DIGI GOV EXPO '24

GovTech THEATRE

Making the UK a Quantum Superpower: NPL's role in standards, testing, and regulation

Tim Prior

Quantum Programme Manager

National Physical Laboratory

DigiGov Expo

DIGIGOVEXPO

Making the UK a Quantum Superpower: NPL's Role in standards, testing and regulation

Tim Prior

NPL National Physical Laboratory | QMI Quantum Metrology Institute

Agenda for talk:

NPL and the importance of measurement

How / why did NPL get involved in quantum?

What do u need to know to use / invest in quantum?

The importance of standards, and measurement (again)

Department for Science, Innovation & Technology

NPL National Physical Laboratory | QMI Quantum Metrology Institute

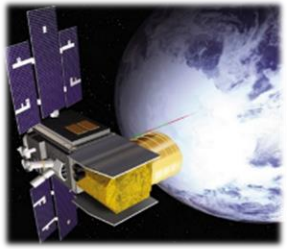
We provide the Measurement capability that underpins the UK's prosperity and quality of life

- Government-owned laboratory
- National Metrology Institute ~1300 staff + ~200 students & visiting researchers/year
- High-spec laboratory infrastructure (~400 labs)

Department for Science, Innovation & Technology

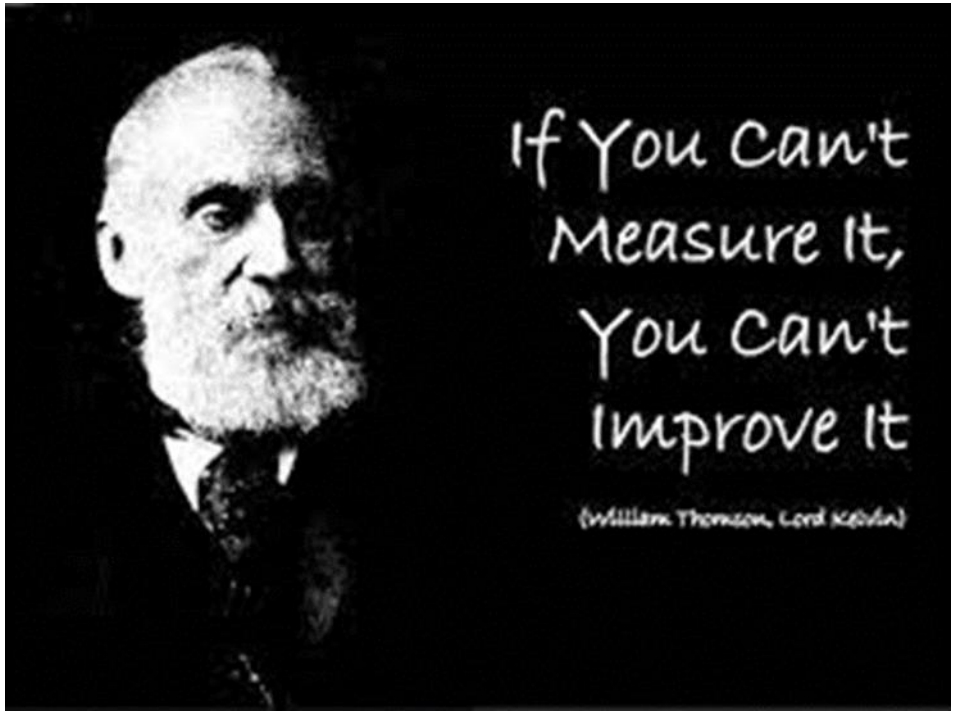
The measure of everything

- Why measure?

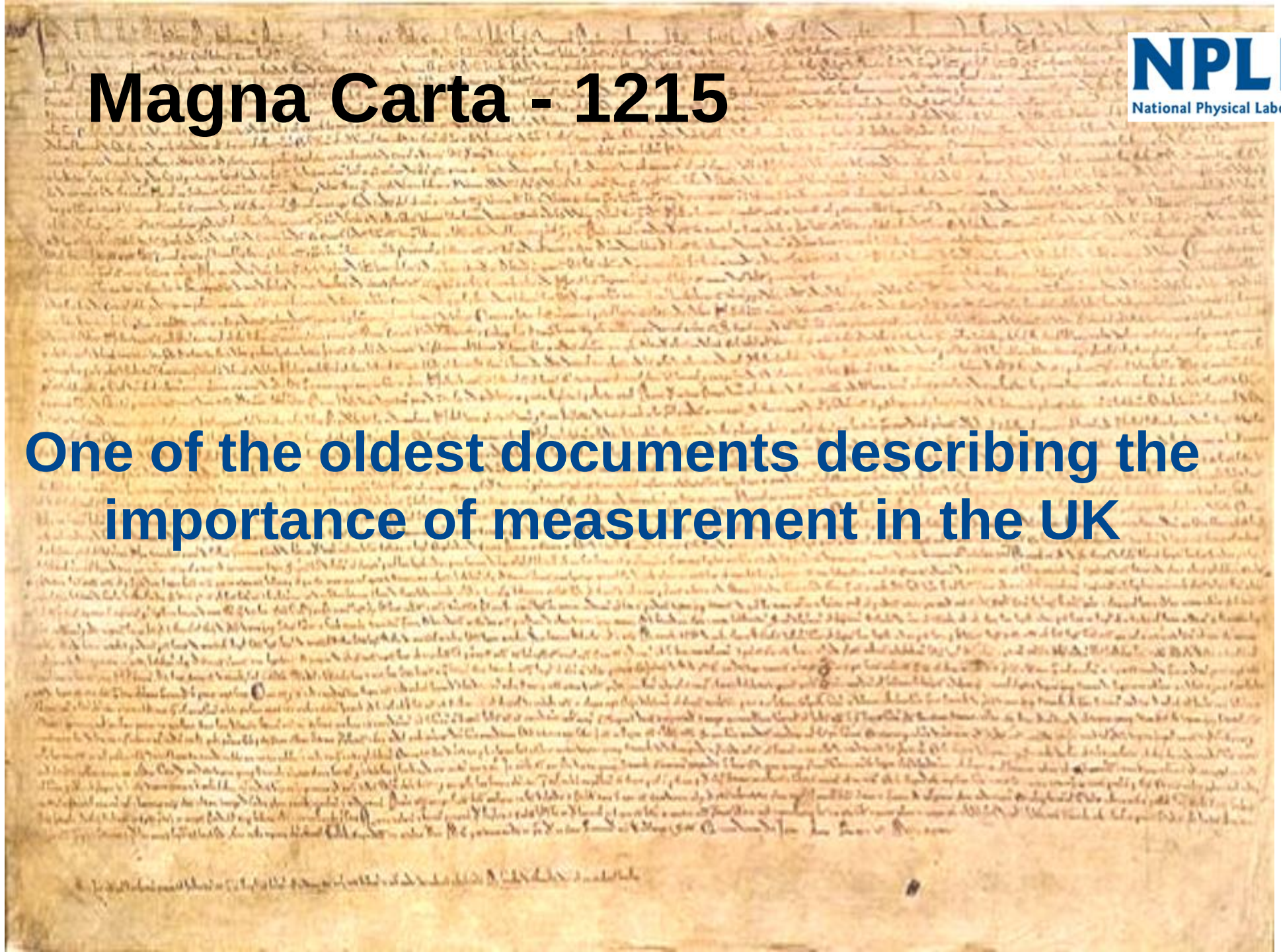






Magna Carta - 1215



One of the oldest documents describing the importance of measurement in the UK

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Magna Carta - 1215

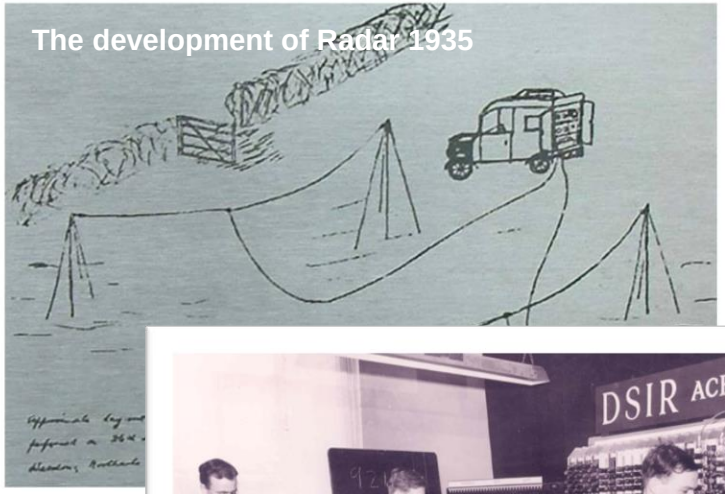
"There is to be one measure of wine and ale and corn within the realm, namely the London quarter, and one breadth of cloth, and it is to be the same with weights."

