Queensland University of Technology

Response to the CSIRO
Quantum Technology Roadmap Discussion Paper

December 2019

Queensland University of Technology (QUT) welcomes the opportunity to comment on the CSIRO *Quantum Technology Roadmap Discussion Paper* (the Discussion Paper). We have restricted our responses to those areas where we feel we can add best value, namely discussion questions 1.1, 2.2, 4.1 and 4.3.

1.1 Do you support the draft vision for Australia's quantum technology sector? If not, why not?

QUT supports in principle the draft vision for Australia's quantum technology sector outlined in the Discussion Paper. However, we propose that the definition of 'quantum technology' be broadened to allow for possibilities not considered in the Discussion Paper.

The Discussion Paper defines quantum technologies as "technologies that make use of our ability to manipulate single quantum objects (e.g., atoms, electrons, photons) to control or enable their function". This narrow definition recognises the subject of quantum technologies as quantum (sub-atomic) objects.

However, this definition arbitrarily excludes quantum research focussing not on *objects* but on *phenomena*. For example, the emerging field of Quantum Cognition is a field of quantum technology research exploring cognitive *phenomena*. In this field, cognitive phenomena can be observed, measured and understood similarly to quantum objects in striking and meaningful ways.

The development of Quantum Cognition has produced an entirely new genre of cognitive models based on the formalism of quantum physics and back by strong scientific support. These models are especially useful in modelling cognitive phenomena that have previously proven recalcitrant (or even paradoxical) to modelling using standard approaches (such as those based on probability theory).

The study of Quantum Cognition has already produced strong models of decision-making, human memory, and conceptual processing. For example, theories of human decision-making will typically make an assumption of humans' rationality. However, decades of research have found a whole range of human judgement deviates substantially from what would be normatively correct according to logic or probability theory. Quantum models allow us to explain perceived "irrationality" in natural human decision-making in an effective and efficient manner.

In summary, QUT recommends that "quantum technologies" be defined more broadly than technologies that exploit objects in the sub-atomic realm. Quantum-like cognitive phenomena that enhance human cognition via associated quantum-like technologies are an emerging frontier with significant possibilities and should be considered within the CSIRO Quantum Technology strategy. One such possibility is in the field of Quantum Decision Technologies (see below).

2.2 What commercial applications of quantum technology is Australia's quantum sector best positioned to develop and commercialise?

In response to section 2.4 Enabling Technologies, QUT highlights Quantum Decision Technologies for complex information environments as a commercial application which Australia is well positioned to develop, commercialise and become a world leader in.

The theories being developed by Quantum Cognition have matured to a degree where new Quantum Decision Technologies can be envisaged. Quantum Decision Technologies form a part of a new genre of technologies which can be dubbed "Quantum Intelligent Systems" – systems which combine quantum theory, artificial intelligence and cognitive science to assist human information interactions in complex information environments.

These technologies have great potential to assist human decision-makers in understanding and utilising complex information in high-stress, high-risk environments. The advantage of Quantum Decision Technologies (above existing decision modelling) is that their derived decision models better align with the "irrationality" of human decision-making. This increased awareness of how humans actually judge information (rather than how a classical model would prefer humans to judge information) allows this technology to be more judicious in advising humans, and more proactive in the way they present information.

In this way, trusted interactions between human and machine can be promoted, a critical step for effective human-machine shared decision-making under the conditions of uncertainty that occur on the battlefield or in disaster situations (to name a few examples). Further promoting usability, such technologies will not require a quantum computer in order to be implemented.

4.1 Do you support the enabling actions listed? Please provide a brief rationale for your responses.

In support of the enabling actions, QUT would like to reinforce the point made that "Australia must continue to leverage its strengths, address existing challenges, and be increasingly coordinated in the investments and enabling actions it pursues".

By its very nature, R&D in quantum technologies is high risk/high reward. In the late 2000s, the Intelligence Advanced Research Projects Activity (IARPA) was set up within the U.S. Office of the Director of National Intelligence to fund such research, prioritising blue sky and long-term payoff research over "quick wins", "low-hanging fruit" or "sure things". Although it is challenging to reliably predict benefits and assess feasibility of this research, "failure" (a term that has been poorly adopted by the public to mean discovering what *doesn't* work) was acceptable as long as it was not due to methodological weakness or a failure in the maintenance of programmatic integrity.

QUT recommends that Quantum Technology be supported through similar schemes with similar principles to those that have proved themselves at IARPA. The U.S. Air Force Office of Aerospace Research and Development provides a model scheme, where light (one-page) approaches are made to an advisory board and program director. Successful approaches are followed up by a fuller proposal (including an overview, budget, and investigators bios; no longer than an ARC Discovery grant project section). This is an iterative and interactive process, with the program director providing input and advice on criteria. By the time a full application is submitted (inclusive of full budget details, etc.) the director-investigator collaboration has effectively shaped the project into a mutually-beneficial and supported endeavour.

4.3 What are the highest priority actions that could be undertaken to enable sustainable commercial growth in Australia's quantum technology sector?

QUT proposes that the following highest priority actions could be undertaken to enable sustainable commercial growth in Australia's quantum technology sector:

- **Focus**: Develop a national strategy based on areas of global leadership within the Australian quantum technology landscape and communicate long-term strategic priorities, commitments and direction to Australia's quantum industry.
- **Capability**: Ensure that quantum science and technology postgraduate programs have strong pathways to opportunities in Australian research, start-ups and defence. Design postdoctoral research opportunities with industry linkages and spinoff potential in mind.
- **Collaboration**: Strengthen incentives and funding for cross-disciplinary research, translation and commercialisation projects. This is critical as quantum opportunities draw on complex science and engineering across varied disciplines (e.g. computer science for quantum computing, chemistry for quantum simulations).
- **Demonstration**: Investigate mechanisms to encourage targeted investment in demonstration and commercialisation of quantum technologies. This could include co-funding or matched investment between venture capital and government partners; or hosting quantum competitions.
- **Readiness**: Formalise channels to connect the quantum industry with potential end-users to identify and scope research and demonstration projects with greater commercial potential.