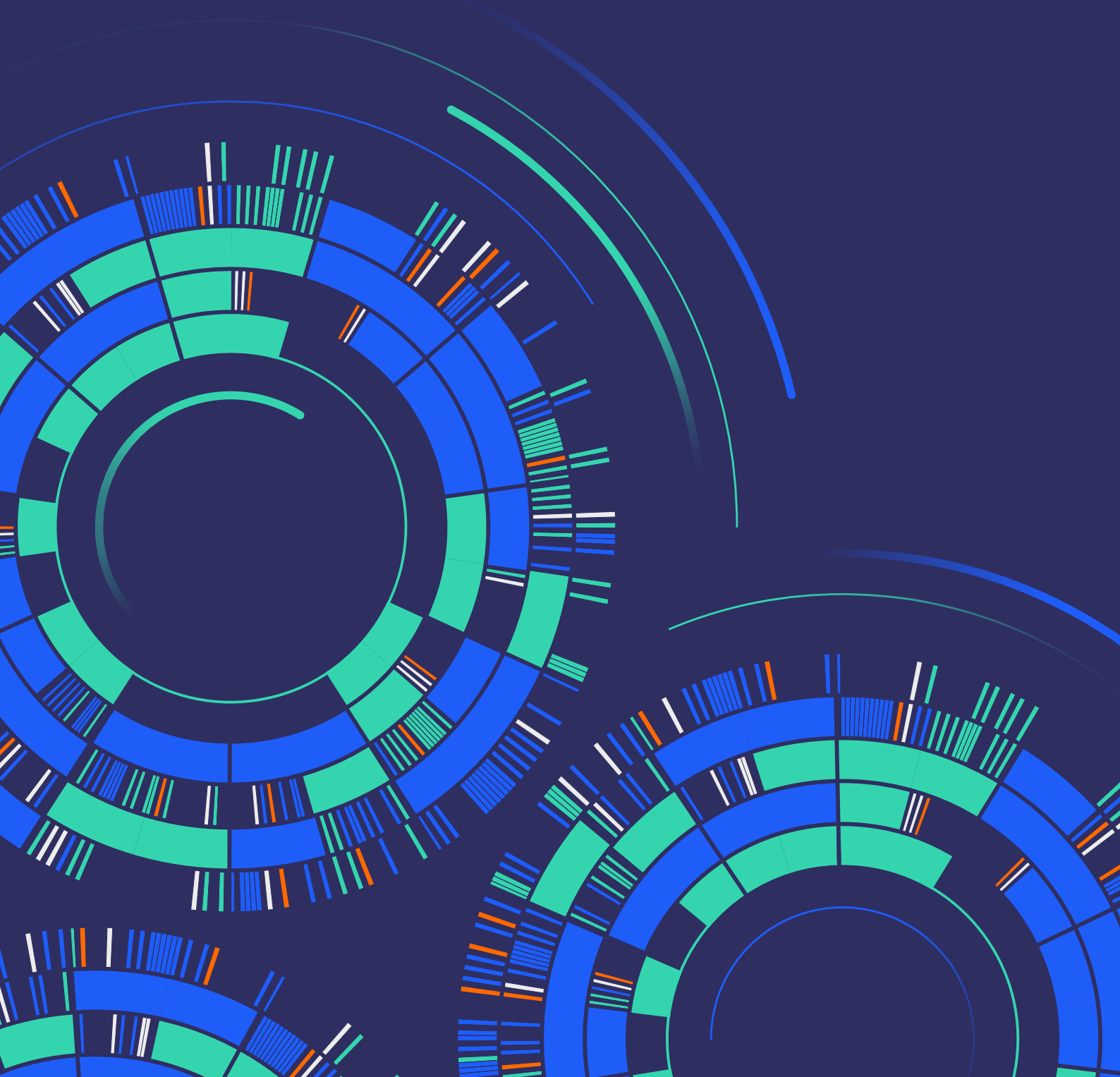
UKRI National Quantum Computing Centre

Quantum Computing Testbed Initiative (QCTI)

Phase 1 Report



Quantum computing is recognised as a potentially transformational technology.

It has the power to reshape industries and to accelerate scientific discovery. In response to growing momentum within the field, the National Quantum Computing Centre (NQCC), working in partnership with Innovate UK, has invested £30m to establish seven prototype quantum computers, or "testbeds", within the UK.

The programme has challenged UK-based quantum computing providers to deliver fully operational prototype systems to the NQCC, capable of enabling rigorous characterisation, benchmarking, verification, and exploratory application development. This aligns with the NQCC's strategic role to build the UK's assured quantum computing infrastructure and establish itself as an informed and independent user of this emerging technology.

All seven testbeds have now been deployed at the Harwell Campus, allowing the testbed providers to demonstrate and validate their technologies in a trusted and independent environment. The NQCC, in collaboration with colleagues from the Quantum Software Lab at the University of Edinburgh, are now in the process of testing and evaluating these platforms.

Each of the testbeds provides a stable and well-characterised development platform that is capable of running quantum algorithms or analogue quantum processes. The platforms have been chosen to represent the range of architectures that offer a realistic pathway to fault-tolerant quantum computing, supporting the NQCC's mission to accelerate the development of quantum computing capabilities and infrastructure within the UK. The companies and their technology platforms are:

- Aegiq (photonics)
- Infleqtion UK (neutral atoms)
- Quantum Motion (spin qubits in silicon)
- QuEra UK (neutral atoms)
- ORCA Computing (photonics)
- Oxford Ionics, an IonQ company (trapped ions)
- Rigetti UK (superconducting circuits).

By bringing together a diverse range of quantum computing platforms within a single national laboratory, the testbed programme has positioned the NQCC as a global leader in quantum technology evaluation. The initiative has drawn significant national and international attention, highlighting the NQCC's early thought leadership in this space. It has also attracted substantial inward investment into the UK's quantum ecosystem, with US company QuEra establishing an office and development facility on the Harwell Campus and both Rigetti and Infleqtion expanding their UK operations.

Crucially, the funding mechanism for the programme, through Innovate UK's Small Business Research Initiative, has enabled the NQCC to act as an "alpha customer" for testbed suppliers. In this role the NQCC has provided expert oversight and guidance throughout the development process, providing challenge to assure the quality and feasibility of the deliverables while also offering a supportive and collaborative environment for solving any technical or operational problems. This approach has provided valuable insights into the transition from laboratory research to the delivery of complex systems at a remote customer site, helping to de-risk development pathways and accelerate innovation.

While it is still early to assess the broader impacts of the programme, the delivery of the testbeds has already generated positive effects for the UK's quantum ecosystem. It has provided direct support to UK-based quantum computing providers, enabling them to advance their technology roadmaps.

Companies taking part in the programme have secured significant funding from private investors, totalling around $715 m in 2025, while Oxford Ionics was acquired by IonQ for more than $1 bn.

The delivery of the seven testbeds represents a significant milestone for quantum computing in the UK, which has been enabled through considerable effort of the project teams alongside dedicated project oversight and facilities provision by the NQCC.

The programme has also strengthened supply chains, created high-value jobs, and developed new collaborations that provide a strong foundation for future research and innovation. Several providers have secured Quantum Mission Pilot grants, with follow-on funding for collaborative projects reaching a total of £4.6 m, and the programme continues to inform and shape aspects of the UK's national Quantum Mission 1 initiative.

Dr Michael Cuthbert
Director, NQCC

The delivery of the seven testbeds represents a significant milestone for quantum computing in the UK, which has been enabled through considerable effort of the project teams alongside dedicated project oversight and facilities provision by the NQCC.

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Quantum computing testbeds accelerate innovation through evaluation and exploration.

The driving rationale of the Quantum Computing Testbeds Initiative (QCTI) has been to place state-of-the-art technology in the hands of expert users for evaluation and exploration, whilst enabling companies to progress along their R&D roadmaps.

The QCTI was designed from the outset to comprise two phases: the first focussed on testbed development and deployment – co-delivered by the NQCC and Innovate UK – whilst the second phase involves performance evaluation and utilisation, led by the NQCC in partnership with the Quantum Software Lab at Edinburgh. It's the combination of cutting edge tech development twinned with rigorous test and validation that has become the hallmark of the programme's value - de-risking technology development and future investment. The role of the NQCC has been to act as a first customer.

This report reviews the progress to date, reflects on the key outcomes from the first phase, and introduces the scope and objectives of the technical test and evaluation phase of the programme. It also provides an opportunity for the seven testbed providers to provide direct feedback on their motivations for taking part in the programme, their most significant technical achievements, and their experiences of working with the NQCC to deliver their testbed systems.

Phase 1 saw the launch of a competition and the award of seven contracts, totalling £30 m in all, to Aeqiq, Infleqtion, Orca Computing, Oxford Ionics (now part of IonQ), Quantum Motion, QuEra and Rigetti. This report focuses on the outputs and near-term outcomes of Phase 1, which successfully concluded at the end of 2025. The key objective of this first phase was to deliver programmable, operational testbeds ready for benchmarking, verification and exploratory applications development.

