QUEENSLAND QUANTUM AND ADVANCED TECHNOLOGIES STRATEGY

Turning deep science into trailblazing industries

Queensland Government

FOREWORD

Over the last 30 years, Queensland researchers have forged a global reputation for excellence in delivering cutting-edge quantum science and innovation. Queensland universities are at the heart of this reputation and have contributed to many of the technologies used in our everyday lives that have their origins in quantum science. Applications such as smart phones and Magnetic Resonance Imaging (MRI) machines were made possible by the knowledge developed through studying quantum science.

Move forward to today and we see that a 'second quantum revolution' is now under way. Advancements in quantum science and advanced fabrication are now bringing to reality new applications and transformative technologies previously thought impossible. Global investment in quantum is also growing in anticipation of the value that will be generated by the technology. For example, the CSIRO estimates that in just six years the quantum sector in Australia could be worth $2.2 billion and growing to $6 billion by 2045, employing thousands of people.

Quantum, along with advanced technologies such as photonics, semiconductors and superconductors, represent a unique opportunity for Queensland, and we are well placed to capture their benefits through careful and timely investment and support.

The Queensland Quantum and Advanced Technologies Strategy sets out our exciting and ambitious plan to strengthen and build upon our capabilities in quantum and related 'deep' technologies to drive high value job creation, scaled-up advanced manufacturing, investment in promising home-grown start-up companies and take-up of transformative solutions across our emerging and traditional industries.

The Strategy will give our world-leading scientists and facilities the support and tools they need to help decarbonise the economy, revolutionise biomanufacturing and biomedicine, showcase Queensland innovation at the Brisbane 2032 Olympic and Paralympic Games and create trailblazing new businesses and industries.

The Honourable Annastacia Palaszczuk MP
Premier of Queensland and Minister for the Olympic and Paralympic Games

The Honourable Leanne Linard MP
Minister for the Environment and the Great Barrier Reef, Minister for Science and Minister for Multicultural Affairs

Cover image: Dr Jacqui Romero from EQUS at The University of Queensland working on a quantum switch for use in quantum computing applications. Credit: For Women In Science, L'Oreal Australia.

ACKNOWLEDGEMENT OF COUNTRY

The Queensland Government acknowledges the Country and people of Queensland's First Nations. We pay our respects to Elders, past and present.

We acknowledge the continuous living culture of First Nations Queenslanders—their diverse languages, customs and traditions, knowledges and systems.

We acknowledge the deep relationship, connection and responsibility to land, sea and sky Country as an integral element of First Nations identity and culture.

This Country is sacred. Everything on the land has meaning and all people are one with it. We acknowledge First Nations peoples' sacred connection as central to culture and being.

First Nations people speak to Country, listen to Country, sing up Country, dance up Country, understand Country and long for Country.

We acknowledge and thank First Nations people for the enduring relationship connecting people, Country and ancestors—an unbreakable bond that safely stewarded and protected the land, waters and sky for thousands of generations.

Researchers at the UQ Centre for Advanced Imaging use quantum-enabled Magnetic Resonance Imaging (MRI) for their leading research

QUEENSLAND: THE QUANTUM STATE

Over the past 30 years, Queensland has steadily built a reputation for being at the global frontier in science and advanced technologies such as robotics, artificial intelligence, nanotechnology, and synthetic biology. These capabilities are attracting significant global recognition and investment for the state. Now, **quantum technologies** are also emerging from Queensland laboratories, with potential to deliver transformative benefits across a wide range of domains.

The Queensland Government has been a long-term investor in quantum and related technologies, co-funding the original two national quantum Centres of Excellence in 2003 under the Smart State Strategy. Since then, the Government has supported the development of complementary strengths in nanotechnology, novel materials and advanced fabrication and, most recently, supported The University of Queensland's successful bid to establish and lead the ARC Centre of Excellence in Quantum Biotechnology—the world's first nation-spanning centre in this field.

What do we mean by "quantum and advanced technologies"?

A key direction of innovation has been the engineering of new materials and devices by working at the level of the fundamental building blocks of nature such as atoms, electrons and photons. These particles obey the laws of quantum physics, which are quite different to the laws of classical physics that apply to large objects. Capabilities in quantum physics have therefore become increasingly critical to the development of cutting-edge, science-based innovations.

There is already a range of existing technologies that exploit quantum physics, including semiconductors, atomic clocks, lasers and magnetic resonance imaging. However, a new generation of quantum technologies is now emerging (sometimes called Quantum 2.0), based on the *systems* properties of quantum such as entanglement, superposition, and wave-particle duality. Whilst these concepts are sometimes regarded as strange and counter-intuitive, potential users of quantum technologies do not need to understand the science, but rather the transformative applications that are enabled, which span computing, sensing, and communications.

This Strategy also recognises that to build a quantum ecosystem it is necessary to ensure a sufficiently developed base of the **advanced technologies** needed to deliver market-ready quantum devices. These include semiconductors, superconductors, photonics, and micro-electromechanical systems (MEMS). Queensland's universities have outstanding testing and fabrication capabilities across these technology areas, and there is an opportunity to develop these into a unique national industry-grade capability for prototyping and pilot-scale production.

By strengthening our quantum and advanced technology manufacturing capabilities, we can make not only quantum products, but also other products with significant markets and very substantial growth trajectories in areas such as energy, decarbonisation, health and biotechnology, defence and aerospace. We can also attract companies and license technologies from across Australia and the world to develop quantum and advanced technology products in Queensland.

BUILDING THE QUEENSLAND QUANTUM ECONOMY

Queensland has a unique opportunity to use emerging, science-based technologies to build new industries and sustain traditional industries.

Past Queensland Government investments under the Smart State Strategy and Advance Queensland have created a rare and compelling suite of 'deep tech' capabilities including quantum, compound semiconductors, photonics, and advanced fabrication.

Developing these strengths into a thriving industry-research ecosystem will help to ensure that Queensland's emerging and traditional industries can stay ahead of the technology curve, amplifying the economic gains from key Queensland Government initiatives such as the $4.5 billion Queensland Renewable Energy and Hydrogen Jobs Fund, the $100 million Queensland Critical Minerals and Battery Technology Fund, and the Queensland New-Industry Development Strategy.

In particular, the industries targeted under the Queensland New-Industry Development Strategy such as batteries, green hydrogen, renewable energy and critical mineral processing are highly likely to be transformed (technologically and economically) in the future by quantum-based innovations.

Being a leader in developing and using quantum innovations will also help to establish Queensland as a deep tech hub in the Indo-Pacific region, attracting investment and talent, growing unicorn startups, participating in global supply chains and exporting quantum-based solutions to the rest of the world.

A recent analysis by CSIRO[1] estimated that, based on conservative global growth and market share assumptions, the Australian quantum industry could achieve $2.2 billion in revenue and 8,700 jobs by 2030, and nearly $6 billion and 19,400 jobs by 2045. The ultimate outcome will depend on how quickly Queensland and Australia can develop and deploy new quantum technologies and new quantum companies.

The coming wave of quantum innovations is generally regarded as falling into three broad categories:

Quantum sensing harnesses the principles of quantum mechanics to achieve ultraprecise measurements of various physical phenomena such as time, gravity, magnetic fields and biological and chemical signatures.

Quantum computing uses the quantum systems properties of superposition and entanglement to perform certain types of calculations exponentially faster than classical computers, making it possible to solve problems regarded as intractable until now.

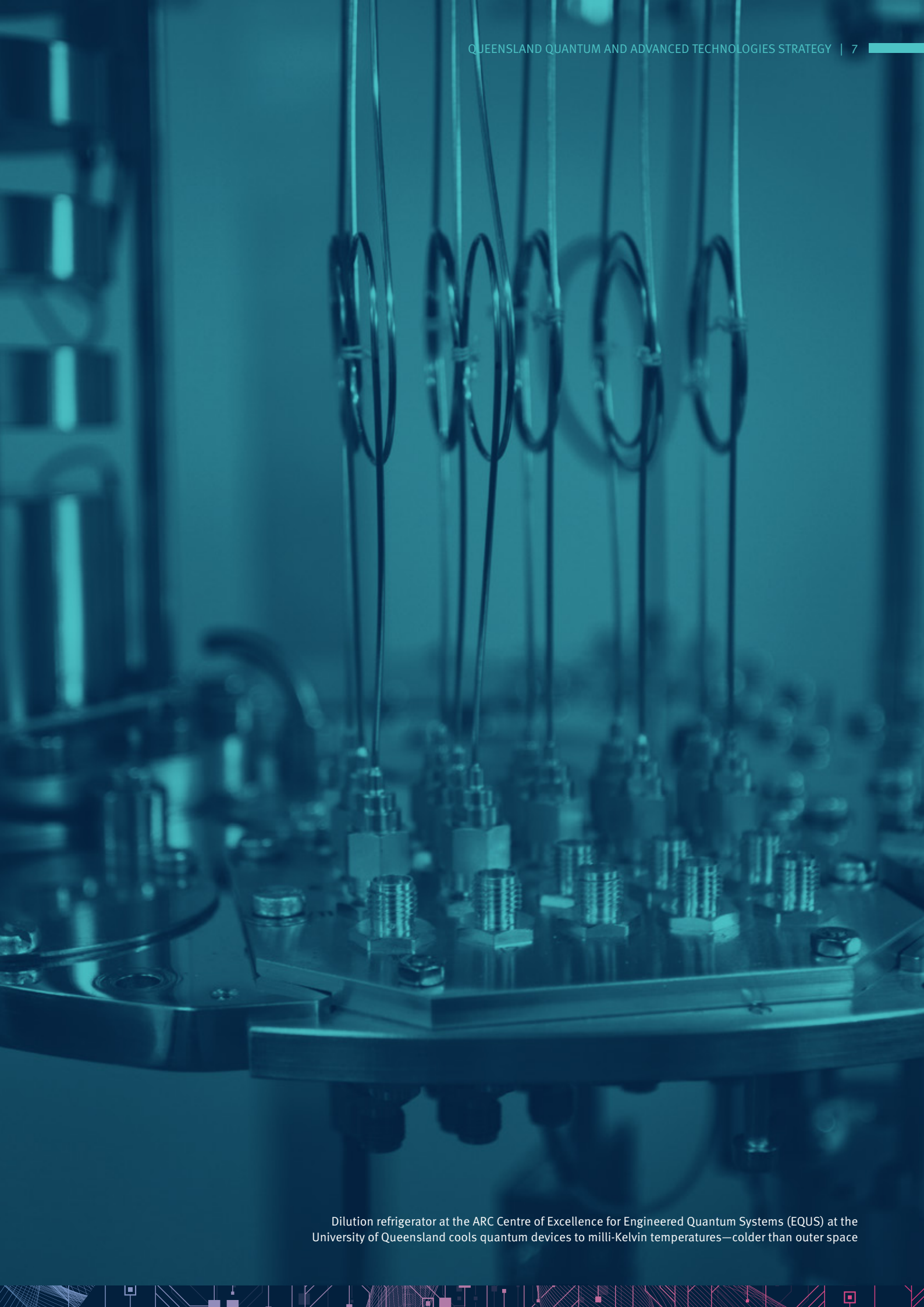
Quantum communication includes ultra-secure communication protocols such as Quantum Key Distribution and communication channels within and between quantum computers.

