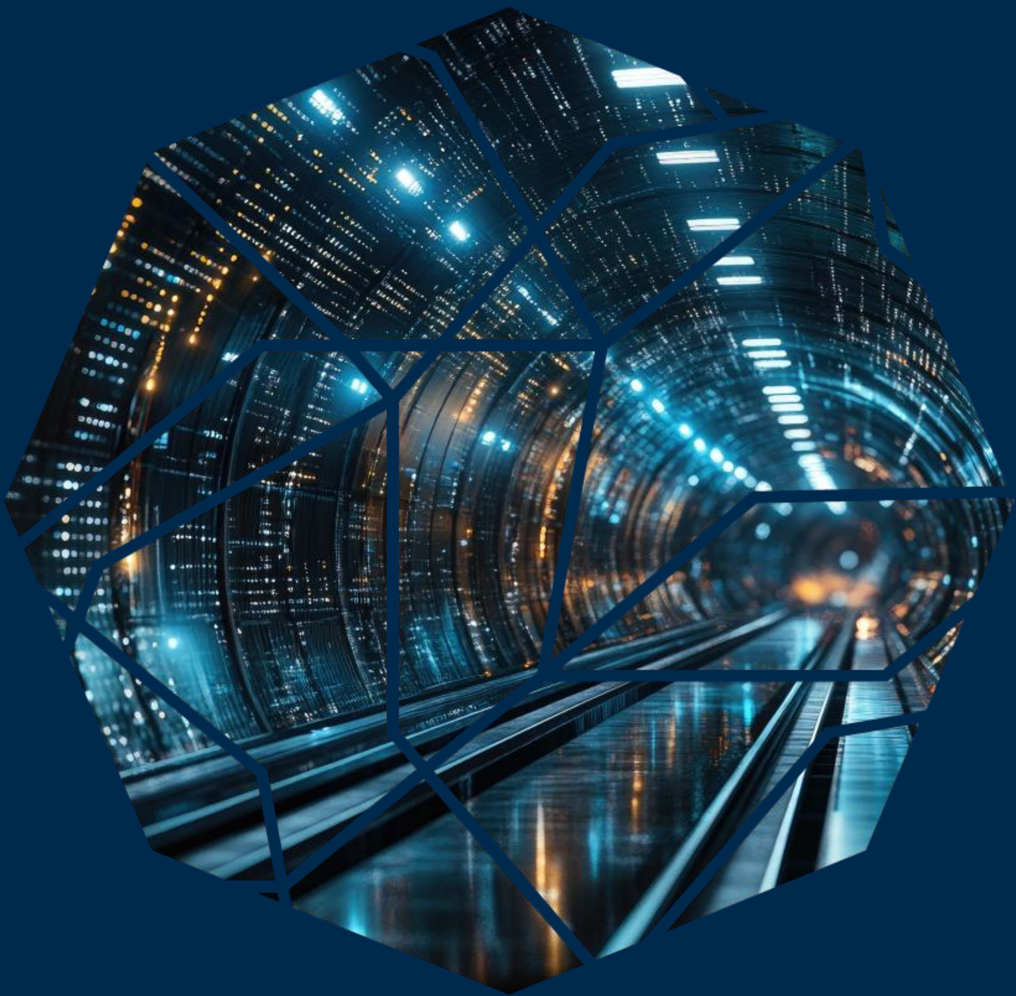
Australian Government
Office of the Chief Scientist



Quantum Meets Communications Workshop Summary

A workshop led by Australia’s Chief Scientist
in partnership with the CSIRO

CSIRO

Acknowledgement of Country

The Office of the Chief Scientist acknowledges the traditional owners of the country throughout Australia and their continuing connection to land, sea and community. We pay our respect to them and their cultures and to their elders past and present.

Artwork: Connection to Country, 2021 by Shaenice Allan

Meeting Place icon by DISR employee Amy Huggins

Microsoft Co-Pilot was used in developing this summary.

Workshop overview

Quantum Meets Communications was an in-person workshop led by Australia's Chief Scientist in partnership with the CSIRO. The workshop took place at ANU Research School of Physics in Canberra on 22 November 2024. Approximately 100 people attended, including representatives from the communications sector, quantum technology companies, universities and government.

The workshop explored the challenges facing Australia's communications sector. One of the primary issues discussed was the sheer size and complexity of the communications network, given Australia's vast landmass and relatively low population density. This results in a complex network of connectivity that requires effective use of telemetry data and constant adjustments to maintain a healthy, secure and operational system. The sector also faces the challenge of managing a constantly evolving system, likened to a natural organism, which requires continuous monitoring and adaptation. Through a series of panels and breakout groups, attendees explored these challenges and the potential of quantum technologies to enhance the efficiency, security and reliability of communication systems in Australia.

