Australian Government

Chief Scientist

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QUANTUM AUSTRALIA CONFERENCE

Quantum in action

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I want to start by acknowledging the traditional custodians of the land on which we meet, the lands of the Gadigal people.

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.

Thank you for your welcome. I’m very pleased to be here.

This conference reinforces my sense that our community is full of energy and activity.

I’m pleased to see that the various parts of our quantum ecosystem are coming together, and the Sydney Quantum Academy is playing a critical role.

This is the way to bring wide expertise to the challenges that remain, and build the scale required in the quantum space.

You all have your own areas of focus, but you’ve come together to share insights and advance our collective goal.

It’s great to see.

For me, quantum feels like a long journey. An odyssey! Decades of work, punctuated by flurries of activity.

As many of you know, I’ve been doing battle in the lab with quantum effects for close on 40 years. It hasn’t all been smooth sailing.

When I was working on the Josephson junction, we had such a tough time getting reproduceable critical currents. The spread was too wide, and we couldn’t get them all working at the specific values we needed.

We knew the device worked, but until we could get that reproducibility, we couldn’t crank the handle to scale up and make multiple devices.

That wasn’t a period of exciting science. I remember it as a slog. Tough, fiddly work to unpack all of the fabrication processes, every aspect of the design, to figure out the parameters and get it all working the way we needed it to.

One foot in front of the other.

But we got there with the Josephson junction, and ever since it's been a source of professional fascination to me to watch the progression of quantum science.

We worked to make a single nanostructured device for years from the 1990s to the 2010s.

And it's been mindboggling to see the shift in capability to the point where we can make hundreds of thousands of junctions on a single chip.

And that was for a macroscopic quantum device which had a nanostructured engineered grain boundary.

At the same time, a new wave of quantum research was set in train with advances in nanotechnology and the ability to manipulate matter at really small scales.

And here we are in 2023.

Quantum has entered the lexicon, not just for people working in the area, and for fans of Marvel movies.

Quantum is on the radar of governments, investors and forward-thinking businesses, who understand how transformative it will be in so many areas.

Quantum technologies are already impacting medicine through better imaging.

They're changing our ability to see through barriers, into structures, into geological formations, as well as into cells.

Quantum optimisation is already making a difference in freight and logistics.

Tomorrow, I understand you have the Minister speaking to you.

I don't think it's stealing his thunder to tell you that the Government is very cognisant of the transformative potential of quantum technologies, as well as the need to ensure we make the most of this moment.

This isn't unique to Australia.

Governments of advanced economies around the world are focused on the potential of quantum.

So we're certainly in a good place.

We don't have people worrying about whether we're going to create mini black holes that will grow to swallow the world like the poor scientists at CERN.

We're not struggling against entrenched positions, as the climate scientists did in the not-too-distant past.

Those of you in quantum research, those of you working to nut out some of the tricky problems that remain, those of you working to commercialise quantum applications – I know your challenges are significant and your work is hard. This is difficult science right at the edge of human capability, but I also know we're in the sweet spot.

This is the part of the odyssey where we should feel optimistic and energised.

We have excellent foundations, built on decades of patient fundamental research funded by government.

We have a lively research community and an energetic set of start-ups and multinationals working on some really novel ideas and applications.

We have momentum and we have cut through among decision-makers.

So we want to capitalise on that, and ensure Australia remains a world leader in quantum expertise and clever innovations.

As you know, I've been leading the development of a National Quantum Strategy on behalf of the Minister. Many of you provided valuable input and feedback and I thank you again for that.

The draft strategy is now before Government, so I'm not going to talk about it today.

Suffice to say that it is designed to ensure we remain at the forefront of this technology as things move quickly.

What I do want to do today is to shift the conversation.

As I said, we’ve had great success in explaining to decision-makers and others why quantum needs their attention.

Now we need to widen the conversation, so that educators, businesses and researchers in other disciplines understand how their new technologies will impact what they do.

I’ve talked before about the need to add the language of quantum to our kids’ backpacks, so they’re learning about quantum science and concepts from the get-go.

Kids have no problem being in two places at once! They will get this faster than we did.

We are even reading our babies books on quantum physics!

Education is always the starting point.

But we’re not progressing quantum in a linear fashion.

At the same time as we teach young people the science, quantum needs to be on the radar of industry sectors and researchers outside the immediate quantum disciplines.

We’re living the quantum revolution as we speak, and it’s important that the broader community understands that.

If you’re in a business that handles data, the security issues are not something for the medium-term to-do list. They’re for attention now, to ensure data can’t be harvested today for future decryption.

