



# Quantum State of India

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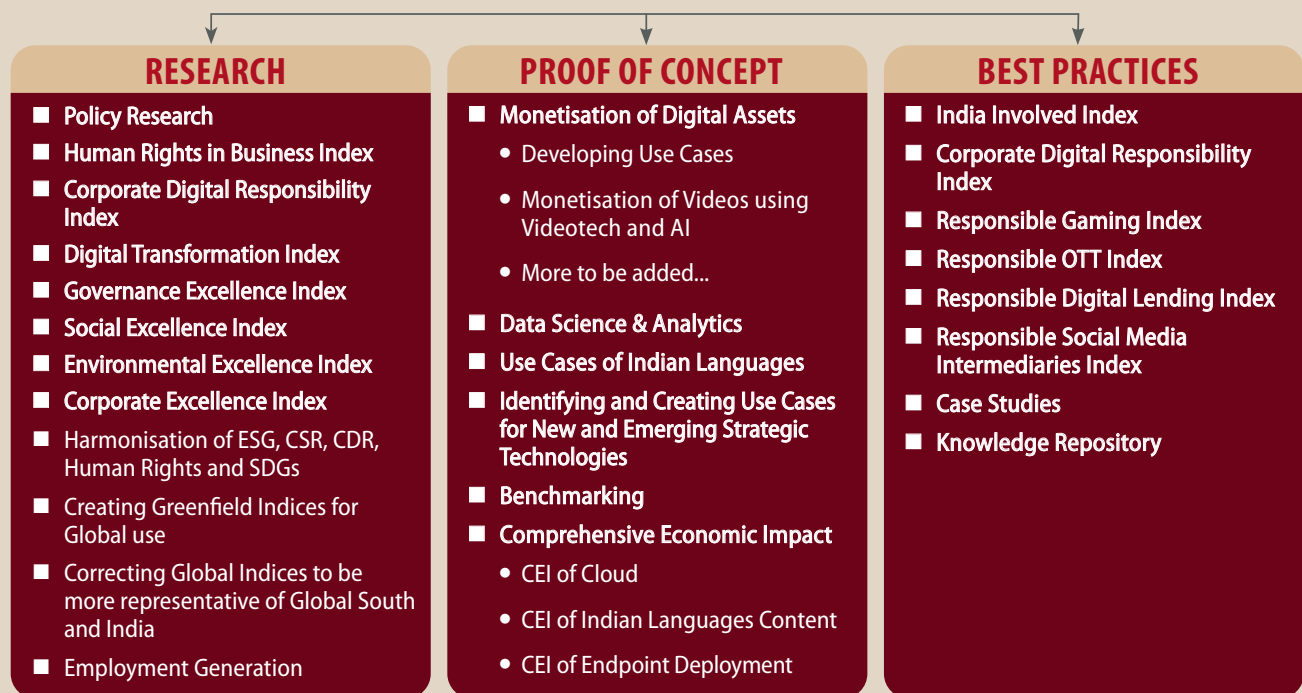
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## Background

- Nationalism dominates global trade and politics post-WTO, shifting focus to non-tariff barriers. However, this narrative overlooks the realities of the Global South, diminishing its moral and spiritual aspects.
- Businesses face uniform expectations for ESG, CSR and Corporate Digital Responsibility (CDR) compliance across trade, alongside perceived moral grandstanding in Human Rights and Democracy indices by the Global North.
- The Global South's issues, context and necessary solutions are often disregarded, mainly due to a lack of institutional capacity in understanding the complexities of compliance and associated indices.
- New and Emerging Strategic Technologies (NEST) will lead to new and emerging strategic challenges in the global context.
- There is a pronounced need to research and propose frameworks either within such Global North standards or as a counter standard that takes cognisance of what the South needs.



## About SKOCH India 2047-Centre of Excellence

- SKOCH India 2047—Centre of Excellence is set up by SKOCH Development Foundation to fill this gap.
- It is Researching, setting up Proof-of-Concept and is documenting Best Practices to create Global Benchmarks and Indices that counterbalance, redefine and build capacity for India's leadership from the Global South viewpoint.
- The Centre of Excellence is developing frameworks, measurement criteria and local and global indices that can be noted, learned from and used for subjects including sovereign ratings.

## About SKOCH Development Foundation

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## 1. Introduction

Emerging technologies are revolutionizing the world and transforming every aspect of life and society. Currently, artificial intelligence (AI) has the spotlight, with each generational update delivering exponentially better results and features. Yet, advancement in another technological realm is poised to redefine economies, industries, national security, and scientific discovery, on a scale comparable to the dawn of the digital age. Quantum technologies – which harnesses the principles of quantum mechanics like superposition and entanglement – promise to unlock levels of computational power and develop new sensing and communications capabilities that are impossible to achieve with traditional technologies.

Unsurprisingly, a fierce global race has commenced. Nations around the world are vying for technological leadership and distinct national strategies, funding models, and geopolitical alignments are emerging, creating a complex and competitive landscape. Countries like the United States and China have committed tens of billions of dollars to secure a first-mover advantage and achieved remarkable early results. For example, China’s “Micius” became the first quantum satellite when it was launched in August 2016 and has showcased the potential for un-hackable, space-based communication networks.<sup>1</sup> The U.S., meanwhile, is leading in efforts to build a quantum computer that can outpace even the most powerful supercomputers across the world.

In today’s geopolitical environment, advanced technologies – like semiconductors, AI, and quantum – are increasingly securitized: treated as national assets, shared only with trusted partners and often under strict controls. Two spheres of adoption are coalescing: one led by U.S. technology among allies and partners, with selective exclusion of Chinese platforms, and another where China builds and exports alternative stacks. The gap

between them has been narrowing. For India, this raises important questions about access to enabling components, governance of intellectual property (IP), and the right balance between alliance-based collaboration and indigenous development. Other key strategic issues for India include: How does India secure reliable access to advanced components and systems? Should India be a passive consumer, a supplier, or a consumer-supplier in priority quantum domains? Can India alone mature quantum without collaboration, or should it walk a dual path – wherein it collaborates with like-minded countries to develop quantum applications for public use, while fostering indigenous capabilities in the areas where quantum would be used for national security purposes?

Having advanced technological tools in a country’s arsenal can provide it with a significant lead in reshaping the contours of its comprehensive national power, as well as position it favorably to exploit the gains of technological innovation in quantum. Recognizing the potential and dangers of quantum, India too has committed to indigenously research and develop this technology for the benefit of its national goals and interests.

This research paper on the state of quantum technologies in India analyzes how quantum technologies can contribute to the economic development and national security of the country, and how national and state-level policies and initiatives can help deliver the desired outcomes of *Viksit Bharat 2047* and *Atmanirbhar Bharat*. To do so, the paper begins with an examination of the contemporary status of quantum research and development in India – including policy initiatives like the National Quantum Mission, state-led programs like the Amaravati Quantum Valley in Andhra Pradesh and the Karnataka Quantum Mission, and research taking place at academic institutions and startups. This section also includes an overview of quantum technologies’ strategic implications for India, as well as the effects of its dual-use potential and securitization.

This progress is then compared with advancements made in other pioneering countries – comprising the United States and China – including the public policy support these countries have

1 Kwon, Karen. “China Reaches New Milestone in Space-Based Quantum Communications.” *Scientific American*, June 25, 2020. <https://www.scientificamerican.com/article/china-reaches-new-milestone-in-space-based-quantum-communications/>.

announced and the formats in which research and development of quantum technologies is taking place. This comparative study will help benchmark India's progress and identify its unique challenges and opportunities. Next, the paper takes an in-depth look at the sectors where quantum can make a significant impact – namely, defense and security, financial services, healthcare and pharmaceuticals, advanced manufacturing, agriculture and food security, weather forecasting and disaster management, and the creative economy.

The lessons learned from this review are then applied to identify India-specific roadblocks and formulate actionable policy recommendations, focusing on the specific ways and means through which quantum can be effectively developed and efficiently integrated. Throughout the paper, special emphasis has been placed on how Indian states can drive innovation and progress in quantum development, and the practical ways in which the technology can be used and incorporated into existing and novel processes.

## 2. Country Case Study: India

The Government of India's flagship initiative on quantum technologies is the National Quantum Mission (NQM). Approved in April 2023 to seed, nurture, and scale a domestic quantum ecosystem, this eight-year initiative – planned to run from 2023 to 2031, has a total budget of ₹6,003.65 crore, or approximately \$682.23 million.<sup>2</sup>

The mission's governance structure is designed to be a whole-of-government effort. Implemented by the Department of Science and Technology (DST), the NQM is one of nine high-priority missions operating under the Prime Minister's Science, Technology, and Innovation Advisory Council (PM-STIAC), highlighting its national importance.<sup>3</sup> The

mission is overseen by a Mission Governing Board (MGB) and a Mission Technology Research Council (MTRC), with the MGB being chaired by Dr. Ajai Chowdhry, a co-founder of HCL who brings crucial private-sector experience to the mission's leadership. Board meetings also include representatives from key government departments, including the Defence Research and Development Organisation (DRDO), Ministry of Electronics and Information Technology (MeitY), Department of Space, Department of Atomic Energy, and Department of Telecommunications, thereby ensuring alignment with India's broader strategic, industrial, and security interests.<sup>4</sup> Moreover, NQM's leadership has been emphatic that the mission should be "product-oriented" with "clear deliverables" to avoid the common pitfall of research remaining confined to laboratories.<sup>5</sup>

Under the NQM, four Thematic Hubs (T-Hubs) have been established – each set up as a separate Section-8 not-for-profit company with their own governing boards and executive teams – that are designed to be national centers of excellence. Each hub leads one of the four core domains, namely Quantum Computing, Quantum Communication, Quantum Sensing & Metrology, and Quantum Materials & Devices.<sup>6</sup> Institutions including the Indian Institute of Science (IISc) Bengaluru and the Indian Institutes of Technology (IIT) in Madras, Bombay, and Delhi have been tasked with consolidating expertise, driving innovation, and nurturing the broader ecosystem.<sup>7</sup>

2 "National Quantum Mission (NQM)." Department of Science and Technology, Government of India. Accessed July 05, 2025. <https://dst.gov.in/national-quantum-mission-nqm>.

3 "National Quantum Mission: India's Quantum Leap." Press Information Bureau, India, March 17, 2025. <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2111953>.

4 "Mission Governing Board finalises implementation strategy and timelines of NQM." Department of Science & Technology, Government of India, January 16, 2024. <https://dst.gov.in/mission-governing-board-finalises-implementation-strategy-and-timelines-nqm>.

