Australian Government
Office of the Chief Scientist

Quantum Meets Logistics Workshop Summary

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

CSIRO

THE UNIVERSITY OF WESTERN AUSTRALIA

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

Disclaimer

The purpose of this publication is to summarise the events and outcomes of the Quantum Meets Logistics event which occurred in Perth on 15 November 2024.

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Microsoft Co-Pilot was used in developing this summary.

Workshop overview

Quantum Meets Logistics was an in-person workshop led by Australia’s Chief Scientist in partnership with the CSIRO and the University of Western Australia (UWA). The workshop took place at the UWA Club in Perth on 15 November 2024. Approximately 110 people attended, including representatives from the logistics sector, energy sector, healthcare, quantum technology companies, universities and government.

The workshop explored the challenges facing Australia’s logistics sector and how to improve the efficiency and resilience of supply chains.

Modern supply chains can be long and complex, involving multiple actors and forms of transportation. Disruptions to the supply chain are costly for companies, frustrating for consumers, and a potential security risk for critical goods not produced in Australia.

The decarbonisation of the transport industry is another issue, with significant investment and innovation required to reduce emissions while maintaining operational efficiency.

New technology solutions are needed to address these challenges in a volatile and changing market.

Quantum technology has potential applications that could make supply chains more robust and adaptable. Quantum computers are particularly adept at solving optimisation problems with large numbers of parameters. This is useful for the simulation and analysis of supply chains which are very complex and interrelated with multiple variables.

Current optimisation solutions for supply chains on classical computers are limited by the computing power and time required. A more efficient solution for route planning, for example, even with less than a 1% change in efficiency, could save a company millions of dollars.

Quantum computers could also help decision makers make more informed decisions by modelling scenarios and forecasting demand for goods. Additionally, quantum sensors could provide sensitive measurements which could be useful for monitoring the condition of goods in transit and speeding up customs clearing processes. Finally, there is potential for quantum cryptography and communications to enhance the security of data transfers.

Discussions throughout the day showed a huge transformative potential for quantum technology to make Australia's logistics system more efficient, secure, and resilient.

Image 1. Professor Jingbo Wang, Mr Neil Kavanagh, Ms Deborah Ellis, Dr Cathy Foley, Mr Mark Stickells AM, Professor Michael Tobar

Scene setting

Australia's Chief Scientist, Dr Cathy Foley, began the workshop by describing Australia's quantum technology ecosystem. As of 2024 there are 38 quantum businesses in Australia, and since May 2023 there has been $1.4 billion investment into quantum from both the government and the private sector. Australia has strengths in software development and has an Australian Quantum Software Network (AQSN). Dr Foley also mentioned that only 27% of businesses are aware of quantum technology and emphasised the importance of engaging with end users from various sectors.

Dr Foley provided an overview of potential quantum technology applications for transport and logistics, including sensors for biosecurity logistics and quantum computers to tackle route and resource optimisation problems. Examples included:

- The collaboration of Groovenauts, a Japanese quantum computing company, with the construction firm Shimizu Corporation to optimise construction truck movement.
- Q-CTRL's work with Transport NSW to optimise quantum algorithm performance for transport networks.

Dr Foley concluded by encouraging collaboration between the logistics sector and the quantum industry, describing the workshop as part of efforts to realise the ambition embodied in Australia's National Quantum Strategy.

Mr Neil Kavanagh, Global Innovation Officer at Woodside Energy, set the scene from an industry perspective. He spoke about the importance of logistics and supply chains in geophysical surveys and asset development. He highlighted the challenges of operating in high-risk environments and the significance of energy shipping; several countries as well as parts of Australia are dependent on imported fuel for energy. The energy industry commits huge investments to future energy infrastructure – often in very remote locations – and business cases need to anticipate technology and economic outcomes years in advance to prepare for complex operations and market dynamics.

Mr Kavanagh went on to discuss current trends in energy production while a video about Woodside Energy showcased energy production facilities. As energy businesses operate on low margins, there is an increasing preference for autonomous, unmanned energy production facilities. He described how consumers wanted energy to be certified throughout the supply chain, and how new energy products are needed as the world transitions to renewable energy.

