I'd like to acknowledge the many lands we're all coming from today, in this highly international space.

I am speaking on the traditional lands of the ***Gadigal*** people of the ***Eora*** nation. I pay my respects to them and to the traditional custodians of other lands where audience members are based.

I acknowledge the elders who are caring for those lands. I pay my respects to the old ones who have come before and the young ones who will follow.

Today I want to talk to you about building quantum industry coherence. It's great to be here speaking to you at Quantum Australia 2022, because things in quantum are really taking off. You can imagine my surprise last weekend reading a media article that suggested there isn't a lot happening in this space, when in reality, I have had to keep changing my presentation as I am seeing things changing daily!

I am seeing evidence of an acceleration in research breakthrough, new applications, new businesses and new investments for all aspects of Quantum.

It's not often that the Prime Minister of Australia talks physics – especially quantum physics. But on the 17th of November last year, our Prime Minister did, announcing a plan to develop a National Quantum Strategy for Australia.

With quantum being a key focus of my own scientific background I was really pleased to be tasked with guiding this work to support the Australian Government – building on the quantum industry roadmap I helped to spearhead in 2020.

Imagine if we can build a strong, sustainable and globally competitive quantum industry here in Australia. This is in Australia's national interest. It can support our economic prosperity, social cohesion and our national security.

So today I want to talk about three things: the case for changing the mix of our economy and where quantum fits into this, quantum applications and its pervasive impact, and what we need to do to make this happen – an update on where we are up to on the National Quantum Strategy and what I need you to do to support the Strategy development.

Let's start with a quick history. Australia has moved from the gold rush days to riding on the sheep's back and most recently mining.

This has led to incredible prosperity for our nation with decades of economic growth. However, if we look at our exports, it's highly dependent on mining, services and agriculture – areas that are sensitive to change. For example, the pandemic and global financial crises have shown that service based economic sectors, such as higher education and tourism are

very vulnerable. Mining is no longer being thought of as just digging the ground, instead it will become a recycling practice by 2050. BHP will therefore become Australia's biggest recycling company. As for agriculture, we really don't know what climate change will bring to that.

When we look at our exports, they are not as complex as they appear to be. Although this is an old piece of data from 2008, it shows the general gist. When you look at our GDP against the complexity of our economy, you can see we're lower [than we would like to be]. This is not because of our work being crumby and not having the innovation we need – our agriculture and mining industries are absolutely world leading – but the things we produce are not then added onto in complexity.

So to combat this, Australia has a renewed-focus on knowledge-based industries. These industries have been identified as the driver of the Australian economy – low emissions tech, pharmaceuticals, AI and automation.

As a result, we're seeing a move towards digital technologies, which are driving the economy – and quantum is going to be part of this. The government is very committed to being in the top 10 digital economies in the world by 2030 – a date not far away. In the most recent budget, it committed $1.2 billion to its Digital Economy Strategy.

In December last year, a further $124 million investment was announced to support the Artificial Intelligence Action Plan and a commitment of $111 million to support Australia being a leader in quantum technologies.

Digital and emerging technologies like quantum and AI will become an increasingly important driver of success for all Australian businesses and sectors. The tech sector is worth $167 billion per year in Australia. Already, we have 1 in 16 workers in the digital space. We can see the sector has grown 66% since 2005. By 2030, we expect that more of our GDP will be coming from tech industries, as opposed to Primary Industries and manufacturing.

So why Quantum now?

Now is a moment in time where we have a chance to see acceleration on what we [already] have today.

Basic research in quantum has been happening globally for a long time, and is now reaching a level of maturity. We are now at the point of taking quantum breakthroughs out of the lab and into real-world applications – we are seeing this begin to happen already. And these new quantum technologies will improve our lives in many ways.

For example, unlike classical computers, quantum computers can perform multiple operations simultaneously. This gives them a unique capability for modelling systems with many interacting parts.

Companies are already developing software for quantum computers to model biological molecules and chemical reactions which are too complex to be simulated on classical computers.

