Quantum Meets Infrastructure (including logistics)

Dr Cathy Foley

Australia's former Chief Scientist and Quantum Enthusiast

11 August 2025



Space Environment Wildlife Archaeology

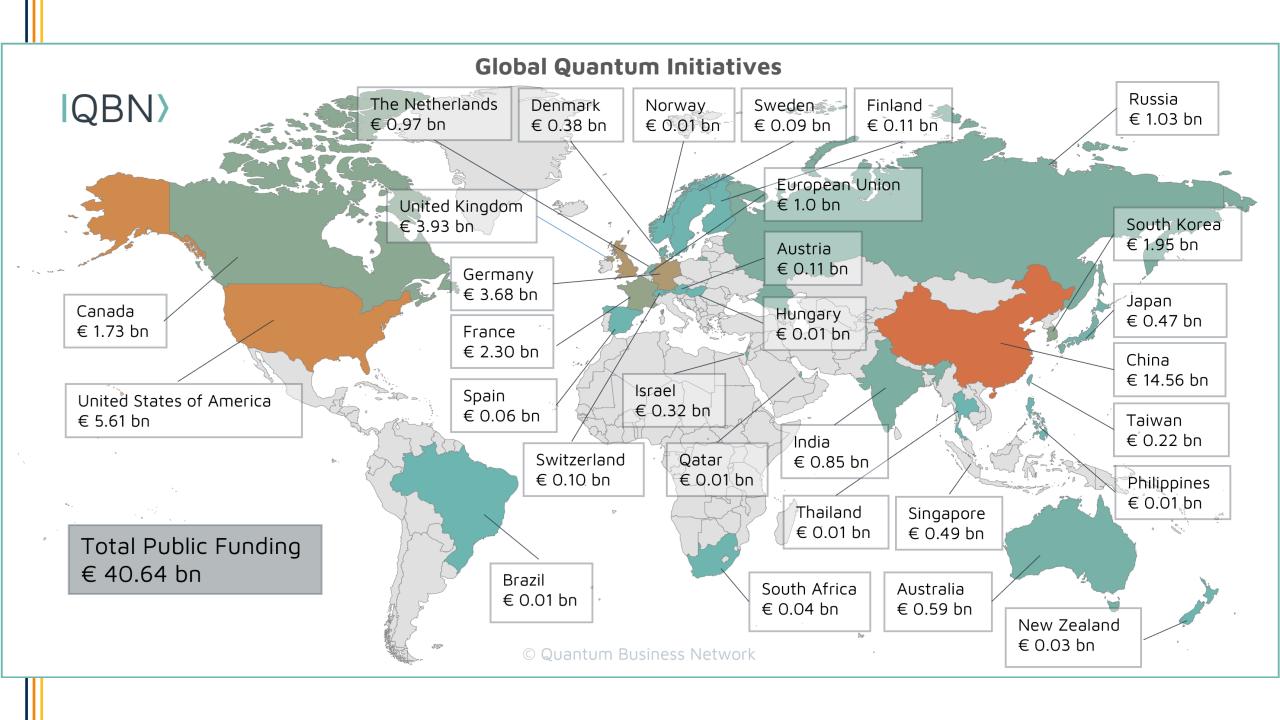
SCIENCE

Why the world is now in a race to achieve 'Quantum Superiority'

By Eric Spitznagel

Published May 3, 2025, 2:00 p.m. ET





Who's backing quantum?

Corporate investors:

- Intel, Google, IBM, Microsoft, AWS and many others
- Private investment reached >\$2B in 2024
- Generated \$650-750M revenue in 2024 expect >\$1B in 2025

Governments:

- Considered "urgent" and "critical"
- Strategies produced by China, USA, UK, Europe, Japan, Canada, S. Korea (>20 countries)
- **Public investment** increased >50% in 2022
- Global public funding now \$44.5B
- **Singapore hub** collaborates with businesses on use cases.
- UK 5 quantum hubs to speed up commercialisation
 - Govt GBP 606M industry GBP 54M
- Australia's investment \$1.2B through multiple programs

