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ANALYSIS

THE IMPACT OF QUANTUM TECHNOLOGY ON INTERNATIONAL RELATIONS IN THE CONTEXT OF U.S.-CHINA RIVALRY

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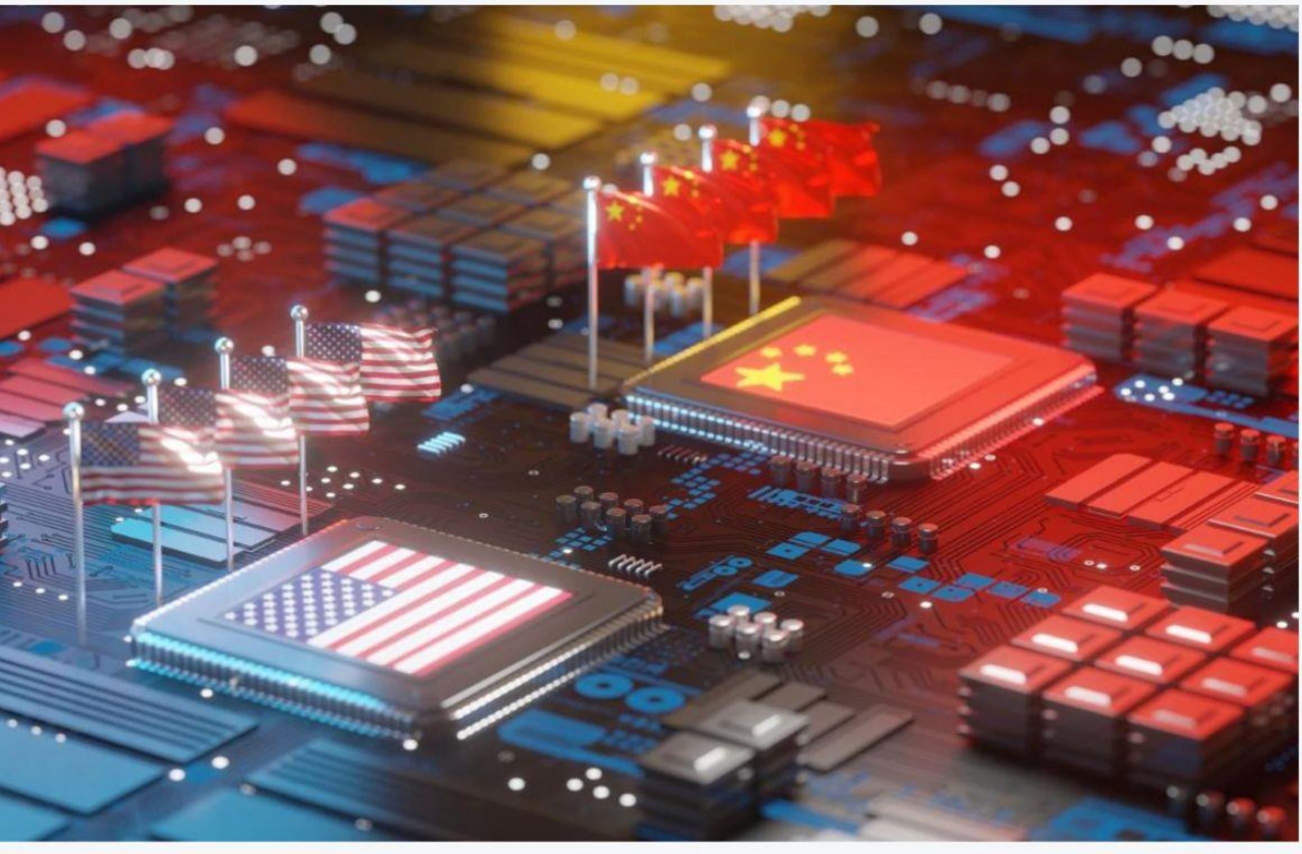

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THE IMPACT OF QUANTUM TECHNOLOGY ON INTERNATIONAL RELATIONS IN THE CONTEXT OF U.S.-CHINA RIVALRY

The United States and the People's Republic of China are engaged in competition across nearly all domains—from the economy and defense to artificial intelligence and space technologies. One of the newest and most striking dimensions of this multifaceted rivalry is quantum technologies, which are gaining increasing strategic importance. As a new dimension of systemic competition, quantum technologies add yet another layer to the multi-level rivalry between these two powers.