This work promises breakthroughs such as greatly speeding up pharmaceutical development, designing new catalysts for more environmentally friendly batteries, or better modelling weather events.

Here are some concrete examples of what is happening now in other areas of quantum.

Quantum Batteries – Researchers at the University of Adelaide are developing quantum batteries, potentially a whole new class of energy storage devices. Quantum batteries take advantage of quantum mechanics principals and can reduce their charging time the bigger they get.

Quantum Microscopes – Researchers at the University of Queensland have created a quantum microscope that reveals biological structures otherwise impossible to see. Current light microscopes use lasers and fragile biological systems can only survive these for a short time. A quantum microscope can view biological structures without destroying the biological system, with reports of up to 35% improved clarity over traditional light microscopes.

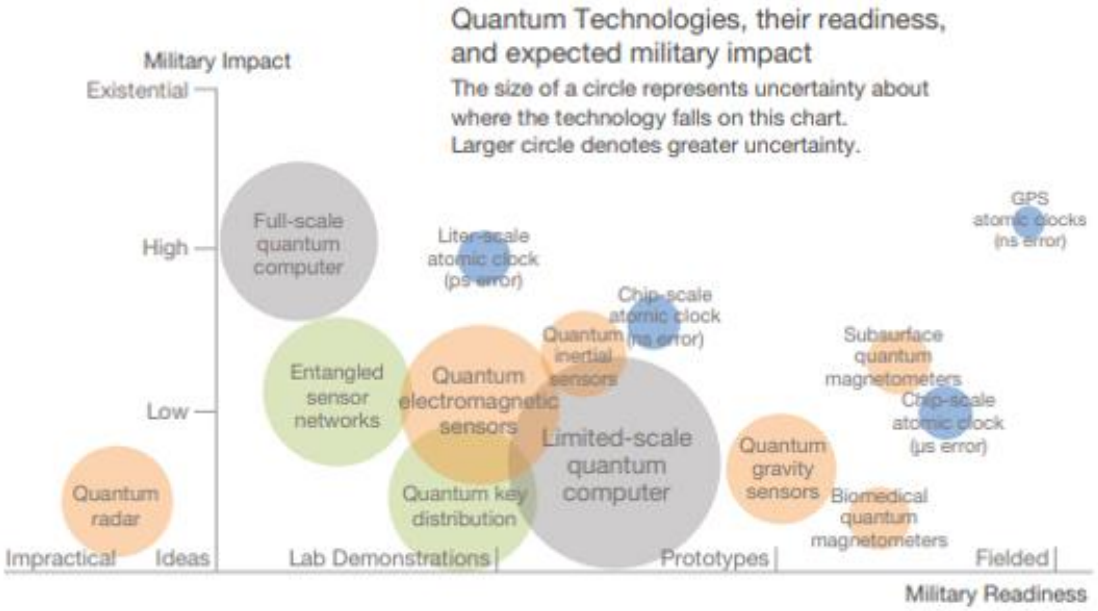
Quantum Powered Financial Systems – Quantum computers, and the algorithms they use, are uniquely suited to improving investment returns; helping investors determine what to invest in, how much to invest, and when to invest. Financial services company BBVA (a Spanish multinational) has experimented with using quantum computing to optimize portfolios with a given risk profile, finding the right combination of assets to maximise returns while minimising risk. They are also exploring the potential of quantum computing to develop new credit scoring algorithms to deal with the increasing size of the datasets, which could provide faster and more accurate credit decisions for customers.

Quantum Sensors for Mining and Construction - Quantum gravity sensors and magnetometer are being developed that will be more sensitive and faster than existing sensors used in mining or construction industries. This could help find ore deposits more quickly, while in cities this could reduce the cost of construction and excavation. An example from my own research is CSIRO's LandTEM system (a portable magnetic sensor for detection of deep mineral deposits).

We're talking about a whole new range of technologies, and the thing is, they're not all readily available. What we're seeing, though – and this is something that came out in a report released at the end of last year from the US to their congress – is that we should be looking at the defence space. The x-axis of this graph is the technology readiness availability, the y-axis is the impact. As is evident in this graph, there are a range of technologies useful to defence that can be transferred into other areas in time as well. You can see that they're

all the different stages, from quantum radar that is a nice glint in the eye, through to GPS which we all know and love.

