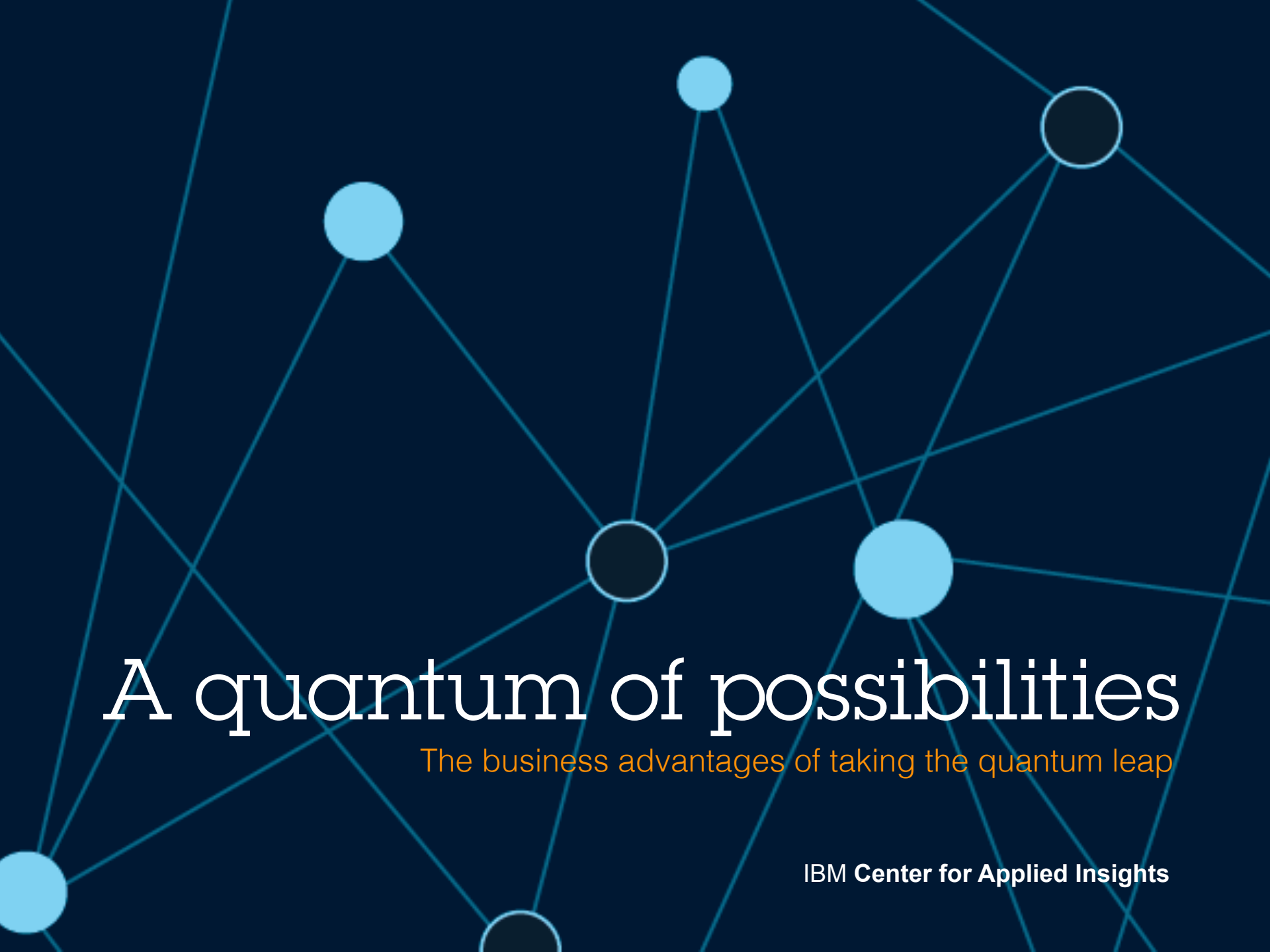


A quantum of possibilities

The business advantages of taking the quantum leap

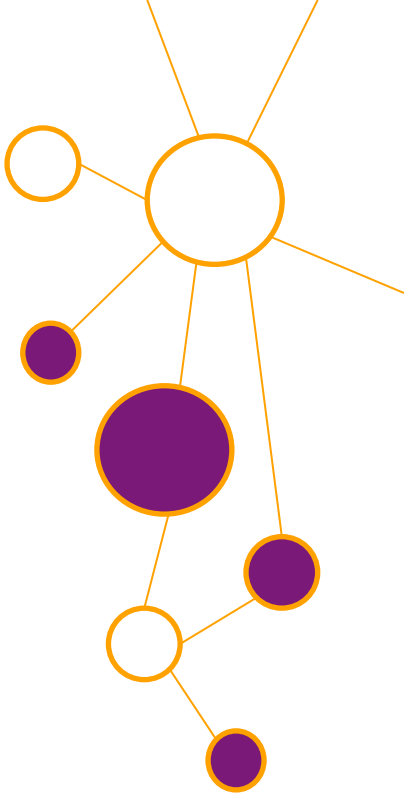
IBM **Center for Applied Insights**

Quantum computers promise exponentially more speed and power than what is achievable with computers today.

They have the potential to impact problems on a global scale. The possibilities of solving what is unsolvable today are significant for businesses and for the planet.

And the wait may be shorter than you think.

Source: IBM Center for Applied Insights, *A quantum of possibilities: The business advantages of taking the quantum leap* ibm.com/ibmcai/quantumcomputing



About this study