All but one of the testbed providers elected to deploy their machines into NQCC-operated facilities at Harwell Campus, whilst QuEra chose to invest in its own facility to co-locate on the same campus as the NQCC. For some, this was the first time they had deployed one of their systems outside of their own premises, at a customer site. For all, this has marked a period working closely with the NQCC. At the same time, the NQCC was undertaking its own 5-year mission to establish a national centre in quantum computing, and was able to offer brand new and newly refurbished lab spaces in which to host and operate the testbeds on our premises. These arrangements have helped to establish the NQCC as something of a proving ground for quantum computers, within known operational test environments.

Thanks to the delivery of operational testbeds integrated into NQCC facilities, Phase 2 is already well underway – with the important preparatory work to design the test regimes in train before the end of the first phase – to establish a performance evaluation framework. The main programme of work on Phase 2 is due to complete in Q2 2027.

What is striking to me is the shared sense of endeavour this programme has engendered. Not only is it a story of technology development, it is also one of investment, job creation and growth, helping to seed a core capability in quantum computing for the UK.

I wanted to take this opportunity to express sincere thanks to all those involved as part of this shared endeavour, but in particular to the testbed providers, the QCTI core team, Innovate UK, the Quantum Software Lab, all those at the NQCC and our partners, who have made the realisation of this vision possible. It has been a complex programme with many twists and turns, but your dedication and perseverance have led to the many successful outcomes we see today.

Dr Simon Plant
NQCC Deputy Director for Innovation
and QCTI Programme Sponsor

QCTI programme overview

Rapid progress in quantum computing has been driven by growing investments in research and development over the last decade. However, significant technical challenges must still be overcome to realise the full power of quantum computing. It is widely recognised that quantum processors must be scaled up, with thousands or even millions of qubits required to execute more complex quantum algorithms efficiently. The quantum states used for computation are also prone to noise, generating errors in the calculations that can quickly accumulate and return faulty results.

The UK's National Quantum Computing Centre (NQCC) recognised the need to understand the current capabilities of different technology platforms and their possible uses for solving real-world problems. The NQCC considered establishing quantum computing testbeds to be a vital step in building the UK's quantum computing capabilities, enabling the technology to be demonstrated and showcased.

The NQCC therefore devised a two-phase programme, comprising build and deployment in the first phase (2023-25), and test and evaluation in the second phase (2025-27). The NQCC has therefore invested £30m to establish seven prototype quantum computers, or "testbeds", representing a range of technology approaches that could offer a pathway towards fault-tolerant quantum computing. To deliver the testbed programme, commercial companies were challenged to build and deploy a fully operational system within the UK. The strategic objectives of the programme are to:

- Deliver a series of quantum computing testbeds to enable rigorous characterisation, benchmarking and verification, as well as exploratory development of practical applications
- Accelerate the development of assured quantum computing capabilities and infrastructure within the UK
- Establish the NQCC as an informed and independent user of quantum computing resources, acting as a lead customer and supporting the transition from laboratory development to the delivery of fully operational systems
- Support technology providers in their efforts to develop and progress their technology roadmaps, while also providing a mechanism for them to demonstrate the delivery of a full-stack quantum computer that is ready for external validation.

Programme overview

Funding for the contracts as part of Phase 1 was delivered through Innovate UK, using the Small Business Research Initiative (SBRI). Through this funding mechanism the NQCC took the role of lead customer, providing guidance and challenge to the testbed providers from the initial call for proposals through to the delivery of the testbed systems.

The scope of the testbed programme required hardware providers to deliver fully operational prototype systems that meet a clear set of criteria:

- The testbed should provide a stable and well characterised platform that can be operated and tested at system level
- The system should be capable of running quantum algorithms or analogue quantum processes through a clearly documented software environment
- The testbed must be built, commissioned, validated, and made ready for operation in the UK within the defined timeframe
- The system should be made available to the NQCC for at least two years after the end of the project for test, evaluation and exploratory applications development.

An initial call for "expressions of interest" was launched at the end of May 2023 to assess the scope and level of engagement with the programme, understand what might be technically feasible within the funding levels and timeline, and provide early feedback to potential applicants on their project proposals. This yielded 27 responses with a combined budget request of £135m, providing unequivocal evidence that hardware companies could see clear value in working with the NQCC to advance their technologies and support their commercial roadmaps.

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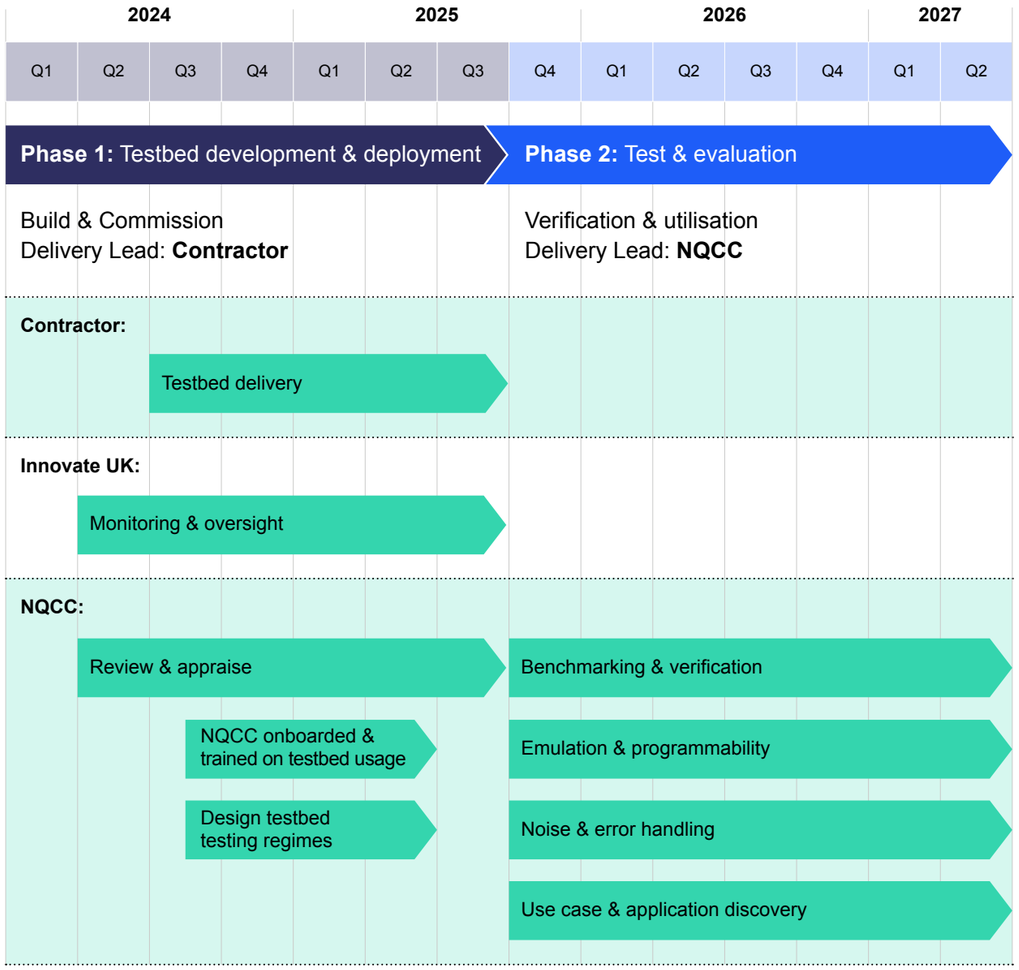
QCTI programme structure



550+
Co-ordination meetings

33
Contractor milestones were evaluated

120+
Contractor staff involved

49
UKRI project team members

Company	Technology platform
Aegiq	Photonic system with a single-photon source
Infleqtion UK	Neutral-atom array with 16x16 qubit sites
Quantum Motion	Spin qubits in a manufacturable silicon platform
QuEra UK	Neutral-atom system with a zoned architecture for computation
ORCA Computing	Photonic system incorporating multiple light-source technologies
Oxford Ionics, an IonQ company	Trapped-ion system designed for scalability, including support for in-field upgrades
Rigetti UK	Superconducting system with 24 qubits, now upgraded to 36 qubits in a 6x6 lattice architecture

A formal call for proposals was launched through Innovate UK in August 2023.[1] Following detailed independent assessment of the project proposals, seven companies were awarded contracts in November 2023 to build and deploy their testbed systems. The chosen cohort represents a range of architectures that offer a route to scalable quantum computing, with each qubit modality presenting unique advantages and specific technical challenges that can be further investigated through ongoing collaborations with the NQCC and its partners.

Project delivery

All seven contracts to develop testbeds on behalf of the NQCC were completed by the end of 2025. Six of the testbed providers deployed their systems in facilities operated by the NQCC at Harwell, Oxfordshire. The seventh company, QuEra, decided to invest in establishing their own facility at Harwell, splitting their development work to deliver a demonstrator system in Boston, Massachusetts, and developing a more advanced testbed at Harwell. The successful delivery of the testbeds has helped to establish the NQCC as a 'proving ground' that provides the expertise and facilities to host prototype quantum computers, fulfilling its original vision of providing a place for people to come together to build, test and operate quantum computers.