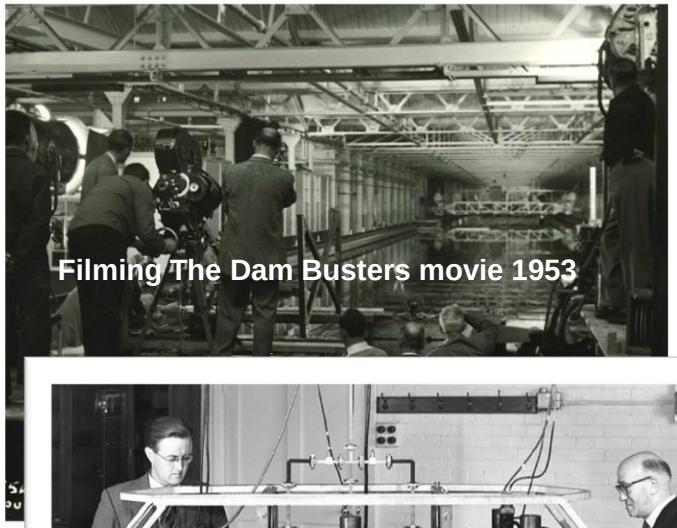
NPL: A Proud Legacy

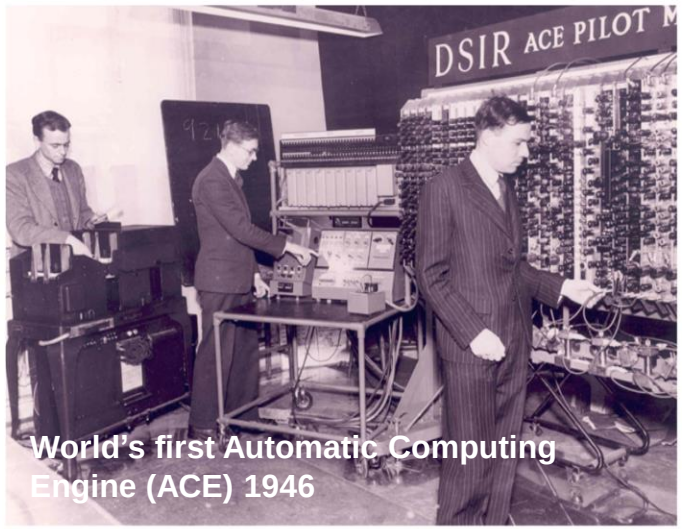
NPL National Physical Laboratory | QMI Quantum Metrology Institute


Opening NPL 1902


Packet-switching developed at NPL 1966


The development of Radar 1935


Filming The Dam Busters movie 1953



World's first Automatic Computing Engine (ACE) 1946


World's first accurate Caesium Atomic Clock 1955

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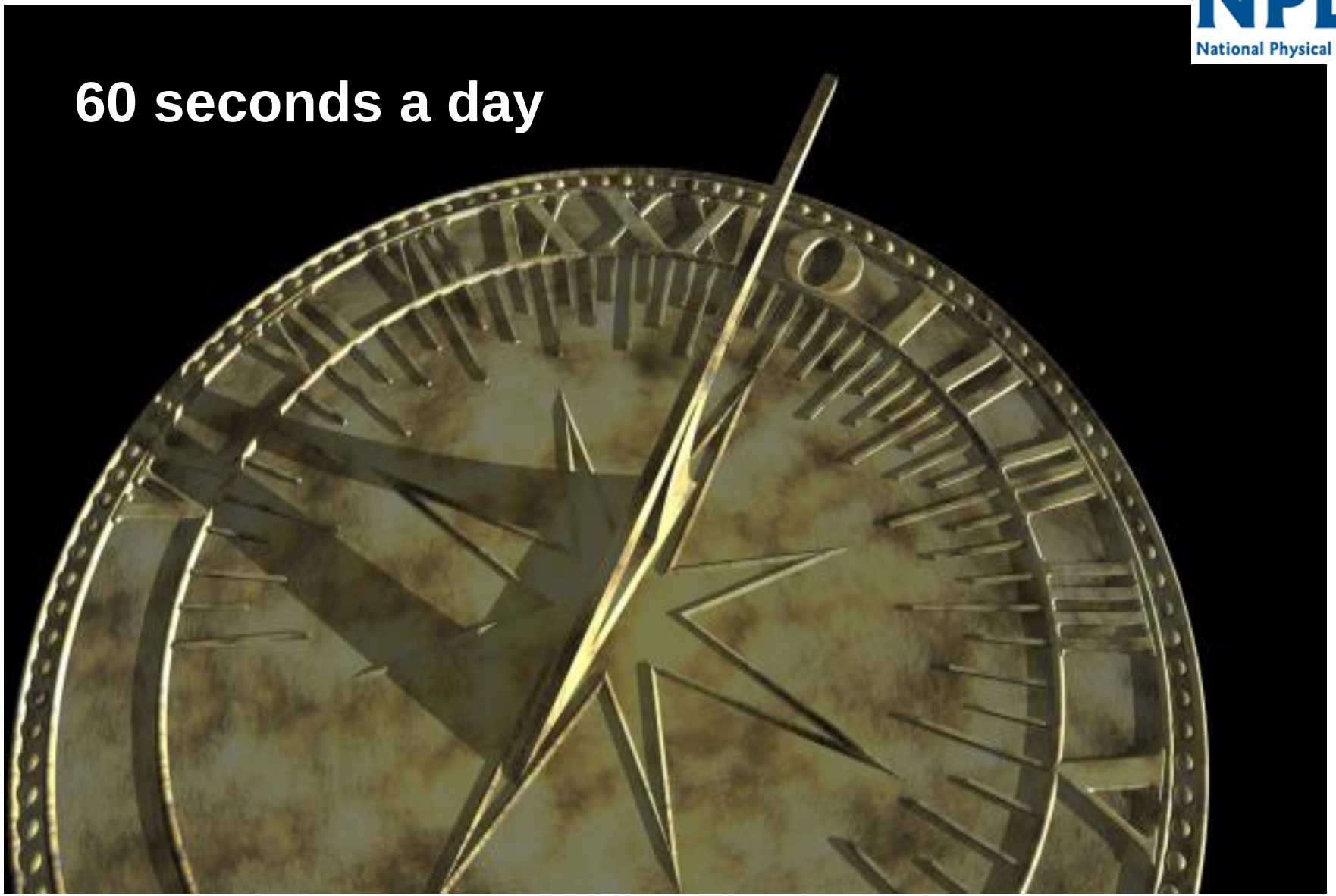
60 seconds a day



