The Quantum Race: How Emerging Technologies Reshape Global Security Governance

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Technological shifts have always reshaped international relations. The nuclear revolution redefined the global order after 1945, splitting the world into deterrence-based camps and spurring the creation of arms control treaties. The digital revolution of the late twentieth century brought both the promise of connectivity and the peril of cyber vulnerabilities, forcing states to rethink sovereignty in cyberspace. Artificial intelligence today raises questions of ethics, surveillance, and competitive advantage, pressing policymakers to create frameworks that balance innovation and restraint. Now, a new frontier is opening: the second quantum revolution.

Quantum technologies, computing, communication, and sensing are no longer confined to experimental physics labs. They are being branded as strategic assets, pursued with intensity by the United States, China, the European Union, India, Japan, and others. Their potential is staggering. Quantum computers could simulate chemical interactions with unprecedented accuracy, accelerating drug discovery and green energy solutions. Quantum sensors could map underground resources or detect submarines with levels of precision beyond classical devices. Quantum communications promise theoretically unbreakable cryptography, relying on the fundamental properties of entanglement. Yet alongside these breakthroughs lie equally disruptive risks. A sufficiently powerful quantum computer could undermine the cryptographic backbone of modern digital life, threatening banking systems, secure communications, and military command structures (Mosca 2018).

The stakes are therefore not simply scientific but geopolitical. Governments see quantum not just as a new tool of innovation but as a lever of power. The metaphor of a ‘quantum race’ has entered policy discussions, evoking Cold War imagery of nuclear competition. But unlike nuclear weapons, which exploded into international consciousness in 1945 with devastating clarity, quantum technologies are developing incrementally, in laboratories and corporate research centres, with uneven visibility and uncertain timelines. This ambiguity creates both danger and opportunity. The danger is that mistrust and secrecy could accelerate an arms race dynamic, where states hoard breakthroughs and fear adversaries’ hidden progress. The opportunity is that, because quantum remains at an early stage, there is still time to craft governance frameworks before its most destabilising impacts unfold (Just Security 2024).

This article argues that the quantum race represents a profound challenge to global security governance but also a unique window for cooperative action. It begins with a plain-language explanation of quantum principles to ground the discussion for a general audience. It then examines national strategies, focusing on how major powers approach quantum as both opportunity and risk. It explores the security threats in detail, particularly the vulnerability of encryption and the potential for strategic instability. Historical analogies with nuclear, AI, and biotechnology governance provide lessons for how to proceed. Possible scenarios for the quantum future, cooperation, fragmentation, or confrontation, are analysed. Finally, the article proposes a governance agenda rooted in multilateralism, standards, and equity, concluding that the quantum race, if governed wisely, can be transformed from a destabilising competition into a cooperative leap forward for humanity.

Quantum in Plain English

Quantum physics often evokes images of paradox and mystery. Schrödinger's cat, both alive and dead until observed, is perhaps the most famous metaphor. But the principles behind quantum technologies can be explained without heavy mathematics.

At the heart of quantum computing is the qubit, or quantum bit. Unlike a classical bit, which is either 0 or 1, a qubit can be in a superposition of both states at once. When multiple qubits are entangled, their states become linked such that measuring one instantly influences the other, even across vast distances. This allows quantum computers to explore many possible solutions simultaneously, rather than sequentially, giving them exponential speed-up for certain problems (Shor 1997). A metaphor often used is solving a maze: a classical computer tries each path one by one, while a quantum computer can, in principle, test all paths at once and pick the correct exit.

This power has profound implications. Modern cryptography relies on the difficulty of factoring large prime numbers, a problem that classical computers cannot solve efficiently. In 1994, mathematician Peter Shor developed an algorithm showing that a quantum computer could factor such numbers in polynomial time (Shor 1997). The result was a bombshell: once sufficiently large quantum computers exist, widely used encryption systems like RSA and elliptic curve cryptography will collapse. While no machine today can perform such a calculation at the necessary scale, the theoretical feasibility has spurred intense concern.

Quantum sensing, another branch, uses phenomena like quantum interference and superposition to achieve ultra-precise measurements. These devices could detect submarines by sensing tiny magnetic variations or monitor underground structures by measuring gravitational anomalies. Quantum communication, meanwhile, uses entanglement and photon polarisation to enable secure key exchange. If intercepted, the act of measurement would disturb the quantum state, alerting the sender to eavesdropping.

