National Quantum Computing Centre

Annual Report 2022

3D model of the NQCC facility by Hawkins/Brown

Foreword

Dr Michael Cuthbert
Director, NQCC

For the NQCC, 2022 has been a notable pivot point in moving from development and planning through to implementation and growth of the centre. It has also been a year of partnerships and collaboration – activities at the core of our purpose – across our programme.

A year ago I was delighted to report the site was cleared and that we had broken ground at Harwell. Twelve months on, and we continue to make good progress. Construction of the new laboratory started in February and remains on plan for completion in July next year. As we watch the steel structure rise from the ground, construction has been a daily talking point among our growing team. The team has also made progress through the year with recruitment being a key priority. We have grown almost fourfold to over 30 in number, with our technical, operations and innovation teams all welcoming new team members. It is great to see colleagues join us from overseas as well as from around the UK with such a wealth of knowledge and passion for our subject.

As the team has grown, so has our capacity to move from planning into the delivery of the centre, and as we shake off any remaining anxieties of the pandemic, we have enjoyed opportunities to host events and bring people together.

Our key external objectives in 2022 centred around skills and training, quantum readiness and technology collaborations to enable the development of a multi-faceted quantum user community. Through collaboration with Institution of Engineering and Technology (IET)'s

Quantum Engineering Network, sponsorship of EPSRC early career fellowships, procurement of online training tools and collaboration with University of Bristol on technical training courses, we have helped support the drive for skills and knowledge across the quantum ecosystem.

We have been working with EPSRC colleagues to establish early career fellowships in quantum computing with three NQCC sponsored fellowships appointed in April 2022. Our links with the research community have been further strengthened through the appointment of our Chief Scientist, Prof Elham Kashefi at University of Edinburgh, who will lead an exciting research programme in quantum software, algorithms and applications.

Quantum Readiness has been a major theme over the past year. Through collaboration across government, industry, regulatory bodies and the QCS Hub initial work has focused on the financial services sector. By bringing organisations together we have been able to explore potential applications, identify sector opportunities and converge on mechanisms for solution development. In parallel we developed and launched our application discovery programme – **SparQ**. With this programme we seek to raise awareness; create engagement; enable evaluation; encourage action and support advocacy of quantum computing across industry sectors. We are doing this by providing access to QC resources, technical support, applications expertise and training materials. One of the more memorable events of the year was our first hackathon held at Royal Holloway University of London. Students and QC practitioners came together to tackle nine industry-led challenges. The enthusiasm, excitement and engagement of the hackers was fantastic and we will be running further events as we grow our user community in the months ahead.

Our technical teams have been mapping out detailed plans, procuring equipment and setting up temporary lab space ahead of the new facility being completed. Early plans will build on the trapped ions work pioneered at the University of Oxford in collaboration both on techniques and devices. In parallel, control hardware has been developed with a keen eye on scaling as our qubit count grows. Finally, we have had extensive engagement in a variety of technical projects both externally funded collaborative consortia and NQCC commissioned technology work packages. Benchmarking, open standards, cryo-electronics and integration of QC with high performance computing being some of the key themes we are working on.

Contents

On behalf of the leadership team, I welcome this second annual report of the NQCC and thank our Programme Delivery Board, Programme Advisory Committee and project and programme partners for their support throughout the year.

National Quantum Computing Centre

Background

Quantum computing has the potential to unlock unprecedented parallel processing, creating a step change in computing power. By harnessing and exploiting this capability, the UK has an ambition to become the world's first quantum ready nation. To achieve this, a renewed effort is required leveraging the £1bn, 10 year investment already committed into quantum technologies since 2014.

Our effort is part of a global race with significant international investment in hardware, software and skills. Recruiting and retaining top talent is of key importance. The long term impact of quantum computing on society and the economy is potentially huge with a projected global market of $450-850 billion annually over the next 15 to 30 years.

Building on the investments made in enabling science, the National Quantum Computing Centre (NQCC) is being established on the Harwell Campus with an initial investment of £93m over five years by UK Research and Innovation (UKRI). The primary purpose of the NQCC is to fill a key gap in the research and innovation landscape addressing the challenge of scaling quantum computing.

The NQCC's initial five years will focus on developing a Noisy Intermediate-Scale Quantum (NISQ) machine to demonstrate the technology. The initial technology focus of the NQCC will be to develop superconducting and trapped ion hardware, with prototype projects commissioned since 2021.

The NQCC will give assured and direct access to developers and promote the formation of a strong UK based quantum computing supply chain, whilst driving efforts towards a universal fault tolerant quantum computer.

Our Vision

As a trusted authority, our vision is to enable the UK to solve some of the most complex and challenging problems facing society by harnessing the potential of quantum computing.

Our Mission

In order to realise our Vision, the NQCC is focusing on three key areas: technology development, quantum readiness, and establishing a state-of-the-art quantum computing infrastructure. We act responsibly, as an independent and objective trusted authority, both nationally and internationally, across these areas.

To drive effective technology development, we are building, testing and hosting first generation quantum computers, collaborating on innovative and diverse solutions to meet the key challenge of scaling. We address the whole quantum computing stack; hardware, software, and user applications. We own and are evolving the UK's quantum computing technology roadmap, which will guide our journey from the Noisy Intermediate-Scale Quantum (NISQ) computing era towards universal fault-tolerant quantum computing. To ensure the UK as a quantum-ready nation, we are facilitating the user journey from awareness to advocacy.

To establish a state-of-the-art quantum computing infrastructure we advocate for, and invest to build equipment and facilities to deliver an assured, secure, sovereign capability. We are creating the environment and space to inspire talented people to collaborate and innovate, ensuring UK leadership in this pioneering area. As the focal point of UK quantum computing, the NQCC anchors activities across the nation.

UKRI National Quantum Computing Centre

Our Sponsors

Engineering and Physical Sciences Research Council

Science and Technology Facilities Council

Our Partners

Department for Business, Energy & Industrial Strategy

[dstl]
The Science Inside

GCHQ

NPL

Innovate UK

Ministry of Defence

National Quantum Computing Centre

Sponsors and Partners

UK Research and Innovation

UK NATIONAL QUANTUM TECHNOLOGIES PROGRAMME

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The NQCC delivers the capabilities needed for the UK to be internationally competitive in achieving the world's first quantum-ready economy. As well as playing an important role in training the future quantum computing workforce, the NQCC fosters industry and academia collaborations to accelerate the future of quantum computing and its potential applications across sectors."

Professor Dame Lynn Gladden
Executive Chair, EPSRC

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The NQCC has made excellent strides to ramp up delivery of its programme and grow a team of skilled and talented individuals. It has established a presence at RAL, as well as a unique position within the wider international landscape for quantum computing. The NQCC is a welcome addition to STFC's national lab framework, and I very much look forward to the completion of the main facility's construction in 2023."

Professor Mark Thompson
Executive Chair, STFC

The NQCC is a flagship programme of UK Research and Innovation (UKRI) that seeks to drive the development and exploitation of quantum computers in the UK. It builds on the strengths in quantum computing established during the first phase of the National Quantum Technologies Programme (NQTP), and operates within a wider landscape for quantum development in the UK that includes the Quantum Technologies Research Hubs, the quantum challenges and programmes within the Industrial Strategy Challenge Fund, doctoral training programmes, and the activities of the emerging quantum industrial sector.

The NQCC partners with academia, government and industry to solve technology challenges and realise the benefits of quantum computers for social and economic development. The centre aims to provide research institutions and companies with early access to emerging quantum computing resources, enabling organisations in different industry sectors to explore its potential for addressing relevant use-cases and applications. In supporting the government's ambition to establish the UK as the world's first quantum-ready nation, the NQCC seeks to accelerate the technology roadmap towards the commercialisation of quantum computing.

The NQCC's programme is jointly delivered by two UKRI research councils – the Engineering and Physical Sciences Research Council (EPSRC) and the Science and Technology Facilities Council (STFC).

Located within STFC's Harwell campus, the NQCC is well connected to a growing community of technology suppliers, start-up companies and industrial end users, as well as major research institutions across the UK. The NQCC also has access to the wide range of facilities on the Harwell site, such as engineering and fabrication facilities, business incubators and collaborative spaces.

Governance

The NQCC is managed through a Programme Delivery Board that delegates the day-to-day management of the Centre to the Leadership Team via the Director. Oversight is maintained through our Programme Advisory Committee (PAC) and Technical Advisory Group (TAG), which provides advice, support and challenge on the activities of the NQCC to the Leadership Team. Governance is assured through monitoring and evaluation to Engineering and Physical Sciences Research Council (EPSRC) and Science and Technology Facilities Council (STFC). The NQCC Director sits on the Operations Board of STFC and on both the NQTP Programme Board and NQTP Strategic Advisory Board. Our Programme Board meet quarterly and our TAG twice per year. The TAG is chaired by our Chief Scientist and works with the Leadership Team to review and update the technical programme, roadmap and milestones.