Quantum technologies are high-tech fields that aim to surpass the limits of classical technologies by utilizing the fundamental principles of quantum mechanics. These technologies are generally grouped under three main categories: quantum computing, quantum communication, and quantum sensing.

Due to their dual-use nature, quantum technologies can be applied in both civilian and military domains. Therefore, a state that achieves quantum superiority would not only gain a scientific or technological edge but also secure advantages in areas such as defense, cryptography, intelligence, and cybersecurity. Such a technological breakthrough could also grant states an upper hand in terms of establishing hegemony. Consequently, it seems likely that technological superiority will play a crucial role in shaping the future global order.

For all these reasons, quantum technologies have become central not only to bilateral competition but also to the global agenda. The United Nations' declaration of 2025 as the "International Year of Quantum Science and Technology" clearly demonstrates the strategic significance this field has attained. However, since the development of quantum technologies requires extremely costly infrastructure, advanced expertise, and long-term R&D investments, it remains a high-threshold area of competition where only a limited number of actors can operate effectively. These conditions position the United States and the People's Republic of China—both of which have made significant investments in terms of financial resources and scientific capacity—as the leading players in the quantum race.

What is Quantum 3.0?

The first quantum revolution ended World War II with the invention of the atomic bomb, triggered the Cold War, and paved the way for the establishment of a bipolar international order. The second quantum revolution, on the other hand, laid the foundation of a new digital society and globalization by connecting individuals and institutions on a global scale through semiconductors, lasers, fiber optics, GPS, and computers. The ongoing 'Quantum 3.0' process, which is still too early to be called a revolution, is not only a continuation of scientific advancement but also stands out as a harbinger of a new strategic, economic, and geopolitical transformation.

The Quantum 3.0 era revolves around three core fields: **quantum computing, quantum communications, and quantum sensing.** Classical computers encode information in binary form—either 0 or 1—and each of these values is called a "bit".

However, encoding information this way imposes limits on computational power due to the finite number of possible bit combinations. In contrast, quantum computers use "qubits", which can represent both 0 and 1 at the same time. Qubits operate based on two fundamental physical principles: superposition and entanglement. Superposition refers to a particle's ability to exist in multiple states simultaneously—being both 0 and 1 at once. Entanglement means that two particles, even if separated by vast distances, remain interconnected in such a way that a change in one instantly affects the other. These two principles form the foundation of quantum technologies.

By harnessing these principles, quantum computers can process data and perform calculations at speeds that far exceed classical computers. These qubit-based systems hold tremendous potential in areas that require high computational power, such as code-breaking, drug discovery, and military simulations. In addition, they offer practical benefits in everyday applications like more accurate climate modeling, weather forecasting, medical imaging and diagnostics, and enhanced efficiency in financial management.

Quantum communication technologies have enabled the development of Quantum Key Distribution (QKD), which opens the door to unbreakable encryption systems. QKD allows the creation of encryption keys that are resilient to external interference and ensure secure communication infrastructures. If a third party (an eavesdropper) attempts to interfere during a quantum key transmission, the intrusion causes a measurable disturbance in the signal, alerting the system to the breach. Thus, the confidentiality and integrity of communication are preserved. This technology is expected to bring revolutionary changes in areas such as intergovernmental diplomatic communication, military security protocols, and high-precision data transfer.