To learn about the potential impact of quantum computers, the IBM Center for Applied Insights interviewed experts in the field to learn about the latest breakthroughs in quantum computing and the business benefit across applications and industries.

For more information visit
ibm.com/ibmcai/quantumcomputing

The new horizon

The pace of technological innovation in computing has been astonishing.

It has triggered an equally stunning rise in the volume and complexity of challenges that test the limits of today's computers.

Acknowledging the constraints, even Gordon Moore predicts the end of his eponymous Moore's Law by 2025

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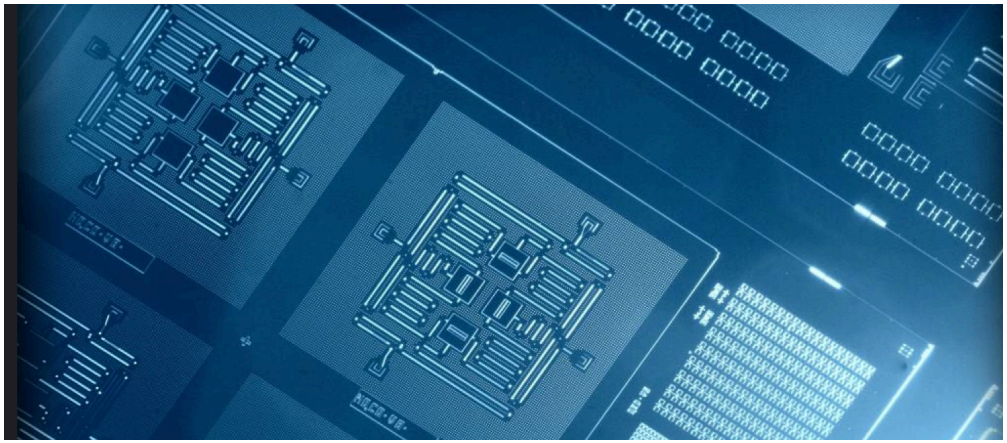
Making great strides

Some quantum capabilities already exist.

By harnessing quantum physics, a full-blown quantum computer may be here in 10 to 20 years.

A new quantum bit circuit design from IBM Research.