Additionally, **semiconductors** and **superconductors** are regarded as inherently quantum materials because their useful properties arise from the quantum behaviour of electrons.

The dominant semiconductor platform is silicon, but this is reaching the limits of its potential and the focus of semiconductor development is increasingly moving to **compound semiconductors** which are made of two or more elements, for example, Silicon Carbide and Gallium Nitride, which require advanced quantum physics and fabrication capabilities. The quantum properties of compound semiconductors open up a range of performance enhancements and new applications. The current global market for compound semiconductors is estimated to be around $46 billion, with a forecast growth rate of around 11% per annum[2]. Compound semiconductor products include power electronics, light-emitting diodes (LEDs), and communications technologies (such as 5G, radar, Internet of Things) for application in industry sectors such as renewable energy, information and communication technology, defence and aerospace, consumer electronics, healthcare and automotive.

Superconducting technologies are used in some types of quantum sensors and form the prevailing platform for quantum computing. Capability in superconductors enables Queensland to be a valuable player in these quantum supply chains (see the Analog Quantum Circuits case study).

1 Growing Australia's Quantum Technology Industry: Updated economic modelling, October 2022
2 Mordor Intelligence, Compound Semiconductor Market Size & Share Analysis - Growth Trends & Forecasts (2023 - 2028)



Dilution refrigerator at the ARC Centre of Excellence for Engineered Quantum Systems (EQUS) at the University of Queensland cools quantum devices to milli-Kelvin temperatures—colder than outer space

THE QUEENSLAND QUANTUM ADVANTAGE

The Queensland Quantum and Advanced Technologies Strategy builds on a range of key strengths that have been developed over more than 30 years of quantum-related science in the state.

World-leading quantum research programs

Queensland's quantum science base is both broad and deep, with world-class quantum theory and experiments. It covers a broad range of topics and technologies such as sensors and devices, learning machines, simulations, computing, thermodynamics, atom-optics, and biotechnology. Further, there is significant scientific activity in advanced technologies such as photonics, semiconductors, superconductors and micro-electromechanical systems (MEMS). In addition to these technical disciplines, Queensland researchers are also working to understand the social and behavioural aspects of the adoption of advanced technologies.

Queensland is at the centre of Australia's quantum industry. Queensland universities host the headquarters of two of the four national quantum-related ARC Centres of Excellence and have a significant presence in the other two.

Queensland: Front door to Quantum Australia	
EQUS Australian Research Council Centre of Excellence for Engineered Quantum Systems	**10 Chief Investigators in Qld:** quantum error correction, quantum computing architectures, characterising and modelling noise in quantum computer systems, quantum machine learning, integrated optics, e-beam lithography, cryogenics (including dilution refrigerators), design and fabrication of superconducting devices, quantum optics, quantum sensing and device packaging and testing.
CENTRE FOR QUANTUM COMPUTATION & COMMUNICATION TECHNOLOGY AUSTRALIAN RESEARCH COUNCIL CENTRE OF EXCELLENCE	**3 Chief Investigators in Qld:** quantum crytography, scalable photonic quantum computing, quantum memories and quantum communications.
FLEET ARC CENTRE OF EXCELLENCE IN FUTURE LOW-ENERGY ELECTRONICS TECHNOLOGIES	**1 Chief Investigator in Qld:** a collaboration of physicists, electrical engineers, chemists and material scientists from seven Australian universities developing ultra-low energy electronics aimed at reducing energy use in information technology.
QUBIC The Australian Research Council Centre of Excellence in Quantum Biotechnology	**6 Chief Investigators in Qld:** CQBT will target application areas for quantum computing, including pharmaceutical development, quantum simulation, catalysis modelling and optimisation, biological processes, and proteomics by mid-2025. Queensland will lead Australia's only quantum-focused Centre of Excellence.

Queensland also has a track record of producing global quantum leaders:

- Professor Gerard Milburn made the first proposal for a quantum gate in 1989 and is widely considered the founder of optical quantum computing
- Professor Andrew White demonstrated the first entangling quantum-logic gate in 2003
- Professor Howard Wiseman is one of the founders of quantum control
- Queensland has produced founders and leaders of quantum computing in Xanadu, PsiQuantum and IBM.

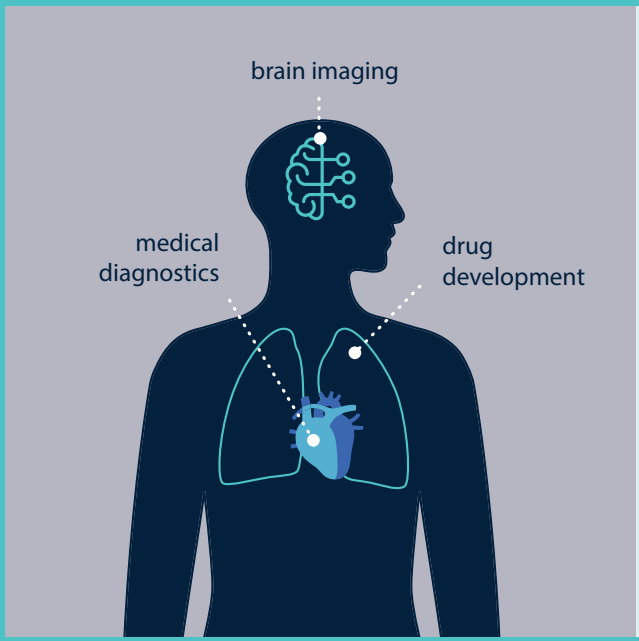
CASE STUDY:

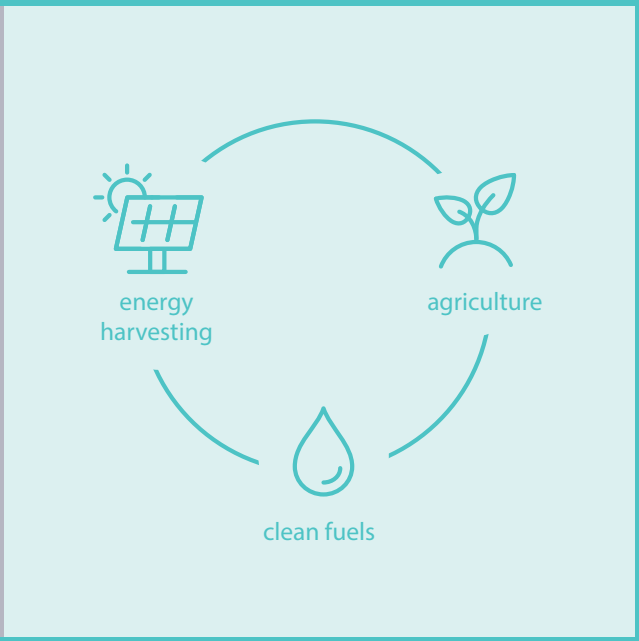
THE ARC CENTRE OF EXCELLENCE IN QUANTUM BIOTECHNOLOGY (QUBIC)

The bioeconomy is the largest predicted market for quantum technologies, where they are projected to have a multi-billion dollar impact on energy technologies, healthcare, pharmaceuticals and agriculture. However, this market is largely under-developed compared to other quantum technology markets. This presents a major opportunity for Queensland to lead the world at the convergence of quantum and biotechnology, and to secure the economic and social benefits that will accrue.

As a first stage to seize this opportunity, the Queensland Government has supported the establishment of the *Australian Research Council Centre of Excellence in Quantum Biotechnology (2023-2030)* (QUBIC), headquartered at The University of Queensland. This is the first nation-spanning centre in quantum biotechnology anywhere in the world. It will create a first-class Australian environment for pioneering research at the quantum-bio interface, with its core in Queensland and nodes in New South Wales, South Australia and Victoria.

