Quantum Strategy Issues Paper

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Science & Technology Australia is the peak body for the nation's science and technology sectors, representing 95 organisations and more than 90,000 scientists and technologists. We connect science and technology with governments, business and the community to advance science's role in solving some of humanity's greatest challenges.

We thank the Department of Industry, Science, Energy and Resources for this opportunity to offer input on the broad themes in the Quantum Strategy issues paper.

Context for this consultation

In November 2021, the Australian Government announced a $111 million investment in quantum technologies. $70 million was earmarked for a Quantum Commercialisation Hub.

The Australian STEM sector welcomes this timely investment. Quantum is a revolutionary emerging technology field that is set to transform technological capabilities, industries, our economy and our society. Global investment in quantum is growing rapidly – for good reason – and Australia must keep pace to be a contender in the global quantum race. We have outstanding emerging quantum research capacity. Clever, strategic and swift support for quantum technologies will help cement Australia's position as a world leader.

A comprehensive approach

The pivotal guiding principle for the Quantum Strategy will be to recognise the breadth of potential quantum applications – the synergies and overlap with directly related technologies but also the applications in what would appear to be a completely disparate field. An overly narrow focus that places an overemphasis on any single aspect or application of quantum technology will risk missing vital opportunities.

A comprehensive approach that ranges from pure quantum physics capabilities to understanding how quantum technologies will be realised in other STEM disciplines – from environmental monitoring and biomedical applications, to completely separate industries such as transport or financial services – will be crucial. Key to this will be integrating quantum technology into conventional approaches where appropriate – supplementing, not necessarily replacing, the tools and techniques we already have. Quantum capabilities need to be developed in tandem with other competencies, such as high performance computing, artificial intelligence and machine learning.

An option is to create quantum technology hubs that span academia and industry. These would integrate quantum applications with existing technologies, and develop quantum approaches with deep insight into fields in which they will ultimately be deployed.

Currently in Australia there are significant deep and long investments in quantum research. These include investment in the Australian Research Council Centre of Excellence for Engineered Quantum Systems, which explores the interface between quantum physics and

engineering to develop practical applications and tools. It also includes the ARC Centre for Excellence for Quantum Computation and Communication Technology, which has a focus on quantum computing hardware development.

These types of long and deep investments highlight the scale and focus of activity needed to achieve the levels of academic excellence and intentional translational success to assure Australia's leadership of quantum technologies into the future. Importantly, both these schemes fall in the ARC Linkage Program, which seeks to *"encourage and extend cooperative approaches to research and improve the use of research outcomes by strengthening links within Australia's innovation system and with innovation systems internationally. Linkage promotes national and international research partnerships between researchers and business, industry, community organisations and other publicly funded research agencies. By supporting the development of partnerships, the ARC encourages the transfer of skills, knowledge and ideas as a basis for securing commercial and other benefits of research".*

We strongly advocate for further support for schemes in the ARC Linkage Program such as the ARC Centres of Excellence and the ARC Industrial Transformation Research Program that foster cross-institutional and cross-sectoral collaborations exploring research and technologies at various stages along the Technology Readiness Level pipeline. This will ensure the opportunities are identified and pursued by Australia's leading experts, and in areas where Australia would hold a competitive-edge or a differentiated advantage.

Targeted efforts to address a quantum skills shortage will also need to be part of this comprehensive strategy, from undergraduate level through to post-PhD. Developing quantum proficiencies requires students to be equipped with a fundamental understanding of quantum physics. Reskilling programs through micro-credential and professional accreditations will also enable the industry to gain much needed quantum literacy.

Internships, such as those offered by the Pawsey Supercomputing Centre, enrich students with an understanding of potential quantum computing applications. These sorts of programs will be needed across the STEM sector, as quantum literacy will need to extend beyond single fields or applications.

Discovery research

To truly progress Australia's quantum capabilities, it must be remembered that discovery research is the foundation of all new knowledge. This knowledge can later be developed into applications, with the possible (but not certain) eventual goal of translation and commercialisation. Funding for all stages of the quantum pipeline is needed to shore up our ability to capitalise on our talented researchers and the potential of their work.

Support for discovery research that pushes the boundaries of quantum knowledge across disciplines – convergent and/or multi-disciplinary projects – is needed to complement any investments in applied research and commercialisation ventures.

Quantum commercialisation hub

As with commercialisation efforts of research from across the STEM sector, a vital component is to equip more scientists with the skills and know-how to identify when, how and where a promising piece of research could have commercialisation potential. We need to train more of Australia's scientists to be entrepreneurs, or to develop their entrepreneurial skills and networks alongside their vast research skills. This will create a culture of seeking industry collaboration, turning ideas into new technologies and products, and truly capitalising on Australia's research commercialisation potential.

Drawing on the deep expertise of commercialisation experts within the STA membership, Science & Technology Australia has proposed a Bench-to-Boardroom training program to create Australia's first ***generation*** of bench-to-boardroom scientists. Many of these skills are transferable across STEM research disciplines, but there is scope for the program to include tailored content for quantum technologies.

