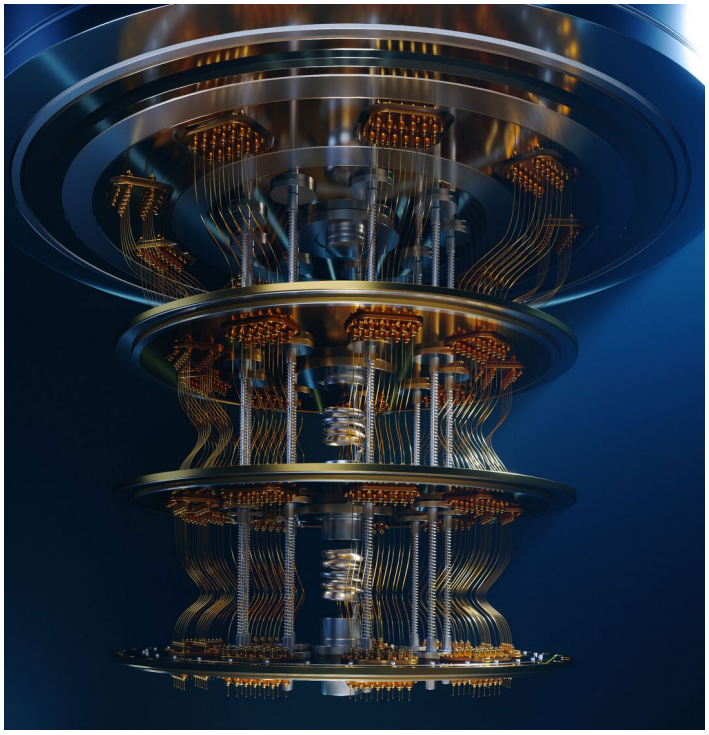
Quantum technologies: a new frontier for systems engineering?

Executive summary

The world is currently experiencing the second quantum revolution which has huge potential across a diverse range of applications, including environmental monitoring, health care, defence and navigation. The 2023 McKinsey Quantum Technology Monitor indicates a vibrant and flourishing quantum ecosystem[1]. It expects the global quantum computing market to reach $93 billion by 2040, with the overall quantum technology market potential estimated at $106 billion; quantum sensing, timing, imaging, and communications, each have an estimated market size ranging from $1 billion to $7 billion by 2040[2].

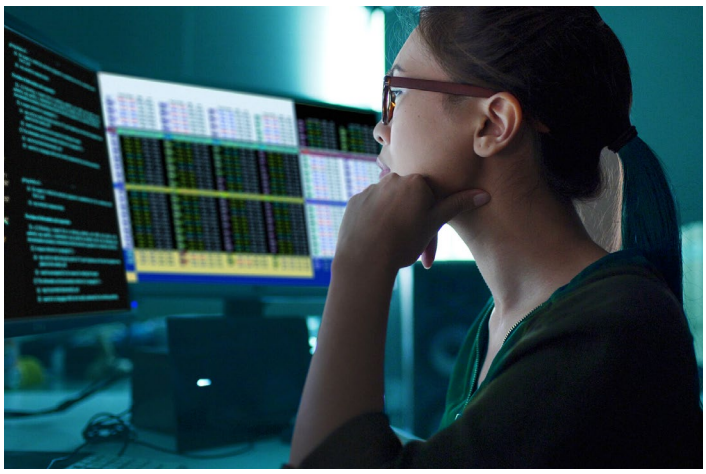
However, before those advantages can be realised in practice, the quantum technologies must be integrated into wider systems. Even though quantum is beginning to move from laboratories to tangible application, it faces specific challenges from a systems engineering perspective to ensure it can integrate with other systems safely and effectively.

1. Quantum will present challenges for systems engineering, as the very nature of the technology means it is nondeterministic. So, unlike traditional systems, this increased uncertainty will make it more challenging for systems engineering to measure and predict outcomes and therefore how it interacts with other parts of a system.
2. Quantum states are also highly fragile and susceptible to interactions with outside systems.
3. Quantum information also cannot be copied in the same way classical information can, which makes it harder to replicate.