QUBIC's mission is to lead the world in applying quantum physics to biotechnology, driving fundamental understanding and applications across a diverse range of fields including biomedical imaging, chemical design and clean energy. Its research program aims to develop quantum technologies that go far beyond what is possible today, from portable brain imagers to super-fast single protein sensors, and to use them to unravel key problems including how enzymes catalyse reactions and how higher brain function emerges from networks of neurons. QUBIC has partnerships with leading Australian and international universities and companies, such as MIT, Johns Hopkins, CSIRO, IBM and Olympus.





Professor Halina Rubinsztein-Dunlop, AO, FAA, FRSB at the Australian Research Council Centre of Excellence for Engineered Quantum Systems (EQUS) at The University of Queensland, is a pioneer of the field of optical micromanipulation

Collaborative, cutting-edge infrastructure

Accessible, state-of-the-art scientific infrastructure is a vital component of modern innovation ecosystems. It empowers academic and industry researchers, facilitates interdisciplinary collaboration and accelerates the translation of discoveries into new businesses and jobs.

Importantly, Queensland's universities work together under the **Queensland Major Research Infrastructure Alliance** to ensure that the state's major scientific facilities function as a shared resource.

Queensland's key quantum and advanced technologies infrastructure

The **Queensland Micro- and Nanotechnology Centre** at Griffith University has expertise in the fundamental theory of materials, materials development, microelectronics, micro electromechanical systems and microfluidics. The Queensland Microtechnology Facility within the Centre has $20 million of processing and characterisation equipment with a focus on compound semiconductors such as silicon carbide and gallium nitride, with application to power electronics, micro-electromechanical systems photonics and sensors.

The Queensland node of the **Australian National Fabrication Facility** has facilities for processes such as deposition, etching, lithography, cleanroom device fabrication and production of materials for microelectronics to semiconductor-industry standards.

The **Centre for Materials Science** at the Queensland University of Technology conducts advanced materials synthesis and characterisation, including semiconducting metal oxides, quantum dots, flexible semiconductors and organic semiconductors.

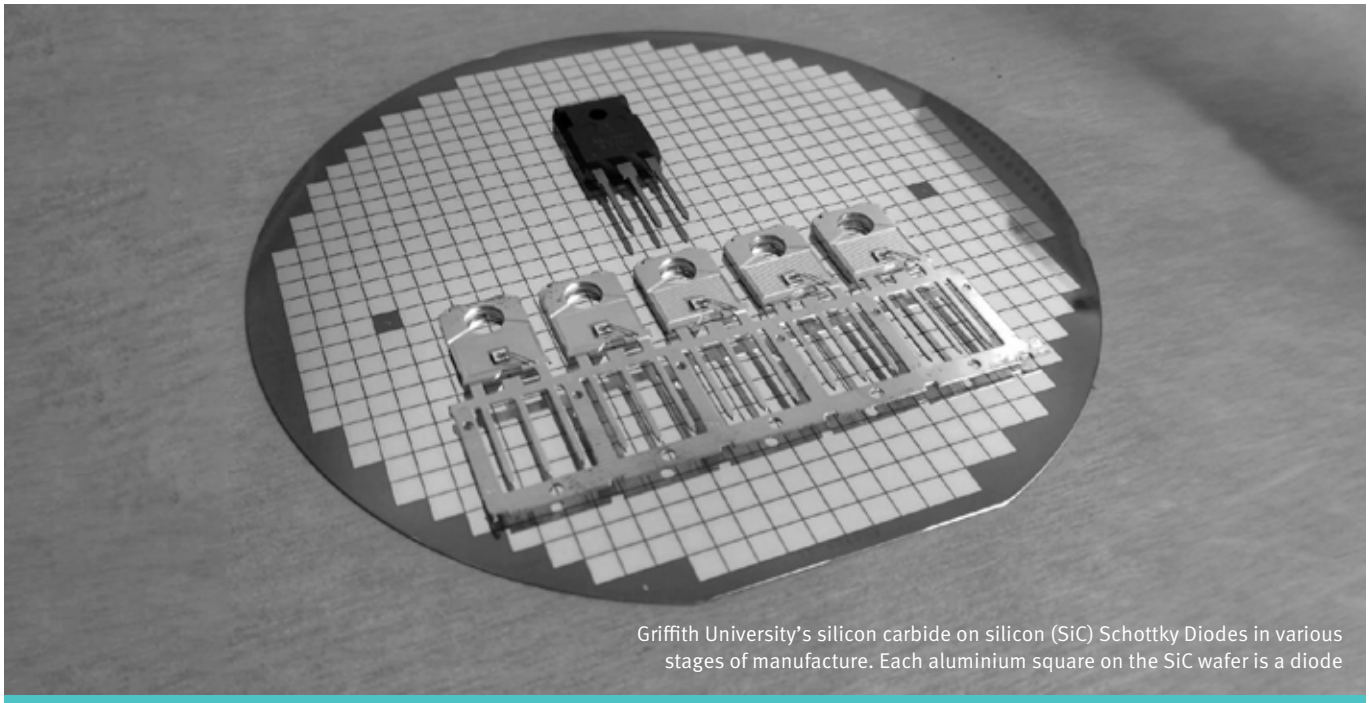
The **Central Analytical Research Facility** (CARF) at the Queensland University of Technology is a multi-campus facility that uses a wide range of established and experimental techniques to discover the composition, structure and function of molecules and materials and to develop new materials with enhanced properties.

The **Applied Superconductivity Laboratory** at the Queensland University of Technology has the capability to research, characterise and apply the fundamental properties of the new generations of high-temperature superconducting (HTS) material compounds with applications including power system devices, cryocooling devices and microwave communications.

The **Australian Institute of Bioengineering and Nanotechnology** at The University of Queensland has a focus on materials development and manufacturing, quantum circuits, quantum dots and quantum sensors with application to health, energy and the bioeconomy. The Institute's Nanomaterials Centre develops functional nanomaterials drawing on capabilities in chemical engineering, chemistry, electrochemistry, materials science and engineering, nanotechnology, catalysis, and materials chemistry and physics.

The **Centre for Organic Photonics and Electronics** (COPE) at The University of Queensland is an interdisciplinary physics and chemistry centre specialising in synthesis, materials and device characterisation, molecular modelling and condensed matter theory, photonics and electronics in organic materials.

The **Institute for Advanced Engineering and Space Sciences** (IAESS) at the University of Southern Queensland provides a dedicated facility for Space and Defence research with a focus on hypersonic propulsion systems, rockets, advanced materials and astrophysics. Housed at IAESS is the Centre for Future Materials, which works at a molecular level to develop a diverse range of advanced materials, including nanomaterials, polymers, metals and composites each having tailored properties and functions towards specific real-world applications.



Griffith University's silicon carbide on silicon (SiC) Schottky Diodes in various stages of manufacture. Each aluminium square on the SiC wafer is a diode

CASE STUDY:

COMMERCIAL SILICON CARBIDE POWER ELECTRONICS DEVICE PRODUCTION AT GRIFFITH UNIVERSITY

Silicon Carbide (SiC) is an example of a compound semiconductor, in that it consists of chemical elements from two or more different groups of the periodic table. It provides advantages in switching speed, efficiency and high temperature operation compared to conventional semiconductors such as silicon. This makes SiC ideal for power electronics applications such as electric vehicle power trains, inverters for solar and wind farms, fast chargers and uninterruptable power supplies. However, SiC devices are more challenging to develop and fabricate.

Researchers at the Queensland Microtechnology Facility (QMF) of the Queensland Micro-and Nanotechnology Centre (QMNC) at Griffith University have developed a new technology that allows for more efficient and low-cost fabrication of SiC components. The benefits of this new technology include more efficient energy conversion and reduced-size systems for applications such as battery-operated vehicles and renewable energy generation. QMF is the only facility in Australia that has proven capability in industry grade production of SiC power electronics devices. This innovative technology can support Australia's commitment to reduce greenhouse gas emissions and is an important step towards supporting sovereign capability in advanced manufacturing and critical technologies that are in the national interest.

A pilot production facility has been set up at QMF to develop and fabricate SiC-based semiconductors providing a great example of business-research collaboration where local manufacturers, universities and international businesses unite to fast-track commercialisation, design and manufacture of devices to meet local demand for applications such as EV battery chargers, drones, solar inverters, industrial motor drives, and high-frequency power converters.

Conventional SiC power electronics device manufacturing is complex and generally associated with high capital investment, but the technology developed by Griffith researchers uses steps that are common to standard silicon wafer processing, dramatically simplifying the manufacturing process and associated costs.

Workforce and talent pipeline

The workforce and talent pipeline plays a pivotal role in the development and advancement of quantum and advanced technologies. As the table below shows, Queensland has a strong supply of quantum and advanced technologies training and talent from undergraduate to post-doctoral level.