Supporting the quantum ecosystem

The promise of quantum is real, but will require significant support to flourish. As with all new innovation and entrepreneurial success stories, there must be an understanding and acceptance of a rate of failure in the pursuit of large-scale commercial successes. Not all developments will come to fruition, and this insight must be embraced in investment plans.

Supporting the burgeoning quantum industry will also require a careful risk-based approach to security. Universities and research institutions have faced a significantly tightened regulatory environment over recent years, navigating a vast array of new legislation on national security, cyber security and foreign interference[1].

Universities and researchers take these security concerns very seriously and understand the importance of a robust approach to these issues. However, over-regulation and overlapping duplicative legislation designed with a 'catch-all' approach risk curtailing research collaborations and industry investment and development. The industry must be supported – and protected – by developing collaborative and targeted, risk-based solutions.

Transformative solutions come from diverse input. Australia must harness the full range of talent across the diverse STEM workforce. Funding programs and initiatives must include a focus on diversity, and be held accountable for diversity and inclusion at all levels of activity and leadership. The high risk involved with endeavours at the very frontier of knowledge traditionally presents barriers to women and culturally diverse researchers. Without such diversity by design, there is a grave risk the design of technologies will exclude and marginalise currently disadvantaged and under-represented groups. This risk must be proactively addressed through concerted and accountable effort to support diversity in quantum research schemes. This principle must be key to Australia's quantum strategy.

Responses to selected specific questions posed in the Issues Paper are included below. Please do not hesitate to contact us if we can assist as you consider the next steps in this process.

Yours faithfully,

Professor Mark Hutchinson
President, Science & Technology Australia

Misha Schubert
CEO, Science & Technology Australia

[1] These include the *Defence Trade Controls Act 2012* and the Defence and Strategic Goods List; the Sanctions Regime; the Blueprint for Critical Technologies; the University Foreign Interference Taskforce Guidelines to Counter Foreign Interference in the University Sector; the *Australia's Foreign Relations (State and Territory Arrangements) Act 2020;* the *Foreign Influence Transparency Scheme Act 2018;* the *Security Legislation Amendment (Critical Infrastructure) Act 2021* and *Security Legislation Amendment (Critical Infrastructure Protection) Act 2022*

Consultation Questions

Why Quantum Technologies and Why Now

1. What are the potential and realistic use cases of quantum technologies? What timescale do you expect to see these potential and realistic use cases?

Developing quantum technologies to reach full realisation of their potential will broadly follow three key steps. The first stage is developing a solid understanding of quantum technology and progressing the work already being done in the area of quantum sensing and communications.

This can then be applied to understand physical, chemical and environmental systems as well as human, animal and plant biology – enabling huge growth in the fundamental knowledge and understanding in these disciplines.

We can then progress to understanding the quantum realms where new quantum processes we have not yet realised are at play. This is a massive field that will only see progress if we have quantum literate and convergent science teams working on the quantum fundamentals, as well as discipline-specific fundamentals – and then the merged space between the two. This has the potential to improve understanding across the spectrum of disciplines – for example, within the biological and biomedical realm, there will be applications in understanding plants, pathogens and through to complex mammalian systems.

2. Are there other technologies, skills and industries that need to be developed in parallel with quantum technologies for the benefits of quantum technologies to be realised?

Australia will need to develop quantum literacy beyond – but also in tandem with – the field of fundamental quantum discovery science. Like with other industries, there will be both push and pull factors – without the requisite understanding and appreciation of quantum technologies, pull factors from industry will remain insufficient to drive the quantum push we are working to create and then sustain.

3. What conditions are needed for Australia to deliver world class quantum technology capabilities? What are Australia's competitive advantages compared to other countries and how can we capitalise these?

Australia will need to train our students and scientists to be able to take their ideas from the lab bench and into the boardroom – a cohort of scientists with deep expertise not only in quantum science and technologies but also the knowledge of how to connect and navigate the world of industry and commercialisation.

We need quantum experts who are industry-literate, and industry leaders who are quantum-literate. Importantly, these skills and expertise must be able to span multiple sectors – the range of potential quantum technology applications is vast, yet the Australian economy is unlikely to be large enough to support start-ups within niche industries.

Science & Technology Australia can play a pivotal role in training this skilled workforce. As the peak body for the nation's science and technology sectors, we have a uniquely deep reach into the worlds of both research and industry. Our membership includes start-up incubators and scientists based in industry as well as researchers with a strong successful track record of commercialising. This positions us to broker expertise, deliver commercialisation skills, transfer and draw on proven track records of strong commercialisation success from our own leadership, membership and networks.

With a proven record of delivering high-quality and bespoke training programs for the STEM sector, a quantum-focused 'Bench-to-Boardroom' training program that reaches across STEM disciplines and into industry would drive both the quantum push and pull to progress Australia's quantum industry.