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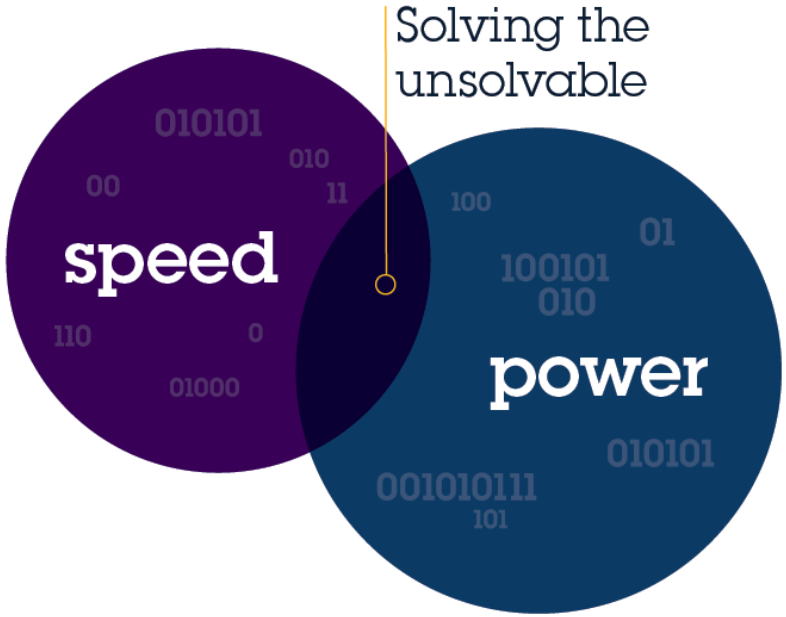
The quantum advantage for business

Greater speed and power offer clear benefits across industries. But the real differentiator is that these benefits compound quantum's true strength—an entirely new way to tackle problems.



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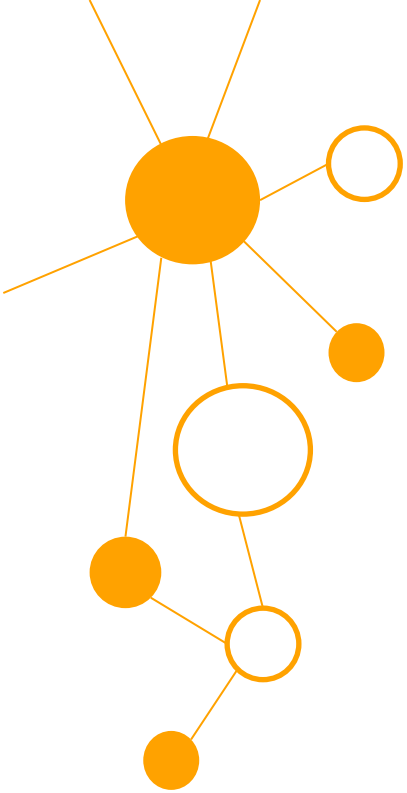

Speed and power

"An analogy is the way people think about big data today. If you go back 30 years ago, people didn't imagine having the amount of data we are gathering today. Quantum computers will open not only a higher processing speed but also applications that we never thought about before."

– Ray Lafamme, University of Waterloo

A new way to solve problems

"The idea is not just to build faster computers, but also to use a quantum advantage to exploit different quantum algorithms that have completely different scaling. So speed—in the end—simply translates to being able to do a much, much larger scale of problem."

