Microsoft aims to win the race to build a new kind of computer. So does Amazon

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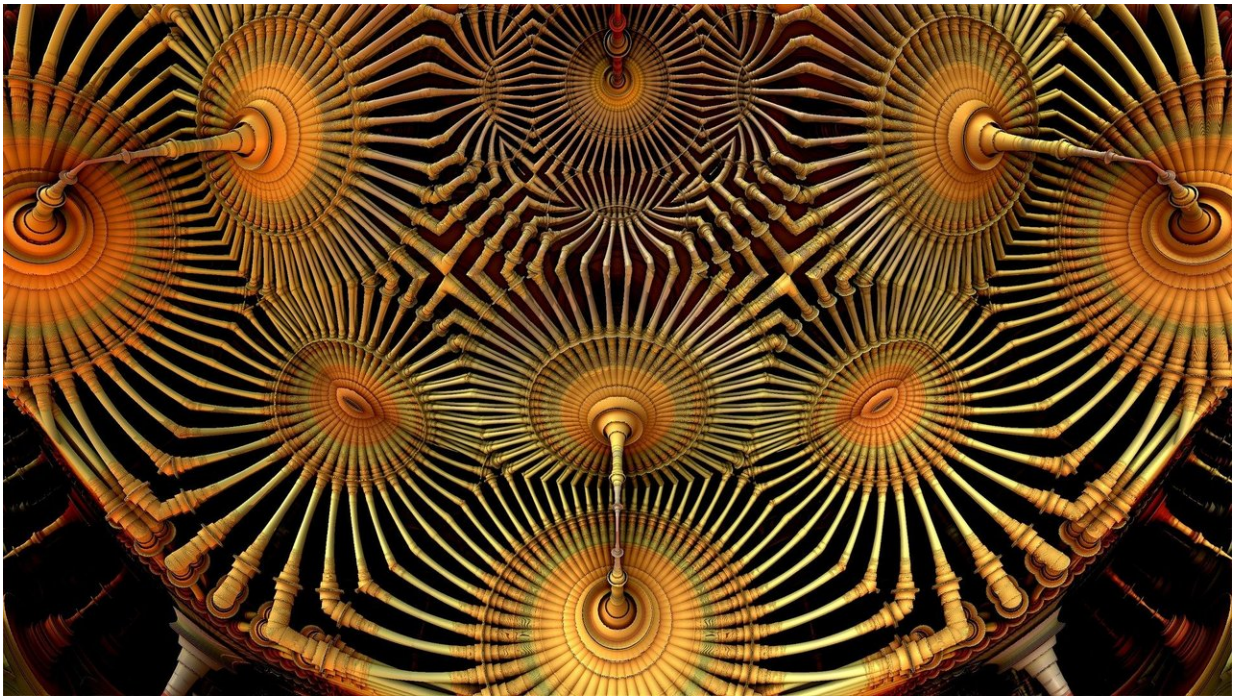

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The tech giants are locked in a race.

It might not end for another decade, and there might not be just one winner. But, at the finish line, the prize they promise is a speedy machine, a quantum computer, that will crack in minutes problems that can't be solved at all today. Builders describe revolutionary increases in

computing power that will accelerate the development of artificial intelligence, help design new drugs and offer new solutions to help fight climate change.

Ready. Set. Quantum.

Relying on principles of physics and computer science, researchers are working to build a quantum computer, a machine that will go beyond the capabilities of the computers we use today by moving through information faster. Unlike the laptop screen we're used to, quantum computers display all their inner organs. Often cylindrical, the computers are an intimidating network of coils, plates, wires and bolts. And they're huge.

"We're talking about computing devices which are just unimaginable in terms of their power in what they can do," said Peter Chapman, president and CEO of IonQ, a startup in the race alongside tech giants Microsoft, Amazon, Google, IBM, Intel and Honeywell.

The companies are riding a swell of interest that could grow to $9.1 billion in revenue by 2030, according to Tractica, a market intelligence firm that studies new technologies and how humans interact with tech advancements.

Right now, each company is deciding how to structure the building blocks needed to create a quantum computer. Some rely on semiconductors, others on light. Still others, including Microsoft, have pinned their ambitions on previously unproven theories in physics.