Leadership Team

Dr Michael Cuthbert, Director

With a background in superconductivity and cryogenic systems, Michael has had a number of technical and commercial leadership roles with Oxford Instruments in Japan, US and the UK, most recently as Head of Quantum Technologies. Michael is a member of the Institute of Physics, sits on several advisory panels, including the NQTP Strategic Advisory Board and is an Aegis Professor in Quantum Technologies at the University of Bristol.

Professor Elham Kashefi, Chief Scientist

Elham is Professor of Quantum Computing at the School of Informatics, University of Edinburgh, and Directeur de recherche au CNRS at LIP6 Sorbonne Universite. She co-founded the fields of quantum cloud computing and quantum computing verification and has pioneered a trans-disciplinary interaction of hybrid quantum-classical solutions from theoretical investigation to actual experimental and industrial commercialisation. Elham is seconded 30% of her time from University of Edinburgh to the NQCC in her capacity as Chief Scientist.

Ash Vadgama, Deputy Director for Operations

Ash has worked within high-performance computing (HPC) for over 30 years for UK Government. He led early developments in secure Linux clusters, petascale HPC systems and resilient facilities, as well as collaborations with US national laboratories and other international partners on a variety of emerging technologies. Ash has extensive experience in business leadership, HPC programmes, emerging technologies (such as quantum) and finance.

Dr Simon Plant, Deputy Director for Innovation

Simon's technical background spans quantum nanomaterials, nanophysics and quantum sensors. He has led work across various roles in research, government and the public sector to drive the development and commercialisation of quantum technologies (QT) and support the growth of the industry. He was previously the technology lead at Innovate UK responsible for shaping and implementing the UK's innovation strategy for QT.

Programme Advisory Committee

Professor Sheila Rowan, Chair

Professor Rowan is an experimental physicist, and since 2009 she has been Director of the Institute for Gravitational Research in the University of Glasgow in the UK. She was elected to Fellowship of the Royal Society of Edinburgh in 2008, and awarded Fellowship of the American Physical Society in 2012. She received the Hoyle Medal and Prize of the Institute of Physics in 2016 in recognition of her pioneering research on aspects of the opto-mechanical technology of gravitational wave observatories.

Professor Sir Peter Knight

Sir Peter Knight is Emeritus Professor at Imperial College, a past President of both the Institute of Physics and Optical Society of America, chairs the National Quantum Technology Programme Strategy Advisory Board and the Quantum Metrology Institute at the National Physical Laboratory.

Professor Tom Rodden

Professor Rodden is Chief Scientific Advisor for the Department for Digital Culture Media and Sport (DCMS) and a Professor of Computing at the University of Nottingham. His research is highly interdisciplinary, bringing together a range of disciplines as computing becomes a ubiquitous feature of our world and we increasingly use personal data and AI technologies.

Roger McKinlay

Roger McKinlay is the Challenge Director – Quantum Technologies for UK Research and Innovation. He has been involved in the National Quantum Technologies Programme since 2015, and was a panel member of the 2016 Quantum Technologies Blackett Review. Roger is a Chartered Engineer and a past president of the Royal Institute of Navigation.
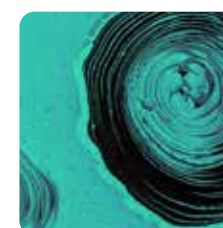
Michael Groves

Michael is Head of the Heilbronn Institute for Mathematical Research. He has worked as a security researcher at Government Communications Headquarters (GCHQ) for over 25 years and served as Vice Chair of the ETSI quantum-safe cryptography working group from 2015 to 2019.

UKRI National Quantum Computing Centre

Quantum computing: Outlook and opportunities

What is Quantum Computing?

Quantum computers operate in a fundamentally different way to conventional digital computers. Quantum computing is based on the rules of quantum mechanics, harnessing effects that exist at the level of atoms, electrons and photons. It involves encoding and processing information by controlling quantum states, relying on the uniquely quantum phenomena of superposition and entanglement.

Qubits

In conventional computing, information is encoded as binary digits or 'bits' – a basic unit of information – that can be represented as either a '0' or '1'. In quantum computing, the equivalent unit is a quantum bit or 'qubit', which can exist either in a state uniquely as '0' or '1' or as a simultaneous combination of both '0' and '1', owing to superposition.

A register can be constructed from multiple qubits, which can then become correlated with each other in a subtle and powerful way that cannot exist in the ordinary, classical world – this is called quantum entanglement. The combination of superposition and entanglement means that a quantum register can encode information in a large number of states simultaneously.

This feature is crucial in enabling a quantum computer's power, allowing it to perform computations for tasks that are intractable for even the largest current supercomputers.

Full stack/architecture

Quantum computers can have different architectures, being based on alternative designs and constructed in different ways. As with conventional computers, there are several hardware and software layers involved in constructing a quantum computer, that go from the processor through to the user interface – this is referred to as the full stack. Current leading architectures for qubit development across academic and industrial programmes are; trapped ions, superconducting circuits, spins in silicon, cold atoms and photonic devices.

National Quantum Computing Centre

	NISQ (Noisy Intermediate-Scale Quantum) regime	Broad quantum advantage	Universal fault tolerance
	Now	Beyond 2030	Beyond 2040
Attributes	Few tens of qubits Noisy and error-prone qubits limit computational power	Technology scales to incorporate more qubits Strategies emerge for error correction	Quantum computers achieve large-scale information processing for general-purpose use Noise resilience through full error correction
Computational power	Only able to challenge conventional computers in specific use cases	Capable of outperforming classical computers across different problem types	Able to perform precise calculations on demand
Example applications	Boosting the performance of specific simulations tasks to aid the development of new products, materials and pharmaceuticals	Optimising the performance of complex systems to reduce risk in the financial sector, manage supply chains and logistics, and achieve more efficient network resourcing	Broad applicability across all industry sectors

Applications

The availability of quantum computing is expected to impact many sectors, enabling improvements in efficiency, productivity and competitiveness, as well as the creation of new products and services.

Promising early applications include:

- Simulation – the modelling and analysis of molecular structures and chemical processes to accelerate the discovery of new materials and pharmaceuticals
- Machine learning – the use of quantum enhanced methods to generate unbiased synthetic data to aid machine learning in areas such as fraud detection
- Optimisation – cost minimisation of complex planning and scheduling for logistics and networking, such as the routing of traffic, telecommunications and energy distribution
- Enhancing the design and manufacturing processes in sectors such as aerospace and automotive.

Technical challenges

There are several candidate hardware architectures on which to base quantum computers, each with their own merits and at various stages of technology maturity. The common feature is that physical qubits are inherently fragile, requiring precise control and protection from the external environment.

The states need to be as long-lived as possible and the operations on them high-fidelity, otherwise errors accumulate, and more computational resource is required for error correction.

Architectures that require limited or even no error correction, are being investigated. Technical hurdles have continually been overcome as the field has advanced, but there are significant engineering challenges that lie ahead in scaling to ever increasing numbers of qubits with low noise. We also need to learn more about the merits of the different hardware architectures as quantum computers are scaled.

A real breakthrough would be to build and demonstrate quantum computers that provide enhanced performance for a range of different tasks. In the near term, we can explore how to tackle some of these challenges by developing NISQ (Noisy Intermediate-Scale Quantum) machines, which can provide a pathway to a general-purpose quantum computer in the future.

Towards a universal quantum computer

Scaling current technologies to support larger numbers of qubits poses major engineering challenges. The inherent fragility of the physical qubits requires them to be protected from the outside environment, and also demands precise and reliable control systems to manipulate the quantum states without destroying them. Any noise in the system causes errors to accumulate, requiring even more qubits to provide the computing resource needed for error-correction techniques.

The NQCC is leading efforts in the UK to address these scalability challenges. In the near term, the focus will be to develop modest-scale machines operating in the NISQ regime. These will allow us to learn about the merits of different hardware architectures for scaling the technology, and provide a pathway towards a general-purpose quantum computer.

To support these activities the NQCC will also establish benchmarks for testing the performance of emerging devices and platforms, develop open standards to ensure their interoperability, and foster a robust UK supply chain for quantum hardware and software. As well as owning and developing the UK's technology roadmap for quantum computing, the NQCC will be a responsible and trusted authority that will provide an independent assessment of the capabilities and opportunities for quantum computing.

Opportunities

Promising applications of quantum computing on the horizon include:
- Accelerating the discovery of new materials and pharmaceuticals by enhancing simulations of molecular structures and chemical processes
- Improving fraud detection in financial services by applying quantum-enhanced methods to machine learning
- Optimising complex supply-chain logistics across different industry sectors, and improving the efficiency of critical networks for transport, communications and energy distribution
- Improving healthcare provision through more personalised diagnosis and treatment
- Enhancing the design and manufacturing processes in the aerospace and automotive sectors

As the technology matures, organisations will be able to realise significant benefits from quantum computation even before a universal, fully error-corrected quantum computer becomes available. Meanwhile, early experimentation with quantum hardware and software will enable companies to start developing the resources, skills and technologies needed to harness the capabilities of future quantum computers.

