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QUANTUM COMPUTING FOR PUBLIC VALUE

Insights from Australia

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Table of Contents

Foreword 5

Introduction 6

Themes 8

Theme 1: Curiosity to learn more on leveraging quantum computing for public value. 8

Theme 2: Quantum computing is different than previous generations of computing advances.. 8

Theme 3: Government as the orchestrator of the quantum computing innovation ecosystem. 8

Theme 4: International strategic partnerships will have a significant impact on Australia's quantum computing capabilities. 9

Theme 5: The need to develop a quantum-ready workforce. 9

Theme 6: Developing Australia's sovereign quantum computing capability. 9

Recommendations for Realising Quantum Computing for Public Value 10

Recommendation 1: Outline the quantum computing possibilities and the ambition appetite. 10

Recommendation 2: Design platforms to orchestrate the quantum computing ecosystem to advance public value. 10

Recommendation 3: Leverage strategic international partnerships to accelerate and scale quantum computing discoveries and capabilities. 11

Recommendation 4: Invest in creating a public workforce that is quantum computing literate and skilled. 11

Recommendation 5: Establish an office to coordinate quantum computing initiatives across the public sector. 12

Recommendation 6: Publicise use cases on quantum computing in the public sector. 12

Recommendation 7: Identify risks and disruptions to digital systems across the public sector. 12

Conclusion 13

About The Authors 14

Key Contact Information 15

Recent Reports from the IBM Center for The Business of Government 16

Foreword

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On behalf of the IBM Center for The Business of Government, we are pleased to release this new report: *Quantum Computing for Public Value: Insights from Australia*, by Kevin C. Desouza of the Queensland University of Technology and Dr. Samar Fatima of RMIT University.

Quantum computing is evolving from the fantastical to the achievable. Accelerated developments show promise for leveraging quantum computing to address previously intractable problems in government. The technology can foster immense potential benefits for the public, alongside far-reaching implications from using quantum technologies are likely to be widespread. Developing "quantum-safe" capabilities is crucial to maintaining data security and integrity for critical applications. Government leaders face an urgent need to develop a quantum-safe strategy and roadmap.

A recent roundtable discussion with leaders from the Australian government informed this new report, outlining themes and recommendations for governments as they embark on the journey to quantum. Participants discussed major questions to help inform government decision making and design principles, including:

1. How are agencies planning for the adoption of quantum strategies?

2. How can agencies be "quantum safe" and address related protocols to address emerging government and regulatory standards?

3. What is the potential of Large Language Models (LLMs) for quantum computing?

4. What are best practice insights from other governments?

We hope that this report, which draws on insights from the roundtable and analysis by the authors, provides government leaders and stakeholders with a practical set of considerations and potential actions that enable them to capture benefits from quantum computing.

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Introduction

Advances in quantum computing will revolutionise how government tackles some of its most vexing challenges and spur new spaces for innovation. Simply put, quantum computing leverages quantum mechanics to solve problems classical computing find intractable due to their complexity. Today, applications of quantum computing can be found across a wide assortment of industries, from healthcare to transportation, finance, telecommunications, and defence.

However, the interest in quantum computing is not new. In 2016, over 3,400 individuals across academia and industry signed onto the Quantum Manifesto[1] calling for the European Union and its member states to invest €1 billion into research and development. The EU launched its Quantum Technologies Flagship[2] program in 2018, and all member states have signed onto the European Quantum Communication Infrastructure[3] (EuroQCI) Initiative since June 2019. In 2018, the United States of America passed the National Quantum Initiative Act[4] to coordinate the federal government's research and development efforts on quantum information sciences.

Quantum computing interest has increased due to its evolution from experimental initiatives in research labs to commercially viable applications and devices.[5] The potential of quantum to transform semiconductors and telecommunications equipment used for national security applications attracted the interest of policymakers.[6] Quantum's potential to decrypt public key cryptography has moved governments to prepare for post-quantum cryptography. The U.S. government passed the Quantum Computing Cybersecurity Preparedness Act to migrate government information systems to quantum enabled cryptographic platforms.[7] Competition to attract quantum investment is fierce among countries. A host of nations have developed national-level quantum computing strategies (see Table 1 on page 13).