Although the energy market is changing, companies can thrive through the transition with openness to new technology, markets and research partnerships. Mr Kavanagh expressed keenness to learn how quantum technology could help energy businesses thrive and maintain a resilient portfolio in this changing market.

Areas of industry impact

Reducing supply chain disruptions

Together with AI, there is potential for quantum computers to analyse huge and complex data sets to diagnose potential disruptions to the supply chain, enhancing preparedness. This could reduce supply chain disruptions or enable faster and more informed decisions to resolve them. Better prediction of equipment failure, driven by better modelling and sensing, could improve system resilience while lowering maintenance costs.

Optimising load layout

Quantum computing could provide more efficient solutions to constrained scheduling and optimisation problems. For example, container ships must arrange the placement of containers based on factors such as ship aerodynamics, container weight and unloading schedule based on arrival at destination ports. Often this problem cannot be solved in real time with current technology, so ships depart port with their hold only 50-60% optimised.

Better demand signals

Quantum computers could be used to forecast changes in demand and supply. Some supply chains have very long timelines from production to consumption. More accurate demand signals and forecasting could help companies better prepare for surges in demand and minimise wastage of time sensitive products like food or medicine that have a maximum shelf life.

More precise data

Quantum sensors can provide much more sensitive measurements of electronic and magnetic fields, vibration, gravity and density. This can be particularly useful for biosecurity logistics and could be used to improve detection of prohibited substances. Quantum sensors could also be used to assist with emissions monitoring or providing better imaging through poor visibility conditions such as dust or turbid water.

Program schedule

Setting the scene

- Dr Cathy Foley, Australia's Chief Scientist
- Mr Neil Kavanagh, Global Innovation Officer at Woodside Energy

Keynotes – sector challenges and quantum opportunities

- Dr David Gozzard, Senior Research Fellow (and former Forrest Fellow) at the International Centre for Radio Astronomy Research at the UWA
- Ms Deborah Ellis, Supply Chain Advisor at Gattorna Alignment
- Professor Jingbo Wang, Director of QUISA (Research Hub for Quantum Information, Simulation, and Algorithms) at the UWA
- Mr Mark Stickells AM, CEO of the Pawsey Supercomputing Research Centre

Panel 1 – Future of global logistics

Chair: Professor Kavan Modi, Professor at Monash University

- Dr John Gattorna, Partner at Gattorna Alignment
- Mr Michael Hall, National Portfolio Manager – Quantum Solutions, NEC Australia
- Professor Vinayak Dixit, Professor of Transport Systems in the School of Civil and Environmental Engineering at the University of New South Wales (UNSW)
- Ms Sue Hellyer, Director of Freight at the Department of Transport

Panel 2 – Quantum logistics for energy and resources

Chair: Professor Chris Vale, Professor of Physics and Director of the Quantum Technologies Future Science Platform at the CSIRO

- Dr Qi Chu, Data Scientist at Woodside Energy
- Ms Anita Logiudice, Manager Resource Development & Sustainability at the Chambers of Minerals and Energy WA
- Professor Michael Tobar, Professor of Physics at the UWA
- Dr Sam Marsh, Q-Ctrl, Senior Solutions Engineer at Q-Ctrl

Panel 3 – Quantum logistics in healthcare

Chair: Dr Pejman Rowshan Farzad, Medical Physics Program Chair at the UWA

- Dr Shiv Akarsh Meka, Chief Data Scientist at Royal Perth Hospital
- Ms Martina Killackey, Vice President of Supply Chain at NovaCina
- Ms Emma Paterson, PhD Candidate at the UWA: The Twisted Anyon Cavity Resonator as a Potential Dark Matter Detector and Sensing Device
- Professor Jingbo Wang, Director of QUISA (Research Hub for Quantum Information, Simulation, and Algorithms) at the UWA

Panel 4 – Securing global supply chains

Chair: Dr Ben Travaglione, quantum computing Discipline Leader at the Defence Science and Technology Group, an adjunct Professor in the Department of Physics at the UWA