Simulation	Machine learning	Optimisation	Cryptography
□ Accelerating the design and discovery of new drugs	□ Enhancing the safety of autonomous vehicles and driver assistance systems	□ Managing financial portfolios and reducing risk	□ Establishing private networks for secure financial trading
□ Enhanced modelling of fluid dynamics in automotive and aerospace design	□ Enabling faster and more accurate fraud detection in financial services	□ More efficient resourcing in telecoms networks	□ Ensuring secure and resilient communications links for national security
□ Developing improved catalysts for chemical processes	□ Improving healthcare through personalised diagnostics and medicine	□ Managing complex supply chains	□ Distributing computing resources among the research community
□ Evaluating different market scenarios in the finance sector	□ Enhancing the performance of search engines	□ Reducing congestion in transport networks and cutting emissions	
□ Understanding molecular function in biochemical research	□ Identifying signals in large experimental datasets	□ Analysing and improving the properties of novel materials	

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Recent surveys of UK business leaders suggest that 94% believe quantum computing will impact their organisation or sector significantly, 72% intend to start strategic planning or create a pilot team by 2024 but only 6% have development teams in place today. Demonstration of quantum advantage is vital to help drive industry end-users adopt this break-through technology. The SparQ programme seeks to ensure resources are in place to provide access and support for industry and government user adoption."

Dr Michael Cuthbert
Director, NQCC

National Quantum Computing Centre

Programme timeline

NQCC
Leadership Team appointed

BEIS approval

NQCC
Chief Scientist appointed

SparQ Application Discovery
Programme launch
May '22

NQCC launch at London Tech Week
Sep '20

Prototyping roadmap
building blocks
(Oct '20 - Mar '22)

Scaling roadmap
prototypes
Oct '21 – Sep '23

Integrating roadmap
deliverables
Oct '21 – Sep '23

| 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |

Concept design
Dec '19 - Jun '20

Developed design
Mar - Feb '21

Staff recruitment,
internal and external facing communications
and user engagement

Preparation & brief
Jul - Dec '19

Technical design
Nov '20 - Apr '21

Construction commenced
Feb '22

National Quantum Computing Centre operational

Strategic Intent release
Jan - Jul '19

Site Clearance
Procurement, relocations, surveys &
demolition

Breaking ground
Sep '21

Construction handover
Autumn 2023

National Quantum
Computing Centre

The NQCC programme at a glance

The NQCC is leading an ambitious programme of activities that aims to accelerate the technology roadmap for quantum computing in the UK. It is working alongside government, industry and the research community to drive technical innovation, enable the evolution of a quantum-ready economy, and provide the training and expertise needed for businesses and other organisations to prepare for a quantum future.

The last year has seen significant progress in all key activity areas. Initial design work has been completed on a first-generation quantum processor based on trapped-ion technology, with experimental work expected to start early in 2023. A number of technology work packages have also been awarded to various organisations to support the development of quantum algorithms and software.

At the same time, a series of meetings and workshops with end users in research, government and businesses has informed a programme of initiatives aimed at boosting the awareness and early adoption of quantum computing. One key highlight was in May 2022, the launch of SparQ, an applications discovery programme that aims to enable UK-based companies and researchers to explore the potential of quantum computing for real-world applications.

As part of efforts to foster a quantum workforce, two courses that introduce non-specialists to quantum information and computing have already been delivered in collaboration with the University of Bristol. An online training platform, due for trial release early next year, will also enable non-experts to develop the skills needed to programme quantum processors.

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The last year has seen exciting progress across a wide range of important activities, in advancing technical workpackages, in industry engagement and in launching the 'SparQ' program. This program has been a particular highlight with the NQCC having partnered with OQC to provide access to quantum computing resources to support companies and researchers in discovery and development of quantum computing applications."

Professor Sheila Rowan
University of Glasgow
Chair NQCC Programme Advisory

Technology
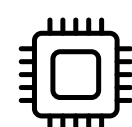
- Demonstrate a practical quantum computer with more than 100 qubits, operating in the noisy intermediate-scale quantum (NISQ) regime
- Develop quantum algorithms for emerging quantum computers that address real-world applications in different sectors of the UK's economy.

Infrastructure

- Deliver a landmark facility that provides the infrastructure for researchers, technology providers and end-users to collaborate on the development of quantum computers and applications
- Create laboratory space for the design, construction and operation of quantum computers, and for testing and benchmarking the performance of quantum devices and systems.

Quantum Readiness
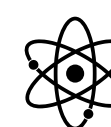
- Drive knowledge exchange between quantum developers, technology providers and end users in both industry and academia
- Provide learning resources and expertise to help researchers and companies develop the skills needed to work with quantum computers
- Build a quantum supply chain that leverages the contributions of emerging quantum businesses and technology suppliers.

Recruitment

- Building a talented team of individuals who are passionate about quantum computing and its potential to transform our world
- Staff recruitment accelerated, building a team of over 30 people
- Through ongoing recruitment the NQCC aims to reach its full complement of 65 team members by the time the facility opens in 2023.

National Quantum Computing Centre

Technology

Technology readiness

Through extensive consultation across academia and industry experts, the NQCC has developed a technology roadmap identifying detailed initial steps towards the goal of a 100+ qubit NISQ-era machine by 2025. These first steps are being realised through a series of technology project commissions, ahead of the NQCC facility completion in early 2023. Work streams addressing hardware, software, algorithms and applications have been established. Within these work streams the topics of underpinning technologies, scaling, error and noise mitigation, bench marking and verification as well as solution packaging and user accessibility is being tackled.

Our initial focus is on superconducting and trapped ion qubit platforms as these are currently the most mature. However, the roadmap will be reviewed over time to enable other modalities to be brought into the technology programme as they mature.

Three critical objectives have been identified as the Centre establishes its technical delivery.

1. Demonstration of early quantum advantage
2. Securing state-of-the-art access and providing quantum computing test-beds and demonstrator hardware for the UK user community
3. Ensuring the technologies required to define and deliver the necessary technology building blocks for a future universal fault-tolerant qubit architecture.

Through verification and benchmarking, as well as international participation on identification of QC standards and metrics, progress towards compiler enhanced NISQ hardware is anticipated to be a key aspect of software-enhanced hardware performance.

Delivery mechanisms

No single organisation can solve the complex technical issues necessary to bring quantum computing to fruition. The NQCC is therefore utilising a number of mechanisms;

- Public procurement – de-risking technology development for industry and instilling confidence for investors and end-users alike.
- Collaborative R&D – bringing together key players across the UK to leverage existing capabilities, resources and investment to support development
- In-house technology development – building internal capabilities and knowledge to support the delivery of the NQCC and our milestones.

External technology work packages

In commissioning work packages with external suppliers, the NQCC has prioritised the delivery of new capabilities in software and algorithms for quantum computing. The NQCC approach aligns to our strategic objective of supporting the development of products and services in the supply chain.

In 2021 the NQCC commissioned Riverlane, the Cambridge-based quantum software company, to develop a software benchmarking suite that will allow us to make performance comparisons across different types of quantum processor. We have been working closely with Riverlane throughout the development phase, undertaking acceptance testing and validation of the software suite. The final release of the software will be delivered for deployment on NQCC servers towards the end of 2022.

In a complementary activity, the NQCC has commissioned a consortium led by the National Physical Laboratory (NPL) to investigate standard metrics for quantum computing, with a view towards developing open standards. Working alongside the Universities of Edinburgh, Warwick and Durham, NPL is leading the development of standardised measurement methodologies and the associated software that will be used to test their approach on emulators and real quantum processors. The development of open standards relies strongly on achieving a broad consensus across national and international communities, and an integral part of the initiative involves active engagement and dissemination of the findings, including with international standards bodies.

The development of novel applications for quantum computing requires the development and implementation of quantum algorithms, and Bristol based company Duality Quantum Photonics (DQP) has been working on two projects on behalf of the NQCC. In the first project, DQP has been investigating photonic quantum sampling for computational chemistry and evaluating the prospects for three different applications: molecular docking for drug discovery, molecular dynamics in photo-catalysis, and vibronic spectra in molecular electronics.

The second project focuses on measurement-based quantum computing related to deep variational quantum eigen-solvers. The approach is being used to explore the simulation of high-temperature superconductors and for modelling iron–sulphur clusters that are used in applications such as sensing oxygen. Finally, NPL has been working on on a further project for materials simulation, developing a quantum algorithm for simulating strongly correlated electron systems that aims to reduce the computational resource requirements, or increase the speed, of the calculation.

Each of these work packages represents a key step in the journey towards quantum advantage, and uncovering early applications of quantum computing.

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> *The growing collaboration between the National Physical Laboratory and the National Quantum Computing Centre helps bring together the capabilities of National Labs in coordinated support of the UK quantum computing community. The collaboration on development of standardised metrics and benchmarks, as well as on algorithms for quantum advantage, has enabled significant progress in these core areas within quantum computing."*

Ivan Rungger
Senior Research Scientist, NPL

National Quantum Computing Centre

Technology

Internal technology development

Trapped ions are one of the most promising platforms for quantum computing hardware, as these systems are resilient to environmental noise and so retain their quantum behaviour over long time periods. These long-lived quantum states make it possible to create high-quality qubits that perform accurate logical operations, which in turn requires fewer physical qubits to run disruptive routines such as the fast factorisation of large numbers. These routines have applications in a range of areas, offering a pathway to solve complex real-world problems.