– Peter Zoller, University of Innsbruck

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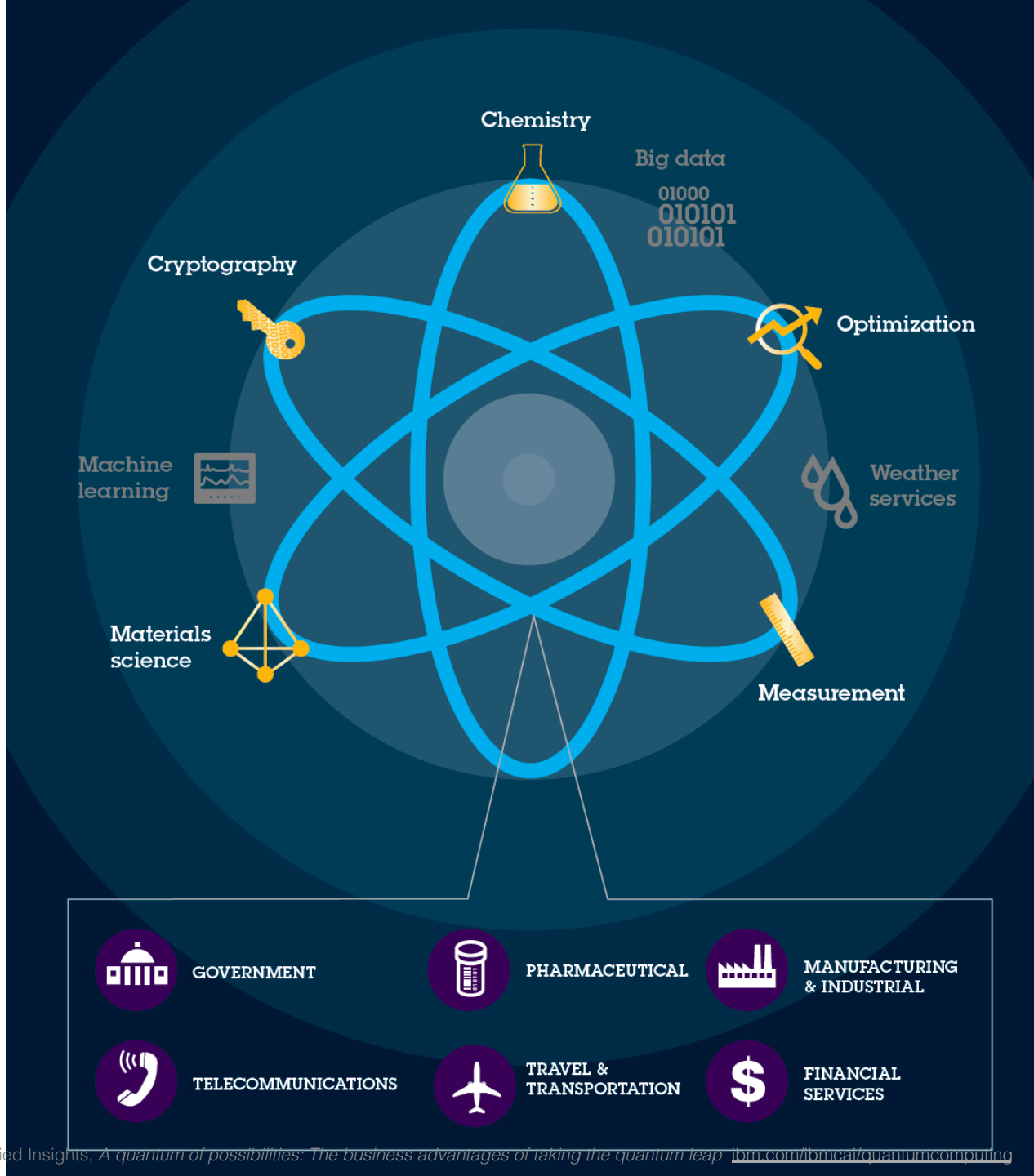
Impact on applications & industries

Materials science, optimization and cryptography are likely to benefit the most—and the soonest—from quantum computing.



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Cryptography

"The potential impact is enormous. Everything we are encrypting today that is stored somewhere will be decrypted by quantum computers when we have them."
– Ray Lafamme, University of Waterloo

Optimization

"There will potentially be a big impact on optimization problems in bioinformatics, such as gene sequence alignment, metabolic networks and other areas from quantum devices. This also, of course, means business opportunities."
– Alan Aspuru-Guzik, Harvard University

Materials Science

"If we improve material science, that would affect many industries. Also there are technologies related to quantum computing, like sensing or better clocks, that could be practically useful."
– Arram Harrow, MIT

Chemistry

"It's going to be a disruptive paradigm shift the moment we are able to actually perform meaningful quantum chemistry simulations with a quantum computer. Because in that moment, quantum computing becomes a predictive tool for chemistry."
– Alan Aspuru-Guzik, Harvard University

Measurement

"A role for quantum technology could be in metrology for the problem of sensing and measuring accurately very small quantities of things or very minute amounts of energy. That's a promising area where there could be commercial development on the early end of the scale, earlier than 10 years."
– David DeVincenzo, Aachen University

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Overcoming economic & technical hurdles

The viability of quantum computers will depend on the cost of producing feasible prototypes as well as the ROI for organizations that want to implement these innovations.