	Researchers	Postgrad students	Undergrads trained
Quantum physics	UQ, GU, QUT	UQ, GU	UQ, GU, QUT, UniSQ
Lasers and photonics	UQ, GU, QUT, UniSQ	QUT, UQ, GU, UniSQ	UQ, GU
Integrated optics	UQ, GU, QUT	UQ, GU	UQ, GU
Micro-fabrication and MEMS	CMM, ANFF, UQ, GU	UQ, GU	GU, UQ
Silicon photonics	UQ, GU	UQ, GU	UQ, GU
Test and measurement	CMM, ANFF, CARF	UQ, GU, UniSC	UQ, GU, QUT
Cryogenics and superconductors	UQ, GU, QUT	UQ, GU, QUT	UQ, QUT
Electronics design	UniSC, UQ, GU, QUT	UniSC, UQ, GU, QUT	UQ, GU, QUT
Robotics and automation	UQ, QUT, UniSC, ARM Hub	UQ, QUT, UniSQ, UniSC	UQ, QUT
Power systems and engineering	UQ, QUT	UQ, QUT	UQ, QUT, GU
Software and firmware	UQ, GU, QUT, UniSC	UQ, GU, QUT, UniSC	UQ, GU, QUT
Semiconductors	QUT, UQ, GU	QUT, UQ, GU	QUT, UQ, GU

Legend

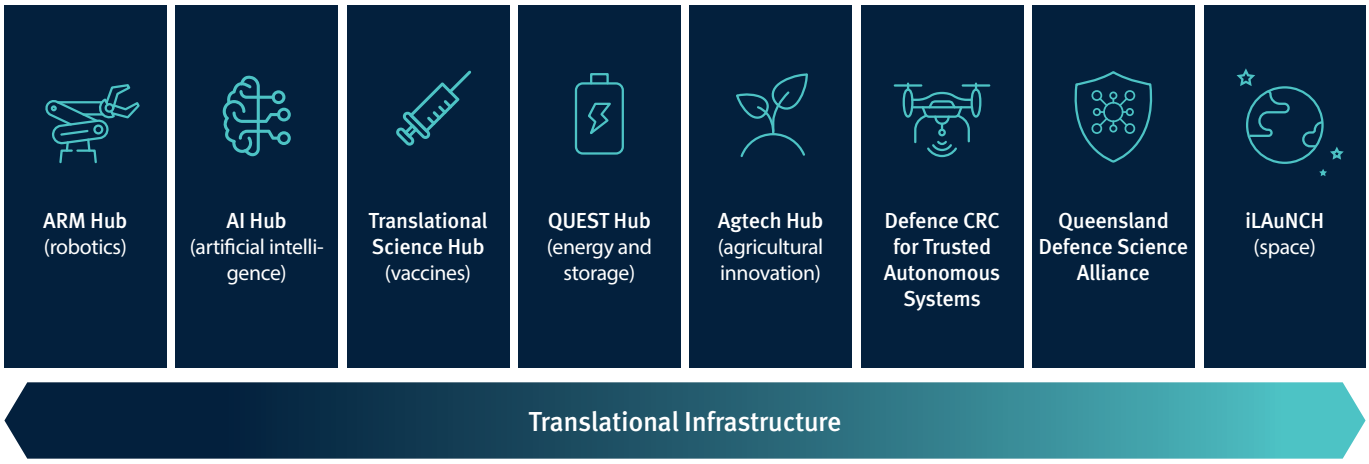
ANFF	Australian National Fabrication Facility
ARM Hub	Advanced Robotics for Manufacturing Hub
CARF	Central Analytical Research Facility
CMM	Centre for Microscopy and Microanalysis
GU	Griffith University
QUT	Queensland University of Technology
UniSC	University of the Sunshine Coast
UniSQ	University of Southern Queensland
UQ	The University of Queensland

Strong translational ecosystem connected to science-based industries

Queensland's innovation ecosystem is characterised by industry, research and government working together as 'Team Queensland' to grow new industries and support traditional industries, using innovation to gain a competitive edge. Key government strategies such as the Advance Queensland Industry Roadmaps and the Queensland New-Industry Development Strategy are underpinned by an exceptional translation capability that spans robotics, artificial intelligence, vaccines, defence technology and space.

The effectiveness of the Team Queensland approach is evidenced by the increasing number of homegrown and international deep tech companies choosing to locate in our state. For example, companies such as Silanna Semiconductor and Quest Semi (an affiliate of UK company Semefab) are both active in the fabrication of compound semiconductors for power electronics and photonics and now all have a presence in Queensland.

The Queensland Quantum and Advanced Technologies Strategy will reinforce these strengths and also connect the state to new supply chains, markets and companies.



THE QUEENSLAND QUANTUM AND ADVANCED TECHNOLOGIES STRATEGY

This Strategy aims to turn Queensland's quantum advantage into new trailblazing industries, companies and jobs. It provides a comprehensive approach to building a quantum research and commercialisation ecosystem that will be a magnet for talent and investment in the Indo-Pacific.

As discussed earlier, the Strategy's technology focus encompasses not only quantum, but also photonics, microelectromechanical systems (MEMS), superconductors, compound semiconductors and the testing, engineering and fabrication capabilities needed for prototyping and small batch production.

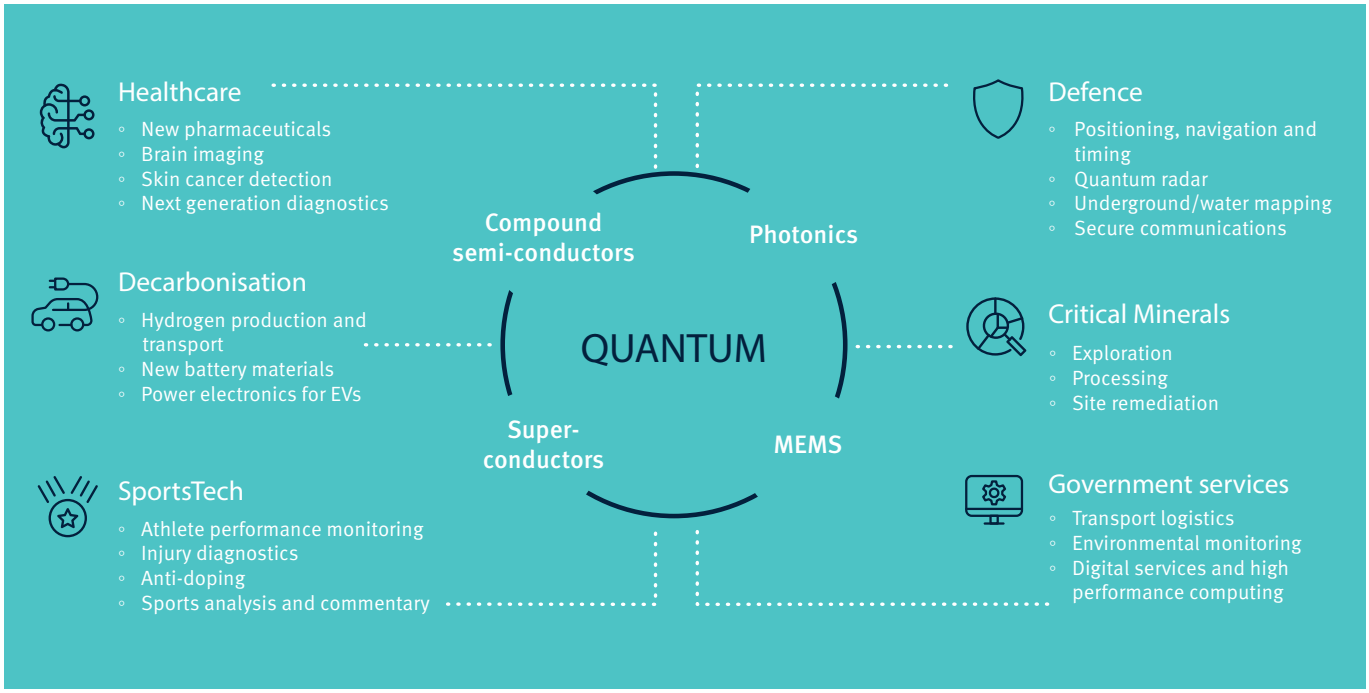
This strategic approach means that:

- all the capabilities needed to take new quantum products to market are in one place
- significant commonalities in manufacturing processes can be exploited
- each supporting technology also has its own distinct product and market opportunities
- common training and workforce requirements create the opportunity to build an integrated education and training framework across universities
- facilities can be organised and managed to suit the needs of industry.

Together, these technology groups open up a huge array of potential applications that will make a significant difference to the Queensland economy, the wellbeing of Queenslanders and the planet.

Example applications across a range of domains include:

- **Healthcare**—wearable microsensors for health conditions as developed by Brisbane company WearOptimo.
- **Decarbonisation**—using compound semiconductor technology developed at Griffith University, Brisbane company Quest Semi is manufacturing power electronics devices called Schottky diodes.
- **SportsTech**—quantum brain imaging for concussion diagnosis at The University of Queensland.
- **Defence**—the Australian Government's Defence Science and Technology Group has a STaR Shot project for Quantum-Assured Positioning, Navigation and Timing to overcome the current critical reliance on GPS.
- **Critical minerals**—a quantum sensing product already used in mining is the CSIRO-developed LANDTEM system which detects underground ore bodies.
- **Government services**—governments in Australia and overseas are using innovative procurement policies to investigate potential quantum solutions to problems such as public transport efficiency.



CASE STUDY:

QUANTUM BRAIN IMAGING FOR CONCUSSION DIAGNOSIS AND ASSESSMENT

Concussion in sport is a matter of growing community concern. While the majority of sport-related concussions are short lived, repeated head trauma is associated with increased risk of degenerative brain diseases.

Concussion is challenging to diagnose. With current clinical methods there is uncertainty about the severity of a given injury, the recovery time and when it is safe for the athlete to return to the field. Consequently, an "if in doubt, sit them out" policy is advocated widely.