5 Mishra, Ashutosh. "Charting India's quantum future: Policy, startups, and pursuit of technological leadership." *The Economic Times*, May 12, 2025. <https://government.economictimes.indiatimes.com/news/digital-india/charting-indias-quantum-future-policy-startups-and-pursuit-of-technological-leadership/121113275>.

6 "National Quantum Mission (NQM)." Department of Science and Technology, Government of India.

7 Ibid.

Technology	Lead Institution	Objective	Research Areas	Sectors Impacted
Quantum Computing	IISc Bengaluru (Foundation for Quantum Computing Innovation) <sup>8</sup>	Indigenization of essential components to build a quantum computer; creating intellectual property of Indian origin <sup>9</sup>	Quantum computers with superconducting qubits; highly scalable quantum computer using semiconducting qubits; 50-qubit quantum information processor; programmable photonic quantum computing; photonic quantum processor <sup>10</sup>	Defense and Security, Healthcare and Pharmaceuticals, Advanced Manufacturing, Agriculture and Food Security, Weather Forecasting and Disaster Management, Creative Economy
Quantum Communication	IIT Madras (CDoT Samgnya Technology Foundation) <sup>11</sup>	Leveraging properties of quantum mechanics to enhance the security of India's digital infrastructure.	Quantum Key Distribution (QKD) networks; satellite-based QKD; quantum memory and repeaters; post-quantum cryptography <sup>12</sup>	Defense and Security, Financial Services, Healthcare
Quantum Sensing and Metrology	IIT Bombay (QMet Technology Foundation) <sup>13</sup>	To drive innovation in quantum sensing and metrology applications	Quantum inertial navigation system, Gravimeter, thermal sensors, quantum biosensors, precision machining <sup>14</sup>	Defense and Security, Healthcare
Quantum Materials and Devices	IIT Delhi (QMD Foundation) <sup>15</sup>	To achieve long-term sustainability and innovation in quantum materials and devices <sup>16</sup>	Superconductors, novel semiconductor structures, topological materials for the fabrication of qubits, and quantum sensing and metrological devices <sup>17</sup>	Development of quantum technologies, indigenization of supply chains and components

8 “Quantum Computing Innovation.” QC Innovation. Accessed August 12, 2025. <https://qcinnovation.co.in>.

9 “Startup Initiative.” QC Innovation. Accessed August 12, 2025. <https://qcinnovation.co.in/startup-initiative>.

10 “Projects.” QC Innovation. Accessed August 12, 2025. <https://qcinnovation.co.in/projects>.

11 “IITM CDOT SAMGNYA TECHNOLOGIES.” IITM CDOT Samgnya Technologies. Accessed August 12, 2025. <https://www.samgnya.in/>.

12 “Our Research.” IITM CDOT Samgnya Technologies. Accessed August 12, 2025. <https://www.samgnya.in/ourresearch>; “Our Technology & Impact.” IITM CDOT Samgnya Technologies. Accessed August 12, 2025. [https://www.samgnya.in/Technology\\_and\\_Impact](https://www.samgnya.in/Technology_and_Impact).

13 “Home Page.” Qmet Tech. Accessed August 12, 2025. <https://qmettech.com/>.

14 “Quantum Sensing” Qmet Tech. Accessed August 12, 2025. <https://qmettech.com/quantum-sensing/>; “Quantum Metrology.” Qmet Tech. Accessed August 12, 2025. <https://qmettech.com/quantum-metrology/>.

15 “QMDHUB.” QMDHUB. Accessed August 12, 2025. <https://www.qmdhub.co.in/>.

16 “R&D Vision.” QMDHUB. Accessed August 12, 2025. <https://www.qmdhub.co.in/rd-vision/>.

17 “About Us.” QMDHUB. Accessed August 12, 2025. <https://www.qmdhub.co.in/about-us/>.

As of August 2025, all four T-Hubs have put out request for proposals from startups seeking funding which work in their respective focus areas. Based on the stage of development the startup is in, funds up to ₹25 crores (\$2.84 million) can be allocated, with clear thresholds set at up to ₹1 crore (\$113,636) until the proof of concept (POC) has been prepared, up to ₹5 crores (\$568,181) if the POC has been approved but pilot product or service is yet to be delivered, and full allocation to scale up the demonstrated technology, further develop the product, and commercialize it.<sup>18</sup> Interestingly, the T-Hub will charge a fee in the form of equity in the startup based on the level of funds disbursed. While the percentage is negotiable, it is listed as 3% and 4.5% for the first two thresholds mentioned above.<sup>19</sup>

To be eligible, a startup should be registered with the Department for Promotion of Industry and Internal Trade (DPIIT) – which falls under the Ministry of Commerce and Industry; must have a business idea to develop a product or a service that is marketable, viable, commercial, and scalable; be an “Indian Company” – defined as the holding company being registered in India, intellectual property residing in India, and being majority owned in India; and 51% of shareholders should be Indian promoters as per the 2013 Companies Act and the 2018 SEBI (ICDR) Regulations.<sup>20</sup> Eligible applications submitted would then be evaluated by the relevant T-Hub based on criteria such as the need for the idea, its feasibility and impact, strength of the startup team, their fund utilization plan, and whether any additional funding has been raised from other sources.<sup>21</sup> The startups selected will undergo legal and financial vetting as well.<sup>22</sup>

Importantly, the duration of the process – from receiving the application to disbursal of funds – has been estimated to take up to a maximum of three months.<sup>23</sup>

The NQM has also been focusing on skilling and talent development. For example, it has developed an undergraduate curriculum in quantum technology which is scheduled to be introduced at 75 universities starting from the 2025-2026 academic year.<sup>24</sup> Faculty training is also being conducted, and laboratory equipment is being supplied to universities.<sup>25</sup> Further, a Master of Science program is reportedly under development and is expected to be ready this year.<sup>26</sup>

Importantly, even though the NQM functions under the Department of Science and Technology, India’s quantum innovation drive is supported by other government departments – namely, the Department of Space, Atomic Energy, Defence, and the Ministry of Electronics and Information Technology, each contributing a share of the mission’s total budget.<sup>27</sup> This landscape shows the diverse range of use-cases quantum technologies can enable. It also highlights the strategic importance of achieving indigenous technological advancement of this technology and India’s whole-of-government effort to realize it.

Apart from funding under the NQM, the Government of India is utilizing two other programs to finance R&D in deep technologies like quantum. The first is a DeepTech Fund of Funds wherein ₹10,000 crores (\$1.136 billion) have been allocated toward supporting startups and “foster[ing] the development of cutting-edge technologies such as AI, robotics, quantum computing, machine learning, precision manufacturing, biotech and

18 “NextSense – Call for Proposal 2025.” Qmet Tech. Accessed August 13, 2025. <https://qmettech.com/entrepreneurship-development/nextsense-call-for-proposal-2025/>; “Call for Startup Innovation.” Foundation for QC Innovation. Accessed August 13, 2025. [https://drive.google.com/file/d/1iO38Sgi\\_yKWf5nXxUfX2TNutP-H0fttd/view](https://drive.google.com/file/d/1iO38Sgi_yKWf5nXxUfX2TNutP-H0fttd/view).

19 “Call for Startup Innovation.” Foundation for QC Innovation.

20 Ibid.

21 Ibid.

22 Ibid.

23 Ibid.

24 Mishra, Ashutosh. “Charting India’s quantum future: Policy, startups, and pursuit of technological leadership.”

25 Ibid.

26 Ibid.

27 Ibid.

alike.”<sup>28</sup> The funds will primarily target providing financial support to startups in their early stage during which access to traditional forms of capital is often times challenging.<sup>29</sup> The second is DST’s Research, Development, and Innovation (RDI) Scheme under which a budget of ₹1 lakh crore (\$11.363 billion) was approved by the Government of India in July 2025.<sup>30</sup> It aims to foster private sector participation in high-impact areas by financing long-term loans at low or nil interest rates, infuse equity – especially in startups – and contribute to the Deep-Tech Fund of Funds.<sup>31</sup>

Significantly, both initiatives have complementary, yet different focus areas. While the DeepTech Fund of Funds looks to bolster public finance options for startups – signifying the need for early seeding in emerging technologies, the RDI highlights the need to de-risk and incentivize the flow of private investments into R&D. Furthermore, the lack of private capital investments in India’s quantum ecosystem – while predictable and understandable for a greenfield technology in its early stage of development – is nonetheless a challenge that is crucial to overcome if the country wants to match and keep pace with developments taking place in pioneering nations like the U.S. and China.

### 3. Case Study: Indian States

While the NQM provides a national framework, the state of Andhra Pradesh is set to launch an initiative of unprecedented scale and ambition on January 01, 2026: the Amaravati Quantum Valley (AQV). The driving force behind this venture is the personal vision and engagement of Chief

Minister N. Chandrababu Naidu, who has framed the AQV as the defining technological sequel to Hyderabad’s Hitech City, which had catalyzed the city’s transformation into a global IT hub in the 1990s.<sup>32</sup> With the goal of transforming Amaravati into a global capital for quantum technologies, the state government has forged an understanding with three industry giants – IBM, Tata Consultancy Services (TCS), and Larsen & Toubro (L&T) – to build a full-stack quantum ecosystem from the ground up.<sup>33</sup> Under the public-private partnership, IBM will install its state-of-the-art Quantum System Two – featuring a 156-qubit ‘Heron’ processor, it will be the most powerful quantum computer in India and the first of its kind in South Asia – at the AQV.<sup>34</sup> TCS, on the other hand, is to develop the software layer, algorithms, and real-world applications that will make the quantum hardware useful, while L&T is tasked with building the entire Quantum Valley Tech Park – a dedicated 50-acre campus in Amaravati that will house the quantum computers, research labs, and innovation centers.<sup>35</sup>

Adding substance to the AQV and Andhra Pradesh’s quantum vision, the state hosted the Amaravati Quantum Valley National Workshop in June 2025 during which the “Amaravati Quantum

28 “India to boost DeepTech startups with ₹10,000 cr Fund of Funds: Piyush Goyal.” *The Hindu Business Line*, April 05, 2025. <https://www.thehindubusinessline.com/info-tech/india-to-boost-deeptech-startups-with-10000-cr-fund-of-funds-piyush-goyal/article69417286.ece>.

29 Ibid.

30 “Research, Development, and Innovation (RDI) Cell.” Department of Science and Technology, Government of India. Accessed August 10, 2025. <https://dst.gov.in/rdi-scheme/research-development-and-innovation-rdi-cell>.

31 Ibid.

32 Samritan, Sampat G. “Quantum Valley In Amaravati To Be Akin To Silicon Valley In US: Naidu.” *Deccan Chronicle*, June 30, 2025. <https://www.deccanchronicle.com/southern-states/andhra-pradesh/quantum-valley-in-amaravati-to-be-akin-to-silicon-valley-in-us-naidu-1888471>.