- Dr Casey Myers, Senior Lecturer in Quantum Computing at the UWA and a Quantum Supercomputing Researcher at the Pawsey Supercomputing Research Centre
- Professor Gia Parish, Director of the Defence & Security Institute and a Professor at the UWA
- Mr Dominique Thatcher, Digital Transformation Leader in Logistics
- Dr Pascal Elahi, Quantum Supercomputing Research Lead, at the Pawsey Supercomputing Research Centre

Breakout sessions

- Five breakout sessions explored logistic sector challenges where there could be applications for quantum technology

Overview of government funding opportunities

- Dr Olgatina Bushi, Acting Manager within Quantum Branch, Department of Industry, Science and Resources

Next steps and closing statement

- Dr Cathy Foley, Australia's Chief Scientist

Keynote

Challenges and opportunities

Ms Deborah Ellis, Supply Chain Advisor at Gattorna Alignment, described the challenges and changing expectations and environment in the logistics sector. This sector is characterised by large scale and low margins and faces constant pressure to balance service and cost. It must continually adapt to changing markets and customer expectations influenced by the "Amazon effect," which has increased expectations for shorter delivery timeframes. Meanwhile, companies are under pressure to make meaningful sustainability gains without compromising return on investment or system resilience. Since COVID-19, most boards also require a resilience strategy. However, managing trade-offs such as high resilience at high cost is a significant challenge.

The complexity and scale of supply chains, combined with increased market volatility and unpredictability, make it difficult to apply insights from current demand forecasting effectively in day-to-day operations. Companies do not readily share logistics data, limiting the efficiency and adaptability of supply chains. It is impossible for CEOs or any one person to have a complete understanding of the full supply chain and make well-informed decisions at a strategic level.

Opportunities lie within new technologies, such as developing sophisticated and integrated management systems, or analytical tools that support more accurate decision making. Enhancing data availability and data sharing could also facilitate collaboration and problem-solving at an industry level. Ms Ellis concluded that at the end of the day harnessing ‘people power’ was critical. She emphasised the need for supply chain leaders to be proactive, adaptable and resilient in order to navigate the complexities of the modern supply chain environment.

Meeting the challenges with quantum

Professor Jingbo Wang, Director of QUISA (Research Hub for Quantum Information, Simulation, and Algorithms) at the UWA, gave an overview of quantum mechanics. She described how at the atomic scale things behave differently to how we intuitively expect them to. This gives rise to unique properties such as superposition and entanglement which can be used to create very sensitive technology. The most worthwhile problems for quantum computers to solve will likely be multifaceted, with some parts of them better solved by quantum computers and other parts better solved by classical computers. A hybrid approach that combines both quantum and classical computers would leverage their unique capabilities to handle specific components of a problem more efficiently.

Dr David Gozzard, Senior Research Fellow at the International Centre for Radio Astronomy Research at UWA, explored how enhanced sensors and communications could benefit the logistics sector. Quantum sensors could provide much more sensitive and precise measurements to allow visibility through dust or turbid water and remote scanning of goods. Quantum communications could provide assured sources of information, enhanced security, more precise navigation, and time synchronisation. Dr Gozzard stated that it would be necessary to overcome the noise and imperfections in the data but that the potential benefits of quantum technology in logistics were significant, with better data and outcomes for businesses.

Mr Mark Stickells AM, CEO of the Pawsey Supercomputing Research Centre, presented on the recent construction of a supercomputer at Pawsey. It provided a three-fold increase in computing capacity, with a focus on energy efficiency. The supporting infrastructure spanned three to four rooms, and the power requirements were comparable to those of a suburb. Mr Stickells went on to discuss the installation of the first-generation quantum accelerator which took over a week, comparing it to the second generation which was installed in a day. This project was successful in getting the quantum and classical computer systems to talk together, one of the first in the world to do so. Further construction is planned in the 5-year roadmap for building capability in quantum and high-performance computing at Pawsey.