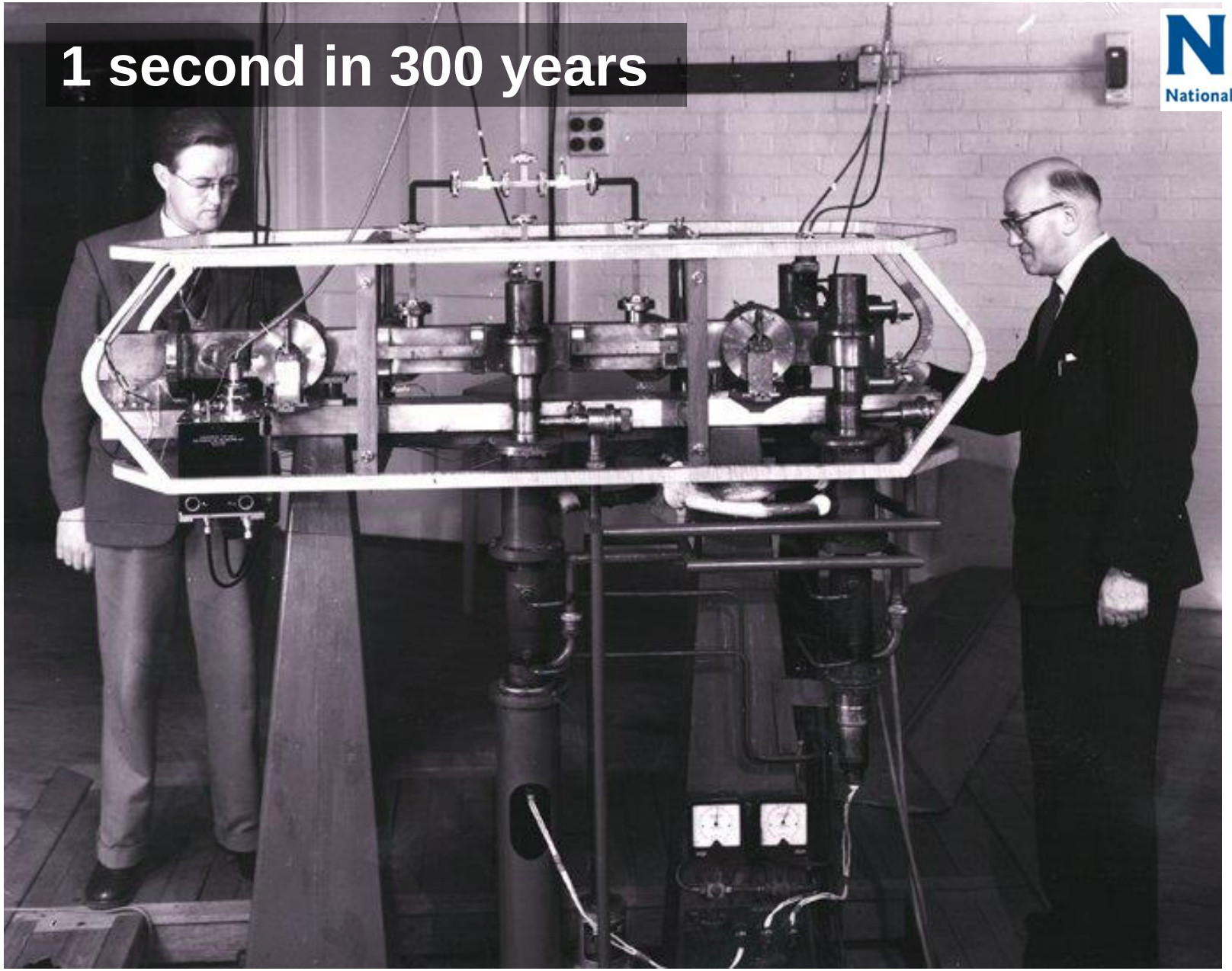
1 second a day

NPL National Physical Laboratory | QMI Quantum Metrology Institute

1 second in 30 years

NPL National Physical Laboratory | QMI Quantum Metrology Institute

1 second in 300 years



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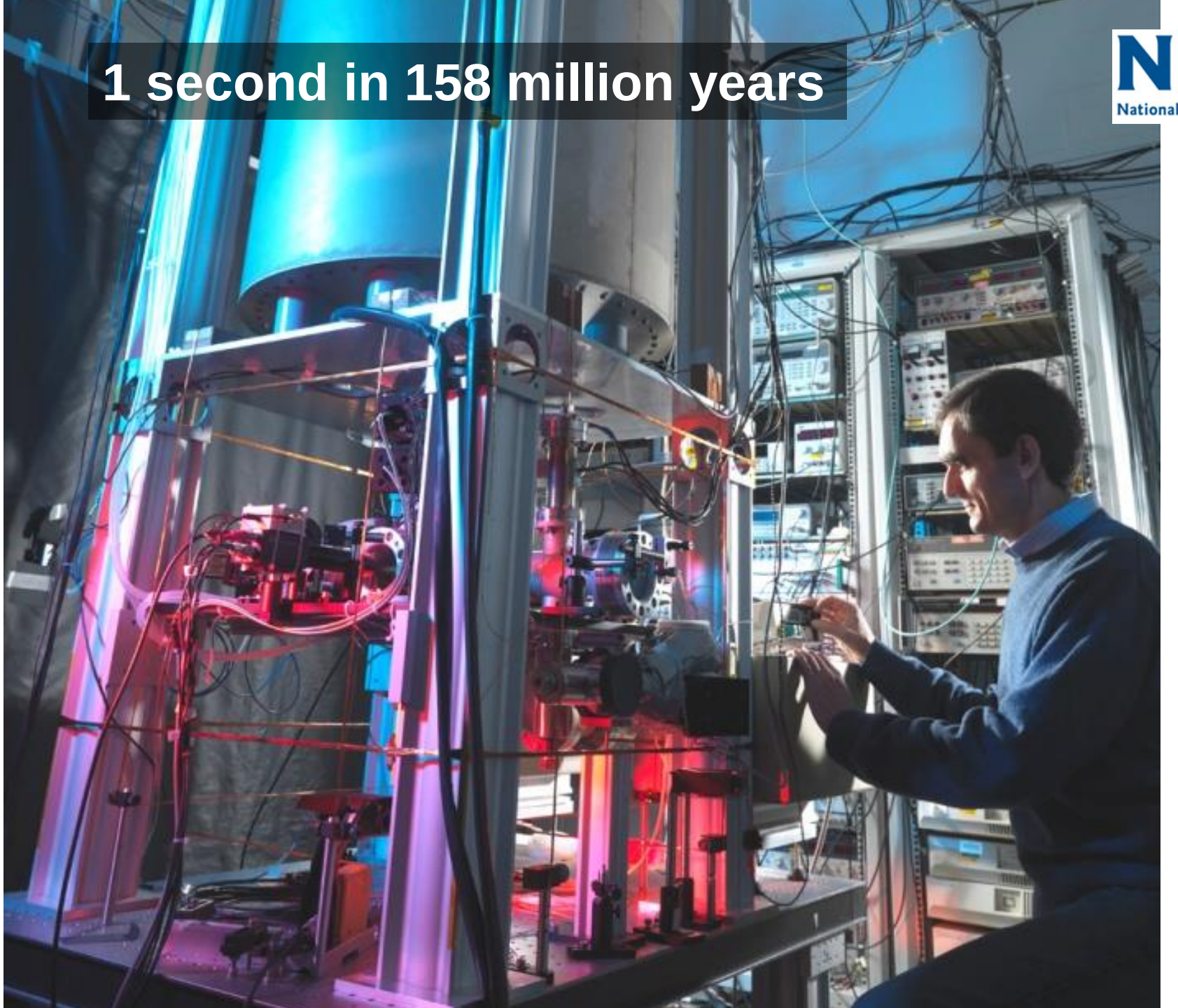
1 second in 158 million years



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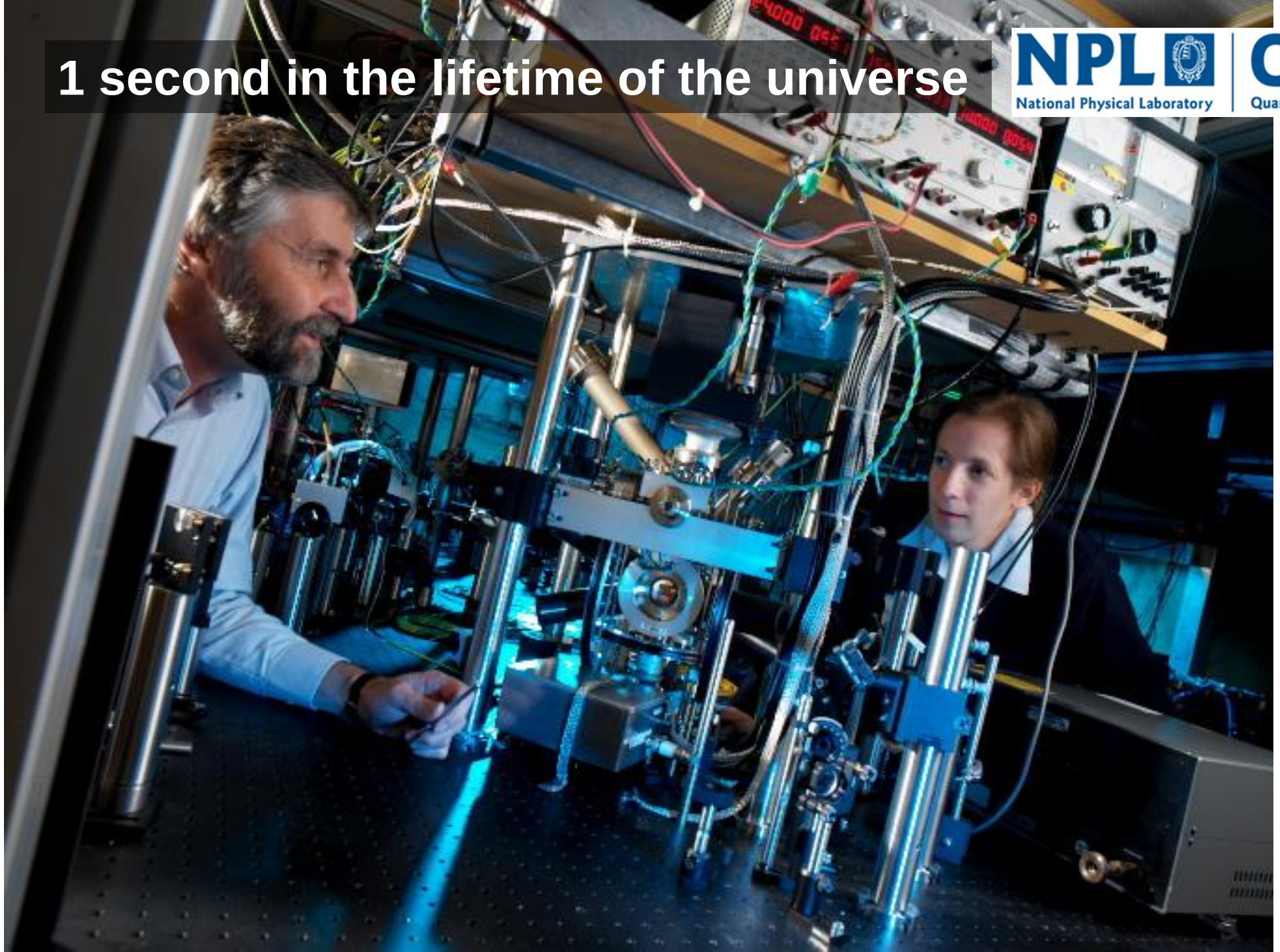

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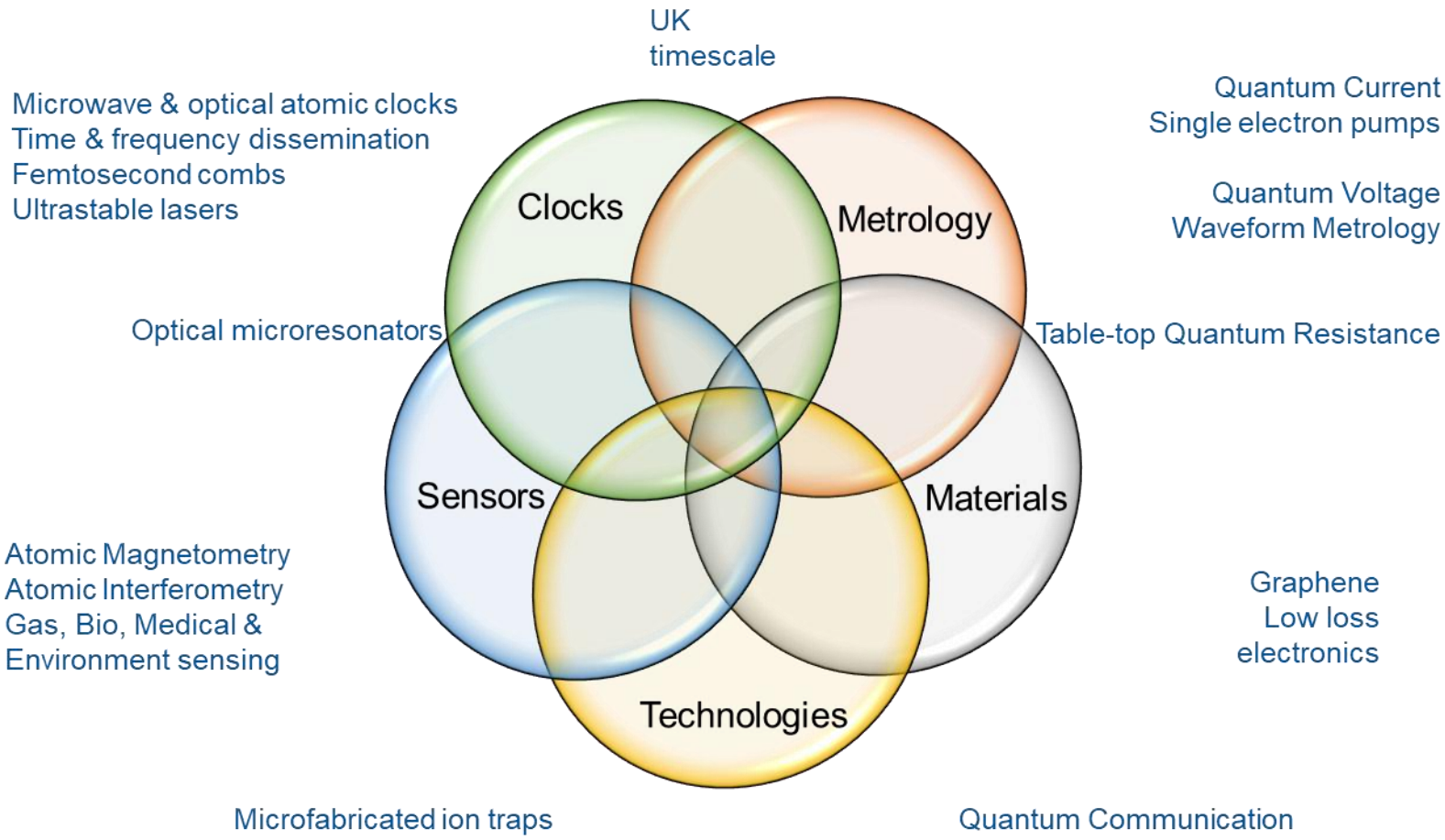
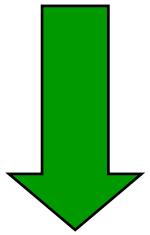
How / why did NPL get involved in quantum?

