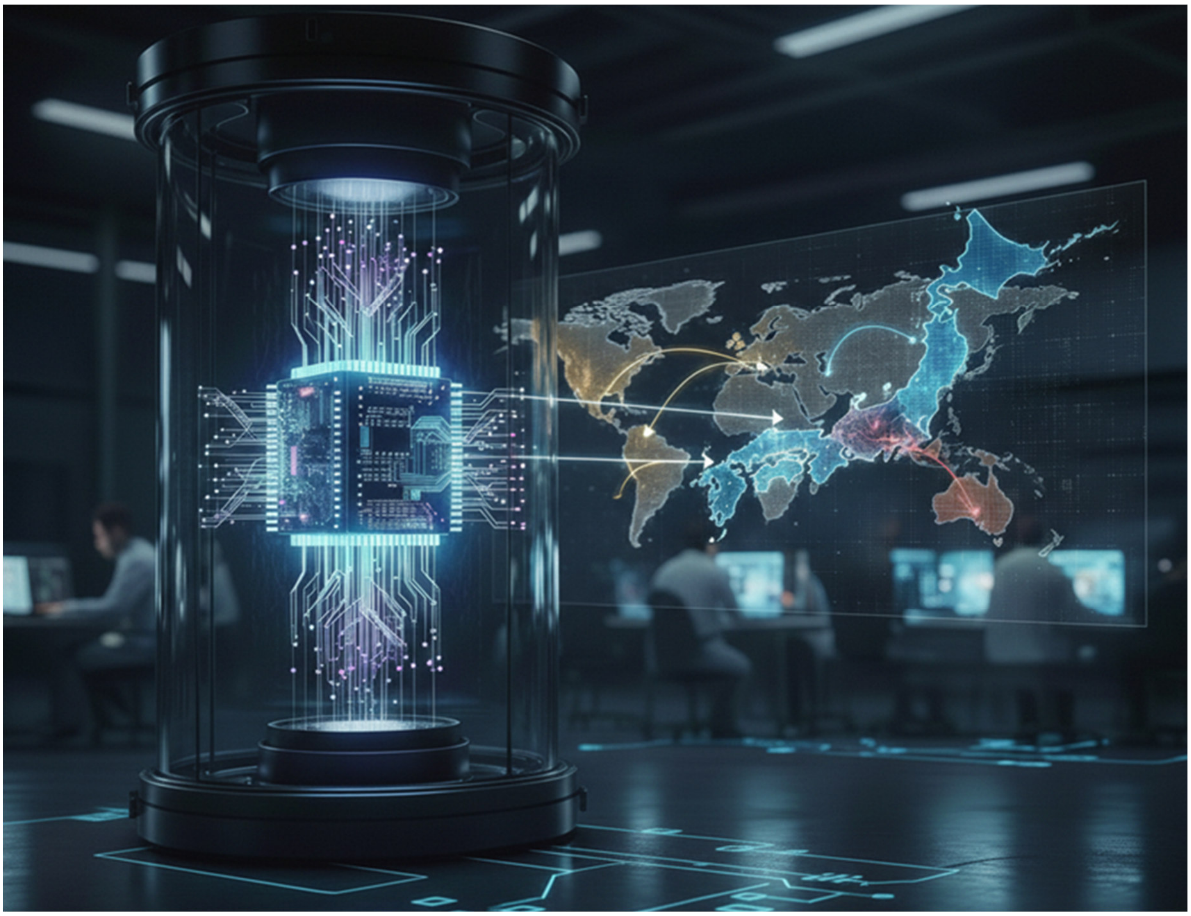
Japan's Path to Success in Quantum Computer Development



The digital society relies on semiconductor technology now nearing its physical limits. Quantum computers can overcome this and transform computation. Japan has strengths in components and devices essential for quantum computers. The author argues the planned technology research association should center on these manufacturers, alongside hardware/software firms, users, and research institutions.
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The innovations in quantum computers are bringing about immeasurable changes to industry and society. At the same time, however, international competition for technological superiority is intensifying, and we have reached a critical juncture where Japan's standing is being called into question.

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The future opened by quantum computers and security threats

The digital society, which forms the foundation of modern civilization, has been built upon the staggering pace of progress in semiconductor technology. However, this progress is approaching its physical limits. The technology that holds the potential to fundamentally break through this sense of stagnation and fundamentally change the nature of computation is "quantum computers." They are entirely different from conventional computers, bringing about a leap in computational power by orders of magnitude. As a result, for specific problems, they are expected to solve in just a few seconds calculations that would take a conventional supercomputer thousands of years to complete.