Panel composition and discussions

Panel 1 – Future of global logistics

Chair: Professor Kavan Modi, Professor at Monash University

- Dr John Gattorna, Partner at Gattorna Alignment
- Mr Michael Hall, National Portfolio Manager – Quantum Solutions, NEC Australia
- Professor Vinayak Dixit, Professor of Transport Systems in the School of Civil and Environmental Engineering at the University of New South Wales (UNSW)
- Ms Sue Hellyer, Director of Freight at the Department of Transport

The future of global logistics involves optimising multi-modal supply chains, including road, air and sea, to improve efficiency. Decarbonisation is another critical focus, with the transport industry needing to meet emissions targets by 2050 through cleaner vehicles. Building resilience in supply chains to recover from disruptive events, such as flooding and pandemics, is also vital. New technologies and optimisation strategies could provide cost savings, reduced emissions and improved decision-making. In particular, the ability to make fast decisions was emphasised as a critical factor in solving many logistical problems.

Emerging technologies, including quantum sensors and computing, offer potential benefits in optimisation and data analysis. The panel stressed that quantum computing is not a silver bullet. Generating and accessing data is crucial, but challenges like data ownership and sharing must be addressed to create a robust supply chain. For quantum computing to provide a significant advantage in logistics, it needs to handle large data sets effectively. Current quantum devices, like those from D-Wave, can manage millions of variables and have shown improvements in solution quality and time.

The panel discussed examples where quantum solutions are being employed to increase efficiencies such as shipping container routing at the port of Los Angeles. The value of quantum will be to tackle optimisation problems that are unfeasible with current conventional computing and to drastically shorten the time to generate an answer – meaning the solution will be informed by more recent information. However, the technology is still in its early stages, and its full potential to address logistics problems remains an open question. A supportive environment is needed to explore and adopt new technologies such as quantum.

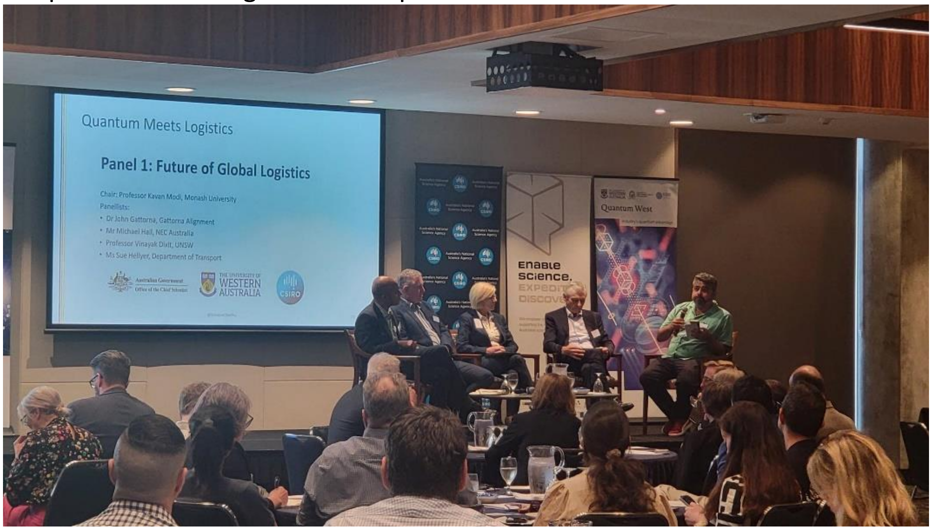

Image 2. Panel 1

Panel 2 – Quantum logistics for energy and resources

Chair: Professor Chris Vale, CSIRO

- Dr Qi Chu, Woodside Energy
- Ms Anita Logiudice, Chamber of Minerals and Energy WA
- Professor Michael Tobar, UWA
- Dr Sam Marsh, Q-Ctrl

The panel explored various issues affecting logistics within the energy and resources sector. With the market-driven nature of supply chains it is important to adapt to changing markets and technology. Post-COVID there has been increased pressure on service delivery times and greater focus on having resilience strategies. Technology that improves supply chain reliability or removes people from working in a hazardous or remote situation is highly desirable. A good logistics solution can have a significant impact on a company's performance. For example, a small improvement in logistic efficiencies (<5%) was reported to have saved a company $450 million annually.