NPL National Physical Laboratory | QMI Quantum Metrology Institute



Primary quantum standards

Standards which only depend on the fundamental constants of nature



- Independent of time
- Can be generated everywhere in the world
- Accuracy only limited by our ability to measure

NMIs

- Often first to develop
- Often first to benefit

Examples:

- Josephson junctions for voltage standards
- Ion traps for clocks

What does industry need from NMI's to develop quantum technologies?

Examples:

- Josephson junctions for voltage standards…
  and superconducting qubits
- Ion traps for clocks
  … and computing

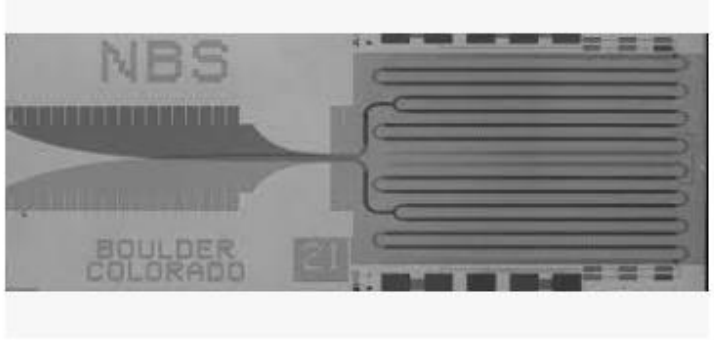
And these technologies need entirely new ways to measure & characterize

Metrology has often been both the motivation for and a direct beneficiary of ground-breaking discoveries. The **Josephson and the quantum Hall effects** provide the basis for the **realization of electrical units**. **Rabi and Ramsey spectroscopy** methods are essential to the operation of **hydrogen maser and other atomic clocks. The invention of lasers led to even more accurate length metrology. Frequency standards** now rely on **ion and cold atom trap** techniques, **frequency combs** and methods to manipulate the quantum state of matter.

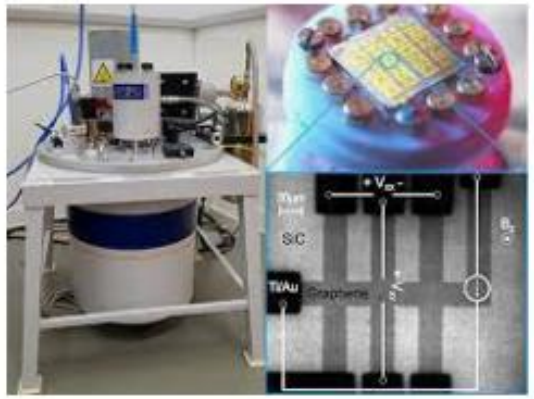
The expanding role of National Metrology Institutes in the quantum era

Alexander Tzalenchuk, Nicolas Spethmann, Tim Prior, Jay H. Hendricks, Yijie Pan, Vladimir Bubanja, Guilherme P. Temporão, Dai-Hyuk Yu, Damir Ilić & Barbara L. Goldstein

Nature Physics volume 18, pages724–727 (2022)Cite this article

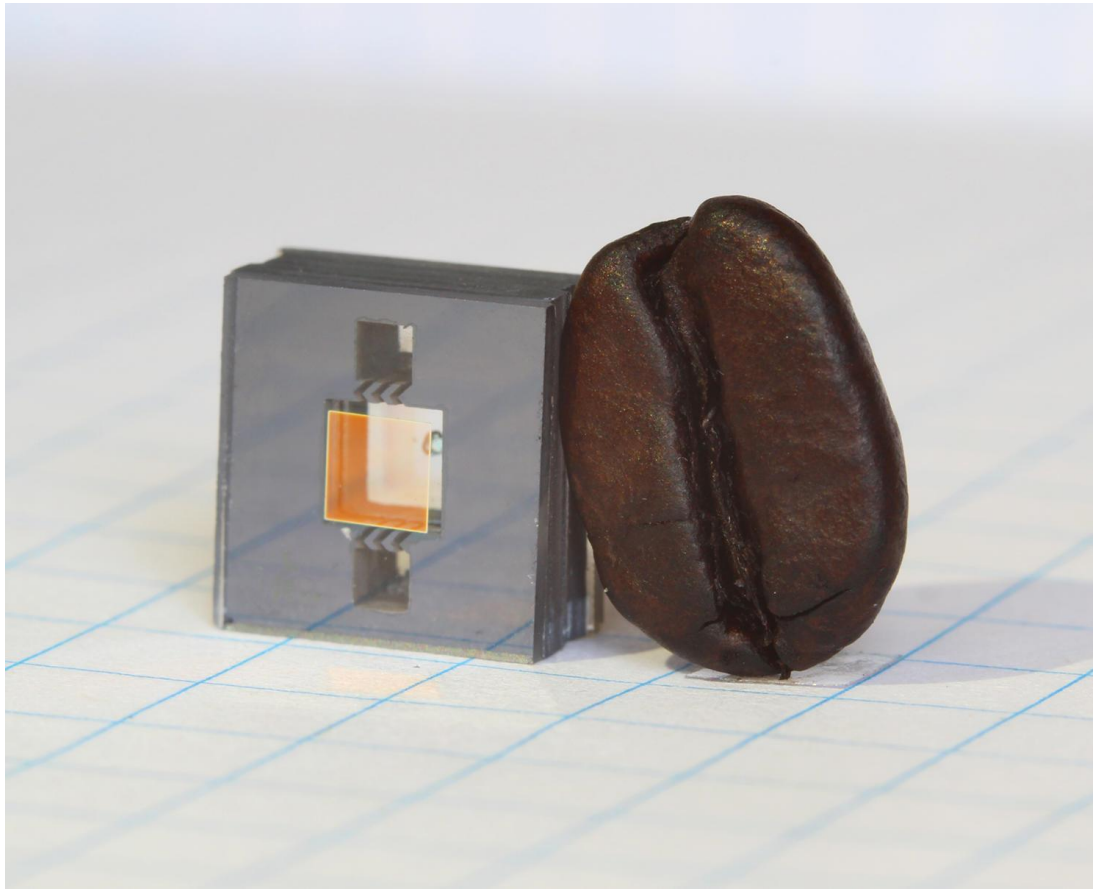


A Practical Josephson Voltage Standard ...
nvlpubs.nist.gov

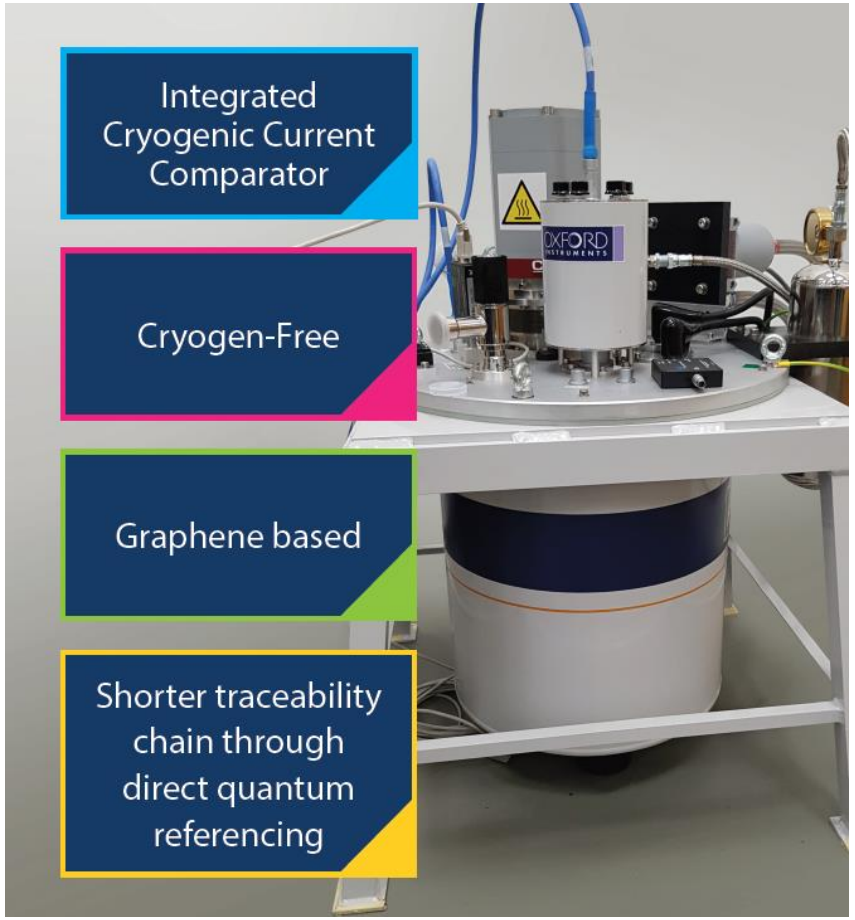


Quantum Materials standards - NPL
npl.co.uk

We may and we can realise units anywhere anytime



NIST's compact optical clock vapor cell beside a coffee bean.