At the outset of the programme, the delivery team at the NQCC defined three metrics for success:

- Establish a portfolio of projects that deliver at least three distinct modalities
- Deliver two thirds of testbeds that are functional against target performance criteria by 31 March 2025
- Retain more than 50% of testbeds for the technical evaluation in Phase 2.

Two of these have been exceeded, while the third was partially met.

It was both ambitious and challenging to deliver, deploy and commission the seven testbed systems within such an accelerated timeframe. Reaching this milestone was achieved through considerable effort from each of the project teams, alongside dedicated project oversight and facilities provision by the NQCC. Overall, over 550 co-ordination meetings and more than 120 specialist contractors were needed to complete the delivery of the seven projects.

That significant effort was aided by the co-location of the project teams on the Harwell Campus at various stages, allowing regular interaction and feedback between the testbed providers and the NQCC. Strong relationships have developed as a result, with the NQCC establishing itself as a trusted partner for ongoing collaborations with the quantum industry.

The testbed contractors particularly valued the insights they have gained from deploying their systems at a remote customer site, while the NQCC has gained more technical knowledge about the different hardware platforms by overseeing the delivery of the contracts through its lead customer role. The experience of delivering such a complex programme with many moving parts has informed the development of new processes, policies and solutions at the NQCC.

1 https://apply-for-innovation-funding.service.gov.uk/competition/1700/overview/974d27b0-9ab4-4060-82e7-e1d9cfaaf263

Metric	Measure
Establish a portfolio of projects that deliver at least three distinct modalities	**Exceeded** Five distinct modalities represented
Two thirds of testbeds delivered and functional against target performance criteria by 31 March 2025	**Partially met** Some of the contracts were extended, but all were delivered during 2025
More than 50% of testbeds retained for the second technical evaluation phase	**Exceeded** Six accepted, one pending in pre-evaluation status

Key takeaways

While too early to assess the full impact of the testbed programme, the successful delivery of seven state-of-the-art testbed systems provides useful validation of the project framework and delivery process. An independent study of the programme, conducted by the Institute of Manufacturing at the University of Cambridge during the delivery process and published in October 2025[2], identified several key strengths of the programme structure through in-depth interviews with the testbed providers. The findings of this external study are supported by direct feedback from the hardware companies to the NQCC, which forms the main part of this report (see pages 10–25).

While each of the testbed providers have different technical priorities and commercial strategies, some common themes emerged from their feedback.

1. The role of the NQCC as a lead customer offered significant benefits to the testbed providers, providing challenge to ensure the quality and feasibility of the deliverables while also establishing a supportive environment for solving technical and operational problems. Strong relationships have been developed, which will further strengthen collaboration across the UK's quantum ecosystem.
2. For many companies the programme provided a first-time experience of delivering a fully operational system to a remote customer site, offering valuable insights that will help them to establish efficient workflows when engaging with commercial customers. The testbed systems can now be demonstrated to prospective customers, while independent validation of the platforms by the NQCC will also support their customer conversations.
3. The testbed providers took the opportunity to develop, test and validate new components and subsystems that advance their technology roadmaps. The project framework helped to de-risk development pathways and drive internal innovation, supporting the NQCC's mission to accelerate the development of quantum computing in the UK.
4. Deploying the testbeds within the NQCC's facilities on the Harwell Campus provided the companies with access to state-of-the-art infrastructure and operations support. Working with the NQCC has also allowed the companies to develop connections within the UK's wider technology ecosystem, enabling them to strengthen their supply chains and develop new collaborations. Many of the testbed providers have now won follow-on funding for projects to further develop their testbed systems or to explore their capability for solving real-world problems.
5. The programme provided an opportunity for overseas companies to establish or strengthen their UK-based operations. Notably, the programme provided the impetus for US company QuEra to establish a base in the UK, with an office and development facility now fully operational on the Harwell Campus. Other companies have expanded their technical teams and engaged with new suppliers within the UK, further strengthening the UK's quantum ecosystem.

Next steps

The successful delivery of QCTI Phase 1 has enabled the NQCC to progress to the test and evaluation phase of the programme. Over a two-year period the technical teams at the NQCC, working in collaboration with the Quantum Software Lab at the University of Edinburgh, are benchmarking and verifying the performance of the testbeds using an independent framework. The testbed systems will also be used to explore potential applications of the different hardware architectures, with each one providing a development platform that will allow hands-on experimentation by academic researchers, industry developers and public sector stakeholders. For more information, see page 26.

The successful delivery of QCTI Phase 1 has enabled the NQCC to progress to the test and evaluation phase of the programme. Over a two-year period the technical teams at the NQCC, working in collaboration with the Quantum Software Lab at the University of Edinburgh, are benchmarking and verifying the performance of the testbeds using an independent framework.

2 https://www.ifm.eng.cam.ac.uk/uploads/News/NQCC_Quantum_Computing_Testbed_Pilot_Study_Oct_2025.pdf

Artemis is Aegiq's first-generation photonic quantum computer.

This testbed, the first system Aeqiq has installed on a customer's premises, is designed for exploration and validation of use cases through co-development with UK partners.

aegiq

Strategic drivers

Aeqiq recognised the opportunity to develop a photonic quantum computing platform using a range of novel subsystems that exploit hybrid semiconductor components. We wanted to show that all of the subsystems could be integrated into a chassis that can be installed in a standard data-centre rack, allowing for on-premises deployment at the NQCC.

Working with the NQCC

The NQCC was the first customer for for Aeqiq's photonic quantum computing technology. Nothing can replace the discipline of delivery to a real customer, ensuring milestones are met on time and to specification.

The feedback we have received from the NQCC and its users, and the subsequent opportunity we have had to work with external partners on projects using our hardware, has also been immensely valuable.

Impact and benefits

Aegiq has benefitted from having a customer proof point for the successful delivery of the Artemis system. This will be important as we engage with new customers and build confidence among current and potential future investors.

The programme has triggered a collaboration with Fraunhofer Centre for Applied Photonics (CAP) in Glasgow, and we have also been able to provide several companies with developer access to the testbed installed at the NQCC.

The investment has enabled Aegiq to grow its team in Sheffield, making a significant contribution to technology-led growth within the region.

Main achievements

This has been a significant project for Aeqiq, from the initial design through to manufacturing, delivery, test and acceptance. Some of the headline achievements have been:

- Designing, fabricating and testing a hybrid semiconductor architecture interfaced via optical fibre
- Developing an upgradable and modular platform, consisting of single-photon source, switching, routing, measurement and control
- Creating an integrated system for installation into a standard rack mount
- Developing a software development kit (SDK) for photonic circuit design and job scheduling
- Deploying the complete system at the NQCC, including commissioning, testing and performance verification.

The physical delivery of our system required minimal infrastructure. Assembled units in 19-inch racks were delivered to NQCC and deployed on-premises without the need for any exotic or expensive environmental requirements.

Delivery process

Delivery included design, assembly, installation and on-site commissioning of the Artemis quantum computer, along with dedicated Aegiq Cloud deployment for job scheduling and user management.

The physical delivery of our system required minimal infrastructure. Assembled units in 19-inch racks were delivered to NQCC and deployed on-premises without the need for any exotic or expensive environmental requirements.

Forward look

Quantum computers will transform industries, but only when they become economically viable. Aegiq's approach is built on a modular optically-networked architecture and standard semiconductor manufacturing, using deterministic photon sources to eliminate the probabilistic overhead that drives up complexity and component count in conventional photonic approaches.

Artemis has been critically important in de-risking key technical milestones around modularity and the semiconductor supply chain. The deployment has helped Aeqiq to prove out several hypotheses and to validate our technological approach to fault-tolerant quantum computing at scale.

We have also been able to utilise the installed system in collaborative projects with end-users, helping to improve our understanding of the use cases where future fault-tolerant quantum computers are likely to deliver most value.