For non-specialists, the takeaway is this: quantum technologies are not just faster computers. They represent a fundamentally new way of processing, sensing, and communicating information. This novelty explains both the excitement and the anxiety surrounding them.

National Strategies and Geopolitics

Quantum technologies are now a theatre of strategic competition. While collaboration among scientists remains common, governments are increasingly framing quantum as a domain of national security and sovereignty. The strategies of leading actors reveal how the quantum race is shaping global politics.

The United States has combined federal funding with defence priorities. The 2018 National Quantum Initiative Act authorised more than US$1.2 billion in research funding, coordinating across agencies such as the National Science Foundation, the Department of Energy, and the Department of Defence (NIST 2022). The Pentagon views quantum sensing as critical for navigation in GPS-denied environments, while the intelligence community monitors quantum's potential to undermine cryptography. At the same time, the U.S. leads efforts to develop post-quantum cryptography standards, recognising that defensive measures must accompany offensive research (NIST 2022). The private sector, Google, IBM and Microsoft play a major role, with partnerships blurring the line between commercial innovation and national interest.

China has placed quantum at the heart of its quest for technological self-sufficiency. In 2017, Chinese scientists demonstrated the world's first satellite-based quantum key distribution using the 'Micius' satellite, an achievement hailed as a milestone in secure communications. China has invested billions in quantum research centres in Hefei and Beijing, with state-owned enterprises driving development (Reuters 2024). Official rhetoric casts quantum as a domain where China must not be dependent on foreign powers, especially given Western restrictions on semiconductors. The strategic messaging suggests that Beijing sees quantum not only as an economic opportunity but as a geopolitical equaliser against the dominance of the U.S.

The European Union emphasises sovereignty and industrial capacity. The €1 billion Quantum Technologies Flagship, launched in 2018, supports projects in computing, simulation, sensing, and communication. The EU frames quantum as integral to its broader 'digital sovereignty' agenda, which seeks to reduce dependence on U.S. and Chinese platforms. Recent EU reports highlight the need to pool resources, support start-ups, and integrate quantum into defence planning (Financial Times 2023b). Member states like Germany and France have also launched national programs, sometimes overlapping with EU efforts but increasingly coordinated.

India and Japan, though less advanced, are rising actors. India's National Mission on Quantum Technologies and Applications, launched in 2020, has allocated nearly US $1 billion over five years. The initiative is both scientific and symbolic, signalling India's ambition to be a major technological player. Japan has integrated quantum into its Society 5.0 vision, promoting public-private partnerships. Both countries have partnered with the United States through the U.S.–India Initiative on Critical and Emerging Technology (iCET) and the U.S.–Japan Competitiveness and Resilience Partnership, showing how quantum is also shaping alliances (U.S. State Department 2023).

These strategies reveal both commonality and divergence. All major powers see quantum as a strategic frontier requiring heavy investment. Yet while the U.S. and China emphasise security and competition, the EU stresses sovereignty and industrial autonomy, and India and Japan focus on symbolic positioning and alliances. The result is a fragmented global landscape where cooperation exists within blocs but mistrust dominates across them.

Security Threats

The most discussed security threat is the collapse of encryption. Nearly all online transactions, government communications, and classified data rely on public-key cryptography. If quantum computers become powerful enough to run Shor's algorithm on large keys, this infrastructure will fail (Mosca 2018). Even if such a breakthrough is decades away, adversaries can already engage in 'harvest now, decrypt later' strategies, storing encrypted data to decrypt once the capability emerges (Just Security 2024). Sensitive diplomatic cables, military orders, and personal data could be compromised retroactively.

Military command-and-control systems are particularly vulnerable. Secure communications undergird nuclear deterrence and alliance cohesion. If adversaries believed they could intercept or decrypt communications in wartime, the stability of deterrence could collapse, increasing incentives for pre-emptive action. Quantum sensing further complicates matters. Submarine-based nuclear deterrents rely on stealth, but quantum magnetometers could, in principle, detect submarines at depth, undermining second-strike capabilities. These possibilities remain speculative but are being taken seriously by defence planners.