1. European Commission (2016) Quantum Manifesto. http://www.qtflagship.cnr.it/wp-content/uploads/2016/10/Quantum-Manifesto.pdf.
2. European Commission (2018) Quantum Flagship. https://qt.eu/about-quantum-flagship/.
3. European Commission (2023). The European Quantum Communication Infrastructure (EuroQCI). https://digital-strategy.ec.europa.eu/en/policies/european-quantum-communication-infrastructure-euroqci.
4. The U.S. Government Publishing Office (2018) National Quantum Initiative Act. https://www.congress.gov/bill/115th-congress/house-bill/6227/text.
5. Shivakumar, S., C. Wessner, T. Howell, "Quantum Can't Be Business as Usual: Issues for the Reauthorization of the National Quantum Initiative Act," Center for Strategic and International Studies, August 2023. https://www.csis.org/analysis/quantum-cant-be-business-usual-issues-reauthorization-national-quantum-initiative-act.
6. Messmer, M., J. Shires, A. van Rij, "Quantum technology competition must not become an arms race," *The World Today,* October & November 2023 Issue. https://www.chathamhouse.org/publications/the-world-today/2023-10/quantum-technology-competition-must-not-become-arms-race.
7. The U.S. Government Publishing Office (2018) National Quantum Initiative Act. https://www.congress.gov/bill/115th-congress/house-bill/6227/text.

> I describe Australia as 'quantum's early bird.' This is a reference to the depth of Australian investment and expertise in quantum. We've been at it a long time. We invested early—largely because our researchers and public funding bodies recognised the promise of quantum, and the physicists were organised and had strong leadership.
>
> —*Dr Cathy Foley AO PSM, Australia's Chief Scientist, from remarks at the Quantum World Congress in Washington, D.C., on 30 November 2022*[8]

Australia has an enviable position in the quantum computing race given its legacy of investments and research and development successes. Building on this momentum, the time is ripe for the Australian government to outline the possibilities for leveraging quantum computing to enhance the delivery of public services, bolster national security, and enhance public value.

Australia's National Quantum Strategy[9] launched earlier this year, and lays out the nation's ambition: "In 2030, Australia is recognised as a leader of the global quantum industry, and quantum technologies are integral to a prosperous, fair and inclusive Australia." The Australian National Quantum Strategy is built around five themes, which cover 1) research and development into the design, development, and use of quantum technologies, 2) securing access to quantum infrastructure and materials, 3) upskilling and developing a quantum ready workforce, 4) participating in development of global standards and ensuring a responsible regulatory framework, and 5) ensuring that the quantum ecosystem is trustworthy, ethical, and inclusive.

The IBM Center for The Business of Government hosted a roundtable workshop with senior executives across the Australian public sector to ascertain perceptions on the affordances on deploying quantum computing to create public value on 10 October 2023.

8. Foley, Dr. Cathy, AO PSM, Australia's Chief Scientist, remarks at the Quantum World Congress in Washington, D.C., on 30 November 2022. https://www.chiefscientist.gov.au/news-and-media/australia-quantums-early-bird.
9. Australian Government (2023) National Quantum Strategy. https://www.industry.gov.au/sites/default/files/2023-05/national-quantum-strategy.pdf.

Themes

The discussion on quantum computing affordances for the public sector was wide-ranging. There was a robust exchange of ideas on how public agencies should engage with quantum computing innovations. Governance and policy considerations to support responsible innovation on quantum computing were also explored.

Theme 1: Curiosity to learn more on leveraging quantum computing for public value.

There is a high level of curiosity when it comes to quantum computing affordances for innovation in the public sector. Tempering this curiosity is the need to raise the general awareness on what is quantum computing and how is it a paradigm shift from classical computing. Moreover, in the near and medium term, quantum computing will not replace classical computing. Hence, there is also a need to understand how public agencies can leverage and incorporate quantum computing with traditional computing solutions.

Theme 2: Quantum computing is different than previous generations of computing advances.