Summary of Military Readiness and Impact of Various Quantum Technologies



SOURCE: Provided to RAND by the Office of the Undersecretary of Defense for Research and Engineering.
NOTE: This chart updates a previous version published in the Fiscal Year 2020 Industrial Capabilities Report to Congress, 2021.

Australia has great research and definitely performs at a much higher level than expected for the size of our population. You have to remember, Australia is only 0.3% of the world's population.

When I looked at Australia's quantum research when I led the development of the CSIRO Quantum Roadmap in 2018, Australia ranked 14th globally by quantum research output, 10th by Normalised Citation Index and was cited 60% more than the global average. We've seen that our numbers, our quality research, continues to impress. But we have areas where I think there is still room to improve. We are ranked 46th by relative specialisation, and the focus on quantum research is 27% below the global average.

Australia has been working on quantum for several decades and has a long history of quantum research.

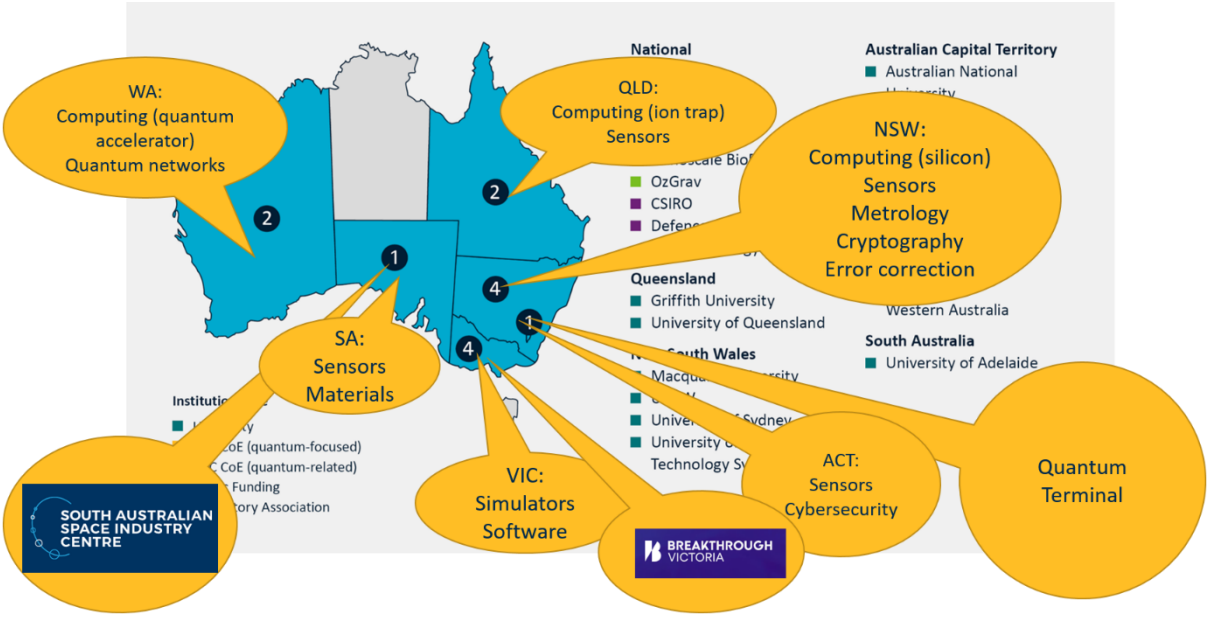
- 1960s – Jim Zimmerman invented the super-conducting quantum interference device. The National Measurement Institute has been really critical in the use of superconductors, which are the first states of macroscopic quantum effects that allowed us to do things like create Josephson voltage standard in the 70s.
- 1970s – Josephson voltage standard was developed. Tens of thousands of devices which NIST (USA - National Institute of Standards and Technology) now leads – makes sure our voltage is a voltage.