If you use data in your research, you need to be thinking about interoperability and also how current platforms that combine classical and quantum computing will impact your research.

You need to be ambitious and think well beyond the ways you have considered data in the past.

If you’re solving computationally large problems, you’ll be able to do it faster, and with lower energy consumption.

If you're in any sector that requires super precise measurements, or need to make decisions where time is everything, then you should be thinking about whether this can help you.

People who work in finance, in mining and mapping, in measurement, in the transport and logistics sector – these are the first cabs off the rank.

But none of us can present the full dance card of quantum applications.

This is a task for each sector to consider. And you in industry need to be taking action now.

I liked the way Jim Rabeau put it last week at the CSIRO Conversations event, when he suggested that specific industries should be asking themselves: What are the killer problems in my day-to-day work that we've never been able to solve? Could quantum be a possible solution?

This is the right question, and I encourage everyone who is thinking about the shape of their business, or their research, or teaching over the next few years to turn their mind to it.

I discovered a good example recently when I spoke with Dom Thatcher at the Fremantle Port.

I was quite blown away by what he's doing there.

I don't know if you've ever sat on the footpath while your parents packed and repacked the boot for a family holiday.

But it's an experience that really brings home the scale of optimisation problems – or what are known as bin packing problems.

They're logarithmic and the bigger the boot, the exponentially harder the problem.

At Fremantle, they're dealing with around 12,500 trucks, 40 train-paths and up to 15,000 containers each week. The efficient flow of cargo is crucial to success, but it's just excruciatingly complex.

As Dom says, every part of the chain makes a difference – from where the container is placed on the ship, so the right container is available at the right terminal at the right time, to the placement of that container on the terminal ground, so it coordinates with the right truck arriving through the gates.

It's the orchestration of so many moving parts, and the aim is to minimise the number of times any one container is touched, to limit having to shift things around.

The Monte Carlo systems using classical computers can take a couple of days to consider just one plan of action. And then when things change – delays from weather or breakdown or traffic – the model becomes useless.

The beauty of quantum optimisation is that it can be done much faster, perhaps twice as fast, and the model can be adjusted in real time to take account of changes.

At the Fremantle Port, they took the plunge and reached out to experts to ask the question: could quantum make a difference?

And now they're working on putting together a consortium among the shipping lines, the container terminal and the trucking companies to try to make this happen using quantum annealers.

It's not straightforward. There's work to do on the technology side. And companies will need to be prepared to share their data, and to invest.

It will also take, to use Dom's words, "audacious aspiration". What a great way to describe it.

All of us, each of us, need to be audacious to make this happen.

I know Transport NSW is working with Q-CTRL to explore the potential of quantum optimisation across the transport network, where there are thousands of routes, and the complexity is beyond the best supercomputers.

In quantum sensing, the QuantX sapphire clock is being used to improve Australia's over-the-horizon military surveillance.

And of course, it has huge application well beyond the military for satellite-based global positioning and communications, and for sectors such as banking, to guarantee the time and date stamps of high-frequency transactions with super levels of accuracy.

My old team at the CSIRO made big strides in remote underground mapping in the 1990s, building on that slog developing the Josephson junction. But the ability to commandeer more quantum properties, such as entanglement, could well leave those mapping advances in their wake.

Airbus speaks about quantum technologies as having the potential to bring about a paradigm shift in the way aircraft are built and flown. This goes across air traffic control and precise navigation, aircraft loading optimisation, aerodynamics, and other complex systems.

Last week, I read reports on how quantum combined with robotics and AI can enable robots to achieve better sensing of the environment, faster decision making, and so, lower latency.

If you’re in disaster preparedness and weather forecasting, quantum-enhanced modelling offers better predictions and a longer lead time so that communities can prepare.

In the all-important task of reducing greenhouse gas emissions, quantum technologies offer a suite of possible solutions. It may offer new ways to catalyse hydrogen or design batteries, using the ability to create new molecules and materials. It may bring new ways to fix nitrogen.

These would be profoundly consequential outcomes of quantum computing.

In the research sector, the University of Melbourne team headed by Lloyd Hollenberg has shown that hydrogen binding energies can be calculated more precisely with a Noisy Intermediate Scale Quantum computer than with classical computation. This has implications across many research disciplines.

When I was at the CSIRO, one of my colleagues designed a new high-ZT thermoelectrical material that looked amazing in theory.

He designed it on a classical computer using a Green’s function, and it looked fantastic. It offered improvements of more than an order of magnitude on the best we’d seen before.

