PRIVATE AND CONFIDENTIAL

National Physical Laboratory – Evaluation of the National Physical Laboratory (NPL) Quantum Programme

Evaluation of the National Physical Laboratory (NPL) Quantum Programme – Final Report

October 2025

Contents

List of Abbreviations

AQML: Advanced Quantum Metrology Laboratory

BIPM: Bureau International des Poids et Mesures

BSI: British Standards Institute

DFM: Danish Fundamental Metrology

DSIT: Department for Science, Innovation and Technology

EMPIR: European Metrology Programme for Innovation and Research

EPSRC: Engineering and Physical Sciences Research Council

ICON: International Cooperation on Optical Networks

IDBR: Inter-Departmental Business Register

ISCF: Industrial Strategy Challenge Fund

MoD: Ministry of Defence

MoU: Memorandum of Understanding

M4Q: Measurement for Quantum

NIST: National Institute of Standards and Technology

NMI: National Measurement Institute

NPL: National Physical Laboratory

NRC: National Research Council

NQCC: National Quantum Computing Centre

NPLQP: National Physical Laboratory Quantum Programme

NQTP: National Quantum Technologies Programme

PGI: Postgraduate Institute for Measurement Science

PTB: Physikalisch-Technische Bundesanstalt

QED-C: Quantum Economic Development Consortium

QKD: Quantum Key Distribution

QT: Quantum Technology

QT&E: Quantum Test and Evaluation

QTFP: Quantum Technologies for Fundamental Physics

QTZ: Quantum Technology Competence Center

QVLS: Quantum Valley Lower Saxony

SME: Small-Medium Enterprise

UKRI: UK Research and Innovation

Glossary

Evaluation-focused terminology

Term	Definition
4Es Framework	A way to assess value for money by looking at: Economy (cost-efficiency), Efficiency (resource use), Effectiveness (goal achievement), and Equity (fair access).
Alternative Hypothesis (¬H)	The assumption that something other than the programme caused the observed outcome.
Attribution	Determining whether the outcomes observed were caused by the programme or by other factors.
Bayesian Updating	A method for updating the level of confidence in a claim based on new evidence.
Contribution Tracing	A method used to assess whether a programme contributed to an observed outcome, especially when direct cause and effect are hard to prove.
Counterfactual	A scenario showing what would have happened without the programme, used to assess its true impact.
Doubly Decisive Test	A process tracing test that confirms a claim if evidence is found and rejects it if not.
Economic Evaluation	An analysis of whether the programme provided good value for money, often using tools like cost-benefit analysis.
Effectiveness	A measure of how well a programme achieved its intended outcomes.
Efficiency	A measure of how well resources were used to produce outputs.
Equity	Ensuring fair access and benefits across different groups.
Evaluation Methodology	The overall approach used to assess the design, delivery, and impact of a programme.
Hoop Test	A process tracing test where missing key evidence leads to rejection of the claim.
Impact Evaluation	An assessment of the changes or benefits that occurred as a result of the programme.
Null Hypothesis (H)	The assumption that the programme did not cause the observed outcome.
Posterior Confidence	The updated belief or probability that a claim is true after considering the evidence.
Prior Confidence	The initial belief or probability that a claim is true before looking at new evidence.
Process Evaluation	A type of evaluation that looks at how a programme was delivered and what could be improved.
Process Tracing Tests	Tests used in contribution tracing to assess the strength of evidence: Hoop, Smoking Gun, Straw-in-the-Wind, and Doubly Decisive.
Propensity Score Matching (PSM)	A statistical technique used to compare programme participants with similar non-participants to estimate impact.
Sensitivity	The likelihood of seeing certain evidence if the claim is true.
Smoking Gun Test	A process tracing test that strongly confirms a claim if the expected evidence is observed.
Straw-in-the-Wind Test	A process tracing test that suggests support for a claim but is not decisive.
Theory of Change (ToC)	A visual and narrative explanation of how a programme's activities are expected to lead to its intended outcomes.
Type I Error	A false positive — when evidence suggests a claim is true, but it is not.
Type II Error	A false negative — when evidence fails to show a claim is true, even though it is.
Value for Money (VfM)	A measure of whether the programme achieved its goals efficiently and effectively, considering the resources used.

Quantum-focused terminology

Term	Definition
Quantum Benchmarking	The development and application of standardised metrics and procedures to assess the performance of quantum systems, such as qubit fidelity or photon detection efficiency[1].
Quantum Company	A business that develops, applies, or commercialises quantum technologies, including quantum computing, sensing, communication, or materials. These companies may be fully dedicated to quantum or integrate quantum capabilities into broader tech portfolios[2].
Quantum Computing	Quantum computing is a new kind of computing that uses the principles of quantum physics — the science that explains how things behave at the tiniest scales, like atoms and particles. Unlike regular computers, which use bits that are either 0 or 1, quantum computers use quantum bits, or qubits, which can be in a state of 0, 1, or both at the same time[3].
Quantum Key Distribution	A secure communication method that uses quantum mechanics to generate and share encryption keys, ensuring security based on the laws of physics rather than computational complexity[4].
Quantum Metrology	The science of measurement applied to quantum systems, enabling ultra-precise measurements of time, frequency, and other physical quantities using quantum effects[5].
Quantum Materials	Materials whose properties are governed by quantum mechanics, such as superconductors or topological insulators, which are essential for building quantum devices[6].
Quantum Networks	Communication systems that use quantum signals (e.g., entangled photons) to transmit information securely and with high fidelity, forming the basis for quantum internet infrastructure[7].
Quantum Photonics	A subfield of quantum technology that uses photons (light particles) to encode, transmit, and process quantum information[8].
Quantum Sensors	Devices that exploit quantum effects to measure physical quantities (e.g., magnetic fields, gravity, acceleration) with unprecedented sensitivity and accuracy[9].
Quantum Standards	Agreed-upon definitions, protocols, and measurement methods developed to ensure consistency, interoperability, and trust in quantum technologies across international markets[10].
Quantum Technology	Technologies that exploit quantum mechanical phenomena such as superposition, entanglement, and tunnelling to enable new capabilities in computing, sensing, communication, and measurement[11].
Quantum Test and Evaluation	The process of independently validating and characterising quantum devices and systems to ensure performance, reliability, and interoperability, often using metrological standards[12].
Quantum Timing	The use of quantum-based systems, such as atomic clocks, to achieve ultra-precise timekeeping for applications in navigation, telecommunications, and finance[13].

[1] IEC/ISO JTC 3 - Quantum technologies
[2] Beauhurst Data
[3] Quantum Computing Explained | NIST
[4] GS QKD 011 - V1.1.1 - Quantum Key Distribution (QKD); Component characterization: characterizing optical components for QKD systems
[5] European Metrology Network for Quantum Technologies
[6] Henry Royce Institute
[7] NIST Quantum Network Grand Challenge
[8] EPSRC Quantum Technology Hub in Quantum Communications
[9] National quantum strategy - GOV.UK
[10] IEC/ISO JTC 3 - Quantum technologies
[11] National quantum strategy - GOV.UK
[12] Test and evaluation in support of quantum technology development in the UK - ScienceDirect
[13] National Institute of Standards and Technology

Executive Summary

Introduction

The National Physical Laboratory Quantum Programme (NPLQP), also known as the Quantum Test and Evaluation (QT&E) Programme, was initiated in June 2020 and ran until March 2024. It was established in response to the GO-Science's Blackett Review, which emphasised the need for a dedicated test and evaluation infrastructure and work on standards to support the commercialisation of quantum technologies. The Programme received over £39 million in central government funding between 2020 and 2024 and was part of the National Quantum Technologies Programme (NQTP).

The purpose of the NPLQP was to develop the independent facilities, methods, and skills required to accelerate the transition of quantum technologies from laboratory research to market-ready products and services. It complements other public investments in the quantum ecosystem, including the Engineering and Physical Sciences Research Council (EPSRC) Quantum Technology Research Hubs, the National Quantum Computing Centre (NQCC), and Industrial Strategy Challenge Fund (ISCF)/Innovate UK (Innovate UK) funding (e.g. Innovate UK Commercialising Quantum Technologies Challenge) by focusing on product validation, standards, and skills for testing and evaluation.

RSM UK Consulting LLP were appointed by the National Physical Laboratory (NPL) to conduct an end of Programme evaluation of the NPLQP. The evaluation i) assesses the Programme's impact on quantum technologies, the UK's leadership, and broader societal and economic effects; ii) evaluates delivery effectiveness, including strengths, weaknesses, and lessons learned; and iii) aims to inform future funding decisions by strengthening the evidence base. This report incorporates:

Process Evaluation: Assesses effectiveness, identifies strengths and areas for improvement, ensuring lessons learned can be applied to future iterations of the Programme.

Impact Evaluation: Substantiates the Programme's impact by assessing its contributions to quantum technologies, the UK's leadership, and its broader impact.

Economic Evaluation: Assesses the value for money (VfM) of the Programme and the potential for modelling future economic impacts.

To deliver on its objectives, the Programme operated through four key mechanisms:

- **Research and Development:** NPLQP supported collaborative research projects with academia, industry and government, including partnerships with the EPSRC Quantum Technology Research Hubs, ISCF, Quantum technologies for fundamental physics (QTFP) and direct engagement with Small-Medium Enterprises (SMEs). It provided access to national facilities such as the Advanced Quantum Metrology Laboratory (AQML), enabling the co-creation of industry relevant quantum measurement techniques.
- **Innovation:** The Programme provided QT&E services to companies to de-risk the development of new quantum technologies. Furthermore, through the Measurement for Quantum (M4Q) scheme, 50 UK SMEs have accessed NPL's expertise in validating product performance, calibrating instruments, and ensuring interoperability. These non-competitive services are tailored to the needs of early-stage companies and aim to reduce time-to-market and improve investor confidence.
- **Standards:** Developed the technical bases for new standards. This was done by working closely with partner institutions, such as, BSI (British Standards Institute) and NQCC, and collaborations with other international metrology institutes (e.g. National Institute of Standards and Technology (NIST) and Physikalisch-Technische Bundesanstalt (PTB) in Germany).
- **Skills and training:** Provided training and upskilling opportunities for the current quantum workforce, as well as attracting and facilitating recruitment of new talent (e.g. via supporting PhD students and

apprentices) and connecting students / apprentices with industry. This was provided primarily through the Postgraduate Institute for Measurement Science (PGI).

The Business Case included five core objectives:

- Facility provision
- Knowledge transfer
- Standards development
- Industry engagement
- Skills development

Key Findings and Recommendations

Key findings from this early-stage evaluation are outlined below. Due to the long-term nature of the NPLQP it is likely significant outcomes and impacts will lag for approx. six years. As such, this evaluation has focused on processes, outputs against objectives in the business case and emerging outcomes / benefits. This timing also means analysis of benefits to date against total costs will provide a small number.

Programme Performance and Delivery

The Programme has strong management and governance processes in place, with progress monitored for most of the business case KPIs and additional KPIs developed to reflect the additional areas of focus for the Programme. Delivery was effective, especially given the impact of Covid at the outset of implementation. NPLQP achieved strong outcomes in standards development, industry engagement, skills development and knowledge transfer, meeting most of the KPIs set out in the initial business case. Facility provision saw partial success due to some gaps in sustainability planning. Strengthening the monitoring and focus on risks for this area should help ensure increased performance in the future.

The Programme Board for the NPLQP proactively managed risks by maintaining structured risk registers for each objective area, using a scoring system to prioritise mitigation efforts and escalating strategic risks for resolution. While risk management was generally robust, featuring contingency planning, stakeholder engagement, and governance improvement, analysis identified small gaps in alignment between tracked risks and original programme targets.

Recommendation – metrics data should be collected (where applicable / appropriate) to align with Business Case KPIs that would allow for comprehensive assessment of performance against targets.

Recommendation – performance monitoring should combine descriptive statistics (e.g. number of collaborations; number of companies receiving QT&E support; number of secondments and joint appointments hosted; number of apprentices hosted and sustainability metrics) with data on the impacts these have achieved.

Recommendation – risk assessment and mitigation processes should fully cover the targets and KPIs relevant to each objective area / workstream to ensure they are on track to be achieved. This would increase potential for the Programme to achieve target outcomes and – in any cases where targets are not reached – provide rationale for this.

Recommendation – the NPLQP programme should have a dedicated M&E resource.[14]

Process Evaluation

Programme rationale and design

The Programme was designed to address key market failures hindering quantum technology (QT) commercialisation in the UK, including poor coordination between academia and industry, a growing quantum skills gap, and underinvestment in testing infrastructure. Its implementation focused on five strategic pillars:

[14] The 2020-24 programme was more than half way through before an analyst was brought in to lead/develop the M&E activities

building national QT&E facilities, promoting best practice in measurement, leading international standards development, improving industry access, and delivering targeted training. These elements aimed to create a more cohesive, skilled, and innovation-ready quantum ecosystem.

Were activities delivered as expected?

The Programme made strong progress in establishing national infrastructure, advancing international standards, and supporting early-stage quantum firms. While the Programme laid a solid foundation for future initiatives, key areas for improvement include strengthening industry outreach, enhancing training uptake, and ensuring more consistent delivery against planned objectives.

Were users engaged as expected?

The Programme successfully engaged most of its intended user groups, including QT companies, academic institutions, government stakeholders, and standards bodies, with strong collaboration results and strategic partnerships. It also supported early-career talent through PhD and apprenticeship schemes. However, engagement with non-quantum industry end-users was limited, hindered by unclear messaging and a lack of visibility into NPL's service offer. Future efforts should focus on improving outreach and communication to broaden adoption across sectors beyond the core quantum community.

What would users have done if NPL's services were not available?

Without the Programme, many users, particularly SMEs and academic partners, would have faced significant barriers in accessing specialised quantum facilities, credible validation, and interdisciplinary expertise. It also supported standards and skills development. In its absence, users would likely have relied on fragmented, lower-quality alternatives or faced delays in achievement of outcomes, weakening the UK's quantum innovation pipeline.

How is NPL positioned globally?

NPL is a key player in the global quantum landscape, offering strong capabilities in measurement science, skills development, and standards leadership. Its training model and contributions to international standardisation efforts position it well among peers like NIST (USA), National Research Council (NRC) (Canada), PTB (Germany), and Danish National Metrology Institute (DFM). NPL offers a comparable suite of commercialisation support services to international peer institutions, particularly in terms of technical expertise, testing infrastructure, and collaborative R&D support. However, there are key differences:

- **Incubation and start-up support:** NPL does not operate its own physical incubator space or structured start-up programme. However, this gap is mitigated by its partnerships with the EPSRC Quantum Technology Research Hubs. Through these partnerships and the M4Q Programme, the NPLQP has supported spinouts and SMEs.
- **IP support:** Unlike some institutions such as NRC and NIST, NPL does not currently provide dedicated in-house IP advisory services. This is a notable gap where international counterparts often embed IP guidance directly within commercialisation supports. NPL could collaborate with others to ensure this is available.
- **Formal qualifications:** NPL does not currently provide expertise to shape formal professional qualifications, such as the co-designed Master's programmes available through Canada's NRC. This aligns with findings from the UK Quantum Skills Taskforce report[15], which highlighted the need for more industry-aligned quantum MSc programmes and stronger collaboration between academia and industry in their design and delivery.

[15] UK Quantum Skills Taskforce report (May 2025)

Recommendation – To enhance its support, NPL should continue and even strengthen its linkages with other services. While organisations like NRC and PTB integrate technical services with financial support or incubator networks, similar support mechanisms already exist within the UK's broader quantum and innovation ecosystem. NPL should ensure these linked supports are effective for their client base.

Impact Evaluation

The NPLQP has played a pivotal role in shaping the UK's QT landscape between 2020 and 2024.

R&D and Innovation

The Programme has made a strong contribution to advancing the UK's quantum R&D capabilities. Through strategic partnerships, such as those with Royal Holloway and the University of Manchester, and investments in facilities like AQML and SuperFab, NPL has enabled cutting-edge research and improved reproducibility and readiness of quantum technologies.

However wider stakeholders across both public and private sectors noted that the Programme could do more to support the coordination of quantum materials R&D. This provides the opportunity for NPL to map and connect the UK's expertise in different material types and link these to broader strategies (e.g. semiconductors, telecommunications). While acknowledged that other stakeholders (e.g. Innovate UK and Catapults) are also likely to have core roles within this space, NPL has potential to contribute via provision of definitions for assurance protocols and standards for quantum materials, which are essential for device reliability and commercialisation.

Standard Setting

NPL experts have contributed to key ETSI and ISO/IEC standards, including QKD (Quantum Key Distribution) and quantum computing terminology. In the UK, NPL co-founded the national quantum standards committee with BSI, now with over 60 members. The Programme has led national workshops, influenced the CEN-CENELEC quantum roadmap, and proposed a new ISO/IEC technical committee. Internationally, NPL collaborates with NIST under a joint MoU and has convened global metrology leaders through a National Measurement Institute (NMI) 'mini summit'. It also supports global engagement through IMEKO TC25, advancing quantum sensing and metrology.

Private Sector

The Programme has had a moderate however meaningful impact on the private sector. It has enabled early-stage quantum companies to develop and validate new products which has helped build trust and credibility; these validations are important as without them the companies may not be able to sell their products.

In addition, the M4Q scheme contributed to 30+ new or improved products and 22 companies securing additional investment. While attribution is complex due to overlapping support from other initiatives, the Programme has shown some contribution to commercialisation and supply chain development. However, engagement with downstream users and tiered manufacturing remains limited.

The Programme's contribution to the wider adoption of quantum technologies and societal awareness is currently negligible, likely because it is an emerging sector, with limited evidence of systemic uptake in sectors like healthcare or defence, unlike some international comparators

Recommendation – NPL should widen their engagement to support the greater adoption of quantum technologies, particularly in healthcare and defence.

Upskilling the Workforce

The Programme has helped develop the quantum workforce. By 2024, NPL supported 79 PhD students (6% fully funded, 69% partly funded), delivered training to 100+ individuals, and hosted apprenticeships and joint academic appointments. QT organisation survey data shows 64% of organisations faced hiring challenges, and 69% of those who responded agreed NPL helped recruit staff.

Future Proofing Impact

The NPLQP has laid essential groundwork for the UK's quantum future. It has delivered tangible benefits in research, early-stage innovation, and skills, while also establishing NPL as a trusted authority in quantum measurement and standards. However, there are areas it can develop:

Recommendation – we recommend that NPL utilise its expertise and role as a convening force in quantum to lead national efforts surrounding quantum materials while ensuring alignment with semiconductor and telecoms strategies to ensure maximum relevance and impact.

Recommendation – we recommend a further summative evaluation in completed in 2-5 years after ensuring the collection of quantitative data on private investment in quantum technologies and sales and exports to more fully demonstrate NPL's impact.

Economic Evaluation

The economic evaluation assessed the NPLQP's VfM by examining the relationship between costs, outcomes, and delivery performance, drawing on Cost-Benefit Analysis (CBA) and a structured assessment against the 4Es framework: Economy, Efficiency, Effectiveness, and Equity.

The CBA assessed the extent to which the following four anticipated economic benefits have been realised and compared these to the costs.

Economic Benefits:

- **Follow on Funding -** Analysis of the Beauhurst database indicates that 31% of NPL-supported firms raised funding between 2020 and 2024, compared to only 11% of quantum firms that did not receive NPL-support. Median fundraising was also higher among NPL-supported firms. However, it is uncertain how much of these differences are attributable to NPL support.
- **New Products / Services -** There is also strong qualitative evidence via case studies, interviews, QT organisation survey responses, and NPLQP monitoring information that the NPLQP has contributed to the development of new and improved products across a range of UK QT companies. While some companies attributed progress directly to NPL's support - particularly access to validation facilities and expertise - attribution is complex due to overlapping funding and support from universities and other national initiatives. The contribution analysis concluded with cautious confidence that NPL accelerated product development beyond what would have occurred otherwise. In addition, there is evidence of patent development that can be directly and indirectly attributed to NPL support. However, insufficient time has passed to assess the impact of this innovation activity on the long-term commercialisation in the sector.
- **Export and Employment Growth -** Information is more limited on the extent to which export and employment growth have been generated by NPL due to limited survey responses. The QT organisations survey did elicit responses for some organisations that felt that NPL support had led to them increasing the size of the workforce, but the number of responses was too small to generalise from this finding.

CBA Analysis: The total spending on the NPLQP between 2020 and 2024 was £38.8 million. An indicative CBA was conducted, although the attribution challenges outlined above limit the extent to which this can provide a true reflection of the value achieved by the Programme. Based on assumptions informed by the findings on fundraising and commercialisation, the indicative Benefit-Cost Ratio (BCR) is estimated at between 0.34 and 1.17. There are several gaps that, if addressed in future Programme monitoring or evaluation, would enable a more robust and definitive CBA.

4Es: To complement the CBA approach, a 4Es VfM assessment was undertaken to provide a broader view of the VfM provided by NPL:

- The Programme broadly demonstrated sound economy, with over 95% of the allocated budget spent and the majority directed toward delivery activities rather than overheads. However, the M4Q programme spent less than two thirds of its budget, perhaps indicating lower than anticipated demand from SMEs.
- Delivery was broadly efficient. Qualitative feedback indicates effective use of resources and minimal downtime in later years. The distinctive capabilities established—such as AQML and advanced characterisation tools—filled market gaps and served unique sector needs.
- The Programme was effective in achieving its core objectives in enabling innovation, advancing applied R&D, and supporting the early development of QT. It contributed to the UK's leadership in standards, built research capacity, and enabled impactful collaborations across academia and industry.
- Although not a central Programme objective, equity considerations were addressed through open-access support, geographic investment in regional facilities, and skills development via student and early-career placements.

Overall, there is evidence that the Programme has delivered VfM, having effectively achieved its core objectives and contributed to longer-term economic impacts, including attracting further funding and supporting commercialisation across the wider quantum sector.

Recommendation – we recommend that NPL develop monitoring and tracking tools that can strengthen attribution of long-term economic outcomes to the Programme. Areas of focus are capturing data on private investment in QT and sales and exports that are linked to NPL activity such as patent development.

Recommendation – we recommend that NPL develop a clearer definition of 'treated' firms drawing on scale of support as well as length of time supported. This will enable identification of where NPL support may make the biggest contribution to long-term economic outcomes.

Recommendation – we recommend that given the underspend on M4Q further consideration is given by NPL to understand if this reflects lower than anticipated demand for the Programme by SMEs.

1. Introduction and Background

1.1. Introduction

RSM UK were appointed by the NPL to conduct an end of programme evaluation of the NPLQP. The evaluation period runs from December 2024 to July 2025. The evaluation will: i) assess the Programme's impact on QT, the UK's leadership, and broader societal and economic effects; ii) evaluate delivery effectiveness, including strengths, weaknesses, and lessons learned; and iii) inform future funding decisions by strengthening the evidence base.

1.2. Terms of Reference

This report incorporates:

- **Process Evaluation:** Assesses effectiveness, identify strengths and areas for improvement, ensuring lessons learned can be applied to future iterations of the Programme.
- **Impact Evaluation:** Substantiates the Programme's impact by assessing its contributions to quantum technologies, the UK's leadership, and its broader impact.
- **Economic Evaluation:** Assesses the VfM of the Programme and the potential for modelling future economic impacts.

1.3. Overview of the UK Quantum Technologies landscape

The UK has emerged as a global leader in QT, driven by a robust national strategy and significant public investment. The UK's National Quantum Strategy, launched in 2023, outlines a 10-year vision to transform the country into a quantum-enabled economy[16]. This strategy builds on the success of the £1 billion NQTP[17] and sets out five missions, including the deployment of quantum navigation systems and the development of quantum computers that outperform classical supercomputers by 2035. The strategy emphasises quantum's potential to contribute to development in sectors such as healthcare, cybersecurity, and energy, while also acknowledging the risks, particularly in data security and national defence.

The UK's quantum ecosystem is supported by a diverse and expanding network of institutions and companies. Innovate UK's Quantum Landscape Map identifies over 300 businesses, and 300 research groups actively engaged in quantum technologies, spanning areas such as computing, sensing, communications, and metrology[18].

1.4. Overview of the National Physical Laboratory (NPL) Quantum Programme

The NPLQP (formally referred to as the QT&E Programme) was approved in June 2020 and ran from June 2020 to March 2024. It received over £39 million in central government funding[19], with £12.5 million allocated in 2020/21 and the remaining funding profiled through to 2023/24. It was set up in response to the GO-Science's Blackett Review[20], which highlighted the need for dedicated T&E infrastructure and early work on standards to support the commercialisation of quantum technologies. The Programme was delivered by NPL as part of the UK's one-billion-pound NQTP[21], a whole-system programme involving government, academia and industry to maximise UK economic growth and increase security and resilience through the exploitation of quantum technologies. The purpose of the NPLQP was to develop the independent facilities, methods, and skills required to accelerate the transition of quantum technologies from laboratory research to market-ready products and services. It complements other public investments in the quantum ecosystem, including the EPSRC Quantum Technology Research Hubs, the NQCC, and ISCF/Innovate UK funding (e.g. Innovate

16 National quantum strategy - GOV.UK
17 NQTP | UK National Quantum Technologies Programme
18 Quantum Landscape - Innovate UK Business Connect
19 Quantum T&E Business Case 2020-2024
20 Quantum technologies: Blackett review - GOV.UK
21 NQTP | UK National Quantum Technologies Programme

UK Commercialising Quantum Technologies Challenge) by focusing on product validation, standards, and skills for testing and evaluation.

The Programme sought to address several market failures that had resulted in limited commercial uptake of quantum technologies:

- Coordination failure across fragmented test efforts;
- knowledge gaps in industry around measurement (to reduce skills gaps); and
- the lack of shared infrastructure due to positive spillovers.

As a core element of NPL's remit, the Programme also provided opportunity to explore development of agreed test methods and standards (areas which were, at the time of the programme's implementation, an underdeveloped aspect of the quantum ecosystem).

The Business Case highlighted while other organisations were supporting R&D activities (e.g. EPSRC, UKRI, Ministry of Defence (MoD)), there was a need for NPL to focus on building trusted test and measurement capability to underpin industrial confidence and standardisation.

To deliver on its objectives, the Programme operated through four key mechanisms:

- **Research and Development:** NPLQP supported collaborative research projects with academia, industry and government, including partnerships with the EPSRC Quantum Technology Research Hubs, ISCF, QTFP and direct engagement with SMEs. It provided access to national facilities such as the AQML, enabling the co-creation of industry relevant quantum measurement techniques.
- **Innovation:** The Programme provided T&E services to companies to de-risk the development of new quantum technologies. Furthermore, through the M4Q scheme, 50 UK SMEs have accessed NPL's expertise in validating product performance, calibrating instruments, and ensuring interoperability. These non-competitive services are tailored to the needs of early-stage companies and aim to reduce time-to-market and improve investor confidence.
- **Standards:** Developed the technical bases for new standards. This was done by working closely with partner institutions, such as, BSI and NQCC and collaborations with other international metrology institutes (e.g. NIST and DFM).
- **Skills and training:** Provided training and upskilling opportunities for the current quantum workforce, as well as attracting and facilitating recruitment of new talent (e.g. via supporting PhD students and apprentices) and connecting students / apprentices with industry. This was provided primarily through the PGI.

1.5. Structure of this report

The structure of the report is as follows:

- **Chapter 2: Evaluation Overview –** provides an overview of the evaluation methodology.
- **Chapter 3: Programme Performance and Delivery –** assesses performance of the Programme as at end of 2024.
- **Chapter 4: Process Evaluation Findings –** assesses the effectiveness and efficiency of Programme delivery, identify strengths and areas for improvement of Programme delivery, ensuring lessons learned can be applied to future iterations of the Programme.
- **Chapter 5: Impact Evaluation Findings –** assess the contribution of the Programme to quantum technologies, the UK's leadership, and its broader impact.
- **Chapter 6: Economic Evaluation Findings –** assesses the VfM of the NPLQP and examine the Programme's broader economic contribution to the UK QT sector.
- **Chapter 7: Conclusions and Recommendations –** details the conclusions and recommendations based on the key findings identified.

The chapters are supplemented by appendices which provide supporting detail and further information on the evaluation methodology.

2. Evaluation Overview

2.1. Overall evaluation approach

This chapter details the evaluation aims and the approach for the process, impact and economic assessments. The following table summarises the evaluation aims and research questions. Appendix A.1 provides the full list.

Table 1: Evaluation Aims and Research Questions

Evaluation Element/ Aim	Relevant Research Questions
Process Evaluation Assess effectiveness, identify strengths and areas for improvement, ensuring lessons learned can be applied to future iterations of the programme.	• What was the rationale for the programme and was the design appropriate to support this? • What were the key components of the implementation strategy and how were they executed: • How cost-effective was the programme? • How could the programme activities have been delivered more efficiently, e.g. time, money, human capital? • How effective were the monitoring and evaluation mechanisms used to track progress, and how could they have been improved? • How is NPL positioned globally?
Impact Evaluation Substantiate the programme's impact by assessing its contributions to quantum technologies, the UK's leadership, and its broader impact.	• What is the impact of the programme on R&D and innovation activities in the QT sector? • What is the direct impact of the programme on the private sector? • Quantified and non-quantified measures: • What is the contribution of the programme to impacts: • How can impact be future proofed?
Economic Evaluation Assess the VfM of the programme and assess the potential for modelling future economic impacts	• What was the VfM of the programme? • How many job years were created to support the NMS labs involved with the programme? Is the programme the best use of resources?

2.2. Evaluation methodology

2.2.1 Process evaluation

The process evaluation consisted of a policy/wider context write up, synthesis of findings from primary and secondary data and global comparator institutions analysis to answer the research questions outlined above. The following approaches and methods were used to answer the key process evaluation questions:

- **Qualitative interviews** with NPL delivery and partnerships staff (seven) and beneficiaries (customer organisations and students) (three) – to provide information related to programme delivery and lessons learned.
- **Focus group sessions** with wider stakeholders from industry (one focus group consisting of six individuals) and the public sector (one focus group consisting of four individuals) to provide information related to Programme rationale and gaps it was intended to address.
- **Survey of QT organisations** as a follow-up to the 2023 Ipsos baseline survey of QT organisations to address relevant evaluation questions, with additional questions on skills development, economic impacts and changes post-baseline. The survey received 30 complete responses (9% response rate).
- **Project background documents review** of Business Cases, KPIs, governance reports and risk registers to provide information and develop an understanding of the Programme resources and delivery mechanisms.

- **Secondary data analysis** drawing on the following documents to provide information on lessons learned related to Programme delivery and the role of NPL support:
  - Staff surveys and lessons learned surveys (2017-2024); and
  - case studies with QT customers and collaborators
- **Review of wider literature** to inform a policy context section outlining why the NPLQP was publicly funded and how it sits within the broader quantum ecosystem. It also enabled an assessment of how NPL's strategy aligns with national goals and industry recommendations. Wider literature reviewed includes:
  - Wider relevant Innovate UK, DSIT (formerly BEIS (Business, Energy and Industrial Strategy)), and Office for Quantum Reports; and
  - UK policy documents, including the National Quantum Strategy (NQS) and TechUK reports, and NPL internal reports such as Quantum TQE reports and NPLQP Annual Reports

In addition, the process evaluation reviewed NPL position globally and the impact this has on its ability to deliver intended outcomes and impacts. This was completed via a global comparator institutions analysis consisting of a rapid evidence review to compare how leading international institutions, namely NIST (USA); NRC (Canada); PTB (Germany); and DFM (Denmark) support their quantum sectors and drive economic growth. For institutions where there were significant gaps in publicly available information (namely DFM and NRC), follow-up interviews were also completed with senior members in those organisations.

2.2.2 Impact evaluation

The impact evaluation uses Contribution Tracing, drawing on both qualitative and quantitative approaches. The resulting evidence was compared against the contribution claims outlined in section 5.8, and impact attribution assessed through a four Process Tracing tests:

- **Hoop Test:** if key evidence is missing, the claim is rejected.
- **Smoking Gun Test:** strongly confirms the claim if observed.
- **Straw-in-the-Wind Test:** suggests support but isn't decisive.
- **Doubly Decisive Test:** confirms the claim if evidence is found; rejects it if not.

To further quantify the evidence strength, we applied Bayesian Updating to produce confidence measurements by estimating impacts using the Bayes formula to calculate a probability for each hypothesis linked to the contribution statements outlined in section 5.8.

2.2.3 Economic evaluation

The economic evaluation of the NPLQP was designed to assess the VfM of the Programme, in line with HM Treasury Green Book guidance. It involved both a quantitative CBA and a structured qualitative assessment using the National Audit Office (NAO) 4E's Framework (Economy, Efficiency, Effectiveness, Equity). Together, these approaches provide a holistic picture of the Programme's economic contribution and delivery performance.

Costs were identified drawing on Programme financial records and Programme budgets. Four main expected long-term economic benefits were considered: *further fundraising by NPL-supported firms, commercialisation of new products and services, export growth and employment growth.* Evidence for these benefits was assessed drawing on a range of sources including NPLQP monitoring information, QT organisation survey responses, stakeholder interviews, the Beauhurst database and the Dimensions dataset. Propensity Score Matching (PSM) was used during analysis of the Beauhurst database to identify a matched cohort of firms that did not receive NPL support. However, small sample sizes limited the extent to which it was possible to perform statistically rigorous analysis using this approach.

The 4Es assessment was structured around a predefined rubric and evidence framework, using scoring criteria agreed with NPL's evaluation team. Each component was informed by triangulated evidence, including interview insights, project documentation, delivery metrics, and benchmarking data. Particular attention was given to non-market benefits such as knowledge spillovers, standards leadership, and skills development, which are not readily captured in monetised terms but form a critical part of the Programme's overall value.

Number of Quantum companies referred to in this report:

- **804 quantum companies in the UK:** This figure represents the total number of defined quantum companies, combining those listed in Beauhurst's Quantum Ecosystem Mapping Report with additional firms engaged through the M4Q Programme but not captured in the Beauhurst dataset. It is provided for context only, to illustrate the proportion of UK quantum companies that have received support from NPL.
- **86 quantum companies supported by NPL**: this figure reflects the number of firms identified in Beauhurst's Quantum Ecosystem Mapping Report that engaged with NPL by collaborating and using at least one of its services in one or more of the past six years. These companies are treated as NPL's supported cohort and form the basis for the impact and economic analysis, as they are the most likely to have been influenced by NPL's support. **Metrics relating to these firms can therefore be reasonably attributed, in part, to NPL's contribution**.,
- **382 unique private sector collaborations:** this figure – based on QT Department collaboration metrics[22] – represents the number of unique collaborations between the QT Department as a whole across the 2020 – 2024 time period. This is not specific to quantum companies and requires a lower threshold for achievement than 'supported' companies (hence the lower figure for this group). Unlike the 'supported' figure, this is drawn from internal NPL tracking, rather than Beauhurst analysis.
- **50 M4Q companies supported:** this figure represents the total number of unique successful applicants within the M4Q scheme delivered as part of the overall Programme. This figure was tracked internally by NPL and reported by Programme delivery staff.

2.2.4 Methodological challenges and limitations for the evaluation

Several challenges were encountered in completing the evaluation which should be considered when interpreting the findings.

Table 2: Methodological challenges and limitations for the evaluation

Limitation / challenge	How this was addressed
Low response rates to survey and interview requests. Survey distribution was negatively impacted by: ▪ A high proportion of email bounce-backs and outdated contact details were identified, this is why the sample was determined to be c.300 -350 up-to date and accessible contacts; ▪ Low engagement from companies & students for interviews. Though the reasoning for this is not certain, it is likely due to a combination of the time of year (that May & June are busy periods in academia); ▪ Many companies had already been interviewed to inform development of M4Q case studies (seven) and case studies with private sector QT customers (ten). To avoid repetition and potential evaluation fatigue, NPL asked that engagement would focus on those who were not M4Q supported and not	Multiple data sources were used to complete each stage of this evaluation including both evidence already collected by NPL (highlighted in green) along with additional sources of data collected by RSM (highlighted in orange) • NPL Staff surveys/lessons learned surveys • NPL Annual reporting • NPL Project management documents • NPL Project management documents • Case studies and project interviews (customer and M4Q) • 2023 bibliometric analysis • NPL QTE metrics • NPL Knowledge reports • Market mapping report • Beauhurst data • Dimensions API • UKRI Gateway to Research • Collaborators interviews • Follow-up survey of quantum organisation • Global comparator institutions analysis

[22] List of NPL supported firms (2020-2023) (provided to RSM by NPL June 2025)

Limitation / challenge	How this was addressed
involved in previous case study development. However, these companies tended to be the most engaged and therefore would likely have increased response rates. Their feedback has been incorporated using evidence from the existing / previously completed case study work.	• NPL delivery and partnerships staff interviews • Wider stakeholder focus group • NPLQP customer interviews • PhD interviews A range of attempts were used to boost response rates, including: ▪ NPL involvement in stakeholder mapping in order to identify the most relevant organisations / contacts for inclusion in the fieldwork; ▪ initial 'warm up' engagement from NPL to raise awareness of the evaluation; ▪ three reminders from the evaluation team; ▪ direct engagement from the NPL team with business managers to source more direct contacts; and ▪ direct telephone follow-up by RSM. However, this additional work only generated a few more responses and survey numbers remained low, with an estimated 8.5-10% response rate (30 responses with a sample of c.300-350 companies contacted).
Difficulty in attributing impact to the NPLQP: One of the challenges faced was attributing impact to the NPLQP due to the complex ecosystem in which it operates.	We used interview questions to capture both how and why the Programme contributed to observed outcomes and used a qualitative counterfactual, asking participants what they would have done without NPL's support. This helped to understand the direct role of the Programme. However, attempts to separate and attribute impact were limited by the interviewees' ability to confidently assess impact of the Programme compared to other supports / funding provided. The evaluation also applied a mixed-methods theory-based approach (Contribution Tracing) to assess the extent to which observed outcomes could be attributed to the NPLQP. This method allows contribution to be examined where there is no clear counterfactual; combined with Bayesian Updating, which strengthened the assessment, the likelihood (as opposed to cause and effect) of impact was estimated. This method also triangulated data from interviews, surveys, and secondary data to help build consensus.
Difficulties in attributing long-term economic outcomes to NPL support limited the ability to conduct a rigorous cost CBA of the Programme. This is partially the result of other funding resources NPL customers and collaborators have accessed during the Programme's lifecycle, including: ▪ Innovate UK ISCF for QT (e.g. projects focused on commercialisation of quantum products and technology and collaborative R&D) ▪ Innovate UK QT Feasibility Study Projects (e.g. those focused on quantum computing applications) ▪ Innovate UK Eureka Quantum Collaborative R&D projects (focusing on supporting international collaboration on R&D projects)	An indicative CBA was developed based on the evidence available and a conservative set of assumptions. Recommendations for strengthening this CBA in future were also developed.

3. Programme Performance and Delivery

3.1. Purpose

This chapter provides an assessment of the performance and delivery of the NPLQP during 2020 – 2024 against the Business Case KPIs (dated July 2020). Findings in this chapter are based on a desk review of Programme annual and knowledge reports (2020-2024), NPL monitoring information capturing progress up to the end of March 2024, as well as consultation with Programme stakeholders (e.g. NPL delivery staff, NPLQP customers and wider strategic stakeholders).

Overview: The Programme has strong management and governance processes in place, with progress monitored for most of the business case KPIs and additional KPIs developed to reflect the additional areas of focus for the Programme. Delivery was effective, especially given the impact of Covid at the outset of implementation. NPLQP achieved strong outcomes in standards development, industry engagement, and skills development, meeting most of the KPIs set out in the initial business case. Facility provision and knowledge transfer saw partial success due to some gaps in sustainability planning and formal guidance output target. Strengthening the monitoring and focus on risks for these two areas should help ensure increased performance in the future.

3.2. Performance overview (2020 – 2024)

The Business Case for the Programme included static Key Performance Indicators (KPIs) for its five core objectives listed below:

- **Facility provision: 1)** Operational facility hosted in NPL's AQML with all planned capital procured by the end of year 2; **2)** Further (minimum three) operational facilities, located in most appropriate area for the capability concerned. Installed in partnership with local organisations but owned and operated by NPL to ensure independence; **3)** A plan for future funded use and maintenance in place for each facility to ensure its sustainability beyond the funding programme.
- **Knowledge transfer: 1)** A research programme of testing development with a roadmap published in Year 1; **2)** Published testing guidance throughout the four-year Programme using a range of appropriate media.
- **Standards development: 1)** NPL will represent the UK in international standards groups and provide a regular report back to the NQTP of the world-wide quantum developments; **2)** NPL will provide technical expertise to support the development of standards, working with BSI, European and international standards communities. New draft standards in circulation by year four; **3)** Establish a process which will fund the maintenance and future development of standards beyond the funding of the Programme; **4)** NPL will report on this activity annually with an international status report.
- **Industry engagement: 1)** Increased awareness within industry of the importance of testing and evaluation of quantum technology through a targeted communications campaign throughout the Programme to accelerate innovation through the use of Test and Evaluation; **2)** Production of a review of industry needs in year one; **3)** Delivery of test and evaluation support to 50+ UK quantum companies across the NPLQP; **4)** Ensure that the test & evaluation facilities are sustainable beyond the Programme by establishing measurement services and a model for bespoke consultancy.
- **Skills development: 1)** Deliver specialist Continuous Professional Development (CPD) training courses for academics, innovators, companies etc; **2)** Host Postgraduates within the programme; **3)** Host several junior scientist or technician apprentices focusing upon testing quantum technologies; **4)** Host secondments or joint appointments with partner organisations in the first two years to support the knowledge development.

Analysis of Programme performance against the above objectives was hindered by a lack of directly-relevant data. The QTE metrics database[23] – one of the central sources used to inform performance analysis – contains 22 separate metrics. Of these, just under half (nine) do not directly relate to the KPIs in the Business Case as outlined below. However, these metrics provide additional valuable evidence of overall performance and should be retained. This is illustrated in the following table with numbers detailing the number of KPIs included in the metrics database.

Table 3: QTE Metrics

QTE metrics directly linked to objective KPIs (with relevant KPIs highlighted)	QTE metrics with no direct links to objective KPIs
▪ (1) Number of business collaborations (KPI: Increased awareness within industry of the importance of testing and evaluation of QT through a targeted communications campaign throughout the programme to accelerate innovation through the use of Test and Evaluation) ▪ (2) Number of treated firms (KPI: Delivery of test and evaluation support to 50+ UK quantum companies across the NPLQP) ▪ (3) Number of active measurement services and reference materials & (4) Income from measurement services *(KPI: Deliver specialist CPD training courses for academics, innovators, companies etc)* ▪ (5) Number of M4Q projects agreed upon & (6) Percentage of M4Q projects completed (KPIs: Delivery of test and evaluation support to 50+ UK quantum companies across the NPLQP & Increased awareness within industry of the importance of testing and evaluation of QT through a targeted communications campaign throughout the programme to accelerate innovation through the use of Test and Evaluation) ▪ (7) Total number of standards committee memberships held by employees (KPI: NPL will represent the UK in international standards groups and provide a regular report back to the NQTP of the world-wide quantum developments) ▪ Number of people accessing (8) online & (9) in-person measurement training (KPI: Deliver specialist CPD training courses for academics, innovators, companies etc) ▪ (10) Number of PhD students; (11) Percentage of PhD students who are fully funded; and (12) Percentage of PhD students who are partly funded *(KPI: Host Postgraduates within the programme)*	▪ (13) Number of academic collaborations ▪ (14) Number of peer reviewed papers ▪ (15) Average of relative citation ratio of papers ▪ (16) Average of field-weighted citation impact of papers ▪ (17) Number of grants ▪ (18) Total value of grants provided to projects involving NPL [in US Dollars (USD), undeflated] ▪ (19) Percentage of grants involving one or more international collaborator(s) ▪ (20) Number of close-to-treated firms ▪ (21) Percentage of papers that received one or more patent mentions ▪ (22) Percentage of papers that received one or more policy mentions

While this database was supplemented by a review of Programme annual reporting and primary data collection, the lack of data detailing progress against all Business Case objectives and KPIs limited aspects of the evaluation.

Detailed analysis of progress and performance against each KPI within the 5 objective areas is provided in Appendix A.5: Programme performance (2020-2024), with the summary below providing an overall analysis of performance at a Programme-level.

[23] Central NPL metrics tracking database used to inform performance assessments against relevant KPIs.

3.2.1 Overall assessment of performance

Overall, 4 out of the 5 objectives as set out in the July 2020 Business Case were largely achieved or fully achieved.

Under objective 1 (Facility Provision), progress was partial: while operational facilities were delivered, the absence of sustainability plans and lack of evidence of complete NPL ownership limited full achievement. Objective 2 (Knowledge Transfer) was fully achieved with delivery of a needs assessment, and the publishing of testing guidance. Objective 3 (Standards Development) was largely successful, with NPL playing a leading role in international standards bodies and contributing to draft standards, although no mechanism was established to fund ongoing standards development post-Programme. Objective 4 (Industry Engagement) was mostly achieved, with strong industry outreach, delivery of support to 86 companies, and a consultancy model established. Objective 5 (Skills Development) met all targets, delivering training, supporting PhD students and apprentices, and facilitating joint appointments.

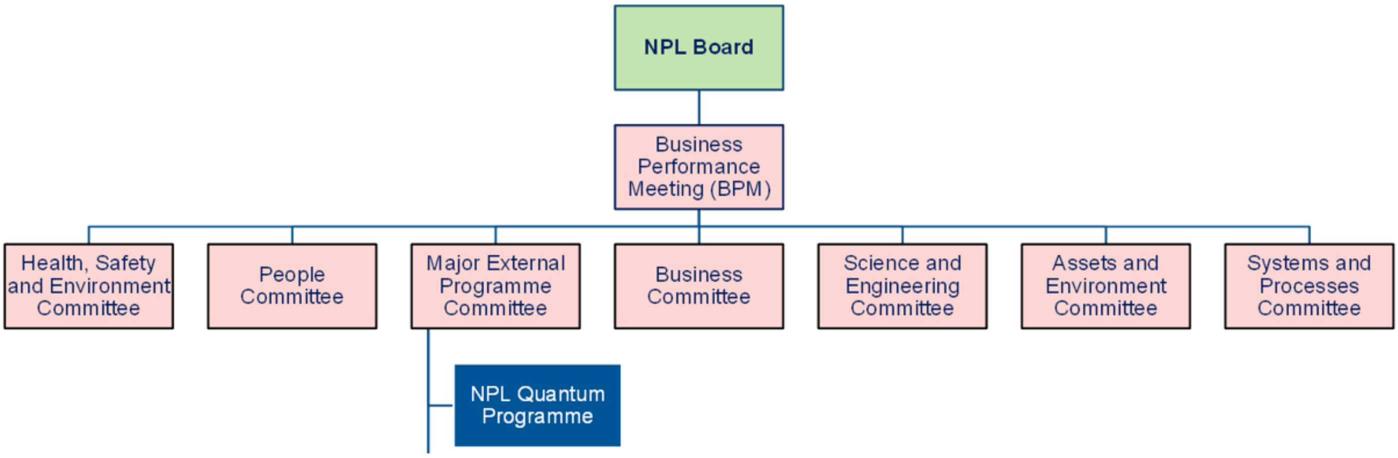
3.3. Programme governance and reporting

3.3.1 Governance

3.3.1.1 NPL-wide governance

As for all NPL-delivered activities, the NPL Board was the highest level of governance for Programme delivery, with the monthly Business Performance Meeting (BPM) acting as the main opportunity for reporting into the Board on Programme delivery and progress to-date. This reporting was completed by the Major External Programme Committee (MEPC), which provided oversight on delivery of all externally-funded NPL programmes. The committee was chaired by NPL's Partnership Director and was responsible for ensuring the Programme achieved agreed outcomes, provided an escalation route for risks and issues beyond the authority level of the Programme Director, and managed any conflict between externally-funded NPL programmes. The MEPC was the first point of access beyond Programme-level governance, with the Programme Director providing a monthly Programme report to the committee and – by extension – the BPM[24].

Figure 1: NPL-wide governance structure[25]

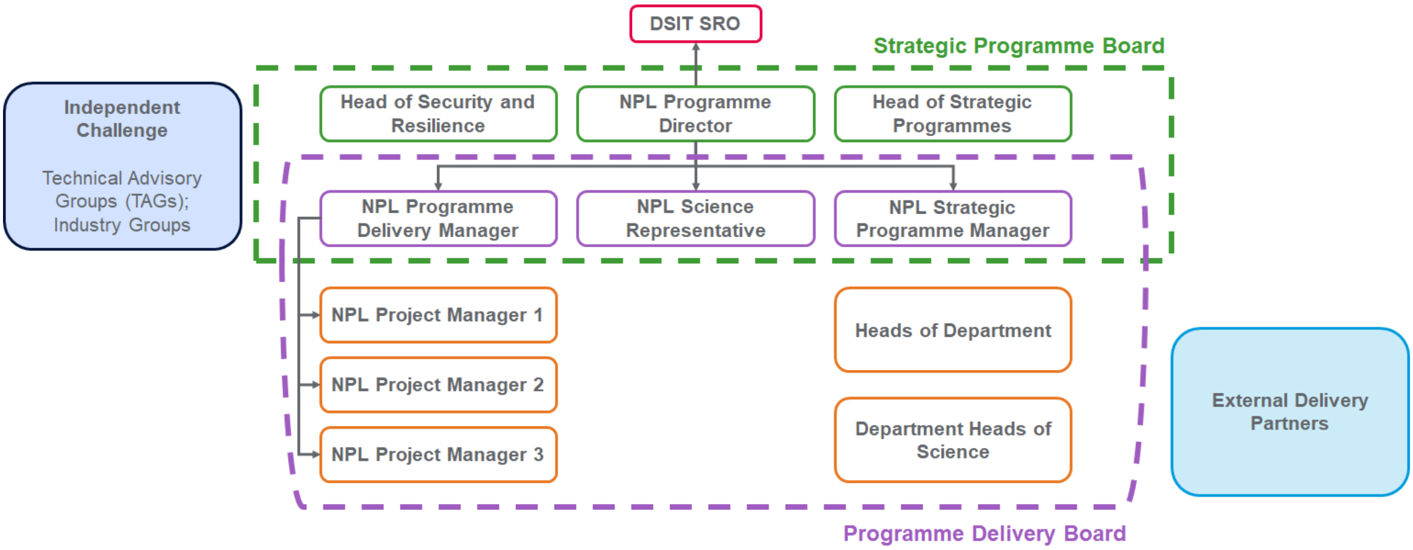


[24] Quantum Programme Governance_FINAL (provided to RSM by NPL July 2025)
[25] Quantum Programme Governance_FINAL (provided to RSM by NPL July 2025)

3.3.1.2 Programme-level governance

The following diagram illustrates the governance in place at a programme level.

Figure 2: Programme-level governance structure[26]



At the senior level, the DSIT Senior Responsible Officer (SRO) held ultimate accountability for the delivery of Programme outcomes and the realisation of benefits alongside the MEPC. The SRO provided strategic direction and oversight and held ultimate responsibility for managing strategic risks raised by the Strategic Programme Board.

Management of the Programme was led by the Programme Director, who was responsible for coordinating the delivery of all Programme objectives in line with agreed plans, budgets and risk tolerances. This included managing interdependencies across projects, overseeing stakeholder engagement and communications, and authorising changes within Programme-level tolerances. The Director reported directly to the SRO and played a key role in translating strategic oversight into operational delivery.