Post-quantum cryptography provides one line of defence. Algorithms resistant to quantum attacks are being standardised by NIST and adopted by governments (NIST 2022). Yet the transition will take years, given the ubiquity of current systems. Moreover, not all applications can be easily updated, particularly in legacy systems. Quantum key distribution offers another approach, but its scalability remains limited, and China's lead in this area raises strategic concerns (Reuters 2024). In short, the quantum threat to security is not hypothetical; it is pressing and requires anticipatory measures.

Lessons from History

History provides analogies that illuminate the stakes of the quantum race. Nuclear governance shows the dangers of delay but also the potential of treaties. The first nuclear weapon was detonated in 1945, but it was not until 1968 that the Nuclear Non-Proliferation Treaty was signed. In the interim, the U.S., Soviet Union, UK, France, and China developed arsenals, locking in a world of deterrence. The NPT slowed further proliferation and created mechanisms for cooperation, but it came late, after arms races had already escalated. For quantum, waiting until technologies are fully operational risks a similar outcome: governance playing catch-up with destabilising realities.

Artificial intelligence illustrates the risks of fragmented regulation. AI spread rapidly into commercial and military domains before global standards were developed. Today, the U.S., EU, and China pursue divergent models, with little prospect of convergence. Quantum could repeat this trajectory unless coordination begins early. Biotechnology offers a more hopeful precedent. The Asilomar Conference of 1975 established voluntary guidelines for recombinant DNA research, showing that scientists and policymakers can proactively address dual-use dilemmas. More recently, the Cartagena Protocol on Biosafety created international rules for genetically modified organisms. These examples suggest that early engagement, even if voluntary at first, can shape norms before risks spiral. Together, these analogies teach that governance must come early, must be inclusive, and must balance restriction with cooperation. Quantum is not yet at the stage of nuclear deployment or AI ubiquity. That gives policymakers a rare chance to learn from history rather than repeat it.

Scenarios for the Quantum Future

The trajectory of the quantum race is not predetermined. Several plausible scenarios illustrate the stakes. One possibility is cooperative governance. In this scenario, states recognise shared vulnerabilities and agree to multilateral frameworks. A treaty under UN auspices, combined with standards for post-quantum cryptography and equitable access to research, could embed quantum technologies in peaceful cooperation. This would mirror the cooperative aspects of nuclear governance while avoiding its arms race dynamic. A second scenario is fragmented blocs. The U.S. and its allies, the EU, and China pursue separate ecosystems, with limited interoperability and growing mistrust. Export controls and competing standards reinforce divisions. Scientific collaboration diminishes, and states fear hidden breakthroughs. This resembles today's AI landscape, where divergent models have entrenched geopolitical blocs.

A third scenario is a 'quantum cold war'. Here, secrecy and competition dominate. States hoard advances, deploy quantum sensing for military advantage, and weaponise vulnerabilities in encryption. Strategic stability erodes, and alliances strain under uncertainty. While speculative, this scenario is plausible if governance mechanisms fail. These scenarios are not mutually exclusive. Elements of each may coexist, with some domains governed cooperatively and others fragmented or competitive. The challenge is to push the trajectory toward cooperation before mistrust hardens.

Toward a Governance Agenda

A coherent governance agenda for quantum technologies must rest on multilateral frameworks, standards, and equity. At the treaty level, a UN-facilitated agreement could establish transparency and oversight. Scholars have proposed a 'Quantum IAEA', tasked with monitoring research and ensuring peaceful applications (SIPRI 2024). Such a body could coordinate verification, oversee export regimes, and embed quantum in the Sustainable Development Goals. While ambitious, early discussion of such mechanisms can shape expectations.

Standards are equally vital. The transition to post-quantum cryptography must be interoperable across borders. Ethical guidelines for surveillance and defence applications must be formalised, not left to voluntary principles. International standards bodies, working with governments and industry, can embed these norms. Equity is the third pillar. Without deliberate mechanisms, quantum risks exacerbate a technological divide. Joint research hubs, funding consortia, and capacity-building initiatives can ensure that the Global South is not excluded. Positioning quantum as a tool for climate monitoring and health can help mobilise support.

Ethics and Society

Quantum technologies raise not only strategic but also ethical questions. Quantum sensing could enable pervasive surveillance, threatening privacy and civil liberties. Quantum computing could accelerate AI capabilities, raising concerns of control and accountability. More broadly, the indeterminacy of quantum physics resonates with philosophical debates about uncertainty and determinism, challenging how societies think about knowledge and security.

