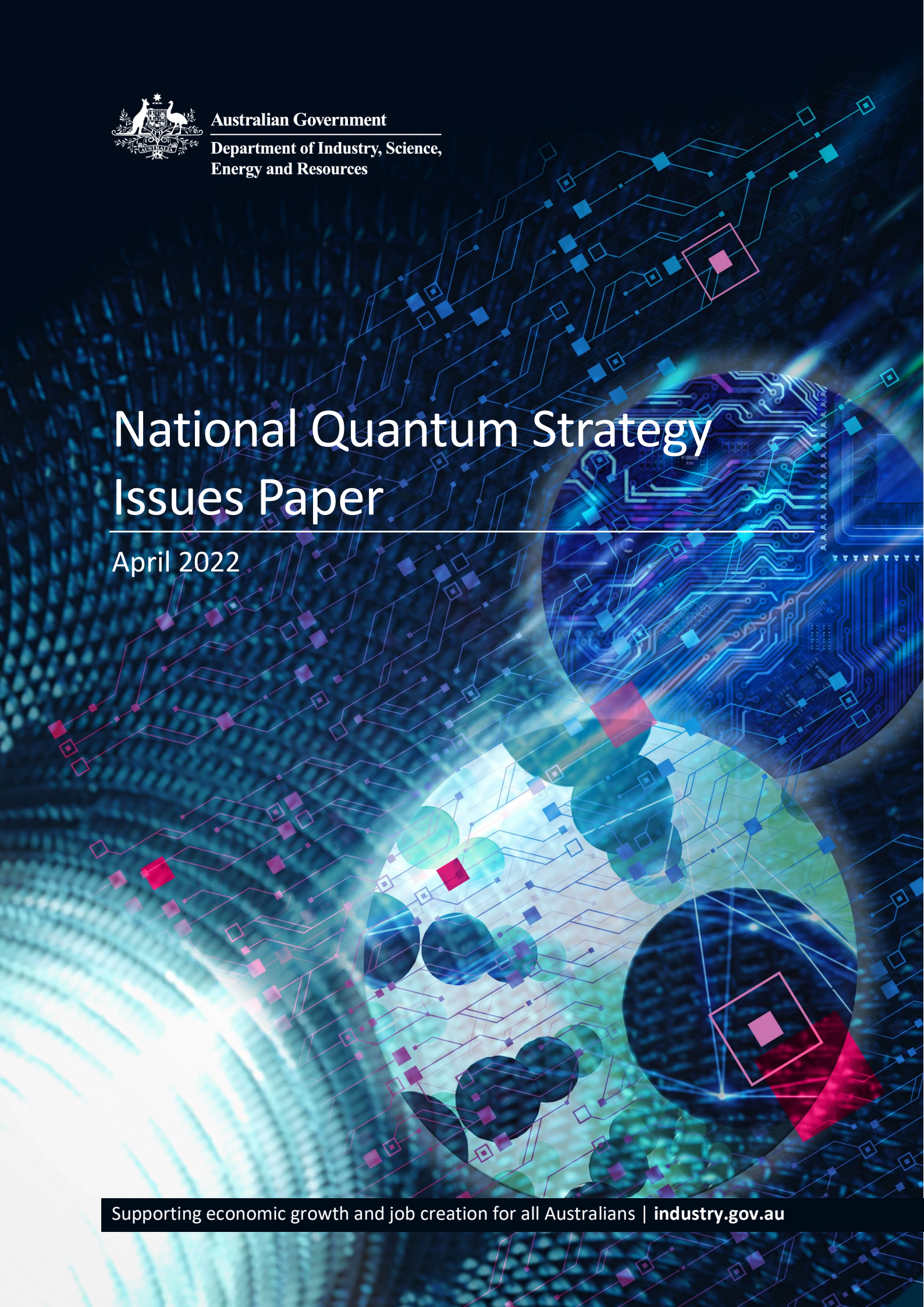

Australian Government
Department of Industry, Science, Energy and Resources

National Quantum Strategy Issues Paper

April 2022

Supporting economic growth and job creation for all Australians | **industry.gov.au**

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Ministerial Foreword

I am pleased to invite you to take part in shaping Australia's quantum future.