Supporting this, the Programme included a Lead Programme Delivery Manager and a team of Project Managers, who each worked closely with Project Sponsors (who provided senior level commitment to the project(s)), Group Leaders and Department Heads to manage the lifecycle of individual projects. Each project team included a Technical Lead, who ensured the scientific and technical integrity of deliverables, managed technical risk, and liaised with stakeholders on requirements and acceptance criteria, with a delivery team executing project tasks and providing feedback loops. These roles were defined and managed within NPL's Project Delivery Framework. These stakeholders – alongside support from the Head of Security and Resilience and Head of Strategic Programmes (provide strategic advisory support); NPL Science Representative (providing scientific advice); and the NPL Strategic Programme Manager (providing support with DSIT engagement) – formed the basis of the internal strategic and delivery programme boards. The role – and administrative elements – of each board is outlined below:

- **Strategic Programme Board:** maintained overall accountability for Programme delivery. The board met quarterly, and was attended by Programme Director (Chair); Programme Delivery Manager, NPL Science Representative, NPL Strategic Programme Manager, Head of Security & Resilience, and Head of Strategic Programmes; and
- **Delivery Programme Board:** provided overall coordination and sequencing of projects within the remit of the Programme. The board met quarterly and is attended by the Programme Delivery Manager; NPL Strategic Programme Manager; NPL Science Representative; Project Managers; and Heads of Department.

[26] Quantum Programme Governance_FINAL (provided to RSM by NPL July 2025)

Independent oversight of Programme delivery was reinforced through additional bodies/committees in the form of Technical Advisory Groups (TAGs) and industry groups which were convened as needed to provide expert input on specialist areas such as infrastructure design and innovation delivery[27].

3.3.2 Reporting

Reporting processes for the NPL Programme Management were strong. However, while key metrics and milestones were monitored, Programme data was reported on a calendar-year basis, rather than by financial year or a more granular timeline. This misalignment makes it difficult to assess outputs and progress against KPIs, which are aligned to the Programme's funding period i.e. on a financial year basis.

The M4Q scheme had an advanced monitoring and reporting system. This included PowerBI dashboards that track performance data, capture customer feedback, and highlight delivery bottlenecks. NPL delivery staff have noted these tools enabled them to refine service delivery, enhance user experience, and communicate impact more effectively to stakeholders.

In addition to metrics tracking, NPL submitted a number of reports (both internal and external) on a monthly; quarterly; and annual basis, as outlined in the following table.

Table 4: NPLQP – methods of reporting

Reporting method	Relevant stakeholders	Purpose
External reporting		
DSIT quarterly progress report	NPL leadership; DSIT	Provided assessment of achievement of deliverables specified in the DSIT contract. This was a formal requirement of the contract, providing an updated assessment of Programme risks and was the mechanism by which change requests were made.
Monthly financial reporting	NPL leadership; Programme Board members; DSIT	Reported on spend against agreed categories and provided a monthly forecast for the remainder of the year to DSIT. The reporting was also used internally and reported to the Programme Board.
Monthly NQTP report	NQTP	Provided an update on Programme delivery and achievement of outcomes to-date. Formed the basis of NQTP Board discussions on the Programme.
Internal reporting		
Monthly Programme report from the Programme Director	MEPC Member; BPM Members; NPL Board Members	Provided the internal escalation route by which critical issues from programmes could flow up to the NPL Board.
NPL internal monthly report	NPL leadership; all interested internal stakeholders	Report provided an accessible monthly snapshot of progress within the Programme, including finances, deliverables, risks, and highlights.
Fortnightly programme meeting	NPL leadership	To discuss the most pressing current issues on projects and the Programme, and to support the day-to-day management of the Programme.
Quarterly project board meetings	NPL leadership; all interested internal stakeholders	To report on progress against contractual deliverables at a project level, to report upon and manage finances, and to discuss key risks.

Source: Quantum Programme Governance_FINAL (provided to RSM by NPL July 2025)

In addition, NPL submitted annual end of year highlight reports to DSIT, summarising achievements and outputs. However, while these reports were comprehensive, they were not clearly aligned with the objectives and KPIs set out in the original Business Case, limiting their usefulness for tracking strategic progress. Several

[27] Quantum Programme Governance_FINAL (provided to RSM by NPL July 2025)

NPL interviewees noted that while operational monitoring is robust, particularly in M4Q, there was a lack of integrated, Programme-level reporting to systematically track outcomes against targets.

3.3.3 Risk management

The Programme Board defined the overall risk profile for the NPLQP and maintained risk registers for each objective area, ensuring appropriate thresholds and mitigation plans were in place. Key features of the registers included a structured scoring system for risk probability and impact, which helped prioritise mitigation efforts. Risk management was proactive and adaptive, with many risks being actively monitored and addressed through contingency planning, stakeholder engagement, and governance enhancements[28]. Project-level risks were captured in individual Risk Quantification Tools (RQTs) and reviewed by Project Managers and Sponsors. Strategic and cross-cutting risks – such as reputational risks, interdependencies with external partners, or delivery constraints, were escalated to the Programme Board for resolution. However, analysis of the risk registers highlights some small gaps:

- **Objective 1 (Facility Provision):** Risks surrounding availability of equipment for facilities; availability of capital to meet facility needs; delivering facilities and equipment to-schedule; and impact of relocation / facility development on science delivery - all directly relate to key targets within this objective. *However, no risks or tracking of progress on the target to develop a plan for each facility to ensure its sustainability beyond the funding programme.*
- **Objective 2 (Knowledge Transfer):** Risks included do not directly align with this objective. *This is particularly important, as analysis indicates underperformance in this area and highlights a misalignment with what was tracked and monitored for this objective when compared to Business Case targets.*
- **Objective 3 (Standards Development):** The risk register for this objective area includes a combination of standards-specific risks (e.g. those related to successful development and adoption of new standards frameworks) that directly align with targets alongside more generic delivery-focused risks around data protection and GDPR concerns. *However, the risk register does not include the development of a platform to support and maintain standards development in the future. This is notable due to a lack of evidence of this target being achieved (again indicating misalignment with performance / risk tracking and initial targets).*

Across the objectives there is a pattern of partial alignment between risk tracking and original Programme targets. While objectives 1, 3, 4, and 5 include risks that directly support delivery, there are also gaps eg on sustainability and long-term planning. Additionally, the inclusion of clear mitigation measures is not consistent throughout the risk registers, with only objective 4 clearly outlining this.

3.4. Key findings

Performance analysis highlights that three of the five objectives were either achieved or largely met. Key successes included standards development, industry engagement, and skills development, while facility provision and knowledge transfer saw partial success due to some gaps in sustainability planning and formal guidance output target. This success is notable as the COVID-19 Pandemic would have impacted delivery during the evaluation period.

Enhancement of the performance data collected will help measure future impacts, namely:

- Metrics data should be collected (where applicable / appropriate) to align with Business Case KPIs.
- Performance monitoring should combine descriptive statistics (e.g. number of collaborations) with data on the impact these collaborations.
- Performance monitoring should track the following areas:
  – number of companies (both quantum-born and otherwise) specifically receiving T&E support (to complement descriptive tracking of business collaborations);

[28] Quantum Programme Risk Register (provided to RSM by NPL July 2025)

- number of secondments and joint appointments hosted;
- number of apprentices hosted; and
- sustainability metrics (e.g. production of sustainability plans for facilities developed).

- Risk assessment and mitigation processes should cover that targets and KPIs relevant to each objective area / workstream are on track to be achieved. This would increase potential for the Programme to achieve outcomes and – in cases where targets are not reached –provide the rationale for these.
- The NPLQP programme should have M&E resource to support delivery of the above work.[29]

[29] The 2020-24 programme was more than half way through before an analyst was brought in to lead/develop the M&E activities

4. Process Evaluation Findings

4.1. Purpose

The purpose of the Process Evaluation is to assess effectiveness and efficiency of Programme delivery, identify strengths and areas for improvement of Programme delivery, ensuring lessons learned can be applied to future iterations of the Programme. This chapter presents findings against each of the key process research questions. This data is drawn primarily from primary data sources including qualitative interviews with key stakeholders, secondary data sources, including NPL staff surveys, and global comparator institutions analysis.

Overview: The Programme was designed to address key market failures in the UK quantum sector – namely gaps in coordination, skills, infrastructure, and standards. While delivery was uneven, the Programme successfully built critical facilities, supported SMEs, and led international standards efforts. NPL's embedded training and technical validation model proved impactful, though commercialisation support remains narrower than international peers. Strengthening cross-sector engagement and expanding M4Q into a structured support model are key recommendations.

4.2. What was the rationale for the Programme and was the design appropriate to support this?

4.2.1 Rationale for the Programme

As highlighted in the Business Case for the QT&E Programme[30], the rationale for public intervention in the QT space was based on the following market failures:

- **A lack of coordination in T&E**. As outlined in the Business Case, research teams across academia and industry have a track record of doing their own testing and validation of technologies. A lack of coordination of testing activities can lead to inefficiencies in government funded research and innovation spending, as well as inconsistency and duplicate efforts across teams. *The Programme sought to address this coordination failure by setting up the frameworks and infrastructure for standardised testing of quantum technologies across the UK*.
- **A quantum skills gap.** The quantum sector faced a widening skills gap, shifting demand to a broader range of both technical and commercial capabilities as quantum technologies continue to advance. *The Programme sought to actively tackle this skills gap by providing tailored quantum training opportunities for apprentices and postgraduates, as well as wider industry training courses in QT&E and secondments with partner organisations*.
- **A lack of QT&E facilities and a lack of common standards**. As highlighted in the Go-Science Blackett Review, there is broad applicability of QT to other sectors including healthcare, security and defence[31]. This means that the benefits of investing in QT&E facilities often spills over into adjacent sectors, therefore there is a disincentive for firms to invest in these facilities themselves and instead rely on facilities invested in by other firms. This creates a gap in investment that requires public intervention, or an increase in private investment, to ensure continuity in the growth of the quantum sector. *The Programme sought to address this market failure by developing and disseminating best practice QT&E guidance to support the use of QT&E facilities developed as part of the Programme*.

[30] National Physical Laboratory - Full Business Case for the Quantum Test & evaluation (QT&E) Programme
[31] Quantum technologies: Blackett review - GOV.UK

4.3. What were the key components of the implementation strategy and how were they executed?

4.3.1 Key components of the implementation strategy

The Programme's implementation strategy was structured on five key areas:

- Establishing a network of **state-of-the-art test and evaluation facilities** (including a flagship centre at NPL's AQML and regional hubs);
- developing and disseminating **best practice** in quantum measurement and testing to support **knowledge transfer**;
- ensuring UK **leadership in international standards development**;
- enabling industry access to facilities and expertise to encourage greater industry engagement; and
- addressing the **quantum skills** gap through training and education.

4.3.2 Were activities delivered as expected?

Delivery against the Programme's objectives had notable achievements with some shortfalls. The Programme's core ambition – to establish the UK as a leader in quantum testing and evaluation – is being realised, which specific progress is as follows:

Standards development: the NPLQP has played a key role in shaping both UK and global landscapes for quantum standards (see section 4.4.2).

Facility provision: Significant capital investment enabled the development of advanced T&E facilities across quantum computing, timing, communications, materials, and sensing. Key infrastructure includes the AQML, superconducting circuit testbeds, ion trap platforms, and cryogenic systems.

Knowledge transfer: Annual reporting and stakeholder feedback indicates that a variety of supporting processes and activities were carried out to strengthen knowledge transfer within the quantum ecosystem. This includes: advancement of knowledge transfer via the development of new T&E capabilities across quantum computing, timing, communications, and materials; and the deepening of collaborations with academic and industrial partners, including through joint symposia, strategic Memorandums of Understanding (MoUs), and regional testbed deployments, ensuring that metrology expertise is embedded across the UK's quantum innovation landscape.

Industry engagement: Through the M4Q scheme, the Programme delivered low-barrier-to-entry measurement and consultancy support to 50 companies between 2020-2024 (many of whom were first time customers of NPL). Though stakeholders felt engagement improved over time, this aspect of the Programme required significant effort to initiate. Early challenges included limited business development engagement and capacity, unclear messaging, and a lack of visibility into NPL's service offerings. The Programme team attempted to address this through targeted marketing, workshops, and executive roundtables however some industry stakeholders – particularly those in sectors like finance and defence – remained unclear about how to engage with NPL.

Skills and training: The Programme delivered both online and in-person skills and training opportunities (both in the form of bitesize learning modules and certified training courses), allowing for the development of an overall CPD package to support skills development. The Programme also helped early-career scientists gain experience in applied research and industry collaboration via initiatives such as the PhD-at-work scheme (allowing researchers to study for their PhD whilst also being employed by NPL). However, some NPL delivery staff members noted that the uptake of training offers could have been stronger had the team developed a stronger understanding of specific training and skills needs within the quantum ecosystem.

Overall, the NPLQP has delivered significantly in a new and emerging technology area. It built critical infrastructure, supported industry innovation, contributed to international standards, and helped grow the UK's quantum workforce. While not all activities were delivered exactly as planned, the Programme demonstrated adaptability and a strong commitment to national impact. Stakeholders felt the Programme has laid a solid foundation for future quantum initiatives and positioned NPL as a central player in the UK's quantum ecosystem.

4.3.3 Who were users expected to be, and were these groups successfully supported?

The following table provides an assessment of anticipated service users / Programme beneficiaries, along with a rationale for their inclusion within the Programme and an assessment of whether they were successfully engaged. This, combined with the performance assessment provided in section 3.2, and the analysis of whether activities were delivered as intended above provides a comprehensive evaluation of intended versus realised delivery of the Programme.

Table 5: Assessment of service user engagement

Anticipated service users (as per Business Case)	Rationale (as per Business Case)	Were these groups successfully engaged?
UK QT Companies	To support commercialisation of quantum technologies and accelerate product development.	**Yes:** 382 private sector collaborations were reported with the QT department within NPL between 2020-2024[32], with 86 quantum-specific companies receiving support through the Programme and 50 companies receiving support via the M4Q scheme. **Note –** 'collaborations' ae considered a lower level of engagement than those receiving support, hence the lower number of supported firms. This figure also relates to NPL activity overall – rather than Programme-specific activity.
Academic Researchers & Universities	To ensure consistency in testing methodologies and support the transition from research to commercial application.	**Yes:** over 900 academic collaborations were reported from 2020-2024 through the Programme (note – not all collaborations reported are unique), and a range of public research institutions were named as key collaborating partners for the programme (e.g. Henry Royce Institute, University of Manchester, University of Birmingham, Royal Holloway University). **Note –** extent / value of these collaborations is not tracked in monitoring data[33].
Government Stakeholders (e.g. MoD)	To ensure national security and strategic interests are supported through robust, independent testing of quantum technologies.	**Yes:** feedback from a focus group with wider stakeholders suggests MoD and NQCC have partnered with NPL on national security and quantum computing priorities, reinforcing NPL's role as a trusted authority in quantum metrology and innovation.
Standards Bodies (e.g. BSI, ISO)	To ensure UK leadership and influence in the development of international quantum standards.	**Yes:** NPL has worked closely with BSI, co-developing the UK Quantum Standards Network and supporting the UK secretariat for ISO/IEC JTC 3. NPL experts have contributed to major bodies including ISO, IEC, ETSI, ITU-T, and CEN/CENELEC, chairing working groups and helping define global standards in quantum computing, communications, and metrology.
Industry End-Users (non-quantum)	To build confidence in quantum technologies and encourage adoption across sectors.	**Partially:** Extent of Programme engagement with non-quantum end users is limited. Two end users in the finance and defence sectors questioned NPL's approach to marketing and engagement, noting confusion around exactly how NPL can support them[34]. However, limited engagement in consultations (ten interviews and two focus groups) – particularly from industry end-users – prevents a comprehensive assessment of views on this.

---

32 List of NPL supported firms (2020-2023) (provided to RSM by NPL June 2025)
33 Ibid (2025)
34 Information sourced from stakeholder consultations

Anticipated service users (as per Business Case)	Rationale (as per Business Case)	Were these groups successfully engaged?
Apprentices, Technicians, PhD Students	To address the skills gap in quantum testing and evaluation and build a future-ready workforce.	**Yes:** NPL supported 42 PhD students in 2024. Of these, 76% were either fully or partially funded[35]. A number of apprentices were also hosted during delivery of the programme, focusing on areas such as Measurement Science. However, the exact number of apprentices was not reported.

The Programme successfully engaged with the target service user groups in the Business Case. Engagement was particularly effective for UK QT companies, academic researchers, students and institutions, standards bodies and government stakeholders. However, success in engaging non-quantum industry end users (i.e. those with potential to adopt / access QT developed by quantum-born companies) is less clear. This could be improved by tracking of engagement and marketing campaign engagement and clarity on NPL's strategy for these.

4.3.4 What would users have done if NPL's services were not available?

Based on findings from stakeholder consultations and survey data collection, an assessment of what end users likely would have accessed or achieved without the Programme, categorised based on each key objective area, is provided below.

Facility Provision: In the absence of the Programme, many users – particularly startups, SMEs, and academic collaborators – would have faced significant challenges in accessing the specialised facilities necessary for advancing quantum technologies. The Programme provided critical infrastructure such as cryogenic labs, dilution refrigerators, single-photon metrology systems, and quantum timing apparatus, which were not readily available elsewhere in the UK.

Survey responses and interviews consistently highlighted that without NPL's support users would have attempted to replicate some of the work in-house however acknowledged that the results would have been of lower quality, less credible, or significantly delayed. Several respondents indicated they would have needed to seek multiple grants – introducing logistical, financial, and technical barriers. In some cases, users admitted they might not have pursued their projects at all, particularly where independent validation or high-precision measurement was essential for securing investment or regulatory approval. However, this was not universal and some users (particularly those supported via M4Q) noted that they would have likely received funding and support elsewhere in the scheme's absence. Despite this, many felt that, even if they had pursued other options, the support would have been of a lesser quality.

"Would have been done at a university but would have been lower precision" – M4Q Scheme Participant

Knowledge Transfer: Survey responses and interviews revealed that – without NPL's involvement – many users would have lacked a credible, independent partner to help translate complex scientific knowledge into practical applications. Startups, in particular, noted that NPL's support helped them understand and navigate technical challenges that would have otherwise required costly trial-and-error or external consultancy.

Academic collaborators similarly highlighted that NPL introduced them to new research areas and provided access to interdisciplinary expertise that would not have been available within their own institutions.

NPL was seen as a trusted convener and connector within the quantum ecosystem. It facilitated workshops, roundtables, and collaborative projects that brought together stakeholders from academia, industry, and government. These engagements not only fostered knowledge exchange but also helped align national strategy with emerging technological trends. Without the Programme, such convening power would have been diminished.

[35] QTE Metrics (provided to RSM by NPL January 2025)

Standards Development: Had the Programme not been delivered, users would have lacked a trusted, technically authoritative institution to lead or even participate in these discussions. This would have left UK industry and academia at a disadvantage, potentially subject to standards developed by other nations without UK input.

Several interviewees noted that NPL's contributions to benchmarking, calibration, and measurement protocols were not only unique but essential for enabling interoperability, investor confidence, and regulatory compliance. Without these contributions, UK-based quantum companies would have faced greater uncertainty and higher barriers to market entry, particularly in export-sensitive sectors like defence, telecommunications, and healthcare.

Without NPL, companies would have had to rely on fragmented, less authoritative sources, or develop internal standards at significant cost and risk, potentially leading to inconsistencies across the sector.

Industry Engagement: Had the Programme not existed, many quantum companies, especially early-stage ventures, would have struggled to identify appropriate partners or navigate the complex landscape of quantum R&D. However, the landscape would likely not have changed drastically, as non-quantum end users noted they remain more likely to access more specific / targeted funding from bodies such as Innovate UK (via their challenge funding).

Skills and training: Interviewees and survey respondents noted that their career trajectories – including transitions into quantum startups, national labs, and advanced research roles – were directly enabled by their training at NPL. In particular, the PhD-at-Work model allowed individuals to gain deep technical expertise while contributing to real-world projects, a model that is not commonly available in traditional academic settings. Moreover, the Programme's emphasis on interdisciplinary training – spanning quantum computing, sensing, timing, and materials – ensured that participants developed a broad and adaptable skill set. This was especially valuable in a rapidly evolving field where the ability to work across domains is increasingly important.

Without NPL's involvement, stakeholders felt that training would have been more siloed, less applied, and more dependent on university-led programmes that often prioritise publication over practical application. However, a lack of detailed tracking of specific skills developed via training limits the ability to comprehensively assess the Programme's contribution to upskilling in individual aspects of quantum.

4.4. How is NPL positioned globally?

This section benchmarks NPL against peer institutions with similar capabilities and strategic focus on quantum science / technologies. Specifically, NPL is compared with:

- National Institute of Standards and Technology (NIST - United States);
- National Research Council (NRC - Canada);
- Physikalisch-Technische Bundesanstalt (PTB - Germany); and
- Dansk Fundamental Metrologi (DFM - Denmark).

These institutes were selected based on their comparable national investment in quantum (e.g., USA – $3.8bn; Germany – $5.2bn; UK – $4.3bn between 2022–2023) and their significant engagement in supporting the quantum ecosystem. DFM was also included due to its strong collaborative ties with NPL and due to its niche expertise in quantum hardware and commercial focus. This comparison enables an assessment of how each institution contributes to quantum commercialisation and ecosystem development.

4.4.1 Context

Each of these institutes operates under a distinct funding model shaped by national governance structures, strategic priorities, and their institutional mandates within the quantum ecosystem.

- **Germany's PTB**, the federal authority for metrology, receives stable core funding from the Federal Ministry for Economic Affairs and Climate Action and serves as a key delivery body for Germany's €650 million Quantum Technologies Framework Programme. This is supplemented by competitive funding from European Union (EU) initiatives (such as Horizon Europe) and regional programmes like Quantum Valley Lower Saxony (QVLS);
- **Canada's NRC** operates on a dual-funding model: it allocates significant base funding (A-base) to Research Centres, such as the Quantum and Nanotechnologies Centre, while delivering challenge-led quantum programmes that align with Canada's National Quantum Strategy. These include collaborative R&D grants distributed to academic and industrial partners;
- **The U.S. NIST**, a bureau within the Department of Commerce, is a global leader in quantum standards, receiving federal appropriations to support core quantum metrology work. This is reinforced by targeted project funding under the National Quantum Initiative Act, enabling close public–private collaboration through mechanisms such as the Quantum Economic Development Consortium (QED-C).
- In contrast, **Denmark's DFM**, a nonprofit subsidiary of the Technical University of Denmark (not government-owned), operates on a hybrid funding model with approximately half of its revenue derives from government contracts, with the remainder coming from commercial services and EU-funded projects.
- Meanwhile, the **UK's NPL** a government-owned public corporation, serves as the UK's NMI and plays a central role in delivering the NQTP. It is funded through a combination of core support from DSIT, project-based grants via Innovate UK and UKRI, and commercial income from metrology services and industrial partnerships.

While these institutes provide valuable comparators for understanding international approaches, comparisons with NPL should be caveated by differences in institutional scope, scale, and strategic positioning. NPL, while central to UK measurement science and QT&E, has a more focused remit than broader multi-mission agencies like NIST and NRC, which also serve national coordination functions across the entire quantum R&D landscape. DFM operates at a smaller scale with a strong emphasis on commercial service provision, while PTB holds a statutory leadership role in Germany's quantum ecosystem and benefits from extensive integration with EU programmes. These institutional differences directly influence delivery mechanisms, and the types of quantum activities each organisation is positioned to support. **As such, international comparisons should inform, but not be directly equated with, strategic decisions regarding NPL's future role and development within the UK's evolving quantum landscape.**

4.4.2 Comparison with other Institutes – summary of key findings

A detailed comparison with other institutes is in Appendix A.11 and a summary of key findings is provided below.

Standard Setting: NPL is a key player in global quantum standardisation efforts, alongside peers like NIST and PTB. Its strengths lie in technical leadership and standard development. To maintain and expand its influence, NPL should continue to strengthen the QSN to sustain its leadership and participation in global and European standards committees and forums and to ensure industry engagement as the market expands**.**

Skills Development: NPL offers skills development support that is broadly comparable to international peers, with a particular strength in embedding training directly within live quantum research projects. This applied, hands-on model is a distinctive feature of NPL's approach. However, the review also identified several areas for potential enhancement. NPL does not currently provide expertise to shape formal professional qualifications, such as the co-designed Master's programmes available through Canada's NRC. **This aligns**

with findings from the UK Quantum Skills Taskforce report[36], which highlighted the need for more industry-aligned quantum MSc programmes and stronger collaboration between academia and industry in their design and delivery.

Commercialisation Supports: NPL offers a comparable suite of commercialisation support services to international peer institutions, particularly in terms of technical expertise; testing infrastructure; and collaborative R&D support. However, there are two key differences:

- **Incubation and start-up support:** NPL does not operate its own physical incubator space or structured start-up programme. However, this gap is mitigated by its partnerships with the EPSRC Quantum Technology Research Hubs.
- **IP support:** Unlike some institutions such as NRC and NIST, NPL does not currently provide dedicated in-house IP advisory services. This is a notable gap where international counterparts often embed IP guidance directly within commercialisation supports. NPL could collaborate with others to ensure this is available.

NPL's M4Q programme and other supports have led to some tangible commercial outcomes, however comparatively, NRC's support has generated broader national market impact. Canadian firms have spun out and commercialised technologies across **defence, healthcare, and environmental sectors**. NIST also directly **supports applications through the department of defence, healthcare and telecoms, however, there has been limited evidence from our review to suggest any of these have occurred with direct NIST support.**

4.5. Conclusions

The Programme has successfully delivered a range of activities designed to address several critical market failures in the UK's quantum ecosystem, including gaps in infrastructure, skills, and standardisation. The Programme delivered significant achievements in establishing advanced T&E facilities, supporting business and academic collaborations, and contributing to international standards development. It also played a key role in skills development through PhD and apprenticeship schemes. However, delivery was uneven, with delays in facility provision, underperformance in knowledge transfer, and limited engagement with non-quantum industry stakeholders. Despite these challenges, the Programme has laid a strong foundation for future quantum innovation and positioned NPL as a central actor in the UK's quantum landscape. Moving forward, NPL could consider improving cross-sector engagement by developing clearer messaging and targeted outreach to better engage non-quantum sectors like finance, defence and healthcare.

The international comparator analysis highlights NPL's crucial role in supporting UK quantum SMEs through its M4Q initiative. This initiative offers rapid, high-quality technical validation, which has significantly accelerated product development and attracted investment. However, NPL's commercialisation support is more limited compared to international peers, as it lacks comprehensive integration of business mentoring, IP guidance, and funding pathways. To enhance its support, NPL should broaden its linkages with other services. While organisations like NRC and PTB integrate technical services with financial support or incubator networks, similar support mechanisms already exist within the UK's broader quantum and innovation ecosystem. It is essential for NPL to provide linkages and referrals where needed and ensure these supports are effective for their client base. In addition, there is evidence that Canada has spun out and commercialised technologies across **defence, healthcare, and environmental sectors** and these are sectors identified in the business case for the Programme and therefore should be areas of focus moving ahead.

[36] UK Quantum Skills Taskforce report (May 2025)

5. Impact Evaluation Findings

5.1. Purpose

The purpose of the Impact Evaluation is to assess its contributions to quantum technologies, the UK's leadership, and its broader impact.

Overview: The Programme has advanced UK quantum R&D through infrastructure investment, strategic partnerships, and support for SMEs via the M4Q scheme. It enabled development of new products, strengthened international standards leadership, and contributed to workforce upskilling. However, broader commercial adoption and societal impact remain emergent. Future impact depends on scaling capacity, deepening/widening end-user engagement, sustained strategic alignment and evidence collection of the additionality being created through the Programme.

5.2. What is the impact of the Programme on R&D and innovation activities in the QT sector?

The impact of the Programme on R&D and innovation activities in the QT sector was assessed through interviews with wider stakeholders, delivery staff, customers, and students, surveys with QT organisations, and secondary data from Beauhurst. Given the stage of the Programme, this evaluation covers near-term impact because most impacts will be realised beyond the timeframe of this evaluation.

Facilities have supported research and commercialisation nationally and internationally

NPL's investment in state-of-the-art facilities, such as the AQML and cryogenic systems, were repeatedly described as national assets in stakeholder consultations. These essential facilities support a wide spectrum of QT, including computing, sensing, and timing, and are among the few globally that can deliver such specialised capabilities. Stakeholders consistently emphasised that this infrastructure enables critical services like measurement, calibration, and validation, which are essential for both research and commercialisation. This is supported by findings in the IPSOS Baseline Survey carried out in 2023, where it was noted that 75% of respondents either strongly or somewhat agreed that NPL facilities helped them to progress to the next stage of development.

Facilities have also contributed to increased collaboration beyond the UK's domestic quantum ecosystem. As noted in the Programme's knowledge reports, NPL has successfully embedded several of its QTQT facilities into high-impact international collaborations, such as the newly developed fibre-coupled single-photon detector calibration facility. This system, designed to support traceable measurements in the visible and near-infrared spectral regions, has been used in bilateral measurement comparison with the NIST. This collaboration not only validated the facility's technical robustness but also positioned it for international service delivery. This – alongside collaborations centred on NPL facilities with the South African National Metrology Institute (NMISA) and European Partnership on Metrology (EURAMET) projects – highlights the significant impact of the Programme on facilities development in support of both domestic and international R&D activities.

Partnerships have helped widen delivery of QT

NPL's contribution to R&D is supported by the development of key strategic partnerships, particularly with institutions like Royal Holloway and the University of Manchester. The collaboration with Royal Holloway, for instance, has been instrumental in advancing low-temperature research, with joint appointments facilitating the development of scalable national capabilities. Additionally, at Royal Holloway, NPL collaborates closely through the SuperFab facility, the UK's national centre for superconducting QT. This partnership has led to the deployment of a cryogenic probe station capable of automated, on-wafer testing of superconducting circuits at temperatures as low as 4K. NPL's collaboration with the University of Manchester has yielded the precision test of the quantum Hall effect in graphene, which led to the development of the world's first tabletop quantum resistance standard. Also, at the University of Manchester, NPL has co-located equipment within the Henry Royce Institute's facilities, enabling shared access to advanced microscopy tools and fostering new research directions in quantum materials. This collaboration has not only expanded the scope of research into 2D semiconductors and terahertz systems but also provided Manchester-based researchers with access to NPL's unique scientific facilities. The partnership has been described as transformative, opening up research avenues that would not have been pursued otherwise. This partnership model has been credited with enhancing the UK's ability to deliver QT at scale, especially in areas requiring deep technical expertise and specialised environments.

Knowledge Transfer and Increased Efficiency of Product Development/ Innovation Activities

NPL's R&D activities are also deeply aligned with broader quantum market trends and national innovation goals. Through initiatives, such as the M4Q scheme, NPL supported 50 businesses. Of the 37 M4Q survey participants 77% reported new or improved products, with the following aspects of the scheme highlighted as most impactful for participants:

- Provision of technical expertise and support via knowledge sharing: "M4Q has provided us with access to experts who understand deep tech challenges…" – M4Q Scheme Participant
- Contribution to improvements in efficiency within their projects: "It has saved us a year, saved us errors and mistakes..." – M4Q Scheme Participant
- Contribution to improved validation and verification processes via NPL's independent validation expertise: "It has allowed to add traceability which is crucial for cyber security"– M4Q Scheme Participant
- Provision of access to NPL resources (e.g. tools, facilities and equipment) they would otherwise not have been able to access due to cost and logistical constraints, meaning that barriers to entry were lowered to accelerate innovation.

The scheme also demonstrated strong reach among early-stage businesses. Of the 50 successful applications to the M4Q programme, 71% were from micro or small enterprises (29% were medium or large) and 58% were new to NPL. NPL's involvement in the quantum networking programme and efforts to connect to the national Dark Fibre Network reflect a commitment to foundational infrastructure that underpins the UK's ambitions in secure quantum communications. This commercial impact is underpinned by NPL's validation and benchmarking services, which stakeholders cited as critical for investor confidence and product readiness.

With regard to technological innovation, NPL has directly enabled the development of high-quality quantum products through provision of expert technical support via knowledge sharing, improved validation and verification, and provision of resources. Specific examples include the deployment of the MINAC atomic clock on HMS Prince of Wales and the acceleration of Aquark's cold atom clock demonstrator by six months. For the former, NPL contributed critical expertise in clock design, performance evaluation, and component characterisation while also helping to establish a UK-based supply chain for key components. For the latter, NPL provided expert guidance on clock architecture, component selection, and integration challenges specific to Aquark's novel cold atom trap technology. These outcomes demonstrate the Programme's contribution to technology readiness and innovation. Such early-stage deployments demonstrate the UK's ability to deliver operational quantum technologies, leading to stronger national infrastructure. This supports future integration into defence, navigation, and timing systems.

Additionality

Although participants were positive about the impact and support provided by NPL through the Programme, many noted they would likely have pursued other funding streams or completed their project independently in the absence of the M4Q scheme. This theme is further explored in section 4.3.4 which assesses whether these results would likely still have taken place, if this programme had not existed.

Market mapping against NPL's quantum capabilities

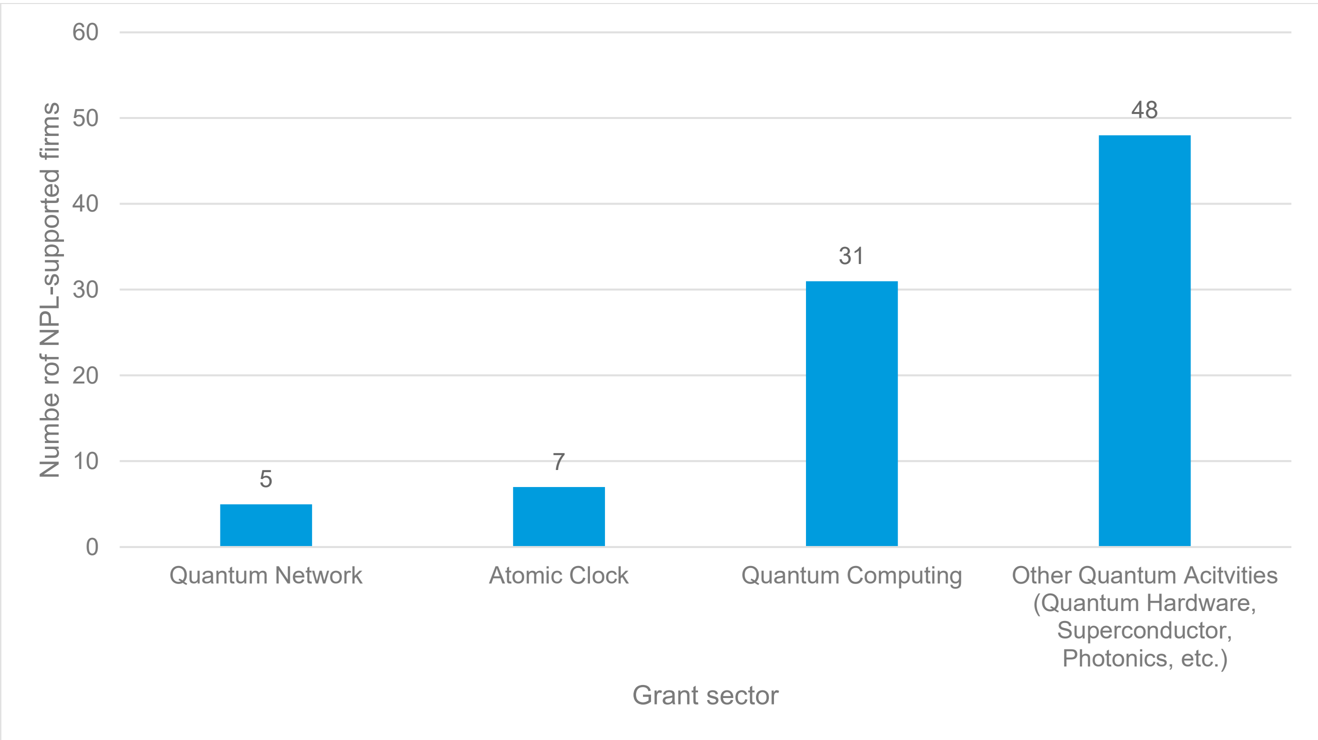
Secondary data sources (including the recent sector mapping report[37] drawing on Beauhurst data) indicate that NPL's quantum research and commercialisation activities are strongly aligned with the UK's evolving QT landscape and market dynamics. Sectorial data identifies 804 active companies across the UK operating in quantum-related domains that correspond to NPL's six strategic capability areas, spanning quantum computing, sensing, communication, and materials.

It is important to note that this figure likely overstates the number of quantum-focused companies in the UK. As acknowledged in the Beauhurst quantum ecosystem mapping report, the count more accurately reflects firms that have embedded some degree of quantum activity, rather than those exclusively dedicated to QT.

The quantum mapping report indicates that nearly half of these companies in the UK quantum market operate in areas aligned with NPL's electrical measurement capabilities, with quantum computing emerging as the second most prevalent focus - underscoring the broader relevance of NPL's capabilities to evolving market trends.

Within the 804 quantum companies identified, we were able to analyse 86 firms from the Beauhurst mapping report that received some form of NPL support. A breakdown of their sectoral activity is presented in Figure 3 showing that approximately 43 of these companies received grants in quantum-specific areas of interest to NPL - namely quantum networks, atomic clocks, and quantum computing. It is important to note that several of the 86 companies may have received grants spanning multiple quantum-related sectors.

Figure 3: Grants received by quantum sector by NPL-supported firms

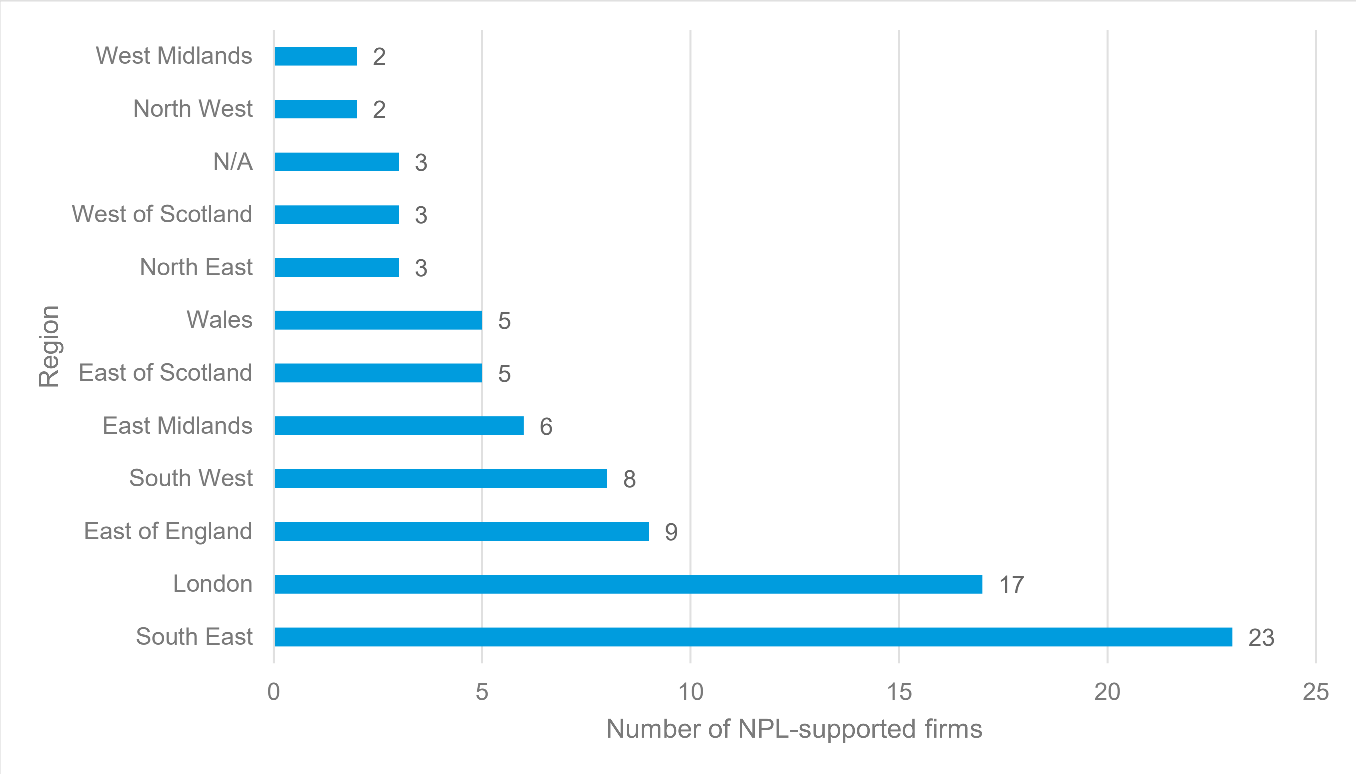


Source: Beauhurst – quantum mapping report data

[37] Quantum Ecosystem Mapping report – NPL and Beauhurst

The regional concentration of NPL-supported firms in the Golden Triangle - particularly London and the South East (which includes Oxford and Cambridge) - highlights the alignment of NPL's quantum support with the UK's leading innovation hubs.

Figure 4: Regional distribution of NPL-supported firms



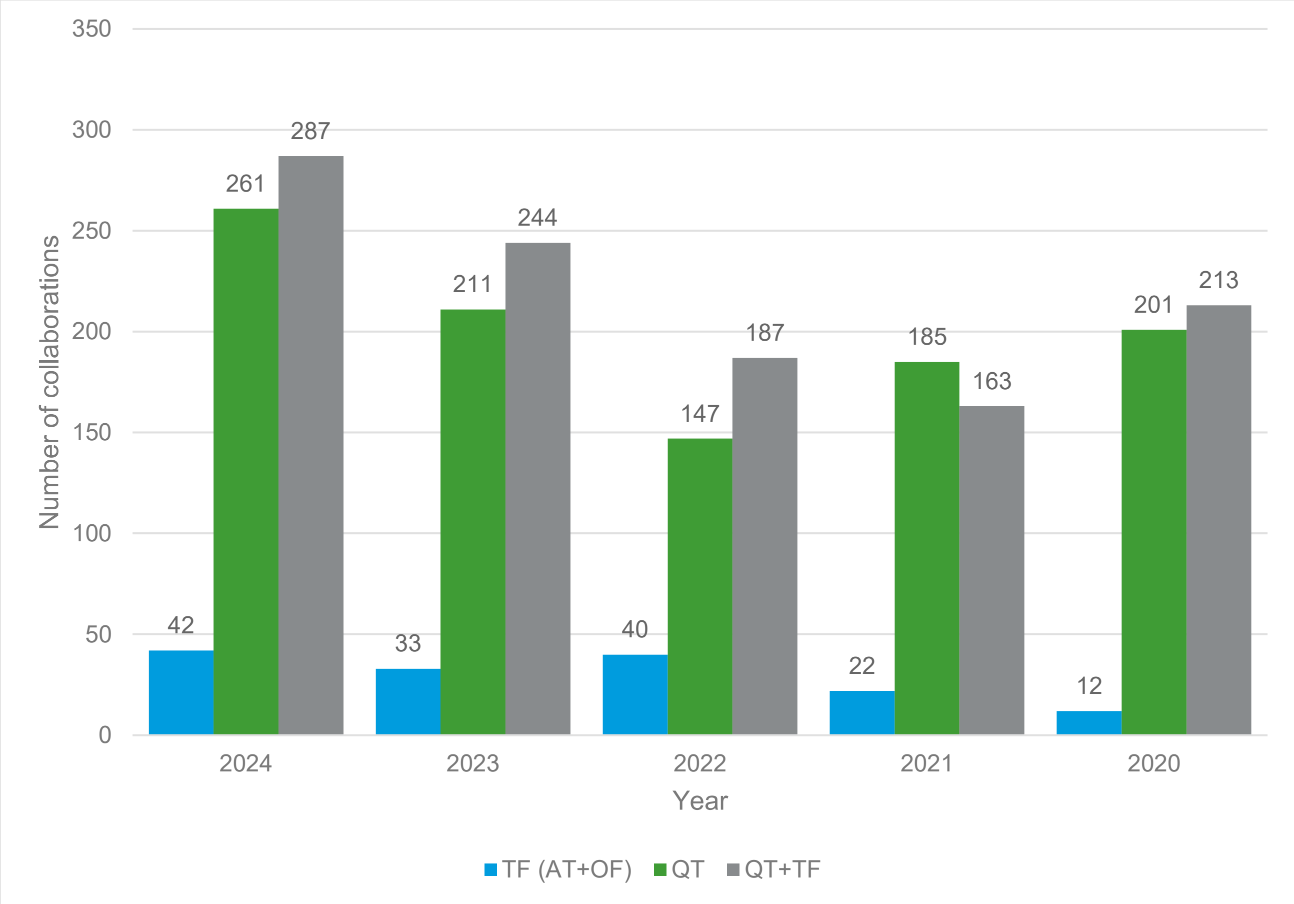
Source: Beauhurst – quantum mapping report data

Emerging activity in regions such as Scotland, the North West, and the East of England suggests a widening geographical reach and reinforces the thematic relevance of NPL's capabilities within the broader national innovation ecosystem.

Internal metrics alignment with quantum market trends

Between 2020 and 2024, almost 93% of the NPLQP funding received by NPL was concentrated in four groups within the QT Department and two within the Time and Frequency (T&F) Departments at NPL. These groups focus on areas such as quantum timing, sensing, and communications – domains identified as key growth priorities in the NQS. The concentration of funding in these specific groups reflects a strategic alignment with high-demand application areas, underlining NPL's responsiveness to national market needs. Over the same period, the number of business collaborations on QT-specific projects grew from 201 to 261, further demonstrating increased industry engagement and reflecting the commercialisation ambitions of the NQS (see Figure 5).

Figure 5: Number of collaborations (count) with business institutions by NPL department[38]



Academic collaborations remained stable, while sustained peer-reviewed paper outputs and improving citation quality (e.g. rising Field-Weighted Citation Impact) point to the continued relevance and scientific standing of NPL's research. The T+F Department's work underpins development in precision timing, frequency standards, and signal processing, capabilities that are increasingly critical for AI systems, advanced sensing, and microelectronic integration. These areas are supported through collaborative activities (e.g. joint publications between the QT department and relevant groups within the TF department at NPL), spanning foundational R&D and early translational application. This positions NPL well to continue supporting both core quantum research and wider enabling technologies as the UK's quantum landscape matures.

While trends are consistent with the overall QT landscape, wider stakeholders across both public and private sectors noted that the Programme could do more to support the coordination of quantum materials R&D moving forward. This will provide opportunity for NPL to map and connect the UK's expertise in different material types and link this to broader strategies (e.g. semiconductors, telecommunications). While acknowledged that other stakeholders (e.g. Innovate UK and Catapults) are also likely to have core roles within this space, NPL has potential to contribute via provision of definitions for assurance protocols and standards for quantum materials, which are essential for device reliability and commercialisation.

[38] QT refers to the Quantum Technologies department. TF(AT+OF) refers to the two out three Groups within the Time and Frequency department (Atomic Clocks & Sensors and Optical Frequency Metrology). QT+TF refers to the combined value for QT department and the two relevant Groups in T&F department. It is not always the sum of QT and TF(AT+OF) because some activities are undertaken by them togethers, for e.g. publications, etc.

5.3. What is the direct impact of the Programme on the private sector?

The direct impact of the Programme on the private sector was assessed through interviews with wider stakeholders, delivery staff, customers, and students, surveys with QT organisations, and secondary data from Beauhurst. This impact was measured through increased demand for commercialisation of quantum concepts. It refers to the benefits, financial and otherwise, to the private sector and efficacy of the M4Q alongside its impact. Notably, given the stage of the Programme, this evaluation covers near-term impact as most impacts will be realised beyond the timeframe of this evaluation.

5.3.1 Primary benefits to the private sector

NPL is not currently positioned to attract significant direct industrial funding, largely because the QT sector is still in its early stages and not yet transactional. However, its role remains crucial in supporting innovation and building confidence among both investors and internal stakeholders. Customer organisations highlighted NPL's role as a trusted authority and technical partner for quantum startups and SMEs.

"[On support from NPL as a start-up] It's probably the most impactful, because again you're a startup that's fewer than 10 people and everyone's wearing multiple hats and trying to do multiple things and you're promising investors that you can do all sorts of stuff very quickly. Being able to get access to state-of-the-art scientific consulting really is an accelerating force in that sense." – NPL customer

Another recurring theme was the value of NPL's independent validation in building investor and customer trust.

"When people say, 'It's done by NPL,' that opens doors." – NPL delivery staff member

This credibility is particularly important for startups seeking to attract investment or enter new markets. Customers confirmed that NPL's involvement often made the difference in securing internal and external investment. The ability to demonstrate that a product or process had been validated by NPL gave companies a competitive edge and helped them justify further R&D spending.

The Programme has also played a critical role in helping companies move from research to market. A key example of this is Oxford Quantum Circuits (OQC), where it was noted that NPL's involvement was central in their ability to expand their product offering and increase commercial capabilities. As a startup with fewer than ten employees at the time, OQC faced the challenge of rapidly establishing a functional, safe, and technically capable lab environment. NPL's significant expertise in infrastructure development was a key enabler in this context, enabling NPL to provide expert guidance on lab design, safety protocols, and infrastructure requirements. The lab that NPL helped design became the foundation for OQC's subsequent technological milestones. It supported the development of their 4-qubit platform, which later evolved into the 8-qubit platform hosted on Amazon Web Services (AWS), and eventually the 32-qubit platform deployed in data centres globally. These achievements were made possible, at least in part, by the early infrastructure and technical consulting facilitated by NPL.

Beyond infrastructure, NPL's involvement also contributed to workforce development. Several OQC staff members, including the CEO at the time, had prior affiliations with NPL, either through PhD training or employment.

Findings from RSM survey of QT organisations includes:

- Of the 23 private sector respondents (including those from business, manufacturing, and consulting), eight (35%) provided feedback on whether NPL's facilities, such as infrastructure and apparatus, supported their progression to the next stage of development. Among these, five respondents (63%) agreed that NPL's facilities were strongly or somewhat beneficial. Specific examples cited include cryogenic testing, QKD metrology and validation, metrology methodology and equipment, and benchmarking using NPL's timing capabilities.
- All 23 respondents identified areas where NPL's support had an impact. Ten respondents (43%) agreed that the support aided decision-making, while 13 (57%) reported it helped avoid resource wastage. 14

(61%) agreed that NPL's involvement helped them realise the feasibility of their projects, and 13 (57%) said it accelerated progress toward key milestones.

- When asked about collaboration, eight respondents provided feedback, with five (63%) indicating that NPL played a role in helping them connect with new partners to a fair or great extent. Additionally, four of these eight respondents (50%) reported that NPL's support contributed to bringing more resources into their area of quantum work.
- Wider stakeholders emphasised that NPL's involvement in standards development and benchmarking was essential for enabling companies to demonstrate compliance and performance in emerging markets. This is particularly important in QT, where formal standards are still evolving. NPL has played an active leadership role in a number of key standards working groups, including ISO/IEC JTC 1/WG 14 and the newly formed ISO/IEC JTC 3; Standardisation Evaluation Group on Quantum Technologies (IEC/SEG 14); European Joint Technical Committee on Quantum Technologies (CEN/CENELEC JTC 22); ETSI ISG on QKD; ITU-T SG13 and related groups; and IEEE quantum-related working groups.

5.3.2 Efficacy of the Measurement for Quantum (M4Q) scheme and resultant impact

The M4Q scheme provided specialist quantum measurement expertise to UK businesses. It aimed to solve measurement challenges related to QT and accelerate product development. The M4Q scheme was widely recognised by interview respondents (wider stakeholders, delivery staff, customers, and students) as an effective mechanism for supporting early-stage quantum companies and accelerating innovation in the UK's quantum sector. It provided rapid, non-competitive access to NPL's specialist measurement capabilities for up to 20 days, which are not commercially available elsewhere, providing support to 50 companies throughout the programme lifecycle. The scheme also acted as an effective tool to encourage first-time engagement with NPL, with a key delivery staff member involved in the scheme noting that around 80% of M4Q participants were new to NPL. This indicates that the scheme has succeeded in broadening access and engaging previously unreached parts of the quantum and adjacent industries.