"Bottom line, we are in very heavy experimentation mode in quantum computing, and it's fairly early days," said Chirag Dekate, who studies the industry for research firm Gartner. "We are in the 1950s state of classical computer hardware."

There's not likely to be a single moment when quantum computers start making the world-changing calculations technologists are looking forward to, said Peter McMahon, an engineering professor at Cornell University. Rather, "there's going to be a succession of milestones."

At each one, the company leading the race could change.

In October 2019, Google said it had reached "quantum supremacy," a milestone where one of its machines completed a calculation that would have taken today's most advanced computers 10,000 years. In October last year, startup IonQ went public with an initial public offering that valued the company at $2 billion. In November, IBM said it had also created a quantum processor big enough to bypass today's machines.

In March, it was Microsoft's turn.

After a false start that saw Microsoft retract some research, it said this spring it had proved the physics principles it needed to show that its theory for building a quantum computer was, in fact, possible.

"We expect to capitalize on this to do the almost unthinkable," Krysta Svore, an engineer who leads Microsoft's quantum program, said in a company post announcing the discovery. "It's never been done before. ... [Now] here's this ultimate validation that we're on the right path."

As envisioned by designers, a quantum computer uses subatomic particles like electrons instead of the streams of ones and zeros used by computers today. In doing so, a quantum computer can examine an unimaginable number of combinations of ones and zeros at once.

A quantum computer's big selling points are speed and multitasking, enabling it to solve complex problems that would trip up today's technology.

To understand the difference between classical computers (the computers we use today) and quantum computers (the computers researchers are working on), picture a maze.

Using a classical computer, you're inside the maze. You choose a path at random before realizing it's a dead end and circling back.

A quantum computer gives an aerial view of the maze, where the system can see several different paths at once and more quickly reach the exit.

"To solve the maze, maybe you have to go 1,000 times to find the right answer," said IonQ's Chapman. "In quantum computing, you get to test all these paths all at once."

Researchers imagine quantum computers being used by businesses, universities and other researchers, though some industry leaders also talk about quantum computing as a technology that will unlock new ideas our brains can't yet imagine. (It's not likely the average household will have a quantum computer room any time soon.)

Microsoft recently partnered with paints and coatings company AkzoNobel to create a "virtual laboratory" where it will test and develop sustainable products using quantum computing to overcome some of the constraints that jam up a traditional lab setting, like access to raw materials, lack of space and concerns about toxicity.

Goldman Sachs is working to use quantum computing to speed up risk evaluation done by Wall Street traders. Boeing wants to use the advanced tech to model how materials will react to different environments, while ExxonMobil has plans to use it to simulate the chemical properties of hydrogen, hoping to develop new materials that can be used to make renewable energy.

In the long run, companies are aiming for a "fault-tolerant" quantum computer that will keep operating correctly even if components go awry. To get there, researchers are focused on keeping one thing happy: the qubit.

The computers we use today to look up the best restaurants or check the weather rely on bits, a unit of information in the computing world that is usually a zero or a one. Quantum computers rely on qubits, short for quantum bits, a unit of quantum information that can be (confusingly) both zero and one at the same time.

In a classical computer, a bit flips between zero and one. In a quantum computer, a qubit can be in both states at once, allowing it to simultaneously evaluate different possibilities.

It helps to think about qubits like a spinning coin, said Jim Clarke, director of quantum hardware for Intel. (Clarke himself is so devoted to qubits he named his German shepherd after them.)

While a coin is spinning, it is briefly both heads and tails, before it lands on one side or the other. The electrons used to make quantum calculations in Intel's machines are mid-spin.

But qubits are easily disturbed by pretty much anything, including light, noise and temperature changes. "Qubits are notoriously fickle," said Chapman from IonQ. "They are the introverts of the world."

If a qubit gets too bothered, it will lose the information it is carrying, making the computer's calculations less reliable.

When computer scientists, physicists and engineers think about their quantum strategy, a lot of the discussion revolves around the best way to keep those qubits comfortable. That discussion then sparks another:

What is the best way to build a qubit?

Intel is using semiconductors. Google, IBM and Amazon Web Services are using superconductors. IonQ is taking an approach that puts atoms in a vacuum sealed chamber to create something called "trapped-ion" qubits. Other companies are using light.