We have started to design and build a first-generation quantum processor, working in collaboration with the Ion Trapping Quantum Computing Research Group at the University of Oxford. This project leverages the partnership between the NQCC and the Quantum Computing and Simulation Hub.

Over the past year we have built up our team and worked through initial key technical decisions on control architecture, choice of ion species, trap design and laboratory configuration. Furthermore, we have designed and procured the equipment necessary to assemble our first ion trapping system.

Such rapid progress has required us to establish temporary laboratory space before the main NQCC facility is complete. Having identified a suitable location on the Harwell Campus, and made the necessary lab refurbishments, commissioning of the experimental equipment is underway.

A crucial part of the in-house programme is the control architecture for the experimental platforms – this also needs to scale as the qubit count scales. We have implemented agile methodology for implementing our software and control work packages and recruited a collaborative engineering team capable of producing high quality solutions across different quantum systems. As our internal efforts develop we are producing a well-documented, easy to use library of supported software, control equipment and flexible laboratory tools.

> " We are excited to collaborate with the NQCC in a technical programme to design and build a first-generation quantum processor using trapped ions as the quantum computing platform. This programme leverages the partnership with the NQCC and the QCS Hub, to advance the field of quantum computing for the benefit of the UK and unlock the advantages for wider society."
>
> **Professor David Lucas**
> Ion Trapping Quantum Computing Group, University of Oxford

National Quantum Computing Centre

Collaborative R&D projects

Proof-of-concept projects in quantum computing

The NQCC supported three-month proof-of-concept projects during 2021 that were led and match-funded by businesses. The grant funding was awarded through a highlight call on quantum computing, sponsored by the NQCC, as part of STFC's Cross-Cluster Proof of Concept Grant award scheme.

Proof of concept for automated control software for quantum technologies to tune, stabilise and optimise qubits
Lead: QuantrolOx Ltd., Partners: University of Oxford, NQCC
This project investigated possible routes for creating an automated control software system to tune, stabilise and optimise qubits. Prototypes were implemented to explore alternative solutions for governing the qubit-control process, and the project also defined a research roadmap towards an automated qubit-control framework.

Towards a quantum materials genome programme
Lead: Phasecraft Ltd., Partners: STFC Scientific Computing Department (SCD), NQCC
Building on tools developed by Phasecraft, this project paved the way for an accessible database of quantum tools for modelling key materials. The vision for the database is to create a substantial core quantum-computing resource, comparable to the Materials Genome Initiative, that incorporates multiple aspects of quantum-algorithm design for materials simulation, as well as sample quantum circuits and experimental results, along with direct links to the source of the data.

Integrated photonics for ion trap quantum computing
Lead: Duality Quantum Photonics Ltd., Partner: NQCC
This proof-of-concept explored the potential of thin-film lithium niobate as a versatile and future-proof material for photonics infrastructure in trapped ion quantum computing. The aim was to model, fabricate, and test photonic circuitry in lithium niobate to show that it can be used for the laser control of calcium ions.

Photonic quantum time-bin processing for image recognition
Lead: Orca Computing Limited, Partner: NQCC
ORCA Computing has developed a time-domain photonic quantum-computing system based on time-bin interferometry (TBI). The proof-of-concept aimed to use software simulation of ORCA's hardware environment to model image recognition problems on an ORCA PT-series system. It also offered a feasibility assessment of the technology for further development of the hardware and algorithms.

Commercialising quantum technologies

The NQCC continues to engage in collaborative technical projects in support of UK businesses and the development of key technologies in the quantum computing supply chain. The NQCC is a self-funded partner on three such projects, starting this autumn and running until 2024, which have been successfully awarded funding through Innovate UK's Commercialising Quantum Technologies: Feasibility Studies Round 3 Call.

Realistic machine learning based ultra-fast simulator for semiconductor spin qubit devices
Lead: QuantrolOx Ltd., Partners: University of Oxford, NQCC
This project aims to deliver an ultrafast simulator for semiconductor spin-qubit devices based on developments in classical machine learning, quantum software and quantum hardware. The simulator offers an offline solution for testing and developing qubit-control software when there is limited access to quantum hardware. The project represents a key step in achieving automated qubit tuning, optimisation and stabilisation.

M-PIT: Miniature packaged ion traps
Lead: ColdQuanta UK Ltd., Partners: University of Oxford, NQCC
ColdQuanta, the University of Oxford and the NQCC will work together to develop a high-performance, miniature and self-contained ion-trap system. A new route for producing ion traps commercially will be achieved by integrating Oxford's microfabricated 3D radio-frequency trap into ColdQuanta's miniature vacuum packaging. The NQCC will investigate use cases for miniature packaged systems and provide input into the design and development process, ensuring alignment with the roadmap for building the UK's quantum computing infrastructure.

INTERCOM: A high-performance ion-photon interface to enable multi-core trapped ion quantum computing
Lead: Nu Quantum Ltd., Partners: University of Oxford, NQCC
The project aims to create a device that enables quantum information to be transferred through photonic links between remote ion traps to provide a scalable and modular architecture. The solution exploits the confinement of light between two micro-mirrors in a resonant optical cavity, ensuring a strong interaction between the ion (or atom) and the optical field. The project will deliver a robust, turn-key cavity interface that allows scalable integration in ion and atom-based quantum networks.

Infrastucture

Following an extensive procurement exercise during 2021, Wates Construction was appointed as the NQCC's main contractor in December 2021. This followed a 12-month period in which Wates worked with UKRI and the NQCC team to develop the design and construction programme for the building.

The NQCC's landmark facility on the Harwell Campus is starting to take shape, and remains on track for completion in July 2023. In preparation for the new building, the NQCC's technical teams have been planning out laboratory spaces and procuring equipment for building, operating and testing quantum computers.

The ambition for the facility is to create a vibrant environment that promotes collaboration between quantum hardware and software researchers, providing a world-class research centre that attracts visitors and industry interest from across the UK and internationally. The mixed provision of office, meeting and laboratory spaces will enable multidisciplinary teams to work together to design and develop quantum devices and systems, and will allow the NQCC to respond to the changing needs of the UK's quantum computing ecosystem.

The NQCC is one of four major science buildings currently being constructed on the Harwell Campus, providing access to specialist skills for designing and building state-of-the-art scientific facilities.

Sustainability

The NQCC building has been designed to:

- Achieve a BREEAM rating of "Excellent"
- Follow an energy strategy of "Be Lean, Be Clean, Be Green"
- Minimise energy use
- Integrate features to optimise energy efficiency
- Achieve a 40% reduction in regulated CO_2 emissions
- Ensure a combustion-free environment
- Recycle at least 95% of all construction waste.

"
Delivering the NQCC facilities has taken significant collaboration between NQCC, STFC, UKRI and the Design and Construction teams. Over the next year we will focus on commissioning, enabling quantum computing and quantum readiness."

Ash Vadgama,
Deputy Director for Operations, NQCC

UKRI National Quantum Computing Centre

Construction

Wates established a base on the Harwell Campus in January 2022, with the construction of the NQCC building starting in February. Early works included the construction of concrete foundations, lift cores, ground beams and a sustainable drainage system for the building.