Commercial viability

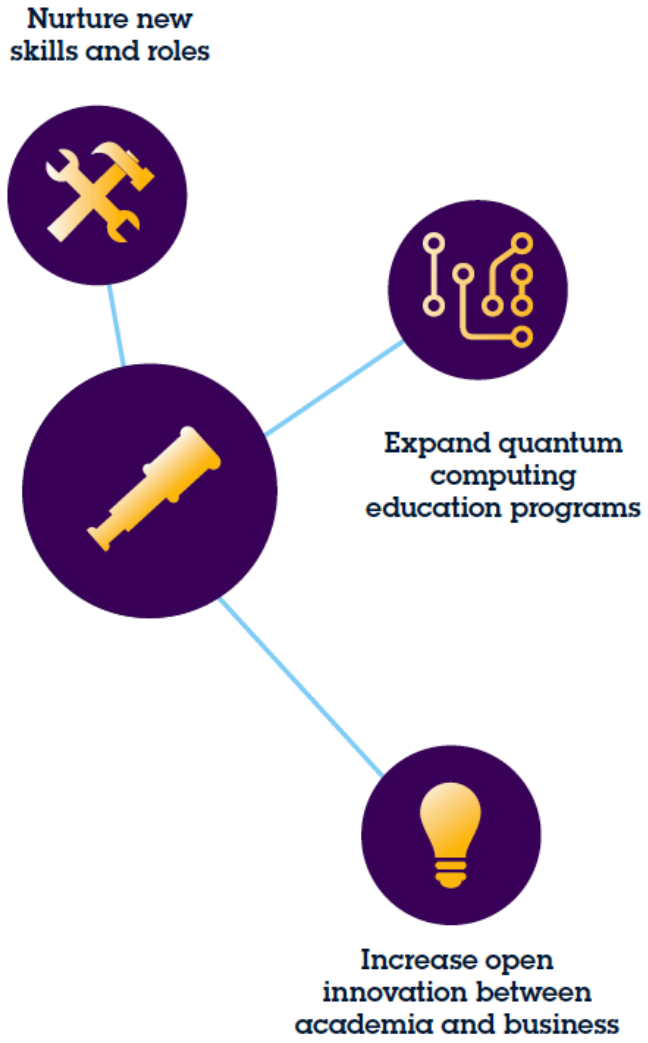
"Many things exist in a lab. But the step to industry is something that's completely different. At the end, you need a product that you're able to sell to a certain market."
– *Peter Zoller, University of Innsbruck*

Economic value

"It's probably going to come down to an economic question. 'Will we build it?' in part depends on the level of effort we make to build it. And how much effort we invest depends on the perceived economic value."
– *Aram Harrow, MIT*

Preparing for a quantum future

What can business and academic communities do to ensure that we're ready to use quantum computers?



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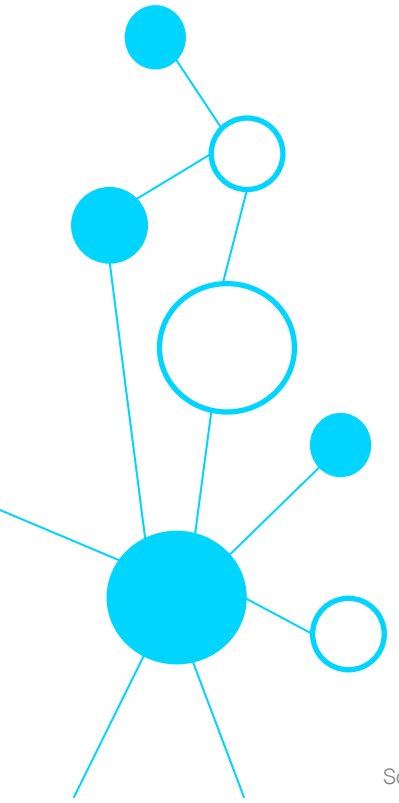
Nurture new skills & roles

Not only quantum scientists and engineers, but also entrepreneurs and quantum generalists will be in demand, with new skills to design, build and manage these machines.