Magnetoencephalography (MEG) is the best available clinical imaging tool for capturing functional changes in the brain. It not only fills a diagnostic gap, but also provides a pathway for more personalised and safer management of athletes who have suffered a concussion. However, the complexity of the necessary instrumentation means that MEG is only available in a few sophisticated facilities in Australia and requires the patient to remain still.

Researchers at the ARC Centre of Excellence in Quantum Biotechnology are developing quantum magnetic sensors which will revolutionise the accessibility of MEG, removing much of the complex instrumentation and allowing measurements on people who are in motion. Queensland and Australia have the multiple-domain-spanning expertise, infrastructure and industry needed to translate this new quantum technology into on-field quantum brain imaging systems.

Queensland has an unparalleled opportunity to showcase our quantum expertise at the Brisbane 2032 Olympic and Paralympic games and establish the state as a global leader in the application of deep science to real-world challenges.

The vision informing the Queensland Quantum and Advanced Technologies Strategy is:

Harnessing Queensland's expertise in quantum technologies for accelerated economic growth and transformative solutions.

Underpinning this vision are the five pillars of the Strategy:

Deep science capability—the price of entry to the quantum economy is excellent science and it is vitally important that our leadership position in quantum science is maintained.

Science commercialisation—the complex nature of deep technologies such as quantum means that we need entrepreneurial scientists to create new companies and take them forward, supported by mentoring and venture capital.

Quantum workforce—in a climate of intense global competition for talent, we must train home-grown talent, attract talent from external sources, and increase the participation of women and other underrepresented groups in quantum.

Engagement and missions—Queensland end-user industries and government agencies have the opportunity to be global leaders by becoming 'quantum ready' and learning how to deploy quantum and advanced technologies for maximum impact.

Investment—national and global pools of capital for deep tech venture investment are increasing and Queensland is also benefiting from Australia's position in the AUKUS Alliance, which has raised our attractiveness among companies and investors looking for an Indo-Pacific base—we can leverage these developments to grow the Queensland quantum ecosystem.

The Queensland Quantum and Advanced Technologies Strategy complements the broad national effort to build Australia's sovereign capability in quantum technologies. On 3 May 2023, the Australian Government released the National Quantum Strategy to provide a national framework for sector growth and investment attraction and will continue to implement actions under the strategy over the next seven years.

Key Australian Government initiatives announced to date include:

- The National Quantum Collaboration Initiative to enhance national collaboration and interconnection in workforce development across Australia's quantum ecosystem.
- The $19.8 million Australian Centre for Quantum Growth to support development of a quantum technology industry in Australia.
- The $40.2 million Critical Technologies Challenges Program (with quantum being the initial focus) to address challenges of national significance using quantum technologies.
- A Quantum Workforce report including modelling to identify workforce and educational needs for our quantum sector and adjacent industries.

The Queensland Government will continue to work closely with the Australian Government and the other States and Territories to build a vibrant and cohesive national quantum ecosystem.

Equipment at the Surface Science Laboratory at the Central Analytical Research Facility of Queensland University of Technology

Queensland Quantum and Advanced Technologies Strategy

Vision

Harnessing Queensland's expertise in quantum technologies for accelerated economic growth and transformative solutions

Strengths

- Home to four national quantum-related Centres of Excellence
- Highly skilled advanced technologies workforce with world class teaching and research higher degree programs
- Strong ecosystem of emerging and traditional science-based industries
- Complementary strengths in semiconductors, materials, robotics, and nanotechnology
- Network of industry-facing advanced fabrication and materials facilities
- Geographic proximity to the high-growth Indo-Pacific region

Opportunities

- Support scientist entrepreneurs
- Engagement of deep science capabilities in societal challenges
- Improve commercialisation skills and access to venture capital
- Increase industry understanding of quantum technologies
- Raise Queensland's international profile in deep technologies
- Access rapidly expanding global markets for sensors and power electronics

Pillar 1
Deep science capability

Maintain Queensland's leadership position in quantum science

- Support the establishment of the ARC Centre of Excellence for Quantum Biotechnology
- Support bids into federal research and infrastructure programs supporting quantum and advanced technologies
- Support international science collaboration with priority partners

Pillar 2
Science commercialisation

Grow the quantum and advanced technologies commercialisation pipeline

- Harness joined-up, industry-facing R&D infrastructure to turn discoveries into products
- Create a supportive ecosystem for quantum and advanced technologies startups
- Leverage external sources of commercialisation skilling, grants and venture funding
- Support high-potential companies to manufacture at commercial scale

Pillar 3
Quantum workforce

Train, attract and retain the skilled people needed for a quantum ecosystem

- Work with state and federal agencies to map and build scientific and technical skills
- Work with the schools sector to strengthen diversity and student awareness relevant to quantum-related employment pathways
- Support entrepreneurial early career researchers, especially women and other underrepresented groups

Pillar 4
Engagement and missions

Become adept at using deep science to solve Queensland's challenges

- Build 'quantum readiness' across Queensland industries
- Connect quantum and related capabilities to key Queensland challenges such as decarbonisation and the Olympics
- Explore applications for quantum government services

Pillar 5
Investment

Attract external investment into the Queensland quantum ecosystem

- Build Queensland's reputation as the best ecosystem in the Indo-Pacific for quantum, semiconductors and deep tech
- Attract overseas quantum and advanced technologies companies and investors to locate in Queensland
- Connect Queensland companies into global quantum markets and supply chains

Research by Associate Professor Josh Lipton Duffin uses an ultra-high vacuum scanning probe microscope (UHV-SPM) at the Centre for Material Science at Queensland University of Technology

PILLAR 1: DEEP SCIENCE CAPABILITY

Deep science capability is the backbone of quantum innovation. It empowers researchers to understand quantum phenomena, design novel quantum technologies, and overcome technical challenges. Investments in quantum and related science over a long period by the Queensland and Australian Governments mean that Queensland now has a quantum capability that is rare in global terms. Maintaining our leadership position in quantum science will keep Queensland at the forefront of quantum innovation.

What's required

- Reinforce Queensland's status as a strong force in Australian quantum science.
- Support quantum initiatives that complement other Queensland science strengths.
- Build science collaborations with priority partners.

What the Queensland Government will do

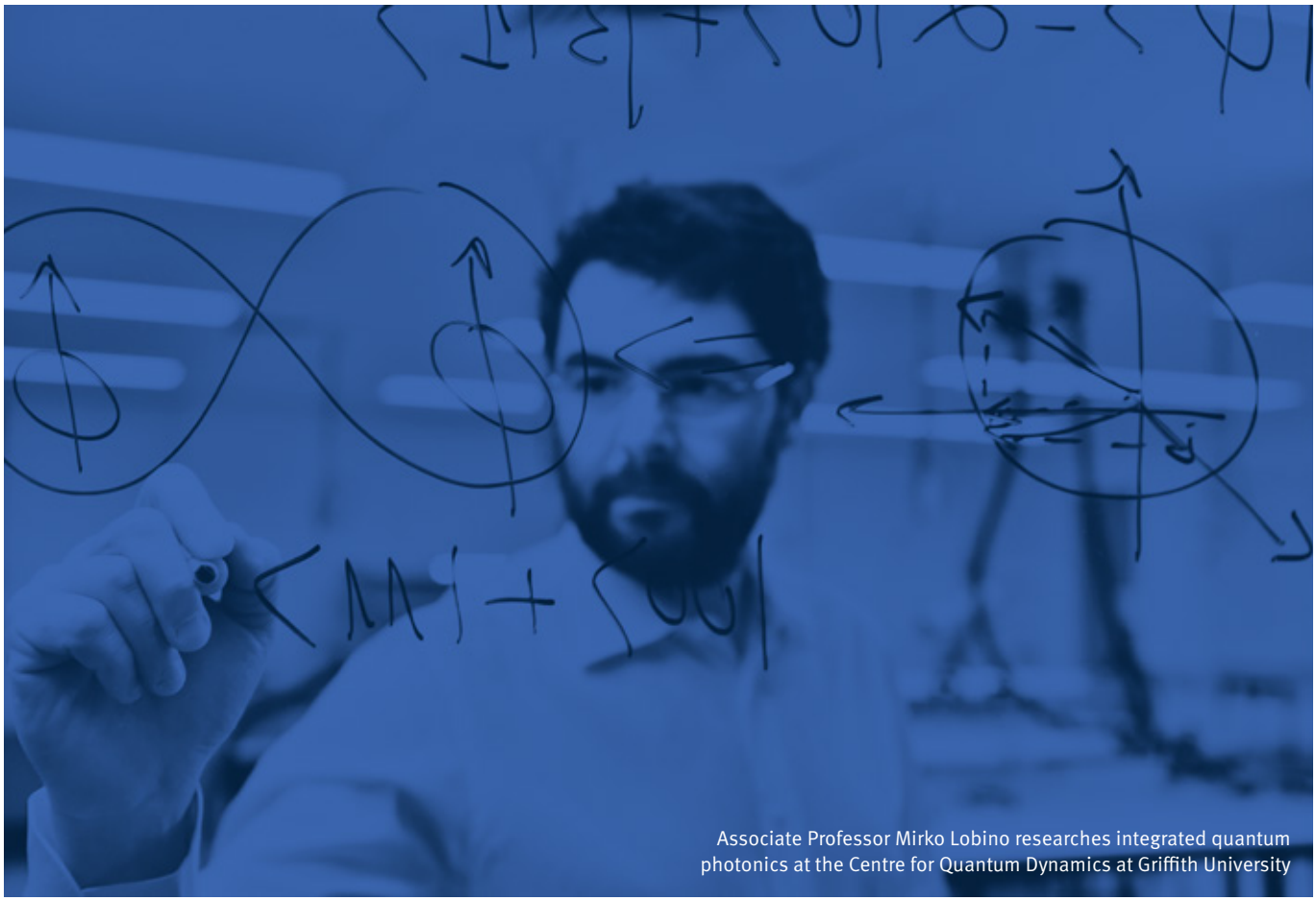
- Work with the university sector to enhance the competitiveness of Queensland bids into federal quantum programs.
- Support the establishment of the ARC Centre of Excellence for Quantum Biotechnology.
- Continue to strengthen ties with Australia's partners in AUKUS and the Quad.