- 1980s – Calculable capacitor, which uses SQUIDs and superconducting bowtie antennas for radio astronomy, and magnetoencephalography, which looks at the magnetic fields that come from the brain, were both being developed at this time.
- 1990s – We saw here my own research area in High Temperature Superconducting devices getting to a point where they're commercial. The foundry continues doing amazing research today.
- 2000s – It was here that we saw quantum really take off in the university sector, with Bruce Kane QC coming up with the idea of having a phosphorus atom in silicon to create a quantum computer (Qubit). Bob Clarke set up the first Centre of Excellence (ARC), he had the meeting in 2000 at the Convention Centre – I remember being at that. ARC has been refunded two times, now led by Michelle Simmons, and seen the spin out of others such as the EQUS Centre of Excellence which was led by Jerry Milbourn, who was spearheading quantum photonics – and is now led by Andrew White.

Now we have a number of strengths in Australia – to name a few, cyber key distribution, magnetic sensing, phosphorus in silicon, qubits, error correction, timekeeping quantum clocks and quantum simulation.

You can see we've got an extraordinary list of research organisations that contribute to the world-leading research happening across the country. Australian jurisdictions are making major contributions. Centres of Excellence have proven to be amazing ways for bringing cohorts together for these rich collaborations – both nationally and internationally.
Looking at the Australian states and territories, and the strengths they have across them, we've had input from Chief Scientists and Science Advisors in each [jurisdiction] that help put this figure together. Therefore, if there are some inaccuracies you notice here, go to your Chief Scientists and Science Advisors and get this corrected.
Australia's quantum activities:

- Queensland – Computing (ion trap) and sensors is their main focus.
- Western Australia – Computing with quantum accelerators on high performance computers as well as quantum networks.
- South Australia – Sensors and materials.
- New South Wales – There is a lot happening here – silicon based quantum computers, sensors, metrology, cryptology, error correction.
- Victoria – Simulators and software.
- ACT – Sensors and cybersecurity, and I've added 'communications' as that wasn't noted on this graph.



We are seeing the willingness of these jurisdictions, and the Chief Scientist of all the states and territories, saying we want to have a fundamental agreement to work across all the stakeholders and have a coordinated quantum sector approach with industry as well as the research sector.

There's good work happening across the country, but the nature of the close proximity of the universities in Sydney is particularly telling – University of Sydney, UTS, UNSW, Macquarie, CSIRO, ANSTO and DST. So we are seeing that the clustering of universities is extremely beneficial to support joint initiatives.

The Quantum Terminal provides a centralised collaboration space for NSW, and it builds upon the strength of these collaborations and it will promote our potential internationally.

South Australia has a Space Industry Centre with a major quantum focus, and Q-CTRL has been established here as well. Victoria has announced their breakthrough Victoria fund, which they're planning to invest in quantum with.

It's not only quantum research blooming in Australia, it's quantum partnerships and investments – both of which are growing by the day!

Already, Australia has:

- Established itself as a leader in quantum research.
- Attracted major multinational companies, including IBM, Microsoft and Google, to invest here in Australia.
- Grown an impressive number of quantum start-ups and businesses.
- Trained world-class quantum scientists and engineers through our world-class universities – 11 were ranked as performing quantum physics research above world standard.
- Demonstrated its commitment to quantum through impressive research and commercialisation initiatives across our States and Territories.

Australia is well-positioned to engage and be part of this global opportunity. As I have said, there are so many start-ups now – it's hard to keep track of them – which tells us something really great about the confidence and optimism that surrounds this sector in Australia. But there is room for many more, and we are committed to making Australia an attractive place to start and grow your quantum business.

I'm looking forward to further progressing development of the National Quantum Strategy throughout 2022. Having a National Quantum Strategy will be crucial to developing and growing a sustainable, coordinated and thriving quantum ecosystem.

We need to get everyone within Australia's quantum sector united behind the same vision – working together for a common goal.