Developing technology that helps manage trade-offs across various factors, such as high resilience at high cost, would be beneficial to the sector. Collaboration is important; the people who understand the practical problems need to connect with the people who are developing the technology. It is also important to make new technology applicable across all types and sizes of businesses. Government could play a role in incentivising investment and sharing risks around the development of new technology.

Quantum computing's capacity to improve logistics within the energy and resources sector is limited by the work needed to be done on correcting and reducing errors in quantum computing. Further work is also needed to explore applications of quantum sensors to address decarbonisation and minimise a company's environmental footprint. However, the potential benefit of quantum technologies is significant enough that it should be included in planning of future logistics infrastructure. Retrofitting existing infrastructure is difficult and expensive, so preparation now could make integration of quantum technology in the future much easier.

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Image 3. Panel 2

Panel 3 – Quantum logistics in healthcare

Chair: Dr Pejman Rowshan Farzad, Medical Physics Program Chair at the UWA

- Dr Shiv Akarsh Meka, Chief Data Scientist at Royal Perth Hospital
- Ms Martina Killackey, Vice President of Supply Chain at NovaCina
- Ms Emma Paterson, PhD Candidate at the UWA
- Professor Jingbo Wang, Director of QUISA (Research Hub for Quantum Information, Simulation, and Algorithms) at the UWA

Panellists discussed the importance of logistics in healthcare, the challenges posed by an aging population and the need for eco-friendly supply chain management. In healthcare, real-time supply chain management is crucial. Many products have a limited shelf life, such as chemotherapy medicines, and are subject to rigorous testing and regulatory compliance. These products cannot be stockpiled so clear demand signals are needed to support forecasting that ensures a steady supply and minimises waste.

Quantum computing could have significant potential in optimising supply chain management and patient scheduling. While machine learning is effective in predicting outcomes, quantum computing excels in scheduling and constrained optimisation. Together, a combined machine learning and quantum computing approach could be used to improve hospital occupancy rates and reduce readmission. This approach could also run predictive models that improve the accuracy and efficiency of healthcare predictions and decisions. To harness the full potential of quantum computing in healthcare, collaboration between data scientists, clinicians and quantum researchers is needed.

Though not directly linked to logistic efficiencies, quantum sensors are also a promising technology for improving medical diagnostics. Quantum microscopes can double the resolution of traditional microscopes without an increase in power that damages cells. This allows detailed observation of living cells which could enhance the sensitivity of brain imaging for early detection of diseases like Parkinson's and Alzheimer's. Advances in quantum sensing will lead to reductions in SWaP (size, weight and power) which improves performance, but also portability and field deployability – enabling more pervasive sensing and diagnostic imaging, e.g., remote locations. Quantum communications was also mentioned as a possible way to enhance the security of patient data through advanced encryption methods.