33 “Andhra Pradesh signs MoUs with IBM, TCS, and L&T to establish India’s first Quantum Valley in Amaravati.” *The New Indian Express*, June 01, 2025. <https://www.newindianexpress.com/states/andhra-pradesh/2025/Jun/01/andhra-pradesh-signs-mous-with-ibm-tcs-and-lt-to-establish-indias-first-quantum-valley-in-amaravati>.

34 Ibid.

35 Ibid.

Declaration” was unveiled.<sup>36</sup> This declaration provides a detailed blueprint with aggressive targets across multiple pillars, thereby setting the AQV apart as a well-structured and ambitious undertaking. The pillars introduced include Infrastructure – targeting the installation of IBM’s Quantum System Two and establishing “QChipIN,” which is to be India’s largest open quantum testbed, by mid-2026; R&D & Application – aiming to develop the capability to test 100 new quantum algorithms, test over 1,000 new quantum algorithms annually, and generate 100 quantum use-cases for industry and governance; Talent Development – intending to launch the Amaravati Quantum Academy for specialized training, train 200 specialists in its first year and scale up to 5,000 annually, and empower 20 universities in Andhra Pradesh and 100 across India with quantum curricula; Startup Ecosystem – detailing the creation of a National Startup Forum with a dedicated ₹1,000 crore Quantum Fund, and supporting at least 20 quantum hardware and security startups; Investment – attracting quantum technology investments to the tune of \$500 million (₹4,400 crore) by January 2027 and \$1 billion (₹8,800 crore) by January 2029; Economic Impact – achieving an annual domestic production and export of quantum hardware valued at ₹5,000 crore (\$568.18 million) by 2030, and creating over 100,000 high-paying jobs by 2026; and Global Collaboration – establishing a Global Quantum Collaboration Council (GQCC) in Amaravati and convening the annual “World Quantum Expo” starting 2026.<sup>37</sup>

The AQV’s most important long-term investment may be in developing and training human resources. To build a quantum-ready workforce, two parallel tracks are being developed.

36 Sudhir, SNV. “Andhra unveils Amaravati Quantum Valley vision, to be ready by January 2026.” Deccan Herald, June 30, 2025. <https://www.deccanherald.com/india/telegana/andhra-unveils-amaravati-quantum-valley-vision-to-be-ready-by-january-2026-3609122>; Aluri, Srikanth. “Amaravati to be ‘quantum gateway’ of the country.” The Times of India, July 01, 2025. <https://timesofindia.indiatimes.com/city/vijayawada/amaravati-to-be-quantum-gateway-of-the-country/articleshow/122165515.cms>.

37 Ibid.

The first is aimed at mass-skilling wherein all state universities have been directed to introduce quantum computing into their curricula. Andhra University, for example, is holding workshops with national experts to design the syllabus and train its faculty, aiming to launch both major and minor degree programs in quantum computing from the 2025-26 academic year.<sup>38</sup> This statewide mandate targets the creation of a large pool of engineers and scientists with foundational quantum literacy and ultimately feeding the workforce needed for a burgeoning quantum industry. The second track focuses on elite specialization through initiatives like the Amaravati Quantum Academy, which is slated to launch in 2025-26 and will offer integrated PhD fellowships and advanced certifications to train the top-tier researchers and specialists who will lead the R&D efforts.<sup>39</sup> Initiatives at other institutions within the state, such as research in quantum cryptography and secure multiparty computation at the Indian Institute of Information Technology (IIIT) Sri City, SRM University’s Master of Science program with a specialization in Quantum Technology, and SRM Institute of Science & Technology Tiruchirappalli’s “Quantum Computing Honours Track” for its undergraduate engineering students, will complement the effort.<sup>40</sup>

Andhra Pradesh’s ambitious push does not exist in a vacuum. Other Indian states, such as Karnataka and Telangana, are making significant

38 Rao, Umamaheswara. “Andhra University to introduce engineering courses in quantum computing.” The Times of India, May 21, 2025. <https://timesofindia.indiatimes.com/city/vijayawada/andhra-university-to-introduce-engineering-courses-in-quantum-computing/articleshow/121298254.cms>.

39 Sudhir, SNV. “Andhra unveils Amaravati Quantum Valley vision, to be ready by January 2026.”

40 “Dr. Kartick Sutradhar.” Indian Institute of Information Technology Sri City. Accessed July 05, 2025. <https://www.iiits.ac.in/people/regular-faculty/dr-kartick-sutradhar/>; “Overview, Department of Physics, School of Engineering and Sciences.” SRM University. Accessed July 05, 2025. <https://srmap.edu.in/seas/physics-overview/>; “Next-Gen Learning: Quantum Track.” SRM Institute of Science & Technology Tiruchirappalli. Accessed July 05, 2025. <https://www.srmtrichy.edu.in/next-gen-learning-quantum-track>.

plays in the quantum domain as well. For example, the Karnataka state government has partnered with the Indian Institute of Science (IISc) to establish a Quantum Research Park on the Bengaluru campus which will provide shared access to R&D infrastructure, workforce training, and startup support to advance quantum computing and sensing applications.<sup>41</sup> Recently, Karnataka held the inaugural Quantum India Bengaluru summit in July 2025 and unveiled its own Karnataka Quantum Mission (KQM) to establish the state as a leading hub for quantum technology in Asia, in addition to building a \$20 billion quantum economy.<sup>42</sup> The state policy lays out five pillars – comprising skilling, research, infrastructure, industry support, and global partnerships – and is supported by a ₹1,000 crore (\$113.636 million) budget.<sup>43</sup> Further, a Quantum Technology Task Force will be established to steer policy and strategic direction, and new quantum parks, manufacturing zones, and the integrated quantum innovation hub (Q-City) will drive technological advancement.<sup>44</sup> Under the KQM, 150 PhD fellowships will be supported every year, quantum skilling programs will be introduced across 20 colleges, 1,000-qubit quantum processors will be developed, pilot applications in cybersecurity, healthcare, and defense will be explored, more than 100 quantum startups will be nurtured, and support for filing at least 100 patents will be extended.<sup>45</sup>

Meanwhile, Telangana has teamed up with Switzerland's QuantumBasel to set up a Quantum

Hub in Hyderabad, offering startup mentorship, promoting academia-industry collaboration, and advancing research in quantum technology.<sup>46</sup> The state has also unveiled a Quantum Frontier Tech Charter, in collaboration with NITI Aayog's Frontier Tech Hub (FTH), that outlines a roadmap to advance research and applications in quantum computing, communication, and security.<sup>47</sup> The initiative will focus on key sectors like finance, healthcare, cybersecurity, and logistics, and will be guided by an advisory board of national and international experts from government, academia, and industry.<sup>48</sup>

#### 4. Strategic Implications for India

For India, the pursuit of indigenous quantum capabilities to bolster its defense apparatus has a deep-seated strategic imperative, exemplified by its experience in the 1999 Kargil War with Pakistan. During the conflict, the United States is said to have denied India access to high-accuracy GPS data meant for military use, limiting New Delhi's strategic options and the effectiveness of its most advanced assets – like fighter jets, missiles, and artillery.<sup>49</sup> This event exposed a profound strategic vulnerability, one that is still embedded in the institutional memory of India's defense and strategic establishments. Reliance on foreign-

41 Swayne, Matt. "Karnataka Approves Second Phase of Quantum Research Park to Boost India's Tech Ambitions." *Quantum Insider*, June 06, 2025. <https://thequantuminsider.com/2025/06/06/karnataka-approves-second-phase-of-quantum-research-park-to-boost-indias-tech-ambitions/>; "IQTI." Indian Institute of Science. Accessed July 05, 2025. <https://iqti.iisc.ac.in/>.

42 Swayne, Matt. "Karnataka's Chief Minister Outlines Plan To Build A \$20 Billion Quantum Economy." *Quantum Insider*, July 31, 2025. <https://thequantuminsider.com/2025/07/31/karnatakas-chief-minister-outlines-plan-to-build-a-20-billion-quantum-economy/>.

43 Ibid.

44 Ibid.

45 Ibid.

46 "Telangana partners with Swiss firm to establish India's first Quantum Hub in Hyderabad." *The New Indian Express*, January 27, 2025. <https://www.newindianexpress.com/states/telangana/2025/Jan/27/telangana-partners-with-swiss-firm-to-establish-indias-first-quantum-hub-in-hyderabad>.

47 "Government to foster quantum innovation ecosystem in Hyderabad." *The New Indian Express*, April 14, 2025. <https://www.newindianexpress.com/states/telangana/2025/Apr/14/government-to-foster-quantum-innovation-ecosystem-in-hyderabad>.

48 Ibid.

49 Srivastava, Ishan. "How Kargil spurred India to design own GPS." *The Times of India*, April 05, 2014. <https://timesofindia.indiatimes.com/science/how-kargil-spurred-india-to-design-own-gps/articleshow/33254691.cms>; Monacelli, Nicholas. "Regaining the GPS Strategic Advantage." U.S. Naval Institute, April 2021. <https://www.usni.org/magazines/proceedings/2021/april/regaining-gps-strategic-advantage>.

controlled critical infrastructure, hence, is seen as an unfavorable liability that may compromise national sovereignty. This concern was a key driver of the Atmanirbhar Bharat (Self-Reliant India) initiative, of which India's quantum ambitions are an important part.

Over the last two and a half decades, the geopolitical landscape has undergone significant changes. Today, India collaborates on and shares a host of advanced technologies and weapons systems with the U.S. and other major like-minded partners. Yet, two challenges remain. First, the very best and latest foreign defense and security equipment are still either barred from being exported or only transferred among security treaty allies. Relatedly, exported weapons systems often do not include access to their source code, making the importer dependent on the original equipment manufacturer and the country of origin for upgrades, repairs, and integration of indigenous platforms. As New Delhi highly values its strategic autonomy, preaches multipolarity, and shies away from formal alliances, it must then be prepared to rely more on its own capabilities and resources rather than expect transfers of high technologies and their source codes from even its closest partners.

Second, given the increasingly complex and conflict-prone international environment, the demand for current and next-generation military systems is outpacing its supply. Hence, even if India's partners are willing to supply the hardware and critical components, their availability and manufacturing timelines may get delayed or prove to be unviable. In the context of quantum technologies, especially those intended for dual-use or military applications, both these reasons may manifest and hinder India's national interests.