New quantum-specific programs

- **ARC Centre of Excellence for Quantum Biotechnology**—$900,000 over three years (from the Science Into Industry initiative).
- $20 million **Quantum and Advanced Technologies Co-investment Program** (refer also to Pillar 5).

Related programs

- Research Infrastructure Co-investment Fund (RICF) (Department of Environment and Science)—attracts cutting-edge scientific infrastructure under the National Collaborative Research Infrastructure Strategy, with a key example being the Queensland node of the Australian National Fabrication Facility.
- Science into Industry Initiative ($17 million) (Department of Environment and Science)—aims to make Queensland's science sector more competitive by accelerating the translation of research and development, supporting universities and research institutes to partner with industry to build new products and services, and increasing Queensland's share of Australian Government funded industry-science programs.
- International Science Agreements (Department of Environment and Science)—with government entities in the United States of America, India, Germany and China.



Associate Professor Mirko Lobino researches integrated quantum photonics at the Centre for Quantum Dynamics at Griffith University

PILLAR 2: SCIENCE COMMERCIALISATION

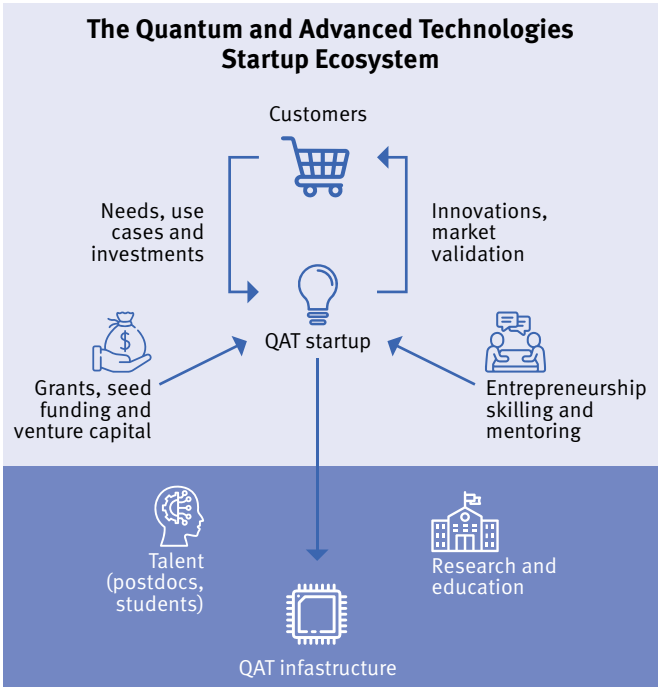
Innovations emerging from deep science require scientific expertise along the commercialisation pathway, which often relies on scientist inventors being supported to develop and lead startup companies all the way to market. A feature of the quantum landscape is a very ambitious startup sector which is taking on technological challenges that in the past might only have been attempted through large government-led initiatives—such as the challenge of building the first useful-scale quantum computer.

Historically, the Australian university and venture capital ecosystem hasn't supported science-based ('deep tech') startups, preferring to focus on better-established commercialisation pathways in the life sciences and information technology. This has meant that ambitious deep tech startups have needed to move offshore to locations such as Silicon Valley. More recently however, the local and global venture capital community is starting to embrace deep tech—but for Queensland to benefit from this trend we need our universities to adopt a 'founder friendly' approach to commercialisation.

During consultation for this Strategy, stakeholders identified two key requirements:

Access to scientific infrastructure on reasonable terms–this is critical for deep tech startups who typically need to iterate through multiple rounds of research, prototyping, testing and small batch production for field trials. Infrastructure access charges in excess of marginal cost can rapidly deplete seed funding, causing development delays while startups try to find new sources of funds. The Australian National Fabrication Facility (part of the National Collaborative Research Infrastructure Strategy and supported by the Queensland Government's Research Infrastructure Co-investment Fund) provides a good model of infrastructure access that should be adopted, wherever possible, to foster industry and startup R&D.

Timely access to intellectual property on reasonable terms–in the Australian research system, universities are granted ownership of intellectual property (IP) emerging from publicly funded research. The universities then make decisions about the terms under which their IP is licensed or assigned to existing companies and startups. For cases where scientist founders wish to create a startup around the IP, venture capital companies stress the importance of the founder (rather than the university) holding a large proportion of the company's equity. Additionally, it is important that the IP is not tied up in administrative or legal processes for long periods of time.



A core initiative under this pillar is the Queensland Quantum Foundry, which will provide a supportive environment for scientist entrepreneurs including access to a network of quantum and advanced technologies infrastructure to turn their inventions into engineered products across quantum, photonics, MEMS, superconductors, and compound semiconductors.

A combination of best-practice startup support and accessible, industry-grade testing and fabrication infrastructure will position Queensland as the best location in the Indo-Pacific for companies developing quantum and advanced technologies innovations. Even within Australia there is an extensive bank of IP waiting for the prototyping and fabrication capabilities that this Strategy will help deliver.

In addition to the Queensland Quantum Foundry, there is a need to support the state's unique quantum biotechnology capability with a specialised translation facility. Queensland has long been at the forefront of biotechnology, beginning with the genomics revolution and more recently mRNA, where the state's capabilities were key to attracting the $280 million Sanofi Translational Science Hub. The next step in the evolution of biotechnology is *quantum* biotechnology. However, quantum labs are incompatible with most bioscience activities, and bioscience labs are incompatible with most quantum technologies. This creates a major barrier for translation. The Quantum Bioinnovator will overcome this obstacle by providing industry-facing quantum biotechnology laboratory space, scientific infrastructure, collaboration spaces and startup spaces.

What's required

- Joined-up, industry-accessible science and fabrication infrastructure for quantum, photonics, MEMS, superconductors, and compound semiconductors.
- Augmenting Queensland's strengths in biotechnology with quantum capabilities.
- Support for scientist entrepreneurs.
- Connections to seed and venture funding.

What the Queensland Government will do

- Work with Queensland universities and industry to ensure advanced testing and fabrication infrastructure is optimised to support commercialisation.
- Support a startup-focused quantum and advanced technologies incubator that supports scientist entrepreneurs and provides ready access to intellectual property and prototyping facilities.
- Support a translation capability around quantum biotechnology.
- Work with Queensland universities to strengthen support for deep tech startups.
- Engage deep tech venture funds on becoming part of the Queensland ecosystem.

New quantum-specific programs

- **$5 million Queensland Quantum Foundry** to support a quantum and advanced technologies incubator to foster science-led startup company development and scale-up.
- **$10 million Quantum Bioinnovator** to translate quantum biotechnologies into biomedical and bioeconomy applications.
- **$20 million Commercialisation Infrastructure Program** for co-investment alongside the Australian Government, universities and industry in testing and fabrication infrastructure to support prototyping and small batch production of quantum and advanced technology devices.
- See also the $3 million Innovation PhD program under Pillar 3.

Related programs

- Advance Queensland (AQ) (Department of Tourism, Innovation and Sport)—Queensland's quantum researchers have access to a range of support programs to commercialise their technologies through the AQ initiative. AQ programs and services that quantum researchers can access include:
  - Industry Research Fellowships—supporting researchers partnering with industry to complete original research that will positively impact the translation of research outcomes into practical application.
  - Industry Research Projects—a new AQ program supporting researchers and industry to collaborate and translate research outcomes into commercialisation opportunities.
  - Ignite Ideas—supporting early-stage innovative businesses that have high-growth potential to commercialise highly innovative and new products or services that are at minimum viable product stage or beyond.
  - Ignite+—launched in 2023, Ignite+ provides founders with the opportunity to engage in bespoke and tailored business support programs to expand their commercial skills. Participation is by invitation-only, engaging companies that have received AQ funding or taken part in an AQ program.
  - Private Sector Pathways program—creating commercial opportunities for innovative Queensland businesses by connecting them to corporates and providing a risk-managed process to explore and co-fund solutions to corporate challenges.
- The Queensland Investment Corporation's Queensland Venture Capital Development Fund seeks to accelerate, develop and enhance the venture capital industry in Queensland. By providing matched funding, accelerator funding and a development program, the fund will help to attract more investment into early-stage businesses, create more high-value jobs and boost the state's economy.
- Australian Government programs such as Australia's Economic Accelerator, Australian Centre for Quantum Growth, Industry Growth Program and National Reconstruction Fund.
- Research Infrastructure Co-investment Fund (Department of Environment and Science)—refer to Pillar 1.

CASE STUDY:

ANALOG QUANTUM CIRCUITS

Analog Quantum Circuits (AQC) is Queensland's first quantum technology startup, based on research by Professor Tom Stace and Associate Professor Arkady Fedorov in the ARC Centre of Excellence in Engineered Quantum Systems. In 2023, AQC was awarded The University of Queensland's Startup of the Year.