This positivity is reflected in impact data collected by the M4Q delivery team. M4Q directly supported the development of 30 new or improved products, alongside three new services and 11 new processes[39]. These outcomes reflect the scheme's success in enabling companies – particularly SMEs and startups – to overcome technical barriers and accelerate their research and development pipelines. By offering access to specialist metrology that is often unavailable elsewhere, M4Q has helped firms validate prototypes, refine designs, and build confidence in their technologies.

The scheme has also generated tangible financial benefits, with 18 companies reporting increased sales, ten companies reporting cost reductions, and 22 companies securing additional investment (either internally or from external sources)[40]. These figures highlight M4Q's role in de-risking early-stage innovation and enhancing the commercial readiness of emerging technologies and is strengthened by the fact that many participants noted that the scheme helped them justify internal investment, attract new funding, or enter new markets with greater confidence. The schemes impact data shows that 52% of participants expect to increase sales, and 58–59% anticipate securing further investment, reinforcing the scheme's commercial impact. Furthermore, willingness to pay for NPL services rose from 59% to 97% post-engagement, indicating strong perceived value.

These trends are exemplified in the projects detailed below, where involvement in the scheme contributed to key developments both related to product development / testing and financial / commercial growth:

- **Quantum Motion** leveraged M4Q to assess charge noise in silicon-based quantum transistors. The data provided by NPL saved them approximately 12 months of development time and helped avoid costly errors. The project significantly boosted internal confidence and supported future funding applications.

[39] M4Q overall impact data (covering 2020-2024) (provided to RSM by NPL January 2025)
[40] Ibid (2025)

- **Paragraf** sought to understand how nanoscale defects in graphene affected electrical performance. M4Q gave them access to advanced characterisation tools, enabling them to validate materials, improve product quality, and inform future R&D investment.
- Facing delays due to COVID-19, **QLM** used M4Q to validate an Unmanned Aerial Vehicle (UAV)-mounted quantum gas camera. The support enabled them to complete critical tests, maintain momentum post-seed funding, and approach commercial trials. The company described the scheme as "*pivotal, crucial, essential, hyper effective*."
- **Graphene Star Ltd** cited NPL's validation data as instrumental in attracting investment, further illustrating the scheme's role in enabling commercial traction.

These findings indicate the scheme's positive impact and efficacy for UK-registered quantum start-ups and SMEs, further strengthened by the fact that the scheme received achieved a Net Promoter Score of 94.6, with 35 out of 37 respondents classified as promoters and none as detractors. Participants praised the scheme's ease of access, the professionalism of NPL staff, and the high quality of technical support. Many expressed a strong desire to continue working with NPL in future projects.

Despite positive reported outcomes by SMEs involved in the scheme, M4Q reported significant underspend against its initial budget. It is important that NPL investigate the reason for this underspend as to whether it is due to a lack of demand or another reason.

5.4. What is the role and impact of the Programme on upskilling the workforce?

Though NPL is not the central stakeholder in driving upskilling within quantum (this is a role performed via the UK Quantum Skills Taskforce; EPSRC funded Training & Skills Hubs and quantum-relevant CDTs among other mechanisms), NPL has contributed to upskilling in quantum through assessment, education, and industry engagement. NPL has created structured and flexible pathways for early-career scientists and technicians to gain hands-on experience in quantum metrology and device development. For example, to ensure that workforce development aligns with the evolving needs of the quantum sector, NPL conducted a comprehensive QT&E skills assessment. This assessment, based on surveys, stakeholder discussions, and landscape research, led to a recommendation for a national training blueprint, positioning NPL as a thought leader in shaping the UK's quantum workforce strategy.

The NPLQP has made significant contributions to academic training and education. By 2024, NPL supported 79 PhD students[41], with 6% fully funded and 69% partly funded, and provided online training access to 100 individuals. These efforts were complemented by the launch of certified training modules such as "Introduction to Clock Performance" and the establishment of three joint academic appointments with UK universities. NPL also collaborated with the Universities of Birmingham and York to deliver joint studentships, reinforcing its commitment to long-term talent development. Programmes like "PhD-at-Work" allow individuals to pursue doctoral studies while working at NPL, enhancing both technical and professional development. NPL is cultivating a skilled workforce to sustain long-term growth in the sector.

NPL's apprenticeship scheme is also noted as having significant impact by supporting school leavers and graduate apprentices who receive both academic education and technical training. This has been vital in supplying skilled support to the NPLQP and ensuring a pipeline of talent. Beyond technical training, NPL also fosters soft skills such as project delivery, science communication, and customer engagement. These are essential for innovation and collaboration in industry settings. Early-career scientists benefit from real-world problem-solving experiences and exposure to interdisciplinary teams.

A notable dynamic is NPL's indirect contribution to industry through staff mobility. Interview respondents highlighted that NPL "haemorrhages" staff to startups, marking a testament to its role in training and validating talent that becomes foundational to the wider quantum sector. This talent migration reflects NPL's influence in shaping the technical capabilities of emerging companies. Personal accounts from PhD students further

[41] PhD Annual Data provided by NPL

illustrate the Programme's impact. One student described gaining deep expertise in quantum device design, fabrication, and testing, including making qubits and learning advanced measurement techniques from experienced mentors. This hands-on training, combined with theoretical guidance, exemplifies the high-quality learning environment NPL provides.

Additionally, NPL's academic collaborations and training programmes, such as joint PhDs with the Universities of Birmingham and York, and certified courses like "Introduction to Clock Performance", are cultivating a skilled workforce to sustain long-term growth in the sector. In terms of ease of recruitment of necessary skills: 28 of the 30 respondents (93%) to the RSM survey provided feedback. A majority of those who provided feedback (n=18; 64%) reported facing difficulty hiring staff with required skills. When asked about NPL's role in developing these skills, 13 of the 30 respondents (43%) provided feedback, and nine of those who provided feedback (69%) agreed that NPL had helped recruit staff to some extent.

The survey findings indicate a strong demand for specialised skills and persistent recruitment challenges, reinforcing the strategic importance of NPL's role in delivering practical, industry-aligned training. However, while NPL has delivered training packages, uptake and alignment with industry needs could be improved. Defining the required skills is difficult due to the evolving nature of quantum products and associated metrology, therefore it is an area that should be kept under review working with other partners in this space.

5.5. What are the wider indirect impacts of the programme on society and the economy?

Though there is some qualitative evidence of economic spillovers, particularly through the M4Q scheme, which has enabled startups and SMEs from outside of the quantum ecosystem to access high-value expertise and infrastructure, tangible evidence of broader impact of the Programme remains limited. According to stakeholders, this is largely due to the early-stage nature of the majority of technologies, with provisional work in areas such as sensing, timing and navigation likely to have broad spillover effects and impacts in several sectors (e.g. healthcare and defence). Though these technologies are not yet at the point to achieve realised societal and economic impact, stakeholders consistently stressed that this impact is highly likely to be achieved in the future:

"We discussed healthcare, defence, these quantum-adjacent sectors that are not directly engaging potentially with the NPLQP, but there is potential for spillover into those sectors. There is obviously drug discovery, aircraft flying without GPS, it's touching every single industry." – NPL delivery staff member.

The Programme has contributed to spillover benefits in areas like precision navigation and timing and quantum networks, with emerging potential in healthcare and logistics.

NPL has contributed to societal awareness and acceptance of QT. Public engagement activities such as the NPL Open Day, which reached over 2,700 visitors, and the STEM Hub Assembly, which engaged 1,000+ students from 47 schools, have helped demystify quantum science.

Real-world applications, such as QLM's quantum-based emissions monitoring demonstrate the societal relevance of quantum innovation. NPL has made significant efforts to engage industry audiences, including through events like the Quantum Showcase, workshops, executive roundtables, and targeted marketing. In-person engagement, has increased, suggesting deeper and more meaningful connections with stakeholders. Although, participants noted that many quantum companies are reluctant to engage openly due to concerns around IP and the novelty of their technologies, which makes storytelling and impact reporting difficult.

There are 804 quantum companies in the UK market, spanning a wide range of industries and exhibiting varying levels of involvement in QT. Of these, 86 were identified through the Beauhurst mapping report[42] as

[42] Beauhurst Quantum Ecosystem Mapping report (developed for NPL). Provided to RSM by NPL (January 2025). **Note: the company list includes firms with varying levels of involvement in quantum technologies. This may include businesses not solely focused on quantum, which should be considered when interpreting the mapping outputs and the associated economic evaluation.**

having received direct NPL support during 2020-2024 and operating in sectors with some degree of quantum activities.

In addition, while many operate in quantum-specific areas like computing and materials, others are active in adjacent domains such as electronics hardware, software development, data analytics, and medical imaging, which are fields with known pathways to cross-sector application. Given that analysis of Beauhurst datasets indicates that 86 quantum companies have received support from NPL, NPL's reach in supporting the breadth of the quantum ecosystem is seen to be proportionate to the number of companies in the sector.

The diversity of quantum activity, particularly in firms receiving grant funding and equity investment, reinforces the potential for longer-term economic spillovers into mainstream industries, even if these effects remain embryonic at present. This is highlighted by monitoring data shared by NPL, which shows that supported firms come from approximately 60 different sectors (based on 2-digit SIC 2007 codes). This reflects a high level of sectoral diversity, spanning manufacturing, information and communication, professional services, and advanced instrumentation.

The distribution of turnover highlights wide variation in firm size too. According to Beauhurst quantum mapping report, the mean turnover of firms funded by the NPLQP is £786,728, while the median is just £32,238, indicating a strongly right-skewed distribution. A small number of high-turnover firms (244 of the 752 firms reporting turnover in 2019) significantly raise the average: the largest firm reported turnover of over £51 million. Turnover is extremely uneven across firms. Around one-third of firms (32.4%) are classified as large (turnover > £100,000), underlining the presence of high-revenue firms that drive overall turnover upwards.

While turnover is highly skewed, with a small number of large firms raising the average, the reported benefits reflect insights from a wide range of firms - including many SMEs.

Moreover, data from M4Q indicate that there are an additional 46 quantum-related firms in the economy beyond the NPL-supported firms flagged in the Beauhurst quantum mapping report. Some of these M4Q firms overlap with those already tracked in Beauhurst, while others were not previously considered in the analysis. These have therefore been analysed separately.

5.6. What were the long-term benefits, both tangible and intangible, of the programme?

Given the nature of the intervention and the early-stage maturity of the quantum sector, not all observed benefits are able to be measured and monetised. The following four long-term benefits were selected for assessment; monetisation of these impacts, where feasible, is undertaken in section 6.

1. Follow-on funding leveraged by quantum companies supported by NPL, particularly through the M4Q scheme;
2. New or improved products and services developed as a result of NPL support, leading to commercial outcomes;
3. Export growth linked to increased product validation and international standards alignment; and
4. Employment and skills outcomes, including jobs created and sustained through the use of NPL facilities and expertise.

These benefits were prioritised based on their materiality, traceability to the Programme, and the availability of supporting evidence - including interview data, survey responses, sector analysis, and Business Case logic. Together, they provide a representative picture of the Programme's contribution to long-term economic value.

While export benefits were considered as a potential area of long-term impact, there was insufficient evidence to support their inclusion in the current analysis. While some firms referenced improved international credibility, no specific export outcomes could be confidently attributed to the NPLQP at this stage.

A summary of the benefits is outlined below, with further detail and supporting evidence in Appendix A.6.

5.6.1 Further fundraising

This section summarises evidence from qualitative interviews, the impact survey and analysis of the Beauhurst database on the extent to which NPL activities have enabled quantum firms to secure further fundraising from the public and private sectors. In line with wider NMS evidence (IEA28, Sections 2.3 and 3.2[43]), the analysis also recognises that attributable revenue impacts are reported by companies across scientific domains, highlighting that investment flows linked to measurement support are material and consistent with observed firm-level fundraising patterns.

NPL's validation services enhance investment readiness:

- Interviewees consistently cited the importance of independent performance validation provided by NPL in demonstrating commercial viability and supporting due diligence processes.
- Stakeholders emphasised NPL's credibility as the UK's National Measurement Institute (NMI) as a key factor in attracting both public and private investment.

Increased quantum grant activity signals ecosystem growth: NPL's programme monitoring data shows a significant increase in quantum-related grant activity, indicating growing investment flows into the sector:

- The number of quantum-related grants rose from 5 in 2018 to 64 in 2024.
- Total grant value reached over £11 million in 2024, down from a peak of £37 million in 2020, likely due to COVID-era funding spikes.
- 77% of grants in 2024 involved international collaboration.

NPL has contributed to fundraising:

- 39% of respondents who engaged with NPL reported its support directly contributed to securing Innovate UK funding between 2020–2024.
- Ipsos baseline survey (2023) found ~40% of private sector respondents received Innovate UK funding for quantum work.
- 50% of respondents (n=7 of 14) said NPL had a "great deal" or "fair amount" of positive impact on attracting further resources.

NPL supported firms outperform their peers in fundraising conversion rates and deal sizes:

- Beauhurst data shows 27 of 86 NPL-supported firms raised equity investment between 2020–2024—a conversion rate of 31%.
- Fundraising activity peaked in 2022 (17 deals), with consistent annual activity (12–16 deals).
- Median fundraising ranged from £10 million to £13 million, indicating strong external capital attraction.
- Stakeholder feedback aligned with this, noting NPL support often coincided with critical phases of product development and investor engagement.

NPL-supported firms outperform the wider quantum sector in fundraising metrics:

- Only 78 of 686 non-NPL firms raised funds (conversion rate ~11%).
- NPL-supported firms raised £929 million vs. £2.25 billion by non-NPL firms, but with higher median values (~£13 million vs. ~£1.7 million in 2023).
- Maximum deal sizes for NPL-supported firms reached £162 million in 2023, showing competitiveness at the top end.

[43] A survey of UK-based businesses using laboratories funded through the National Measurement System (2023) - NPL

Matched analysis suggests positive impact but limited causality: Propensity Score Matching (PSM) analysis supports the view that NPL-supported firms raise more, though causality remains unproven:

- NPL-supported firms showed higher median fundraising, especially in 2023, but sample size was too small for statistical significance.
- Structural differences and data limitations (e.g. firm maturity, reporting inconsistencies) prevent definitive causal attribution.

Indicative estimate of attributable funding: the qualitative interviews and survey provide convincing evidence that the NPLQP has had an impact on further fundraising. However, it is not possible to robustly attribute a scale of further fundraising secured to the NPQP. To provide a reasonable estimate of potential additional funding attributable to the Programme, the following conservative calculations were applied:

$$F = N \times s \times I \times a$$

$Where:$

$F\ =\ Estimated\ attributable\ funding$
$N\ =\ Number\ of\ supported\ firms\ raising\ further\ fundraising\ (2020 - 24)$
$s\ =\ Share\ attributable\ to\ NPL$
$I\ =\ Average\ investment\ raised\ per\ firm\ (£)$
$a\ =\ Additionality\ (NPL\ contribution)$

Inputs / Assumptions:

N=27
s=0.38 (≈10 firms)
I=£10,000,000
a=0.10 to 0.20

Step-by-step:

1. Firms where fundraising is attributable to NPL:

N×s=27×0.38 = 10.26 firms

2. Total funding raised by these firms:

10.26 × £10,000,000 = £102.6 million

3. Apply attribution factor:

F_{min} = £102.6m × 0.10 = £10.3m
F_{max} = £102.6m × 0.20 = £20.5m

Estimated Range:

F ∈ [£10.3m, £20.5m]

These assumptions, informed by the data available, suggest that the total estimated additional funding attributable to NPL lies in the range of £10.3 million to £20.5 million over the period.

While indicative, this estimate suggests the NPLQP may have helped leverage a significant volume of follow-on investment. Future evaluation will benefit from improved tracking of funding outcomes linked to Programme services (e.g. systematic use of project exit surveys or follow-up metrics).

5.6.2 Commercialisation of new or improved products

NPLQP enables product development and improvement:

- 38% of interviewed participants (n=14 of 37) reported that NPL support helped develop a new product.
- 65% (n=24) stated it contributed to improving an existing product.
- Case studies revealed that NPL's support helped firms validate proof-of-concept devices, identify design flaws, and progress from prototype to minimum viable product.
- Interviewees highlighted the value of NPL's measurement services in deep tech hardware, where precision is essential but often inaccessible to early-stage firms.

Acceleration of commercialisation:

- Validation of the MINAC atomic clock enabled deployment on HMS Prince of Wales for Arctic navigation.
- Aquark's cold atom clock demonstrator was accelerated by six months due to NPL's technical support.
- Seeqc UK developed multiple generations of superconducting processors with NPL's assistance.
- NPL participated in 23 Innovate UK projects and partnered with 60 industry representatives across 23 initiatives, spanning the full quantum supply chain.

Patent activity indicates NPL supported firms are actively engaged in innovation and intellectual property generation:

- Dimensions database identified 27 patents granted or published directly linked to NPL-supported quantum activities.
- Beauhurst database analysis showed NPL-supported firms had a median patent count of 49, compared to 17 for the matched counterfactual group.
- Among the top 25% of patent holders, NPL-supported firms accounted for 23.5%, despite being a smaller share of the sample.
- These findings suggest NPL is engaging with or enabling firms at the frontier of R&D, although causality cannot be definitively established due to data limitations.

Indicative estimate of economic value from product commercialisation: While precise monetisation is not feasible, an illustrative estimate suggests NPLQP may contribute significantly to future revenue generation.

The evidence suggests that a meaningful share of firms supported through the NPLQP are likely to generate revenue from new or improved products within the next 2–5 years, with NPL support playing a contributory role. For example, if 10 firms go on to achieve modest commercial success (e.g. £500k–£1m in annual product sales), the cumulative benefit over a 5-year horizon could exceed £25–50 million, depending on attribution assumptions and the pace of market adoption. However, given the early stage of most technologies, this should be treated as an illustrative scenario, not a definitive valuation.

In summary, while monetisation of product impacts is currently limited by evidence constraints and commercial immaturity, the underlying impact pathway is well-supported. The NPLQP has contributed to product development progress among supported firms - enabling improved designs, faster development, and greater investor or customer confidence and is likely to deliver growing economic benefits as these technologies mature and reach the market.

While data limitations prevent definitive monetisation, we can develop an illustrative estimate based on available evidence. For example:

$$Attributable\ benefit = N * R * Y * a$$

Where:

$\boldsymbol{N} = number\ of\ firms\ generating\ revenue\ (\approx\ 10)$
$\boldsymbol{R}\ =\ annual\ revenue\ per\ firm\ (£0.25m\ -\ £1m)$
$\boldsymbol{Y}\ =\ years\ (5)$
$\boldsymbol{\alpha}\ =\ proportion\ attributable\ to\ NPL\ support\ (25\% - 50\%)$
Then the total attributable benefit is approximated as:

$$Attributable\ benefit =\ N \times R \times Y \times \alpha =\ 10 \times (£0.25m\ -\ £1m) \times 5 \times (25\%\ -\ 50\%)$$

This gives a range of £3m – £25m, representing a conservative scenario based on current data and reflecting only a subset of likely commercial outcomes.

5.6.3 Employment

Employment outcomes were assessed as a potential long-term benefit of the NPLQP, reflecting the programme's strategic aim to support the growth of UK-based quantum companies. The key findings include:

Lack of direct attribution to job creation:

- Interviews with supported organisations did not identify any instances where NPL engagement resulted in new hires.
- Firms prioritised technical progress and investment readiness over workforce expansion.

Evidence of capacity building and skills development:

- Between 2020 and 2024, NPL supported 79 unique PhD students.
- 1,243 individuals accessed online measurement training in 2023–2024.

Attribution challenges and evaluation constraints: it should be noted that employment impacts are difficult to attribute in innovation programmes, especially in early-stage, grant-intensive sectors like quantum as:

- Staffing fluctuations are often driven by internal strategies and market conditions, not external support.
- Time lags between technical milestones and hiring decisions complicate causal analysis.
- Absence of detailed job type, duration, and attribution data limits the ability to quantify employment outcomes.

5.6.4 Additional benefits

Knowledge spillovers: Significant cross-sectoral and international knowledge diffusion, particularly through the M4Q scheme:

- Nearly 50% of the 30+ M4Q projects supported organisations outside the quantum sector, including semiconductors and healthcare, indicating early cross-sectoral spillovers.
- M4Q engagements created a feedback loop, informing NPL's own research agenda and upskilling its scientific staff.
- In 2024, 77% of NPL's quantum-related grant projects included international partners, and 126 academic collaborations were recorded.
- NPL's quantum publications received 60% more citations than the global average, with a field-weighted citation score 33% above the international benchmark.
- Between 2013 and 2023, 13–19% of NPL's quantum publications were co-authored with private sector partners, reinforcing its role in transferring knowledge from academia to industry

- NPL's research has seen a 10.7 percentage point higher uptake in news media than the global average and increasing citations in policy literature.

Catalyst for applied quantum research, accelerating technology readiness and enabling new research directions. For example:

- Stakeholders consistently highlighted NPL's role in de-risking early-stage innovation and opening new R&D pathways. Examples include:
  - MINAC atomic clock validated and deployed on HMS Prince of Wales.
  - Aquark's cold atom clock demonstrator accelerated by six months.
  - Seeqc UK developed multiple generations of superconducting processors with NPL's support.
- 100% of M4Q projects were completed annually, and 71% of participants reported that NPL accelerated their R&D activities.

Collaborative Activity / Impact:

- NPL was described as a "connector" and "credible neutral party" that reduced barriers between researchers and companies, especially SMEs
- Structured engagement mechanisms like M4Q facilitated trust and long-term partnerships.
- Between 2020 and 2024, NPL recorded 126 quantum-related academic partnerships with institutions such as the University of Manchester, University of Birmingham, Royal Holloway, and the Henry Royce Institute.
- NPL's facilities provided unique capabilities not available in partner institutions, such as high-precision characterisation tools and standards expertise.
- In 2024, 77% of quantum-related grant projects involved international partners, supporting co-development and benchmarking of early-stage technologies.
- NPL's leadership in global quantum standardisation forums (ISO/IEC JTC 3 and IMEKO TC25) enabled UK contributions to shape international norms.

5.7. How can impact be future proofed?

The assessment of how the impact could be future-proofed was through interviews with wider stakeholders, delivery staff, customers, and students, surveys with QT organisations, and secondary data from Beauhurst. These were measured through customer satisfaction, demand that indicates potential market coverage with higher capacity, and the current extent of access to end-users and future possibilities.

5.7.1 Is there evidence of high-customer satisfaction/repeat customers and for services being delivered cost-efficiently?

Respondents to the RSM QT organisations survey were asked to rank their satisfaction of NPL's products/services across three dimensions of 'price', 'quality', and 'timeliness of delivery.' Out of 30 respondents, 14 provided feedback, however only up to ten offered actual rankings, with the remainder indicating uncertainty. The results were (where n=number of total responses):

- **Price (n=6)** received an average satisfaction rating of 7.6, with four respondents rating it above eight, and three respondents rating it at five.
- **Quality (n=10)** scored an average of 8.9, with nine respondents awarding it above eight, and one rating it at seven.
- **Timeliness of delivery (n=10)** had an average rating of 8.3, with eight respondents rating it above eight, one respondent rating it a seven, and another rating it at three.

There are high satisfaction scores, especially for quality, which appears to be a clear strength. However, the mixed feedback on price and the significant proportion of respondents who were unsure or did not provide ratings limits the ability to draw firm conclusions.

The M4Q scheme also demonstrated high customer satisfaction and cost-efficiency, achieving an NPS of 94.6 with zero detractors, and increasing willingness to pay for NPL services from 59% to 97%. It exceeded its target by supporting 50 companies. Participants widely praised the scheme's accessibility and technical support[44]. Stakeholder consultations also indicated strong satisfaction with NPL services, with all customers interviewed noting a desire to continue working with NPL in the future. This is shown in the quotes below, highlighting the importance of NPL as a trusted and expert collaborator for quantum industry stakeholders.

"We're looking for [the hosting agreement] to be extended by another three years." – NPL customer

"There are continuing collaborations around the simulation and design of superconducting circuits, the access to chips for like round robin comparative studies… and contribution towards fabrication." – NPL customer

NPL's role as a collaborator also goes beyond those directly supported via the programme. NPL's role as trusted partners within the EPSRC Quantum Technology Research Hubs and Innovate UK challenge funds highlights this, along with the significant and ongoing work NPL is currently doing with the NQCC:

"On the NQCC side, there are different collaborations that would have happened mainly in 2024… One would be on the trapped ion side… a government Office of Technology Transfer project which has been around micro trap technology from NPL getting transferred to NQCC." – NPL customer

Collaboration is demonstrated by NPL's consistent inclusion as core delivery partners and expert consultants on a range of publicly-funded programmes in the quantum ecosystem.

5.7.2 Is there evidence of demand that indicates greater potential market coverage of NPL if higher capacity was available?

There is evidence that further market coverage could be developed through:

Coordination of efforts around materials for QT. This area has been recognised as underdeveloped within the current Programme. NPL is well-positioned to address this by leveraging its convening power to coordinate stakeholders, map national capabilities, and align quantum materials research with broader industrial strategies, including semiconductors and telecoms.

Sector Expansion: QT in healthcare is currently being under explored. Although NPL has some early-stage collaborations with pharmaceutical and medical companies and has started to explore this over the past year, the transition from basic research to clinically relevant tools remains a challenge. This represents a significant opportunity for future growth, especially given the UK's strengths in life sciences. The same is clear for defence.

Third Party Assurance: NPL also plays a critical role in providing third-party assurance for emerging QT. Its reputation as a trusted authority enables it to validate new tools and systems, particularly in cybersecurity and other sensitive domains, where internal organisational capabilities may be lacking. This assurance function is increasingly important as QT move closer to deployment, and it is essential it grows as QT develops

Capacity and Funding: Structurally, NPL's quantum headcount has grown substantially over the past decade, reflecting rising demand (40 to 70 FTEs). However, this growth has been increasingly supported by external project funding, which is more fragile than the stable funding from the National Measurement System (NMS). This reliance on project-based income introduces potential instability and highlights the need for more sustainable funding models.

In summary, NPL has the potential to fill critical gaps in the UK's quantum strategy, while continuing to provide assurance, coordination, and technical leadership, as long as its resources and funding grow in tandem with the demand for its services.

[44] M4Q overall impact data (covering 2020-2024) (provided to RSM by NPL January 2025)

5.7.3 What is NPL's current extent of access to end-users and future possibilities?

NPL's current access to end-users is evolving, with clear opportunities for expansion. Its strongest connections are with academic researchers, spinouts, and select industrial partners. Engagements have enabled NPL to support early-stage innovation and provide trusted third-party assurance for emerging quantum technologies. Though some delivery staff members felt the Programme has made strides in engaging some of the most relevant sectors for quantum (e.g. Finance, Telecoms, and Construction) via awareness and engagement campaigns (e.g. industry workshops), challenges remain in bolstering NPL's role in direct end-user engagement, especially with non-academic sectors.

Feedback from stakeholders indicates that direct engagement with broader industry (e.g. defence, healthcare, and advanced manufacturing) remains limited despite initial efforts via the Programme. Many companies are either unaware of NPL's capabilities or unsure how to engage effectively. This is particularly true for SMEs with limited resources to explore potential collaborations or navigate NPL's offerings. Some stakeholders also suggested NPL's visibility at key industry events and in public discourse is inconsistent, which further limits its reach. Despite these challenges, stakeholders highlighted models like the Huddersfield Advanced Manufacturing facility, where companies can co-locate and collaborate, as a blueprint for quantum that NPL could look to apply more readily. Additionally, NPL's role as a convener and validator of emerging technologies positions it well to support industry growth, provided it continues to invest in partnerships, marketing, and user-friendly service models.

5.8. Contribution Tracing

Contribution tracing was completed against four contribution claims set for the Programme at the outset of this evaluation. This section provides a summary assessment on the extent these hold true using process tracing tests (see Appendix A.7 which provides further detail on the methodology and assessment).

Based on the evidence available results from the contribution tracing show:

Contribution Claim 1: NPL's Quantum Programme has contributed to the UK producing world leading quantum research and innovation at a faster pace than would have occurred otherwise.

Contribution Analysis for this contribution claim **highlighted some contribution of the NPLQP** to the UK producing world leading research and innovation. While NPL's direct influence on IP and broader ecosystem impact is limited, NPL remains a central enabler, with evidence supporting its contribution to national and international quantum leadership. The evidence presents **cautious confidence** in the contribution claim.

Contribution Claim 2: The NPL Quantum Programme has enabled UK companies to further develop new quantum products faster than would have occurred otherwise.

Contribution Analysis for this contribution claim **highlighted some contribution of the NPLQP**. The Programme has supported early-stage quantum companies by providing access to facilities and expertise, helping validate technologies and grow the UK quantum supply chain. However, its broader impact is limited, with little evidence of increased private investment or commercialisation directly linked to its involvement. The evidence presents **cautious confidence** in the contribution claim.

Contribution Claim 3: NPL's Quantum Programme has contributed to greater and faster adoption of quantum technologies in the UK than would have occurred otherwise.

Contribution Analysis for this contribution claim **highlighted negligible contribution of the NPLQP**. Broader societal engagement and commercial adoption remain limited. While the Programme plays a key role in R&D, evidence for its direct causal impact is weak due to overlapping influences and emerging rather than systematic government adoption. The evidence presents **no more confidence** in the contribution claim than prior to data collection.

Contribution Claim 4: NPL's Quantum Programme has contributed to a better equipped and connected quantum technologies landscape in the UK than would have been the case otherwise.

Contribution Analysis for this contribution claim of **highlighted negligible contribution the NPLQP**. NPL plays a leading international role in quantum standards and skills development, attracting collaboration through its unique capabilities. However, its direct impact on exports and commercial adoption is limited, with other institutions also contributing significantly, making attribution complex. The evidence presents **no more confidence** in the contribution claim than prior to data collection.

The Contribution Analysis, supported by Process Tracing and Bayesian Updating, indicates cautious confidence in the validity of two of the four Programme's contribution claims. While some impacts are already visible, many are still evolving and have not yet emerged. To assess future impact, continuous data and evidence collection will be essential.

6. Economic Evaluation Findings

The purpose of the Economic Evaluation is to assess the VfM of the NPLQP and examine the Programme's broader economic contribution to the UK QT sector. It draws on a range of quantitative and qualitative evidence sources to assess whether the Programme delivered net benefits to the UK economy and society and whether those benefits justify the level of public investment.

This assessment includes both monetisable and non-monetisable benefits and is informed by recognised evaluation frameworks, including:

- **CBA** to estimate the ratio of economic benefits to programme costs; and
- **NAO's 4Es framework** to evaluate the Economy, Efficiency, Effectiveness and Equity of Programme delivery.

The Economic Evaluation supports DSIT and HM Treasury in understanding the return on investment from the NPLQP, helping to inform future funding decisions and NPL's strategic positioning within the UK's national quantum ecosystem.

Overview: The Programme delivered value for money, with 95% budget utilisation and strong performance in economy, efficiency, and effectiveness. Indicative Benefit-Cost Ratios range from 0.34 to 1.17, with estimated benefits of £13.3m–£45.5m driven by follow-on funding and early-stage product commercialisation. Attribution remains challenging due to data limitations, but NPL's strategic role in standards, SME support, and skills development is clear. Future impact hinges on improved tracking, longitudinal evaluation, and targeted outreach.

6.1. Costs of the Programme

6.1.1 Overview of Cost Categories

This section outlines the total economic costs associated with delivering the NPLQP between 2020 and 2024. The cost analysis adopts a public sector perspective, focusing on the direct financial investment made by government through DSIT, as well as indirect and opportunity costs incurred by other actors — particularly industry partners engaging with NPL. Costs are categorised as:

- **Direct Programme delivery costs**: Capital and resource spending used to develop and operate the facilities, services, and support mechanisms delivered by the Programme.
- **Indirect/opportunity costs**: Time and resources committed by participating businesses and research partners, which represent economic costs even in the absence of direct financial transfer.

These cost estimates form the denominator in the Programme's CBA and are critical to understanding the overall VfM of the investment.

6.1.2 Direct Programme Costs (Public Sector Investment)

The NPLQP received a total of £38,776,388 in public funding between June 2020 and March 2024. This was allocated across four financial years, with £12.5 million disbursed in the initial year (2020/21) and the remaining amount profiled across the following three years. Based on Programme documentation and annual reporting, this funding supported:

- **Capital investment** in new infrastructure and equipment (e.g. AQML, regional testbeds);
- **Programme delivery and operations**, including staff costs, administration, and technical services;
- **Targeted support programmes**, notably the M4Q scheme, which provided free metrology and validation services to UK-based SMEs; and
- **Standards development**, knowledge transfer, and skills-related activities.

Understanding how the Programme's funds have been allocated and utilised provides a foundation for cost-effectiveness and VfM. The following table gives a high-level overview of the total budget allocations vs the actual spend for the total length of the Programme to detect under/overspend.

Table 6: Overall Programme Budget vs. Actual Spend

Category	Total actual spend	Total budgeted spend	% of budget used
EPSRC Quantum Technology Research Hubs	£8,851,209	£9,250,426	95.7%
R&D and capability building	£20,380,300	£21,607,605	94.3%
M4Q Programme	£750,769[45]	£1,189,502	63.1%
Total per year (excl. depreciation	£29,982,278	£31,137,228	96.3%
	Depreciation	£7,639,160	
	Total budget	£38,776,388	77.3%

Sources: NPL programme data and RSM analysis (2025)

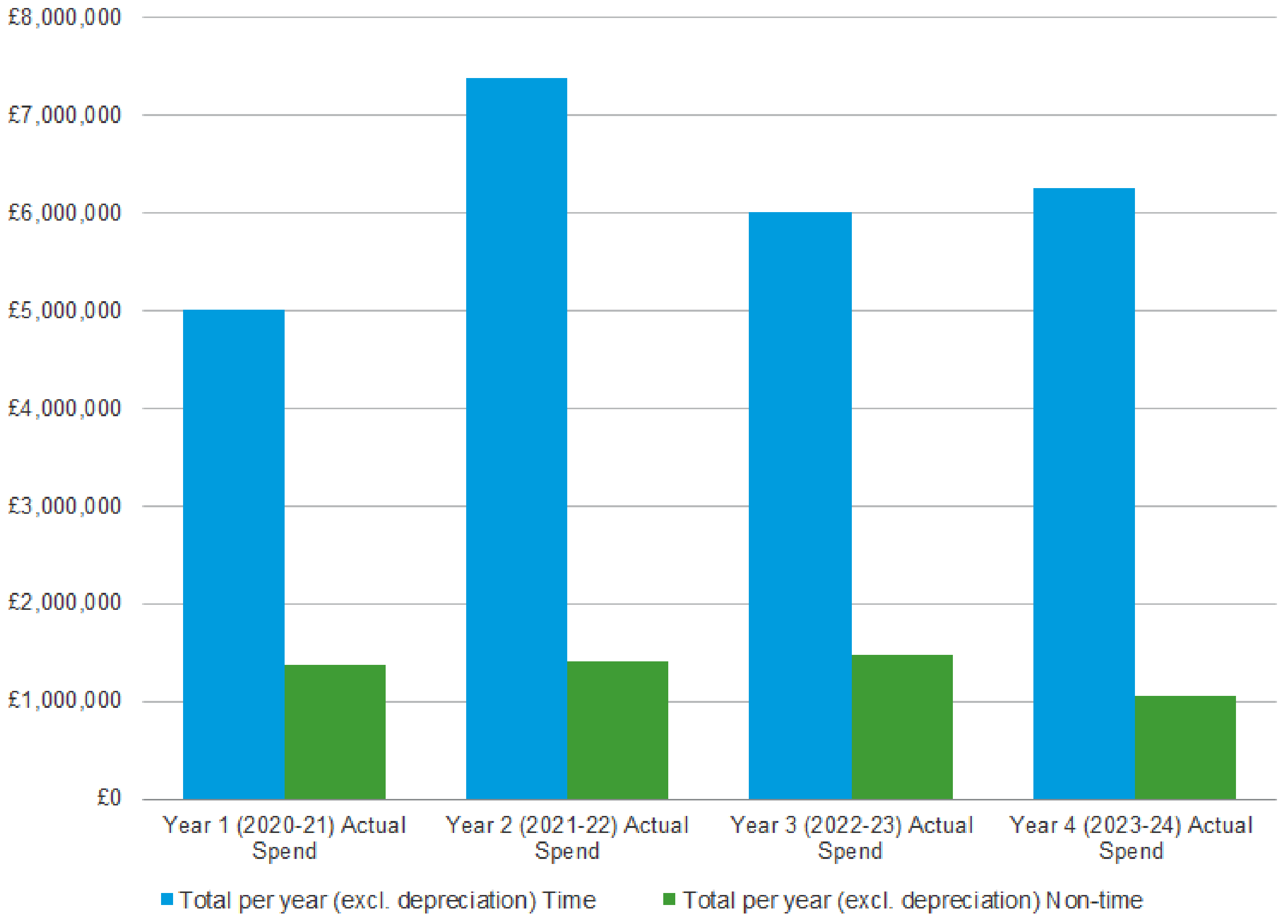
The only part of the Programme with a substantial underspend was the M4Q scheme[46], which spent less than two thirds of its original budget. This is potentially concerning and may reflect lower than anticipated demand for the Programme by SMEs.

The following figure shows the distribution of time and non-time spending and how this changed across the duration of the programme.

[45] Note this figure includes some spending on R&D and capability building that was identified as supporting the M4Q programme as well as direct spending on administering the M4Q scheme

[46] This is explained by the fact that much of the spending to support the M4Q programme is included in the QT Hubs and R&D and capability building budget lines. Once all activities that support the M4Q programme are included, the costs of the M4Q programme amounts to £750,849.

Figure 6: Time vs non-time spend per year



Sources: NPL programme data and RSM analysis (2025)

Note: Time costs refer to the value of time spent in delivering the Programme; these include staff and management time, as well as time contributed by participants.

6.2. Cost Benefit Analysis

Conducting a CBA of the NPLQP presents a number of methodological challenges. While the programme is widely viewed as having delivered important support to the UK quantum sector, the nature of that support, and the early-stage maturity of many of its beneficiaries, makes it difficult to robustly monetise impacts at this stage. In particular, CBA is limited by:

- The relatively short timeframe between programme delivery and this evaluation, meaning many benefits (especially commercialisation and export impacts) are still emerging. While longer term monitoring may help capture these outcomes, robust attribution to NPL remains challenging due to the presence of multiple influencing interventions. Nonetheless, NPL should continue monitoring both quantitative and qualitative indicators of impact over time;
- A lack of counterfactual data that would allow for rigorous attribution of observed outcomes directly to NPL support;
- Limited quantification of downstream outcomes such as sales, exports or employment, due to the pre-commercial status of many supported firms;
- Small sample sizes for both survey and interview data, which constrain the ability to extrapolate from observed impacts; and

- A lack of longitudinal tracking data, such as routine follow-up with M4Q participants, to measure change over time.

Despite these limitations, the evaluation has developed a conservative and illustrative CBA, drawing on the two impact areas with the strongest supporting evidence: follow-on funding and product commercialisation. These are presented as ranges to reflect the underlying uncertainty and variation in attribution assumptions. The following table summarises the estimated economic costs of the programme alongside indicative benefit ranges. All figures relate to the 2020–2024 funding period for costs and a 5-year future horizon (2024–2029) for benefits and are presented in nominal terms for simplicity.

Table 7: Illustrative CBA of the programme

Benefits (2020 to 2024)	Estimated range of attributable benefit (£m)
Further funding	£10.3 million – £20.5 million
Commercialisation	£3 million – £25 million
Employment	No evidence of positive net benefit of NPL[47]
Exports	Insufficient evidence to assess[48]
Total benefits	£13.3 million – £45.5 million
Total programme costs	£38.8 million
Implied benefit-cost ratio	0.34 – 1.17
Implied net present value	-£25.5 million – +£6.7 million

These figures indicate that, under conservative assumptions and given current data, the programme is likely to have delivered positive VfM only in the upper-bound scenario. This reflects the fact that most commercial and economic outcomes are still in development, and the programme's return on investment is expected to materialise over a longer time horizon than is currently observable.

Opportunities for Strengthening Future CBA

The evaluation identified several data gaps that, if addressed in future programme monitoring or evaluation, would enable a more robust and definitive CBA:

- NPL should **develop monitoring and tracking tools** that can strengthen attribution of long-term economic outcomes to the programme. Areas of focus are capturing data on **private investment in quantum technologies** and **sales and exports** that are linked to NPL activity such as the testing and validating of products and patent development. Additional data collection tools could include:
  - **Routine follow-up surveys** with NPL participants 6–12 months post-engagement, to track funding raised, product outcomes, and employment changes;
  - **More systematic recording of outcome data** at the point of project exit, including technology readiness level (TRL) progression, anticipated revenue, or customer interest;
  - **Integration of programme data with public datasets** (e.g. UKRI, Companies House, Beauhurst) to track commercial progress over time;
  - **Larger, structured survey samples** to improve statistical power and enable segmentation by firm size, sector, or region;
  - Development of a **longitudinal evaluation framework**, to revisit supported firms at regular intervals over 3–5 years and capture lagged impacts.

[47] It is important to note that variation in employment across firms is extremely high, with some supported companies reporting only a few hundred employees while others employ over 100,000. Given this dispersion, employment statistics are not comparable across groups, even after matching on turnover. For this reason, the employees variable from Beauhurst was not used in the matched analysis, as it would not provide a reliable basis for comparison or attribution of benefits. Moreover, employment activities - particularly for larger, more generalist firms that are only partly involved in quantum - do not specifically relate to quantum activities

[48] Similarly to employment data, export figures reported in Beauhurst (and other available sources) are not systematically captured at the firm level and, where available, are not specific to quantum-related activities. As such, export impacts cannot be robustly assessed within this analysis.

- NPL should **develop a clearer definition of 'treated' firms** drawing on scale of support as well as length of time supported to enable identification of a subset of treated firms where NPL support may make the biggest contribution to long-term economic outcomes.
- NPL should **draw on additional datasets** such as the IDBR to extend the Beauhurst database for the quantum sector and provide more complete measures such as turnover. Attributing changes in turnover to NPL support alone will remain challenging due to overlapping interventions (e.g. Innovate UK funding), and the large size of many of the firms involved where quantum activities represent only a small part of overall operations. However, incorporating this data would allow for a fuller picture of long-term outcomes. As an enabling project, NPL plays a foundational role in supporting firms' progress alongside other ecosystem actors.

With these improvements, future CBAs could more accurately capture the long-term economic contribution of the NPLQP and the full return on public investment in quantum metrology infrastructure and services.

6.3. 4Es Value for Money assessment

To complement the CBA approach, a 4Es VfM assessment was undertaken to provide a broader view of the VfM provided by NPL. This section utilises qualitative and quantitative evidence gathered through interviews, programme documentation, performance metrics, and desk research. The assessment considers both the delivery of the programme and the outcomes achieved, providing a structured evaluation of the Programme's VfM and its contribution to wider public benefit.

6.3.1 Economy

The NPLQP broadly demonstrated sound economy by securing necessary inputs (facilities, expertise, partnerships, and services) at reasonable cost and with proportionate use of public funds. The programme received £39.05 million in central government funding between 2020 and 2024. According to programme documentation, approximately 95% of this budget was spent by the end of the delivery period, indicating a high level of budget utilisation. The one area of concern was the M4Q programme, which spent less than two thirds of its budget, perhaps indicating lower than anticipated demand from SMEs.

Notably, £8.5 million was allocated to capital investment in Year 1 alone, enabling the early procurement of advanced T&E equipment and laying the foundation for facility development at NPL's AQML and two regional hubs. The high rate of capital spend in the early stages may have helped avoid later inflationary costs and ensured that core infrastructure could be delivered without the need for costly mid-programme reprofiling or re-scoping.

Furthermore, economy was supported through partnerships with existing institutions including the EPSRC Quantum Technology Research Hubs, the PGI and international metrology bodies; enabling co-investment and shared use of infrastructure. Though delivery shortfalls were noted in areas such as the production of formal knowledge transfer outputs and planning for regional facility sustainability, these did not result in material overspending. Instead, resources were flexibly reallocated to higher-impact activities, such as international standards development and expanded industry engagement, reflecting effective stewardship of public funds and agile programme management.

6.3.2 Efficiency

Efficiency refers to the extent to which a programme delivers its intended outputs and services with optimal use of resources (including time, funding, personnel, and infrastructure) while minimising waste and duplication. This assessment considers the utility and efficiency of the assets and services created through the NPLQP, as well as the distinctiveness of its contributions to the UK's quantum ecosystem.

Utility is defined as the usefulness and usability of assets and services developed through the programme for the intended beneficiaries (ie quantum companies, researchers, and policy actors). Evidence from interviews, surveys and programme documentation indicates core assets such as the AQML, the SuperFab facility at Royal Holloway, and the SNOM facility at the Henry Royce Institute were actively used by both internal and external stakeholders. The AQML in particular enabled a wide range of T&E activity in quantum clocks, superconducting devices, and quantum secure communications. While formal utilisation data (e.g. equipment bookings or facility usage hours) was not systematically recorded across all facilities, the evidence available supports the conclusion that key programme assets had good functional uptake, especially in later years.

In terms of efficiency, qualitative feedback suggests that delivery was affected by equipment delays and staffing challenges, particularly in the early phase of the programme, which led to underutilisation in Year 1 and part of Year 2. Despite this, there were no reports of major cost overruns or ongoing operational inefficiencies. For example, the AQML facility was brought into operation by Year 3, with most capital procured as planned, and was subsequently used to deliver both internal R&D and third-party support. The M4Q scheme also demonstrated operational efficiency by using existing NPL expertise and infrastructure to deliver rapid, targeted services at minimal marginal cost. Future iterations of the programme could benefit from more robust tracking of facility downtime and maintenance costs to better inform resource planning.

The distinctiveness of the capabilities established through the programme is a key aspect of its efficiency. NPL's role as the UK's National Metrology Institute allowed it to develop high-precision measurement capabilities that are either not available elsewhere in the UK or not available with the same level of credibility and traceability. These include characterisation of single-photon sources, cryogenic terahertz detectors, and microwave and optical metrology for quantum devices, areas where few commercial providers operate. Feedback from both quantum SMEs and academic researchers highlighted that NPL's independence, technical authority, and international standards involvement gave its services unique value. By developing capabilities that filled clear market gaps, and by focusing investment on strategically significant areas, the programme avoided duplication and ensured efficient use of public funding to deliver services that would not have been viable on a commercial basis alone.

6.3.3 Effectiveness

Effectiveness considers the extent to which the NPLQP achieved its intended objectives and contributed to wider strategic outcomes, including accelerating QT commercialisation, addressing market failures, and strengthening the UK's quantum R&D base. Evidence from stakeholder interviews, programme documentation, and survey data indicates that the programme was largely effective in delivering impact in its core focus areas, despite some delivery shortfalls.

A key aim of the programme was to address knowledge gaps in industry around measurement and testing, which were acting as barriers to commercialisation. Interviews with company representatives suggest that NPL's support often helped firms overcome critical uncertainties in system behaviour, calibration, or interoperability. These interventions directly supported firms' progress through TRLs, with some stakeholders indicating that NPL's validation enabled investment, prototyping, or trials that would not otherwise have been feasible.

In the standards and interoperability space, the programme achieved high effectiveness. NPL played a leading role in the development of new international quantum standards, including through its work with ISO/IEC JTC 3 and ETSI, as well as its coordination of the UK Quantum Standards Network. These activities contributed to the credibility and coherence of the UK's quantum offer and positioned the country as a serious participant in global quantum markets. By shaping pre-normative definitions, test methods and use cases, NPL enabled UK firms to better anticipate and meet future compliance requirements, an important strategic advantage as quantum markets begin to formalise.

The programme also contributed to the wider quantum R&D ecosystem. NPL supported over 79 students[49] through its different working groups, PGI, embedded technical apprenticeships in its labs, and provided bespoke training sessions accessed over 1,200 times. These efforts directly responded to the national

[49] PhD annual data provided by NPL (September 2025)

quantum skills gap identified in DSIT's UK Quantum Skills Taskforce report[50] and helped build a workforce with more applied measurement expertise.

However, effectiveness was more mixed in some areas. The absence of sustainability plans for regional facilities and the limited engagement with non-quantum industry end users suggest room for improvement in maximising long-term impact and cross-sector diffusion. Additionally, while many activities were impactful, stakeholders noted that progress was often reactive (ie responding to demand rather than shaping it) which limited the programme's influence over broader market formation.

The available evidence suggests the NPLQP was largely effective in achieving its core objectives. It addressed key market failures, supported commercialisation of early-stage technologies, developed internationally recognised standards, and strengthened the UK's quantum R&D and skills infrastructure. These contributions collectively positioned NPL as a critical enabler of quantum innovation in the UK and laid a foundation for future policy and investment.

6.3.4 Equity

Equity in the context of the NPLQP can be considered in terms of access to programme benefits across different types of organisations and geographies. While the programme did not have explicit distributional objectives, it made efforts to support a broad range of users, particularly through the non-competitive M4Q scheme. This scheme provided free access to testing and evaluation services for 50 UK-based SMEs, including many first-time collaborators, helping to level the playing field for early-stage companies that might otherwise face barriers to high-quality metrology support.

The programme also contributed to regional equity through the development of satellite facilities beyond NPL's main site in Teddington. Facilities were established at Royal Holloway (SuperFab) and the SNOM facility at the Henry Royce Institute, with a third site under development at the University of Strathclyde. These centres extended access to quantum infrastructure and expertise across different parts of the UK, although formal data on regional usage patterns is limited.

In terms of skills equity, the programme supported a range of PhD students and apprentices and worked with academic partners across multiple UK regions. However, engagement with underrepresented or non-academic groups, such as schools, FE colleges, or diverse industry sectors, was limited. There is also limited evidence of targeted support to address gender or socio-economic disparities within the quantum workforce.

Overall, while equity was not a primary focus of the programme, there is evidence that its design—particularly the open-access nature of M4Q and the geographic spread of facilities—contributed to a reasonably inclusive offer. Future programmes could enhance this further by embedding equity as an explicit objective, improving monitoring of participation by region, sector, and demographic group, and strengthening outreach to underserved communities.

6.4. Conclusions

The NPLQP was delivered with a total cost of £38,776,388 between 2020 and 2024. This funding was primarily directed towards the development of specialist T&E infrastructure, the delivery of support to early-stage quantum companies, and contributions to international standards and collaborative R&D. Approximately 95% of this budget was spent by the end of the delivery period, indicating a high level of budget utilisation. The one area of concern was the M4Q programme, which spent less than two thirds of its budget, possibly indicating lower than anticipated demand from SMEs.

The evaluation identified a broad range of benefits, including encouraging further fundraising, accelerated R&D, increased firm confidence and investment readiness, and early-stage knowledge spillovers into adjacent sectors such as semiconductors and healthcare. It is very challenging to attribute changes in economic outcomes to the NPLQP, meaning estimated benefits and metrics, such as the benefit-cost ratio, are extremely uncertain.

[50] DSIT (2025) UK Quantum Skills Taskforce report

The indicative benefit-cost ratio (BCR) for the programme, based on available evidence and assumptions is in the range of 0.34 to 1.17. While this suggests the programme is likely to have delivered positive value for money only in the upper-bound scenario, it reflects the necessity of making conservative assumptions based on the limited data available and that some economic outcomes will take time to be realised. Developing tailored monitoring and tracking to capture future data would enable a more robust and definitive CBA to be conducted and is a key focus of the recommendations made in chapter 7.