Scene setting

Australia's Chief Scientist, Dr Cathy Foley, set the scene for the workshop by highlighting the significant progress made in Australia's quantum ecosystem over the past two years. She discussed the potential of quantum technologies for sensors, communications and computing. Dr Foley emphasised the importance of the Australian quantum software network (AQSN) and the recent release of the National Institute of Standards and Technology Post-Quantum Cryptography standards in August 2024. She also touched on the potential applications of quantum technology in increasing security, improving performance, system optimisation and clock synchronisation. Dr Foley introduced the wide range of applications that quantum technologies could impact in the communications industry sector. These included improved earth observation, super broadband antennas, high frequency receivers, 6G communications, quantum sensors for satellite control to enable high speed connectivity, and quantum communication networks such as those piloted in China and USA. She touched on plans for a satellite demonstration, planned for 2026, of quantum entanglement swapping in space, an advance that could lead to a global quantum internet. As a result, quantum networking used in space industries could revolutionise climate science, navigation and encrypted communications by improving data processing and sensor precision. She also considered the role of quantum for cyber security, position navigation and timing (PNT).

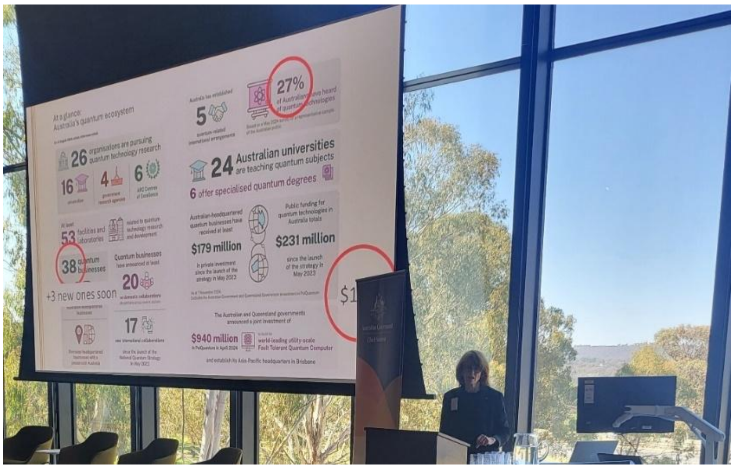


Image 1. Dr Foley speaking at Quantum Meets Communications workshop

Areas of industry impact

Network performance and reliability

Quantum computers could improve network operational efficiencies by monitoring large amounts of variables and freeing up resources. The unique ability of quantum algorithms to consider many combinations simultaneously could be more efficient in solving certain problems where real-time solutions or small increases in efficiency are hugely impactful.

Enhanced Security

Quantum communication technologies, such as quantum key distribution (QKD), offer theoretically tamper-proof communication networks. These networks could detect any interception or eavesdropping attempts, ensuring highly secure data transmission.

Optimisation through enhanced machine learning

Quantum enhanced machine learning could help solve complex combinatorial problems in communication networks, such as optimising spectrum usage by devices or finding the optimum antenna angle that minimises interference and maximises transmission. For example, quantum algorithms could potentially reduce the energy consumption of data centres by optimising data processing and storage operations.

Quantum machine learning examples

A quantum neural network is a type of artificial neural network that leverages the principles of quantum mechanics to enhance its computational capabilities and potentially more efficient learning algorithms. This could be used to develop advanced machine learning applications, such as pattern recognition, optimisation problems, and complex data analysis.

Program schedule

Setting the scene

- Dr Cathy Foley, Australia's Chief Scientist

Keynotes – sector challenges and quantum opportunities

- Professor Michelle Simmons, Founder and CEO of Silicon Quantum Computing (SQC), Director of the Centre of Excellence for Quantum Computation and Communication Technology, Scientia Professor of Quantum Physics in the Faculty of Science at the University of New South Wales
- Mr Sandy Cameron, CEO of Quantium Telstra
- Dr Vikram Sharma, Founder and CEO of QuintessenceLabs
- Ms Connie McIntosh, Head of Security at Ericsson
- Dr Marcus Doherty, co-founder and the Chief Scientific Officer of Quantum Brilliance