The steel frame of the building started to take shape in May. By August, work had started on the ground floor slab, which underneath the laboratories is reinforced with stainless steel to reduce background electromagnetic interference that would otherwise interfere with experimental equipment. At the same time internal features such as the timber floors and staircases were being fabricated off-site to reduce the carbon footprint and shorten the amount of time needed for construction.
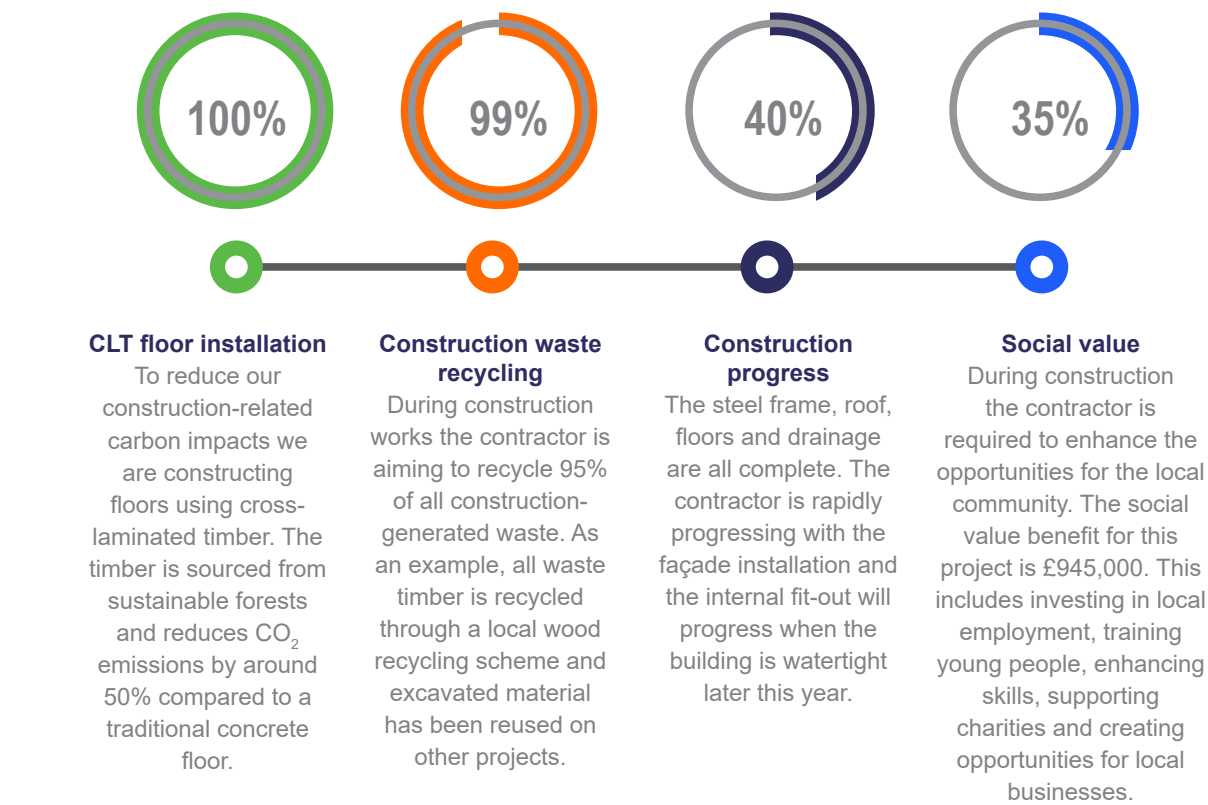
By September, work had started on the roof and outer façade, and the building should be substantially waterproof by the end of the year.

This will enable the internal fit-out of the building to get underway in early 2023, with the construction programme on track for completion in July 2023.

To date, the NQCC construction works have delivered £340,000 of social value benefit. Employment and skills initiatives associated with the project have directly benefitted 19 people from the local community.

Maintaining an excellent health and safety track record is important to all parties involved in the construction of the NQCC. To date, we are pleased to confirm that no lost-time accidents have occurred during the first six months of the building works.

Recycling during the building project remains high, with Wates exceeding the 95% recycling target set for all construction waste produced.

100%

99%

40%

35%

CLT floor installation
To reduce our construction-related carbon impacts we are constructing floors using cross-laminated timber. The timber is sourced from sustainable forests and reduces CO_2 emissions by around 50% compared to a traditional concrete floor.

Construction waste recycling
During construction works the contractor is aiming to recycle 95% of all construction-generated waste. As an example, all waste timber is recycled through a local wood recycling scheme and excavated material has been reused on other projects.

Construction progress
The steel frame, roof, floors and drainage are all complete. The contractor is rapidly progressing with the façade installation and the internal fit-out will progress when the building is watertight later this year.

Social value
During construction the contractor is required to enhance the opportunities for the local community. The social value benefit for this project is £945,000. This includes investing in local employment, training young people, enhancing skills, supporting charities and creating opportunities for local businesses.

National Quantum Computing Centre

"

I am really pleased with the design and construction progress of the NQCC building. Last year, we were completing the site clearance activities on the site and now we have the frame, floors and roof of the NQCC constructed. The delivery team have successfully steered the project though the pandemic lockdown and a tough economic environment. We are now looking forward to enclosing the building and commencing with the building fit-out for completion next autumn."

Jason Lowe,
Head of Capital Delivery, STFC

Quantum Readiness

The NQCC is committed to bringing together different organisations to accelerate the development of quantum computers and stimulate the creation of novel products and services. Through networking and collaboration with its partners, the NQCC will be able to:

- Share skills and knowledge to drive innovation and identify potential use cases for quantum computing
- Design key components and subsystems for building quantum computers
- Enable both students and industry professionals to gain the skills needed to work with quantum computers
- Provide access to quantum computing resources to enable early experimentation with quantum hardware and software
- Drive demand for early products and services enabled by quantum computing

The NQCC is engaging with stakeholders across the UK's quantum ecosystem to speed up the technology roadmap for quantum computers and to drive the development of high-impact applications in both the private and public sectors.

Suppliers	• Identify potential suppliers of component technologies for quantum computing, and understand the strengths and weaknesses in the UK supply chain • Support the development of enabling technologies that offer new and innovative solutions for quantum computing.
Quantum developers	• Build a strong developer community with expertise in both hardware and software • Understand the value of proof-of-concept and prototype technologies.
NQCC users	• Establish an open framework for organisations to access the facilities and resources provided through the NQCC • Develop mechanisms for the NQCC to evaluate potential use-cases and to allocate resources.
User community	• Collaborate with end-users in the research community, the public sector and across different industry sectors to understand their requirements and identify use cases for further exploration • Enable the NQCC to optimise the resources it provides to the end-user community to support the development of novel applications.

The QC researchers spread across over 65 institutions in the UK provide a rich ecosystem for NQCC to tap into excellence to accelerate the development of QC in the UK. We have actively started building partnerships with both businesses and universities to accelerate the development as well as real-world use of quantum computing. To name a few:

- Collaboration with Oxford Quantum Circuits (OQC) to provide the QC resources through their platform Lucy for NQCC's **SparQ** programme
- Collaboration with University of Bristol to deliver online courses in quantum computing
- Working with consortium partners on QuPharma project to tackle some of the key engineering bottlenecks to the commercial delivery of NISQ applications
- A growing partnership with Riverlane to support QC applications
- MoU with Quantum Computing and Simulation (QCS) Hub.

The NQCC has established a strategic partnership with the Quantum Computing & Simulation Hub, a collaboration of 17 UK universities supported by the UK National Quantum Technologies Programme. Led by the University of Oxford, the Hub is addressing the critical research challenges for quantum computing across a range of hardware and software disciplines.

Through the partnership, the NQCC and QCS Hub will pursue joint research, both through collaborative development projects and by sharing access to resources and facilities. The two organisations are also working together to develop the UK's quantum workforce, supporting joint training schemes and enabling quantum developers to move between different parts of the UK's quantum ecosystem.

Through an agreement with the NQCC, OQC will provide quantum computing resources to support proof-of-concept projects funded through SparQ, the NQCC's applications discovery programme.

Successful applicants will be able to develop and demonstrate their use-case by exploiting quantum compute time on OQC's Lucy quantum computer, an eight-qubit system. The partnership will also ensure data onshoring for critical applications.

EY releases its Quantum Readiness Survey 2022, produced in collaboration with the NQCC

EY surveyed senior executives across all sectors of UK economy to understand how they are positioning their businesses to take advantage of quantum computing. The research, carried out in collaboration with NQCC, will help to further inform our quantum readiness initiatives.
Read the report at https://www.ey.com/en_uk/emerging-technologies/how-can-you-prepare-now-for-the-quantum-computing-future/.

The NQCC joins the QuPharma project for drug development using quantum computing

The QuPharma project will enable the UK to build a commercially scalable quantum computer designed specifically for applications in drug design, with the aim of reducing both the cost and time needed to develop new pharmaceuticals. As devices are scaled up, the NQCC will support the hardware testing and the integration of quantum resources into established classical infrastructure.

National Quantum Computing Centre

Building a quantum-ready economy

The NQCC is committed to ensuring that UK organisations and businesses are ready to take early advantage of the transformative power promised by quantum computing. Early adopters stand to gain expertise and market insight, while also developing intellectual property and building the skills and resources needed to incorporate quantum computing into their businesses.

A key priority for the NQCC over the past twelve months has been to launch a series of initiatives aimed at boosting the UK's quantum readiness. Our team has been meeting with end-users from different organisations and industry sectors to understand the opportunities for quantum computing as well as the barriers to adoption, and to find out how businesses could benefit from engaging with the NQCC.

A webinar with this cohort of companies allowed us to present our conclusions and share our plans for user engagement, which are centred around applications discovery. These activities culminated in the launch of the NQCC's applications discovery programme, **SparQ**, which was announced by the UK's Science Minister at an international gathering of the quantum community.

A survey of senior executives commissioned by consultancy firm EY, working in collaboration with

the NQCC, also offered an insight into attitudes towards quantum computing across all sectors of the UK economy. This research, along with the NQCC's ongoing engagement with industry, will enable the NQCC to develop a high-level view of the UK's quantum ecosystem, and to identify any gaps in understanding or resources that need to be addressed for each industry sector to boost its quantum readiness.

SparQ
Applications Discovery Programme

In May 2022, the NQCC launched **SparQ**, an applications discovery programme that enables UK based companies and researchers to explore the potential of quantum computing for solving real-world problems. The programme aims to build a UK community of end-users who have the knowledge and skills to identify use cases and develop applications that are relevant for their industry.