This breakthrough in computational power is not limited to mere technological innovation; it has the potential to become a force that brings immense benefits to our lives and society. In the medical field, for example, it may pave the way for tailor-made medicine suited to each patient's constitution and condition, as well as the overcoming of intractable diseases such as Alzheimer's. In the environmental and energy fields, expectations are high for ultimate battery technologies that resolve the instability of renewable energy and the development of new materials that transform carbon dioxide into a resource.

Furthermore, the technology could contribute to making social infrastructure smarter and more resilient—for instance, by predicting global financial crises before they occur or optimizing logistics and energy grids across society. In other words, quantum computers can become a "game changer" that overturns existing industries from their very foundations. Additionally, in the field of AI, which is currently undergoing rapid development, quantum computing is expected to further accelerate its evolution.

At the same time, it will bring about significant impacts in terms of security. Today's Internet society ensures the safety of communications through advanced cryptographic technologies that are considered "virtually impossible to crack" with conventional computers. However, a practical quantum computer is said to possess the ability to easily decrypt these, rendering such cryptography powerless. This means that state secrets, financial transactions, and critical infrastructure will be exposed to grave danger.

The Intensifying "Quantum Hegemony Race"

Recognizing the strategic importance of this technology, nations have entered a "quantum hegemony race" with their national prestige at stake. This is not merely a technological development competition between companies; it is a total war among nations over "quantum sovereignty," wagering whether they can bring the very foundations of future economy and security under their own control.

Further complicating this hegemonic race is technical uncertainty. Multiple principles for realizing quantum computers are currently in contention, such as "superconductivity," "ion traps," "neutral atoms," and "photons," and at this point, it remains undecided which method will ultimately become the mainstream. Consequently, nations are proceeding with the development race while bearing the immense strategic risk of deciding "which technological method to wager national resources on."

The United States is deploying a "Whole-of-Nation" approach, in which the government and private sector act as one. While the government enacted the "National Quantum Initiative Act" in 2018 and is injecting public funds, the true strength of the US model lies in private investment from giant IT companies such as Google, IBM, Microsoft, Amazon, and Intel. They are investing on a scale ranging from hundreds of billions to one trillion yen—surpassing government budgets—and are establishing *de facto* standards by advancing everything from basic research to practical application through cloud services in an end-to-end manner. Recently, NVIDIA, which holds an overwhelming share of the AI semiconductor market, has also announced its full-scale entry, unveiling a system that connects AI semiconductors with quantum computers. In addition to these tech giants, emerging ventures such as IonQ, Rigetti Computing, and PsiQuantum are further solidifying US competitiveness by rapidly commercializing cutting-edge basic research.

China has positioned quantum technology as a "national project" and a top priority, making investments on a staggering scale. Its government investment is said to exceed one trillion yen, reaching more than 20 times that of Japan. China leads the world particularly in the field of "quantum communication," which is considered absolutely impossible to eavesdrop on or decrypt. This can be described as a national strategy that directly reflects the threat of cryptography being broken. Of particular note is its intellectual property strategy; China has surpassed the United States to become the world leader in the number of published patent applications related to quantum technology. China's national strategy, which seeks to dominate the world in both quantity and quality, is the greatest threat to the United States and an even more profound threat to Japan.

Following the two superpowers of the United States and China, Europe, India, and Middle Eastern countries have also begun making massive investments in quantum development as part of their national strategies. The "Quantum Europe Strategy," announced by the EU in July 2025, states that the EU and its member states have invested more than two trillion yen in quantum technology over the past five years. Furthermore, with the goal of becoming a global leader in the field of quantum technology by 2030, Europe will invest up to approximately 54 billion yen in public funds to establish six quantum chip pilot lines. India also approved the "National Quantum Mission (NQM)" in 2023, and is accelerating the development of quantum computers and quantum communication networks with a budget of approximately 100 billion yen over eight years. In addition, Middle Eastern countries such as the United Arab Emirates and Saudi Arabia, backed by their abundant financial resources, are partnering with prominent ventures worldwide one after another, seeking to establish their status as "hubs" for cutting-edge technology.

Japan's Strengths: "Promising Seeds" and "Supply Chains"

In response to such global trends, Japan also possesses a diverse range of world-class players and an accumulation of technological expertise.

Among the multiple realization methods mentioned in the previous section, in the superconducting method, RIKEN has put the first domestically produced machine into operation, while Fujitsu and Osaka University are collaborating with the aim of establishing their original "STAR architecture." In the photonic approach, NTT leads the world based on its long-standing research. Regarding the neutral atom approach, US-based QuEra Computing, where Takuya Kitagawa serves as president, is promoting practical application in Japan through initiatives such as the introduction of its machines to the National Institute of Advanced Industrial Science and Technology (AIST).