Quantum engineers

"Engineers have this really important role of convincing companies or building new companies that will create wealth out of quantum ideas and develop them into quantum technologies."
– Ray Lafamme, University of Waterloo

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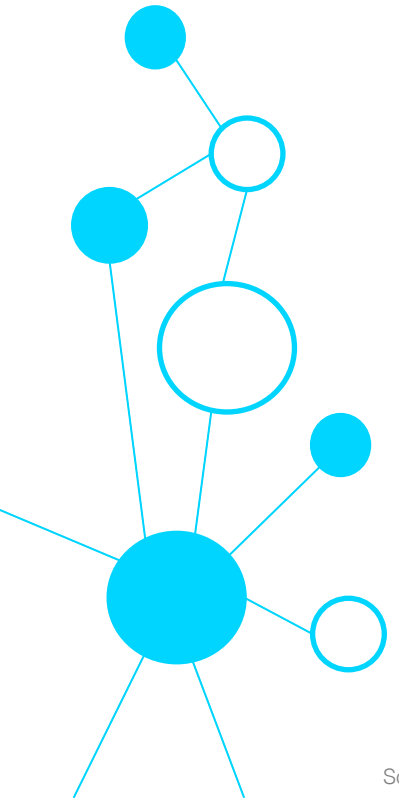
Expand quantum education programs

Universities will need to take a leading role in training for new roles that encompass physics, engineering, computer science and business.

Investment in education

"Remember that even the presence of computer science departments is a relatively recent development in universities. So a quantum science department is something that probably will start springing up in many universities very soon when devices are available."
– Alan Aspuru-Guzik, Harvard University



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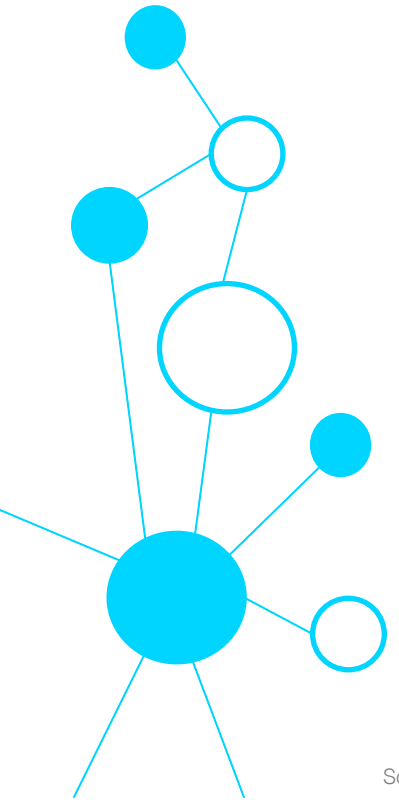
Open innovation between academia & business

A culture of open collaboration between business, government and academia will be necessary to accelerate quantum innovation, finance projects and encourage adoption.

Collaboration breeds innovation

"I hope that companies will get involved in the research and try to do things in a more synchronized way with universities. I'm hoping for a network of companies doing academic research for mutual benefit."
– Peter Zoller, University of Innsbruck



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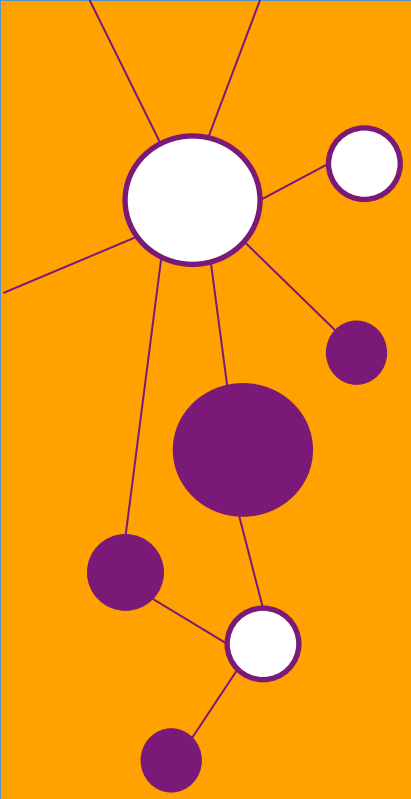

Focusing on the long view

With the potential to accelerate innovation across industries, technology and business leaders and the academic community alike approach the future with curiosity and optimism.