Meanwhile, quantum sensing goes far beyond classical sensor technologies by detecting physical changes—such as magnetic fields, gravity, and motion—with extraordinary precision. This provides critical advantages in strategically important areas like radar systems, the detection of nuclear submarines, and precise navigation.

From an international relations perspective, the first country to reach the next stage in quantum technologies could trigger a seismic shift in the global balance of power, leading to the emergence of a new power asymmetry. James Der Derian suggests that, quantum-like phenomena could mark a turning point in the global order—moving from a traditionally state-centered, bounded system to one characterized by "global heteropolarity," where powerful individuals, non-governmental actor networks, and large tech companies offer alternatives to traditional state governance[1]. Before such a structural transformation takes place, a transitional period marked by increased global cooperation, alliance-building, and emerging blocs appears likely. In this context, states may seek alliances with countries that have already achieved—or are close to achieving—superiority in

[1] James Der Derian and Stuart Rollo, "'Quantum 3.0': What Will It Mean for War, Peace, and World Order?" Global Perspectives 5 (1). 2024 https://doi.org/10.1525/gp.2024.93888

quantum technologies in order to enhance their own sense of security. Conversely, rival countries that believe they possess similar capabilities may band together to form counter-blocs. A notable example is the joint statement released after the April meeting between U.S. President Donald Trump and Italian Prime Minister Giorgia Meloni at the White House, where they declared: "As we transition to and innovate on the technologies of the future, such as 6G, AI, quantum computing, and biotechnology, we also commit to exploring opportunities for enhanced partnerships in these critical industries that protect our data from adversaries that would exploit it."[2] At the same time, NATO's release of a Quantum Technology Strategy[3] may indicate that a bloc-based approach is becoming institutionalized within the Western alliance, which shares a long history of partnership. As a result, the nuclear competition and polarization of the Cold War era may now evolve into a new form of rivalry centered around quantum technologies.

In this ongoing transformation process, at the heart of which lie quantum computers, the point at which cryptographically relevant quantum computers (CRQCs) gain enough processing power to break standard encryption methods is referred to in the literature as "Q-Day" (Quantum Day). This day signifies the moment when current encryption algorithms—used across countless domains such as banking transactions, e-government systems, military communications, cloud-based data protection, and the security of emails and messaging—can be broken by quantum computers. Therefore, Q-Day is regarded as a critical turning point that will radically reshape not only digital security but also interstate competition and the very foundations of the information age.

The uncertainty of when Q-Day might arrive has already prompted major powers to begin stockpiling encrypted data with the goal of decrypting it in the future. This strategy, known as "Harvest Now, Decrypt Later," is based on the practice of archiving encrypted data that cannot yet be deciphered with today's technology but may become readable once quantum computing capabilities mature. This situation has the potential to deeply affect numerous sectors—from commerce and banking systems to healthcare infrastructure—and most significantly, national security. The country that first develops a functioning quantum computer will have the capacity to decrypt the encrypted communications of other nations. This would dramatically enhance cyber-espionage activities, allowing the leading state to eavesdrop on the diplomatic communications of its rivals and access classified government information—while simultaneously safeguarding its own secrets. Such a one-sided transparency would grant the quantum-superior state strategic and asymmetric advantages in intelligence, military, and economic domains.

When examining the potential military impacts of quantum technologies, the transformation expected from quantum sensors is particularly noteworthy. These sensors can detect even the slightest

[2] The White House, "United States – Italy Joint Leaders' Statement." May 2, 2025, https://www.whitehouse.gov/briefings-statements/2025/04/united-states-italy-joint-leaders-statement/

[3] NATO, "Summary of NATO's Quantum Technologies Strategy," Jan 16, 2024, https://www.nato.int/cps/en/natohq/official_texts_221777.htm

anomalies in gravity or magnetic fields, making it possible to locate submarines or stealth aircraft that are designed to evade radar detection[4]. Additionally, they can provide high-precision positioning and navigation even in environments where GPS signals are unavailable. Quantum communication technologies, especially in terms of command-and-control systems, are of critical importance. Thanks to QKD, communication infrastructures can be established that are immune to external interference and cannot be hacked.