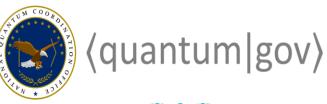


Department for Science, Innovation & Technology







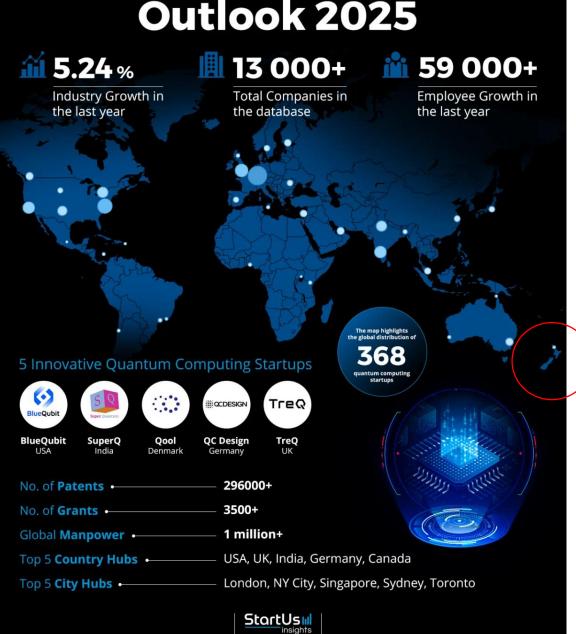




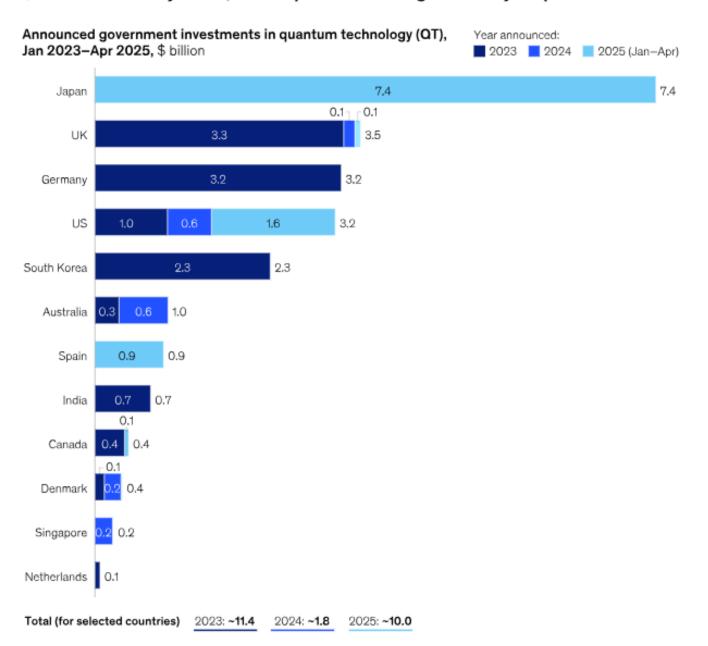




Quantum Computing Outlook 2025



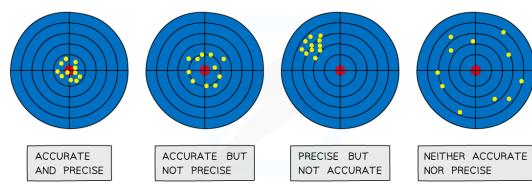
Announcements of public investments in quantum technology reached \$10 billion in early 2025, with Japan accounting for nearly 75 percent.



Quantum What will quantum encryption **Quantum secure** communications deliver? Quantum Quantum metrology biology Quantum key **Phosphorus in** Quantum distribution silicon Quantum Quantum computation sensors Quantum simulators **Timekeeping** quantum clocks

Quantum sensors

- Higher sensitivity
- Better accuracy
- Precision
- Size weight power
- Atomic to macro size
- Spatial resolution
- They can measure physical quantities:
 - Magnetic fields
 - Electric fields
 - Temperature
 - Pressure
 - Chemical composition
 - Gravity
 - Shapes







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Quantum Sensing

Electric Fields

- Atomic electric field sensors
- Solid-state defects

Time and Frequency

Atomic clocks

Magnetic Fields

- Atomic magnetometers
- Superconducting magnetometers
- Solid-state defects

Quantum Sensors

leverage quantum phenomena to measure fields, forces, or time

Inertial Acceleration

- Atomic accelerometers and gyros
- Superconducting accelerometers and gyros
- NMR gyros

Acceleration due to Gravity

- Atomic gravimeters
- Superconducting gravimeters

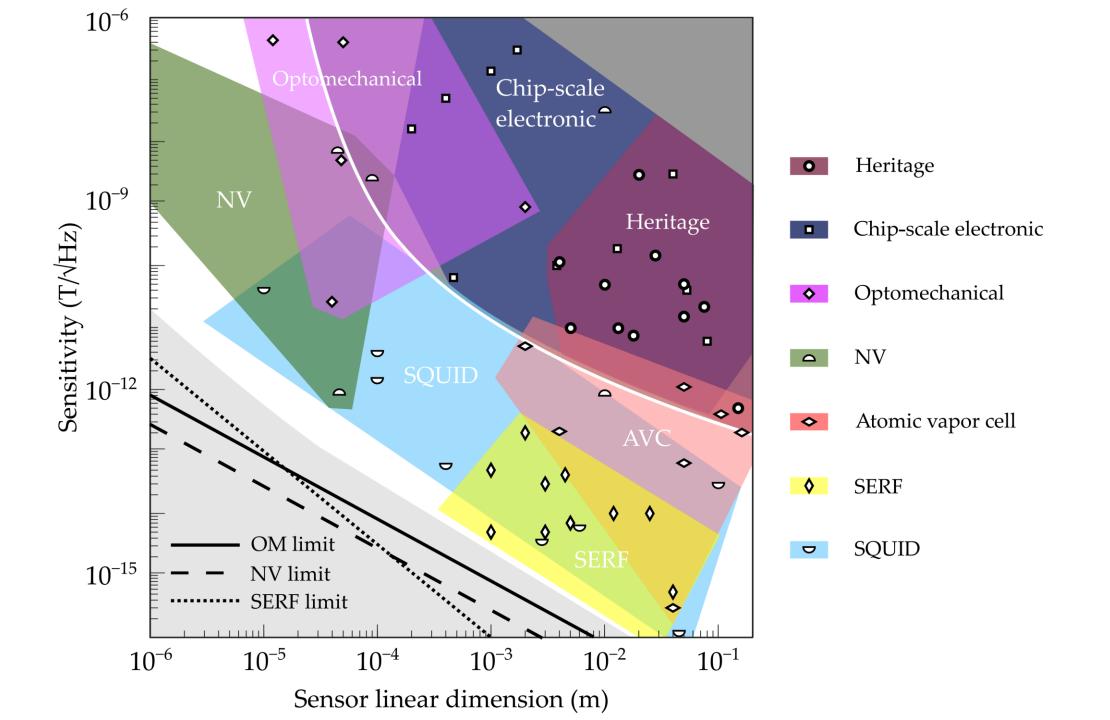
WHY BUILD QUANTUM SENSORS?

