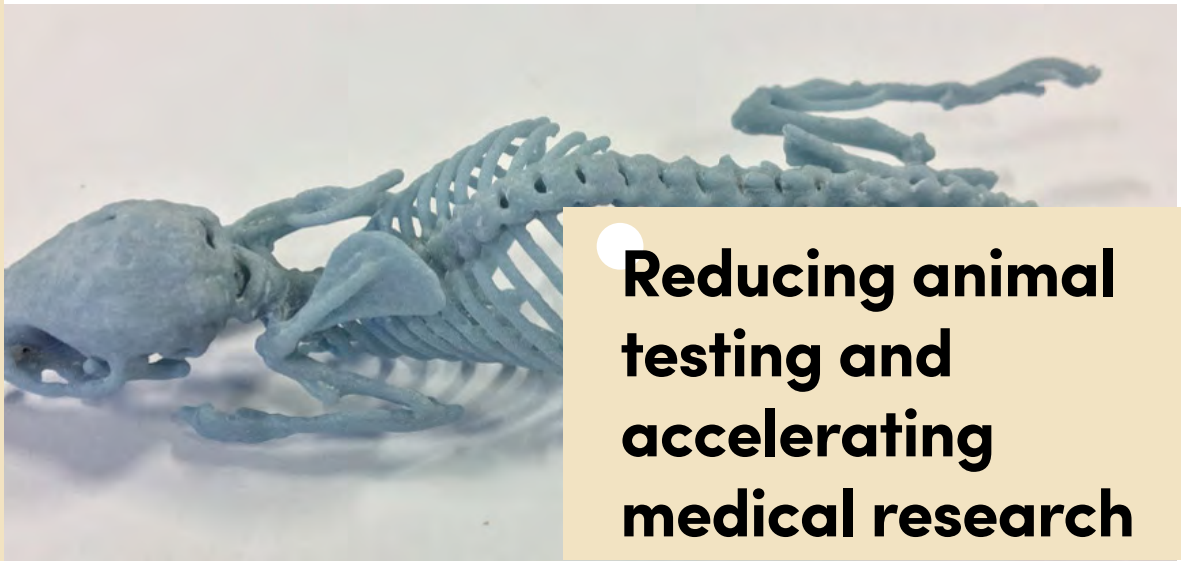


Reducing animal testing and accelerating medical research

Realistic patient models, known as 'phantoms', have important uses at many points of a biomedical pathway – from diagnostic imaging through to treatment planning and delivery. By utilising a variety of materials to mimic the physical characteristics of human and animal tissue, phantoms are employed worldwide to ensure the safety and quality of many treatments and diagnostic tools.

Medical research requires highly-accurate measurements to be taken, albeit when administering a treatment, carrying out a procedure or measuring an outcome. In this context, phantoms can provide more consistent results than the use of a living subject or cadaver. There is an opportunity here for the research community to reduce the number of animals used in biomedical studies, by maximising the information obtained from animal models, where possible. This is particularly relevant to radiotherapy, where pre-clinical biomedical studies are affected by a lack of standards and guidelines needed to ensure accurate, consistent doses of radiation are delivered to animal models. The mismatch between pre-clinical and clinical results means that many treatments may never reach the 14 million new cancer patients diagnosed across the world every year.