Panel 1 – Securing Communications

Chair: Dr David Liebowitz, Principal Technologist at Penten

- Dr Stephen Gensemer, Team Leader in Space Optics at the CSIRO
- Dr Andrew Lance, Senior Research Fellow at the University of Western Australia
- Dr Rajiv Shah, Managing Director of MDR Security
- Ms Jocelinn Kang, Program Manager and Technical Specialist at the Australian Strategic Policy Institute

Panel 2 – Quantum Computing Impact for Communications

Chair: Dr Rose Ahlefeldt, Senior Research Fellow at ANU

- Associate Professor Jacquiline Romero, Associate Professor at the University of Queensland
- Professor Udaya Parampalli, Professor in the School of Computing and Information Systems at the University of Melbourne
- Mr Sean Rinas, Head of Network Operations at NextDC
- Associate Professor Eryn Newman, Associate Professor at the ANU and Honorary Fellow at the University of Southern California

Panel 3 – Future of Mobile Communications

Chair: Mr Mike Baylis, Manager of the Quantum Policy team in the Department of Industry, Science and Resources

- Dr Howard D'Costa, Assistant Director and Space Communications Lead at the Australian Space Agency
- Associate Professor Matt Sellars, Senior Research Fellow at the ANU and at the Centre for Quantum Computation and Communication Technology.
- Industry Professor Mike Boers, Founder and Chief Technical Officer of Atto Devices

- Dr David Skellern, Chair of: Quasar Satellite Technologies Pty Ltd, Semiconductor Sector Service Bureau (S3B), Australian Innovation eXchange Pty Ltd (AIX) and The International Centre for Radio Astronomy Research (ICRAR). A Director of: Trovio Pte Ltd, METS Ignited Limited and digi.cash Pty Ltd.

Breakout sessions

- Four breakout sessions explored communication sector challenges where there could be applications for quantum technology

Overview of government funding opportunities

- Mr Mike Baylis, Manager of the Quantum Policy team in the Department of Industry, Science and Resources

Next steps and closing statement

- Dr Cathy Foley, Australia's Chief Scientist

Keynotes

Professor Michelle Simmons, founder and CEO of SQC, delivered a keynote speech highlighting the advancements and strategic direction of SQC in the communications sector. SQC's strategy is to create a fully integrated chip (qubit) using only two elements, phosphorus and silicon. Professor Simmons emphasised SQC's made-in-Australia solution, leveraging local advantages and open access to hardware, with Telstra as a key customer. Professor Simmons discussed the high efficiency of running Grover's Algorithm on a multi-qubit processor, which allows for scalable quantum computing. Real-world applications and trials of quantum-enhanced machine learning processors by companies like CommBank, Telstra and Transport for NSW were also mentioned. Professor Simmons highlighted the development of quantum-enhanced machine learning for applications such as scam and fraud detection, and analogue quantum simulators for drug design and battery optimisation. Professor Simmons concluded her speech by discussing the broader implications of quantum technology in telecommunications, optimisation, data analytics, AI, encryption and database searching.

The keynote speech by Sandy Cameron, CEO of Quantium Telstra and board member of SQC, highlighted the collaboration between Telstra and SQC to leverage quantum technology for network anomaly detection and operational efficiency. Mr Cameron emphasised the unique capabilities of SQC in manufacturing with atomic precision, which allowed for rapid prototyping and innovation. Mr Cameron also talked about the challenges of managing Australia's vast and complex network, underscoring the importance of using telemetry data effectively. He described the Quantum Feature Generator that could enhance operational efficiencies and potentially enable quicker identification of network anomalies. Mr Cameron concluded by expressing optimism about the future of quantum technology in communications, noting current capabilities and the need for industry partnerships to capture value for Australia.