The 4Es assessment indicates the Programme delivered VfM. It performed strongly on economy, with the majority of funds directed towards direct delivery and limited overheads. It demonstrated good efficiency, particularly in leveraging existing NPL capabilities and maintaining high project completion rates, however systematic tracking of facility usage and downtime could be improved. The programme effectively addressed key market failures and enabled R&D progress including in standards leadership and SME engagement. While equity was not a central design objective, there is evidence of broad access to support through the M4Q scheme and early steps towards geographic distribution of infrastructure.

Overall, the evidence indicates that the NPLQP has delivered good VfM and contributed materially to the development of the UK's emerging QT sector.

7. Conclusions and Recommendations

Programme Performance and Delivery

The Programme has strong management and governance processes in place, with progress monitored for most of the business case KPIs and additional KPIs developed to reflect the additional areas of focus for the Programme. Delivery was effective, especially given the impact of Covid at the outset of implementation. NPLQP achieved strong outcomes in standards development, industry engagement, skills development and knowledge transfer, meeting most of the KPIs set out in the initial business case. Facility provision saw partial success due to some gaps in sustainability planning. Strengthening the monitoring and focus on risks for this area should help ensure increased performance in the future.

The Programme Board for the NPLQP proactively managed risks by maintaining structured risk registers for each objective area, using a scoring system to prioritise mitigation efforts and escalating strategic risks for resolution. While risk management was generally robust, featuring contingency planning, stakeholder engagement, and governance improvement, analysis identified small gaps in alignment between tracked risks and original programme targets.

Recommendation – metrics data should be collected (where applicable / appropriate) to align with Business Case KPIs that would allow for comprehensive assessment of performance against targets.

Recommendation – performance monitoring should combine descriptive statistics (e.g. number of collaborations; number of companies receiving QT&E support; number of secondments and joint appointments hosted; number of apprentices hosted and sustainability metrics) with data on the impacts these have achieved.

Recommendation – risk assessment and mitigation processes should fully cover the targets and KPIs relevant to each objective area / workstream to ensure they are on track to be achieved. This would increase potential for the Programme to achieve target outcomes and – in any cases where targets are not reached – provide rationale for this.

Recommendation – the NPLQP programme should have a dedicated M&E resource.[51]

Process Evaluation

Programme rationale and design

The Programme was designed to address key market failures hindering QT commercialisation in the UK, including poor coordination between academia and industry, a growing quantum skills gap, and underinvestment in testing infrastructure. Its implementation focused on five strategic pillars: building national QT&E facilities, promoting best practice in measurement, leading international standards development, improving industry access, and delivering targeted training. These elements aimed to create a more cohesive, skilled, and innovation-ready quantum ecosystem.

Were activities delivered as expected?

The Programme made strong progress in establishing national infrastructure, advancing international standards, and supporting early-stage quantum firms. While the Programme laid a solid foundation for future initiatives, key areas for improvement include strengthening industry outreach, enhancing training uptake, and ensuring more consistent delivery against planned objectives.

Were users engaged as expected?

The Programme successfully engaged most of its intended user groups, including QT companies, academic institutions, government stakeholders, and standards bodies, with strong collaboration results and strategic

[51] The 2020-24 programme was more than half way through before an analyst was brought in to lead/develop the M&E activities

partnerships. It also supported early-career talent through PhD and apprenticeship schemes. However, engagement with non-quantum industry end-users was limited, hindered by unclear messaging and a lack of visibility into NPL's service offer. Future efforts should focus on improving outreach and communication to broaden adoption across sectors beyond the core quantum community.

What would users have done if NPL's services were not available?

Without the Programme, many users, particularly SMEs and academic partners, would have faced significant barriers in accessing specialised quantum facilities, credible validation, and interdisciplinary expertise. It also supported standards and skills development. In its absence, users would likely have relied on fragmented, lower-quality alternatives or faced delays in achievement of outcomes, weakening the UK's quantum innovation pipeline.

How is NPL positioned globally?

NPL is a key player in the global quantum landscape, offering strong capabilities in measurement science, skills development, and standards leadership. Its training model and contributions to international standardisation efforts position it well among peers like NIST (USA), National Research Council (NRC) (Canada), PTB (Germany), and Danish National Metrology Institute (DFM). NPL offers a comparable suite of commercialisation support services to international peer institutions, particularly in terms of technical expertise, testing infrastructure, and collaborative R&D support. However, there are key differences:

- **Incubation and start-up support:** NPL does not operate its own physical incubator space or structured start-up programme. However, this gap is mitigated by its partnerships with the EPSRC Quantum Technology Research Hubs. Through these partnerships and the M4Q Programme, the NPLQP has supported spinouts and SMEs.
- **IP support:** Unlike some institutions such as NRC and NIST, NPL does not currently provide dedicated in-house IP advisory services. This is a notable gap where international counterparts often embed IP guidance directly within commercialisation supports. NPL could collaborate with others to ensure this is available.
- **Formal qualifications:** NPL does not currently provide expertise to shape formal professional qualifications, such as the co-designed Master's programmes available through Canada's NRC. This aligns with findings from the UK Quantum Skills Taskforce report[52], which highlighted the need for more industry-aligned quantum MSc programmes and stronger collaboration between academia and industry in their design and delivery.

Recommendation – To enhance its support, NPL should continue and even strengthen its linkages with other services. While organisations like NRC and PTB integrate technical services with financial support or incubator networks, similar support mechanisms already exist within the UK's broader quantum and innovation ecosystem. NPL should ensure these linked supports are effective for their client base.

Impact Evaluation

The NPLQP has played a pivotal role in shaping the UK's QT landscape between 2020 and 2024.

R&D and Innovation

The Programme has made a strong contribution to advancing the UK's quantum R&D capabilities. Through strategic partnerships, such as those with Royal Holloway and the University of Manchester, and investments in facilities like AQML and SuperFab, NPL has enabled cutting-edge research and improved reproducibility and readiness of quantum technologies.

However wider stakeholders across both public and private sectors noted that the Programme could do more to support the coordination of quantum materials R&D. This provides the opportunity for NPL to map and connect the UK's expertise in different material types and link these to broader strategies (e.g.

[52] UK Quantum Skills Taskforce report (May 2025)

semiconductors, telecommunications). While acknowledged that other stakeholders (e.g. Innovate UK and Catapults) are also likely to have core roles within this space, NPL has potential to contribute via provision of definitions for assurance protocols and standards for quantum materials, which are essential for device reliability and commercialisation.

Standard Setting

NPL experts have contributed to key ETSI and ISO/IEC standards, including QKD and quantum computing terminology. In the UK, NPL co-founded the national quantum standards committee with BSI, now with over 60 members. The Programme has led national workshops, influenced the CEN-CENELEC quantum roadmap, and proposed a new ISO/IEC technical committee. Internationally, NPL collaborates with NIST under a joint MoU and has convened global metrology leaders through a National Measurement Institute 'mini summit'. It also supports global engagement through IMEKO TC25, advancing quantum sensing and metrology.

Private Sector

The Programme has had a moderate however meaningful impact on the private sector. It has enabled early-stage quantum companies to develop and validate new products which has helped build trust and credibility; these validations are important as without them the companies may not be able to sell their products.

In addition, the M4Q scheme contributed to 30+ new or improved products and 22 companies securing additional investment. While attribution is complex due to overlapping support from other initiatives, the Programme has shown some contribution to commercialisation and supply chain development. However, engagement with downstream users and tiered manufacturing remains limited.

The Programme's contribution to the wider adoption of quantum technologies and societal awareness is currently negligible, likely because it is an emerging sector, with limited evidence of systemic uptake in sectors like healthcare or defence, unlike some international comparators

Recommendation – NPL should widen their engagement to support the greater adoption of quantum technologies, particularly in healthcare and defence.

Upskilling the Workforce

The Programme has helped develop the quantum workforce. By 2024, NPL supported 79 PhD students (6% fully funded, 69% partly funded), delivered training to 100+ individuals, and hosted apprenticeships and joint academic appointments. QT organisation survey data shows 64% of organisations faced hiring challenges, and 69% of those who responded agreed NPL helped recruit staff.

Future Proofing Impact

The NPLQP has laid essential groundwork for the UK's quantum future. It has delivered tangible benefits in research, early-stage innovation, and skills, while also establishing NPL as a trusted authority in quantum measurement and standards. However, there are areas it can develop:

Recommendation – we recommend that NPL utilise its expertise and role as a convening force in quantum to lead national efforts surrounding quantum materials while ensuring alignment with semiconductor and telecoms strategies to ensure maximum relevance and impact.

Recommendation – we recommend a further summative evaluation in completed in 2-5 years after ensuring the collection of quantitative data on private investment in quantum technologies and sales and exports to more fully demonstrate NPL's impact.

Economic Evaluation

The economic evaluation assessed the NPLQP's VfM by examining the relationship between costs, outcomes, and delivery performance, drawing on CBA and a structured assessment against the 4Es framework: Economy, Efficiency, Effectiveness, and Equity.

The CBA assessed the extent to which the following four anticipated economic benefits have been realised and compared these to the costs.

Economic Benefits:

- **Follow on Funding -** Analysis of the Beauhurst database indicates that 31% of NPL-supported firms raised funding between 2020 and 2024, compared to only 11% of quantum firms that did not receive NPL-support. Median fundraising was also higher among NPL-supported firms. However, it is uncertain how much of these differences are attributable to NPL support.
- **New Products / Services -** There is also strong qualitative evidence via case studies, interviews, QT organisation survey responses, and NPLQP monitoring information that the NPLQP has contributed to the development of new and improved products across a range of UK QT companies. While some companies attributed progress directly to NPL's support - particularly access to validation facilities and expertise - attribution is complex due to overlapping funding and support from universities and other national initiatives. The contribution analysis concluded with cautious confidence that NPL accelerated product development beyond what would have occurred otherwise. In addition, there is evidence of patent development that can be directly and indirectly attributed to NPL support. However, insufficient time has passed to assess the impact of this innovation activity on the long-term commercialisation in the sector.
- **Export and Employment Growth -** Information is more limited on the extent to which export and employment growth have been generated by NPL due to limited survey responses. The QT organisations survey did elicit responses for some organisations that felt that NPL support had led to them increasing the size of the workforce, but the number of responses was too small to generalise from this finding.

CBA Analysis: The total spending on the NPLQP between 2020 and 2024 was £38.8 million. An indicative CBA was conducted, although the attribution challenges outlined above limit the extent to which this can provide a true reflection of the value achieved by the Programme. Based on assumptions informed by the findings on fundraising and commercialisation, the indicative BCR is estimated at between 0.34 and 1.17. There are several gaps that, if addressed in future Programme monitoring or evaluation, would enable a more robust and definitive CBA.

4Es: To complement the CBA approach, a 4Es VfM assessment was undertaken to provide a broader view of the VfM provided by NPL:

- The Programme broadly demonstrated sound economy, with over 95% of the allocated budget spent and the majority directed toward delivery activities rather than overheads. However, the M4Q programme spent less than two thirds of its budget, perhaps indicating lower than anticipated demand from SMEs.
- Delivery was broadly efficient. Qualitative feedback indicates effective use of resources and minimal downtime in later years. The distinctive capabilities established—such as AQML and advanced characterisation tools—filled market gaps and served unique sector needs.
- The Programme was effective in achieving its core objectives in enabling innovation, advancing applied R&D, and supporting the early development of QT. It contributed to the UK's leadership in standards, built research capacity, and enabled impactful collaborations across academia and industry.
- Although not a central Programme objective, equity considerations were addressed through open-access support, geographic investment in regional facilities, and skills development via student and early-career placements.

Overall, there is evidence that the Programme has delivered VfM, having effectively achieved its core objectives and contributed to longer-term economic impacts, including attracting further funding and supporting commercialisation across the wider quantum sector.

Recommendation – we recommend that NPL develop monitoring and tracking tools that can strengthen attribution of long-term economic outcomes to the Programme. Areas of focus are capturing data on private investment in QT and sales and exports that are linked to NPL activity such as patent development.

Recommendation – we recommend that NPL develop a clearer definition of ‘treated’ firms drawing on scale of support as well as length of time supported. This will enable identification of where NPL support may make the biggest contribution to long-term economic outcomes.

Recommendation – we recommend that given the underspend on M4Q further consideration is given by NPL to understand if this reflects lower than anticipated demand for the Programme by SMEs.

A.1. Evaluation Questions

Evaluation Element/ Aim	Relevant Research Questions

Process Evaluation
 	
Assess effectiveness, identify strengths and areas for improvement, ensuring lessons learned can be applied to future iterations of the programme.
	• What was the rationale for the programme and was the design appropriate to support this?
	  ○ What is the rationale for public intervention in this space and for funding measurement institutes like NPL?
	  ○ What market failures are being addressed by the programme?
	  ○ What would users have done if NPL's services were not available?
	• What were the key components of the implementation strategy and how were they executed:
	  ○ Who was reached (i.e. User-profile for NPL's services, who uses NPL's services? Which sector/area of research do they represent? Why are they using NPL?)
	  ○ Were activities and outputs delivered as planned?
	  ○ What challenges were encountered during implementation and how were they addressed?
	• How cost-effective was the programme?
	  ○ What is the utility, efficiency (in terms of cost of maintenance and downtime), and distinctiveness of capabilities established as part of the programme?
	• How could the programme activities have been delivered more efficiently, e.g. time, money, human capital?
	• How effective were the monitoring and evaluation mechanisms used to track progress, and how could they have been improved?
	• How is NPL positioned globally?
	  ○ How does it compare with other equivalent institutions with comparable assets?
	  ○ What capabilities and services are unique to NPL and what are the gaps they fulfil across industry?
	  ○ How has this affected the ability to deliver the desired outcomes and impacts?

Impact Evaluation
 	
Substantiate the programme's impact by assessing its contributions to quantum technologies, the UK's leadership, and its broader impact.
	• What is the impact of the programme on R&D and innovation activities in the QT sector?
	  ○ To what extent do NPL's R&D activities align with overall QT landscape and market trends.
	• What is the direct impact of the programme on the private sector?
	  ○ Benefits (financial and otherwise e.g. capabilities and services provided)
	  ○ Efficacy of the Measurement for Quantum (M4Q) scheme and resultant impact
	• Quantified and non-quantified measures:
	  ○ What is the role and impact of the programme on upskilling the workforce?
	  ○ What are the wider indirect impacts of the programme on society and the economy?
	  ○ What were the long-term benefits, both tangible and intangible, of the programme?
	• What is the contribution of the programme to impacts:
	  ○ Can the benefits be segregated and linked to the NMS versus the Quantum Programme versus the AQML (Advanced Quantum Metrology Laboratory)?
	• How can impact be future proofed?
	  ○ Is there evidence of high-customer satisfaction/repeat customers and for services being delivered cost-efficiently?
	  ○ Evidence of demand that indicates greater potential market coverage of NPL if higher capacity was available?
	  ○ What is NPL's current extent of access to end-users and future possibilities?

Economic Evaluation
 	
Assess the VfM of the programme and assess the potential for
	• What was the VfM of the programme?
	  ○ What were the monetisable and non-monetisable benefits of the programme?
	  ○ What were the spillover effects in furthering technical advancements in QT and its adjacent sectors?
	  ○ What were the applications of NPL's R&D activities in spheres like health and life sciences, environment, and defence?
	  ○ What were the knowledge spillovers?

Evaluation Element/ Aim	Relevant Research Questions
modelling future economic impacts	○ What was the relevance of the programme’s capabilities in terms of investment demand and supply from other sources? ○ What was NPL’s role in attracting talent and businesses from overseas? • How many job years were created to support the NMS labs involved with the programme? Is the programme the best use of resources? ○ What is the ratio of costs to (monetisable) benefits? ○ What was the economy, efficiency, effectiveness and equity (4Es) of the programme?

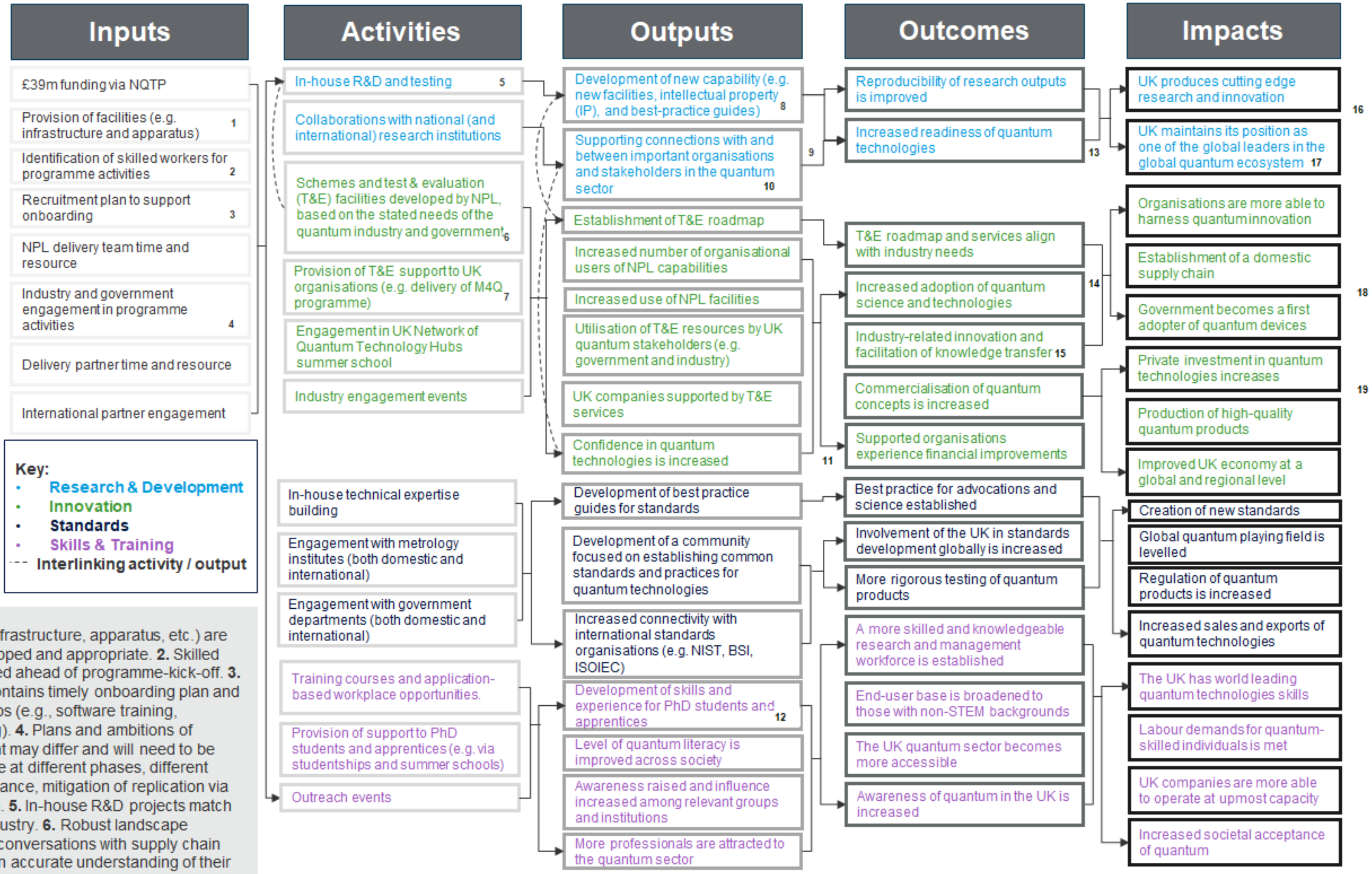
A.2. Theory of Change

The scoping phase of the evaluation led to a light touch revision of the existing ToC for the overall NPLQP. This revision has been supported through the review of existing documents and evidence provided by NPL, and 6 scoping interviews with programme staff. This has included the addition of metrics and provision of additional detail on the wider context influencing outcomes and impacts. This will be further updated to reflect feedback following a workshop with NPL representatives.

The ToC on the following page shows a diagrammatic representation of the ToC and the expected causal pathways of how programme inputs and activities ultimately lead to desired outcomes and impacts.

This is a key tool to develop contribution hypotheses to test in the impact evaluation, and to identify pathways to impact to test effectiveness of programme design and delivery as part of the process evaluation.

Figure 7: NPLQP Theory of Change



Assumptions:

1. Existing facilities (infrastructure, apparatus, etc.) are prepared, well-equipped and appropriate. **2.** Skilled workers are identified ahead of programme-kick-off. **3.** Recruitment plan contains timely onboarding plan and addresses skills gaps (e.g., software training, equipment-handling). **4.** Plans and ambitions of industry/government may differ and will need to be understood - may be at different phases, different levels of risk acceptance, mitigation of replication via central coordination. **5.** In-house R&D projects match the needs of the industry. **6.** Robust landscape analysis (based on conversations with supply chain companies) gives an accurate understanding of their needs. **7.** Training modules are produced in time using inputs from NPL staff. **8.** R&D yields substantial resources (best practice guides, data, methodologies, protocols, etc. for test and evaluation) and reputable research outputs (papers, patents, etc.). **9.** NPL's quantum metrology research aligns with UK standardisation needs. **10.** NPL's reputation in the R&D and standards ecosystem enable collaborations/liaisons with academic consortiums, companies, government, etc. (domestic and international) **11.** Efficient data management and information sharing to ensure that measurement data is accurate, accessible, and reliable. **12.** Timely recruitment of apprentices, PhD scholars, and secondment staff.

13. Proper mechanisms in place to protect intellectual property rights. **14.** Practices in measurement and testing recommended by NPL are picked up and applied rigorously by research institutions and the industry. **15.** Efficient and expeditious channel of communication between NPL and its collaborators for sharing knowledge and services. **16.** A strong and growing ecosystem of quantum companies, academia, and the public sector. **17.** UK's quantum advancement rivals other frontrunners, thereby guaranteeing a seat at the table at international forums. **18.** Regulatory compliance in areas like environmental monitoring, healthcare, and product safety. **19.** Public awareness and understanding of quantum technologies and its benefits for garnering support and funding.

Risks:

1. Organisations do not understand the role of NPL and its value. **2.** Underestimation of project costs due to optimism bias. **3.** UK companies do not utilise NPL's facilities to its full capacity, reducing the opportunity to create economic benefit for the UK. **4.** Difficulty in procuring capital and products within the right timeframe. **5.** Difficulty in scaling up the programme to keep up with the broadening of its scope as necessitated by the UK Quantum Strategy. **6.** Potential lack of resources and interest in quantum standards from other key countries inhibiting progress of standard making process.

ToC Theory of Change - Detail

This section outlines assumptions, wider context and details of each box in the overall logic map diagram.

Assumptions

Programme assumptions have been identified for specific pathways in the ToC as listed below:

Inputs to activities:

- Existing facilities (infrastructure, apparatus, etc.) are prepared, well-equipped and appropriate.
- Skilled workers are identified ahead of programme-kick-off.
- Recruitment plan contains timely onboarding plan and addresses skills gaps (e.g., software training, equipment-handling).
- Plans and ambitions of industry/government may differ and will need to be understood.

Activities to outputs:

- In-house R&D projects match the needs of the industry.
- Robust landscape analysis (based on conversations with supply chain companies) gives an accurate understanding of their needs.
- Training modules are produced in time using inputs from NPL staff.

Outputs to outcomes:

- R&D yields substantial resources (best practice guides, data, methodologies, protocols, etc. for test and evaluation) and reputable research outputs (papers, patents, etc.).
- NPL's quantum metrology research aligns with UK standardisation needs
- NPL's reputation in the R&D and standards sector enable collaborations/liaisons with academic consortiums, companies, government, etc. (domestic and international)
- Efficient data management and information sharing to ensure that measurement data is accurate, accessible, and reliable.
- Timely recruitment of apprentices, PhD scholars, and secondment staff.

Outcomes to impacts:

- Proper mechanisms in place to protect intellectual property rights.
- Practices in measurement and testing recommended by NPL are picked up and applied rigorously by research institutions and the industry.
- Efficient and expeditious channel of communication between NPL and its collaborators for sharing knowledge and services.
- A strong and growing ecosystem of quantum companies, academia, and the public sector.
- UK's quantum advancement rivals other frontrunners, thereby guaranteeing a seat at the table at international forums.
- Regulatory compliance in areas like environmental monitoring, healthcare, and product safety.
- Public awareness and understanding of quantum technologies and its benefits for garnering support and funding.

Wider context

Drivers for development of the NPLQT:

The NPLQT was introduced to support the NQTP by advancing quantum technologies in key areas (measurement standards, precision, and commercialisation) in order to contribute towards strengthening the UK's position as a global leader in quantum science and technology, building on NPL's strong position as a leader of science and innovation in the UK's quantum ecosystem (as shown by NPL containing the highest number of quantum scientists of any organisation in the country).

Enablers:

- Strong global position of the UK with regard to quantum
- A willingness for key quantum stakeholders in the UK to collaborate and establish key partnerships to contribute towards long-term goals
- Synergies across the innovations, and with other investments across the UK Quantum Technologies landscape supporting accelerated progress towards outcomes and impacts
- Previous expertise and experience of NPL (the work of this NPL-funded phase builds on – and is enabled by –previous NPL work such as the National Measurement System)

Barriers/risks:

- Organisations do not understand the role of NPL and its value
- Underestimation of project costs due to optimism bias
- UK companies do not utilise NPL's facilities to its full capacity, reducing the opportunity to create economic benefit for the UK
- Difficulty in procuring capital and products within the right timeframe
- Difficulty in scaling up the programme to keep up with the broadening of its scope as necessitated by the UK Quantum Strategy
- Potential lack of resources and interest in quantum standards from other key countries inhibiting progress of standard making process

Inputs

Table 8: ToC inputs

Box	Explanation
£36m funding via NQTP	Funding secured for delivery of the NPLQT via overall funding for NQTP.
Provision of facilities	This includes infrastructure and apparatus required to produce research and innovation outputs
Identification of skilled workers for programme activities	Skilled workers are required to ensure outputs are of the necessary level to advance quantum technologies.
Recruitment plan to support onboarding	Timely recruitment is required to ensure activities can commence on time and to the required scope.
NPL delivery team time and resource	Incorporates coordination and delivery of the NPLQT.
Industry and government engagement in programme activities	Incorporates all engagement and outreach activities, along with provision of T&E support for industry.
Delivery partner time and resource	Incorporates support required from partners to deliver the NPLQT.
International partner engagement	Incorporates support / engagement from international partner institutes involved in key elements of the programme (e.g. metrology institutes).

Activities

Table 9: ToC activities

Box	Explanation
In-house R&D and testing	A key element of the programme, this incorporates testing required for advancement of quantum technologies.
Collaborations with national (and international) research institutions	All aspects of delivery focused on partnership building with other research institutions.
Schemes and test & evaluation (T&E) facilities developed by NPL, based on the stated needs of the quantum industry and government	All activities related to advancement and strengthening of the UK's T&E facilities / capabilities, designed to ensure relevance to industry and government requirements.
Provision of T&E support to UK organisations (e.g. delivery of M4Q programme)	Complementary to the activity above, this incorporates support provided to UK organisations to strengthen T&E capabilities.
Engagement in UK Network of QT Hubs summer school	Networking and development event for those participating in the programme.
Industry engagement events	This includes industry engagement work completed, such as the quantum showcase, industry workshops and consultation with start-ups.
In-house technical expertise building	Upskilling support provided through the programme.
Engagement with metrology institutes (both domestic and international)	A key element of delivery to ensure development of fitting standards, this incorporates all engagement and communication with metrology institutes in the standards ecosystem both domestically and abroad.
Engagement with government departments (both domestic and international)	A key element of delivery to ensure development of fitting standards, this incorporates all engagement and communication with government departments in the standards ecosystem both domestically and abroad.
Provision of support to PhD students	Financial and educational support in the form of studentships and summer schools (among others) for PhD students.
Training courses and application-based workplace opportunities.	Upskilling opportunities for participants, focused on developing in-work / practical skills required to advance quantum technologies.
Outreach events	Events aimed at raising public awareness and interest in quantum (e.g. school visits)

Outputs

Table 10: ToC outputs

Box	Explanation	Indicator
Development of new capability	This includes production of peer-reviewed publications, intellectual property (IP), and best-practice guides).	Number of peer-reviewed publications, IP and best-practice guides produced.
Supporting connections with and between important organisations and stakeholders in the quantum sector	Establishment of new partnership working opportunities and collaboration across the sector.	Number of partnerships formed within the quantum sector.

Box	Explanation	Indicator
Establishment of T&E roadmap	Development of a new roadmap to support understanding and advancement of T&E capabilities.	A new T&E roadmap is established.
Increased number of organisational users of NPL capabilities	The programme leads to increased adoption of NPL's technical capabilities within organisations (e.g. technical measurement and timing capabilities and expertise)	Number of organisational users of NPL technical capabilities.
Increased use of NPL facilities	Through supporting innovation, use of NPL facilities required for IP / research development increases.	Number of projects using NPL facilities.
Utilisation of T&E resources by UK quantum stakeholders (e.g. government and industry)	The quantum community uses T&E support to overcome barriers faced to-date.	Number of industry stakeholders using NPLQT T&E resources.
UK companies supported by T&E services	Adoption of T&E services by UK companies	Number of Uk companies using NPLQT T&E resources.
Confidence in quantum technologies is increased	Through supporting T&E work, confidence in quantum is increased in key sectors (e.g. amongst the finance community)	Level of confidence in quantum products and technologies.
Development of best practice guides for standards	Best practice guides are developed through the 'standards' element of the programme to support standards creation.	Number of best practice guides for standards produced.
Development of a community focused on establishing common standards and practices for quantum technologies	Increased engagement and collaboration within the standards ecosystem to contribute towards development of new standard for quantum technologies.	Number of partnerships formed within the standards ecosystem via the NPLQT.
Increased connectivity with international standards organisations (e.g. NIST, BSI, ISOIEC)	Through increased engagement in the standards ecosystem and engagement with key international stakeholders, partnerships and connections are formed.	Number of partnerships formed with members of the international standards ecosystem.
Development of skills and experience for PhD students	PhD students supported through the programme are able to develop new skills and experiences	Number of PhD students supported through the NPLQT. Positive feedback provided from supported students.
Awareness raised among relevant groups and institutions	Outreach and public engagement activities leads to awareness of quantum technologies increasing.	Level of engagement via public outreach campaigns (e.g. attendance at engagement events).
Level of quantum literacy is improved across society	Outreach and public engagement activities leads to understanding of quantum technologies increasing.	Increased understanding of quantum concepts and ideas.
More professionals are attracted to the quantum sector	Engagement activities leads to increased attraction of skilled workers from other industries.	Number of new entrants to the UK quantum sector.

Outcomes

Table 11: ToC outcomes

Outcomes have been categorised under four key categories of interest for NPL. These are: research and development outcomes, innovation outcomes, standards outcomes, and skills and training outcomes. Categorising the outcomes in this way helps highlight the causal chains in the ToC.

Outcome area	Box	Explanation
Research and development	Reproducibility of research outputs is improved	The application of tried and tested evaluation methods will improve the reproducibility of research outputs. This increase in research efficiency and effectiveness will promote adoption of the best technologies.
	Increased readiness of quantum technologies	Development of innovative outputs will contribute to increased adoption of quantum technologies.
Innovation	T&E roadmap and services align with industry needs	By working with UK companies and industry stakeholders to develop the roadmap, it will accurately reflect needs and concerns of the ecosystem.
	Increased adoption of quantum science and technologies	By working with industry and increasing confidence across key sectors, adoption is increased.
	Industry-related innovation and facilitation of knowledge transfer	By increasing collaboration and engagement with industry, scope for innovation and knowledge exchange increases through improved partnership working.
	Demand for commercialisation of quantum concepts is increased	Support provided via the programme increases confidence across industry and raises demand for the commercialisation of innovative quantum concepts
	Supported organisations experience financial improvements	Access to improved T&E services e.g. via the M4Q programme leads to improved financial performance for contributing organisations.
Standards	Best practice for advocations and science established	New best practice guides for standards development are created to support processes and make the development of new standards more straightforward.
	Involvement of UK in standards development globally is increased	Awareness of standards development is raised amongst industry and academia in the UK, leading to increased involvement of the UK in standards development globally.
	More rigorous testing of quantum products	Introduction of new standards / increased engagement in developing current standards, will result in more uniform and consistent testing of quantum products.
Skills and training	A more skilled and knowledgeable research and management workforce is established	Workforce upskilling takes place through support provided to PhD students and the growth in the number of opportunities open to students.
	End-user base is broadened to those with non-STEM backgrounds	Enhanced interest in quantum technologies leads to broadening of end-user base, via successful delivery of outreach and engagement campaigns.

Outcome area	Box	Explanation
	The UK quantum sector becomes more accessible	Increased opportunities provided to students and non-quantum workers leads to a widening of the talent pool and ability to access the required information and resources.
	Awareness of quantum in the UK is increased	By delivering outreach and engagement activities, understanding and interest in quantum is expanded.

Impacts

The same four categories for outcomes have been applied to impacts.

Table 12: ToC impacts

Impact area	Box	Explanation
Research and development	UK produces cutting- edge research and innovation	Support for new research and concepts strengthens the domestic supply of research and innovative concept development in the UK.
	UK maintains its position as one of the global leaders in the global quantum ecosystem	If achieved, research and development outcomes would put the UK in a position to maintain its place as a top 3 global hub for quantum.
Innovation	Organisations are more able to harness quantum innovation	Increased adoption of – and confidence in – quantum products and technologies leads to better utilisation and delivery of innovative products / concepts.
	Establishment of a domestic supply chain	Through increased commercialisation and investment in quantum technologies, a domestic supply chain can be established.
	Government becomes a first adopter of quantum devices	Increased confidence in quantum technologies, aligned product/concept development and increased innovation leads to government demand for quantum increasing.
	Private investment in quantum technologies increases	Increased demand for commercialisation leading to increased inward investment in quantum technologies companies.
	Production of high-quality quantum products	Improved domestic supply chain and growth in investment leads to product development becoming more advanced and larger-scale.
	Improved UK economy at a global and regional level	Developments within the UK quantum sector (e.g. growth, investment and innovation) contribute more broadly to the UK economy and that of specific regions home to quantum hotspots / hubs.
Standards	Creation of new standards	Standards-supporting activities delivered through the programme leads to the creation of new standards within the quantum technologies (and quantum relevant) sectors.
	Global quantum playing field is levelled	Widespread adoption of standards and increased international collaboration ensures a more level approach to development of quantum science and technologies and removes barriers for involvement in standards development.

Impact area	Box	Explanation
	Regulation of quantum products is increased	Through more rigorous testing and better standardisation measures, regulation of quantum products is improved.
	Increased sales and exports of quantum technologies	Increased standardisation of UK products leads to greater interest of adoption for international stakeholders.
Skills and training	The UK has world leading quantum technologies skills	By upskilling the UK's quantum workforce, its position as a global leader in quantum is strengthened and advanced.
	Labour demands for quantum-skilled individuals is met	The demand of labour with the right set of skills will be fulfilled by polishing the existing (and upcoming) talent and by attracting new talent from abroad and supporting domestic quantum researchers and workers.
	UK companies are more able to operate at upmost capacity	Increased recruitment of highly-skilled workers and satisfaction of labour demands enables UK companies to operate without facing resourcing and knowledge constraints.
	Increased societal acceptance of quantum	Raised quantum awareness and literacy leads to improved understanding of the use of quantum, resulting in increased acceptance of quantum concepts and products.

A.3. Quantum Technology Organisations Follow-up Survey

The follow-up survey will be used to track changes in user profiles, customer feedback, and delivered outcomes building on from the baseline survey. Questions have been replicated, with additional questions focusing on progress, and unmet needs (e.g. additional support required for commercialisation). The survey will provide the opportunity to capture progress / changes in response overall from comparable companies, whilst also providing potential to capture feedback from companies that did not respond originally.

Introduction

Thank you for your interest in participating in this survey. This research is being conducted by RSM UK Ltd, an independent consultancy, on behalf of the National Physical Laboratory (NPL). The purpose of this research is to understand your views of services NPL – or the support provider relevant to you – provided specifically related to quantum. This is a follow-up survey to the baseline survey distributed by Ipsos Mori in 2023, which was used to identify key learnings and recommendations for NPL moving forward (e.g. the importance of NPL's facilities and the need to address barriers faced by respondents in accessing funding and developing proofs of concept). This follow-up survey will be used to track progress to-date against these key findings (e.g. whether respondents are now more able to access funding) and any changes in perspectives following the initial survey. This will contribute towards development of an overall evaluation of the NPLQP, generating recommendations that will shape future delivery of quantum technologies support. Even if you did not respond to the original baseline survey issued in 2023, your response at this stage would be hugely appreciated.

Topics to be covered include:

- Commercialisation (this refers to the process of introducing a new product to market. As such, we define this to include products at TRL levels 8 and 9)
- Product/service (this refers to the focus of your research / development (e.g. the product, platform, or technical service you intend to bring to market – if relevant)
- Facilities (this refers to the physical resources accessed through NPL – or other support mechanisms – to enable your research – e.g. laboratories)

This survey will take approximately 10-20 minutes to complete.

Any information you share will be treated in the strictest confidence and results will only be reported on an aggregated and anonymous basis.

Your opinion is important to us, and this survey is not intended to change your opinion, or to promote or sell you anything. You have the right to withdraw from the survey at any time. For more information about your rights please see our privacy note, which you can access here.

Can you please confirm that you understand and accept these points and are happy to proceed with the market research survey on this basis?

a) Yes

b) No

If no – end survey

About the respondent

Thank you for agreeing to participate in the survey. Before we begin, we are going to ask you some questions about where you work and the area of quantum that you work in. We would like to remind you again that all your answers are strictly confidential and will not be identifiable, these are purely asked for analytical purposes.

1. Which of the following categories, if any, most accurately describes your area of work? Please select one. [one selection allowed] [Ask all]

a) Academia

b) Public Sector Research Establishment (PSRE)

c) Research and Technology Organisation (RTO)

d) Private Sector Business

e) Other, please specify

f) Don't know

2. Which department at your university do you fall under? [one selection allowed] [Ask if A to Q1]

a) Engineering

b) Electronics

c) Physics

d) Chemistry

e) Biology

f) Biochemistry

g) Mathematics

h) Geology

i) Medicine

j) Other, please specific

k) None of the above

l) Don't know

3. Which of the following funding councils are you associated with? Please select all that apply. [multiple selections allowed] [Ask if B or C to Q1]

a) Biotechnology and Biological Sciences Research Council
b) Engineering and Physical Sciences Research Council
c) Innovate UK
d) Medical Research Council
e) Natural Environment Research Council
f) Science and Technology Facilities Council
g) Other, please specify

h) None of the above
i) Don’t know

4. If you are a private sector business, are you a spinout from a university/other academic institution? [one selection allowed] [Ask if D to Q1]

a) Yes
b) No
c) Don’t know

5. Which of the following, if any, best describes the segment of the quantum ecosystem you belong to? If multiple options apply, please select the area you spend most of your time on. [one selection allowed] [Ask if D to Q1]

a) Technology provider (“deep tech” / “quantum born” organisations, which have most likely spun out from quantum research)
b) Supply chain (suppliers of components, lasers, control systems, etc. to the technology providers)
c) End User (organisations applying products and services from quantum to their businesses – e.g. using quantum computing to advance drug discovery and healthcare)
d) Supporting services (organisations at the periphery of the quantum ecosystem - e.g. investors, patent attorneys, networking groups)
e) Other, please specify
f) Don’t know

6. Where is your organisation based? [one selection allowed] [Ask all]

a) North East England
b) North West England
c) Yorkshire and the Humber
d) East Midlands
e) West Midlands
f) East of England
g) London
h) South East England
i) South West England
j) Wales
k) Northern Ireland
l) Scotland
m) Don't know

Your work in the quantum sector and support received

Thank you for your answers so far. We will now ask you some questions about your work and how NPL / other relevant organisations have provided support.

7. Now thinking about quantum specifically, which of the following best describes the area of quantum that you work in? If you work across multiple areas, please select the area you spend most of your time on. [one selection allowed] [Ask all]

a) Quantum Positioning/Navigation/Timing
b) Quantum Communication
c) Quantum Computing
d) Quantum Sensing/Imaging
e) Quantum Metrology
f) Quantum Materials
g) Other, please specify
h) Don't know

8. Have you worked with NPL on your current area of quantum? [one selection allowed] [Ask all]

a) Yes
b) No
c) Don't know

9. Which of the following scientific/engineering area best describes your interaction with NPL? [one selection allowed] [Ask if A to Q9]

a) Atmospheric Environmental Science
b) Chemical & Biological Sciences
c) Data Science
d) Electromagnetic & Electrochemical Technologies
e) Materials & Mechanical Metrology
f) Medical, Marine & Nuclear
g) Quantum Electrical Metrology
h) Quantum Information Processing
i) Quantum Materials and Sensors
j) Quantum Computing
k) Thermal & Radiometric Metrology
l) Optical Frequency Metrology
m) National Time Scale
n) Atomic Clocks & Sensors
o) Other, please specify
p) Don't know

10. Which of the following category best describes your interaction with NPL? [one selection allowed] [Ask if A to Q8]

a) We interacted with NPL in 1-2 years out of 6 years.
b) We interacted with NPL in 3-4 years out of 6 years.
c) We interacted with NPL in 5-6 years out of 6 years.
d) Don't know

11. How – if at all – has the type of support provided by NPL evolved from when you first received support? [Ask if A to Q8]

12. In the area of quantum that you primarily work in, which of the following stages would you place yourself in? [one selection allowed] [Ask if A in Q5]

a) Basic Research
b) Application-oriented basic research
c) Applied Development
d) Technical prototyping
e) Demonstration
f) Commercial prototyping
g) Manufacturing / sales
h) Other, please specify
i) Don't know

13. To what extent, if at all, did NPL help you reach this stage? [one selection allowed] [Ask if A to Q8]

a) A great deal
b) A fair amount
c) Not very much
d) Not at all
e) Don't know

14. If applicable, what more could NPL have done to increase contribution to your progress? [Ask if C,D to Q13]

15. When do you envisage being at the commercialisation stage (TRL levels 8: actual technology completed and qualified through test and demonstration or TRL 9: actual technology qualified through successful mission operations) for your product/service? [one selection allowed] [Ask if A,B,C,D,E to Q12]

a) In the next year
b) 2-5 years' time
c) More than 5 years' time
d) Don't know

16. **Which of the following provisions by NPL, if any at all, are likely to help make commercialisation possible? Please select all that apply. [multiple selections allowed] [Ask if F,G to Q12 and A to Q8]**

   a) Strategy and direction to new ideas
   b) Reduced risk in the process for commercialisation of new products/services
   c) Working with NPL accelerated progression of our products/services through the different TRL levels
   d) Our project might not have gone ahead without support from NPL
   e) Working with NPL resulted in increased sales in new or existing markets
   f) Working with NPL enabled us to see reduced costs through decreased production or material costs
   g) Access to NPL's facilities
   h) Benchmarking, metrics and standards
   i) Engagement with NPL provided a mark of credibility
   j) Helped to reach new collaborators
   k) Enabled support for further investment either internally or externally
   l) None of the above [ANCHOR]
   m) Don't know [ANCHOR]

17. **Do you seek support from any other organisations, apart from NPL? [one selection allowed] [Ask all]**
   a) Yes
   b) No
   c) Don't know

18. **You mentioned that you seek support from organisations other than NPL. What sort of support and why? [Ask if A to Q17]**

19. **Which of the following category best describes your interaction with the other organisation(s)? [one selection allowed] [Ask if A to Q17]**
   a) We interacted with the other support provider in 1-2 years out of 6 years.
   b) We interacted with the other support provider in 3-4 years out of 6 years.
   c) We interacted with the other support provider in 5-6 years out of 6 years.
   d) Don't know

20. **Have you exported a quantum product? [one selection allowed] [Ask if G to Q12]**

   a) Yes
   b) No
   c) Don't know

21. Have you increased your quantum export value since 2020? Quantum export value refers to the total economic value generated from the international sales, commercialisation, and licensing of quantum technologies, products, and services. This includes revenue from hardware, software, quantum-enabled services, and intellectual property related to quantum innovation [one selection allowed] [Ask if A to Q20]

a) Yes
b) No
c) Don't know

22. If possible, please provide an estimate of the increase in your quantum export value since 2020. [numeric textbox] [Ask if A to Q20]

23. To what extent do you agree or disagree, if at all, that this increase is at least in part due to support provided by NPL? [one selection allowed] [Ask if A to Q20 and A to Q8]

a) Strongly agree
b) Somewhat agree
c) Neither agree nor disagree
d) Somewhat disagree
e) Strongly disagree
f) Don't know

24. To what extent do you agree or disagree, if at all, that the facilities, e.g. infrastructure, apparatus provided at NPL helped you progress to the next stage of your development process? [one selection allowed] [Ask if A to Q8]

a) Strongly agree
b) Somewhat agree
c) Neither agree nor disagree
d) Somewhat disagree
e) Strongly disagree
f) Don't know

25. Please provide specific examples of facilities that helped you progress. [Ask if A,B to Q24]

26. We will now show you a series of statements. To what extent do you agree or disagree, if at all, with each of them regarding the support you received on your work in quantum? [one selection allowed per statement] [Ask all]

Statement	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	Don't know
The support helped with decision making						
The support helped avoid wastage of resources						
The support helped realise the feasibility of the project						
The support helped speed up the process for reaching key milestones						

27. To what extent, if at all, did NPL play a role in helping your organisation reach more collaboration partners? [one selection allowed] [Ask if A to Q8]

a) A great deal
b) A fair amount
c) Not very much
d) Not at all
e) Don't know

28. In the current area of quantum that you work in, do you own any of the following intellectual property rights? [multiple selections allowed] [Ask all]

a) Trademark
b) Patent
c) Copyright
d) Trade secret
e) Other, please specify
f) None
g) Don't know

29. To what extent, if at all, did NPL help you obtain any of these intellectual property rights? [one selection allowed] [Ask if A to Q8 and A,B,C,D to Q28]

a) A great deal
b) A fair amount
c) Not very much
d) Not at all
e) Don't know

30. To what extent, if at all, did NPL's support help with bringing in more resources to the area of quantum you work in? [one selection allowed] [Ask if A to Q8]

a) A great deal
b) A fair amount
c) Not very much
d) Not at all
e) Don't know

31. On a scale of 0 to 10 where 0 is not at all satisfied and 10 is completely satisfied, how satisfied or dissatisfied, if at all, are you with the products/services provided by NPL, specifically for quantum? [one selection allowed per statement] [Ask if A to Q9]

Area of support provided	0	1	2	3	4	5	6	7	8	9	10	Don't know
Price												
Quality												
Timeliness of delivery												

32. Thinking now about your quantum programme, what is the gap, if any at all, your project is facing between the support you receive and reaching commercialisation? [Ask all]

a) [ ] – open text box
b) Prefer not to say

33. Thinking now about the support you receive from NPL, what areas, if any at all, would you say they can improve on? [Ask if A to Q8]

a) [ ] – open text box
b) Prefer not to say

Skills development

Thank you for your answer so far. We will now ask you some questions about the development of technical skills.

34. How many people are currently employed at your organisation? [Ask if D to Q1]

a) 1-9
b) 10-49
c) 50-249
d) More than 250
e) Don't know

35. What is the name of the department in the organisation you currently work in?

36. How many employees currently work in your department? [Ask all]

a) 1-9
b) 10-49
c) More than 50
d) Prefer not to say
e) Don't know

37. Within your department, how many employees did you have in each division in the year 2024? [One selection allowed per category] [Ask all]

Category	1-9	10-49	More than 50	None	Prefer not to say	Don't know
Research						
Technical/application division						

38. For each department, would you say that the staff has increased, decreased, or stayed the same since 2020? [One selection allowed per category] [Ask all]

Category	Increased a lot	Increased a little	Stayed about the same	Decreased a little	Decreased a lot	Don't know
Research						
Technical/application division						

39. To what extent, if at all, do you think that the current number of employees in your organisation / department would be different if you had not been supported by NPL? [One selection allowed] [Ask if A to Q8]

a) Decreased a lot
b) Decreased a little
c) Stayed about the same
d) Increased a little
e) Increased a lot
f) Don't know

40. Please provide a brief explanation for your answer. [Ask if A,B,C,D,E to Q38]

41. To what extent, do you think the increase in staff has replaced or displaced existing jobs within your company or other companies? [One selection allowed] [Ask those who answered increased a lot or increased a little in Q37]

a) Yes, with significant displacement
b) Yes, with minimal displacement
c) No, mostly new jobs were created
d) No impact on jobs

42. Of those total jobs created by NPL, what percentage would you estimate has gone to individuals, businesses or organisations outside of the Quantum sector? [numeric textbox]

43. **To what extent would you agree or disagree, if at all, that it is easy to recruit people with the right skills in your area? [One selection allowed] [Ask all]**

a) Strongly agree
b) Somewhat agree
c) Neither agree nor disagree
d) Somewhat disagree
e) Strongly disagree
f) Don't know

44. **Please provide examples of skills you are particularly interested in potential recruits possessing. [Ask all]**

45. **To what extent do you agree or disagree, if at all, that NPL has a role to play in developing these skills? [One selection allowed] [Ask if A to Q8]**

a) Strongly agree
b) Somewhat agree
c) Neither agree nor disagree
d) Somewhat disagree
e) Strongly disagree
f) Don't know

Funding and R&D budget

The final questions of this survey will ask you about your funding (if applicable) and R&D budget. We would like to remind you that your answers are completely confidential and are purely for analytical purposes. If you do not want to share that information, there is a prefer not to say option.

*When thinking about your R&D spend, please think about your **UK based spend** only.*

46. **Have you received any Innovate UK funding for your specific work on quantum? [one selection allowed] [Ask if D to Q1]**

a) Yes
b) No
c) Don't know

47. To the best of your knowledge, what was your R&D budget for the year 2024? [one selection allowed] [Ask all]

a) [ ] – open text box

b) Prefer not to say

48. And now thinking about quantum, to the best of your knowledge, how much of your R&D spend in 2024 was on quantum? If you are unsure of the exact amount, give a rough number. [one selection allowed] [Ask all]

a) [ ] – open text box

b) Prefer not to say

49. Would you say that your R&D spend on quantum has increased, decreased, or stayed about the same since 2020? [one selection allowed] [Ask all]

a) Increased a lot

b) Increased a little

c) Stayed about the same

d) Decreased a little

e) Decreased a lot

f) Don't know

50. To what extent, if at all, do you feel that your R&D budget would be different if you hadn't received support from NPL [one selection allowed] [Ask if A to Q8]

a) Decreased a lot

b) Decreased a little

c) Stayed about the same

d) Increased a little

e) Increased a lot

f) Don't know

Closing statement

That is the end to the survey. Thank you for all yours answers today. Please get in touch if you have any questions.

A.4. Topic guides

A.4.1. Wider stakeholder focus group guide

Introduction and consent (3 mins)

Introduction: Thank you for taking the time to participate in this session today. RSM UK have been appointed by National Physical Laboratory (NPL) to conduct an evaluation of the NPLQP.

NPL delivers the NPLQP as part of the UK's National Quantum Technologies Programme (NQTP), to meet the objectives of driving significant economic growth, enhance national security and resilience through the development and application of quantum technologies through using the capabilities of NPL. Some examples of the NPL's quantum programme include its contributions to global timekeeping, and the Measurement for Quantum (M4Q) programme, which provides businesses with specialist quantum measurement expertise to help solve their measurement challenges. The programme is designed to assist companies in moving from a prototype to a new product or service that is ready for market. Other examples include co-funding and training of PhD students and staff within companies to contribute to a larger more skilled workforce, contribution towards developing new standards and regulations for quantum technologies and supporting collaborations across the sector between universities, research institutions and companies to address commercialisation struggles.