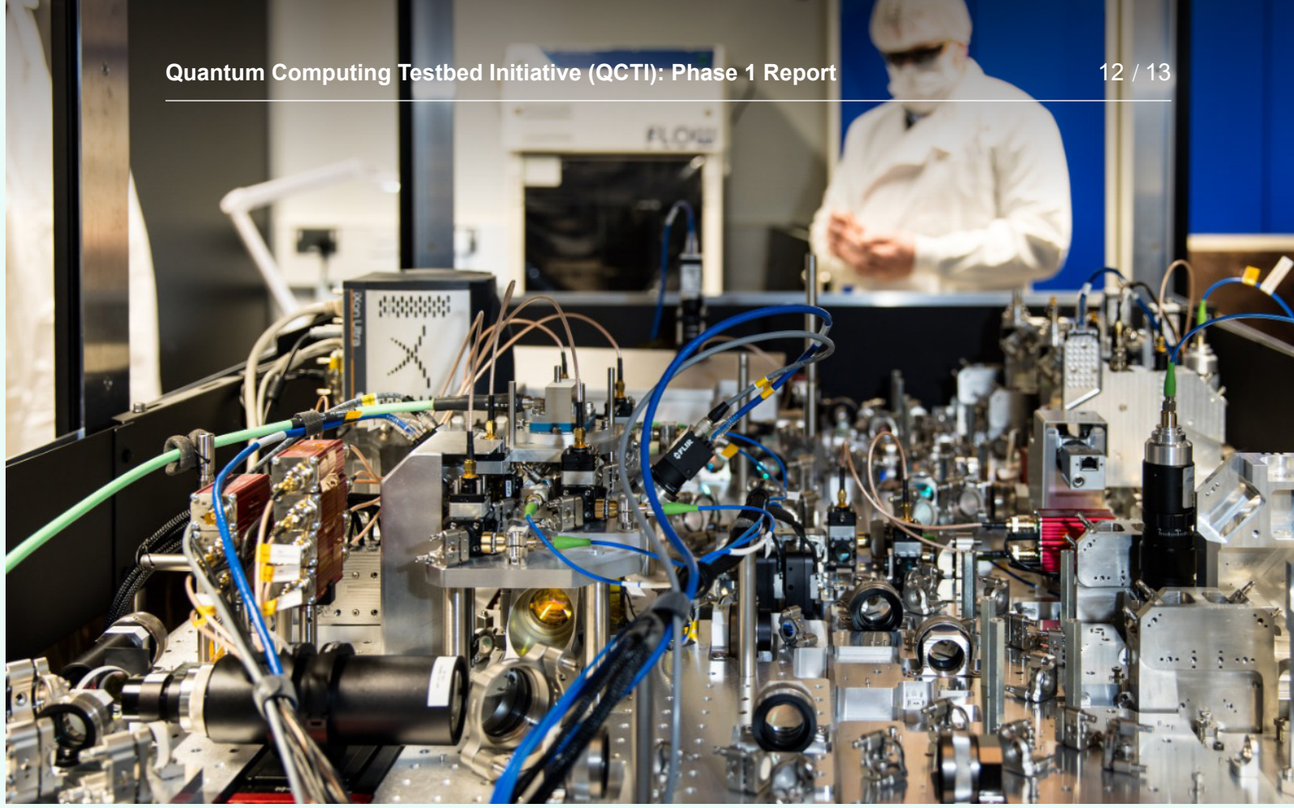
Platform technology:
Neutral atom tweezer array

Infleqtion's Sqale system

Infleqtion delivered a full-stack neutral-atom quantum computer to the NQCC that can perform a universal set of high-fidelity gate operations.

Infleqtion's neutral-atom technology provides in situ entanglement via Rydberg excitation across an array of 16x16 qubit sites. We have combined this hardware architecture with Infleqtion's integrated cloud service, allowing users to submit quantum computations that can be run on the testbed within the NQCC.

Infleqtion



Strategic drivers

The testbed initiative has allowed Infleqtion to build on its strong UK footprint to deploy a platform at the NQCC that showcases the power of neutral-atom quantum computing. At Infleqtion, we recognised the importance of supporting the NQCC in establishing a sovereign quantum computing capability that would drive forward the quantum infrastructure and ecosystem in the UK. The programme was closely aligned with our technology roadmap, which at the time was aiming to mature large-scale, defect-free atom arrays that support high-fidelity gate operations.

Through the testbed programme we have established thriving partnerships across the UK quantum ecosystem, sharing our knowledge with partners to accelerate the adoption of quantum computing.

Working with the NQCC

Infleqtion's involvement with the NQCC has put our company at the centre of the UK's quantum computing community. We have benefitted from wide engagement with research and industry, including the NQCC's Quantum Applications Team and the Quantum Software Laboratory at the University of Edinburgh.

We have gained valuable experience from working with the NQCC, providing Infleqtion with the know-how needed to deploy customer-hosted quantum computing platforms.

Impact and benefits

Infleqtion's involvement in the programme has been a catalyst for the growth of our neutral-atom quantum computing team in the UK. We are proud of the talent we have trained and how this supports the quantum community in the UK. Through the testbed programme we have established thriving partnerships across the UK quantum ecosystem, sharing our knowledge with partners to accelerate the adoption of quantum computing. We have also been able to onboard users to our quantum computing platform through hackathons, workshops and partnerships.

Main achievements

The deployment of a fully operational full-stack quantum computer is an enormous achievement that we are proud to have fulfilled in partnership with the NQCC.

Infleqtion's testbed has enabled the delivery of a UK objective to deploy an operational 100-qubit quantum computer at the NQCC, along with the opportunities that brings.

Delivery process

We tailored our testbed system to the goals of the programme and the objective of establishing a full-stack scalable quantum computer at the NQQC. The delivery of our neutral-atom testbed started from the design phase and continued right through to the hardware installation and optimisation, and ultimately to onboarding users. We started from an empty quantum computing laboratory and worked with the NQCC to establish the environmental conditions and infrastructure needed to support a world-class quantum computing platform.

Next steps

Infleqtion are incredibly excited to be starting Phase II of the testbed initiative, working alongside experts from the NQCC and the QSL to verify the performance of our world-class neutral-atom quantum computing platform. We feel this puts a huge spotlight on what the NQCC has achieved for the UK alongside testbed providers such as Infleqtion UK. We are truly excited about the trajectory of the UK's Quantum Missions programme, and how we can play a leading role in the growth of the quantum computing ecosystem in the UK.

The NQCC is truly world-leading in establishing a sovereign quantum computing ecosystem, and has provided a spotlight on Infleqtion's neutral-atom quantum computing platform as well as those of the other testbed providers.

ORCA delivered a photonic quantum computing testbed that integrates multiple light-source technologies into a single, flexible system.

The technology is designed to advance practical quantum computing at the NQCC, and enables detailed exploration of photonic approaches to complex use cases, including machine learning, optimisation and hybrid quantum–classical applications.

Based on ORCA’s PT Series platform, the testbed features an embedded GPU resource for hybrid applications and supports multiple quantum light sources to enable different boson sampling regimes. These include heralded single photons from a cavity-enhanced spontaneous parametric down conversion source, single-mode squeezed vacuum from a cavity-enhanced parametric down conversion process, and deterministic single photons from a quantum-dot source.

ORCA’s testbed is integrated into an onsite data centre to provide a versatile and configurable foundation for developing quantum algorithms and exploring real-world use cases that offer a route to realising near-term commercial value from photonic quantum computers. Our testbed now serves as a national platform for benchmarking, application development and long term photonic innovation, reinforcing the UK’s ambition to lead globally in quantum technologies.

Strategic drivers

The testbed initiative provided ORCA with a valuable opportunity to accelerate innovation in applications development for photonic quantum computing, advancing both our technical roadmap and our commercialisation efforts. It allowed us to build and deploy our photonic platform in an operational data-centre environment, integrating multiple advanced technologies within a single, flexible system.

The initiative has also enabled ORCA to strengthen its relationships with leading UK organisations in photonics, electronics, and quantum optics, while also encouraging key international photonic technology partners to deepen their collaboration and expand their engagement with the UK ecosystem. At the same time it has created an ideal framework for supporting growing demand for hybrid quantum–classical machine learning, providing researchers, developers, and industry partners with access to real hardware for experimentation and innovation.

Working with the NQCC

Engaging with the NQCC has enabled ORCA to deploy a fully operational system within a live data centre, allowing validation of both hardware and software and performance benchmarking by an expert and independent customer.

In addition, the partnership with the NQCC has strengthened ORCA’s engagement across the wider UK quantum ecosystem. Through the testbed programme, we have deepened our connections with a diverse community of researchers, developers, and industry users who can now access and experiment with real hardware, particularly for hybrid quantum–classical applications. This early user engagement has been instrumental in shaping system capabilities and informing ORCA’s product roadmap.

Beyond technical validation, the NQCC’s role as a national centre has further amplified the impact of the ORCA testbed. Collaborative research programmes such as SparQ have extended access to the platform through industrially focused calls, ensuring that the testbed directly supports applied research and real-world innovation.

Impact and benefits

ORCA’s involvement in the programme has enhanced the UK’s capability in photonic quantum computing by providing a first of its kind operational testbed that integrates multiple light-source technologies into a full-stack platform for applications development and benchmarking.

The delivery of the testbed has also delivered benefits for both the supply and demand sides of the UK quantum ecosystem. By bringing together leading domestic partners and encouraging international suppliers to expand their UK presence, the project has driven supply chain innovation and fostered deeper collaboration. On the demand side, early access to real quantum hardware has increased user adoption, engaging organisations across industry, academia, and government.

The testbed now serves as a long term national resource at the NQCC, supporting ongoing benchmarking, R&D, and future innovation. It provides valuable feedback into ORCA’s roadmap for technology and product development, enables further applications exploration, and offers a platform for conducting customer demonstrations.

Main achievements

ORCA successfully delivered the first photonic quantum computing testbed that integrates multiple light source technologies – including quantum dots, frequency multiplexed sources, and squeezed state systems – into a production ready data-centre environment.

The programme enabled ORCA to evaluate and deploy several light source technologies, develop faster processors and electronics, create new photonic architectures, and integrate cryogenics into the platform for the first time. The project also delivered innovations such as new phase locking protocols and background optimisation routines, each representing a key advancement required for scaling ORCA’s photonic quantum computing platforms.

Building on ORCA’s proven PT 1 system, the testbed has accelerated progress across both our technology and product roadmaps, culminating in the successful launch of ORCA’s next generation products. The PT

2 was introduced in 2025, while the PT 3, due to be released in 2026, is designed to deliver quantum advantage in a commercial machine.