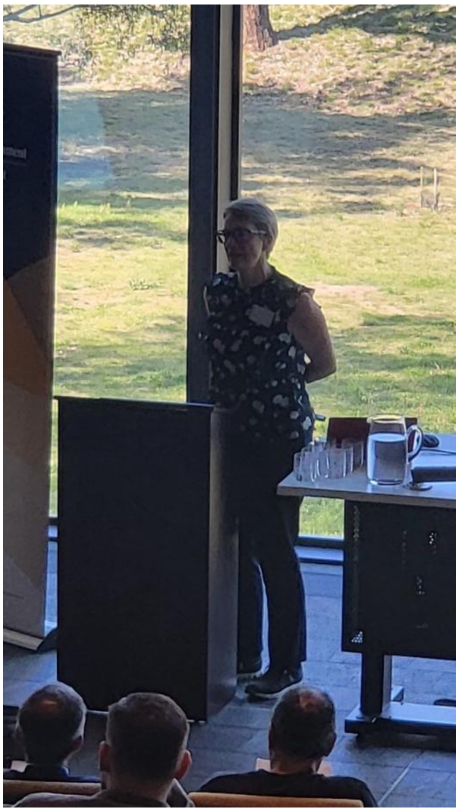


Image 2. Professor Michelle Simmons

Dr Vikram Sharma, Founder and CEO of QuintessenceLabs spoke about the pervasive impact of quantum technology in our lives, such as in MRI, GPS and semiconductors. He emphasised Australia's world-class research and the imminent second quantum revolution, which promises to transform various sectors including sensing, metrology, computing, communication and cybersecurity. Dr Sharma warned that current cryptographic systems would be vulnerable to capable quantum computers, urging the need for quantum-resilient security approaches. He outlined four key elements to address these security needs: true random number generators, enterprise key management at scale, quantum-resistant algorithms and quantum-secure communication links.

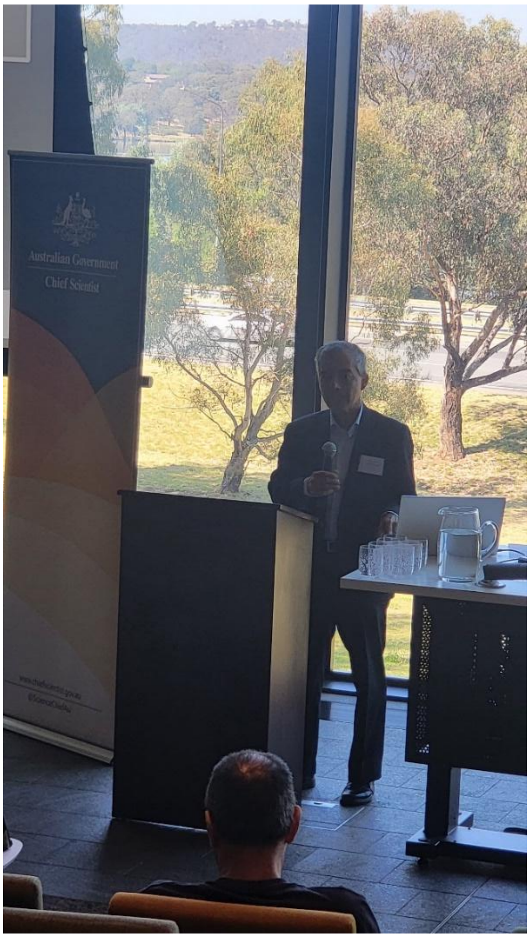


Image 3. Dr Vikram Sharma

Dr Marcus Doherty, co-founder and Chief Scientific Officer of Quantum Brilliance, presented on the diverse applications of diamond technology, emphasising the unique position of Quantum Brilliance's technology in the quantum technology landscape. He discussed the scalability and depth of the industry, ranging from universities to large corporations, and the mass deployability of diamond-based sensors and devices. Dr Doherty noted that diamond technology operates at room temperature and is already being used in pre-production products, including medical devices and quantum computers. He mentioned that Quantum Brilliance planned to deliver a cluster of quantum computers to explore hybrid and parallel computing. Australian companies and research organisations were also making significant strides in diamond quantum technology, aiming to enter manufacturing. Dr Doherty provided examples of diamond quantum applications, such as navigation without GPS, efficient high-performance AI and compact Very low frequency (VLF) communications. He concluded by highlighting the potential of diamond quantum radio receivers for future communication networks and the ongoing development of diamond quantum technologies across various sectors.