Quantum technologies will improve our lives in many ways, providing major advances in areas such as meteorology, healthcare, finance, energy and resources, and defence. In our day-to-day lives these technologies will help the more efficient movement of people and goods, with better supply chain management or traffic lights that adjust in real time to prevent traffic jams. By supporting extremely strong data encryption that is almost impossible to hack, quantum communication will keep our information safer and more secure. Quantum technologies can also improve health outcomes with more accurate imaging, more precise and effective medical treatment and more effective vaccines.

Globally, the quantum technology sector is forecasted to grow by 33 per cent over the next five years. By 2040, quantum technologies have the potential to generate $4 billion in revenue in Australia and create 16,000 jobs here.

Australia is well-positioned to seize the opportunities quantum technologies offer. We are globally renowned for our quantum research; our universities produce top talent that is highly sought after and Australia is home to world-leading quantum companies. To date, our expanding quantum industry has over 16 quantum-related companies which have attracted investments totalling over $405 million.[1]

The Morrison Government recognises that emerging technologies like quantum will become an increasingly important driver of success for all Australian businesses and sectors. For example, quantum computing was identified as one of five emerging technologies in the Government's $1.2 billion Digital Economy Strategy. Quantum was also identified in our Government's Action Plan for Critical Technologies as one of nine priority technology areas for initial focus.

[1] DISER analysis from publicly available data on disclosed investments and grants

As worldwide attention and investment in quantum technologies grows, the Coalition Government is acting to secure Australia's place in the quantum future. We are investing $111 million to develop a National Quantum Strategy, $70 million of which will fund a Quantum Commercialisation Hub to help Australian businesses access the support and infrastructure they need to grow, gain access to new markets and attract investment. The Hub will also allow businesses to leverage the benefits of strategic quantum partnerships that are being established with likeminded countries, fostering international cooperation and supply chains.

I welcome your views on how to best support the commercialisation, research, innovation, adoption and use of quantum to create jobs and support Australian businesses.

The Hon Melissa Price MP

Minister for Defence Industry
Minister for Science and Technology

Introduction

This Issues Paper marks the formal launch of the Australian Government's consultation on quantum technologies in Australia. Gathering diverse views from industry, academia, government and the broader community is critical for Australia to set a vision and plan to grow a sustainable and thriving quantum ecosystem in Australia.

By sharing your views, you will inform the Australian Government's development of a National Quantum Strategy, a Quantum Commercialisation Hub, international partnerships to facilitate cooperation with likeminded nations and other quantum-related initiatives. The development of the National Quantum Strategy will be guided by Australia's Chief Scientist as Chair of the National Committee on Quantum.

In particular, responses to this Issues Paper will assist the Australian Government to identify:

- the conditions needed for a thriving quantum industry;
- opportunities for growth;
- gaps in existing initiatives and programs;
- how these technologies can support greater social cohesion and inclusion;
- our areas of competitive advantage; and
- how collaboration can improve between parties involved in quantum.

To stay informed about our work on quantum technologies and contribute to other stages of our consultation, please subscribe to our mailing list.

What are Quantum Technologies?

Our current digital electronics are powered by transistors and we are reaching the physical limit of how efficient these components can be as they get smaller and smaller. Quantum technologies will take us beyond these limits by allowing us to control really tiny particles that behave in ways we could not control until now. Being able to control these different behaviours, for example how these particles interact, has a wealth of applications that will revolutionise computing, sensing and communications as well as a range of uses that we are still discovering.

Quantum technologies can be grouped into four broad categories:

- **Quantum sensing** will allow us to detect and map with extreme precision through barriers and at vast distances. For example, this will change our ability to map and understand the brain, the heart and other organs and transform the way we detect and diagnose disease at extremely small scales. It will also help find yet to be discovered mineral deposits.
- **Quantum communications** may enable the development of a robust quantum internet infrastructure, develop new cryptography methods to protect our information and advance our cybersecurity capabilities.
- **Quantum biology** will allow us to solve biological puzzles taking into account quantum mechanical effects at the sub-molecular level, for example to explain why DNA spontaneously mutates.
- **Quantum computers** are a type of computer that can perform certain kinds of operations that are impossible for classical computers. For example, quantum computers can simultaneously calculate by controlling the interaction of particles. By harnessing these capabilities, we will be able to better optimise transport routes and financial transactions, as well as support more precise modelling of molecules for drug development.

Why Quantum Technologies and Why Now

A strong and competitive quantum industry is in Australia's national interest as it will support our economic prosperity, national security and society. In order for Australia to deliver on these benefits, a coordinated and national approach that brings together government, industry, the research sector and the broader community is needed. This coordination will allow Australia to quickly build scale to ensure we are a world leader in quantum capabilities.