AQC is using microelectronics manufacturing techniques to design and build integrated superconducting circuits for microwave signal routing in quantum computers. The components that AQC is developing, including microwave circulators and amplifiers, are based on superconducting electronics. This is the leading hardware platform for quantum computing, being developed by IBM, Google, Amazon Web Services and others globally.

AQC's miniaturised superconducting circuits provide the interface between the quantum computer and the external controls that make the quantum components work. Practical quantum computers will need these interface components fabricated "on-chip", as miniaturised arrays of millions of components, integrated adjacent to the quantum processor itself. AQC's goal is to provide this capability in an integrated superconducting circuit.

AQC secured substantial seed funding in 2022 to develop its technology and has research partnerships with The University of Queensland and Griffith University. The development of advanced quantum technology, and associated manufacturing processes, is critical to enabling Australia's technological sovereignty in this sector, both as an AUKUS partner and as a technology provider to other major economies.

Carbon fibre composite research using a robotic double carrier braiding machine at the Centre for Future Materials the University of Southern Queensland

PILLAR 3: QUANTUM WORKFORCE

The quantum economy relies on a skilled quantum and advanced technologies workforce. Increased activity and investment across the world is placing a high premium on advanced technology skills. Our challenge is to give Queenslanders from all backgrounds the skills needed to gain access to the considerable emerging employment opportunities in quantum and related industries.

Consultation for this Strategy revealed a need to focus not only on the scientist workforce, but also the technical workforce needed to run quantum and advanced technologies facilities. Vocational Education and Training (VET) was identified as critical to this, providing direct pathways into technical jobs and as a bridge to tertiary study.

The Good people. Good Jobs. Queensland Workforce Strategy 2022-2032 (QWS), is the Queensland Government's first whole-of-government workforce strategy and provides the framework for growing STEM and advanced trade skills. Since its release in August 2022, significant progress has been made in achieving its vision of a strong and diverse workforce ready to seize today's jobs and adapt to future opportunities. The Strategy is supported by a $70 million investment in new and expanded initiatives that build on the Queensland Government's $1.2 billion annual investment in skills and training programs. In particular, TAFE Queensland is experienced at developing and delivering skills and workforce development strategies for new and emerging industries as well as creating new recruitment pathways for entry level and skilled workers into emerging industries.

Equity and Excellence: Realising the potential of every student outlines the Queensland Government's vision for a progressive, high-performing education system that realises the potential of every student. Schools of the future: A strategy for STEM in Queensland state schools aims to lift teacher capability, student engagement and student performance in science, technology, engineering and mathematics (STEM), including initiatives to support the participation of girls and Aboriginal and Torres Strait Islander students in STEM learning and pathways.

What's required

- Build the pipeline of early career quantum researchers developing new technologies.
- Increase the representation of women in quantum.
- Understand the current supply of quantum and related technical skills.
- Increase awareness of employment opportunities in quantum, physics and related technical occupations.

What the Queensland Government will do

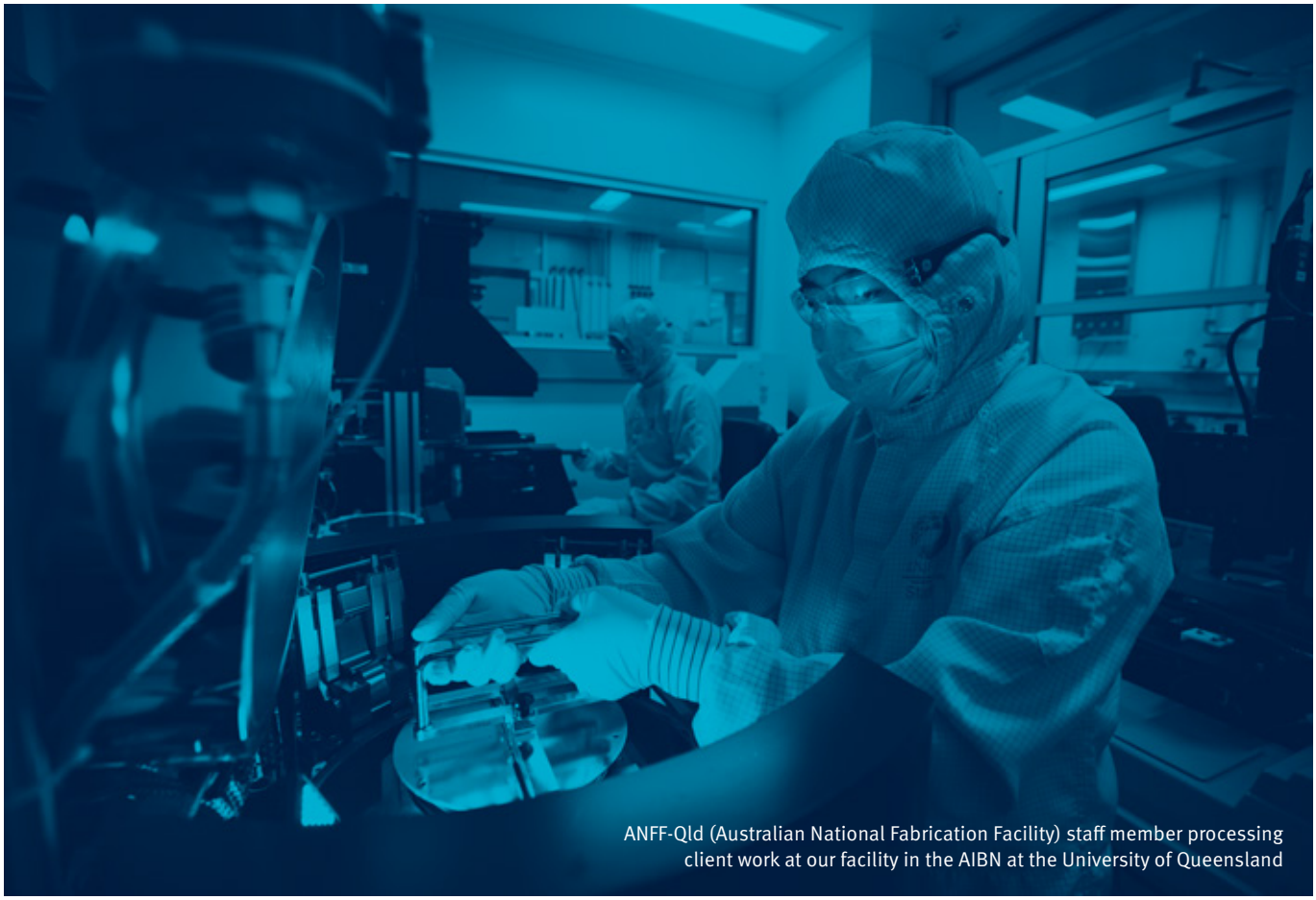
- Work with universities on strategies to support entrepreneurial early career researchers and attract women and other underrepresented groups in quantum and related disciplines.
- Work with universities and TAFE under the Queensland Workforce Strategy to understand and build the technical skill base for quantum and advanced technologies.
- Support the Australian Government's quantum workforce study and the National Quantum Collaboration Initiative.
- Work with the schools sector to strengthen diversity and student awareness relevant to quantum-related employment opportunities and pathways.

New quantum-specific programs

- **$3 million Innovation PhD program** to attract and retain talented prospective scientist-founders with top-up stipends and commercialisation mentoring and skilling, with a support component for women's participation in quantum-related disciplines (including support for women re-entering the workforce).
- **$1 million Stem Education and Employment Pathways program** to support the development of resources and approaches to encourage quantum-related employment and study through schools, vocational education and training, and tertiary education.

Related programs

- Queensland Workforce Strategy (Department of Youth Justice, Employment, Small Business and Training) and associated actions and programs.
- Engaging Queenslanders in Science Strategy (Office of the Queensland Chief Scientist) which includes the Queensland Women in STEM Prize.
- Accelerating Female Founders Program (Department of Tourism, Innovation and Sport) funds business support initiatives that foster a pipeline of innovative Queensland female founders, for every stage of their business and innovation journey.
- Australian Government initiatives such as the Quantum Workforce study and the National Quantum Collaboration Initiative.
- Equity and Excellence: Realising the potential of every student (Department of Education).
- Schools of the future: A strategy for STEM in Queensland state schools (Department of Education) including the STEM Girl Power Initiative.



ANFF-Qld (Australian National Fabrication Facility) staff member processing client work at our facility in the AIBN at the University of Queensland

PILLAR 4: ENGAGEMENT AND MISSIONS

As the world witnesses the rapid evolution of quantum technologies, businesses face a pivotal choice: to become ‘quantum ready’ or risk falling behind in a highly competitive landscape. Quantum readiness refers to a business’s preparedness to harness the potential of quantum computing, communication and sensing for its advantage. By engaging with quantum technologies now, businesses and industries can pre-empt potential disruptions and be well-positioned to capitalise on emerging opportunities.

Quantum readiness also includes planning for the likely cybersecurity impacts of quantum computing. It is anticipated that quantum computers will eventually compromise the main data encryption methods currently in use. Businesses and governments need to understand their levels of exposure to this risk and take appropriate action.

There are also opportunities for government in enhancing service delivery and in actively engaging deep science as a policy tool for addressing Queensland's challenges and opportunities. As a society, we need to become better organised to 'pull' solutions from the science base.

What's required

- Increased business and government awareness of the potential of quantum technologies.
- Ability to readily engage local quantum experts in business problems.
- Identification and development of transformative quantum and technology solutions to societal challenges.

