

SFC Alliances for Research
Challenges (ARCs)

Quantum Computing Application (QCA) Cluster: Expression of Interest

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Academic Disciplines:	Computer Science, Physics, Mathematics, Engineering



**QUANTUM
COMPUTING
APPLICATION
CLUSTER**

Challenge

Today, Scotland has reached a key turning point in participating in the National Quantum Technology Programme. The ecosystem built over the last few decades now has the potential to bridge the gap between fundamental research of quantum technologies, and real-world quantum computing applications for end-users benefiting businesses and citizens. The hardware engineering challenges in scaling quantum technology to make it economically feasible for deployment are already targeted by a number of well-funded UK initiatives, like the National Quantum Computing Centre (NQCC).

Tomorrow, therefore, the greatest gains are in *Quantum Applications*. Quantum Technology operates on fundamentally different principles than classical IT, so one cannot simply translate an existing classical solution to a quantum setting and expect benefits. Solutions have to be redesigned from the ground up. This makes embedding Quantum Computing in existing IT ecosystems highly challenging. An additional challenge is interfacing Quantum Computing with High-Performance Computing. Edinburgh is a strategic leader in strengthening Quantum Software to benefit Scotland through integration with hardware in the QCA cluster, and UK-wide through the Quantum Computing and Simulation Hub.

Furthermore, there is a significant lack of (Scottish and UK) public investment in Quantum Applications, Software, and Algorithms to support HEI education, research, and innovation programmes. Private investment in this field is largely situated outside of the UK, predominantly residing in the USA, Canada, and Asia.

Benefits

This Alliance for Research Challenges (ARC) will address the academic capacity by recruiting a *Knowledge Exchange Fellow in Quantum Applications*. We will work with Scottish Development International to target global corporates, attracting them to set up in Scotland with our unique academic expertise, talent pool, and existing capital infrastructure, facilities, and equipment designed specifically to cater for quantum computing needs. The knowledge exchange fellow will work directly with these newly located global corporates to develop end user applications that target key economical and societal challenges within Scotland. It is essential the fellow supports classical IT firms in this roadmap, as academia and businesses need each other to convert research into tangible products and services for our economic and social benefit. To overcome the challenge of interfacing Quantum Technology into existing IT solutions, we will focus on recruiting and upskilling IT talent from both academia and corporates, so that they can confidently evaluate and work with Quantum technology.

Scottish priorities

Aligning with the Logan Review, we will support knowledge exchange, entrepreneurialism, and new enterprise development by supporting the existing academic and student base to spinout commercially viable research into future

high-growth ventures through robust IP strategies. Thus, this ARC aligns with Scotland's National Strategy for Economic Transformation:

- Project 2: this ARC will create infrastructure for institutions and companies that want to evaluate or use quantum technology.
- Project 7: this ARC attracts and deploys domestic and international private investment in Scotland in scalable Quantum IT.
- Project 13: this ARC will expand Scotland's available talent pool to give employers the skills needed to take advantage of Quantum opportunities.

We believe that our ambitions are well aligned with the Scottish Government's National Performance Framework, because this ARC will provide citizens and businesses with the skills and education to benefit from quantum opportunities:

- This ARC supports businesses in adopting Quantum opportunities, in an open way, making a positive contribution internationally, and indeed building towards a globally competitive economy.
- This ARC contributes to climate action in two ways. First, Quantum Algorithms benefit optimisation problems, and are used by e.g. aeroplane engineers, and by logistical planners to optimise flight paths or cargo loading, to reduce emissions. Second, by its nature Quantum Computing uses much less energy than classical High-Performance Computing.

Thus, this ARC also embodies the following UN Sustainable Development Goals: (4) Decent work and economic growth; (9) Industry, innovation, and infrastructure; (13) Climate action; and (17) Partnerships for the goals. Scotland has the academic, economic, and social prowess to become a market leader in Quantum Computing Applications. However, capacity, investment, and co-location remains a barrier to first mover advantage that must be overcome.

Multidisciplinary

By its very nature, Quantum Applications is a multidisciplinary area: even though this ARC primarily focus on software, algorithms, and applications, it necessarily combines insights from not only computer science, but also physics, mathematics, and engineering. These are all areas of Scottish research excellence, as evidenced by the Research Excellence Framework 2021. This multidisciplinary nature gives the QCA cluster natural breadth. This proposal identifies a specific need that will enable it to deliver on its promise.

Coalition

The Quantum Computing Applications (QCA) cluster brings together world-class expertise across quantum informatics at the Universities of Edinburgh, Glasgow, and Strathclyde. By joining capability in software for end-user applications with expertise in developing novel quantum hardware, QCA will accelerate the development of quantum technologies in Scotland. QCA's activities comprise scientific, technical, training, and educational aspects of quantum technology. We undertake collaborative research, run workshops to educate students, and engage with industry to maximise the beneficial impact of quantum computing on the Scottish and UK economy and wider society.