Compared to traditional sensors, quantum sensors offer the potential for:

Improved Performance

and/or

Smaller SWaP (size, weight, and power)



Quantum communications

- Quantum networks with space links
- Quantum satellites
- Date security
- Improved energy efficiency for optical communications
- Improved bandwidth efficiency for optical communications
- Positioning, navigation and timing without GPS

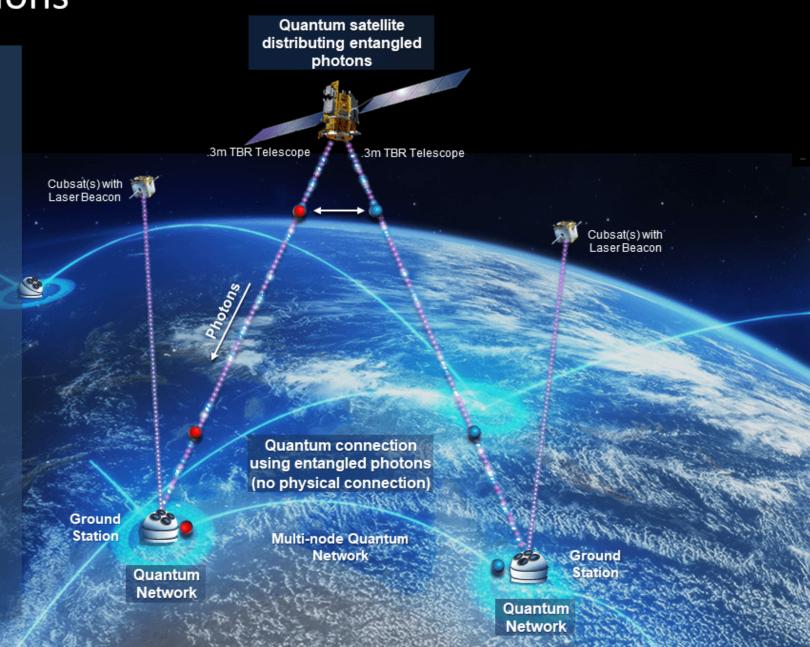
Quantum Communications

Information can now be encoded (represented) by multi-state quantum bits (qubits)

- Entangled photons as qubits can interact with each other at any distance
- By having a satellite distribute entangled photons via optical links to well separated stations on Earth, those stations can "talk" to each other via the entangled photons - without needing to be physically connected

Benefits

- Quantum networks with space links
- Data security
- Improved energy efficiency for optical communications
- Improved bandwidth efficiency for optical communications



Quantum Computers Global race

- Exponential computational speedup for specific problems
- Ability
 to simulate quantum systems,
- Potential breakthroughs in cryptography and materials science

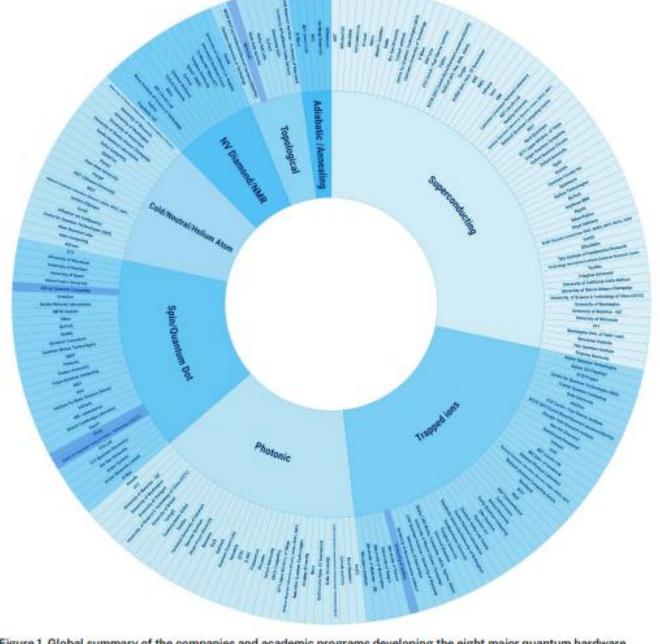


Figure 1. Global summary of the companies and academic programs developing the eight major quantum hardware technologies. Sourced from the Michel Kur, CEO of Multiverse Systems SAS, 46 and modified to highlight companies and academic efforts specific to NSW. Companies specific to NSW