These questions must be addressed alongside security governance. Ethics should not be an afterthought but a parallel track. Embedding principles of privacy, human rights, and social responsibility into quantum governance will enhance legitimacy and public trust.

Ethics, Philosophy, and the Politics of Uncertainty

Quantum technologies are not only reshaping geopolitics; they also touch on deeper philosophical and ethical questions about knowledge, power, and human rights. The very foundations of quantum mechanics, with their indeterminacy and probabilistic nature, have long inspired reflections on the limits of certainty and control. As Niels Bohr famously argued, 'Anyone who is not shocked by quantum theory has not understood it' (quoted in Folse 1985). This indeterminacy is not merely a scientific curiosity but a reminder that the tools we build upon quantum principles inherit some of this unpredictability. When such tools are embedded in security architectures, governance systems must grapple with uncertainty not as an exception but as a structural condition.

One ethical concern is the potential use of quantum sensing for pervasive surveillance. Quantum magnetometers and gravimeters could, in principle, detect movements behind walls, monitor underground activities, or track individuals without their consent. If deployed in urban environments or integrated into authoritarian surveillance regimes, these technologies might erode privacy in ways even more intrusive than facial recognition or digital tracking. The ethical challenge is not only technical but political: how to prevent tools meant for scientific discovery from becoming instruments of repression. Civil liberties groups already warn that quantum-enhanced surveillance could outpace legal safeguards, creating what some scholars call a 'quantum panopticon' (Balkin 2020). The democratic dilemma is stark: societies that embrace quantum sensing for defence must ensure strong oversight to prevent its misuse domestically.

Quantum computing itself raises questions of fairness and control. If only a handful of corporations or states possess machines capable of breaking existing cryptographic systems, they will wield unprecedented power over financial systems, state secrets, and individual data. This risks concentrating informational power in ways that undermine democratic accountability. Philosophers of technology argue that such concentration can generate 'epistemic asymmetries', where some actors gain privileged access to knowledge, and others are structurally excluded (Fricker 2007). In a world where trust in institutions is already fragile, quantum breakthroughs that magnify inequality in information access could intensify political polarisation.

There are also ethical issues related to the dual-use nature of quantum research. As in biotechnology, the same tools that could revolutionise medicine or climate science can also be militarised. Ethical reflection must therefore accompany technical development from the outset. The Asilomar Conference on recombinant DNA research in 1975 showed that scientists can establish norms to mitigate dual-use risks (Berg et al. 1975). A similar initiative for quantum technologies could help establish ethical baselines, even before governments intervene. The question is whether today's fragmented geopolitical environment allows for the kind of cross-border trust that enabled Asilomar.

Beyond specific applications, quantum technologies invite reflection on uncertainty in international politics. International relations theory often assumes rational actors making decisions under conditions of risk. Quantum physics, however, challenges deterministic frameworks, reminding us that systems can evolve in probabilistic and counterintuitive ways. While it would be a mistake to overextend scientific metaphors into politics, the resonance is striking: the indeterminacy of quantum systems mirrors the unpredictability of global politics in the twenty-first century. Scholars of complexity and resilience suggest that embracing uncertainty, rather than seeking total control, may be a healthier basis for governance (Kello 2018). In this sense, the philosophy of quantum mechanics offers a metaphorical guide: rather than attempting to eliminate unpredictability, governance should focus on building resilient systems that can adapt to shocks.

Another ethical question concerns intergenerational justice. The infrastructure we build today, cryptographic standards, sensing networks, and research institutions, will shape the technological environment of future generations. If governments prioritise secrecy and competition, they may lock the world into a trajectory of mistrust that future policymakers find difficult to reverse. Conversely, embedding openness, equity, and human rights into quantum governance now could create a legacy of cooperative innovation. Ethical responsibility in the quantum age is therefore not only about immediate risks but about the path dependency of choices made today.

The Global South and the Quantum Divide

The geopolitics of quantum technologies also raises urgent questions of equity and inclusion. Most investment, expertise, and infrastructure are concentrated in a handful of states and corporations in the Global North. The United States, China, the European Union, and Japan account for the overwhelming majority of quantum patents, start-ups, and national programs (Qureca 2023). By contrast, many countries in Africa, Latin America, and parts of Asia remain peripheral, with limited capacity to shape or benefit from the emerging quantum ecosystem. This asymmetry risks creating what some analysts describe as a 'quantum divide', echoing the digital divide of the late twentieth century but with even higher stakes (UNESCO 2022).