We do however, face the challenge of a rapidly changing landscape. We need to adapt, and be responsive to these changes so that we can best support our quantum industry. With this in mind, we will not be developing a linear response.

The Strategy will not be developed in isolation and I need your help to achieve this. There will be multiple opportunities to provide input into the development of the Strategy and I hope I can rely on you, this wonderful community, to assist me in these processes. Building a quantum industry requires us to be brave. There are many uncertainties. It is not like building a single product, process or service.

It involves many industries, sectors, technologies and applications, it includes materials, products and supply chains – and this makes uptake more complex.

Australia has strong foundations for a quantum industry, to build the ecosystem we need all parts of the community working together towards a common vision. This means industry, government, states and territories and the research sector all pulling in the same direction.

We have the advantage of starting with a clean sheet so we can design an industry that is fit for the future *(I don't want to take the Canadian Quantum Strategy and just cross out Canada and write Australia).*

So how do we build an industry?

Firstly, Australia's quantum industry needs to be industry led. We don't want competition to hinder cooperation – we want to build an organised and coordinated industry that will attract talent and investment and be globally competitive. We need to set the direction for skills, supply chains, and regulation.

Finally, we need to take action. Total money invested is less important than having a joint vision that everyone is working towards.

There's a lot to be done, but it's important to emphasise that we have a head start. With

impressive research outputs, numerous quantum start-ups, world-class research centres and tremendous talent, we are well-positioned to be a global leader in quantum technology. This has been my 'go to' explanation in the past on how industry should work together. It's not quite as linear as this diagram suggests, but the premise remains. *How do we fill in the gaps and encourage collaboration from discovery through to the commercialisation of products?*

To realise the enormous potential, we are building bridges. Along with areas of expertise pulling together, understanding that we are within a global paradigm, we're also seeing a concerted and coordinated pull to bring the full spectrum of stakeholders from research, industry, governments and start-ups together.

Research and its translation requires a whole-of-ecosystem approach – true co-design and development between both federal and state governments, industry and researchers.

Success will not be defined by the actions of one institution, but by the collective efforts and collaboration of a strong network. This is where there is potential to make improvements.

There are 4 key things that we need to get right:

- Keep supporting fundamental research – Human curiosity has brought us a long way so far and will continue to lead the way to new discoveries
- Quantum needs to be demystified
- We need to get the social licence right, and
- Getting the regulatory preparedness right is crucial.

It is important to remember that science will not do this alone. It's not just Quantum mechanics. Rather it is what I call 'Science PLUS'. Science and research are the first steps. But we also need all the other pieces of the puzzle.
This means:

- Engineering – We take science into an engineering process and outcome.
- Design and user interface – We have to engage with the designers and the humanities, arts and social sciences.
- Social licence
- The right Business model – We need to have the right business model which is critical and I think we're seeing a bit of this now with businesses making the early stage quantum computers accessible via the Cloud.
- Marketing – In order to let people know what is upcoming.
- Policy and regulation

This means we must take a holistic approach. As such, the National Quantum Strategy will focus on three key areas:

- Research
- Investment, commercialisation and supply chains
- Skills, societal Impacts, and diversity.

I will go into a bit more detail on each of these three areas in the coming slides.

With Australia's significant head start in quantum research, we're well-placed to grow our research capacity. As we do this, our research must focus on being high quality and focussed on relevant areas. Everything we do must be guided by high standards of research integrity.

The National Quantum Strategy will provide this direction, which will help Australia capitalise on our research strengths. International partnerships will be key to this.

The Strategy will identify priority areas for investment. What we choose to prioritise now will have enormous consequences for the future of our quantum industry. Investment and commercialisation activities must be targeted – we cannot spread ourselves too thin.

We need to establish and leverage international partnerships that will allow us to share skills and infrastructure, while supporting supply chains and market-access to quantum businesses.

The Strategy will also identify the actions that can be taken – by all players – in order to make Australia an attractive place for businesses and talent to invest in quantum.

It will be important to understand the role of government, industry and the research sector and who takes the risk and when.

Global investment in quantum is growing rapidly.