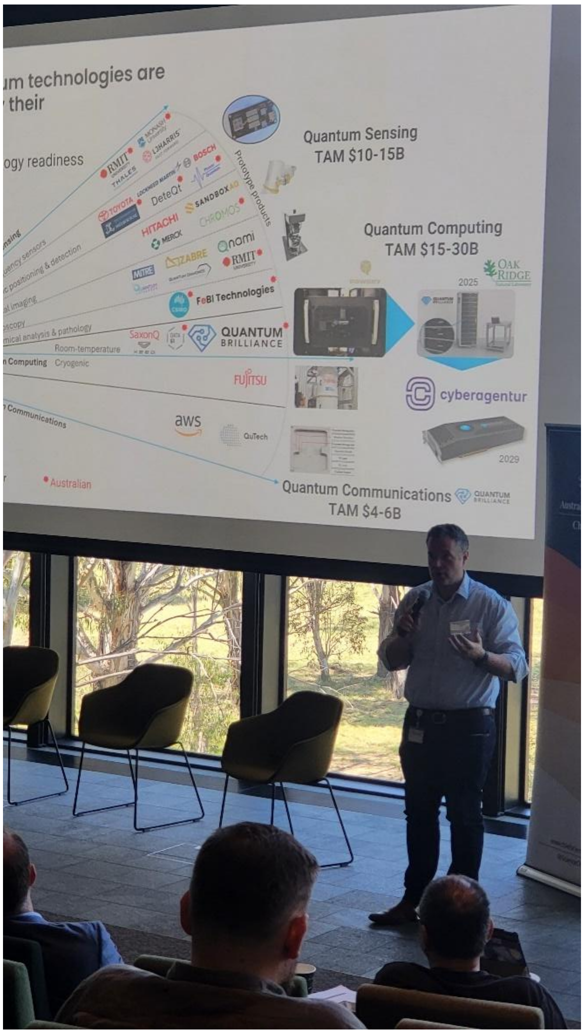


Image 4. Dr Marcus Doherty

Ms Connie McIntosh, Head of Security at Ericsson, delivered a keynote speech focusing on the integration of quantum computing in telecommunications. She highlighted the creation of Ericsson's Quantum Program aimed at achieving limitless connectivity to improve lives. Ms McIntosh discussed the potential of quantum computing as part of mobile network accelerators and emphasised the need for flexible and specialised hardware. She explained the concept of a hybrid classical-quantum data centre and presented a 5G quantum AI use case for antenna tilting, which enhances network quality. Ms McIntosh also stressed the importance of balancing the integration of quantum technology with cost-efficiency for consumers. She mentioned Ericsson's active role in quantum standards and post-quantum cryptography, collaborating with academic and private partners. She concluded her speech with a focus on the future of telecom as a hybrid system, the necessity of low latency for critical infrastructure, and the importance of government and regulatory support for advancing quantum technology.

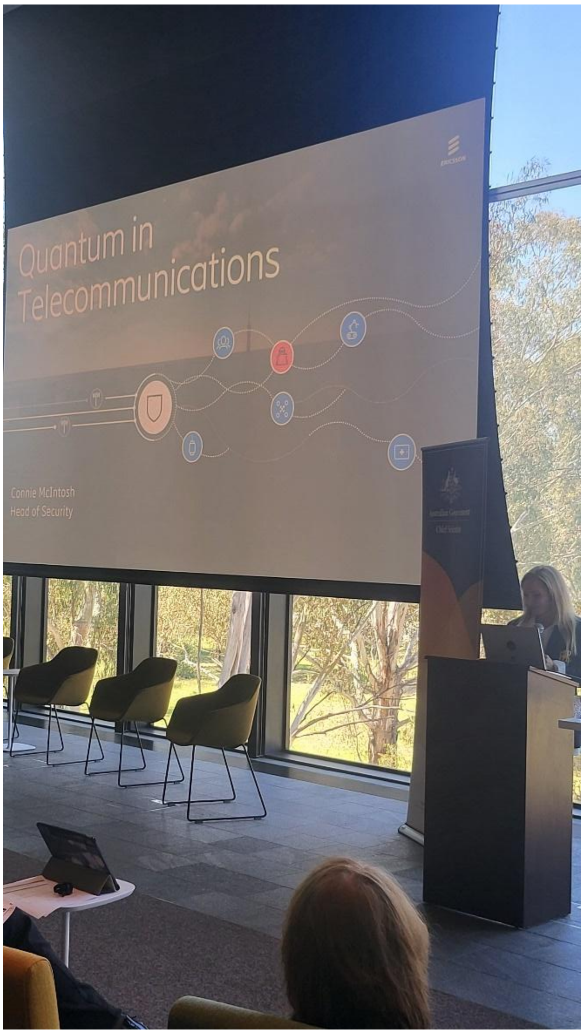


Image 5. Ms Connie McIntosh

Panel composition and discussions

Panel 1 – Securing Communications

Chair: Dr David Liebowitz, Principal Technologist at Penten

- Dr Stephen Gensemer, Team Leader in Space Optics at the CSIRO
- Dr Andrew Lance, Senior Research Fellow at the University of Western Australia
- Dr Rajiv Shah, Managing Director of MDR Security
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As networks become more complex, optimising communication performance and security is becoming more challenging. Quantum technology such as quantum key distribution (QKD) could be used to enhance communications security and improve global networking. While QKD offers strong potential for secure communications, it is limited and expensive. It requires a secure environment and an optical link, making it challenging to implement widely and making it most suitable for niche sectors such as government. It is also important to note that QKD is not 100% secure, rather its advantages are that any interference can be detected.