The digital divide demonstrated that unequal access to technology is not merely a question of hardware but of structural power. Countries without robust digital infrastructure found themselves disadvantaged in trade, education, and governance. If the same pattern repeats with quantum, states lacking access to quantum-secure communications or computational capacity may face structural vulnerability. For example, if post-quantum cryptography becomes standard in advanced economies while developing countries continue to rely on outdated systems, the latter could become targets of cyber exploitation. The divide would not only be economic but strategic, locking some states into dependence on the technological guardianship of others.

There are also risks of dependency through market dynamics. If Global South states must purchase quantum solutions from a small number of providers in the North, they may find themselves in relationships of technological dependency reminiscent of colonial trade patterns. Critics of global political economy argue that such asymmetries reproduce structural inequalities, undermining sovereignty in practice even when it is preserved formally (Wallerstein 2004). The politics of quantum sovereignty, already prominent in Europe, could therefore have an even sharper edge in the Global South: the fear of being permanently excluded from technological self-determination.

Yet the Global South is not without agency. Emerging centres of research in India, Brazil, and South Africa show that investment in human capital and regional cooperation can make a difference. India's National Mission on Quantum Technologies is one example of a state seeking to leapfrog into the frontier by mobilising domestic talent (U.S. State Department 2023). Brazil's efforts to integrate quantum into its national innovation strategy demonstrate how middle powers can position themselves as regional hubs. South Africa has incorporated quantum into discussions of its science diplomacy, linking it to broader African Union goals. These initiatives remain modest compared to those of the major powers, but they signal that the Global South is not entirely passive.

International organisations also have a role. UNESCO has begun to frame quantum as part of its broader science and development agenda, emphasising the importance of knowledge sharing and open science (UNESCO 2022). The World Economic Forum's Quantum Governance Network, though dominated by Northern stakeholders, has included calls for inclusion of voices from developing states (World Economic Forum 2023). The challenge is translating rhetoric into practice. Without concrete mechanisms for funding consortia, technology transfer programs, and joint research hubs, the risk is that the Global South is once again marginalised in the setting of global technological standards.

The stakes are particularly high because quantum technologies intersect with issues of development and sustainability. Quantum computing could accelerate climate modelling, helping states adapt to extreme weather. Quantum sensing could improve groundwater management in drought-prone regions. If access to these tools is restricted, the countries most vulnerable to climate change may also be those most excluded from the solutions. This would compound existing injustices in the global response to the climate crisis, where those who contributed least to emissions suffer most from their effects. Equity in quantum governance is therefore not merely a matter of fairness but of survival for many communities.

Addressing the quantum divide requires rethinking governance in inclusive terms. One proposal is to establish 'quantum commons' initiatives, where certain research outputs and protocols are shared openly, much like the Human Genome Project. Another is to create multilateral funding pools, supported by both advanced economies and international organisations, dedicated to building quantum capacity in the Global South. Regional organisations such as the African Union and ASEAN could also play a role, coordinating investment and ensuring that their members are not left behind.

Ultimately, the politics of quantum in the Global South will determine whether this technology becomes another driver of inequality or a tool for shared human progress. If governance frameworks embed equity from the start, quantum could help address pressing global challenges. If not, it may deepen the stratification of the international system, locking in new hierarchies of power. The ethical imperative is therefore clear: governance must be global, inclusive, and attentive to the needs of those most at risk of exclusion.

Conclusion

The quantum race is real, and it is accelerating. Major powers are investing billions, developing strategies that blend science, industry, and security. The risks to encryption, deterrence, and strategic stability are profound. Yet quantum's immaturity offers a unique opportunity. Unlike nuclear or AI, where governance lagged, quantum still allows time for proactive frameworks. The choice is stark. If left unchecked, quantum could fuel mistrust, fragment the global order and destabilise security. If governed wisely, it could become a tool for cooperation, enabling breakthroughs in health, climate, and communication. The task is urgent: the governance window is open, but it will not remain so indefinitely. To transform the quantum race into a cooperative leap forward, states must act now.

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