Against this backdrop, India's National Quantum Mission (NQM) was approved in April 2023 to seed, nurture, and scale a vibrant domestic ecosystem for quantum research and industrial development, in alignment with national priorities

like Make in India and Atmanirbhar Bharat.<sup>50</sup> This eight-year initiative, planned to run from 2023 to 2031, has a total budget of ₹6,003.65 crore, or approximately \$682.23 million.<sup>51</sup> Under the NQM, four Thematic Hubs (T-Hubs) have been established that are designed to be national centers of excellence. Each hub leads one of the four core domains, namely Quantum Computing, Quantum Communication, Quantum Sensing & Metrology, and Quantum Materials & Devices.<sup>52</sup>

Relevant to India's national security are the NQM's goals to develop satellite-based secure quantum communications – which are capable of operating between ground stations across distances of up to 2000 kilometers within India, as well as facilitating long-distance communication with other countries; magnetometers – which can be used to detect stealth aircraft and submarines, identify underground military facilities, and enhance navigation systems on aerial, naval, and ground vehicles; and atomic clocks – used for precision timing, communications, and navigation.<sup>53</sup>

The task of translating quantum science into battlefield-ready capabilities is being led by the Defence Research & Development Organisation (DRDO), which functions under the Ministry of Defence. Its pursuit of indigenous quantum technologies includes research and development of quantum machine learning technology, ultra small atomic clocks, atomic vapor magnetometer, QKD for free space communication, 7-qubit quantum processor using superconducting circuit technology operating at milli-Kelvin temperatures,

50 “National Quantum Mission (NQM).” Department of Science and Technology, Government of India. Accessed July 05, 2025. <https://dst.gov.in/national-quantum-mission-nqm>.

51 Ibid.

52 Ibid.

53 “National Quantum Mission (NQM).” Department of Science and Technology, Government of India; “Military-Grade Magnetometers: Precision in Magnetic Field Detection and Navigation.” Aardvark Infinity, September 10, 2024. <https://medium.com/aardvark-infinity/military-grade-magnetometers-precision-in-magnetic-field-detection-and-navigation-11c5f625fd9d>.

and quantum computing capable hub for AI enabled video, image and data processing, among others.<sup>54</sup>

To do so, DRDO utilizes a network of specialized laboratories and centers, such as the Pune-based DRDO Young Scientist Laboratory – Quantum Technologies (DYSL-QT) and the Quantum Technology Research Centre (QTRC) at Metcalfe House in Delhi. The organization is also working with the Indian Institute of Technology (IIT) Delhi to drive progress and, in June 2025, successfully demonstrated free-space QKD using quantum entanglement, wherein a secure communication link was established over a distance of more than one kilometer on the IIT Delhi campus.<sup>55</sup> The experiment achieved a secure key rate of approximately 240 bits per second with a quantum bit error rate below 7%, validating the potential for creating secure, line-of-sight communication channels for tactical battlefield environments, naval vessels, and airborne platforms.<sup>56</sup>

Earlier, in August 2024, scientists from DYSL-QT partnered with the Tata Institute of Fundamental Research (TIFR) and Tata Consultancy Services (TCS) to conduct end-to-end testing of a 6-qubit superconducting quantum processor.<sup>57</sup> While the qubit count of the system is modest compared to international efforts, the significance of this milestone lies in the demonstration of a full-stack, sovereign capability as the project involved indigenous qubit design and fabrication at TIFR, the development of a cloud-based user interface

by TCS, and the complex system integration and control apparatus assembled by DRDO.

Parallel to DRDO's efforts, a domestic private quantum ecosystem is beginning to take shape as well. For example, QNu Labs specializes in QKD and post-quantum cryptography systems, QpiAI is developing a full-stack quantum computer, BosonQ Psi is creating quantum-powered simulation software, and Quanfluence is focused on building photonic quantum computers.

## 5. Dual-Use & Geopolitical Securitization of Technology

Quantum has pronounced dual-use characteristics, i.e., it can be used for both civilian purposes – like quantum-enabled Digital Public Infrastructure (DPI) applications, including secure financial messaging and electric grid monitoring – and strategic functions – like securing military command-and-control systems and PNT resilience.

At the same time, advanced technologies like quantum, AI, and semiconductors are being securitized – i.e., treated as national assets subject to strict sharing restrictions. Resultantly, two dominant spheres of technological adoption are taking shape – one led by the U.S. and adopted by its allied and partner countries, and another being developed by China and offered as an alternative, especially to countries in the Global South. Though a qualitative gap currently exists between the two, China's technological advancements have been rapidly filling it in the last few years.

As access, IP, and supply chains tighten, India must plan for technology pathways that are collaboration-friendly on civilian tracks while indigenizing sensitive, national-security-relevant capabilities. A practical policy answer is a dual development approach, under which India collaborates with like-minded partners on civilian stacks – such as global standards setting, interoperability, and workforce development – while ring-fencing indigenous R&D, manufacturing, and deployment for strategic use cases – like PNT and ISR sensors, and QKD networks underpinning sensitive infrastructure.

54 “Quantum Technologies.” Defence Research & Development Organisation. Accessed July 10, 2025. <https://drdo.gov.in/drdo/quantum-technologies>.

55 “DRDO & IIT Delhi demonstrate Quantum Entanglement-Based Free-Space Quantum Secure Communication over more than 1 km distance.” Press Information Bureau, Government of India, June 16, 2025. <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2136702>.

56 Ibid.

57 “DRDO's young scientists complete end-to-end testing of 6-qubit quantum processor based on superconducting circuit technology.” Press Information Bureau, Government of India, August 28, 2024. <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2049356>.

Moreover, Indian policymakers must build consensus on some key strategic issues, such as: How does India gain access to critical technologies? Should it join a bloc, attempt to go it alone, or find a middle path? The meaning of self-reliance must also be answered: Does it require every component to be researched, designed and manufactured in India? Or should the possibility of transfers of technology and joint ventures with foreign firms be explored and encouraged?

## 6. Country Case Study: The United States

Policy support for quantum technologies in the United States is anchored in the 2018 National Quantum Initiative (NQI) Act. This legislation established a federal framework and authorized \$1.2 billion over five years to accelerate research and development (R&D) in Quantum Information Science and Technology (QIS) and its technological applications for the nation’s economic and national security.<sup>58</sup> To execute its vision, the NQI Act established the National Quantum Coordination Office – housed under the White House Office of Science and Technology Policy – and the National Quantum Initiative Advisory Committee – an independent advisory body composed of experts from industry, academia, and federal laboratories who are appointed by the President.<sup>59</sup>

Further, the Act designated three key science agencies – namely, the National Institute of Standards and Technology (NIST), the National Science Foundation (NSF), and the Department of Energy (DOE) – to lead the research efforts.<sup>60</sup> Specific funding levels for each were authorized as well. NIST – with a funding of up to \$80 million

a year – was tasked with supporting R&D of basic and applied QIS, as well as convene a consortium of stakeholders to identify future industry needs in areas like standards and cybersecurity.<sup>61</sup> NSF – funded up to \$10 million for each center established, per year – was directed to carry out basic research and education program on QIS and engineering.<sup>62</sup> Meanwhile, DOE was tasked with conducting a basic research program in QIS and establishing between two and five National Quantum Information Science Research Centers – with each authorized to receive up to \$25 million per year.<sup>63</sup>

Analyzing the Act’s language, the emphasis on “supporting research,” “improving interagency planning,” and “promoting collaboration,” suggests that it is aimed at creating a fertile ground for scientific discovery rather than dictating specific technological outcomes. In fact, the Act’s primary deliverables: the establishment of research centers at NSF and DOE and R&D support at NIST, are the cornerstones of a basic science infrastructure.

However, a five-year assessment of the NQI Act – carried out by the National Quantum Initiative Advisory Committee (NQIAC) and published in June 2023 – identified critical gaps in translating the scientific progress achieved into tangible economic and national security benefits.<sup>64</sup> The report noted that even though quantum sensing – which currently is the most mature application of quantum technology – is likely to make a significant short-term impact, “[u]ntil technologies mature, market demand will remain insufficient to establish a robust supply chain for QIST [Quantum Information Science and Technology] R&D, relegating important components and materials to only a few and sometimes unreliable

58 Giles, Martin. “President Trump has signed a \$1.2 billion law to boost US quantum tech.” MIT Technology Review, December 22, 2018. <https://www.technologyreview.com/2018/12/22/138149/president-trump-has-signed-a-12-billion-law-to-boost-us-quantum-tech/>.

59 “Actions - H.R.6227 - 115th Congress (2017-2018): National Quantum Initiative Act.” Congress.gov, December 21, 2018. <https://www.congress.gov/bill/115th-congress/house-bill/6227/all-actions>.

60 Ibid.

61 Ibid.

62 Ibid.

63 Ibid.

64 “Renewing the National Quantum Initiative: Recommendations for Sustaining American Leadership in Quantum Information Science.” National Quantum Initiative Advisory Committee, June 2023. <https://www.quantum.gov/wp-content/uploads/2023/06/NQIAC-Report-Renewing-the-National-Quantum-Initiative.pdf>.

sources.”<sup>65</sup> Further, the report added that “industry participation in NQI Centers has been somewhat limited to date, in part due to administrative and intellectual property (IP) requirements that slow or inhibit collaboration.”<sup>66</sup>

These observations hold valuable lessons for India’s NQM. Much like the limitations being experienced in the U.S., India too would have to contend with limited supply chains, at least in the short-to-medium term. This may constrict the pace of development and prove to be a strategic vulnerability that hampers New Delhi’s interests and ambitions. Moreover, industry participation and private investment remains a challenge even in India. Time-taking evaluation and due diligence processes at T-Hubs, as well as concerns over the protection of intellectual property may be contributing factors.

More recently, the proposed National Quantum Initiative Reauthorization Act – which was proposed in December 2024 but has not yet been passed by the U.S. Congress – signals a strategic pivot for U.S. quantum policy.<sup>67</sup> Aiming to bridge the research-to-commercialization gap, it focuses on practical applications by expanding the initiative to include mission-oriented agencies like NASA and the National Institute of Health (NIH), and mandating plans for supply chain resilience and international cooperation.<sup>68</sup> The bill seeks to overcome the “valley of death” – defined as the “phase where promising technologies often stall between research and commercialization” due to a lack of funding, infrastructure, and trained personnel – by prioritizing advancements in

65 Ibid.

66 Ibid.

67 “Actions - S.5411 - 118th Congress (2023-2024): National Quantum Initiative Reauthorization Act of 2024.” Congress.gov, December 3, 2024. <https://www.congress.gov/bill/118th-congress/senate-bill/5411/all-actions>.