Delivery process

The delivery of the testbed brought together multiple quantum technologies, specialist suppliers, and advanced engineering workflows to create and validate a fully functional photonic quantum computing system. It involved cross-partner hardware development, complex system integration, and rigorous testing to ensure performance at data-centre standards.

Key activities included:

- Installation and operation of high-efficiency superconducting nanowire single-photon detectors (SNSPDs) from ID Quantique (Switzerland) in a live data centre, one of the first such deployments
- Development of a quantum-dot subsystem with Sparrow Quantum (Denmark), involving multiple integration campaigns across Copenhagen and London and resolving fabrication and packaging challenges to achieve a robust rack-mount cryogenic unit
- Design, development, and testing of key hardware sub-modules by Redwave Labs (UK), culminating in full delivery of their unit
- Miniaturisation and ruggedisation of a squeezed-vacuum source with Bay Photonics (UK), transitioning from table-top experiments to a compact, deployable unit
- Integration of high-performance squeezed-vacuum systems achieving high efficiency, purity, and squeezing required for Gaussian boson sampling applications
- Development of advanced single-photon and squeezed-light sources, including multimode heralded systems with high indistinguishability and frequency-resolved capability
- Creation of a high-speed 2 MHz photonic processor, supporting more powerful architectures for increased computational complexity
- Implementation of an overclocking technique, enabling parallel execution across four time bins to significantly boost photon generation rates.

Deployment into the onsite data centre required ORCA to meet a broad range of operational, safety and security criteria, including integration of the testbed with the power and network infrastructure, and engaging with operational staff, procedure and policy.

Forward look

The testbed programme has played a significant role in shaping and accelerating ORCA's product and technology roadmap, serving as a vehicle for developing next generation systems and stimulating strong commercial interest. Deploying the testbed has enabled rigorous evaluation of every aspect of the platform and its deployment, allowing ORCA to refine its hardware, software, and integration strategies.

Now fully operational in the test and exploitation phase, the ORCA testbed is enabling deeper and broader exploration of the application landscape, building a robust ladder of evidence toward demonstrating commercial value from photonic quantum computing.

Looking ahead, the ORCA testbed will continue to serve as a strategic development asset, supporting the validation of new subsystems, refinement of photonic architectures, and accelerated innovation across the PT product line. This will ensure that the PT series remains at the forefront of scalable photonic quantum computing.

> **Now fully operational in the test and exploitation phase, the ORCA testbed is enabling deeper and broader exploration of the application landscape, building a robust ladder of evidence toward demonstrating commercial value from photonic quantum computing.**

Platform technology: Trapped ions

Oxford Ionics' QuARTET system

QuARTET (Quantum Advantage-Ready Trapped-Ion Exploration Testbed) is a trapped-ion system for quantum computing installed at the NQCC.

The full-stack system is designed for both near-term use and future scalability through in-field upgrades to its quantum processor unit (QPU).

IONQ oxford ionics

QuARTET integrates three core technology innovations into a single system: barium ion qubits that provide long coherence times, a robust detection system for high-fidelity readout, and scalable ion loading via magneto-optical trapping. All qubit control is achieved with standard on-chip electronics to improve scalability, manufacturability, and operational performance. The system is contained within a compact chassis and requires 13 kW of power.

QuARTET is equipped with a full-stack software package that allows quantum circuits to be run using the industry-standard OpenQASM and Qiskit formats, as well as a pulse-level control API for studying hardware performance and bottlenecks. The capabilities of QuARTET can be expanded with simple QPU swaps, with the current infrastructure engineered to host QPUs with up to 256 qubits.

Strategic drivers

QuARTET was designed to demonstrate a deployable, prototype universal quantum computer that offers state-of-the-art performance and enables continuous scaling towards practical quantum advantage. Our strategic goals were to:

- Build, commission and validate the trapped-ion quantum computing testbed
- Accelerate the growth of UK's quantum technology ecosystem, infrastructure and technological capabilities
- Drive user adoption of quantum computing in industry and among developers, and grow the UK's community of users, developers, and partners
- Explore and address technological bottlenecks in readiness, integration, performance, and system-level operation of quantum hardware
- Support continued innovation through QPU upgrades that incorporate novel and expanded capabilities.

Working with the NQCC

The NQCC has been a key partner for Oxford Ionics, not just as a customer but as an expert collaborator with a shared interest in seeing the UK quantum computing ecosystem succeed. Installing QuARTET at the NQCC gave us access to a nationally significant facility and a team deeply engaged in the practical challenges of making quantum computing useful across industry, academia, and government. That combination is rare, and has made the partnership particularly valuable.

- The NQCC provided the infrastructure and environment for us to install a full-stack system, allowing us to demonstrate our technology in the context of a real-world deployment
- The NQCC's focus on algorithm development and use case research will allow QuARTET to give us meaningful feedback on system performance and practical utility, and will expose our technology to end-users across industry sectors crucial to the UK economy. Moreover, we are excited to partner with the NQCC's technical teams to drive technology innovation, and to understand the optimal pathways to scaling quantum computing hardware

- Being part of the NQCC's testbed program has brought credibility and visibility to support our broader commercial trajectory. The NQCC sits at the heart of the UK's quantum ambitions, and working closely with the facility has strengthened our relationships with national stakeholders, positioning us as a trusted and capable supplier within the UK's quantum landscape.

Impact and benefits

The testbed programme has been a significant accelerant for Oxford Ionics across several dimensions.

- Delivering QuARTET to the NQCC represented a major commercial and technical milestone, validating our ability to design, manufacture, and deploy a full-stack quantum computer on time and to specification
- The programme has allowed us to refine our delivery roadmap. QuARTET has been designed to allow in-field upgrades, and working within the NQCC's environment has helped us refine how we package and deliver that capability in practice. It has also reinforced just how important that design principle is for our commercial customers
- Our involvement has also fed directly into further recognition from the government. Oxford Ionics, an IonQ company, was selected for a Quantum Missions Pilot program, leading the Q-TATA consortium alongside Riverlane and Bay Photonics. Q-TATA will deliver a powerful upgrade to QuARTET, introducing 2D qubit connectivity and opening a pathway to systems capable of executing over one trillion operations. Through this project we are contributing to the national capability base and helping to build a quantum supply chain with depth
- QuARTET's installation at the NQCC provides users and developers with access to a trapped-ion quantum computer that delivers world-beating performance. Oxford Ionics currently holds the global records for single-qubit gate fidelity, two-qubit gate fidelity, and quantum state preparation and measurement. Through continued field upgrades, QuARTET will provide leading performance to UK researchers, application developers, and industry partners through the NQCC, strengthening the country's position as a leading quantum nation.

Main achievements

QuARTET represents a major milestone in the transition of trapped-ion quantum computing from laboratory research to deployable, scalable infrastructure. It combines operational reliability, full programmability, and architectural extensibility to provide a credible pathway to fault-tolerant quantum computing.

- Measured coherence times have exceeded ten seconds, providing a large execution window for complex quantum algorithms and significantly reducing susceptibility to environmental noise
- The fidelity of state preparation and measurement fidelity has reached 99.97(3)%, providing the high reliability needed for both algorithm execution and quantum error correction
- Two-state entangling gates have been demonstrated alongside precise single-qubit rotations, enabling execution of arbitrary quantum circuits and confirming full computational universality
- Quantum algorithms have been executed through the full-stack software interface, confirming seamless integration between hardware and software layers. Users can define arbitrary quantum programs at the application level and execute them directly on the system
- Rapid and reliable qubit loading for efficient qubit utilisation and scaling to large ion registers
- An upgrade-ready architecture allows the QPU to be replaced with minimal on-site disruption.

Future outlook

The testbed programme has shown that the QuARTET architecture is operationally ready, programmable, and scalable to larger ion registers. These results establish a strong foundation for future development and contribute to the UK's quantum technology ecosystem, infrastructure, and technological capabilities in quantum computing.

Moving forward, QuARTET represents the ideal infrastructure to test, validate, and exploit our QPUs as they are released, ensuring the NQCC and the UK maintain a position of global leadership. The Q-TATA project funded by Innovate UK will be the first field upgrade, providing QuARTET with enhanced connectivity and transport capabilities to support the implementation of quantum error correction. Over time, this progress will enable more complex quantum algorithms to be run on the system, supporting efforts to accelerate user adoption of quantum computing and helping to grow the wider ecosystem of users and developers.

Platform technology: Silicon spin

Quantum Motion's QM One system

Quantum Motion delivered the QM One, a scalable system for quantum computing based on our spin-qubit technology.

The quantum processing unit (QPU) was designed by Quantum Motion and manufactured by our fabrication partner in Europe using 300 mm wafer-scale industrial CMOS fabrication, an approach that will allow us to scale to the millions of qubits necessary for deploying utility-scale quantum computers. The system also provides the flexibility for future upgrades to the QPU chip without the need for extensive changes.

QUANTUM MOTION

Strategic drivers

It is Quantum Motion's goal to create a quantum computer able to deliver benefits beyond the capabilities of a classical supercomputer. Our involvement in the testbeds initiative was a great opportunity to showcase our progress on the way to achieve that goal. This was our first opportunity to build a full-stack quantum computer for an external client and we were eager to rise to the challenge.