Quantum computers, with their enormous computational power, could revolutionize military planning by enabling complex simulations, optimization models, and strategic analyses used in defense. Therefore, the impact of quantum technology should not be reduced merely to faster computers or advanced technologies.

Countries regard advanced quantum technologies as strategic assets and invest heavily in them, viewing these technologies as keys to future economic power, military capability, and technological sovereignty.[5] However, quantum research is significantly more expensive than classical technologies due to the need for highly complex experimental environments, ultra-low temperatures, sensitive measurement devices, and high-capacity laboratories. As a result, in this field led by the United States and the People's Republic of China, other key players such as the European Union, the United Kingdom, Australia, Canada, Japan, and Singapore are also making their presence felt to a certain degree, provided they can afford the high costs.

The U.S. Quantum Strategy

The United States follows a market-based development model in its quantum technology strategy, relying on private sector investments and market dynamics. Within this framework, most of the groundbreaking innovations and technological advancements are carried out by the private sector. Tech giants like IBM, Google, and Microsoft stand out through their R&D activities and practical applications. The state, meanwhile, plays a guiding and incentivizing role by providing an institutional framework.

In this regard, the *National Quantum Initiative Act (NQIA)*, signed in December 2018 under President Donald Trump, was the United States' first major comprehensive national policy step in the field of quantum technologies. This act aimed to develop a centralized and coordinated quantum strategy, support research efforts in the field by federal agencies, academia, and the private sector, and foster inter-institutional collaboration. It created a legislative foundation to institutionalize the U.S. quantum ecosystem and reinforce the country's leadership in quantum technologies. Since the act's passage, federal spending on quantum R&D, which stood at $449 million in 2019, rose to $1 billion by 2022—doubling in just three years.[6]

[4] Marin Ivezic. "Quantum Geopolitics: The Global Race for Quantum Computing." PostQuantum - Quantum Computing, Quantum Security, PQC. April 21, 2025. https://postquantum.com/quantum-computing/quantum-geopolitics/

[5] Ivezic, "Quantum Geopolitics."

[6] Noah Berman, "What Is Quantum Computing?" *Council on Foreign Relations*, October 7, 2024. https://www.cfr.org/backgrounder/what-quantum-computing

In May 2022, under the Biden administration, a National Security Memorandum titled *"Promoting United States Leadership in Quantum Computing and Reducing Risks to Vulnerable Cryptographic Systems"* was signed.[7] This directive set a goal to minimize quantum-related risks by 2035 and emphasized the necessity for federal agencies to adopt quantum-resistant cryptography in anticipation of quantum computers' ability to break current encryption systems. In line with this, the *Quantum Computing Cybersecurity Preparedness Act*[8], signed in December of the same year, translated the memorandum into concrete policy implementation.

In August 2023, a presidential executive order was issued to restrict American capital from investing in strategic sectors—such as quantum information technologies, artificial intelligence, and semiconductors—in China.[9] The aim was to regulate capital flows that could pose a threat to national security.

Looking at the private sector, from 2019 to 2023, total private investment in quantum technologies in the U.S. reached approximately $8 billion. This relatively modest amount is largely due to the private sector's preference for investing in artificial intelligence, which offers quicker commercial returns compared to the more uncertain and long-term nature of quantum technology. The high level of risk and limited short-term demand in the quantum field discourage early-stage investment.[10]

Nonetheless, major tech companies have taken important steps, recognizing the long-term potential of quantum technologies. One of the industry leaders, Google, attracted significant attention in October 2019 with the unveiling of its 54-qubit Sycamore processor, claiming that the chip had achieved quantum supremacy by completing a computation in 200 seconds that would take the world's most powerful classical supercomputer approximately 10,000 years to solve.[11]

