Building your quantum capability

The case for joining an "ecosystem"

A quantum collaboration

Quantum computing has the potential to solve difficult business problems that classical computers cannot. Within five years, analysts estimate that 20 percent of organizations will be budgeting for quantum computing projects and, within a decade, quantum computing may be a USD15 billion industry.[1,2] To place your organization in the vanguard of change, you may need to consider joining a quantum computing ecosystem now. The reality is that quantum computing ecosystems are already taking shape, with members focused on how to solve targeted scientific and business problems. Joining the right quantum ecosystem today could give your organization a competitive advantage tomorrow.

The quantum landscape

Quantum computing is gathering momentum. Today, major tech companies are backing sizeable R&D programs, venture capital funding has grown to at least $300 million, dozens of startups have been founded, quantum conferences and research papers are climbing, students from 1,500 schools have used quantum computing online, and governments, including China and the European Union, have announced billion-dollar investment programs.[3,4,5]

How can your organization get in on the action? You could already be partnering with the world's leading quantum computing hardware, software and application developers to solve business problems previously thought intractable. If you move first, there could be financial windfalls, like those from significantly reducing your supply chain costs. Longer term, you may be able to achieve a game-changing competitive advantage due to the discovery of a breakthrough product, such as more efficient solar cells or more profitable financial trading algorithms.

By joining a burgeoning quantum computing ecosystem, your organization can get a head start today.

A quantum ecosystem brings together business experts with specialists from industry, research, academia, engineering, physics and software development/coding across the quantum stack to develop quantum solutions that solve business and science problems that classical computers can't solve. In fact, 55 percent of executives surveyed in an IBM Institute for Business Value (IBV) survey reported that new capabilities gained via partner ecosystems are essential to building their futures, highlighting the tight links between the development of an ecosystem and that of its constituent organizations.[6] In such an ecosystem, everyone contributes and shares in the value that's created.

Quantum computing ecosystems are rapidly taking shape, paving the way for addressing business opportunities.

What is quantum computing?

Unlike "classical" computers, quantum computers can represent a superposition of multiple states at the same time. This characteristic is expected to provide more efficient solutions for certain complex business and scientific problems, such as drug and materials development, logistics and artificial intelligence. For more information, see "Taking the quantum leap: Why now?" and "Coming soon to your business: Quantum computing – Five strategies to prepare for the paradigm-shifting technology."[7,8]

Why join a quantum ecosystem now?

Your organization may not currently have access to a quantum computer. Nor may your enterprise have the deep expertise necessary to investigate quantum computing solutions on its own. But those aren't reasons to put off engaging with quantum computing. Even if you had the skills and vast financial resources to build your own personal quantum infrastructure, you'd almost certainly be better off in the right quantum ecosystem. Here are three reasons why joining a quantum ecosystem makes sense now:

1. *Quantum technology is evolving too quickly for lone organizations to keep up.* Quantum computing is an accelerating hotbed of innovation. Fueled by funding from governments, venture capitalists and tech giants, the quantum industry is creating an explosion of intellectual property. In the two years since the first free quantum computer was made available to the public, IBM's Q Experience has logged more than 6.5 million quantum experiments.[9]

Further energizing quantum development, other vendors, including Rigetti, Google and Microsoft, have made quantum computing resources, including simulators, available. With this upsurge in quantum development globally, your organization may find it unmanageable to keep track of the relevant R&D for your industry and the implications for your business.

2. *There is a war for scarce quantum talent.* Can you compete with major technology companies who are scouring universities, startups and vendors for quantum expertise? Until quantum skills are plentiful enough to build your own in-house "Quantum Center of Competency," why not access the talent you need, already assembled, via a quantum ecosystem?

