ROYAL ACADEMY OF ENGINEERING

Quantum Technologies

A response to the House Commons Science and Technology Select Committee inquiry on the opportunities and challenges for quantum technologies

March 2018

The Royal Academy of Engineering welcomes this opportunity to submit evidence to The House of Commons Science and Technology Select Committee inquiry on the opportunities and challenges for quantum technologies (QT). As the UK's national academy for engineering, we bring together the most successful and talented engineers from across the engineering sectors for a shared purpose: to advance and promote excellence in engineering.

Through its Fellowship, the Academy has access to highly qualified individuals with industrial and academic interests in QT. This response is based on the views of Fellows.

Q1. The progress that has been made on the recommendations in the Government Office for Science's 2016 report *The Quantum Age: technological opportunities*;

No comment

Q2. The relative contribution/support from government, researchers and businesses needed to make QT a success;

The continued collaboration between industry, academia and government to combine new ideas from research, product delivery and funding to reduce risk is key to the success of QT. Development of a national strategy for QT has created an alignment of these areas allowing QT to overcome technical barriers quickly and forming a strong position for the UK.

Government funding for research is still needed to support new approaches to solving current issues. As these technologies develop the UK business appetite for QT must increase to take advantage of the opportunities as the technologies near maturity. Business involvement is critical in terms of testing and providing feedback on commercial applications.

Q3. The current state of the UK quantum industry and its potential going forward, including particular strengths and challenges;

While the UK has some very promising areas of research such as sensor and metrology applications, the amount of funding required to scale-up to market readiness should not be underestimated. Private funding is of course important, but as an area of such strategic significance the government should be ambitious and willing to take risks in its funding targets in order for the UK to be able to compete.

Annual UK investment in non-classified quantum technology research is estimated to be less than one third of US investment[1]. Interest from UK industry has been limited, with just a few start-ups and large companies (e.g. BT, Airbus[2]) making significant investments in QT. In comparison, the USA's industrial investment in QT has been huge, largely the efforts from Google, Intel, Microsoft and IBM in their battle for quantum supremacy[3] alongside military interest. Indications are Toshiba and Hitachi laboratories are investing more in QT in the UK that any British company.

However, industrial involvement in QT is growing. Innovate UK have funded three rounds of QT projects. The recent announcement of the £20m Industrial Strategy Challenge Fund pioneer fund for quantum technologies[4] should support this further. Increasing this industry engagement needs to remain a priority within the national programme going forward.

Q4. What oversight or regulation is needed;

Regulation and oversight are integral elements in the national strategy for QT with all hubs required by the research councils to consider these aspects. Public dialogue has shown that while QT offer significant potential benefits, on the whole the risks they present are generally the same as completing the same task using conventional technology.

[1] https://www.economist.com/news/essays/21717782-quantum-technology-beginning-come-its-own

[2] https://www.cbinsights.com/research/quantum-computing-corporations-list/

[3] https://www.ft.com/content/4b40be6c-0181-11e8-9650-9c0ad2d7c5b5

[4] Industrial Strategy White Paper – building a Britain fit for the future

For quantum communication, the European Telecommunications Standards Institute have been working with UK scientists to develop regulations. Collaboration between UK industry, research and the regulatory bodies creates opportunities for the UK to gain a competitive advantage by leading the development of global standards. While not all applications of QT are at a stage where regulation is a priority it is important that current trials are constructed in a way to inform what regulation should occur and when so as to both support innovation and ensure safety.

Q5. Potential barriers for developing QT, and how these might be overcome;

The UK needs to continue attracting talented researchers and the connection between academic research and industry is a vital component. One means of stimulating industrial support might be an offer of long term funding for collaborations to attract large international corporations. Such a mechanism would have numerous benefits: attracting talent, encouraging risk taking and ambition for QT applications and positioning the UK as a strong competitor in terms of commercialisation as well as research. This would complement the ongoing Innovate UK strategy which provides a relatively small amount of funding for short term work and research expertise.

Additionally, to see QT turned into commercial products there needs to be a strong emphasis on manufacturability, reproducibility and validation. Some of these elements are being tackled through the involvement of the National Physical Laboratory but further collaborations could be beneficial.

Q6. What research priorities there should be for QT and their possible uses, and who is best placed to undertake/fund that work;

While there is still a need to fund basic science research this must be accompanied with a focus on taking the technology from concept to prototype in order to open up commercial opportunities.

QT are expanding in applications and therefore may need increasing UKRI support. The existing quantum hubs have been evaluated by international experts. This process highlighted areas of particular excellence and gaps, these outcomes should be used to assess whether new hubs are required. Tackling the gaps will require an integrated programme of research, development and infrastructure funding across academia, innovation and industry which should be a role for UKRI.

UKRI together with the other National Programme partners is best placed to take this forward. It is important there is a greater focus on industry priorities and stronger executive oversight and governance.

Q7 The role of international collaboration in quantum technology research and development; and the risks and opportunities of Brexit in this area;

There were no specific opportunities identified as a result of Brexit, with concerns raised about challenges for continued collaborations with European nations. The UK has been heavily involved in the proposals for the EU sponsored QT Flagship programme[5], due to start in 2019, and must continue to be included. There is a further risk of the UK losing key expertise as the rest of the world invests in QT and the demand for these skills rise.

Typical academic methods of international partnerships remain the best approach to collaboration as this allows researchers to draw upon complementary skills.

Q8. Any challenges from potential civil/military 'dual-use' applications of the technologies, and how these can be addressed;

While quantum cryptography can enable more secure messaging the main risk from QT is that the computing speeds will make current cryptographic techniques obsolete. This makes

[5] FET flagship on quantum technologies
http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/fetflag-03-2018.html

securing the developing encryption technologies a critical priority. From the dual-use technologies there are further risks in terms of loss of intellectual property and prosecution for accidentally breaching international regulations (e.g. United States International Traffic in Arms Regulations).

Q9. Any potential societal implications—positive and negative—of the development of QT, including on health, security, privacy or equality.

There are potential economic benefits from UK leadership in QT. However, by accelerating the scope of artificial intelligence there will be positive and negative societal implications across the areas of health, security, privacy and equality. There is a risk that the ethical considerations of artificial intelligence will not be managed so that it has benefits for all of society. QT don't necessarily change the issues but the potential speed and capacity it creates for data analysis make ethical frameworks more important.

Inclusion of QT in wider public debates on technological advancement would be beneficial. The inclusion of public outreach and responsible research and innovation research strands within the hub programmes is an important factor which should be continued going forward. It must be recognised there will always be unforeseen risks with new technological capabilities.