Technically speaking, quantum computing is markedly different than classical computing. However, when it comes to management and governance around how it will be designed, developed, and deployed, we should not expect much difference to how public agencies leveraged previous generations of computing advances. There will still be a need to identify a clear business case that centres on how the technology advances public value and national interest, enhances the delivery of public services, and improves the lives of citizens. The public sector needs to learn from experiences with recent computing innovations (e.g., cognitive computing systems) and be more proactive in getting ahead when it comes to uncovering policy puzzles (e.g., ethical and security considerations) that will need to be addressed.

Theme 3: Government as the orchestrator of the quantum computing innovation ecosystem.

The public sector's role is to orchestrate a thriving quantum computing innovation ecosystem. The private sector, both the major technology players and the start-up communities, will play a critical role in helping the nation in developing its quantum capabilities. Universities and research institutions will need to be supported to ensure that they are hotbeds for discoveries and experimentation. The launch of the National Quantum Strategy is a good first step to coalesce the major stakeholders on key national priorities. However, this will need to be followed up with more tactical and operational initiatives.

Theme 4: International strategic partnerships will have a significant impact on Australia's quantum computing capabilities.

Australia is party to several international alliances, including AUKUS (trilateral security partnership among Australia, the United Kingdom, and the United States of America), QUAD (diplomatic partnership among Australia, India, Japan, and the United States), and Five Eyes (FVEY) (intelligence and national security alliance among Australia, New Zealand, Canada, the United Kingdom, and the United States of America), among others. These strategic partnerships offer interesting opportunities and challenges when it comes to Australia's development and deployment of quantum computing capabilities. The AUKUS Quantum Arrangement (AQuA), launched in April 2022, incentivises collaborative experimentation on emerging quantum technologies. Similarly, the QUAD partnership has committed to accelerate investments and capability development. There are also several bilateral partnerships. For instance, Australia and the United Kingdom announced a partnership on 3 November 2023, focused on advancing cooperation on quantum computing, which includes investments into the private sector and research partnerships.[10] While strategic international alliances foster innovation and scaling quantum capabilities, they also bring along a set of challenges. Navigating these challenges will be critical. For instance, the development of standards on quantum computing—and who or what sets of nations will lead on this effort—remains unclear.

Theme 5: The need to develop a quantum-ready workforce.

Developing a quantum-ready workforce will be a critical facing all nations. Some of the pioneering research on quantum computing has come out of Australia.[11] However, this has not yet translated into creating a workforce that is ready for the quantum age. While there are pockets of excellence in education programs on quantum computing, a more systematic approach is needed. It is not sufficient to rely just on the tertiary education sector to develop the nation's quantum talent.

Theme 6: Developing Australia's sovereign quantum computing capability.

Australia will need to ensure that it secures its sovereign computing capability. Doing so will require an understanding of the competitive landscape on quantum computing. Ensuring access to critical resources needed to power quantum computing will be vital. A thorough examination of current dependencies that exist in the multitude of global supply chains that support the quantum computing ecosystem should drive national-level responsible innovation policies. Consider for example, the issue of human capital. While Australia should invest in developing and nurturing homegrown quantum talent, this will not be enough to meet future demands. As such, how to modernise programs around attracting overseas talent, which is a supply chain issue, will need to be revisited.

10. Minister for Industry and Science Ed Husic and UK Secretary of State for Science, Innovation and Technology Rt Hon Michelle Donelan 3rd November 2023. https://www.minister.industry.gov.au/ministers/husic/media-releases/australia-and-uk-sign-quantum-joint-statement.
11. Australia's Chief Scientist, "Australia: Quantum's early bird," November 2023. https://www.chiefscientist.gov.au/news-and-media/australia-quantums-early-bird.

Recommendations for Realising Quantum Computing for Public Value

Below are a set of recommendations that were inspired by the workshop and independent research by the authors of the report.

Recommendation 1: Outline the quantum computing possibilities and the ambition appetite.

Outlining the possibilities for quantum computing applications across the public sector is critical to be able to set out a digital transformation roadmap. This will enable the public sector to be clear on what its ambition appetite is when it comes to near-, medium-, and long-term engagement with quantum computing. Outlining the quantum computing strategy for the Australian public sector, akin to what the National Quantum Strategy is for the nation, will be a worthwhile exercise.

Recommendation 2: Design platforms to orchestrate the quantum computing ecosystem to advance public value.

