How We Can Meet The Measurement Challenges Of The Coming Decade

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Measurement is important. It has a critical role in sustaining a fair, efficient and technological society. Whether you are developing new products, services and processes, or looking to trade successfully internationally, you will rely on measurement and an established infrastructure of traceable measurements linked seamlessly to internationally recognised standards. The UK's leading measurement laboratory, NPL, needs to assess thoroughly what the future metrology needs of our society are, and plan accurately to meet them.

In the 1950s Louis Essen led a team to develop the first atomic clock at NPL. At the time none of them could have known how far their work would impact on our everyday lives, providing timing for GPS, mobile phones and the internet more than half a century later. However, for our work at NPL to continue to underpin prosperity and quality of life in the UK, we need to make informed decisions about where we should direct our work to support UK innovation. In today's age of austerity this is essential – we need to be sure that what we are working on will help to meet the challenges of the not too distant future.

Decisions on where to focus activity are not made lightly. Our vision is based on consultations with stakeholders in Government, industry and the research community – including our own world class scientists. From these discussions we have identified that technological progress in the 2020s will be driven and constrained by the need to achieve the following:

- A sustainable low-carbon economy
- Innovation through scientific discovery
- The well-being and security of the citizen

As one of the top three National Measurement Institutes (NMIs) in the world, the work we do with academia and industry is at the cutting edge of contemporary metrology. Through this activity, NPL and its partners have an understanding of what the future needs of measurement will be. We know the state of the art across all areas of metrology and what potential there is for progression. We have an idea of the type of new technology emerging over the next 10 years and what end users will expect of it. Perhaps, most importantly, we know how all of this interacts with the metrology supply chain from the SI units to measurement systems.

What will this mean outside research laboratories like NPL? If we examine the three areas we believe will drive research into the 2020s, we can show how metrology can address these challenges through real world applications.

A SUSTAINABLE LOW-CARBON ECONOMY

Monitoring the state of the planet

Our need to monitor the Earth will drive measurements of climate and the environment. We need to be able to monitor accurately the changes in our climate, to be able to assess how policies to address this are working. Autonomous, self-calibrating and self-validating networks of sensors will help us to achieve this – measuring atmospheric and ocean composition as well as land and sea temperature.

This could include traceable data publicly accessible in real time via embedded sensors in mobile devices or cars, helping individuals to monitor and minimise their personal exposure. Also, improved measurement through the new quantum SI could provide direct traceability for Earth observation systems at uncertainties of 0.01%.

Efficient and diverse energy

More efficient energy and a more diverse supply are key to achieving ambitious targets around carbon reduction and maintaining security of supply. Measurement will ensure the reliability of these systems and provide investors with the confidence to bring about a step change in security of supply and consumption.

Measurement will help with new structural health monitoring techniques which could identify micro-scale and chemical changes – underpinning the long term accuracy and integrity of structures. Similarly, traceable measurement will provide the parameters associated with new generation fission plants, particularly in materials, temperature and neutron fluence.

SCIENTIFIC DISCOVERY, INNOVATION AND R&D INTENSIVE GROWTH

Big science

Metrology is critical to the successful delivery of large-scale basic science or high investment R&D. These will be the most ambitious projects of the future, aimed at pushing the boundaries of science and technology to meet society's challenges.

An example is deep space exploration. Accurate navigation would need atomic clocks to be stable to better than parts in 10^{17} to ensure that expensive missions safely reach their intended targets. Another example is cyber security. Through the use of single-photon measurement technologies we could enable quantum key distribution over existing fibre networks that will provide the ultimate in secure communications.

The future factory

The future factory will be a smart facility where design and manufacture integrate into a single process that enables bespoke products to be accurately fabricated on demand.

Measurement will need to assess and guarantee the fit, performance and functionality of every part. Metrology will also support the interconnection of these new factories to form an independent industrial base that merges production and R&D and achieves the lowest energy consumption and environmental impact possible.

This could result in machine tools that calibrate themselves with traceability to the SI and can be used as in-situ metrology devices for factories around the world producing parts in parallel and monitored and controlled via a customer's design department.

THE WELL-BEING AND SECURITY OF THE CITIZEN

A healthy population

Future healthcare systems will provide personalised medicine tailored to the needs of individuals. They will increase health and well-being throughout their life using point of care diagnostics, better-targeted therapies, and 24/7 assessment of critical patient parameters and health indicators.

To make personalised diagnostics that are both economically viable and clinically effective, new measurement techniques must provide the knowledge to underpin them. One example of this in practice is calibrated diagnostic devices directly connected to knowledge databases and treatment plans to provide therapeutic interventions tailored to individuals. A further example is accurate and reliable implantable multi-analyte sensors with operating lives of years rather than weeks.

Managing key resources and infrastructure

By the mid-2020s the planet's population will surpass eight billion which will present a challenge in terms of managing resources such as food and water and stretching the lifetime of infrastructure.

Measurement is critical in accurately monitoring the status of resources, and ensuring we move to a more sustainable future. Microbial and temperature sensors in food packaging using remote data acquisition could assess food quality to prolong shelf life and help reduce waste and shortage of supply. Measurements can be integrated over wide areas of soil fertility, carbon content, biodiversity, water retention capacity, and contaminants with quality of water and air to mitigate the linked risk of food shortages and climate change.

WHAT WILL THIS MEAN TO THE MEASUREMENT COMMUNITY?

Metrology in the 2020s will lead to some basic changes in how the research and capability we develop reaches users.

The services that NPL and other NMIs deliver could eventually be superseded by self-calibrating portable standards that enable in-site traceability. NMIs may move towards delivering traceable measurements to end users seeking to achieve traceable measurements in harsh or challenging situations. As a result, this will see a shift from traditional traceability models to a problem solving approach that utilises the expertise of measurement scientists.

TAKING THE VISION FORWARD

Our vision is not carved in stone. It is open for discussion and debate, and can only be developed further in partnership with our customers, stakeholders and collaborators. We welcome contributions from the parliamentary community, industry and academia to help us refine further our vision.

An online version is available for comment, together with a series of questions at: www.npl.co.uk/2020vision

THE FOUR THEMES WITHIN WHICH THE NATIONAL PHYSICAL LABORATORY (NPL) BELIEVE METROLOGY WILL DEVELOP IN THE 2020s:

1. The new quantum SI

Traceability of measurement results to National Measurement Institutes like NPL are the cornerstone of metrology. By introducing the new quantum SI we will see several units revised and redefined, removing the last physical artefacts and fixing values to fundamental physical and atomic constants enabling the chains of traceability to be substantially shortened and support research at the vanguard of scientific and technological development.

2. Measurement at the frontiers

As science advances it naturally takes measurement with it driving the need for new capabilities that go beyond what we can currently measure. In the next 10 years this is expected to include measuring everything from the atomic to the extremely large, measuring in extreme and harsh environments, in the presence of interference and at timescales from attoseconds to millennia.

3. Smart and interconnected measurement

The availability of networked information will enable new capabilities in computing, software and communication technologies. It will be driven by new sensors developed on quantum-, bio- and nano-technologies being integrated into measurement networks, integrating data from myriad systems and enabling calibration across networks.

4. Embedded and ubiquitous measurement

New products and systems will have in-built metrology capability. This will be embedded into machines at the design stage and will be easily accessible through functionality, ensuring that critical measurement systems will be permanently on and always calibrated.