As an appointed external evaluator, our role is to research the process, impacts and VfM of the Programme.

Focus group purpose: This session will contribute to the evaluation. In particular, understanding the programme's role in fostering collaboration between academia, industry, and government, its role in market growth, and the potential for increasing demand for services in the quantum sector. You may have previously taken part in providing feedback to NPL directly or supported other evaluations for the National QT Programme (NQTP). The purpose of this evaluation however is to provide an independent assessment for government of the value of the NPL programme and the extent to which this is distinct to other government funded NQTP initiatives/programmes.

Consent and confidentiality: Your participation is entirely voluntary. You can leave the session at any time if you wish. We have scheduled this for 2 hours given the number of participants. Please do respect the views of others and keep anything discussed in these sessions as confidential.

With your permission, we would like to record the session. This helps ensure we do not miss any details and the recording will only be used for this evaluation. It will be securely deleted after the project ends.

Your information will be kept confidential and anonymous in our report to NPL. We may use anonymised quotes to illustrate key findings, however there will be nothing that could directly identify you or your organisation. All information will be stored securely on password-protected computers in line with data protection regulations and RSM's data handling protocols, after which it will be securely destroyed.

Before we start recording, we would like to confirm:

- Do you understand the purpose of this session?
- Are you comfortable with our approach to confidentiality and data handling?
- Do you agree to have our conversation recorded for accuracy?
- Do you have any questions or need any further clarification before we begin?

Section 1: Introductions and warm up (10 mins)

1. **Go around the table. Please briefly introduce yourself: name, organisation and role within the organisation/quantum sector:**
   - *What interaction have you/your organisation had with the NPLQP and or level of awareness of its activities?*
   - *Would you describe your organisation as an end user, a member of the supply chain, technology provider, or supporting service within the quantum ecosystem? (definitions below for reference):*
     - ***End user:** those who will apply products and services from quantum to their business*
     - ***Supply chain:** suppliers of components, lasers, control systems, etc. to technology providers*
     - ***Technology providers:** 'quantum born' companies (often spinouts) that sit in the middle of the quantum ecosystem.*
     - ***Supporting services:** organisations at periphery of the quantum ecosystem (e.g. patent attorneys, investors, networking groups)*

Section 2: Rationale and engagement with quantum ecosystem (30 minutes)

2. **What role has the NPLQP played in contributing towards the National Quantum Technologies Programme aims?** Note: have a slide prepped with the NQTP aims summarised to prompt if needed.
   - *What key aims of the NQTP has the NPL programme addressed?*
   - *How has it built on/progressed/complimented other quantum supports (e.g. support programmes provided within the quantum ecosystem. This includes EPSRC quantum research hubs, and the QTAP programme)? Note: skip if covered in detail in question 2.*
   - *Has it duplicated or created competition for other quantum supports?*

3. **In addition to contributions to the NQTP aims, what role has the NPLQP played in addressing challenges facing organisations operating within the UK quantum ecosystem?**
   - *What specific challenges has the programme helped to address?*
   - *If relevant, what are the key challenges not currently being addressed through the programme?*
   - *What more could be done through the programme to address these key challenges?*

Section 3: Demand for engagement with NPL (25 minutes)

4. **What is the current level of demand for support from NPL within the UK quantum ecosystem and by whom?**
   - *Probe in relation to the 4 areas (Skills and Training, standards development, research and development activities and accelerating innovation through T&E support).*
   - *Are some elements of NPL support more in demand than others and why?*
   - *Does demand for NPL support vary depending on organisation size and category within the quantum ecosystem (refer to first question on categorisation)*
   - *Are there any market conditions/considerations that affect this demand and/or the ability to capitalise on this?*
   - *Who should be paying for the work carried out by NPL and has this changed over time (appetite/ability to pay)?*

5. **Are there other areas of support, that NPL does not offer, that there is demand for in the quantum market?**
   - *These are areas that are not currently being served (at all, poorly or with low capacity) by other quantum support mechanisms (e.g. via EPSRC or through Innovate UK-funded programmes such as QTAP)*

6. **Looking to the future, what do you anticipate being the key areas of need / demand for NPL support moving forward?**
   - Note: *These are areas that are not necessarily currently demanded within the quantum ecosystem, but may become more necessary in the near to medium-term.*
   - *Probe depending on answers to previous demand questions: this could include complex supply chain vulnerabilities, lowering cost / technical barriers to support widespread adoption, and supporting ethical widespread adoption.*

Section 4: Programme outcomes and impacts (35 minutes)

7. **In your view, to what extent have you witnessed improvements in R&D and innovation within the QT ecosystem in recent years, and how do you feel the NPLQP has contributed to this?**
   - *Please can you provide some key examples of why/how?*
   - *What more could the Programme have done to ensure this outcome was achieved?*
   - *Probe on the extent of the role (scale/unique contribution) the NPLQP played in this vs.* other programmes/initiatives.

8. **In your view, to what extent has the work of NPL contributed to the growth of the UK quantum sector?**
   - *Probe on the extent of the role (scale/unique contribution) the NPLQP played in this vs. other programmes/initiatives.*

9. **In your view, to what extent has the work of NPL impacted the availability of skills and training provision within the UK QT ecosystem?**
   - *How has this programme specifically enhanced or added to other provisions in this area?*
   - *Were there opportunities to better link up these provisions, e.g. outreach events etc*
   - *Has any of the work been duplicative?*
   - *What more could NPL have done/do to support skills and training in the QT sector?*
   - *If not covered already: Probe on the extent of the role (scale/unique contribution) the NPLQP played in this vs. other programmes/initiatives.*

10. **In your view, has the work of NPL accelerated the routes to commercialisation of quantum technologies?**

Note for facilitator: this can include e.g. support for testing and evaluation of products to bring new products to market, support to demonstrate technology and its value to customers, end users and investors etc.

   - ***IF YES*** *– please can you provide some key examples of why?*
   - ***IF NO* –** *what more could the Programme have done to ensure this outcome was achieved?*
   - *Probe on the extent of the role (scale/unique contribution) the NPLQP played in this vs. other programmes/initiatives.*
   - ***If unable to comment on the role of NPL*** *– what more could be done within the QT ecosystem to better support commercialisation?*

11. **In your view, has the work of NPL contributed to the development of new quantum standards and processes?**

12. **[If yes to Question 10] What impact have these new standards had on the UK quantum ecosystem?**
    - *Probe on perceived involvement of industry in the process (and role of the programme in this) and extent to which this has emerged/helped.*
    - *What more could NPL/ the Programme have done to support processes for new standards in Quantum?*
    - *Role of NPL in contributing to these processes and new standards compared to other QT programmes/organisations supporting this work.*
    - *Probe on perceived impact of the programme on the UK's international presence and influence on standards setting.*

Section 5: Wider and unexpected outcomes and impacts (10 minutes)

13. **In your view, has work of NPL had wider indirect impacts on society and the economy?**
    - *For example, spillover effects in furthering technical advancements in QT and its adjacent sectors.*

Section 6: Key learnings and concluding remarks (10 minutes)

14. **Do you have any reflections on the work NPL currently does to support the UK quantum ecosystem (both the NPLQP and NPL's broader work)?**

15. **Thank you for your contributions today. Are there any final comments or thoughts you would like to share?**

A.4.2. Collaborator interview topic guide

Introduction and consent (3 mins)

Introduction: Thank you for taking the time to participate in this session today. RSM UK have been appointed by National Physical Laboratory (NPL) to conduct an evaluation of the NPLQP.

NPL delivers the NPLQP as part of the UK's National Quantum Technologies Programme (NQTP), to meet the objectives of driving significant economic growth, enhance national security and resilience through the development and application of quantum technologies through using the capabilities of NPL. Some examples of the NPL's quantum programme include its contributions to global timekeeping, and the Measurement for Quantum (M4Q) programme, which provides businesses with specialist quantum measurement expertise to help solve their measurement challenges. The programme is designed to assist companies in moving from a prototype to a new product or service that is ready for market. Other examples include co-funding and training of PhD students and staff within companies to contribute to a larger more skilled workforce, contribution towards developing new standards and regulations for quantum technologies and supporting collaborations across the sector between universities, research institutions and companies to address commercialisation struggles.

As an appointed external evaluator, our role is to research the process, impacts and value for money of the programme.

Interview purpose: The purpose of this interview is to discuss your role in delivery of the programme, aims and objectives of involvement, and realisation of any impacts to date. You may have previously taken part in providing feedback to NPL directly or supported other evaluations for the National QT Programme (NQTP). The purpose of this evaluation however is to provide an independent assessment for government of the value of the NPL programme and the extent to which this is distinct to other government funded NQTP initiatives/programmes.

Consent and confidentiality: Your participation is entirely voluntary. You can skip any questions you do not want to answer or leave the interview at any time. The interview should take around 60 minutes, and with your permission, we would like to record our conversation. This helps ensure we do not miss any details and the recording will only be used for this evaluation. It will be securely deleted after the project ends. Your information will be kept confidential and anonymous in our report to NPL. We may use anonymised quotes to illustrate key findings, however there will be nothing that could directly identify you or your organisation. All information will be stored securely on password-protected computers in line with data protection regulations and RSM's data handling protocols. The data will be kept for a minimum of six years and then securely destroyed.

Before we start recording, we would like to confirm:

- Do you understand the purpose of this evaluation and your role within it?
- Are you comfortable with our approach to confidentiality and data handling?
- Do you agree to have our conversation recorded for accuracy?
- Do you have any questions or need any further clarification before we begin?

Section 1: Background info (5 mins)

1. Please tell me about the nature of your collaboration with NPL [*interviewer to have this detail – it is a 'warm up' question*].
    - Was it a grant-funded project (e.g. via Innovate UK) or a short-term free consultancy project?
    - What was your / your organisation's specific role within the collaboration?
    - How did your role change (if at all) during delivery?

Section 2: Programme delivery (10 mins)

2. **Through your involvement with NPL in this collaboration, have you developed an understanding of what the NPLQP is and what it's aims are?**
    - *What does the programme mean to you?*
    - *Is it just a nominal concept or do you benefit from an entire programme contributing to QT?*
    - *Has it helped you access the wider network of the sector?*

3. **What were the aims and objectives of your organisation's involvement in the collaboration?**
    a. *What were your main reasons for collaborating with NPL on the R&D project(s) you were involved in?*
    b. *What did NPL offer that was unique to other organisations/funders?*

4. **To what extent have these aims and objectives been realised?**

5. **Did you encounter any challenges during the delivery of the collaborative project?**
    - ***IF YES*** **–** *what were the challenges and how were they addressed?*
    - *Lessons learned from the delivery*

6. **[Only if they are a grant-funded collaborator and if not already answered] What did your organisation provide as part of the collaboration?**

7. **Do you plan to continue collaboration with NPL?**
    - *What are the opportunities for continued collaboration?*
    - ***IF YES*** **–** *what plans are in place for this collaboration? Any perceived challenges?*
    - ***IF NO*** **–** *why not?*

Section 3: Programme outcomes and impacts (25 minutes)

8. **In your view, to what extent has your collaboration with NPL resulted in an improvement in your organisation's R&D / innovation capabilities?**
    - *What were the main outcomes of the programmes R&D activities? For example, applications in the spheres of health and life sciences, environment, and defence?*
    - ***IF YES*** *– please can you provide some key examples of why/how?*
    - ***IF NO*** **–** *what more could the Programme have done to ensure this outcome was achieved?*
    - *Probe on the extent of the role (scale/unique contribution) the NPLQP played in this vs. other programmes/initiatives.*
    - *[**Follow-up – MUST ASK if not covered**] Did your collaboration with NPL lead to the development of a new product or service?*
9. **In your view, to what extent has your involvement contributed to the growth of your organisation?**
    - *[if able to speak on broader trends] have you witnessed broader growth of the UK's quantum ecosystem as a result of NPL support?*

10. **[If not covered in response to Q9] In your view, to what extent has your involvement contributed to improved awareness or credibility of your organisation within the UK quantum ecosystem?**

11. **In your view, has the programme facilitated more private investment for supported companies or laid the foundations for this to occur?**

12. **In your view, to what extent has the Programme fostered collaboration between academia, industry, and government?**

Probes: are you aware of activities conducted to support collaborative relationships across groups e.g. NPL presence at industry engagement events/seeking involvement of industry inputs in forums for standards development, encouraging further collaboration in research and development by bringing together industry and academic institutions, building sustainable/continuing relationships outside of the R&D project, etc.

- ***IF YES*** *– please can you provide some key examples of how? What have been the benefits/outcomes of this?*
- ***IF NO*** *– what more could the Programme have done to ensure this outcome was achieved?*
- *Probe on the extent of the role (scale/unique contribution) the NPLQP played in this vs. other programmes/initiatives.*

Section 4: Wider and unexpected outcomes and impacts (10 minutes)

13. **In your view, to what extent has your collaboration with NPL resulted in additional skills/knowledge transfer for your organisation?**
    - *Did collaborating with NPL result in building additional capacities or capabilities within your own organisation?*
    - *For others involved in delivery of the R&D project, e.g. funded students (if applicable)?*
    - *For those receiving the services provided by NPL and your organisation as part of this programme? (if applicable)*

14. **Were there any additional spillover effects in furthering technical advancements in QT?**
    - *E.g. impact on adjacent sectors?*
    - ***IF YES*** **–** *could you please provide some examples of this?*

15. **Have you experienced any other unintended or unexpected outcomes through delivery of the R&D project?**
    - *Probe for both positive and negative unexpected outcomes*

Section 5: Counterfactual (5 minutes)

16. **Imagine a scenario where the NPLQP P had not occurred. From your perspective, in what way do you think things would be different with respect to the outcomes and impacts discussed?**
    - *Could these have been achieved in the absence of this programme through other means? E.g. would the R&D project have been funded by other means/organisations? If yes by whom?*
    - *Would these have occurred eventually but at a slower pace?*

Section 6: Key learnings and concluding remarks (5 minutes)

17. **In your opinion, what are the most important lessons learned from being involved in the Programme?**

18. **Thank you for your contributions today. Are there any final comments or thoughts you would like to share?**

A.4.3. NPL delivery and partnerships staff topic guide

Introduction and consent (3 mins)

Introduction: Thank you for taking the time to participate in this interview today. My name is [Name], a [role] at RSM UK Consulting LLP (RSM). RSM UK have been appointed by National Physical Laboratory (NPL) to conduct an evaluation of the NPLQP. As an appointed external evaluator, our role is to research the process, impacts and value for money of the programme.

Interview purpose: The purpose of this interview is to establish what has been delivered to date, how successful key delivery of support has been, performance against key metrics, and potential impact. You may have already participated in previous staff surveys to provide feedback for NPL directly. This information will also be used as part of the evaluation. The purpose of this interview is to provide an independent assessment for government of the value of the NPL programme and key learnings from delivery.

Consent and confidentiality: Your participation is entirely voluntary. You can skip any questions you do not want to answer or leave the interview at any time. The interview should take around 60 minutes, and with your permission, we would like to record our conversation. This helps ensure we do not miss any details and the recording will only be used for this evaluation. It will be securely deleted after the project ends.

Your information will be kept confidential and anonymous in our report to NPL. We may use anonymised quotes to illustrate key findings, however there will be nothing that could directly identify you. All information will be stored securely on password-protected computers in line with data protection regulations and RSM's data handling protocols, after which it will be securely destroyed.

Before we start recording, we would like to confirm:

- Do you understand the purpose of this evaluation and your role within it?
- Are you comfortable with our approach to confidentiality and data handling?
- Do you agree to have our conversation recorded for accuracy?
- Do you have any questions or need any further clarification before we begin?

Section 1: Background info (5 mins)

1. Please tell me about your role in relation to delivery of the NPLQP. [interviewer will have some brief detail from NPL as part of the sampling]
    - *How long have you been / were involved in delivery of the Programme?*
    - *How did your role change (if at all) during delivery?*
    - *What activities were you involved in delivering as part of the Programme?*

Section 2: Programme delivery (15 minutes)

2. **Were activities and outputs delivered as planned?** *Note for interviewer: select the appropriate areas to probe on depending on the extent of the interviewee's role across the 4 areas of delivery.*
    - *Were activities and outputs delivered as planned?*
    - *How successful has commercialisation / product development support been? E.g., the M4Q programme*
    - *How successful has upskilling resources been? E.g., the training modules and PhD funding*
    - *How successful has the standards development been? E.g., the collaboration with national and international standards institute*
    - *Were there any challenges with delivery and how were these addressed?*

3. **Reflections on the objectives of the NPLQP**
    - To what extent were the objectives of the NPLQP in relation to your role clear to you?
    - To what extent were the wider objectives of the NPLQP clear to you?
    - If objectives were unclear – how could these have been shared better?

4. **Reflection on delivery partners/collaborators:**
    - *How has working with partners/collaborators supported delivery against activities and outputs?*
    - *Have there been challenges working with partners/collaborators?*
    - *How have these challenges been addressed?*
    - *Key lessons learned from working with partners/collaborators.*

5. **How effective were the monitoring and evaluation mechanisms used to track progress?**
    - *What were the mechanisms?*
    - *What worked well?*
    - *What didn't work so well or could be improved on?*

6. **How could the programme activities have been delivered more efficiently?**
    - *Planning and team working.*
    - *Allocation of resources – monetary and human capital.*
    - *Other.*

Section 3: Wider ecosystem (10 minutes)

7. **How does NPL compare, regarding capabilities and impact on the market, with other equivalent institutions with comparable assets?**

8. **What capabilities and services are unique to NPL and what are the gaps they fulfil across industry?**
    - *How has this affected the ability to deliver the desired outcomes and impacts?*

    - **Has the Programme delivery been impacted due to alignment with other quantum organisations or delivery of broader NPL objectives.** *Has there been any synergies or dependencies, e.g. role/importance of the* Advanced Quantum Metrology Laboratory (AQML), other funding via UKRI/EPSRC for quantum technologies research and development, Innovate UK funding for quantum technologies, etc*?*
    - *Has there been any tensions or conflict?*

Section 4: Programme outcomes and impacts (15 minutes)

9. **In your view, to what extent has the Programme improved R&D and innovation in the QT sector?**
    - *What were the main outcomes of the programmes R&D activities? For example, applications in the spheres of health and life sciences, environment, and defence?*
    - ***IF YES*** *– please can you provide some key examples of why/how?*
    - ***IF NO*** **–** *what more could the Programme have done to ensure this outcome was achieved?*
    - *Probe on the extent of the role (scale/unique contribution) the NPLQP played in this vs. other programmes/initiatives.*

10. **In your view, to what extent has the Programme contributed to the growth of the UK quantum sector?**
    - ***If advanced****, have any outcomes resulted from this advancement?*
    - ***If duplicated****, what more could have been done to ensure this was avoided?*
    - *Probe on the extent of the role (scale/unique contribution) the NPLQP played in this vs. other programmes/initiatives.*

11. **In your view, what impact has the Programme had on skills and training available in the Quantum sector?**
    - *How has this programme enhanced or added to other provisions in this area?*
    - *Were there opportunities to better link up these provisions? E.g., Outreach events etc*
    - *Has any of the work been duplicative?*
    - *What more could the programme have done/do to support skills and training in the QT sector?*
    - *Probe on the extent of the role (scale/unique contribution) the NPLQP played in this vs. other programmes/initiatives*

12. **In your view, has the Programme accelerated the routes to commercialisation of quantum technologies?**
    - **IF YES –** *please can you provide some examples of this and has the new quantum products led to increased sales and exports?*
    - **IF NO –** *what more could have been done to ensure this outcome was achieved?*
    - *Probe on the extent of the role (scale/unique contribution) the NPLQP played in this vs. other programmes/initiatives*

13. **In your view, has the programme facilitated more private investment for supported companies or laid the foundations for this to occur?**

14. **In your view, to what extent has the Programme fostered collaboration between academia, industry, and government?**
    a. ***IF YES*** *– please can you provide some key examples of how? What have been the benefits/outcomes of this?*
    - ***IF NO*** **–** *what more could the Programme have done to ensure this outcome was achieved?*
    - *Probe on the extent of the role (scale/unique contribution) the NPLQP played in this vs. other programmes/initiatives*

Section 5: Wider and unexpected outcomes and impacts (10 minutes)

15. **In your view, has the Programme had wider indirect impacts on society and the economy?**
    - ***IF YES*** **–** *could you please provide some examples of this?*

16. **Have you experienced any unintended or unexpected outcomes through delivery of the Programme?**
    - *Probe for both positive and negative unexpected outcomes*

Section 6: Counterfactual (5 minutes)

17. **Imagine a scenario where Programme had not occurred. From your perspective, in what way do you think things would be different with respect to the outcomes and impacts discussed?**
    - *Could these have been achieved in the absence of this programme through other means?*
    - *Would these have occurred eventually but at a slower pace?*

18. **How much of the Programme's outcomes and impacts can be attributed to the NPLQP as opposed to other organisations / programmes?**
    - *E.g. NMS*
    - *Note: if not covered in sufficient detail in section 5: Probe on synergies and additionalities of what has been delivered*

Section 7: Key learnings and concluding remarks (5 minutes)

19. **In your opinion, what are the most important lessons learned from implementing the Programme?**

20. **Thank you for your contributions today. Are there any final comments or thoughts you would like to share?**

A.4.4. NPLQP customer topic guide

Introduction and consent (3 mins)

Introduction: Thank you for taking the time to participate in this session today. RSM UK have been appointed by National Physical Laboratory (NPL) to conduct an evaluation of the NPLQP.

NPL delivers the NPLQP as part of the UK's National Quantum Technologies Programme (NQTP), to meet the objectives of driving significant economic growth, enhance national security and resilience through the development and application of quantum technologies through using the capabilities of NPL. Some examples of the NPL's quantum programme include its contributions to global timekeeping, and the Measurement for Quantum (M4Q) programme, which provides businesses with specialist quantum measurement expertise to help solve their measurement challenges. The programme is designed to assist companies in moving from a prototype to a new product or service that is ready for market. Other examples include co-funding and training of PhD students and staff within companies to contribute to a larger more skilled workforce, contribution towards developing new standards and regulations for quantum technologies and supporting collaborations across the sector between universities, research institutions and companies to address commercialisation struggles.

As an appointed external evaluator, our role is to research the process, impacts and value for money of the programme.

Interview purpose: The purpose of this interview is to assess NPL's role in supporting your development, level of satisfaction with the services provides, and economic growth / performance following involvement. You may have previously taken part in providing feedback to NPL directly. The purpose of this evaluation however is to provide an independent assessment for government of the value of the NPL programme and the extent to which this is distinct to other government funded QT initiatives/programmes.

Consent and confidentiality: Your participation is entirely voluntary. You can skip any questions you do not want to answer or leave the interview at any time. The interview should take around 60 minutes, and with your permission, we would like to record our conversation. This helps ensure we do not miss any details and the recording will only be used for this evaluation. It will be securely deleted after the project ends.

Your information will be kept confidential and anonymous in our report to NPL. We may use anonymised quotes to illustrate key findings, however there will be nothing that could directly identify you or your organisation. All information will be stored securely on password-protected computers in line with data protection regulations and RSM's data handling protocols, after which it will be securely destroyed.

Before we start recording, we would like to confirm:

- Do you understand the purpose of this evaluation and your role within it?
- Are you comfortable with our approach to confidentiality and data handling?
- Do you agree to have our conversation recorded for accuracy?
- Do you have any questions or need any further clarification before we begin?

Section 1: Background info (5 mins)

1. Could you please tell me a little bit about yourself, your organisation, and role within that?
    - *Probe on type of organisation within the quantum ecosystem, e.g. technology provider, company that is part of the supply chain for quantum technologies, apply quantum services to your business, support services, other.*

2. Please tell me about the products and services you used from NPL
    - *How long have you been using the products and services provided by NPL?*
    - *Note: If the respondent is not aware of products/services used from NPL, this interview will need to be scheduled with someone in the company who is.*

3. Does your organisation face any skill gaps in quantum?

Section 2: Support received (15 minutes)

4. **Have you been satisfied with NPL's support?**
    - ***IF YES*** *– please can you provide some key examples of why?*
    - *What more could NPL have done to provide good quality support?*

5. **Have there been any barriers to using the products and services provided by NPL?**
    - ***IF YES*** *– please can you provide some key examples of why?*

6. **What part of NPL's support could have been delivered more efficiently or effectively?**
    - *Are there any gaps in the support you received that could be improved?*

7. **Do you plan to continue accessing services/collaborating with NPL?**
    - ***IF YES* –** *what plans are in place for this collaboration?*
    - ***IF NO* –** *why not?*
    - *Perceived challenges to future support/access to services? E.g. finance, information, communication, legal issues etc.*
    - *Other organisations you plan to engage instead and why?*

Section 3: Outcomes and impacts (15 minutes)

8. **What have been the key outcomes of the service provided to your organisation?** *Note for the interviewer: start broad and let them answer fully first, and then probe on the areas below as needed.*

9. **As a result of NPL support, has your organisations performance improved?**
    - ***IF YES*** *– please can you provide some key examples of how e.g., development / capacity building, financially, efficiency etc?*

10. **Have there been any knowledge spillovers to your organisation as a result of your involvement with NPL? Please provide example.**

11. **Have you been able to reach new collaborators as a result of working with NPL?**

12. **Has engagement with NPL helped you meet any standards used by your organisations?**
    - *Probe for details of what these are*

13. **Has using NPL services/collaborating with NPL helped your organisation progress development of new technology/products?**
    - ***IF YES*** *- please can you provide some examples e.g., applications in spheres like health and life sciences, environment, and defence*
    - *What was NPL's role in helping?*
    - *Did NPL support help accelerate this process?*

14. **Has working with NPL facilitated your ability to bring in more investment or financial support? Provide details.**

15. **Has working with NPL helped you commercialise any of your products/new technologies at this stage? Provide details.**

16. **Did NPL help fill any skill gaps that your organisation faces?**

17. **Due to the fast-moving nature of quantum technologies, did the knowledge and skills provided by NPL depreciate over time?**

Section 4: Wider and unexpected outcomes and impacts (5 minutes)

18. **Have you experienced any unintended or unexpected outcomes through your involvement with NPL?**
    - *Probe for both positive and negative unexpected outcomes*

Section 5: Counterfactual (5 minutes)

19. **Imagine a scenario where you had not engaged with the support provided by NPL. From your perspective, in what way do you think things would be different with respect to the outcomes and impacts discussed for your organisation?**

20. **What would you have done in the absence of this support?**

    - Probe on other routes they would have used/have used in the past

Section 6: Key learnings and concluding remarks (5 minutes)

21. **In your opinion, what are the most important lessons learned from being involved in the Programme?**

22. **Thank you for your contributions today. Are there any final comments or thoughts you would like to share?**

A.4.5. PhD student topic guide

Introduction and consent (3 mins)

Introduction: Thank you for taking the time to participate in this session today. RSM UK have been appointed by National Physical Laboratory (NPL) to conduct an evaluation of the NPLQP.

NPL delivers the NPLQP as part of the UK's National Quantum Technologies Programme (NQTP), to meet the objectives of driving significant economic growth, enhance national security and resilience through the development and application of quantum technologies through using the capabilities of NPL. Some examples of the NPL's quantum programme include its contributions to global timekeeping, and the Measurement for Quantum (M4Q) programme, which provides businesses with specialist quantum measurement expertise to help solve their measurement challenges. The programme is designed to assist companies in moving from a prototype to a new product or service that is ready for market. Other examples include co-funding and training of PhD students and staff within companies to contribute to a larger more skilled workforce, contribution towards developing new standards and regulations for quantum technologies and supporting collaborations across the sector between universities, research institutions and companies to address commercialisation struggles.

As an appointed external evaluator, our role is to research the process, impacts and value for money of the programme.

Interview purpose: The purpose of this interview is to assess NPL's role in supporting your career and skills development and level of satisfaction with the training provided. You may have previously taken part in providing feedback to NPL directly. The purpose of this evaluation however is to provide an independent assessment for government of the value of the NPL programme and the extent to which this is distinct to other government funded QT initiatives/programmes.

Consent and confidentiality: Your participation is entirely voluntary. You can skip any questions you do not want to answer or leave the interview at any time. The interview should take around 60 minutes, and with your permission, we would like to record our conversation. This helps ensure we do not miss any details and the recording will only be used for this evaluation. It will be securely deleted after the project ends.

Your information will be kept confidential and anonymous in our report to NPL. We may use anonymised quotes to illustrate key findings, however there will be nothing that could directly identify you. All information will be stored securely on password-protected computers in line with data protection regulations and RSM's data handling protocols, after which it will be securely destroyed.

Before we start recording, we would like to confirm:

- Do you understand the purpose of this evaluation and your role within it?
- Are you comfortable with our approach to confidentiality and data handling?
- Do you agree to have our conversation recorded for accuracy?
- Do you have any questions or need any further clarification before we begin?

Section 1: Background info (15 mins)

1. Could you please tell me a little bit about yourself and your studies, and what you are currently doing?
2. Please tell me about the PhD funded by NPL. [interviewer will have this detail – it is a 'warm up' question]
    - How long have you been receiving this support?

Section 2: Programme delivery (15 minutes)

3. **What did you hope to get out of the PhD funding provided via NPL?**
    - How did this differ to other sources or types of PhDs?
    - What was/is unique about the NPL funding/support?

4. **In your view, to what extent have you been satisfied with the support received by NPL?**
    - ***IF YES*** *– please can you provide some key examples of why?*
    - ***IF NO*** **–** *what more could NPL have done to ensure this was achieved?*

5. **Have there been any barriers to accessing the support provided by NPL?**
    - ***IF YES*** *– please can you provide some key examples of why?*

6. **What part of NPL's support could have been delivered more efficiently or effectively?**

7. **Do you plan to or have you continued working at NPL?**
    - ***IF YES*** **–** *what plans are in place for this collaboration?*
    - ***IF NO*** **–** *why not?*

Section 3: Programme outcomes and impacts (15 minutes)

8. **What have been the key outcomes of the support provided to you?** *Note for the interviewer: start broad and let them answer fully first, and then probe on the areas below as needed.*

9. **How has NPL's support contributed to your quantum skill development?**
    - ***IF YES*** *– please can you provide some key examples of how?*
    - ***IF NO*** **–** *what more could the Programme have done to ensure this outcome was achieved?*

10. **Has your involvement in the Programme provided you with practical experience you can apply to your future career?**
    - ***IF YES*** *– please can you provide some key examples of how?*
    - ***IF NO*** **–** *what more could the Programme have done to ensure this outcome was achieved?*
    - *Has your involvement in the Programme increased clarity or awareness of what your future plans are within the quantum ecosystem (e.g. area of focus, destination)?*

11. **In your view, do you think the Programme been successful in fostering collaboration between academia, industry, and government?**
    - ***IF YES*** *– please can you provide some key examples of why?*
    - ***IF NO*** **–** *what more could the Programme have done to ensure this outcome was achieved?*

12. **[**if collaboration has taken place**] In your view, to what extent do you feel this collaboration has led to wider impacts on the quantum ecosystem?**
    - *This could include increased capabilities, growth of organisations involved in the collaboration, formal partnership working, increased access to funding / resources*

13. **In your view, to what extent has the funding provided by NPL to support PhD students resulted in improved mobility and / or ability to access the quantum ecosystem in the UK?**
    - *Could more be done to broaden the researcher base within the UK quantum ecosystem?*

Section 4: Wider and unexpected outcomes and impacts (5 minutes)

14. **Have you experienced any unintended or unexpected outcomes through your involvement of the Programme?**
- *Probe for both positive and negative unexpected outcomes*

Section 5: Counterfactual (5 minutes)

15. **Imagine a scenario where you had not been involved in the Programme. From your perspective, in what way do you think things would be different with respect to the outcomes and impacts discussed?**

Section 6: Key learnings and concluding remarks (5 minutes)

16. **In your opinion, what are the most important lessons learned from being involved in the Programme?**

17. **Thank you for your contributions today. Are there any final comments or thoughts you would like to share?**

A.5. Programme performance (2020-2024)

A.5.1. Introduction

This appendix provides a detailed breakdown of performance against each core objective area within the Programme, assessing progress against individual KPIs to inform an overall performance analysis.

A.5.2. Objective 1: Facility provision

This objective aimed to deliver QT&E facilities to accelerate the commercialisation of new products based on quantum technologies. The Business Case targets for each KPI and the progress against each of these are outlined below:

Table 13: Progress against Facility Provision KPIs in the Business Case (dated July 2020)

KPIs	Progress at Programme end (March 2024)	Evidence
Operational facility hosted in NPL's AQML with all planned capital procured by the end of year 2 (March 2022)	**Achieved.** The AQML facility became fully operational in year 3 of the programme, with capital procurement taking place over years 1 and 2 of the Programme.	Annual reports (year 1 – 4)
Further (minimum three) operational facilities, located in most appropriate area for the capability concerned. Installed in partnership with local organisations but owned and operated by NPL to ensure independence.	**Partially achieved.** Annual reporting highlights that the 'operational facilities' aspect of the target has been met, with facilities such as the Quantum Timing Fibre Link Facility at the University of Birmingham; SuperFab Cryogenic Probe Station at Royal Holloway University; and Quantum Materials Characterisation (s-SNOM Facility) all being delivered. However, they are mostly partly owned and operated by NPL in partnership with the host institutions not fully operated and owned as targeted in the KPI.	Annual reports (year 1 – 4)
A plan for future funded use and maintenance in place for each facility to ensure its sustainability beyond the funding programme.	**Not achieved.** Across annual reporting, there is no explicit reference to formalised or documented plans for future funded use and maintenance of the regional facilities.	Annual reports (year 1 – 4)

A.5.3. Objective 2: Knowledge transfer

This objective aimed to develop and disseminate best practice in measurement and testing, which was expected to lead to the widespread and consistent use of QT&E facilities across the UK by suitably qualified people. The Business Case targets for each KPI and the progress against these are outlined below:

Table 14: Progress against Knowledge Transfer KPIs in the Business Case (dated July 2020)

KPIs	Progress at Programme end (March 2024)	Evidence
A research programme of testing development with a roadmap published in Year 1	**Achieved.** While annual reporting does not confirm that a formal roadmap was created or disseminated, feedback from NPL delivery stakeholders notes that this KPI evolved to focus on the production of a report focused on UK industry needs related to quantum which was successfully delivered.	Annual reports (year 1 – 4)
Published testing guidance throughout the four-year programme using a range of appropriate media.	**Achieved.** Several examples of testing guidance documents have been produced by NPL during the 2020-2024 programme window. This includes: *Lall, et al. A review and collection of metrics and benchmarks for quantum computers: definitions, methodologies and software. arXiv preprint arXiv:2502.06717. 2025 Feb 10* and *Tilly, et al. The variational quantum eigensolver: a review of methods and best practices. Physics Reports. 2022 Nov 5;986:1-28.*	Annual reports (year 1 – 4)

A.5.4. Objective 3: Standards development

This objective aimed to ensure that the UK maintained a visible and influential presence in international quantum forums, particularly in shaping emerging global standards, to reinforce its leadership in the field. The Business Case targets for each KPI and the progress against each of these are outlined below:

Table 15: Progress against Standards Development KPIs in the Business Case (dated July 2020)

KPIs	Progress at Programme end (March 2024)	Evidence
NPL will represent the UK in international standards groups and provide a regular report back to the NQTP of the world-wide quantum developments.	**Achieved.** NPL participated in numerous international standards bodies and working groups, including: ○ International Organisation for Standardisation (ISO) / International Electrotechnical Commission (IEC) Joint Technical Committee (JTC) 1/ Working Group (WG) 14 and the newly formed ISO/IEC JTC 3. ○ IEC/SEG 14 (Standardisation Evaluation Group on Quantum Technologies). ○ CEN/CENELEC JTC 22 (European Joint Technical Committee on Quantum Technologies). ○ European Telecommunications Standards Institute (ETSI) Industry Specification Group (ISG) on Quantum Key Distribution (QKD). ○ ITU-T SG13 (a statutory group of the ITU Telecommunication Standardization Sector concerned with future networks and emerging network technologies) and related groups. ○ Institute of Electrical and Electronics Engineers (IEEE) quantum-related working groups. Additionally, QTE metrics data highlights that 37 NPL staff members held memberships to at least one standards committee. Though formal reporting was not referenced in annual reports, the NPL team provided consistent feedback on standards development through events, workshops and bilateral meetings. Additionally, NPL tracked global quantum developments through engagement with global National Measurement Institutes (NMIs) and standards bodies; National Metrology Institute – Quantum (NMI-Q) and the Bureau International des Poids et Mesures (BIPM) workshop.	Annual reports (year 1 – 4); interviews with NPL delivery staff and wider stakeholders; QTE Metrics (2020-2024)
NPL will provide technical expertise to support the development of standards, working with BSI, European and international standards communities. New draft standards in circulation by year four.	**Achieved.** NPL actively participated – and provided leadership for – a number of standards bodies (as shown in the row above). Additionally, NPL collaborated with numerous institutions (e.g. BSI, NIST and DFM). Finally, drafts from ISO/IEC JTC 1, CEN/CENELEC JTC 22, and ETSI ISG on QKD were all in circulation as of year 4.	Annual reports (year 1 – 4); interviews with NPL delivery staff and wider stakeholders
Establish a process which will fund the maintenance and future development of standards beyond the funding of the Programme.	**Not achieved.** Annual reporting outlines extensive engagement in standards development and international collaboration but does not describe a formal process or mechanism to fund the maintenance and future development of standards beyond the Programme's end. NPL stakeholders noted that this was not feasible based on learnings discovered over the course of delivery.	Annual reports (year 1 – 4)
NPL will report on this activity annually with an international status report.	**Achieved.** Annual reporting for the programme includes summaries of contribution to international standards development and activity.	Annual reports (year 1 – 4)

A.5.5. Objective 4: Industry engagement

This objective was to provide opportunities for UK companies to make use of the T&E facilities and knowledge within the NPLQP. The Business Case targets for each KPI and the progress against each of these are outlined below:

Table 16: Progress against Industry Engagement KPIs in the Business Case (dated July 2020)

KPIs	Progress at Programme end (March 2024)	Evidence
Increased awareness within industry of the importance of testing and evaluation of QT through a targeted communications campaign throughout the programme to accelerate innovation through the use of Test and Evaluation.	**Achieved.** NPL significantly increased industry awareness of the importance of QT&E through widespread engagement at events and workshops. 382 unique private sector collaborations were also recorded during the time period (though the focus and outcome of collaborations is not specified).	Annual reports (year 1 – 4); Interviews with NPL delivery staff; QTE metrics; NPL supported firms (2020-2024)
Production of a review of industry needs in year one.	**Achieved.** NPL delivery team members confirmed that an industry needs assessment was carried out in year one. An assessment was also carried out in year three.	Annual reports (year 1 – 4)
Delivery of test and evaluation support to 50+ UK quantum companies across the NPLQP	**Achieved.** 86 quantum companies received support from the programme between 2020-2024, highlighting success in achieving this target. 50 UK quantum companies were supported via the M4Q scheme.	Beauhurst database and ecosystem mapping report
Ensure that the test & evaluation facilities are sustainable beyond the programme by establishing measurement services and a model for bespoke consultancy.	**Partially achieved** via the M4Q scheme which provides a model for delivering measurement services and bespoke consultancy, with demonstrated industry uptake. Facilities developed by NPLQP have supported both industry (e.g. M4Q, ISCF collaborations) and academia (e.g. Quantum Hubs) and continue to do so beyond the Programme. They now form the foundation for future capabilities NPL is developing to meet NQTP needs, funded by government and industry services.	Annual reports (year 1 – 4); M4Q scheme reporting

A.5.6. Objective 5: Skills development

This objective responds to the need for education and skills in QT by supporting the broader quantum skills initiative providing opportunities for training, education and research with the Programme. The Business Case targets for each KPI and the progress against each of these are outlined below:

Table 17: Progress against Skills Development KPIs in the Business Case (dated July 2020)

KPIs	Progress at Programme end (March 2024)	Evidence
Deliver specialist CPD training courses for academics, innovators, companies etc	**Achieved.** Online training sessions on measurement were delivered in 2023 and 2024 through the programme. During this time, online training was accessed 1,243 times. The programme also delivered an average of 4 active measurement services and reference materials per year from 2020-2024, generating an income of c.£136k.	QTE Metrics (2020 – 2024)
Host Postgraduates within the programme	**Achieved.** NPL supported 42 PhD students in 2024. Of these, 76% were either fully or partially funded. PhD students have been supported through PhD in-work and PGI initiatives offered through NPL.	QTE Metrics (2020 – 2024); Interviews with NPL delivery staff; Annual reports (year 1 – 4)

KPIs	Progress at Programme end (March 2024)	Evidence
Host several junior scientist or technician apprentices focusing upon testing quantum technologies.	**Achieved.** NPL hosted a number of apprentices during delivery of the programme, focusing on areas such as Measurement Science. However, the exact number of apprentices was not reported.	Interviews with NPL delivery staff; Annual reports (year 1 – 4)
Host secondments or joint appointments with partner organisations in the first two years to support the knowledge development.	**Achieved.** NPL met the KPI through joint appointments with partner universities in the first two years, although planned secondments were postponed due to COVID-19 and not reported as completed by the end of Year 2.	Annual reports (year 1 – 4)

A.6. Long-Term Benefits

Further fundraising

This section summarises evidence from qualitative interviews, the impact survey and analysis of the Beauhurst database on the extent to which NPL activities have enabled quantum firms to secure further fundraising from the public and private sectors. In line with wider NMS evidence (IEA28, Sections 2.3 and 3.2[53]), the analysis also recognises that attributable revenue impacts are reported by companies across scientific domains, highlighting that investment flows linked to measurement support are material and consistent with observed firm-level fundraising patterns.

Qualitative evidence

There is strong qualitative evidence that NPL's support has played a meaningful role in helping UK quantum companies secure further funding. For example, interviewees consistently highlighted the importance of NPL's validation and T&E services in enabling investment readiness. These services were described as particularly valuable for early-stage firms that require independent performance evidence to demonstrate commercial viability or support due diligence processes. Stakeholders also emphasised that NPL's credibility as the UK's NMI added significant weight when engaging with private investors and public funders.

Programme monitoring data

NPL's internal metrics demonstrate R&D grant activity and provides signals of investment flows into the ecosystem. The number of grants involving quantum increased from just five in 2018 to 64 in 2024. While NPL was one of the recipients of these grants, many awards were made to other organisations across the sector. The corresponding total grant value across quantum projects rose to over £11 million in 2024, although this is down from a 2020 peak of nearly £37 million - potentially reflecting the high base effect of COVID-era funding or large individual project awards during that period. The proportion of grants involving international collaboration has grown over time as well, reaching 77% in the latest year recorded. These signals are consistent with NMS survey evidence, which shows that users of measurement services report substantial attributable revenue impacts (c.£500m annually after attribution, see IEA28 Section 3.2.1.4), reinforcing that public metrology support can unlock commercial returns and follow-on funding.

RSM QT Organisations Survey

There is also some evidence from the impact survey that NPL support enabled firms to secure further funding.

While based on a small sample, 11 (39%) respondents that had engaged with NPL reported that its support directly contributed to the organisation securing further funding, from Innovate UK for quantum-related workstreams during 2020-2024, although a higher share of respondents (n=16; 53%) reported not having received Innovate UK funding. This distribution suggests that public co-funding of quantum R&D is material but not yet universal across NPL's business-facing cohort.

This is reflected in the Ipsos baseline survey (2023) where around 40% of respondents in the private sector reported receiving Innovate UK funding for their quantum work.

When asked about the programme's influence on attracting further resources (n=14), half of those who responded (n=7; 50%) indicated that NPL support had a "great deal" or a "fair amount" of positive impact. However, more than half of total survey respondents (n=16; 53%) did not respond to this question, which may indicate low perceived visibility of NPL's contribution to subsequent fundraising. These findings align with NMS-wide survey patterns (IEA28 Section 2.3), where quantum metrology users are a small proportion (<1%) of the broader measurement population, but nevertheless report measurable economic contributions - including additional sales revenue from new and improved products (with ~£500m annually attributed to NMS

[53] A survey of UK-based businesses using laboratories funded through the National Measurement System (2023) - NPL

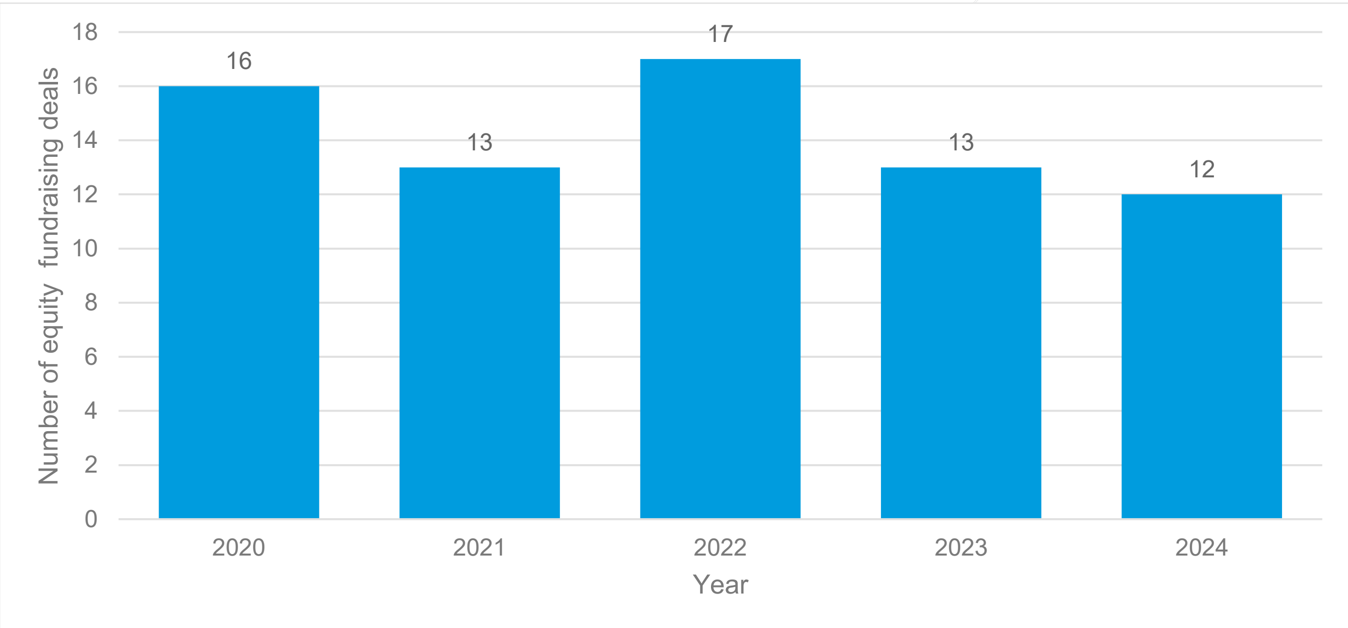
support), increased employment and wages, and wider spillovers through product diffusion - in line with other scientific domains.

Beauhurst database

To complement the qualitative and survey-based findings, a quantitative analysis using Beauhurst quantum mapping data identified companies supported by NPL and tracked their fundraising activity. A sample of NPL-supported firms was matched against publicly available company fundraising records between 2020 and 2024.

This exercise found evidence of substantial investment raised by supported companies during or following their engagement with the programme. According to Beauhurst data, 27 of the 86 firms identified as receiving NPL support raised equity investment between 2020 and 2024 - a conversion rate of 31%. Figure 7 shows the annual distribution of these, with activity peaking in 2022 (17 deals) but remaining consistent across the five-year period (12–16 deals per year). Median fundraising among this group ranged from £10 million to £13 million, indicating that firms engaged with NPL tend to attract significant levels of external capital. This is consistent with patterns of increased commercial readiness and signals the potential for follow-on private investment stimulated through public support and aligns with stakeholder feedback that NPL support often coincided with critical phases of product development and investor engagement.

Figure 8: Annual number of equity fundraising deals among the 27 NPL-supported firms that raised investment, 2020–2024



Source: Beauhurst data (figures reflect NPL-supported companies tracked in the Beauhurst database).

However, attributing this investment activity directly to NPL support is analytically challenging. Most quantum firms access multiple sources of support (e.g. UKRI, university partnerships, private accelerators), and Beauhurst data does not distinguish which interventions influenced fundraising success. Furthermore, the data available did not permit a statistically robust treatment–control analysis, due to:

- Small population sizes (the UK quantum SME base remains narrow);
- Inconsistent reporting of support received outside formal grant funding; and
- Variability in firms' technology maturity and investment timelines.

Since a robust treatment-control analysis was not feasible, two approaches were taken to identifying a baseline for comparing NPL-supported firms to using the Beauhurst database, which are reported in the following sections.

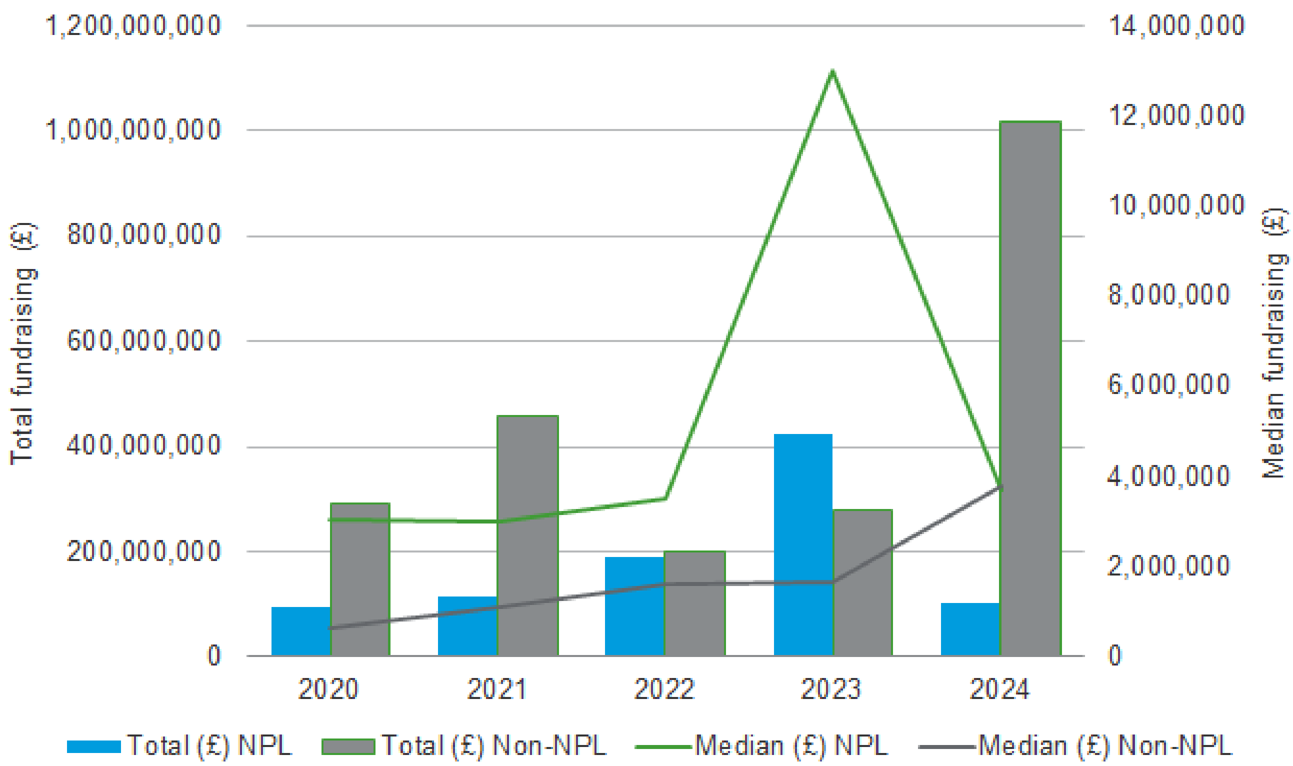
Comparison between NPL-supported firms and the wider quantum sector

Firms in the wider quantum sector were identified in the Beauhurst database drawing on NPL's quantum mapping report, which identified 804 firms that are part of the UK's quantum ecosystem according to the Beauhurst database. Of these firms, 86 received support from NPL during 2020-2024. The remaining 686 firms were used as a comparator group to demonstrate attribution.