Quantum computers can help tackle

Predictive analysis

Improving supply chain management and logistics

Increasing efficiency

Fraud detection

Searching unsorted data

Optimization problems

Modelling extreme weather events

Design new material exactly

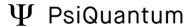
Simulating complex phenomena

Demand forecasting











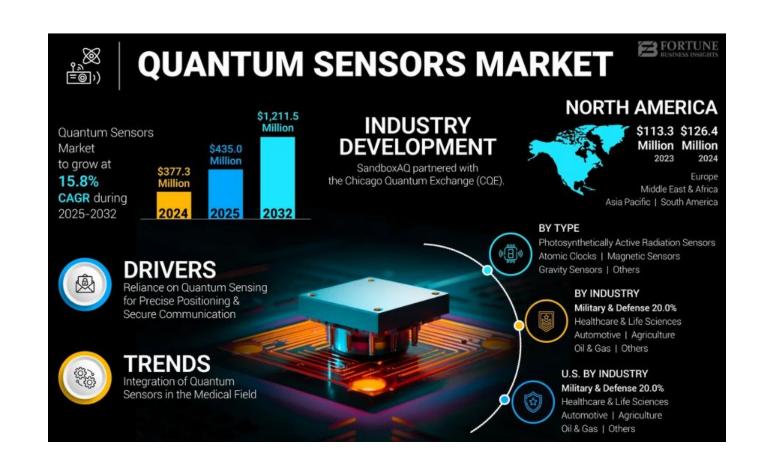
Global race

Different types of quantum computers:

- Useful/Fault Tolerant here soon
- Fully error corrected different views on when that will be delivered
- Annealers available now on the cloud D-Wave
- Analogue quantum simulations
- Noisy Intermediate Scale Quantum (NISQ) Computer available now via cloud - AWS, Rigetti, Xanadu, IBM, Google
- Quantum accelerator on HPC available now Quantum Brilliance on Pawsey high-performance computer

Industry sectors

- Health and biotech
- Resources
- Communications
- Transport
- Environmental protection
- Defence
- Infrastructure
- Agriculture
- Energy
- Research
- Sport
- Financial services



What does this mean for New Zealand?

Figure 1: New Zealand's infrastructure challenge



The average Auckland commuter spends over **5 days in traffic per year**



By 2050 one in four NZers will be over the age of 65



\$90 billion bill to fix up water networks



\$5 billion of council infrastructure is exposed to sea level rise



115,000 more homes are needed to fix the current housing crisis



There is a **75% chance** of an Alpine Fault rupture by 2070



Electricity generation capacity needs to **increase by 170%**



We need to spend **\$60 on maintenance** and renewal for every \$40 we spend on new infrastructure



New Zealand's population will grow to **6.2 million people** (or more) over 30 years



2/3 of population growth will be in **five major centres**



Infrastructure construction costs have risen
60% faster than prices elsewhere in the economy

Source: Sense Partners

Summit Outcomes

The outcomes for the Summit were:

Outcome 1

Outcome 2

Outcome 3

To enhance New

To grow international

To display the bold and

Zealand's repart great place to

business.

Quantum needs to be part of this plan

The **Minister** infrastructure his six prioritie

- 1. Establis
- 2. Develor
- 3. Improving infrastructure funding and financing.
- 4. Improving the consenting trainework.
- 5. Improving education and health infrastructure.
- 6. Strengthening asset management.