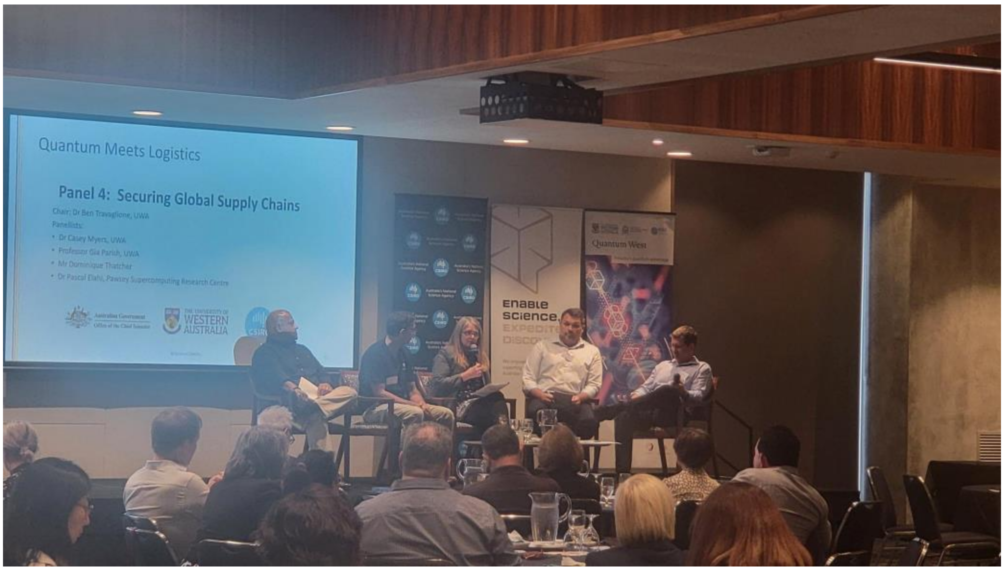

Image 4. Panel 3

Panel 4 – Securing global supply chains

Chair: Dr Ben Travaglione, Quantum Computing Discipline Leader at the Defence Science and Technology Group, an adjunct Professor in the Department of Physics at the UWA

- Dr Casey Myers, Senior Lecturer in Quantum Computing at the UWA and a Quantum Supercomputing Researcher at the Pawsey Supercomputing Research Centre
- Professor Gia Parish, Director of the Defence & Security Institute and a Professor at the UWA
- Mr Dominique Thatcher, Digital Transformation Leader in Logistics
- Dr Pascal Elahi, Quantum Supercomputing Research Lead at the Pawsey Supercomputing Research Centre

The discussion on securing global supply chains illustrated the complexities and challenges involved in ensuring a secure and stable supply of goods. The analogy of farm-to-plate for food supply chains illustrates the many stages with their uncertainties and variables that can disrupt smooth transport. The supply of a food product could be affected by the workforce available for harvesting, the availability of trucks to take products to port, the shipping schedule and more. These problems also rapidly scale with busier ports. For instance, at Fremantle port 2,500 trucks are estimated to leave daily with each carrying around 1.5 containers. Fremantle port exports 800,000 containers per year, a small number relative to Shanghai port which exports 800,000 containers in a week.

Trucks and ships are often not full and delivery sequences not optimally calculated as such calculations takes a vast amount of data and computational power. Quantum computing could significantly speed up this task as it can handle large data sets and large parameter spaces more efficiently than classical computing, making it suitable for solving complex optimisation problems. Ultimately though these multifaceted problems require a hybrid approach using both classical and quantum computing for the tasks they are most suitable for. For instance, classical computers can manipulate data and prepare it for quantum computers to solve.

Ultimately, a vision for future supply chains would be a system capable of detailed end-to-end monitoring combined with the processing ability to self-diagnose and then self-heal before the system is compromised or fails. Such a supply chain would be more resilient to disruptions such as blockades and sanctions – even sudden unavailability of critical raw materials or products. The system could also be used to monitor and enforce sanctions by more comprehensive tracking of freight provenance, origin and routing.

This introduces ethical concerns over allowing technology to control such a critical aspect of human life. The aggregation of data needed to solve these large-scale optimisation problems is another concern. Aggregated data can expose vulnerabilities to adversaries and leave the supply chain vulnerable to blockades. Building security and trust in the logistics sector to facilitate data sharing will be a critical first step to developing quantum applications that can secure global supply chains. The panel reinforced the observation of a previous panel that while there is a massive amount of logistical data produced it is held within companies who presently are extremely protective of the data and unlikely to share. It may be easier to aggregate "open" data sources such as port and truck movements. No matter how this challenge is solved, it presents the associated vulnerability to the aggregated data being maliciously accessed for nefarious intents.

Breakout sessions

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

- Decarbonisation efforts to meet 2050 emission targets.
- Building resilience in supply chains to recover from disruptive events such as flooding and pandemics.
- Overcoming data sharing barriers and trust issues to optimise supply chains.
- Managing trade-offs between high resilience and high cost.
- Volatility, security and complexity in the operating environment.
- Optimisation of complex multi-modal supply chains (road, air, sea).
- Decision-making constraints such as human limitations in understanding and the need for better tools.

Attendees discussed potential quantum applications for:

- Enhanced data generation and access.
- Faster decision-making capabilities.
- Handling large data sets and providing industry-wide solutions.
- Improved efficiency and cost savings through optimisation of routes and resources.

Use cases explored during these smaller group discussions were:

- Logistics optimisation use cases – small data sets with high complexity.
- Logistics industry use cases for quantum communications.
- Hospital utilisation – a quantum use case.
- A coalition for data sharing in logistics.
- Initiatives to combine classical and quantum programming.