SparQ provides end-users with an opportunity to work with emerging quantum algorithms and hardware, allowing them to build their quantum skill-sets and gain an understanding of the current and future capabilities of quantum computers. By making connections between quantum developers, technology providers and end-users in different organisations, the programme aims to facilitate knowledge exchange and accelerate the adoption of quantum computing in both the public and private sectors.

The four elements of **SparQ**

Access to quantum computing resources	Technical support and applications expertise
Workshops, hackathons, networking events	Learning resources and skills development

An important partner in the **SparQ** programme is Oxford Quantum Circuits (OQC), which is providing access to UK based quantum computing resources. Collaborative projects will be able to run their applications on OQC's Lucy platform, an eight-qubit quantum processor that can be programmed via the cloud.

The first call for proposals to be funded through **SparQ** was launched in late 2022. As part of the STFC's Proof-of-Concept (POC) Grant Call, the NQCC is supporting a special highlight call on quantum computing for business-led feasibility studies. Successful projects, which are due to run in the first quarter of 2023, will explore the requirements and constraints of specific use-cases and identify possible solutions offered by quantum algorithms and hardware.

Spotlight on Engagement: UK financial services

The financial services sector is a major contributor to the UK's economy, generating income of more than £173 bn in 2021 to account for 8.3% of total economic output in 2021 [1]. Financial services rely on assessing and determining potential outcomes from a large and complex system of inputs. This requires powerful statistical algorithms and models to deliver products such as optimal portfolios, crisis forecasting and personalised banking.

Given the nature of these computational problems, several companies in the financial services sector have started to investigate the potential of quantum computing for their businesses. Key drivers include the scarcity of computational resources, the complexity of solving optimisation problems, and the limits of classical cryptography [2].

The NQCC has been working to stimulate and facilitate this early exploration of quantum computing. After some initial engagement in 2020 by working with the Department for Business, Energy & Industrial Strategy, the NQCC chaired a workshop in September 2021 that brought together the Bank of England, the Treasury and the Financial Conduct Authority, as well as bank representatives, and the Quantum Computing and Simulation Hub.

A series of one-to-one meetings then followed with multiple UK banks, and the findings were presented during a roundtable event that identified key priority topics for further exploration. One clear outcome was that the banks wanted to focus on use-case discovery and development to explore the potential for quantum computing. They were also keen to understand the potential for collaborative projects spanning the sector through a series of deep-dive workshops.

The NQCC organised the first of these deep dives in October 2022, focusing on use-case discovery and development. Our role in the activity is to help organisations identify opportunities, as well as any barriers to adoption, with the aim of accelerating the use of quantum computing technology in the UK. The experience gained through these workshops will help to shape the NQCC's engagement with other major sectors of the UK's economy.

Q3 2021	Initial workshop brings together representatives of UK-based banks, government officials and financial services regulators to explore the potential of quantum computing in the financial services sector.
Q1 2022	Working with Treasury, BEIS and others, the NQCC meets with a number of different banks to understand their level of engagement with quantum computing, as well as their future priorities and potential barriers.
Q2 2022	Working with the QCS Hub and other stakeholders, the NQCC delivers a workshop to identify priority activities to accelerate the adoption of quantum computing within the sector.
Q3-Q4 2022	NQCC organises a series of deep-dive workshops to explore key areas of interest.

Sector engagement convening:

- **End-users:** Banks and Financial Services organisations
- **Regulators:** FCA, Bank of England
- **Government:** HMT, BEIS
- **National laboratories:** NQCC
- **Academia:** QCS Hub
- **Tech developers:** Start-ups, Industries, IT Majors

Understand status and potential applications	→	Identify sector opportunities and actions	→	Converge on potential mechanisms and solutions

Data privacy and sharing	Financial crime - detection and reporting, collaboration between banks, secure multi-party computation
Data identification and preparation	Speed up data analytics for risk profiling, security analyses to improve monitoring capabilities
Optimisation	Streamlined settlement processes and improved portfolio diversification
Quantum AI	Fraud detection, anticipative personalised products and services
Quantum-resistant cryptography	Quantum-safe Distributed Ledger Technology, encryption to secure data in motion and at rest

References:
[1] Financial services: contribution to the UK economy - House of Commons Library (parliament.uk)
[2] How quantum computing could change financial services | McKinsey
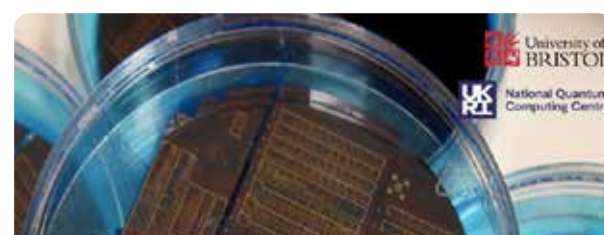
National Quantum Computing Centre

Enabling a quantum future

A crucial priority for the NQCC is to expand the UK's quantum workforce by enabling more people to gain the knowledge and skills needed to work with quantum computers. Quantum-enabled machines operate in a fundamentally different way to conventional computers. This requires new approaches and specialist training to exploit quantum computers for solving real-world problems.

The NQCC aims to address this skills gap by fostering an exchange between quantum experts, and both researchers and industry professionals from different technical backgrounds. A series of workshops and interactive events such as, the UK's first quantum hackathon has been designed to help newcomers develop their quantum skills, while also opening up new opportunities for quantum specialists to exploit their expertise within the commercial sector.

Training and resources

The NQCC is working with several education providers to offer dedicated training in quantum computing. In 2022 the NQCC collaborated with the University of Bristol to develop two six-week online courses aimed at researchers or professionals with a background in mathematics, physics or computer science. The first course, delivered by leading academics at the University of Bristol, describes key concepts and mathematical techniques in quantum information theory, while the second builds on that knowledge to enable participants to learn how to use quantum computing tools and algorithms.

Outcomes for participants:

» *"Refreshed my memory on the fundamentals of quantum computing… learnt some new subjects and better understanding of material I had covered before"*
» *"Firmer grasp of the subject matter"*
» *"Deeper understanding of theoretical possibilities / limitations relating to the field"*

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Quantum Information & Computation Courses
Six-week courses offered in association with the University of Bristol. https://www.nqcc.ac.uk/online-courses/

Educational Platform
Self-guided introduction to quantum computing https://www.nqcc.ac.uk/learning-resources/

Hackathons
Tackle real-world problems working in a team from the quantum community

PhD, Grad Schemes & Internships
Launching autumn 2023

Secondments
Work with us through partner companies and academic institutions.

Educational platform

An online learning platform commissioned by the NQCC will be launched to enable graduate students and early-career professionals from different technical backgrounds to develop the skills needed to programme a quantum computer. The training provides users with a solid grounding in the key concepts of quantum computing, offering a pathway into quantum programming as well as an understanding of quantum circuit design.

The platform includes a series of training modules that enable users to learn at their own pace, test their knowledge retention, and monitor their progress. The NQCC is providing funding for two individuals per organisation to complete the training. The learning experience will be supplemented with access to an online community network, driven by users offering mutually supportive learning.

The UK Quantum Hackathon

Quantum hackers tackle real-world problems

Nine teams of research students and early-career scientists lined up at the end of July 2022, to compete in the UK's first quantum computing hackathon. Organised by the NQCC in collaboration with QuantX, the event challenged the teams to devise novel quantum solutions to problems set by end users BT, MBDA, NHS, Rolls Royce, TCS and Thales.

Mentors from each of the end-user organisations worked alongside the teams to offer expert domain knowledge, explain the context for the problem, and guide the hackers towards potential solutions.

The hackathon was the first hands-on event organised by the NQCC to bring together quantum developers, end-users and technology providers to work on real-world problems.

Mentors from each of the end-user organisations also worked alongside the teams to offer expert domain knowledge, explain the context for the problem, and guide the hackers towards potential solutions.

By the end of the two-day event, several teams had run their algorithms on quantum hardware provided by technology partners D-Wave, OQC, and Rigetti through AWS and IBM Quantum. Hackers, who had developed solutions beyond the capabilities of current quantum processors, tested their solutions on quantum simulators. The programming experts from each of the technology providers were available on hand to provide support and advice.

Download a full report from https://www.nqcc.ac.uk/uk-quantum-hackathon-july2022/.

"
A problem set by the NHS challenged the hackers to devise a strategy for allocating patients to beds while also taking account of various constraints. It's an extremely complex problem that is usually worked out by people on the ground with a lot of domain knowledge. We are probably quite a few steps away from having any quantum computing solutions in the NHS, but it has been really interesting to find out how quantum approaches might be able to solve the sort of problems we're looking at."

