FIVE THINGS YOU SHOULD BE DOING NOW TO PREPARE FOR QUANTUM COMPUTING

Your competitors are likely already experimenting with quantum computing. If you don't want to be left behind, you need to get started now.

ABSTRACT

Quantum computing has long seemed like the stuff of science fiction. But the truth is that quantum computers are available right now. Today.

This white paper provides an overview of how quantum computing works and takes a look at the current state of the technology. It also lays out five practical steps that organizations can — and should — take immediately in order to prepare for the day when this revolutionary breakthrough goes mainstream.

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For decades now, people have been saying that quantum computing is right around the corner.

As far back as the 1980s, scientists like Paul Benioff, Richard Feynman, David Deutsch, and others began developing the theories that would make a quantum computer possible. Since that time, engineers have been experimenting with new designs and materials that might one day make quantum computing possible. And the press has been full of articles hyping the future promise of the technology.

But the truth is that quantum computing is here. Today.

Right now, anyone can download tools like Qiskit that allow them to experiment with quantum programming. Quantum simulators are allowing a wide range of people to experience the technology at an affordable price. Companies like IonQ, IBM, Google, and Honeywell have actual physical quantum machines that they are using to run real workloads. Since 2016, Dell has been experimenting with quantum and showing customers what they can do with the technology.

In short, if you aren't researching quantum right now, you're falling behind.

The potential of quantum acceleration to enable new discoveries and ignite entirely new fields of exploration, has created a 'quantum leadership' race. As a result, countries around the world are investing heavily in quantum research. According to McKinsey, "Nine governments have each announced funding of $500 million or more. China has announced $15 billion in funding, more than all other governments combined."

But countries aren't the only ones investing. Companies like FedEx, JPMorgan, BMW, Merck, and many others are also pouring money in quantum research and development. McKinsey said the total private investment so far is at least $3.3 billion.

Quantum computing is available today. Now companies are competing to see who will be first to make the technology useful.

In an interview, Ken Durazzo, vice president of Dell Technologies' OCTO Research Office, explained, "There is a race toward quantum." In the very near future, the computational capabilities of quantum will be available to accelerate applications and reveal new forms of business value. The companies that are experimenting today, "will be well-positioned and poised to extract immediate value out of it, and those that have not started the journey yet are not going to be ready."

WHAT IS QUANTUM COMPUTING?

The first step in any quantum initiative is understanding what a quantum computer is and how it differs from typical, or classical, computers. “Quantum systems fundamentally behave and compute much, much differently than our normal systems, our classical systems, do,” said Durazzo.

The computers you use every day rely on silicon-based transistors to store and process data. These transistors can be either off or on, represented as 1s and 0s in binary code. In computer science lingo, each 1 or 0 is a bit of information, and taken together 8 bits make up a byte. If you combine 1,024 bytes, you get a kilobyte, and if you combine 1,024 kilobytes, you get a megabyte. Keep multiplying, and you’ll get to gigabytes and terabytes.

Over the years, technological advancements have allowed manufacturers to squeeze more and more transistors into smaller and smaller packages, enabling faster processors and denser storage. But today, advances in the manufacture of chips have begun to slow.

This is where quantum mechanics — what Einstein called “spooky action at a distance” — comes into play. If we can harness the power of quantum, we can augment today’s classical systems.

Quantum mechanics explains that until it is measured, an atom can be said to exist in multiple states at once. A quantum computer takes advantage of this fact to perform much more complex calculations. While a classical computer can store information in bits that can be either 1 or 0 — just two possibilities — a quantum computer uses qubits to compute all the possibilities simultaneously.

Also, while classical computing deals in absolutes — the bit is either 1 or 0 and nothing in between — quantum computing deals in probabilities. The quantum computer can tell you a range of the most likely answers to a question, but it can’t provide the definitive answer.

That means that quantum computers are only useful for certain types of workloads. Durazzo noted, “You wouldn’t want the quantum computer to calculate your bank account balance. You don’t want to know your balance is kind of in this zone; you want to know exactly how much is in there.”