68 “Cantwell, Young, Durbin, Daines Introduce National Quantum Initiative Reauthorization Act.” U.S. Senate Committee on Commerce, Science, & Transportation, December 03, 2024. <https://www.commerce.senate.gov/2024/12/cantwell-young-durbin-daines-introduce-national-quantum-initiative-reauthorization-act>.

quantum sensing, computing and communications applications, and translate scientific discoveries into solutions that can enhance economic competitiveness and national security.<sup>69</sup>

Here, India’s NQM seems to be at an advantage due to its early focus on developing practical applications of quantum technologies and fostering an enabling environment with adequate funding and policy support.

While the NQI provides the civilian and economic framework, the U.S. Department of Defense (DOD) has been pursuing a parallel, mission-driven effort to harness quantum technologies for military advantage. The Defense Science Board (DSB), an independent advisory board to the DOD, has identified three application areas as holding the most promise for the military – namely, quantum sensing, quantum computing, and quantum communications.<sup>70</sup>

Multiple annual National Defense Authorization Acts (NDAA) – legislation that authorizes DOD’s budget – have also included provisions on quantum technologies. For example, the FY2019 NDAA directed the Secretary of Defense to execute a quantum technology R&D program in coordination with other government agencies and the private sector; the FY2020 NDAA required DOD to develop ethics guidelines for the use of quantum technologies, create plans to support the quantum workforce and reduce the cybersecurity risks associated with quantum technologies, and authorized each military department to establish its own QIS Research Centers; the FY2021 NDAA directed the military services to identify technical challenges that quantum computers could address in the near term and to establish programs with small and medium-sized businesses to provide access to quantum computing capabilities; the FY2022 NDAA asked the President to establish the Subcommittee on the Economic and Security Implications of Quantum Information Science (ESIX) and mandated activities to accelerate

69 Ibid.

70 Saylor, Kelley M. “Defense Primer: Quantum Technology.” Congress.gov, November 04, 2024. <https://www.congress.gov/crs-product/IF11836>.

the development and deployment of dual-use quantum capabilities; and the FY2024 NDAA had DOD establish a public-private talent exchange program for quantum research and authorized a pilot program for quantum computing.<sup>71</sup>

Thus, U.S. quantum policy is driven by dual imperatives: securing economic competitiveness in a transformative technology sector and addressing urgent national security threats. Foremost among these threats is the risk posed by quantum computers to current cryptographic standards. Specifically, if a sufficiently powerful quantum computer is developed, it could break most of the public-key cryptography that underpins the security of the internet, financial systems, and classified government communications. As a result, adversaries and malign actors could decrypt vast amounts of sensitive data to the detriment of U.S. national security and its interests. Analysts estimate that a quantum computer with 20 million qubits would be required to break current encryption methods.<sup>72</sup> Since the current standard is around 1,000 qubits, this risk is not an imminent one. Yet, the phenomenon of “harvest now, decrypt later” – wherein encrypted data could be collected and stored today, only to be decrypted and read later when sufficiently powerful quantum computers have been developed – means that immediate steps need to be taken to tackle future problems.

To address this challenge, the Biden Administration issued the National Security Memorandum on Promoting United States Leadership in Quantum Computing While Mitigating Risks to Vulnerable Cryptographic Systems (NSM-10) in May 2022.<sup>73</sup> It directed a multi-year, government-wide effort to migrate

vulnerable computer systems to post-quantum cryptography (PQC), with NIST and the National Security Agency (NSA) being tasked with developing, standardizing, and promoting PQC algorithms for use by the private sector and civilian government agencies, as well as National Security Systems of the U.S. government.<sup>74</sup> NIST released the first tranche of these standards in August 2024, and NSA has stated that it “expects the transition to [quantum-resistant] algorithms for [national security systems] to be complete by 2035 in line with NSM-10.”<sup>75</sup>

After taking office, the Trump Administration issued an Executive Order (EO) on June 06, 2025, that again acknowledged the risk of public-key cryptography being broken by “[a] quantum computer of sufficient size and sophistication.”<sup>76</sup> It went on to direct the U.S. Department of Homeland Security, the Cybersecurity and Infrastructure Security Agency (CISA), and NSA to “release and thereafter regularly update a list of product categories in which products that support post-quantum cryptography (PQC) are widely available.”<sup>77</sup> Moreover, NSA and the Office of Management and Budget (OMB) were asked to issue requirements for agencies to “support” PQC as soon as practicable, but not later than January 02, 2030.<sup>78</sup> Importantly, NSM-10’s requirements mandating and promoting PQC algorithms for use by the private sector were dropped in Trump’s EO.

71 Ibid.

72 Ibid.

73 “National Security Memorandum on Promoting United States Leadership in Quantum Computing While Mitigating Risks to Vulnerable Cryptographic Systems.” The White House, May 04, 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/>.

74 Ibid.

75 “NIST Releases First 3 Finalized Post-Quantum Encryption Standards.” National Institute of Standards and Technology, U.S. Department of Commerce, August 13, 2024. <https://www.nist.gov/news-events/news/2024/08/nist-releases-first-3-finalized-post-quantum-encryption-standards>; Sayler, Kelley M. “Defense Primer: Quantum Technology.”

76 “Sustaining Select Efforts to Strengthen the Nation’s Cybersecurity and Amending Executive Order 13694 and Executive Order 14144.” The White House, June 06, 2025. <https://www.whitehouse.gov/presidential-actions/2025/06/sustaining-select-efforts-to-strengthen-the-nations-cybersecurity-and-amending-executive-order-13694-and-executive-order-14144/>.

77 Ibid.

78 Ibid.

Complementing the federal strategy, individual states have begun to launch their own initiatives to compete for leadership in the emerging quantum industry. Case in point, the U.S. state of Texas has introduced the Texas Quantum Initiative that aims to accelerate quantum's role in the state economy, identify commercial opportunities, support workforce training, and promote the development of a Texas-based quantum supply chain.<sup>79</sup> Prioritizing commercial relevance, it calls for investments in practical quantum technologies and scalable infrastructure such as networks, hardware systems, and real estate.<sup>80</sup> A state-level fund and an executive committee have also been created to drive quantum research and manufacturing within the state.<sup>81</sup>

Ultimately, U.S. quantum strategy has matured into a whole-of-nation endeavor, treating quantum not just as a scientific field but as a foundational industry for the 21st century, yet its success hinges on sustained investment, stable policy, and effective execution.

## 7. Country Case Study: China

China's pursuit of quantum technology is not merely a scientific endeavor but a core component of its grand national strategy, considered as essential for achieving the "great rejuvenation of the Chinese nation" and for fundamentally altering the global balance of technological and military power. This national vision frames quantum science as a critical domain for securing China's future economic prosperity, military strength, and international standing and is deeply interwoven with the overarching national strategic objective of transforming China into a "science

and technology superpower."<sup>82</sup> In fact, a 2024 government work report stated that development plans for emerging industries, including quantum computing, will be formulated as part of a broader push for technological self-sufficiency.<sup>83</sup>

Hence, Beijing's interest and strategic objectives around quantum technologies are very similar to those of India. Both countries recognize the potential of developing indigenous systems and applications centered on quantum and the advantages doing so would provide in the economic and security realms. As the two Asian nations strive to become self-reliant and gain independence in their strategic decision-making, leveraging quantum may boost their efforts and enable them to better reap the gains of the coming technological transformation.

Unsurprisingly, China's development of quantum capabilities is explicitly cast in the language of geopolitical and strategic competition. For example, President Xi Jinping has personally identified quantum technology as "another front in global S&T competition."<sup>84</sup> Aiming to move beyond a model reliant on the "absorption" of foreign technologies, China is seeking to achieve "truly disruptive, even 'radical' innovation" in strategic emerging technologies where no nation, including the United States, yet possesses an insurmountable or decisive advantage.<sup>85</sup>

79 Swayne, Matt. "Texas Statewide Quantum Initiative Becomes Law." *Quantum Insider*, June 24, 2025. <https://thequantuminsider.com/2025/06/24/texas-quantum-initiative-passed/>.

80 Ibid.

81 Ibid.

82 Kania, Elsa B. and John K. Costello. "Quantum Hegemony? China's Ambitions and the Challenge to U.S. Innovation Leadership." *Center for a New American Security*, September 12, 2018. <https://www.cnas.org/publications/reports/quantum-hegemony>.

83 "China to step up quantum computing, AI in tech self-sufficiency drive." *Reuters*, March 05, 2024. <https://www.reuters.com/technology/china-step-up-quantum-computing-ai-efforts-its-aims-tech-self-sufficiency-2024-03-05/>.

84 Groenewegen-Lau, Jeroen and Antonia Hmaid. "China's Long View on Quantum Tech has the US and EU Playing Catch-up." *Mercator Institute for China Studies*, December 2024. <https://merics.org/en/report/chinas-long-view-quantum-tech-has-us-and-eu-playing-catch>.

85 Kania, Elsa B. and John K. Costello. "Quantum Hegemony? China's Ambitions and the Challenge to U.S. Innovation Leadership."

A primary catalyst for the urgency and scale of China’s quantum program is national security, particularly in the realm of information and cybersecurity. Analysts suggest that the 2013 revelations by former NSA contractor Edward Snowden, which allegedly detailed the extent of U.S. intelligence activities in China, served as a pivotal moment.<sup>86</sup> These disclosures intensified “anxieties over domestic information security and vulnerabilities to cyber espionage,” spurring a determined search for indigenous cybersecurity solutions that could not be compromised by foreign powers.<sup>87</sup>

China’s quantum strategy is codified and driven through a comprehensive and evolving architecture of national policies. Over the years, quantum technology has been elevated from a foundational research area to a top-tier national strategic priority with specific, actionable goals. Initial state support for basic research in quantum control and information was provided through foundational science and technology programs, including the 1986 National High-Technology Research and Development Plan, or “863 Plan,” and the 1997 National Key Basic Research and Development Plan, or “973 Plan.”<sup>88</sup> These early initiatives laid the groundwork for more ambitious efforts. A key policy document from this period, the 2006 National Medium- and Long-Term Science and Technology Development Plan Outline (2006-2020), identified “quantum control research” as a priority, calling for exploration into quantum phenomena and the development of quantum communications and computing.<sup>89</sup>

The Thirteenth Five-Year Plan period – from 2016 to 2020 – marked a significant escalation in the prioritization and funding of quantum technologies. For example, the National Science and Technology Innovation Program designated quantum communications and quantum computing as a prioritized “S&T Innovation 2030 Major Project.” This project calls for major advances

in metropolitan and inter-city free space quantum communications technology, the development and manufacture of common-use quantum computing prototypes, and the development and manufacture of actual-use quantum simulators by 2030.<sup>90</sup> The Thirteenth Five-Year Science and Technology Military-Civil Fusion Special Projects Plan – released in August 2017 – included quantum communications and quantum computing among its key priorities and specifically highlighted the development of quantum satellites.<sup>91</sup> Further, official media states that China spent about 1.9 billion RMB (over \$302 million) in quantum science between 2013 and 2015.<sup>92</sup>

More recently, Beijing’s interest in and support of indigenous quantum innovation has been featured in government documents such as the Fourteenth Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035 – released in March 2021. It lists plans to “research and develop intra-city, inter-city, and free-space quantum communication technologies, develop a general quantum computing prototype and a practical quantum simulator, and make breakthroughs in quantum precision measurement technology.”<sup>93</sup> The Plan also calls for the establishment of national laboratories focused on quantum information.<sup>94</sup> Additionally, the Fourteenth Five-Year Plan for National Informatization – issued in December 2021 – recommends “research to explore quantum

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86 Ibid.