Other types of quantum technologies could also contribute to communications security. Quantum sensing technologies could offer new ways to secure and monitor critical communications infrastructure, such as submarine cables in the Pacific Ocean. Quantum clocks could also help distribute time more accurately and securely for time distribution networks, critical for communications.

The IT industry faces a significant challenge of securing the internet in a post-quantum world and implementation of QKD and other quantum technologies will need to be carefully considered. It will be important to clarify terminology, for instance post-quantum cryptography is also known as quantum-resistant cryptography and refers to encryptions that are secure against future attacks from a fully functional quantum computer.

Image 6. Panel 1 discussion

Panel 2 – Quantum Computing Impact for Communications

Chair: Dr Rose Ahlefeldt, Senior Research Fellow at ANU

- Associate Professor Jacquiline Romero, Associate Professor at the University of Queensland
- Professor Udaya Parampalli, Professor in the School of Computing and Information Systems at the University of Melbourne
- Mr Sean Rinas, Head of Network Operations at NextDC
- Associate Professor Eryn Newman, Associate Professor at the ANU and Honorary Fellow at the University of Southern California

Quantum computing could play a significant role in optimising communication networks. Current network monitoring often lags behind real-time events and quantum computers could improve real-time monitoring. Quantum computers could also be used to predict network health, allowing the identification and resolution of issues before they affect the network.

Networked quantum computers could potentially form a 'Quantum Internet', a network that uses quantum signals to transmit information. This network is proposed to leverage the principles of quantum mechanics, such as superposition and entanglement, to enhance communication security and offer new computational capabilities. Significant technological advancements and infrastructure change would be required to achieve such a large-scale application, and it will be challenging to integrate quantum and classical communications technology. Current fibre networks operate at telecom wavelengths, which are not compatible with the wavelengths used by matter-based quantum computers.

Successfully implementing quantum computing applications for communications networks will require further interdisciplinary research such as quantum computer error correction. There is also a need to develop a skilled quantum workforce and build public trust in quantum technologies. Effective communication and education are necessary to prevent misinformation and build the social license for quantum technology in communications.

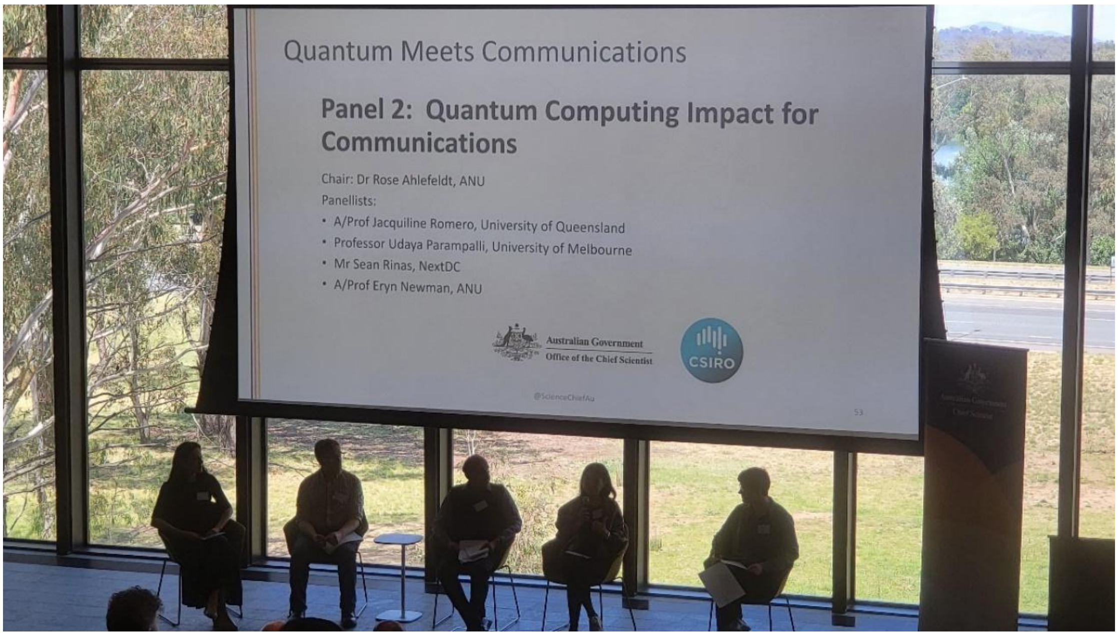

Image 7. Panel 2 discussion

Panel 3 – Future of Mobile Communications

Chair: Mr Mike Baylis, Manager of the Quantum Policy team in the Department of Industry, Science and Resources

- Dr Howard D'Costa, Assistant Director and Space Communications Lead at the Australian Space Agency
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Coverage, capacity and energy efficiency are critical issues in mobile communications. Ensuring adequate coverage, especially in remote areas, and maintaining sufficient capacity to handle high data traffic are ongoing challenges.

