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WHAT I LEARNED THIS WEEK

Excerpt from November 9, 2017

7 A massive global race is underway to achieve "exascale" and quantum computing supremacy—a potential winner takes all battle with huge implications.

This battle for global dominance is not being fought on a battlefield, nor at the WTO, nor in Brussels, nor in Washington D.C. Rather, it is being waged in laboratories in Santa Barbara, Oxford, Moscow, Zurich, and Hefei, China. The race may be even more intense than the battle for leadership in AI—and the U.S. is at risk of falling behind. Over 30 firms and all major nations have quantum programs.

Historically, the U.S. has led the quantum race—investing about $200 million per year—but the main focus has been on atomic clocks and navigation technologies. Recently, the Department of Energy said it would award an additional $258 million toward producing an exascale supercomputer that would include quantum processors. America's technology leaders—IBM, Google, Microsoft—are also pouring millions into quantum computing.

But, as other countries make even larger investments, the U.S.'s leadership is beginning to wane. China is building a $10 billion quantum computing center, initially focusing on quantum metrology to improve the stealth capability of its submarines, and building a quantum computer that could break encrypted messages in seconds. "Our plan is that by 2020, or maybe as soon as next year, to achieve 'quantum supremacy' with calculation power one million times to all existing computers around the world combined," states Pan Jianwei, China's lead quantum scientist.

Over the next three years, Alibaba is doubling R&D spending to $15 billion in order to focus on quantum computing/AI and other cutting-edge technologies.

The company has also created a public-private partnership with the Chinese Academy of Sciences—called the Alibaba Quantum Computing Lab. Even the E.U. is investing €1 billion, focusing on quantum communication, computing, sensing and simulation. The initiative is on top of several separate quantum programs in the U.K. and European countries (including Germany, France, Italy, and Austria) making the region one of the largest investors in the space.

At a recent U.S. House Science Committee hearing, six quantum information science experts warned that this emerging technology is at a global "inflection point." As Scott Crowder of IBM warned: "When one examines the depth of the commitments other countries are making in quantum computing, our belief is the **U.S. government investment in driving this critical technology is not sufficient to stay competitive."** Arthur Herman, a senior fellow at the Hudson Institute, believes the U.S. will need a "Manhattan Project-style funding focus," to prevent a calamity.

By June 2018, China will have a prototype exascale supercomputer—**10x more powerful than its already top-ranked Sunway TaihuLight supercomputer, which itself is 5x more powerful than America's fastest computer.** In contrast, the U.S. does not expect to have an operational exascale machine until at least 2021.

However, exascale supercomputers will pale in comparison to quantum computers. This is because quantum computers use quantum bits (qubits) that can scale exponentially and represent all combinations of zeros and ones simultaneously. A 49 or 50 qubit quantum computer can reach the equivalence of about 10 quadrillion bits—capable of calculations that no classical computer could ever match. **China is advancing towards a 40-qubit prototype and has already built a quantum machine that can carry out calculations for five photons 24,000 times faster than prior experiments.**