NPL’s table-top quantum Hall system

From quantum standards to quantum sensors

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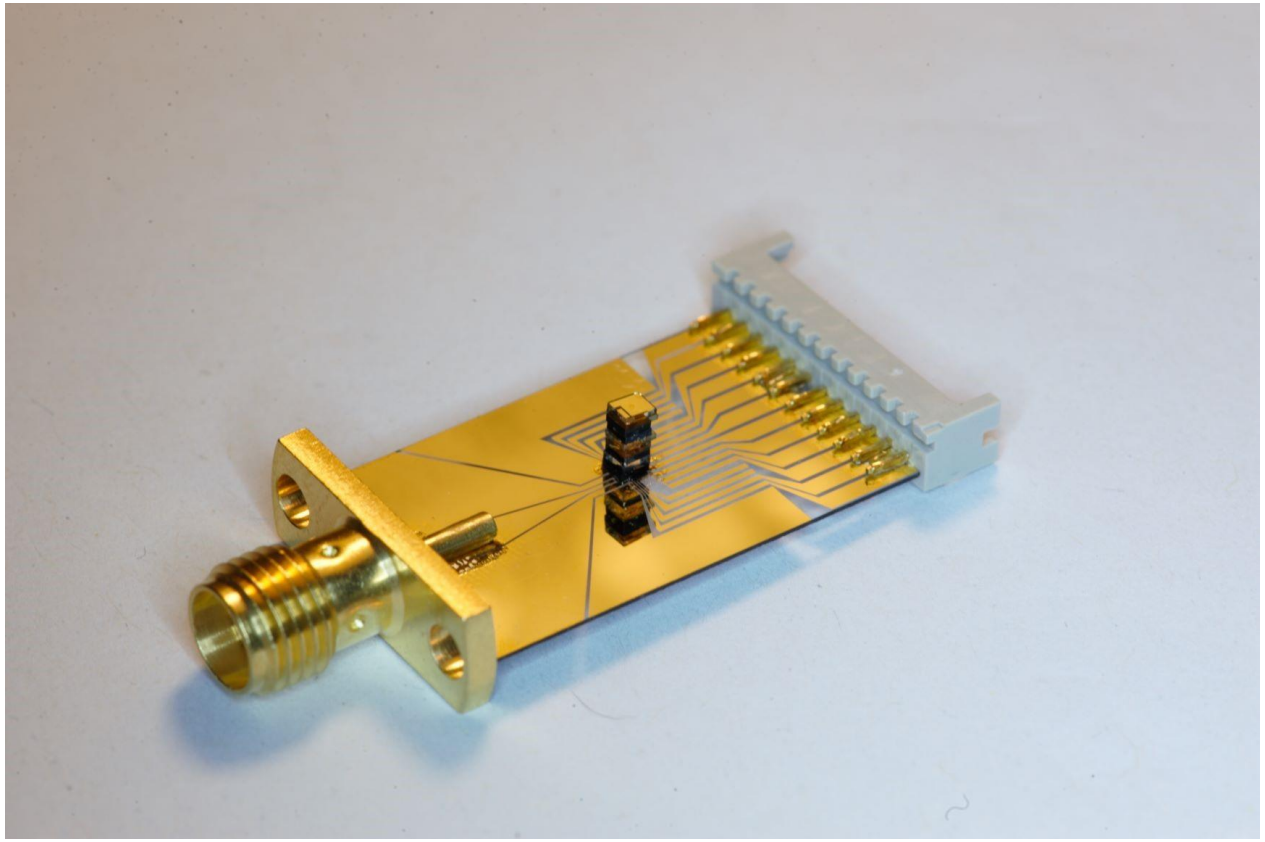
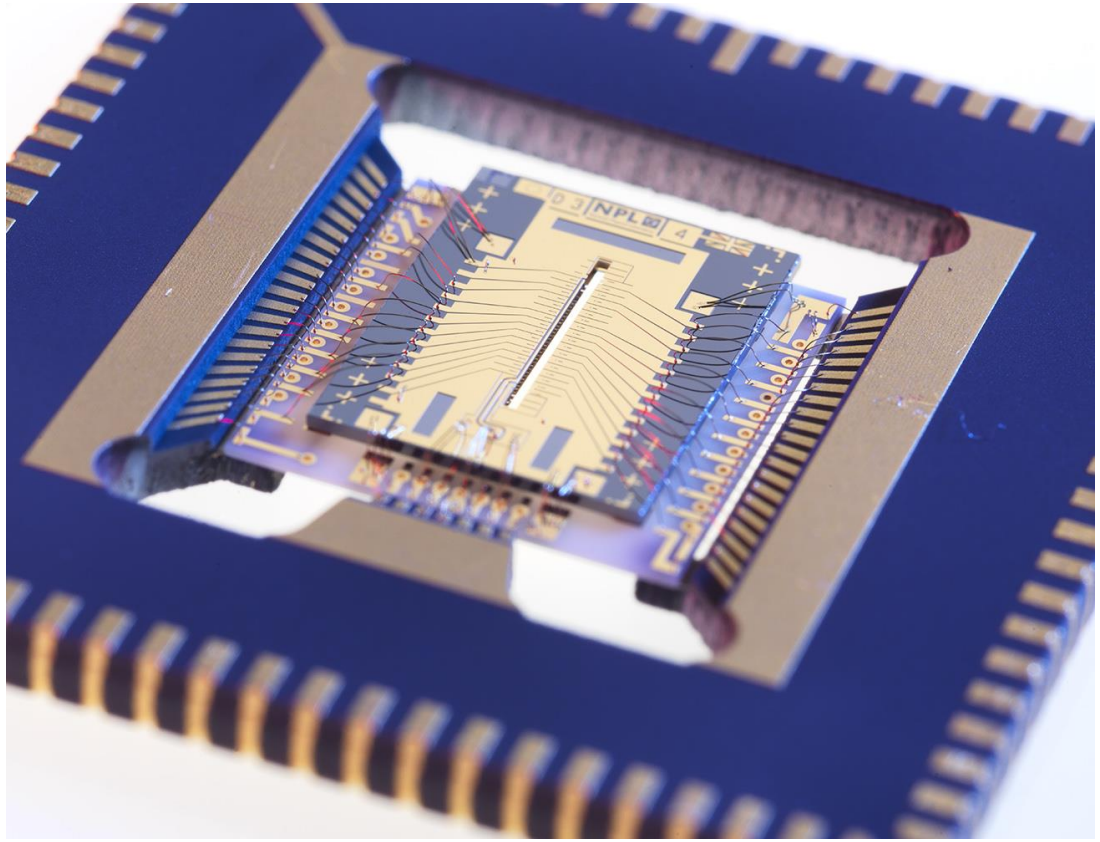