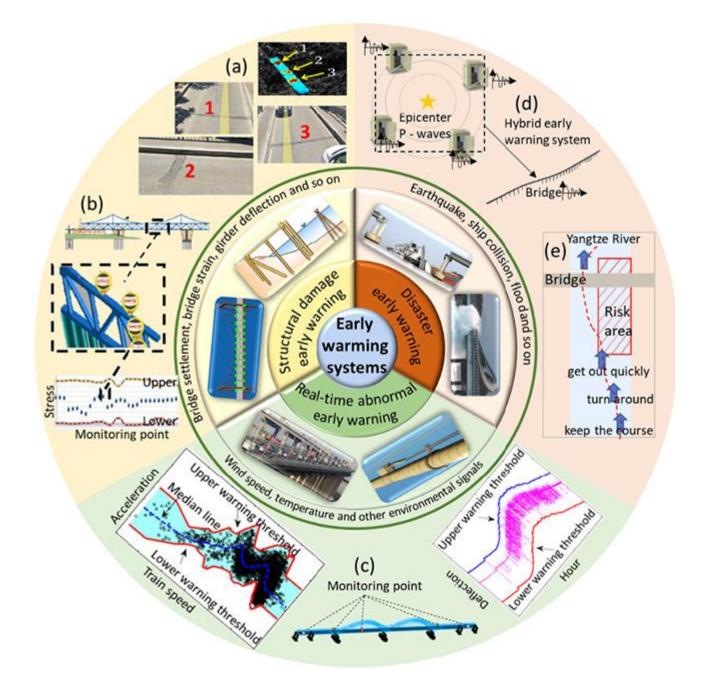




Quantum Sensing: The New Eyes and Ears of Infrastructure

Structural Health Monitoring

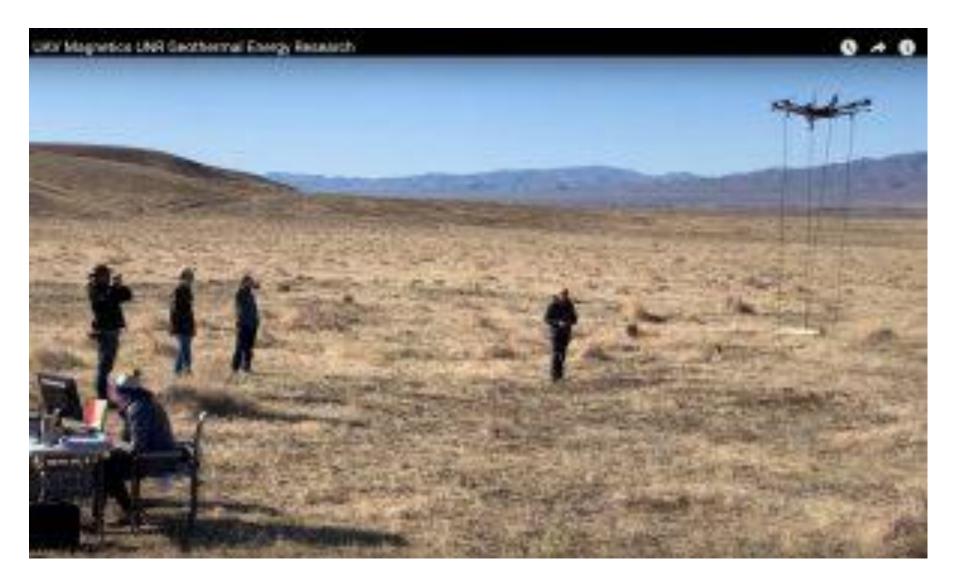
- Bridge and Building Integrity: Quantum magnetometers detecting microscopic stress changes
- Underground Infrastructure: Quantum gravimeters mapping subsurface utilities and detecting leaks
- Seismic Monitoring: Enhanced earthquake detection and building response systems
- **Pipeline Networks**: Real-time corrosion and pressure monitoring across vast distances



Quantum Sensing: The New Eyes and Ears of Infrastructure

Environmental and Geotechnical Applications

- Soil Stability Analysis: Quantum sensors for foundation monitoring and landslide prediction
- Water Infrastructure: Detecting contamination and flow irregularities in supply networks
- Coastal Protection: Monitoring sea-level changes and coastal erosion with millimeter precision
- Weather and Climate Systems: Enhanced forecasting for infrastructure planning



A frame-grab from a Geometrics video, which <u>demonstrates</u> UAV magnetic-field mapping

Quantum Computing: Optimising Complex Infrastructure Networks

Transportation and Traffic Systems

- Route Optimisation: Quantum algorithms solving Auckland's traffic congestion
- Public Transit Networks: Real-time optimisation of bus and rail schedules
- **Port Operations**: Container logistics and supply chain optimisation at Auckland and Tauranga
- Airport Management: Flight scheduling and ground operations optimisation

Cascaded Multiparameter Quantum Metrology

Gregory Krueper,¹ Lior Cohen,² and Juliet T. Gopinath^{1,2,3}

¹Department of Physics, University of Colorado Boulder, Boulder CO 80309, USA

²Department of Electrical, Computer and Energy Engineering,

University of Colorado Boulder, Boulder CO 80309, USA

³Materials Science and Engineering Program, University of Colorado Boulder, Boulder CO 80309, USA*

We present an innovative, platform-independent concept for multiparameter sensing where the measurable parameters are in series, or cascaded, enabling measurements as a function of position. With temporally resolved detection, we show that squeezing can give a quantum enhancement in sensitivity over that of classical states by a factor of e^{2r} , where $r \approx 1$ is the squeezing parameter. As an example, we have modeled an interferometer that senses multiple phase shifts along the same path, demonstrating a maximal quantum advantage by combining a coherent state with squeezed vacuum. Further classical modeling with up to 100 phases shows linear scaling potential for adding nodes to the sensor. The approach can be applied to remote sensing, geophysical surveying, and infrastructure monitoring.

Quantum technique could transform remote sensing, infrastructure monitoring

A team of CU Boulder researchers has introduced a quantum sensing technique that could lead to improvements in how we monitor infrastructure, detect changes in the environment and conduct geophysical studies.

Quantum Computing: Optimising Complex Infrastructure Networks

Energy Infrastructure

- Smart Grid Management: Balancing renewable energy sources with demand
- Electricity Network Optimisation: Minimizing transmission losses and maximising efficiency
- Energy Storage Systems: Optimising battery placement and charging strategies
- Grid Resilience: Rapid response to outages and natural disasters

Quantum Computing: Optimising Complex Infrastructure Networks

Water and Waste Management

- **Distribution Network Optimisation**: Minimising water loss and energy consumption
- Wastewater Treatment: Process optimisation and resource recovery
- Flood Management: Real-time drainage system coordination
- Resource Allocation: Optimising maintenance schedules and crew deployment

Quantum Communications: Securing Critical Infrastructure

A. Cybersecurity for Critical Systems

- Power Grid Protection: Quantum-safe encryption for SCADA systems
- Water Treatment Security: Protecting against cyber threats to public health
- Transportation Safety: Securing air traffic control and railway signaling
- Financial Infrastructure: Quantum-encrypted banking and payment systems

Quantum Communications: Securing Critical Infrastructure

B. Emergency Response Networks

- **Disaster Communication**: Unbreakable communication during emergencies
- First Responder Coordination: Secure real-time information sharing
- Public Warning Systems: Authenticated emergency alerts and instructions