Furthermore, Japan possesses strengths in the supply chain for components as well. A quantum computer is a collection of components that require extremely advanced technical capabilities. For example, to perform accurate calculations, it is necessary to maintain the equipment in an ultra-low temperature state; thus, the performance required of components differs significantly from that under normal environments. Nevertheless, Japan is home to many companies with high technical capabilities capable of meeting these specialized requirements.

The Necessity of a "Sovereign Quantum Computer"

While individual players are striving as described above, Japan is being left with a decisive gap in terms of national strategy, particularly in the amount of resources being invested.

While the United States and China compete with annual investments on the scale of hundreds of billions or even trillions of yen, Japan's government-related budget for the quantum field is less than a fraction, or even less than one-tenth, of that amount. We are facing an overwhelming disparity in the volume of equipment, personnel, and frequency of trial and error required for development compared to the US and China, and this deficiency leads directly to "falling a full lap behind" in hardware development.

Should Japan lose the quantum computer development race in this manner, it would result in nothing less than becoming a "quantum-defeated nation," dependent on other countries for the critical infrastructure of its economy and security, the losses from which would be immeasurable.

(1) Economic dependence on foreign technology

In the future, when the core processes of all industries come to be executed on quantum computers, if Japan depends entirely on overseas companies for its computational platforms, Japanese companies will become entities that do nothing more than continue to pay exorbitant "usage fees." This is an extension of the previous pattern where the Operating System (OS) was seized by Microsoft, the search engine by Google, and the cloud by Amazon Web Services, and it will further exacerbate the overseas dependence of the economy.

(2) Weakening of National Security

This is the most direct threat. A practical quantum computer will render current Public-Key Cryptography (PKC) powerless. The problem is not only that a future computer will break "future" encryption. As symbolized by the phrase "Harvest Now, Decrypt Later," other countries are continuing to intercept and accumulate encrypted confidential information related to Japan's diplomacy, defense, and industry at "this very moment." Then, at the point in the "future" when a quantum computer is completed, they will retrospectively decrypt all of that information.

The development and implementation of new technologies to counter this threat, such as "Post-Quantum Cryptography (PQC)" and "Quantum Key Distribution (QKD)," also cannot be carried out without advanced quantum technology. A state that cannot protect its own information with its own technology, and thus possesses serious vulnerabilities in its national security, cannot be said to be maintaining its national sovereignty.

(3) Delays in Basic Scientific Research

The cutting edge of basic sciences such as physics, chemistry, biology, and space science can no longer be sustained without advanced computer simulations. Quantum computers will significantly raise the accuracy and scale of these simulations. A country that does not possess this cutting-edge computational foundation will fall behind other nations in basic scientific research as well.

Facing this critical situation head-on, the establishment of a "sovereign quantum computer"—which ensures technological autonomy by providing hardware, software, and operational personnel within the country—is the most important national strategy Japan must take as a path to reclaiming its position as a technology-driven nation.

Structural Issues in Japan Leading to a "Full Lap Behind"

The delay in Japan's development of quantum computers stems from structural defects at the very foundation of its national strategy.

(1) The Trap of "Selection and Concentration" Without Strategy

Since the 2000s, Japan's science and technology policy has adopted "selection and concentration" as its fundamental principle to effectively utilize limited resources. This philosophy is deeply inherited by the current “Science, Technology, and Innovation Basic Plan” and the “Integrated Innovation Strategy,” within which “quantum technology” is positioned as a top-priority “selected” field alongside AI and semiconductors.

However, this has become a cause of functional failure. First, there is an absolute shortage in the amount of investment that should be “concentrated,” as already mentioned. Second, even that limited budget is being “dispersed” and allocated domestically. Japan’s investment consistently ends up distributing budgets thinly and broadly across all of the multiple realization methods. Consequently, no single method can reach a technological level capable of competing globally.

(2) Serious Depletion of “Quantum Talent”

The core of the ecosystem supporting a sovereign quantum computer is “talent,” yet Japan faces its most serious crisis here.

The first aspect is a shortage in “quantity”—the infrastructure for nurturing specialized talent is extremely fragile. There are very few universities or graduate schools with curricula that allow students to systematically study both “Quantum Mechanics” and “Information Science,” both of which are essential for quantum computers. In recent years, interdisciplinary programs and departments have finally begun to be established at some universities, but the number of graduates produced from these is only on the scale of several dozen per year, which is insufficient to meet national demand.