NIST's chip-scale atomic magnetometer

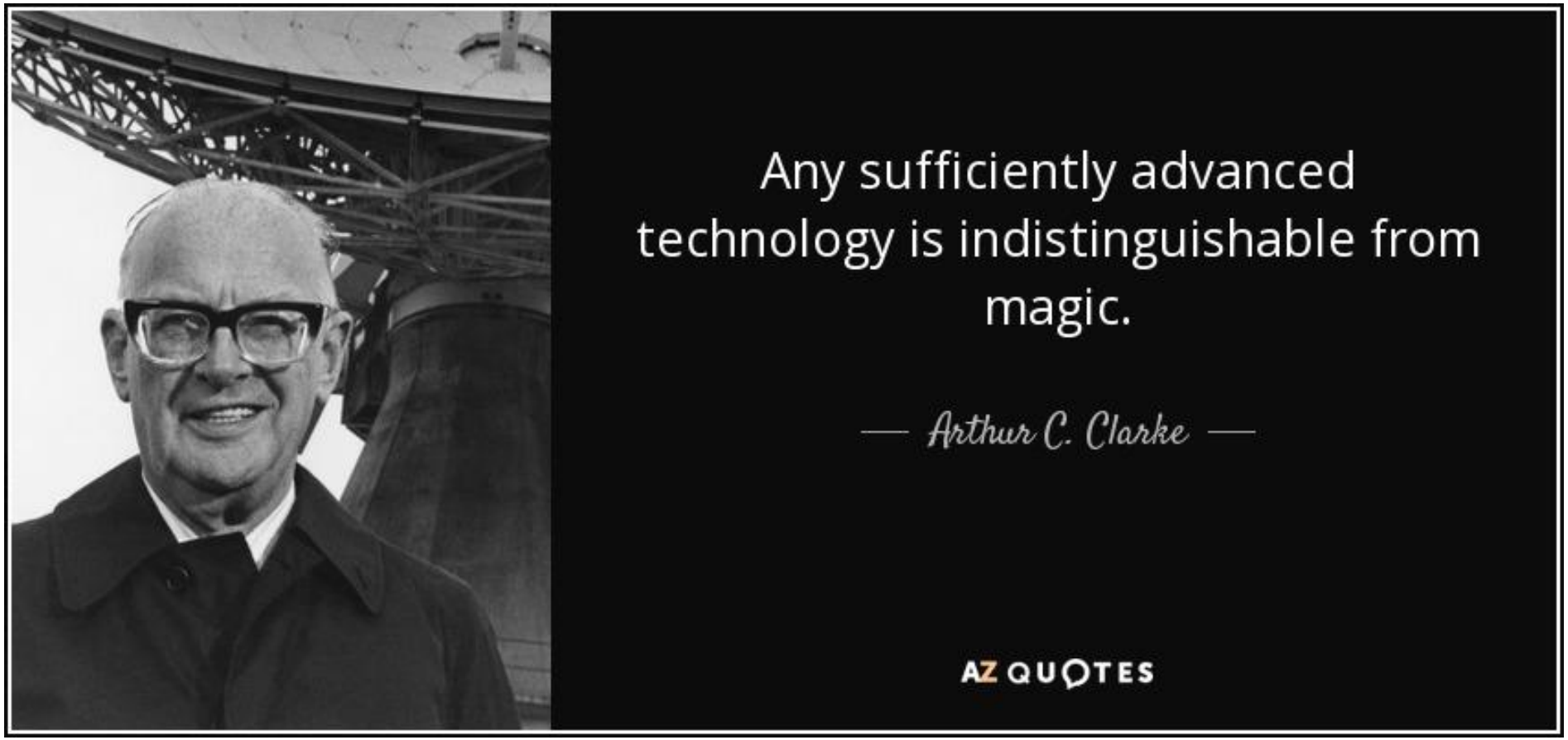


NPL's microfabricated 3D ion trap

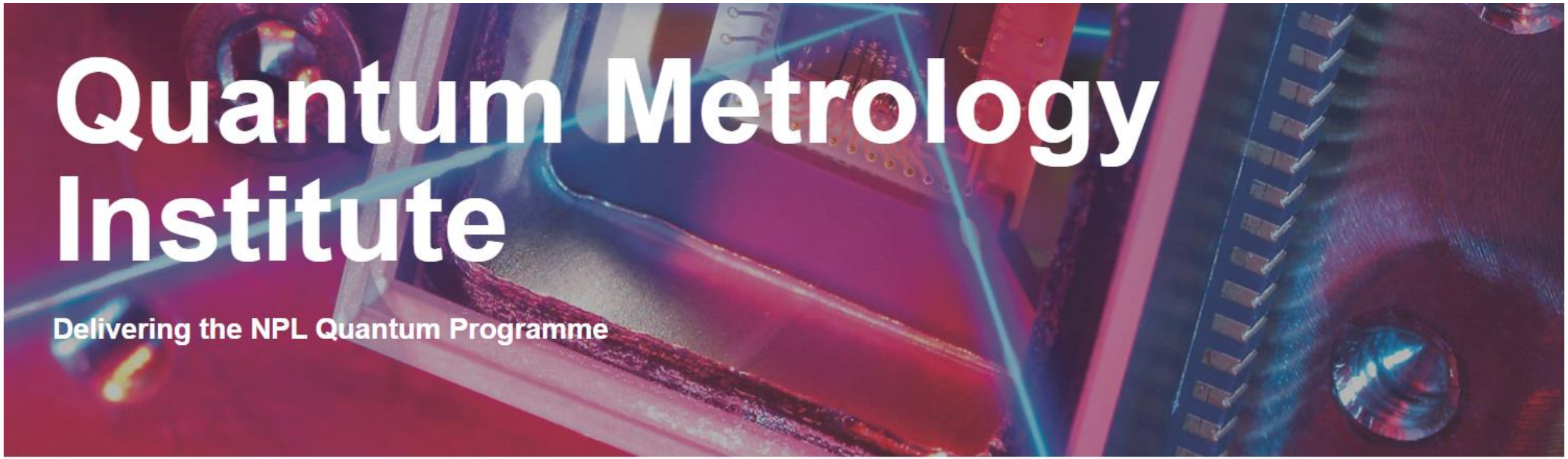
NPL National Physical Laboratory | QMI Quantum Metrology Institute

What do u need to know to use / invest in quantum?

- Does it work?
- How does it compare with existing technologies?
- Is it reliable?
- How much does it cost – including running costs?
- Are there competing new technologies?
- Where can I buy it – is there a robust supply chain?
- Are the products / services scaleable?
- Are there any relevant standards or regulation?


Any sufficiently advanced technology is indistinguishable from magic.
— Arthur C. Clarke —
AZ QUOTES

NPL National Physical Laboratory | QMI Quantum Metrology Institute



Quantum Metrology Institute

Delivering the NPL Quantum Programme

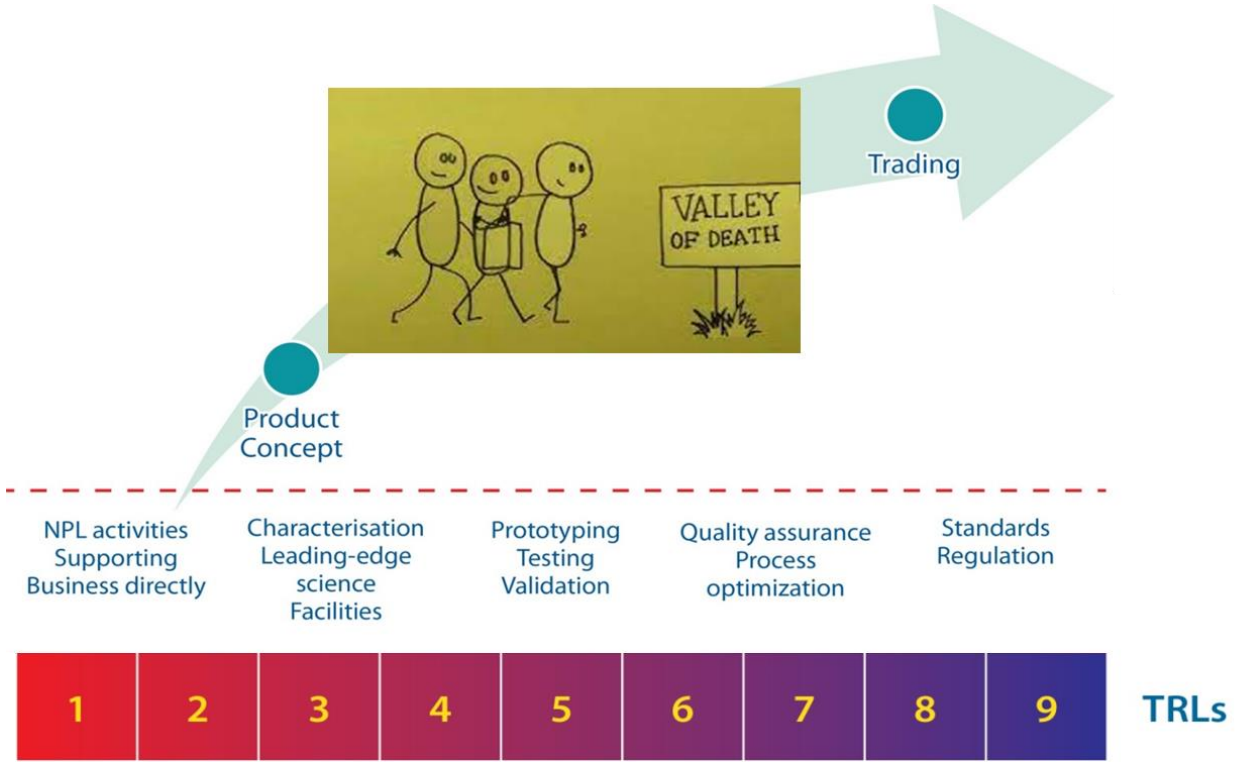
Providing the measurement expertise and facilities needed to underpin the development of quantum technologies

The Quantum Metrology Institute brings together all of NPL's leading-edge quantum science and metrology research. It provides the expertise and facilities needed for academia and industry to test, validate, and ultimately commercialise new quantum technologies.

UK NATIONAL QUANTUM TECHNOLOGIES PROGRAMME

NPL Quantum Programme

NPL will deliver **confidence** in quantum technologies for **manufacturers, investors and end users** by establishing a national capability to **independently demonstrate and test new components, devices and products** being developed within the National Quantum Technologies Programme.