The Australian government has already begun to put in place platforms to bring together various stakeholders on quantum computing. For example, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia's national science agency, has launched the Quantum Technologies Future Science Platform, to work with industry partners to identify opportunities for designing and developing quantum computing solutions that leverage Australia's research leadership in this space.[12] While these efforts are laudable, they are not sufficient. It will be critical to launch platforms that can focus the quantum computing ecosystem on digital transformation opportunities across the public sector. Agencies can use such platforms to crowdsource problems and opportunities, collaborate on pilot projects and testing of protypes, and even realise economies of scale when implementing solutions.

12. CSIRO, "CSIRO's Quantum Technologies Future Science Platform." Accessed November 2023. https://research.csiro.au/qt/.

Recommendation 3: Leverage strategic international partnerships to accelerate and scale quantum computing discoveries and capabilities.

As noted earlier, Australia is a member of several international strategic networks from AUKUS to QUAD, and FVEY, among others. The Australian government should leverage these partnerships to accelerate research and development on quantum computing. In addition, these partnerships enable the Australian public sector to work with their counterparts in other countries to learn from existing use cases where quantum computing applications have been deployed to drive innovations within the public sector. The Australian public sector should provide significant input into the development of international standards, protocols, and policies to ensure interoperable and networked quantum computing systems. For example, Quantum Key Distribution (QKD) is a communication channel based on a cryptographic protocol that exchanges keys between known parties and notifies if a third party intervenes. It offers protection against public key cryptography that can be decrypted in the future for today's data. A universal standard to access quantum key distribution across national agencies (QKD) will likely protect against unauthorised access and misuse of today's data.

Recommendation 4: Invest in creating a public workforce that is quantum computing literate and skilled.

A dedicated investment strategy is required to prepare the workforce, in general, and those who work in the public sector, in particular, for quantum computing. Introduction of quantum mechanics needs to occur from primary school, through to senior secondary school and then to tertiary education. The underlying principles and awareness of quantum mechanics can infiltrate most STEM (Science, Technology, Engineering, and Mathematics) courses. It is important not just to think about quantum computing as learning a new technology. Quantum computing is about new mechanisms to solve problems and think creatively about opportunities for innovation. Even those who are not directly involved in the design or implementation of quantum systems can gain from an understanding of quantum mechanics to create innovations in other domains. Within the public sector, initiatives that support both the upskilling of personnel to be quantum computing literate at the minimum and advanced training must be developed and promoted. Rotational assignments (or secondments) that enable public sector personnel to learn from, and even participate with industry and academia on quantum computing initiatives, should be promoted. Similarly, pathways to draw quantum computing expertise into public agencies for specialised assignments or sabbaticals from academia and industry should be designed.

Recommendation 5: Establish an office to coordinate quantum computing initiatives across the public sector.

The Australian public sector will be well-served to create a dedicated office that can catalyse and coordinate quantum computing initiatives across the public sector. The U.S. government's National Quantum Coordination Office (NQCO) can serve as a model when creating this office. The NQCO was established to 1) provide administrative and technical support to the various committees (e.g., The National Quantum Initiative Advisory Committee and Subcommittee on Quantum Information Science) setup as part of the National Quantum Initiative (NQI) Act, 2) coordinate interagency national quantum initiative programs, 3) be the point of contact for information on federal quantum computing programs, 4) provide coordination across various quantum centres and consortia, 5) undertake public outreach, and 6) be the conduit for early discoveries and applications that arise from NQI initiatives.[13] Quantum computing, much like what we are seeing today with the scaling of AI across the public sector, is best served by a coordinated approach.

Recommendation 6: Publicise use cases on quantum computing in the public sector.

Use cases that capture pilot projects and even full-scale implementation of quantum computing in the public sector should be captured and disseminated. This will ensure that there is awareness on quantum computing initiative and inspire curiosity on other possibilities. Use cases can also be collected from counterpart agencies from international partners. Given that governments are in the early days of quantum computing applications at scale, it is also important to find use cases that outline how quantum computing can be used in conjunction with classical computing. Sharing of use cases is also valuable to encourage the broader ecosystem to engage with quantum computing opportunities in the public sector.

Recommendation 7: Identify risks and disruptions to digital systems across the public sector.