Working with the NQCC

As a company steeped in research and development, working with the NQCC as our first customer has been incredibly valuable. It allowed Quantum Motion to reach beyond its academic roots and gain our first experience of being a commercial organisation, establishing the processes, capabilities and systems to engage with and support real-world customers.
Our approach is to demonstrate a state-of-the-art building block that is also scalable.

The NQCC team will validate and benchmark this device, run sample programs and provide early user feedback. This feedback will be especially valuable when it comes to the evolution towards larger systems, which we plan to make available through an upgrade of the NQCC on-site system and also remotely as a service.

Impact and benefits

Delivering QM One, our first full-stack quantum computing system, was a fantastic milestone for the company and a great source of pride and motivation for all employees. It reinforced the team's enthusiasm and confidence to push for and achieve the next, bigger goal.

Being part of the testbed initiative has also been a vote of confidence for Quantum Motion and a point of validation that we are now able to take to potential clients and investors. It allows to show potential customers not only the physical hardware, but also the interface and how it handles computation in real time. For a technology that is notoriously difficult to grasp, the QM One stands as a testament to Quantum Motion's ability to build a fully working quantum computer.
For the wider UK quantum ecosystem, the testbed initiative is a clear show of strength of the teams building quantum computers in the UK. It offers a valuable path to build a highly skilled user base for quantum computing offerings in the UK.

Main achievements

- We have engineered and deployed the first ever silicon-spin QPU to be produced with a commercial foundry process. Leveraging established semiconductor manufacturing techniques is a strategic choice that ensures scalability and reliability, demonstrating a viable pathway towards larger, more complex quantum systems
- We have engineered a comprehensive and intuitive control software stack that enables users to interact with the QPU using any of the major quantum computing frameworks, including Qiskit, Cirq and Pennylane. This software abstracts the complex physics and engineering details of silicon-spin quantum computing, allowing users to run quantum circuits, perform experiments, and explore the capabilities of the hardware through a high-level interface. This focus on usability facilitates broader adoption and accelerates the development of quantum algorithms
- We have developed and implemented sophisticated and fully automated techniques for calibration and control. These systems are designed to continuously monitor the QPU's performance, diagnose operational drift, and execute any necessary corrective measures. This dramatically improves the uptime, stability, and operational cost-efficiency of the quantum device, moving beyond the traditional reliance on expert personnel for day-to-day maintenance and ensuring consistent, high-fidelity quantum operations.

Delivery process

This is the first time we have engineered a full-stack system for deployment at a secure, off-site location. Building the testbed required a dedicated focus on systems engineering, software development, and operational stability. As part of the delivery process, we have established the processes, capabilities and systems to engage with real-world customers.

Forward look

This project provided the opportunity and impetus to fully optimise a device for use by external stakeholders, and it was the key driver for the development of a software stack that could support circuit-based execution.

It has progressed our development effort from a focus on component development to the engineering of full-stack system. As next steps we are excited to work on increasing the scale of the QM One, which was designed to support ongoing upgrades that will continuously deliver more value to users.

This project provided the opportunity and impetus to fully optimise a device for use by external stakeholders, and it was the key driver for the development of a software stack that could support circuit-based execution.

QuEra has delivered a neutral-atom quantum computing testbed based on our Generation-4 system architecture.

Designed to explore the transition from laboratory-scale quantum processors to fault-tolerant quantum computation, the system is based on programmable arrays of individual rubidium atoms trapped in tightly focused optical tweezers and manipulated using laser-driven interactions between Rydberg states.

QuEra

The testbed system features a zoned architecture that separates the memory from the gate operations, combined with coherent atom shuttling to support non-local and reconfigurable connectivity between qubits. During the project QuEra and our collaborators made major technical advances that were directly relevant to the testbed architecture, allowing us to move beyond the original concept of a moving-atom system towards a more complete processor architecture.

The enhanced platform supports single- and two-qubit gates, mid-circuit measurement and continuous atom replenishment, making it more suitable for longer computations and for exploring practical schemes for quantum error correction. The original design (called CAST) has been used as a development and de-risking platform in Boston, allowing us to accelerate the build of a more capable testbed in the UK.

The Generation-4 system offers an advanced platform for collaborative research and technology development, and for exploring applications that may become economically relevant as quantum processors continue to scale. Neutral-atom processors are particularly well suited for problems involving programmable lattice geometries and many-body dynamics, which includes applications in materials science, quantum chemistry, and optimisation.

Strategic drivers

At the technical level, the programme offered a framework that allowed us to focus on coherent shuttling and zoned operation as enabling technologies. It also provided a rare opportunity to develop and validate an advanced neutral-atom architecture in close partnership with a national quantum centre that is explicitly focused on scalable, fault-tolerant quantum computing. The NQCC's emphasis on architectural diversity, benchmarking, and user access made it an attractive environment for establishing a neutral-atom capability.

The programme also offered an opportunity for us to build a durable UK presence that could support collaboration across academia, national labs, software partners, and component suppliers. It allowed us to engage directly with the UK quantum ecosystem at a time when substantial national investments were being made in quantum technologies, and to work with UK stakeholders on benchmarking, use cases, and integration within a wider national programme of quantum testbeds.

Working with the NQCC

Our engagement with the NQCC placed the project within a national framework designed to support the maturation of quantum computing from isolated technical achievements into practical systems. With its focus on building credible, comparable, and application-relevant quantum computing testbeds, the NQCC has been able to convene the right kinds of discussions around architecture, benchmarking, and long-term relevance.

That has helped to position the latest hardware demonstrations within a broader context of fault tolerance, user access, software integration, and future applications.

The NQCC environment has helped us to engage with a wider group of UK stakeholders, including software and decoding groups, university researchers, prospective application partners, and companies working in areas such as photonics, imaging, vacuum systems, and control technologies. That has led to follow-on research that will advance neutral-atom quantum computing in the UK.

We have benefitted from the NQCC's adaptive approach, which allowed us to adjust our delivery pathway as technical progress accelerated during the project. That flexibility, which was grounded in a strong collaborative relationship and a shared understanding of the programme's objectives, preserved the value of the original CAST design while materially improving the long-term capability located on Harwell Campus in Oxfordshire, alongside the NQCC.

Impact and benefits

For QuEra, one of the most immediate benefits has been the creation and growth of an operating presence in the UK, with QuEra Computing UK Ltd now established on the Harwell Campus. We have invested in a purpose-built facility that is fully equipped with cleanroom-capable infrastructure and precise environmental stabilization systems, providing a stable base for future development and collaboration in the UK. QuEra UK has steadily grown, with technical staff working across software development, experimental physics, system design, and platform integration.

For the UK ecosystem, the most obvious benefit is the addition of a neutral-atom platform into the national portfolio of quantum testbeds. The platform complements existing superconducting, trapped-ion, and photonic approaches while providing a distinctive capability in terms of qubit scalability and reconfigurable connectivity. This architectural diversity broadens the set of systems available for benchmarking, and has helped to strengthen the supply chain of enabling technologies for neutral-atom quantum computing. We have already engaged with a number of relevant organisations in the UK, including Riverlane, Mesolens, Covesion, Fraunhofer CAP, and UKAEA STG.

One particularly important outcome is the ongoing QNABLE R&D programme, a six-month project specifically aimed at mid-term scaling barriers for neutral-atom quantum computing. The programme spans optics, lasers, continuous quantum registers, error correction, decoding, and materials-science algorithms, showing how the testbed activity has already generated follow-on collaboration beyond the initial deployment of the hardware.

Main achievements

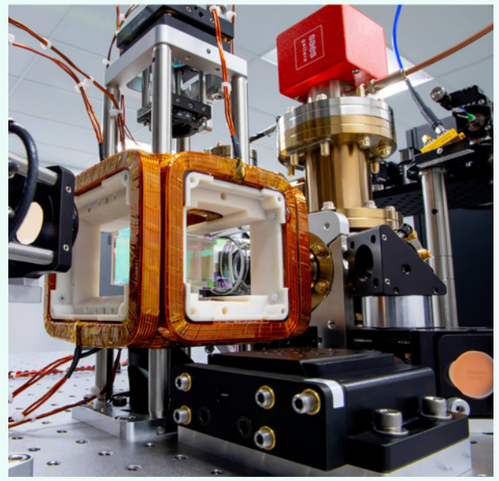
- QuEra has successfully demonstrated coherent shuttling of atoms across a zoned neutral atom processor. With the CAST development platform meeting all the key performance metrics for this architecture, supporting more than 200 physical qubits, more than 2000 addressable register locations, and achieving an atom initialisation success rate above 99%. Atom blocks can be shuttled across the field of view in 150 microseconds with a move fidelity above 99.2%, while the detection fidelity is around 99.5% at longer integration times and above-target performance at shorter times
- The CAST platform can execute movement patterns relevant to quantum information processing and future error-correction workflows, demonstrating that the shuttling architecture can be shaped to meet the requirements of logical protocols and code layouts
- The programme has delivered meaningful advances in control and interface infrastructure. We have validated elements of Quetzal-OS, the latest version of QuEra's physical control-plane operating system, and developed new interfaces between imaging systems, embedded controls, and external hardware frameworks. Work with Teledyne and Riverlane helped establish communication and data-interface pathways relevant to future real-time decoding and control applications
- Our dedicated UK infrastructure also represents a substantial operational milestone, and we now have generated credible and immediate follow-on work, in particular the QNABLE programme, helping to structure a broader UK-facing development pathway around neutral-atom quantum computing.