Dan Schofield
Senior Data Scientist,
NHS Transformation Directorate

Engagement and outreach

How NQCC works with the community

Engagement pathway	Benefits and enabling activities
Networking	• Connect actors across the value chain for quantum computing • Promote the sharing & exchange of knowledge and ideas (pre-competitive) • Initiate collaborative activities/joint working.
Education and training	• Enable students and professionals to gain an understanding of quantum computing capabilities, the underpinning theory and how to programme quantum computers • Support career progression at all levels to allow professionals to gain skills related to quantum computing.
Collaborative R&D	• Understand the value of proof-of-concept and prototype technologies related to quantum computing • Support with end-to-end delivery of projects.
Commercial contracts	• Drive the demand for early products and services related to quantum computing, helping to mobilise the supply/value chain • Provide access to quantum computing resources.
Scoping, ideation & insight	• Opportunity to test the technical and business case related new ideas/concepts/projects • Opportunity to gain insights into the developing landscape for quantum computing to inform business decisions.

Developing a Quantum Industry Cluster

From an early stage, the NQCC has been working with the Harwell Campus cluster team to explore the case for a quantum computing industry cluster.

Plans are in draft to further develop the quantum computing industry through a collaborative cluster, with the NQCC as the anchor institution.

The intended purpose of the quantum computing cluster would be to:

• Provide a gateway for the emerging quantum computing technologies in the UK
• Establish a hub for innovation in quantum computing
• Establish a vibrant network of participating organisations that provides increased visibility and further catalyses the growth of the emerging industry
• Connect tech developers and end-users
• Enable access to the skills, expertise and facilities across Harwell Campus and beyond to support business growth
• Promote the exchange of ideas, knowledge and opportunities across the network
• Encourage and promote collaboration, drive innovation and business investment.

Research awards

October 2022

Highlight call on quantum computing funded by the NQCC as part of STFC's 2022 cross-cluster Proof-of-Concept (POC) grant

The NQCC provided funding for this highlight call through its applications discovery programme, **SparQ**. The call aims to stimulate industry engagement and interactions with the NQCC.

June 2022

Research and leadership role in quantum software and algorithms

The NQCC announced a strategic package award for a research and leadership role, funded by the EPSRC, that will allow the successful candidate to undertake an ambitious programme of research in quantum software and algorithms focusing on their applications. As Chief Scientist, the successful applicant will use current research results to steer and advise on areas of high potential for the NQCC and contributions to the wider UK quantum computing landscape.

Empowering Practical Interfacing of Quantum Computing (EPIQC) project

April 2022

NQCC joins EPSRC to fund researches on the interface of quantum computing and ICT

This £3m project aims to help quantum computing to move from the lab into real-world applications. The Empowering Practical Interfacing of Quantum Computing (EPIQC) project seeks to bring together researchers from different backgrounds to develop the interface between quantum computers and existing information and communication technologies.
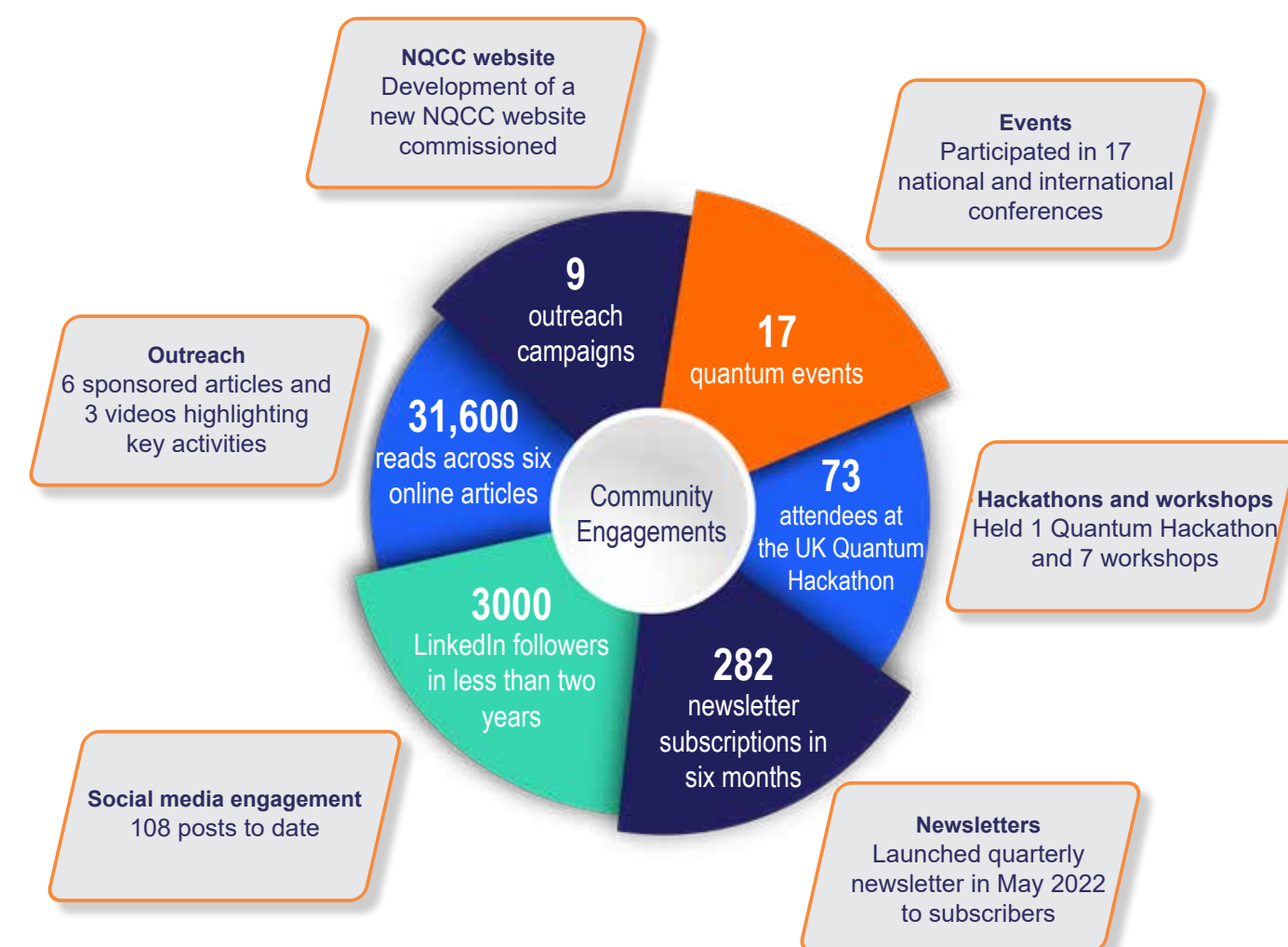

March 2022

Projects awarded for the highlight call on quantum computing as part of STFC's 2022 cross-cluster Proof-of-Concept (POC) grant

The NQCC announced four winning projects under a highlight call on quantum computing. It is part of a wider cross-cluster POC grant call that aims to stimulate industry engagement and interactions with the NQCC, as well other organisations within the Harwell and Sci-Tech Daresbury campuses associated with the Space, Energy, Health, and Digital Tech clusters.

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Staying connected: Communications

It is a challenge keeping pace with the rapid progress being made in the field both technically and commercially. Consequently, the NQCC seeks to engage and stay connected with a wide variety of interested parties ranging from companies and university researchers, to government departments, investors and end-users providing regular updates and insight..

NQCC website
Development of a new NQCC website commissioned

Events
Participated in 17 national and international conferences

Outreach
6 sponsored articles and 3 videos highlighting key activities

9 outreach campaigns

17 quantum events

31,600 reads across six online articles

73 attendees at the UK Quantum Hackathon

Community Engagements

3000 LinkedIn followers in less than two years

282 newsletter subscriptions in six months

Hackathons and workshops
Held 1 Quantum Hackathon and 7 workshops

Social media engagement
108 posts to date

Newsletters
Launched quarterly newsletter in May 2022 to subscribers

Read our articles here: https://www.nqcc.ac.uk/in-the-media/

Subscribe to our newsletter here: https://www.nqcc.ac.uk/newsletter-sign-up/

National Quantum Computing Centre

Events

Over the past year, the NQCC has participated at several events to stay connected with a wide variety of audiences and stakeholders.

New York City Quantum Summit
November 2022

Harwell Science and Innovation Campus: Q-Day 2.0
October 2022

Oxford Science + Ideas Festival
October 2022

Quantum.Tech Europe
September 2022

NPL Joint Symposium on Quantum Technologies
September 2022

CMD29
August 2022

Quantum.Tech Boston
June 2022

London Tech Week 2022
June 2022

Careers in Quantum 2022
June 2022

Café Scientifique 2022
May 2022

Commercialising Quantum 2022
May 2022

The Bristol Quantum Information Tech. (BQIT 2022)
April 2022

Westminister eForum
March 2022

The Future of Computing for Defence
March 2022

Venturefest Oxford 2021
November 2021

Harwell Quantum: Q-Day 1.0
November 2021

Quantum Technologies Showcase 2021
November 2021

Oxford Science + Ideas Festival

Quantum.Tech Europe 2022

QT Showcase 2021

We are recruiting, find our open positions here: https://www.nqcc.ac.uk/vacancies/

UK
RI
**National Quantum
Computing Centre**

Creating a world-class team

The NQCC is building a talented team of individuals who are passionate about quantum computing and its potential to transform our world. Through ongoing recruitment the NQCC aims to reach 65 team members by the time the facility opens in 2023, bringing together people with different backgrounds and expertise to deliver the NQCC's wide-ranging programme. Alongside its own activities, the NQCC will continue to commission external work and collaborate with research groups and industrial partners on co-development projects. The team has grown to more than 30 people during 2022, with talent deployed evenly across our innovation, operations and technology functions. We anticipate growing at the same rate over the next 18 months, predominantly in technical roles.