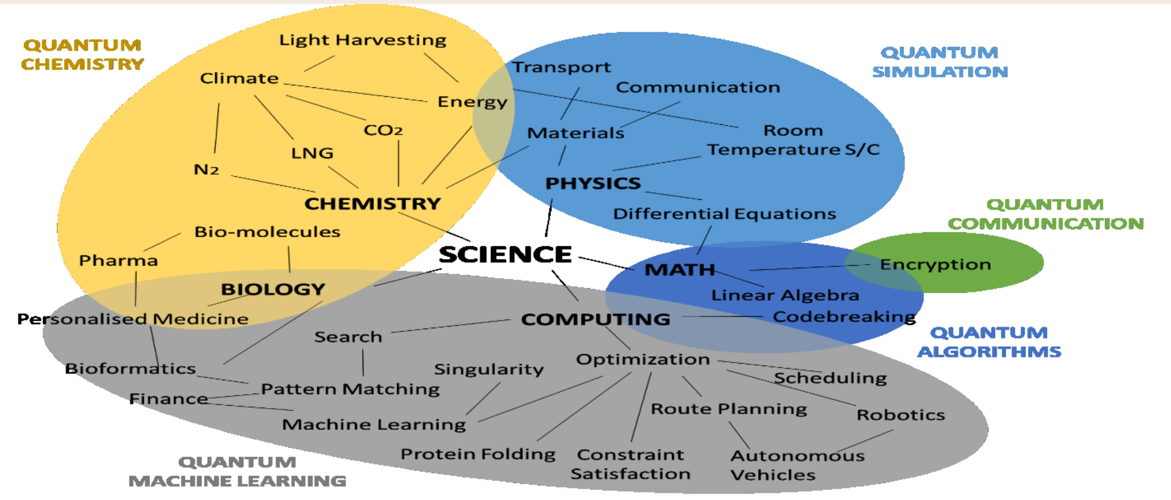
Google's 49-qubit quantum computer was expected to be the highlight at the recent International Conference on Quantum technologies in Moscow. But, a Mikhail Lukin led team at the Russian Quantum Center and Harvard University announced their prototype had surpassed the theoretical threshold of quantum supremacy with a 51 qubit quantum simulator. A quantum supremacy test shows whether a quantum computer is operating in a quantum state and can solve problems classical computers cannot.

Last week, IBM also simulated a 56-qubit machine with a classical computer. However, while IBM achieved the milestone using significantly less memory than prior experiments, the simulator is slower than a pure quantum computer. IBM's quantum simulator took two days to perform the experiments, a billion times slower than a pure quantum computer that could do it in 100 microseconds, notes Robert Wisnieff of IBM.

What are the implications? Whoever produces a universal quantum computer first will likely take the lead across numerous fields, including defense, aerospace, AI and machine learning, pharmaceuticals and materials science, finance, among many others.

Quantum computing promises to supercharge AI and machine learning by processing exponentially more data in parallel—vastly improving image classification, generation and analysis. In medicine, quantum technology will be able to map out trillions of molecular combinations—identifying promising candidates—reducing the cost and time for drug development. In materials science, quantum computing will find superior new materials—such as better superconductors, magnets and materials to create higher-energy-density batteries.

Quantum Computing Will Transform Almost Every Aspect of our Technology, Science, Economy & Life



(Sources – World Economic Forum, HSRC)

Second, **leading developers are putting quantum computing on the cloud—accelerating commercialization and disruption.** Google and IBM have already connected their quantum computing prototypes to the cloud—enabling software developers to integrate quantum computing codes in new applications. Quantum startup Rigetti Computing has built an open-sourced quantum compiler and software development environment for building applications in quantum chemistry and materials science.

Third, **quantum computing decouples energy consumption from computing power.** China's Sunway TaihuLight supercomputer consumes 15.37 MW of power—equivalent to a small town. In contrast, quantum computers use "quantum tunneling"—reducing power consumption by a factor of 100 to 1000.

Fourth, **quantum computing could undermine all current security protocols on the internet.** Today's internet relies on public-key cryptography to establish secure communication between users. But, quantum computers can "factorize" large numbers instantly. This is one reason why China's lead in quantum communications is so important (see *WILTW* July 20, 2017).

Consider the following:

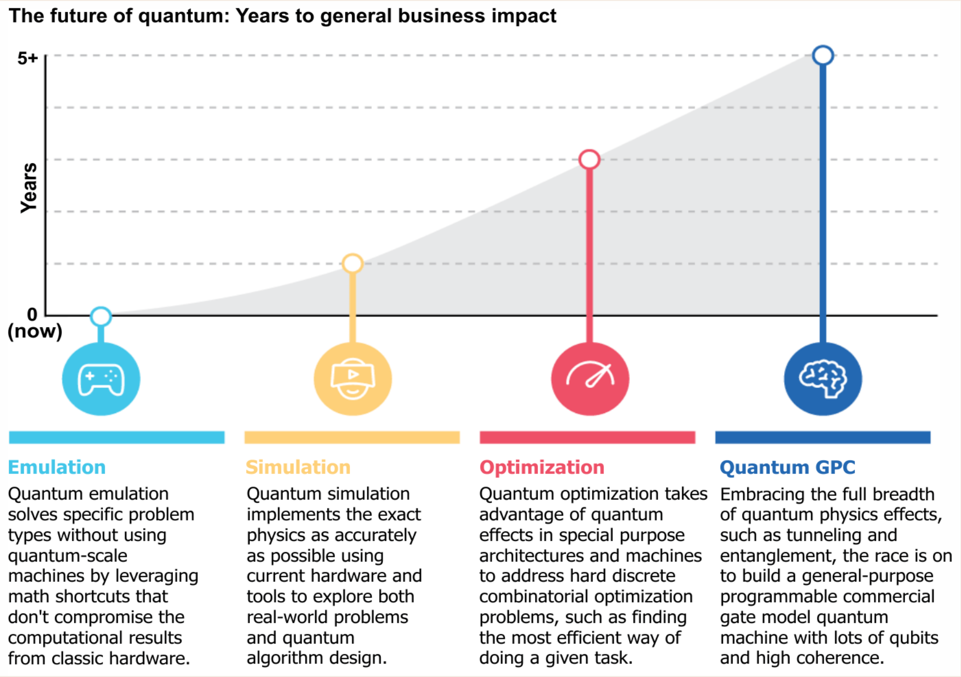
- **Quantum computing is on-track for broad commercialization.** Over the next three years, a recent Deloitte study concludes that commercialization will follow a path of emulation, simulation and optimization—aimed at solving design problems and increasing efficiencies (see chart below). **Quantum optimization can find the shortest, fastest, cheapest, and most efficient way to complete a task.**

  Examples include airline scheduling, image recognition, machine learning and deep learning pattern-based processing. Canadian company D-Wave Systems makes a "quantum annealing" computer aimed at optimization tasks that Google has noted can solve certain problems 100 million times faster than classical computers. D-Wave's $15 million machine has already been purchased by Google, Lockheed Martin, NASA, and the Los Alamos National Laboratory.

  IBM plans to offer commercial quantum machines to businesses within a year. In September, IBM developed a new approach for simulating molecules on a quantum computer. The approach could allow the machines to solve difficult problems in chemistry and electromagnetism—unsolvable by even the most powerful supercomputers.

This week, Volkswagen AG announced three research projects on Google's quantum computer to develop new digital features for cars. The projects include refining traffic-management systems, simulating the structure of electric-car batteries and other materials, and AI for autonomous driving.

Early next year, Google is expected to test a universal quantum computer—aiming to reliably explore the entire space of a 49-qubit superposition to solve quantum sampling problems. Google's lead quantum scientist foresees quantum computers with about 100 reliable qubits in a few years.



Source: Deloitte

- **Intel's breakthrough quantum chip could expedite commercialization.** Intel adapted its existing 300-nanometer "flip chip" processor design to support quantum processing. The chip can handle 17 qubits and was developed in collaboration with QuTech, a Dutch company spun out of the University of Delft. "We're [moving] quantum computing from the academic space to the semiconductor space," underscores Jim Clarke of Intel.

- **Producers of key-enabling exascale and quantum chip technologies are showing relative strength and poised to outperform.** Intel, IBM, and AMD are the largest producers of chips to supercomputers—supplying a respective 464, 21, and six of the world's top supercomputers.

  Nvidia's (NVDA, $209.16) specialized GPU chips are used in 91 supercomputers to make them more powerful. The Swiss National Supercomputing Center inserted Nvidia's chips into its supercomputer recently and doubled the performance—climbing from number 8 to number 3 in global rankings.

  Arm Holdings—part of **Softbank Corp** (9984 JP, 9905 yen)—has launched its 64-bit server chip designs that includes a "Scalable Vector Extension" (SVE). Fujitsu recently confirmed it will use Arm's SVE ARMv8 chip in the Japanese exascale Post-K supercomputer.