87 Ibid.

88 Ibid.

89 Ibid.

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90 Ibid.

91 Ibid.

92 Ibid.

93 Murphy, Ben ed. Translation of “Outline of the People’s Republic of China 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035.” Center for Security and Emerging Technology, Georgetown University, May 12, 2021. [https://cset.georgetown.edu/wp-content/uploads/t0284\\_14th\\_Five\\_Year\\_Plan\\_EN.pdf](https://cset.georgetown.edu/wp-content/uploads/t0284_14th_Five_Year_Plan_EN.pdf).

94 Ibid.

information technology.”<sup>95</sup> Specifically, it asks for “forward-looking” exploration of quantum telecommunications, quantum computing, and quantum sensing technology, and the building of quantum information network technology and standard systems.<sup>96</sup>

The financial commitment underpinning China’s science and technology development strategy is substantial, estimated to be approximately \$15 billion.<sup>97</sup> Moreover, public spending on quantum is reportedly four times higher than that of the U.S. and accounts for over half of all estimated global public investment in the field.<sup>98</sup> Researchers have pointed out that this level of investment reflects a national determination to “brute-force its way to quantum supremacy simply by throwing resources at it.”<sup>99</sup>

On the strategic and national security front, quantum technologies are a clear priority. For example, The National Laboratory for Quantum Information Science is reportedly engaged in research “of immediate use” to China’s armed forces.<sup>100</sup> Even the People’s Liberation Army (PLA) is said to be directly involved in key projects, with the PLA Strategic Support Force (PLASSF) supporting the launch and publicity for the Micius quantum satellite.<sup>101</sup> Furthermore, state-owned defense conglomerates like the Aviation Industry Corporation of China (AVIC) and the China Shipbuilding Industry Corporation (CSIC) have established joint research centers and laboratories

with academic institutions like the University of Science and Technology of China (USTC) to develop military applications for quantum navigation, communications, and detection.<sup>102</sup>

Recent examples of Beijing’s advancements include a quantum communications system linking Beijing and Shanghai that secures transmission of information in government, finance, national defense, and other sensitive domains.<sup>103</sup> This system began operating in September 2017 and will reportedly be expanded nationwide, linking metropolitan-level quantum communications networks intended for use by local enterprises and governments.<sup>104</sup> Other developments include demonstrations of secure data transmission over long distances at speeds sufficient to enable encrypted voice transmission via telephone, and quantum secure direct communication in which the message, rather than just the cryptographic key, is transmitted in quantum form. As these tests were conducted in 2016 and 2017, respectively, it is possible that there have been subsequent qualitative and quantitative improvements.

In 2016, China launched the Micius satellite – also known as Mozi or the Quantum Science Satellite – under its Quantum Experiments at Space Scale (QUESS) project. This satellite facilitated the world’s first quantum-encrypted virtual teleconference – between researchers in Beijing and Vienna – and has subsequently established QKD networks from space, exchanging information in quantum form with ground stations located thousands of kilometers apart, to establish a direct secure link.<sup>105</sup> Quantum-secured connections have been demonstrated between China and Austria,

95 Creemers, Rogier et al. “Translation: 14th Five-Year Plan for National Informatization – Dec. 2021.” DigiChina, Stanford University, January 24, 2022. <https://digichina.stanford.edu/work/translation-14th-five-year-plan-for-national-informatization-dec-2021/>.

96 Ibid.

97 Groenewegen-Lau, Jeroen and Antonia Hmaid. “China’s Long View on Quantum Tech has the US and EU Playing Catch-up.”

98 Ibid.

99 Ibid.

100 Kania, Elsa B. and John K. Costello. “Quantum Hegemony? China’s Ambitions and the Challenge to U.S. Innovation Leadership.”

101 Ibid.

102 Ibid.

103 Ibid.

104 Ibid.

105 Kwon, Karen. “China Reaches New Milestone in Space-Based Quantum Communications.” *Scientific American*, June 25, 2020. <https://www.scientificamerican.com/article/china-reaches-new-milestone-in-space-based-quantum-communications/>; “QSS.” NASA Space Science Data Coordinated Archive. Accessed August 09, 2025. <https://nssdc.gsfc.nasa.gov/nmc/spacecraft/display.action?id=2016-051A>.

China and Russia, and China and South Africa.<sup>106</sup>

On the quantum sensing front, state-owned China Electronics Technology Group Corporation (CETC), along with the University of Science and Technology of China and Nanjing University, have been working on a quantum radar system that uses quantum-entangled photon pairs to detect targets.<sup>107</sup> The aim is to be able to detect and track stealth bombers and high-speed flying objects, like ballistic and hypersonic missiles, in the upper atmosphere and above.<sup>108</sup> Multiple institutes are also researching quantum imaging solutions. For example, the Chinese Academy of Sciences' (CAS) Key Laboratory for Quantum Optics is developing a quantum "ghost imaging" device that can be used on satellites to detect stealth platforms and even see through camouflaging tactics from space, and the CAS Institute of Remote Sensing Applications is researching high-resolution quantum remote sensing.<sup>109</sup> Additionally, scientists at the Shanghai Institute of Microsystems and Information Technology are developing a superconductive magnetic anomaly detection array that could detect submarines and other underwater

platforms.<sup>110</sup>

China has also been interested in quantum's PNT applications. Research institutes of the state-owned China Shipbuilding Industry Corporation have reportedly achieved breakthroughs in quantum-enabled inertial navigation and are working on interferometric atomic gyroscopes/atomic accelerometers, quantum gravity gradiometers, quantum time references, and atomic spin gyroscopes.<sup>111</sup> Parallel efforts to develop quantum navigation solutions are being led by institutions like the Beijing Automation and Equipment Control Research Institute, the China Aerospace Science and Industry Corporation, and Beihang University.<sup>112</sup>

On quantum computers, scientists at the University of Science and Technology of China, in August 2016, announced the successful development of a semiconductor quantum chip which could enable quantum operations and information processing, and in January 2018, launched the world's first semiconductor quantum chip-based quantum computing cloud platform and a 32-bit quantum virtual machine.<sup>113</sup> These components could be further developed into a product that can conduct defensive and offensive cyber operations and let security and intelligence services access these tools remotely over the cloud.

Importantly, while the research and development taking place in the U.S. and China has been in progress for some time and exhibited early success, none of the quantum technologies have yet matured enough to be deployed for security applications at scale. Even so, systems leveraging quantum communications and quantum sensing are estimated to become operational in this decade. Some of the first use-cases may be China's utilization of QKD to secure its most sensitive and strategic communications, effectively shielding them from either being intercepted or decrypted, and covering

106 Swayne, Matt. "China Establishes Quantum-Secure Communication Links With South Africa." *Quantum Insider*, March 14, 2025. <https://thequantuminsider.com/2025/03/14/china-established-quantum-secure-communication-links-with-south-africa/>; Swayne, Matt. "Report: China and Russia Test Quantum Communication Link." *Quantum Insider*, May 09, 2025. <https://thequantuminsider.com/2024/01/02/report-china-and-russia-test-quantum-communication-link/>.

107 Kania, Elsa B. and John K. Costello. "Quantum Hegemony? China's Ambitions and the Challenge to U.S. Innovation Leadership."

108 Ibid.

109 Chen, Stephen. "Could ghost imaging spy satellite be a game changer for Chinese military?" *South China Morning Post*, November 26, 2017. <https://www.scmp.com/news/china/society/article/2121479/could-ghost-imaging-spy-satellite-be-game-changer-chinese>; Kania, Elsa B. and John K. Costello. "Quantum Hegemony? China's Ambitions and the Challenge to U.S. Innovation Leadership."

110 Kania, Elsa B. and John K. Costello. "Quantum Hegemony? China's Ambitions and the Challenge to U.S. Innovation Leadership."

111 Ibid.

112 Ibid.

113 Ibid.

all institutions of national importance – including the military, the security and intelligence apparatus, financial institutions, and party and state offices. Concurrently, both China and the U.S. may employ quantum-enabled sensors for PNT applications, thereby decreasing their reliance on Global Navigation Satellite Systems, such as GPS or BeiDou.

China’s national quantum strategy is complemented by a growing number of provincial and local initiatives, demonstrating a multi-level government effort to build regional quantum innovation ecosystems. For example, the Anhui Quantum Science Industry Development Fund, established in 2017, announced plans to invest CNY 10 billion (\$1.6 billion) in quantum computing, communications, and metrology.<sup>114</sup> Further, the province of Shandong has issued plans to create a quantum technology industrial ecosystem in its capital city of Jinan, aiming to capture “over 70% of the national defense market.”<sup>115</sup> Looking at China’s progress in the dual-use quantum ecosystem, the U.S. has placed sanctions on several Chinese entities. Among them are the Jinan Institute of Quantum Technology, Chinese Academy of Science Center for Excellence in Quantum Information and Quantum Physics, Chinese Academy of Sciences Key Laboratory for Quantum Information, and QuantumCTek.<sup>116</sup>

## 8. Sector-specific Use Cases

**Table 1:** Defense and Security

Technology	Applications	Use Cases
Quantum Sensing	Positioning, Navigation and Timing (PNT)	Utilizing atomic clocks and quantum accelerometers to create highly precise inertial navigation systems that act as alternatives to Global Navigation Satellite Systems (GNSS) like GPS and BeiDou, allowing military platforms – like submarines, aircraft, and missiles – to navigate independently of GNSS that can be jammed or spoofed
	Intelligence, Surveillance and Reconnaissance (ISR)	Deploying quantum magnetometers and gravimeters to detect minute disturbances in magnetic or gravitational fields, enabling the detection of stealth aircraft, submarines, underground facilities, and concealed nuclear materials; employing quantum illumination to detect targets with a low radar cross-section – like stealth aircraft and drones

114 Ibid.

115 Ibid.

116 “Supplement No. 4 to Part 744—Entity List.” Bureau of Industry and Security, U.S. Department of Commerce. Accessed August 18, 2025. <https://www.bis.gov/node/17028>.