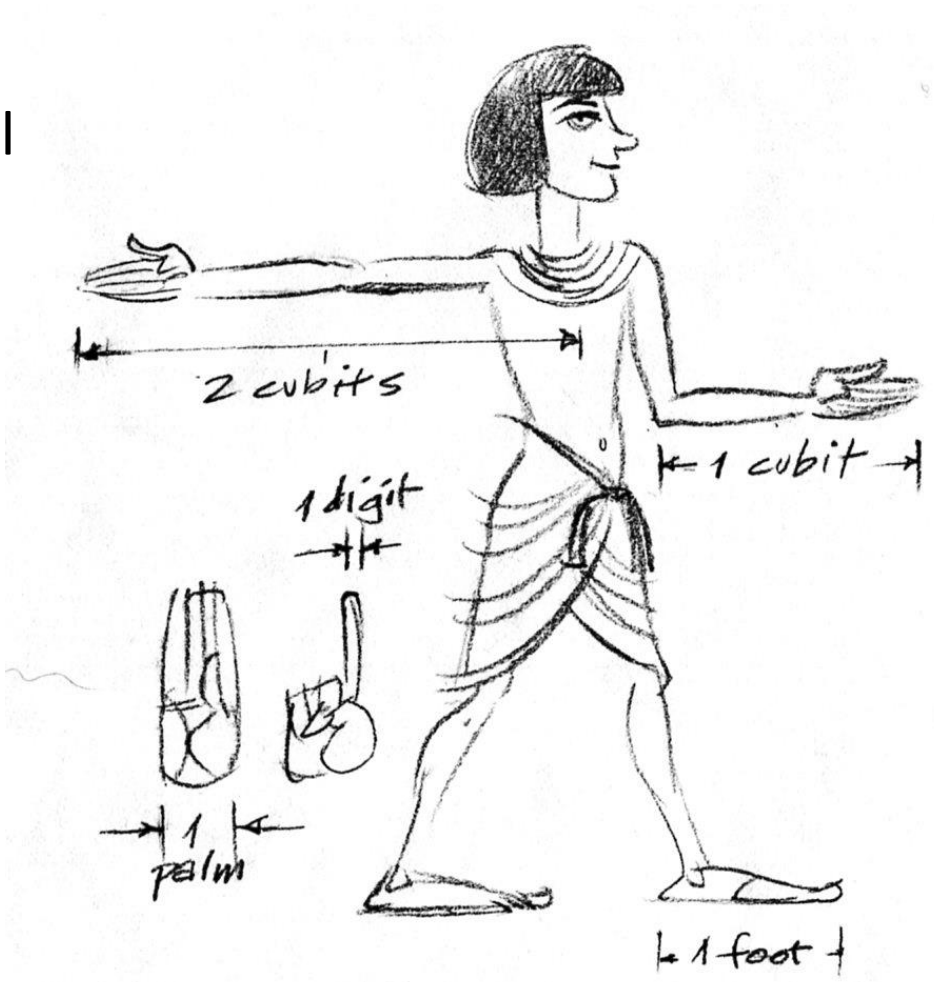


Emerging technologies demand innovations in metrology

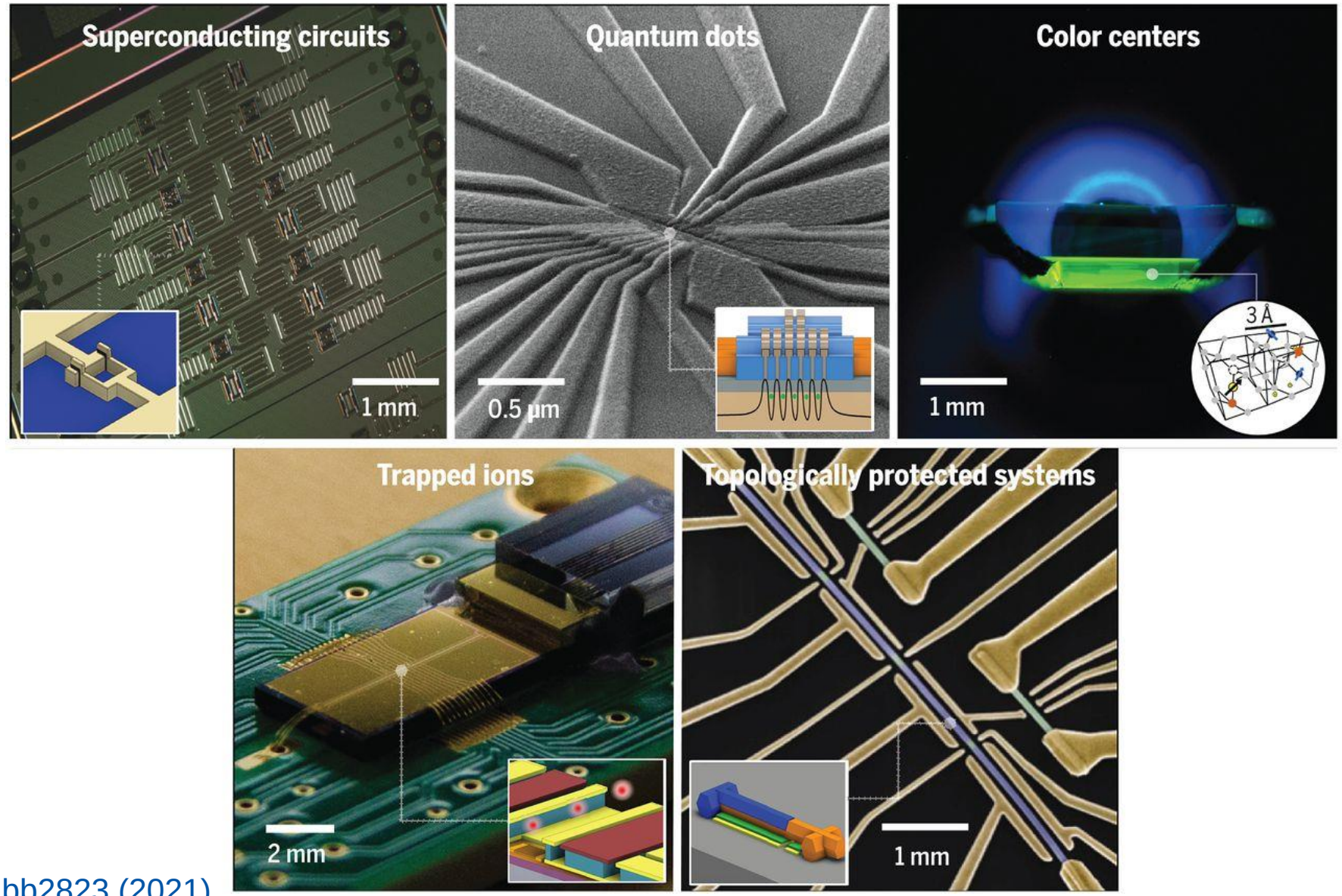
- **Agility:** to keep up with rapidly changing technical landscape
- **Ability:** to make a measurement at all
- **Comparability and interoperability:**

  across vendors, quickly, continuously
- **Accelerated delivery:**

  formal standards may be obsolete by the time they're published



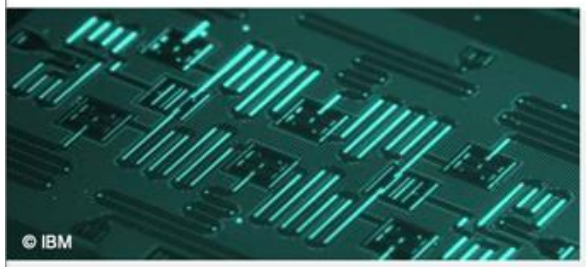
Qubit flavours = physical implementations



N.P. De Leon et al. Science **372**, abb2823 (2021)

The Quantum Computing Platform Zoo

QuantumComputingReport.com Jan 2022
Scorecards – Qubit Quality

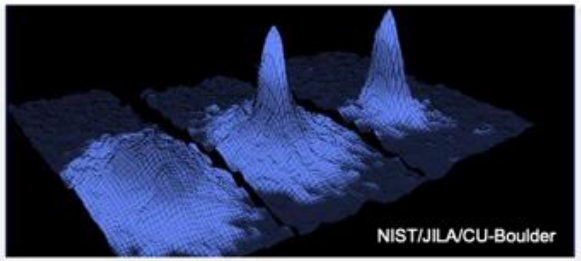


Superconducting Qubits

COMMERCIAL PLAYERS
***Google**, Origin Quantum, IQM, SeeQC, **IBM**, OQC, **Rigetti**, Bleximo, Alibaba, Alice&Bob, Amazon, Intel, Quantum Circuits Inc, Raytheon BBN*

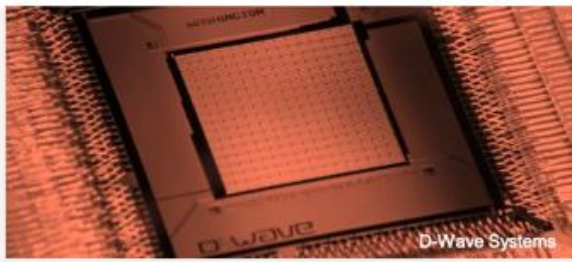
Trapped Ions

COMMERCIAL PLAYERS
***IonQ**, **Honeywell**, Oxford Ionics, Universal Quantum, AQT, AQTION, NextGenQ, MicroQC, Alpine*



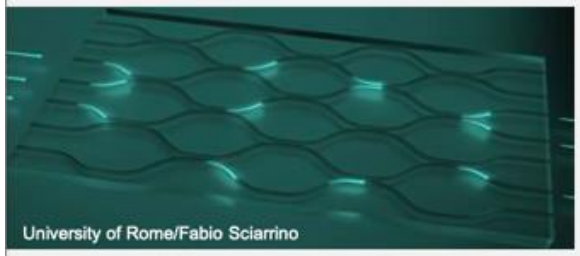
Neutral Atoms

COMMERCIAL PLAYERS
ColdQuanta, QuEra, Pasqal, Atom Computing, MSquared Lasers



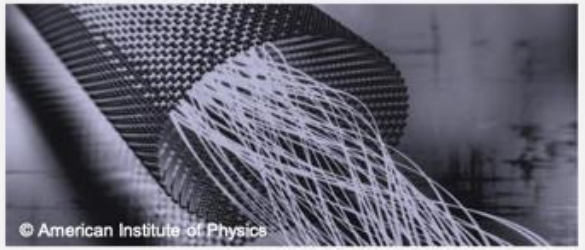
Annealers

COMMERCIAL PLAYERS
***D-Wave Systems**, Qilimanjaro, Northrop Grumman, NEC*



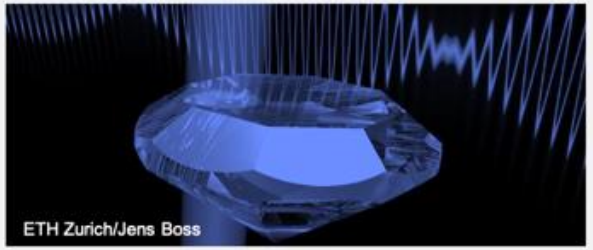
Photonic Circuits

COMMERCIAL PLAYERS
***PsiQuantum**, Xanadu, QuiX, ORCA Computing, Duality, Toshiba, Sparrow Quantum, Quandela, AegiQ, ID Quantique*



Topological States

COMMERCIAL PLAYERS
Microsoft



Colour Centres in Diamond

COMMERCIAL PLAYERS
Quantum Brilliance, Element 6, SpinQ, Archer Materials

Quantum Dots & Spins in Silicon

COMMERCIAL PLAYERS
*Silicon QC, Quantum Motion, Photonic, **Intel**, InfinityQ, Infineon, Equal1, Diraq*

The Importance of Measurement and Standards: ‘Justification’

The Economic Contribution of Standards to the UK Economy

A 2022 report by the Centre for Economics and Business Research summarizes the economic contribution of standards to the UK economy and looks into their use by 1000 companies across all major business sectors.

- Standards also make a significant contribution to the UK economy. The headline economic finding is that an **estimated 23 per cent of all GDP growth since 2000 is attributable to the impact of standards**. This means that standards have boosted the UK’s annual GDP by £161 billion since the start of this century.