It is estimated that quantum technologies could deliver a significant windfall for Australia's economic prosperity by generating at least $4 billion in economic value and creating over 16,000 new jobs for Australia by 2040.

Quantum technologies are critical for Australia's security and defence capabilities. For example, quantum communications will provide opportunities to secure communications channels and quantum-enabled cryptography will complement existing cyber protections. Quantum sensors will allow unprecedented accuracy and sensitivity across all sectors. Quantum computing will allow access to unparalleled computing power important for all data intensive industries.

As other economies grow and expand their quantum footprint, it is crucial that Australia works closely with likeminded nations to ensure that quantum technologies are developed and shaped by those who share our liberal democratic values of openness and transparency. Doing so will ensure that Australia is able to make sovereign decisions about the development of the technology and its applications. Meanwhile, our participation in the global quantum ecosystem will need to come with appropriate security safeguards and export controls to ensure Australia maintains its national and economic security.

Based on conversations we have held to date with industry and academia, three broad themes have emerged and are proposed to be covered under the National Quantum Strategy:

1. Research and Development
2. Investment, Commercialisation and Industry Growth
3. Skills, Social Licence and Diversity

We welcome your views on:

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

Theme 1: Research and Development

Maintaining and growing our world class research and development capabilities

There are a series of quantum applications that are being commercialised at present. Quantum sensors are already being used in the mining sector and quantum random number generators are already available. For example, CSIRO's LandTEM system is being used in Australia's mining industry to detect mineral deposits deep underground, and has been responsible for the discovery of $6 billion of ore deposits globally. However, many of the more transformative applications are still embryonic and at the research phase.

Australia has been a leader in quantum research since the late 1990s, developing proof-of-concepts for key technologies and fostering a strong research community that has developed and attracted global talent. In recent years, the Australian Government has invested over $200 million in quantum technologies research.[2]

Australia's early investment in quantum research represents a competitive advantage. We have 22 quantum-related research institutions, with eight universities performing well-above the world standard in quantum physics research[3] and Australian research is cited 60 per cent more than the global average.[4]

The Australian Government remains committed to funding research and technology as demonstrated through ongoing funding to universities and to the CSIRO, which has a range of programs to encourage innovation and commercialisation.

The quantum community has told us that to capitalise on our research advantage, we should focus on:

- continuing to build on areas of quantum research excellence and global leadership so that we can grow our research capacity;
- ensuring universities attract and retain the best international quantum talent;
- making it easier for universities to collaborate with one another, likeminded countries and industry; and
- improving domestic and global collaboration between research and industry.

[2] This includes funding from the Australian Council of Research of $192 million for research into quantum physics (since 2005) including $65 million through centres of excellence:

a) $33.7 million over seven years for the ARC Centre of Excellence for Quantum Computation and Communication Technology
b) $31.9 million over seven years for the ARC Centre of Excellence for Engineered Quantum Systems

These figures do not include funding provided to universities and other publically funded research organisations and their contributions to quantum technologies research.

[3] Australian Research Council's State of Australian University Research 2018-19 and CSIRO's Growing Australia's Quantum Technology Industry

[4] Dhawan SM, et al. (2018) Global Publications Output in Quantum Computing Research: A Scientometric Assessment during 2007-16. Emerging Science Journal. DOI: 10.28991/esj-2018-01147

Case study: Woodside

Woodside is partnering with IBM via the Q Network, and leveraging local academic expertise at the University of Western Australia. The partnership is focussed on understanding the opportunities of quantum computing over the coming decade and preparing Woodside to realise these opportunities when the next generation of quantum computers are available. It is anticipated that these quantum computers will have the potential to model complex molecular properties beyond anything likely to be achieved by classical computing. Additionally, quantum machine learning and optimisation research is expected to play a role in Woodside's development of cleaner alternative sources of energy.

We welcome your views on:

5. What can Australia do to maintain and grow its quantum research capacity? Are there any specific barriers to undertaking quantum research?
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 likeminded countries?
7. Are there international quantum ecosystems that Australian should use as a benchmark? Are there international lessons that can inform Australia's quantum research and development?
8. How can the collaboration and engagement between industry and academia be improved?