In October 2024, Google took its achievement even further by announcing that it had regained quantum supremacy with its next-generation Sycamore processor, which featured 67 qubits. Shortly afterward, in December 2024, the company introduced a new quantum chip named Willow, marking yet another breakthrough in the tech world. According to Google's statement, the Willow chip

[7] The White House, "National Security Memorandum on Promoting United States Leadership in Quantum Computing While Mitigating Risks to Vulnerable Cryptographic Systems." The White House. May 4, 2022. https://bidenwhitehouse.archives.gov/briefing-room/statements-releases/2022/05/04/national-security-memorandum-on-promoting-united-states-leadership-in-quantum-computing-while-mitigating-risks-to-vulnerable-cryptographic-systems/

[8] Congress.Gov | Library of Congress, "Text - H.R.7535 - 117th Congress (2021-2022): Quantum Computing Cybersecurity Preparedness Act." n.d. https://www.congress.gov/bill/117th-congress/house-bill/7535/text

[9] Congress.Gov | Library of Congress, "Regulation of U.S. Outbound Investment to China." n.d. https://www.congress.gov/crs-product/IF12629

[10] Michael S. Rogers, William Zeng, James Andrew Lewis, Taylar Rajic, and Jonah Force Hill, *CSIS Commission on U.S. Quantum Leadership*, 2025, https://www.csis.org/analysis/csis-commission-us-quantum-leadership

[11] Marin Ivezic, "Google's Sycamore Achieves Quantum Supremacy." PostQuantum - Quantum Computing, Quantum Security, PQC. October 26, 2019. https://postquantum.com/industry-news/google-sycamore/

successfully solved a problem in just five minutes—a problem that would reportedly take the world's fastest classical supercomputers nearly 10 septillion years (10^{25}) to complete.[12]

Although quantum computers have much higher processing capacity compared to classical computers, Microsoft has developed a new type of qubit to increase stability in quantum computations and minimize error rates, because qubits are extremely sensitive and prone to degradation due to external factors such as heat and sound. Unlike conventional qubits, efforts to create more robust and fault-tolerant versions have led to the development of a novel type known as the *topological qubit*. The first topological quantum processor, named *Majorana 1*, was introduced in February 2025.[13] The information encoded in these qubits is naturally protected against minor external errors, making it more securely stored. This characteristic renders Majorana significantly more stable and resilient than standard quantum qubits.

China's Quantum Strategy

The People's Republic of China follows a state-driven, top-down, and long-term planning strategy that contrasts with the relatively fragmented and market-oriented U.S. model, which relies heavily on collaborations between universities and the private sector.

Recognizing the strategic significance of quantum communication for China's long-term goals, President Xi Jinping began promoting policies to support the development of quantum technologies starting with the 13th Five-Year Plan (2016–2020)[14]. In the 14th Five-Year Plan of 2021, quantum technologies were identified as one of the core national priorities extending through 2035[15].

Viewing quantum technologies not only as a scientific endeavor but also as a strategic asset for national security and military advantage, the Chinese government has committed substantial investments to the field. For instance, in 2022, $15.3 billion in public funding was allocated for quantum computing—more than double the €7.2 billion pledged by the European Union and approximately eight times the $1.9 billion committed by the United States. In March 2025, China launched a state-backed fund worth 1 trillion yuan ($138 billion) to advance key technology sectors including quantum computing, artificial intelligence, semiconductors, and renewable energy.