Think big

"Quantum is a very good example of the rapid progress that we can accomplish if we are ambitious and focused as scientists and as a community. Forget about the business opportunity; think about the opportunity for the planet."
– Alan Aspuru-Guzik, Harvard University

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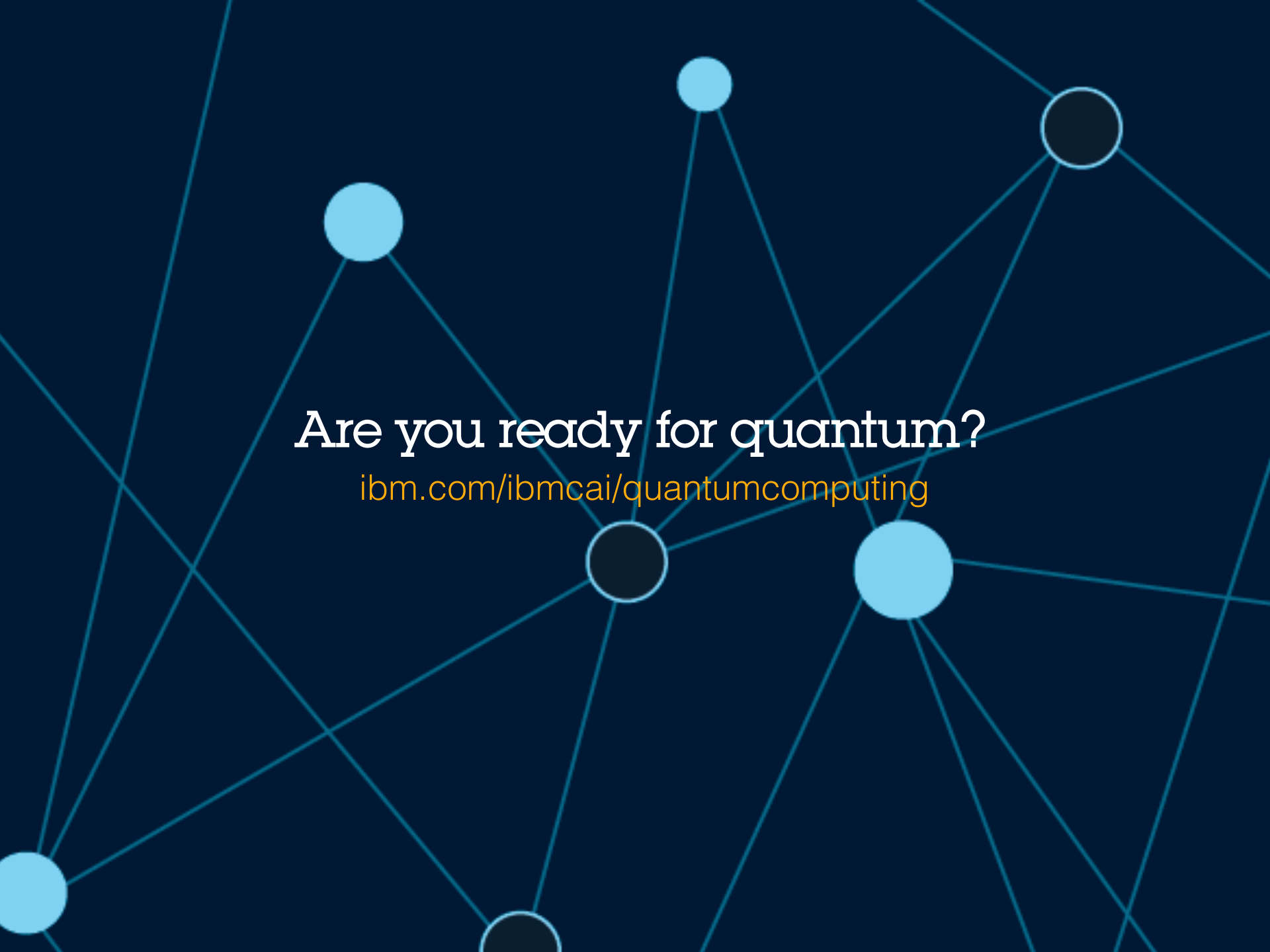
Are you ready for quantum?
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About the IBM Center for Applied Insights

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The IBM Center for Applied Insights introduces new ways of thinking, working and leading. Through evidence-based research, the Center arms leaders with pragmatic guidance and the case for change.

About the author

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- Ray Lafamme, Executive Director of the Institute for Quantum Computing, University of Waterloo
- Peter Zoller, Professor for Theoretical Physics, Institute for Theoretical Physics, University of Innsbruck; Research Director, Institute for Quantum Optics & Quantum Information, Austrian Academy of Sciences