Theme 2: Investment, Commercialisation and Industry Growth

Building a strong quantum ecosystem that maximises Australia's competitive advantage and supports our national interest

Quantum research is at a tipping point – rapidly moving from the conceptual realm into tangible, scalable use cases across a range of industries. For example, quantum sensors are being developed for fast accurate measurements in civil engineering, and the public transport and finance sectors are exploring the potential of quantum computing to optimise their services.

With targeted strategic investment, more commercial applications will continue to emerge. For Australia to capitalise on our established expertise in this area, we need to present a united and coordinated international presence – a cohesive Australian quantum industry. As the industry grows, it will also be important to put in place conditions that allow the industry to be sustainable, and continue to create jobs and economic growth.

The Australian Government is committed to supporting research commercialisation, including quantum technologies. The Australian Government announced its $2.2 billion University Research Commercialisation Action Plan to place university and industry collaboration front and centre of Australia's economic recovery. This Action Plan recognises that increasing research commercialisation is critical to our national interest. Elements of this investment supports the commercialisation of quantum technologies, for example:

- Main Sequence was created by CSIRO to improve commercialisation which has over $500 million through the CSIRO Innovation Fund and a recently announced $150 million capital injection to expand this program. To date, there has been significant investment in various Australian quantum companies including Quantum Brilliance, Q-CTRL and Quintessence Labs.
- $1.6 billion for Australia's Economic Accelerator – a new stage-gated competitive funding program to help university projects bridge the 'valley of death'.

The Australian Government is also looking at the Higher Education Research Commercialisation Intellectual Property Framework to better guide the efficient and effective management of intellectual property (IP) commercialisation. The standardisation will cut complexity and transaction times, make negotiations easier and promote best practice.[5]

[5] Higher Education Research Commercialisation IP Framework Consultation Paper, September 2021, p8

Early investment and commercialisation of quantum technologies will be critical to building a sustainable quantum ecosystem including a viable supply chain and full technology stack. To enable investment and commercialisation, possible focus areas include:

- developing and coordinating a national vision for Australia's quantum technology ecosystem to provide direction, focus and specialisation;
- removing barriers to investment in, development of and adoption of quantum technologies;
- finding suitable infrastructure for commercial quantum technology development in Australia;
- incentivising creation of shared infrastructure;
- communicating the broader benefits of quantum, including promoting use cases and customer education to create demand signals for quantum technologies, including by government being a first or early customer for certain quantum applications;
- identifying and establishing the conditions necessary to support a sustainable quantum technology ecosystem including supply chain considerations;
- connecting to and entering international and domestic quantum industry supply chains;
- continuing to build the pipeline of staff with high end quantum skills to attract overseas firms to establish a presence in Australia;
- attracting and retaining technical support capability to Australia;
- attracting investment in early stage companies, particularly long term, patient capital;
- commercialising research and freeing up university IP;
- encouraging greater movement between academia and industry by supporting academics to make the transition;
- facilitating quantum researchers and companies to form relationships with trusted global partners, for example, by leveraging existing government to government partnerships on technology collaboration;
- navigating regulations related to foreign investment and export of critical or dual use technology such as quantum technologies, given the importance of foreign direct investment and export markets for the growth of Australia's quantum industry;
- identifying Australian quantum applications and boosting demand for Australian made quantum technologies domestically and abroad;
- lowering barriers of entry for start-ups – this ranges from access to infrastructure to general business services;
- considering quantum standards; and
- using a holistic approach to create a full technology stack for quantum including quantum algorithms and software.

We welcome your views on:

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?
10. What is needed to support greater global partnerships and Australia's integration into global quantum supply chains? What are the specific regions or countries that pose an opportunity for Australia and what are those opportunities?
11. What levers are required to increase investment into quantum technologies in Australia and support export of quantum technologies to likeminded countries?
12. What infrastructure is available for quantum technologies in Australia? What infrastructure is needed and in what time horizon?

Case study: QuintessenceLabs

Most security applications use pseudorandom numbers to generate keys for encrypting data. Vulnerabilities and flaws can lead to leakage of information that makes pseudorandom number generator outputs predictable, resulting in security compromises. Quantum random number generators are a way to bolster security by generating truly random numbers using quantum physics.