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

Image 5. Breakout Session

Next steps and closing

Dr Foley reflected on the day's events, starting with high-level discussions about the current state of quantum technology and its hype before moving to more detailed explorations of its applications in logistics. She highlighted the inclusion of student posters in the workshop for the first time which showcased impressive advancements, such as a 30x increase in quantum computational speed for optimisation problems.

Dr Foley noted the significant investment in research fields in Australia, with funding from various programs including the National Innovation Science Agenda, ON program, and Main Sequence Ventures. The results from these programs highlight the impact of national funding programs on innovation. She proposed a bold idea for a future port project, suggesting a systems approach to designing data sharing and infrastructure from the beginning of its design rather than as a later add-on. Dr Foley concluded with a call to action for continued collaboration and encouraged further meetings amongst attendees to develop the ideas explored during the workshop.

Appendix: Case studies

Case study 1: A coalition for data sharing in logistics

Big picture problem

The logistics sector has a lot of fragmented data that is not shared which hinders supply chain efficiency and resilience. Better sharing and integration of data across the sector could lead to significant improvements in decision-making, cost savings, and overall performance.

Breaking the problem down

- The logistics sector deals with fragmented data that is not shared, leading to inefficiencies.
- Challenges to sharing data include privacy regulations, contractual restrictions, the cost and time to map supply chains and the trust required to provide data.
- It is necessary to understand the data better, identifying the core data required, determining the initial scope, and understanding data flows, capacity and emissions.
- Accurate, realistic data and a well-defined problem statement are required.

How could quantum technology help?

- Quantum communications could potentially enable quantum-secure interactions with data.
- Quantum computing could be used to develop a model of the potential benefits of a 'control tower' to form part of a business case.
- Quantum algorithms could be used to produce predictive insights arising from the data, potentially estimating the probability of future scenarios and sensitivities to input parameters.

Next steps

- Proof-of-concept for control tower concept proposal, possibly using synthetic data.
- Shared benefit cases for each segment of data
- Engage a small set of partners to start exploring ideas and building momentum.
- Consider the work done by banks regarding a similar problem of data sharing around cash supply for ATMs.

Case study 2: Integration of quantum computing with classical computing

Big picture problem

The logistics sector faces significant challenges in optimising operations due to the complexity and constraints involved. Classical computing solutions, while effective to a certain extent, often fall short in providing the best possible outcomes. The integration of quantum computing with classical computing is seen as a potential solution to overcome these limitations and achieve optimal results.

Breaking the problem down

- Running a quantum computer requires substantial classical computing power for error mitigation and pulse control.
- The environments required for optimal operation of classical computers and quantum computers are very different. For instance, high performance classical computers require air conditioning, which is a source of noise and thus errors for quantum computing.
- Encoding and optimising the data for quantum computing still rely heavily on classical computing.
- There is currently a lack of efficient middleware and libraries to facilitate the integration of classical and quantum computing. These tools are essential for encoding data, optimising processes, and translating outputs.

How could quantum technology help?

Quantum technology can enhance classical computing by providing more efficient and accurate solutions to complex optimisation problems. It could handle a larger number of constraints and variables, offering better solutions for logistics challenges. Quantum computing could also support classical computing through feedback loops and iterative approaches, improving overall system performance.

Here is an example of an integrated quantum and classical computing optimisation approach for packing containers:

- In this approach, the goal is to optimise the packing of containers in terms of time, space and cost.
- The process begins with classical computing tasks, such as measuring the size of packages and containers.
- This data is then encoded into a format that quantum computers can understand. Once the data is encoded, the quantum computer takes over and performs the optimisation, determining the best order and arrangement of packages to maximise space and minimise time and cost.
- After the quantum computer completes the optimisation, the classical component is used to execute the optimised order. This might involve driving a crane to move the containers or providing a list to a person unpacking the boxes. The classical component also plays a crucial role in feeding the optimised information back into the model, ensuring continuous improvement and adaptation.