The second aspect is a shortage in “quality”—specifically, the “brain drain” of top talent. The few outstanding researchers and students nurtured domestically do not remain in Japan. Large US and Chinese IT companies offer top quantum researchers and talented PhD holders compensation several to ten times higher than what Japanese universities, research institutions, or domestic companies can provide, along with abundant research budgets. For exceptional students, the optimal path to maximize their abilities, receive fair evaluation, and engage in cutting-edge research is, unfortunately, not at home but “employment at a major overseas IT company.” As a result, Japan has fallen into an extremely irrational structure where it continues to provide its finest talent, nurtured with tax money, to its overseas competitors for free.

(3) Siloed bureaucracy and Inefficient Execution Systems

Further exacerbating the two aforementioned issues is the structural defect of the execution system. While the United States and China fight a “Whole-of-Nation” war, Japan, lacking a powerful command post, is inefficiently managing its precious resources through traditional “siloed bureaucracy.”

Specifically, budgets and authority related to quantum are completely dispersed among the Ministry of Education, Culture, Sports, Science and Technology (MEXT), which handles basic research; the Ministry of Economy, Trade and Industry (METI), which handles industrial application; and the Ministry of Internal Affairs and Communications (MIC), which handles communication and cryptography. This system, where sectionalism among ministries and budget allocation may take precedence over achieving national goals, is one of the greatest barriers to realizing a sovereign quantum computer.

The Path toward Realizing a Sovereign Quantum Computer

To avoid the worst-case future of becoming a "quantum-defeated nation," Japan must set the establishment of a sovereign quantum computer as the highest priority of its national strategy and urgently execute the following four pillars simultaneously.

(1) Securing an Unprecedented National Budget and Long-term Commitment

A conventional budget increase of a few percent or tens of percent can no longer make up for being a full lap behind. It is necessary to secure a national budget on a scale comparable to those of the United States and China—namely, "at least several trillion yen over ten years"—and commit to continuous support over multiple fiscal years. A national consensus must be formed that the establishment of a sovereign quantum computer is an "investment" in future economic benefits on the scale of trillions or tens of trillions of yen and in national security, and financial resources should be allocated accordingly.

(2) Quantum Talent Development Plan

To fundamentally resolve the talent issue, which is the foundation of the quantum ecosystem, a large-scale "strategic roadmap for nurturing quantum-native talent" must be formulated. First, the government and companies must collaborate to guarantee compensation and research environments that surpass those of overseas IT companies for world-class researchers, strategically inviting them. Furthermore, in university and graduate school education, a curriculum for studying both physics and information science must be standardized. In addition, large-scale retraining programs in quantum technology for existing engineers and researchers must be deployed under state support.

(3) Establishment of a National Quantum Technology Command Post

To break through the harmful effects of "siloed bureaucracy," a "command post" with powerful authority must be established. This organization will centrally grasp the quantum-related budgets and authority dispersed among various ministries and take charge of everything from the formulation to the execution of the sovereign quantum computer strategy. Like DARPA (Defense Advanced Research Projects Agency) in the United States, it must be an organization capable of taking risks and carrying out speedy budget execution and regulatory reform.

(4) Public-Private Integrated Technology Development

Under the direction of the command post presented in the previous section, a public-private partnership R&D organization will serve as the engine for realizing the sovereign quantum computer. The model to follow here is the success of the "Very Large Scale Integration (VLSI) Technology Research Association," which brought the public and private sectors together in the 1980s to establish a semiconductor technology foundation that surpassed that of the United States. The key to success at that time lay in developing common platform technologies under an "All-Japan" system, involving not only device manufacturers such as Hitachi, NEC, and Fujitsu, but also the entire supply chain, including related manufacturing equipment and material manufacturers.

Quantum computers are also an assembly of high-performance components and devices in which Japan has strengths. The "technology research association" to be established should place the component and device manufacturers, which are Japan's strength, at its core, in addition to hardware development companies, software companies, user companies, and universities/national laboratories. By doing so, Japan should truly "concentrate" its limited resources and build an autonomous sovereign quantum computer ecosystem that completes the entire supply chain domestically.

However, in establishing this association, it is dangerous to rely solely on past successful experiences. We must utilize the reflections on the "semiconductor defeat" since the 1990s—such as the outflow of technology and talent, the loss to South Korea and Taiwan in the memory market, and the failure to transition to new business models. In other words, the public and private sectors must be prepared to share a market strategy that goes beyond the development of common platform technologies, determining how to link that technology to sustainable international competitiveness and business.

Translated from *"Ryoshi Konpyuta Kaihatsu ni okeru Nihon no Kachisuji (Japan's Path to Success in Quantum Computer Development),"* Voice, *January 2026, pp. 120–127. (Courtesy of PHP Institute)* [March 2026]

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