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[12] Neven Hartmut, "Meet Willow, Our State-of-the-art Quantum Chip." *Google*, June 12, 2025. https://blog.google/technology/research/google-willow-quantum-chip/

[13] Chetan Nayak, "Microsoft Unveils Majorana 1, the World's First Quantum Processor Powered by Topological Qubits." Microsoft Azure Quantum Blog, February 19, 2025. https://azure-microsoft-com.translate.goog/en-us/blog/quantum/2025/02/19/microsoft-unveils-majorana-1-the-worlds-first-quantum-processor-powered-by-topological-qubits/?_x_tr_sl=en&_x_tr_tl=tr&_x_tr_hl=tr&_x_tr_pto=tc

[14] Ciel Qi, "China's Quantum Ambitions: A Multi-Decade Focus on Quantum Communications — Yale Journal of International Affairs." May 23, 2024. https://www.yalejournal.org/publications/chinas-quantum-ambitions

[15] Michael S. Rogers, William Zeng, James Andrew Lewis, Taylar Rajic, and Jonah Force Hill, *CSIS Commission on U.S. Quantum Leadership*, 2025, https://www.csis.org/analysis/csis-commission-us-quantum-leadership

The city of Hefei plays a central role in China's quantum ambitions. It hosts the University of Science and Technology of China (USTC) and the National Laboratory for Quantum Information Sciences, established in 2017, where much of the country's quantum research is concentrated.

China has shown particular interest and leadership in the field of quantum communication. In 2016, it launched *Micius*, the world's first quantum communication satellite, designed using QKD technology[16]. This achievement made China the first country to implement quantum encryption technology on a space-based scale. One of *Micius*'s most notable successes was facilitating the first-ever intercontinental quantum-encrypted video call between Beijing and Vienna in 2017—an event that marked the world's first instance of intercontinental quantum cryptographic communication.

Further solidifying its capabilities, China built a 2,000-kilometer quantum fiber network in 2017 connecting the cities of Beijing, Hefei, Jinan, and Shanghai. This network employed QKD to encrypt data along the entire route[17]. The project served as concrete evidence that quantum communication is not merely a theoretical concept but can also function in practice and be integrated into large-scale infrastructure systems.

In July 2022, nearly six years after the launch of Micius, China sent its second quantum communication satellite, Jinan-1, into space. Researchers noted that although Jinan-1 weighs only one-sixth of Micius, it can generate quantum keys two to three times faster[18]. A third quantum communication satellite is planned to be launched by 2026[19].

In May 2025, the company China Telecom announced that it had successfully conducted a 1,000-kilometer quantum-encrypted phone call between the cities of Beijing and Hefei, and that the system had already been implemented in 16 more cities, thereby establishing a nationwide quantum-secure communication infrastructure. The company, using a hybrid system that combines QKD with post-quantum cryptography (PQC) technologies, claims to have developed the world's first distributed cryptographic system built to be resilient against quantum computer attacks, thanks to this dual-layer structure where even if one layer is compromised, the other continues to provide protection[20].

In addition, China has also made significant strides in quantum sensing and computing.

[16] Chinese Academy of Sciences, "China Launches World's First Quantum Communication Satellite 'Micius'----Remarkable Decade of CAS: Explorations Into the Unknown." n.d. https://english.cas.cn/Special_Reports/rd/2016/202210/t20221019_321851.shtml

[17] Chinese Academy of Sciences, "Beijing-Shanghai Quantum Communication Network Put Into Use----Chinese Academy of Sciences." n.d. https://english.cas.cn/newsroom/archive/news_archive/nu2017/201703/t20170324_175288.shtml

[18] Jilian Talenda, "China's Quantum Ambitions: A Multi-Decade Focus on Quantum Communications — Yale Journal of International Affairs." May 23, 2024. https://www.yalejournal.org/publications/chinas-quantum-ambitions

[19] Evan Freidin, "Quantum Game Changer." RealClearDefense. February 25, 2025. https://www.realcleardefense.com/articles/2025/02/24/quantum_game_changer_1093330.html

[20] Matt Swayne, "China Telecom Launches Hybrid Quantum-Safe Encryption System, Completes 1,000-Kilometer Secure Call." The Quantum Insider. May 20, 2025. https://thequantuminsider.com/2025/05/20/china-telecom-launches-hybrid-quantum-safe-encryption-system-completes-1000-kilometer-secure-call/

The 66-qubit Zuchongzhi quantum computer, introduced for the first time in 2021, surpassed Google's 54-qubit Sycamore processor (announced in 2019), earning the title of the world's most powerful quantum computer at the time[21].