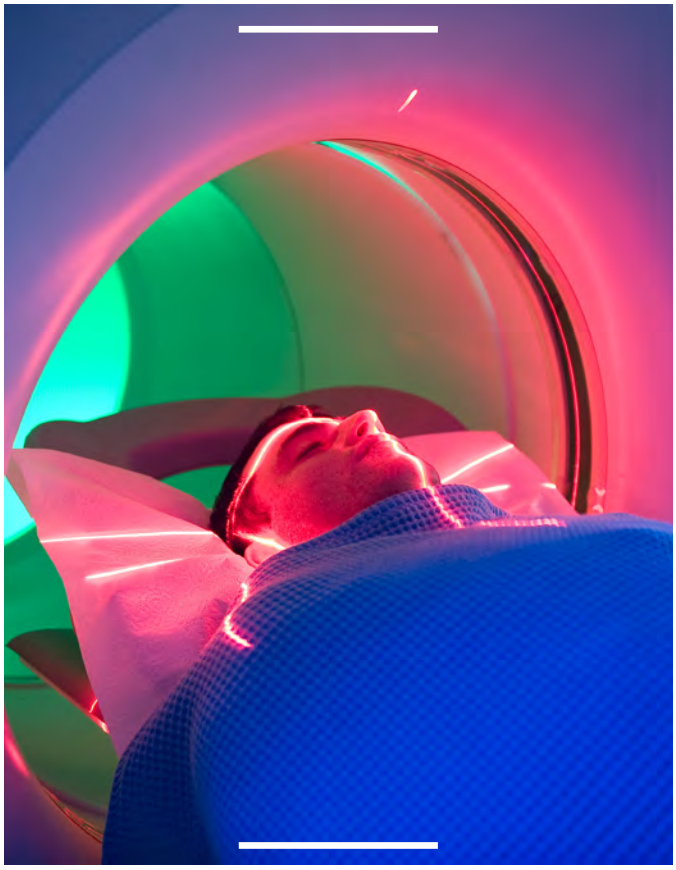
NPL is working to address these issues by optimising the use of medical phantoms in radiotherapy. With funding from Innovate UK's Non-Animal Technologies programme, NPL, in collaboration with the University of Hull and Xstrahl (a designer and manufacturer of X-ray therapy systems), is establishing new guidelines and a dosimetry service for the measurement of radiation dose in pre-clinical studies. This will give researchers access to standardised dosimetry protocols and tools such as a small animal phantom, to increase the reliability and comparability of results, and consequently reduce the number of animals needed.

NPL is also hosting a two-day workshop in September this year, with the Institute of Physics and Engineering in Medicine, to promote collaboration in developing new applications of 3D printing for medical phantoms.

SPOTLIGHT

Improving cancer survival rates through confidence in radiotherapy

Rebecca Nutbrown
Head of Metrology for Medical Physics at NPL



Cancer statistics for the UK make sobering reading; one in two people born after 1960 will be diagnosed with some form of cancer during their lifetime and there are currently approximately 330,000 new diagnoses every year, a number which grows by around 2% per annum. We will all be affected by cancer in some way at some point in our lives, and when it happens we need the reassurance that we will have access to the best treatment possible. Despite significant improvements that have been made in treating cancer over the last 40 years, the UK survival rate continues to lag behind that in countries of similar wealth.

The UK has a deserved reputation for creativity and excellence in designing and developing new interventions with the potential to deliver significant improvements in outcomes. However, apart from a few leading centres, we are slower than other countries to adopt new innovations, even where they are clearly cost-effective and were developed within our own health system. One of the critical enablers for rapid and/or widespread adoption of new innovations is ensuring that their performance, safety and effectiveness can be measured and optimised in what is necessarily a conservative community.

NPL has played a key role in supporting the UK medical physics community from the beginning of the twentieth century. This was initially through the design, construction and calibration of specialised equipment alongside the development of world-leading codes of practice. These professional guidelines are drafted in collaboration with the Institute of Physics and Engineering in Medicine, to ensure rigorous and consistent dissemination of dose quantification into the clinics. A recent review of data collected by NPL over the last 20 years has shown this work has assisted in considerably reducing the variability of the dose delivered across the nation. In more recent times, ground-breaking measurement research has been undertaken to support innovative treatments which require novel approaches to measurement to ensure continued consistency of the dose delivered to the patient.

In 2012, the UK government invested £23 million with the aim of significantly increasing the number of patients benefitting from access to intensity modulated radiotherapy (IMRT), a more

advanced and targeted form of treatment. In order for this to be achieved, it was necessary for the treatment to be delivered using a faster and more complex rotational delivery system (RIMRT). As a much more targeted and advanced form of radiotherapy, it was essential to audit delivery systems with differing capabilities across the UK, and assess whether each had been optimised uniformly before implementing the technique. This provided confidence that regardless where a patient received treatment, it would be of the same standard of excellence. Around two thirds of all UK radiotherapy centres were included, demonstrating an impressive 97% pass rate with a comparative exercise conducted in the USA achieving a 90% pass rate.

NPL plays a unique role in helping to ensure that new innovations in treatment provide the better patient outcomes they promise.