As highlighted above, 27 of the 86 firms identified as receiving NPL support raised equity investment between 2020 and 2024. In comparison, 78 of the 686 firms in the wider quantum industry (from Beauhurst quantum mapping report) that did not receive NPL funding did raise some funds between 2020 and 2024, representing a conversion rate of around 11%, which is lower than the 31% observed among the supported firms.

Over 2020–2024, non-NPL firms collectively raised more in total (£2.25bn vs. £929m), yet NPL-supported firms performed strongly relative to their smaller number. Median fundraising values were consistently higher for NPL-supported firms, peaking at ~£13m in 2023 compared to ~£1.7m for non-NPL firms. Maximum deal sizes also show that NPL-supported firms can compete at the top end, with a £162m raise in 2023, although mega-rounds remain more common among the wider non-NPL group.

Figure 9: Fundraising performance of NPL-supported firms vs non-supported quantum firms (2020–2024)



While these metrics suggest that NPL-supported firms tend to raise more - both in terms of likelihood and amount - this analysis does not establish causality. The groups are not matched, and selection effects may influence outcomes (e.g. NPL may be supporting firms that were already more likely to succeed). A more rigorous comparison using a matched sample is presented below, though the relatively small number of firms and fundraising data remaining after matching the samples, limits statistical power.

In addition, many of the firms in the dataset are large and diversified, and the fundraising figures captured by Beauhurst may relate to activities unrelated to quantum - making it difficult to isolate the specific effect of any quantum-related fundraisings.

Summary statistics for the non-NPL firms prior to matching (e.g., on size) are not presented, as the two groups differ markedly in size, composition, and variation across firms. Pre-matching comparisons risk being misleading given these structural differences. Instead, the focus is on the matched analysis presented below, which provides a more balanced basis for comparison, albeit with limitations arising from the smaller number of firms and fundraising events retained after matching. Further fundraisings activity by sector (for the matched sample – see below) is provided in Appendix A.10.

Comparison between NPL-supported firms and a match comparator group of quantum firms

A second comparative analysis was undertaken using Propensity Score Matching (PSM) to identify a matched subset of quantum firms, who may provide a closer comparison to those receiving NPL support. While the current data environment limits our ability to robustly estimate causal impact - particularly in terms of firm-level performance uplift related to quantum activities or acceleration in quantum-specific activities attributable to NPL- the matching approach nonetheless provides a critical foundation for future analysis.

The PSM exercise established a statistically balanced control group of comparable firms that did not receive NPL support. However, while the matching exercise successfully established a more balanced comparison group, one of the key trade-offs has been a significantly reduced sample size for fundraising observations. Only 8 treated and 10 control firms from the matched sample reported fundraising activity in each year between 2020 and 2024[54].

Moreover, we explored whether firms in the treated group were disproportionately quantum computing firms (which may be more likely to raise investment) however analysis of the structural differences between treated and control firms was inconclusive. This highlights challenges in attribution and the need for cautious interpretation of results.

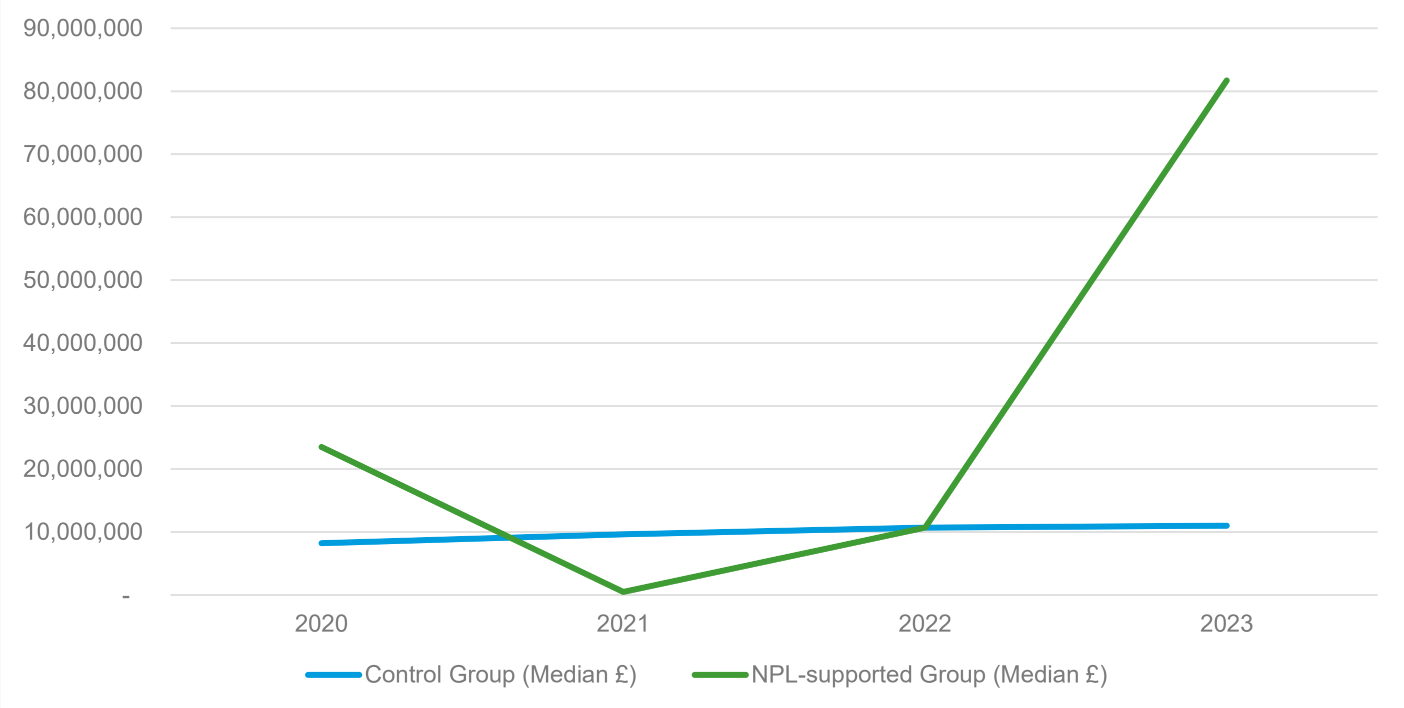
This limited coverage likely reflects limitations in how Beauhurst tracks fundraising events for NPL-funded firms, particularly for firms outside of its primary focus on early-stage, high-growth companies which have remained in the sample due to the matching exercise. While turnover data was available for most firms in the matched sample, fewer corresponding fundraising records were captured - possibly due to the fact that many matched firms are larger and more established and may not have required or pursued external equity finance in recent years.

Although the sample size and data availability constraints mean that no conclusive treatment effects can yet be derived, the creation of this robust counterfactual group is a valuable first step. It lays the groundwork for future longitudinal analysis, especially as the commercialisation of quantum technologies progresses and more quantum-related granular metrics - such as revenue growth, employment, IP generation, or product launches - become more available. This structure enables the evaluation team to return to this counterfactual framework in future years to track divergence and better isolate the long-term economic impact of the NPLQP.

Figure 9 presents the median weighted fundraising amounts reported by firms in the supported group (those supported by NPL) and the matched counterfactual group between 2020 and 2024. It is not possible to make a robust statement about additionality from the observed fundraising outcomes alone. While there is a visible increase in the median amount raised by NPL-supported firms - particularly pronounced in 2023 - the sample size remains very low (2 observations for treated and control group in 2023), limiting the extent to which any performance difference can be interpreted as statistically meaningful. Moreover, without further regression-based controls or firm-level longitudinal data, it is not feasible to isolate the effect of NPL support from other factors.

[54] This is based on the second matching model, which was carried out using a 1:10 matching ratio with replacement — see the Appendix A.10 for further technical details.

Figure 10: Median fundraising (£) for the matched sample



Beauhurst does additionally provide qualitative evidence that at least a subset of the fundraising observed within the NPL-supported firms was directly related to quantum innovation. Several entries in Beauhurst describing the purpose of fundraising include explicit references to QT[55]:

These descriptions suggest that firms within the treated group are not only engaged in fundraising activity but are actively pursuing quantum-related commercialisation strategies. While this cannot be conclusively linked to NPL's support based on available data, it lends some qualitative confidence that the observed fundraisings are at least partially aligned with the Programme's strategic objectives. Further evaluation, including follow-up data collection or case study work, would be required to verify attribution and assess longer-term impact.

[55] Examples include: "To scale the development of high-performance quantum computers and triple its team size over the next two years."; "To launch its photonic quantum computing system and to develop its product processing capabilities."; "To facilitate development of quantum computing technology."; "To facilitate development of quantum computing architecture."; "To bring quantum advantage to businesses globally and develop its research and design sector."; "To accelerate development of its silicon-based quantum computers."

Indicative estimate of the scale of impact

The qualitative interviews and survey provide convincing evidence that the NPLQP has had an impact on further fundraising. However, as outlined above, it is not possible to robustly attribute a scale of further fundraising secured to the NPQP. To provide a reasonable estimate of potential additional funding attributable to the Programme, the following conservative calculations were applied:

$$F = N \times s \times I \times a$$

$Where:$

$F\ =\ Estimated\ attributable\ funding$
$N\ =\ Number\ of\ supported\ firms\ raising\ further\ fundraising\ (2020-24)$
$s\ =\ Share\ attributable\ to\ NPL$
$I\ =\ Average\ investment\ raised\ per\ firm\ (£)$
$a\ =\ Additionality\ (NPL\ contribution)$

Inputs / Assumptions:

N=27
s=0.38 (≈10 firms)
I=£10,000,000
a=0.10 to 0.20

Step-by-step:

1. Firms where fundraising is attributable to NPL:

N×s=27×0.38 = 10.26 firms

2. Total funding raised by these firms:

10.26 × £10,000,000 = £102.6 million

3. Apply attribution factor:

F_{min} = £102.6m × 0.10 = £10.3m
F_{max} = £102.6m × 0.20 = £20.5m

Estimated Range:

F ∈ [£10.3m, £20.5m]

These assumptions (informed by the data available) suggest that the total estimated additional funding attributable to NPL lies in the range of £10.3 million to £20.5 million over the period.

While indicative, this estimate suggests the NPLQP may have helped leverage a significant volume of follow-on investment. Future evaluation will benefit from improved tracking of funding outcomes linked to Programme services (e.g. systematic use of project exit surveys or follow-up metrics).

We recommend that NPL start more detailed tracking of investment success for NPL-supported firms, which could provide a supplementary data source and potentially provide more accurate figures than the Beauhurst database for NPL-supported firms.

Commercialisation of new or improved products

As stated above, the NPLQP has laid critical groundwork for commercial readiness, and the M4Q scheme has helped remove barriers to commercialisation. This section summaries evidence from qualitative interviews, programme data, analysis of patent data and analysis of the Beauhurst database on the extent to which NPL activities have enabled firms to develop and commercialise new quantum products.

Qualitative evidence

There is strong qualitative evidence the NPLQP has contributed to the development of new and improved products across a range of UK QT companies. Interviewees frequently emphasised that access to NPL's T&E capabilities, particularly through the M4Q scheme, enabled them to improve the design, reliability, and performance of their products. This was especially valuable in the context of deep tech hardware, where precise measurement and validation are essential to commercial credibility however are often prohibitively expensive or technically inaccessible to early-stage firms.

To measure the impact of the M4Q initiative of the NPL programme, 37 participants were interviewed. Of these, 38% (n=14) reported that support from NPL had helped their organisation develop a new product; while 65% (n=24) stated it had contributed to the improvement of an existing product. While based on a small sample, these figures indicate a notable proportion of organisations experienced product-related benefits from their interaction with the programme.

Several case study participants stated NPL's support helped them to "unlock" product development barriers, validate proof-of-concept devices, or progress from prototype to minimum viable product. Others pointed to specific measurement work conducted by NPL that identified flaws or confirmed performance claims, which subsequently fed directly into design improvements or customer-facing documentation. These forms of support were consistently described as having accelerated product development timelines and increased companies' confidence in approaching prospective buyers or partners.

Programme data

Programme data and case studies provide further evidence that NPL activities have stimulated commercialisation. NPL has directly supported the transition of several quantum technologies from research to near-market deployment. For example, the MINAC atomic clock was validated by NPL and deployed on HMS Prince of Wales for Arctic navigation. Similarly, Aquark's cold atom clock demonstrator was accelerated by six months due to NPL's technical support, and Seeqc UK developed multiple generations of superconducting processors with NPL's assistance, reflecting iterative product development and increasing technology readiness.

Beyond individual technologies, NPL has played a strategic role in enabling commercialisation through its participation in 23 Innovate UK projects and partnerships with 60 industry representatives across 23 initiatives. These collaborations span the full quantum supply chain from component manufacturers like Teledyne-e2v and Oxford Quantum Circuits to end users such as BT and the National Composites Centre. This ecosystem-wide engagement ensures innovations are not only technically validated but also aligned with real-world market needs.

Patent analysis

One key measure of whether NPL-support has encouraged innovation that will lead to commercialisation of new products is the extent of patent development. This section assesses evidence from two sources – the Dimensions and Beauhurst databases – to assess the extent to which NPL has encouraged patent development.

Patent analysis (Dimensions database)

From the Dimensions patent dataset, 27 patents related to quantum technologies can be assigned directly to NPL-supported activities between 2020 and 2024. The dataset was exported on 15 September 2025 using the following filters: "Quantum computing" OR "Optoelectronics" OR "Metrology" OR "Atomic" OR "Photonics" OR "Quantum randomness" OR "Superconducting" OR "Quantum network" OR "Quantum technologies" OR "Microscopy" OR "Quantum secure" OR "Radio frequency" OR "Nano-scale" OR "Electron" OR "Quantum hardware" OR "Atomic clock" OR "Quantum clock" OR "Wafer scale" OR "Photon" OR "Cryogenic" OR "Linewidth" OR "Frequency combs" OR "Parametric" OR "Superconductor" OR "Atomic sensors" OR "Quantum well" OR "Compact lasers" OR "Laser" OR "Nano" OR "Single photon" OR "Solid-state" OR "Cryogenic temperatures" OR "Electrical resistance" OR "Quantum-secure"' in title and abstract. While also being assigned to the National Physical Laboratory.

Further attribution is challenging as it is not possible to establish a clear link between the entities supported by NPL and the applicants or assignees listed on patents. Many of the firms supported by NPL are large and diversified, operating across multiple technology domains which complicates efforts to isolate their quantum-related patenting activity. This mirrors the difficulty observed in the fundraising analysis - where some Beauhurst-reported fundraising events may reflect activity in other parts of the business unrelated to quantum. In both cases, these complexities make it difficult to isolate the specific contribution of NPL support to observed innovation outcomes.

The following section presents a complementary patent analysis using the Beauhurst database, which aims to partially address the challenge of linking patent records to firms. This approach provides a more direct route for associating patent activity with NPL-supported organisations. However, this remains an area with scope for further refinement. Future improvements to the analysis could include more robust linking of patent data with firm-level identifiers, as well as the adoption of emerging frameworks for valuing intellectual property in deep tech sectors such as quantum. These advances would support future efforts to assign meaningful economic value to patents, which is currently limited by the early-stage nature of commercialisation in the sector.

Patent analysis (Beauhurst database)

Analysis of patents developed by NPL-supported firms and the matched comparison group was conducted in the Beauhurst database. While only a limited number of firms explicitly reported having associated patents, descriptive statistics on total patents granted show notable differences between treated and control groups.

As shown in the following table, NPL-supported firms in the matched sample had a median patent count of 49, compared to 17 for the matched counterfactual group. Although average patent counts were slightly lower for the NPL-supported firms, the higher median suggests a more concentrated distribution among NPL-supported firms. That said, the absence of patent attribution flags for all firms and the limited coverage of patent origin (e.g. whether linked to quantum activity) makes it difficult to definitively attribute observed patent activity to the NPL programme.

Nonetheless, these signals may indicate that NPL-supported firms are more actively engaged in research or IP-generating activities, though further work - such as qualitative case studies or citation tracking - would be needed to validate any causal relationship.

Table 18: Matched sample patent statistics

	Total firms in the matched sample	Average patents	Median patents	Max patents
NPL-supported firms	34	153	49	1443
Matched counterfactual	187	171	17	2964

Moreover, by looking specifically at the top end of the patent distribution, further signals of potential programme impact emerge. Among firms in the top 25% of all patent holders in the matched sample, NPL-supported firms account for 23.5%, despite representing a much smaller share of the overall group. In contrast, only 10.7% of the matched counterfactual firms fall into this top quartile of patent activity.

This overrepresentation suggests treated firms are more likely to be among the most patent-intensive - a possible indication that NPL's support is aligned with, or contributing to, more innovation-active organisations. While this finding does not establish causality, it supports the view that NPL may be engaging with firms at the frontier of research and development or helping to sustain their innovation trajectories.

However, the absence of granular patent-level metadata (e.g. patent timing, technology field, quantum relevance) and the relatively small number of treated firms in the sample means this result should be interpreted with caution. Future evaluations could strengthen this line of analysis by linking patent data to QT classifications, funding timelines, and collaboration records to explore whether NPL has played a direct enabling role. Data availability does not allow for further triangulation at this stage, however future evaluations may benefit from exploring whether firms that hold patents - and in particular, those with patents explicitly related to quantum or referencing NPL's involvement - have raised more investment compared to their matched counterparts. Linking patent records with fundraising outcomes could help isolate the innovation pathways most influenced by the programme and assess the extent to which NPL is contributing to long-term commercialisation and scaling.

Value of an additional patent

A cross-check of available literature and valuation methodologies was conducted to explore whether a usable proxy or benchmark could be applied to estimate the financial value of a quantum-related patent. However, this review was inconclusive. Existing studies are either too general (not specific to the quantum sector), based on early-stage or highly uncertain commercialisation forecasts, or fail to provide a replicable method for assigning value to individual patents.

This challenge is echoed in broader industry commentary. For instance, IPWatchdog[56] highlights that globally, while patenting activity in quantum computing is accelerating - particularly in superconducting and photonic modalities - valuation remains complex due to the nascent state of commercial applications and the diversity of technological approaches. The OECD[57] also notes that while patent-based indicators are useful for tracking innovation trends, they are less effective for assigning financial value in emerging sectors like quantum, where market pathways are still forming.

As a result, it was not possible to identify a robust or defensible approach for monetising patents in the context of this evaluation. This aligns with wider commentary in the sector- as noted by The Quantum Insider, reflecting OECD findings: "Despite potential breakthroughs, commercialisation remains uncertain, with significant technical and investment hurdles still ahead." [58]

Indicative estimate of economic value

The qualitative interviews and survey again provide convincing evidence the NPL programme has had an impact on commercialisation of new products. However, as outlined above, it is not possible to robustly attribute a scale of impact to the NPL programme. To explore potential economic value, the evaluation team reviewed:

- Case study firms' expected sales over the next 3–5 years;
- Survey-based expectations of commercialisation timelines;

[56] Patent Landscape for Quantum Computing: A Survey of Patenting Activities for Different Physical Realization Methods
[57] Quantifying digital innovation for the twin transition | OECD
[58] Governments Face Key Challenges in QT Policy, OECD Report Finds

- Benchmarks from innovation evaluations indicating the average uplift in product success rates associated with T&E support.

While data was not sufficiently robust to support a single point estimate, the evidence suggests that a meaningful share of firms supported through the NPLQP are likely to generate revenue from new or improved products within the next 2–5 years, with NPL support playing a contributory role. For example, if 10 firms go on to achieve modest commercial success (e.g. £500k–£1m in annual product sales), the cumulative benefit over a 5-year horizon could exceed £25–50 million, depending on attribution assumptions and the pace of market adoption. However, given the early stage of most technologies, this should be treated as an illustrative scenario, not a definitive valuation.

In summary, while monetisation of product impacts is currently limited by evidence constraints and commercial immaturity, the underlying impact pathway is well-supported. The NPLQP has contributed to product development progress among supported firms - enabling improved designs, faster development, and greater investor or customer confidence and is likely to deliver growing economic benefits as these technologies mature and reach the market.

While data limitations prevent definitive monetisation, we can develop an illustrative estimate based on available evidence. For example:

$$B = N * R * Y * a$$

Where:

$\boldsymbol{N} = number\ of\ firms\ generating\ revenue\ (\approx\ 10)$
$\boldsymbol{R}\ =\ annual\ revenue\ per\ firm\ (£0.25m\ -\ £1m)$
$\boldsymbol{Y}\ =\ years\ (5)$
$\boldsymbol{\alpha}\ =\ proportion\ attributable\ to\ NPL\ support\ (25\% - 50\%)$
Then the total attributable benefit is approximated as:

$$Attributable\ benefit =\ N \times R \times Y \times \alpha =\ 10 \times (£0.25m\ -\ £1m) \times 5 \times (25\%\ -\ 50\%)$$

This gives a range of £3m – £25m, representing a conservative scenario based on current data and reflecting only a subset of likely commercial outcomes.

Employment

Employment outcomes were assessed as a potential long-term benefit of the NPLQP, reflecting the programme's strategic aim to support the growth of UK-based quantum companies. However, the available evidence does not support a conclusive finding that NPL's support has directly led to job creation or retention, and as such, employment impacts have not been monetised in this analysis. This section summarises the evidence from interviews and the survey on the extent of employment benefits.

It is important to note that variation in employment across firms is extremely high, with some supported companies reporting only a few hundred employees while others employ over 100,000. Given this dispersion, employment statistics are not comparable across groups, even after matching on turnover. For this reason, the employees variable from Beauhurst was not used in the matched analysis, as it would not provide a reliable basis for comparison or attribution of benefits. Moreover, employment activities - particularly for larger, more generalist firms that are only partly involved in quantum - do not specifically relate to quantum activities.

Qualitative evidence

Interviews with supported organisations did not generate substantive evidence that engagement with NPL had resulted in new hires. While several interviewees indicated NPL's support had helped to "de-risk" technical development or strengthen their business case for future investment, none made direct reference to having increased staff numbers as a result of their engagement. Most firms remain in relatively early stages of growth, where funding and technical progress are prioritised ahead of scaling workforce capacity.

Programme data

Evidence from QTE metrics also provides some evidence of NPL's contribution to broader capacity-building efforts. Between 2020 and 2024, the programme supported 79 unique PhD students, helping to cultivate a pipeline of future researchers and innovators. In addition, 1,243 individuals accessed online measurement training during 2023 and 2024, reflecting a strong emphasis on skills development in quantum and measurement science. However, it is not clear the extent to which this human capital development translated into further employment opportunities.

Survey (RSM and IPSOS Baseline)

The RSM survey responses provide insight into staffing trends since 2020, revealing modest growth and overall stability across key divisions. Among 25 (of 30) respondents that provided feedback, 35% in a Research division reported no change in staffing levels, 31% noted a slight increase, and 15% observed a significant increase.

This was reflected in Ipsos's baseline survey (2023), where around 40% of respondents reported an increase in research division staff since 2020, with very few noting any decline. A similar share also reported growth in their technical and application divisions

When asked whether NPL's support had influenced the number of employees in their organisation or department, out of 13 RSM survey respondents, eight (62%) said staffing levels had stayed the same. NPL's involvement was mostly described as project-specific or supplementary and not substantial enough to affect broader hiring decisions. Respondents highlighted that internal strategies and market conditions were the main drivers of workforce changes, independent of NPL's support.

Two respondents reported that staffing would increase slightly in the absence of NPL support. This was attributed to NPL's contribution in reducing hiring pressure - particularly by providing technical expertise that offset the need for additional staff. This was especially helpful for startups, where NPL's support helped ease the burden of scaling up teams.

While these figures suggest that some employment-related benefits may be emerging, the small sample size and lack of detail on job type, duration, or attribution make it difficult to quantify these impacts. In addition, the absence of corroborating case study evidence limits the evaluation's ability to assess whether these responses reflect direct outcomes of NPL support or broader organisational growth influenced by other factors.

Employment impacts are among the most challenging to attribute in innovation programmes, particularly when working with small firms in fast-moving or grant-intensive sectors like quantum. Firms often experience staffing fluctuations for reasons unrelated to external support, and time lags between technical milestones and hiring decisions further complicate causal analysis.

For these reasons, employment has not been included as a monetisable benefit within the cost-benefit analysis. However, it remains a potential downstream outcome, particularly if companies supported through the programme achieve commercial success in the coming years. Monitoring of employment impacts in future evaluations or follow-up surveys would provide a clearer view of how NPL's support may contribute to job creation over time.

Additional benefits

This section considers the extent to which there have been other additional benefits to the programme of support provided by NPL.

Knowledge spillovers

The NPLQP has facilitated significant knowledge spillovers, particularly through the M4Q scheme. NPL delivery staff highlighted that nearly half of the 30+ M4Q projects supported organisations outside the quantum sector including companies in semiconductors and healthcare, demonstrating early evidence of cross-sectoral knowledge diffusion. One delivery team member noted:

“Out of the 30-plus M4Qs delivered, almost 50% was non-quantum industry... so a lot of other industries use the quantum technologies for the benefits.”

Stakeholders also identified potential spillovers into sectors such as health, however acknowledged it is still too early for these wider benefits to fully materialise.

Interviews further suggested M4Q engagements have created a valuable feedback loop between NPL and the companies it supports. Not only have firms benefited from access to NPL expertise to resolve technical challenges, but these collaborations have, in turn, helped shape NPL’s own research priorities. As one staff member observed:

“These engagements informed NPL’s own research agenda, creating a feedback loop that enhanced its scientific capabilities,” and “We were providing access, and that access was impacting UK companies... also upskilling our scientists and technical areas.”

Desk research supports these findings. In 2024, 77% of NPL’s quantum-related grant projects included international partners, and the programme recorded 126 academic collaborations, facilitating widespread diffusion of knowledge across sectors and borders (Evaluation Metrics, 2024). NPL’s scientific output also demonstrates high impact as its quantum publications received 60% more citations than the global average, with a field-weighted citation score 33% above the international benchmark (Bibliometric Analysis – Final Report). Between 2013 and 2023, 13–19% of NPL’s quantum publications were co-authored with private sector partners, reinforcing its role in transferring knowledge from academia to industry.

Additionally, NPL’s research has begun to reach wider public and policy audiences. Its publications have seen a 10.7 percentage point higher uptake in news media than the global average and have been increasingly cited in policy literature, indicating a growing societal and institutional recognition of its work.

R&D applications

The NPLQP has been highly effective in enabling applied research and accelerating QT development. Across interviews, stakeholders consistently highlighted NPL’s role in opening new research directions, advancing technology readiness, and de-risking early-stage innovation. One NPL delivery team member noted:

“The programme enabled the development and validation of novel quantum technologies, often acting as a catalyst for new research directions and collaborations.”

This sentiment was echoed by an NPL customer, who reflected that they:

“Didn’t do anything too material-based until we started collaborating with NPL… now we’re looking at 2D semiconductors and materials we wouldn’t have got into otherwise.”

These examples illustrate how NPL’s facilities and expertise have broadened the scope of industrial R&D, particularly in areas requiring high-precision testing and metrology.

Evidence from desk research reinforces these qualitative findings. The programme supported the progression of several technologies towards deployment, including the MINAC atomic clock, Aquark’s cold atom clock demonstrator, and superconducting processors developed by Seeqc UK. These examples demonstrate NPL’s influence in enabling experimental validation and system integration for cutting-edge quantum technologies.

Furthermore, the programme has delivered consistently high levels of project completion and customer-reported impact. According to Evaluation Metrics (2024), 100% of M4Q projects were completed each year, and 71% of participants stated that NPL’s support accelerated their R&D activities. This highlights the programme’s role in reducing development timelines and enhancing the efficiency of innovation processes for UK quantum firms.

Collectively the evidence indicates NPLQP served not only as a technical enabler but also as a strategic accelerator for the UK quantum research community. By offering access to national facilities, technical consultancy, and collaborative platforms, NPL has contributed materially to the commercial and scientific progress of the UK's emerging quantum sector.

Collaborative activity

Collaboration was a core feature of the NPLQP with evidence indicating its effectiveness in fostering strong partnerships across industry, academia, and international networks. Interviewees described NPL as a "connector" and "credible neutral party" that enabled collaborative R&D to flourish across organisational boundaries. Several NPL delivery staff highlighted the programme helped reduce traditional barriers between researchers and companies, particularly SMEs, by providing structured, low-friction engagement mechanisms through initiatives like M4Q. These projects were widely seen as valuable vehicles for establishing trust, deepening technical exchange, and catalysing long-term partnerships.

The programme also contributed to academic collaboration. Between 2020 and 2024, NPL recorded 126 quantum-related academic partnerships, including with major institutions such as the University of Manchester, University of Birmingham, Royal Holloway, and the Henry Royce Institute. Interviews with researchers indicated that NPL's facilities and technical staff provided unique capabilities not available in their home institutions, such as high-precision characterisation tools and standards expertise, which enabled deeper integration of applied research with metrological rigour.

International collaboration was another area of strength. In 2024, 77% of NPL's quantum-related grant projects involved international partners, underlining NPL's global positioning and influence. These partnerships supported knowledge exchange, benchmarking, and co-development of early-stage technologies. NPL's leadership in global quantum standardisation forums, such as ISO/IEC JTC 3 and IMEKO TC25, further extended its collaborative footprint and enabled UK contributions to shape international norms and protocols.

A.7. Contribution Tracing

This section outlines primary and secondary evidence against four contribution claims set for the Programme at the outset of this evaluation and provides an assessment on the extent these hold true using process tracing tests (see below for detail). Bayesian Updating[59] will be applied to place a numerical value on the level of confidence that a particular claim is true.

Contribution Analysis assesses the available evidence for each claim against that for alternative explanations for the observed outputs and outcomes. The alternative hypotheses use the evidence to find support for the hypotheses that counter the causal hypotheses. The following tables outline the causal and alternative hypotheses for each of the four contribution claims.

The following classification of levels of contribution were used:

- **Strong contribution** - indicates that NPLQP has achieved substantial results with few or no other contributing factors.
- **Some contribution** - indicates that NPLQP has achieved some, but no substantial, results with evidence that other contribution factors are at play.
- **Negligible contribution** - indicates that NPLQP has not or not yet achieved any or only very limited results or that the results are effects of other contributing factors.

Evidence was gathered from interviews, focus groups, surveys, case studies, and Programme monitoring information. Process Tracing examines a single case of change and tests whether a hypothesised causal mechanism, such as that proposed by a ToC, explains the outcome. There are four Process Tracing tests[60] that can be used to assess the qualitative strength of the evidence and the extent to which the specific support provided by NPLQP contributes to the various outcomes/impacts achieved. These are:

- **Smoking Gun** *(confirmatory)*: If the evidence is observed, the hypothesis is confirmed. If the evidence is not observed, the hypothesis is not confirmed, but it is not rejected, either.
- **Hoop Test** *(disconfirmatory)*: If the evidence is not observed, the hypothesis is rejected. If the evidence is observed, the hypothesis is not rejected (it 'goes through the hoop', passes the test), but it is not confirmed, either.
- **Doubly Decisive** *(both confirmatory and disconfirmatory)*: If the evidence is observed, the hypothesis is confirmed. If the evidence is not observed, the hypothesis is rejected.
- **Straw-in-the-Wind** *(neither confirmatory nor disconfirmatory)*: If the evidence is observed, this is not sufficient to confirm the hypothesis. If the evidence is not observed, this is not sufficient to reject the hypothesis.

Collectively, these identify whether the causal mechanisms described in the contribution claims are sufficient and/or necessary to explain the outcomes.

Bayesian Updating[61] strengthens the rigour used in assessing whether the evidence supports contribution claims. It quantifies the probative value of specific pieces of evidence and the power to change pre-intervention confidence that a specific contribution claim holds. Bayesian Updating helps assess the likelihood of impact.

---

[59] Bayesian Updating is an extension of other theory-based methods such as contribution analysis and process tracing to strengthen the rigour used in assessing whether the evidence supports contribution claims.

[60] Befani, B. and Sredman-Byrce, G. (2016). Process tracing and Bayesian updating for impact evaluation. Sage Journals

[61] Bayesian Updating was applied to British International Investment's mobilisation of private sector investment in international projects in 2022 and in case study research about the COVID-19 pandemic. The latter was published in 2023 and is referenced: Bennett, A. (2023). Causal Inference and Policy Evaluation from Case Studies Using Bayesian Process Tracing. In: Damonte, A., Negri, F. (eds) Causality in Policy Studies. Texts in Quantitative Political Analysis. Springer, Cham. https://doi.org/10.1007/978-3-031-12982-7_8

Before data collection, a 'prior' confidence about the contribution claim was quantified as a probability that the claim is true. If there was no prior information about the claim, and no reason to believe it was no more or less valid than not, the prior confidence was 0.5 (i.e. 'no information'). After data collection, the confidence in the contribution claim was updated as a likelihood ratio. The prior confidence and likelihood ratio were plugged into the Bayes formula to calculate the 'posterior' confidence that the claim is true. The Bayes formula used was:

$$P(H|E) = \frac{P(E|H) \cdot P(H)}{P(E|H) \cdot P(H) + P(E|\neg H) \cdot P(\neg H)}$$

where:

$P(H) = Prior\ confidence\ in\ the\ causal\ hypothesis$

$P(E|H) = Likelihood\ of\ observing\ the\ evidence\ if\ the\ causal\ hypothesis\ is\ true$

$P(E|\neg H$[62]$) = Likelihood\ of\ observing\ the\ evidence\ if\ the\ alternative\ hypothesis\ is\ true$

$P(\neg H) = 1 - P(H) = Prior\ confidence\ in\ the\ alternative\ hypothesis$

$P(H|E) = Posterior\ confidence$

The formula shows that the power of the evidence to change the prior confidence, P(H), depends on the 'sensitivity'. The evidence has higher power to change our prior confidence if the sensitivity is high. This can be associated with the Hoop Test; if the sensitivity (P(E|H)), or the expectation of observing a specific piece of evidence under the contribution claim, is high, then failing to observe E drastically reduces our confidence in the claim. While the Type II error is not within this formula as a variable, it is embedded in this sensitivity – the null hypothesis that is false may not be rejected because the sensitivity is low. Likewise, the probative value of evidence E is high when its Type I error (i.e. false positives), denoted as P(E|¬H), is low – this is associated with the Smoking Gun test; confirmatory evidence is highly specific to the claim because it is highly unlikely under alternatives to the claim.

This formula sees the probability of the evidence being represented in a way that explicitly shows the importance of the sensitivity and Type I errors (i.e. false positives) by including the likelihood ratios and prior confidences of the alternative hypotheses.

The likelihood ratios in the following table were assigned against each process tracing test, dependent on whether the process tracing test passed, failed, or was inconclusive.

Table 19: Likelihood Ratios

Process Tracing (PT) Test	Likelihood	Confidence Level	Prior	PT Pass	PT Fail	PT Inconclusive
Smoking Gun	High confirmatory, low disconfirmatory	Practical Certainty (0.99+)	0.99	1	0.99	0.5
Doubly Decisive	High confirmatory, high disconfirmatory	Reasonable Certainty (0.95-0.99)	0.975	0.99	0.85	0.5
Hoop	Low confirmatory, high disconfirmatory	Cautious Confidence (0.70-0.85)	0.775	0.85	0.7	0.5
Straw-in-the-Wind	Low confirmatory, low disconfirmatory	More Confident than not (0.5-0.7)	0.6	0.7	0.5	0.5
No Information	-	No information (0.5)	0.5	0.5	0.5	0.5

The posterior confidence updated the confidence in the contribution claims, based on the process tracing test. The posterior confidence either increased, decreased, or did not change from the prior confidence.

[62] The notation ¬ refers to the complement. For example, if H means the null hypothesis, then ¬H means not the null hypothesis (i.e. the alternative hypothesis).

For example, based on the Process Tracing test, the Hoop Test for CC3 below included the following inputs into the Bayes formula:

$\boldsymbol{P(H) = 0.775}$
$\boldsymbol{P(E|H) = 0.85}$
$\boldsymbol{P(E|\neg H) = 0.7}$
$\boldsymbol{P(\neg H) = 1 - P(H) = 0.225}$

Noticeably, the Hoop Test for the null hypothesis passed and that for alternative hypothesis failed. Therefore, $\boldsymbol{P(H|E) = 0.807}$. This is an increase in confidence from the prior confidence of 0.775.

The four contribution claims are evaluated in the following tables with NPLQP's contribution strength, and the robustness of the evidence.

Contribution claim 1

Contribution claim 1 focuses on analysing the Programme's role in supporting the UK's continued production of world leading quantum research and innovation.

Table 20: Contribution Claim 1

Contribution Claim 1	**NPL's quantum programme has contributed to the UK producing world leading quantum research and innovation at a faster pace than would have occurred otherwise**
Linked impacts in the ToC	• UK produces cutting-edge research and innovation. • UK maintains its position as one of the global leaders in the global quantum ecosystem
Link to EQs	• What is the impact of the Programme on R&D and innovation activities in the QT sector?
Causal Hypothesis	NPL funded support for new research and concepts strengthens the domestic supply of quantum research and innovative concept development in the UK, leading to greater and faster advances in these areas which help the UK maintain its place as a top 3 global hub for quantum.
Alternative Hypothesis	UK academic institutions and quantum companies have produced world leading research and innovation in quantum technologies due to factors independent of the NPLQP (e.g., increased private investment, international demand, or support from other initiatives or government programmes).

Contribution Analysis for this contribution claim highlighted some contribution of the NPLQP to the UK producing world leading research and innovation.

NPL's key role in advancing the UK's QT landscape is in bridging the gap between fundamental research and applied innovation. Through the Programme, NPL provided critical infrastructure, bespoke measurement capabilities, and expert support to quantum organisations. Its contributions include developing standardised benchmarking methods, offering independent validation facilities that boost investor confidence, and collaborating with academic institutions to enhance reproducibility.

While NPL's influence on IP generation appears limited, its leadership in quantum measurement and standards is internationally recognised, particularly in collaboration with institutions in the US, Germany, and Canada. However, its broader impact on the UK's quantum ecosystem beyond its direct activities remains less evident, and survey data indicates that, for many companies, production of quantum innovation has occurred independent of NPL. Although other factors such as university excellence, international demand, and broader government initiatives contribute to the UK's quantum momentum, NPL remains a key enabler through bridging research, industry, and policy to ensure that domestic quantum innovation continues to thrive and scale globally. NPL's tangible contributions to research and innovation, combined with NPL's extensive involvement in other initiatives and government programmes, highlights some evidence for the causal hypothesis and limited evidence for the alternative hypothesis. Based on the process tracing tests, the posterior confidence was calculated using the Bayes formula. The results are presented in the following table.

Table 21: Contribution Claim 1 Posterior Confidence

Process Tracing Test	Prior Confidence	Posterior Confidence	Change in Confidence
Hoop	0.775	0.775	No change
Straw-in-the-Wind	0.600	0.600	No change
Smoking Gun	0.990	0.995	Increase
Doubly Decisive	0.975	0.978	Increase

Given that the posterior confidence increased from the prior confidence for half of the process tracing tests and did not change for the other half of the Process Tracing tests, the evidence presents cautious confidence in the validity of the contribution claim.

Contribution claim 2

Contribution claim 2 provides scope to assess the Programme's contribution to quantum product development, allowing for assessment of the Programme's contribution to the establishment of a domestic quantum supply chain; an increase in private investment; quantum product development; and increased commercialisation.

Table 22: Contribution Claim 2

Contribution Claim 2	The NPLQP has enabled UK companies to further develop new quantum products faster than would have occurred otherwise
Linked impacts in the ToC	• Establishment of a domestic supply chain • Private investment in quantum technologies increases • Production of high-quality quantum products • Improved UK economy at a global and regional level • Labour demands for quantum-skilled individuals is met • UK companies are more able to operate at upmost capacity
Link to EQs	• What is the direct impact of the Programme on the private sector? • What would users have done if NPL's services were not available?
Causal Hypothesis	Greater engagement with industry and provision of relevant T&E facilities leads to UK companies being able to better develop and test products. This results in greater confidence and investment in the technologies which will lead to greater commercialisation of the technology.
Alternative Hypothesis	UK quantum companies have developed new products due to factors independent of the NPLQP (e.g., increased private investment, international demand, or support from other initiatives or government programmes).

Contribution Analysis for this contribution claim highlighted some contribution of the NPLQP.

Through the Programme, NPL has significantly supported early-stage quantum companies by providing access to critical facilities and expertise, aiding in the validation and refinement of technologies and contributing to the growth of a domestic quantum supply chain. However, its engagement with the broader, tiered manufacturing supply chain and downstream end users remains limited. While NPL has played a key role in enabling companies like OQC, Quantum Motion, and CryoCoax to develop commercially viable technologies, attributing outcomes solely to NPL is challenging due to overlapping support from universities and other funding bodies. Survey data indicates that while some stakeholders credit NPL with aiding their development, there is little evidence of increased private investment or significant commercialisation directly resulting from its involvement. This is mirrored in findings from the IPSOS baseline survey, where it was found that 71% of respondents received or sought support from organisations outside of NPL – further highlighting attribution challenges.

Moreover, survey respondents highlighted that gaps remain in areas such as funding, product assurance, and demonstration opportunities, which are seen as barriers to accelerating commercial readiness. As a result, evidence for the causal hypothesis presented above is relatively limited.

Based on the Process Tracing tests; the posterior confidence was calculated using the Bayes formula. The results are presented in the following table.

Table 23: Contribution Claim 2 Posterior Confidence

Process Tracing Test	Prior Confidence	Posterior Confidence	Change in Confidence
Hoop	0.775	0.828	Increase
Straw-in-the-Wind	0.600	0.517	Decrease
Smoking Gun	0.990	0.995	Increase
Doubly Decisive	0.975	0.975	No change

Given that the posterior confidence increased from the prior confidence for half of the Process Tracing tests however did not change for one Process Tracing test and decreased for the other Process Tracing test, the evidence presents cautious confidence in the validity of the contribution claim.

Contribution claim 3

Contribution claim 3 assesses NPL's role in supporting greater and faster adoption of QT in the UK than would have occurred otherwise, incorporating an analysis of the Programme's contribution to: organisations being more able to harness QT; government becoming a first adopter of QT; increased societal awareness and acceptance of quantum; and increased adoption of quantum products.

Table 24: Contribution Claim 3

Contribution Claim 3	NPL's quantum programme has contributed to greater and faster adoption of quantum technologies in the UK than would have occurred otherwise
Linked impacts in the ToC	• Organisations are more able to harness quantum innovation • Government becomes a first adopter of quantum devices • Increased societal acceptance of quantum
Link to EQs	• What are the wider indirect impacts of the Programme on society and the economy? • What were the applications of NPL's R&D activities in spheres like health and life sciences, environment, and defence?
Causal Hypothesis	Awareness and engagement activities increase quantum literacy across society, and creation of common standards and practices for QT produce confidence in the use of QT. This leads to faster adoption of developed QT across UK society including health, life sciences, environment and defence.
Alternative Hypothesis	The UK has adopted QT due to factors independent of the NPLQP (e.g., increased private investment, developments made by other countries, global politics or due to support from other initiatives or government programmes).

Contribution Analysis for this contribution claim highlighted negligible contribution of the NPLQP.

Though NPL has indirectly strengthened the quantum ecosystem by training PhD students and apprentices who have transitioned into industry roles as well as through staff moving from NPL to quantum companies, evidence of widespread growth in awareness and engagement across society is limited. While survey data shows modest increases in R&D spending since 2020, there is limited evidence of increased commercial adoption or export activity, and progress towards ensuring that government acts as a first adopter of QT is emergent rather than systematic. Public awareness of QT also remains limited, though sector-specific outreach, such as showcases and workshops, has somewhat helped foster engagement across industries like Finance, Telecoms, and Construction (though there is no way to quantify this impact). Though NPL plays a central enabling role in the R&D and prototyping stages, lack of widespread commercial and public sector adoption, and potential for global trends in increased quantum adoption also likely contributing to trends witnessed in the UK, means limited evidence for the causal hypothesis and some evidence for the alternative hypothesis (though, isolating impact entirely from NPL is difficult).

Based on the Process Tracing tests; the posterior confidence was calculated using the Bayes formula. The results are presented in the following table.

Table 25: Contribution Claim 3 Posterior Confidence

Process Tracing Test	Prior Confidence	Posterior Confidence	Chang in Confidence
Hoop	0.775	0.807	Increase
Straw-in-the-Wind	0.600	0.600	No change
Smoking Gun	0.990	0.980	Decrease
Doubly Decisive	0.975	0.958	Decrease

Given that the posterior confidence increased from the prior confidence for one of the Process Tracing tests, however, did not change for one Process Tracing test and decreased for the other two Process Tracing tests, the evidence presents no more confidence in the validity of the contribution claim than prior to data collection.

Contribution claim 4

Contribution claim 4 assesses the Programme's role in supporting the establishment of a better equipped and connected QT landscape, allowing for analysis of the Programme's contribution towards: levelling of the global quantum ecosystem; increased sales and exports of QT; contribution to development of world leading skills; and increased UK involvement in standards development.

Table 26: Contribution Claim 4

Contribution Claim 4	NPL's quantum programme has contributed to a better equipped and connected quantum technologies landscape in the UK than would have been the case otherwise
Linked impacts in the ToC	• Global quantum playing field is levelled • Increased sales and exports of quantum technologies • The UK has world leading quantum technologies skills
Link to EQs	• What are the wider indirect impacts of the programme on society and the economy? • What were the long-term benefits, both tangible and intangible, of the programme? • What is the role and impact of the programme on upskilling the workforce? • What was NPL's role in attracting talent and businesses from overseas?
Causal Hypothesis	Through provision of better targeted test and evaluation facilities, upskilled QT researchers and workforce, and development of common standards and practices with industry input, the NPLQP has created a better-connected QT landscape with access to key facilities and services to progress QT research and product development.
Alternative Hypothesis	The QT landscape in the UK is better equipped primarily due to factors independent of the NPLQP (e.g., increased private investment or due to support from other initiatives or government programmes).

Contribution Analysis for this contribution claim highlighted negligible contribution of the NPLQP.

NPL plays a key international role in quantum standards, with NPL stakeholders active in major global committees and recognised for their leadership and technical authority. Its unique capabilities, such as single-photon detector calibration, attract international collaboration and talent and NPL significantly contributes to

UK quantum skills development through hands-on training and industry pathways. However, evidence of increased exports or commercial adoption is limited, and some areas of QT (e.g. gyroscopes and healthcare applications) are still emerging and may not yet involve NPL significantly. Other institutions – like NQCC, Innovate UK, and universities – also play major roles, and some companies have advanced independently or with alternative partners. Despite this, NPL remains a key collaborator in many national support mechanisms, restricting the ability to completely isolate impact from NPL. There is no consistent pattern of complete attribution to alternative supports either and NPL-engaged organisations tend to appear more frequently in advanced stages of development. The UK quantum ecosystem is multi-faceted and collaborative, with NPL playing a central but not exclusive role in its development. There is support for both the causal and alternative hypotheses.

Based on the Process Tracing tests; the posterior confidence was calculated using the Bayes formula. The results are presented in the following table.

Table 27: Contribution Claim 4 Posterior Confidence

Process Tracing Test	Prior Confidence	Posterior Confidence	Change in Confidence
Hoop	0.775	0.775	No change
Straw-in-the-Wind	0.600	0.517	Decrease
Smoking Gun	0.990	0.990	No change
Doubly Decisive	0.975	0.978	Increase

Given that the posterior confidence increased from the prior confidence for one of the Process Tracing tests, however, did not change for two Process Tracing tests and decreased for one Process Tracing test, the evidence presents no more confidence in the validity of the contribution claim than prior to data collection.

A.8. List of Recommendations

Performance Recommendations

Recommendation – metrics data should be collected (where applicable / appropriate) to align with Business Case KPIs that would allow for comprehensive assessment of performance against targets.

Recommendation – performance monitoring should combine descriptive statistics (e.g. number of collaborations; number of companies receiving T&E support; number of secondments and joint appointments hosted; number of apprentices hosted and sustainability metrics) with data on the impacts these have achieved.

Recommendation – risk assessment and mitigation processes should fully cover the targets and KPIs relevant to each objective area / workstream to ensure they are on track to be achieved. This would increase potential for the Programme to achieve target outcomes and – in any cases where targets are not reached – provide rationale for this.

Recommendation – the NPLQP programme should have a dedicated M&E resource.[63]

Process Evaluation Recommendations

Recommendation – To enhance its support, NPL should continue and even strengthen its linkages with other services. While organisations like NRC and PTB integrate technical services with financial support or incubator networks, similar support mechanisms already exist within the UK's broader quantum and innovation ecosystem. NPL should ensure these linked supports are effective for their client base.

Impact Evaluation Recommendations

Recommendation – NPL should widen their engagement to support the greater adoption of quantum technologies, particularly in healthcare and defence.

Recommendation – we recommend that NPL utilise its expertise and role as a convening force in quantum to lead national efforts surrounding quantum materials while ensuring alignment with semiconductor and telecoms strategies to ensure maximum relevance and impact.

Recommendation – we recommend a further summative evaluation in completed in 2-5 years after ensuring the collection of quantitative data on private investment in quantum technologies and sales and exports to more fully demonstrate NPL's impact

Economic Evaluation Recommendations

Recommendation – we recommend that NPL develop monitoring and tracking tools that can strengthen attribution of long-term economic outcomes to the Programme. Areas of focus are capturing data on private investment in QT and sales and exports that are linked to NPL activity such as patent development.

Recommendation – we recommend that NPL develop a clearer definition of 'treated' firms drawing on scale of support as well as length of time supported. This will enable identification of where NPL support may make the biggest contribution to long-term economic outcomes.

Recommendation – we recommend that given the underspend on M4Q further consideration is given by NPL to understand if this reflects lower than anticipated demand for the Programme by SMEs.

[63] The 2020-24 programme was more than half way through before an analyst was brought in to lead/develop the M&E activities

A.9. Quantum Technology Organisations Survey Methodology and Findings

Overview: We developed a quantum technology organisation survey as a follow-up to the 2023 IPSOS baseline survey with the aim of addressing relevant evaluation questions. To build on the baseline, we included additional questions on skills development and economic impacts, while retaining core questions to ensure compatibility with 2023 findings where possible. The organisations surveyed included QT providers (Quantum born), quantum supporting services, quantum end users and those in the quantum supply chain.

The survey was launched in April 2025 and remained open for 3 weeks following an initial piloting phase. Dissemination targeted both organisations supported by NPL and those not directly supported, with the original aim of enabling a comparison between the two groups. The contact database was compiled using industry contacts collected by NPL

Piloting phase: In advance of full dissemination, the survey was piloted with eight organisations, with representation across different types of organisations. Alongside completing the survey, alongside completing the survey, these organisations were asked for feedback on survey length, clarity, and applicability to different types of organisations.

Dissemination approach: We worked closely with NPL to draft an introductory email for distribution to 507 organisations which included a letter of endorsement from DSIT to strengthen credibility and encourage participation. The survey was open for 3 weeks and supported by:

- Two reminder emails sent by the evaluation team to all contacts.
- Two more targeted follow-ups coordinated by NPL for non-respondents especially to their supported firms.