4. What are the security risks associated with the development and adoption of quantum technologies?

As quantum technologies will have broad reach across many domains, there will be security considerations needed in some areas of research and technology. The dual-use attributes will need to be managed well, securing defence applications while enabling broader benefits. Australia's research sector has developed in maturity and sophistication in risk management and navigating complex areas relating to dual use technologies and national security.

Another consideration will be the ethical challenges that quantum research within some domains may pose, particularly in the areas of machine learning, artificial intelligence, and in the deployment of quantum technologies in defence and weapons applications. Cross-disciplinary work with social scientists will be essential to ensure ethical and moral frameworks are incorporated into quantum research and development.

Theme 1: Research and Development

5. What can Australia do to maintain and grow its quantum research capacity? Are there any specific barriers to undertaking quantum research?

As mentioned, the potential applications of quantum technology span the STEM sector, and multiple facets of society. We need specialist expertise, convergence across disciplines and broad quantum literacy that extends into industry and the professional sectors. We will also need to build on this through targeted work in the humanities and social sciences sectors – appreciating the impact of quantum technology within society will be key to its uptake, and future social licence for the quantum industry.

Policy initiatives such as the patent box, which was implemented for medical technologies and expanded in the most recent budget to include clean energy technologies and agricultural technology, are extremely valuable as incentives to support targeted industries.

6. How can Australia continue to strengthen international research and development partnerships in quantum technologies to utilise our talent and IP? How can our quantum research and industry contribute to deepening our partnerships with like minded countries?

As quantum technologies mature, the infrastructure needed for device fabrication scale is extremely expensive. Australia has to strategically partner with countries on translating ideas and IP into technology and products. In the early phases, investing in Australia-based fabrication facilities might not be realistic and require offshore short- and medium-term solutions. However, a long-term view should be taken to ensure sovereign capabilities will be supported.

8. How can the collaboration and engagement between industry and academia be improved?

Training a cohort of scientists with the skills to develop and commercialise their research will be critical, as will developing quantum literacy across STEM sectors and within industry.

Funding programs such as the recently announced Australia's Economic Accelerator will help progress research commercialisation and enhanced collaboration between academia and industry. The new Australian Research Council Industry Fellowships scheme will potentially improve connectivity and mobility between universities and industry partners.

Funding constraints, and grant duration often presents significant challenges to research and stymie progress. Extended grant terms of 5–7 years will be critical to develop sustained momentum. Longer grant terms allow researchers to plan more effective and comprehensive research programs, hire post-doctoral staff on longer and more secure contracts and take on the research students who will be the next generation of quantum leaders.

Theme 2: Investment, Commercialisation and Industry Growth

9. What is needed to support businesses to adopt and adapt to quantum technologies? How do we facilitate quantum small to medium enterprises (SMEs) to bridge the gap to commercial revenue?

Training both scientists to be industry-literate and industry to become quantum-literate will be essential.

11. What levers are required to increase investment into quantum technologies in Australia and support export of quantum technologies to like minded countries?

Improving quantum literacy across all sectors of the economy will progress investment and support exports of quantum technologies. Australia also needs to have an active presence on the world stage, through attendance and participation in international conferences.

Support to develop trial and demonstration sites will also be critical for engagement and improving understanding of potential applications, in both a domestic and international context.

Theme 3: Skills, Social Licence and Diversity

13. What areas does Australia have quantum skills in? What areas do we need more skills both now and in the future? How can Australia reskill established workforces for the quantum industry?

Targeted efforts to address a quantum skills shortage will need to be part of this comprehensive strategy, from undergraduate level through to post-PhD. Developing quantum proficiencies requires students to be equipped with a fundamental understanding of quantum physics. Reskilling programs through micro-credential and professional accreditations will also enable the industry to gain much needed quantum literacy.

Internships, such as those offered by the Pawsey Supercomputing Centre, enrich students with an understanding of potential quantum computing applications. These sorts of programs will be needed across the STEM sector, as quantum literacy will need to extend beyond single fields or applications.

14. How can Australia build social licence alongside developing quantum technologies?

These considerations call for Australia's quantum capabilities and industry to be developed with a multi-disciplinary approach, across both the STEM and HASS sectors, as well as building quantum literacy across industry and professional sectors.

15. How can Australia create an inclusive and diverse quantum ecosystem that is accessible and relevant to the Australian community?

Transformative solutions come from diverse input. Australia must harness the full range of talent across the diverse STEM workforce. Funding programs and initiatives must focus on diversity, and be held accountable for diversity and inclusion at all levels of activity and

leadership. The high risk involved with endeavours at the very frontier of knowledge traditionally presents barriers to women and culturally diverse researchers. These barriers must be proactively neutralised through concerted and accountable effort to support diversity in quantum research programs and schemes.

Creating a Shared Vision for Australia's Quantum Technology Ecosystem

18. What outcomes should Australia focus on in the next 5 years and why?

A key focus should be developing convergent and multidisciplinary teams, working across STEM disciplines to progress dual and multi-purpose quantum technology translation. Members of these teams must also be trained to develop a 'bench-to-boardroom' mindset to create a culture of collaboration with industry and commercialisation.