Delivery process

The testbed comprises a sophisticated set of subsystems with demanding performance requirements that must be assembled in a tightly integrated manner. Delivery therefore involved both procurement of major components and the development and validation of subsystem interfaces.

The Harwell deployment also demanded a substantial logistical effort, including the design and build of a purpose-built facility equipped with the complex optical and vacuum systems needed for neutral-atom hardware. Major system components were shipped from Boston using a specialized climate-controlled shipping container, with around 14,000 kg of material requiring detailed validation, inventory management, and subsequent offloading at the Harwell facility.

Delivering a reliable and maintainable system also required the integration of QuEra's control software and operating systems, validation of imaging and control interfaces, and partial progress toward UK-specific access software and control-stack deployment. Another substantial effort was adapting the programme during the delivery process to accelerate the UK effort into a more capable Generation-4 build.



From QuEra's perspective, the outlook is strong. The company now has a growing UK team, a dedicated Harwell facility, an advanced testbed, and an active follow-on consortium programme.

Forward look

The programme has materially advanced QuEra's roadmap towards scalable, error-corrected neutral-atom quantum computing. It allowed us to validate architectural ideas at the level of real systems while simultaneously building out the next layer of capability in the UK.

CAST continues to support rapid testing of new approaches and experimental modules that are directly relevant to the Harwell system. This twin-testbed model – one platform used to validate and accelerate another – has become a productive way to shorten development cycles and reduce risk in the UK build.

Meanwhile, the advanced testbed deployed at Harwell represents a significant step forward on QuEra's internal roadmap. While the testbed does not yet provide a utility-scale machine, it can be used to validate the subsystems and workflows needed to get there.

The QNABLE programme will now extend the work of the testbed into several of the critical mid-term barriers for scaling neutral-atom systems. It will investigate improved optical schemes for qubit control and more scalable and integrated systems design, including a continuous reloading quantum register and a rack-mounted atom-lattice module. It also brings us together with Riverlane and UCL to study decoders for reconfigurable atom arrays, and it links the platform to applications in materials science through work with Phasecraft, Kings College London, and Oxford.

From QuEra's perspective, the outlook is strong. The company now has a growing UK team, a dedicated Harwell facility, an advanced testbed, and an active follow-on consortium programme. Our involvement in the initiative has helped to establish the UK as a meaningful part of QuEra's long-term roadmap toward fault-tolerant and ultimately utility-scale quantum computing.

Rigetti's original testbed at the NQCC featured a 24-qubit quantum processor.

This fourth-generation Ankaa™-style device had a 4x6 square lattice architecture containing 24 flux-tunable transmon qubits, with 38 transmon-based tunable couplers between them. This was deployed with our Tsunami control system and integrated with Riverlane's Deltaflow system for real-time quantum error correction (QEC).

rigetti

The testbed has since been upgraded as a result of the HERMES project, funded by Innovate UK. We have now deployed a larger 36-qubit Ankaa-style device with a 6x6 square lattice architecture, and have upgraded to our OmegaStar control system. OmegaStar reduces latency in the interface with Deltaflow, thereby cutting full decoding response times. Additionally, OmegaStar incorporates the capability to flag mid-circuit measurement leakage errors, allowing the downstream QEC stack to manage these effectively.

The Rigetti and Riverlane teams have worked to fully integrate Deltaflow with OmegaStar, allowing real-time decoding to be performed on the testbed. Deltaflow supports parallelised and streaming decoding, addressing latency bottlenecks in surface-code experiments with superconducting qubits.

Strategic drivers

The aims of the testbeds initiative was closely aligned with Rigetti's technology roadmap and business goals. A critical element of reaching fault-tolerant quantum computing will be to integrate error correction into our systems. Through our NQCC testbed, we aimed to enhance our QEC capabilities by integrating our NQCC-hosted system with Riverlane's Deltaflow system. Through the project we sought to strengthen our partnership with Riverlane and deepen our understanding of how our technologies integrate and work together.

By delivering improved system capabilities with a higher qubit-count device and enhanced control electronics to the NQCC, we aimed to develop deeper relationships within the UK quantum ecosystem and undertake further R&D in the UK.

Working with the NQCC

Our relationship with the NQCC has deepened our involvement with the UK ecosystem, enabled valuable knowledge sharing with the NQCC's superconducting circuits team, and led to new opportunities for collaboration.

- Through this project we have been able to give the NQCC insights into the operation and capabilities of our quantum computing system. The assurance we gain through their use of the testbed will build Rigetti's credibility and strengthen our position in the UK ecosystem
- We have been involved in NQCC events, such as speaking to NQCC interns and participating in forums and conferences. We have also had the opportunity to be a part of the NQCC's media coverage, which has increased company visibility and brand awareness
- Through this relationship with the NQCC we have identified further opportunities for collaboration, leading to our involvement in several R&D projects.

Impact and benefits

- This project made progress towards the UK's Quantum Mission 1, developing UK-based capabilities while also enabling Rigetti to remain competitive and to showcase the cutting-edge capabilities we have developed
- A deeper relationship has been forged between Rigetti and Riverlane, helping both companies to achieve their goals through collaboration and knowledge sharing
- The project has led to employment and talent development for the UK through the expansion of both Rigetti and Riverlane's teams
- Through the NQCC's SparQ programme, more users have gained experience with developing applications for state-of-the-art quantum computers. This also benefits Rigetti as more users gain familiarity with our QPUs.

Rigetti also reaps economic benefits from having a quantum computer hosted at the NQCC. Having a UK-based quantum computer allows Rigetti to have their technology validated by NQCC researchers and enables Rigetti to further establish themselves in the UK quantum ecosystem, unlocking collaboration and business development opportunities

Main achievements

- Deployed a 24-qubit quantum computer testbed at the NQCC within just nine months of having access to the site, making ours the first operational quantum computer at the NQCC
- Upgraded the QPU to a 36-qubit system with our latest control systems, allowing us to implement a full decoder integration
- Successful running of real-time QEC experiments on the testbed.

Delivery process

To deliver the testbed, Rigetti worked closely with the NQCC operations team to ensure the required facilities would be accessible for the build phase of the project. A Rigetti team worked at the NQCC for nine months to build, optimise, and validate the system.

The testbed was deployed on Rigetti's Quantum Cloud Services (QCS®) to make it accessible to both the project team and NQCC's quantum applications engineers. The Riverlane team developed, built, and tested their Deltaflow system before working with us to integrate it with our control systems. Finally, a QEC experiment was designed and tested to test functionality.

Forward look

The testbed project has deepened our relationship with Riverlane and helped to inform our development roadmap. It has bolstered our QEC workstream, which is a crucial step for us to achieve our goal of building the world's most powerful computers to help solve humanity's most important and pressing problems.

The testbed initiative also enabled us to undertake the Innovate UK-funded HERMES project, which was dependent on upgrading and using the testbed hosted at NQCC. This has supported further research into improving the readout on our quantum processors, as well as continued QEC development with Riverlane through the integration of our testbed with the Deltaflow system. That has allowed us to run real-time QEC experiments on our NQCC-hosted QPU.

Having a UK-based quantum computer allows Rigetti to have their technology validated by NQCC researchers and enables Rigetti to further establish themselves in the UK quantum ecosystem, unlocking collaboration and business development opportunities.

Next steps: Phase 2 test and evaluation

The successful delivery of the testbed systems has enabled the NQCC to progress to the test and evaluation phase of the programme.

Over a two-year period the NQCC, working in partnership with the Quantum Software Lab at the University of Edinburgh, will have access to the testbeds for characterisation, benchmarking and verification, and for exploratory applications discovery. This phase of the programme aims to progress several strategic outcomes:

- Identify pathways to achieve verifiable quantum advantage for different qubit modalities
- Accelerate progress towards fault-tolerant quantum computing, generating knowledge and evidence that will inform roadmaps for future technology development
- Enhance quantum readiness by discovering which application areas and quantum algorithms are best suited to different modalities and architectures.

The work programme has been designed to maximise the learning return from the testbed systems, building the NQCC's technical understanding and knowledge across the available quantum computing modalities. Cross-team engagement with the testbed providers continues to play a crucial role in this phase of the programme, providing continuous feedback and technical expertise to guide our internal R&D efforts. The programme is focussed around three key objectives:

- Benchmark and evaluate the performance of the testbed systems, assessing both their technical performance and their capabilities for applications development
- Implement and run quantum algorithms on the testbeds to explore which modalities and architectures are most suited to tackling particular types of computational problems
- Drive practical use of the available testbeds through exploratory applications discovery.

Programme delivery

The test and evaluation phase encompasses a number of different stages, with progress from one to another mediated by a series of evaluation gates.