Environmental Data Science (2025), 4: e35, 1–20 doi:10.1017/eds.2025.10010



POSITION PAPER

Opportunities and challenges of quantum computing for climate modeling

Mierk Schwabe ¹ D, Lorenzo Pastori ¹ D, Inés de Vega², Pierre Gentine ³ D, Luigi Iapichino ⁴ D, Valtteri Lahtinen ⁵, Martin Leib ², Jeanette Miriam Lorenz ^{6,7} D and Veronika Eyring ^{1,8} D

Corresponding author: Mierk Schwabe; Email: mierk.schwabe@dlr.de

Received: 16 December 2024; Revised: 02 May 2025; Accepted: 04 June 2025

Keywords: climate modeling; data-driven parameterizations; model tuning; quantum computing

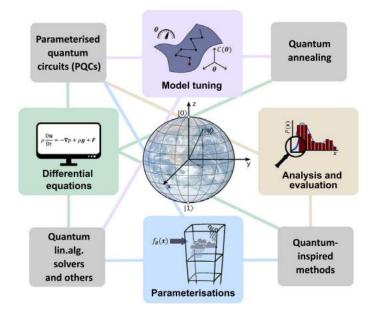


Figure 4. Overview of the climate modeling tasks and the category of matching quantum computing algorithms. (Image of the Earth by NASA/Apollo 17).

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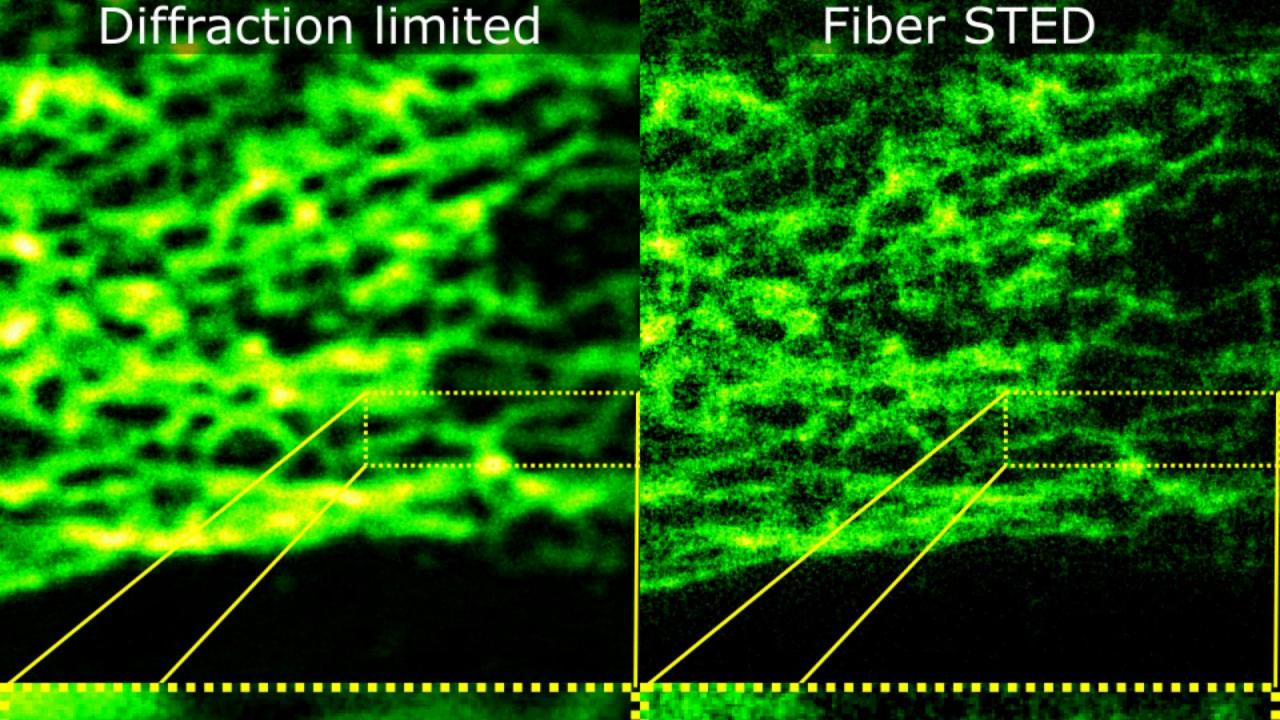
⁴Quantum Computing and Technologies Department, Leibniz-Rechenzentrum der Bayerischen Akademie der Wissenschaften (LRZ), Garching b. München, Germany

⁵Quanscient Oy, Tampere, Finland

⁶Fraunhofer-Institut für Kognitive Systeme IKS, München, Germany

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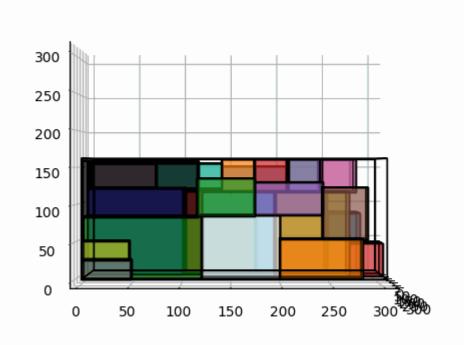