3. *Most organizations don't have the financial means to invest across the entire quantum computing stack.* Using quantum computers to solve specific business and scientific problems beyond the abilities of current classical computers – termed

"quantum advantage" – requires deep expertise and investment in all areas of the quantum computing stack (see Figure 1).[10] Instead of straining to be an end-to-end quantum computing technology developer, why not leverage others' quantum infrastructure to focus on developing quantum computing applications that solve your specific business problems?

**Figure 1**
The quantum computing stack

Quantum stack components	Skills required
Technical services	General technology expertise
Applications	Application architecture and development
Use case specific libraries	Industry/domain knowledge
Performance libraries	Quantum algorithms
Compilers, optimizers, simulators	Advanced math, quantum system expertise
Assembly language and drivers	Quantum physics, quantum system expertise
Quantum hardware	Quantum physics, engineering

Finding the right quantum ecosystem for you

As quantum computing technology matures, a variety of quantum ecosystems are developing. But the right quantum computing ecosystem for you should revolve around your organization's goals and business challenges. As shown in Figure 2, your place in a quantum computing ecosystem is right in the center.

Figure 2
Constituents of a quantum computing ecosystem
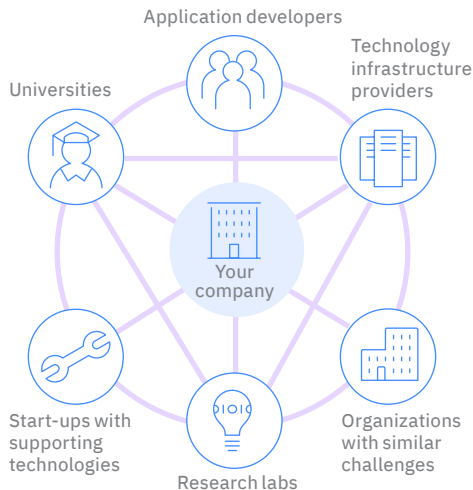
We've identified five criteria to help you determine which quantum computing ecosystem is right for you. Make sure your quantum ecosystem:

1. *Has access to real quantum hardware.* Simulators can be initially useful, but ultimately insufficient if you are serious about using quantum computing to solve your business problems. Quantum advantage will be realized on real quantum hardware and software heavily optimized for the job. Without knowledge of and experience with actual quantum hardware, your quantum application development may founder.

2. *Is based on systems with the potential to evolve into fault-tolerant universal quantum computers.* Fault-tolerant quantum computers should be able to handle a variety of important classes of business

and scientific problems often exponentially faster than classical machines. In the short term, approximate universal quantum computers, also called noisy intermediate-scale quantum (NISQ), are expected to lead to quantum advantage while setting their builders on the road toward fully fault-tolerant quantum computers.[11]

3. *Focuses on your type of business problem.* For example, is your problem a simulation problem based in chemistry? An optimization issue like scheduling transportation routes? Or, are you looking for quantum algorithms that enhance machine learning? Maybe your primary concern is security in the quantum era? Identify which prospective ecosystems are already working on use cases relevant to your specific issue. Be sure the ecosystem you select includes experts in your industry who understand your business problems.

4. *Involves the world's leading organizations and thinkers.* Because of the rapid pace of quantum innovation, you need partners who are at the forefront of scientific breakthroughs and their application to commercial problem-solving. The difference between partnering with Tier 1 and Tier 2 players could mean the difference between being part of a "winner-takes-all" competitive scenario and being left behind.

5. *Connects the right mix of constituents.* The right quantum ecosystem for you consists of the right mix of ecosystem participants concentrating on your business problems alongside your own industry and technical professionals, including:

   – A quantum technology provider who offers easy access to a quantum computer, an open source programming framework, educational resources like tutorials and research papers, quantum researchers, quantum consultants, technical support, and a collaborative community actively engaged in addressing quantum challenges

   – Quantum developers/coders who understand quantum application development using open source code and access to application development libraries, and have access to real quantum hardware

   – Academic partners/universities conducting relevant quantum research and developing budding quantum experts that you may ultimately hire onto your team.