What the Queensland Government will do

- Raise quantum readiness through events and communications, including post-quantum cybersecurity risks.
- Support development of an effective quantum engagement process for industries and government agencies.
- Promote the use of approaches such as innovation procurement, technology roadmapping and venture science to help address major challenges and opportunities.
- Support the Australian Government's forthcoming Australian Centre for Quantum Growth and Critical Technologies Challenge Program.
- Leverage Defence and other advanced customers as early adopters of quantum technologies.

New quantum-specific programs

- **$10 million Quantum Decarbonisation Mission** to solve critical decarbonisation challenges with quantum technologies.
- **$5 million Quantum Olympics Challenge** to showcase Queensland quantum technologies during the Brisbane 2032 Olympic and Paralympic Games.
- **$2 million Quantum Readiness Program** for the development of events and other mechanisms to promote quantum preparedness and uptake across industry and government.

Related programs

- Technology translation hubs (Department of Tourism, Innovation and Sport), including the Advanced Robotics for Manufacturing (ARM) Hub, AI Hub, XR Hub and Agtech and Logistics Hub.
- Queensland Decarbonisation Knowledge Translation Hub (Department of Environment and Science) providing a coordinating mechanism for scientific input into Queensland's transformation to a decarbonised economy.
- Queensland Defence Science Alliance (QDSA) (Department of Environment and Science and Department of State Development, Infrastructure, Local Government and Planning) a university-led initiative funded by the Queensland Government, the Australian Government's Defence Science and Technology Group and member universities with the aim of connecting the best minds from academia, industry and Defence to focus on Defence and National Security Priorities and accelerate the delivery of capability to the Australian Defence Force.
- Australian Government programs such as the Critical Technologies Challenge Program and the Australian Army's Quantum Technology Challenge.

Quantum physicist Dr Nora Tischler specialises in optical information science at the Centre for Quantum Dynamics at Griffith University

PILLAR 5: INVESTMENT

Queensland's success in building a quantum ecosystem critically depends on how effectively we promote the state's quantum advantages and engage with overseas markets, investors and talent.

Quantum is a global industry that is strategically important for sovereign capability and national security which creates both challenges and opportunities. A key opportunity for Queensland is to attract companies that might already have a presence in the United States of America and/or the United Kingdom and are seeking an Indo-Pacific base. Australia's status as an AUKUS partner is a key advantage that differentiates us from other Indo-Pacific locations.

The $150 million Queensland Trade and Investment Strategy 2022–2032 is positioning the state to help trade-orientated businesses adapt, thrive and grow, including targeted actions and initiatives to leverage international opportunities, drive diversity and value, create more jobs across traditional and priority industries, and champion enduring worldwide success. Enabling and innovative technologies are a key priority under the Strategy, including quantum, robotics, artificial intelligence and sportstech.

What's required

- Overseas promotion of Queensland's strengths in quantum and semiconductors.
- Attraction of quantum and semiconductor companies to locate their R&D, manufacturing and services in Queensland.
- Positioning Queensland companies in global quantum and semiconductor supply chains.

What the Queensland Government will do

- Identify new products and markets for Queensland's semiconductor capabilities.
- Showcase Queensland's quantum and advanced technologies capabilities internationally.
- Target key overseas quantum and semiconductor companies and venture capital firms to become part of the Queensland ecosystem.
- Support home-grown Queensland companies to connect with global supply chain opportunities.

New quantum-specific programs

- **$20 million Quantum and Advanced Technologies Co-investment Program** to co-invest in relevant science and translation initiatives alongside the Australian Government and other funders.

Related programs

- aQtivate (Trade and Investment Queensland) offers short term access to office space, lab facilities and business support services, and introductions to assist international companies to establish themselves in Queensland to service the Australian and wider Indo-Pacific market.
- The $100 million Business Investment Fund (BIF) (Queensland Investment Corporation) is dedicated to making direct investment in Queensland business and industry, including international companies looking to establish a substantial footprint in Queensland.
- The Investment Support Scheme (Queensland Treasury) is a rebate program for payroll tax and other state-managed taxes, designed to incentivise international and interstate businesses with proven capability to invest in Queensland through a transfer or expansion of operations.

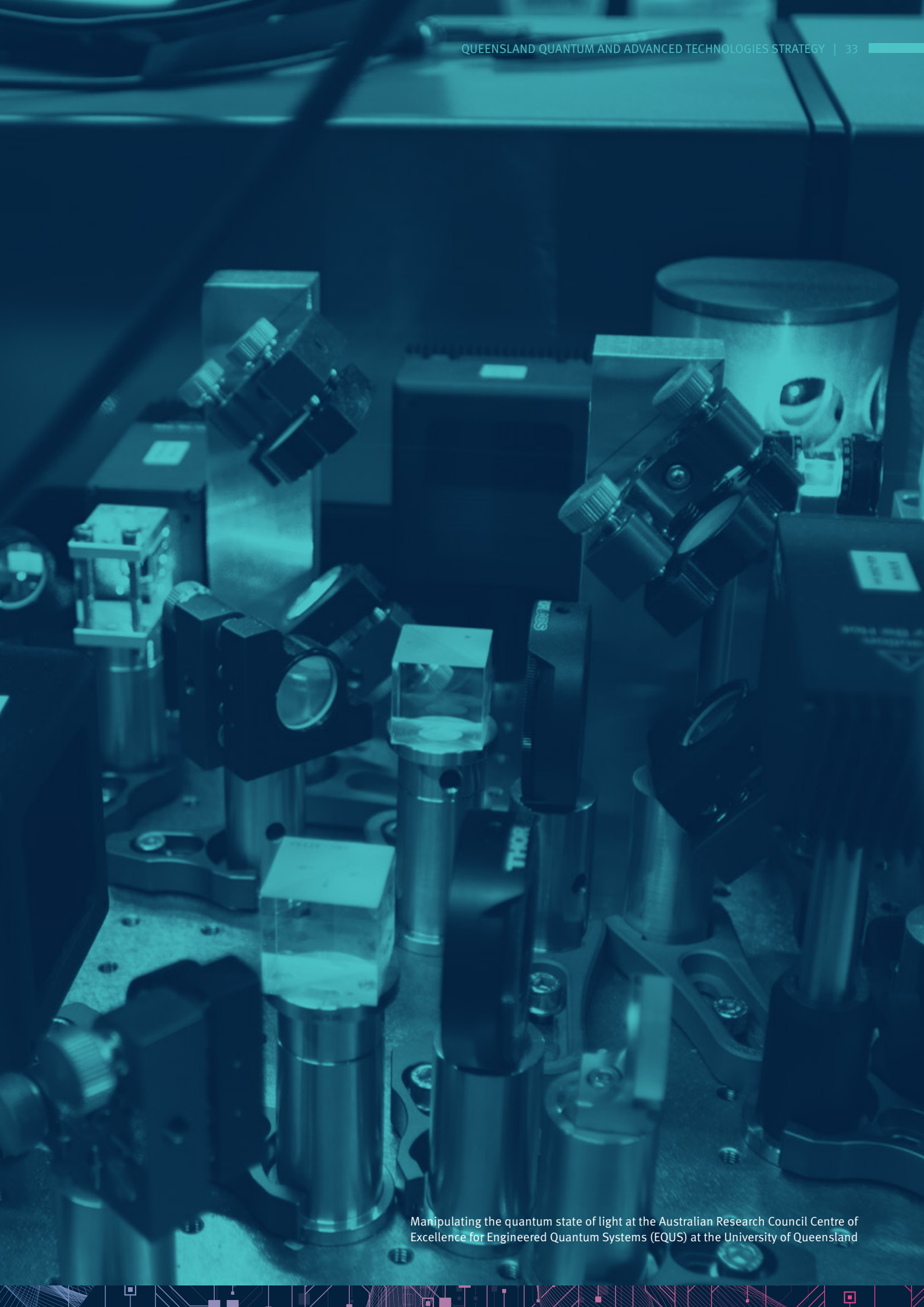
GOVERNANCE AND COORDINATION

To help deliver on the Queensland Quantum and Advanced Technologies Strategy and grow our quantum economy, an advisory council, Quantum Innovation Queensland (QIQ) will be established, led by the Queensland Chief Scientist. QIQ will include representation from universities, venture capital, quantum companies and Queensland Government agencies such as the Department of Environment and Science; Department of State Development, Infrastructure, Local Government and Planning; and Trade and Investment Queensland.

QIQ will be tasked with advising on program design and monitoring progress and outcomes of the Queensland Quantum and Advanced Technologies Strategy. It will also have a broader remit to provide strategic advice on developing the quantum ecosystem which will be particularly important given the pace with which the quantum sector is developing.

Specifically, it is intended that QIQ will:

- position Queensland as a source of expertise in, and leader of, quantum technologies on the global stage
- bring together expertise in research, commercialisation and use of quantum technologies to help chart Queensland's quantum technology future
- ensure Queensland is well placed to take advantage of national programs to support quantum industries
- push to coordinate Queensland's quantum and advanced technologies capabilities across research, industry and government and intervene to remove any impediments to ecosystem development
- showcase ecosystem outcomes and success
- develop key performance indicators and an outcomes framework for the Queensland Quantum and Advanced Technologies Strategy and monitor achievement against them.



Manipulating the quantum state of light at the Australian Research Council Centre of Excellence for Engineered Quantum Systems (EQUS) at the University of Queensland