The first of these assessments determines whether a testbed can be accepted into this part of the programme, based on the following criteria:

Performance	• The testbed has fulfilled the scope and specifications of the delivery phase, as determined by key technical metrics
Usability	• The testbed can be operated by an expert user using a well-defined and documented programming environment with executable scripts • The testbed offers sufficient uptime to provide continuity of access
Potential for follow-on R&D	• The testbed is capable of running benchmarking protocols and quantum algorithms for use case discovery • The architecture provides support for hardware upgrades and scaling to larger systems

Different workstreams have been defined that focus either on the evaluation or the practical utility of the testbed systems. Evaluations at key milestones during the two-year period of the programme make it possible to tailor the programme to the capabilities of each testbed system, providing greater flexibility to focus on the workstreams that deliver most value from each platform.

Evaluation	**Onboarding and training** Providing applications engineers from the NQCC and researchers from the QSL with training and access to the testbeds and their programming environments
	Designing test regimes Establishing comprehensive testing frameworks for each modality, while also identifying common elements to develop a universal test regime
	Characterisation and benchmarking Running different benchmarking protocols and providing independent verification of the testbeds' systems-level specifications
Utilisation	**Emulation and programming** Implementing quantum algorithms to assess the suitability of the testbed systems for applications development
	Noise and error handling Characterising and modelling the noise within the systems and developing strategies for error correction
	Use case and applications exploration Running algorithms to solve (toy) problems and to understand the capabilities of different architectures for solving particular types of problem

Within the broad areas covered by the workstreams, individual projects are taking complementary approaches to deepen our understanding of the different hardware architectures and their use in practical applications. Close collaboration between the QSL and the NQCC is accelerating progress by integrating the latest theoretical insights with the practical application of emerging ideas.

Building block projects

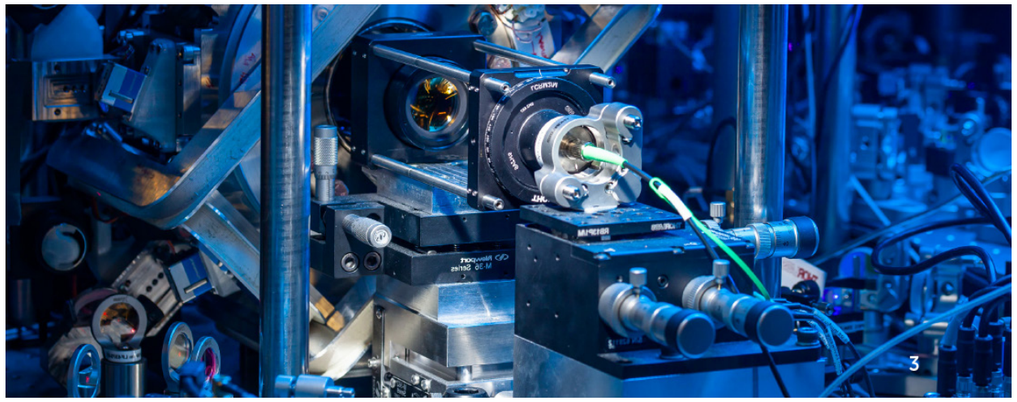
Building block projects are focussing on the theoretical foundations that will be needed for fault-tolerant quantum computing, including strategies for error reduction and correction, quantum algorithms to achieve quantum advantage, and methodologies for verification and benchmarking. These research projects will be led by the QSL, collaborating with the NQCC and the testbed providers.

Pipeline projects

Pipeline projects take a more applied approach, using the testbeds to develop solutions to particular problems within the domains of simulation, optimisation and machine learning. These projects, led by applications engineers at the NQCC, utilise the building blocks developed by the QSL to establish an end-to-end framework for solutions development and delivery. The overall aim of these longer and more complex projects will be to identify pathways towards verifiable quantum advantage for different modalities. Further into the programme, our ambition is to initiate collaborative projects that will enable end-users in academia, industry and government to access the testbed systems for use case and applications discovery. These projects will be managed through the SparQ programme, but will benefit from the pipeline approach to solutions delivery developed by the NQCC.

An outside view

An independent study of the testbed programme was conducted during the delivery phase by Professor Chander Velu and Dr Keith Norman of the Institute of Manufacturing at the University of Cambridge. Published in October 2025, the pilot study aimed to understand the role that the testbeds could play in building the UK's quantum ecosystem and enabling economic growth.



Through in-depth interviews with the testbed providers and representatives from quantum computing industrial communities, the study identified several important strengths of the testbed programme:

- The testbed community appreciated the innovation model, where the NQCC is fully engaged as a lead customer and provides access to critical support infrastructure. With no established commercial market for quantum computers, the testbed programme provided a valuable opportunity for the companies to deploy fully operational systems in a customer-like setting. The NQCC was seen as a sympathetic customer, interested in developing capabilities of the machines with a focus on identifying valuable applications that might benefit society
- The companies valued the funding they received for technical development and the opportunity to test new ideas in a state-of-the-art facility. The programme was seen as an accelerator for internal development, while building a complete system in a remote environment helped companies to identify strategies for future product development
- The testbed providers were keen to engage with the NQCC as a centre of excellence for quantum computing. The technical skills of the NQCC's team were seen as a core strength, as well as its ability to make connections with end-users and technology suppliers. The testbed companies were keen to build relationships across the UK's quantum ecosystem, while the co-location of the testbed companies on the Harwell Campus created a sense of community and offered access to a wider talent pool. For overseas companies, the programme provided a valuable entry point into the UK ecosystem and offered the opportunity to create partnerships with the research community and industry-leading companies such as Riverlane.

More generally, the study explored the potential of the testbed programme to catalyse business and economic growth within the UK. The authors analysed several key factors that would encourage end-users and technology suppliers to engage with the testbed providers and the NQCC to accelerate technical innovation and to exploit the technology for social and economic development.

Technology framing

Benchmarking the prototype systems will provide valuable guidance to the testbed providers on the priorities for future technology development. The NQCC's SparQ programme offers an way to extend this benchmarking to applications development, helping the companies to link the capabilities of their platforms to the real-world requirements of end-users. Developing deep-dive case studies in selected industries would help to develop methodologies for designing user-centric benchmarks, while also strengthening the links between end-users and the testbed vendors.

Some companies reported difficulties in accessing enabling technologies, such as packaging capabilities, electronics testing and cloud provision. The NQCC can act as a natural convener to remove that bottleneck, improving access to the broader supply chain and boosting collaboration.

Business models and economic incentives

There are some key firms, or "anchor tenants", that testbed providers are keen to partner with, such as Riverlane, Phasecraft and academic groups at the Quantum Software Lab and the Quantum Hubs. With the right support, these anchor tenants could play an important role in developing and growing the ecosystem.

Some testbed vendors have "steps on the road" products that could lead to a fault-tolerant quantum computing platform. These interim products and their associated ecosystems are important for both business and technical development, and the testbeds could provide an opportunity for the companies to test emerging business models for interim products.

Critical resources and capabilities

The development of middleware to better understand the costs of testing and development will be important when it comes to reducing the costs of integration into existing legacy systems and increasing the benefits for users. Talent development needs to consider leadership and business skills to complement technical expertise, which would benefit from a dedicated development programme.

The testbed programme offers an opportunity to identify the critical components and services needed to support quantum computing. Mapping the supply chain will be important to establish a national capability in the key enabling technologies and to identify growth opportunities for UK companies.

Download the full report at:
www.ifm.eng.cam.ac.uk/uploads/News/NQCC_Quantum_Computing_Testbed_Pilot_Study_Oct_2025.pdf

Mapping the supply chain will be important to establish a national capability in the key enabling technologies and to identify growth opportunities for UK companies.

QCTI team at NQCC

Core team

Emma Athawes
QCTI Project Manager

Kostas Georgopoulos
Phase 2 Testbed Test and Evaluation Project Lead

Simon Plant
QCTI Sponsor

Rob Whiteman
QCTI Project Lead

Additional project board members

Anne-Claire Blet, Rachael Bartholomew, Jonathan Burnett, Michael Cuthbert, Soma Deshprabhu, Sushma Tiwari

Communications and report production:

Soma Deshprabhu, Communications Manager, NQCC

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NQCC team

Phase 1 technical milestone appraisal
Jonny Bass, Vivek Chidambaram, Georgina Croft, Cameron Deans, Luke Fernley, Nick Spong

Phase 2 test and evaluation
Manav Babel, Vincent Graves, Kenza Hammam, Manqoba Hlatschwayo, Theo Kapourniotis, Kieran McDowall, Juli Romero, Dalila Islas Sanchez

Testbed remote access and networking
Menino Borges, Martin Harrow, Jordan Jeffrey, James Thorne

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The programme has strengthened supply chains, created high-value jobs, and developed new collaborations that provide a strong foundation for future research and innovation. Several providers have secured Quantum Mission Pilot grants, with follow-on funding for collaborative projects reaching a total of £4.6 m.

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Contact information

National Quantum Computing Centre
Rutherford Appleton Laboratory
Harwell Campus, Didcot, Oxfordshire, OX11 0QX

Email: nqccinfo@nqcc.ac.uk

Website: www.nqcc.ac.uk

Follow us: linkedin.com/company/nqcc/

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