Quantum sensors have the potential to improve bandwidth and energy efficiency in mobile networks. The development of 6G networks, envisioned as cyber-physical systems with self-monitoring and pre-emptive error-fixing capabilities, could use quantum sensing networks. These more complex systems will require standardised protocols and systems to function effectively. The panel drew parallels between the development of Wi-Fi and quantum communications, noting the long-term vision of wireless connectivity and the need for standardisation.

Quantum technology could also enhance the last link of mobile networks by addressing the limitations of traditional radio frequency communications. Typically, the last link in mobile networks uses radio frequency, but this method is prone to noise interference, which can compromise the security and reliability of communications. Quantum communications use optical links which are less susceptible to noise and could provide a more secure transmission.

In the long term, integrating quantum technologies into optical satellite networks could also facilitate large-scale rollout of QKD, providing secure communication and enhancing the efficiency and effectiveness of data transmission across networks.

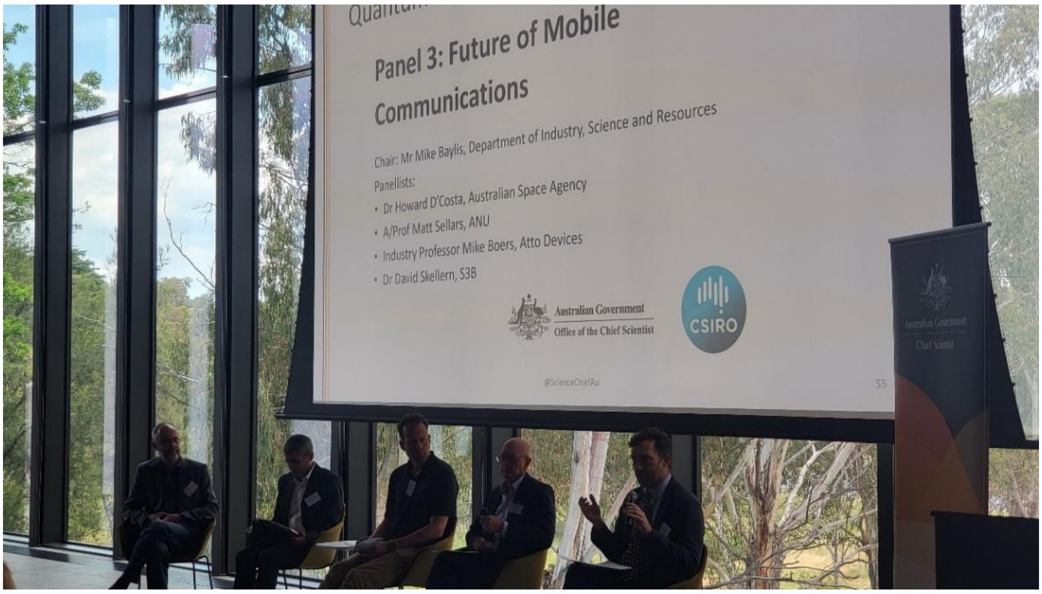

Image 8. Panel 3 discussion

Breakout sessions

During smaller group discussions, attendees further explored challenges in the communications sector including:

- Providing coverage across a small population against Australia's large land mass.
- The need for network resilience strategies in an era with an ever-increasing risk of natural disasters and extreme weather events.
- Sharing practical skills, such as the know-how of managing a large network that talks to other networks.
- Scam and fraud challenges.
- How to build scalable networks with the high cost of connectivity. A significant portion of the cost is in laying the fibre, not the fibre itself.
- Consumers preference for better batteries that last longer.

Use cases explored during these smaller group discussions were:

- Enhancing protection for IoT devices and networks with low compute power
- Quantum sensors and receivers for mobile networks
- Enhancing National Fibre Networks with quantum technology

These topics are the foundation of the case studies in the appendix, which outline opportunities to understand and capture market value by leveraging existing national strengths, infrastructure and expertise.

Appendix: Case studies

Case study 1: Enhancing IoT Device Security and Efficiency with Quantum Technology

Big picture problem

The Internet of Things (IoT) industry faces significant challenges in protecting devices and networks with low compute power. These devices, often deployed in remote locations, operate under constraints such as limited power, memory, and processing capabilities. The lack of constant monitoring and the high cost of adding security measures further complicate the situation.