Technology	Applications	Use Cases
Quantum Computing	Quantum convergence with Artificial Intelligence and Machine Learning	Making autonomous weapon systems more accurate, lethal, and faster; optimizing logistics & troop deployments; enhancing wargaming simulations and scenario modeling for complex battlefields
	Encryption breaking quantum computers	Breaking traditional encryption standards
	Material science via quantum simulation	Designing more effective stealth coatings, high-energy explosives, and superconductors
	SIGINT (signals intelligence) analysis	Decrypting and analyzing collected data, detecting anomalies in data streams
	GEOINT (geospatial intelligence) and IMINT (imagery intelligence) analysis	Analyzing and processing images and geospatial information collected by satellites and other sensors
Quantum Communications	Quantum Key Distribution (QKD) military networks	Enabling secure and un-hackable communications over classical networks, including tamper-proof battlefield communications, command and control links, and connecting sensors and platforms with military systems
	Protecting strategic national assets	Securing communication networks for the most critical national security infrastructure – including nuclear command and control, intelligence agencies, and diplomatic communications, ensuring information secrecy against adversary

**Table 2:** Financial Services

Technology	Applications	Use Cases
Quantum Sensing	High-precision time stamping	Utilizing atomic clocks for precise time synchronization for use in high-frequency trading, ensuring compliance with regulations, and maintaining the integrity of distributed ledgers
	GNSS-independent timing	Building resilience against GNSS jamming or spoofing, reducing outage risk
Quantum Computing	Portfolio optimization	Solving complex optimization problems to find the ideal asset allocation that maximizes returns for a given level of risk
	Risk analysis and simulation	Accelerating complex risk modeling (e.g., market risk, credit risk)
	Derivative pricing	Speeding up solving complex mathematical problems associated with pricing financial derivatives, enabling more accurate and real-time pricing
	Fraud detection	Leveraging Quantum Machine Learning (QML) to improve pattern recognition in vast datasets, helping identify subtle, anomalous patterns indicative of sophisticated financial fraud
Quantum Communications	Quantum Key Distribution (QKD)	Creating secure communication channels for transmitting sensitive data
	Secure authentication	Enhancing security for customer logins and transaction authorizations, using quantum principles to create un-hackable multi-factor authentication protocols
	Securing network infrastructure	Securing data in transit between branches, data centers, and cloud infrastructure, protecting the core of a financial institution's communication network from interception

**Table 3:** Healthcare and Pharmaceuticals

Technology	Applications	Use Cases
Quantum Sensing	Advanced medical imaging	Creating highly sensitive sensors for next-generation MRI and MEG scans to detect faint magnetic signals from the brain and heart
	Early disease detection	Developing nanoscale sensors capable of detecting single-molecule biomarkers in blood or breath samples for early cancer detection and monitoring of diseases
Quantum Computing	Drug discovery and molecular simulation	Accurately simulating the behavior of complex molecules and their interactions with biological targets to accelerate the design of new drugs and predict their effectiveness and side effects, shortening R&D timelines

Technology	Applications	Use Cases
	Personalized medicine (Genomics)	Analyzing vast genomic datasets to identify correlations between genes, diseases, and drug efficacy, paving the way for personalized treatment plans tailored to an individual's genetic makeup
	Radiotherapy optimization	Solving complex optimization problem of planning radiation treatments for cancer, calculating optimal beam angles and intensities to maximize tumor destruction while minimizing damage to surrounding healthy tissue <sup>117</sup>
Quantum Communications	Secure health data transmission	Using QKD to create un-hackable channels for sharing sensitive patient data (e.g., electronic health records, genomic information) between hospitals, labs, and research centers
	Protecting pharmaceutical intellectual property	Securing the transmission of valuable intellectual property, such as new drug formulas, research findings, and clinical trial data, protecting it from corporate espionage
	Secure telemedicine and IoT devices	Ensuring the privacy and integrity of data transmitted during remote doctor-patient consultations and from connected health monitoring devices (Internet of Things)

**Table 4:** Advanced Manufacturing

Technology	Applications	Use Cases
Quantum Sensing	High-precision metrology and quality control	Utilizing quantum sensors to measure physical properties (length, temperature, magnetic fields) with extreme accuracy, ensuring components – especially in aerospace and semiconductor manufacturing; precisely synchronizing robotics and machines <sup>118</sup>
	Non-destructive material analysis	Detecting microscopic internal defects, stresses, or corrosion in materials and finished parts without causing any damage, vital for quality assurance in critical components like semiconductors, turbine blades, and engine parts <sup>119</sup>
	Environmental monitoring	Detecting trace chemicals, radiation, or electromagnetic interference affecting quality
	Inertial navigation for robotics	Employing quantum gyroscopes and accelerometers for precise, GNSS-independent navigation, allowing autonomous factory robots and drones to move and operate with higher accuracy and reliability even in indoor environments

117 Lal, R., Singh, R.K., Nishad, D.K. et al. “Quantum-enhanced intelligent system for personalized adaptive radiotherapy dose estimation.” *Sci Rep* 15 (2025): 19919. <https://doi.org/10.1038/s41598-025-05673-y>.

118 “Quantum Metrology and Sensing.” Hubner Photonics. Accessed August 19, 2025. <https://hubner-photonics.com/knowledge-bank/quantum-metrology-and-sensing/>.

119 Brans, Pat. “Can Quantum Sensors Improve Real-Time Metrology in Fabs?” *EE Times Europe*, November 04, 2024. <https://www.eetimes.eu/can-quantum-sensors-improve-real-time-metrology-in-fabs/>; Vindolet, Baptiste, Benjamin Ducharne, Hoai Nam Nguyen, Xavier Mougnot, Christophe Gallais, and Thomas Hingant. “High-Resolution Non-Destructive Detection of Grinding Burns with NV Diamond Quantum Magnetometer.” *NDT&E International* 155 (October 2025): 103439. <https://doi.org/10.1016/j.ndteint.2025.103439>.

Technology	Applications	Use Cases
Quantum Computing	Materials Discovery and Design	Simulating matter at the atomic level to engineer novel materials with specific, desirable properties (e.g., higher strength, better conductivity, or heat resistance), replacing the slow trial-and-error approach
	Factory and supply chain optimization	Solving complex logistical problems – such as production scheduling and inventory management, leading to more efficient supply chains, reduced operational costs, and minimized waste
Quantum Communications	Securing industrial IoT	Using QKD to secure the network of connected sensors, machines, and controllers on the factory floor, protecting sensitive operational data and prevents cyber-physical attacks
	Protecting intellectual property	Using QKD to secure channels for transmitting proprietary data – such as schematics, CAD files, and trade secrets – between design teams, manufacturing plants, and offices worldwide
	Secure robotics and automation control	Securing the command-and-control communications for automated systems and industrial robots, preventing unauthorized access or malicious takeover that could halt production or cause physical damage

**Table 5:** Agriculture and Food Security

Technology	Applications	Use Cases
Quantum Sensing	Precision soil and water analysis	Deploying hyper-sensitive sensors for real-time, in-field measurement of soil nutrients, moisture levels, and contaminants, potentially reducing fertilizer and water usage while maximizing crop health
	Early crop disease and stress detection	Detecting minute biochemical changes in plants that signal stress from drought, pests, or disease, providing early warning to farmers
	Climate & weather monitoring	Predicting microclimates and farming conditions
	Food safety and quality control	Using quantum sensors to rapidly detect specific pathogens, allergens, or chemical contaminants in food products with high sensitivity, enhancing safety and quality assurance
Quantum Computing	Designing efficient fertilizers	Simulating molecular interactions to develop new catalysts for fertilizer production, drastically cutting the global carbon footprint of agriculture
	Crop yield modeling and optimization	Creating accurate models that simulate the interplay between plant genetics, soil conditions, weather, and farming practices, helping breed more resilient crops with higher yields and optimizing planting strategies for a changing climate
	Food supply chain optimization	Solving logistical problems to optimize the distribution of food from farm to consumer, helping reduce spoilage, cut transportation costs, and improve the resilience of the global food supply chain

**Table 6:** Weather Forecasting and Disaster Management

Technology	Applications	Use Cases
Quantum Sensing	Advanced environmental monitoring	Deploying networks of quantum sensors – including gravimetry and magnetometers – to measure atmospheric pressure, critical climate change indicators, gravity fields, and magnetic fields with extreme precision; providing more granular data for weather models and early warnings for events like volcanic eruptions or tsunamis
	Quantum gravimetry for groundwater and flood risk monitoring	Detecting underground water movement and aquifer depletion to predict droughts or floods
	Quantum magnetometers for volcanic & seismic activity	Early detection of magma movement and fault stress for disaster prevention
	Quantum-enhanced satellite remote sensing	Improving cloud profiling, storm tracking, and atmospheric analysis using quantum lidar and single-photon detectors
	Gas & particle detection	Monitoring greenhouse gas, detecting wildfire smoke, and forecasting pollution

Technology	Applications	Use Cases
	Positioning and navigation	Providing accurate positioning and navigation for drones, emergency vehicles, and first responders operating in disaster zones where GNSS signals are jammed, spoofed, or unavailable
Quantum Computing	High-fidelity weather and climate modeling	Solving complex fluid dynamics equations that govern weather systems, leading to more reliable forecasts for events like hurricanes and improving long-term climate change projections
	Disaster response optimization	Solving logistical problems in real-time to optimize the allocation of emergency resources – like medical supplies, rescue teams, and shelters; minimizing response times, and optimizing evacuation routes and shelter placement
	Wildfire and flood simulation	Running faster and more sophisticated simulations of how wildfires spread or how floodwaters will move through a landscape, allowing better decisions to be made regarding evacuations and resource deployment
Quantum Communications	Secure command & control	Providing secure communication links for coordinating complex, multi-agency disaster response efforts, ensuring that operational commands cannot be intercepted or disrupted