As a result of all these challenges, quantum will be harder to regulate when products eventually come to market.

1. quantum-technology-monitor-april-2023.pdf (mckinsey.com)
2. RHC_regulation_of_quantum_technology_applications.pdf (publishing.service.gov.uk)



Recommendations

1 Make quantum systems engineering a new discipline

The UK already has a strong background in systems engineering and is a global leader in developing quantum technologies (ranked 2nd for number of quantum companies[3]). However, what will make the UK stand out globally in the future, is its strength in bringing both quantum and systems engineering together. Systems engineering is critical to ensure new technologies integrate seamlessly into the existing environment, whether physical or digital, without unforeseen effects.

This is particularly the case for quantum, as it can have non-local effects. Systems engineering can mitigate this through effective planning and strategies such as compartmentalisation to help to contain the quantum effects from the wider system. This would aid validation and verification and regulation of the wider product and help to address some of the regulatory challenges.

2 Improve quantum literacy

Fundamentally, quantum literacy needs improvement. Most employers think that senior management doesn't understand other emerging technologies with 54% not understanding quantum engineering[4]. This is not only about making sure there is greater understanding amongst the general population, but also ensuring that experts can explain quantum clearly and concisely. Examples of its use may also help increase awareness around how quantum can help everyday lives. This can be coupled with publicity around success stories to keep people interested. Examples of quantum in the Science, technology, engineering, and mathematics (STEM) curriculum would help to ensure it was seen as just another technology. These are things that would need to be considered as we continue to develop this.

A strong industrial base is needed to support application of quantum and having the necessary skills, and success stories are key to this. Transferable skills that are required can often be found in a range of backgrounds and reskilling and upskilling are integral to addressing these issues. Apprenticeships will support the necessary skills pipeline for quantum technology, particularly as retention is key.

3 Regulation

Quantum will require a new approach to regulation as it is inherently hard to replicate and predict and can have non-local effects in a system. Government and regulators should use the 2024 Regulation of Quantum Technology Applications report by the Regulatory Horizons Council as a basis for further discussion. Going forward regulators should expand on this to focus on the systems element of regulation in this field[5]. This is an opportunity for the UK to take a leadership position in global regulation and standards for quantum technology.

4 Systems thinking in quantum technology

Further support is needed to engineer solutions to the unique challenges that quantum faces, through systems engineering. Systems thinking should be embedded at an early stage in the development of new quantum technologies and support should be given to the development of new approaches to developing combined quantum and classic systems. Good practice in systems architecture for quantum technology should be shared to increase the pace of development and regulatory approval.

5 Continue to implement the National Quantum Strategy

By continuing to fund work that allows companies and universities to work together across the value chain, the UK's quantum ecosystem can be further strengthened, linking up component manufacturers, quantum system developers, systems integrators, and end users. Of particular importance is ensuring funding for future Contracts for Innovation[6], which enables larger companies such as systems integrators to work more easily with quantum Small and Medium Enterprises (SMEs).

6 International environment

Australia, Canada, Israel and the US are world leading in this technology. A collaborative systems engineering hub with dual qualifications with other countries is a way to ensure that we work closely internationally. The UK has the second most quantum start-ups in the world, however this is only one indicator of success, and a key component of UK success is both national and international collaboration, which the UK should continue to leverage in future.

Source: Quantum Technologies: A new frontier for systems engineering?[7]

For further information, please contact policy@theiet.org

3. national_quantum_strategy.pdf (publishing.service.gov.uk)
4. iet-skills-for-a-digital-future-summary.pdf (theiet.org)
5. RHC_regulation_of_quantum_technology_applications.pdf (publishing.service.gov.uk)
6. Innovate UK Contracts for Innovation – UKRI
7. Quantum technologies: a new frontier for systems engineering? (theiet.org)