While quantum computing is likely to be a force for responsible innovation across the public sector, it does bring with it a novel set of risks and potential disruptions to digital systems. Public agencies cannot wait for quantum computing to mature before they plan for risks and disruption. Identifying how sensitive data that uses current methods of cryptography should be migrated is an important issue. For instance, the U.S. Quantum Computing Cybersecurity Preparedness Act requires federal agencies "to develop a plan, including interim benchmarks, to migrate information technology of the agency to post-quantum cryptography."[14] Understanding the maturity cycles for various quantum computing applications will be critical to uncovering risks and potential disruptions. Applications such as atomic clocks for Global Positioning System (GPS) navigation and nuclear spin control magnetic resonance imaging (MRI) are mature already.[15]

13. The National Quantum Coordination Office of the United States. Accessed November 2023. https://www.quantum.gov/nqco/#THE-NATIONAL-QUANTUM-COORDINATION-OFFICE.
14. The U.S. Government Publishing Office (2022) Quantum Computing Cybersecurity Preparedness Act. https://www.govinfo.gov/content/pkg/BILLS-117hr7535eh/html/BILLS-117hr7535eh.htm.
15. Executive Office of the President of the United States. Bringing Quantum Sensors to Fruition (2022). https://www.quantum.gov/wp-content/uploads/2022/03/BringingQuantumSensorstoFruition.pdf.

Conclusion

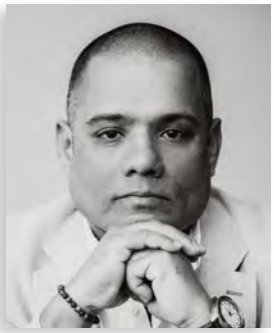
Australia's sovereign capability in quantum computing will add $6.1 billion to Australia's GDP and 35,000 jobs in the next 22 to 25 years.[16] We are in the early days of quantum computing at scale across the public sector. But, if we have learnt anything from how dramatically things changed with deploying machine learning systems across the public sector over the past five years, we know we do not have long to wait before quantum computing systems mature and begin to permeate the public sector. The time for engagement with quantum computing is now. The public sector should at the minimum raise awareness of what quantum computing is—as well as the affordances it provides to tackle some of our most vexing challenges. Additionally, the public sector should identify areas that are ripe for experimental quantum computing initiatives.

Table 1: National-Level Quantum Computing Strategies, Roadmaps, and Frameworks

Country	Document	Year Released
Australia	National Quantum Strategy	2023
Canada	Canada's National Quantum Strategy	2022
China	Quantum Technology in Five-Year Plans	2021
Denmark	Strategy for Quantum Technology - Part 1	2023
Finland	National Quantum Agenda	2022
France	National Strategy for Quantum Technologies	2021
Germany	Action Plan—Quantum Technologies	2023
Hungary	National Quantum Technology Program	2023
India	National Mission on Quantum Technologies & Applications	2020
Israel	National Program for Quantum Science and Technology	2019
Japan	Quantum Technology Innovation Strategy	2020
Netherlands	National Agenda for Quantum Technology	2019
New Zealand	The Quantum Technologies Research Programme	2023
Russia	Quantum Technologies Roadmap	2019
Singapore	National Quantum Strategy	2022
South Korea	National Strategic Plan for Quantum Science and Technology	2021

16. Australian Government (2023) National Quantum Strategy. https://www.industry.gov.au/sites/default/files/2023-05/national-quantum-strategy.pdf.

About The Authors



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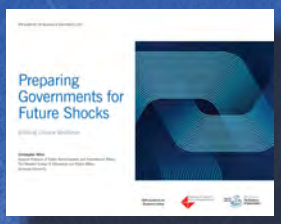

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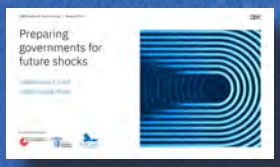

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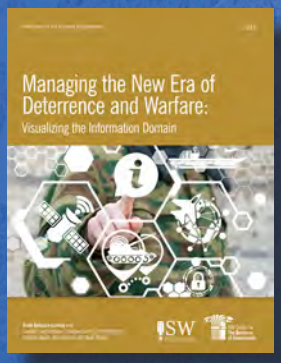

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