Working at the NQCC

The NQCC is creating a vibrant and collaborative work environment, where talented individuals can make a real contribution to the development and adoption of quantum computing in the UK. As a national facility with links into both the research community and the business sector, it offers a unique opportunity to work with people from different backgrounds who are committed to driving technical innovation as well as commercial success.

The NQCC team will soon be moving into its purpose-built facility on the Harwell Campus, which will become a focal point for quantum computing research and development in the UK. This world-class research centre is also expected to attract significant interest from around the globe.

The NQCC is committed to developing a sustainable approach to equality, diversity and inclusion (ED&I) across all of our activities and practices. With support from the STFC's ED&I Advisory Board, it will provide an inclusive workplace with practices, policies and processes that promote equality, diversity and inclusion across all of our functions.

Shaping the NQCC

In October 2022, the NQCC team came together to look back at the progress made in establishing the NQCC over the past 18 months and discuss how its strategy and organisation will evolve in the coming 18 months.

The workshop included presentations from internal and external speakers alongside the discussions on how the new facility will be commissioned and how it will continue to develop as an organisation.

"

Having joined the NQCC in Sept. 2021, it's been really exciting to contribute to shaping and developing the user engagement and innovation programme, building relationships with a variety of organisations across the UK. The NQCC's strong vision and enthusiastic team are truly inspiring!"

Dr Chiara Decaroli
Quantum Innovation Sector Lead

"

I joined the innovation team at the NQCC in a role where I can combine my technical background with my passion for science communication. I'm excited to contribute to the development of the quantum workforce through outreach, education, and training activities."

Daisy Shearer
Outreach & Engagement Officer

"

I am driven by the challenge of designing quantum computers to work in an (inconveniently) noisy 'real world', working in good company!"

Alexander Owens
Ion Trap Physicist

"

As part of the NQCC, I look forward to uncovering quantum computing use-cases across the sectors of Space, AI and Healthcare and driving Quantum Readiness by fostering collaborations, forging partnerships and encouraging commercialisation."

Dr Sonali Mahapatra
Quantum Innovation Sector Lead

Key appointment: Chief Scientist

Professor Elham Kashefi was appointed as Chief Scientist in November 2022. This is a key role within the NQCC's Leadership Team contributing towards shaping and influencing the future UK quantum computing landscape, and meeting the strategic aims of the National Quantum Technologies Programme (NQTP).

Elham is Professor of Quantum Computing at the School of Informatics, University of Edinburgh, and Directeur de recherche au CNRS at LIP6 Sorbonne Universite. She co-founded the fields of quantum cloud computing and quantum computing verification, and has pioneered a trans-disciplinary interaction of hybrid quantum-classical solutions from theoretical investigation all the way to actual experimental and industrial commercialisation.

Elham is the founder of national quantum networks (QuOxIC and QUISCO) and member of multiple international institutions. She served as the Associate Director of the NQIT Hub before being elected to lead quantum software activities within QCS Hub. In her capacity as Chief Scientist, Elham will chair NQCC Technical Advisory Group.

This research and leadership role is a part of a strategic package funded by EPSRC. Elham will spend 30% of her time on secondment to the NQCC in the role of Chief Scientist and use her research results to steer and advise on areas of high potential for the NQCC and contributions to the wider UK quantum computing landscape.

UKRI **National Quantum Computing Centre**

Outlook and next steps

2022 saw several key milestones for the NQCC:

Facility construction is well under way, **SparQ** quantum readiness applications development programme was launched, initial technology work package commissions moved towards completion, equipment was procured and installed in our temporary lab space and staff recruitment accelerated building a team of over 30 people.

Key activities planned for 2023, include further hardware work package procurement, expanding our technical programme to build up superconducting technology platform effort, growth in **SparQ** and quantum readiness efforts and recruitment as priority activities.

As we approach early autumn in 2023 we look forward to taking ownership of the new facility with a huge amount of work to follow in the laboratory commissioning phase including our IT infrastructure.

We are looking forward to supporting a number of collaborative R&D calls with particular focus on use-case and applications development, benchmarking, verification and emulation methods in collaboration with our colleagues at the University of Edinburgh.

To support this effort we will also be launching out gateway access to third-party quantum compute resources to support the UK research community and our **SparQ** programme.

As our organisation grows so we will develop our graduate and studentship programmes with our first cohort, planned to be in the autumn of 2023.

Training and skills remain core to our purpose and we will be rolling out our online platform in 2023.

Ongoing quantum readiness workshops and hackathons are planned throughout 2023 with a range of outreach and engagement activities in tandem.

Finally, as our activities across the Harwell Campus grow we look to cement our footprint at Harwell though our Innovation Hub due for completion in the summer of 2023.

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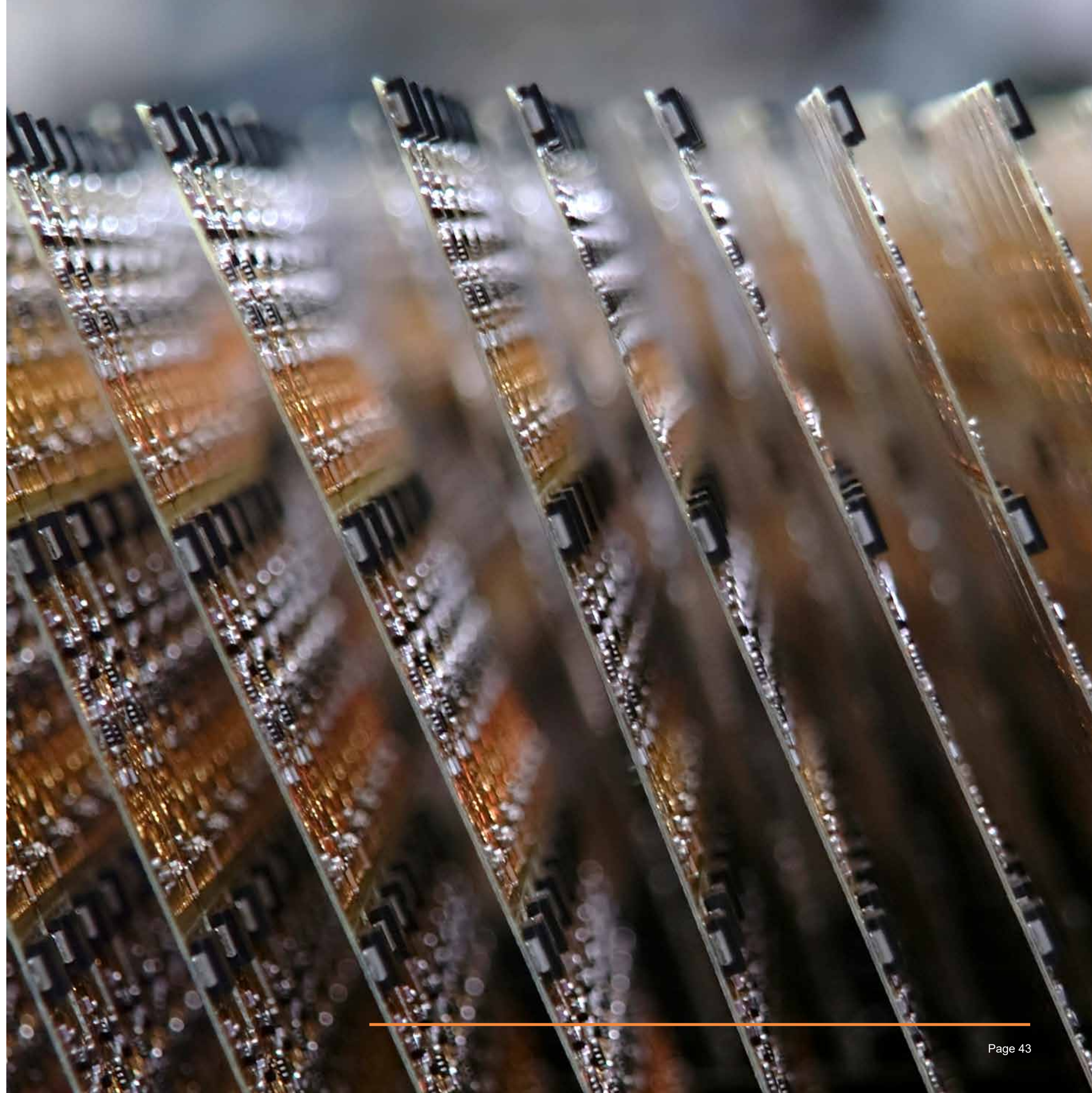
Acknowledgements

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