In response to Google's 2024 breakthrough, China introduced the Zuchongzhi-3 model in March 2025, featuring 105 qubits in an effort to regain its lead in the field. Compared to the latest data published by Google, this next-generation quantum computer demonstrated a computational performance one million times faster, showcasing a clear advantage and reinforcing China's leadership in the global quantum race[22].

In May 2025, the Chinese company Origin Quantum took a major step in quantum computing by unveiling Tianji 4, a quantum control system. This system, crucial for the operation of quantum computers, governs the centralized control of qubits, determining which operations they should perform, when, and for how long. As the number of qubits in quantum computers increases, this control process becomes much more complex and challenging. Designed to manage systems with more than 100 qubits, Tianji 4 was built with the power and precision to address this problem. This not only paves the way for developing larger and more powerful quantum computers but also reflects China's ambition to build a self-sufficient domestic quantum ecosystem, independent of U.S.-based companies such as IBM and Google[23].

Conclusion

The technological transformation processes of the 21st century are fundamentally reshaping the nature of interstate competition. Among these transformations, quantum technologies, alongside artificial intelligence, space exploration, and biotechnology, represent not only a scientific breakthrough but also a new front in the race for strategic superiority.

In this context, quantum technologies signal a transformation that goes beyond a mere race to develop technical capacity. They hold implications for digital sovereignty, cybersecurity, military superiority, and economic independence. Comprising subfields such as quantum computing, quantum communication, and quantum sensing, this technology offers levels of computational power, data security, and sensing capabilities that are unparalleled by classical technologies.

However, rather than asking who is currently ahead in this "race," the more critical question is which actor is strategizing and institutionalizing quantum

[21] Matthew Sparkes, "China Beats Google to Claim the World's Most Powerful Quantum Computer." *New Scientist*, July 5, 2021. https://www.newscientist.com/article/2282961-china-beats-google-to-claim-the-worlds-most-powerful-quantum-computer/

[22] State Council of the People's Republic of China, "China Hits New Landmark in Global Quantum Computing Race." March 4, 2025. https://english.www.gov.cn/news/202503/04/content_WS67c656dbc6d0868f4e8f0489.html

[23] Matt Swayne, "China's Origin Quantum Releases Fourth-Generation Quantum Control System, Heads Toward Mass Production." The Quantum Insider. May 8, 2025. https://thequantuminsider.com/2025/05/08/chinas-origin-quantum-releases-fourth-generation-quantum-control-system-heads-toward-mass-production/

technology for what purposes. In this regard, the two leading states in the field—the United States and the People's Republic of China—are pursuing global leadership in quantum technologies through different strategies. The U.S. follows a private sector-driven, knowledge-based approach, maintaining leadership in quantum computing. In contrast, China adopts a centralized state strategy, focusing less on knowledge production and more on rapidly transforming technology into practical applications, emerging as a leader in quantum communication.

This distinction is also confirmed by the U.S.-based Information Technology and Innovation Foundation (ITIF), which highlights that the U.S. emphasizes knowledge generation, while China follows a strategy centered on implementation and rapid product development[24].

The absence of binding international legal norms in the field of quantum technologies further intensifies this competition. This legal vacuum enhances the desire of leading states to shape emerging norms in line with their own interests and exert long-term influence over the system. In this light, achieving superiority in quantum technologies is not merely a technical accomplishment but also signifies the capacity to define the boundaries of the new global order.

In conclusion, quantum computers have become not only a technological but also a political issue, with the potential to reshape the structure of international relations. It can be said that the actor who will win this "race" will be the one who first overcomes technological barriers and makes quantum computing scalable and applicable. Therefore, it is of great importance to examine not only the scientific dimension of quantum technologies but also their geopolitical implications.

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