The Importance of Measurement and Standards: 'Justification'

- Standards can provide enabling framework conditions for research (Blind and Gauch 2009). This is especially the case for **terminology standards in relation to basic research**, which can facilitate the communication amongst researchers
- **Health, environmental and safety standards** are necessary requirements for the last stage of successful market introduction of innovations by restricting the possible risks of new technologies and products
- Standards **can increase trust and confidence** among users and consumers by defining the **quality** of products and processes
- Standards can help the development of **supply chains**, enabling products to be brought to market economically
- Standards can ensure **compatibility** between existing and new technologies, enabling innovation
- Standards are often the foundations of **regulation**

Two decades of evolution of mobile phones, from a 1992 Motorola 8900X-2 to the 2014 iPhone 6 Plus

WIKIPEDIA
The Free Encyclopedia

Some potential negative outcomes:

- **Premature standard setting** risks early adoption of inferior or less innovative technologies

When standards don’t work, they…

- Give unfair advantage
- Create barriers to trade
- Entrench inferior technologies
- Stifle innovation
- Impede interoperability of products and systems

Department for Science, Innovation & Technology

National Quantum St

March 2023

National Quantum Strategy

Ministerial Foreword

The first generation of quantum technologies created many innovations that we now take for granted in modern society, from the MRI machine to mobile devices. Yet there are lesser known but equally powerful inventions emerging from UK labs that could change our world beyond recognition.

These inventions will improve the lives of everyone in the

We have worked hand in hand with the UK quantum community to bring this national strategy to fruition; I would like to thank everyone who has contributed to this process. The hard work starts now to deliver on its goals together.

UK NATIONAL QUANTUM TECHNOLOGIES PROGRAMME

UK Quantum Standards Network - Pilot

Department for Science, Innovation, & Technology

NPL National Physical Laboratory

bsi.

UKQuantum

National Cyber Security Centre

UKRI National Quantum Computing Centre

strategic advantage

need for greater
been widely recognized
y published national
cument from DSIT.

Department for Business, Energy & Industrial Strategy

UKRI Engineering and Physical Sciences Research Council

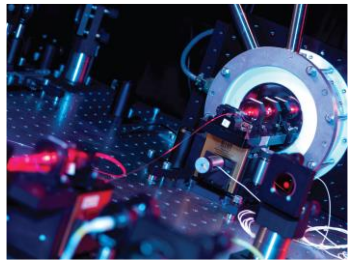
UKRI Innovate UK

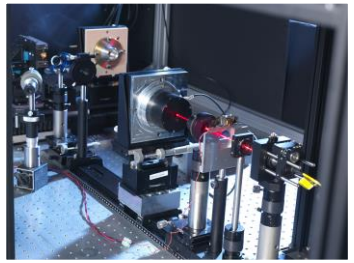
NPL National Physical Laboratory

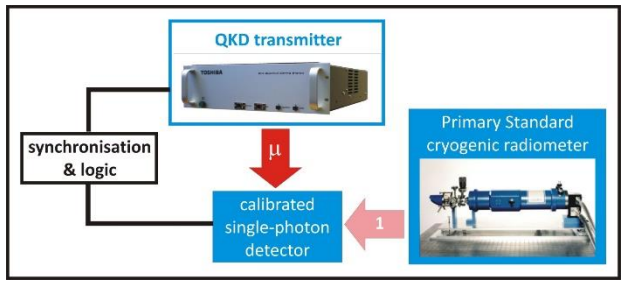
[dstl]

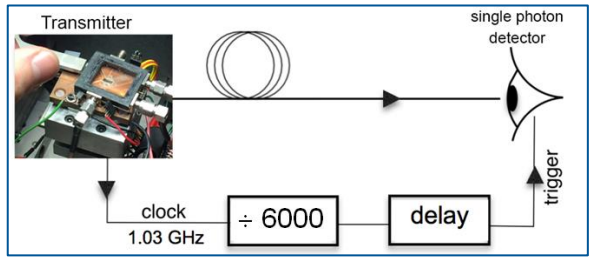
National Cyber Security Centre
a part of GCHQ

Impact: Improving trust and confidence in quantum security products









Underpinning metrology

- Metrology for single- and entangled-photon sources
- Metrology for single-photon detectors

Applied to quantum comms technology

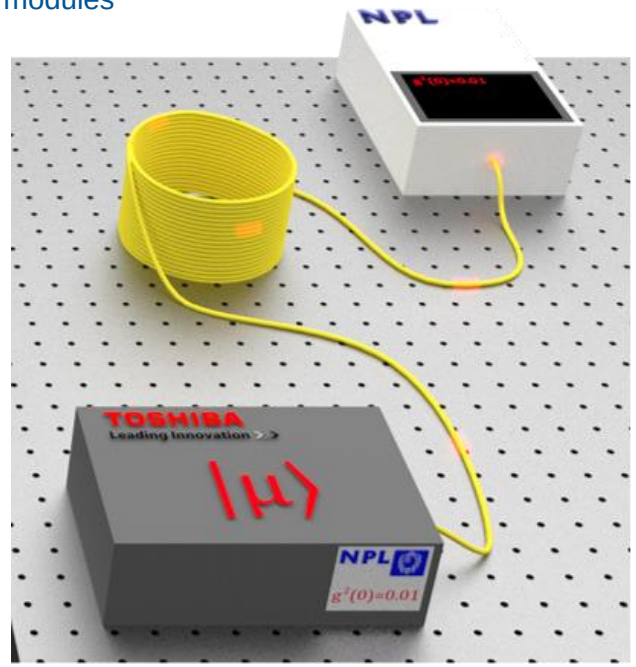
- Coupled fibre-coupled devices at telecom wavelengths
- Public demo with Toshiba, BT and ADVA

Contribute to formal standards

- ETSI standard on QKD components
- ETSI report on future requirements

Serve UK industry

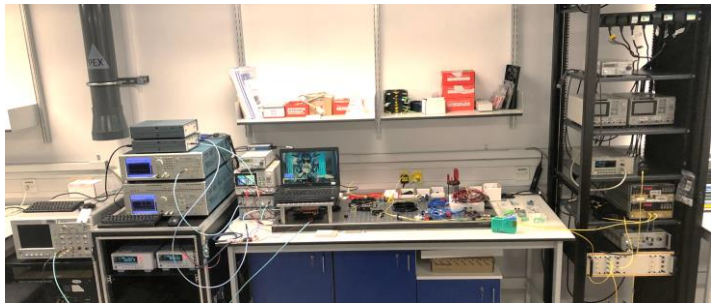
- on-chip QKD prototypes
- complete QKD modules



Test facility for Quantum Communications systems and components

NPL National Physical Laboratory | QMI Quantum Metrology Institute

Currently: testing the quantum layer of modules implementing a specific QKD protocol over fibre.



Attract inward investment

End-users

CRAFT PROSPECT

NATIONAL COMPOSITES CENTRE

Manufacturers /developers

TOSHIBA

IDQ

KETS

nu QUANTUM

CQC CAMBRIDGE QUANTUM COMPUTING LIMITED

QUANTUM COMMUNICATIONS HUB

Components, assemblers

Crypta Labs

QD Quantum Dice

bay photonics Specialists in Photonic and Microelectronic Packaging

wideblue making technology happen

RedWave WWLabs

Collaborators

National Cyber Security Centre

International Collaboration

THE WHITE HOUSE

BRIEFING ROOM

The United States and United Kingdom Issue Joint Statement to Enhance Cooperation on Quantum Information Science and Technology

NOVEMBER 04, 2021 • PRESS RELEASES

Jointly signed by U.S. Presidential Science Advisor and Director of the White House Office of Science and Technology, Dr. Eric Lander, and the U.K. Science Minister, George Freeman, the quantum cooperation statement articulates a shared vision to promote collaborative research efforts, enhance training opportunities for scientists and engineers, and grow the market for quantum technologies.

The joint statement will facilitate continued collaboration between the U.S. National Institute of Standards and Technology (NIST) and the U.K. National Physical Laboratory (NPL) emphasizing metrology research and standards for quantum technologies including next-generation atomic clocks and quantum sensors.

International Collaboration

MEMORANDUM OF UNDERSTANDING

RELATING TO

JOINT SCIENCE AND RESEACH OPPORTUNITES IN THE FIELDS OF QUANTUM INFORMATION SCIENCE AND TECHNOLOGY

BETWEEN

NPL MANAGEMENT LIMITED (NPL)

AND

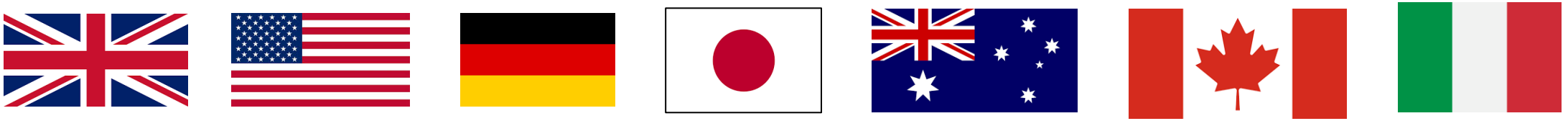
THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

NIST and NPL seek to find new opportunities to build and develop research collaborations, to build upon existing research capability and outputs, and to enhance collaboration with industry.

NPL National Physical Laboratory | QMI Quantum Metrology Institute

BIPM Workshop on Accelerating the adoption of Quantum Technologies through Measurements and Standards

21st and 22nd March 2024
BIPM, Sèvres



Conclusions:

Standardization (& Metrology!)

NPL National Physical Laboratory | QMI Quantum Metrology Institute

Improves the effectiveness and efficiency of science and the trust in its outcomes

Underpins innovation, adoption and commercialisation of new technologies

Gives confidence in quantum technologies for manufacturers, investors and end users (and government!!)

Enables strong regulatory enforcement, including protecting the consumer through standards

Needs to be collaborative and international

Conclusions:

NPL: Supporting the UK's journey to quantum adoption….

Acting as an intelligence customer / trusted advisor - setting the stage for intelligence-driven innovation

Providing test and validation services as well as benchmarks and metrics as standards develop

Leading the development of standardization, working with key strategic partners and industry

Providing the foundations for regulation

NPL
National Physical Laboratory

Get 20 days of quantum consultancy, at no charge*

Could your business benefit from quantum measurement expertise?
The National Physical Laboratory's (NPL) Measurement for Quantum (M4Q) programme provides up to 20 days of specialist support at no charge*.

Learn how M4Q can help your business innovation challenges:

www.npl.co.uk/measurement-for-quantum

*Eligibility criteria applies. See website for full terms and conditions.

Questions