But then we headed into the lab to bring the computer model to a reality, and that's where things fell apart. Far from being a major breakthrough, the theoretical material clumped together when we tried to make it and was useless.

The assumptions and boundary conditions you need in a world of classical computing are just not compatible with the real-world functioning of molecules.

That material went no further. But the idea is very much alive.

And I know the moment is coming when a quantum computer, or a quantum-enabled classical hybrid computer, will be able to do this work of molecule design using accurate real-world parameters. It will also be able to test and simulate its interactions – which means that when we create new materials in the virtual world, we won't have to guess at, or approximate, their real-world behaviour.

This will be a game-changer. It will shift the dial on personalised medicine, as well as materials science.

All of the possibilities that I've mentioned offer huge advances.

Already, optimisation is offering reported improvements in efficiency of somewhere between 0.1 and 5 per cent. That might not seem huge, but when you're dealing in big systems, that's a significant increase.

In 10 years, we'll be looking at quadratic, or exponential, improvements – but some capabilities are closer than others.

Another of the things I love about science is watching the evolution of an invention.

The way a piece of fundamental research becomes decades of ingenuity and what emerges is an unexpected device or application.

Who would have thought that the discovery of Bose-Einstein condensates back in the 1990s would become the basis for our GPS measurements?

Another of the things I find striking about science is seeing something that has been predicted in theory become a reality – like the discovery of gravitational waves, a century after they were predicted.

It begins as an idea, becomes a calculation, and then – sometimes decades later – is discovered or created in the real world.

When I started out in my career, Majorana fermions were in this category – a kind of Holy Grail, an enigmatic particle that was predicted to exist but hadn't been discovered. Now they're the basis of work to create a topographical insulator, which has been suggested as an option to solve the quantum error correcting problem that we face with qubits in quantum computing.

Majorana fermions have a long history. They were first predicted almost a century ago by Ettore Majorana. You probably know his story. He was a brilliant young physicist whose contribution to science was cut short when he disappeared off the Italian coast in his early 30s.

I understand there's still plenty of contention surrounding this research, but it's fair to say that Majorana himself would, no doubt, be astonished to see how his prediction is playing out a century later.

That's how science works. Someone is prepared to contemplate an idea entirely outside the paradigm, and then the hard work begins.

I see you have a session this afternoon called "Ask me anything quantum".

This reminded me of a question my kids had when we were deep in the Harry Potter books.

They wanted to know whether I had a project on the go to use quantum science to make a time-turner.

Sadly, I wasn't working on time travel, but it was good to hear my kids had such faith in what I could do.

And it gave me a perfect opener for a conversation with them on quantum entanglement.

So, on behalf of my kids, I'll get ahead of the schedule and throw that question into the arena for this afternoon's session with Zixin, Simon and Andrew.

I raise this because it reminds me of the importance of imagination in science.

Fresh thinking helps you solve problems when you're down in the weeds trying to make your idea work, and it helps you shake off existing assumptions and limitations when you're thinking about the future.

This is especially the case with quantum science.

The thing all of us need to understand about quantum is that it will make possible what once was considered impossible.

Perhaps not time travel.

But it unlocks a new way of thinking about the problems that you might want to solve, which will lead, in turn, to a new set of problems to tackle.

As I say, none of us can present the full dance card of quantum applications.

We don't know all the ways in which quantum advances might be used. The applications are where things become unpredictable.

As I said, all scientific endeavours have times when progress is slow – and they will continue to happen in the field of quantum.

But the applications are coming to fruition quickly now, and I am optimistic that we are reaching a tipping point where we will be able to maintain the momentum and attention.

If Marvel keeps making quantum movies, you'd have to say we're home and hosed!

But I urge you to keep coming together in this way to advance the science, and to keep reaching out – making the case and making the connections.

I also urge you to use the amazing commercial and research institution web-based tutorials to start building your business' quantum capability.

Those of you in industry, congratulations for recognising the possibilities. Businesses that get in early will be ahead of the game.

If you haven’t already, I encourage you to employ a great quantum graduate, so they can work with you on the ways quantum might be able to advance your sector.

All of us in this room need to do what we can to bring quantum science to young Australians and encourage them to turn their minds to the tricky problems.

It’s always amazing to me what fresh thinking, outside the constraints and assumptions of classical processes, can achieve.

All of us need to adopt that mindset of adventurism, or “audacious aspiration”, as quantum opens new possibilities in the years ahead.

Thank you, and I wish you well for a productive and inspiring three days together.