Dissemination was affected by 67 email bounce backs, largely due to staff departures, incorrect email addresses, or long-term leave. To mitigate this, we drew on back-up contacts and, where necessary, conducted rapid online searches for alternative contacts. As a result, the final number of organisations successfully reached was lower than the initial distribution list.

- Total disseminated: c.492 organisations
- Total responses received: 30 responses
- Response rate: 6%

Within these 14 responses came from NPL-supported organisations and 16 from unsupported organisations.

Due to the unavailability of non-anonymised raw baseline data, it is not possible to track changes at the individual organisation level between the 2023 and 2025 surveys. Instead, we analyse responses at an aggregate level, comparing headline trends across supported and unsupported organisations.

Analysis: Due to the low response rates to the survey, the resulting sample sizes were too small to support robust quantitative analysis. As such, while we report the findings within the main body of the report to capture indicative insights, we have chosen not to present percentages (%) for the majority of question as these could be misleading or overstate the representativeness of the results. Instead, the findings are mostly discussed qualitatively, with counts provided where appropriate.

A.9.1. Summary statistics

A breakdown of the key statistics from the survey is found below:

Organisation demographic

Table 28: Organisation type per respondent

Organisation type	Number of respondents	Proportion of respondents
Research project	1	3%
Private Sector Business	21	70%
Manufacturing	1	3%
Academia	4	13%
Consulting	1	3%
Public Sector Research Establishment (PSRE)	1	3%
Association	1	3%
Total respondents	**30**	**100%**

Base=30 respondents

Note: of these 21 private sector businesses; three identified themselves as a spinout from a university or other institution

Table 29: Number of employees per organisation

Number of employees	Number of respondents
1-9	6 respondents
10-49	6 respondents
50-249	4 respondents
More than 250	5 respondents

Base= 21 respondents

Table 30: Number of employees per department

Number of employees per department	Number of respondents
1-9	17 respondents
10-49	4 respondents
More than 50	6 respondents

Base= 27 respondents

Table 31: Quantum Ecosystem Segment

Quantum segment	Number of respondents
End User (organisations applying products and services from quantum to their businesses – e.g. using quantum computing to advance drug discovery and healthcare)	6 respondents
Supply chain (suppliers of components, lasers, control systems, etc. to the technology providers)	5 respondents
Supporting services (organisations at the periphery of the quantum ecosystem - e.g. investors, patent attorneys, networking groups)	1 respondent
Technology provider ("deep tech" / "quantum born" organisations, which have most likely spun out from quantum research)	9 respondents

Base= 21 respondents

Table 32: Regional distribution of organisations

Region	Number of respondents
East of England	2 respondents
London	6 respondents
Scotland	2 respondents
South East England	9 respondents
South West England	2 respondents
West Midlands	1 respondent
Outside the UK	6 respondents
Don't know	1 respondent

Base= 29 respondents; Note: Among those who responded, 'Outside the UK', four had Headquarters in USA, one in France and one in Germany.

Table 33: Quantum Domain

Quantum Domain	Number of respondents
No quantum	1 respondent
Quantum Communication	6 respondents
Quantum Computing	7 respondents
Quantum Materials	4 respondents
Quantum Positioning/Navigation/Timing	5 respondents
Quantum Sending and Imaging	5 respondents
Quantum Technology Market Advisory	1 respondent
Quantum governance	1 respondent

Base= 30 respondents

Table 34: Scientific/Engineering areas of interaction with NPL

Scientific/Engineering area	Number of respondents
Atomic Clocks & Sensors	5 respondents
Don't know	1 respondent
Medical, Marine & Nuclear	1 respondent
National Time Scale	1 respondent
QKD	1 respondent
Quantum Computing	2 respondents
Quantum Cryptography	1 respondent
Quantum Materials and Sensors	1 respondent
Satellite and PNT	1 respondent

Base=14 respondents

Table 35: Level of interaction with NPL

NPL interactions	Number of respondents
Don't know	2 respondents
We interacted with NPL in 1-2 years out of 6 years.	5 respondents
We interacted with NPL in 3-4 years out of 6 years.	2 respondents
We interacted with NPL in 5-6 years out of 6 years.	5 respondents

Base=14 respondents

Table 36: Technology stage per respondent

Technology Stage	Number of respondents
Basic Research	1 respondent
Application-oriented basic research	1 respondent
Applied development	2 respondents
Technical prototyping	2 respondents
Commercial prototyping	1 respondent
Demonstration	1 respondent
Manufacturing / sales	1 respondent

Base= 9 respondents

Table 37: Extent of support from NPL to reach technology stage

Extent of support	Number of respondents
A great deal	4 respondents
A fair amount	4 respondents
Don’t know	3 respondents
Not very much	2 respondents
Not at all	1 respondent

Base= 14 respondents

Table 38: Did respondents seek support from other organisations apart from NPL

Did they seek support from other organisations (not NPL)	Number of respondents
Yes	24 respondents
No	3 respondents
Don’t know	3 respondents

Base= 30 respondents

Table 39: Extent of support from other organisations (not NPL)

Extent of support from other organisations (not NPL)	Number of respondents
Don't know	3 respondents
We interacted with the other support provider in 1-2 years out of 6 years.	4 respondents
We interacted with the other support provider in 3-4 years out of 6 years.	4 respondents
We interacted with the other support provider in 5-6 years out of 6 years.	13 respondents

Base= 24 respondents

Facilities

Table 40: Extent to which facilities at NPL helped the organisation in their development process

Level of agreement	Number of respondents
Strongly agree	5 respondents
Somewhat agree	3 respondents
Neither agree nor disagree	4 respondents
Somewhat disagree	0 respondents
Strongly disagree	1 respondent
Don’t know	1 respondent

Base=14 respondents

Table 41: NPL's support helped avoid wastage of resources

Level of agreement	Number of respondents
Strongly agree	7 respondents
Somewhat agree	8 respondents
Neither agree nor disagree	9 respondents
Somewhat disagree	0 respondents
Strongly disagree	1 respondent
Don't know	5 respondents

Base= 30 respondents

Table 42: NPL's support helped realise the feasibility of the project

Level of agreement	Number of respondents
Strongly agree	8 respondents
Somewhat agree	10 respondents
Neither agree nor disagree	4 respondents
Somewhat disagree	1 respondent
Strongly disagree	2 respondents
Don't know	5 respondents

Base= 30 respondents

Table 43: NPL's support helped speed up the process for reaching key milestones

Level of agreement	Number of respondents
Strongly agree	9 respondents
Somewhat agree	8 respondents
Neither agree nor disagree	5 respondents
Somewhat disagree	0 respondents
Strongly disagree	3 respondents
Don't know	5 respondents

Base= 30 respondents

Table 44: NPL's role in helping their organisation reach more collaboration partners

Extent	Number of respondents
A great deal	4 respondents
A fair amount	4 respondents
Not very much	2 respondents
Not at all	2 respondents
Don’t know	2 respondents

Base= 14 respondents

Intellectual property

Table 45: Intellectual Property owned by quantum organisations

Intellectual Property	Number of respondents
Patents	10 respondents (33%)
Copyright	4 respondents (13%)
Trade secret	10 respondents (33%)
None of the above	12 respondents (40%)

Base= 30 respondents

Table 46: Extent to which NPL helped obtain these intellectual property rights

Extent	Number of respondents
A great deal	1 respondent
A fair amount	0 respondents
Not very much	1 respondent
Not at all	5 respondents
Don’t know	1 respondent

Base= 8 respondents

Employment

Table 47: Number of employees per division in 2024

Category	1-9	10-49	More than 50	None	Prefer not to say	Don't know
Research	2	10	5	2	3	1
Technical/application division	11	3	5	0	4	2

Base= Research (23 respondents); Technical/Application (25 respondents)

Table 48: For each department, would the respondent say that the staff number have increased, decreased or stayed the same since 2020

Category	Increased a lot	Increased a little	Stayed about the same	Decreased a little	Decreased a lot	Don't know
Research	4	8	9	2	0	3
Technical/application division	3	7	9	3	0	3

Base= Research (26 respondents); Technical/Application (25 respondents)

Table 49: Extent to which the number of employees in your organisation/department would have changed without NPL support

Increased/decreased/stayed the same	Number of respondents
Increased a lot	0 respondents
Increased a little	2 respondents
Stayed about the same	8 respondents
Decreased a little	0 respondents
Decreased a lot	0 respondents
Don't know	3 respondents

Base= 13 respondents

Skills

Table 50: How easy it is for the organisations to recruit those with the right skills

Level of agreement	Number of respondents
Strongly agree	1 respondent
Somewhat agree	5 respondents
Neither agree nor disagree	4 respondents
Somewhat disagree	11 respondents
Strongly disagree	7 respondents
Don’t know	0 respondents

Base= 28 respondents

Table 51: Extent to which NPL has played a role in developing these skills

Level of agreement	Number of respondents
Strongly agree	3 respondents
Somewhat agree	6 respondents
Neither agree nor disagree	2 respondents
Somewhat disagree	0 respondents
Strongly disagree	1 respondent
Don’t know	*1 respondent*

Base= 13 respondents

Further funding (public and private)

Table 52: Responses to "To what extent, if at all, did NPL's support help with bringing in more resources to the area of quantum you work in?"

To what extent, if at all, did NPL's support help with bringing in more resources to the area of quantum you work in?	A great deal	A fair amount	Not very much	Not at all	Don't know	N/A	Total number of respondents
Research project	0	0	0	0	1	0	**1**
Private Sector Business	1	2	1	2	1	14	**21**
Manufacturing	0	1	0	0	0	0	**1**
Academia	1	0	1	0	1	1	**4**
Consulting	0	0	0	0	0	1	**1**
Public Sector Research Establishment (PSRE)	0	1	0	0	0	0	**1**
Association	0	1	0	0	0	0	**1**
Total	**2**	**5**	**2**	**2**	**3**	**16**	**30**
Private Sector Business proportion	5%	10%	5%	10%	5%	67%	100%
Academia proportion	25%	0%	25%	0%	25%	25%	1
Total proportion of respondents	**7%**	**17%**	**7%**	**7%**	**10%**	**53%**	**100%**

Base=14 respondents

Table 53: Responses to "Have you received any Innovate UK funding for your specific work on quantum?"

Have you received any Innovate UK funding for your specific work on quantum?	Yes	No	Don't know
Research project	1	0	0
Private Sector Business	7	13	0
Manufacturing	0	1	0
Academia	3	0	1
Consulting	0	1	0
Public Sector Research Establishment (PSRE)	0	1	0
Association	0	0	0
Total	**11**	**16**	**1**

Base= 28 respondents

Table 54: Responses to "Would you say that your R&D spend on quantum has increased, decreased, or stayed about the same since 2020?"

Would you say that your R&D spend on quantum has increased, decreased, or stayed about the same since 2020?	Increased a lot	Increased a little	Stayed about the same	Decreased a little	Don't know	No response	Total number of respondents
Research project	0	0	0	1	0	0	**1**
Private Sector Business	7	5	2	0	2	5	**21**
Manufacturing	0	1	0	0	0	0	**1**
Academia	1	1	1	0	1	0	**4**
Consulting	0	0	0	0	1	0	**1**
Public Sector Research Establishment (PSRE)	0	0	0	0	1	0	**1**
Association	0	0	0	0	0	1	**1**
Total	**8**	**7**	**3**	**1**	**5**	**6**	**30**
Total proportion	**27%**	**23%**	**10%**	**3%**	**17%**	**20%**	**100%**

Base=24 respondents

Commercialisation

Table 55: Responses to "To what extent, if at all, did NPL's support help with bringing in more resources to the area of quantum you work in?"

To what extent, if at all, did NPL's support help with bringing in more resources to the area of quantum you work in?	A great deal	A fair amount	Don't know	Not very much	Not at all	No response	Total number of respondents
Research project	0	0	1	0	0	0	**1**
Private Sector Business	2	2	1	1	1	14	**21**
Manufacturing	1	0	0	0	0	0	**1**
Academia	1	0	1	1	0	1	**4**
Consulting	0	0	0	0	0	1	**1**
Public Sector Research Establishment	0	1	0	0	0	0	**1**
Association	0	1	0	0	0	0	**1**
Total	**4**	**4**	**3**	**2**	**1**	**16**	**30**
Total proportion of respondents	**13%**	**13%**	**10%**	**7%**	**3%**	**53%**	**100%**

Base=14 respondents

Table 56: Responses to "When do you envisage being at the commercialisation stage (TRL level 8: actual technology completed and qualified through test and demonstration or TRL level 9: actual technology qualified through successful mission operations) for your product/ service?"

Timeline	Number of respondents
2-5 years' time	3 respondents
More than 5 years' time	1 respondent
Don't know	3 respondents

Base= 7 respondents

Table 57: NPL provisions most likely to help make commercialisation possible

Provision	Number of respondents
Reduced risk in the process for commercialisation of new products/services	1 respondent
Working with NPL accelerated progression of our products/services through the different TRL levels	2 respondents
Access to NPL's facilities	2 respondents
Benchmarking, metrics and standards	2 respondents
Engagement with NPL provided a mark of credibility	1 respondent

Base = 2 respondents; Note: respondents had the opportunity to select multiple responses, this is why the total number is greater than the base

Exports

One organisation mentioned they exported a quantum product, with 25% increase in its export value since 2020 and they somewhat agreed that this was in part due to support provided by NPL.

A.10. Propensity Score Matching approach

Purpose and justification

To improve the robustness of the comparative analysis of fundraising outcomes, a Propensity Score Matching (PSM) approach was used to construct a more comparable control group of non-supported firms. This method addresses the limitations of simple descriptive comparisons by reducing observable bias and aligning the treatment and control groups on key firm characteristics.

A second comparative analysis was therefore undertaken using PSM to identify a matched subset of quantum firms who provide a closer approximation to what the outcomes for NPL-supported firms might have looked like in the absence of support. This matched control group includes quantum firms that did not receive NPL support but are statistically similar by size, improving the credibility of any performance comparisons.

While the current data environment limits our ability to robustly estimate causal impacts - particularly in terms of firm-level performance uplift directly attributable to quantum activities or NPL support - the matching exercise lays critical groundwork for future analysis. The resulting matched sample enables more meaningful indicative comparisons and offers a statistically balanced baseline from which to explore differential fundraising patterns between treated and control groups.

Variable selection

The variable selection for the matching algorithm was guided by the objective of controlling for firm size at baseline, prior to the start of the NPLQP. Firm size is a key confounding factor likely to influence both the probability of receiving NPL support and the capacity to raise equity funding.

To operationalise this, turnover data for the financial year ending in 2019 was extracted from Beauhurst financial statements for both the treatment (NPL-supported firms) and potential control groups. Turnover was selected as the primary matching variable due to its availability and consistency across a large share of firms, relative to other potential indicators.

While additional firm characteristics - such as number of employees, company age, and investment history - were considered, these were excluded from the matching specification due to incomplete or inconsistent data coverage. More granular indicators of firm size, such as employment or asset values, could have provided a more comprehensive basis for controlling for scale. However, such data were either unavailable for a significant portion of the sample or not reliably attributable to the quantum-related activities of the firms. Many of the firms included in the dataset have long operational histories and operate across multiple sectors or divisions, making it difficult to isolate characteristics - such as sector classification or firm age - that are specifically relevant to their quantum activities. As matching specifications are ideally grounded in economic reasoning and firm-level context, the inclusion of such ambiguous or non-specific variables was not pursued in this iteration of the analysis.

As such, the matching model takes a parsimonious approach, using 2019 turnover as the key covariate to align treatment and control groups on pre-programme firm size. This provides a reasonable first step in controlling for observable scale differences, but it is recognised that matching could be strengthened in future analyses with more complete baseline data.

7.1.1 Matching specification

Prior to undertaking the matching exercise, the dataset was filtered to include only firms - both treated and untreated - with available turnover data for the year 2019. This step ensures that all units included in the matching process have a common baseline measure of firm size prior to the start of the NPL support programme. Applying this filter reduced the eligible sample from the original 86 treated firms and 686 non-treated quantum firms to 35 treated and 316 untreated firms.

The matching algorithm was implemented using the MatchIt package in R, with the following specification:

Table 58: Initial matching specification

	Specification
Method	nearest
Caliper	0.2[64]
Ratio	1
Replace	TRUE
Model	Logit
Exact	SIC2007

This configuration applies nearest-neighbour matching with replacement and a 1:1 ratio, meaning each treated firm is matched to the most similar control firm in terms of propensity score, with the option for control firms to be matched more than once. A caliper of 0.2 was applied to prevent poor matches by restricting the maximum allowed difference in propensity scores between matched units.

The model used to estimate the propensity score is a **logit regression**, which assumes a logistic cumulative distribution function (CDF) to estimate the probability of treatment assignment based on observed covariates. This is a commonly used specification in Propensity Score Matching due to its interpretability, computational stability, and robust performance across a range of sample sizes. While a probit model - which assumes a normal CDF - can be used as an alternative, the logit model was chosen in this case as it is more standard in applied evaluation settings and provides comparable results with easier interpretation. Given the binary treatment assignment and the continuous nature of the turnover variable, the logit model was deemed appropriate.

The 1:1 ratio was selected as a baseline specification to prioritise tighter matches between treated and control units, reducing the risk of dilution from less comparable firms. This is especially important in small samples, where higher-ratio matching may introduce additional bias if weaker matches are included. However, due to the limited number of treated observations (35), matching with replacement was enabled to maximise the usable control pool and reduce the loss of treated firms due to caliper constraints.

While the specification is intentionally simple - with turnover as the sole matching variable - this reflects both the strategic emphasis on controlling for firm size and the constraints imposed by data availability. The result is a matched sample that provides a credible foundation for indicative comparisons between NPL-supported and non-supported firms, recognising that further refinements would require more complete baseline data across multiple variables.

[64] See Austin, P.C., 2011. Optimal calliper widths for propensity-score matching when estimating differences in means and differences in proportions in observational studies. *Pharmaceutical statistics*, 10(2), pp.150–161. It suggests the optimal calliper width should be obtained by multiplying the logit model standard deviation by 0.2.

Matching assessment

An initial 1:1 matching model was implemented to compare NPL-supported firms to a tightly matched counterfactual group. While the covariate match quality was strong, the resulting sample had very limited coverage for fundraising activity, with zero matched control firms reporting fundraising in any year between 2020 and 2024. This was despite 8 treated firms having fundraising observations each year, as shown below:

Table 59: Fundraisings figures for matched sample with ratio 1:1

Year	Treated firms with fundraising	Matched control firms with fundraising
2020	8	0
2021	8	0
2022	8	0
2023	8	0
2024	8	0

This made the initial matched sample unsuitable for any meaningful statistical comparison of fundraising outcomes. The lack of fundraising data among matched controls likely reflects differences in how Beauhurst tracks fundraising versus financial accounts: while turnover data is widely reported for more established companies, Beauhurst focuses more intensively on early-stage, high-growth firms for its fundraising coverage. As such, larger, mature firms with available turnover data may not have fundraising data captured unless flagged as "innovative" or "investment-active" in the platform's taxonomy.

To address the issue of data scarcity, a second model was estimated using 1:10 matching with replacement - allowing each treated firm to be matched to up to ten control firms. This approach significantly increased the number of control observations in the matched sample while preserving the structure of the propensity score match. In practical terms, this means treated firms are compared not to a single peer, but to a broader distribution of similar firms, improving the coverage of fundraising data at the cost of match precision.

The final matched sample under this model comprised:

- 34 treated firms
- 187 matched control firms

Table 60: Looser matching specification approach

	Specification
Method	nearest
Caliper	0.2[65]
Ratio	***10***
Replace	TRUE
Model	Logit
Exact	SIC2007

Key matching statistics and diagnostics from the 1:10 model show that covariate balance was still achieved:

- 0 covariates with standardised mean difference (SMD) > 0.05, indicating no significant imbalance between groups

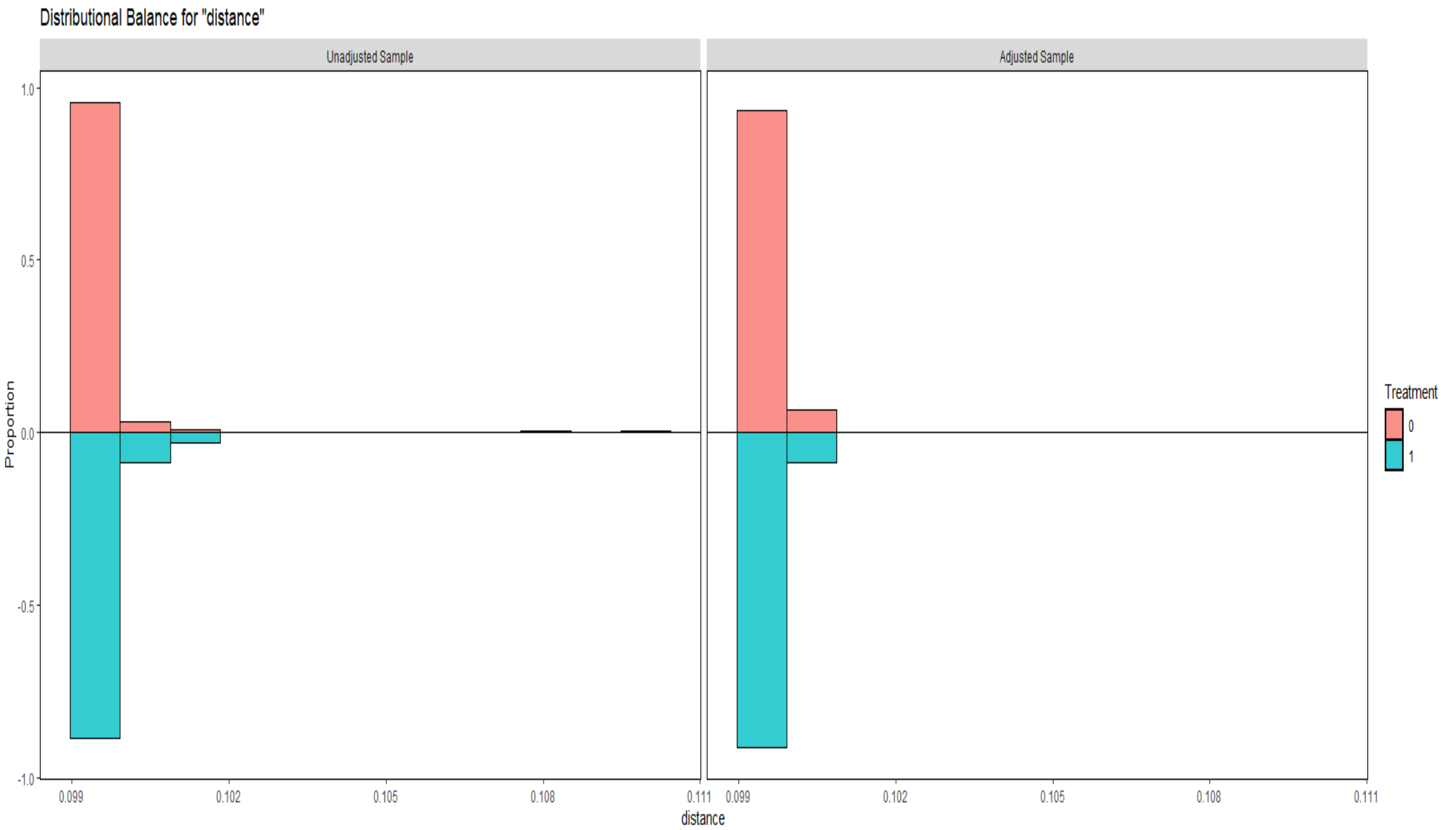
[65] See Austin, P.C., 2011. Optimal calliper widths for propensity-score matching when estimating differences in means and differences in proportions in observational studies. *Pharmaceutical statistics*, 10(2), pp.150–161. It suggests the optimal calliper width should be obtained by multiplying the logit model standard deviation by 0.2.

- **0 covariates with variance ratio outside [0.5, 1.5]**, confirming consistency in covariate distributions
- **Mean variance ratio:** 1.08, indicating close dispersion between treated and control groups
- **Mean empirical CDF distance (eCDF.Mean):** 0.0086, suggesting excellent distributional overlap
- **Mean squared residual deviance (model MSE):** 0.649 - indicating good model fit for a single-covariate logit specification

Matching Quality Visualisation

While the above are good metrics to follow to assess the goodness of a matching approach, the graphical visualisation nis usually the most intuitive way to assess whether the matching has helped bringing characteristics of the two samples closer to each other. The plot below shows distributional balance before and after matching. The adjusted sample shows a tight overlap in propensity scores (distance), suggesting the two groups are statistically comparable on observed turnover:

Figure 11: Distributional balance for "distance"



Finally, while the 1:10 model resolves the issue of fundraising data availability, it comes with limitations:

- The matching is based solely on 2019 turnover, which, while a good proxy for firm size, may not align with a firm's fundraising behaviour, particularly if that turnover comes from long-standing divisions unrelated to quantum innovation.
- Some matched firms are large, diversified organisations, which may not be flagged as investment-active by Beauhurst due to the platform's focus on high-growth, early-stage firms.
- This creates a definitional mismatch: turnover data reflects the entire business, while fundraising data may only be tracked for select subsidiaries or not at all.

Future improvements should aim to source more targeted investment data at the department or business unit level - specifically isolating quantum-related fundraising activity. This would enable a cleaner comparison of financial inputs into quantum innovation across firms and allow for more meaningful evaluation of the role NPL support plays in driving those investments.

Matched sample composition

This section presents a breakdown of fundraising activity across the matched sample of firms, disaggregated by treatment group (NPL-supported vs. control) and sectoral focus. We distinguish between firms operating in quantum computing, atomic clocks, and quantum networks (CCN), and those in other QT areas.

The data shows limited observable patterns due to the small number of fundraising records per year. For instance, most matched control group firms in the "Quantum computing, Atomic clocks, Quantum networks" category reported no fundraising across all years. Meanwhile, a small number of NPL-supported firms in this category showed activity in earlier years (2020–2022), but the dataset does not include values for 2023–2024, reducing confidence in any trends.

The very low number of observations - especially for the CCN category within the control group - limits the extent to which conclusions about additionality or programme influence can be drawn. This highlights a key caveat: while the matched sample improves comparability, it does not provide enough coverage to robustly attribute differences in performance to NPL support.

Nonetheless, early signals suggest that some NPL-supported firms in non-CCN quantum areas may have raised comparatively larger individual fundraises, particularly in 2023. Further research and expanded datasets would be required to verify these patterns and assess whether NPL support had a sustained influence on commercial performance across different quantum sub-sectors.

Table 61: Fundraising activity by group and quantum sector (matched sample, 2020–2024)

Group	Sector	Year	Count	Total	Median
Control group	Quantum computing, Atomic clocks, Quantum networks	2020	N/A	N/A	N/A
Control group	Quantum computing, Atomic clocks, Quantum networks	2021	N/A	N/A	N/A
Control group	Quantum computing, Atomic clocks, Quantum networks	2022	N/A	N/A	N/A
Control group	Quantum computing, Atomic clocks, Quantum networks	2023	N/A	N/A	N/A
Control group	Quantum computing, Atomic clocks, Quantum networks	2024	N/A	N/A	N/A
Control group	Other quantum categories	2020	1	8,235,898	8,235,898
Control group	Other quantum categories	2021	1	9,625,000	9,625,000
Control group	Other quantum categories	2022	N/A	N/A	N/A
Control group	Other quantum categories	2023	2	22,027,470	11,013,735

Group	Sector	Year	Count	Total	Median
Control group	Other quantum categories	2024	N/A	N/A	N/A
NPL-supported Firms	Quantum computing, Atomic clocks, Quantum networks	2020	1	34,058,215	34,058,215
NPL-supported Firms	Quantum computing, Atomic clocks, Quantum networks	2021	1	2,861,673	2,861,673
NPL-supported Firms	Quantum computing, Atomic clocks, Quantum networks	2022	1	10,696,868	10,696,868
NPL-supported Firms	Quantum computing, Atomic clocks, Quantum networks	2023	N/A	N/A	N/A
NPL-supported Firms	Quantum computing, Atomic clocks, Quantum networks	2024	N/A	N/A	N/A
NPL-supported Firms	Other quantum categories	2020	1	13,000,000	13,000,000
NPL-supported Firms	Other quantum categories	2021	2	71,022,450	35,511,225
NPL-supported Firms	Other quantum categories	2022	2	31,683,191	15,841,595
NPL-supported Firms	Other quantum categories	2023	2	163,414,552	81,707,276
NPL-supported Firms	Other quantum categories	2024	N/A	N/A	N/A

A.11. International Comparator Analysis

This appendix contains a full international comparator analysis of the UK's NPL in relation to four leading national metrology institutes: Germany's Physikalisch-Technische Bundesanstalt (PTB), the United States' National Institute of Standards and Technology (NIST), Canada's National Research Council (NRC), and Denmark's Danish Fundamental Metrology (DFM). The analysis explores each institute's funding model and its role in skills development, standards setting, commercialisation support and their impact on their respective quantum markets.

NRC (Canada)

Table 62: Comparative analysis – NRC

Comparison Area	NPL	NRC (Canada)
Funding model and governance	NPLQP is part of the NQTP – a billion-pound programme involving government, academia and industry to maximise UK economic growth and increase security and resilience through the exploitation of quantum technologies. The £39 million ring-fenced funding, provided by core funding from DSIT, is distributed across three main pillars: (1) QT&E Programme, which includes capital investment in facilities and equipment; (2) collaborative projects aligned with the EPSRC Quantum Technology Research Hubs; and (3) participation in grant-funded initiatives such as the ISCF and the QTFP programme. The purpose of the NPL within the NQTP was to focus on product validation, standards and skills for testing and evaluation to accelerate the transition of quantum technologies from laboratory research to market-ready products and services.	The NRC receives nearly CAN$1 billion annually from the Canadian federal government, including funding for its Industrial Research Assistance Program (IRAP). Funding is allocated to research centres through two mechanisms: • A-base funding: Provides stable, recurring core operational funding. • B-base funding: Offers time-limited resources targeted at strategic initiatives, such as the National Quantum Strategy (2023), which funds challenge-led quantum programmes. Funding is non-ring fenced, allowing resources to be distributed across centres based on project needs- particularly in cross-cutting areas like quantum and nanotechnology, metrology and digital technologies. Challenge Programme Funding: combines internal operational funds with external partnership contributions (e.g. from NSERC or industry). A notable example is the Quantum Sensors Challenge Programme, which successfully secured NSERC co-funding of CAN$ 6 million for both universities and SMEs[66]. Other examples of funding received for NRC Quantum Research includes the Quantum Research for Departmental Innovation (QRDI) initiative which has allocated CAN$9 million over 5 years to support quantum research across Canadian government departments.

Skills Development	NPL plays a strategic and multifaceted role in building the UK's quantum skills base, acting as an intermediary between academia, industry, and government. Its activities span formal education, applied training, international collaboration, and responsive workforce development.
	
	NPL embeds training within active quantum research and metrology projects, providing early-career scientists, PhD students, and visiting researchers with hands-on experience:
	• PGI: Enables students to pursue PhDs in collaboration with universities while working on real-world quantum challenges at NPL.
		The NRC is actively shaping Canada's future quantum workforce and recognises the need for education reform to support this transition. Its strategic activities include:
		• Early-stage STEM promotion: Encouraging quantum-related skills from primary and secondary education.
		• Higher education reform:
		  ○ Supporting joint physics-engineering degree programmes.
		  ○ Providing entrepreneurship training tailored to quantum technologies.
		Rather than operating formal training programmes, the NRC embeds skills development within collaborative R&D projects, particularly via challenge-led initiatives. Key mechanisms include:

[66] Interview with senior NRC representative (09.05)

Comparison Area	NPL	NRC (Canada)
	• ‘PhD at Work’ scheme: Offers a full-time, in-house research environment aligned with doctoral studies. • Secondments and placements: Host UK and international early-career researchers, including through collaborations with institutes like NIST. NPL also supports skills development across career stages: • Runs apprenticeship programmes that train technicians in optical, electronic, and quantum measurement techniques. • Provides continuous professional development for technical staff to adapt to evolving demands in quantum instrumentation and standards. NPL delivers school visits, talks, and summer placement schemes for undergraduates. These aim to build awareness and early interest in quantum science and metrology careers. Advanced Quantum Metrology Laboratories (AQML) also serve as a base for training in practical measurement science using cutting-edge equipment, thereby directly supporting hands-on learning for trainees. Between 2020-2024, there was between 31-49 PhD students supported by the NPLQP.	Highly Qualified Personnel (HQP) finding, supporting graduates and postdoctoral researchers. NRC projects are often delivered in collaboration with universities and SMES, integrating HQPs directly into applied quantum research. There are other national programmes which support talent pipelines these include MItacs and NSERC CREATE. A major theme within the NRC is the coordination of quantum talent pipelines between academia and industry. Professional master’s programmes have also been developed, co-designed by industry at the University of Calgary which exemplify this approach[67].
Standards setting	NPL is an active contributor to key global standardisation bodies: • Participates in ISO/IEC JTC 1/WG 14 and ITU, ETSI and contributes to European Metrology Network for Quantum Technologies to shape standards on quantum information technologies. • Contributed to the CEN-CENELEC Focus Group on Quantum Technologies (FGQT) roadmap, outlining European priorities for quantum standardisation. NPL experts were involved in all roadmap sections, and the work now feeds into the formal CEN/CLC/JTC 22 committee. • Actively explores an NMI-led approach to standards development in quantum photonics with NIST, INRIM, and NRC, including proposals for cross-Atlantic “Measurement Clubs” with QED-C and QuIC	NRC serves as Canada’s national measurement institute[69], playing a central role in developing and maintaining standards for emerging technologies, including quantum. It maintains Canada’s realizations of the International System of Units (SI), develops new quantum measurement standards to support interoperability, secure communications, and device benchmarking, and collaborates globally to align with international metrology systems. While NRC does not have a formal mandate to lead standards development, it actively participates through the Standards Council of Canada (SCC), which forms mirror committees aligned with ISO/IEC. NRC ensures representation in key standardisation efforts, including through the JTC 3 Mirror Committee on quantum technologies. However, participation is unfunded, creating internal resource challenges[70]. To address national coordination needs, NRC is launching the National Metrology Institute Quantum (NMIQ) initiative to align quantum

[67] https://cca-reports.ca/wp-content/uploads/2024/03/Quantum-Potential_Full-Report_March-1-2024.pdf
[69] NRC 2024–2029 Strategic Plan

[70] Interview with senior NRC representative (09.05)

Comparison Area	NPL	NRC (Canada)
	NPL is a key player in developing the measurement science foundations required before formal standards are feasible ie the pre-normative work: • Developed traceable calibration techniques for fibre-coupled single-photon detectors, underpinning trust in QKD systems and quantum sensing. • Participates in MetSuperQ, supporting benchmarking and metrology for superconducting qubits and cold electronics. • Works on graphene-based resistance standards and quantum Hall devices via projects like QuAHMET, contributing to the next generation of electrical metrology. NPL conducts bilateral and multilateral comparisons to harmonise standards globally: • Regular metrology exchange with NIST including through forums such as IMEKO TC25 on single-electron and single-photon technologies; includes detector calibration comparisons and work on randomness beacons and quantum networks. • Organised joint workshops and secondments to develop consistent approaches across national metrology institutes (e.g., for single-electron devices and SNSPDs). NPL also plays a key role in leading the Quantum Standards Network Pilot which is aiming to coordinate UK industry, academia and government stakeholder such as DSIT, UKQuantum, BSI, NCSC and NQCC) around shared national quantum standards priorities and providing early engagement with international efforts[68].	metrology efforts and support pre-normative work underpinning future standards[71]. It also works with international partners such as the UK's NPL – "There is a shared recognition that robust measurement science is essential for credible standards"[72] NRC's quantum testbeds support interoperability testing, aiding both commercial readiness and international alignment. Recognising that industry involvement in standards remains limited due to early-stage market development, NRC integrates standards components into challenge programmes (e.g., quantum internetworking) to: • Build industry awareness and engagement with standards; • Support commercialisation through alignment with emerging norms.
Commercialisation support	Measurement for Quantum (M4Q) programme has provided rapid, bespoke metrology services for 50 SMEs, enabling them to validate device performance, characterise materials, and refine prototypes. Several companies receiving M4Q support have reported successful funding rounds following NPL's involvement (e.g. Intrinsic Semiconductor raised £7m). By helping firms evidence performance, NPL builds investor	NRC plays a central role in supporting commercialisation of quantum and other advanced technologies, primarily through the Industrial Research Assistance Program (IRAP). IRAP supports around 10,000 Canadian firms annually[73], offering: • Up to CAN$10 million in funding for eligible SMEs; • Guidance from Industrial Technology Advisors (ITAs); • Support with IP strategy and business networking.

68 Network Pilot - NPL
71 Interview with senior NRC representative (09.05)
72 Interview with senior NRC representative (09.05)

73 NRC 2024–2029 Strategic Plan

<table>
<tr><th>Comparison Area</th><th>NPL</th><th>NRC (Canada)</th></tr>
<tr><td></td><td>confidence and increases technology adoption readiness.

Clients span photonics, quantum computing, and sensing startups; for instance, Intrinsic Semiconductor Technologies used NPL services to characterise memristive devices for low-power quantum circuits.

NPL engages in joint innovation projects with companies under programmes like A4I (Analysis for Innovators). Examples include:
Electrical measurements of graphene-cement composites with First Graphene.
Development of microwave resonator technology for non-contact characterisation of 2D materials, demonstrated with firms like DZP Technologies and Paragraf.
One customer reported that “NPL provided specialist measurement, calibration, and independent validation which would have been unaffordable and unavailable elsewhere.”

NPL also supports innovation translation through government-funded Knowledge Asset Grants (e.g. developing a quantum Orbitrap mass spectrometer in partnership with industry).

Facilities like the AQML provide traceable, high-specification environments for real-world testing and calibration of quantum components.

NPL also leads QT&E activities to help companies validate emerging technologies against reference systems and benchmarks. QT&E services are structured to help firms:
Confirm performance under controlled, traceable conditions.
Meet procurement and investor requirements.
Prepare for integration into standards or regulatory frameworks.
QT&E has been applied to QKD systems (e.g. ID Quantique, Toshiba) and superconducting platforms.</td><td>IRAP helps de-risk adoption of quantum computing and quantum sensing technologies across key sectors such as healthcare, defence, and the environment. Its support includes algorithm development, cloud access, and secure quantum communication infrastructure—laying the groundwork for a Canadian quantum internet. Challenge programmes form a second major pillar of commercialisation support. These initiatives:
Facilitate collaborative R&D between SMEs, academia, and NRC;
Help advance technologies toward market readiness;
Have supported successful spinouts, notably via the Quantum Sensors Challenge Programme.
NRC also offers specialised technical services through its Research Centres to help businesses solve product design and adoption issues. These include calibration, prototyping, demonstrations, certifications, and scale-up support.
Additional enablers include:
A robust IP and patenting strategy: 267 patents filed and 606 licensed in 2022–23;[74]
Ongoing scientific output: NRC’s Quantum and Nanotechnologies team has produced 182 publications and 63 attachments[75];
Strategic linkages with standards development, ensuring alignment of commercial offerings with emerging international norms.</td></tr>
<tr><td>Quantum market Expansion</td><td>NPL plays a critical role in helping quantum SMEs transition from research to market by offering trusted technical expertise, independent validation, and access to advanced infrastructure. Its support has been</td><td>NRC supports Canadian SMEs in niche, high-value areas such as dilution refrigeration, launching challenge calls to drive the development of compact, commercial-ready quantum infrastructure</td></tr>
</table>

[74] NRC 2024–2029 Strategic Plan
[75] Statistics - NRC Publications Archive - Canada.ca

Comparison Area	NPL	NRC (Canada)
	especially valuable for early-stage firms, helping to de-risk innovation, accelerate development, and build investor confidence. The Measurement for Quantum (M4Q) programme has supported 50 companies, 80% of which were new to NPL, indicating success in expanding engagement. M4Q has contributed to: • 30 new or improved products, 11 new processes, and 3 new services • Increased sales (18 firms), cost savings (10), and additional investment (22) • Strong willingness to pay for future services (rising from 59% to 97%) Case studies (e.g. OQC, Quantum Motion, Paragraf) show how NPL's guidance enabled lab setup, prototype validation, and commercial growth. Survey data supports this: • 61% of companies said NPL helped realise project feasibility • 57% avoided wasted resources • 57% accelerated key milestones • 63% gained new partnerships NPL also enables market access through its standards leadership, helping firms demonstrate compliance in emerging international markets—an essential foundation for scaling. However, market expansion beyond the quantum sector remains limited. Despite a national base of 804 quantum-aligned companies, only 86 have engaged with NPL to date. While wider sector uptake (e.g. healthcare, defence) is anticipated, evidence of realised cross-sector impact remains modest so far. Still, NPL's position as a trusted technical authority and its contribution to new product development, investment readiness, and early ecosystem connectivity confirm its importance in expanding the UK quantum market.	(e.g., tabletop dilution fridges[76]). It also promotes patent collectives and IP strategies to help SMEs scale and manage risk in a dynamic tech environment. NRC's efforts span: • Academic hubs (e.g., IQC, Université de Sherbrooke), • Leading Canadian firms (e.g., Xanadu, D-Wave, Photonic), and • Cross-government and international partnerships, to coordinate national growth. Although not a policy-making body, NRC provides technical and strategic advice to the Department for Innovation, Science and Economic Development (ISED) and other government departments to shape national strategy[77]. It identifies: • Ecosystem needs; • Capability gaps; • High-impact growth areas (e.g., quantum computing, comms, sensing); • Enabling technologies such as photonics, microelectronics, and AI. NRC coordinates interdepartmental committees at DG and ADM levels, engaging: • Natural Resources Canada, Defence, Public Safety, • Communications Security, and Environment & Climate Change Canada. The aim is to foster cross-government collaboration and strategic alignment on quantum opportunities. NRC also partners with Quantum Industry Canada and supports awareness-raising initiatives like Quantum Now, a national event showcasing Canadian quantum firms (analogous to the UK's Quantum Showcase) to attract international attention and investment[78].

[76] https://cca-reports.ca/wp-content/uploads/2024/03/Quantum-Potential_Full-Report_March-1-2024.pdf
[77] Interview with NRC representative (09.05)
[78] Interview with NRC representative (09.05)

DFM (Denmark)

Table 63: Comparative analysis - DFM

Comparison Area	NPL	DFM (Denmark)
Funding model and governance	NPLQP is part of the NQTP – a billion-pound programme involving government, academia and industry to maximise UK economic growth and increase security and resilience through the exploitation of quantum technologies. The £39 million ring-fenced funding, provided by core funding from DSIT, is distributed across three main pillars: (1) QT&E Programme, which includes capital investment in facilities and equipment; (2) collaborative projects aligned with the EPSRC Quantum Technology Research Hubs; and (3) participation in grant-funded initiatives such as the ISCF and the QTFP programme. The purpose of the NPL within the NQTP was to focus on product validation, standards and skills for testing and evaluation to accelerate the transition of quantum technologies from laboratory research to market-ready products and services.	DFM operates on a hybrid funding model, combining: • Approx. 50% government funding (DKK 28 million in 2022) • Approx. 50% from commercial revenue and competitive project funding, including contributions from EU and Danish research programmes[79]. In 2022, DFM's total revenue reached DKK 46.7 million, with DKK 9.7 million derived from commercial activity—reflecting a strong public-private funding balance[80]. Commercial revenue is a core expectation, supplementing non-comprehensive government support. DFM defines commercial revenue as any transaction where it sets pricing and issues quotes, encompassing: • Calibration services (a core, long-standing income stream), • Sales of quantum-related measurement instruments, • R&D services for industries such as pharmaceuticals. Sales activity grew strongly in the past year, with a 40% increase in overall commercial revenue. By contrast, activities priced externally are classified as project funding[81]. DFM owns all its intellectual property and functions as a private nonprofit—meaning all profits are reinvested into the organisation, and no profit can be extracted by owners.
Skills Development	NPL plays a strategic and multifaceted role in building the UK's quantum skills base, acting as an intermediary between academia, industry, and government. Its activities span formal education, applied training, international collaboration, and responsive workforce development. NPL embeds training within active quantum research and metrology projects, providing early-career scientists, PhD students, and visiting researchers with hands-on experience: • PGI: Enables students to pursue PhDs in collaboration with universities while working on real-world quantum challenges at NPL.	DFM does not position itself as a general training provider, nor does it offer formal training programmes for universities or industry. However, it contributes to workforce development through targeted, collaborative mechanisms: • Government-commissioned initiatives: In response to industry-identified skills gaps, DFM trained teachers at Danish trade schools to enhance basic-level metrology competencies—critical for improving technician readiness and industrial capability. • Collaborative knowledge transfer: DFM supports skills development by: ○ Participating in joint R&D projects with Danish universities and commercial firms;

[79] Interview with DFM representative (27.05)
[80] https://dfm.dk/wp-content/uploads/2023/05/DFM_Annual_Report_2022_FINAL.pdf
[81] Interview with DFM representative (27.05)

Comparison Area	NPL	DFM (Denmark)
	• 'PhD at Work' scheme: Offers a full-time, in-house research environment aligned with doctoral studies. • Secondments and placements: Host UK and international early-career researchers, including through collaborations with institutes like NIST. NPL also supports skills development across career stages: • Runs apprenticeship programmes that train technicians in optical, electronic, and quantum measurement techniques. • Provides continuous professional development for technical staff to adapt to evolving demands in quantum instrumentation and standards. NPL delivers school visits, talks, and summer placement schemes for undergraduates. These aim to build awareness and early interest in quantum science and metrology careers. Advanced Quantum Metrology Laboratories (AQML) also serve as a base for training in practical measurement science using cutting-edge equipment, thereby directly supporting hands-on learning for trainees. Between 2020-2024, there was between 79 PhD students supported by the NPLQP.	○ Co-developing new services and competencies through long-term collaborations (typically 3–4 years); ○ Using these collaborations as channels for industrial knowledge transfer, rather than delivering standardised training.
Standard Setting	NPL is an active contributor to key global standardisation bodies: • Participates in ISO/IEC JTC 1/WG 14 and ITU, ETSI and contributes to European Metrology Network for Quantum Technologies to shape standards on quantum information technologies. • Contributed to the CEN-CENELEC Focus Group on Quantum Technologies (FGQT) roadmap, outlining European priorities for quantum standardisation. NPL experts were involved in all roadmap sections, and the work now feeds into the formal CEN/CLC/JTC 22 committee. • Actively explores an NMI-led approach to standards development in quantum photonics with NIST, INRIM, and NRC, including proposals for cross-Atlantic "Measurement Clubs" with QED-C and QuIC NPL is a key player in developing the measurement science foundations required before formal standards are feasible ie the pre-normative work:	DFM's core mission is the development and maintenance of national and international measurement standards, ensuring Danish calibration services remain globally recognised and scientifically rigorous. Key achievements include: • Establishing a national atomic clock (Maser) and linking Denmark's timekeeping system to UTC, supporting sectors like finance and telecoms that require precise timestamping. • Verifying international fixed-point temperature calibrations in collaboration with Sweden's RISE, including high-precision benchmarks. • Operating a quantum test centre to develop measurement methods and test components for quantum encryption and sensing technologies. National and International Standardisation Role DFM holds the national responsibility for quantum standardisation in Denmark and leads the Danish Standards Organisation's quantum metrology group, chaired by Michael Kjær. It also engages in international standards forums, collaborating with global metrology leaders such as NPL (UK), US

Comparison Area	NPL	DFM (Denmark)
	• Developed traceable calibration techniques for fibre-coupled single-photon detectors, underpinning trust in QKD systems and quantum sensing. • Participates in MetSuperQ, supporting benchmarking and metrology for superconducting qubits and cold electronics. • Works on graphene-based resistance standards and quantum Hall devices via projects like QuAHMET, contributing to the next generation of electrical metrology. NPL conducts bilateral and multilateral comparisons to harmonise standards globally: • Regular metrology exchange with NIST including through forums such as IMEKO TC25 on single-electron and single-photon technologies; includes detector calibration comparisons and work on randomness beacons and quantum networks. • Organised joint workshops and secondments to develop consistent approaches across national metrology institutes (e.g., for single-electron devices and SNSPDs). NPL also plays a key role in leading the Quantum Standards Network Pilot which is aiming to coordinate UK industry, academia and government stakeholder such as DSIT, UKQuantum, BSI, NCSC and NQCC) around shared national quantum standards priorities and providing early engagement with international efforts[82].	institutions, and other national metrology bodies, with recent participation in global standards meetings, including in Japan. Strategic Positioning in Emerging Quantum Standards Quantum standardisation remains nascent, with many technologies not yet fully defined. DFM plays a proactive role in raising awareness, urging early industry engagement to ensure Danish companies are not left behind as standards begin to shape global quantum markets. To reinforce this, DFM has: • Secured additional base funding from the Danish government to support its quantum standardisation activities. • Taken on an advocacy and education role to encourage early-stage involvement, addressing private-sector hesitation stemming from short-term priorities.
Commercialisation support	Measurement for Quantum (M4Q) programme has provided rapid, bespoke metrology services for 50 SMEs, enabling them to validate device performance, characterise materials, and refine prototypes. Several companies receiving M4Q support have reported successful funding rounds following NPL's involvement (e.g. Intrinsic Semiconductor raised £7m). By helping firms evidence performance, NPL builds investor confidence and increases technology adoption readiness. Clients span photonics, quantum computing, and sensing startups; for instance, Intrinsic Semiconductor Technologies used NPL services to characterise memristive devices for low-power quantum circuits.	DFM plays a key role in enabling quantum innovation and commercial readiness in Denmark by focusing on calibration infrastructure, enabling technologies, and support for quantum hardware firms. It does not invest directly in companies, but instead provides facilities, services, and partnerships that de-risk development and accelerate market entry. Core commercialisation support mechanisms include: • Advanced calibration services: Widely used by SMEs and large enterprises, traceable to primary standards. DFM recently developed an electrolytic conductivity calibration system in response to user demand, offering precise, reproducible calibration across a broader range for industries like

82 Network Pilot - NPL

Comparison Area	NPL	DFM (Denmark)
	NPL engages in joint innovation projects with companies under programmes like A4I (Analysis for Innovators). Examples include: • Electrical measurements of graphene-cement composites with First Graphene. • Development of microwave resonator technology for non-contact characterisation of 2D materials, demonstrated with firms like DZP Technologies and Paragraf. One customer reported that “NPL provided specialist measurement, calibration, and independent validation which would have been unaffordable and unavailable elsewhere.” NPL also supports innovation translation through government-funded Knowledge Asset Grants (e.g. developing a quantum Orbitrap mass spectrometer in partnership with industry) Facilities like the Advanced Quantum Metrology Laboratory (AQML) provide traceable, high-specification environments for real-world testing and calibration of quantum components. NPL also leads QT&E activities to help companies validate emerging technologies against reference systems and benchmarks. QT&E services are structured to help firms: • Confirm performance under controlled, traceable conditions. • Meet procurement and investor requirements. • Prepare for integration into standards or regulatory frameworks. QT&E has been applied to QKD systems (e.g. ID Quantique, Toshiba) and superconducting platforms.	environmental monitoring and chemical manufacturing. • Quantum Test Center: Provides a platform for testing, validation, and prototyping of quantum devices. Also serves as a launchpad for start-ups and is being positioned as a European hub for quantum metrology and validation[83]. • Quantum House Denmark: A €24 million government-funded initiative providing[84]: o Office and lab space for quantum start-ups, o Facilities for testing, validation, and improvement of quantum products, o A model where companies pay rent/fees to access infrastructure, o A focus on reducing risk and fostering university-industry collaboration. • Global commercial product line: DFM develops and exports quantum measurement instruments (e.g., for quantum computing, QKD, and sensors), differentiating itself from local competitors through international orientation. Strategic Positioning: • DFM supports commercialisation by focusing on hardware and metrology, not quantum software. • It enables, rather than directs, quantum commercialisation—providing critical infrastructure but not targeting sector-specific use cases (e.g., in healthcare or transport).