Logistics and Supply Chain Transformation

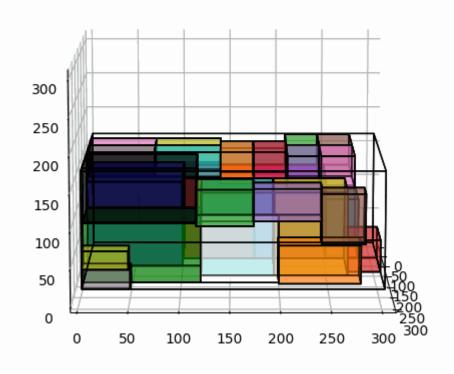
A. Port and Maritime Operations

- Container Tracking: Quantum-enhanced GPS for precise cargo location
- Ship Routing: Weather optimization and fuel efficiency algorithms
- Automated Cargo Handling: Quantum-controlled robotic systems
- Customs and Security: Enhanced scanning and verification technologies

Stowage planning is a combinatorial problem Needs to be solved in a strict timeframe







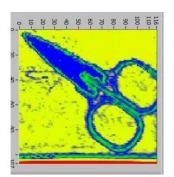
Quantum-South

Complex optimization problems leveraging quantum computing software

Materials differentiation

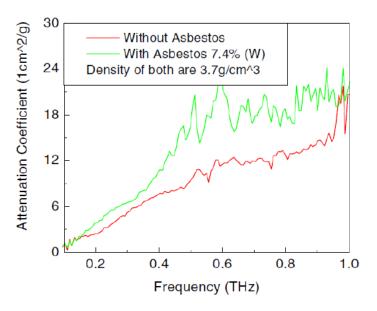
THz imaging





Pest detection using Q sensors

Asbestos



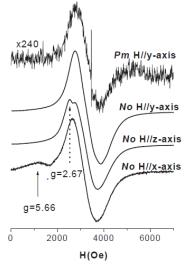
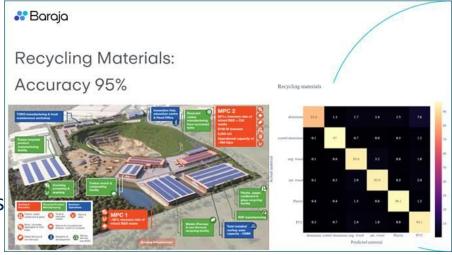
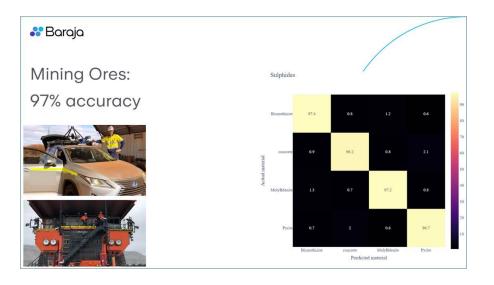


Fig. 3. RT termite FMR spectra with the applied magnetic field parallel to each axis indicated in the Fig. 1 scheme and to *y*-axis for migratory ant.

New LiDAR concept –resources and recycling





Logistics and Supply Chain Transformation

B. Road and Rail Freight

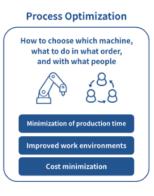
- Fleet Management: Real-time optimisation of delivery routes and schedules
- Inventory Optimisation: Quantum algorithms for warehouse management
- Cross-docking Operations: Streamlined freight transfer at distribution centres
- Last-mile Delivery: Urban logistics optimisation for e-commerce growth

Groovenauts and Shimizu Optimize Construction Related Soil Transport Using the Power of Quantum Computers

-Improved productivity at public works construction sites: Verified 10% increase in transport volume-

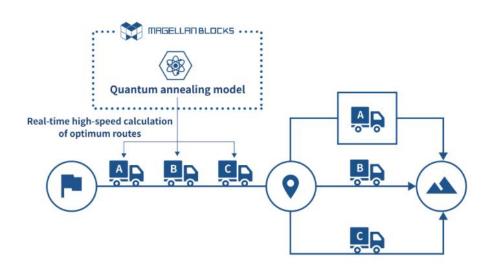






MAGELLAN BLOCKS

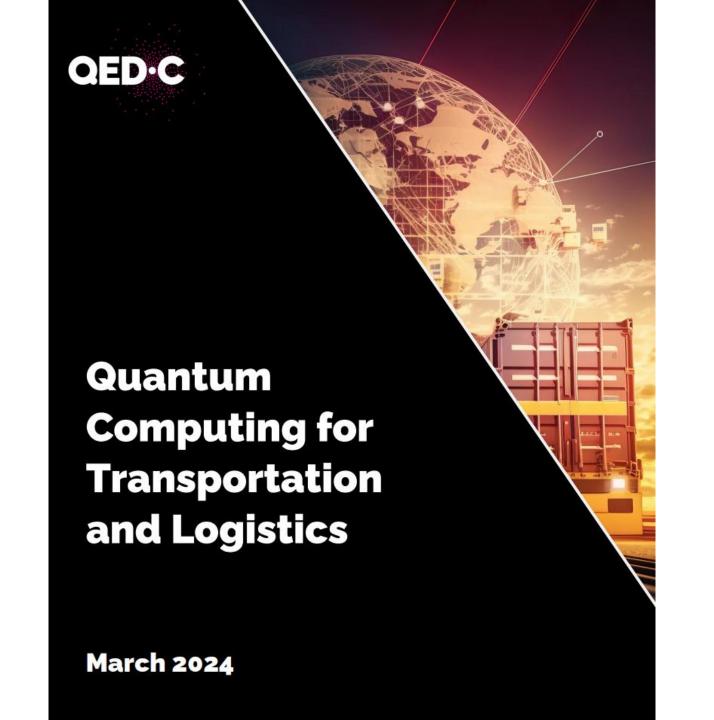




Logistics and Supply Chain Transformation

C. Aviation and Air Freight

- Air Traffic Management: Quantum computing for flight path optimisation
- Cargo Scheduling: Maximising aircraft utilization and reducing delays
- Maintenance Optimisation: Predictive maintenance using quantum sensors
- Fuel Efficiency: Route and altitude optimisation for reduced emissions