Let's begin with start-ups, and have a look at some old data from 2010-2020 that captured disclosed investment in quantum start-ups from around the world.

We can see that investment in quantum start-ups has increased rapidly in the last decade. In 2020, investment in quantum tech start-ups reached $479 million – and that was just in the first 6 months of that year.

And these numbers only include disclosed deals, meaning the actual amount invested in start-ups is likely to be much higher. The majority of this investment has been in quantum computing (hardware).

Next I want to look at the total market. As you might expect, the global quantum computing technologies market has also been experiencing rapid growth.

It was estimated to be worth just over $390.7 million in 2021 and is forecasted to reach an impressive $1.6 billion by 2026. This represents a compound annual growth rate of just over 33.2% (and I have heard some estimates that are even higher than this).

We all know there is a race globally for a quantum edge. We see that in competition for

talent and the contest of ideas.

Competition is good, but collaboration – particularly with likeminded countries – will drive commercialisation of quantum research and help Australian businesses access new markets and drive investment.

The transformative potential of quantum technologies means we can't treat it as a typical industry. There are many sectoral interests and applications.

We all understand that quantum is a dual use technology and it is in our national interest to both maximise the opportunity and mitigate the risk.

This is a nascent industry and Australia is small. If we have the ambition to be a major global player in this technology then participating in international partnerships and multilateral forums will play an important role. This includes shaping international standards that reflect our values and priorities, as well as the development of a targeted investment approach.

We want the quantum community to embrace the full human potential. The Strategy will provide direction to ensure that our quantum skills and education offerings must be accessible, and encourage diversity within our industry and research community.

The benefits of quantum technology should be shared. We have enormous potential to do good by applying quantum technologies in many areas of our lives, and everyone should benefit.

Based on what we've talked about so far, one of the key issues is developing the skills we need for our quantum future.

For Australia to realise the potential of our quantum industry, we are going to need more workers with the skills to do quantum programming. And to achieve that, we need to look along the whole education pipeline, from primary school to the workforce.

We need a quantum ready workforce with programming and digital skills supported by the right technology.

It is important to address STEM career pathways. To increase support for workers in STEM and make the industry more accessible for all. And lastly, to bridge the gaps between research and industry so that people can more easily move between sectors.

However, we know that students can fall behind and lose interest in mathematics in primary school, that the number of secondary school students choosing to take physics and higher maths subjects continues to fall, and that there is a lack of representation of women and other diverse groups in most STEM tertiary courses.

In 2021 the number of students in NSW studying physics dropped from around 9000 to 8000. Physics HSC numbers are the canary in coal mine – we need to turn this around – this is a parallel piece of work as we build a quantum industry.

We need to work hard to address these barriers to creating the STEM workforce that Australia needs. To inspire children to study these subjects and to show them the possibilities.

We also need to access our full human potential. We need to be inclusive, Australia's talent pool is limited by the underrepresentation of half of Australia's population – girls and women – in STEM education and careers.

We've laid our scientific foundations and we have the history… but from here on, we need a collaborative approach – and we're cultivating it as we speak. Having worked in this area for so long, my vision is an industry that is significant, organised and globally competitive.

For Australia to capitalise on our long established expertise in this area, we need to present a united and coordinated international presence – a cohesive Australian quantum industry.

Developing a National Quantum Strategy is about putting our best foot forward.

What has been done so far:

- The Department of Industry, Science, Energy and Resources has established a team that will be leading the consultation and preparation of the Strategy with me.
- The first international partnership on quantum between Australia and the United States is now in place and other negotiations have commenced with other countries.
- An extensive research process to investigate current and future gaps and opportunities in Australia's quantum sector has commenced.
- The team is building its stakeholder outreach nationally with governments, industry and the broader community, and;
- An Issues Paper is currently in development and I look forward to receiving your contributions in response to it.

Quantum is going to create a thriving industry in Australia that supports and drives innovation. Over the coming years there will be multiple opportunities to engage in the Strategy development process. My ask of you is to take those opportunities and let's continue working together.

Thank you very much.