Microsoft is aiming to create something new. It's taking a physics-based approach to create what it calls "topological qubits." In March, it said it got one step closer by successfully demonstrating the physics behind its qubit philosophy.

But it has said that before. In 2018, a team of Microsoft-led researchers published a paper that said it had found evidence of the type of physics it was looking to prove. Last year, the group retracted the paper, writing it could "no longer claim the observation."

Since then, the Microsoft team developed a new protocol meant to "screen out false positives," said Svore, who is working on the quantum project at Microsoft's Redmond headquarters. "We are more confident than ever in our approach."

"Just like I can't prove the sun comes up tomorrow," Microsoft can't prove it can create the qubits it is hoping for, she said. But, "We've now demonstrated on multiple devices that the physics is here."

Though a competitive race, there may be more than one prize.

"All the technologies have advantages and disadvantages," said Fred Chong, a computer science professor at the University of Chicago. "A lot of these things are still evolving. Some of the technologies are good for the near-to-medium term, some of them are a little bit more in the future, some of them are very far in the future."

Determining the shortest route to get from Seattle to Portland might best be solved by one approach, while speeding up a chemical reaction might call for something different.

Most of the companies in the race today will develop "fairly credible quantum machines," Chong said, and customers will look for ways to "take advantage of their strengths and mitigate their weaknesses."

In the meantime, Amazon, Google and Microsoft are hosting quantum technology from their competitors, alongside their own, hoping to let customers play around with the tech and come up with uses that haven't yet been imagined. In the same way companies can buy cloud space and digital infrastructure technology from Amazon Web Services or Google Cloud, the tech companies now offer customers pay-as-you-go quantum computing.

"At this stage of the tech, it is important to explore different types of quantum computers," said Nadia Carlsten, former head of product at the AWS Center for Quantum Computing. "It's not clear which computer will be the best of all applicants. It's actually very likely there won't be one that's best."

Dekate, who analyzes the quantum industry for research and consulting firm Gartner, says quantum may have reached the peak of its "hype cycle."

Excitement and funding for the quantum industry has been building he said, pointing to a rising slope on a line graph. Now, it could be at a turning point, he continued, pointing to the spot right before the line graph takes a nosedive.

The hype cycle is a five phase model Gartner uses to analyze new technologies, as a way to help companies and investors decide when to

get on board and when to cash out. It takes three to five years to complete the cycle—if a new tech makes it through.

Predictive analytics made it to phase five, where users see real-world benefits. Autonomous vehicles are in phase three, where the original excitement wears off and early adopters are running into problems. Quantum computing is in phase two, the peak of expectations, Dekate said.

"For every industry to advance, there needs to be hype. That inspires investment," he said. "What happens in these ecosystems is end-users [like businesses and other enterprises] get carried away by extreme hype."

Some quantum companies are nearing the deadlines they originally set for themselves, while others have already passed theirs. The technology is still at least 10 years away from producing the results businesses are looking for, Dekate estimates. And investors are realizing they won't see profits anytime soon.

In the next phase of the hype cycle, Dekate predicts private investment in quantum computing will go down, public investment will go up in an attempt to make up the difference, and companies that have made promises they can no longer keep will be caught flat-footed. Mergers, consolidation and bankruptcy are likely, he said.

"The kind of macroeconomic dynamics that we're about to enter into, I think means some of these companies might not be able to survive," Dekate said. "The ecosystem is ripe for disruption: way too much fragmentation and companies overpromising and not delivering."

In other words, we could be headed toward a "quantum winter."

But, even during the funding freeze, businesses are increasingly looking for ways to use quantum computing—preparing for when the technology is ready, Dekate said. While Amazon, Microsoft, Google and others are developing their quantum computers, companies like BMW, JPMorgan Chase, Goldman Sachs and Boeing are writing their list of problems for the computer to one day solve.

The real changes will come when that loop closes, Dekate said, when the tech is ready and the questions are laid out.

"At some point down the line, the classical [computing] approaches are going to stall, and are going to run into natural limitations," he said. Until then, "quantum computing will elicit excitement and, at the same time, disappointment."