Founded in 2008 in Canberra, QuintessenceLabs (QLabs) delivers powerful quantum enhanced data protection and cybersecurity solutions. QLabs' qStream™ is a quantum random number generator that generates random numbers to create keys that provide the strongest level of encryption. QLabs' TSF™ is an enterprise key manager that securely generates, distributes, and audits usage of key material, and enforces security policies related to cryptographic protection of information. QLabs' qOptica™ is a key distribution technology that utilises quantum effects to securely distribute key material over optical communications links.

NetDocuments has chosen to partner with QLabs to enhance the security of their cloud-based document and email management services for law firms. qStream generates key material and TSF manages the keys needed for securing and encrypting data. This replaces the reliance on pseudorandom numbers and ensures customers enjoy the strongest security to meet their regulatory and compliance needs. The partnership has helped NetDocuments scale up without compromising data security to its global customer base.

Theme 3: Skills, Social Licence and Diversity

Creating an environment to grow, attract and retain diverse talent and share the benefits of quantum technologies

Having a sustainable pipeline of quantum experts and a quantum-literate workforce is a crucial ingredient to building Australia's quantum ecosystem. While Australia has a strong research base to draw on, globally there is a sense of urgency for countries to advance quantum research. Competition for talent (from high-end research skills to quantum-literacy) is becoming fiercer each year. Australia must be able to effectively grow, attract and retain quantum-proficient talent in order to realise the commercial and national security enhancing possibilities of quantum technologies.

The Australian Government's $1.2 billion Digital Economy Strategy investment recognised that skills and inclusion are a vital part of the foundation for growing the digital economy and for keeping at the forefront of emerging technologies. As part of that investment there was $22.6 million for the Next Generation Emerging Technology Graduates Program which provides over 200 competitive national scholarships in emerging technologies including quantum computing. The Australian Government also recognises the importance of skill diversity and accessibility and has funded under the Digital Business Plan the www.skillfinder.com.au site, which is a micro skill marketplace with free short courses available for improving quantum literacy.

To ensure that the National Quantum Strategy addresses skills needs, social licence and diversity, possible focus areas for future policy development include:

- attracting and retaining quantum expertise within Australia, including via arrangements such as the Global Talent visa program;
- improve attraction of students into quantum related fields starting at secondary school level;
- identifying and addressing skills gaps;
- diversifying the industry with a mix of skills and backgrounds;
- identifying how quantum related fields can support regional and rural communities;
- attracting diverse students from universities and TAFE to become quantum-literate; and
- increasing awareness of quantum technologies and building social licence.

We welcome your views on:

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?
14. How can Australia build social licence alongside developing quantum technologies?
15. How can Australia create an inclusive and diverse quantum ecosystem that is accessible and relevant to the Australian community?

Creating a Shared Vision for Australia's Quantum Technology Ecosystem

With your help, we want to develop a shared vision for Australia's future quantum technology ecosystem that promotes Australia's economic and national security interests and which:

- supports our world-class research and its commercialisation;
- supports quantum small to medium enterprises to reach commercial success and revenue;
- creates quantum technology products and services which are of value to Australians;
- supports the growth of a sustainable quantum industry that positions Australia as a global leader in quantum technologies;
- fosters a culture of inclusion, diversity and positive social impacts;
- creates jobs for Australians;
- provides access to quantum capabilities that meet Australia's safety and security needs; and
- has the right skills to support the Australian quantum industry into the future.

Our measures of success will include:

- achieving $4 billion in economic value and 16,000 jobs for Australia by 2040;
- year-on-year increase in private investment, including foreign direct investment, into Australian quantum technologies and firms;
- year on year increase in commercialisation of Australian quantum research;
- the creation of new competitive Australian quantum technology firms;
- greater availability of skilled workers; and
- greater diversity and gender equity in the quantum technology sector.

We welcome your views on:

16. What else should be in the shared vision to capture Australia's quantum opportunities?
17. Are the three themes and measures of success appropriate? What other themes and/or measures should be included?
18. What outcomes should Australia focus on in the next 5 years and why?

How to Get Involved

We welcome your contribution as we map the current quantum technology landscape in Australia and create a future vision for Australia's quantum ecosystem. To stay informed about additional consultation opportunities on the Department's quantum work going forward: www.industry.gov.au/quantum.

Please provide submissions by **Friday 3 June 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?
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17. Are the three themes and measures of success appropriate? What other themes and/or measures should be included?
18. What outcomes should Australia focus on in the next 5 years and why?

We welcome your views on the National Quantum Strategy. If there are any other insights you want to share with us which is not covered by one of the above questions, please include them in your submission.