On the other hand, quantum computers are very, very good at calculating the possibilities when a problem has multiple possible outcomes. Already, the quantum computers available today outperform classical computers on one very specialized algorithm — prime number factorization. While that algorithm may not be universally applicable, but organizations are close to developing quantum computers that will be useful for a wider range of applications, particularly for machine learning, for simulating complex systems, and for optimizing difficult problems, such as those common in quantitative finance.

Given the right problem, quantum computers can be many orders of magnitude faster than a classical computer.

THE CURRENT STATE OF QUANTUM COMPUTING

But while quantum computing is a reality — it’s still in its infancy. Durazzo compares it to the state that classical computing was in during the 1940s. “I believe we’re in the ENIAC days in terms of quantum computing,” he said.

Right now, much of the work is taking place on the hardware side — developing the materials and designs that will enable large-scale quantum computing. “There’s a bunch of different ways to build qubits, but it’s really too early for us to know which technology is going to be the winner,” Durazzo said.

However, some things are quickly becoming apparent. First, quantum computing is inextricably linked with classical computing. “You can’t have quantum computing without classical computing,” said Durazzo. “It is highly likely that we’ll see hybrid classical-quantum computing as the way forward through the era of fault-tolerant quantum systems.”

In most of the current systems, a classical computer (complete with storage, processors, and networking) provides the input that then goes to a quantum computing layer. The quantum layer does the processing and then transmits the output back to a classical system, which could eventually be a high-performance computing (HPC) system as the number of qubits grows.

This setup makes it possible for anyone to experiment with quantum computing today. You can download the development tools and then interact with a virtual quantum processor (vQPU) or a physical quantum machine in the cloud. Both approaches provide an identical experience as they are programmed the same and are indistinguishable in terms of application or algorithm experimentation.

The hardware manufacturers are currently working to build higher-density quantum machines with more qubits and fewer errors. When they get to the stage where they have thousands or tens of thousands of qubits and can handle large-scale error correction, quantum computers will become extremely useful on a much wider scale.

FIVE STEPS TO TAKE RIGHT NOW

Although you might not be ready to deploy quantum computing applications to production — yet — now is the time to get started with the technology if you don’t want to be left behind. If you haven’t started investigating the technology, here are five steps you should take as soon as possible:

1. LEARN AS MUCH AS YOU CAN.

Quantum computing is so new that no one knows much about the technology. “The amount of people that have quantum information science backgrounds is miniscule,” said Durazzo.

To make up for that lack of expertise, Durazzo recommends doing as much hands-on learning as possible. While you can learn some things about the technology by reading and researching, there is really no substitute for trying the technology for yourself. “At the end of the day, it really does take quite a bit of mental refactoring and a different way of thinking about computing, and getting hands on keyboard is a wonderful way of starting to learn how this all works,” he explained

Durazzo says that this approach has become very popular among the enterprises he visits. “At least 40% of customers right now are doing some level of hands-on learning” with quantum computing, he said.

Also, it may soon be possible to add to your organization’s institutional experience with quantum computing by hiring recent college grads. Many leading university computer science programs are incorporating instruction about quantum into their curriculum, so that recent graduates can go into their jobs with a baseline of knowledge.

2. START EXPERIMENTING.

After you’ve spent a little time getting to know how quantum computing works, Durazzo suggests beginning to experiment with the technology in ways that relate to your business. “Stop looking and start doing,” he advised.

While getting time on physical quantum computers can be difficult — and expensive — quantum simulators allow you to begin this experimentation process without exceeding your budget. “We found that simulation is not only absolutely viable but it is also cost-effective, and it yields the same results,” he said.

Best of all, beginning this experimentation is relatively easy. “We can now have a customer take our software and our Dell hardware and have a working quantum system in about an hour,” said Durazzo. “We have built significant automation in the system to enable a fast and frictionless deployment.”