Next steps and questions for exploration

- **Develop Middleware and Libraries:** Creating efficient middleware and libraries is crucial for integrating classical and quantum computing. These tools should simplify the process of encoding data, optimising computations, and translating outputs.
- **Error Correction:** Improving error correction techniques is essential for the scalability and efficiency of quantum computing. This includes developing adaptive air techniques and low-latency classical machines with high bandwidth.
- **Energy Efficiency:** Addressing the energy requirements and noise issues in high-performance computing environments is necessary for the practical implementation of quantum computing.
- **Iterative Approaches:** Implementing iterative approaches that combine classical and quantum computing can enhance optimisation processes. This involves using classical computing to fire pulses into quantum systems, taking outputs classically and feeding them back into the system.
- **AI code generation:** AI code generation could make it easier to generate code to run on quantum computers.

Case study 3: Optimisation of logistic problems

Big picture problem

Getting the right product in the right place at the right time is a common optimisation problem in logistics. There isn't usually enough time or computing power to produce the optimal solution from a complex web of variables, particularly if disruptions occur and require real time responses. This leads to inefficient processes and underutilising of assets.

Three optimisation examples are considered: Satellite instrument time, the supply chain for a mineral product and hospital occupancy.

Breaking the problem down

- **Satellite Instrument Time:**
  - Instruments must be placed on the satellite, so they are balanced and operational.
- Constraints include power availability, manoeuvrability, and data collection schedules.
  - The spacecraft must plan ground communication passes and avoid pointing certain instruments at the sun to avoid damaging them.
  - The logistics challenge of optimising satellite instrument time is akin to trucks being only 60% full, wasting a $100 million asset.
- **Supply Chain for Minerals:**
  - Shipments must be fulfilled at a specific percentage.
  - Equipment breakdowns and rail delays impact latter stages of the supply chain.
  - Real-time data and adjustments are necessary to maintain efficiency.
  - There is a disconnection between planned medium-term optimisation and actual day-to-day corrections.
- **Hospital occupancy**
  - Hospital occupancy is usually around 90% which means a patient has to leave for every new patient coming in.
  - Hospitals with no availability leads to ambulance ramping which reduces the availability of ambulances in the community.
  - Patients need to be admitted to hospital quickly for best health outcomes.
  - Patients need to be discharged from hospital appropriately, minimising their risk of hospital acquired complications and freeing up hospital resources for new patients.
  - Better hospital scheduling could reduce workforce fatigue and lead to better health outcomes.

How could quantum technology help?

- **Handling Complex Constraints:** Quantum computing can manage a large number of constraints simultaneously, which is crucial for logistics optimisation. For example, in satellite instrument time planning, it could optimise the scheduling of experiments and tasks, ensuring maximum efficiency and minimising the risk of damage to instruments. Similarly, in the supply chain for minerals, it could handle disruptions from equipment breakdowns and rail delays, quickly generating new schedules to maintain efficiency.

- **Exploring the Entire Solution Space:** Quantum computers can explore the entire solution space, processing all possible scenarios simultaneously. This capability allows them to find the best possible solution rather than relying on heuristics or approximations, which is often the case with classical computing. This could be used to provide real-time optimisation solutions, essential for problems such as hospital occupancy which can change rapidly.
- **Speed and Scalability:** Quantum computers have more of an advantage over classical computers with larger datasets, making them more scalable for large-scale logistics operations.
- **Enhanced Risk Assessment:** Quantum computing could provide optimised risk assessments by playing out multiple scenarios simultaneously. This helps in identifying potential risks and making informed decisions to mitigate them.

Next steps and questions for exploration

- Identify and scope out optimisation problems that are well suited to being solved by quantum computers, such as having complex and numerous constraints or requiring solutions in real or limited time.
- Further research into quantum error correction and quantum algorithms for optimisation solutions that can then be trialled on existing quantum computing capabilities.
- Pilot studies of quantum approaches to optimisation solutions that test integration with existing supply chain management tools.
- Collaboration with industry and government to ensure regulatory hurdles are met, especially around privacy and consent such as in a healthcare setting.
- Ultimately development of a fault tolerant quantum computer at scale is needed to fully realise the potential of quantum enhanced logistics optimisation.