Keep in mind that the commercialization of quantum computing is just getting started. New breakthroughs may change the technology frontrunners, necessitating adjustments to your ecosystem partners over time.

Three questions to consider before joining a quantum ecosystem

1. Are you up to speed on which of your industry's thorniest problems quantum computing may solve?

2. Do you know which developing quantum ecosystems are already looking into potentially solving your business's most crucial problems?

3. Have you defined a quantum roadmap, including a path to building or gaining access to the quantum expertise and infrastructure you need to capitalize on quantum computing's promise?
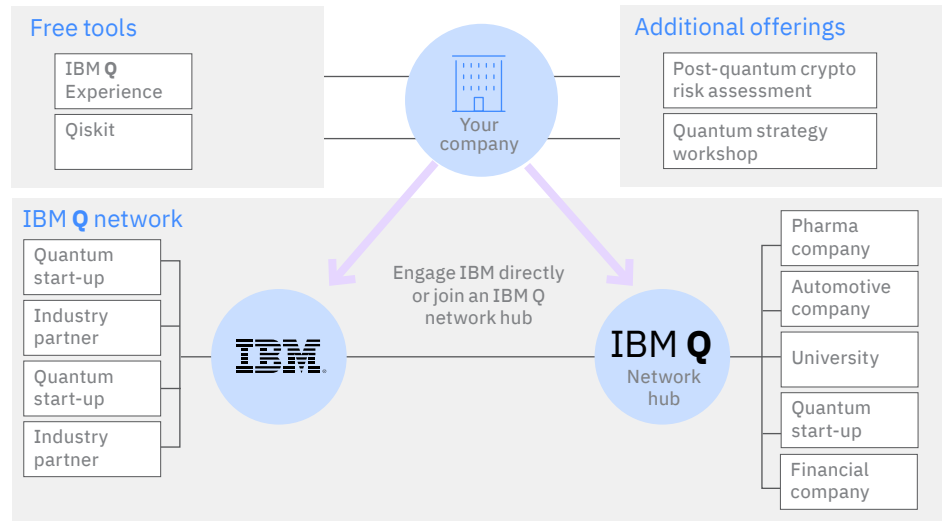

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IBM's quantum computing ecosystem

IBM's quantum computing ecosystem is an exemplar of the type of ecosystem your organization could consider joining (see Figure 3). Encompassing the entire quantum stack, the IBM Q Network is a global ecosystem of Fortune 500 companies, leading academic institutions, startups and national research labs, enabled by IBM's quantum computers, scientists, engineers and consultants.

Participants are already collaborating on early commercial applications.[12] In addition to the IBM Q Network, the IBM Q Experience and Qiskit enable free-tier access to IBM's quantum computers and simulators, and educational resources.[13] IBM Q Industry Consulting enables clients to create quantum roadmaps and identify industry-specific applications.[14] IBM can also help clients define their cryptography strategy for the quantum era.

Free tools
- IBM **Q** Experience
- Qiskit

Additional offerings
- Post-quantum crypto risk assessment
- Quantum strategy workshop

Your company

IBM **Q** network
- Quantum start-up
- Industry partner
- Quantum start-up
- Industry partner

IBM

Engage IBM directly or join an IBM Q network hub

IBM **Q** Network hub

- Pharma company
- Automotive company
- University
- Quantum start-up
- Financial company

Experts on this topic

Robert Sutor

Vice President
IBM Q Strategy and Ecosystem
IBM Research
https://www.linkedin.com/in/bobsutor/
sutor@us.ibm.com

Scott Crowder

Vice President and Chief Technology Officer Quantum Computing
Technical Strategy and Transformation
IBM Systems
https://www.linkedin.com/in/scott-crowder-03650324/
scrowder@us.ibm.com

Frederik Flöther

Global Life Sciences Leader
IBM Q Consulting
IBM Services
https://www.linkedin.com/in/frederikfloether/
frederik.floether@ch.ibm.com

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