Over the past 6 months QCA has partnered with Scottish Government, Scottish Enterprise, and Scottish Development International to undertake a trade mission

in the US west coast, aimed to test QCA's market proposition to attract inward investment. This mission resulted in targeted engagements with 20+ global corporates who are looking to Scotland to address their shortfall in academic expertise, highly skilled workforce, and co-location with physical assets (e.g. facilities, equipment, lab spaces) as part of UK expansion. This proposal to SFC will further our national capacity in Quantum Computing Applications by enabling new academic resource capable of converting leads into tangible opportunities for the benefit of Scotland's science & research community.

Spread across three Scottish universities, QCA comprises over 28 experts in (1) Software, Architectures, and Connections with Classical HPC; (2) Hardware; and (3) Industry relations. Collectively, QCA is one of the largest networks of Quantum Computing Applications experts in academia. Its combined expertise affords a unique position to boost Scotland's international profile.

Funding opportunities

The 2014 National Quantum Technologies Programme investment of £270 million by the UK Government has been highly successful in creating an ecosystem for quantum technologies by bringing together 91 companies with academics largely in physics and engineering-based disciplines, with a competitive share in Scotland. However, these disciplines lack the theoretical understanding of computer systems architecture and the connection between hardware, software, and applications. The knowledge exchange with industry in Quantum Computing Applications has been extremely challenging, and only 9 of 49 ISCF funded business-led projects have been focused on this aspect. More computer sciences methodology needs to be applied to quantum computing to gain quantum advantage, including programming languages, compilers, algorithms, and applications, in addition to interfacing with physical hardware.

The QCA cluster has experience contributing to several major such programmes, including: the UKRI network "Empowering Practical Interfacing of Quantum Computing" project; the industry-led UKRI project "Noise analysis and mitigation for scalable quantum computation"; and the EU-funded flagship project "Pasquans", developing practical applications of quantum simulators. This base puts QCA in a good position to target future funding opportunities, including UKRI, UK Government, Scottish Government, and Horizon Europe. Furthermore, Edinburgh is part of 3 large scale ISCF projects in quantum software; a collaboration of 20+ industry partners at a value of £17 million. This AR will provide the capacity to develop such funding applications at scale.

Proposal

QCA operates as a 'one stop shop' for academics, public sector, and industry to access neutral advice, expertise, and participation in the Quantum Computing Applications ecosystem. Since its establishment in 2020, QCA has subsisted on in-kind contributions by the academic institutions. In early 2022, Scottish Government funding supported a trade mission in collaboration with Scottish

Enterprise and Scottish Development International, resulting in many new industrial leads. However, QCA has neither the academic resources nor the in-house capacity to convert these opportunities into collaborative projects with a direct return on investment. This ARC will bring together expertise from the three QCA universities, and synergistically join these up through joint activities. To facilitate this, we will employ a *Knowledge Exchange Fellow* to bridge the gap between fundamental research and end-user applications, who will:

- Develop research & development plans with industry and public sector partners. Knowledge exchange of research and technical validation of early-stage opportunities for Quantum Computing collaborations. Delivery of technical expertise and advice.
- Manage Business Development activities for QCA. Track research and innovation activity to maximise exposure to appropriate industry partners. Develop a symbiotic relationship with academics to understand their research and ambitions, and develop commercial opportunities.
- Identify and develop sources of funding for commercialisation of research. Supporting academic bid development requiring business input.

The Fellow will be employed by the University of Edinburgh as dedicated resource supporting QCA, via SFC funding and in-kind contributions, as follows:

- *Event convening*: provide a platform for all academics to benefit from QCA's knowledge base; run hackathons to bring together key industrial partners; organise specific events focused at upskilling c-suite executives across Scotland's market sectors that benefit from end-user applications.
- *Horizon scanning*: the Fellow will work with QCA's Industry Relations team, Scottish Enterprise, and Scottish Development International to identify key opportunities for supplementary research and translational funding.
- *Development of leadership groups*: the QCA Leadership Group currently meets bi-weekly. The Fellow will develop the QCA strategy with leadership members, to support our next phase of growth and future sustainability.
- *Early career researcher support*: QCA members, and the Fellow in particular, will upskill industry and academic parties with a background in engineering, physics, or mathematics, in Quantum Computer Science.
- *Creation of credible large-scale multi-disciplinary research funding bids*: the Fellow will leverage funding by focusing QCA along the following roadmap. In 5 years, to achieve a robust understanding of what can be achieved safely and certifiably using quantum computers. For example, to develop semi-automated diagnostic systems to classic problems amenable to quantum assistance. In 2 years, to create a robust pipeline of particular applications where quantum gains are most likely to be achieved. For example, to carry out case studies with end users to survey which problems are amenable to quantum assistance.

This ambitious programme builds on QCA's strengths and the opportunities it has uncovered. It is vital to secure the additional Fellow and administrative overheads for the growth in the delivery of knowledge exchange, events, and ability to secure additional funding. This ARC will enable transfer of QCA research into industrial outcomes for economic and societal benefit, and attract inward investors to Scotland with a direct gain of new jobs and revenue.