NHS England funding has since enabled NPL, in partnership with the national radiotherapy trials group, to play a key role in ensuring the safe and optimised uptake of new radiotherapy techniques such as stereotactic ablative body radiotherapy (SABR) for non-small cell lung cancer and stereotactic cranial radiosurgery (SRS) – a specialist form of radiotherapy that can be used to treat patients with conditions such as benign and malignant brain tumours. Both of these national audits have highlighted and resolved issues with inconsistencies in implementation that have resulted in significantly reduced variation in the dose delivered to the patient.

NPL continues to offer verification services to centres within the UK and abroad, with several countries now basing their audit techniques and protocols on those developed by NPL and its collaborators. We are currently leading an 'audit of auditors' project, supplying international clinical trial audit groups with a set of virtual audit measurements containing known errors, which are then analysed and interpreted by the individual groups and their analysis reported back for assessment. This will allow centres from multiple countries to be included in international clinical trials, which is of particular importance for more rare cancers and/or new techniques such as proton beam therapy (PBT).

The UK has been successfully treating rare eye cancers with proton beam therapy at the Clatterbridge Cancer Centre for many years, yet we have been slower to adopt new high-energy proton beam therapy; higher energies are needed to penetrate further into the body. However cutting-edge PBT technology is now being adopted across both NHS and private centres in the UK. Adopting it later than other countries means we have more work to do in ensuring its best use here. To help meet this challenge, NPL has established a physics research consortium with members from NHS centres and academia, and is running regular workshops aimed at promoting research collaborations within the UK. NPL is also contributing to a code of practice that will be the world's first written specifically for PBT based on a proton beam calibration. This will allow centres to calibrate their beams more accurately, so they know with more certainty how much radiation dose they are giving each patient, reducing side effects and increasing treatment effectiveness.

With our well-established expertise in underpinning and improving the accuracy of cancer therapy delivery, NPL plays a unique role in helping to ensure that new innovations in treatment provide the better patient outcomes that they promise, in order to help realise the NHS's target to deliver consistent, 'world-class' cancer care by 2020.

Events

Come and see us at…

2017 September

26
Autolink Wales,
Cardiff City Stadium, UK

26–27
Sensors and Instrumentation show 2017
NEC Birmingham, UK

27
Energy transition: measurement needs within the battery industry
NPL, Teddington, UK

2017 October

2–5
EU NORM 2017 Conference on Naturally Occurring Radioactive Material
NPL, Teddington, UK

9–11
3DMC: 3D Metrology Conference 201
Tivoli Stadium, Aachen, Germany

17–19
FIA Expo
Hilton Chicago, USA

24–26
Space Tech Expo Europe 2017
Bremen, Germany

29 Oct. – 1 Nov.
IEEE Sensors Glasgow
Scottish Event Campus, Glasgow, UK

2017 November

1
Advanced Engineering Show 2017
NEC, Birmingham, UK

5–8
NCRI Cancer Conference 2017
BT Convention Centre, Liverpool, UK

18
2017 College of Podiatry Annual Conference
ACC, Liverpool, UK

22
Third National Quantum Technologies Showcase
QEII Conference Centre, Westminster, UK

2017 December

6–7
LCNI 2017 - Low Carbon Networks and Innovation Conference
The International Centre, Telford, UK

Dates for your Diary

NPL Open House
We will be opening our doors to the public for our annual Open House event. Save the date to see for yourself the breadth of work that goes on here, explore our labs and speak to our amazing scientists.

15 May 2018

NPL Water Rockets
From school teams, to adult enthusiasts, the annual NPL Water Rocket Challenge is a great day out, which sees teams of rocketeers take to the skies with their own water rockets!

20 June 2018

NPL is the UK's National Measurement Institute, providing the measurement capability that underpins the UK's prosperity and quality of life.

From new antibiotics to tackle resistance and more effective cancer treatments, to unhackable quantum communications and superfast 5G, technological advances must be built on a foundation of reliable measurement to succeed. Building on over a century's worth of expertise, our science, engineering and technology provides this foundation and helps to make the impossible possible. We save lives, protect the environment and enable citizens to feel safe and secure, as well as support international trade and commercial innovation. As a national laboratory, our advice is always impartial and independent, meaning consumers, investors, policymakers and entrepreneurs can always rely on the work we do.

Based in Teddington, south-west London, NPL employs over 500 scientists and is home to 388 of the world's most extensive and sophisticated laboratories. NPL also has regional bases across the UK, including at the University of Surrey, the University of Strathclyde, the University of Cambridge and the University of Huddersfield's 3M Buckley Innovation Centre.

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