While about 40% of Durazzo’s customers are still in the initial learning phase, he believes another 30% to 40% of his customers have moved beyond hands-on learning and are doing some experimentation.

3. BUILD YOUR HPC CAPABILITIES.

As previously mentioned, you need some classical computing hardware to make quantum hardware function. The classical computers provide the inputs and receive the outputs that come from the quantum processing units.

But in order to access those acceleration capabilities, you need some pretty powerful classical hardware. In fact, as quantum computers increase in qubit density, high performance computing capabilities may be necessary to keep up with the speed at which the quantum layer can do its processing. “We foresee a time when more classical horsepower may be needed to bring that final calculation to bear, as well as to feed the quantum system, and to ensure that it’s running optimally and able to perform its resulting calculations without any bottlenecks,” explained Durazzo.

Classical computing is also useful on the input side. “The input layer is interesting,” said Durazzo. “This is effectively where you learn to program or where the quantum machine is programmed, and that all happens on classical gear.” Considering we will need performant systems to create the quantum circuits and eventually turn it into quantum assembly to sustainably feed the QPUs, HPC hardware could yield a potential benefit.

Intel is focusing its quantum hardware research in three areas that are strongly differentiated from other approaches in the industry:

- Intel is leveraging its proven deep expertise in the design and manufacturing of transistors at massive scale by using silicon spin qubits, which closely resemble transistors.
- Intel is building a custom, highly-integrated system-on-chip (SoC) called Horse Ridge for quantum controls that is designed to operate at cryogenic temperatures and minimize the complexity of quantum interconnects as those systems scale.
- Intel is investing in capabilities like a custom-designed cryoprober that dramatically speeds up time-to-information for our quantum testing and validation workflows.

Learn more

Ultimately, the quantum computer acts as an extension of your HPC systems. "You could logically think of the quantum computer as an acceleration vector for very specific algorithms, much like a GPU today is an acceleration for AI, deep learning, and machine learning," Durazzo said.

4. CONSIDER YOUR APPLICATIONS.

After you done some learning and experimentation and you have robust HPC systems in place, the next step is to start a proof of concept for an actual application that might be of use to your organization. According to Durazzo, very few of his customers have progressed to this point, but he expects more to do so soon.

Ideally, the experimentation phase allows organizations to better understand which of their applications and use cases could benefit from quantum processing. They can then partner with an experienced vendor that can expedite the proof of concept process.

"We have a ton of new things that we're developing within our research office right now that allow us to potentially even choose the best accelerator for the problem that you're trying to solve," said Durazzo. "We're using AI as intelligent orchestration to be able to allow us to analyze the properties of the applications, and then use the properties of that application to invoke the right level of quantum system or accelerator to optimize your time to result."

5. CHOOSE PARTNERS WITH QUANTUM EXPERTISE.

Because quantum is so new, it makes sense for businesses to leverage the capabilities of vendors who have more experience in the space. Many vendors, including Dell, have invested significant resources into quantum, and they are making their hard-won knowledge available to customers.

"Everything that we do is to try and make it easier for customers to adopt and take rapid advantage of new technology to accelerate their business. That's our primary goal as a research organization," said Durazzo. "We take some of the friction out for customers because we're learning ahead of them."

He added, "We have a lot of outreach to customers, showing them what we're doing, giving them access to some of our leading-edge demonstrations and research areas." If you would like to be one of those customers getting early access, email quantum@dell.com.

TO LEARN MORE

If you're ready to get started on the learning phase of your quantum journey, check out the following resources:

- The Importance of On-Premises Hybrid Classical-Quantum Computing
- Exploring Hybrid Classical-Quantum Compute
- Quantum Supremacy: Datacenter Transformation
- Qiskit open-source quantum software development kit (SDK)
- McKinsey Quantum computing: An emerging ecosystem and industry use cases
- U.S. Department of Energy Explains Quantum Computing
- Final Report of the National Security Commission on Artificial Intelligence

To learn more, visit Dell.com/quantum-computing.