[83] Interview with DFM representatives (27.05)
[84] Interview with DFM representatives (27.05)

PTB (Germany)

Table 64: Comparative analysis – PTB

Comparison Area	NPL	PTB (Germany)
Funding model and governance	NPLQP is part of the NQTP – a billion-pound programme involving government, academia and industry to maximise UK economic growth and increase security and resilience through the exploitation of quantum technologies. The £39 million ring-fenced funding, provided by core funding from DSIT, is distributed across three main pillars: (1) QT&E Programme, which includes capital investment in facilities and equipment; (2) collaborative projects aligned with the EPSRC Quantum Technology Research Hubs; and (3) participation in grant-funded initiatives such as the ISCF and the QTFP programme. The purpose of the NPL within the NQTP was to focus on product validation, standards and skills for testing and evaluation to accelerate the transition of quantum technologies from laboratory research to market-ready products and services.	PTB serves as Germany's National Metrology Institute (NMI) and operates as a federal research institution under the authority of the Federal Ministry for Economic Affairs and Climate Action (BMWK)[85]. It is a departmental research institute, formally classified as a subordinate authority within BMWK's business domain. PTB is primarily funded through a hybrid model that blends: • Federal public funding for statutory services and core research; • Project-specific competitive funding, including: ○ German national programmes administered by BMWK and the Federal Ministry of Education and Research (BMBF); ○ EU and international sources such as the EU Quantum Technologies Flagship, Horizon Europe, and EURAMET; ○ The European Metrology Research Programme (EMRP). In addition to public sources, PTB generates revenue from: • Calibration and measurement services; • Licensing of patented technologies; • Collaborative research contracts with industry. PTB is a strategic delivery partner in the German Government's €650 million Quantum Technologies Framework Programme. It also connects with broader innovation instruments including: • EXIST (start-up support), • High-Tech Gründerfonds, and • INVEST (early-stage investment incentives), which collectively strengthen the commercialisation environment for quantum spinouts and SMEs. PTB plays a leading role in quantum infrastructure, coordinating national facilities such as the QT Competence Center (QTZ) and contributing to regional and cross-border initiatives like Quantum Valley Lower Saxony (QVLS).
Skills development	NPL plays a strategic and multifaceted role in building the UK's quantum skills base, acting as an intermediary between academia, industry, and government. Its activities span	PTB plays a central role in developing a skilled quantum workforce, addressing the current lack of structured training opportunities by leveraging its strong industry

[85] https://www.quantentechnologien.de/fileadmin/public/Redaktion/Dokumente/PDF/Publikationen/Federal-Government-Framework-Programme-Quantum-technologies-2018-bf-C1.pdf

Comparison Area	NPL	PTB (Germany)
	formal education, applied training, international collaboration, and responsive workforce development. NPL embeds training within active quantum research and metrology projects, providing early-career scientists, PhD students, and visiting researchers with hands-on experience: • PGI: Enables students to pursue PhDs in collaboration with universities while working on real-world quantum challenges at NPL. • 'PhD at Work' scheme: Offers a full-time, in-house research environment aligned with doctoral studies. • Secondments and placements: Host UK and international early-career researchers, including through collaborations with institutes like NIST. NPL also supports skills development across career stages: • Runs apprenticeship programmes that train technicians in optical, electronic, and quantum measurement techniques. • Provides continuous professional development for technical staff to adapt to evolving demands in quantum instrumentation and standards. NPL delivers school visits, talks, and summer placement schemes for undergraduates. These aim to build awareness and early interest in quantum science and metrology careers. Advanced Quantum Metrology Laboratories (AQML) also serve as a base for training in practical measurement science using cutting-edge equipment, thereby directly supporting hands-on learning for trainees. Between 2020-2024, there was between 79PhD students supported by the NPLQP.	connections and advanced infrastructure to deliver hands-on, applied learning experiences. Key initiatives include: • QT Competence Center (QTZ) serves as a central hub for quantum training and capacity-building. It provides access to state-of-the-art infrastructure and facilities that support hands-on learning for engineers, SMEs, and start-ups. Through practical exposure to advanced metrology tools, QTZ contributes to the Europe-wide network for QT training[86] • Applied learning and outreach PTB also engages the broader scientific and professional community through thematic events, laboratory tours, and expert lectures at major conferences. These initiatives offer early-career researchers and professional's insights into cutting-edge quantum science and engineering. In addition, the QTZ is expected to play a public-facing role, hosting training seminars that communicate the possibilities and boundaries of quantum technologies to a wider audience, helping raise awareness of quantum beyond specialist domains. • Academic collaboration and embedded student training In collaboration with major universities such as TU Braunschweig and Humboldt University, PTB integrates students into its research programmes from an early stage. Undergraduate and graduate students are embedded in PTB's research environment to complete Bachelor's and master's theses, internships, and doctoral projects[87]. • International and capacity-building engagement PTB extends its training efforts globally by hosting postdoctoral researchers and doctoral students through collaborative projects. It also participates in long-term capacity-building programmes in countries such as Brazil, South Africa, and India, helping to strengthen quantum skills development in emerging economies[88].
Standard setting	NPL is an active contributor to key global standardisation bodies: • Participates in ISO/IEC JTC 1/WG 14 and ITU, ETSI and contributes to European Metrology Network for	As Germany's official National Metrology Institute (NMI), PTB plays a foundational role in developing the standards and infrastructure necessary for the safe, interoperable deployment of quantum

[86] PTB-Annual_Report_2023-web.pdf

[87] What PTB offers students - PTB.de
[88] https://www.ptb.de/cms/fileadmin/internet/presse_aktuelles/broschueren/ptb_abteilungen/Infoblatt_Die_PTB_en_RZ_WEB.pdf

Comparison Area	NPL	PTB (Germany)
	Quantum Technologies to shape standards on quantum information technologies. • Contributed to the CEN-CENELEC Focus Group on Quantum Technologies (FGQT) roadmap, outlining European priorities for quantum standardisation. NPL experts were involved in all roadmap sections, and the work now feeds into the formal CEN/CLC/JTC 22 committee. • Actively explores an NMI-led approach to standards development in quantum photonics with NIST, INRIM, and NRC, including proposals for cross-Atlantic "Measurement Clubs" with QED-C and QuIC NPL is a key player in developing the measurement science foundations required before formal standards are feasible ie the pre-normative work: • Developed traceable calibration techniques for fibre-coupled single-photon detectors, underpinning trust in QKD systems and quantum sensing. • Participates in MetSuperQ, supporting benchmarking and metrology for superconducting qubits and cold electronics. • Works on graphene-based resistance standards and quantum Hall devices via projects like QuAHMET, contributing to the next generation of electrical metrology. NPL conducts bilateral and multilateral comparisons to harmonise standards globally: • Regular metrology exchange with NIST including through forums such as IMEKO TC25 on single-electron and single-photon technologies; includes detector calibration comparisons and work on randomness beacons and quantum networks. • Organised joint workshops and secondments to develop consistent approaches across national metrology institutes (e.g., for single-electron devices and SNSPDs). NPL also plays a key role in leading the Quantum Standards Network Pilot which is aiming to coordinate UK industry, academia and government stakeholder such as DSIT, UKQuantum, BSI, NCSC and NQCC) around shared national quantum standards priorities	technologies. It holds a unique global position, operating the only complete production lines for superconductor, semiconductor, and graphene-based electrical quantum standards, and is a recognised leader in quantum electrical metrology. PTB leads the development of quantum-based SI units, including through advanced infrastructure like its Centre of Excellence for Quantum Technologies. The Centre will host initiatives such as: • A test route for quantum cryptography over fibre optic cables; • New methods to automate quantum-based electrical measurements; • Systematic testing of new materials to improve the performance and industrial scalability of quantum standards. PTB also supports independent characterisation of quantum components, ensuring device reliability, and helping companies align with evolving certification and calibration standards. Through its QT Competence Center (QTZ), PTB offers technical support to SMEs and start-ups, including access to advanced metrology tools, training infrastructure, and expert-led seminars to help bridge standards and innovation. PTB collaborates extensively with national metrology institutes such as NIST, NPL, and INRIM, contributing to next-generation optical clocks, quantum radiometry, and quantum communication protocols. Notable collaborations include: • The ICON project with NPL, supporting portable optical clocks for global navigation and telecom; • The EMPIR "QuADC" initiative, where PTB provided a quantum voltage synthesizer to enhance quantum waveform metrology with NPL. At the international level, PTB is a leading force in quantum standardisation, participating in over 1,400 standardisation bodies in 2023, with leadership roles in more than 200[90]. It provides the vice-chair of the Focus Group on Quantum Technologies (FGQT) and is an active member of the European Metrology Network for Quantum Technologies (EMN-Q). Contributions to Global Measurement Systems PTB has long contributed to redefining and maintaining the International System of Units (SI), playing a key role in recalibrating the

[90] PTB-Annual_Report_2023-web.pdf

Comparison Area	NPL	PTB (Germany)
	and providing early engagement with international efforts[89].	kilogram, mole, kelvin, and ampere based on fundamental constants. Through its world-class fountain clocks, it supports precision atomic timekeeping, and it participates in 50 to 100 international comparison measurements annually to harmonise global standards.
Commercialisation support	Measurement for Quantum (M4Q) programme has provided rapid, bespoke metrology services for 50 SMEs, enabling them to validate device performance, characterise materials, and refine prototypes. Several companies receiving M4Q support have reported successful funding rounds following NPL's involvement (e.g. Intrinsic Semiconductor raised £7m). By helping firms evidence performance, NPL builds investor confidence and increases technology adoption readiness. Clients span photonics, quantum computing, and sensing startups; for instance, Intrinsic Semiconductor Technologies used NPL services to characterise memristive devices for low-power quantum circuits. NPL engages in joint innovation projects with companies under programmes like A4I (Analysis for Innovators). Examples include: • Electrical measurements of graphene-cement composites with First Graphene • Development of microwave resonator technology for non-contact characterisation of 2D materials, demonstrated with firms like DZP Technologies and Paragraf One customer reported that "NPL provided specialist measurement, calibration, and independent validation which would have been unaffordable and unavailable elsewhere." NPL also supports innovation translation through government-funded Knowledge Asset Grants (e.g. developing a quantum Orbitrap mass spectrometer in partnership with industry). Facilities like the Advanced Quantum Metrology Laboratory (AQML) provide traceable, high-specification environments for real-world testing and calibration of quantum components. NPL also leads QT&E activities to help companies validate emerging technologies against reference systems and benchmarks. QT&E services are structured to help firms: • Confirm performance under controlled, traceable conditions. • Meet procurement and investor requirements.	PTB plays a central role in advancing the commercial readiness of quantum technologies in Germany, particularly through partnerships, infrastructure access, and its leadership in measurement validation and standardisation. **Platforms for Technology Transfer and SME Support** At the core of PTB's commercialisation strategy is its QT Competence Center (QTZ)—a flagship initiative focused on enabling the transfer of quantum technologies from research to application, with an emphasis on supporting start-ups and SMEs. QTZ provides: • Access to user facilities for characterising quantum components, such as ion traps; • Technology validation services for researchers and industry partners; • Demonstrators and shared labs that trial applications in fields like geodesy, medical imaging, and secure communications. PTB also leads projects that aim to produce market-ready technologies. These include: • Opticlock, a compact and robust optical atomic clock developed with industry partners; • SQUID-based magnetometers for brain imaging; • Ion-trap quantum processors, patented by PTB to support scalable quantum computing applications. Centre of Excellence and Regional Innovation Networks Through its Centre of Excellence for Quantum Technologies, PTB is developing a recognised testing and validation structure that will accelerate small-batch production of quantum systems. The Centre includes a global-first platform for rapid and reliable ion trap characterisation, enabling innovations in quantum computing, spectroscopy, and metrology. PTB also plays a foundational role in the Quantum Valley Lower Saxony (QVLS) network—a regional umbrella organisation connecting PTB with top research institutions (e.g., Leibniz University Hanover, Max Planck

[89] Network Pilot - NPL

Comparison Area	NPL	PTB (Germany)
	• Prepare for integration into standards or regulatory frameworks. QT&E has been applied to QKD systems (e.g. ID Quantique, Toshiba) and superconducting platforms.	Institute, TU Braunschweig)[91]. This ecosystem supports sustainable R&D infrastructure and fosters long-term technology transfer pathways. Validated Systems, Certification, and Scaling PTB enables the industrial deployment of quantum technologies through validated quantum measurement systems, collaborative development of Josephson voltage standards, and support for quantum clocks and sensors (e.g., accurate strontium ion measurements for geophysical applications). *"PTB supports other major research institutes such as CERN, national metrology institutes, and industry with its Josephson voltage standards and in-house developed measuring devices."*[92] In addition, PTB's subsidiarity model allows calibration tasks to be ceded to third-party accredited labs—amplifying scale while maintaining reliability across Germany's high-tech sectors. • PTB conducts several thousand calibrations per year, which form the backbone of millions of industrial calibrations across the country[93]. • Its certificates are globally recognised, boosting the export-readiness of German quantum technologies.
Quantum market expansion	NPL plays a critical role in helping quantum SMEs transition from research to market by offering trusted technical expertise, independent validation, and access to advanced infrastructure. Its support has been especially valuable for early-stage firms, helping to de-risk innovation, accelerate development, and build investor confidence. The Measurement for Quantum (M4Q) programme has supported 50 companies, 80% of which were new to NPL, indicating success in expanding engagement. M4Q has contributed to: • 30 new or improved products, 11 new processes, and 3 new services • Increased sales (18 firms), cost savings (10), and additional investment (22) • Strong willingness to pay for future services (rising from 59% to 97%) Case studies (e.g. OQC, Quantum Motion, Paragraf) show how NPL's guidance enabled lab setup, prototype validation, and	PTB plays a central role in building and supporting both the German and European QT ecosystem, with a particular emphasis on infrastructure development, SME support, and technology transfer. Its Centre of Excellence for Quantum Technologies, backed by the Federal Ministry for Economic Affairs and Climate Action (BMWK), has a direct mandate to support industry and translate research into practical applications. The Centre focuses on three key areas: • Component and technology development, including single photon sources, sensors, oscillators, and industry-ready clocks; • Calibration and services, by establishing dedicated measurement stations and SME-tailored services to ensure quantum device accuracy and reliability; • User platforms, offering fibre-optic networks and prototyping tools for small-scale production—supporting companies

[91] https://www.quantentechnologien.de/fileadmin/public/Redaktion/Dokumente/PDF/Publikationen/Federal-Government-Framework-Programme-Quantum-technologies-2018-bf-C1.pdf
[92] PTB-Annual_Report_2023-web.pdf
[93] https://www.ptb.de/cms/fileadmin/internet/presse_aktuelles/broschueren/ptb_abteilungen/Infoblatt_Die_PTB_en_RZ_WEB.pdf

Comparison Area	NPL	PTB (Germany)
	commercial growth. Survey data supports this: • 61% of companies said NPL helped realise project feasibility • 57% avoided wasted resources • 57% accelerated key milestones • 63% gained new partnerships NPL also enables market access through its standards leadership, helping firms demonstrate compliance in emerging international markets—an essential foundation for scaling. However, market expansion beyond the quantum sector remains limited. Despite a national base of 804 quantum-aligned companies, only 86 have engaged with NPL to date. While wider sector uptake (e.g. healthcare, defence) is anticipated, evidence of realised cross-sector impact remains modest so far. Still, NPL's position as a trusted technical authority and its contribution to new product development, investment readiness, and early ecosystem connectivity confirm its importance in expanding the UK quantum market.	that cannot afford to develop their own infrastructure. These activities contribute to the emergence of a broader national and European quantum market ecosystem, with infrastructure supporting secure communication and synchronisation via international fibre links. PTB's QT Competence Center (QTZ) provides user-accessible metrology facilities and office space at its Braunschweig and Berlin sites[94], creating a low-barrier environment for external partners to experiment and advance their own quantum products without high upfront investment. Public engagement efforts at QTZ also aim to demystify quantum technologies and expand societal acceptance. Participation in strategic initiatives like the Quantum Valley Lower Saxony (QVLS), as well as regular contributions to EU-wide quantum forums and events, further cements PTB's role as a national and continental enabler of quantum innovation[95]. Through its infrastructure, partnerships, and advanced measurement tools, PTB supports innovation in key sectors such as: • Aerospace, cybersecurity, health, and climate monitoring; • Metrology-driven technologies, including SQUID magnetometers, atomic clocks, and self-calibrating sensors.

[94] PTB-Annual_Report_2023-web.pdf
[95] https://www.quantentechnologien.de/fileadmin/public/Redaktion/Dokumente/PDF/Publikationen/Federal-Government-Framework-Programme-Quantum-technologies-2018-bf-C1.pdf

NIST (USA)

Table 65: Comparative analysis – NIST

Comparison Area	NPL	NIST (USA)
Funding model and governance	NPLQP is part of the NQTP – a billion-pound programme involving government, academia and industry to maximise UK economic growth and increase security and resilience through the exploitation of quantum technologies. The £39 million ring-fenced funding, provided by core funding from DSIT, is distributed across three main pillars: (1) the QT&E Programme, which includes capital investment in facilities and equipment; (2) collaborative projects aligned with the EPSRC Quantum Technology Research Hubs; and (3) participation in grant-funded initiatives such as the ISCF and the QTFP programme. The purpose of the NPL within the NQTP was to focus on product validation, standards and skills for testing and evaluation to accelerate the transition of quantum technologies from laboratory research to market-ready products and services.	NIST's Quantum Information Science (QIS) programme is a central pillar of the U.S. federal quantum strategy, backed by a dedicated budget of $40.5 million[96]. NIST combines: • Federal base funding for foundational research and operational continuity; • Strategic project funding targeting quantum-enabling technologies such as optical clocks, quantum repeaters, and ion-trap networks; • Public-private partnerships with both government agencies (e.g., the Department of Defence) and industry consortia like QED-C (Quantum Economic Development Consortium), which help align research with emerging commercial needs.
Skills development	NPL plays a strategic and multifaceted role in building the UK's quantum skills base, acting as an intermediary between academia, industry, and government. Its activities span formal education, applied training, international collaboration, and responsive workforce development. NPL embeds training within active quantum research and metrology projects, providing early-career scientists, PhD students, and visiting researchers with hands-on experience: • PGI: Enables students to pursue PhDs in collaboration with universities while working on real-world quantum challenges at NPL. • 'PhD at Work' scheme: Offers a full-time, in-house research environment aligned with doctoral studies. • Secondments and placements: Host UK and international early-career researchers, including through collaborations with institutes like NIST. NPL also supports skills development across career stages: • Runs apprenticeship programmes that train technicians in optical, electronic, and quantum measurement techniques.	NIST supports workforce development through a range of training programmes that serve high school students, undergraduates, graduates, postdoctoral researchers, and visiting scientists[97]. Key initiatives include: • The Summer High School Internship Program (SHIP) and Pathways Program, which provide hands-on research opportunities in NIST labs, often acting as bridges to federal employment; • The Summer Undergraduate Research Fellowship (SURF) or Professional Research Experiences (PREP) programmes; • Collaboration with NIST-NRC Postdoctoral Research Associateships, offering

96 NIST's Program in Quantum Information Science
97 https://www.quantum.gov/wp-content/uploads/2024/12/NQI-Annual-Report-FY2025.pdf

Comparison Area	NPL	NIST (USA)
	• Provides continuous professional development for technical staff to adapt to evolving demands in quantum instrumentation and standards. NPL delivers school visits, talks, and summer placement schemes for undergraduates. These aim to build awareness and early interest in quantum science and metrology careers. Advanced Quantum Metrology Laboratories (AQML) also serve as a base for training in practical measurement science using cutting-edge equipment, thereby directly supporting hands-on learning for trainees. Between 2020-2024, there was between 79PhD students supported by the NPLQP.	transitional roles into the federal quantum research landscape. NIST also partners with joint institutes such as JILA, Joint Quantum Institute (JQI), and QuICS, which host and train PhD students, postdocs, and international visiting scholars. NIST enhances practical training through workshops, testbeds, and prototype facilities, covering critical areas such as cryogenics, quantum lasers, control systems, and optical measurement systems. New short courses, such as Single Photon Measurements Training, are delivered in partnership with SPIE, QED-C, and photonics companies in Colorado. Budget proposals outline an ambition to increase participation significantly, with performance metrics indicating plans to grow from 0 to 8 trained quantum researchers annually by 2029 under new funding streams.
Standard setting	NPL is an active contributor to key global standardisation bodies: • Participates in ISO/IEC JTC 1/WG 14 and ITU, ETSI and contributes to European Metrology Network for Quantum Technologies to shape standards on quantum information technologies. • Contributed to the CEN-CENELEC Focus Group on Quantum Technologies (FGQT) roadmap, outlining European priorities for quantum standardisation. NPL experts were involved in all roadmap sections, and the work now feeds into the formal CEN/CLC/JTC 22 committee. • Actively explores an NMI-led approach to standards development in quantum photonics with NIST, INRIM, and NRC, including proposals for cross-Atlantic “Measurement Clubs” with QED-C and QuIC NPL is a key player in developing the measurement science foundations required before formal standards are feasible ie the pre-normative work: • Developed traceable calibration techniques for fibre-coupled single-photon detectors, underpinning trust in QKD systems and quantum sensing. • Participates in MetSuperQ, supporting benchmarking and metrology for superconducting qubits and cold electronics.	NIST leads and coordinates the development of standards within key quantum domains, including: • Quantum Key Distribution (QKD) and single-photon devices; • Post-quantum cryptography (PQC) — a major focus area where NIST has led an international process since 2016 to evaluate and standardize quantum-resistant public-key cryptographic algorithms; • The Quantum SI — providing traceable measurement systems based on quantum properties. In a milestone achievement, NIST published the first three PQC encryption standards in August 2024[99]. NIST also plays a leading role in international quantum standards forums. It co-chairs the ISO/IEC

[99] https://www.quantum.gov/wp-content/uploads/2024/12/NQI-Annual-Report-FY2025.pdf

Comparison Area	NPL	NIST (USA)
	• Works on graphene-based resistance standards and quantum Hall devices via projects like QuAHMET, contributing to the next generation of electrical metrology. NPL conducts bilateral and multilateral comparisons to harmonise standards globally: • Regular metrology exchange with NIST including through forums such as IMEKO TC25 on single-electron and single-photon technologies; includes detector calibration comparisons and work on randomness beacons and quantum networks. • Organised joint workshops and secondments to develop consistent approaches across national metrology institutes (e.g., for single-electron devices and SNSPDs). NPL also plays a key role in leading the Quantum Standards Network Pilot which is aiming to coordinate UK industry, academia and government stakeholder such as DSIT, UKQuantum, BSI, NCSC and NQCC) around shared national quantum standards priorities and providing early engagement with international efforts[98].	Joint Technical Committee 3 on quantum technologies and actively collaborates with peer NMIs around the world to ensure standards interoperability and technical alignment[100]. NIST also contributes to ITU-T Telecom activities and collaborates with the Quantum Economic Development Consortium (QED-C) to represent U.S. interests in international forums. NIST's Quantum Information Science (QIS) programme supports a broad array of measurement standardisation efforts, including: • Calibration of single-photon sources, chip-scale quantum sensors, and atomic clocks; • Development of a metrology framework for quantum networks, including time synchronisation and signal fidelity standards as part of its Quantum Network Grand Challenge. These activities are underpinned by fundamental research conducted through NIST's national labs and user facilities, which enable the translation of metrological science into operational standards for both industry and defence applications.
Commercialisation support	Measurement for Quantum (M4Q) programme has provided rapid, bespoke metrology services for 50 SMEs, enabling them to validate device performance, characterise materials, and refine prototypes. Several companies receiving M4Q support have reported successful funding rounds following NPL's involvement (e.g. Intrinsic Semiconductor raised £7m). By helping firms evidence performance, NPL builds investor confidence and increases technology adoption readiness. Clients span photonics, quantum computing, and sensing startups; for instance, Intrinsic Semiconductor Technologies used NPL services to characterise memristive devices for low-power quantum circuits.	A cornerstone of NIST's commercialisation efforts is its creation and ongoing support of the Quantum Economic Development Consortium (QED-C), established in partnership with SRI International. QED-C was launched in 2018 to de-risk quantum innovation and enable technology transfer, and now includes over 250 members from industry, academia, and government[101]. QED-C serves as the primary mechanism for addressing supply

98 Network Pilot - NPL
100 https://www.quantum.gov/wp-content/uploads/2024/12/NQI-Annual-Report-FY2025.pdf

101 https://www.commerce.gov/sites/default/files/2024-03/NIST-NTIS-FY2025-Congressional-Budget-Submission.pdf

Comparison Area	NPL	NIST (USA)
	NPL engages in joint innovation projects with companies under programmes like A4I (Analysis for Innovators). Examples include: • Electrical measurements of graphene-cement composites with First Graphene. • Development of microwave resonator technology for non-contact characterisation of 2D materials, demonstrated with firms like DZP Technologies and Paragraf. One customer reported that "NPL provided specialist measurement, calibration, and independent validation which would have been unaffordable and unavailable elsewhere." NPL also supports innovation translation through government-funded Knowledge Asset Grants (e.g. developing a quantum Orbitrap mass spectrometer in partnership with industry). Facilities like the Advanced Quantum Metrology Laboratory (AQML) provide traceable, high-specification environments for real-world testing and calibration of quantum components. NPL also leads QT&E activities to help companies validate emerging technologies against reference systems and benchmarks. QT&E services are structured to help firms: • Confirm performance under controlled, traceable conditions. • Meet procurement and investor requirements. • Prepare for integration into standards or regulatory frameworks. QT&E has been applied to QKD systems (e.g. ID Quantique, Toshiba) and superconducting platforms.	chain resilience, industry standards, testbed development, and workforce training. It supports the development of components and platforms essential to real-world deployment, including: • Prototype compact optical clocks for GPS backup; • Quantum repeaters based on ion-trap networks; • The NIST-on-a-Chip (NoaC) initiative, focused on manufacturable, self-calibrating measurement tools; • Collaborative workshops on superconducting qubits, laser systems, and cryogenic control electronics. Beyond policy leadership, NIST contributes direct infrastructure support to commercialisation efforts, including: • Fabrication services for superconducting circuits and ion traps; • Cryogenic and nanofabrication facilities; • Deployment of compact quantum metrology systems, such as NIST-on-a-Chip, designed for portable field use in civilian and defence contexts. These resources are made accessible to external partners through mechanisms such as CRADAs (Cooperative Research and Development Agreements), enabling joint development of quantum technologies and measurement solutions with industry.
Quantum market expansion	NPL plays a critical role in helping quantum SMEs transition from research to market by offering trusted technical expertise, independent validation, and access to advanced infrastructure. Its support has been especially valuable for early-stage firms, helping to de-risk innovation, accelerate development, and build investor confidence. The Measurement for Quantum (M4Q) programme has supported 50 companies, 80% of which were new to NPL, indicating success in expanding engagement. M4Q has contributed to:	NIST has supported quantum market growth by developing critical infrastructure for scalable technologies, including: • A record-breaking optical atomic clock with 8×10^{-19} uncertainty developed at JILA; • Photon source integration using silicon carbide for scalable quantum systems;

Comparison Area	NPL	NIST (USA)
	• 30 new or improved products, 11 new processes, and 3 new services • Increased sales (18 firms), cost savings (10), and additional investment (22) • Strong willingness to pay for future services (rising from 59% to 97%) Case studies (e.g. OQC, Quantum Motion, Paragraf) show how NPL's guidance enabled lab setup, prototype validation, and commercial growth. Survey data supports this: • 61% of companies said NPL helped realise project feasibility • 57% avoided wasted resources • 57% accelerated key milestones • 63% gained new partnerships NPL also enables market access through its standards leadership, helping firms demonstrate compliance in emerging international markets—an essential foundation for scaling. However, market expansion beyond the quantum sector remains limited. Despite a national base of 804 quantum-aligned companies, only 86 have engaged with NPL to date. While wider sector uptake (e.g. healthcare, defence) is anticipated, evidence of realised cross-sector impact remains modest so far. Still, NPL's position as a trusted technical authority and its contribution to new product development, investment readiness, and early ecosystem connectivity confirm its importance in expanding the UK quantum market.	• Cryostat redesigns that improve energy efficiency for quantum hardware. deployment of Post-Quantum Cryptography (PQC) standards. NIST's leadership in this domain has enabled early commercial adoption of PQC algorithms across several sectors. Companies such as Meta and IBM (a co-developer of the standards) have integrated these into quantum-resilient products, alongside adoption by firms in banking (e.g. LGT Financial) and manufacturing (e.g. NXP Semiconductors), demonstrating the cross-sector relevance of this work. NIST's quantum programmes deliver high returns. Independent studies estimate a 47:1 return on investment for every dollar spent on NIST R&D[102], underscoring the broader economic benefit of its role in commercialisation and technology transfer.

[102] https://www.commerce.gov/sites/default/files/2024-03/NIST-NTIS-FY2025-Congressional-Budget-Submission.pdf

Key Findings

Standard setting

NPL plays a strategic role in international quantum standards, leveraging its metrology expertise and position as the UK's National Metrology Institute (NMI), It contributes to:

- ISO/IEC JTC 3 – newly established committee to coordinate international quantum standards;
- co-leads IMEKO TC25 alongside PTB and NIST, an international forum where NMIs collaborate to define, test and promote measurement standards for quantum technologies; and
- active in the QSN, including leading the QSN Pilot launched in 2023 to coordinate UK industry, academia, and government stakeholders (e.g. DSIT, UKQuantum, BSI, (NCSC and NQCC) around shared quantum standards priorities and provide early engagement with international efforts[103].

According to NPLQP documentation and interviews with delivery staff, NPL plays a key role in pre-normative work—defining terminology, establishing use cases, and developing test and characterisation methods, such as playing a major role in the development of the world's first QT standard, ETSI GS QKD 011 on component characterisation for QKD. This also includes vital work on single-photon metrology and quantum benchmarking. These foundational activities are critical in the early phases of quantum standardisation and ensure that emerging international frameworks are grounded in robust and reproducible measurement science. NPL has procured and commissioned the development of two testbeds for T&E of quantum research, AQML and SuperFab, however it plays a specific role in eight others (e.g. Superconducting Qubit Testbed at NQCC), such as developing measurement, software and benchmarking systems and techniques.

To facilitate standardisation, NPL has hosted two national workshops on quantum standardisation priorities and stakeholder coordination. It also coordinated a six-country 'mini summit' of National Measurement Institutes and, in partnership with BSI, initiated the proposal for ISO/IEC JTC 3[104]. As of 2024, NPLQP staff have held 37 memberships of standards committees[105]. These activities highlight its leadership in shaping standards both nationally and internationally.

NPL is also actively engaged in nearly all major international Standards Development Organisations (SDOs), including ISO, IEC, ITU, ETSI, and CEN/CENELEC, and contributes to European and international metrology groups such as the European Metrology Network for Quantum Technologies and the CCL-CCTF Frequency Standards Working Group.

Compared to international peers:

- NIST plays a global leadership role in quantum standardisation, particularly through its Post-Quantum Cryptography (PQC) programme, coordination of the QED-C and early publication of national standards. Supported by significant federal quantum investment (estimated at around $66 million per year) and extensive infrastructure, NIST leads formalisation efforts and provides industry with access to national quantum testing laboratories such as the Physical Measurement Laboratory. It is also actively engaged in international standardisation bodies such as IEEE, ISO, and ITU, working alongside other national institutes including the NPL and PTB. In contrast, NPL has developed a distinctive niche through its scientific leadership in measurement science, contributing high-quality pre-normative work that underpins emerging standards and supports long-term global interoperability—despite operating with comparatively more limited resources.
- PTB (Germany) chairs over 200 standards committees and integrates standards into its QT Competence Centres (QTZ), supported by access to shared infrastructure and testbeds. PTB plays a central role in European standards coordination and contributes to many working groups under the European Quantum Flagship. This deep integration of R&D and standardisation enables German firms to meet international certification requirements, especially in medical diagnostics and secure communications. NPL's approach

[103] Network Pilot - NPL
[104] NPLQP Year 4 Annual Report
[105] QTE metrics provided by NPL (April 2025)

is similar to PTB's scientific approach through giving access to laboratories and testbeds for testing and evaluation, and its committee participation.

- NRC (Canada) contributes through mirror committees and is building its quantum standards capabilities via the NMI Quantum (NMIQ) initiative. NRC is also active in international collaborations and joint workshops (e.g., with NPL and Italian National Institute for Metrology (INRIM)) and uses challenge-led R&D programmes such as the Quantum Sensors Challenge and Quantum Research and Development Initiative (QRDI) to embed metrology and early standards development. Although NRC does not have a formal national mandate on standards, it plays a key coordination role through the Standards Council of Canada. NPL currently has stronger formal influence but can learn from NRC's integration of standards into applied challenge-led programmes and broader industry engagement.
- DFM (Denmark) maintains a more focused role but has positioned itself strategically through collaborations with NPL and PTB on quantum hardware and pre-normative work.

NPL's influence has been amplified by sustained partnerships with NMIs such as NIST, and NRC. It has played a formative role in developing international comparisons and test methods for single-photon and quantum electronic systems. Notably, NPL helped shape the CEN-CENELEC roadmap for quantum technologies, now formalised under CEN/CLC/JTC 22. Furthermore, NPL's testing facilities, such as the AQML, provide industry with access to advanced infrastructure to support calibration and measurement aligned with national and international standards.

In summary, NPL is a core player in global quantum standardisation efforts—alongside peers like NIST and PTB. Its strengths lie in technical leadership and standard development. To maintain and expand its influence, NPL should continue to strengthen the QSN to sustain its leadership and participation in global and European standards committees and forums and to ensure industry engagement as the market expands.

Skills Development

NPL role in developing quantum skills in the UK is through embedding training directly within its live research and development environment. Through the PGI, NPL provides applied, training opportunities via PhD-at-Work schemes, technical apprenticeships, and undergraduate placements. These schemes allow early-career researchers to work alongside NPL scientists and industrial collaborators on active quantum metrology projects, with direct access to national facilities such as the AQML. Between 2020 and 2024, between 79 PhD students were supported each year, meaning they met their target of funding PhD students, as set out in the Business Case[106]. On the other hand, there is limited available data on the number of apprenticeships and placements available / taken, making it difficult to assess the scale, reach, or overall impact of these initiatives.

This approach aligns in principle with their comparable international counterparts. At NIST training is structured through academic partnerships, such as the Summer Undergraduate Research Fellowship (SURF), the Summer High School Internship Program (SHIP), and joint research appointments via the Joint Quantum Institute (JQI)[107]. These initiatives are strongly tied to the academic pipeline and less focused on technical application within a commercial or SME context. In contrast, NPL's model places early-career professionals directly into environments where measurement, calibration, and performance validation are being used to support product development and commercialisation such as through the M4Q programme.

A similar academic-institutional partnership model exists at PTB in Germany, where supported students complete bachelor's and master's theses or undertake PhD research in collaboration with universities[108]. Many PTB researchers hold dual academic roles, and the institute's QTZ centre provides access to testbeds and training seminars for SMEs and early-career professionals. While this embeds learning across both academic and industrial contexts, the emphasis remains more on research exposure than on applied skills tailored to commercial deployment.

[106] QTE metrics provided by NPL (April 2025)
[107] https://www.quantum.gov/wp-content/uploads/2024/12/NQI-Annual-Report-FY2025.pdf
[108] What PTB offers students - PTB.de

The NRC helps shape Canada's quantum workforce by embedding skills development into usual business, such as through collaborative R&D programmes rather than formal training programmes. They do this through funding Highly Qualified Personnel (HQP) by integrating graduate and postdoctoral researchers into applied quantum research delivered with academia and SMEs, a similar practice to NPL's PhD-at-Work scheme. It also offers, early-stage STEM promotion, support for joint physics-engineering degrees, entrepreneurship training tailored to quantum technologies. However, unlike NPL, NRC provides expertise within industry to co-design professional masters' programmes such as those at the University of Calgary.

DFM does not run structured academic schemes but contributes to skills development through long-term collaborations with universities and firms, co-developing new services and competencies over the course of multi-year projects. Where national skills gaps are identified, DFM delivers bespoke training, such as vocational metrology instruction for educators. While NPL's approach is more comprehensive in scale, DFM's bespoke model demonstrates a different strategy for addressing quantum skills shortages.

NPL offers skills development support that is broadly comparable to international peers, with a particular strength in embedding training directly within live quantum research projects. This applied, hands-on model is a distinctive feature of NPL's approach. However, the review also identified several areas for potential enhancement. NPL does not currently provide expertise to shape formal professional qualifications, such as the co-designed Master's programmes available through Canada's NRC. **This aligns with findings from the UK Quantum Skills Taskforce report[109], which highlighted the need for more industry-aligned quantum MSc programmes and stronger collaboration between academia and industry in their design and delivery**.

Commercialisation Support

The table below summarises the key areas commercialisation support provided by NPL, NRC, NIST, PTB and DFM:

Table 66: Commercialisation supports provided by NPL, NRC, NIST, PTB and DFM

Commercialisation support	NPL	NRC	NIST	PTB	DFM
Facilities and infrastructure	T&E facilities such as the AQML for QKD, superconducting devices, and clocks. These provide characterisation and calibration capabilities, whilst also providing measurement services to SMEs through the M4Q Programme.	Quantum testbeds for QKD and sensors; dedicated infrastructure for cryogenic and photonic systems; embedded labs in research hubs (e.g. Université de Sherbrooke)	National photonic and networking testbeds; NIST-on-a-Chip platform; scalable atomic clock infrastructure; shared use of secure quantum facilities Engages with the U.S. quantum industry through cooperative research and development agreements (CRADAs) to address specific technology gaps.	The QTZ at PTB offers advanced metrology, nanofabrication, and calibration facilities—including cleanrooms, chip packaging, and shielded environments—supporting SME-led experiments, training, and pre-certification. The QTZ user platforms provide dedicated measuring facilities and demonstrators for external partners	Quantum Test Centre supports calibration and characterisation of single-photon detectors, QKD modules, and quantum sensors. Quantum House Denmark provides subsidised access to labs and infrastructure for SMEs.
Direct funding for companies	No direct funding – Innovate UK and other bodies provide direct funding to companies through	Up to CAN$10 million per SME via Industrial Research Assistance Programme (IRAP) and Challenge-led	No direct funding - firms access federal research programmes or partner with testbed facilities for non-	No direct funding – access to pre-seed (EXIST) and seed (High-Tech Gründerfonds) funding via PTB links.	No direct funding

109 UK Quantum Skills Taskforce report (May 2025)

Commercialisation support	NPL	NRC	NIST	PTB	DFM
	challenge-led programmes	programmes such as the Quantum Sensors Challenge	financial technical support.		
IP support	No direct IP support	Embedded IP advisory and business services within IRAP and other challenge calls	Coordinates IP policy use cases, roadmaps, and technical barriers to entry across its 240 members	No direct IP support	No direct IP support
Technical expertise	Delivered by in-house physicists, quantum engineers, and metrologists across programmes such as M4Q, Analysis for Innovators (A4I), and other commercial T&E; NPL staff support firms in precision device characterisation, single-photon detector calibration, QKD protocol validation, microwave and optical measurement refinement, and materials assessment. Expertise is also deployed in collaborative R&D, such as through projects with Innovate UK and EPSRC Quantum Technology Research Hubs. NPL also contributes to UK Quantum and leads the standards work package.	Industrial Technology advisors which provide advice through IRAP; NRC scientists embedded in collaborative R&D; NRC also provides technical mentorship during challenge programmes and helps design product validation plans and test regimes in line with industrial standards.	NIST staff contribute technical leadership to QED-C working groups focused on quantum networking, sensing, and measurement science. They help develop standardised test protocols, interoperability metrics, and validation criteria, which are applied through QED-C pilot projects with academic and industry partners to guide infrastructure alignment and commercial readiness.	In-house validation, calibration and certification experts within the QTZ collaborate with SMEs on device tuning, benchmarking, and market testing. Training and workshops provided alongside infrastructure use. PTB also assigns technical staff to long-term research-industrial consortia for emerging quantum applications.	DFM staff provide project-specific calibration assistance, electronic and photonic diagnostics, device performance simulations, and technical report validation. They also support SMEs in aligning measurements with emerging European standards and connect them with national and EU-level R&D networks. Expertise is shared via collaborative test activities and industry training packages.
Start-up ecosystem links	No physical incubation space or cohort-based model but provides project-based support via M4Q, access to T&E facilities and collaborations with EPSRC Quantum Technology Research Hubs, who have span out numerous companies.	Embedded in regional innovation hubs; and connects with accelerator programmes (e.g. Creative Destruction Lab)	No physical start-up hub but founded the QED-C with over 180 companies and 250 member organisations which supports convening, networking, and ecosystem gap analysis; facilitates testbed-user connections across academia, defence, and private sector.	PTB is a key partner in QVLS, a regional initiative that connects universities, research institutes, and start-ups to accelerate commercialisation. QVLS provides support for scaling deep-tech quantum ventures. PTB also provides user platforms, accessible	Quantum House Denmark initiative - a dedicated physical hub for start-ups—offering subsidised lab space and infrastructure access

Commercialisation support	NPL	NRC	NIST	PTB	DFM
				spaces (via QTZ) for external firms mainly SMEs to experiment and advance products without high level of investment	

Under the NPLQP, NPL was tasked with providing measurement infrastructure, T&E services, and technical expertise to support the commercialisation of quantum technologies. Its interventions aim to bridge the gap between research and market readiness for UK-based quantum innovations.

NPL's principal commercialisation mechanism is the M4Q programme. M4Q offers rapid, non-competitive access to bespoke metrology and characterisation services. "Rapid" refers to fact they provide up to 20 days of specialist expertise rather than months, while "non-competitive" indicates that the support is not awarded through a competitive grant process but is open to eligible SMEs on a first-come basis at no charge to the business. As of March 2023, the programme had supported 50 UK-based SMEs, with these distributed across the UK, over a four-year period (2020–2024). These firms span sectors including quantum photonics, superconducting qubits, and quantum secure communications. M4Q services are delivered directly by NPL technical staff and include component-level characterisation, device testing, and problem-solving advice. Support is typically non-exclusive, and tailored to the specific technical needs of clients, with firms often able to re-engage across multiple years. M4Q plays a key role in de-risking commercial innovation and enhancing investor confidence.

Customer feedback captured through annual programme reports and interviews indicate that the M4Q model is particularly valued by first-time SME users for its flexibility, speed and the credibility NPL's validation confers in discussions with partners and investors.

Additional commercialisation supports include:

- Joint industry projects through A4I (e.g. with First Graphene and DZP Technologies);
- government-funded Knowledge Asset Grant partnerships (e.g. for a quantum Orbitrap mass spectrometer);
- access to the AQML and other national facilities for high-spec component testing and calibration; and
- application of QT&E services to validate QKD and superconducting technologies.

NPL offers a comparable suite of commercialisation support services to international peer institutions, particularly in terms of technical expertise, testing infrastructure, and collaborative R&D support. However, there are two key differences:

- **Incubation and start-up support:** NPL does not operate its own physical incubator space or structured start-up programme. However, this gap is mitigated by its partnerships with the EPSRC Quantum Technology Research Hubs. Through these partnerships and the M4Q Programme, the NPLQP has supported spinouts and SMEs in some form.
- **IP support:** Unlike some institutions such as NRC and NIST, NPL does not currently provide dedicated in-house IP advisory services. This is a notable gap where international counterparts often embed IP guidance directly within commercialisation supports. NPL could collaborate with others to ensure this is available.

The supports outlined above, particularly those focused on commercialisation, form a foundation for these institutes to stimulate the growth of their national quantum ecosystems and markets. The following section explores how these institutes have influenced the development of the quantum market, as well as their impact on other sectors through the application of quantum technologies.

Evidence of Commercial Impact and Market Expansion

NPL's M4Q programme and other supports have led to some tangible commercial outcomes. The M4Q programme has led to new products, processes and services, cost savings and additional investment secured. Companies also credited NPL's independent validation and project feasibility as beneficial. However, there is no clear evidence to date of widespread cross-sector uptake beyond core quantum fields, with impacts in broader fields (e.g health and finance) anticipated but not yet realised.

Comparatively, NRC's support has generated broader national market impact. Through IRAP and challenge programmes like the Quantum Sensors Challenge, Canadian firms have spun out and commercialised technologies across **defence, healthcare, and environmental sectors**. NRC's support contributed to the scaling of leading quantum firms such as Xanadu and Photonic, and the coordination of national IP strategies and interdepartmental initiatives. However, this does not provide an accurate comparison, as the NRC's IRAP Programme and the NRC as a whole have a much broader national mandate and financial capability within the quantum sector compared to NPL's role in the UK's quantum ecosystem.

NIST has focused on creating shared infrastructure. such as the QED-C consortium with over 250 members, which facilitates industry coordination and standardisation. Its work underpins testbed development for quantum networking and metrology tools (e.g. NIST on a Chip), foundational to scaling innovation without direct SME funding. However, NIST also directly engages with industry needs through CRADA's which addresses specific technology gaps and is leading to **support applications through the department of defence, healthcare and telecoms, however, there has been limited evidence from our review to suggest any of these have occurred yet with direct NIST support.** One clear area of impact is in the development and deployment of PQC standards. NIST's leadership in this domain has enabled early commercial adoption of PQC algorithms across several sectors. Companies such as Meta and IBM (a co-developer of the standards) have integrated these into quantum-resilient products, alongside adoption by firms in banking (e.g. LGT Financial) and manufacturing (e.g. NXP Semiconductors), demonstrating the cross-sector relevance of this work[110].

Germany's PTB provides infrastructure-intensive support through its QTZ centre, which facilitates prototyping, testing, and validation for SMEs. This approach is underpinned by the German Quantum Technologies Framework Programme, which emphasises investment in **shared fabrication facilities, modular testbeds, and small-batch production services designed to be accessible to industry**. The primary benefit of this model is that it enables SMEs to engage with quantum technologies without the need to establish costly and time-consuming infrastructure themselves. However, our review did not identify evidence of tangible outcomes for SMEs that have used these facilities or support mechanisms to date. There is some, but limited evidence of PTB's role in fostering spinouts from the quantum ecosystem. For example, Qudora Technologies – a spinout from PTB and the QVLS consortium – has gone on to secure funding from the DLR (German Aerospace Centre) Quantum Computing Initiative. PTB has also supported start-ups indirectly through collaborative projects such as Opticlock, which involved at least two early-stage companies. Beyond the quantum sector, however, our review found no clear evidence of PTB's quantum work generating wider cross-sector impacts at this stage. Similarly, DFM's creation of Quantum House Denmark provided a **physical hub for quantum start-ups**. This hub offers subsidised laboratory space and shared equipment and supports Denmark's export-oriented quantum instrumentation sector. However, there is no evidence of impacts on quantum companies to use the hub and test centre provided. DFM does not focus on quantum application sector, their priority remains on supplying quantum hardware, rather than end-use cases.

[110] Companies Prepare to Fight Quantum Hackers - WSJ

A.12. Bayesian Updating Example

Befani et al. (2016)[111] provide the following example of applying Bayesian Updating to a public-funded project.

The Universal Health Care Campaign in Ghana was a civil society-led movement that aimed to use the upcoming 2012 presidential election as a window of opportunity to promote their health-related policy priorities. The campaign had significant reach comprising over 500 health-focused civil society organizations, who when taken together, were operational in all regions of Ghana. The ultimate goal of the campaign was to have the Government of Ghana legislate for free universal health care for all.

In the course of the campaign a research report was produced and widely disseminated that highlighted a number of alleged shortcomings in the country's National Health Insurance Scheme (NHIS). The scheme, administered by the National Health Insurance Authority (NHIA) – a government department – is for all Ghanaians, who, with some exceptions, are eligible to receive health care assuming they pay an annual membership fee. The main contention between the campaign and the NHIA related to the number of people registered on the scheme: the NHIA claimed 67% of all Ghanaians were registered, and hence eligible for free health care, while the campaign claimed only 18% were registered.

At the crux of the debate was the methodology used by the NHIA to calculate membership of the scheme. The campaign claimed the methodology was flawed, while the NHIA countered that the campaign had inaccurate information and stood by their methodology and calculations. Remarkably, several months after the publication of the campaign's report, and in a context of vociferous debate between the campaign and the NHIA, each defending their position, the NHIA announced it would be changing its methodology for calculating membership in the scheme, citing methodological inaccuracies. This led the NHIA to reduce its coverage figures from 67% to 34%. The campaign claimed that their report and lobbying efforts contributed to this turnaround by the NHIA – to change its methodology and revise its coverage figures.

The contribution claim – 'The advocacy campaign affected the Government's decision to revise the methodology for calculating membership of the NHIS' – was tested.

In order to illustrate how the Bayes formula can be applied, consider that the expected evidence to support this contribution claim could be the Government admitting the campaign's influence.

The Bayes formula used was:

$$P(H|E) = \frac{P(E|H) \cdot P(H)}{P(E|H) \cdot P(H) + P(E|\neg H) \cdot P(\neg H)}$$

where:

$\boldsymbol{P(H) = Prior\ confidence\ in\ the\ causal\ hypothesis}$
$\boldsymbol{P(E|H) = Likelihood\ of\ observing\ the\ evidence\ if\ the\ causal\ hypothesis\ is\ true}$
$\boldsymbol{P(E|\neg H) = Likelihood\ of\ observing\ the\ evidence\ if\ the\ alternative\ hypothesis\ is\ true}$
$\boldsymbol{P(\neg H) = 1 - P(H) = Prior\ confidence\ in\ the\ alternative\ hypothesis}$
$\boldsymbol{P(H|E) = Posterior\ confidence}$

Assuming that no prior information on how likely the intervention is to have influenced the NHIA's decision to revise the formula in that particular way sets the prior probability of the contribution claim at 0.5.

To assess the power of the Government's admission to change our initial confidence, the sensitivity and Type I error of this piece of evidence for the claim were estimated. The Type I error is set at 0.01: a government admitting being influenced by an NGO (while this is actually not the case) can be considered an extremely

[111] Ibid.

rare event, happening in only 1% of situations where Governments take decisions without being influenced by Non-Government Organisations. At the same time, the probability that the Government admits influence when having been influenced (the sensitivity) is higher, although the event is not very frequent either because Government in general tend to be resistant to admitting influence of NGOs. The standard estimate for this context is 0.2, meaning that there is a 20% chance that Government admit influence when they have actually been influenced. These values are summarised in Table 67.

Table 67: Bayes formula input values

	Probabilities
The probability of the Government admitting to being influenced by an NGO under the null hypothesis of influence taking place (sensitivity) – P(E|H)	0.2
The probability of the Government admitting to being influenced by an NGO under the alternative hypothesis of no influence taking place (Type I Error) – P(E|¬H)	0.01
Prior Confidence in the null hypothesis – P(H)	0.5

In this scenario, observing the Government admit influence increases the confidence in the contribution claim from 0.5 to 0.95. The evidence makes the evaluator reasonably certain of the validity of the contribution claim. There is reasonable certainty that the advocacy campaign affected the Government's decision to revise the methodology for calculating membership of the NHIS.

THE POWER OF BEING UNDERSTOOD
AUDIT | TAX | CONSULTING

RSM UK Consulting LLP
The Ewart
4th Floor
3 Bedford Square
Belfast
BT2 7EP
United Kingdom
T +44 (0)28 90234343
rsmuk.com