**Table 7:** Creative Economy

Technology	Applications	Use Cases
Quantum Sensing	Advanced brain-computer interfaces	Using ultra-sensitive quantum magnetometers to read brain signals with incredible detail, potentially enabling artists to create digital paintings with their thoughts or allow for new, immersive control schemes in gaming and virtual reality
	High-fidelity media capture	Developing next-generation image and audio sensors that capture light and sound with a precision beyond classical limits, enabling filming in near-total darkness or recording audio with perfect clarity
	Physical asset authentication	Employing quantum sensors to detect and verify unique atomic-level signatures embedded in physical goods, providing an unforgeable method for authenticating high-value art, limited-edition collectibles, and merchandise
Quantum Computing	Next-generation procedural content	Generating vast, complex, and non-repetitive virtual worlds, characters, and assets for video games and computer-generated imagery (CGI), creating simulated environments with a level of detail and realism that is currently computationally impossible
	Hyper-realistic rendering	Accelerating complex calculations needed for physically accurate light simulation (ray tracing) in visual effects and animation, drastically reducing rendering times and enabling a new level of photorealism in films and games
	Enhanced generative AI	Leveraging Quantum Machine Learning (QML) to power generative AI that can understand deeper context and abstract concepts, leading to AI capable of co-writing nuanced scripts, composing original music, and developing entirely new artistic styles
Quantum Communications	Unbreakable Digital Rights Management (DRM)	Using QKD to securely deliver encryption keys for streaming content, making it virtually impossible to pirate movies, music, or games
	Protecting pre-release assets	Creating secure channels to transmit high-value, confidential content – like movie files or AAA game builds – between studios, vendors, and distributors, preventing costly pre-release leaks
	Secure digital provenance	Enabling the creation of unclonable digital watermarks or tokens to prove the ownership and authenticity of digital art and collectibles (e.g., NFTs)

## 9. Roadblocks for India

This paper's research has identified three roadblocks to India's development of quantum technologies. First, there is negligible private funding for pre-commercial R&D. While this is not a surprising observation – India's private sector has

long been risk-averse and more focused on short-to-medium term gains – public funding alone may not give efficient and promising results in the greenfield sector of quantum. Hence, it is imperative that the national and state governments find ways to de-risk and incentivize the private industry. Concurrently, the larger private sector must also

become better informed as to how quantum can be adopted and used in their respective areas.

Second, India's indigenous supply chains related to quantum components and systems is insufficient. Further, short-to-medium term development of this ecosystem in India currently has a low probability. Hence, import of hardware from countries like the U.S., Europe, and China would be required. This situation, when connected with the dual-use and securitization challenges New Delhi faces, means that greater momentum needs to be applied to targeted self-reliance in quantum and developing foundational quantum capabilities.

Third, there is an absence of effective coordination among the many stakeholders. While the national government, several state governments, academia, and industry, all have a stake and interest in the successful development and adoption of quantum technologies in India, suitable platforms and forums are required on which a coordinated and whole-of-society effort can be discussed, outlined, and followed.

## 10. Policy Recommendations

Executing NQM, state-led, and other government initiatives

- **Partnerships between the various stakeholders** – including the NQM, T-hubs, state governments, industry, and academia – requires active, large-scale coordination wherein each delivers on time and efficiently within their defined area of responsibility. NQM's Mission Governing Board (MGB) and Mission Technology Research Council (MTRC) are best poised to assume this coordinating role. This will ensure a whole-of-society effort that drives quantum development in India in a manner that best utilizes the resources available.

- **Time-taking evaluation and due diligence processes at T-Hubs, as well as concerns over the protection of intellectual property may delay timely progress and frustrate stakeholders.**

- **Now that funding and budget allocation** for the various government initiatives have been finalized, the executing bodies of each must create and publish evaluation standards that are practical and transparent. These standards should cover every step of the application, funding, and output cycle. Further, the existence and adherence to these benchmarks would also act as a means to de-risk private investment in the ventures that receive government support.

- Streamline the NQM's administrative and funds disbursement mechanisms by implementing a single window, fast-track clearance system for both funding approvals and the import of critical research equipment. Consider adhering to a 10-business-day decision period, clearly and transparently describing the reasons if the application is declined and creating a pre-cleared vendor catalogue for NQM grantees.

- NQM may consider publishing an Intellectual Property framework – modeled under the U.S. Bayh-Dole Act of 1980 – governing the ownership and commercialization of quantum R&D it funds wherein the rights are retained by the developers and can be licensed by them to others.<sup>120</sup> To safeguard the IP's use, both within the country and for beneficial purposes, restrictions may be adopted. These could include mandating that only Indian companies be eligible to acquire a license; NQM reserving the right to itself license the technology to other parties under specific circumstances; and the Government of India holding a non-exclusive, royalty-free license to use the patented invention for its own purposes.

<sup>120</sup> "U.S.C. Title 35 – PATENTS." Govinfo.gov. Accessed August 30, 2025. <https://www.govinfo.gov/content/pkg/USCODE-2011-title35/html/USCODE-2011-title35-partII-chap18.htm>.

- **The NQM – in close collaboration with** industry and academia, and with national development goals as the basis – may establish sector-specific milestones as one of the funding criteria. For example, field-testing of QKD line-of-sight kits with  $\geq 200$  bps (bits per second) secure key rate and  $< 10\%$  QBER (quantum bit error rate) in mobile scenarios; demonstrating magnetometer-based anomaly detection for naval use; or deploying atomic-clock timestamping at two locations within the financial sector.
- **As the talent and skilling pipeline** envisioned will take a few years to mature, execution of NQM and state governments' initiatives should focus on a scaling-up approach where the potential short-term skills bottleneck does not slow progress.

## 11. Complementary and supplementary programs to tackle near-term challenges

- **India must contend with limited supply** chains, at least in the short-to-medium term, that may constrict the pace of development and prove to be a strategic vulnerability that hampers New Delhi's interests and ambitions.
  - There exists a critical structural challenge in the form of India's heavy dependence on imported hardware. Key components required for quantum research – such as specialized cryostats and high-performance sensors – are not manufactured domestically and must be procured from overseas, exposing researchers to long procurement delays and the risk of tightening global export controls.<sup>121</sup>
  - In response, India may set up a

121 “Quantum challenge: On IIT-DRDO demonstration of quantum key-distribution scheme.” The Hindu, June 21, 2025. <https://www.thehindu.com/opinion/editorial/quantum-challenge-on-iit-drdo-demonstration-of-quantum-key-distribution-scheme/article69717803.ece>.

- “National Quantum Foundry” to counter India's heavy reliance on imported core components for quantum hardware – such as cryogenic systems, high-precision lasers, and control electronics – which is a strategic vulnerability.
- The planned Central Fabrication Facilities – to be established at IISc Bengaluru and IITs Bombay, Delhi and Kanpur to make devices and materials that are essential components in quantum systems – is a promising step. The next step should focus on not only adding more local suppliers to the indigenous supply chains but also look at collaborating with the private industry to scale the infrastructure and make it accessible to the wider quantum ecosystem in India.
- Invest in building indigenous fabrication capabilities (fabs) for critical quantum components – particularly high-coherence superconducting qubits and integrated photonics.

- **While strategic autonomy is a key** imperative for India, it should not result in an isolated development strategy. Global cooperation in quantum R&D will be crucial to foster innovation and ensure fast-paced progression. This includes exploring opportunities to co-develop and jointly manufacture quantum components – thereby integrating indigenous industries with global supply chains – and participating in multilateral forums that will set international standards related to quantum technologies.
  - Thus, India should develop a formal roadmap to partner with like-minded nations on fundamental research, talent exchange, and building resilient, non-critical supply chains, balancing self-reliance with the benefits of global scientific advancement.
  - A dual-track policy may identify and designate civilian quantum stacks

for partner collaboration and restrict strategic tracks for indigenous development and procurement.

- The ratio of government funding to private funding is significantly lacking in India. This scenario may limit the pace of quantum progress in the country. Hence, there is an immediate need to bolster the participation of the private sector.
  - The DST's Research, Development, and Innovation (RDI) Scheme and the DeepTech Fund of Funds are both novel and beneficial attempts at encouraging the private sector's participation in investing in the R&D of quantum technologies. Still, there is a need to increase the private sectors buy-in from the private sector in the form of investment and R&D commitments.
  - To achieve this, non-financial de-risking by the government can be achieved through setting evaluation standards for the different quantum technologies, in addition to enacting policy that would commit to the adoption of certain uses of quantum into the national infrastructure – such as QKD to secure communications and quantum sensing products in the defense, security, space, weather forecasting, and disaster management sectors.
  - Subsequently, private investors should be invited to invest in the startups and projects identified as practical and viable by the government initiatives. A 1:1 match between public and private funding may also be considered.
  - Thus, RDI and DeepTech Funds of Fund could evolve into collaborations between the government, institutional investors, and corporate venture arms.
- Catalyze the private sector by de-risking private investment through targeted Production-Linked Incentive (PLI) schemes

that encourages domestic manufacturing of quantum components and creating viable commercial markets for quantum technologies. A target of  $\geq 50\%$  domestic bill of materials by FY2030 may be considered.

- A national “1,000 Quantum Algorithms” program may be launched wherein participants are rewarded with credits to access the cloud-based quantum infrastructure – like the one coming up at AQV – for meeting pre-defined benchmarks and competing on category-specific leaderboards.
- Create a national “Quantum Bharat Consortium” – modeled after the U.S. Quantum Economic Development Consortium – that brings together Indian original equipment manufacturers (OEMs) in the telecom, defense, and semiconductor sectors, along with stakeholders in the Government of India, state governments, academic institutions, and startups, under one roof to coordinate supply-chain and R&D roadmaps.
- A “Quantum Technician Corps” may be created across Industrial Training Institutes (ITIs) and polytechnics – especially those near initiatives like AQV and KQM. Further, 1-year reskilling programs may be instituted at public-sector undertakings (PSUs) such as Bharat Electronics Limited (BEL) and Electronics Corporation of India Limited (ECIL) to include them as suppliers of quantum components.

## 12. Other steps to enhance policy support

- **Commit to develop, procure, and deploy** indigenous quantum technologies, including QKD systems to secure domestic networks, military command and control systems, and critical infrastructure; and quantum sensing products in the defense, security, space, weather forecasting, and disaster management sectors.

- **Institutions of strategic importance – such** as the DRDO and the Indian Space Research Organisation (ISRO) – should establish a dedicated hub for indigenous strategic quantum support. Further, they may start funding research beyond their walls or collaborate directly with the private sector, startups, and the T-hubs to drive innovation and share technologies and processes.
- **A nationwide advisory on adopting PQC –** while mandating the same for government, security, and military agencies – should be formulated, building on an existing technical report issued by the Department of Telecommunications’ Telecommunication Engineering Centre in January 2025.<sup>122</sup>

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122 “Technical Report: Migration to Post Quantum Cryptography.” Telecommunication Engineering Centre, Department of Telecommunications, January 2025. <https://www.tec.gov.in/pdf/TR/Final%20technical%20report%20on%20migration%20to%20PQC%2028-03-25.pdf>.