OUANTUM COMPUTING CALLED IN TO HELP SOLVE SYDNEY TRANSPORT SCHEDULING CONUNDRUMS

Posted by Trevor Long | Apr 13, 2021 | News, Tech

Q-CTRL's Founder and CEO, Professor Michael Biercuk spoke of the power of NSW in the next few years. The possibilities are endless,"

Q-CTRL's Founder and CEO, Professor Michael Biercuk spoke to Transport for NSW in the next few years. Q-CIRL'S Founder and CEO, Professor Michael Biercuk spoke of the power of Quantum computing to tackle the oldgest."

Completely transform the computing tools available to Transport for NSW in the next few years. The possibilities are endless, completely transform the computing tools available to Transport for NSW in the next few years. Imagine though, the power of a computer that could re-route buses, change train timetables and assist in the flow of traffic in real-time when anything happens—

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Imagine though, the power of a computer that could re-route buses. This is a research project, launched as one of many initiatives in the government's future of transport technology roadmap. amazing to think!

are opportunity for some of our leading transport innovators and quantum computing experts to come together to tackle complex transport and congestion problems,"

ruture applications of the technology could include mapping all transport modes and crowd movements simultaneously in real time, and automatically updating the schedule to solve disruption issues.



BATCH Revolutionizes Logistics Pricing with AI and Quantum Computing

- combination of artificial intelligence and quantum computing
- prices 200,000 freight lanes daily across the continental United States
- for drayage containers, dry vans, refrigerated units, and flatbeds
- up-to-date and competitive pricing information enabling rapid and informed decision-making
- accurate and dynamic price quoting
- resource allocation and potentially lower costs for shippers

New Zealand-Specific Applications and Opportunities

A. Geographic and Geological Advantages

- Alpine Infrastructure: Monitoring avalanche risks and mountain pass conditions
- **Volcanic Monitoring**: Enhanced early warning systems for infrastructure protection
- Coastal Infrastructure: Sea-level monitoring and coastal defense optimization
- Remote Area Connectivity: Quantum communications for isolated communities

New Zealand-Specific Applications and Opportunities

B. Economic Infrastructure Priorities

- Tourism Infrastructure: Optimising visitor flows and transportation networks
- Primary Industry Support: Logistics optimisation for agricultural and forestry exports
- **Urban Development**: Smart city applications for Auckland, Wellington and Christchurch
- Regional Connectivity: Improving infrastructure links between major centres

Economic Impact and Value Proposition

A. Productivity Gains

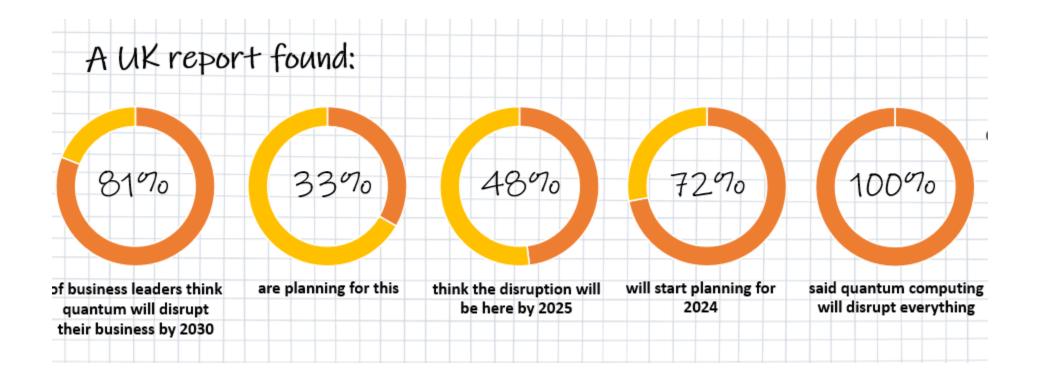
- Reduced Maintenance Costs: Predictive monitoring preventing expensive failures
- Improved Efficiency: Optimized operations reducing energy and resource consumption
- Enhanced Capacity: Better utilisation of existing infrastructure assets
- Reduced Downtime: Faster response to problems and system optimisation

Economic Impact and Value Proposition

B. Competitive Advantages

- Trade Facilitation: More efficient ports and logistics networks
- Business Attraction: Advanced infrastructure attracting international investment
- Innovation Hub: Positioning New Zealand as a testbed for quantum infrastructure
- Export Opportunities: New Zealand expertise in quantum infrastructure solutions

Quantum impact and readiness?



Today

- Could quantum tech help support infrastructure, logistics and transport?
- Looking for great ideas
- Start to link up the infrastrucuture, logistics and transport sector with quantum
 - Speed dating
 - Fall in love?
- What are some specific projects?
- Where could these projects get funding?
- Are there business opportunities for any start-ups?