Breaking the problem down

- Isolation and Scale: IoT devices are often isolated and deployed on a large scale, making it difficult to monitor and manage them effectively.
- Low Power Usage: Many IoT devices are designed to operate on minimal power, which limits their ability to perform complex tasks, including security functions.
- Cost Constraints: Adding security measures to IoT devices can significantly increase costs, making it difficult to justify their deployment especially when there is an expectation they could be stolen.
- Latency: IoT devices used for telemetry purposes require low latency, which can be affected by additional security measures.

How could quantum technology help?

- Quantum Batteries: These could provide rapid recharging and longer battery life, reducing the need for frequent maintenance and replacements.
- Energy Harvesting: Quantum technology could enable devices to harvest energy from their environment, further extending their operational life.
- Quantum Feature Generators: These tools could enhance network anomaly detection, making IoT networks more reliable and robust.
- Quantum Security: Quantum-resistant algorithms and quantum secure communication links could provide enhanced security for IoT devices.

Next steps

- Research and Development: Invest in research to develop quantum batteries and energy harvesting technologies that can be integrated into IoT devices.
- Standardisation: Work towards standardising quantum security measures for IoT devices to ensure widespread adoption and interoperability.
- Collaboration: Engage in collaborations with academic institutions, think tanks, and private partners to implement pilot projects such as smart meters and wearables.

Case study 2: Quantum Sensors and Receivers for Mobile Networks (6G)

Big picture problem

The communications industry is constantly evolving and with the advent of 6G technology, there are new challenges and opportunities. One of the significant challenges is ensuring network resiliency and high-quality signal with low latency, especially in mobile networks.

Breaking the problem down

- Network Resiliency: Ensuring a high-quality signal with low latency at all times and in all locations is a major challenge. This requires robust network infrastructure and effective management of data rates.
- Scam and Fraud Detection: The industry needs to improve its capabilities in detecting and preventing scams and frauds, which are significant issues.
- Government Regulations: Navigating government regulations can be a tedious and challenging aspect of implementing new technologies.
- Redundancy in Telco Systems: There is a need for multiple backup options to ensure continuous service during natural disasters or other disruptions. This includes developing lower power devices that can operate with the same infrastructure.

How could quantum technology help?

- Quantum Sensors: Quantum sensors excel in detecting magnetic fields and other parameters, making them ideal for mobile devices. They are low weight, size, and power, which is perfect for integration into mobile networks.
- High Data Rates: Quantum sensors could improve data rates and network resilience by sensing tampering with communication and providing more reliable connections.
- Redundancy and Backup: Quantum technology could be used to develop lower power devices that provide redundancy during natural disasters, ensuring continuous service.

Next steps

- Research and Development: Invest in research to develop quantum sensors and receivers that can be integrated into mobile networks.
- Collaboration: Engage in collaborations with academic institutions, think tanks, and private partners to drive innovation and advance the industry.
- Regulatory Navigation: Work closely with government bodies to navigate regulations and ensure compliance while implementing new technologies.

Case study 3: Enhancing National Fibre Networks with Quantum Technology

Big picture problem

Large-scale fibre networks are crucial for connecting various institutions, such as universities, and providing access to academia. However, the cost of connectivity, particularly in laying the fibre, and the practical know-how required to manage these networks are substantial hurdles in managing and maintaining these networks.

Breaking the problem down

- Network Management: Managing a large network that interacts with other networks requires extensive practical knowledge and resources.
- Technological Limitations: The current technology may not be sufficient to build quantum repeaters, which are essential for improving network scalability.
- Data Rate and Attenuation: Breaking the network into shorter links can improve data rate attenuation, but this requires advanced technology to manage entanglement effectively.
- Environmental Challenges: Natural disasters such as floods, bushfires, termite damage, and the natural movement of tectonic plates pose significant risks to the network's integrity.

How could quantum technology help?

- Quantum Repeaters: Developing quantum repeaters could improve network scalability by linking nodes together more effectively.
- Improved Entanglement: Quantum technology could help turn bad entanglement into good entanglement, enhancing data rate attenuation.
- Enhanced Fault Tolerance: Quantum sensors could provide better fault tolerance by localising issues more accurately and efficiently.
- Data Management: Quantum feature generators could enhance network anomaly detection, making the network more reliable and robust.

Next steps

- Research and Development: Undertake further research into quantum repeaters and whether to build a single network or a community of interconnected networks.
- Collaboration: Work with universities and other owners of large-scale fibre networks to identify areas where quantum technology could provide significant performance upgrade over current classical technologies.